# TECHNISCHE FAKULTÄT DER CHRISTIAN-ALBRECHTS-UNIVERSITÄT ZU KIEL

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# almanach 14

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Christian-Albrechts-Universität zu Kiel

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# Preface

Dear Reader,

The year 2014 was again a very impressive year for the Faculty of Engineering. The researchers of the three institutes were very successful in their research, as documented by many publications in high-ranking journals, and in raising a remarkable amount of third-party funds. Additionally professors, team members and students got a number of prestigious prizes for their scientific work, such as the "Dr. Bimal Bose Energy Systems Award" for Prof. Liserre. Furthermore, mechanical parts, built in the faculty's workshop 15 years ago, travelled more than 6.5 billion kilometers in an ESA-mission and met a small heap of matter in November 2014 in outer space between Jupiter and Mars, a comet called T67P/Churyumov-Gerasimenko.

Other members of the faculty were involved in activities outside the university. Especially the activities in and with schools are worth mentioning. This involvement is important for the faculty not only to get talented and enthusiastic young students but also to enhance the prestige of the faculty in the eyes of the public. Examples of such activities are „Girls day" and the „Software-Challenge", among many others.

Since the Almanac focuses mainly on researchers' activities, the work of the student body is not considered in the way it should be. Nonetheless, I do not want to overlook the activities of our students, as these activities are very important for the faculty in taking care of all students. The student body council organizes many social and helpful events to encourage their colleagues to finish their studies successfully. In this respect, the student body and its council are very dynamic members of our faculty.

A special event in the year 2014 was the retirement of Prof. Dr. Helmut Föll at the end of September. After 23 years of service in the faculty, he retired from his remarkable and very successful work. He was the Founding Dean of the Faculty of Engineering in 1991 and stayed in this position until September 2014. His work formed the base of the prosperous development of our faculty, which has become one of the most esteemed academic institutions in Schleswig-Holstein. We are very pleased that Prof. Föll will still be active in the field of his interests beyond his former scientific work: steel as the material of swords and old guns. Considering all the benefits for the faculty, special thanks and best wishes for the future go to Helmut Föll.

I hope the reader of this Almanac will find many interesting facts about the research of our faculty. We would be glad if this leads to some inspiring ideas that can help to establish further collaborations and cooperations, in addition with companies in Schleswig-Holstein or elsewhere.

Prof. Dr.-Ing. Eckhard Quandt
Dean of the Faculty of Engineering

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# Department of Computer Science

The Department of Computer Science was founded in 1971 and awarded its first degree in 1973. The department joined the newly created Faculty of Engineering in 1994.

It currently comprises:

- 12 groups in computer science,
- 3 groups in applied mathematics, and
- 3 groups at the Leibniz Information Centre for Economics (Deutsche Zentralbibliothek für Wirtschaftswissenschaften, ZBW).

The department focuses on *algorithm engineering*, e.g. the design, implementation and mathematical analysis of algorithms, and on *software engineering*, e.g. the modelling, realization and operation of reliable hard- and software for complex information and communication systems. The combination of both research areas gives rise to new solutions, both in science and industry.

The department is engaged in interdisciplinary research, for instance within the clusters of excellence ''Future Ocean'', ''Inflammation at Interfaces'', and the ''Graduate school, Human Development in Landscapes''. It enjoys close ties with groups in engineering, marine and life sciences, and in particular with the ZBW Leibniz Information Centre for Economics and the GEOMAR Helmholtz Centre for Ocean Research.

The department is an important factor in Schleswig-Holstein's information technology industry and cooperates closely with for example, ''Digitale Wirtschaft Schleswig-Holstein e.V. '' (DiWiSH), and ''Unabhängiges Landeszentrum für Datenschutz Schleswig-Holstein'' (ULD). A competence centre for software and systems engineering (KoSSE) was created together with the University of Life Sciences, Lübeck, to foster technology transfer and joint projects with companies in Schleswig-Holstein.

Teaching activities focus on B.Sc. and M.Sc. programmes in computer science and business information systems, including special programmes for school teachers.

Students can specialize in a wide variety of areas, including programming languages, efficient algorithms, software engineering, database systems, and business process modelling. Due to the close integration of groups working in applied mathematics, the students can also choose to focus on fields like numerical simulations and high performance computing. Unique features are courses in applications from marine sciences such as climate simulations.

These programmes are taught in close cooperation with the Department of Mathematics, the Faculty of Business, Economics, and Social Sciences, and the Institute of Electrical Engineering and Information Technology.

International relations both within and outside Europe are of great importance to the department. The faculty maintains close ties to universities worldwide, for example in North America, the United Kingdom, Australia, China, India, and Russia. These relationships include an active exchange on both student and faculty level.

## Results

In the academic year 2013/2014, more than 300 students took up studies in the institute's B.Sc. and M.Sc. programmes in Computer Science and Business Information Technology. 121 students graduated in these programmes.

65 pupils took part in the ''Schnupperstudium'', a one-week course giving an applied introduction to programming.

The Leibniz Information Centre for Economics (Deutsche Zentralbibliothek für Wirtschaftswissenschaften, ZBW) was awarded the title „Bibliothek des Jahres" . The jury emphasized that the ZBW, headed by Prof. Dr. Klaus Tochtermann, is a „radically modern library" and that its focus on customers and innovation can serve as an example for other libraries.

Fig. 1: Graduates 2014 (Picture/Copyright: Fabian Frühling/CAU)

The project ''Software Challenge'', headed by Prof. Dr. Manfred Schimmler, received the ''Kai-Uwe von Hassel-Förderpreis 2014'' for its outstanding success in inspiring pupils to take an interest in computer science.

The annual conference ''Software Engineering 2014'' was organized by Prof. Dr. Wilhelm Hasselbring. 270 participants found their way to Kiel.

The annual ''KoSSE-Tag'' of the competence centre for software systems engineering took place in Kiel. The topic ''Usability Engineering'' attracted 100 participants.

Dr. Robert Mercaş of the group ''Dependable Systems'' was one of only two CAU scientists to obtain funding by a new DAAD programme for outstanding postdoctoral researchers. The ''Postdoctoral Researchers International Mobility Experience'' (P.R.I.M.E.) programme allowed him to spend 12 months at King's College, London.

Dr. Lilian Zhang of the group ''Multimedia Information Processing'' received the ''Best Dissertation Award'' of the Förderverein TF for his dissertation ''Line primitives and their applications in geometric computer vision''.

Dr. Lars Prädel of the group ''Theory of Parallelism'' received the faculty award for his dissertation ''Approximation Algorithms for Geometric Packing Problems''.

Ph.D. students Thorsten Ehlers and Philipp Sieweck of the group ''Dependable Systems'' won the ''Sonderpreis IT'' of the initiative ''Ideenwettbewerb Schleswig-Holstein 2014''.

M.Sc. student Sandra Dylus of the group ''Programming Languages and Compiler Construction'' received an ''ACM-W Scholarship Award'' and participated in the conference ICFP 2014 in Gothenburg, Sweden.

M.Sc. student Claudius Zelenka of the group ''Multimedia Information Processing'' was awarded the ''Fokusfinderpreis 2014'' for his thesis ''Underwater Bubble Shape Measurement and Analysis''.

M.Sc. student Tom Frotscher of the group ''Software Engineering'' was awarded the ''b+m Software & Systems Engineering Prize'' for his thesis ''Architecture-based Multivariate Anomaly Detection for Software Systems''.

Rebecca Raddatz won the contest ''movingart 2014'' with her contribution ''Reise zum Glück''. The project ''movingart'' inspires pupils to use computer animation in art projects.

In 2014 the department's IT-Infrastructure has undergone major changes. All student labs are now fitted with modern linux-based terminals and in the ''back office'' a VMware cluster is providing virtual machines for infrastructure, research, and teaching.

## Personnel

Head of the group: Prof. Dr. S. Börm, Prof. Dr. T. Wilke;

Staff:

| | | | |
|---|---|---|---|
| A. Bock | 01.01.-31.12.2014 | (50%) | Land |
| Computer Science and Business Information Technology Examination Office | | | |
| W. Burmeister | 01.01.-31.12.2014 | | Land |
| Computer and IT support team | | | |
| T. Grebien | 01.01.-31.12.2014 | | Land |
| Computer and IT support team | | | |
| PD Dr. F. Huch | 01.01.-31.12.2014 | | Land, 65 percent |
| Computer Science and Business Information Technology Examination Office | | | |
| C. Ohlsen | 01.01.-31.12.2014 | | Land |
| Computer and IT support team | | | |
| Dr. I. Pfannschmidt | 01.01.-31.12.2014 | | Land |
| Computer Science Department's Office | | | |
| B. Scheidemann | 01.01.-31.12.2014 | (50%) | Land |
| Computer Science and Business Information Technology Examination Office | | | |
| M. Sotiriadis-Gräßler | 01.01.-31.12.2014 | (50%) | Land |
| Computer Science and Business Information Technology Examination Office | | | |
| R. Staecker | 01.01.-31.12.2014 | (50%) | Land |
| Computer Science Department's Office | | | |

Scientific Staff:

| | | |
|---|---|---|
| Prof. Dr. F. Foders | 01.01.-31.03.2014 | Lecturer |
| Information Systems | | |
| H. Krasemann | 01.04.-30.09.2014 | Lecturer |
| Privacy Protection | | |
| Dr. H. Lindhorst | 01.04.-30.09.2014 | Lecturer |
| IT Law | | |
| Dr. A. Salski | 01.01.-31.12.2014 | Lecturer |
| KI | | |

## Lectures, Seminars, and Laboratory Course Offers

*Winter 2013/2014*

Inf-Fuzzy: Fuzzy Methoden, 2 (+ 2) hrs Lecture (+ Exercises)/Week,
A. Salski (+ A. Salski)

Winf-MSC-Sem1: Interdisziplinäres Seminar (Informationssysteme), 2 hrs Seminar/Week,
F. Foders

*Summer 2014*

Inf-InfRecht: Informatikrecht, 2 hrs Lecture/Week,
H. Lindhorst

Inf-DatSchutz: Datenschutz, 2 hrs Lecture/Week,
H. Krasemann

Inf-KI: Künstliche Intelligenz, 2 (+ 2) hrs Lecture (+ Exercises)/Week,
A. Salski (+ A. Salski)

*Winter 2014/2015*

Inf-Fuzzy: Fuzzy Methoden, 2 (+ 2) hrs Lecture (+ Exercises)/Week,
A. Salski (+ A. Salski)

# Algorithmic Optimal Control - $CO_2$ Uptake of the Ocean

### What is Algorithmic Optimal Control?

In many scientific and technological applications, optimization problems for differential equations occur. Such tasks are called problems of optimal control. These problems are very complex in the field of mathematical analysis, numerical transformation, and algorithmic realization. They are a main topic of our research group. Important research areas are:

- mathematical analysis and development of algorithms for optimal control problems,
- nonlinear optimization methods,
- analysis and numerical mathematics of nonlinear partial differential equations (transport equations, equations of fluid mechanics),
- algorithmic sensitivity and gradient calculations (automatic differentiation).

### What is oceanic $CO_2$ uptake?

Oceans are able store large amounts of carbon dioxide ($CO_2$) by its fixation from the atmosphere. The oceans act as an enormous carbon sink and have taken up about a third of the $CO_2$ emitted by human activity. This fact is quite important for climate discussion where the central topic concerns $CO_2$ as a greenhouse gas and its effects on global climate changes. The change of oceanic uptake of $CO_2$ caused by climate changes (e. g. increasing temperatures) is able to generate feedback effects. As the uptake of $CO_2$ is mainly driven by geobiochemical mechanisms, the aims of the project A3 are sensitivity analysis and data assimilation (i.e. adaptation of model parameters to measured results) in geobiochemical models coupled with ocean circulation models. These aims are implemented by using applied mathematics and computer science.

## Results

### 3-D Parameter Identification in Marine Ecosystems with Surrogate-based Optimization

We have applied the Surrogate-based Optimization (SBO) method on a parameter identification problem for a 3-D biogeochemical model. SBO is a method for acceleration of optimization processes when the underlying model itself is of very high computational complexity. In these cases, pure simulation runs already require a huge amount of computer time, whereas optimization runs may become unfeasible even with high-performance hardware. As a consequence, the key idea of SBO is to replace the original, and computationally expensive, (high-fidelity) model by a so-called surrogate that is created from a less accurate but computationally cheaper (low-fidelity) model with a suitable correction approach to increase its accuracy. To date, the SBO approach has been widely and successfully used in engineering applications and also for parameter identification in a 1-D marine ecosystem model of NPZD type. In this report, we apply the approach to a two-component biogeochemical model. The model is spun-up into a steady seasonal cycle via the Transport Matrix Approach. The low-fidelity model we use consists of a reduced number of spin-up iterations (several decades instead of the millennia used for the original model). A multiplicative correction operator is further exploited to extrapolate the rather inaccurate low-fidelity model onto the original one. This corrected model builds our surrogate. We validate this SBO method by twin-experiments that use synthetic observations generated by the original model. The proposed SBO technique is shown to yield a solution close to the target with a significant gain of computational efficiency. Without further

regularization techniques, the method is able to identify most model parameters. The method is simple to implement and presents a promising and pragmatic tool to calibrate biogeochemical models in a global three-dimensional setting.

### GPU hardware accelerates Ecosystem Simulations

We have ported an implementation of the spin-up for marine ecosystem models based on transport matrices to graphics processing units (GPUs). The original implementation was designed for distributed-memory architectures and uses the Portable, Extensible Toolkit for Scientific Computation (PETSc) library that is based on the Message Passing Interface (MPI) standard. The spin-up computes a steady seasonal cycle of ecosystem tracers with climatological ocean circulation data as forcing. Since the transport is linear with respect to the tracers, the resulting operator is represented by matrices. Each iteration of the spin-up involves two matrix-vector multiplications and the evaluation of the biogeochemical model used. The original code was written in C and Fortran. On the GPU, we use the Compute Unified Device Architecture (CUDA) standard, a customized version of PETSc, and a commercial CUDA Fortran compiler. We have described the extensions to PETSc and the modifications of the original C and Fortran codes required. Here we make use of freely available libraries for the GPU. We analyze the computational effort of the main parts of the spin-up for two exemplar ecosystem models and compare the overall computational time to those necessary on different CPUs. The results show that a consumer GPU can compete with a significant number of cluster CPUs without further code optimization.

### Linear Quadratic Optimal Control leads to an improved Ecosystem Model

We use an optimization method for enhancement of a climate model, namely a one dimensional non-linear marine ecosystem model of NPZD type. The original model contains temporally constant parameters that are subject to optimization in order to improve the fit of the model output to observational data. In several publications, this fit turned out to be rather poor. In this work, the method of Linear Quadratic Optimal Control (LQOC) is used to allow for temporally variant but annually periodic parameters, in a linearized version of the original model. The periodicity of the parameters is assured by a special choice of the reference trajectory needed in the linearization process. The optimal periodic parameters obtained are used in the original non-linear model. In both validation and prediction experiments, they lead to a significant reduction of the model-data misfit, compared to results obtained with optimized constant parameters.

## Personnel

Head of the group: Prof. Dr. T. Slawig; Secretary: J. Eitzen (50%)

Scientific Staff:

| | | | |
|---|---|---|---|
| Dipl.-Math. J. Gördes | 01.01.-31.03.2014 | (50%) | CAU |
| Dipl.-Math. C. Kratzenstein | 01.01.-31.12.2014 | | DFG |
| SPP 1253(Jan-Oct)/Cluster the Future Ocean (Nov-Dec) | | | |
| Dipl.-Math. J. Piwonski | 01.01.-31.12.2014 | | CAU |
| Dipl.-Math. J. Reimer | 01.01.-31.12.2014 | | DFG |
| Cluster The Future Ocean | | | |
| Dipl.-Math. C. Roschat | 01.01.-31.12.2014 | (50%) | DFG |
| Cluster The Future Ocean | | | |

## Lectures, Seminars, and Laboratory Course Offers

*Winter 2013/2014*

Algorithmische Aspekte numerischer Verfahren, 2 (+ 2) hrs Lecture (+ Exercises)/Week,

T. Slawig (+ J. Burmeister)

Nichtlineare Optimierung, 4 (+2) hrs Lecture (+ Exercises)/Week,
T. Slawig (+ J. Piwonski)

Nichtlineare Optimierung für Wirtschaftsinformatikstudierende, 2 (+2) hrs Lecture (+ Exercises)/Week,
T. Slawig (+ J. Piwonski)

Masterprojekt - Algorithmische Optimale Steuerung / Klimasimulation, 4 hrs Exercise/Week,
T. Slawig

Oberseminar Algorithmische Optimale Steuerung - Informatik in der Meeresforschung, 2 hrs Seminar/Week,
T. Slawig

MATLAB Intro ISOS Course, 2 hrs Seminar/Week,
T. Slawig (+ J. Piwonski)

*Summer 2014*

Programmierpraktikum, 1 (+2) hrs Lecture (+ Exercises)/Week,
T. Slawig (+ J. Piwonski, S. Schulmeister, I. Stucke)

Programmierpraktikum für Mathematiker, 1 (+2) hrs Lecture (+ Exercises)/Week,
T. Slawig (+ J. Piwonski, S. Schulmeister, I. Stucke)

Klimamodelle und Klimasimulation, 4 (+2) hrs Lecture (+ Exercises)/Week,
T. Slawig (+ J. Burmeister)

MATLAP Intro ISOS Course, 2 hrs Seminar/Week,
T. Slawig

Abschlussprojekt - Softwareentwicklung für mobile Geräte, 6 hrs Exercise/Week,
T. Slawig

Masterprojekt - Softwareentwicklung für mobile Geräte, 4 hrs Exercise/Week,
T. Slawig

Oberseminar Algorithmische Optimale Steuerung - Informatik in der Meeresforschung, 2 hrs Seminar/Week,
T. Slawig

MATLAB Intro ISOS Course, 2 hrs Seminar/Week,
T. Slawig (+ J. Piwonski)

*Winter 2014/2015*

Algorithmische Aspekte numerischer Verfahren, 2 (+2) hrs Lecture (+ Exercises)/Week,
T. Slawig (+ J. Burmeister)

Nichtlineare Optimierung, 4 (+2) hrs Lecture (+ Exercises)/Week,
T. Slawig (+ J. Piwonski, J. Reimer)

Nichtlineare Optimierung für Wirtschaftsinformatikstudierende, 2 (+2) hrs Lecture (+ Exercises)/Week,
T. Slawig (+ J. Piwonski, J. Reimer)

Masterprojekt - Algorithmische Optimale Steuerung / Klimasimulation, 4 hrs Exercise/Week,
T. Slawig

Oberseminar Algorithmische Optimale Steuerung - Informatik in der Meeresforschung, 2 hrs Seminar/Week,
T. Slawig

Algorithmische Aspekte numerischer Verfahren, 2 (+ 2) hrs Lecture (+ Exercises)/Week,
T. Slawig (+ J. Burmeister)

Nichtlineare Optimierung, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
T. Slawig (+ J. Piwonski, J. Reimer)

Nichtlineare Optimierung für Wirtschaftsinformatikstudierende, 2 (+ 2) hrs Lecture (+ Exercises)/Week,
T. Slawig (+ J. Piwonski, J. Reimer)

Masterprojekt - Algorithmische Optimale Steuerung / Klimasimulation, 4 hrs Exercise/Week,
T. Slawig

Oberseminar Algorithmische Optimale Steuerung - Informatik in der Meeresforschung, 2 hrs Seminar/Week,
T. Slawig

MATLAB Intro ISOS Course, 2 hrs Seminar/Week,
T. Slawig (+ J. Piwonski)

## Third-Party Funds

DFG Cluster The Future Ocean, *Personal*, 01.01.2012-31.12.2014 (132300 EUR)
DFG SPP 1253, *Personal/Sachmittel*, 01.01.2012-31.10.2014 (141500 EUR)
BMBF PerLe, *Personal*, 21.02.2014-20.02.2015 (5136 EUR)
DFG Cluster The Future Ocean, *Personal*, 01.01.2012-31.12.2014 (132300 EUR)

## Further Cooperation, Consulting, and Technology Transfer

The group cooperates with the following individuals and organisations:

Prof. Dr. Andreas Oschlies **GEOMAR Helmholtz-Zentrum für Ozeanforschung Kiel**,
Prof. Dr. Martin Wahl **GEOMAR Helmholtz-Zentrum für Ozeanforschung Kiel**,
Dr. Iris Kiest, **GEOMAR Helmholtz-Zentrum für Ozeanforschung Kiel**,
Prof. Dr. Andreas Griewank, **MATHEON** and **Humboldt-Universität zu Berlin**,
Prof. Dr. Nicolas Gauger, **RWTH Aachen**,
Dr, Uwe Prüfert, **TU Bergakademie Freiberg**,
Prof. Dr. Slawomir Koziel, **Reykjavik University** (Iceland),
Prof. Dr. Kai Graf, **FH Kiel**,
Prof. Dr. Giovanni Samaey **KU Leuven**, (Belgium).

## Diploma, Bachelor's and Master's Theses

L. Schwartkop, *Entwicklung einer Android-App im Beratungs- und Therapiekontext mit Jugendlichen - Gestaltung der WEb-Anwendung für den Therapeuten*, 01.09.2014
T. Jakumeit, *Weiterentwicklung einer Android-Lernapp mit Schwerpunkt auf den Import von Inhalten im QTI-Format*, 24.09.2014
L. Hamer, *Weiterentwicklung einer Android-Lernapp mit Schwerpunkt auf Extraktion von Lerninhalten aus Skripten*, 24.09.2014
F. Kamguia Komogne, *Portierung von Teilen des Klimamodells NEMO auf GPUs*, 25.09.2014
D. Mittag, *Entwicklung einer Android-App zur Erfassung von Umweltdaten unter Verwendung von ArcGIS*, 25.09.2014
K. Thambia, *Parallelizing Artificial Neural Networks in OpenCL demonstrated by implementing the AQUASHIFT model of marine ecology*, 25.09.2014

H. Strubel, *Entwicklung eines Umsatzdatenmeldesystems für Shopping Center - Usermanagement und Userflow*, 26.09.2014

F. Echternkamp, *Entwicklung eines Umsatzdatenmeldesystems für Shopping Centre- WebApp in ASP.net MCV*, 26.09.2014

D. Schmidt, *Entwicklung eines Umsatzdatensystems für Shoppingcentre - iOS-App und Schnittstellendesign*, 26.09.2014

## Dissertations / Postdoctoral Lecture Qualifications

Mustapha El Jarbi, *Linear Control Theory to Introduce Periodic Parameters for a Marine Ecosystem Model*, 04.12.2014

## Publications

Published in 2014

T. Bosse, N.G. Gauger, A. Griewank, S. Günther, L. Kaland, C. Kratzenstein, L. Lehmann, A. Nemili, E. Ozkaya, T. Slawig, *Optimal Design with Bounded Retardation for Problems with Non-separable Adjoints*, Leugering, G., Benner, P., Engell, S., Griewank, A., Harbrecht, H., Hinze, M., Rannacher, R., Ulbrich, S.: Trends in PDE Constrained Optimization, Springer International Publishing, International Series of Numerical Mathematics, **165**, 67 - 84 (2014)

C. Roschat, T. Slawig, *Mathematical analysis of a marine ecosystem model with nonlinear coupling terms and non-local boundary conditions*, ArXiv e-prints, **1403.4461**, (2014)

M. El Jarbi, T. Slawig, *Extension of a Marine Ecosystem Model using Discrete Open Loop Optimal Control*, International Journal of Mathematical Modelling and Numerical Optimisation, (2014)

T. Slawig, M. Prieß, C. Kratzenstein, *Surrogate-Based and One-shot Optimization Methods for PDE-Constrained Problems with an Application in Climate Models*, Springer Proceedings in Mathematics & Statistics, Springer Verlag, **97**, 1 - 14 (2014)

J. Reimer, M. Schürch, T. Slawig, *Optimization of experimental designs and model parameters exemplified by sedimentation in salt marshes*, Geoscientific Model Development Discussions, **7**, 6439 - 6487 (2014)

C. Roschat, T. Slawig, *Nontrivial Periodic Solutions of Marine Ecosystem Models of N-DOP type*, ArXiv e-prints, ArXiv, **1409.7540**, (2014)

## Presentations

J. Reimer, *Optimal Experimental Design in Marine Research*, CAU, Kiel, Germany, 08.-08.01.2014

J. Reimer, *Optimizing Model Parameters and Measurement Conditions for the N-DOP Model*, Group Meeting GEOMAR, Kiel, Germany, 18.-18.03.2014

C. Roschat, *Weak Solutions of Marine Ecosystem Model Equations*, Young Researchers Meeting, Plön, Germany, 24.-25.03.2014

J. Reimer, *Optimal Experimental Design in Marine Science*, Young Researchers Meeting, Plön, Germany, 24.-25.03.2014

C. Kratzenstein, *The Oneshot Optimization Strategy: Simultaneous Model Spin-Up and Parameter Optimization*, Young Researchers Meeting, Plön, Germany, 24.-25.03.2014

J. Piwonski, *Parameter Estimation for Marine Ecosystem Models in 3-D*, Young Researchers Meeting, Plön, Germany, 24.-24.03.2014

T. Slawig, M. Prieß, J. Piwonski, A. Heinle, *Surrogate-based Methods for Parameter Identification in Climate Models*, Workshop, Plön, Germany, 26.-28.03.2014

C. Kratzenstein, T. Slawig, J. Piwonski, *The Oneshot Optimization Strategy: Simultaneous Model Spin-Up and Parameter Optimization*, Group Meeting GEOMAR, Kiel, Germany, 01.-01.07.2014

T. Slawig, C. Kratzenstein, J. Piwonski, M. Prieß, C. Roschat, A. Heinle, *Methods for Parameter Estimation in Climate Models*, Seminar Analysis und Numerik des Fachbereichs Mathematik an der Uni Konstanz, Konstanz, Germany, 03.-03.07.2014

T. Slawig, C. Kratzenstein, J. Piwonski, M. Prieß, C. Roschat, *Parameter Estimation in Marine Ecosystem Models,*, GAMM-Workshop on Computational Optimization, Dortmund, Germany, 10.-12.09.2014

J. Reimer, *Optimal Experimental Design in Marine Research,* Tagung des Clusters, Schleswig, Germany, 29.-30.09.2014

J. Reimer, *Optimization of Model Parameters and Experimental Designs for a Global Marine Biogeochemical Model,* AGU Fall Meeting, San Francisco, USA, 15.-19.12.2014

# Business Information Technology

The working group focuses on the development and integration of business application systems. The key issues are improved development by capturing business requirements as system specifications and automated validation if the system's models or the real systems meet these requirements. Examples of such commercial systems are ERP systems , e-commerce systems, or the combination of both realizing a web shop.

The accessibility of such systems for elderly and disabled persons is a new challenge addressed by the workgroup. The work in this area started in late 2014.

The working group provides lectures, seminars, and practical courses for business information system and computer science students as well as economic studies (B.Sc. and M.Sc.).

## Results

A key issue is the quality of commercial systems. The experimental automated validation system has been extended with new transformation concepts capturing further semantics.

The validation system has been presented to the scientific community at the Requirements Engineering Conference (RE), 2014. In consequence, we had exchanges with partners in requirements engineering at the University of Trento in Italy.

## Personnel

Head of the group: Prof. Andreas Speck; Secretary: Sylvia Lassen (50%)
Technical Staff: B.Sc. Timo Wilgen

Scientific Staff:

| | | | |
|---|---|---|---|
| Dr.Ing. Sven Feja | 01.01.-31.12.2014 | | CAU |
| Dipl.Ing. Sören Witt | 01.01.-30.09.2014 | | HSP |
| Dipl.Ing. Sören Witt | 01.10.-31.12.2014 | (50%) | |

## Lectures, Seminars, and Laboratory Course Offers

*Winter 2013/2014*

Grundlagen Wirtschaftsinformatik I, 2 (+ 2) hrs Lecture (+ Exercises)/Week,
A. Speck (+ S. Witt)

Betriebliche Standardsoftware, 2 (+ 3) hrs Lecture (+ Exercises)/Week,
A. Speck (+ S. Feja)

Projektgruppe, 4 hrs Practical/Week,
A. Speck (+ S. Feja)

Seminar Wirtschaftsinformatik, 3 hrs Seminar/Week,
A. Speck (+ S. Witt)

Abschlussprojekt Wirtschaftsinformatik (Betriebliche Anwendungssysteme), 3 hrs Practical/Week,
A. Speck

*Summer 2014*

Betriebliche Informationssysteme, 2 (+ 4) hrs Lecture (+ Exercises)/Week,
A. Speck (+ S. Feja, S. Witt)

Generative Programmierung, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
A. Speck (+ S. Feja, S. Witt)

Projekt Wirtschaftsinformatik (betriebliche Anwendungssysteme), 5 hrs Practical/Week,
A. Speck (+ S. Feja, s. Witt)

Wirtschaftsinformatik II, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
A. Speck (+ S. Feja, S. Witt)

Abschlussprojekt Wirtschaftsinformatik - Betriebliche Anwendungssysteme, 4 hrs Practical/Week,
A. Speck (+ S. Feja, S. Witt)

## Diploma, Bachelor's and Master's Theses

H. Dubaschny, *Konzeptionierung und prototypische Entwicklung eines Management-Cockpits auf Basis von SAP Business Warehouse*, 30.09.2014

C. Hadler, *Automatisierte Analyse von Prüfwerkzeugergebnissen und Ableitung von Visualisierungen in Geschäftsprozessmodellen im Business Application Modeler*, 31.03.2014

J. Hauke, *Testkonzept für mobile Anwendungen im Bankenumfeld am Beispiel von EBICS-Mobile*, 01.09.2014

T. Hilbring, *Konzeption eines Dokumentationsmanagementsystems für EMF-basierte Metamodelle*, 16.09.2014

J.C. Fontius, *Kennzahlen gestütztes Business Modeling junger Unternehmen . Ein Vorschlag zur Verknüpfung von grafischen Business Modelling und Kennzahlensystemen im Kontext der Erfolgsüberwachung junger Unternehmen*, 13.02.2014

J. Mangelsdorf, *Sicherheit in SIP-Netzen: Überblick und Vergleich in Forschung und Praxis*, 30.10.2014

J. Matthiesen, *Ausführung von validierbaren Prozessmodellen am Beispiel der ereignisgesteuerten Prozesskette*, 15.05.2014

M. Nannt, *Ein nutzerzentrierter Ansatz zur Verwaltung personen bezogener Daten im Internet*, 30.12.2014

M. Peers, *Einsatz, Nutzen und Anforderungen von Modellen im Verlauf der Softwareentwicklung aus betrieblicher und wissenschaftlicher Sicht*, 01.09.2014

D. Peters, *Entwurf und Vergleich prototypischer Implementierungen eines Lagerverwaltungssystems auf Basis einer Workflow Enginge und eines Content Management Systems*, 31.03.2014

B. Rathje, *Webanwendung zur Erstellung von Risikoanalysen auf Basis des BSI-Grundschutzmodells*, 30.09.2014

T. Richter, *Gamification als Kundenbindungsintrument im E-Commerce*, 15.10.2014

T. Riemer, *Einführung einer Softwarelösung für Sitzungsmanagement in Unternehmen. Entwicklung eines Konzeptes zur Durchführung der Anforderungsanalyse und Evaluation bestehender Produkte*, 15.03.2014

C. Witthöft, *Konzept und prototypische Implementierung eines Recommender System für semantisch ähnliche Stellenangebote am Beispiel von StuJo*, 01.10.2014

## Publications

Published in 2014

A. Speck, S. Feja, S. Witt, *Applying Pattern-Based Graphical Validation Rules to Business Process Models*, Software Testing, Verification and Validation Workshops (ICSTW), **IEEE 7th Conference**, 274 - 283 (2014)

A Speck, S. Feja, S. Witt, C. Hadler, *Business Application Modeller: A process model Validation and Verification tool*, Requirements Engineering Conference (RE), **IEEE 22nd International**, 333 - 334 (2014)

# Communication Systems

The Research Group for Communication Systems (AG ComSys) was established in the Dept. of Computer Science of the CAU Kiel in Oct. 2000 and has been directed since by Prof. Dr.-Ing. Norbert Luttenberger. The AG ComSys performs research in different application-orientated areas.

## Results

1. Semantic Web Technologies for Historical Data

In 2014, AG ComSys started to build experience in modelling historical data with semantic web modelling languages, especially OWL-2 and RDF. As proof of concept, a complete directory of CAU professors since CAU's foundation in 1665 is going to be implemented. For this purpose, AG ComSys closely cooperates with the research group of Prof. Oliver Auge of the Historical Seminar. First results are expected in mid 2015.

2. Conceptual modelling with UML and OWL-2

Both OWL-2 and UML static class diagrams lend themselves very well to conceptual modelling of complex information systems. Though nowadays the Web Ontology Language (OWL) is mostly considered as a language for knowledge representation, it can also be used as a language for conceptual modelling of complex information systems, i.e. as a language for representing the entities of a certain domain, for expressing the meaning of various (usually ambiguous) terms, and to identify the relationships between these. In this respect, OWL can be seen as a direct competitor to static Unified Modelling Language (UML) class diagrams for example that are in the ISO 191xx series of standards often used for this purpose. Both languages have their benefits. UML's visual syntax is easy to understand and there is a variety of software tools to choose from. OWL is backed up by formal logic and logical conclusions can be drawn on models using reasoner software. In order to benefit from the advantages and software tools of both languages, it was usually necessary to repeat the modelling process for each language. Jesper Zedlitz of AG ComSys investigated if and how conceptual models written in one language can be automatically transformed into those written in the other language. The result of his research work is a transformation tool that can be applied to complex software engineering problems.

## Personnel

Head of the group: Prof. Norbert Luttenberger; Secretary: Nicole Mard-Azad (50%)
Technical Staff: BSc. Matthias Westphal (50%)

Scientific Staff:

Dr.-Ing. Jesper Zedlitz 01.01.-31.12.2014

## Lectures, Seminars, and Laboratory Course Offers

*Winter 2013/2014*

Betriebssysteme, 3 (+2) hrs Lecture (+ Exercises)/Week,
Norbert Luttenberger (+ Jesper Zedlitz)

XML in Communication Systems, 4 (+2) hrs Lecture (+ Exercises)/Week,
Norbert Luttenberger (+ Jesper Zedlitz)

Commucations Systems, 2 hrs Seminar/Week,
Norbert Luttenberger

*Summer 2014*

Kommunikationssysteme, 3 (+ 2) hrs Lecture (+ Exercises)/Week,
Norbert Luttenberger (+ Jesper Zedlitz)

Academic Writing, 2 (+ 2) hrs Lecture (+ Exercises)/Week,
Norbert Luttenberger (+ Norbert Luttenberger)

Web Technologies, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
Norbert Luttenberger (+ Jesper Zedlitz)

## Further Cooperation, Consulting, and Technology Transfer

Prof. Dr. Oliver Auge, Professur für Regionalgeschichte mit Schwerpunkt zur Geschichte Schleswig-Holsteins im Mittelalter/Früher Neuzeit, Historisches Seminar der CAU

## Diploma, Bachelor's and Master's Theses

Daniel Krawutschke, *Shibboleth-geschützer Zugang zu WebDAV und Rechnern,* 06.05.2014
Benjamin Zingelmann, *Ein System zur Anreicherung manuell erfasster strukturierter Daten unter Verwendung fester Vokabulare und OCR,* 07.09.2014
Christoph Diehr, *Semi-automatische Zuordnung von Ortsnamen und Ortsobjekten,* 09.07.2014
Christoph Dornieden, *Erfassung historischer Quellen auf Mobilgeräten,* 25.06.2014
Maria Kandsorra, *Nutzung von Captchas zur Erfassung historischer Quellen,* 06.08.2014
Niclas Hoyer, *Verarbeitung von SPARQL-Anfragen und OWL-2-Inferenz mit Neo4J,* 20.11.2014
Fiona Schmidtke, *Generierung anwendungsorientierter User Interfaces aus OWL-2,* 15.11.2014

## Dissertations / Postdoctoral Lecture Qualifications

Michael Lodemann, *Modellierung und Verifikation von Eisenbahn-Infrastrukturen mit semantischen Technologien,* 10.12.2014

## Publications

Published in 2014

Jesper Zedlitz, Norbert Luttenberger, *A Survey on Modelling Historical Administrative Information on the Semantic Web.,* International Journal On Advances in Internet Technology., **vol 7, no 3**, 218 - 231 (2014)
Jesper Zedlitz, Norbert Luttenberger, *Conceptual Modelling in UML and OWL-2.,* International Journal On Advances in Software., **vol 7, no 1-2**, 182 - 196 (2014)
Jesper Zedlitz, Norbert Luttenberger, *Modelling (Historical) Administrative Information on the Semantic Web.,* WEB 2014, The Second International Conference on Building and Exploring Web Based Environments., (2014)

# Computer-Aided Program Development

As in previous years, in 2014 the research group concentrated on several areas:

- the investigation of the fundamentals of programming languages,
- the application of formal methods for problem specification and program development,
- the use of relation-algebraic, order-theoretic and related methods in mathematics and computer science,
- the application of graphs and binary decision diagrams as modelling and implementation tools and as objects for the formal development of declarative as well as relational algorithms, and
- computational problems from Simple Games Theory and Social Choice Theory. Again this has been done with specific regard to tool support.

Besides the Kiel RelView system for the manipulation of relations and relational programming we mainly used the proof assistant tool Coq, the automated theorem prover Prover9 and the associated counterexample generator Mace4.

## Results

With regard to relational algorithms and Computational Social Choice Theory, we have further developed our technique for the choice problem of tournaments, i.e. asymmetric and complete dominance relations. The technique rests upon a relation-algebraic modelling of the objects in question and uses the RelView software for the evaluation of the relation-algebraic expressions that specify the solutions and for the visualization of the computed results. Having solved in this way during recent years most of the well-known tournament solutions, in 2014 we have attacked the so-called minimal extending set (introduced by F. Brandt) and were able also to solve this very difficult case. Again our technique proved to be very flexible and appropriate for experimenting with minimal extending sets.

Another problem of Social Choice Theory we have investigated in 2014 is the control problem of voting systems. Here it is assumed that the authority conducting the election knows all preferences of the voters over the alternatives in question. Its goal is to achieve a specific result by a strategic manipulation of the election, e.g. to make a preferred alternative win by removing as few alternatives as possible. The knowledge of all individual preferences and the ability to manipulate by 'dirty tricks' are worst-case assumptions that are not entirely unreasonable in some practical settings. As a new complexity result we have shown that for Condorcet voting, control by removing voters is NP-hard if instead of the classical Condorcet winners the alternatives in the so-called uncovered set (a specific tournament solution) win. Concerning algorithmic solutions of hard control problems, we have developed relation-algebraic models of Condorcet voting, approval voting, and plurality voting and relation-algebraic specifications of solutions of certain control problems. The latter can be translated immediately into RelView-programs such that the system can be used for solving the control problems. Besides relation algebra, we also have developed integer linear programming models of certain control problems and used the LP-solver Cplex to solve them. Compared with the relation-algebraic approach, by this we are able to treat the control of much larger elections successfully. Our results show that the hardness of a certain control problem is not a secure protection for the fraudulent falsification of outcomes of elections by its use.

A lot of hard problems, especially in the context of Simple Games and Social Choice Theory, require the computation of all minimal and/or maximal sets of a generally very large set of sets. The identification of Banks winners is a typical example since this tournament solution is defined by means of the set of all maximal transitive sets, subject to the given dominance relation. Binary decision diagrams provide an efficient way to implement sets of sets. Based on this, we have developed efficient algorithms which compute, from the BDD-implementation of a set of sets , that of the set of all minimal sets and that of the set of all maximal sets. Assuming heredity conditions which frequently hold in practice, we have obtained variants which are even more efficient. Meanwhile the algorithms are integrated into RelView and lead to amazing

results. For instance, they allowed us to compute within some seconds the so-called Holler-Packel power index of the members of the European Community after the treaty of Nice (2003).

When we develop relational programs, e.g. for the tool RelView, then we always assume an imperative programming language with relations as data structure, in contrast with other approaches that consider data as well as programs as relations. Our approach bears a decisive methodical advantage: since all problem specifications are expressed via relation-algebraic formulae, the developments allow us to intertwine approved program development and verification techniques with relation-algebraic calculations. This mathematical rigour drastically reduces the danger of making errors. Furthermore, it allows tool support for theorem proving. Experience has shown that full automatization of proofs can frequently be achieved by off-the-shelf automated theorem provers such as Prover9. In 2014 we used this tool and the associated counterexample generator Mace4 for the automated verification of the proof obligations appearing in the assertion-based verification of relational programs for graph-theoretic problems.

To overcome some restrictions of the automated theorem prover, especially concerning the missing types and the weaker expressiveness of its language compared to other provers, we have started also to work with proof assistants. Coq is one of the most common interactive theorem provers and works in the theory of the calculus of inductive constructions. For Coq, libraries for homogenous as well as for heterogenous relation algebra already exist. We used these libraries in the context of the automated verification of a relational vertex-colouring program.

Regarding our work on graph algorithms from a purely functional perspective, we have elaborated the matrix-vector multiplication framework. We have extended several details and have implemented a prototypical version as a project on GitHub (https://github.com/nikitaDanilenko/vmm) which can be used as a lightweight Haskell library.

Additionally, we have studied non-determinism in graph algorithms in terms of case studies for maximum matching and maximum flow problems. We have implemented these algorithm in the functional-logic programming language Curry and studied the non-deterministic computation of augmenting paths and their effects on the results. Due to confluence reasons, any choice of a sequence of augmenting paths yields a valid result. However, the observation of outcomes allows insight into the structure of the underlying graph. We have implemented a lightweight Curry library that is also available on GitHub (https://github.com/nikitaDanilenko/ndga). It can be used without either deeper knowledge of graph algorithms or Curry and is thus suited for teaching in courses on graph theory for beginners.

Finally, we have improved a result from 2012 concerning the computation of Kleene closures. The new result is applicable to any Kleene algebras with tests which are a generalisation of homogeneous relational algebra and, in particular, matrix algebras over a Kleene algebra. We have used this new result for an improved implementation that is also available as a light-weight Haskell library on GitHub (https://github.com/nikitaDanilenko/functionalKleene). In addition to the improved version for matrices, we provided a generic algorithm that is applicable in the general case of Kleene algebras with tests, given some minor restrictions. We have improved the comparison of our implementation with other versions, in particular one that was recently developed in Haskell by Stephen Dolan (ICFP 2013). Our implementation is almost always faster than any of the implementations in our comparison (and when it is not, it is very close to the respective fastest version) and is always best in terms of space consumption.

## Personnel

Head of the group: Prof. Dr. R. Berghammer; Secretary: M. Bradler (50%), L. Haberland (50%)

Scientific Staff:

Dipl.-Math. N. Danilenko 01.01.-31.12.2014
Functional algorithms for discrete problems

Dipl.-Math I. Stucke 01.01.-31.12.2014
Computer-aided verification of algebraic programs

## Lectures, Seminars, and Laboratory Course Offers

*Winter 2013/2014*

Arbeitsgemeinschaft Informatik, Logik und Mathematik, 2 hrs Seminar/Week,
R. Berghammer (+ M. Hanus)

Inf-Math-A: Mathematik für Informatiker A - Grundlagen und diskrete Strukturen, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
R. Berghammer (+ N. Danilenko, I. Stucke, Ch. Gießen)

Inf-Sem-MathMed: Mathematische Methoden in der Informatik, 2 hrs Seminar/Week,
R. Berghammer (+ N. Danilenko, I. Stucke)

*Summer 2014*

Inf-AP-RPE: Abschlussprojekt - Rechnergestützte Programmentwicklung, 6 hrs Exercise/Week,
R. Berghammer

Inf-SemPS: Semantik von Programmiersprachen, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
R. Berghammer (+ N. Danilenko)

Arbeitsgemeinschaft Informatik, Logik und Mathematik, 2 hrs Seminar/Week,
R. Berghammer (+ M. Hanus)

MS0402: Ordnungen und Verbände, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
R. Berghammer (+ I. Stucke)

Oberseminar - Rechnergestützte Programmentwicklung, 2 hrs Seminar/Week,
R. Berghammer

*Winter 2014/2015*

Arbeitsgemeinschaft Informatik, Logik und Mathematik, 2 hrs Seminar/Week,
R. Berghammer (+ M. Hanus)

Inf-Math-A: Mathematik für Informatiker - Grundlagen und Diskrete Strukturen, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
R. Berghammer (+ N. Danilenko, M. El Ouali, I. Stucke, Ch. Roschat)

Inf-Sem-MathMed: Mathematische Methoden in der Informatik, 2 hrs Seminar/Week,
R. Berghammer (+ N. Danilenko, I. Stucke)

Oberseminar - Rechnergestützte Programmentwicklung, 2 hrs Seminar/Week,
R. Berghammer

## Third-Party Funds

DAAD, *Joint Research Co-operation Scheme Australia*, 01.01.2015-31.12.2016 (10.508 EUR)
NICTA, *Visiting the NICTA Institute*, 21.02.-23.03.2014 (2700 EUR)

## Further Cooperation, Consulting, and Technology Transfer

Applications of relational methods in computer Science: with B. Möller (Augsburg), W. Guttmann (Christchurch, New Zealand), G. Schmidt (München), R.A. Schmidt (Manchester, UK), G. Struth , (Sheffield, UK), and M. Winter (St. Catheriens, Canada).

Automated theorem proving: with P. Höfner (Sydney, Australia).

Social choice theory: with A. Rusinowska (Paris, France), H. Schnoor (working group *Theoretical Computer Science* of the CAU) and H. de Swart (Tilburg, The Netherlands).

Evolutionary and approximation algorithms, binary decision diagrams: with F. Neumann (Adelaide, Australia).

Programming languages and program development: with the members of the working group *Programming Languages and Compiler Construction* of the CAU).

## Diploma, Bachelor's and Master's Theses

J. Angres, *Automatentheoretische Untersuchung einfacher Spiele*, 14.03.2014
M. Kulczynski, *Automatische Verifikation relationaler Aussagen*, 16.09.2014
Y. Potdevin, *Vergleich verschiedener Implementierungen von Graphalgorithmen in Haskell*, 15.10.2014

## Publications

Published in 2014

R. Berghammer, *Mathematik für Informatiker: Grundlegende Begriffe und Strukturen*, (2014)

R. Berghammer, B. Möller, M. Winter, *Special issue, Commemoration in Honour of Gunther Schmidt on the Occasion of his 75th Birthday*, Journal of Logical and Algebraic Methods in Programming, **83.2**, (2014)

R. Berghammer, *Computing minimal extended sets by relation-algebraic modelling and development*, Journal of Logical and Algebraic Methods in Programming, **83**, 103 - 119 (2014)

R. Berghammer, A. Rusinowska, H. de Swart, *Spatial voting games, relation algebra and* RelView, Journal of Logical and Algebraic Methods in Programming, **83**, 120 - 134 (2014)

R. Berghammer, M. Winter, *Gunther Schmidt's life as a mathematician and computer scientist*, Journal of Logical and Algebraic Methods in Programming, **83**, 300 - 308 (2014)

R. Berghammer, N. Danilenko, H. Schnoor, *Relation algebra and* RelView *applied to approval voting*, Höfner P., Jipsen P., Kahl W., Müller M. (eds.): Proc. 14th International Conference on Relational and Algebraic Methods in Computer Science, Marienstatt, April 27 to May 1, 2014, LNCS 8428, Springer, 173 - 199 (2014)

R. Berghammer, P. Höfner, I. Stucke, *Automated verification of relational while-programs*, Höfner P., Jipsen P., Kahl W., Müller M. (eds.): Proc. 14th International Conference on Relational and Algebraic Methods in Computer Science, Marienstatt, April 27 to May 1, 2014, LNCS 8428, Springer, 309 - 326 (2014)

R. Berghammer, H. Schnoor, *Control of Condorcet voting: Complexity and a relation-algebraic approach (extended abstract)*, Lomuscio A., Scerri P., Bazzan A., Huhns M. (eds.): Proc. 13th International Conference on Autonomous Agents and Multiagent Systems, Paris, France, Mat 5 to 9, 2014, IFAAMAS, 1365 - 1366 (2014)

R. Berghammer, *Relation algebra,* RelView *and plurality voting*, Gerdt V.P., Koepf W., Mayr E.W., Vorozhtsov E.V. (eds.): Proc. 16th International Workshop on Computer Algebra in Scientific Computing, Warsaw, Poland, September 8 to 12, 2014, LNCS 8660, Springer, 13 - 27 (2014)

R. Berghammer, *ROBDD-based computation of sets of minimal and maximal sets with applications*, Steinbach B. (ed.): Proc. 11th International Workshop on Boolean Problems. Freiberg, September 17 to 19, 2014, TU Bergakademie Freiberg, 55 - 66 (2014)

N. Danilenko, *And... Action! - Monoid Actions and (Pre)orders*, M. Hanus and R. Rocha (eds.): Declarative Programming and Knowledge Management - Declarative Programming Days, KDPD 2013, LNCS 8439, Springer, 83 - 98 (2014)

N. Danilenko, *Functional Kleene Closures*, Preliminary Proceedings of the 24th International Symposium on Logic-based Program Synthesis and Transformation, Technical Report IASI-CNR R. 3 - September 2014 (ISSN 1128-3378), (2014)

N. Danilenko, *Graph Problems and Vector-Matrix Multiplication in Haskell*, J. Hage and J. McCarthy (eds.): Trends in

Functional Programming, LNCS 8843, Springer, 51 - 67 (2014)

## Presentations

R. Berghammer, *And the winner is - A relational approach to voting,* Optimization Group Seminar, University of Adelaide, Australia, 03.-03.03.2014

R. Berghammer, N. Danilenko, H. Schnoor, *Relation algebra and* RelView *applied to approval voting,* 14th International Conference on Relational and Algebraic Methods in Computer Science, Marienstatt, Germany, 27.04.-01.05.2014

R. Berghammer, P. Höfner, I. Stucke, *Automated verification of relational while-programs,* 14th International Conference on Relational and Algebraic Methods in Computer Science, Marienstatt, Germany, 27.04.-01.05.2014

R. Berghammer, H. Schnoor, *Control of Condorcet voting: Complexity and a relation-algebraic approach,* 13th International Conference on Autonomous Agents and Multiagent Systems, Paris, France, 05.-09.05.2014

R. Berghammer, *Relation algebra,* RelView *and plurality voting,* 16th International Workshop on Computer Algebra in Scientific Computing, Warsaw, Poland, 08.-12.09.2014

R. Berghammer, S. Bolus, *ROBDD-based computation of sets of minimal and maximal sets with applications,* 11th International Workshop on Boolean Problems, TU Bergakadiemie Freiberg, Germany, 17.-19.09.2014

N. Danilenko, *Searching Disjoint Paths Functionally,* 31. Workshop der GI-Fachgruppe Programmiersprachen und Rechenkonzepte, Physikzentrum Bad Honnef, Germany, 28.-30.04.2014

N. Danilenko, *Graph Problems and Vector-Matrix Multiplication in Haskell,* 15th Symposium on Trends in Functional Programming (TFP 2014), Utrecht University, Soestenberg, The Netherlands, 26.-28.05.2014

N. Danilenko, *Functional Kleene Closures,* 24th International Symposium on Logic-Based Program Synthesis and Transformation (LOPSTR 2014), University of Kent, Canterbury, United Kingdom, 09.-11.09.2014

N. Danilenko, *Exploring Non-Determinism in Graph Algorithms,* 23rd International Workshop on Functional and (Constraint) Logic Programming (WFLP 2014), HTWK Leipzig, Lutherstadt Wittenberg, Germany, 15.-17.09.2014

## Further Activities and Events

R. Berghammer, N. Danilenko and I. Stucke worked as reviewers for various scientific publications.

R. Berghammer visited the NICTA institute (Sydney, Australia) and the School of Computer Science (Adelaide, Australia) from February 21 to March 9, 2014.

R. Berghammer is a member of the international working group "Relational Methods in Computer Science". He is the chair of the Steering Committee of the conference series "Relational and Algebraic Methods in Computer Science" (RAMiCS) and one of the editors of the electronic journal "Journal on Relational Methods in Computer Science".

In 2014 R. Berghammer was a member of several conference programme committees: the 14th International Conference RAMiCS, that took place in Marienstatt from April 28 to May 1, 2014, the 11th IWSBP, that took take place in Freiberg from September 17 to 19, 2014, and the 12th International Conference AISC, that took place in Seville, Spain, from December 11 to 13, 2014.

Currently, R. Berghammer is a member of several other programme committees: the 15th International Conference RAMiCS, that will take place in Braga, Portugal, from September 28 to October 2, 2015, the workshop SKILL 2015, that will take place in Cottbus from October 1 to 2, 2015, and the workshop KPS 2015, that will take place in Pörtschach, Austria, from October 5 to 7, 2015.

I. Stucke visited the NICTA Institute (Sydney, Australia) from February 21 to March 23, 2014.

Guests in 2013: G. Schmidt (München) from May 8 to 11, 2014, W. Guttmann (Christchurch, New Zealand) from April 7 to 13, 2014, and F. Neumann (Adelaide, Australia) from September 30 to October 2, 2014.

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# Computer Media

Prof. Dr. Klaus Tochtermann is Managing Director of the Leibniz Information Centre for Economics (ZBW - Deutsche Zentralbibliothek für Wirtschaftswissenschaften Leibniz-Informationszentrum Wirtschaft).

Further information about the Leibniz Information Centre for Economics is available on the web: http://www.zbw.eu/

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# Computer Science Education

The computer science education group mainly runs the high school teacher programme of the department.

## Personnel

Head of the group: Th. Wilke - in charge on behalf of the department;

Staff:

| | | |
|---|---|---|
| G. Braune (0,25 Abordnung) | 01.08.-31.12.2014 | CAU |
| Dr. rer. nat. D. Kähler (0,125 Abordnung) | 01.01.-31.12.2014 | CAU |
| Dr. rer. nat. L. Willert (0,25 Abordnung) | 01.01.-31.07.2014 | CAU |

## Lectures, Seminars, and Laboratory Course Offers

*Summer 2014*

Inf-FD1: Grundlagen fachbezogenen Lehrens und Lernens im Fach Informatik Seminar, 2 hrs Seminar/Week,
Detlef Kähler

Inf-FD4: Fachdidaktisches Urteilen und Forschen sowie Weiterentwicklung von Unterrichtspraxis, 2 hrs Lecture/Week,
Lars Willert

Seminar zu: Fachdidaktisches Urteilen und Forschen sowie Weiterentwicklung von Unterrichtspraxis (Sem.(Inf-FD4)), 2 hrs Seminar/Week,
Lars Willert

*Winter 2014/2015*

Inf-FD2: Planung, Durchführung und Analyse von Unterricht im Fach Informatik, 2 hrs Lecture/Week,
Detlef Kähler

Inf-FD3: Fachunterricht - Konzeption und Gestaltung im Fach Informatik, 2 hrs Lecture/Week,
Gert Braune

Seminar zu: Fachunterricht - Konzeption und Gestaltung im Fach Informatik (SemInfFD3), 2 hrs Seminar/Week,
Gert Braune

## Diploma, Bachelor's and Master's Theses

Ingo Czarnowski, *discipulus-duellum*, 08.10.2014
Jan Hittig, *Kommunikationssysteme im Unterricht*, 22.05.2014
Patrick Kellermann, *Unterricht zu Lego Mindstorms*, 05.12.2014
Eric Noske, *Ein Rollenspiel zum Thema Kommunikation im Fach Angewandte Informatik*, 18.11.2014
Julius Obermeit, *Einführung in Processing*, 13.10.2014
Yannick Schneider, *Spiele als didaktisches Werkzeug im Informatikunterricht*, 27.05.2014
Johanna Todt, *Ein Schülerarbeitsheft zur fortgeschrittenen visuellen Programmierung*, 06.06.2014

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# Dependable Systems

The Dependable Systems Group investigates *mathematical methods for the discovery and prevention of errors in computer systems.* Modern computer systems are too complex to guarantee a high level of safety (that is, correct functionality) by mere testing or code inspection. Our research helps us to find rigorous proofs, or at least strong indications, that a system possesses a certain safety feature or, in the case where it does not, to deliver a counter example. Formal methods not only serve to discover errors in software but also prevent them from being introduced in the first place. The first stage of fixing the functionality of software is the definition of requirements. This process of formalizing an initially informal idea is a fascinating research field which we pursue from a mathematical point of view. In particular, we work in the field of formal specification and verification, model-checking, and the satisfiability problem of certain logics.

Another field of research of our group is the investigation of *algorithmic and combinatorial problems of sequential structures.* Sequences are the most basic, nontrivial structures. Research on finding ways to efficiently transform, search, compress, generate, and analyse sequences is fundamental with an extremely wide application area.

## Results

### Verification of Concurrent Systems

We consider the problem of software safety in the context of embedded multi-core systems. Embedded systems are often used in safety critical applications, like airbag systems in cars or aircraft controllers. There exists a variety of methods for preventing and detecting errors in embedded code. For single-core systems such methods have worked reasonably well in practice, however, the introduction of multicore embedded systems changes the situation drastically since programs are executed in parallel on the same system now. The most prominent error class introduced with such parallelism is called a race condition. Race conditions occur when two or more processes compete for a resource in an unregulated, and hence unpredictable, fashion. Such errors are extremely hard to detect by testing or code inspection alone. Therefore we investigate formal methods to analyse concurrent systems so that race conditions are reliably detected. These analysis methods are aimed at, and tailored for, real-world industrial applications. They can be used to consider other kinds of concurrent systems but here we chose to deal with the particularities of an application to the embedded systems world. The goal is to construct a method (and the appropriate tool support) that finds race conditions reliably.

We consider the problem in two stages: firstly, we investigate a fast but only approximative preprocessing step to detect possible error candidates, and secondly, we consider a particular error candidate and verify it with a precise but computationally expensive procedure. Appropriate to these two analysis steps, we have implemented our algorithms in two tools GROPIUS and MEMICS, respectively.

GROPIUS is a tool to execute preprocessing steps of low computational complexity in order to limit the analysis problem size as much as possible to its core. This preprocessing step is very fast but approximate; that means, it delivers error-candidates which may include so called false- positives. It is our goal to limit the number of false- positives as much as possible by sophisticated but fast heuristics. In practice, a total elimination of false-positives is neither possible, since the definition of error often depends on a larger engineering context which is not information that the verification tool has, nor necessary, since GROPIUS is meant to be employed in an interactive process with a software engineer. In that scenario, a tool that allows critical parts of the code to be considered quickly and is equipped with a comfortable user interface is important to achieve the goal of improved software quality in an industrial context.

MEMICS implements an interval constraint solving algorithm for code analysis. This approach has a very high (exponential) worst case complexity. Our goal is to push the borders of using such formal methods to such a degree that real-world industrial code can be verified with reasonable efforts. There are several strategies that we employ and implement in our verification tool MEMICS. We optimise our solver to work best on constraints that are generated from actual software and are not random. Constraints that model actual programs have a certain implicit structure that distinguishes them

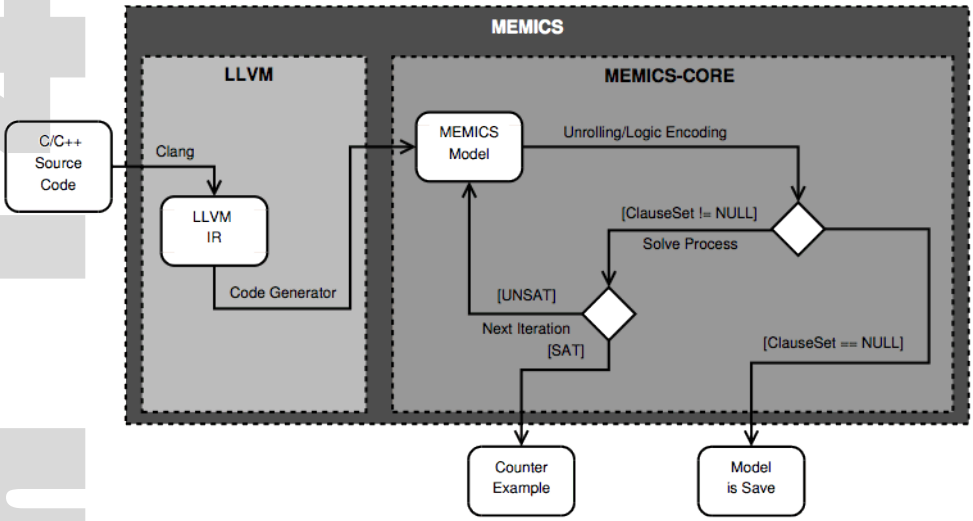


Fig. 1: An overview of the structure of MEMICS.

from other possible inputs. Our tool should work well on such special inputs instead of all possible inputs. Moreover, we embedded the theory of memory arithmetics and access into the core of our solver in order to limit the size of the input model. Traditionally, the entire computational environment of a program is modelled in the logic of a constraint solver, which increases the model considerably. We try to circumvent that problem with our approach. The tools GROPIUS and MEMICS are developed together with an industrial partner within the BMBF ARAMiS research project.

### High Performance Software Verification

The formal verification of software is a method for gaining more trust in safety critical systems that is rapidly growing in importance, as outlined in the previous paragraph. A precise analysis is only possible by applying formal methods. A core technique in that approach involves constraint solving procedures. These (decision) procedures for certain suitable logics are powerful but also of high algorithmic complexity. In fact, their asymptotic worst case complexity is exponential in most cases. Therefore, there is no hope in applying this approach to all possible input instances. Yet, the advantages of the approach in terms of the precision of the analysis make it indispensable. On the positive side, growth occurs not just in the complexity of the analysed systems but also the performance of computers.

In recent decades that speed-up was mainly due to faster processing units and expanded memory; new hardware increased the speed of solvers, basically without any modification of the implementation. However, that situation has changed drastically. Currently, a computational speed-up is achieved by parallel hardware only. Ranging from desktop computers to simple smart phones, parallel processing units are employed. The number of processor cores has replaced the clock speed as a measure of performance. That means that tools that are to take advantage of faster computers need to employ algorithms that work in parallel. In the field of constraint solving so far, parallel approaches can mostly be found only in a very mild form, for example, solvers working on quad-core PCs. Scaling up such programs is a nontrivial task. In fact, new algorithms and approaches are needed. We have investigated approaches for constraint solvers especially designed for massively parallel hardware.

One project focused on large shared-memory computers like the CRAY XMT. We did this for two reasons: firstly, the low data locality of constraint satisfaction problems indicates a shared memory for a first approach, and secondly, current developments suggest that future PCs will employ architectures using a shared memory, as seen in modern CPUs and coprocessors such as the recent Intel Xeon Phi. Developing efficient verification tools on a CRAY supercomputer may therefore lead the way to efficient verification tools on future consumer hardware.

Another approach is our tool TOPOSAT which is a distributed SAT-solver that has been developed to investigate different

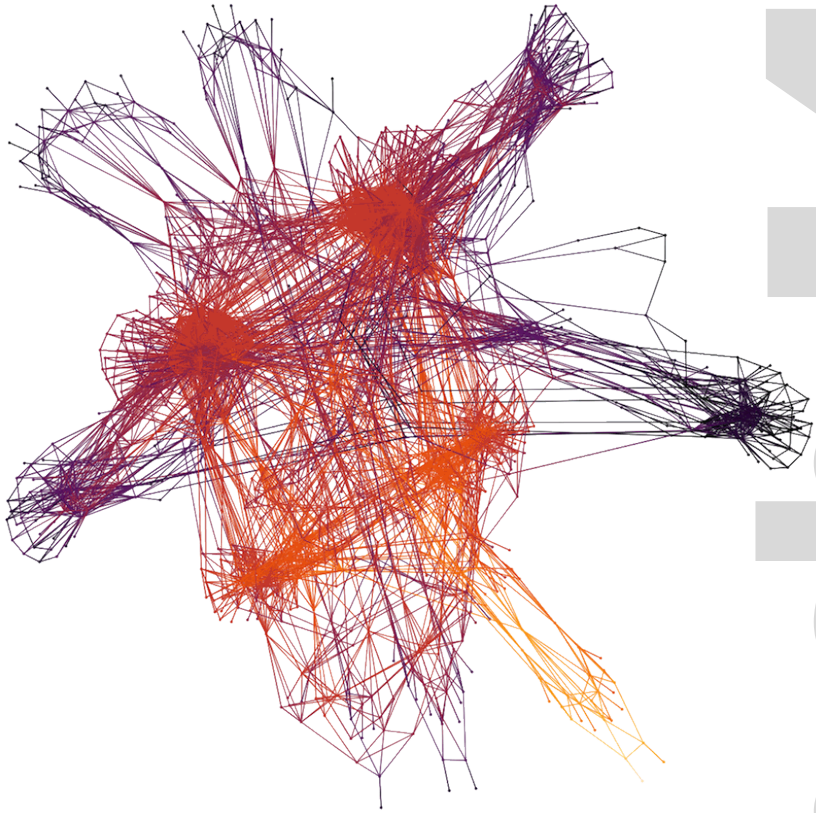

Fig. 2: The dependency graph of a verification problem.

communication patterns between the distributed nodes. First trials have been successful with respect to the speed-up of up to a few hundred nodes (more has not been available to us so far) and in suggesting an efficient communication topology for the exchange of learnt clauses for solving so called ''structured'' SAT-problems.

### Algorithms on Sequences

Sequences of symbols of a finite alphabet are the most fundamental nontrivial data structure. The examples range from bit streams in data communication, text, and speech processing to RNA sequences in molecular biology, and number theoretical questions in mathematics. Algorithmic questions on sequences arise therefore in many areas. Search, pattern matching, encodings, and sequence alignments are tasks that frequently occur and need to be computed efficiently. Naturally, algorithms on sequences have been investigated for a long time. However, many new questions emerge with new applications of data processing: for example the handling of large genomic data bases in microbiology, or fast online pattern matching for monitoring data streams.

One particular area of interest for us is the detection of repetitions in sequences, modulo morphic or antimorphic permutations. A morphic permutation is the extension of a permutation on the alphabet to sequences over that alphabet. In other words, a morphic permutation is a function that takes a sequence and gives a sequence of the same length generated by permuting the letters (not the positions of letters!) of the input. In the antimorphic case, the same happens but additionally the order of letters is reversed, like reading a word from right to left instead of the conventional left to right direction. A well-known instance of an antimorphic permutation (involution in fact) is the Watson-Crick complement of the DNA polymerase.

Matching patterns in some way parametrized by permutations, or more general morphisms and antimorphisms, is a largely unexplored field which we investigate. Repetitions modulo permutations have many facets ranging from genomic data to

musical forms. In particular, the newly developing field of digital sciences, where more and more scientific progress is made by the computational analysis of huge amounts of experimental data, promises a wide area of applications of these new and more general matching algorithms. Considerable progress was made by our group in 2014 in the investigation of algorithms on sequences, as documented by a number of publications.

### Combinatorics on Words

Combinatorics on words is the field of investigation of properties of sequences. The motivation for dealing with sequential structures has been indicated in the paragraph above by pointing out the ubiquity of those structures and the need to understand and process them. In fact, combinatorics on words provides the theoretical foundation for algorithms on sequences. Consequently, much of our work in 2013 was focused on questions involving morphic and antimorphic permutations. In particular, avoidance questions were discussed, i.e. questions on whether certain repetitions under permutations can be avoided in a sequence at all. Moreover, the inferences of different pseudo-periods (periods modulo morphisms and antimorphisms) were investigated.

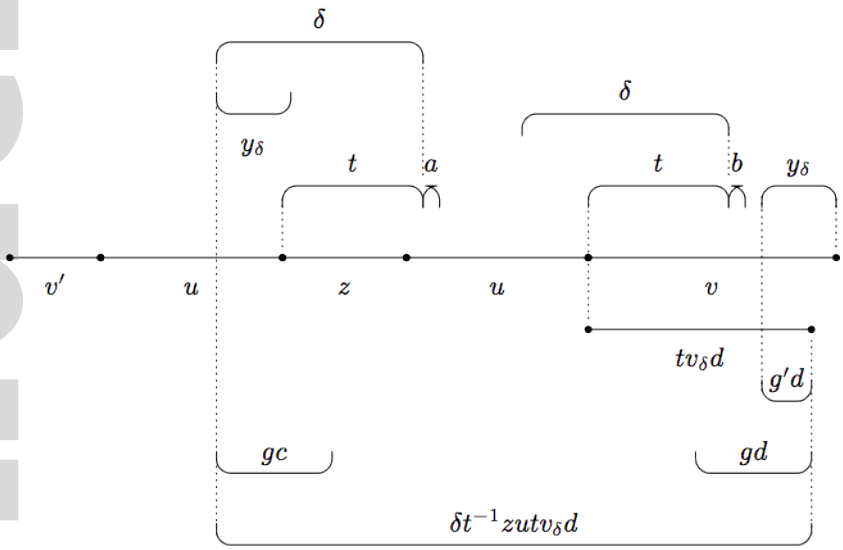


Fig. 3: Some word factorisation.

When the application of processing of real world data from application areas like microbiology is considered, one often has to deal with imperfect data, that is, sequences that contain false or incomplete information due to sensoric or experimental conditions. The investigation of partial words, that is words that contain undefined positions, addresses this fact.

Moreover, we were able finally to give a complete characterization of the pseudo-periodic extension of the so called Lyndon-Schutzenberger equation, a problem which has been open for some time. The final proof resulted in a paper of 47 pages.

## Personnel

Head of the group: Prof. Dr. D. Nowotka; Secretary: G. Walsdorf (50%)

Scientific Staff:

M.Sc. T. Ehlers 01.01.-31.12.2014
BMBF

| | |
|---|---|
| Dr. F. Manea<br>DFG | 01.01.-31.12.2014 |
| Dr. R. Mercas<br>DAAD P.R.I,M.E. | 01.09.-31.12.2014 |
| Dr. R. Mercas<br>DFG | 01.01.-28.02.2014 |
| Dipl.-Inf. M. Müller<br>DFG | 01.01.-31.12.2014 |
| Dipl.-Inf. P. Sieweck<br>BMBF | 01.01.-31.12.2014 |

## Lectures, Seminars, and Laboratory Course Offers

*Winter 2013/2014*

Inf-EntVerf: Entscheidungsverfahren, 3 (+1) hrs Lecture (+ Exercises)/Week,
D. Nowotka

Inf-SWT: Softwaretechnik, 4 (+2) hrs Lecture (+ Exercises)/Week,
D. Nowotka (+ Nils Ehmke, Jan Waller)

Inf-HPC: Hochleistungsrechnen, 2 (+1) hrs Lecture (+ Exercises)/Week,
D. Nowotka (+ S. Christophersen)

Inf-Sem-FSV: Formale Softwareverifikation, 2 hrs Seminar/Week,
D. Nowotka

Inf-AlgSeq: Algorithms on Sequences, 2 (+1) hrs Lecture (+ Exercises)/Week,
F. Manea

*Summer 2014*

Inf-Sem-Sequenzen: Algorithmik und Kombinatorik von Sequenzen, 2 hrs Seminar/Week,
D. Nowotka

NF-Inf-2: Systematisches Programmieren, 2 hrs Seminar/Week,
D. Nowotka

Inf-CombWords: Combinatorics on Words, 2 (+1) hrs Lecture (+ Exercises)/Week,
D. Nowotka

Inf-AlgSpec: Algebraic Specification, 2 (+1) hrs Lecture (+ Exercises)/Week,
F. Manea

*Winter 2014/2015*

Inf-GSoZu: Grundlagen der Softwarezuverlässigkeit, 4 (+2) hrs Lecture (+ Exercises)/Week,
D. Nowotka

Inf-AlgSeq: Algorithms on Sequences, 2 (+1) hrs Lecture (+ Exercises)/Week,
F. Manea

Inf-Sem-FSV: Formale Softwareverifikation, 2 hrs Seminar/Week,
D. Nowotka

## Third-Party Funds

DFG, *Heisenberg-Professorship*, 15.11.2011-31.07.2014 (324,800 EUR)
DFG, *Heisenberg-Professorship*, 01.08.2014-31.07.2016 (187,300 EUR)
DFG, *Combinatorial Aspects of Words and their Applications*, 01.05.2011-31.10.2014 (365,000 EUR)
DFG, *Combinatorial Aspects of Words and their Applications*, 01.11.2014-31.10.2016 (320,400 EUR)
DFG, *Algorithmic Combinatorics on Sequences*, 01.05.2013-30.04.2016 (192,900 EUR)
BMBF, *ARAMiS - Automotive, Railway and Avionics Multicore Systems*, 01.04.2012-30.11.2014 (327,030 EUR)
BMBF, *ARAMiS - Automotive, Railway and Avionics Multicore Systems*, 01.12.2014-31.03.2015 (34,860 EUR)
DAAD, *P.R.I.M.E.*, 01.09.2014-28.02.2016 (109,673 EUR)

## Further Cooperation, Consulting, and Technology Transfer

Academic cooperation:

- Charles University of Prague, Czech Republic (Prof. Dr. Dr. Stepan Holub),
- Turku University, Finland (Prof. Dr. Tero Harju, Prof. Dr. Juhani Karhumäki),
- University of Winnipeg, Canada (Prof. Dr. James Currie),
- University of Bucharest, Romania (Prof. Dr. Victor Mitrana).

Industrial cooperation and technology transfer:

- Daimler AG (R&D) and 20 more companies within the BMBF ARAMiS project.

## Diploma, Bachelor's and Master's Theses

D. Sen, *SAT-Solven auf verteilten Systemen - Untersuchung und Optimierung von Topologien*, 31.08.2014
N. Tavares de Sousa, *Untersuchung eines Ansatzes zum Lösen von SAT-Problemen auf einer Cray XMT*, 30.09.2014

## Dissertations / Postdoctoral Lecture Qualifications

M. Müller, *Avoiding and Enforcing Repetitive Structures in Words*, 17.11.2014

## Publications

Published in 2014

T. Ehlers, D. Nowotka, P. Sieweck, *Communication in Massively-Parallel SAT Solving*, IEEE International Conference on Tools with Artificial Intelligence (ICTAI), 709 - 716 (2014)
F. Manea, M. Müller, D. Nowotka, S. Seki, *Generalised Lyndon-Schützenberger Equations*, Mathematical Foundations of Computer Science (MFCS), Lecture Notes in Computer Science, **8634**, 402 - 413 (2014)
T. Ehlers, D. Nowotka, P. Sieweck, J. Traub, *Formal software verification for the migration of embedded code from single- to multicore systems*, Software Engineering (SE), LNI, **227**, 137 - 142 (2014)
T. Ehlers, F. Manea, R. Mercas, D. Nowotka, *k-Abelian Pattern Matching*, Developments in Language Theory (DLT), Lecture Notes in Computer Science, **8633**, 178 - 190 (2014)
T. Ehlers, D. Nowotka, P. Sieweck, *Finding race conditions in real-time code by using formal software verification*, FORMS/FORMAT, 1 - 8 (2014)

M. Dumitran, J. Gil, F. Manea, V. Mitrana, *Bounded Duplication Languages,* International Conference on Implementation and Application of Automata (CIAA), Lecture Notes in Computer Science, **8587**, 176 - 187 (2014)
P. Gawrychowski, F. Manea, D. Nowotka, *Testing Generalized Freeness of Words,* Symposium on Theoretical Aspects of Computer Science (STACS), LIPIcs, **25**, 337 - 349 (2014)
N. Jonoska, F. Manea, S. Seki, *Stronger Square Conjecture on Binary Words,* International Conference on Current Trends in Theory and Practice of Computer Science (SOFSEM), Lecture Notes in Computer Science, **8327**, 339 - 350 (2014)
H. Bordihn, F. Manea, V. Mitrana, D. Voinescu, *Two Variants of Synchronized Shuffle on Backbones,* Discrete Mathematics and Computer Science, 77 - 87 (2014)
F. Manea, R. Mercas, C. Tiseanu, *An Algorithmic Toolbox for Periodic Partial Words,* Discrete Applied Mathematics, **179**, 174 - 192 (2014)
S. Fazekas, F. Manea, R. Mercas, K. Shikishima-Tsuji, *The Pseudopalindromic Completion of Regular Languages,* Information and Computation, **239**, 222 - 236 (2014)
J. Garcia Lopez, F. Manea, V. Mitrana, *Prefix-Suffix Duplication,* Journal of Computer and System Sciences, **80**, 1254 - 1265 (2014)
F. Manea, B. Truthe, *Accepting Networks of Evolutionary Processors with Subregular Filters,* Theory of Computing Systems, **55**, 84 - 109 (2014)
J. Dassow, F. Manea, R. Mercas, *Regular Languages of Partial Words,* Information Sciences, **268**, 290 - 304 (2014)
L. Dinu, R. Gramatovici, F. Manea, *Syllabic languages and go-through automata,* Fundamenta Informaticae, **131**, 409 - 424 (2014)
D. Diaconescu, F. Manea, A. Paun, M. Popescu, *Proceedings of DAC4S,* Annals of the University of Bucharest (computer science series), (201)
M. Crochemore, J. Currie, G. Kucherov, D. Nowotka, *Combinatorics and Algorithmics of Strings (Dagstuhl Seminar 14111),* Dagstuhl Reports, **4**, 28 - 46 (2014)

## Presentations

D. Nowotka, *Communication in Massively-Parallel SAT Solving,* IEEE International Conference on Tools with Artificial Intelligence (ICTAI), Limassol, Cyprus, 10.-12.11.2014
F. Manea, *Generalised Lyndon-Schützenberger Equations,* Mathematical Foundations of Computer Science (MFCS), Budapest, Hungary, 25.-29.08.2014
T. Ehlers, *Formal software verification for the migration of embedded code from single- to multicore systems,* Software Engineering (SE), Kiel, Germany, 25.-28.02.2014
D. Nowotka, *k-Abelian Pattern Matching,* Developments in Language Theory (DLT), Ekaterinburg, Russia, 26.-29.08.2014
P. Sieweck, *Finding race conditions in real-time code by using formal software verification,* FORMS/FORMAT, Braunschweig, Germany, 30.09.-02.10.2014
F. Manea, *Bounded Duplication Languages,* International Conference on Implementation and Application of Automata (CIAA), Gießen, Germany, 30.07.-02.08.2014
F. Manea, *Testing Generalized Freeness of Words,* Symposium on Theoretical Aspects of Computer Science (STACS), Lyon, France, 05.-08.03.2014
F. Manea, *Stronger Square Conjecture on Binary Words,* International Conference on Current Trends in Theory and Practice of Computer Science (SOFSEM), Nový Smokovec, Slovakia, 25.-30.01.2014

## Further Activities and Events

All members of the group served as reviewers for several international conferences and journals.

D. Nowotka co-organised, together with M. Crochemore (King's College, London, UK), J. Currie (University of Winnipeg, Manitoba, Canada), and G. Kucherov (University Paris-Est - Marne-la-Vallée, France) the seminar "Combinatorics and

Algorithmics of Strings'' at Schloss Dagstuhl, Germany, from March 9-14.

D. Nowotka acquired an SGI UV 2000 computer together with S. Börm and T. Slawig. The computer has 36 Intel Xeon processors with a total of 288 cores, 2.25 TB of RAM and 8 modules with special processing units (Nvidia K20x and Intel Xeon Phi). The necessary funds of 300,000 Euros were raised from the federal state of Schleswig-Holstein, the Petersen-Stiftung, and starting grants.

D. Nowotka has successfully passed the evaluation of the first period of his DFG Heisenberg-Professorship.

D. Nowotka has been elected to serve as a vice-dean of the Faculty of Engineering for two years starting from July 2014.

D. Nowotka organised the students' programme (Studierendenprogramm) track at the Software Engineering conference (SE 2014) in Kiel.

D. Nowotka has served as a programme committee member of ENVISION, DACS, DLT, and Informatik.

F. Manea served as a member of the steering committee of the CiE conference.

F. Manea organised and chaired the programme committee of the Romanian Theory Day in Computer Science in Bucharest, September 15-16.

T. Ehlers and P. Sieweck, mentored by D. Nowotka, received the special prize for computer science at the ''Ideeenwettbewerb Schleswig-Holstein'' for their project RaceGuard. RaceGuard is a tool and business idea to provide a service for verifying embedded software.

R. Mercas received a DAAD P.R.I.M.E. grant for a stay at King's College, London, UK, over 12 months and an additional 6 months at Kiel. Only 10% of applicants succeed in being awarded this grant.

# Discrete Optimization

Discrete or combinatorial optimization is a branch of mathematical optimization. It is concerned with solving discrete, finite optimization problems efficiently. ''Algorithm Engineering'' in discrete optimization is a key area of the discrete optimization group in Kiel.

Among our international collaborations a special focus is on Indo-German projects in Algorithm Engineering (DFG priority programme 1307).

The methods and results of modern discrete optimization touch many different areas of discrete mathematics and computer science, for example, combinatorics, graph theory, discrete probability theory, finite harmonic analysis, and the theory of complexity.

A central topic in discrete optimization is the design of efficient algorithms for NP-hard discrete optimization problems using sub-optimal paradigms such as randomization or approximation. Specific topics are:

- approximation algorithms,
- randomized and de-randomized algorithms,
- algorithms for multicast-networks,
- combinatorial and geometric discrepancy theory,
- combinatorial game theory, and
- discrete geometry.

## Results

A major focus of the group is on interdisciplinary research projects within the cluster of excellence ''The Future Ocean'', and further projects with economics, medicine, life sciences and industrial partners.

The group is part of several highly competitive research clusters. Among them are the DFG priority programme 1307 ''Algorithm Engineering'', the cluster of excellence ''The Future Ocean'', the DFG-DST Indo-German network on ''Algorithm Engineering'', and the DFG priority programme 1736 ''Algorithms for Big Data''.

In Kiel, the group is actively participating in the CAU research foci Kiel Marine Science (KMS) and Kiel Life Science (KLS). Prof. Srivastav is PI in the cluster of excellence ''The Future Ocean'' and coordinator (Sprecher) of the Research Platforms. He is member of the executive boards of ''The Future Ocean'' and KMS.

## Personnel

Head of the group: Prof. Dr. A. Srivastav; Secretary: A. Lochte-Holtgreven (50%)

Scientific Staff:

| | | | |
|---|---|---|---|
| MA A. Afanasyeva | 01.01.-31.12.2014 | | DFG (25%) |
| Algorithm Engineering | | | |
| Dr. M. El Ouali | 01.10.-31.12.2014 | | CAU (25%) |
| Engineering randomisierter Algorithmen für Optimierungsprobleme in Hypergraphen | | | |
| Dr. M. El Ouali | 01.01.-31.12.2014 | (50%) | DFG |
| Cluster of Excellence 'The Future Ocean', coordination Research Platform | | | |

| | | | |
|---|---|---|---|
| Dipl. Inf. Ch. Gießen | 01.01.-31.08.2014 | (50%) | CAU |
| Engineering von Matching u. Überdeckungsalgorithmen in großen Graphen und Hypergraphen | | | |
| Priv.-Doz. Dr. M. Gnewuch | 01.01.-31.12.2014 | | Guest professor |
| Hochdimensionale numerische Integration | | | |
| Priv.-Doz. Dr. G. Jäger | 01.01.-31.12.2014 | | Guest professor |
| Combinatorial Optimization (Umea University, Sweden) | | | |
| Dr. L. Kliemann | 01.01.-31.12.2014 | | CAU/DFG |
| Algorithms for Big Data | | | |
| Dipl. Math. P. Munstermann | 01.01.-31.12.2014 | (50%) | DFG / CAU |
| Engineering randomisierter Algorithmen für Optimierungsprobleme in Hypergraphen | | | |
| Dr. V. Sauerland | 01.01.-31.12.2014 | | DFG |
| Optimization in Marine Science, Cluster of Excellence 'The Future Ocean' | | | |
| MSc E. Shirazi | 01.01.-31.12.2014 | | |
| Algorithmic Game Theory | | | |
| MSc Mayank Singhal | 01.01.-31.12.2014 | (50%) | DAAD |
| Algorithm Engineering, Discrepancy Theory | | | |

## Lectures, Seminars, and Laboratory Course Offers

*Winter 2013/2014*

Graphentheorie, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
A. Srivastav (+ M. El Ouali)

Seminar Kombinatorik, 2 hrs Seminar/Week,
A. Srivastav

Fortgeschrittenenseminar: Algorithmen, Kombinatorik und Komlpexität, 2 hrs Seminar/Week,
A. Srivastav

Seminar Diskrete Mathematik, 2 hrs Seminar/Week,
A. Srivastav

Diskrete Probabilistische Methoden, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
A. Srivastav (+ A. Srivastav)

*Summer 2014*

Fortgeschrittenenseminar: Algorithmen, Kombinatorik und Komplexität, 2 hrs Seminar/Week,
A. Srivastav (+ A. Srivastav)

Seminar - Diskrete Mathematik, 2 hrs Seminar/Week,
A. Srivastav (+ A. Srivastav)

Masterprojekt ¨Algorithm engineering and discrete structures¨, 4 hrs Lecture/Week,
A. Srivastav

Kombinatorische Optimierung - Approximation and Randomization, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
A. Srivastav (+ M. El Ouali)

Kombinatorik, 2 hrs Seminar/Week,
A. Srivastav (+ A. Srivastav)

*Winter 2014/2015*

Graphentheorie, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
A. Srivastav (+ M. El Ouali)

Seminar Kombinatorik, 2 hrs Seminar/Week,
A. Srivastav

Theoretische Grundlagen der Informatik, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
A. Srivastav (+ H. Schnoor)

M.Sc. Project ¨Algorithms engineering and discrete structures¨, 4 hrs M.Sc. project/Week,
A. Srivastav

Fortgeschrittenenseminar - Algorithmen, Kombinatorik und Komplexität, 2 hrs Seminar/Week,
A. Srivastav

Diskrete Mathematik, 2 (+ 2) hrs Seminar (+ Exercises)/Week,
A. Srivastav (+ L. Kliemann)

## Third-Party Funds

DFG SPP 1307 Phase 2, *Engineering randomisierter Algorithmen für Optimierungsprobleme in Hypergraphen*, 01.10.2009-31.03.2014 (136000 Euro)
DFG, *Exzellenzcluster The Future Ocean - Optimization in Marine Science*, 01.01.2012-31.12.2016 (61.600 Euro)
DFG, *The Future Ocean - Research Platform Coordination*, 01.04.2009-31.10.2016 (117000 Euro)
DFG SPP 1307 Phase 3, *Engineering von Matching- und Überdeckungsalgorithmen in großen Graphen und Hypergraphen*, 25.08.2011-31.10.2014 (177650 Euro)
DFG SPP Phase 3 Teil 2, *Algorithm Engineering for Evolutionary Algorithms (Indo-German Project)*, 23.01.2012-23.01.2014 (19900 Euro)
DFG SPP KL2078/1, *Algorithm for Data Streaming Processing (Indo-German Project)*, 23.01.2012-23.08.2015 (12700 Euro)
DFG SPP 1736, *Algorithmic Foundation of Genome Assembly*, 01.08.2014-31.07.2017 (250000 Euro)
DFG SPP 1307 Phase 2, *Engineering randomisierter Algorithmen für Optimierungsprobleme in Hypergraphen*, 01.10.2009-31.03.2014 (136000 Euro)
DFG, *Exzellenzcluster The Future Ocean - Optimization in Marine Science*, 01.01.2012-31.12.2016 (61.600 Euro)
DFG, *The Future Ocean - Research Platform Coordination*, 01.04.2009-31.10.2016 (117000 Euro)
DFG SPP 1307 Phase 3, *Engineering von Matching- und Überdeckungsalgorithmen in großen Graphen und Hypergraphen*, 25.08.2011-31.10.2014 (177650 Euro)
DFG SPP Phase 3 Teil 2, *Algorithm Engineering for Evolutionary Algorithms (Indo-German Project)*, 23.01.2012-23.01.2014 (19900 Euro)
DFG SPP KL2078/1, *Algorithm for Data Streaming Processing (Indo-German Project)*, 23.01.2012-23.08.2015 (12700 Euro)

## Further Cooperation, Consulting, and Technology Transfer

The group cooperates with the following individuals and organizations:

DFG-DST project on ''Algorithms for Data Stream Processing'', PIs: L. Kliemann (CAU) and S. Ganguly (IIT Kanpur, India),

DFG-DST project on ''Engineering of Evolutionary Algorithms'', PIs: A. Srivastav and C. Patvardhan (DEI Dayalbagh, India),

N. Garg, Indo-German-Max-Planck-Centre for Computer Science (IIT Delhi, India),

E. Bampis, Université Pierre et Marie Curie (Paris, France).

## Diploma, Bachelor's and Master's Theses

O. Schink, *Der Price of Anarchy und die Komplexität von stabilen Graphfärbungen, Masterthesis,* 22.09.2014

## Publications

Published in 2014

W. Chen, A Srivastav, G. Travaglini, *A Panorama of Discrepancy Theory*, Springer International Publishing, Series: Lecture Notes in Mathematics, Vol. 2107, 1 - 695 (2014)

N. Hebbinghaus, A. Srivastav, *Multicolour Discrepancy of Arithmetic Structures,* in: A Panorama of Discrepancy Theory, W.W.L. Chen, A. Srivastav, G. Travaglini (eds.), 319 - 424 (2014)

L. Kliemann, *Practical Algorithms for Low-Discrepancy 2-Colourings,* in: A Panorama of Discrepancy Theory, W.W.L. Chen, A. Srivastav, G. Travaglini (eds.), 459 - 484 (2014)

C. Patvardhan, S. Bansal, A. Srivastav, *Balanced Quantum-Inspired Evolutionary Algorithm for Multiple Knapsack Problem,* International Journal of Intelligent Systems and Applications, **Volume 6, Issue 11**, 1 - 11 (2014)

C. Patvardhan, S. Bansal, A. Srivastav, *Solution of ´Hard´ Knapsack Instances Using Quantum Inspired Evolutionary Algorithm,* International Journal on Applied Evolutionary Computation, **Volume 5, Issue 1**, 52 - 68 (2014)

A. Baltz, M. El Ouali, G. Jäger, V. Sauerland, A. Srivastav, *Exact and heuristic algorithms for the Travelling Salesman Problem with Multiple Time Windows and Hotel Selection,* Journal of the Operational Research Society, (2014)

N. Hebbinghaus, A. Srivastav, *Discrepancy of Centred Arithmetic Progressions in* $\mathbf{Z}_p$, European Journal of Combinatorics, **35**, 324 - 334 (2014)

M. El Ouali, P. Mustermann, A. Srivastav, *Randomized Approximation for the Set Multicover Problem in Hypergraphs,* Algorithmica, (2014)

M. El Ouali, H. Fohlin, A. Srivastav, *An approximation algorithm for the partial vertex cover problem in hypergraphs,* Journal of Combinatorial Optimization, (2014)

M. El Ouali, H. Fohlin, A. Srivastav, *A randomised approximation algorithm for the hitting set problem,* Theor. Comput. Sci., 23 - 24 (2014)

Ch. Gießen, T. Kötzing, *Robustness of Populations in Stochastic Environments,* Proc. of GECCO (Genetic and evolutionary computation), 1383 - 1390 (2014)

## Presentations

A. Srivastav, *Randomized Approximation for the Multiset Cover problem in Hypergraphs,* Université Pierre et Marie Curie, Paris, France, 30.-30.04.2014

A. Srivastav, *Randomized Algorithms for Covering Problems,* Faculty of Science, Deemed University Dayalbagh Educational Institute, Agra, India, 13.-13.03.2014

A. Srivastav, *Streaming Algorithms for genome Assembly,* High-Performance Graph algorithms and Applications in Computional Science, Leibniz-Zentrum für Informatik, Schloss Dagstuhl, Germany, 09.-14.11.2014

A. Srivastav, *Algorithmic Foundation of Genome Assembly,* Faculty of Science, Deemed University Dayalbagh Educational Institute, Agra, India, 18.-18.10.2014

A. Srivastav, *Algorithmic Foundation of Genome Assembly,* Annual Meeting DFG SPP 1736 ¨Algorithms for Big Data¨, Wolfgang Goethe-Universität Frankfurt am Main, Germany, 29.09.-01.10.2014

L. Kliemann, *Price of Anarchy in Link Destruction (Adversary) Model*, OR 2014, invited Presentation, Aachen, Germany, 03.-03.09.2014

L. Kliemann, *Algorithms for Graph and Data Streams*, ICES ASC2014, Open Session for Big Data, La Coruna, Spain, 17.-17.09.2014

V. Sauerland, *Mathematical Optimization in Marine Science*, Future Ocean Retreat, Post Doc Project Espresso, Schleswig, Germany, 29.-29.09.2014

Ch. Gießen, *Robustness of Populations in Stochastic Environments*, 67. Workshop über Algorithmen und Komplexität (Theorietag), CAU, Kiel, Germany, 22.-22.05.2014

## Further Activities and Events

V. Sauerland: Visit to Dayalbagh Educational Institute, Deemed University, Dayalbagh, Agra, India, 02.05-14.05.2014

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# Information Systems Engineering

Research and teaching in the department of Information Systems Engineering concentrate on the following topics:

- integrated development of information systems based on co-design of structuring, functionality, distribution, and interaction,
- theory of models, modelling, and conceptual modelling,
- intelligent information systems, and intelligent data exploration,
- theory of database systems, and semantics of databases,
- analysis and prediction of crystal structures,
- theory and technology of content management systems,
- development, languages, methodologies, and programming of web information systems and the knowledge web,
- migration, evolution, performance assessment, forecasting, and tuning for large database applications.

## Results

### Theory of models and modelling

Conceptual modelling is one of the central activities in Computer Science. A theory of conceptual models and a theory of modelling acts have been developed in our group. They are based on a general theory of modelling as an art, an apprenticeship, and a technology. Modelling is based on an explicit choice of languages, on application of restrictions, on negotiation, and on methodologies. Languages are defined through their syntactics, semantics, and pragmatics. Modelling is a process and is based on modelling acts. These modelling acts are governed by the purpose of modelling itself and of the model or models.

Conceptual modelling has changed over the years. Nowadays small scale conceptual modelling has become state-of-the-art for specialists and educated application engineers. Large scale conceptual modelling has been developed mainly within companies that handle large and complex applications. It covers a large variety of aspects such as models of structures, of business processes, of interaction between applications and with users, of components of systems and abstractions, or of derived models such as data warehouses and OLAP applications. We developed new architectural techniques for large scale conceptual modelling.

In software and information systems development different aspects and facets of the system being developed are usually analyzed and modelled independently from each other. A recurring challenge is the integration of the different partial models of the software system into one single consistent model. With the notion of model suites we introduce an approach which can be used to integrate heterogeneous models, to check consistency between those models, and to facilitate a consistent evolution of them. Model suites are based on explicit controllers for maintenance of coherence. They apply application schemata for their explicit maintenance and evolution, use tracers for establishment of their coherence, and thus support co-evolution of information system models. The use of model suites helps to minimize or completely avoid the risks, ambiguities, and contradictions that normally result from the parallel use of different modelling languages and modelling tools.

### BPMN (Business process modelling and notation)

An abstract model for the dynamic semantics of the core process modelling concepts in the OMG standard for BPMN 2.0 has been created based on the development of a complete formalization of BPMN 1.0 and 1.1 that is the result of an international collaboration over the last few years. The UML class diagrams associated therein with each flow element are

extended with a rigorous behaviour definition, which reflects the inheritance hierarchy structure by refinement steps. The correctness of the resulting precise algorithmic model for an execution semantics for BPMN can be checked by comparing the model directly with the verbal explanations in the BPMN standard. Thus, the model can be used to test reference implementations and to verify properties of interest for (classes of) BPMN diagrams. Based on the model a native BPMN 2.0 Process Engine and a BPMN debugger have been implemented.

### Co-design of structuring, functionality, interaction and distribution of information systems

Traditional software engineering and information systems engineering are structured, comprising requirements analysis and definition, systems design, systems implementation and testing, and systems operation and maintenance. For web information systems the traditional approach s hindered by three obstacles: late integration of architectural decisions, neglect of user expectations, and late implementations. The co-design approach integrates application domain description with development of presentation and information systems. At the same time the specification is executable due to our simulation system. The co-design methodology has been assessed by the SPICE committee and has been evaluated to be one of the first methodologies at maturity level 3. The methodology has been extended to web information systems. Coherence and co-existence of UML diagrams can be based on a global ASM-backed systems model. This model supports co-evolution and co-development of sets of UML diagrams. Component systems are becoming the main approach for efficient and effective development of large systems. Based on the approaches to application modelling that have been developed in the department in the past, an approach to component-based information systems has been developed and tested in application projects. The theory of component systems has been extended by facilities for view exchange among components.

### Data mining design

Data mining algorithms aim to provide some means to expose the hidden information behind data. However, considering a particular problem statement raises the question as to which algorithm should be employed, and moreover, how and which processing steps should be nested to convey a target-aimed knowledge discovery process. Present approaches, such as the CRISP-DM, are mainly focused on the management or description of such processes but they do not really describe how such a discovery process should be designed. A novel framework has been developed that aims at the design of knowledge discovery processes where the prior knowledge of a user and his goals are central to the process design.

### Database technology

Many modern applications are becoming performance critical. At the same time, the size of some databases has been increasing to levels that cannot be well supported by current technology. Performance engineering has been ruled in the past mainly by reactive techniques such as performance monitoring. A new active method for performance improvement has been developed. One of the potential methods for active performance improvement is performance forecasting based on assumptions of future operations and on extrapolations from the current situation.

Exceptions are considered to be unusual states that could be, but must not be, taken primarily into account. They form exclusions, represent cases to which a rule does not apply, and form specific states that are not going to be handled (at least by the current system) or might represent legal objections against the typical state. Information systems architectures can be made more flexible to cope with exceptions in such a way that these systems become exception-aware, exception-reactive, and provide a management of exceptions in a coherent form.

Modernization of information systems is a fundamental but sometimes neglected aspect of conceptual modelling. The management of evolution, migration, and refinement and the ability for information systems to deal with modernization is an essential component in developing and maintaining truly useful systems that minimize service disruption and down-time, and maximize availability of data and applications. Migration and evolution are interwoven aspects. Migration strategies such as ''big bang'', ''chicken little'', and ''butterfly'' can be based on systematic evolution steps. Evolution steps use the theory of model suites.

Classical software development methodologies take architectural issues as given or pre-determined. Web information systems pay far more attention to user support and thus require sophisticated layout and playout systems. These systems go beyond what has been known for presentation systems. A framework has been developed that is based either on early architectural decisions or on integration of new solutions into existing architectures. It allows co-evolution of architectures and software systems.

### Database theory

The theory of integrity constraints has led to a large body of knowledge and many applications. Integrity constraints are however often misunderstood, are given in the wrong database context or within the wrong database models, often combine a number of very different facets of semantics in databases, and are difficult to specify. A unifying approach to specification and treatment of integrity constraints has been developed.

NULL is a special marker used in SQL to indicate that a value for an attribute of an object does not exist in the database. The three-valued and many-valued logics developed in the past do not properly reflect the nature of this special marker. To support this we introduce a non-standard generalization of para-consistent logics. These logics reflect the nature of these markers. The solutions developed can be used without changing database technology.

Modelling with multi-level abstraction refers to representing objects at multiple levels of one or more abstraction hierarchies, mainly classification, aggregation, and generalization. Multiple representation, however, leads to accidental complexity that complicates modelling and extension. A theory of m-objects has been developed that offers powerful techniques for modular and redundancy-free models, query flexibility, heterogeneous level-hierarchies, and multiple relationship-abstraction.

Local database normalization aims at the derivation of database structures that can be supported easily by the DBMS. Global normalization has not received appropriate attention in research despite the interest in its implementations. Our research on systematic treatment of this normalization resulted in new ER-based normalization techniques.

A general theory of database transformations defines the background for queries and updates, which are two fundamental types of computation in any database: the first provides the capability to retrieve data, and the second is used to maintain databases in the light of ever-changing application domains. In theoretical studies of database transformations, considerable effort has been directed towards exploiting the close ties between database queries and mathematical logics. It is widely acknowledged that a logic-based perspective for database queries can provide a yardstick for measuring the expressiveness and complexity of query languages.

Practical experience shows that the maintenance of very large database schemata causes severe problems and no systematic support is provided. Based on the analysis of a recent study, larger schemata may be built by composing smaller ones with frequently recurring meta-structures. Our approach leads to a category of schemata that is finitely complete and co-complete. We show that all constructors of the recently introduced schema algebra are well-defined in the sense that they give rise to schema morphism. The algebra is also complete in the sense that it captures all universal constructions in the category of schemata.

### Graph-based analysis of inorganic crystal structures and superconductivity

A crystal-chemical approach to high-temperature superconductivity has been applied to all data of the ICSD, the largest database for inorganic crystal structures (more than 170,000 entries). Data have been analysed with respect to the existence of infinite units of strongly overlapping orbitals (IUSOOs). The existence of IUSOOs in a structure is considered as a necessary condition for a crystal structure to become superconducting at low temperatures by doping and/or applying pressure. Much effort had to be made to control results with respect to plausibility and compare them with the open literature.
It could be shown that for cuprates as well as for iron pnictides the application of the approach to data available in the years 1985 (in 1986, the first high-temperature superconductor, a cuprate, was discovered) and 2007 (in 2008, the

first iron-based superconductor was found that was superconducting at high temperatures) results in lists with a very high percentage of structures discovered later to be superconductors or parent compounds of superconductors. The major goal now is to generate tables of potential superconductors for different classes of crystal structures covering the complete set of available data.
Bond valence parameters play an important role in the approach. Since such parameter values are not available for some interesting pairs of elements, we plan a recomputation of these values. As a first step, the systematic collection and storing of distance data and the computation and classification of coordination polyhedra has been implemented using database technology for flexible access.

### Information privacy

Privacy is becoming a major issue of social, ethical, and legal concern on the Internet. The development of information technology and the Internet have major implications for the privacy of individuals. A new conceptual model for databases that contain exclusively private information has been developed. The model utilizes the theory of infons to define "private infons", and develops taxonomy of these private infons based on the notions of proprietary possession. The proposed model also specifies different privacy rules and principles, derives their enforcement, and develops and tests architecture for this type of database. The model allows several variants for privacy supporting systems. The concept of privacy wallets has been implemented.

### Application of database techniques in pharmacovigilance

Large collections of reports describing adverse reactions that have been observed in connection with the application of pharmaceutical products are publicly available for evaluation. One of their major uses is the detection of signals in the data giving hints to adverse events in responses to drugs. A great problem with the largest data collection, which is offered by the Food and Drug Administration (FDA) of the United States, is the quality of data. This problem may cause wrong statistics and conclusions.

In close cooperation with the Institute of Experimental and Clinical Pharmacology of the CAU we have implemented a system called OpenVigil 2 that checks automatically all FDA-data for consistency thereby using information of trusted web sources for possible corrections. This process is conservative insofar as all data are rejected if corrections cannot be done in a way considered as unique. Data passing this cleansing step are stored in a database offering comfortable interfaces for users. Standard evaluation methods have been implemented and can be used with different parametrization.
OpenVigil 2 is freely available on the net and open-source. Currently we are working on the improvement of the cleansing process by using information of further web sources.

### Random databases

We consider stochastic modelling for databases with uncertain data and for some basic database operations (e.g. join, selection) with exact and approximate matching. Approximate join is used for merging data or removing duplication in large databases. Distribution and mean of the join sizes are studied for random databases. A random database is treated as a table with independent random records with a common distribution (or a set of random tables). Our results can be used for integration of information from different databases, multiple join optimization, and various probabilistic algorithms for structured random data.

### Quality management and assessment for information and software systems

The design and development of software and information systems coexist and co-evolve with quality provision, assessment and enforcement. However, most (including current) research provides only bread-and-butter lists of useful properties without giving a systematic structure for evaluating them. Software engineers have been putting forward numerous quantities of metrics for software products, processes and resources but a theoretical foundation is still missing. We developed and applied a framework for quality property specification, quality control, quality utilization, and quality

establishment. Our framework has a theoretical basis that is adaptable to all stages of software development.

### Web information systems

We developed a general specification method for clouds. Technically, we understand a cloud as a federation of software services that are made available via the web and can be used by any application. A common understanding in the web services community is that a service is defined as a function or operation with the appropriate input/output specification. We take a general view by regarding a service as a piece of software that not only provides functionality but also data. Services thus combine a hidden database layer with an operation-equipped view layer and can be anything from a simple function to a fully-fledged web information system or a data warehouse.

Web information systems should also support speech dialogues. Their workflow and supporting infrastructure can be specified by storyboards. The integration of speech dialogues is however an unsolved issue due to the required flexibility, wide variety of responses, and expected nativeness. Speech dialogues must be very flexible in both recognition of questions and in generation of appropriate answers. We thus introduce a pattern-based approach to specification and utilization of speech dialogues. These patterns reflect the dialogue speech since answers and responses with a speech dialogue are instantiations or refinements of these patterns. It is possible to create patterns for common dialogue-forms. The results of this work show that only small adaptations regarding the storyboard concept are necessary and the extension of the presentation layer with a channel-dependent renderer is sufficient to be able to model natural language dialogues.

The design and reification of web information systems is a complex task for which many integrated development methods have been proposed. While all these methods ultimately lead to the construction of web pages, very little attention is paid to the layout of these pages. Screenography developed in our group provides principles and rules for page layout that originate from knowledge of visual perception and communication; it then investigates how layout can support the intentions associated with the WIS. This amounts to guidelines for partitioning pages and using layout objects, colour, light, and texture to obtain rhythm, contrast, and perspective as the carriers for web page comprehension. We use a pattern approach to systematic development of laying and playouting. These patterns can be combined to larger complex patterns. Therefore, an algebra for pattern construction will be developed.

On a high level of abstraction the storyboard of a web information system specifies who will be using the system, in what way, and for which goals. Storyboard pragmatics deals with the question as to what the storyboard means for its users. One part of pragmatics is concerned with usage analysis by means of life cases, user models, and contexts. We also addressed another part of pragmatics that complements usage analysis by WIS portfolios. These comprise two parts: the information portfolio, and the utilization portfolio. The former is concerned with information consumed and produced by the WIS users, which leads to content chunks. The latter captures functionality requirements which depend on the specific category to which the WIS belongs.

## Personnel

Head of the group: Prof. Dr. B. Thalheim; Secretary: S. Jureit (50%)
Technical Staff: Steffen Gaede

Scientific Staff:

| | | |
|---|---|---|
| apl.-Prof. Dr. H.-J. Klein, | 01.01.-31.12.2014 | CAU |
| Dipl.-Inf. F. Kramer | 01.01.-31.12.2014 | CAU |
| Dipl.-Inf. O. Sörensen | 01.01.-31.07.2014 | CAU |
| Dipl.-Inf. M. Tropmann-Frick | 01.01.-31.12.2014 | AIF, CAU |

*Winter 2013/2014*

MSS0504: Oberseminar - Technologie der Informationssysteme, 2 hrs Seminar/Week,
H.-J. Klein, B. Thalheim

MS0506: Verteilte Informationssysteme, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
H.-J. Klein,

WInf-ISADD: IS Analysis, Design and Development, 3 (+ 2) hrs Lecture (+ Exercises)/Week,
B. Thalheim (+ O. Sörensen, F. Kramer)

WInf-MSc-Pro1: Projekt - Wirtschaftsinformatik, 5 hrs Exercise/Week,
B. Thalheim (+ F. Kramer)

WInf-MSc-Sem1: Interdisziplinäres Seminar (Informationssysteme), 4 hrs Seminar/Week,
B. Thalheim (+ F. Foders, F. Kramer)

WInf-WInf3: Wirtschaftsinformatik 3, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
B. Thalheim (+ F. Kramer)

Mathematik-Coaching Wirtschaftsinformatik, 4 hrs Exercise/Week,
B. Thalheim

*Summer 2014*

MSS0504: Oberseminar - Technologie der Informationssysteme, 2 hrs Seminar/Week,
H.-J. Klein, B. Thalheim

Data Mining, Data Application and Statistics (ISOS), 2 (+ 1) hrs Lecture (+ Exercises)/Week,
B. Thalheim (+ F. Kramer)

Inf-IS: Informationssysteme (DB), 4 (+ 2) hrs Lecture (+ Exercises)/Week,
H.-J. Klein (+ F. Kramer, P. Munstermann)

WInf-InfMan: Informationsmanagement, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
B. Thalheim (+ B. Thalheim)

WInf-ModIS: Modellierung von Informationssystemen, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
B. Thalheim (+ O. Sörensen)

WInf-MSc-Pro1: Projekt - Wirtschaftsinformatik (Informationssysteme), 5 hrs Exercise/Week,
B. Thalheim (+ F. Kamer)

WInf-Proj-BA2: Abschlussprojekt - Wirtschaftsinformatik (Informationssysteme), 4 hrs Exercise/Week,
B. Thalheim

WInf-Proj-InfSys: Projektgruppe Informationssysteme, 4 hrs Practical/Week,
B. Thalheim

WInf-WebInfSys: Web Information Systems, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
B. Thalheim (+ O. Sörensen)

*Winter 2014/2015*

MSS0504: Oberseminar - Technologie der Informationssysteme, 2 hrs Seminar/Week,
H.-J. Klein, B. Thalheim

MSP0501: Masterprojekt - Datenbankprogrammierung, 4 hrs Exercise/Week,
H.-J. Klein,

WInf-BAppE: Selected Topics in Business Application Engineering, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
B. Thalheim

WInf-DBProg: Datenbankprogrammierung, 2 (+ 2) hrs Lecture (+ Exercises)/Week,
B. Thalheim (+ M. Tropmann-Frick)

WInf-MSc-Pro1: Projekt - Wirtschaftsinformatik, 5 hrs Exercise/Week,
B. Thalheim (+ M. Tropmann-Frick)

WInf-MSc-Sem1: Interdisziplinäres Seminar (Informationssysteme), 2 hrs Seminar/Week,
B. Thalheim (+ M: Tropmann-Frick)

Mathematik-Coaching Wirtschaftsinformatik, 4 hrs Exercise/Week,
B. Thalheim

## Third-Party Funds

AIF, *ZIM - Zentrales Innovationsprogramm Mittelstand*, 01.01.-30.09.2014 (171.184,00 EUR)
DAAD, *Projektbezogener Personenaustausch mit Finnland - PPP Finnland*, 01.01.-31.12.2014 (9.654,00 EUR)

## Diploma, Bachelor's and Master's Theses

E. Belova, *Anwendungsspezifische Erfassung und Übertragung von Forschungsdaten*, 15.09.2014
S. Ben Slama, *Intelligente Suche*, 15.11.2014
M.-J. Friese, *Entwurf und Realisierung einer DB-Anwendung für die Analyse von Bindungsstärken in anorganischen Kristallstrukturen*, 15.09.2014
Y. Kropp, *Entwicklung einer Provenance-Metadatenbank-Komponente*, 15.09.2014
C. Llebers, *Visualisierung und Dokumentation von SQL-Anfragen*, 15.10.2014
S. Liermann, *Kulturabhängige E-Commerce Szenarien*, 15.10.2014
S. Masog, *Adaption und Verfeinerung abstrakter Handlungsabläufe zur automatischen Ausführung*, 01.12.2014
A. Nordmann, *Entwicklung einer Zeit-Metadaten-Komponente*, 16.09.2014
J. Ohlemacher, *Realisierung einer Adressverwaltung in heterogenen und sicherheitskritischen Kommunikationsnetzen*, 16.09.2014
F. Ralfs, *Konzeptbasierte Generierung von Anfrageoberflächen für wissenschaftliche Datenbanken*, 08.05.2014
N. Sasse, *Automatische Adaption von Workflow-Pattern*, 01.11.2014
F. Warthenpfuhl, *Entwicklung einer administrativen Metadaten-Komponente*, 15.09.2014

## Dissertations / Postdoctoral Lecture Qualifications

M. Berg, *Modelling of Natural Dialogues in the Context of Speech-based Information and Control Systems*, 24.07.2014

## Publications

Published in 2014

S. S. Bhowmick, C. Dyreson, C. S. Jensen, M. L. Lee, A. Muliantara, B. Thalheim, *Database Systems for Advanced Applications, 19th International Conference, DASFAA 2014*, Lecture Notes in Computer Science, **8421**, (2014)
F. Kramer, B. Thalheim, *Component-Based Development of a Metadata Data-Dictionary*, Lecture Notes in Business Information Processing, Springer, **176**, 110 - 121 (2014)

F. Kramer, B. Thalheim, *A Metadata System for Quality Management,* Information Modelling and Knowledge Bases XXVI, Frontiers in Artificial Intelligence and Applications, IOS Press, **272**, 224 - 242 (2014)

F. Kramer, O. Jäger, B. Thalheim, *Secure Data Storage and Exchange with a Private Wallet,* New Trends in Database and Information Systems II, Advances in Intelligent Systems and Computing, Springer, **312**, 59 - 70 (2014)

M. Tropmann-Frick, B. Thalheim, D. Leber, C. Liehr, G. Czech, *Generic Workflows - A Utility to Govern Disastrous Situations,* Information Modelling and Knowledge Bases XXVI, Frontiers in Artificial Intelligence and Applications, IOS Press, **272**, 417 - 428 (2014)

M. Tropmann-Frick, T. Ziebermayr, *Generic Approach for Dynamic Disaster Management System Component,* Proceedings of the 25th International Workshop on Database and Expert Systems Applications, IEEE Computer Society, 160 - 164 (2014)

B. Thalheim, *The Conceptual Model - An Adequate and Dependable Artifact Enhanced by Concepts,* Information Modelling and Knowledge Bases XXV, Volume 260 of Frontiers in Artificial Intelligence and Applications, IOS Press, 241 - 254 (2014)

R. Noack, B. Thalheim, *Multi-Dimensional Schema Composition for Conceptual Modelling in the Large,* Information Modelling and Knowledge Bases XXV, Volume 260 of Frontiers in Artificial Intelligence and Applications, IOS Press, 25 - 44 (2014)

S. Torge, W. Esswein, S. Lehmann, B. Thalheim, *Categories for Description of Reference Models,* Information Modelling and Knowledge Bases XXV, Volume 260 of Frontiers in Artificial Intelligence and Applications, IOS Press, 229 - 240 (2014)

B. Thalheim, M. Tropmann-Frick, T. Ziebermayr, *Application of generic workflows for disaster management,* Information Modelling and Knowledge Bases XXV, Volume 260 of Frontiers in Artificial Intelligence and Applications, IOS Press, 64 - 81 (2014)

H. Jaakkola, T. Nakanishi, S. Sasaki, K.-D. Schewe, B. Thalheim, *Conceptual Modelling of Collaboration for Information Systems,* Information Modelling and Knowledge Bases XXV, Volume 260 of Frontiers in Artificial Intelligence and Applications, IOS Press, 272 - 305 (2014)

H. Jaakkola, B. Thalheim, *Adaptive Systems for Multicultural Deployment,* Proceedings of the International Conference on Information Modelling and Knowledge Bases (EJC 2014), Kiel Computer Science Series, **4/2014**, 210 - 229 (2014)

M. Tropmann-Frick, B. Thalheim, D. Leber, G. Czech, C. Liehr, *Generic Workflows - A Utility to Govern Disastrous Situations,* Proceedings of the International Conference on Information Modelling and Knowledge Bases (EJC 2014), Kiel Computer Science Series, **4/2014**, 493 - 305 (2014)

F. Kramer, B. Thalheim, *A Metadata System for Quality Management,* Proceedings of the International Conference on Information Modelling and Knowledge Bases (EJC 2014), Kiel Computer Science Series, **4/2014**, 281 - 299 (2014)

B. AlBdaiwi, R. Noack, B. Thalheim, *Database Structure Modelling by Stereotypes, Pattern and Templates,* Proceedings of the International Conference on Information Modelling and Knowledge Bases (EJC 2014), Kiel Computer Science Series, **4/2014**, 1 - 19 (2014)

K. Jannaschk, H. Jaakkola, B. Thalheim, *A Framework for Systematic Change Management,* EuroSPI, Communications in Computer and Information Science, Springer, **425**, 60 - 72 (2014)

K. Jannaschk, H. Jaakkola, B. Thalheim, *Technologies for database change management,* New Trends in Database and Information Systems II, Advances in Intelligent Systems and Computing, Springer, **312**, 271 - 286 (2014)

B. Thalheim, *The pragmatic notion of information,* Annales Univ. Sci. Budapest., Sect. Comp, **43**, 69 - 87 (2014)

B. AlBdaiwi, R. Noack, B. Thalheim, *Pattern-Based Conceptual Data Modelling,* Information Modelling and Knowledge Bases XXV, Volume 260 of Frontiers in Artificial Intelligence and Applications, IOS Press, **272**, 1 - 20 (2014)

H. Jaakkola, B. Thalheim, *Multicultural Adaptive Systems,* Information Modelling and Knowledge Bases XXV, Volume 260 of Frontiers in Artificial Intelligence and Applications, IOS Press, **272**, 172 - 191 (2014)

F. Kramer, *Component-Based Development of a Metadata Data-Dictionary,* 17th International Conference on Business Information Systems BIS 2014, Larnaca, Cyprus, 22.-22.05.2014

F. Kramer, *A Metadata System for Quality Management,* 24th International Conference on Information Modelling and Knowledge Bases EJC 2014, Kiel, Germany, 03.-03.06.2014

B. Thalheim, *Privatsphäre oder Ego-Striptease im Internet,* Schleswig-Holsteinische Universitäts-Gesellschaft (SHUG), Fehmarn, Germany, 13.-13.02.2014

B. Thalheim, *Privatsphäre oder Ego-Striptease im Internet,* Schleswig-Holsteinische Universitäts-Gesellschaft (SHUG), Glücksburg, Germany, 25.-25.02.2014

B. Thalheim, *Modelle: Der Kieler Modellbegriff und seine Anwendung auf Modellbegriffe der Informatik,* Gesellschaft für Informatik, Workshop, Kiel, Germany, 26.-26.02.2014

B. Thalheim, *Modellansätze in der Informatik,* Modellierung 2014 Wien, Wien, Austria, 19.-19.03.2014

B. Thalheim, *Codesign of information systems,* Colloquium Science Faculty, Kuwait University, Kuwait City, Kuwait, 22.-22.03.2014

B. Thalheim, *Web information system development,* Colloquium Science Faculty, Kuwait University, Kuwait City, Kuwait, 23.-23.03.2014

B. Thalheim, *Open problems of information systems research,* Colloquium Science Faculty, Kuwait University, Kuwait City, Kuwait, 24.-24.03.2014

B. Thalheim, *Codesign of information systems,* Colloquium Science Faculty, Kuwait University, Kuwait City, Kuwait, 25.-25.03.2014

B. Thalheim, *Codesign of information systems,* Colloquium Science Faculty, Kuwait University, Kuwait City, Kuwait, 26.-26.03.2014

B. Thalheim, *Data Support for Disaster Management,* INDYCO Project Meeting, Georgsmarienhütte, Germany, 03.-03.04.2014

B. Thalheim, *Modelle und Methoden der Modellierung in der medizinischen Forschung,* Inflammation@ Interfaces, Borstel, Germany, 08.-08.04.2014

B. Thalheim, *Privatsphäre oder Ego-Striptease im Internet,* Schleswig-Holsteinische Universitäts-Gesellschaft (SHUG), Bargdeheide, Germany, 10.-10.04.2014

B. Thalheim, *Database Structure Modelling by Stereotypes, Pattern and Templates,* European Japanese Conference 2014 (EJC 2014), Kiel, Germany, 04.-04.06.2014

B. Thalheim, *Adaptive Systems for Multicultural Deployment,* European Japanese Conference 2014 (EJC 2014), Kiel, Germany, 05.-05.06.2014

B. Thalheim, *Datenbankprogrammierung auf andere Art,* Kieler Uni Live, Kiel Week 2014, Kiel, Germany, 23.-23.06.2014

B. Thalheim, *A Framework for Systematic Change Management,* EuroSPI 2014, Luxembourg, Luxembourg, 26.-26.06.2014

B. Thalheim, *Die Theorie und Praxis des konzeptuellen Modelles,* Kolloquium der Fakultät Informatik, Dortmund, Germany, 08.-08.07.2014

B. Thalheim, *Database change management,* ADBIS 2014, Ohrid, Republic of Macedonia, 07.-07.09.2014

B. Thalheim, *The pragmatic notion of information,* Conference Mathematics meets data management, Budapest, Hungary, 03.-03.10.2014

B. Thalheim, *Web-Informationssysteme,* Software Competence Centre, Hagenberg, Austria, 13.-22.10.2014

B. Thalheim, *Albträume mit Daten,* Night of the Profs, Kiel, Germany, 21.-21.11.2014

B. Thalheim, *Multi-Cultural Engineering for Websites,* Colloquium, Tampere University of Technology, Pori, Finland, 02.-02.12.2014

M. Tropmann-Frick, *Generic Workflows - A Utility to Govern Disastrous Situations,* European Japanese Conference 2014

(EJC 2014), Kiel, Germany, 06.-06.06.2014

M. Tropmann-Frick, *Generic Approach for Dynamic Disaster Management System Component,* 4th International Workshop on Information Systems for Situation Awareness and Situation Management (ISSASiM'14), Ludwig-Maximilians-University, Munich, Germany, 01.-01.09.2014

## Further Activities and Events

**24th International Conference on Information Modelling and Knowledge Bases - EJC 2014, Kiel, Germany, June 3-6, 2014**

Local organisation chair

S. Gaede, F. Kramer, S. Jureit, B. Thalheim, M. Tropmann-Frick.

**H.-J. Klein** Reviewer for Journals:

Chemistry of Materials,
Journal of Physics and Chemistry of Solids,
Acta Crystallographica.

**B. Thalheim**

Kolmogorow-Professor, Lomonossow-University, Moscow, since 2005.

Member of programme committee:

ABZ 2014, June 2014, Toulouse, France,
ADBIS 2014, September 2014, Ohrid, Republic of Macedonia,
APCCM 2014, January 2014, Auckland, New Zealand,
BIR 2014, September 2014, Lund, Sweden,
BIS 2014, May 2014, Cyprus,
CroWE 2014, July 2014, Toulouse, France
DATA 2014, August 2014, Vienna, Austria,
DEXA 2014, September 2014, Munich, Germany,
EJC 2014, June 2014, Kiel, Germany,
ER 2014, October 2014, Atlanta, USA,
FoIKS 2014, March 2014, Bordeaux , France,
Modellierung 2014, March 2014, Vienna, Austria,
NLDB 2014, June 2014, Montpellier,
NLDB (Demonstration Session) 2014, June 2014, Montpellier, France
TQCMA 2014, September 2014, Ohrid, Republic of Macedonia.

Member of steering committees of international conferences:

ABZ, ADBIS, Baltic DB, EJC, ER, ISTA, NLDB, SDKB.

Editorial board membership:

Data and Knowledge Engineering (DKE),
Journal of Intelligent Information Technologies,
Journal of Web Engineering,
Enterprise Modelling and Information Systems Architectures,

Serdica Journal of Computing,
Graduate School Human Development in Landscape,
Foundation Board and Advisor of DAMA International.

Chair:

- of the 24th International Conference on Information Modelling and Knowledge Bases - EJC 2014, June 2014, Kiel,
- of the Workshop on Technologies for Quality Management in Challenging Applications (TQMCA2014), September 2014, Ohrid, Republic of Macedonia.

Co-Chair:

- of the German group of DAMA International,
- of the Rotary-Club, Kiel-Düsternbrook,
- ombudsman of German Computer Science Society, Schleswig-Holstein.

Member of the Scientific Advisory Board: with Dataport.

PI (Primary Investigator):

-Cluster of Excellence Inflammation at Interfaces,
-Cluster of Excellence Future Ocean,
-Graduate School: Human Development in Landscapes.

Reviewer of doctoral theses: Johannes-Kepler-University, Linz, Austria,
Charles University, Prague, Czech Republic,
Victoria University, Victoria, New Zealand,
Lomonossow- University Moscow, Russia,
Christian-Albrechts-University Kiel, Germany,
Helsinki University, Helsinki, Finland,
University of Technology, Melbourne, Australia,
Technion, Haifa, Israel.

Deputy:

for German Computer Science Society at the Max-Planck Society.

Reviewer:

-for the German Research Foundation, DAAD, Australian Science Foundation, National Science Foundation (USA),
-AQAS (accreditation agency),
and a series of conferences and journals in Mathematics, Computer Science and Engineering.

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# Knowledge Discovery

Prof. Dr. Ansgar Scherp is professor of the Leibniz Information Centre for Economics (ZBW - Deutsche Zentralbibliothek für Wirtschaftswissenschaften Leibniz-Informationszentrum Wirtschaft).

Further information is available on the web: http://www.zbw.eu/ and http://zbw.eu/de/forschung/knowledge-discovery/

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Internet http://www.zbw.eu

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# Multimedia Information Processing

The Multimedia Information Processing group (MIP) is active in education, research and application of 3D technology, computer vision, and computer graphics. Ten researchers were involved in many diverse projects, ranging from driver recognition in the car, through 3D modelling (with fully automatic systems) of indoor rooms, to high-quality plenoptic scene capture and rendering algorithms for multiscopic displays. Funding for new projects has been acquired from the DFG to study deformable object analysis and time-depending lightfield processing. The research will be conducted over the coming years. Close collaboration has started in new areas: with Testo GmbH on 3D indoor modelling, with Dräger, Lübeck, on driver identification, and with the MOIN CC radiology centre. The successful work on plenoptic full-parallax displays was presented in the Doctoral Thesis of Daniel Jung; 23 successful B.Sc., M.Sc., and Diploma theses also were prepared in the group. Currently, the biggest challenge for further research will be in attracting qualified researchers to pursue high quality research. As in many fields, there are not sufficient candidates and industry is too tempting an employer.

## Results

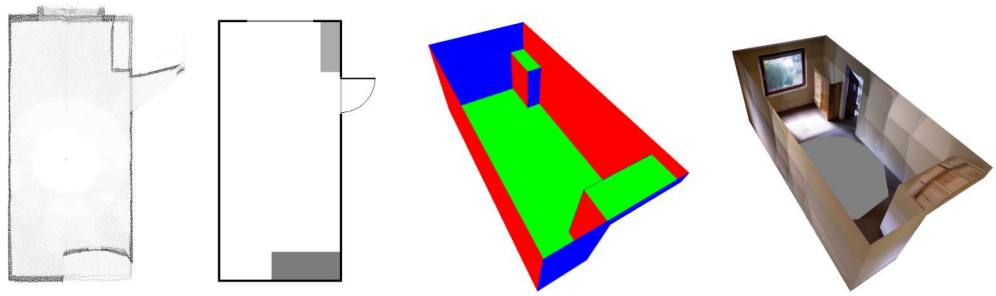
The successful 2014 doctoral thesis of Daniel Jung has shown that it is possible to render multiscopic full-parallax 3D scenes with an enormous speed-up and compression gain by using the concept of depth-compensated interpolation and rendering, combined with efficient data structures like quad- and octtrees, and by developing a pipeline for high-throughput interpolation that will be processed on FPGA hardware in future. The developed algorithms will allow data to be fed to very high-resolution 3D displays with holographic quality. This was made possible by combining orthographic and perspective views of the interpolated scene in an intelligent way.

The 2013 doctoral thesis of Lilian Zhang was honoured by the TF Förderverein Dissertation Award 2014 for his outstanding work on 3D line reconstruction. This thesis was also the starting point for further collaboration with the company Testo GmbH on 3D indoor room reconstruction and for another BMBF-funded AIF project for panoramic room reconstruction. Since then we have had a close collaboration with Testo and will continue this work over the coming years. Mutual interests with the home University (NUDT Changsha, China) of Lilian Zhang have led to further scientific exchange and the welcoming of new Ph.D. scholars from China.

Underwater image processing has been an important research topic in the past and will continue to be so in the future. Although the former Doctoral student Anne Jordt is now working at GEOMAR since July 2014, this connection is invaluable in tightening the cooperation between GEOMAR and our group on deep sea image processing and underwater vision, especially since another former Doctoral student Kevin Köser also has started his work on underwater vision within GEOMAR. The former M.Sc. student Claudius Zelenka was awarded the Focusfinder Award 2014 for his work on underwater gas bubble measurements. This work, amongst others, will be continued by him and other researchers in the group.

Processing of deformable objects and scenes from depth data is the speciality of the doctoral student Andreas Jordt. His work is ground breaking in its efficient modelling of highly complex deformations and new DFG research funding has been awarded to this group to continue the research. Fortunately, another candidate has joined the group: Stefan Reinhold will continue to work on deformable scenes in 3D volumetric data with close connection to medicine. He holds a joint research position, half at MIP, half at the MOIN CC centre of Imaging in Radiology. This will strengthen the bonds between computer science and medicine.

The sucessful M.Sc. thesis of Dominik Wolters has paved the way to industrial cooperation in 3D indoor room scanning. In his work, Dominik has utilized a standard Kinect depth-camera sensor from Microsoft, attached to a pan-tilt rotation head mounted on a tripod. The sensor system automatically scans a room with floor, walls, and furniture, and allows the reconstruction of both a 2D floor plan from the depth data and a 3D room model with plane fitting and surface colours. Figure 1 shows such a reconstructed room. From left to right: point cloud projected onto the floor, 2D floor plan, and 3D room reconstruction.



(a) Point cloud (b) Floor plan (c) 3D model (d) Textured 3D model

Fig. 1: 3D room reconstruction from panoramic reconstruction with the Kinect sensor

## Personnel

Head of the group: Prof. Dr.-Ing. R. Koch; Secretary: R. Staecker (50%)
Technical Staff: T. Storm

Scientific Staff:

| | | | |
|---|---|---|---|
| S. Esquivel | 01.01.-31.12.2014 | | AIF |
| Intelligentes 3D Aufmaß | | | |
| Dr.-Ing. O. Fleischmann | 01.11.-31.12.2014 | | CAU |
| Land | | | |
| A. Jordt | 01.01.-31.12.2014 | | DFG |
| Seafloormodelling/Deformable Objects | | | |
| A. Jordt ( Sedlazeck) | 01.01.-31.07.2014 | | Bund/DFG |
| Excellenzcluster Future Ocean/Seafloormodelling | | | |
| D. Jung | 01.01.-31.12.2014 | | CAU/Industrie |
| Land/3D Signage | | | |
| F. Kellner | 01.09.-31.10.2014 | | CAU |
| Land | | | |
| S. Reinhold | 01.07.-30.11.2014 | | DFG |
| Seafloormodelling | | | |
| S. Reinhold | 01.-31.12.2014 | (50%) | DFG |
| Deformable Objects | | | |
| D. Wolters | 01.04.-14.05.2014 | | Industrie |
| Testo | | | |
| D. Wolters | 01.01.-31.03.2014 | | Stipendium |
| Transferprämie | | | |
| R. Wulff | 01.01.-31.03.2014 | | Stipendium |
| Industrie | | | |

| | | |
|---|---|---|
| C. Zelenka<br>Land | 01.07.-31.12.2014 | CAU |
| C. Zelenka<br>DFG Overhead | 01.03.-30.06.2014 | Stipendium |

## Lectures, Seminars, and Laboratory Course Offers

*Winter 2013/2014*

MSP0601 Vertiefende Übung Visuelle Modellierung, 4 hrs M.Sc. project/Week,
R. Koch (+ D. Jung, O. Fleischmann, J. Brünger)

080092 Inf-EinfBV: Einführung in die Bildverarbeitung, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
R. Koch (+ D. Jung, O. Fleischmann)

MSS0601: Seminar - Visuelle Modellierung, 2 hrs Seminar/Week,
R. Koch (+ O. Fleischmann)

MS0603: 3D-Szenenrekonstruktion aus Bildfolgen, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
R. Koch

Inf-AP-CG: Abschlussprojekt - Computer Graphic/Computer Vision, 6 hrs B.Sc project/Week,
R. Koch (+ D. Jung, J. Brünger, O. Fleischmann)

*Summer 2014*

Seminar Visuelle Modellierung, 2 hrs Seminar/Week,
R. Koch (+ S. Esquivel)

MS0602 Multimediale Signal- und Bildverarbeitung, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
R. Koch (+ S. Esquivel)

BA6.7 Projektmodul, B.Sc., 2 hrs Thesis seminar/Week,
R. Koch (+ S. Esquivel)

Informatik II für Ingenieurwissenschaften, 3 (+ 3) hrs Lecture (+ Exercises)/Week,
R. Koch (+ D. Jung, O. Fleischmann)

*Winter 2014/2015*

MSP0601 Vertiefende Übung Visuelle Modellierung, 4 hrs M.Sc. project/Week,
R. Koch (+ D. Jung, O. Fleischmann, J. Brünger)

080092 Inf-EinfBV: Einführung in die Bildverarbeitung, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
R. Koch (+ D. Jung, O. Fleischmann)

MSS0601: Seminar - Visuelle Modellierung, 2 hrs Seminar/Week,
R. Koch (+ O. Fleischmann)

MS0603: 3D-Szenenrekonstruktion aus Bildfolgen, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
R. Koch

Inf-AP-CG: Abschlussprojekt - Computer Graphic/Computer Vision, 6 hrs B.Sc. project/Week,
R. Koch (+ D. Jung, J. Brünger, O. Fleischmann)

## Third-Party Funds

DFG, *Seafloor Modelling Folgeprojekt*, 01.09.2012-31.05.2015 (156.500,00)
AIF/BMWI/ZIM, *3D Aufmaß*, 02.04.2013-31.03.2015 (150.388,00)
DFG, *Rekonstruktion komplexer Deformationen in 3D Szenen aus Bild- und Tiefendaten*, 01.06.2014-31.05.2017 (256.030,00 Euro)
DFG, *Effiziente Rekonstruktion und Darstellung großflächiger dynamischer Lichtfelder*, 01.05.2014-31.10.2016 (220.000,00 Euro)
Fa. Testo Industrie, *Algorithmen zur Verarbeitung von Bildgeraden in Bildern*, 19.11.2013-31.01.2014 (8.000,00 Euro)
Fa. Dräger, *Studie Gesichtserkennung für Interlock*, 01.09.-30.11.2014 (20.000,00 Euro)

## Further Cooperation, Consulting, and Technology Transfer

The group has collaborated with the following individuals, institutes and organizations: Dr. Hunger, **Fa. IBAK**, Kiel,

Prof. Dr.-Ing. Michael Felsberg, **Linköping University**, Linköping, Sweden,

Fabian Doil, **VW**, Wolfsburg,

Prof. Joachim Weickert, **Uni Saarland**, Saarbrücken,

Yoav Schechner, **Israel Institute of Technology** Haifa, Israel,

Soenke Ehlers, **Fa. WISKA** Kaltenkirchen,

Prof. Bernhard Wagner, **Fraunhofer Institut, ISIT**, Itzehoe,

Dr. Uwe Franke, **Daimler AG**, Sindelfingen,

Dr Jürgen Steimle, **Saarland University Cluster of Excellence Multimodal Computing and Interaction**,

Prof. Dr. Reinhard Klette **CITR - The University of Auckland**, Auckland, New Zealand,

Dr. Jan-Friso Evers-Senne **TESTO**, Leutkirch,

Prof. Dr. Jens Greinert **IFM GEOMAR**,

Dr. Peter Linke **IFM GEOMAR**.

## Diploma, Bachelor's and Master's Theses

C. Zelenka, *Underwater Bubble Shape Measurement and Analysis*, 05.02.2014
L. Husvogt, *Calibration of Underwater Dome Port Cameras*, 05.02.2014
H. Möller, *Splat-Basierte Rekonstruktion dynamischer Szenen aus Tiefenkarten*, 08.04.2014
M. Kardel, *Bewegungsanalyse in der Nutztierhaltung aus Videodaten*, 08.04.2014
D. Grevismühl, *Hard-Softwareentwurf eines Embedded Systems zur Panoramaaufnahme*, 08.04.2014
S. Reinhold, *Automatic 3D Segmentation of Human Vertebrae from Quantitative Computed Tomographs*, 16.04.2014
R. Weiß, *Aufbau, Kalibrierung und Einsatz eines Verbundsystems aus Kamera- und Lasermessgerätes*, 05.05.2014
E. Gardei, *Ansteuerung eines Roboterarms unter Verwendung eines deterministischen Netzwerkes*, 20.06.2014
A. Timpl, *Autonome Rekonstruktion von Innenräumen aus Tiefendaten eines mobilen Roboters*, 19.09.2014
M. Schmöhl, *Automatische Erstellung von Grundrissen aus Panoramabildern*, 19.09.2014
N. Peters, *Echtzeitrendering dynamisch rekonstruierter impliziter Oberflächen auf einer GPU*, 26.09.2014
D. Finkes, *Dynamische Stereo-Tiefenschätzung mit Hilfe der massiv parallelen Plattform XEON PHI*, 26.09.2014
L. Lovisa, *Linsenbasierte Defokus-Schätzung in multi-fokalen plenoptischen Kamerabildern*, 26.09.2014

H. Bell, *Implementierung einer Hol-und Bring-Service-Anwendung auf einem mobilen Roboter*, 26.09.2014
T. Schwede, *Genauigkeitsabschätzung akkumulierter Odometriedaten für mobile Roboter*, 26.09.2014
A. Rohden, *Automatische Driftkorrektur aus Tiefenbildern für Mobile Roboter*, 26.09.2014
K. Slowikowski, *Kollisionsvermeidung mittels Tiefenkameradaten auf einem mobilen Roboter*, 26.09.2014
D. Neumärker, *Linienbasierte 3D-Rekonstruktion aus Panoramabildern auf dem Raspberry Pi*, 19.09.2014
V. Behrends, *Bildverarbeitung auf einer Smart Camera*, 19.09.2014
E. Fließwasser, *Dynamische Rekonstruktion impliziter Oberflächen mit Hilfe der massiv parallelen Plattform XEON PHI*, 26.09.2014
E. Gardein, *Ansteuerung eines Roboterarms unter Verwendung eines deterministischen Netzwerks (Bachelor der ET-IT)*, 03.06.2014
J. Dutta, *Integrative Lane Recognition System (Master Digital Communication, ET-IT)*, 18.12.2014
F. X. Schmidt, *Efficient JPEG2000 decoding for diagnostic purposes on the RIVYERA-Architecture (Master der ET-IT)*, 10.12.2014

## Dissertations / Postdoctoral Lecture Qualifications

D. Jung, *Depth Image-Based Rendering for Full Parallax Displays*, 07.11.2014

## Publications

Published in 2014

O. Fleischmann, R. Koch, *Lens-based Depth Estimation for Multi-Focus Plenoptic Cameras*, Proceedings of the German Conference on Pattern Recognition (GCPR'14), **LNCS 8753**, 373 - 384 (2014)
D. Wolters, *Automatic 3D Reconstruction of Indoor Manhattan World Scenes Using Kinect Depth Data*, Proceedings of the German Conference on Pattern Recognition (GCPR'14), **LNCS 8753**, 715 - 721 (2014)
C. Zelenka, *Gas Bubble Shape Measurement and Analysis*, Proceedings of the German Conference on Pattern Recognition (GCPR'14), **LNCS 8753**, 701 - 707 (2014)
L. Bodenhagen, A. Fugl, A. Jordt, M. Willatzen, K. Andersen, M. Olsen, R. Koch, N. Krüger, *An Adaptable Robot Vision System Performing Manipulation Actions with Flexible Objects*, IEEE transactions on Automation Science and Engineering, **Vol. 11 No. 3**, (2014)
L Zhang, R. Koch, *Structure and Motion from Line Correspondences: Representation, Projection, Initialization and Sparse Bundle Adjustment*, Journal of Visual Communications and Image Representation, **25 (5)**, 904 - 915 (2014)
R. Koch, *Depth Estimation*, Computer Vision: A Reference Guide, 183 - 186 (2014)
C. Rabe, U. Franke, R. Koch, *Dense 3D Motion Field Estimation from a Moving Observer in Real-time*, Smart Mobile in Vehicle Systems, 19 - 34 (2014)
X. Jiang, J. Hornegger, R. Koch, *Pattern Recognition*, Proceedings of the 36th German Conference on Pattern Recognition GCPR 2014, Münster, Germany. Springer, **LNCS 8753**, (2014)

## Presentations

O. Fleischmann, *Lens-based Depth Estimation for Multi-Focus Plenoptic Cameras*, GCPR 2014, Münster, Germany, 03.09.2014
D, Wolters, *Automatic 3D Reconstruction of Indoor Manhattan World Scenes Using Kinect Depth Data*, GCPR 2014, Münster, Germany, 03.09.2014
C. Zelenka, *Gas Bubble Shape Measurement and Analysis*, GCPR 2014, Münster, Germany, 04.09.2014

## Further Activities and Events

The **International Time of Flight Imaging Workshop** in Ein-gedi, Israel from March 9th to March 12th 2014 heard the presentation by **Prof. Dr.-Ing. Reinhard Koch** of *Model-based Analysis of Dynamic Scenes from Range-Colour Video.*

As a faculty reviewer for the Ph.D. defence of Sebastian Schwarz on June 6th in Sundsvall, Sweden **Prof. Dr.-Ing. Reinhard Koch** spoke on *3D scene reconstruction from active and passive camera systems.*

**Prof. Dr.-Ing. Reinhard Koch** was Keynote Speaker at the **International Conference on Mechanical Engineering, Automation & Intelligent Computing (ICMEAIC-2014)** from June 27th to 28th, 2014 in Bhopal India. He spoke on *Depth cameras for 3D Computer Vision*,

The Multimedia group knows that computers just see more clearly. *Rechner sehen einfach besser* was a contribution by **Prof. Dr.-Ing. Reinhard Koch** on May 15th 2014 to a lecture series called ''Everyone can program, or not? '' by the Institute of Computer Science in Summer 2014 explaining Computer Vision in Practice.

**Claudius Zelenka** was awarded the Fokusfinder Preis 2014 in the category Bildaufnahmetechniken und Bildsignalverarbeitung für den UV/VIS/IR-Bereich for his M.Sc. thesis *Underwater Bubble Shape Measurement and Analysis*. The prize is endowed with 1000 Euro and was presented on June 5th on the Computer Vision Day in Schleswig-Holstein.

On June 13th during the summer party of the Technische Fakultät, **Lilian Zhang** was awarded with the **Förderpreis**, a prize for the best dissertation of the Faculty of Engineering. Lilian Zhang wrote his dissertation *Line Primitives and their Applications in Geometric Computer Vision* under the supervision of Prof. Koch. He is now a junior professor at the NUDT in Changsha, China.

*Kameramodelle zur Unterwasser-Objektvermessung* was the title of a speech given by **Prof. Dr.-Ing. Reinhard Koch** on September 23rd 2014 on the occasion of the **12th Marketplace Kiel** initiated by the **Maritimes Cluster Norddeutschland**.

Scientific exchange was the object of a trip to China and *Depth Cameras: 3D reconstruction and tracking in dynamic scenes* was the title of a speech given by **Prof. Dr.-Ing. Reinhard Koch** in Chansha at the NUDT on October 13th and at Peking University on October 24th.

A delegation from Zhejiang University, China was welcomed at the CAU on November 19th 2014 and the Institute for Informatics contributed with *Aquatic Vision - Camera Model for Underwater Object Recognition* by **Prof. Dr.-Ing. Reinhard Koch**. **Prof. Dr.-Ing. Reinhard Koch** has been Vice-President of the German Association for Pattern Recognition (DAGM e.V.) since 2012,

He is also a member of the programme committees of the following international conferences and workshops:

- 3DV 2014,
- CVMR 2014,
- GCPR 2014,
- ECCV 2014,
- VMV 2014.

He is a reviewer for the DFG and is a

member of the editorial boards of the following journals:

- Journal of Realtime Image Processing (JRTIP), Springer, since 2007,

- Journal of Visual Communications and Image Representation (JVCI) Elsevier, since 2008.

He is also a reviewer for the following journals:

- IEEE-IE Transactions IE, Special Issue on Optomechatronics,
- International Journal of Image and Graphics,
- IEEE T-PAMI Transactions of Pattern Analysis and Machine Intelligence,
- Journal on CVIU Computer Vision and Image Understanding,
- International Journal on Computer Vision.

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# Programming Languages and Compiler Construction

The research group "Programming Languages and Compiler Construction" is interested in the design, implementation and application of programming languages intended to support the reliable implementation of complex systems. The research ranges from object-orientated design methods and the analysis of concurrent and distributed systems to the implementation and application of declarative programming languages, particularly in the area of web-based systems.

During the period reported below, the research group worked on a new advanced implementation of the multi-paradigm language Curry and achieved new research results related to the design, semantics, implementation, and analysis of declarative programming methods.

## Results

The scientific work of the research group involved all areas related to declarative programming languages, e.g. design, semantics, implementation, development tools, and application of such languages. Declarative programming languages are based on clear mathematical foundations. They abstract from the underlying computer architecture and thus provide a higher programming level, leading to more reliable systems. In particular, much of the research is focused on the integration of the most important declarative programming paradigms: functional and (constraint) logic programming. Because of our well-known activities in the area of multi-paradigm languages, we were invited to contribute a chapter on this topic in the new edition of the Computing Handbook that was published in 2014.

In order to evaluate the concepts of declarative programming in practice, we worked on the *application and implementation* of the functional logic programming language Curry. In particular, we continued the development of our recent implementation of Curry, called KiCS2, which is based on compiling Curry programs into purely functional Haskell programs. The advantages of this implementation are the good performance of purely functional computations and the explicit representation of non-deterministic computed results in a single data structure that supports a variety of search strategies. Due to the compilation into a purely functional target language, the implementation of features for constraint programming, like constraints over finite domains that have important applications in the area of operations research, is challenging. Therefore, we developed new techniques to integrate these features also into a functional implementation context; the promising results were published.

In another research project, we worked on improving the implementation of declarative programs by source code transformations. Declarative programs often consist of the implementation of general schemes, enabled by higher-order functions or polymorphic typing, that are used in various contexts in application programs. This style supports an efficient and reliable software development process. However, it could create a run-time overhead compared to writing similar code pieces that are tailored to their precise usage. Automatic source code transformations like partial evaluation can help to close this gap. If general code schemes are partially instantiated with parameters, a partial evaluator transforms these instantiations and produces new code specific to these situations. In the reported period, we worked on a partial evaluator for Curry that takes the specific language features (non-determinism, demand-driven evaluations) into account in order to perform correct and effective program transformations. The first results on this tool were published.

A good implementation of high-level programming languages like Curry requires advanced *program analysis* techniques. For instance, the KiCS2 compiler analyzes dynamic program properties, like potential non-deterministic computations, to produce efficient target code. However, building program analyzers for realistic applications is not an easy task. In order to support developers of language tools in this respect (e.g. compiler, editor, documentation generator), we developed a new framework and implementation for the generic and modular analysis of declarative programs. This tool, called CASS (Curry Analysis Server System), is based on a plug-in architecture to accommodate various program analyzers. Moreover, CASS provides various usage interfaces so that it can be used by a variety of tools such as compilers and documentation generators, as well as Eclipse plug-ins for Curry. Finally, CASS itself is implemented as a master/worker architecture in

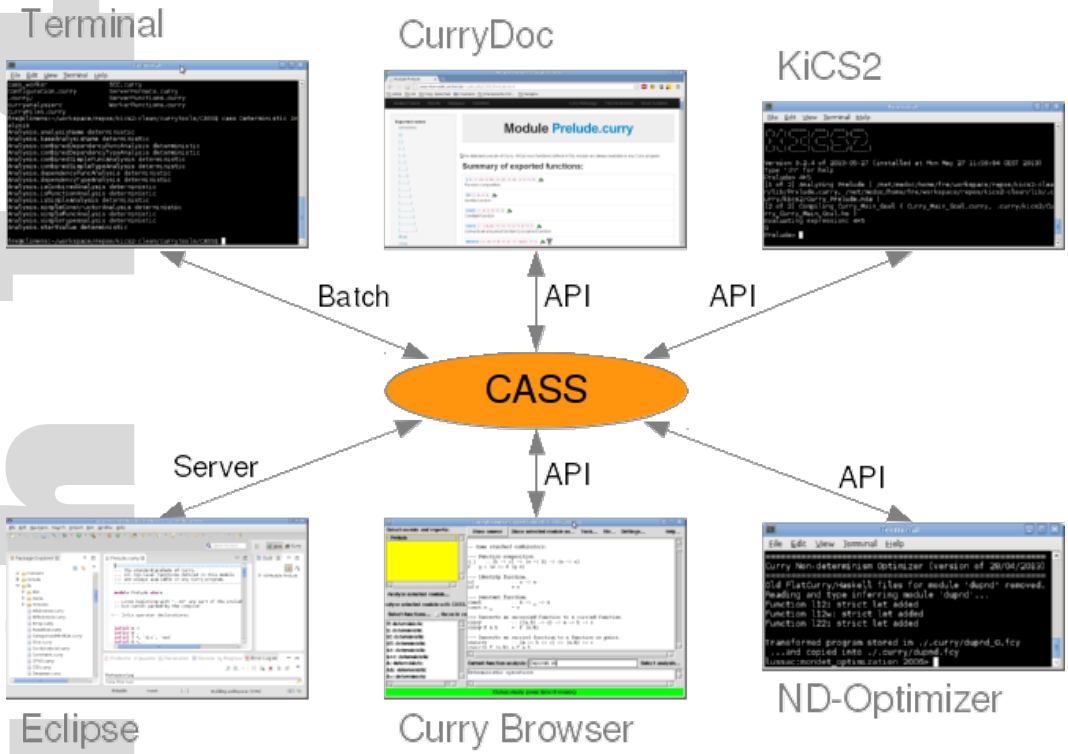


Fig. 1: The application structure of CASS

order to exploit parallel or distributed hardware environments. Since its publication and distribution in 2014, it has been used to develop new advanced program analysis techniques.

During the reported period, we also worked in the area of the *design* of Curry in a collaboration with the Portland State University (Oregon, USA). Since Curry integrates features from functional and logic programming, operations can be defined by case distinctions via pattern matching and conditional rules, as in functional programming, or also with unification and constraints, as in logic programming. This development led to similar but different concepts on the type level, namely Boolean values and constraints. Since the differences are subtle and choice of the right concept in a program might not be obvious, we proposed a radical change in the language design to simplify the language definition and join both concepts. Of course, this has consequences for the usage and implementation of Curry, which we discussed in a first paper. Nevertheless, the advantages being manifold we started to work on this new design in more detail.

On the practical side, we developed a system that should help people to play with the features of declarative languages without effort, i.e. without installing complex software systems. For this purpose, we developed Smap, a web-based editor and execution environment for programs written in various programming languages. Users can browse through example programs, execute or modify them, or develop their own programs and store them in Smap for other users. Smap supports web services for various programming languages and it can also be used in on-line books on programming languages to include example programs that are immediately executable. As a first practical use, all example programs contained in the tutorial on Curry are directly executable with Smap.

## Personnel

Head of the group: Prof. Dr. M. Hanus; Secretary: M. Bradler (50%), L. Haberland (50%)
Technical Staff: M. Gabriel (50%)

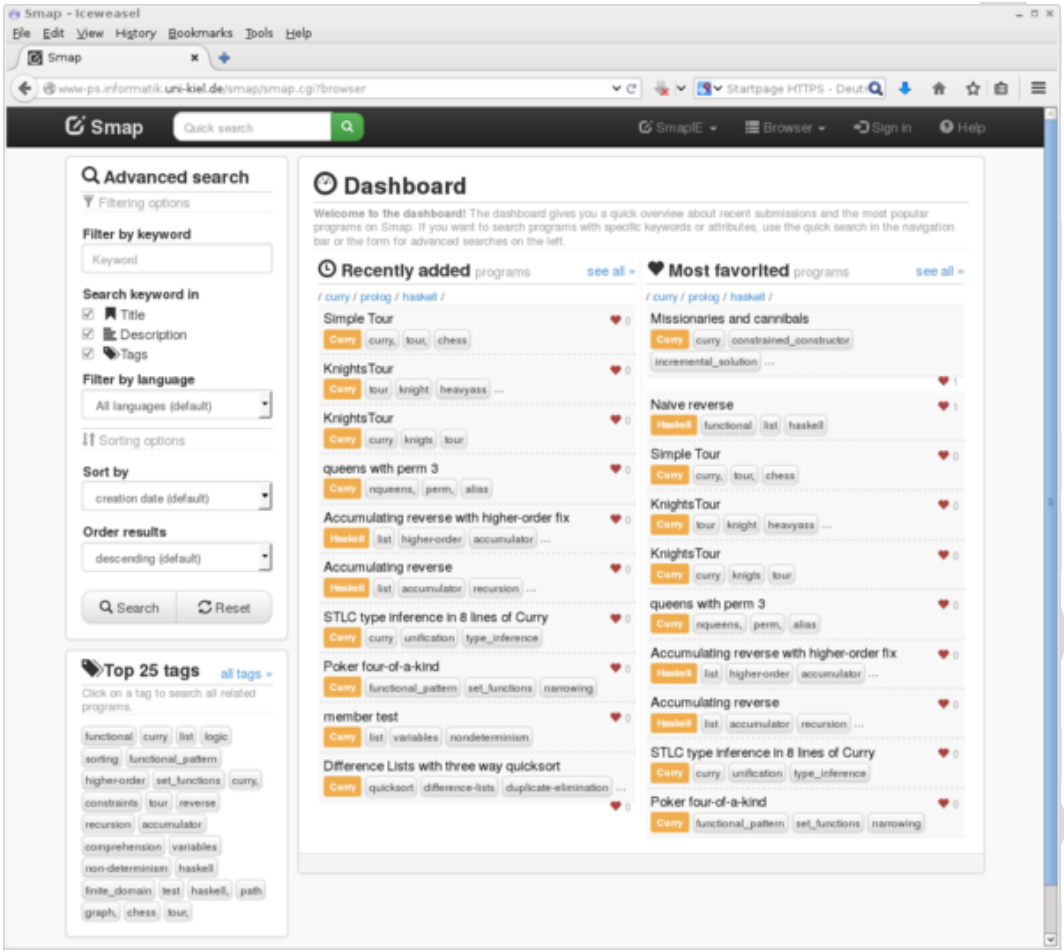


Fig. 2: The browser view of the web-based program development and execution environment Smap

Scientific Staff:

| | | |
|---|---|---|
| M. Sc. S. Dylus | 01.11.-31.12.2014 | CAU |
| Dr. S. Fischer | 01.01.-31.12.2014 | Guest |
| PD. Dr. F. Huch | 01.01.-31.12.2014 | CAU (35%) |
| M. Sc. B. Peemöller | 01.01.-31.12.2014 | CAU |
| Dr. F. Simon | 01.01.-31.12.2014 | Guest |
| Dipl.-Inf. F. Skrlac | 01.01.-31.12.2014 | CAU / Guest |
| Dipl.-Inf. J. R. Tikovsky | 01.01.-31.12.2014 | CAU |

## Lectures, Seminars, and Laboratory Course Offers

*Winter 2013/2014*

Arbeitsgemeinschaft Informatik, Logik und Mathematik, 2 hrs Seminar/Week,
M. Hanus (+ R. Berghammer)

MSS0303: Masterabschlussseminar - Programmiersprachen, 2 hrs Seminar/Week,
M. Hanus

Inf-MS-Sem-PS: Programmiersprachen und Programmiersysteme, 2 hrs Seminar/Week,
M. Hanus (+ F. Huch)

Inf-Prog: Programmierung, 4 (+2) hrs Lecture (+ Exercises)/Week,
M. Hanus (+ J. R. Tikovsky, B. Peemöller, P. Munstermann)

MS0301: Prinzipien von Programmiersprachen, 4 (+2) hrs Lecture (+ Exercises)/Week,
M. Hanus (+ B. Peemöller)

Inf-MP-PS: Masterprojekt - Programmiersprachen und Programmiersysteme, 6 hrs Practical/Week,
M. Hanus

NF-Inf-1: Informatik für Nebenfächler, 2 (+2) hrs Lecture (+ Exercises)/Week,
F. Huch (+ F. Skrlac, J. Piwonski)

NF-Inf-1v: Informatik für Nebenfächler (vertiefend), 4 (+2) hrs Lecture (+ Exercises)/Week,
F. Huch (+ F. Skrlac, J. Piwonski)

*Summer 2014*

Arbeitsgemeinschaft Informatik, Logik und Mathematik, 2 hrs Seminar/Week,
M. Hanus (+ R. Berghammer)

Inf-MP-PS: Masterprojekt - Programmiersprachen und Programmiersysteme, 4 hrs Exercise/Week,
M. Hanus (+ F. Skrlac)

Inf-MS-Sem-PS: Programmiersprachen und Programmiersysteme, 2 hrs Seminar/Week,
M. Hanus (+ F. Huch)

MS0303: Deklarative Programmiersprachen, 4 (+2) hrs Lecture (+ Exercises)/Week,
M. Hanus (+ J. R. Tikovsky)

MSS0303: Masterabschlussseminar - Programmiersprachen, 2 hrs Seminar/Week,
M. Hanus

MS0306: Nebenläufige und verteilte Programmierung, 4 (+2) hrs Lecture (+ Exercises)/Week,
F. Huch (+ N. Danilenko)

Inf-FortProg: Fortgeschrittene Programmierung, 3 (+2) hrs Lecture (+ Exercises)/Week,
F. Huch (+ B. Peemöller, J. R. Tikovsky)

*Winter 2014/2015*

Arbeitsgemeinschaft Informatik, Logik und Mathematik, 2 hrs Seminar/Week,
M. Hanus (+ R. Berghammer)

Inf-MS-Sem-PS: Programmiersprachen und Programmiersysteme, 2 hrs Seminar/Week,
M. Hanus (+ F. Huch)

Inf-Prog: Programmierung, 4 (+2) hrs Lecture (+ Exercises)/Week,
M. Hanus (+ J. R. Tikovsky, B. Peemöller)

MS0302: Übersetzerbau, 4 (+2) hrs Lecture (+ Exercises)/Week,
M. Hanus (+ B. Peemöller, S. Dylus)

MSS0303: Masterabschlussseminar - Programmiersprachen, 2 hrs Seminar/Week,
M. Hanus

NF-Inf-1: Informatik für Nebenfächler, 2 (+ 2) hrs Lecture (+ Exercises)/Week,
F. Huch (+ Ch. D. Schulze, T. Wilke)

Inf-InfNat: Informatik für Naturwissenschaftler, 4 hrs Lecture/Week,
F. Huch (+ Ch. D. Schulze, T. Wilke)

NF-Inf-1v: Informatik für Nebenfächler (vertiefend), 4 (+ 2) hrs Lecture (+ Exercises)/Week,
F. Huch (+ Ch. D. Schulze, T. Wilke)

## Further Cooperation, Consulting, and Technology Transfer

During the reported period, the research group collaborated with:

Sergio Antoy (Portland State University),

Ricardo Rocha (University of Porto).

## Diploma, Bachelor's and Master's Theses

Mirko Heinold, *Automatisiertes Testen von Webanwendungen im Scala-Framework Play*, 25.11.2013
Torsten Krause, *Entwicklung eines sprachunabhängigen Tools zum modellbasierten schnellen Prototyping*, 24.03.2014
Lasse K. Meyer, *Entwicklung einer Webanwendung zur Erstellung, Verwaltung und Ausführung von Programmen in Curry*, 25.03.2014
Jan Bracker, *A Web-Based Editor for Cloud-Based Programming*, 27.03.2014
Lennart Spitzner, *Extending an Eclipse-Plugin for Curry by Features for Program Analysis, Type-Checking and Debugging*, 27.03.2014
Jasper P. Sikorra, *Foreign Code Integration in Curry*, 31.03.2014
Max A. Deppert, *Integration von Auszeichnungssprachen in Curry*, 31.03.2014
Bastian Holst, *Integration of Parallel and Fair Search Strategies for Non-Deterministic Programs into the Curry System KiCS2*, 27.05.2014
Florian Micheler, *A Transaction Framework for Web Applications in Haskell*, 10.06.2014
Daniel Stark, *Konfigurierbare Übersetzer von Java nach C++ und C# zur Unterstützung betrieblicher Anwendungen*, 11.08.2014
Folke Will, *Maschinencode-Obfuscation als Schutz vor Reverse Engineering*, 25.09.2014
Mike Tallarek, *Implementierung einer Datenbank-Schnittstelle für Curry*, 30.09.2014
Sandra Dylus, *Lenses and Bidirectional Programming in Curry*, 30.09.2014

## Publications

Published in 2014

M. Hanus, F. Skrlac, *A Modular and Generic Analysis Server System for Functional Logic Programs*, Proc. of the ACM SIGPLAN 2014 Workshop on Partial Evaluation and Program Manipulation (PEPM'14), **ACM Press**, 181 - 188 (2014)
M. Hanus, B. Peemöller, J. R. Tikovsky, *Integration of Finite Domain Constraints in KiCS2*, Proc. of the 7th Working Conference on Programming Languages (ATPS 2014), 151 - 170 (2014)
M. Hanus, S. Koschnicke, *An ER-based Framework for Declarative Web Programming*, Theory and Practice of Logic Programming, **14(3)**, 269 - 291 (2014)
M. Hanus, *Multiparadigm Languages*, Computing Handbook: Computer Science and Software Engineering, **Third Edition**, 6601 - 6617 (2014)

M. Hanus, *Declarative Multi-Paradigm Programming*, Proceedings of the 23rd International Workshop on Functional and (Constraint) Logic Programming (WFLP 2014), 5 - 7 (2014)

S. Antoy, M. Hanus, *Curry without Success*, Proceedings of the 23rd International Workshop on Functional and (Constraint) Logic Programming (WFLP 2014), 40 - 54 (2014)

M. Hanus, B. Peemöller, *A Partial Evaluator for Curry*, Proceedings of the 23rd International Workshop on Functional and (Constraint) Logic Programming (WFLP 2014), 55 - 71 (2014)

M. Hanus, R. Rocha, *Declarative Programming and Knowledge Management*, Springer Lecture Notes in Artificial Intelligence, **8439**, (2014)

## Presentations

M. Hanus, *A Modular and Generic Analysis Server System for Functional Logic Programs*, ACM SIGPLAN 2014 Workshop on Partial Evaluation and Program Manipulation (PEPM'14), San Diego, USA, 21.01.2014

J. R. Tikovsky, *Integration of Finite Domain Constraints in KiCS2*, 7th Working Conference on Programming Languages (ATPS 2014), Kiel, Germany, 26.02.2014

B. Peemöller, *A Partial Evaluator for FlatCurry*, 31st GI-Workshop Programmiersprachen und Rechenkonzepte, Bad Honnef, Germany, 28.04.2014

F. Will, *Kianxali: Kieler Analyzer for Executables and Libraries*, 31st GI-Workshop Programmiersprachen und Rechenkonzepte, Bad Honnef, Germany, 28.04.2014

F. Huch, *Stolpersteine bei der Integration funktionaler Konzepte in die imperative Programmierung*, 31st GI-Workshop Programmiersprachen und Rechenkonzepte, Bad Honnef, Germany, 28.04.2014

S. Fischer, *Backtracking in unterschiedlichen Programmierparadigmen*, 31st GI-Workshop Programmiersprachen und Rechenkonzepte, Bad Honnef, Germany, 28.04.2014

J. R. Tikovsky, *Solving FD constraints incrementally using KiCS2*, 31st GI-Workshop Programmiersprachen und Rechenkonzepte, Bad Honnef, Germany, 28.04.2014

M. Hanus, *Declarative Multi-Paradigm Programming*, 23rd International Workshop on Functional and (Constraint) Logic Programming and the 28th Workshop on (Constraint) Logic Programming, Wittenberg, Germany, 16.09.2014

M. Hanus, *Curry without Success*, 23rd International Workshop on Functional and (Constraint) Logic Programming and the 28th Workshop on (Constraint) Logic Programming, Wittenberg, Germany, 16.09.2014

B. Peemöller, *A Partial Evaluator for Curry*, 23rd International Workshop on Functional and (Constraint) Logic Programming and the 28th Workshop on (Constraint) Logic Programming, Wittenberg, Germany, 16.09.2014

## Further Activities and Events

M. Hanus is a programme committee member of the following: -Seventh Working Conference on Programming Languages (ATPS 2014), Aachen, February 2014 (part of the conference Software Engineering 2014),

-International Joint Workshop on Implementation of Constraint and Logic Programming Systems and Logic-based Methods in Programming Environments 2014 (CICLOPS-WLPE 2014), Vienna (Austria), July 2014,

-30th International Conference on Logic Programming (ICLP 2014), Vienna (Austria), July 2014.

He also chairs the programme committees below:

-28th Workshop on (Constraint) Logic Programming (WLP 2014), Wittenberg, September 2014,

-23rd International Workshop on Functional and (Constraint) Logic Programming (WFLP 2014), Wittenberg, September 2014.

M. Hanus also has the following positions:

-Chair of the steering committee of the ACM SIGPLAN Symposia on Principles and Practice of Declarative Programming,

-Member of the steering committee of the Symposia on Logic-based Program Synthesis and Transformation,

-Member of the executive committee and vice-chair of the GLP (Gesellschaft für Logische Programmierung), German-speaking branch of the Association for Logic Programming (ALP),

-Member of the advisory board of the GLP (Gesellschaft für Logische Programmierung), German-speaking branch of the Association for Logic Programming (ALP),

-Member of the advisory board of the „Berufsakademie an der Wirtschaftsakademie Schleswig-Holstein" ,

-Member of the executive board of the „Fakultätentag Informatik der Bundesrepublik Deutschland" ,

-Chair of the selection committee of the award for the best diploma or M.Sc. thesis in computer science in Germany 2014,

-Chair of the examinations board of computer science studies, University of Kiel

-Member of the Senate Curriculum Committee, University of Kiel,

-Vice-member of the Senate Equal Opportunities Committee, University of Kiel.

S. Dylus received an ACM-W Scholarship Award in order to support her stay in Gothenborg, Sweden, to participate in the 19th ACM SIGPLAN International Conference on Functional Programming (ICFP 2014).

M. Gabriel was interviewed by FLOSS Weekly (Episode 295, http://twit.tv/show/floss-weekly/295) on May 21, 2014 about the remote desktop solution X2Go.

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# Real Time Systems / Embedded Systems

The research interest of the RTSYS group is the systematic design and analysis of "computers that are not perceived as such"; this one definition of *embedded systems*. These systems appear in all contexts of daily life: miniaturized hearing aids, x-ray scanners, cell phones, airbag controllers, anti-lock brakes, and fly-by-wire aircraft. Such systems not only have to provide the correct outputs to the environment but also have to provide them promptly. In other words, these are *real-time systems*. Of particular interest for us are *reactive systems* that react continuously to (mainly discrete) input events of the environment with corresponding output events.

## Results

Current research activities concentrate on the development of reactive embedded real-time systems. Key areas are:

- deterministic concurrency and synchronous languages,
- pragmatics-aware model-based design of complex reactive systems, and
- automatic layout of graphical models.

**deterministic concurrency and synchronous languages** In this area we have concentrated on *Sequential Constructiveness* (SC). This model of computation (MoC) combines deterministic synchronous concurrency with the sequential scheduling information inherent in traditional programming languages such as C or Java. This builds on a large body of theoretical work that has emerged from the synchronous programming community since the 1980s, but is also of practical interest for designing safety-critical systems. It has emerged from a collaboration with colleagues working in theoretical computer science, notably Prof. Michael Mendler (U Bamberg), and with industrial users, notably National Instruments. Two languages that use the SC MoC are *Synchronous Java* and the graphical *SCCharts* language, a dialect of statecharts. The SCCharts editor and compiler has now matured to a point where it is regularly used in projects and in the classroom. The participants in the Railway Project, conducted in the Summer Semester 2014, used SCCharts to control the institute's model railway. The SCCharts model they developed can control 11 trains simultaneously. It contains about 10.000 SCChart nodes before "normalization," and 135,000 nodes in normalized form. It produces about 650,000 lines of C code and is compiled in about two minutes, resulting in a controller with a cycle time of about 2 msecs.

**pragmatics-aware model-based design** This area concentrates on the practical aspects of creating, maintaining, and visualizing graphical system models, with the goal of enhanced designer effectiveness and productivity. The Kiel Integrated Environment for Layout Eclipse Rich Client (KIELER) is a prototypical modelling environment that serves as a test bed to explore and validate novel modelling approaches. A key enabler is the ability to automatically compute the layout of graphical models. This frees the user from the tedious task of manually drawing diagrams and allows novel techniques such as customized views during simulation. 2014 saw improvements in KLay Layered, our implementation of a layer-based layout algorithm. On the algorithmic side, we developed improved algorithms for reducing edge crossings in diagrams, an NP-complete problem, evaluated an approach for configuring layout algorithms through the use of evolutionary algorithms, and added extended support for routing edges as spline curves. On the engineering side, we made KLay Layered available to JavaScript developers.

## Personnel

Head of the group: Prof. Dr. R. von Hanxleden; Secretary: G. Walsdorf (50%)
Technical Staff: T. Grebien (50%), G. Stechmann (50%)

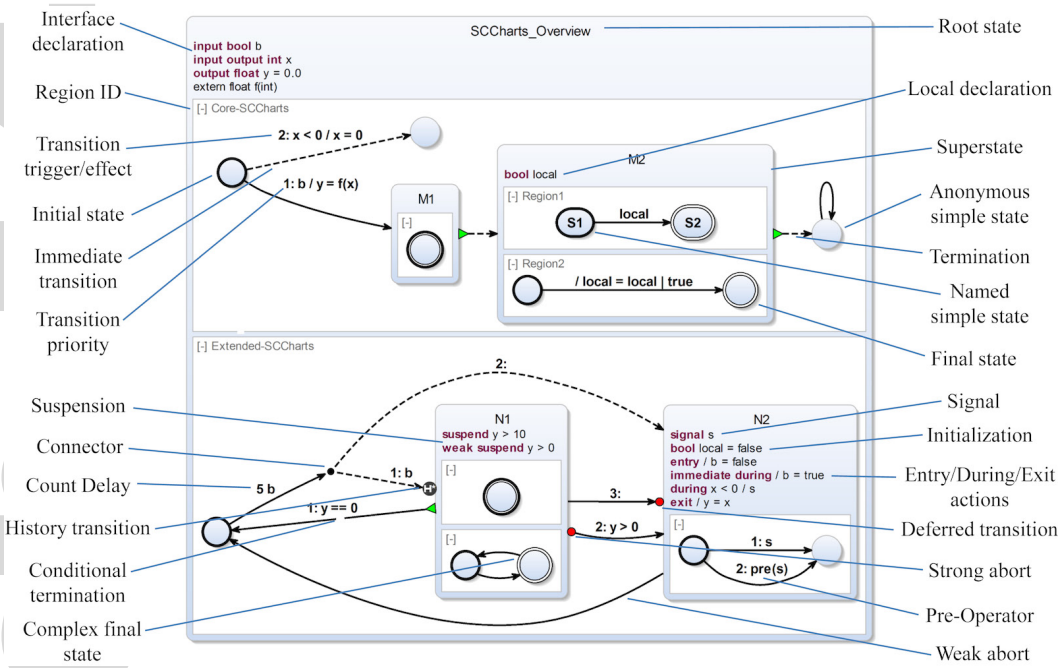


Fig. 1: Syntax overview of SCCharts. The upper region contains Core SCCharts elements only, the lower region illustrates Extended SCCharts [von Hanxleden et al., PLDI'14].

Scientific Staff:

| | | |
|---|---|---|
| Dipl.-Inf. I. M.-A. Fuhrmann | 01.01.-31.12.2014 | DFG |
| Dipl.-Inf. C. Motika | 01.01.-31.12.2014 | Land |
| M.Sc. U. Rüegg | 01.10.-31.12.2014 | DFG |
| Dipl.-Inf. C. D. Schulze | 01.01.-31.12.2014 | Land |
| Dipl.-Inf. S. Smyth | 01.10.-31.12.2014 | Land |
| Dipl.-Inf. M. Spönemann | 01.01.-31.07.2014 | Land |

## Lectures, Seminars, and Laboratory Course Offers

*Winter 2013/2014*

MS1102: Synchrone Sprachen, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
R. von Hanxleden

Übung zu: Synchrone Sprachen, 2 hrs Exercise/Week,
R. von Hanxleden (+ C. Motika)

MSS1101: Seminar - Echtzeitsysteme / Eingebettete Systeme, 2 hrs Seminar/Week,
R. von Hanxleden (+ I. Fuhrmann)

MSS1102: Masterabschlussseminar - Echtzeitsysteme / Eingebettete Systeme, 2 hrs Seminar/Week,
R. von Hanxleden

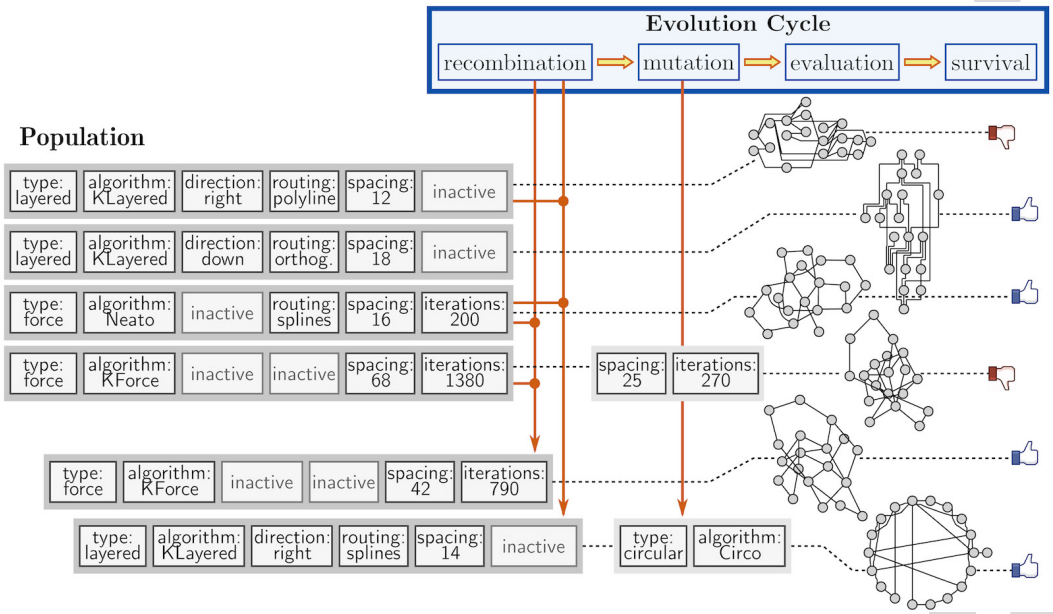


Fig. 2: Evolutionary layout example: starting with a population of four genomes, two new genomes are created through recombination, two genomes are mutated, and four of the resulting genomes survive after their evaluation [Spönemann et al., DIAGRAMS'14]

Übung zu: Modellierung nebenläufiger Systeme, 2 hrs Exercise/Week,
R. von Hanxleden (+ M. Spönemann)

*Summer 2014*

Inf-AP-ES: Abschlussprojekt - Echtzeitsysteme/Eingebettete Systeme (Modellbahn), 6 hrs Practical/Week,
R. von Hanxleden (+ M. Motika, S. Smyth)

Inf-OAR: Organisation und Architektur von Rechnern, 3 (+ 2) hrs Lecture (+ Exercises)/Week,
R. von Hanxleden

Übung zu: Organisation und Architekturen von Rechnern, 2 hrs Exercise/Week,
R. von Hanxleden (+ C. D. Schulze)

Inf-Sem-Echtz: Bachelorseminar Echtzeitsysteme / Eingebettete Systeme (Synchrone Sprachen), 2 hrs Seminar/Week,
R. von Hanxleden (+ I. Fuhrmann, S. Smyth)

MS1101: Modellierung nebenläufiger Systeme, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
R. von Hanxleden

MSP1101: Masterprojekt - Echtzeitsysteme/Eingebettete Systeme (Modellbahn), 4 hrs Practical/Week,
R. von Hanxleden (+ C. Motika, S. Smyth)

MSS1101: Seminar - Echtzeitsysteme / Eingebettete Systeme (Synchrone Sprachen), 2 hrs Seminar/Week,
R. von Hanxleden (+ I. Fuhrmann, S. Smyth)

MSS1102: Masterabschlussseminar - Echtzeitsysteme / Eingebettete Systeme, 2 hrs Seminar/Week,
R. von Hanxleden

*Winter 2014/2015*

Inf-BS: Betriebssysteme, 3 (+ 2) hrs Lecture (+ Exercises)/Week,

Fig. 3: Seminar "Real-Time and Embedded Systems" (07.02.2014).

R. von Hanxleden

Übung zu: Betriebssysteme, 2 hrs Exercise/Week,
R. von Hanxleden (+ C. Motika, S. Smyth)

Inf-EmSysDes: Embedded System Design, 2 (+2) hrs Lecture (+ Exercises)/Week,
R. von Hanxleden

Übung zu: Embedded System Design (Exercises), 2 hrs Exercise/Week,
R. von Hanxleden (+ S. Smyth)

Inf-EntEinSys: Entwurf eingebetteter Echtzeitsysteme, 4 (+2) hrs Lecture (+ Exercises)/Week,
R. von Hanxleden

Übung zu: Entwurf eingebetteter Echtzeitsysteme, 2 hrs Exercise/Week,
R. von Hanxleden (+ S. Smyth)

Inf-Sem-Echtz: Bachelorseminar Echtzeitsysteme/Eingebettete Systeme (Layout), 2 hrs Exercise/Week,
R. von Hanxleden (+ C. D. Schulze, U. Rüegg)

MSS1101: Masterseminar - Echtzeitsysteme / Eingebettete Systeme (Layout), 2 hrs Seminar/Week,
R. von Hanxleden (+ C. D. Schulze, U. Rüegg)

MSS1102: Masterabschlussseminar - Echtzeitsysteme / Eingebettete Systeme, 2 hrs Seminar/Week,
R. von Hanxleden

## Third-Party Funds

DFG, *Precision- Timed Synchronous Reactive Processing,* 07.09.2011-15.04.2015 (251.925,00 EUR)
DFG, *Kompaktes Graphenzeichnen mit Ankerpunkten,* 18.03.2014-30.09.2016 (166.183,00 EUR)

## Further Cooperation, Consulting, and Technology Transfer

The group cooperates with the following individuals and organizations:

Edward A. Lee, University of California, Berkeley, on the automatic layout of Ptolemy II diagrams and simulation of SyncCharts,

Kim Marriott, Monash University, Melbourne, Australia, on automated graph drawing,

John Grundy, Swinburne University of Technology, Melbourne, Australia, on modelling pragmatics,

ETAS/Bosch, on visual model exploration,

National Instruments, on automatic graph drawing,

Michael Mendler, Bamberg University, on sequential constructiveness,

Petra Mutzel, University of Dortmund, on layout algorithms with port constraints,

Partha Roop, University of Auckland, New Zealand, on reactive processors and timing analysis,

Irkutsk State University, on model-based design and reactive processors (funded by DAAD, Ostpartnerschaften-Programm).

## Diploma, Bachelor's and Master's Theses

T. Toepffer, *(Diploma Thesis) Schöne Kurven: Ebenenbasiertes Kantenrouting mit Splines,* 07.11.2014
M. Richter, *(B.Sc. Thesis) Visualisierung von Schienennetzinfrastrukturdaten,* 30.09.2014
K. Petrat, *(B.Sc. Thesis) Erweiterung und Implementierung eines Knotenplatzierungsalgorithmus,* 31.03.2014
C. Sprung, *(B.Sc. Thesis) Inkrementelles Update von Knoten-Kanten-Diagrammen mit EMF Compare,* 31.03.2014
E. Schwanke, *(B.Sc. Thesis) Generierung von UML Klassendiagrammen aus Java Code in Eclipse,* 31.03.2014
A. Schulz-Rosengarten, *(B.Sc. Thesis) Framework zum Tracing von EMF-Modelltransformationen,* 31.03.2014

## Publications

Published in 2014

M. Spönemann, B. Duderstadt, R. von Hanxleden, *Evolutionary Meta Layout of Graphs,* Technical Report, Christian-Albrechts-Universität zu Kiel, Department of Computer Science, **1401**, (2014)

P. Frey, R. von Hanxleden, C. Krüger, U. Rüegg, C. Schneider, M. Spönemann, *Efficient Exploration of Complex Data Flow Models,* In Proceedings of Modellierung 2014, Vienna, Austria, **LNI P-225**, 321 - 336 (2014)

I. Fuhrmann, D. Broman, S. Smyth, R. von Hanxleden, *Towards Interactive Timing Analysis for Designing Reactive Systems,* Technical Report, EECS Department, University of California, Berkeley, **2014-26**, (2014)

I. Fuhrmann, D. Broman, S. Smyth, R. von Hanxleden, *Towards Interactive Timing Analysis for Designing Reactive Systems,* Reconciling Performance and Predictability (RePP'14), satellite event of ETAPS'14, (2014)

M. Spönemann, C. D. Schulze, U. Rüegg, R. von Hanxleden, *Drawing Layered Hypergraphs,* Technical Report, Christian-Albrechts-Universität zu Kiel, Department of Computer Science, **1404**, (2014)

J. Aguado, M. Mendler, R. von Hanxleden, I. Fuhrmann, *Grounding Synchronous Deterministic Concurrency in Sequential Programming,* In Proceedings of the 23rd European Symposium on Programming (ESOP'14), Grenoble, France, **LNCS 8410**, 229 - 248 (2014)

R. von Hanxleden, B. Duderstadt, C. Motika, S. Smyth, M. Mendler, J. Aguado, S. Mercer, O. O'Brien, *SCCharts: Sequentially Constructive Statecharts for Safety-Critical Applications,* In Proceedings of the ACM SIGPLAN Conference on Programming Language Design and Implementation (PLDI'14), Edinburgh, UK, **Volume 49 Issue 6**, 372 - 383 (2014)

C. Gutwenger, R. von Hanxleden, P. Mutzel, U. Rüegg, M. Spönemann, *Examining the Compactness of Automatic Layout Algorithms for Practical Diagrams,* In Proceedings of the Workshop on Graph Visualization in Practice (GraphViP'14), Melbourne, Australia, (2014)

R. von Hanxleden, M. Mender, J. Aguado, B. Duderstadt, I. Fuhrmann, C. Motika, S. Mercer, O. O'Brien, P. Roop, *Sequentially Constructive Concurrency-A Conservative Extension of the Synchronous Model of Computation,* In ACM

Transactions on Embedded Computing Systems, Special Issue on Applications of Concurrency to System Design, **13(4s) article 144**, 1 - 26 (2014)

I. Avazpour, U. Rüegg, J. Grundy, *CONVErT Meets KIELER: Integrating Advanced Layout Algorithms into By-Example Visualizations (Showpiece)*, In Proceedings of the IEEE Symposium on Visual Languages and Human-Centric Computing (VL/HCC'14), Melbourne, Australia, (2014)

M. Almory, J. Grundy, U. Rüegg, *HorusCML: Context-aware Domain Specific Visual Languages Designer*, In Proceedings of the IEEE Symposium on Visual Languages and Human-Centric Computing (VL/HCC'14), Melbourne, Australia, 133 - 136 (2014)

M. Spönemann, C. D. Schulze, U. Rüegg, R. von Hanxleden, *Counting Crossings for Layered Hypergraphs*, In Proceedings of the 8th International Conference on the Theory and Application of Diagrams (DIAGRAMS'14), Melbourne, Australia, **LNAI 8578**, 9 - 15 (2014)

M. Spönemann, B. Duderstadt, R. von Hanxleden, *Evolutionary Meta Layout of Graphs*, In Proceedings of the 8th International Conference on the Theory and Application of Diagrams (DIAGRAMS'14), Melbourne, Australia, **LNAI 8578**, 16 - 30 (2014)

C. D. Schulze, M. Spönemann, C. Schneider, R. von Hanxleden, *Two Applications for Transient Views in Software Development Environments (Showpiece)*, In Proceedings of the IEEE Symposium on Visual Languages and Human-Centric Computing (VL/HCC'14), Melbourne, Australia, (2014)

C. D. Schulze, R. von Hanxleden, *Automatic Layout in the Face of Unattached Comments*, In Proceedings of the IEEE Symposium on Visual Languages and Human-Centric Computing (VL/HCC'14), Melbourne, Australia, 41 - 44 (2014)

C. D. Schulze, M. Spönemann, R. von Hanxleden, *Drawing Layered Graphs with Port Constraints*, Journal of Visual Languages and Computing, Special Issue on Diagram Aesthetics and Layout, **25(2)**, 89 - 106 (2014)

U. Rüegg, S. Kieffer, T. Dwyer, K. Marriott, M. Wybrow, *Stress-Minimizing Orthogonal Layout of Data Flow Diagrams with Ports*, In Proceedings of the 22nd International Symposium on Graph Drawing (GD'14), **LNCS 8871**, 319 - 330 (2014)

C. Motika, R. von Hanxleden, *Light-weight Synchronous Java (SJL)-An Approach for Programming Deterministic Reactive Systems with Java*, Journal of Computing, Special Issue on Software Technologies for Embedded and Ubiquitous Systems, **97(3)**, 281 - 307 (2014)

C. Motika, S. Smyth, R. von Hanxleden, *Compiling SCCharts-A Case-Study on Interactive Model-Based Compilation*, In Proceedings of the 6th International Symposium on Leveraging Applications of Formal Methods, Verification and Validation (ISoLA 2014), Corfu, Greece, **LNCS 8802**, 443 - 462 (2014)

P. Axer, R. Ernst, H. Falk, A. Girault, D. Grund, N. Guan, B. Jonsson, P. Marwedel, J. Reineke, C. Rochange, M. Sebastian, R. von Hanxleden, R. Wilhelm, W. Yi, *Building Timing Predictable Embedded Systems*, In ACM Transactions on Embedded Computing Systems, **Volume 13 Issue 4**, (2017)

## Presentations

P. Frey, R. von Hanxleden, C. Krüger, U. Rüegg, C. Schneider, M. Spönemann, *Efficient Exploration of Complex Data Flow Models*, Modellierung 2014, Vienna, Austria, 20.03.2014

I. Fuhrmann, D. Broman, S. Smyth, R. von Hanxleden, *Towards Interactive Timing Analysis for Designing Reactive Systems*, Reconciling Performance and Predictability (RePP'14), satellite event of ETAPS'14, Grenoble, France, 06.04.2014

R. von Hanxleden, *Taming Graphical Modelling - On Pragmatics-Aware Model-Driven Engineering*, Workshop on Current Trends, Challenges, and Solutions in Model-Driven Engineering, Hasso Plattner Institute, Potsdam, Germany, 30.05.2014

R. von Hanxleden, B. Duderstadt, C. Motika, S. Smyth, M. Mendler, J. Aguado, S. Mercer, O. O'Brien, *SCCharts: Sequentially Constructive Statecharts for Safety-Critical Applications*, ACM SIGPLAN Conference on Programming Language Design and Implementation (PLDI'14), Edinburgh, UK, 09.-11.06.2014

R. von Hanxleden, *Programmierst Du schon, oder malst Du noch - Chancen und Tücken visueller Sprachen,* Programmieren kann jede(r), oder? Ringvorlesung des Instituts für Informatik, CAU Kiel, Germany, 19.06.2014

R. von Hanxleden, *Taming Graphical Modelling - On Pragmatics-Aware Model-Driven Engineering,* Colloquium at INRIA, Grenoble, France, 15.07.2014

M. Spönemann, C. D. Schulze, U. Rüegg, R. von Hanxleden, *Counting Crossings for Layered Hypergraphs,* 8th International Conference on the Theory and Application of Diagrams (DIAGRAMS'14), Melbourne, Australia, 28.07.-01.08.2014

M. Spönemann, B. Duderstadt, R. von Hanxleden, *Evolutionary Meta Layout of Graphs,* 8th International Conference on the Theory and Application of Diagrams (DIAGRAMS'14), Melbourne, Australia, 28.07.-01.08.2014

C. D. Schulze, M. Spönemann, C. Schneider, R. von Hanxleden, *Two Applications for Transient Views in Software Development Environments (Showpiece),* IEEE Symposium on Visual Languages and Human-Centric Computing (VL/HCC'14), Melbourne, Australia, 28.07.-01.08.2014

C. D. Schulze, R. von Hanxleden, *Automatic Layout in the Face of Unattached Comments,* IEEE Symposium on Visual Languages and Human-Centric Computing (VL/HCC'14), Melbourne, Australia, 28.07.-01.08.2014

C. Gutwenger, R. von Hanxleden, P. Mutzel, U. Rüegg, M. Spönemann, *Examining the Compactness of Automatic Layout Algorithms for Practical Diagrams,* Workshop on Graph Visualization in Practice (GraphViP'14), Melbourne, Australia, 01.08.2014

U. Rüegg, S. Kieffer, T. Dwyer, K. Marriott, M. Wybrow, *Stress-Minimizing Orthogonal Layout of Data Flow Diagrams with Ports,* 22nd International Symposium on Graph Drawing (GD'14), Würzburg, Germany, 24.-26.09.2014

C Motika, S. Smyth, R. von Hanxleden, *Compiling SCCharts-A Case-Study on Interactive Model-Based Compilation,* 6th International Symposium on Leveraging Applications of Formal Methods, Verification and Validation (ISoLA 2014), Corfu, Greece, 08.-11.10.2014

C. Motika, *SCCharts in Motion-Interactive Model-Based Compilation for a Railway System,* 21th International Open Workshop on Synchronous Programming (SYNCHRON'14), Aussois, France, 01.12.2014

R. von Hanxleden, K. Rathlev, *SCEst - Sequentially Constructive Esterel,* 21th International Open Workshop on Synchronous Programming (SYNCHRON'14), Aussois, France, 02.12.2014

## Further Activities and Events

**R. von Hanxleden** has the following roles:

- member of the *ArtistDesign European Network of Excellence on Embedded System Design*, - programme committee member for the EDOC 2014 workshop *Methodical Development of Modelling Tools* (ModTools14). - reviewer for the *Journal of Signal - Processing Systems*, *Formal Methods in System Design*.

**I. Fuhrmann:** is a reviewer for *Formal Methods in System Design*.

**C. Motika, C. Schneider, C. D. Schulze, S. Smyth:** were responsible for a demonstration of the Model-Railway, Girls Day 2014 (27.03.2014) and the *Schnupperstudium* (20.-24.10.2014).

**U. Rüegg,** and **C. D. Schulze:** attended the Ph.D. School of the Graph Drawing 2014 conference in Würzburg (22.09.-23.09.2014).

**C. D. Schulze:** is a reviewer for *Journal of Experimental Algorithmics*.

**S. Smyth:** is a reviewer for the *Journal of Signal Processing Systems*.

**M. Spönemann, C. D. Schulze:** visited Kim Marriott at Monash University, Melbourne, Australia (10.07.-25.07.2014).

**Further Activities**: Visit of Priyanka Sajjan from Robert Bosch Engineering and Business Solutions (RBEI) Bangalore, India (30.06.-15.08.2014).

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# Scientific Computing

The Scientific Computing group focuses on the development of fast solvers for partial differential equations and integral equations arising in scientific applications. Since these equations usually cannot be solved analytically, they have to be approximated by a discretization scheme, and the accuracy of these schemes typically depends crucially on the number of variables. Applications frequently require us to handle systems of equations with hundreds of thousands or even millions of variables.

For *partial differential equations*, we can approach this challenge by using a *preconditioner*, i.e. an approximation of the solution operator that can be evaluated efficiently. The preconditioner leads to an iteration scheme that computes a sequence of increasingly better approximations of the solution. For simple partial differential equations with smooth coefficients, multigrid methods provide good preconditioners that lead to rapid convergence.

We are interested in developing preconditioners that can also handle non-smooth coefficients arising, for example, in geophysical or medical simulations where different materials with different material parameters appear in the computational domain. As with multigrid methods, we rely on a multi-level approach: the domain is split into a hierarchy of subdomains, and each subdomain is equipped with a local basis that can be used to approximate its interaction with other domains. The resulting $\mathcal{H}^2$-matrix representation can be constructed by a recursive algorithm; is possible to prove that it leads to preconditioners that can handle discontinuous and anisotropic coefficients.

For *integral equations*, on the other hand, even representing the system of equations poses a challenge since each variable depends on all other variables. Again $\mathcal{H}^2$-matrix methods can be used: we split the computational domain into a hierarchy of subdomains and construct bases for these subdomains by interpolation, quadrature, or cross approximation. Taking advantage of connections between different levels of the hierarchy allows us to obtain algorithms of linear or nearly linear complexity that can handle very large matrices efficiently.

In order to take advantage of modern computing hardware, it is not enough to develop fast algorithms, it is also very important to consider the efficient implementation of these algorithms. Today's supercomputers typically rely on parallelization to reach their high performance, splitting a large computational task into sub-tasks that can be assigned to different computing units.

We are interested in several kinds of parallelization:

- *distributed computing* involves multiple computers that are connected by a network. Algorithms have to manage communication between the computers explicitly, giving the programmer a significant degree of control but also demanding a careful analysis of communication patterns in order to avoid waiting for data. Most of today's supercomputers are constructed based on the principle of distributed computing since it leads to very cost-effective and flexible systems.

- *Shared-memory computing* is based on multiple processors or processor cores sharing the same storage. In this model, the programmer does not have to worry about communication between the processors, as long as the proper synchronization of the different steps of larger computations is ensured and all processors are kept busy most of the time. Since most of today's personal computers and workstations are shared-memory machines involving one or several processors with multiple processor cores, this approach is very attractive for medium-sized applications. Together with the groups "Dependable Systems" (Prof. Dr. Dirk Nowotka) and "Algorithmic Optimal Control — $CO_2$ Uptake of the Ocean" (Prof. Dr. Thomas Slawig), we use a powerful state-of-the-art NUMA shared-memory computer to develop a new generation of parallel algorithms for very large systems of equations e.g. those arising in simulations of acoustic and electrostatic fields.

- *Vectorization* uses processors equipped with multiple arithmetic/logic units that carry out the same task simultaneously. Vectorization can increase the execution speed of an algorithm significantly, if the algorithm can

be organized in a way that requires the *same* operation to be performed uniformly on large arrays of data. Vector units are present in most of today's processors, for example for handling video or audio signals, and more prominently, in graphics processors that can contain several thousand arithmetic/logic units able to work in parallel, leading to a dramatically increased performance for certain applications. We have demonstrated that the vector units included in today's standard processors can be used to reduce the computing time for the approximation of singular integrals arising in boundary integral discretizations by a factor of four and that the processors of standard graphics cards can even reach a factor of 60.

## Results

The first version of the `H2Lib` software package developed by the Scientific Computing group was released to the public in October 2014. The package provides a full-featured implementation of state-of-the-art methods for handling integral equations and elliptic partial differential equations by hierarchical matrices and $\mathcal{H}^2$-matrices. In addition to flexible algorithms for building cluster trees and block trees, compressing matrices, approximating matrix algebraic operations, and constructing preconditioners, the package contains the first implementation of the recently developed GCA algorithm for treating boundary integral equations as well as the first implementation of matrix algebraic operations for $\mathcal{H}^2$-matrices based on local low-rank updates. The package is published under an open source license and is available at `http://h2lib.org`.

We have joined a consortium of scientist spanning the United Kingdom, Spain, France, Belgium, Switzerland, and Germany that has submitted an EU Horizon 2020 proposal to develop and implement the next generation of boundary element algorithms for acoustic and electromagnetic waves.

Following the completion of the DFG project "Separation der Fundamentallösungen elliptischer Differentialgleichungen mit Hilfe von Quadraturverfahren," we have developed a new approximation scheme for boundary integral equations that combines Green's representation formula with a quadrature scheme and a hybrid cross approximation scheme to obtain a very fast and efficient algorithm for constructing $\mathcal{H}^2$-matrix approximations of the required integral operators. Our technique is superior to existing techniques both in terms of computational complexity and storage requirements. A paper containing a description of the new method and a mathematical analysis of its convergence properties has been submitted to "Numerische Mathematik".

In the DFG project "$\mathcal{H}^2$-Matrix-Vorkonditionierer für Integral- und elliptische partielle Differentialgleichungen," we have found a new approach for handling local low-rank updates to $\mathcal{H}^2$-matrices that takes advantage of recursive structures in order to significantly reduce the number of operations. First experiments with an early prototype indicate that the new algorithm is particularly attractive for three-dimensional problems.

A paper describing the original algorithm for local low-rank updates to $\mathcal{H}^2$-matrices and another treating the application of this algorithm to eigenvalue problems have been published in "Computing and Visualization in Science".

During work on the notes for the lecture "Numerik nicht-lokaler Operatoren," a new idea arose for reducing the computational complexity of algebraic operations with $\mathcal{H}$-matrices. The new algorithm has already been implemented, and first experiments indicate that it can reduce the runtime for the construction of preconditioners by up to 50 percent.

## Personnel

Head of the group: Prof. Dr. Steffen Börm; Secretary: Anne Bock, Linda Leonora Haberland

Scientific Staff:

| | | |
|---|---|---|
| Dipl.-Math. Nadine Albrecht | 01.01.-30.09.2014 | Land, 50% |
| $\mathcal{H}^2$-Matrix-Techniken für partielle Differentialgleichungen | | |

| | | |
|---|---|---|
| Dipl.-Math. Nadine Albrecht | 01.10.-31.12.2014 | Future Ocean, 75% |
| Employing high-resolution simulations of reactive flows through porous media to predict seafloor resources | | |
| Dipl.-Math. Dirk Boysen | 01.01.-30.09.2014 | Land, 50% |
| Matrix-Galerkin-Verfahren | | |
| Dipl.-Math. Dirk Boysen | 01.10.-31.12.2014 | Land, 75% |
| Matrix-Galerkin-Verfahren | | |
| Dipl.-Math. Jens Burmeister | 01.01.-31.12.2014 | Land |
| Dipl.-Inf. Sven Christophersen | 01.01.-30.09.2014 | Land, 50% |
| Parallelisierung von $\mathcal{H}$- und $\mathcal{H}^2$-Matrizen | | |
| Dipl.-Inf. Sven Christophersen | 01.10.-31.12.2014 | Land, 75% |
| Parallelisierung von $\mathcal{H}$- und $\mathcal{H}^2$-Matrizen | | |
| Dipl.-Math. Knut Reimer | 01.01.-31.12.2014 | DFG, 75% |
| $\mathcal{H}^2$-Matrix-Vorkonditionierer für Integral- und elliptische partielle Differentialgleichungen | | |

## Lectures, Seminars, and Laboratory Course Offers

*Winter 2013/2014*

Einführung in die numerische Mathematik, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
Steffen Börm (+ Jens Burmeister, Nadine Albrecht)

Wissenschaftliches Rechnen, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
Steffen Börm (+ Dirk Boysen)

Elementare numerische Methoden der Mathematik und ihre Implementierung I, 1 (+ 1) hrs Lecture (+ Exercises)/Week,
Jens Burmeister

*Summer 2014*

Algorithmen und Datenstrukturen, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
Steffen Börm (+ Sven Christophersen)

Numerische Mathematik für Ingenieure, 2 (+ 2) hrs Lecture (+ Exercises)/Week,
Steffen Börm (+ Nadine Albrecht)

Numerische Verfahren für Differentialgleichungen, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
Steffen Börm (+ Jens Burmeister)

Elementare numerische Methoden der Mathematik und ihre Implementierung II, 1 (+ 1) hrs Lecture (+ Exercises)/Week,
Jens Burmeister

*Winter 2014/2015*

Einführung in die numerische Mathematik, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
Steffen Börm (+ Jens Burmeister, Dirk Boysen)

Hochleistungsrechnen, 2 (+ 2) hrs Lecture (+ Exercises)/Week,
Steffen Börm (+ Sven Christophersen)

Numerik nicht-lokaler Operatoren, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
Steffen Börm (+ Sven Christophersen)

Elementare numerische Methoden der Mathematik und ihre Implementierung I, 1 (+1) hrs Lecture (+ Exercises)/Week, Jens Burmeister

## Third-Party Funds

DFG, *Projekt "$\mathcal{H}^2$-Matrix-Vorkonditionierer für Integral- und elliptische Differentialgleichungen"*, 01.01.2013-31.12.2014 (115000 EUR)

## Diploma, Bachelor's and Master's Theses

Katharina Köpper, *Das Getvec-Verfahren für die Behandlung von Eigenwertproblemen*, 27.06.2014
Janina Gnutzmann, *Induzierte Clusterbasen für $\mathcal{H}^2$-Matrizen*, 28.05.2014
Markus Pfeil, *Konvergenzanalyse des Verfahrens der hierarchischen Basen*, 12.03.2014
Erik Steffen, *Parallele Implementierung eines Algorithmus zur Wellenpaketpropagation mit adaptiver Basis und Symplektischen Integratoren mittels OpenMP*, 16.07.2014

## Publications

Published in 2014

Steffen Börm, Knut Reimer, *Efficient arithmetic operations for rank-structured matrices based on hierarchical low-rank updates*, Computing and Visualization in Science, **16**, 247 - 258 (2014)
Peter Benner, Steffen Börm, Thomas Mach, Knut Reimer, *Computing the eigenvalues of symmetric $\mathcal{H}^2$-matrices by slicing the spectrum*, Computing and Visualization in Science, **16**, 271 - 282 (2014)
Steffen Börm, Sven Christophersen, *Approximation of integral operators by Green quadrature and nested cross approximation*, submitted to "Numerische Mathematik", (2014)

## Presentations

Steffen Börm, *H2Lib - $\mathcal{H}^2$-matrices for FEM and BEM applications*, FEM / BEM Network Meeting, London, UK, 20.02.2014
Steffen Börm, *Efficient $\mathcal{H}^2$-matrix preconditioners for FEM and BEM problems*, GAMM Annual Meeting, Erlangen, Germany, 12.03.2014
Steffen Börm, *$\mathcal{H}^2$-matrix preconditioners*, Lothar Collatz CSE Workshop, Plön, Germany, 28.03.2014
Steffen Börm, *$\mathcal{H}^2$-matrix preconditioners*, Workshop Fast PDE Solvers, Oberwolfach, Germany, 16.05.2014
Steffen Börm, *Hochleistungsrechnen auf dem PC*, RIngvorlesung Informatik, CAU Kiel, Germany, 26.06.2014
Steffen Börm, *Advanced Numerical Methods for Non-local Operators*, Zurich Summer School, ETH Zürich, Switzerland, 18.-22.08.2014
Steffen Börm, *Hierarchical matrices*, BeTSSi II Benchmark Workhop, Kiel, Germany, 02.09.2014
Steffen Börm, *$\mathcal{H}^2$-matrix preconditioners*, European Multigrid Conference, Leuven, Belgium, 10.09.2014
Steffen Börm, *$\mathcal{H}^2$-Matrices*, Kolloquium für angewandte Mathematik, TU Hamburg-Harburg, Germany, 05.12.2014
Knut Reimer, *$\mathcal{H}^2$-matrix based preconditioner*, Norddeutsches Kolloquium über Angewandte Analysis und Numerische Mathematik (NoKo), Kiel, Germany, 09.-10.05.2014
Dirk Boysen, *An $\mathcal{H}^2$-matrix Galerkin approach for solving matrix equations*, Norddeutsches Kolloquium über Angewandte Analysis und Numerische Mathematik (NoKo), Kiel, Germany, 09.-10.05.2014
Sven Christophersen, *Approximation of Galerkin BEM matrices by quadrature*, BeTTSI II Benchmark Workshop, Kiel, Germany, 03.09.2014

Hierarchical Matrices: winter school at the Max Planck Institute for Mathematics in the Sciences, Leipzig, 24th to 28th of February, 2014.

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# Software Engineering

The research of the Software Engineering Group focuses on Software Engineering for parallel and distributed systems. Traditionally, software engineering addresses the process of constructing and evolving software systems. The operation of systems that are expected to provide services continuously with required quality properties is another great challenge. One goal of the Software Engineering Group is to investigate innovative techniques and methods for engineering, evolving, and operating continuously running software systems.

Of particular interest are our **KoSSE** network with colleagues of the Computer Science Institutes in Kiel and Lübeck (https://www.kosse-sh.de), and the KoSSE office that we are establishing together with the Cluster Management DiWiSH (http://www.diwish.de/).

We contribute to several **research data management** activities, for instance, in the Excellence Cluster Future Ocean, and the project PubFlow on publication workflows for research data.

## Results

### Kieker

In addition to studying the construction and evolution of software services, the software engineering discipline needs to address the operation of continuously running software services. Methods for effective monitoring of software runtime behaviour are needed for robust operation. In contrast to profiling for development activities, monitoring of operational services should only impose a small performance overhead. Furthermore, instrumentation should be non-intrusive to the business logic, as far as possible.

The Kieker framework supports monitoring of software runtime behaviour, e.g. performance or (distributed) trace data. The flexible architecture allows the replacement or addition of framework components, including monitoring probes, analysis components, and record types shared by logging and analysis. Kieker creates Sequence Diagrams, Dynamic Call Trees, Markov chains, and Component Dependency Graphs from monitoring data. As a non-intrusive instrumentation technique, Kieker currently employs, but is not restricted to, aspect-oriented programming.

Extensive lab studies quantified the low overhead caused by the framework components. Qualitative evaluations provided by industrial case studies demonstrate the practicality of the approach.

Kieker is available as open-source software. For more information on Kieker, refer to http://www.kieker-monitoring.net

Kieker is a recommended tool of the SPEC Research Group: http://research.spec.org/projects/tools.html

### ExplorViz

ExplorViz uses dynamic analysis techniques to provide live trace visualization of the communication in large software landscapes. It targets system and program comprehension in those landscapes while still providing details on the communication within an application. A landscape perspective enriches current system visualizations with additional abstraction levels for efficient comprehension of communication between hundreds of applications, which is often encountered in Cloud environments for instance. On the application level perspective, ExplorViz utilizes the 3D city metaphor combined with an interactive concept of showing only details that are in the focus of the analysis. For best accessibility, ExplorViz is a web-based tool featuring cutting-edge technologies like WebGL and HTML 5.

Given the 3D city metaphor visualization of an application, we investigate new interaction styles and higher immersion for a more effective and efficient program comprehension process. For this purpose, we utilize rising technologies like the Microsoft Kinect v2 and the Oculus Rift. Furthermore, we explore possibilities to physically touch and interact with the 3D software models by utilizing 3D printing. We evaluate those approaches in controlled experiments with real test subjects.

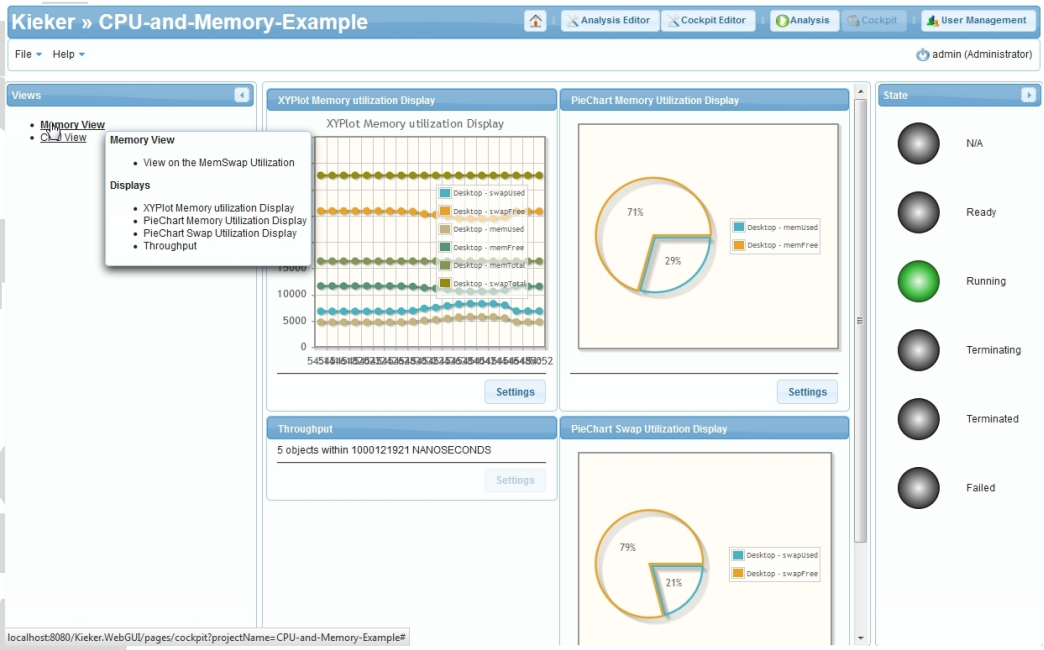


Fig. 1: Web-based Kieker Cockpit

The usability and effectiveness of ExplorViz has been investigated in controlled experiments, which resulted in increased efficiency and effectiveness over competing approaches.

ExplorViz is available as open-source software. For more information on ExplorViz, we refer to http://www.explorviz.net

## PubFlow

The goal of PubFlow is to investigate workflow support for research data publication and build a software prototype to assist researchers in their daily work with such data. PubFlow is not about long-term preservation but is about the workflows from institutional archives towards publication of research and archival data in world data centres. The goals of the project are to create a workflow environment for the work with research data, based on established business workflow systems, and to increase the degree of automation in the publication process. The assumption is that the quality of the published data will increase if the data is enriched with automatically collected provenance data.

To meet the requirements that scientific workflows pose on the business workflow systems that are employed in PubFlow, a software environment will be developed in which the business workflow engine is embedded. This software environment provides tools for the automatic collection of provenance information as well as enhanced business workflow monitoring features and interfaces for the interaction with the users and the data archives. The software architecture is a service-oriented architecture such that individual software components can be exchanged independently. In PubFlow, Kieker is extended for workflow monitoring.

To facilitate the work with scientific workflows, the PubFlow system will provide various abstraction mechanisms. Scientists and data managers will be able to define their workflows in a BPMN 2.0 compliant, customized, domain-specific workflow language which then will be translated to BPEL for execution. During their daily work, scientists interact through a simple, easy-to-use task-management interface with the PubFlow system. There should be no need for them to deal with complex workflows.

In the first phase of the project the ideas and tools created will be tested in the field of Marine Sciences. The PubFlow project started in August 2011 and was finished in July 2014.

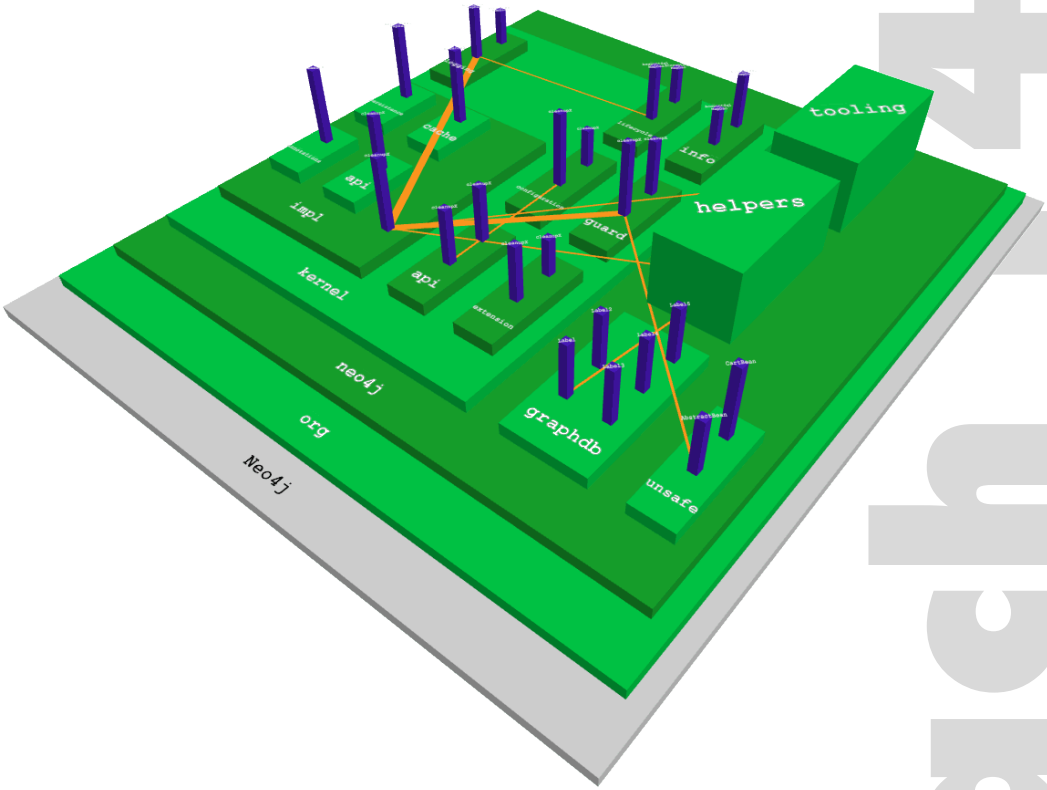


Fig. 2: 3D Program Visualization with ExplorViz

For more information on PubFlow, refer to http://www.pubflow.uni-kiel.de/

### iObserve

The increased adoption of service-oriented technologies and cloud computing creates new challenges for the adaptation and evolution of long-living software systems. Software services and cloud platforms are owned and maintained by independent parties. Software engineers and system operators of long-living software systems only have limited visibility and control over those third-party elements. Traditional monitoring provides software engineers and system operators with execution observation data which are used as a basis to detect anomalies. If the services and the cloud platform are not owned and controlled by the engineers of the software systems, monitoring the execution of the software system is not straightforward.

The aim of the iObserve project is to develop and validate advanced techniques which empower the system engineers to observe and detect anomalies, as well as privacy violations, of the execution of software systems. It will extend and integrate previous work on adaptive monitoring, online testing, and benchmarking and will use models at runtime as a means to adjust the observation and anomaly detection techniques during system operation. To demonstrate the feasibility and potential benefits gained, and for providing feedback to guide the research, the results will be evaluated continuously using an established research benchmark (CoCoME) as well as an industry-driven open-source application (Eclipse Skalli) that runs on a cloud platform.

The iObserve project started in November 2012 and will last until October 2015.

For more information on iObserve, refer to http://www.dfg-spp1593.de/iobserve

### TeeTime

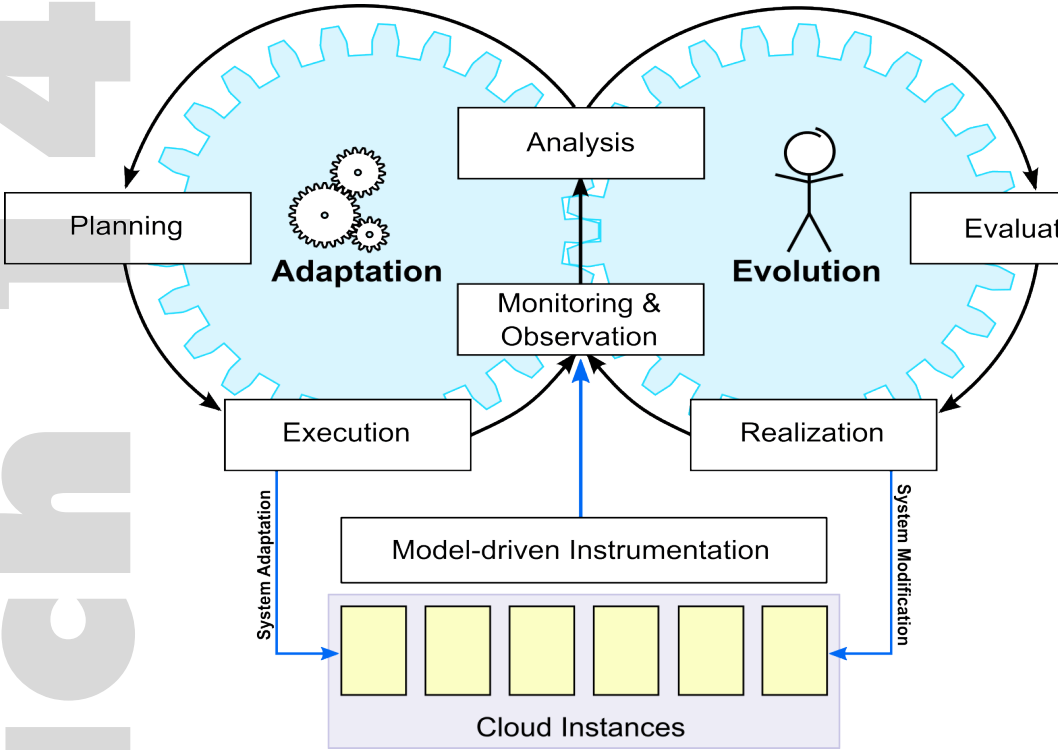


Fig. 3: Integrated Adaptation and Evolution Cycles via Cloud Observation in iObserve

The well-known Pipes-and-Filters architectural pattern organizes and executes components with sequential dependencies. Therefore, the pattern is often used to perform several tasks consecutively on large data streams, e.g. during image processing, dynamic analysis, or big data streams in general.

In contrast to this popularity and its applications, there is a lack of flexible, feature-rich, fast, and concurrency-aware Pipes-and-Filters frameworks. So far, it is common practice that most developers write their own implementation tailored to their specific use cases and demands, thus hampering any effective re-use.

TeeTime fills this gap by providing a generic and concurrency-aware framework to develop and execute arbitrary pipeline architectures in an efficient way. It manages pipes and filters as first-class entities allowing a decoupling of the communication logic and the filters' computation logic. In this way, a filter developer can focus on the domain logic and let the framework decide whether the communication between two stages needs to be synchronized or not. Moreover, TeeTime supports the concept of combining multiple stages in a single stage. This enables the hierarchical encapsulation and the reusability of stages, leading to an improvement in software development productivity.

TeeTime is available as open-source software for the Java programming language. For more information on TeeTime, we refer to http://teetime.sf.net.

### ESN Software Lab

ESN Software Lab is a collaborative project between ESN EnergieSystemeNord GmbH and the software engineering group to advance technology transfer in software engineering. In the first phase, we are inventing a new product line architecture for web-based software cockpits.

Head of the group: Prof. Dr. Wilhelm Hasselbring; Secretary: Christine Krüger (50%)
Technical Staff: B. Sc. Arnd Plumhoff, B. Sc. Matthias Westphal (50%)

Scientific Staff:

| | | |
|---|---|---|
| Dipl. Inf. Peer Brauer<br>PubFlow, Kieker | 01.01.-31.07.2014 | DFG |
| M. Sc. Nils Ehmke<br>Kieker | 01.01.-31.12.2014 | CAU |
| M. Sc. Florian Fittkau<br>Kieker, ExplorViz | 01.01.-31.12.2014 | CAU |
| Arne Johanson<br>HOSST | 01.01.-31.12.2014 | GEOMAR |
| Dipl. Inf. Reiner Jung<br>Kieker, iObserve, GECO | 01.01.-31.12.2014 | DFG |
| Dipl. Inf. Jan Waller<br>Kieker, MooBench | 01.01.-30.09.2014 | CAU |
| M. Sc. Christian Wulf<br>ESN Software Lab, Kieker, TeeTime | 01.01.-31.12.2014 | CAU, ESN |

## Lectures, Seminars, and Laboratory Course Offers

*Winter 2013/2014*

Abschlussprojekt - Software Engineering, 6 hrs Exercise/Week,
W. Hasselbring (+ F. Fittkau, J. Waller, C. Wulf)

Softwarearchitektur, 2 (+1) hrs Lecture and Exercise (+ Exercises)/Week,
W. Hasselbring

Softwareprojekt, 3 hrs Exercise/Week,
W. Hasselbring (+ N. Ehmke, F. Fittkau)

Softwaretechnik, 4 (+2) hrs Lecture and Exercise (+ Exercises)/Week,
D Nowotka (+ N. Ehmke, J. Waller)

Masterprojekt - Software Engineering für parallele und verteilte Systeme, 4 hrs Exercise/Week,
W. Hasselbring (+ F. Fittkau, J. Waller, C. Wulf)

M.Sc. Seminar - Software Performance Engineering, 2 hrs Seminar/Week,
W. Hasselbring (+ N. Ehmke, F. Fittkau, J. Waller, C. Wulf)

*Summer 2014*

Abschlussprojekt - Software Engineering, 6 hrs Exercise/Week,
R. von Hanxleden (+ N. Ehmke, F. Fittkau, J. Waller, C. Wulf)

B.Sc. Seminar Software Engineering, 2 hrs Seminar/Week,

R. von Hanxleden (+ N. Ehmke, F. Fittkau, J. Waller, C. Wulf)

Softwareprojekt, 3 (+1) hrs Seminar and Exercise (+ Exercises)/Week,
R. von Hanxleden (+ N. Ehmke, C. Starke)

M.Sc. Projekt - Software Engineering für parallele und verteilte Systeme, 4 hrs Exercise/Week,
R. von Hanxleden (+ N. Ehmke, F. Fittkau, J. Waller, C. Wulf)

M.Sc. Seminar - Software Performance Engineering, 2 hrs Seminar/Week,
R. von Hanxleden (+ N. Ehmke, F. Fittkau, J. Waller, C. Wulf)

*Winter 2014/2015*

Abschlussprojekt - Software Engineering, 6 hrs Exercise/Week,
W. Hasselbring (+ N. Ehmke, F. Fittkau, C. Wulf)

B.Sc. Seminar Software Engineering, 2 hrs Seminar/Week,
W. Hasselbring (+ N. Ehmke, F. Fittkau, C. Wulf)

Software Architecture, 2 (+1) hrs Lecture and Exercise (+ Exercises)/Week,
W. Hasselbring

Softwareprojekt, 3 (+1) hrs Seminar and Exercise (+ Exercises)/Week,
W. Hasselbring (+ F. Fittkau)

Softwaretechnik, 4 (+2) hrs Lecture and Exercise (+ Exercises)/Week,
H. Hasselbring (+ N. Ehmke, C. Wulf)

M.Sc. Projekt - Software Engineering für parallele und verteilte Systeme, 4 hrs Exercise/Week,
W. Hasselbring (+ F. Fittkau)

M.Sc. Seminar - Software Performance Engineering, 2 hrs Seminar/Week,
W. Hasselbring (+ F. Fittkau, C. Wulf)

## Third-Party Funds

DFG, *iObserve: Integrated Observation and Modelling Techniques to Support Adaptation an Evolution of Software Systems*, 01.11.2012-31.10.2015 (247.683 Eur)
DFG, *PubFlow: Publikationsprozesse für Forschungsdaten: Von der Erhebung und Verarbeitung zur Archivierung und Publikation*, 01.08.2011-31.07.2014 (218.500 Eur)
ISH:, *Transferprämie 2012*, 01.11.2012-15.11.2014 (10.000 Eur)
ESN, *ESN Software Lab*, 16.11.2012-15.11.2014 (128.475 Eur)
Helmholtz Association, *Helmholtz Research School Ocean System Science and Technology (HOSST)*, 01.11.2012-31.10.2015 ((Ph.D. Scholarship))

## Further Cooperation, Consulting, and Technology Transfer

During his sabbatical in spring 2014, Prof. Hasselbring visited the Web Science Institute at the University of Southampton, UK.

In the excellence cluster Future Ocean, we cooperate with the Kiel Data Management Team at GEOMAR.

In HOSST (Helmholtz Research School Ocean System Science and Technology), we cooperate with GEOMAR.

In Kieker, we cooperate with several industrial partners such as b+m Informatik AG, Airbus, and XING AG as well as with researchers from other universities, such as Karlsruhe Institute of Technology (KIT) and the University of Stuttgart.

In KoSSE (Kompetenzverbund in Software Systems Engineering, http://www.kosse-sh.de/), we cooperate with several groups of the computer science departments of Kiel and Lübeck, with the Cluster Management DiWiSH, and with several regional companies.

In PubFlow, we cooperate with GEOMAR (their Library and Data and Computing Centre), ZBW (Leibniz-Informationszentrum Wirtschaft), as well as the Library and Computing Centre of the CAU, and the excellence cluster Future Ocean.

In iObserve, we cooperate with the Karlsruhe Institute of Technology (KIT) and the University of Duisburg-Essen.

In ESN Software Lab, we cooperate with ESN EnergieSystemeNord GmbH.

In the SPEC Research Group, we cooperate with the Universities of Stuttgart and Würzburg, the KIT and Fortiss.

## Diploma, Bachelor's and Master's Theses

A. Barbie, *Stable 3D City Layout in ExplorViz*, 30.09.2014
M. Barzel, *Evaluation von Clustering-Verfahren von Klassen für hierarchische Visualisierung in ExplorViz*, 30.09.2014
S. Finke, *Automatische Anleitung einer Versuchsperson während eines kontrollierten Experiments in ExplorViz*, 26.09.2014
S. Mahmens, *Architektur Rekonstrukion mit Kieker durch AOP-basierte Instrumentierung einer C++-Anwendung*, 17.04.2014
N. Matthiesen, *Monitoring Remote Procedure Calls - Concepts and Evaluation*, 11.04.2014
E. Schulz, *Integrating Performance Tests in a Generative Software Development Platform*, 02.06.2014
P. Stelzer, *Scalable and Live Trace Processing in the Cloud*, 31.03.2014
J. Weiland, *Performance-Analyse und Architektur-Rekonstruktion von Delphi-Anwendungen mit Hilfe von Kieker*, 17.07.2014
B. Weißenfels, *Evaluation of Trace Reduction Techniques for Online Trace Visualization*, 12.05.2014
L. Zhou, *Umsetzung von Human Task zentrierten Business Workflows in PubFlow*, 29.09.2014
M. Zloch, *Automatisierte Durchführung und Auswertung von Microbenchmarks in Continuous Integration Systemen*, 31.03.2014

## Dissertations / Postdoctoral Lecture Qualifications

A. van Hoorn, *Model-Driven Online Capacity Management for Component-Based Software Systems*, 18.09.2014
M. Rohr, *Workload-sensitive Timing Behaviour Analysis for Fault Localization in Software Systems*, 02.10.2014
J. Waller, *Performance Benchmarking of Application Monitoring Frameworks*, 12.12.2014

## Publications

Published in 2014

S. Becker, W. Hasselbring, A. van Hoorn, S. Kounev, R. Reussner, *Proceedings of the 2014 Symposium on Software Performance (SOSP '14): Joint Descartes/Kieker/Palladio Days*, Konferenzband, (2014)
P. C. Brauer, A. Czerniak, W. Hasselbring, *Start Smart and Finish Wise: The Kiel Marine Science Provenance-Aware Data Management Approach*, 6th USENIX Workshop on the Theory and Practice of Provenance (TaPP 2014),, (2014)
P. C. Brauer, F. Fittkau, W. Hasselbring, *The Aspect-Oriented Architecture of the CAPS Framework for Capturing, Analyzing and Archiving Provenance Data*, 5th International Provenance and Annotation Workshop (IPAW 2014), (2014)
F. Fittkau, A. van Hoorn, W. Hasselbring, *Towards a Dependability Control Centre for Large Software Landscapes*, Tenth European Dependable Computing Conference (EDCC 2014), (2014)

F. Fittkau, P. Stelzer, W. Hasselbring, *Live Visualization of Large Software Landscapes for Ensuring Architecture Conformance*, ECSAW 2nd International Workshop on Software Engineering for Systems-of-Systems 2014 (SESoS 2014), (2014)

S. Frey, *Conformance Checking and Simulation-based Evolutionary Optimization for Deployment and Reconfiguration of Software in the Cloud*, Faculty of Engineering, Kiel University, (2014)

U. Goltz, R. H. Reussner, M. Goedicke, W. Hasselbring, L. Märtin, B. Vogel-Häuser, *Design for future: managed software evolution*, Computer Science - Research and Development, (2014)

W. Hasselbring, N. Ehmke, *Software Engineering 2014: Fachtagung des GI-Fachbereichs Softwaretechnik*, Konferenzband, (2014)

A. Johanson, W. Hasselbring, *Sprat: Hierarchies of Domain-Specific Languages for Marine Ecosystem Simulation Engineering*, Spring Simulation Multi-Conference (SpringSim 2014), (2014)

A. Johanson, W. Hasselbring, *Hierarchical Combination of Internal and External Domain-Specific Languages for Scientific Computing*, International Workshop on DSL Architecting & DSL-based Architectures (DADA'14), (2014)

R. Jung, *GECO: Generator Composition for Aspect-Oriented Generators*, Doctoral Symposium - Models 2014, (2014)

R. Jung, R. Heinrich, E. Schmieders, S. Misha, W. Hasselbring, *A Method for Aspect-oriented Meta-Model Evolution*, 2nd Workshop on View-Based, Aspect-Oriented and Orthographic Software Modelling, (2014)

M. Rohr, *Workload-sensitive Timing Behaviour Analysis for Fault Localization in Software Systems*, Faculty of Engineering, Kiel University, (2014)

E. Schulz, W. Goerigk, W. Hasselbring, A. van Hoorn, H. Knoche, *Model-Driven Load and Performance Test Engineering in DynaMod*, Workshop on Model-based and Model-driven Software Modernization (MMSM '14), (2014)

A. van Hoorn, H. Grow, J. Waller, R. Jung, *Kieker Poster*, 5th ACM/SPEC International Conference on Performance Engineering (ICPE 2014), (2014)

A. van Hoorn, *Model-Driven Online Capacity Management for Component-Based Software Systems*, Faculty of Engineering, Kiel University, (2014)

A. van Hoorn, C. Vögele, E. Schulz, W. Hasselbring, H. Krcmar, *Automatic Extraction of Probabilistic Workload Specifications for Load Testing Session-Based Application Systems*, 8th International Conference on Performance Evaluation Methodologies and Tools (ValueTools 2014), (2014)

J. Waller, F. Fittkau, W. Hasselbring, *Application Performance Monitoring: Trade-Off between Overhead Reduction and Maintainability*, Symposium on Software Performance (SOSP 2014), (2014)

J. Waller, *Benchmark for: Performance Benchmarking of Application Monitoring Frameworks*, ZENODO, (2014)

J. Waller, *Data for: Performance Benchmarking of Application Monitoring Frameworks*, ZENODO, (2014)

J. Waller, *Performance Benchmarking of Application Monitoring Frameworks*, Faculty of Engineering, Kiel University, (2014)

C. Wulf, N. Ehmke, W. Hasselbring, *Toward a Generic and Concurrency-Aware Pipes & Filters Framework*, Symposium on Software Performance (Joint Descartes/Kieker/Palladio Days), (2014)

C. Wulf, *Pattern-based Detection and Utilization of Potential Parallelism in Software Systems*, Software Enginnering 2014, (2014)

## Presentations

P. C. Brauer, *CAPS : Capturing and Managing Provenance Information in Scientific Workflows*, ZBW PHD Springschool 2014, Hamburg, Germany, 24.-24.03.2014

P. C. Brauer, *Start Smart and Finish Wise: The Kiel Marine Science Provenance-Aware Data Management Approach*, 6th USENIX Workshop on the Theory and Practice of Provenance (TaPP 2014), Cologne, Germany, 12.-13.06.2014

P. C. Brauer, *The Aspect-Oriented Architecture of the CAPS Framework for Capturing, Analyzing and Archiving Provenance Data*, 5th International Provenance and Annotation Workshop (IPAW 2014), Cologne, Germany, 10.-11.06.2015

P. C. Brauer, *PubFlow: A Scientific Data Publication Framework for Marine Science,* Oceanology International 2014, London, UK, 12.-12.03.2014

P. C. Brauer, *Präsentation von PubFlow auf dem Gemeinschaftsstand auf der Oceanology International-2014,* Oceanology International 2014, London, UK, 11.-13.03.2014

P. C. Brauer, *Das PubFlow Framework : Business Workflows für die Wissenschaft,* PubFlow Workshop, Hamburg, Germany, 18.-18.03.2014

P. C. Brauer, *Die Architektur des PubFlow Workflow Management Systems,* b+m A-Team, Melsdorf, Germany, 21.-21.03.2014

N. C. Ehmke, *The Kieker Analysis Framework & Kieker's WebGUI,* b + m A-Team, Melsdorf, Germany, 07.-07.11.2014

N. Ehmke, *Continuous Integration in Kieker (Experience Report),* Symposium on Software Performance (Joint Descartes/Kieker/Palladio Days), Stuttgart, Germany, 28.-28.11.2014

N. C. Ehmke, *Kieker Monitoring Framework (Tutorial),* 5th ACM/SPEC International Conference on Performance Engineering, Dublin, Republic of Ireland, 23.-23.03.2014

F. Fittkau, *Towards a Dependability Control Centre for Large Software Landscapes,* Tenth European Dependable Computing Conference (EDCC 2014), Newcastle upon Tyne, UK, 13.-16.05.2014

F. Fittkau, *Hands on EPrints - Haptic Software Systems through 3D Printing,* Hands on EPrints Presentation, Southampton, UK, 06.-06.06.2014

F. Fittkau, *Live Visualization of Large Software Landscapes for Ensuring Architecture Conformance,* ECSAW 2nd International Workshop on Software Engineering for Systems-of-Systems 2014 (SESoS 2014), Vienna, Austria, 26.-26.08.2014

F. Fittkau, *Application Performance Monitoring: Trade-Off between Overhead Reduction and Maintainability,* Symposium on Software Performance (SOSP 2014), Stuttgart, Germany, 27.-27.11.2014

W. Hasselbring, *Application Performance Monitoring and Reverse Engineering with Kieker,* Vortrag Airbus Group, Bremen, Germany, 07.-07.03.2014

W. Hasselbring, *Modernisierung von Altsoftware,* Vortrag Kieler Salon, Kiel, Germany, 11.-11.03.2014

W. Hasselbring, *Technologie-Transfer im Software Engineering,* DiWiSH-Beirat, Kiel, Germany, 17.-17.03.2014

W. Hasselbring, *Publication Workflows for Scientific Data,* National Oceanography Centre, Southampton, UK, 05.-05.06.2014

W. Hasselbring, *Architektur und Einsatz des Kieker Monitoring und Analyse Frameworks,* Otto Group, Hamburg, Germany, 04.-04.07.2014

W. Hasselbring, *Application Performance Monitoring & Architecture Discovery with Kieker,* WAIS Seminar, Southampton, UK, 23.-23.04.2014

W. Hasselbring, *Publication Workflows for Scientific Data,* WAIS Seminar, Southampton, UK, 23.-23.04.2014

A. Johanson, *Sprat:: Hierarchies of Domain-Specific Languages for Marine Ecosystem Simulation Engineering,* Spring Simulation Multi-Conference (SpringSim 2014), Florida, USA, 12.-17.04.2014

A. Johanson, *Hierarchical Combination of Internal and External Domain-Specific Languages for Scientific Computing,* International Workshop on DSL Architecting & DSL-based Architectures (DADA'14), Vienna, Austria, 26.-26.08.2014

R. Jung, *Evolution of the Palladio Component Model: Process and Modelling Methods,* Symposium on Software Performance (SOSP 2014), Stuttgart, Germany, 26.-28.11.2014

R. Jung, *GECO: Generator Composition for Aspect-Oriented Generators,* Doctoral Symposium - Models 2014, Valencia, Spain, 28.09.-03.10.2014

R. Jung, *A Method for Aspect-oriented Meta-Model Evolution,* 2nd Workshop on View-Based, Aspect-Oriented and Orthographic Software Modelling, York, UK, 22.-22.07.2014

R. Jung, *GECO: Automatic Generator-Composition for (Aspect-oriented) DSLs,* Doctoral Symposium SE 2014, Kiel, Germany, 26.-26.02.2014

R. Jung, *Integrating Run-Time Observations and Design Component Models for Cloud System Analysis,* 9th Workshop on Models@run.time, Valencia, Spain, 30.09.2014-30.09.3014

C. Wulf, *Pattern-Based Detection and Utilization of Potential Parallelism in Software Systems*, International Summer School in Parallel Patterns 2014, Dublin, Republic of Ireland, 09.-12.06.2014

C. Wulf, *Mock Me If You Can - An Introduction to the Mocking Framework Mockito*, Symposium on Software Performance 2014: Joint Descartes/Kieker/Palladio Days, Stuttgart, Germany, 26.-28.11.2014

C. Wulf, *Pattern-based Detection and Utilization of Potential Parallelism in Software Systems*, Software Engineering 2014, Kiel, Germany, 26.-26.02.2014

C. Wulf, *Toward a Generic and Concurrency-Aware Pipes & Filters Framework*, Symposium on Software Performance 2014: Joint Descartes/Kieker/Palladio Days, Stuttgart, Germany, 26.-28.11.2014

## Further Activities and Events

**P. Brauer:**

- Organization of PubFlow Workshop 2014.

**F. Fittkau has been a reviewer for:**

- 4th Track on Adaptive and Reconfigurable Service-oriented and component-based Applications and Architectures (AROSA 2014),
- 9th Trends in Enterprise Architecture Research Workshop (TEAR 2014).

**W. Hasselbring has had the following activities:**

- Dean of the Faculty of Engineering (until April 2014)
- Member of the Excellence Cluster Future Ocean (Principal Investigator for the second Phase)
- Member of the Excellence Cluster Inflammation at Interfaces,
- Member of the Computational Sciences Center at CAU,
- Chairman of the Kiel KoSSE Projects,
- Chairman of the Board of GI-Fachgruppe Softwaretechnik,
- Board of GI-Fachgruppe Software-Architektur.
- He has also been a reviewer for the following funding agencies:
  - BMBF: Bundesministerium für Bildung und Forschung,
  - BMWFW: Bundesministerium für Wissenschaft, Forschung und Wirtschaft (Österreich),
  - DFG: Deutsche Forschungsgemeinschaft,
  - FWF: Fonds zur Förderung der wissenschaftlichen Forschung (Österreich).
- He is on the Editorial Board of the following journals:
  - Advances in Software Engineering,
  - Enterprise Modelling and Information Systems Architectures - An International Journal,
  - International Journal of Software Architecture,
  - International Review on Modelling and Simulations,
  - Softwaretechnik-Trends.

- He is also a reviewer for the following journals and publishers:
  - IEEE Transactions on Cloud Computing,
  - International Journal of Cloud Computing,
  - Journal of Software: Evolution and Process.
- He is a member of the programme committees for various conferences and workshops such as

  **SE 2014:** Sofware Enginnering 2014,

  **ICPE 2014:** 5th ACM/SPEC International Conference on Performance Engineering,

  **CSE 2014:** International Workshop on Continuous Software Engineering,

  **MAT2014:** Workshop Modellierung in der Automatisierungstechnik,

  **ECSA2014:** 8th European Conference on Software Architecture,

  **DFF 2014:** Workshop Design for Future,

  **MMSM2014:** Workshops Modellbasierte und modellgetriebene Softwaremodernisierung,

  **RCoSE 2014:** International Workshop on Rapid Continuous Software Engineering,

  **PESOS 2014:** 6th International Workshop on Principles of Engineering Service-Oriented and Cloud Systems,

  **WETICE 2014:** IEEE 23rd International Conference on Enabling Technologies: Infrastructure for Collaborative Enterprises,

  **CBI 2014:** 16th IEEE Conference on Business Informatics,

  **TEAR 2014:** 9th Trends in Enterprise Architecture Research Workshop,

  **ECIS 2015:** 23rd European Conference on Information Systems,

  **SESoS 2015:** 2nd International Workshop on Software Engineering for Systems-of-Systems,

  **SERA 2015:** 13th International Conference on Software Engineering Research, Management and Applications,

  **PESOS 2015:** 7th International Workshop on Principles of Engineering Service-Oriented and Cloud Systems,

  **RCoSE 2015:** 2nd International Workshop on Rapid Continuous Software Engineering,

  **ESEC/FSE 2015:** European Software Engineering Conference and the ACM SIGSOFT Symposium on the Foundations of Software Engineering ,

  **ECSA 2015:** 9th European Conference on Software Architecture,

  **TEAR 2015:** 10th Trends in Enterprise Architecture Research Workshop,

  **EMISA 2015:** 6th International Workshop on Enterprise Modelling and Information Systems Architectures.
- Finally he has been responsible for the organization of:
  - KoSSE-Tag 2014,
  - Sofware Engineering 2014.

**R. Jung has had the following avtivities:**

- Organization of EMLS 2014: 1st Collaborative Workshop on Evolution and Maintenance of Long-Living Software Systems,
- Reviewer for 6th International Workshop on Principles of Engineering Service-Oriented and Cloud Systems (PESOS 2014).

# Technical Computer Science

The research group "Technical Computer Science" works in the area of the physical design of computer systems and their applications in different fields. The main focus is on massively parallel systems, particularly systems that can speed up computer intensive operations by the use of special purpose hardware architectures. The activities during 2014 can be subsumed under three headings:

- the on-going development of new massively parallel architectures,
- the development and implementation of new parallel algorithms for specific computationally demanding problems in bioinformatics,
- the deployment of massively parallel algorithms for economic optimisation problems.

## Results

### Bio-Engine

Many problems in scientific computing and cryptanalysis are currently intractable due to the limitations of standard PC architectures or clusters of them. Solutions for that lack of performance are problem specific architectures such as supercomputers, grid computing, or even application specific circuits (ASICs). Lately, a new architectural approach has proved its benefits: using field programmable gate arrays. These reconfigurable silicon devices combine the flexibility of general-purpose circuits, like CPUs in computers, with the speed-up of ASICs.

The Technical Computer Science research group utilizes these reconfigurable devices in a parallel architecture called RIVYERA that is equipped with 128 Xilinx Spartan6-LX150 FPGAs. It has been in operation since July 2012 and is still the basis of some research projects in 2014. However, the investigation of a new architecture consisting of several development boards with Xilinx' recent 7-series FPGAs (i.e. Kintex7 and Virtex7) has been started.

### Massively Parallel Implementation of Algorithms in Bioinformatics

Current research in the area of bioinformatics is focused on two externally funded projects. Firstly, in collaboration with the ICMB, the challenge is to massively parallelize the process of SNP imputation on the architecture RIVYERA S6-LX150, containing 128 Xilinx Spartan6-LX150 FPGAs.

SNP imputation is used by biologists to determine the two haplotype vectors of an individual from its genotype information on a set of SNP positions. The imputation process consists of two parts, phasing and imputation, where phasing is the more computationally intensive one. Phasing is based on Hidden Markov Models (HMMs) and the Viterbi algorithm. It becomes computationally very intensive due to a runtime and memory complexity proportional to the number of sites (SNPs), number of references, number of states per site, and the number of iterations. A normal run for a standard dataset takes from several hours up to days on a workstation cluster. Our realization of the phasing part is based on the method SHAPEIT2 (Delaneau et al., 2013) and will be finished in early 2015; the expected speedup will be about 100 compared to a standard Xeon octo-core processor.

Secondly, in 2013 we started an AiF project (ZIM-KOOP), in cooperation with SciEngines GmbH and Johannes Gutenberg University Mainz. to combine the advances of FPGAs with those of GPU technology with a focus on particular areas of algorithms in bioinformatics, including SNP-SNP interactions in Genome-Wide Association Studies (GWAS) and Short-Read-Alignment (SRA). In 2014 we published the implementations of the tools iLOCi (Piriyapongsa et al., 2012) and BOOST (Wan et al., 2010) on the RIVYERA architecture. Furthermore, we implemented BOOST and a third-order interaction measurement on the KC705 development board equipped with a Xilinx Kintex7 FPGA. This board together with an Nvidia GeForce GTX Titan will be the basis for our hybrid solution of this problem. Together with our collaboration partners in Mainz, we have published also GPU only solutions of these tools as well as a solution in UPC++.

### Cryptanalysis with FPGAs

Although already considered unsecure, the tool TrueCrypt is still widely used. Since an encrypted TrueCrypt container always contains a small part where the plaintext is known, we could easily attack the encryption by simply trying passwords from a password list. Our implementation on the RIVYERA S6-LX150 is able to try about 250,000 passwords per second on a TrueCrypt container encrypted with AES-256 and RIPEMD-160 hash (the standard setting), where an Intel Core i7-970 hexa-core processor reaches a performance of only 740 passwords per second.

### Massively Parallel Portfolio Optimization

The Bio-Engine has turned out to be very suitable also for optimization problems in the area of financial mathematics (portfolio optimization, strategy analysis). In 2014 we developed a number of parallel financial mathematics algorithms for the architecture. These algorithms have been implemented in VHDL. The results achieved are impressive in terms of runtime and energy efficiency. The start-up company ''Innovative Prognostic Services GmbH'' has been created to exploit the results of the research in this area.

## Personnel

Head of the group: Prof. Dr. M. Schimmler; Secretary: B. Scheidemann (50%)
Technical Staff: Dipl.-Ing. G. Diesner

Scientific Staff:

| | | |
|---|---|---|
| M. Sc. A. Abbas | 01.01.-31.12.2014 | |
| M. Sc. S. Koschnicke | 01.01.-31.12.2014 | CAU / Software-Challenge |
| M. Sc. J. Kässens | 01.01.-31.12.2014 | AiF/ZIM |
| M.Sc. F. Schatz | 01.01.-25.11.2014 | getDigital |
| Dr.-Ing. Ch. Starke | 01.01.-31.12.2014 | CAU |
| Dipl.-Inf. L. Wienbrandt | 01.01.-31.12.2014 | Excellenzcluster |

## Lectures, Seminars, and Laboratory Course Offers

*Winter 2013/2014*

Digitale Systeme, 3 (+ 2) hrs Lecture (+ Exercises)/Week,
M. Schimmler (+ J. Brünger, S. Koschnicke, Ch. Starke)

Digital Systems, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
M. Schimmler (+ M. Schimmler)

Hardwarepraktikum, 4 hrs Practical/Week,
M. Schimmler (+ S. Koschnicke, J. Brünger)

*Summer 2014*

Hardwarepraktikum, 4 hrs Practical/Week,
M. Schimmler (+ Ch. Starke)

Implementierung massiv paralleler Systeme, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
M. Schimmler (+ S. Koschnicke)

Rechnergestützter Entwurf digitaler Systeme, 2 (+ 2) hrs Lecture (+ Exercises)/Week,
M. Schimmler

*Winter 2014/2015*

Digitale Systeme, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
M. Schimmler (+ Ch. Starke, C. Zelenka)

Digital Systems, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
M. Schimmler (+ M. Schimmler)

Hardwarepraktikum, 4 hrs Practical/Week,
M. Schimmler (+ Ch. Starke, J. Brünger)

Algorithmen der Bioinformatik, 2 hrs Seminar/Week,
M. Schimmler

## Third-Party Funds

Dr. Werner Petersen-Stiftung, *Software-Challenge*, 24.02.2014 (35.000,00)
dataport AöR, *Software-Challenge*, 29.12.2014 (4.000,00)
Provinzial Nord, *Software-Challenge*, 20.06.2014 (10.000,00)
Exzellenzcluster, *Inflammation at Interfaces*, 01.01.-31.12.2014 (65.000,00)
AiF-Projekt GmbH, *FuE-Kooperationsprojekt Rechnerarchitektur für Bioinformatik*, 01.01.-31.12.2014 (55.584,00)
DiWiSH, *Software-Challenge*, 13.06.2014 (1.541,05)

## Further Cooperation, Consulting, and Technology Transfer

The group cooperates in research with the following organizations and individuals:

- Sci-Engines GmbH and Johannes Gutenberg, Universität Mainz on a project concerning hybrid-parallel algorithms for short-read alignment of NGS dates and hybrid-parallel algorithms for genome-wide association studies

- Institute of Clinical Molecular Biology, Comprehensive Centre for Inflammation Medicine, and Muthesius Academy of Fine Arts Design on a project in the Inflammation Clinic concerning a power-saving benchtop machine for ultra-fast genetic data analysis and interpretation.

## Diploma, Bachelor's and Master's Theses

S. Timmermann, *Short Read Error Correction on the Parallel Platform RIVYERA*, 05.02.2014
A. Pooch, *Entropienanalyse und Kompression*, 30.09.2014

## Dissertations / Postdoctoral Lecture Qualifications

Florian Schatz, *Modellierung und Alignment von Genom-Sequenzdaten*, 25.11.2014

## Publications

Published in 2014

J. González-Domínguez, B. Schmidt, J. Ch. Kässens, L. Wienbrandt, *Hybrid CPU/GPU Acceleration of Detection of 2-SNP Epistatic Interactions in GWAS*, Lecture Notes on Computer Science, **vol. 8632**, 680 - 691 (2014)

J. Ch. Kässens, J. González-Domínguez, L. Wienbrandt, B. Schmidt, *UPC++ for Bioinformatics: A Case Study Using Gnome-Wide Association Studies,* Proceedings of 2014 IEEE International Conference on Cluster Computing, 248 - 256 (2014)

L. Wienbrandt, *The FPGA-based High-Performance Computer RIVYERA for Applications in Bioinformatics,* Language, Life, Limits, Lecture Notes in Computer Science, **Volume 8493**, 383 - 392 (2014)

L. Wienbrandt, J. Ch. Kässens, J. González-Domínguez, B. Schmidt, D. Ellinghaus, M. Schimmler, *FPGA-based acceleration of detecting statistical epistasis in GWAS,* Procedia Computer Science, **Volume 29**, 220 - 230 (2014)

S, Koschnicke, V. Grossmann, M. Schimmler, Ch. Starke, *Quality and Consistency Assurance of Quote Data for Algorithmic Trading Strategies,* Proceedings of 2014 IEEE Conference on Computational Intelligence for Financial Engineering & Economics (CIFEr 2014), 255 - 261 (2014)

A. Abbas, R. Voß, L. Wienbrandt, M. Schimmler, *An Efficient Implementation of PBKDF2 with RIPEMD-160 on Multiple FPGAs,* Prodeedings of 2014 IEEE 20th International Conference on Parallel and Distributes Systems (ICPADS), 454 - 461 (2014)

## Presentations

S. Koschnicke, V. Grossmann, M. Schimmler, Ch. Starke, *Quality and Consistency Assurance of Quote Data for Algorithmic Trading Strategies,* IEEE Computational Intelligence for Financial Engineering und Economics, London, UK, 27.-28.03.2014

J. Ch. Kässens, J. González-Domínguez, L. Wienbrandt, B. Schmidt, *UPC++ for Bioinformatics: A Case Study Using Gnome-Wide Association Studies,* 15th IEEE International Conference on Cluster Computing, Madrid, Spain, 22.-26.09.2014

L. Wienbrandt, J. Ch. Kässens, J. González-Domínguez, B. Schmidt, D. Ellinghaus, M. Schimmler, *FPGA-based acceleration of detecting statistical epistasis in GWAS,* 2014 International Conference on Computer Science (ICCS), Cairns, Australia, 10.-12.06.2014

A. Abbas, R. Voß, L. Wienbrandt, M. Schimmler, *An Efficient Implementation of PBKDF2 with RIPEMD-160 on Multiple FPGAs,* IEEE 20th International Conference on Parallel and Distributed Systems (ICPADS), Taipeh, Taiwan, 16.-19.12.2014

L. Wienbrandt, *The FPGA-based High-Performance Computer RIVYERA for Applications in Bioinformatics,* Invited talk: Computability in Europe (CiE) 2014, Special Session on Bio-inspired Computation, Budapest, Hungary, 23.-28.06.2014

## Further Activities and Events

The Technical Computer Science group received the"Kai-Uwe von Hassel-Förderpreis" of the "Hermannn-Ehlers-Stiftung" for the project Software-Challenge-Germany in November 2014.

# Theoretical Computer Science

The group studies topics in cryptography, complexity theory, logic in computer science, automata theory, computational social choice, and computer science education.

## Results

### Team-based Modal Logics.

Dependence logic, introduced by Väänänen, adds so-called dependency atoms to first-order or modal logic. These atoms allow the expression of dependencies between values of variables and are naturally evaluated on *teams*, i.e. sets of assignments (in a first-order context) or worlds (in a modal context). Together with researchers from Hannover and Helsinki, the group achieved complexity and expressivity results on a natural extension of modal dependence logic, namely modal independence logic. Additionally, we could show a van-Benthem style theorem which states that MTL (modal team logic, which is modal logic with team semantics extended with classical negation) can express exactly the bisimulation-invariant properties that can be expressed in first-order logic over a suitable signature.

### Succinctness and Expressivity of Modal Logic.

Recently, the *relative succinctness* of logical languages has received much attention. We proved that succinctness relationships between different modal logics can be as complex as any countable partial order. We achieved an analogous result for the expressivity of other logics. For this, we used two uniform formalisms to define modal operators and obtained results on succinctness and expressiveness in these two settings. Our proofs are based on formula size games introduced by Adler and Immerman and bisimulations.

### Computational Social Choice.

Control of elections refers to the ability of the electoral authority to influence the result of an election, e.g. by removing voters or candidates from the election. Together with researchers from the working group *Computed-Aided Program Development* , we obtained relational models and algorithms for the computationally hard control problems for the approval voting system.

### Automata and Logic.

Prophetic automata are a special type of $\omega$-automata, which the group has shown to be very versatile. For instance, such automata can be used to classify temporal logic properties. In 2014, preliminary results were obtained about the connection between prophetic automata and formulas of the modal $\mu$-calculus. In particular, a direct translation from formulas of this logic into prophetic automata was described for the first time.

### Formal Models in IT Security.

Key exchange procedures have been of interest for a long time. The group is working on a new kind of security paradigm for problems like key exchange and its theoretical foundation. In 2014, a soundness and (computational) completeness proof of a protocol developed along this paradigm has been obtained. In a different direction, the group has continued its work on information flow security. New results on non-interference in non-deterministic models were obtained.

## Personnel

Head of the group: Prof. Dr. Th. Wilke; Secretary: K. Flöth (50%)
Technical Staff: Dipl.-Ing. H. Schmidt (50%)

Scientific Staff:

| | | | |
|---|---|---|---|
| Dipl.-Math S. Eggert | 01.01.-31.03.2014 | | CAU |
| Dipl.-Math S. Eggert | 01.04.-30.09.2014 | (50%) | CAU |
| Dipl.-Inf. Björn Kinscher | 01.01.-30.09.2014 | (50%) | CAU |
| Dipl.-Math S. Preugschat | 01.01.-31.12.2014 | | DFG |
| Dr. H. Schnoor | 01.01.-31.12.2014 | | CAU |
| Dipl.-Inf. Oliver Woizekowski | 01.01.-30.09.2014 | (50%) | CAU |

## Lectures, Seminars, and Laboratory Course Offers

*Summer 2014*

Abschlussarbeiten AG Wilke, 2 hrs Lecture/Week,
Th. Wilke (+ S. Eggert, H. Schnoor)

Inf-LogInf: Logik in der Informatik, 4 (+2) hrs Lecture (+ Exercises)/Week,
Th. Wilke (+ B. Kinscher, O. Woizekowski)

Inf-MS-Sem-TIKALK: Kryptographie, Automaten, Logiken, Komplexitätstheorie, 2 hrs Seminar/Week,
Th. Wilke (+ H. Schnoor)

MS0101: Kryptographie, 4 (+2) hrs Lecture (+ Exercises)/Week,
Th. Wilke (+ S. Eggert)

*Winter 2014/2015*

Abschlussarbeiten AG Wilke, 2 hrs Lecture/Week,
Th. Wilke (+ H. Schnoor)

Inf-EinfPP: Einführendes Programmierpraktikum, 3 hrs Exercise/Week,
Th. Wilke (+ S. Dylus)

Inf-KompTheo: Einführung in die Komplexitätstheorie, 2 (+1) hrs Lecture (+ Exercises)/Week,
H. Schnoor

## Third-Party Funds

DFG, *Eindeutige endliche Automaten auf unendlichen Wörtern*, 04.05.2013-03.05.2016 (220.230,00 EUR)
DiWiSH, *Schnupperstudium Informatik*, 20.-24.10.2014 (1.500,00 EUR)

## Further Cooperation, Consulting, and Technology Transfer

The group works with others in Hannover (Prof. Heribert and Vollmer), Helsinki, Finland (Juha Kontinen), Rochester, USA (Prof. Edith and Lane Hemaspaandra), Sydney, Australia (Ron van der Meyden) and Luxemburg (Wojtek Jamroga).

## Diploma, Bachelor's and Master's Theses

A. Boysen, *Implementierung von String-Matching-Algorithmen in Haskell*, 02.06.2014
O. Claußen, *Querying XML with Regular Expressions*, 17.04.2014
C. Dolu, *Entwicklung einer Webanwendung zur Konzeption kryptographischer Sachverhalte*, 12.09.2014

A. Gongoll, *Ein System für verschlüsselten verteilten Speicher*, 18.11.2014
J. Greve, *Working on encrypted data*, 25.07.2014

## Dissertations / Postdoctoral Lecture Qualifications

S. Eggert, *Security by Noninterference*, 10.07.2014

## Publications

Published in 2014

R. Berghammer, N. Danilenko, H. Schnoor, *Relation Algebra and RelView Applied to Approval Voting*, RAMICS, **2014**, 309 - 326 (2014)
E. Hemaspaandra, L. Hemaspaandra, H. Schnoor, *A Control Dichotomy for Pure Scoring Rules*, AAAI, **2014**, 712 - 720 (2014)
J. Kontinen, J.S. Müller, H. Schnoor, H. Vollmer, *Modal Independence Logic*, Advances in Modal Logic, **2014**, 353 - 372 (2014)
R. Berghammer, H. Schnoor, *Control of condorcet voting: complexity and a relation-algebraic approach*, AAMAS, **2014**, 1365 - 1366 (2014)
W. Jamroga, M. Melissen, H. Schnoor, *On Defendability of Security Properties*, SR, **2014**, 17 - 25 (2014)

## Presentations

R. Berghammer, H. Schnoor, *Relation Algebra and RelView Applied to Approval Voting*, RAMiCS 2014, Marienstatt, Germany, 28.04.-01.05.2014
E. Hemaspaandra, L. Hemaspaandra, H. Schnoor, *A Control Dichotomy for Pure Scoring Rules*, 67. Workshop über Algorithmen und Komplexität (Theorietag), Kiel, Germany, 23.-24.05.2014
E. Hemaspaandra, L. Hemaspaandra, H. Schnoor, *A Control Dichotomy for Pure Scoring Rules*, Twenty-Eighth AAAI Conference on Artificial Intelligence (AAAI-14), Québec, Canada, 27.-31.07.2014
J. Kontinen, J.S. Müller, H. Schnoor, H. Vollmer, *Modal Independence Logic*, Advances in Modal Logic, Groningen, The Netherlands, 05.-08.08.2014
R. Berghammer, H. Schnoor, *Control of condorcet voting: complexity and a relation-algebraic approach*, AAMAS 2015, Paris, France, 05.-09.05.2014
W. Jamroga, M. Melissen, H. Schnoor, *On Defendability of Security Properties*, International Workshop on Strategic Reasoning, Grenoble, France, 05.-06.04.2014

## Further Activities and Events

The working group organized the *Workshop über Algorithmen und Komplexität* with about 25 participants. The program consisted of 11 talks from different algorithmic and complexity-theory research areas. Prof. Dr. Heribert Vollmer (Hannover) gave an invited lecture with the title ''Team-based logics over Kripke structures''.

The group organized a computer animation contest for high school children.

Thomas Wilke was elected *Sprecher des Fachbereichs Grundlagen der Gesellschaft für Informatik e.V.*

and member of the Council of the European Association for Theoretical Computer Science.

He was also on the board of editors of Lecture Notes in Logic.

Henning Schnoor served on the programme committee for AAMAS 2015.

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# Theory of Parallelism

Our group performs research in the field of optimization problems. On the one hand, we are interested in efficient approximation algorithms, and on the other, in algorithm engineering in order to use these algorithms for practical applications. The group's main areas of interest include:

- faster approximation schemes for linear and convex programming (including maximum flow, minimum cost flow, minimum fractional bin packing) ,
- efficient polynomial time approximation schemes (EPTAS) for different optimization problems (e.g. scheduling and knapsack problems) with focus on running time. Lower bounds on the running time of approximation schemes (using complexity theoretical assumptions),
- algorithm engineering for approximation algorithms and approximation schemes (design, analysis, implementation and experiments),
- design of approximation algorithms with improved approximation ratio for 2D and 3D packing problems (e.g. 2D knapsack, 2D bin packing and 2D strip packing) and other combinatorial optimization problems (e.g. bin packing, scheduling on unrelated machines),
- design of robust online algorithms with focus on small migration factors and fast running time (e.g. for scheduling on identical and uniform processors and bin packing),
- design of robust approximation algorithms for classical optimization problems (e.g. linear optimization, knapsack, and scheduling problems) that work also under uncertain data; including modelling of robustness and modification of solutions,
- algorithms for practical applications in logistics and production planning,
- and algorithms for practical applications in grid-computing, multi-core scheduling and communication networks.

## Results

### Ph.D. student of the Department for Computer Science received the Faculty Award

Traditionally, every year at the *Universitätstag der Christian-Albrechts-Universität zu Kiel* in Bordesholm, the Faculty Awards are given to the best of the 500 Ph.D. theses.

Fig. 1: Faculty Award Winners in Bordesholm. Dr. Lars Prädel is the sixth from the left.

Dr. Lars Prädel received the Faculty Award of the Technical Faculty on the 14th of July 2014 for his Ph.D. thesis with the title *Approximation Algorithms for Geometric Packing Problems*. His doctoral thesis was supervised by Prof. Klaus Jansen.

His dissertation is about the design and analysis of approximation algorithms for the following optimization problems:

- two-dimensional Strip Packing,
- two-dimensional Bin Packing, and
- Scheduling with Fixed Jobs.

A brief description of the essential results of the thesis:

**2D Strip Packing.**

For this problem a set of $n$ rectangles $R_i$ with heights $h_i \geq 0$ and widths $w_i \leq 1$ and a strip of width $1$ is given. The objective is to find an orthogonal, non-overlapping packing in the strip of minimal height of all $n$ rectangles. The previous best known algorithm for this problem is by Harren and van Stee with an absolute ratio of $1.9396$. In cooperation with Rolf Harren, Rob van Stee and Klaus Jansen, Lars Prädel developed an approximation algorithm with ratio $5/3 + \epsilon$ and improved the previously best known algorithm. The algorithm is based on the idea to approximately estimate the height of the packing by binary search and to find an approximate solution of the 2D Knapsack problem (where the area of the packed rectangles is maximized). Afterwards, the still unpacked rectangles (that have a small total area when the height is chosen well) are packed in the solution, so that the total height of the packing increases by only up to $5/3 + \epsilon$. This is done with a difficult structure analysis of possible solutions and clever repacking algorithms. This algorithm was presented by Lars Prädel at the well-known international Workshop on Algorithms and Data Structures (WADS 2011) in New York and has been published in the Journal of Computational Geometry.

**2D Bin Packing.**

Here as well, a set of $n$ rectangles $R_i$ of height $h_i \leq 1$ and widths $w_i \leq 1$ is given. Additionally, we have a set of target squares of width and height $1$. The objective is similar to that of the classical Bin Packing problem: to find an orthogonal and non-overlapping packing of the $n$ rectangles in the minimal number of $2D$ bins or squares. The previous best known approximative algorithm by Bansal, Caprara and Sviridenko has an asymptotic ratio of $\ln(T_\infty + 1) = 1.52..$ Lars Prädel developed in cooperation with Klaus Jansen an approximation algorithm with asymptotic ratio $1.5 + \epsilon$ and improved the previous best known techniques further. The essential new idea is an accurate analysis of optimal solutions and a skilled rounding technique. Interestingly, it is possible to round either the large widths or the large heights of all rectangles in one bin to the next multiple of $\epsilon^2$, so that the solution with the modified rectangles has at most $(1.5 + \epsilon)OPT(I) + 69$ bins. This rounding technique leads to an improved approximation algorithm that selects whether the width or the height of one rectangle has to be rounded. This work was presented by Lars Prädel at the high-level international Symposium on Discrete Algorithms (SODA 2013) in New Orleans.

**Scheduling with Fixed Jobs:**

The last part of Lars Prädel's thesis is about scheduling of jobs on machines where some jobs are already allocated. More formally an instance consists of $m$ machines and $n$ jobs with executions times $p_1, \ldots, p_n \in \mathbb{N}$. The first $k$ jobs are fixed via a list $(m_1, s_1), \ldots, (m_k, s_k)$, where $m_i$ is the assigned machine and $s_i$ is the starting time of job $j_i$. The previous best known algorithm by Diedrich and Jansen had an approximation ratio of $3/2 + \epsilon$ and a doubly exponential running time in $1/\epsilon$. In cooperation with Ola Svennson, Ulrich Schwarz and Klaus Jansen, Lars Prädel developed an algorithm with ratio $3/2$ and a distinctly faster running time. Besides the number of jobs $n$ and the maximal

execution time $p_{\max} = \max p_j$, the running time $O(n \log n + \log(n\, p_{\max})(n + T_{MSSP}(n, 1/8)))$ of this algorithm depends only on an algorithm for the Multiple Subset Sum problems (MSSP) with ratio $1/8$. Interestingly, it is possible to pack all non-packed jobs with execution time $p_j > T/2$ after completion of the MSSP algorithm in a solution of the length $T$ (under the presumption that $T \geq OPT(I)$ holds). As a consequence there is only a doubling of the area of the non-packed jobs. If $T \geq OPT(I)$ holds, the total area of the non-packed jobs is at most $mT/4$. These jobs of length no greater than $T/2$ can be packed at the end of the schedule in an additional length of at most $T/2$ and we obtain the desired ratio of $3/2$. The work which contains these results was presented by Lars Prädel at the Conference of Computing in Perth (the Australasian Theory Symposium (CATS 2011)) and has been published in the well-known Journal ACM Transactions on Algorithms.

### Successful international Workshop organized

In 2014 we organized the workshop BiCi *Frontiers and Connections between Parametrization and Approximation (COPA 2014)* together with Mike Fellows (Charles Darwin University), Vangelis Paschos (University Paris-Dauphine), and Hadas Shachnai (Technion): it was held at the University Residential Centre in Bertinoro, Italy. The workshop focused on the following research area.

Two well-known paradigms for solving NP-hard problems are exact computation and polynomial time approximation. While the former relaxes the requirement that the running time is polynomial in the input size, the latter relaxes the requirement that the algorithm produces an optimum solution and our main goal is to design a polynomial-time algorithm. The parallel studies of these paradigms have reached hardness of approximation barriers and highly impractical running times of the best known exact algorithms for NP-hard problems. These hardness results cannot be overcome by applying classic complexity measures. A refined analysis of running time can be achieved through parameterization. Parameterized complexity is concerned with a multivariate analysis of computational complexity where, in addition to the overall instance size, one takes account of the influence on computational complexity of secondary measurements. Most of the earlier work in parameterized complexity has focused on obtaining a refined classification for the hardness of optimization problems (using the W-hardness hierarchy), and on designing exact algorithms for NP-hard problems which are fixed parameter tractable.

Fig. 2: Participants of the Bertinoro Seminar *Frontiers and Connections between Parameterization and Approximation*.

### Prize for the best programming idea

*To get into gear with higher mathematics*: this was the motto of the programming challenge for students of the Department for Computer Science, whose value was set at 5000 Euro.

According to the jury Kevin Prohn and Niklas Paulsen found the best result for a given optimization problem from everyday business practice. The concrete problem was a scheduling and routing problem of service workers. The competitors searched for the best algorithm: a program for the fastest order for visits under consideration of the driving times depending on the day and traffic patterns. The contest was cooperatively organized by the workgroup *Theory of Parallelism* of the Department of Computer Science and the software company FLS from Heikendorf, a worldwide provider of programs for dynamical routing optimization and mobile solutions.


Fig. 3: Winners of the programming challenge organized with the software company FLS were Kevin Prohn and Niklas Paulsen.

## Personnel

Head of the group: Prof. Dr. K. Jansen; Secretary: U. Iaquinto (50%)
Technical Staff: P. Karimi Massouleh (50%)

Scientific Staff:

| | | | |
|---|---|---|---|
| M. Kaluza | 01.01.-30.09.2014 | (50%) | DFG |
| Laufzeitschranken für Scheduling- und Packungsprobleme unter Annahme der Exponentialzeithypothese | | | |
| M. Kaluza | 01.10.-31.12.2014 | | CAU |
| 1/4 Stelle HSP 2020 | | | |
| M. Kaluza | 01.10.-31.12.2014 | | DFG |
| 1/4 Stelle Laufzeitschranken für Scheduling- und Packungsprobleme unter Annahme der Exponentialzeithypothese | | | |
| K.-M. Klein | 01.01.-31.12.2014 | (50%) | CAU |
| K.-M. Klein | 01.01.-31.12.2014 | (50%) | DFG |
| Entwicklung von effizienten polynomiellen Approximationsschemata für Scheduling- und verwandte Optimierungsprobleme | | | |
| S. Kraft | 01.01.-30.09.2014 | (50%) | DFG |
| Entwicklung von effizienten polynomiellen Approximationsschemata für Scheduling- und verwandte Optimierungsprobleme | | | |
| S. Kraft | 01.01.-31.12.2014 | (50%) | CAU |

F. Land 01.-22.01.2014 (50%) DFG
Approximative Algorithmen für zwei- und dreidimensionale Packungsprobleme und verwandte Schedulingprobleme

F. Land 01.-14.02.2014 DFG
Approximative Algorithmen für zwei- und dreidimensionale Packungsprobleme und verwandte Schedulingprobleme

F. Land 01.-31.03.2014 DFG
Programmpauschale

F. Land 01.10.-31.12.2014 (50%) CAU
HSP 2020

F. Land 01.10.-31.12.2014 (50%) DFG
Laufzeitschranken für Scheduling- und Packungsprobleme unter Annahme der Exponentialzeithypothese

K. Land 01.01.-31.12.2014 DFG
Elternzeit, dann ab 23.10.2014 3/4 Stelle Entwicklung von Approximationsalgorithmen für Scheduling auf heterogenen Maschinen

M. Maack 01.01.-30.09.2014 (50%) CAU
Hochschulpakt 2020

M. Maack 01.01.-30.09.2014 (50%) DFG
Laufzeitschranken für Scheduling- und Packungsprobleme unter Annahme der Exponentialzeithypothese

M. Maack 01.10.-31.12.2014 DFG
1/4 Stelle Laufzeitschranken für Scheduling- und Packungsprobleme unter Annahme der Exponentialzeithypothese

M. Maack 01.10.-31.12.2014 CAU
1/4 Stelle HSP 2020

## Lectures, Seminars, and Laboratory Course Offers

*Winter 2013/2014*

Theoretische Grundlagen der Informatik, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
K. Jansen (+ K.-M. Klein)

Algorithmen für praktische Optimierungsprobleme, 2 (+ 4) hrs Lecture (+ Exercises)/Week,
K. Jansen (+ S. Kraft)

Projektgruppe Operations Research, 4 hrs Exercise/Week,
K. Jansen (+ M. Maack)

Seminar - Algorithmen und Komplexität, 2 hrs Seminar/Week,
K. Jansen (+ F. Land, K. Land)

Seminar - Theoretische Informatik (Aktuelle Forschungsfragen der theoretischen Informatik), 2 hrs Seminar/Week,
K. Jansen (+ F. Land, K. Land)

Masterprojekt - Effiziente Algorithmen, 4 hrs Practical/Week,
K. Jansen (+ S. Kraft)

*Summer 2014*

Effiziente Algorithmen, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
K. Jansen (+ K.-M. Klein, S. Kraft)

Operations Research, 3 (+ 2) hrs Lecture (+ Exercises)/Week,
K. Jansen (+ M. Maack)

Seminar - Theoretische Informatik (Aktuelle Forschungsfragen der theoretischen Informatik), 2 hrs Seminar/Week,
K. Jansen (+ M. Maack)

Seminar Operations Research, 2 hrs Seminar/Week,
K. Jansen (+ M. Maack)

*Winter 2014/2015*

Approximative Algorithmen, 2 (+ 3) hrs Lecture (+ Exercises)/Week,
K. Jansen (+ K.-M. Klein)

Algorithmen für praktische Optimierungsprobleme, 2 (+ 4) hrs Lecture (+ Exercises)/Week,
K. Jansen (+ S. Kraft)

Wirtschaftsinformatik 3, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
K. Jansen (+ M. Kaluza)

Projekt Wirtschaftsinformatik (Operations Research), 5 hrs Exercise/Week,
K. Jansen (+ M. Maack, F. Land)

Seminar - Algorithmen und Komplexität, 2 hrs Seminar/Week,
K. Jansen (+ K. Land)

Seminar - Theoretische Informatik (Aktuelle Forschungsfragen der theoretischen Informatik), 2 hrs Seminar/Week,
K. Jansen (+ K. Land)

Masterprojekt - Effiziente Algorithmen, 4 hrs Practical/Week,
K. Jansen (+ M. Maack, K. Land)

## Third-Party Funds

DFG-Projekt, Entwicklung von effizienten polynominellen approximationsschemata für Scheduling- und verwandte Optimierungsprobleme, *Personel, travel, and acquisition,* 01.01.2014-31.12.2016 (224.350 EUR)

DFG-Projekt, Laufzeitschranken für Scheduling- und Packungsprobleme unter Annahme der Exponentialzeithypothese, *Personel, travel, and acquisition,* 01.10.2013-30.09.2016 (222.510 EUR)

DFG-Projekt, Entwicklung von Approximationsalgorithmen für Scheduling auf heterogenen Maschinen, *Personel, travel, and acquisition,* 01.02.2012-24.03.2016 (228.100 EUR)

DFG-Projekt, Entwicklung und Analyse von approximativen Algorithmen für zwei- und dreidimensionale Packungsprobleme, *Personel, travel, and acquisition,* 01.10.2011-31.03.2014 (213.709 EUR)

## Further Cooperation, Consulting, and Technology Transfer

Our group cooperates closely with that of Prof. Guochuan Zhang from the College of Computer Science of Zhejiang University, China, with Roberto Solis-Oba from the University of Western Ontario, Canada, as well as with Denis Trystram, who is working at the LIG - Laboratoire d'Informatique de Grenoble, France, and with whom we have an ERASMUS partnership. In addition we have established an active ERASMUS exchange of students with Janka Chlebikova, who is a senior lecturer at the University of Portsmouth, United Kingdom.

## Diploma, Bachelor's and Master's Theses

Diekert R.-T., *Optimierung von Spielplänen auf mehreren Feldern, M.Sc. thesis,* 07.05.2014
Pal M., *Approximationsalgorithmen für das Färben von Unit-Disk-Graphen, M.Sc. thesis,* 19.05.2014
Paulsen N., *Entwicklung praxistauglicher Algorithmen für die Tourenplanung mobiler Mitarbeiter, M.Sc. thesis,* 31.12.2014
Mahlstedt T., *Gewinnteamermittlung und die magische Punktzahl, B.Sc. thesis,* 26.03.2014
Theesen E., *Implementation und Test eines moderat-exponentiellen Algorithmus für Scheduling auf uniformen Maschinen, B.Sc. thesis,* 31.03.2014
Millar P., *Strip-Packing mit konstant vielen Itemtypen, Bachelor´s thesis,* 24.04.2014
Ladewig L., *Geografische Dekomposition für das PESP in Anwendung auf Zugfahrpläne, Bachelor´s thesis,* 29.09.2014
Böteführ C. M., *Restricted Assignment mit wenigen Ausführungszeiten, Bachelor´s thesis,* 30.09.2014
Lauenroth A., *Produktionsplanung in der Holzwirtschaft, Bachelor´s thesis,* 30.09.2014

## Publications

Published in 2014

R. Harren, K. Jansen, L. Prädel, R. van Stee, *A $(5/3+\epsilon)$ Approximation for Strip Packing,* Computational Geometry: Theory and Applications, **47**, 248 - 267 (2014)
L. Chen, K. Jansen, G. Zhang, *On the optimality of approximation schemes for the classical scheduling problem,* SODA, (2014)
K. Jansen, L. Prädel, *A New Asymptotic Approximation Algorithm for 3-Dimensional Strip Packing,* SOFSEM, 327 - 338 (2014)
K. Jansen, N.R. Devanur, C. Moore, J.P.D. Rolim, *Approximation, Randomization, and Combinatorial Optimization,* Algorithms and Techniques, APPROX/RANDOM 2014, September 4-6, 2014, Barcelona, Spain. LIPIcs 28, Schloss Dagstuhl - Leibniz-Zentrum fuer Informatik 2014, ISBN 978-3-939897-74-3, (2014)
S. Berndt, K. Jansen, K.-M. Klein, *Fully Dynamic Bin Packing Revisited,* CoRR abs/1411.0960, (2014)

## Presentations

L. Chen, K. Jansen, G. Zhang, *On the optimality of approximation schemes for the classical scheduling problem,* SIAM-ACM Symposium on Discrete Algorithms (SODA 2014), Portland, OR, USA, 05.-07.01.2014
K. Jansen, L. Prädel, *A new asymptotic approximation algorithm for 3-dimensional strip packing,* 40th International Conference on Current Trends in Theory and Practice of Computer Science (SOFSEM 2014),, High Tatras, Slovakia, 25.-30.01.2014
K. Jansen, K.-M. Klein, *A Robust AFPTAS for Online Bin Packing with Polynomial Migration,* Frontiers and Connections between Parametrization and Approximation COPA 2014, Bertinoro, Italy, 25.-30.05.2014
K. Jansen, K.-M. Klein, *A Robust AFPTAS for Online Bin Packing with Polynomial Migration,* 9th Scheduling for Large Scale Systems Workshop, Lyon, France, 01.-04.07.2014
K. Jansen, K.-M. Klein, *A Robust AFPTAS for Online Bin Packing with Polynomial Migration,* SWORDS 2014 - Szeged WORkshop on Discrete Structures, Szeged, Hungary, 09.-10.10.2014
K. Jansen, *Approximation algorithms for a knapsack and related scheduling problem,* Colloqium at Université Paris-Dauphine, Paris, France, 17.-22.11.2014

## Further Activities and Events

Prof. Jansen has been a member of the steering committee of the Special Interest Group on Algorithms of the Gesellschaft für Informatik (GI) since 2010.

Prof. Jansen was involved in the organization of the following conferences:

*Bertinoro Seminar, Frontiers and Connections between Parametrization and Approximation (COPA 2014)* together with M. Fellows, H.Shachnai and V. Paschos,

he was a workshop Co-Chair at the *Workshop on Approximation Algorithms for Combinatorial Optimization Problems (APPROX 2014)* and the *Workshop on Randomization and Approximation Techniques in Computer Science (RANDOM 2014)* in Barcelona, Spain, and a steering committee member of the *Symposium on Experimental Algorithms (SEA 2014)* in Copenhagen, Denmark.

Prof. Jansen was a programme committee member of the following conferences:

- the *40th International Conference on Current Trends in Theory and Practice of Computer Science (SOFSEM 2014)* in Novy Smokovec, High Tatras, Slovakia,
- the *20th Annual International Computing and Combinatorics Conference (COCOON 2014)* in Atlanta, GA, USA,
- the *11th Workshop on Parallel Algorithms and Systems and Algorithms (PASA 2014)* in Lübeck, Germany, and
- the *8th International Frontiers of Algorithmics Workshop (FAW 2014)* in Zhangjiajie, China.

# Web Science

Prof. Dr. Isabella Peters is professor of the Leibniz Information Centre for Economics (ZBW - Deutsche Zentralbibliothek für Wirtschaftswissenschaften Leibniz-Informationszentrum Wirtschaft).

Further information is available on the web: http://www.zbw.eu/ and http://zbw.eu/de/forschung/web-science/isabella-peters/

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Internet http://www.zbw.eu

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# Institute of Electrical and Information Engineering

The Institute of Electrical Engineering and Information Technology (ET&IT) at Kiel University stands for thorough, contemporary teaching and future-oriented cooperative research at the highest scientific level. In addition to a balanced mixture of theoretical and experimental basic research as well as industrially orientated research, the Institute strives to fulfil its founding mission of knowledge and technology transfer. Education is adapted to both long-term requirements and current trends in cutting edge research.

The Institute consists of 11 professorships including the external professorship held by Prof. Dr.-Ing. Wolfgang Benecke, who is also the Managing Director of the Fraunhofer Institute for Silicon Technology (ISIT) in Itzehoe. In 2014 Prof. Dr.-Ing. Sabah Badri-Höher joined the institute as an adjunct professor. She is professor at the University of Applied Sciences in Kiel. Since September 2014, Prof. Dr. Martina Gerken has been Managing Director (Geschäftsführende Direktorin) of the Institute's board.

The number of new students who enrolled in the five academic courses offered by the Institute of ET&IT in 2014, stayed nearly the same as in the previous year. In the summer semester 2014, 29 freshmen enrolled in the M.Sc. programmes Electrical and Information Engineering and Electrical and Information Engineering and Business Management. For the winter semester 2014/2015 a total of 226 new students enrolled in the Institute's academic courses. In detail, 65 students started in the B.Sc. programme Electrical and Information Engineering and 108 enrolled in the B.Sc. programme Electrical and Information Engineering and Business Management. In the corresponding M.Sc. programmes 34 students began their studies, and 19 new students enrolled in the international 4-semester M.Sc. programme Digital Communications, where all courses are offered in English.

## Results

The Institute of Electrical and Information Engineering (ET&IT) of Kiel University is extensively integrated into cooperative and interdisciplinary research projects. In 2014 The German Research Foundation (DFG) began funding a new Research Group (FOR2093) entitled ''Memristive Devices for Neural Systems''. The Research Group is headed within ET&IT by Prof. Kohlstedt of AG Nanoelektronik. The Research Group 2093 focuses on the transfer of the principles of neuronal, synaptic plasticity as well as biological storage to mixed-signal circuitry comprising memristive devices. Basic cellular forms of learning, as known on the cellular level forming neurons and synapses, will be implemented in technical systems. Both implicit and explicit types of learning should be realized in networks. The memristive devices will be studied in detail with respect to static and dynamic properties. In particular the research is orientated to the trisynaptic circuit of the hippocampus, which is an essential part of the basal learning processes in vertebrates and a few invertebrates. For example, the hippocampus is crucial for pattern recognition and is the transfer region between short term and long term memory. Finally, central neurobiological concepts such as cognitive cards and place cells will be mimicked by analogue circuits using memristive devices. To focus on this interdisciplinary research goal a broad spectrum expertise is mandatory. The Research Group consists of partners from the Ruhr University Bochum, the Technische Universität Hamburg-Harburg, and from the Department of Neurobiology, Material Science, and the Institute of Electrical and Information Technology, of CAU Kiel, with individual strengths in interface physics, material science, electronic devices, systems theory and simulation, as well as modelling of neurobiological networks. The first three years are funded by 2 million Euro. More details can be found under: http://www.for2093.uni-kiel.de/de.

Within the topic ''Information Engineering'' members of ET&IT cooperate closely with the Department of Computer Science. ET&IT also maintains a close research partnership with the Institute for Materials Science mainly in the research area ''Nanosystems Engineering''. In particular, several members of ET&IT are engaged in the research on magneto-electric sensors based on nanocomposite materials for biomedical applications. This is a joint effort with the Institute for Materials Science and the Faculty of Medicine. At the end of 2014 this research was awarded with several 2-year grants within the DFG packet proposal PAK 902. In addition, the Institute has been engaged in the Excellence Cluster ''Future Ocean'',

Fig. 1: The photograph shows members of the Research Group 2093 at the kick-off meeting in December 2014 at the Technical Faculty of the CAU.

the Computational Sciences Centre of CAU, and in the regional research network CEwind - Centre of Competence in Wind Energy.

In 2014 Prof. Marco Liserre was awarded the first IEEE Dr. Bimal Bose Energy Systems Award and he was in the ISI-Thomson list of ''the world's most influential scientific minds''. Nils Hoffmann received the ETG-Literaturpreis 2014 for a journal publication.

Fig. 2: A group of four students tests a self-built metal detector that they created in the new ET&IT project week at the start of the first B.Sc. semester. Photo/Copyright: Denis Schimmelpfennig/CAU.

We are continuously improving our course programme. In autumn 2014 a new project week was offered to all first-semester B.Sc. students. The aims were to give the students hands-on experience, to motivate them for the theoretical topics in the first semesters, and to introduce them to the Institute of ET&IT. Working in groups, the students built a metal detector with 8-LED display and microcontroller. In a sensor challenge they competed in finding small pieces of metal below a wooden board. The best three groups received book prizes. 82 students participated in the project and it is planned to integrate the project into the curriculum.

# Automatic Control

The research activities of the Chair of Automatic Control focus on:

- mathematical modelling of dynamic systems,
- model-based control,
- observer design for nonlinear and distributed-parameter systems with applications in smart adaptive structures, chemical, biochemical and thermal processes,
- cooperative multi-agent systems, as well as
- computational methods for control.

Research here has a strong emphasis on the development of analytic and semi-analytic methods and their evaluation in simulations and experiments.

Teaching addresses:

- control design for linear systems using frequency and state space techniques,
- nonlinear control systems (taking into account differential geometric and Lyapunov-based approaches),
- optimization and optimal control,
- mathematical modelling,
- control of distributed-parameter systems, and
- model-based estimator and observer design.

Basic and advanced student lab hours complete the curriculum.

## Results

### Distributed-Parameter Systems and Control Theory

Distributed-parameter systems are characterized by state variables depending on both time and space. Mathematical modelling hence yields a system description in terms of partial differential equations (PDEs). Well known examples include not only elastomechanic or thermomechanic structures in mechatronics or aeronautics, fixed-bed and tubular reactors in chemical and process engineering, reheating and cooling processes as well as forming in the steel industry , heat exchangers, fluid flow and fluid-structure interactions, but also collective dynamics of robots, crowds and flocks.

The research activities in particular address the development of systematic model-based analysis and design techniques for motion planning, feedback stabilization, and observer design. To this end, so-called late lumping approaches are considered which directly exploit the underlying mathematical PDE structure. For this, novel flatness-, backstepping- and passivity-based techniques are developed for linear and nonlinear distributed-parameter systems with single, and in particular, higher-dimensional spatial domains. In addition, it is shown that the combination of the various determined approaches yields sophisticated tracking control concepts to realize prescribed spatial-temporal paths. Stability (exponential or asymptotic) of the feedback and tracking control schemes is analyzed using operator and semigroup theory. In order to address the complexity arising in many applications, e.g. due to complex shaped geometries or the number of dependent state variables, semi-analytical design techniques are deduced by combining the developed analytical approaches with numerical discretization and approximation schemes such as finite difference, finite volume, or finite element methods.

## Nonlinear Control

Many control problems include unknown (time-varying) perturbations, parameter errors, and state disturbances, which can be modelled by so called unknown inputs. Most of the common control design techniques are unable to achieve robust stability in the presence of unknown inputs and thus explicit adaptive control techniques have to be developed for this purpose. For the particular class of differentially flat single-input-single-output systems with identical relative degree of the control and the unknown input, a particularly simple adaptive two-degrees-of-freedom control structure has been proposed and its robust stability properties have been demonstrated in simulation scenarios. It was shown that due to the inherently strong observability and controllability properties of these systems, a flatness-based state and (quasi-) unknown input estimator can be designed and combined with a flatness-based trajectory tracking algorithm. The design and controller performance have been illustrated for a system with double saddle-node bifurcation, steady-state bistability, and the associated typical hysteretic behaviour.

## Smart Material Structures

Smart material structures denote elastic carriers with embedded distributed actors and sensors. These structures occur in a large variety of technical applications including vibration suppression, static or dynamic shape control, or fault detection. In addition, new application areas have evolved such as adaptive optics in telescopes, adaptive wings or so-called smart skins (where transiently varying shapes are used for the modulation of optical wave fronts), the adaption of drag for specific flight conditions, or the improvement of aeroelastic characteristics. For these structures, piezoelectric elements typically serve as actuators by exploiting the indirect piezoelectric effect to convert electrical voltage into mechanical strain.

For the mathematical modelling of smart material structures, the spatial extension of the structure and the distribution of actors and sensors have to be considered and lead to a description in terms of partial differential equations (PDE). This PDE formulation can be exploited for motion planning, stabilization and observer design. For piezo-actuated beam and plate structures systematic flatness-based motion planning techniques have been developed to realize the desired transient behaviour by an open-loop controller. Taking into account passivity-based feedback control within the so-called two-degrees-of-freedom (2DOF) control concept yields an asymptotically stable tracking error dynamics. Here, the research activities address non-collocated feedback control design, which results in a dynamic output feedback scheme involving a distributed-parameter state observer. The asymptotic stability of the closed-loop control can be verified in a rather general setting by making use of operator and semigroup theory. State-of-the-art experimental benchmark examples confirm the high tracking accuracy of the proposed motion planning and 2DOF control concept. An example is provided in Fig. 1, illustrating a carbon-fibre carrier with embedded piezoelectric macro-fibre composite (MFC) actuators.

Current research addresses interconnected structures of coupled elements, optimal actuator and sensor placement, as well as applications in active flow control for maritime structures.

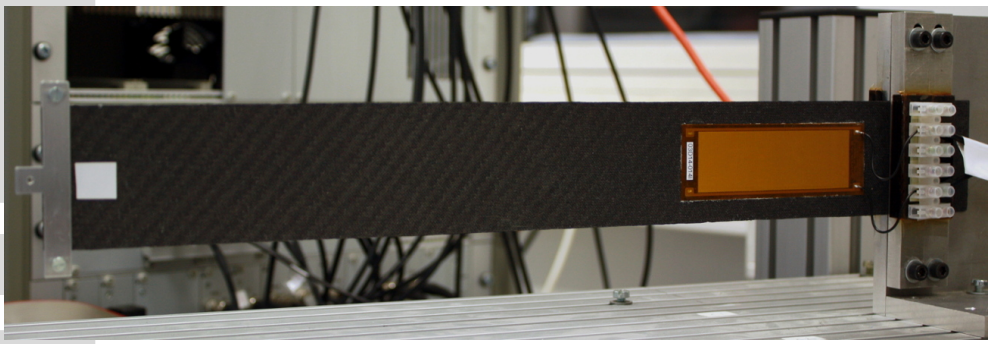

Fig. 1: Fig. 1: Flexible beam structure with embedded piezoelectric macro-fibre composite (MFC) actuators.

## Control in Biotechnology

This research addresses fermentation and growth processes of micro-organisms: in particular, microalgae growth processes in photo-bioreactors have been analyzed. Microalgae are important primary resources for the biotechnology industry, especially the food, cosmetics, and pharmaceutical industries. Due to the high complexity of growth processes different semi-empirical models are known which the group has begun to analyze with respect to process control and process optimization, in collaboration with the research group of Prof. Dr. Rüdiger Schulz from the Institute for Botanics. The most simple and widely used microalgae model is the Droop model that describes the dynamics of extra- and intracellular substrate (nitrogen, phosphorus) and biomass (cell) concentration. The associated dynamics includes multiple steady-states and a transcritical bifurcation dependent on the dilution rate (i.e. the ratio of volumetric flow rate to reactor volume). For the Droop model an inversion-based trajectory planning and feedforward control has been developed and evaluated in simulation studies. This approach shows good performance and is robust against perturbations in the feed concentration. The simultaneous estimation of the state and the unmeasured feed concentration has been achieved by quasi-unknown input observer.

In addition, the control of anaerobic digestion problems has been considered, leading to a complete description of the process dynamics in terms of steady-state multiplicity, structural instabilities (bifurcations) and associated robustness properties, as well as the design of a robust output-feedback control scheme for the stabilization of the steady-state of maximum volatile fatty acid production. The results were obtained in collaboration with Prof. Jesus Alvarez (Metropolitan University, Mexico City), Prof. Juan Paulo Garcia Sandoval and Prof. Victor Gonzalez-Alvarez (University of Guadalajara, Mexico).

### Control of thermal and fluid-dynamical systems

Thermal and fluid-dynamical systems comprise a large class of challenging control problems. Examples include heat-up of metal slabs in reheating furnaces or the prevention of flow separation in aeroelastic structures. For these, the distributed-parameter nature of the system dynamics has to be taken into account explicitly for the control and observer design. Since typically complex geometries arise, methods of approximation and model order reduction techniques have to be integrated for the explicit evaluation.

The research activities of the group address heat-up processes in smart forming tools, where heating cartridges are embedded into the tool to realize a desired temperature distribution in selected parts of it. For this, a flatness-based design technique has been developed that makes use of the spectral properties of the corresponding system operator. This enables the systematic design of an open-loop controller to achieve finite time transitions between stationary temperature profiles within the forming tool. Extensions to tracking control using the two-degrees-of-freedom control concept have been considered and analyzed. Besides simulation results, our research is made unique by the experimental validation of the control concept.

Research in fluid-dynamical systems focuses on motion planning, i.e. the determination of an open-loop control to achieve a desired prescribed flow velocity profile. Based on the Stokes equations for this, a flatness-based design technique has been developed that enables the control problem to be solved systematically. Simulation results confirm both the applicability and the control performance.

### Multi-Agent Systems

In the past decades, extensive research has been conducted on the cooperative formation control of multi-agent systems with possible applications ranging from UAVs, through transportation systems, to micro-satellite clusters. Thereby, different analysis and design approaches have emerged depending on the available communication topology and the multi-agent formation control task considered. Besides the discrete analysis of the interconnected individual agents, continuous models based on PDEs have been used to model, analyse, and control many particle systems, traffic flow, or large vehicular platoons.

The research activities focus on the application of PDE-based motion planning and feedback control strategies to

achieve consensus, formation control, and synchronization of multi-agent systems. For this, flatness-based techniques are considered and combined, e.g. with backstepping-based state feedback control and observer design for the tracking error dynamics. The transfer from the agent continuum to the discrete formulation is finally achieved by discretization which imposes the communication topology. Hence, rather generic analysis and design tools are developed which are, in particular, independent of the actual communication topology.

## Personnel

Head of the group: Prof. Dr.-Ing. T. Meurer; Secretary: S. Marquardt-Hansen (50%)
Technical Staff: Dipl.-Ing (FH) B. Doneit (50%), Dipl.-Ing (FH) M. Lieb (50%)

Scientific Staff:

| | | |
|---|---|---|
| Dipl.-Ing. M. Herrmann<br>Process control | 17.03.-31.12.2014 | Industry |
| Dipl.-Ing. A. Kater<br>Smart adaptive structures | 01.01.-31.12.2014 | CAU |
| Dipl.-Wirtsch.-Ing. E. Peter<br>Process Control in the Dairy Industry | 01.01.-31.03.2014 | CAU |
| Dr. A. Schaum<br>Control of nonlinear and distributed-parameter systems | 01.04.-31.12.2014 | CAU |

## Lectures, Seminars, and Laboratory Course Offers

*Winter 2013/2014*

Regelungstechnik I, 3 (+ 2) hrs Lecture (+ Exercises)/Week,
T. Meurer (+ A. Kater, E. Peter)

Project Brain Controlled Robotics, 3 hrs Project/Week,
T. Meurer (+ A. Kater)

Masterpraktikum Regelungstechnik, 4 hrs Practical/Week,
T. Meurer (+ E. Peter, A. Kater)

Optimization and Optimal Control, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
T. Meurer (+ A. Kater)

Ausgewählte Kapitel der Regelungstechnik, 2 hrs Seminar/Week,
T. Meurer (+ E. Peter, A. Kater)

*Summer 2014*

Project Brain Controlled Robotics, 3 hrs Project/Week,
T. Meurer (+ A. Kater)

Bachelorpraktikum Regelungstechnik und Systemdynamik, 4 hrs Practical/Week,
T. Meurer (+ M. Herrmann, A. Kater, A. Schaum)

Regelung nichtlinearer Systeme, 3 (+ 1) hrs Lecture (+ Exercises)/Week,
T. Meurer

Regelung verteilt parametrischer Systeme, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
T. Meurer

Ausgewählte Kapitel der Regelungstechnik, 2 hrs Seminar/Week,
T. Meurer (+ E. Peter, A. Kater)

*Winter 2014/2015*

Regelungstechnik I, 3 (+ 2) hrs Lecture (+ Exercises)/Week,
T. Meurer (+ A. Kater, M. Herrmann, A. Schaum)

Project Lego Robotics, 3 hrs Project/Week,
T. Meurer (+ A. Kater)

Masterpraktikum Regelungstechnik, 4 hrs Practical/Week,
T. Meurer (+ M. Herrmann, A. Kater, A. Schaum)

Optimization and Optimal Control, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
T. Meurer

Ausgewählte Kapitel der Regelungstechnik, 2 hrs Seminar/Week,
T. Meurer (+ A. Schaum)

Mathematische Modellierung, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
T. Meurer

## Third-Party Funds

DFG, *Großgeräteantrag Smart Maritime Control Lab*, 06.08.-31.12.2014 (150.000 EUR)

## Diploma, Bachelor's and Master's Theses

Niels Launert, *Untersuchung des Einsatzes von Voting-Mechanismen in in Regelkreisen von Flugzeugsystemen*, 10.04.2014

Jörn Grabs, *Modellierung und Regelung eines Ball/Platte-Systems*, 04.05.2014

Dennis Rösch, *Entwicklung einer Betriebsstrategie für einen elektrischen Antriebsstrang und deren Implementierung auf einem Prototypensteuergerät*, 17.05.2014

Iris Schwärter, *Erfassung einer Zentralschmieranlage als Streckenmodell- Entwicklung u. Optimierung von Statistikfunktionen und Füllstandserkennung*, 24.05.2014

Henning Weisbarth, *Simulation und Implementierung eines verteilten Regelungskonzepts für Multiagentensysteme*, 27.05.2014

Philipp Rosenzweig, *Modellierung und Regelung einer Verladebrücke*, 07.07.2014

JanPhilipp Wriedt, *Pfandplanung für mobile Roboter*, 14.07.2014

Jan Freund, *Regelung und Visualisierung eines aktiven Dämpfungs- systems in einer virtuellen Umgebung*, 16.07.2014

Benjamin Breuell, *Regler- u. Beobachterentwurf für Rührkesselreaktoren*, 28.07.2014

Franziska Ott, *Regelungsorientierte thermische Modellierung und Analyse von Gebäuden*, 12.08.2014

Pascal Jerono, *Analyse der Koppelnavigation mit nicht synchronisierten Standardsensoren*, 13.09.2014

Stefan Kaatz, *Modellprädiktive Regelung eines Tunnelpasteurs*, 16.09.2014

Thomas Reich, *Modellierung und Identifikation der analogen Signal- verarbeitung eines kapazitiven MEMS Scanners*, 23.09.2014

Martin Günther, *Modellierung und Regelung eines biacial MEMS scanner mit piezoelektrischen Aktuatoren*, 23.09.2014

Sven Tore Bielfeld, *Regler- u. Beobachterentwurf für Rührkesselreaktoren*, 30.09.2014

Nina Willwacher, *Konstruktion und Regelung eines Segways mittels Lego Mindstorms EV3*, 04.10.2014

Kim Chr. Bestmann, *Optimale Aktor- und Sensorplatzierung für thermische Probleme*, 16.12.2014
Marco Klein, *Nichtlineare Regelung einer Verladebrücke*, 23.12.2014

## Dissertations / Postdoctoral Lecture Qualifications

M. Koschmieder, *Schnelle Amplituden- und Phasenregelung schwach gedämpfter Schwingungssysteme mit zeitvariabler Eigenfrequenz und Dämpfung am Beispiel eines Coriolis Massendurchflussmessers*, 09.10.2014

## Publications

Published in 2014

T. Meurer, *Motion planning for PDEs. In: Samad T. (Ed.)*, Encyclopedia of Systems and Control, (2014)
T. Meurer, A. Kater, *Motion planning for a piezo-actuated structure modelling a wingsail*, Proc. Appl. Math. Mech (PAMM), **14**, 895 - 896 (2014)
T. Böhm, T. Meurer, *Trajectory planning for a deep drawing tool*, IFAC World Congress, 665 - 670 (2014)
J. Jadachowski, T. Meurer, A. Kugi, *Backstepping observers for quasi-linear parabolic PDEs*, IFAC World Congress, 7761 - 7766 (2014)
T. Böhm, T. Meurer, *Modellbasierte Temperaturregelung für ein Tiefziehwerkzeug*, Theoretische Verfahren der Regelungstechnik, 193 - 206 (2014)
C. Rodriguez Lucatero, A. Schaum, L. Alarcon Ramos, R. Bernal, *Message survival and decision dynamics in a class of reactive complex systems subject to external fields*, Physica A:Statistical Mechanics and its Applications, 338 - 351 (2014)
P. Schmidt, J. Moreno, A. Schaum, *Observer design for a class of complex networks with unknown topology*, IFAC World Congress, 2812 - 2817 (2014)

## Presentations

T. Meurer, *Folgeregelung für verteilt-parametrische Systeme*, Plenary Talk Workshop, Elgersburg, Germany, 02.-06.03.2014
A. Kater, *Motion planning for a piezo-actuated structure modelling a wingsail*, 85th Annual Meeting of the International Association of Applied Mathematics and Mechanics (GAMM), Erlangen, Germany, 10.-14.03.2014
T. Meurer, *Model-based control and estimation in process systems engineering*, Bioprocess Technology Working Group, TU Vienna, Austria, 03.-03.07.2014
T. Meurer, *Trajectory planning for a deep drawing tool*, IFAC World Congress, Kapstadt, South Africa, 24.-29.08.2014
J. Jadachowski, T. Meurer, A. Kugi, *Backstepping observers for quasi-linear parabolic PDEs*, IFAC World Congress, Kapstadt, South Africa, 24.-29.08.2014
T. Meurer, *Modellbasierte Temperaturregelung für ein Tiefziehwerkzeug*, Fachausschuss 1.4 Theoretische Verfahren der Regelungstechnik, Anif, Austria, 21.-23.09.2014

## Further Activities and Events

Prof. Meurer serves as Chair of the IFAC Technical Committee 2.6 Distributed Parameter Systems and as Associate Editor for the Conference Editorial Board of the IEEE Control Systems Society (since 2012). He also serves as Associate Editor for the IFAC Journals Automatica (since 2014) and Control Engineering Practice. Prof. Meurer has served as IPC Associate Editor for IFAC World Congress 2014 in Cape Town.

He is Vice member of the Council of the Faculty of Engineering, a member of the Doctoral Board of the Faculty of Engineering, and a member of the Examination Boards for Electrical Engineering and Industrial Engineering.

# Communications

The research activities of this group are as follows:

- optical communications (measurement, prototyping, and simulation of high speed data communication systems, equalization of optical transmission channels, optical modulation formats, optical line coding, WDM networks),
- simulation and modelling of communication systems (development and application of modular simulation tool on the system level), and
- synchronization in communication systems (clock and carrier synchronization, PLL-applications, deep space laser communication systems).

## Results

*Flexible Coherent Transceivers*

In the last few years we have witnessed a growing demand for flexibility which should be taken into account in the design of future fibre-optic communication systems. One aspect of this goal concerns flexible transceivers that should be capable of handling a range of baud rates. Flexible optical transceivers are implemented in a system which allows reconfiguration by software to implement the most suitable transmission protocols. The networks are called Software-Defined-Networks (SDN). The optical transmitter and receiver in such elastic SDNs with flexible grids should be programmable to allow variations in modulation format, data rate or forward-error correction (FEC) protocols. These parameters should therefore be set to fit the available bandwidth, signal quality, and reach.

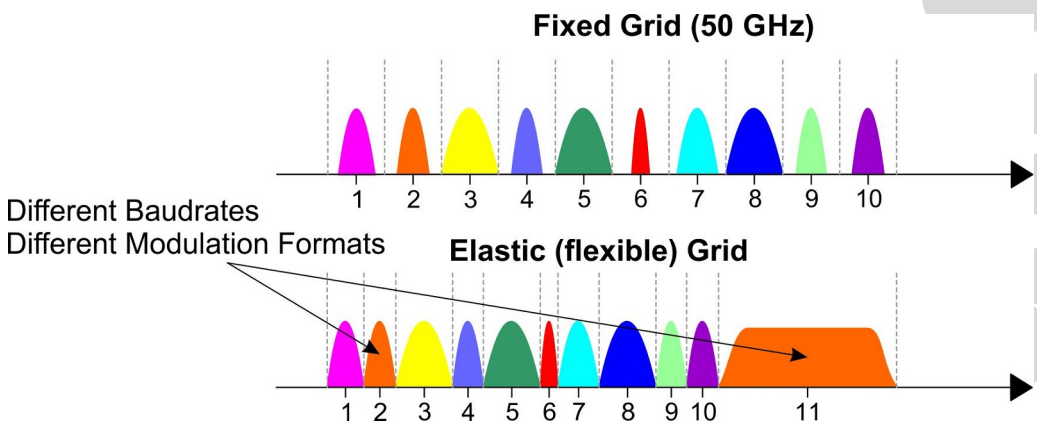


Fig. 1: Difference of an elastic network with flexible grids from the ITU grid (50 GHz)

Coherent (CO) fibre-optic transmission systems, where both the phase and magnitude of the optical signal are detected, offer the possibility to compensate for transmission impairments using digital signal processing (DSP) techniques. Linear transmission impairments, such as chromatic dispersion (CD) and polarization-mode dispersion (PMD), can be compensated by using a digital finite impulse response (FIR) feed forward equalizer (FFE) in a butterfly structure. The conventional FFE could operate at the symbol rate but its performance depends heavily on the sampling delay. Considering the receiver side, and assuming an analog-to-digital converter (ADC) with a fixed sampling rate, the number of samples-per-symbol (SPS) might not result in an integer value, e.g. a 20 GBaud signal sampled with a 30 GSamples/s ADC will result in 1.5 SPS. Thus applying a non-integer FSE that possesses the advantages of an integer FSE will greatly improve the receiver flexibility, with regard to the ADC sampling rates and the baud rate. Furthermore by using a proper anti-aliasing filter preceding the ADC, the number of SPS can be reduced below two, hence relaxing the ADC speed requirements. This department is currently investigating techniques for flexible transceivers regarding digital signal processing in SDN.

Using coherent detection on the receiver side, the resulting ISI can be efficiently compensated by using digital signal processing (DSP) techniques. Equalization can be done either with a plain feed-forward equalizer (FFE) or a combined FFE and a decision-feedback equalizer (DFE). In addition, in order to avoid its error propagation effect and to allow a straight-forward application with channel-coding schemes, the feedback structure of the DFE can be replaced by a precoder on the transmitter side: a structure referred to in the literature as Tomlinson-Harashima precoding (THP). Considering the joint equalization of CD and filtering-induced ISI, THP was shown to outperform FFE and to offer a similar performance as DFE, with the advantage of the elimination of error propagation which was shown to be potentially catastrophic in the vicinity of the FEC limit. Due to the increasing demand for high data rates and long reach, transmission with higher launch-power becomes inevitable, e.g. in order to meet the required optical signal to noise ratio (OSNR). Unfortunately, by increasing the launch-power, transmission will suffer not only from ISI but fibre nonlinearities as well, namely self-phase modulation (SPM) for single-carrier transmission. Since fibre nonlinearities cannot be compensated using an equalizer designed for linear ISI, the equalizers mentioned above have to be redesigned in order to be applied in the nonlinear regime. This can be achieved using a Volterra nonlinear equalizer (VNLE) that can replace the FFE structure or can be combined with the DFE/THP feedback structure. A Volterra nonlinear equalizer (VNLE) should in general provide us with a model of the inverse of the transmission system. From a practical point-of-view, the VNLE has to be of a finite-order. The realization can be done either in the frequency domain or entirely in the time domain, as was done in our contribution. Finding the VNLE coefficients is in fact an estimation problem. Using the minimum mean-squared error (MMSE) criterion, this problem can be considered as a generalization of Wiener filtering. In this work, which was presented in the 15th ITG Fachtagung in Leipzig, the performance of a combined THP-VNLE in a nonlinear fibre-optic communication system was investigated. THP was shown to outperform FFE but was itself slightly outperformed by DFE for a short transmission distance of 100 km, due to the increased size of the effective data sequence in comparison with the original constellation. By applying VNLE equalization in conjunction with the investigated equalizers, system performance was in general improved. THP and DFE have shown comparable performance, whereas they have both outperformed FFE, and that with a reduced number of VNLE coefficients. VNLE was shown to reduce the BER by at least one order of magnitude around the minimum BER value.

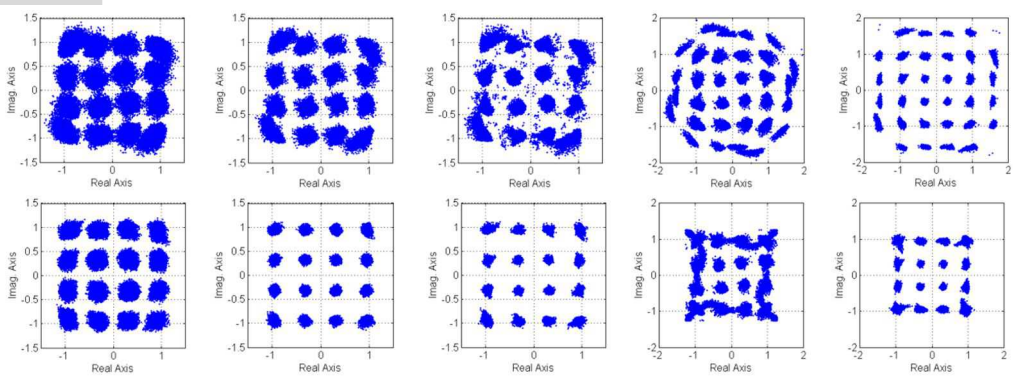


Fig. 2: Equalized constellation diagrams after 100 km transmission at 8 dBm launch-power. First row left to right: FFE(3), FFE(4), FFE(3) DFE(1), THP(1) FFE(3) before modulo decoding, THP(1)-VNLE(3) before modulo decoding. Second row left to right: VNLE(3), VNLE(4), VNLE(3)-DFE(1), THP(1)-FFE(3) after decoding, THP(1)-VNLE(3) after decoding

## Personnel

Head of the group: Prof. Dr. Werner Rosenkranz; Secretary: Petra Usinger
Technical Staff: Dipl.-Ing. (FH) Sandra Robien

Scientific Staff:

| | | |
|---|---|---|
| Dipl-Wirth.-Ing. Dennis Clausen<br>SASER - Signalverarbeitung für sichere Übertragung | 01.01.-31.12.2014 | Industry/CAU |
| Dr.-Ing. Jochen Leibrich<br>Modulationsformate und Simulationswerkzeuge | 01.01.-31.07.2014 | CAU |
| M.Sc. Roi Rath<br>SASER - Signalverarbeitung für sichere Übertragung | 01.01.-31.12.2014 | Industry |
| Dipl.-Ing. Christian Ruprecht<br>OFDM-Konzepte für das optische Zugangsnetz | 01.01.-31.12.2014 | BMBF |
| M.Sc. Semjon Schaefer<br>Optical Satellite Communications | 01.01.-31.12.2014 | CAU |
| Dipl.-Ing. Johannes von Hoyningen-Huene<br>Optical Communication | 01.01.-31.12.2014 | CAU |

## Lectures, Seminars, and Laboratory Course Offers

*Winter 2013/2014*

Nachrichtenübertragung II, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
W. Rosenkranz (+ J. von Hoyningen-Huene)

High-speed Communication Networks, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
W. Rosenkranz (+ C. Ruprecht)

Numerische Simulation analoger und digitaler Nachrichtensysteme, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
J. Leibrich (+ S. Schaefer)

Project, 3 hrs Project/Week,
W. Rosenkranz und Mitarbeiter

Communications Lab, 4 hrs Lab/Week,
W. Rosenkranz und Mitarbeiter

Seminar Nachrichtentechnik, 3 hrs Seminar/Week,
W. Rosenkranz und Mitarbeiter

Seminar über Bachelor- und Masterarbeiten der Nachrichtentechnik, 2 hrs Seminar/Week,
W. Rosenkranz und Mitarbeiter

Anleitung zum wissenschaftlichen Arbeiten für Studierende der Elektrotechnik und Informationstechnik, 2 hrs Seminar/Week,
W. Rosenkranz und Mitarbeiter

Digital Communications, 3 (+ 2) hrs Lecture (+ Exercises)/Week,
W. Rosenkranz (+ R. Rath)

Advanced Topics Lab, 6 hrs Lab/Week,
W. Rosenkranz und Mitarbeiter

*Summer 2014*

Nachrichtenübertragung, 3 (+ 2) hrs Lecture (+ Exercises)/Week,

W. Rosenkranz (+ J. von Hoyningen-Huene)

Optical Communicatons, 2 (+1) hrs Lecture (+ Exercises)/Week,
W. Rosenkranz (+ J. Leibrich)

Project, 3 hrs Project/Week,
W. Rosenkranz und Mitarbeiter

Bachelorpraktikum Nachrichten- und Informationstechnik, 4 hrs Lab/Week,
W. Rosenkranz und Mitarbeiter

Seminar Nachrichtentechnik, 3 hrs Seminar/Week,
W. Rosenkranz und Mitarbeiter

Seminar über ausgewählte Kapitel der Nachrichtentechnik, 3 hrs Seminar/Week,
W. Rosenkranz und Mitarbeiter

Seminar über studentische Arbeiten der Nachrichtentechnik, 2 hrs Seminar/Week,
W. Rosenkranz und Mitarbeiter

Anleitung zum wissenschaftlichen Arbeiten für Studierende der Elektrotechnik und Informatonstechnik, 2 hrs Seminar/Week,
W. Rosenkranz und Mitarbeiter

*Winter 2014/2015*

Nachrichtenübertragung II, 2 (+1) hrs Lecture (+ Exercises)/Week,
W. Rosenkranz (+ J. von Hoyningen-Huene)

Numerische Simulation analoger und digitaler Nachrichtensysteme, 2 (+1) hrs Lecture (+ Exercises)/Week,
J. Leibrich (+ S. Schaefer)

Project, 3 hrs Project/Week,
W. Rosenkranz und Mitarbeiter

Communications Lab, 4 hrs Lab/Week,
W. Rosenkranz und Mitarbeiter

Seminar Nachrichtentechnik, 3 hrs Seminar/Week,
W. Rosenkranz und Mitarbeiter

Seminar über Bachelor- und Masterarbeiten der Nachrichtentechnik, 2 hrs Seminar/Week,
W. Rosenkranz und Mitarbeiter

Anleitung zum wissenschaftlichen Arbeiten für Studierende der Elektrotechnik und Informationstechnik, 2 hrs Seminar/Week,
W. Rosenkranz und Mitarbeiter

Digital Communications, 3 (+2) hrs Lecture (+ Exercises)/Week,
W. Rosenkranz (+ R. Rath)

Advanced Topics Lab, 6 hrs Lab/Week,
W. Rosenkranz und Mitarbeiter

## Third-Party Funds

BMBF, *Signalverarbeitung für sicher Übertragung,* 01.08.2012-31.07.2015 (313.284)
Industry, *Intersatellitenkommunikation,* 15.01.2014-15.04.2015 (53.550)

## Further Cooperation, Consulting, and Technology Transfer

The chair belongs to the contact group which annually arranges the workshop **Optical Communications**:

- TU Munich(Prof. N. Hanik),

- ''Research Centre COM" , TU Kopenhagen (Prof. P. Jeppesen),

- FhG Heinrich Hertz Institut, Berlin,

- Deutsche Telekom T-Systems, Berlin, Darmstadt.

## Diploma, Bachelor's and Master's Theses

N. Eiselt, *Kompensation von Phasenrauschen in optischen Nachrichtensystemen mit kophärenter Detektion*, 12.02.2014

C. Heusmann, *Optimierung der Frequenzaquisition in einem Phasenregelkreis für die optische Satellitenkommunikation*, 26.08.2014

C.M. Castro Posada, *Experimental Investigation of Long-Haul Transmission using a Recirculating Loop and Coherent Detection*, 06.10.2014

O. Mittag, *Kompensation und Entzerrung von Kanal- und Implementierungseinflüssen bei OFDM-basierten optischen Zugangsnetzen*, 02.12.2014

S. Seetharama Ramachandra, *Investigation of the Optical Phase Lock Loop as a Demodulator for Optical Intersatellite Communication Links*, 06.12.2014

## Publications

Published in 2014

J. Leibrich, W. Rosenkranz, *Flexibility of Spectral Efficiency by Means of Power-Efficient Multidimensional Constellations*, 16 th International Conference on Transparent Optical Networks (ICTON), **Tu.A3.3**, (2014)

Y. Chen, C. Ruprecht, W. Rosenkranz, N. Hanik, *Power budget improvement for coherent optical - OFDM access upstream transmission using TCM with constellation shaping*, 16 th International Conference on Transparent Optical Networks (ICTON), **Tu.A3.3**, (2014)

C. Ruprecht, Y. Chen, D. Fritzsche, J. von Hoyningen-Huene, N. Hanik, E. Weis, D. Breuer, W. Rosenkranz, *Field trial of an OFDMA-PON system*, 16 th International Conference on Transparent Optical Networks (ICTON), **Tu.A3.2**, (2014)

R. Rath, J. von Hoyningen-Huene, W. Rosenkranz, *Combined Precoding and Volterra Equalization for the Mitigation of Fibre-Optic Nonlinear Channel Impairments*, 15. ITG Fachtagung Photonische Netze, (2014)

J. Leibrich, W. Rosenkranz, *Power Efficient Multidimensional Constellations*, 15. ITG Fachtagung Photonische Netze, (2014)

C. Ruprecht, Y. Chen, D. Fritzsche, J. von Hoyningen-Huene, N. Hanik, E. Weis, D. Breuer, W. Rosenkranz, *37.5-km Urban Field Trial of OFDMA-PON using Colourless ONUs with Dynamic Bandwidth Allocation and TCM*, OFC, **Th3G.5**, (2014)

J. von Hoyningen-Huene, H. Grießer, M. Eiselt, C. Ruprecht, W. Rosenkranz, *Comparison of Rx-DSP-Structures in Experimental OFDMA-PON Uplink Transmission Systems*, OFC, **Tu2F.4**, (2014)

D. Clausen, *Experimentelle Untersuchung kohärenter optischer 16QAM Übertragung mit Polarisationsmultiplexing bis 25 GBaud*, Workshop der ITG Fachgruppe 5.3.1, Optische Multiplextechniken, (2014)

J. von Hoyningen-Huene, *Subträger-Multiplexing im PON: Wann ist OFDM orthogonal?*, Workshop der ITG Fachgruppe 5.3.1, Optische Multiplextechniken, (2014)

## Presentations

J. Leibrich, W. Rosenkranz, *Flexibility of Spectral Efficiency by Means of Power-Efficient Multidimensional,* 16 th International Conference on Transparent Optical Networks (ICTON), Graz, Austria, 06.-10.06.2014

Y. Chen, C. Ruprecht, W. Rosenkranz, N. Hanik, *Power budget improvement for coherent optical - OFDM access upstream transmission using TCM with constellation shaping,* 16 th International Conference on Transparent Optical Networks (ICTON), Graz, Austria, 06.-10.06.2014

C. Ruprecht, Y. Chen, D. Fritzsche, J. von Hoyningen-Huene, N. Hanik, E. Weis, D. Breuer, W. Rosenkranz, *Field trial of an OFDMA-PON system,* 16 th International Conference on Transparent Optical Networks (ICTON), Graz, Austria, 06.-10.06.2014

R. Rath, J. von Hoyningen-Huene, W. Rosenkranz, *Combined Precoding and Volterra Equalization for the Mitigation of Fibre-Optic Nonlinear Channel Impairments,* 15. ITG Fachtagung Photonische Netze, Leipzig, Germany, 05.-06.05.2014

J. Leibrich, W. Rosenkranz, *Power Efficient Multidimensional Constellations,* 15. ITG Fachtagung Photonische Netze, Leipzig, Germany, 05.-06.05.2014

C. Ruprecht, Y. Chen, D. Fritzsche, J. von Hoyningen-Huene, N. Hanik, E. Weis, D. Breuer, W. Rosenkranz, *37.5-km Urban Field Trial of OFDMA-PON using Colourless ONUs with Dynamic Bandwidth Allocation and TCM,* OFC 2014, San Francisco, CA, USA, 09.-13.03.2014

J. von Hoyningen-Huene, H. Grießer, M. Eiselt, C. Ruprecht, W. Rosenkranz, *Comparison of Rx-DSP-Structures in Experimental OFDMA-PON Uplink Transmission Systems,* OFC 2014, San Francisco, CA, USA, 09.-13.03.2014

A. Razmtouz, K. Habel, C. Kottke, C. Ruprecht, W. Rosenkranz, *Initial ranging scheme based on interpolated Zadoff-Chu sequences for OFDMA-PON,* OSA 2014, 10.-10.02.2014

J. Leibrich, W. Rosenkranz, *Multidimensional Constellations for Power-Efficient and Flexible Optical Networks,* IEEE Photonics Technology Letters, 08.-08.04.2014

## Further Activities and Events

Prof. Rosenkranz is active on the following committees:

- Fachausschuss 5.1 der ITG im VDE: *" Signal- und Systemtheorie"*
- Fachausschuss 5.3 der ITG im VDE: *" Optische Nachrichtentechnik"*
- Fachgruppe 5.3.1 der ITG im VDE: *" Simulation und Modellierung in der optischen Nachrichtentechnik"*
- Normungsausschuss 412.2 *" Komponenten für Kommunikationskabelanlagen"* der DKE
- Deutsche Kommission Elektrotechnik Elektronik Informationstechnik im DIN und VDE

Prof. Rosenkranz is active on the programme committees of the following international conferences:

- *" European Conference on Optical Communications (ECOC)"*
- *" IEEE International Conference on Transparent Optical Networks (ICTON)"*
- *" Asia Communications and Photonics Conference and Exhibition (ACP)"*
- *" International Conference on Computers, Communications and Power (ICCCP)"*
- Chair of the Photonic Detection Technical Group of OSA (Optical Society of America)

**Awards**

The third-party project 100GET was nominated by Eureka Celtic-Plus as '' candidate for the Innovation Award 2013''.

Prof. Rosenkranz was awarded ''Fellow of the OSA'' for ''sustained contributions to the field of optical communications for more than 20 years, most recently in equalization and compensation of impairments in fibre optic systems''.

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# Computational Electromagnetics

The activities in the Computational Electromagnetics Group include the analytical and numerical treatment of electromagnetic fields and corresponding applications towards the solution of relevant technical problems. Research in these areas focuses on the development of methods to analytically and numerically calculate electromagnetic fields (e.g. multipole analysis, finite-difference methods, finite-element methods, integral-equation methods). These methods are then applied to improve existing codes (such as Finite-Difference Time-Domain (FDTD) algorithms) and to investigate and solve problems in the area of Electromagnetic Compatibility (EMC), among others. Furthermore, the research comprises fundamental investigations regarding electromagnetic fields (e.g. uniqueness theory and its application to inverse problems, scattering by canonical objects). Finally, new multipole-based approaches are being investigated to solve biomagnetic problems with the objective to improve corresponding medical applications like magnetoencephalography (MEG) and magnetocardiography (MCG). On the educational side, the group offers courses in electromagnetic theory, computational electromagnetics, mathematical methods in field theory, electromagnetic compatibility, fields and waves in biological systems, and tomographic methods in medicine.

## Results

### a) Numerical and analytical examination of shielding and shielding effectiveness

Shielding is one of the most important steps to ensure the electromagnetic compatibility of devices and systems. Shape and position of the shielding structures depend on its desired mechanical features and on the frequency range of the anticipated disturbances. Quantitative measures of the capability of a shield to reduce the influence of electric and magnetic disturbances at low frequencies are the electric shielding effectiveness and the magnetic shielding effectiveness. However, these measures are not applicable for high frequency disturbances or pulsed (transient) disturbances. Consequently, this research project concentrates on the evaluation of definitions of the shielding effectiveness for these cases. We are particularly interested in the case where the source of interference is located in the near-field as compared when it is in the far-field.

### b) Statistical EMC

Statistical EMC is an important part of statistical electromagnetics because many parameters in EMC (frequencies, amplitudes, waveforms, geometry) are known only by means of their statistical parameters. Such statistically varying parameters might be given in terms of the first few statistical moments of their distributions. The special direction of this research is the combination with a spherical-multipole expansion of the electromagnetic field where the spherical-multipole amplitudes are described through their statistical moments. This leads to a very compact and non-redundant description of the field statistics, applicable for instance to investigate the statistical moments of the shielding effectiveness as a function of the statistical moments of the geometrical parameters of the shielding structure. The method is particularly useful in the case of small variations of these parameters.

### c) Complex rays and multipole analysis

Geometric Optics is used to handle scattering of fields by electrically large objects, i.e. structures of dimensions much larger than the wavelength. At geometric singularities like edges or tips, geometric optics fails and diffraction must be taken into account. This leads to diffraction coefficients which can be shown to dominate the field outside the directions of reflection. Usually, these diffraction coefficients are calculated from solutions for canonical structures. As an example, the edge diffraction coefficient has been derived from the series expansion of the field diffracted by a wedge. The associated special case of a half-plane has been solved by Sommerfeld.

In this DFG-sponsored research project we have determined diffraction coefficients for the elliptic cone. This structure is most interesting, particularly because it includes a very general tip. Moreover, by appropriately choosing the ellipticity

parameters the elliptic cone includes the circular cone, the plane angular sector, and the corresponding tip geometries as special cases. The associated diffraction coefficients are obtained by a numerical evaluation of the corresponding spherical-multipole expansion in sphero-conal coordinates. The commonly observed convergence problems in case of plane-wave incidence are avoided by choosing a complex-source beam as the incident field. Possible applications include a more precise consideration of the fields scattered by aircraft and airport constructions to improve instrument landing systems.

### d) Multipole-based reconstruction methods for the biomagnetic problem

The project is part of the Collaborative Research Centre (SFB) 855 on Magnetoelectric Composites - Future Biomagnetic Interfaces , created by the Deutsche Forschungsgemeinschaft (DFG). It focuses on new strategies for the measurement of biomagnetic fields (from the brain and heart), on optimized surfaces, and new algorithms for the solution of the corresponding inverse problem.

## Personnel

Head of the group: Prof. Dr.-Ing. L. Klinkenbusch; Secretary: S. Thielbörger (50%)
Technical Staff: Dipl.-Ing. J. Buschmann (50%)

Scientific Staff:

| | | | |
|---|---|---|---|
| Dipl.-Phys. H. Ahrens | 01.01.-31.12.2014 | | DFG |
| SFB855 - D1: Multipole-based reconstruction schemes | | | |
| Dipl.-Phys. F. Argin | 01.01.-31.03.2014 | | DFG |
| SFB855 - D1: Multipole-based reconstruction schemes | | | |
| M.Sc. H. Brüns | 01.01.-31.12.2014 | | DFG / CAU |
| Scattering by semi-infinite structures | | | |
| Dipl.-Phys. K. Körber | 01.01.-31.03.2014 | | CAU |
| Statistical EMC | | | |
| M.Sc. A. Reinhardt | 01.01.-31.12.2014 | (50%) | CAU |
| Multipole analysis | | | |

## Lectures, Seminars, and Laboratory Course Offers

*Winter 2013/2014*

Elektromagnetische Felder 2, 3 (+1) hrs Lecture (+ Exercises)/Week,
L. Klinkenbusch (+ K. Körber)

Numerische Feldberechnung, 2 (+1) hrs Lecture (+ Exercises)/Week,
L. Klinkenbusch (+ H. Brüns)

Intensivübung Elektromagnetische Felder, 1 hrs Exercise/Week,
L. Klinkenbusch (+ F. Argin, K. Körber, H. Ahrens)

Projekt, 3 hrs Lecture/Week,
L. Klinkenbusch (+ K. Körber)

Tomgraphische Verfahren in der Medizin, 2 (+1) hrs Lecture (+ Exercises)/Week,
L. Klinkenbusch (+ H. Ahrens)

*Summer 2014*

Elektromagnetische Felder 1, 3 (+1) hrs Lecture (+ Exercises)/Week,
L. Klinkenbusch (+ H. Ahrens)

Elektromagnetische Verträglichkeit, 2 (+1) hrs Lecture (+ Exercises)/Week,
L. Klinkenbusch (+ H. Brüns)

Seminar Feldtheorie, 1 hrs Seminar/Week,
L. Klinkenbusch

Mathematische Methoden in der Feldtheorie, 2 (+1) hrs Lecture (+ Exercises)/Week,
L. Klinkenbusch (+ H. Brüns)

Projekt, 3 hrs Exercise/Week,
L. Klinkenbusch (+ K. Körber)

Felder und Wellen in biologischen Systemen, 2 (+1) hrs Lecture (+ Exercises)/Week,
L. Klinkenbusch (+ F. Argin)

*Winter 2014/2015*

Elektromagnetische Felder 2, 3 (+1) hrs Lecture (+ Exercises)/Week,
L. Klinkenbusch (+ K. Körber)

Numerische Feldberechnung, 2 (+1) hrs Lecture (+ Exercises)/Week,
L. Klinkenbusch (+ H. Brüns)

Intensivübung Elektromagnetische Felder, 1 hrs Exercise/Week,
L. Klinkenbusch (+ F. Argin, K. Körber, H. Ahrens)

Tomgraphische Verfahren in der Medizin, 2 (+1) hrs Lecture (+ Exercises)/Week,
L. Klinkenbusch (+ H. Ahrens)

## Third-Party Funds

DFG, *Semi-infinite Strukturen*, 01.01.-31.07.2014 (1/1 E13 + 1 WiMi + Sachmittel)
DFG, *SFB 855 TP D1 (Auslauffinanzierung)*, 01.01.-31.12.2014 (1 E13 + Sachmittel)

## Further Cooperation, Consulting, and Technology Transfer

The group collaborates with the following individuals:

Prof. Dr. R. Sikora, Westpommeranian University Szczecin (Poland). Subject: Non-destructive Evaluation,

Prof. Dr. E. Cardelli, University Perugia (Italy). Subject: ERASMUS partnership,

Prof. Dr. E. Heyman, Tel-Aviv University (Israel). Subject: Complex-Source Beams and Multipole Expansions,

Prof. L. Pichon, University Paris-Sud (XV), Paris (France). Subject: EMC of complex systems, ERASMUS partnership,

Prof. G. Manara, University of Pisa (Italy). Subject: Ray Methods & ERASMUS partnership.

## Diploma, Bachelor's and Master's Theses

Tim Fülbier, *Modelling of non-cartesian structures in FDTD and its application to the solution of canonical problems*, 12.08.2014

Nora Stroetzel, *Scattering of a complex-source beam by dielectric spherical shells*, 16.06.2014
Andreas Gocht, *The cylindrical multipole expansion and its applicatiobn to magnetocardiography*, 19.06.2014

## Publications

Published in 2014

H. Brüns, L. Klinkenbusch, *Acoustic scattering of a complex-source beam by the edge of a plane angular sector*, Advances in Radio Science, **12**, 179 - 186 (2014)

M. Katsav, E. Heyman, L. Klinkenbusch, *Converging beam diffraction by a wedge*, Proc. XXXIth URSI General Assembly and Scientific Symposium, Beijing (China), (2014)

M. Katsav, E. Heyman, L. Klinkenbusch, *Beam Diffraction by a Wedge: Exact and Complex Ray Solutions*, IEEE Transactions on Antennas and Propagation, **62**, 3731 - 3740 (2014)

L. Klinkenbusch, H. Brüns, *Diffraction of a uniform complex source beam by a circular cone*, Proc. of the 2014 International Conference on Electromagnetics in Advanced Applications, Aruba, 470 - 472 (2014)

A. Reinhardt, H. Brüns, L. Klinkenbusch, M. Katsav, E. Heyman, *Scattering and diffraction of an arbitrarily directed complex-source beam by a semi-infinite circular cone*, Proc. XXXIth URSI General Assembly and Scientific Symposium, Beijing (China), (2014)

## Presentations

H. Brüns, L. Klinkenbusch, *GTD diffraction coefficients from complex-source beam solutions of canonical problems*, Kleinheubacher Tagung 2014, Miltenberg (Bayern), Germany, 29.09.-01.10.2014

A. Reinhardt, H. Brüns, L. Klinkenbusch, *Spherical-multipole analysis of an arbitrary complex source beam diffracted by a circular cone*, Kleinheubacher Tagung 2014, Miltenberg (Bayern), Germany, 29.09.-01.10.2014

L. Klinkenbusch, H. Brüns, A. Reinhardt, E. Heyman, M. Katsav, *Multipole expansions and complex-source beams*, Kleinheubacher Tagung (Memorial Session for K.-J. Langenberg and H. Chaloupka), Miltenberg (Bayern), Germany, 29.09.-01.10.2014

L. Klinkenbusch, H. Brüns, *Diffraction of a uniform complex-source beam by a circular cone*, ICEAA Offshore 2014, Palm Beach, Aruba, 03.-09.08.2014

L. Klinkenbusch, *Spherical-multipole analysis of electromagnetic fields - History and current applications (Invited)*, Colloquium University of Pisa, Pisa, Italy, 14.-14.07.2014

A. Reinhardt, H. Brüns, L. Klinkenbusch, E. Heyman, M. Katsav, *Scattering and Diffraction of an arbitrarily directed complex-source beam by a circular cone (Invited)*, URSI GASS 2014, Beijing, China, 16.-23.08.2014

## Further Activities and Events

Since 2009 Prof. Klinkenbusch has been a Committee member of the German Academic Exchange Service (Deutscher Akademischer Austauschdient - DAAD) for the region Near-East/ North Africa. Until June 2014, he was acting as Vice Dean of the Faculty of Engineering. He has also been the representative of the Faculty in the Schleswig-Holsteinische Universitätsgesellschaft.

Prof. Klinkenbusch serves on the IEEE Antennas and Propagation Education Committee. Since 2012 he has been an elected member of the URSI Commission B Technical Advisory Board (B-TAB). In 2014, he has been serving as technical and conferences. reviewer, chairman, and organizer of special sessions for several international scientific journals

# Digital Signal Processing and System Theory

In 2014 the group "Digital Signal Processing and System Theory" (abbreviated in the following as DSS) comprised two professors, Prof. Dr. Ing. Gerhard Schmidt (head) and Prof. Dr.-Ing. Ulrich Heute, a secretary, and a technician (both also working for the Information & Coding Theory group), two external lecturers, about 20 Ph.D. students (internal and external), as well as several co-workers on a short-term job basis. As in previous years, we focused on three major research topics, namely, **speech and audio processing**, **medical signal processing**, and **underwater signal processing**:

- The investigation of speech communication in automotive environments (e.g. hands-free or in-car communication systems) was continued in 2014; both our research cars were equipped with even more sensors and actuators as well as real-time signal processing capabilities, in order to verify our theoretical approaches in real automotive environments. Also, the investigation of automatic evaluation schemes for in-car communication continued successfully and we further extended our fruitful cooperation with the linguistics department of Kiel University (Prof. Niebuhr and colleagues). In addition, we started with our second audio and medical lab which will serve in the future for combined research on acoustic and medical topics.

- We continued our cooperation with the Neurology and the Neuropaediatrics departments of the University Clinics Kiel with great success. In particular, we worked with the groups of Prof. Deuschl, Prof. Siniatchkin, and Prof. Stephani on analysis of signals that are created in the human brain. We continued to improve the magneto-electric sensors concerning the removal of external distortions. Research on our real-time brain-computer interface was continued and our systems run more and more pattern recognition schemes in real-time.

- Furthermore, we continued our cooperation with partners such as the Federal-Navy Research Institute for Under-Water Acoustics and Geophysics (FWG), and GEOMAR, the Helmholtz Centre for Ocean Research, with interesting research projects: marine-mammal protection, underwater telephony, and real-time MIMO SONAR processing. Besides investigating and implementing new algorithms we also extended our multi-channel SONAR hardware.

Also in 2014, we were very happy that our external lecturers, Dr.-Ing. M. Krini (from paragon AG Delbrück) and Dr.-Ing. M. Muthuraman (from the Neurology Department of Kiel University), continued with their lectures. Dr.-Ing. M. Krini teaches artificial neural networks and Dr.-Ing. M. Muthuraman teaches medical-signal processing with special emphasis on frequency-domain approaches.

## Results

Ongoing work led to numerous publications, presentations, and results. A few of them are listed below:

- **Real-Time Signal Processing**

  Meanwhile, all of our Ph.D. students are using, improving, and extending our real-time framework called *KiRAT* in their research projects. This tool is a soft- and hardware combination. Since we use it now in all branches of our research, we changed its name in 2014 from *Kiel Real-Time Audio Toolkit* to *Kiel Real-Time Application Toolkit*. It is used now for speech and audio research in some of our SONAR projects, and for medical research.

  Besides connecting several new medical sensors such as EEG (electroencephalography) and MEG (magnetoencephalography) systems, we ported the system also to new operating systems such as several Linux versions. Also in terms of hardware, we started with the third extension phase that includes several video components (e.g. for video recording and transmission).

- **Automotive Signal Enhancement**

In 2014, this was one of our major research topics. We extended several algorithmic details, such as specific suppression schemes for highly non-stationary noise components, and we were able to investigate and implement several schemes for feedback control (both suppression and cancellation). Besides presenting our results at national and international conferences, we had also several meetings with our industry partners (Fig. 1 shows our team for in-car communication (ICC) in Stuttgart during a three day workshop with one of our collaborating partners).

Fig. 1: The ICC part of the DSS team at a workshop in Stuttgart.

- **Signal Processing for Breathing Protection Masks**

Two years ago we began the enhancement of the quality of speech transmitted by breathing protection masks as part of cooperation with Dräger in Lübeck. The idea was to develop a real-time signal processing system for such masks. Therefore, our real-time toolkit KiRAT was used to provide a system for improving the speech quality when firefighters try to communicate while wearing their masks.

This project continued in 2014. Two of our students worked on improved signal enhancement techniques for the breathing protection mask and on the evaluation of the designed algorithms. Since this work was very promising, Michael Brodersen M.Sc. continued on that topic as an external Ph.D. student (again in cooperation with Dräger).

- **SONAR Signal Processing**

Concerning our cognitive real-time SONAR system, we made great progress in 2014. Firstly, our MIMO system was extended by an adaptive transmit-beamforming unit and we are now able to correlate with several spread versions of our send signals (Doppler-sensitive processing): the spreading takes place in real-time. Secondly, we started to build soft- and hardware for underwater telephony.

- **Audio-Visual Ambiance Simulation**

In order to support the research and development of automotive signal processing algorithms, we have been

working on an acoustic ambiance simulation that is able to reproduce driving noise inside a car. In 2014, this simulation was extended by a visual driving simulation. It consists of calibration and synchronization software as well as a projector and projection screen inside our audio lab (see Fig. 2). Furthermore, a digital simulation tool was created that can simulate the acoustics within a car. Using this tool, the parameterization and evaluation of in-car communication systems can be performed not only in the lab, but also at the workplace.

Fig. 2: The audio-visual ambiance simulation in the DSS audio lab.

- **Medical Signal Processing**

Source and network analysis in EEGs and future MEGs were analyzed by Abdul Rauf Anwar, M.Sc., cooperating closely with our lecturer Dr.-Ing. M. Muthuraman, who has been a member of the Neurology group of Kiel's University Clinics since 2010. The aim is to find a deeper understanding of tremor diseases and especially the information flow in the human brain. Kidist Gebremariam Mideksa, M.Sc., also works with these signals, aiming for a comparison between EEG and MEG information and possibly a combination of the same. The results of both scientists led to a doctoral dissertation and several conference publications.

As mentioned already above, our research on magneto-electric (ME) sensors has made great progress in 2014. We are able now to record, improve (in terms of signal-to-noise ratio), and analyze signals from most of our currently available sensor types. Now we can cancel and suppress acoustic distortions in real-time. Besides that, analysis of the signals of the human heart began in 2014 (in cooperation with the Cardiology departments, Prof. Frey and colleagues).

Research on brain-computer interfaces (BCIs) continued in 2014. We are now able to connect two further BCI hardware components (BCIs from Neurowerk and from gtec). In terms of algorithms, we moved forward from artifact-based control to P-300-based and visually-evoked potential-based schemes. Apart from the brain signals themselves, we also investigate combined speech and brain recordings (see Fig. 3).

Fig. 3: Combined speech and brain measurements.

## Personnel

Head of the group: Prof. Dr.-Ing. G. Schmidt; Secretary: S. Schuchardt (50%)
Technical Staff: Dipl.-Ing. T. Rabsch (50%)

Staff:

| | | |
|---|---|---|
| Prof. Dr.-Ing. U. Heute | 01.01.-31.12.2014 | Ph.D. supervisor |
| Dr.-Ing. M. Krini | 01.01.-31.12.2014 | Lecturer |
| Dr.-Ing. M. Muthuraman | 01.01.-31.12.2014 | Lecturer |

Scientific Staff:

| | | |
|---|---|---|
| M. Sc. A. R. Anwar<br>Brain Information Flow | 01.01.-31.10.2014 | DAAD / Ph.D. student |
| M.Sc. C. Baasch<br>Analysis of Parkinson Speech | 15.11.-31.12.2014 | DFG / Ph.D. student |
| M. Sc. H. Bakkari<br>Automotive Signal Processing | 01.10.-31.12.2014 | External Ph.D. student |
| Dipl.-Wirtsch.-Ing. T. Claussen<br>Sonar-System Realization | 01.01.-31.12.2014 | FWG /Ph.D. student |
| Dipl.-Ing. S. Graf<br>Robust Voice Activity Detection | 01.01.-31.12.2014 | External Ph.D. student |

| | | |
|---|---|---|
| M.Sc. M. Haide<br>Environmental Signal Processing | 01.01.-31.12.2014 | External Ph.D. student |
| M.Sc. P. Hannon<br>Model-Based Speech Enhancement | 01.01.-31.12.2014 | ExternalPh.D. student |
| M.Sc. V. Kandade Rajan<br>Automotive Speech Enhancement | 01.01.-31.12.2014 | Industry / Ph.D. tudent |
| M.A. R. Landgraf<br>Analysis of Communication Quality | 01.10.-31.12.2014 | External Ph.D. student |
| Dipl.-Phys. C. Lüke<br>Adaptive Ambiance Simulation | 01.01.-31.12.2014 | CAU / Ph.D. student |
| M.Sc. K. G. Mideksa<br>EEG and MEG Combination | 01.01.-31.12.2014 | SH and FAZIT Fell. / Ph.D. st. |
| Dipl.-Wirtsch.-Ing. D. Nguyen<br>Sensor Fusion and Tracking | 01.01.-31.10.2014 | PITAS / Ph.D. student |
| M.Eng. K. Pikora<br>Tracking of Underwater Objects | 01.01.-31.12.2014 | FWG / Ph.D. student |
| M.Sc. J. Reermann<br>MEG Signal Procressing | 01.01.-31.12.2014 | DFG /Ph.D. student |
| Dipl.-Wirtsch.-Ing. S. Rohde<br>Automotive Signal Enhancement | 01.01.-31.12.2014 | Industry / Ph.D. student |
| M. Sc. S. Senkbeil<br>In-Car Communication | 01.01.-31.12.2014 | Industry /Ph.D. student |
| M.Sc. S. Stenzel<br>Multi-Channel Speech Enhancement | 01.01.-31.08.2014 | ExternalPh.D. student |
| M.Sc. A. Theiß<br>Automatic Evaluation of Automotive Speech Enhancement Systems | 01.01.-31.12.2014 | CAU / Ph.D. student |
| Dipl.-Ing. J. Withopf<br>In-Car Communication | 01.01.-31.12.2014 | CAU / Ph.D. student |
| M.Sc. A. Wolf<br>In-Car Communication | 01.01.-31.12.2014 | External Ph.D. student |

## Lectures, Seminars, and Laboratory Course Offers

*Winter 2013/2014*

Advanced Digital Signal Processing, 2 (+1) hrs Lecture (+ Exercises)/Week,
G. Schmidt (+ V. Kandade Rajan, S. Rohde)

Advanced Signals and Systems, 3 (+2) hrs Lecture (+ Exercises)/Week,
G. Schmidt (+ A. Theiß)

Speech and Audio Processing - Recognition and Audio Effects, 2 (+1) hrs Lecture (+ Exercises)/Week,
G. Schmidt (+ C. Lüke)

Signals and Systems II, 2 (+1) hrs Lecture (+ Exercises)/Week,
G. Schmidt (+ J. Withopf)

Communications Lab, 3 hrs Lab/Week,
G. Schmidt (+ together with several members of the faculty)

Medical Signal Processing, 2 (+1) hrs Lecture (+ Exercises)/Week,
M. Muthuraman

Advanced Topics Lab, 3 hrs Lab/Week,
G. Schmidt (+ together with several members of the faculty)

*Summer 2014*

Speech and Audio Processing - Adaptive Filters, 2 (+1) hrs Lecture (+ Exercises)/Week,
G. Schmidt (+ C. Lüke)

Digital Signal Processing, 2 (+1) hrs Lecture (+ Exercises)/Week,
G. Schmidt (+ S. Rohde)

Signals and Systems I, 3 (+2) hrs Lecture (+ Exercises)/Week,
G. Schmidt (+ J. Withopf)

Neural Networks, 2 (+1) hrs Lecture (+ Exercises)/Week,
M. Krini

System Theory Lab, 3 hrs Lab/Week,
G. Schmidt (+ A. Theiß)

Seminar on Topics in Digital and Optical Communications, 3 hrs Seminar/Week,
G. Schmidt (+ together with several members of the faculty)

Real-Time Processing Lab, 3 hrs Lab/Week,
G. Schmidt (+ C. Lüke)

*Winter 2014/2015*

Advanced Digital Signal Processing, 2 (+1) hrs Lecture (+ Exercises)/Week,
G. Schmidt (+ V. Kandade Rajan, S. Rohde)

Advanced Signals and Systems, 3 (+2) hrs Lecture (+ Exercises)/Week,
G. Schmidt (+ A. Theiß)

Speech and Audio Processing - Recognition and Audio Effects, 2 (+1) hrs Lecture (+ Exercises)/Week,
G. Schmidt (+ C. Lüke, C. Baasch)

Signals and Systems II, 2 (+1) hrs Lecture (+ Exercises)/Week,
G. Schmidt (+ J. Withopf, J. Reermann)

Communications Lab, 3 hrs Lab/Week,
G. Schmidt (+ together with several members of the faculty)

Medical Signal Processing, 2 (+1) hrs Lecture (+ Exercises)/Week,
M. Muthuraman

Advanced Topics Lab, 3 hrs Lab/Week,
G. Schmidt (+ together with several members of the faculty)

## Third-Party Funds

Industry, *Research on the topics described before*, 01.01.-31.12.2014 (Adequate payment)
Bundesamt für Wehrtechnik und Beschaffung (BMV), *Underwater Signal Processing*, 01.01.-31.12.2014 (Adequate payment)
DFG, *Digital Signal Processing for Magneto-electric Sensors*, 01.01.-31.12.2014 (1 Ph.D. position + overhead)
DFG, *Analysis of Parkinson Speech*, 15.10.-31.12.2014 (1 Ph.D. osition + overhead)

## Diploma, Bachelor's and Master's Theses

J. Wieland, *Entwicklung und Implementierung eines drahtlosen Unterwassertelefoniesystems (in German)*, 01.11.2014
T. Sebastian, *Real-Time Implementation of Automatic Speech Recognition*, 01.10.2014
M. Yalaz, *Untersuchung einer Verstärkungssteurung zur Verbesserung der Sprachverständlichkeit (in German)*, 01.09.2014
A. Karim, *Untersuchung von Parameterjitter in einem Unterwassersimulationsframework (in German)*, 01.09.2014
M. Munch, *Analyse von EKG-Signalen mit dem Ziel der Detektion von Vorhofflimmern (in German)*, 01.09.2014
L. Prigge, *Untersuchung qualitätsrelevanter Fahrzeugeigenschaften für Innenraumkommunikationssysteme (in German)*, 01.09.2014
T. Borchert, *Klassifikationsbasierte Echtzeitauralisierung von EEG-Signalen (in German)*, 01.08.2014
L. Lindemann, *Real-Time Detection of Event-Related Potentials by Means of EEG*, 01.07.2014
C. Baasch, *Development of a Test Platform for Hands-Free Systems*, 01.06.2014
P. Roser, *Lokalisierung mehrerer Sprecher in stark geräuschbehafteter Umgebung (in German)*, 01.05.2014
S. A. Almasri, *Real-Time Implementation of a Brain-Computer Interface*, 01.04.2014
M. Grupp, *Entwicklung und Visualisierung eines Echtzeit-Trackingsystems unter Berücksichtigung des Doppler-Effekts (in German)*, 01.05.2014
H. Hinkelmann, *Echtzeitauralisierung der elektrischen Aktivität des Gehirns (in German)*, 01.05.2014
H. Singh, *Development of an Autonomous Real-Time Communication with a Variable Number of Speakers*, 01.04.2014
N. U. Babacan, *Real-Time Design and Implementation of Active Artificial Reverberation*, 01.02.2014
M. Schell, *Entwicklung eines Echtzeit-Upmix-Verfahrens zur räumlichen Wiedergabe von Stereoquellen (in German)*, 01.01.2014
S. Jaschke, *Signal Analyses on EEG Recorded During Driving a Car*, 01.04.2014
S. Kumar, *Dipole Simulations with Different Phasic Oscillatory Signals*, 18.03.2014
M. Yousuf, *EEG and MEG Source Analysis Using a Bayesian Approach*, 16.01.2014

## Dissertations / Postdoctoral Lecture Qualifications

C. Norrenbrock, *Instrumental Quality Estimation for Synthesized Speech Signals*, 23.01.2014
A. R. Anwar, *Multimodal Analysis of Directional Interactions in Oscillatory Networks of the Brain*, 06.10.2014
S. Stenzel, *Multichannel Signal Processing for Spatially Distributed Microphones*, 01.09.2014

## Publications

Published in 2014

K. G. Mideksa, A. Santillan-Guzman, N. Japaridze, A. Galka, U. Stephani, G. Deuschl, U. Heute, M. Muthuraman, *Validating the Effect of Muscle Artifact Suppression in Localizing Focal Epilepsy*, Proc. EMBC 2014, IEEE-EMBS, Chicago, USA, (2014)
K. G. Mideksa, N. Hoogenboom, H. Hellriegel, H. Krause, A. Schnitzler, G. Deuschl, J. Raethjen, U. Heute, M.

Muthuraman, *Impact of Head Modelling and Sensor Types in Localizing Human Gamma-band Oscillations,* Proc. EMBC 2014, IEEE-EMBS, Chicago, USA, (2014)

R. Landgraf, *Are You Serious? Irony and the Perception of Emphatic Intensification,* Proc. of the 4th International Symposium on Tonal Aspects of Languages (TAL), Nijmegen, The Netherlands, (2014)

S. Graf, T. Herbig, M. Buck, G. Schmidt, *Improved Performance Measures for Voice Activity Detection,* Proc. ITG, Erlangen, Germany, (2014)

V. K. Rajan, C. Baasch, G. Schmidt, M. Krini, *Improvement in Listener Comfort Through Noise Shaping Using a Modified Wiener Filter Approach,* Proc. ITG, Erlangen, Germany, (2014)

C. Baasch, V. K. Rajan, G. Schmidt, M. Krini, *Low-Complexity Noise Power Spectral Density Estimation For Harsh Automobile Environments,* Proc. International Workshop on Acoustic Signal Enhancement (IWAENC), Antibes, France, (2014)

J. Withopf, S. Rohde, G. Schmidt, *Application of Frequency Shifting in In-Car Communication Systems,* Proc. International Workshop on Acoustic Signal Enhancement (IWAENC), Antibes, France, (2014)

A. Theiß, G. Schmidt, J. Withopf, C. Lüke, *Instrumental Evaluation of In-Car Communication Systems,* Proc. ITG Conf. Speech Commun., Erlangen, Germany, (2014)

J. Withopf, G. Schmidt, *Estimation of Time-Variant Acoustic Feedback Paths in In-Car Communication Systems,* Proc. International Workshop on Acoustic Signal Enhancement (IWAENC), Antibes, France, (2014)

A. Theiß, G. Schmidt, *Investigation of Self-Masking Effects for the Evaluation of In-Car Communication Systems,* Proc. International Workshop on Acoustic Signal Enhancement (IWAENC), Antibes, France, (2014)

K. Pikora, F. Ehlers, *Tracking Performance Loss due to False Associations of Contacts from Semi-Coherent Signal Processing Chains,* Proc. International Conference on Information Fusion, Salamanca, Spain, (2014)

D. Nguyen, T. Claussen, *Individual-Gating-by-Sorting in MHT,* Proc. International Conference on Information Fusion, Salamanca, Spain, (2014)

U. Heute, A. Santillán Guzmán, *Removing Cleaned Eye-Blinking Artifacts from EEG Measurement,* Proc. SPIN, Delhi, India, (2014)

T. John, R. Landgraf, C. Lüke, S. Rohde, G. Schmidt, A. Theiß, *Über die Verbesserung der Sprachkommunikation in geräuschbehafteten Umgebungen (in German),* chapter in O. Niebuhr (ed.): Formen des Nichtverstehens, Peter Lang, (2014)

C. Lüke, G. Schmidt, A. Theiß, J. Withopf, *In-Car Communication,* chapter in G. Schmidt, H. Abut, K. Takeda, J. Hansen (eds.), Smart Mobile In-Vehicle Systems, Springer, (2014)

M. Krini, G. Schmidt, *Refinement and Temporal Interpolation of Short-Term Spectra: Theory and Applications,* chapter in G. Schmidt, H. Abut, K. Takeda, J. Hansen (eds.), Smart Mobile In-Vehicle Systems, Springer, (2014)

H. W. Gierlich, S. Möller, U. Heute, *Advances in Perceptual Modelling of Speech Quality in Telecommunications,* Proc. ITG Conf. Speech Commun., Erlangen, Germany, (2014)

M. Muthuraman, H. Hellriegel, N. Hoogenboom, H. Krause, A. Schnitzler, J. Raethjen, G. Deuschl, K. Mideksa, *Coherent Source and Connectivity Analysis on Simultaneously Measured EEG and MEG Data during Isometric Contraction,* Proc. IEEE-EMBS, Chicago, USA, (2014)

M. Muthuraman, H. Hellriegel, N. Hoogenboom, A. R. Anwar, K. Mideksa, H. Krause, A. Schnitzler, G. Deuschl, J. Raethjen, *Beamformer Source Analysis and Connectivity on Concurrent EEG and MEG Data during Voluntary Movements,* PLoS One, vol. 9, no. 3, (2014)

A. R. Anwar, M. Muthalib, S. Perrey, S. Wolff, G. Deuschl, U. Heute, M. Muthuraman, *Differences in Hemispherical Thalamo-cortical Causality Analysis during Resting-state fMRI,* Proc. IEEE-EMBS, Chicago, USA, (2014)

A. R. Anwar, K. Mideska, H. Hellriegel, N. Hoogenboom, H. Krause, A. Schnitzler, G.. Deuschl, J. Raethjen, U. Heute, M. Muthuraman, *Multi-modal Causality Analysis of Eyes-open and Eyes-closed Data from Simultaneously Recorded EEG and MEG,* Proc. IEEE-EMBS, Chicago, USA, (2014)

Ulrich Heute, *DSP for Brain Signals (Keynote Speech)*, Int. Conf. Sig. Process. and Integr. Networks (SPIN'14), Delhi - Noida, India, 20.-21.02.2014

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# Information and Coding Theory

The **research activities** of the Information and Coding Theory (ICT) group of the University of Kiel are in the general area of signal processing for wireless digital communication and localization. Currently, focus is on the following areas:

- Development of advanced signal processing algorithms suitable for future radio systems like 5G mobile radio and ultra-fast near-range wireless internet access. We develop and analyse key enabling techniques such as massive MIMO and cognitive radio. Among the goals is to increase the data rate, to reduce transmission power and signal bandwidth per data bit, and to support more licensed and unlicensed users.
- Visible Light Communications (VLC). VLC is an emerging technique employing light emitting diode (LED) arrays. The LEDs can simultaneously be used for lighting purposes as well as for data communications. VLC is an alternative to wireless local area networks (WLAN) but can be applied in many other applications, like aircraft cabins, hospitals, factories, optical underwater communication systems, etc. Among the goals are high data rates and reliable transmission at low cost.
- Molecular communications. One promising approach to solve the problem of in-body communication is molecular communication, which uses molecules as the information carrier. Molecular communication is expected to provide an energy efficient solution for in-body information transmission, because the molecules diffuse freely through the medium without spending any extra energy for propagation. Molecular communication is expected to be applicable both for sensing and actuation purposes.
- Underwater techniques. High-speed underwater communications, swarm communication and navigation, as well as localization and exploration are among our research interests in the area of underwater techniques.

The main expertise is in the field of channel coding (turbo codes, low-density parity check codes, decoding with reliability information, space-time codes), applied information theory (particularly multi-user information theory), digital modulation schemes (adaptive modulation and channel coding, superposition modulation, orthogonal frequency-division multiplexing), joint communication and localization, and the development of modern receiver algorithms (equalization, channel estimation, synchronization, interference rejection).

Since 2013, ICT has started activities in the area of underwater robotics. The goal is to design and build a swarm of autonomous underwater vehicles (AUVs), serving as a teaching and research platform. Advanced techniques like cooperative communication and cooperative localization can be implemented and tested on this platform.

Concerning **teaching**, we offer lectures and exercises, mostly in English, on channel coding, information theory, wireless communications and advanced wireless communications with a focus on baseband processing. Lectures on time series analysis (with emphasis on medical applications), radar signal processing, and underwater techniques are offered in the form of teaching assignments. Furthermore, several labs and seminars are provided for our B.Sc. and M.Sc. students.

## Results

**Molecular Communication** (Martin Damrath). Due to recent progress in nanotechnology, so-called nanomachines become more and more realistic. Nanomachines are simple ''machines'' whose components have sizes of up to a few hundred nanometres. Thus they are limited to the specific task they are designed to perform, e.g. processing, sensing, and actuation.

To enable even more complex tasks like targeted drug delivery or health monitoring, an autonomous swarm of nanomachines, a nanonetwork, is proposed. One of the key technologies regarding this swarm realization is the communication between nanomachines. However, the communication is very challenging with respect to the limitations

of nanomachines in energy, size and complexity. Furthermore, biocompatibility is necessary, to enable operation in the human body.

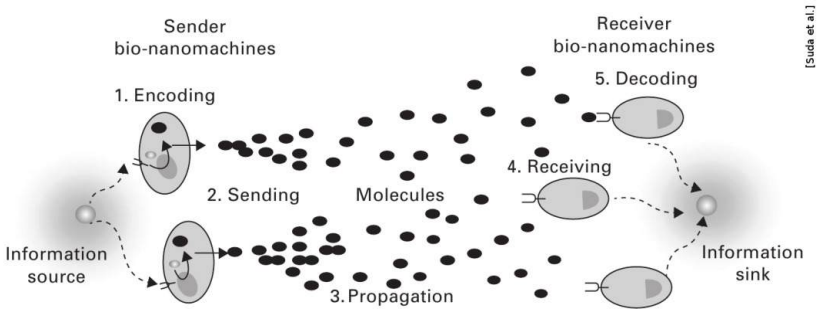


Fig. 1: Principle of molecular communication

One promising approach to solve the communication task is molecular communication, which uses molecules as the information carrier. Molecular communication not only guarantees biocompatibility, but also provides an energy efficient way to transmit information, because the molecules diffuse freely through the medium without expending any extra energy on propagation. However the diffusion-based channel is different to the classical radio-based channel and thus provides different challenges. Our research is concentrated on the questionof how we can adopt classical communication methods with the molecular communication approach. Furthermore we try to connect nanomachines to in-brain scenarios, such as in-brain EEG or targeted neuronal stimulation. This is an interesting interdisciplinary research field occupying engineers, biologists, and medical scientists.

**Ultra-High-Speed Wireless Indoor Communication** (Niklas Doose). Recent developments in industry and consumer electronic products demand reliable communication employing very high data rates. One famous example is the upcoming fifth mobile radio standard (5G), which demands higher peak data rate, greater coverage, more reliability, and a shorter latency compared to state-of-the-art wireless radio systems like LTE-A and WLAN. The German Research Foundation (DFG) has recently initiated a research focus programme that targets data rates of 100 Gb/s and beyond suitable for wireless internet access. This huge data rate is currently only available in wired and optical networks.

In our contribution to the DFG research focus programme, a system concept is being proposed and investigated that comprises the following enabling key techniques: firstly the implementation as an ultra-wideband (UWB) system provides high bandwidth that can be utilised with multiple OFDM systems, secondly, the deployment in a so-called massive MIMO scenario promises great beamforming gains and the ability to offer an SNR that is needed for high-level modulation schemes, and thirdly, the required data rate leads to modulation orders that are unfeasible for practical receivers so the application of multi-mode antennas is absolutely essential to be able to process multiple streams in hand-held mobile devices; consequently, the spectral efficiency can be distributed over the streams and the decoding bottleneck is relaxed.

While we concentrate on the baseband signal processing, the project is a cooperative venture with the Wireless Communications group (CWC), who develop the multi-mode antennas and work on hardware issues of the system concept. In an initial step, the suitability of multi-mode antennas for application in MIMO systems has been shown with respect to correlation of the elements and the channel capacity. Current research focus is the joint optimization of beamforming and power control to maximize the system throughput and to minimize the interference on other systems.

**LED-based Communication with Special Focus on Underwater Communication** (Gilbert J.M. Forkel). With increasing bandwidth requirements for mobile communication, optical free-space communication employing light emitting diodes (LEDs) (so-called visible light communication (VLC)), is developing as a promising candidate for the fifth generation of mobile telecommunications technology (5G). Most importantly the available optical spectrum is extremely wide compared to radio communication. Additionally, very-low cost and high-power transmitters have become available with the boom of LEDs in lighting applications.

The focus of our research interest is the use of optical free-space communication in underwater scenarios, e.g. a swarm of cooperating autonomous underwater vehicles (AUV). This can enable many new applications in an environment where nowadays only low-speed communication is available using acoustic waves or low frequency electromagnetic waves.

**Resource Allocation in Cognitive Radio** (Abdullah Yaqot). Due to increasing demands for new services and applications given the observation that nowadays the radio spectrum is scarcely used, reusing this partially occupied spectrum intelligently and opportunistically becomes a candidate solution: this is where the cognition concept comes in.

Cognitive radio (CR) is an intelligent communication strategy that adapts itself according to the surrounding environment. CR has the ability to reconfigure its transmission parameters such as modulation order, resource allocation, bandwidth, transmission power, etc. through programmable modules based on the software-defined radio principle. However, CR has limitations due to interference, mainly because of the coexisting primary radio on the same spectral and geographical area. Given a dynamic environment, CR has to offer reliable, seamless, and high-quality services in order to fulfil the requirements. Furthermore, CR has to manage the inter-user interference spectrally efficiently to be able to become a reliable technology for upcoming 5G networks. Motivated by the aforementioned, optimal resource allocation strategies can meet the required high data rates by developing spectrally efficient strategies for power and subcarriers as well as cutting-edge precoding designs.

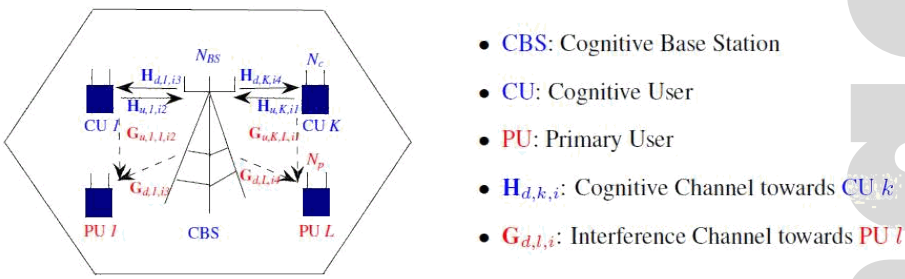


Fig. 2: Block diagram of a cognitive radio system

By means of multicarrier and multiantenna structures (like MIMO and OFDM), some benefits can be gained such as beamforming and more degrees of freedom in subcarrier allocation. Moreover, the frequency selectivity can be mitigated. CR network could work with several primary technologies like WiMAX, LTE, GSM, CDMA, etc. if synchronization and channel knowledge issues are addressed accordingly. The main challenge in practical CR networks happens to be the trade-off between spectral and time efficiencies. Towards this goal, promising results have been obtained.

## Personnel

Head of the group: Prof. Dr.-Ing. P. A. Hoeher; Secretary: S. Schuchardt (50%)
Technical Staff: Dipl.-Ing. T. Rabsch (50%)

Scientific Staff:

| | | |
|---|---|---|
| Dipl.-Ing. R. Adam<br>Joint Navigation and Communication | 01.04.2009-31.12.2014 | DFG/CAU |
| Prof. Dr.-Ing. S. Badri-Höher<br>Lecturer | 01.10.-31.12.2014 | FH Kiel |
| M.Sc. N. Doose<br>Ultrawideband Communication | 01.12.2013-31.12.2014 | DFG |

| | | |
|---|---|---|
| Dipl.-Ing. G. Forkel<br>Visible Light Communications | 01.10.2012-31.12.2014 | CAU |
| Dr. rer. nat. A. Galka<br>Lecturer | 01.06.2009-31.12.2014 | UKSH |
| Dipl.-Ing. M. Gregory<br>Free-space Optical MIMO Communications | 01.01.2010-02.06.2014 | External PhD Student |
| Dr.-Ing. J. Mietzner<br>Lecturer | 01.10.-31.12.2014 | Industry |
| M.Sc. A. Mourad<br>In-Car Interference Cancellation | 26.09.-31.12.2014 | External PhD Student |
| M.Sc. M. Noemm<br>Sonar Signal Design | 01.06.2009-31.03.2014 | BMWi |
| Dipl.-Ing. (FH) J. Sticklus<br>Optical Underwater Channel Modelling | 15.-31.12.2014 | GEOMAR |
| M.Sc. L. Wolff<br>Sonar Processing | 01.12.2013-31.12.2014 | External PhD Student |
| M.Sc. A. Yaqot<br>Convex Optimization for Cognitive Radio | 01.10.2012-31.12.2014 | DAAD |
| Dipl.-Wirtsch.-Ing. V. Zeiger<br>Underwater Navigation | 01.01.2010-31.12.2014 | External PhD Student |
| M.Sc. S. Zhang<br>Swarm Navigation | 01.09.-31.12.2014 | External PhD Student |

## Lectures, Seminars, and Laboratory Course Offers

*Winter 2013/2014*

Grundlagen der Kanalcodierung, 2 (+1) hrs Lecture (+ Exercises)/Week,
P.A. Hoeher (+ and Research Assistants)

Information Theory and Coding I, 2 (+1) hrs Lecture (+ Exercises)/Week,
P.A. Hoeher (+ and Research Assistants)

Advanced Wireless Communications (DSP), 2 (+1) hrs Lecture (+ Exercises)/Week,
P.A. Hoeher (+ and Research Assistants)

Communications Lab, 4 hrs Practical/Week,
P.A. Hoeher (+ W. Rosenkranz, G. Schmidt, and Research Assistants)

Advanced Topics Lab, 4 hrs Practical/Week,
P.A. Hoeher (+ W. Rosenkranz, G. Schmidt, and Research Assistants)

Informationstechnik und Codierung, 1 hrs Seminar/Week,
P.A. Hoeher

B.Sc. Project, 3 hrs Seminar/Week,

P.A. Hoeher (+ and Research Assistants)

*Summer 2014*

Theoretische Grundlagen der Informationstechnik, 2 (+1) hrs Lecture (+ Exercises)/Week,
P.A. Hoeher (+ and Research Assistants)

Information Theory and Coding II, 2 (+1) hrs Lecture (+ Exercises)/Week,
P.A. Hoeher (+ and Research Assistants)

Wireless Communications (DSP), 2 (+1) hrs Lecture (+ Exercises)/Week,
P.A. Hoeher (+ and Research Assistants)

Real-time Signal Processing Lab, 4 hrs Practical/Week,
P.A. Hoeher (+ W. Rosenkranz, G. Schmidt, and Research Assistants)

Informationstechnik und Codierung, 1 hrs Seminar/Week,
P.A. Hoeher

Time Series Analysis, 2 (+1) hrs Lecture (+ Exercises)/Week,
A. Galka

B.Sc. Project, 3 hrs Seminar/Week,
P.A. Hoeher (+ and Research Assistants)

*Winter 2014/2015*

Grundlagen der Kanalcodierung, 2 (+1) hrs Lecture (+ Exercises)/Week,
P.A. Hoeher (+ and Research Assistants)

Information Theory and Coding I, 2 (+1) hrs Lecture (+ Exercises)/Week,
P.A. Hoeher (+ and Research Assistants)

Advanced Wireless Communications (DSP), 2 (+1) hrs Lecture (+ Exercises)/Week,
P.A. Hoeher (+ and Research Assistants)

Communications Lab, 4 hrs Practical/Week,
P.A. Hoeher (+ W. Rosenkranz, G. Schmidt, and Research Assistants)

Advanced Topics Lab, 4 hrs Practical/Week,
P.A. Hoeher (+ W. Rosenkranz, G. Schmidt, and Research Assistants)

Informationstechnik und Codierung, 1 hrs Seminar/Week,
P.A. Hoeher

B.Sc. Project, 3 hrs Seminar/Week,
P.A. Hoeher (+ and Research Assistants)

Radar Signal Processing, 2 (+1) hrs Lecture (+ Exercises)/Week,
J. Mietzner

## Third-Party Funds

DFG, *Joint Navigation and Communication based on Interleave-Division Multiple Access (HO 2226/11-1)*, 15.03.2009-05.01.2014 (1xE13 + Working and Travelling Expenses)

DFG, *Ultrawideband Communication based on Massive MIMO and Multimode Antennas for Mobile Terminals*, 01.12.2013-30.11.2016 (1xE13 + Material and Travelling Expenses)

## Further Cooperation, Consulting, and Technology Transfer

Besides cooperation with other universities, the Information and Coding Theory Lab has collaborations with numerous companies and research institutes, including:

- BMW, Munich
- German Aerospace Research Establishment (DLR), Oberpfaffenhofen
- DoCoMo Eurolabs, Munich
- Elac Nautik, Kiel
- Fraunhofer Institute for Integrated Circuits (FHG-IIS), Erlangen
- GEOMAR Helmholtz Centre for Ocean Research, Kiel
- Huawei Technologies, Shanghai
- Raytheon Anschütz, Kiel
- Tesat Spacecom, Backnang
- Universitätsklinikum Schleswig-Holstein (UKSH), Kiel.

## Diploma, Bachelor's and Master's Theses

A. Joecks, *Detektionsalgorithmen für aktive Sonarsysteme*, 17.03.2014
D.M. Mielke, *Kanalangepasste Unterwasserkommunikation*, 14.04.2014
M. Thordsen, *Signalentwurf und Signalauswertung mit Anwendung in der maritimen Exploration*, 15.04.2014
M. Damrath, *Aufwandsreduzierte Symboldetektion für hochstufige Modulationsverfahren*, 28.04.2014
Ch. Manß, *Towards a Swarm Navigation System on Mars - Test Data Generation and Evaluation*, 02.06.2014
A. Krohn, *Messtechnische Charakterisierung induktiver Übertragungskanäle*, 25.08.2014
F.X. Schmidt, *Efficient JPEG2000 Decoding for Diagnostic Purposes on the RIVYERA-Architecture*, 10.12.2014

## Dissertations / Postdoctoral Lecture Qualifications

Z. Shi, *Low-Density Hybrid-Check Coded Superposition Mapping and its Application in OFDM and MIMO*, 02.04.2014
M. Gregory, *Hybrid Microwave/Free-Space Optical Transmission in the Maritime Environment*, 02.06.2014
Ch. Knievel, *Multi-Dimensional Channel Estimation for MIMO-OFDM*, 02.07.2014

## Publications

Published in 2014

Ch. Knievel, P.A. Hoeher, *Coded Sampling Bound - How much training is needed for iterative semi-blind channel estimation*, IEEE Transactions on Communications, **62**, 2422 - 2431 (2014)
A. Yaqot, P.A. Hoeher, *Efficient Resource Allocation for MIMO-OFDM Cognitive Networks with Adaptive Precoding*, Proc. 18th Int. OFDM Workshop, (2014)
Z. Shi, *Low-Density Hybrid-Check Coded Superposition Mapping and its Application in OFDM and MIMO*, Shaker Verlag, (2014)
M. Gregory, *Hybrid Microwave/Free-space Optical Transmission in the Maritime Environment*, Shaker Verlag, (2014)
Ch. Knievel, *Multi-Dimensional Channel Estimation for MIMO-OFDM*, Shaker Verlag, (2014)

## Further Activities and Events

In January 2014, Prof. Dr. Peter Adam Hoeher became an IEEE Fellow "for contributions to decoding and detection that include reliability information".

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# Integrated Systems and Photonics

The research activities of the group for Integrated Systems and Photonics (ISP) focus on projects in the areas of nanotechnology, optical technologies, and integrated systems. The research covers the entire spectrum of modelling, design, fabrication, and experimental characterization. 2014 was a successful research year with many results that are detailed below. Furthermore, 3 Ph.D. theses and 15 B.Sc. and M.Sc. theses were finished. We further intensified our collaborations with other groups in Electrical Engineering and in Material Sciences in Kiel as well as with external partners. We thank our collaborators for the many discussions and exchanges of knowledge in which we participated.

In 2014 we focused on further improving our educational programme for students. We conducted a workshop evaluating our course programme and decided to modify some of the class content to better prepare the advanced students for research. The M.Sc. practical course on optoelectronic devices is now carried out as an „Optoelectronics Challenge“ . Instead of fixed fabrication protocols, the students get the task to design and fabricate an optoelectronic device given certain boundary conditions (e.g. the emitter material). In the first rounds, this approach led to motivated students and very nice results that are interesting for our research activities. In the winter semester 2014/15, we offered for the first time an M.Sc. course on quantum mechanics for engineers. Here, we tried a new concept using online lectures offered by Stanford University in combination with exercises at the CAU. A large and successful effort was the organization of a project week for the new B.Sc. electrical engineering students at the beginning of classes. In this project week, the students working in groups built metal detectors on breadboards controlled by a micro controller.

Since September 2014, Prof. Gerken has been the Managing Director (Geschäftsführende Direktorin) of the Institute's board.

## Results

Organic optoelectronics

Organic light emitting diodes (OLEDs) and organic photodiodes (OPDs) are optoelectronic devices based on organic semiconductor materials. OLEDs are already used in commercial displays. These devices are also particularly interesting for integrated systems as they may be processed on a variety of substrates including plastics and flexible substrates. In 2014 we developed a method for the co-evaporation of organic molecules in our evaporation system; we used this process to build blue OLEDs employing emission layers based on a combination of BCzVBi and DPvBi (see photograph). These OLEDs are promising for switching functional molecules on smart surfaces.

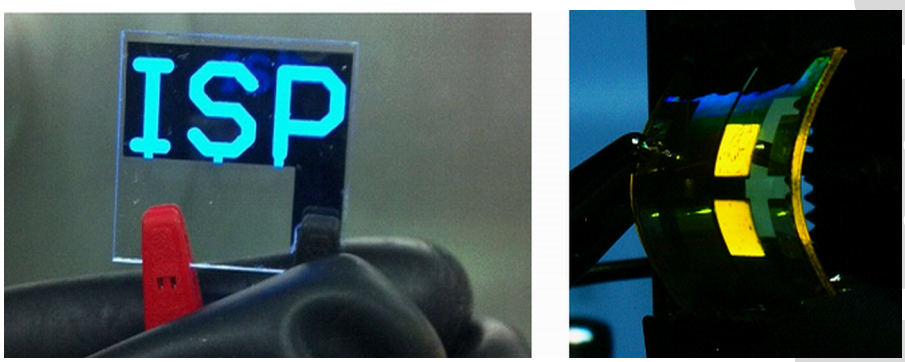


Fig. 1: (Left) Blue organic light emitting diode (OLED) tested directly after fabrication in the glove box. (Right) Operation of yellow OLED on a flexible substrate under bending.

We continued our research on the integration of nanostructured layers into the OLED stack for improved emission characteristics as well as a tailoring of the emission properties. We developed a process for fabricating nanostructured

flexible OLEDs. Here, a combination of nanoimprint lithography and refractive index tailoring by the addition of dielectric nanoparticles is employed. For bendable OLEDs we demonstrated successful electroluminescence operation. In nanostructured stretchable OLEDs a tuning of the emission colour could be demonstrated in photoluminescence measurements. Currently we investigate suitable anode materials to achieve electroluminescence in flexible OLEDs. On the system side in 2014, first validation experiments were performed to employ OLEDs and OPDs for integrated biomedical fluorescence sensors.

Optical biosensors

Compact optical biosensors are of high interest for point-of-care applications. In 2014 we investigated three different system approaches for compact optical measurement systems: a camera-based system, a smartphone-based approach, and a 96-microwellplate reader. Traditionally, fluorescent or radioactive markers are used for detection. These markers however, can affect the process of interest and require more complex preparation procedures. All of the systems we investigated in 2014 are based on a label-free detection method employing guided-mode resonances in periodically nanostructured sensor surfaces (photonic crystal slabs). For biochemical measurements these nanostructured surfaces are functionalized with selective biological recognition units. Cell processes are directly observed due to the mass redistribution and associated refractive index change; this causes a change in the observed guided-mode resonances.

For the camera-based experiments we functionalized the photonic crystal slabs at different positions and evaluated the position-dependent change in the RGB-channels of the camera. From this data we successfully measured the binding kinetics of thrombin to an anti-thrombin aptamer. As every smartphone has a camera as well as the flash as a light source, we designed and fabricated by 3D printing a smartphone adapter platform. Using this smartphone-based approach, we successfully evaluated refractive index changes. In compact systems the multi-angular and broadband excitation is a challenge and we evaluated the effects using finite-difference time-domain (FDTD) calculations. We also designed a microfluidic chip with a blood filter unit and a nanostructured measurement field and performed preliminary experiments with these chips in collaboration with the group of Dr. Buhmann at the university hospital of the LMU in Munich.

Fig. 2: (Left) Prototype for a smartphone-based optical biosensor platform. We envisage that microfluidic test chips will be inserted with the small drawer. (Right) Microfluidic chip designed with blood filter unit at the top and measurement field at the bottom.

In the EXIST project, funded since mid 2013 by the Federal Ministry for Economic Affairs and Energy, we aim to transfer research results to the label-free detection market. In particular, we are developing a label-free reader device for 96-microwellplates. In 2014 we focused on issues such as the sensitivity and stability of our device. To reach the desired sensitivity we designed the optics from the ground up. We use spherical lenses that are ideal for the assembly process. They collimate the light from the light source (light emitting diode) and focus the reflected light from the photonic crystal slab onto the light detector (photodiode). To obtain signal stability for our device, we first established a

reference channel beside the signal channel. This eliminates electrical drift issues which have their origin in the electric components used on our circuit board. Secondly, we redesigned the body of the device to guarantee mechanical stability which influences the optical pathway and hence the signal stability. With our prototypes we successfully demonstrated cellular and biochemical label-free assays with the desired sensitivity. We performed the following experiments: adhesion experiments, G protein-coupled receptor experiments, and antibody-antigen binding experiments. Beyond these technical approaches, we developed a business strategy to enter the market for label-free detection and started negotiations with strategic partners.

Integrated optics

Integrated optical systems are interesting for many applications. In 2014 we investigated two types of integrated optical system: a pressure sensing system, and thermally tunable apertures.

The pressure measurement system consists of a small chamber sealed by a flexible circular photonic crystal membrane. This photonic crystal is composed of a polydimethylsiloxane (PDMS) membrane imprinted with a linear nanostructure and a high index layer of TiO nanoparticles on top. When the pressure outside of the chamber is raised the membrane is deformed towards the inside. The guided-mode resonances of such linear photonic crystal slabs are angle dependent. Due to the curve of the membrane, the observation angle of different areas of the photonic crystal changes from vertical to lower angles. This leads to a split and shift of the modes. The change of resonance wavelengths may be observed remotely in optical transmission or reflection measurements. A particularly elegant method of evaluation is to use the colour change observed with a camera and employing crossed polarization filters. The colour shift directly depends on the amount of deformation which correlates to the pressure to be monitored.

In 2014 we successfully prototyped a thermally tunable thin-film slit diaphragm for monochromatic applications. The thin-film diaphragm consists of a thin transparent elastomer layer made of PMDS sandwiched between two semi-transparent silver mirrors forming an optical cavity. The silver mirror on top of the thin-film stack is structured into separate bars. Tuning is achieved by connecting electric currents to the silver bars. Resistive losses cause thermal expansion of the PDMS below current-carrying bars. This allows for locall tuning of the cavity thickness, which results in varying light intensity as both transmission and reflection depend on matching the interference condition for the system design wavelength. Therefore, this thin-film slit diaphragm can be used in transmission or in reflection. The image shows the device schematic as well as measurement results for two different states of operation. For the change in light intensity for the „closed" slit condition a segment in the middle is clearly visible. Currently we are working on improving the tuning mechanism, as thermal crosstalk deteriorates device performance and delays the system response time. This aperture approach is promising as any combination of closed and open segments in many different shapes can be imagined and no mechanically movable parts are necessary. In a joint project with the Fraunhofer Institute for Silicon Technology in Itzehoe we are working towards the demonstration of a tunable system fabricated in a wafer-level process.

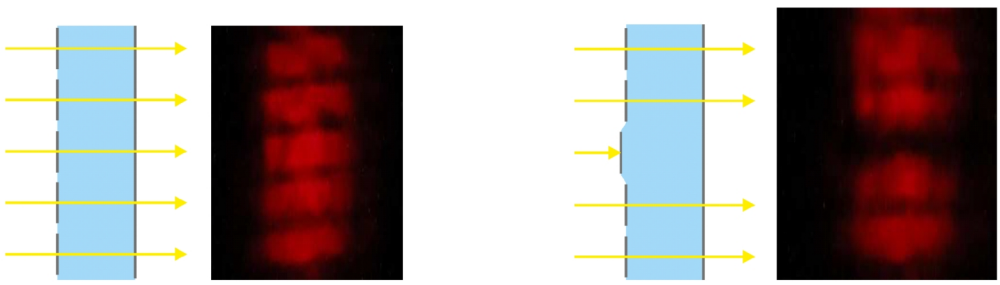

Fig. 3: Schematic of a tunable thin-film based slit aperture for monochromatic applications and a measured transmission intensity profile for all slits open (left) and with one slit closed (right). Tuning is achieved electrically.

Smart surfaces

The creation of artificial surfaces enhancing wettability changes from superhydrophobic to superhydrophilic triggered by an external stimulus, for example light, has attracted many research groups in recent decades. For that purpose hierarchical structures functionalized with photo-switchable molecules are utilized. The most commonly applied molecule for this purpose is azobenzene. It can be switched reversibly between two states triggered by light irradiation: the stretched trans- and compact cis-isomer. This switching process is called isomerization. Simultaneously to the conformational transition, the dipole moment of the molecule changes, thus surfaces linked with azobenzenes can exhibit photo-responsive wettability while isomerization takes place.

In the ERC project „Photo-switching of smart surfaces for integrated biosensors (PhotoSmart)" we aim at realizing switchable surfaces with an integrated light source. As the topic of photo-switchable molecules is new to the group, in 2014 we established procedures for functionalizing transparent dielectric substrates (glass and high-refractive index materials) with azobenzene molecules. In these first experiments the isomerization process is observed by UV-spectroscopy. We also started on functionalizing nanostructured surfaces.

Modelling of magnetoelectric sensors

We continued our scientific simulation work on layered magnetoelectric nanocomposite sensors. We employed two modelling approaches: analytic calculations for layered cantilever sensors, and finite element method (FEM) simulations for cantilever sensors with more complicated geometries such as trenches, structured electrodes, partial layer coverage etc. We extended the simulation activities by augmenting the models simulating the open circuit magnetoelectric sensor signals with new models for short circuit operation, yielding greatly different optimized sensor geometries for signals. In addition we developed models including the sensor and amplifier noise behaviour, yielding overall signal-to-noise ratio and limit of detection (LOD) values for a wide range of sensor geometries, functional layer sequences, and materials in open and short circuit operation. As a result, we find that the optimized sensor geometries for sensor signals and LOD differ greatly and require a combined optimization of the sensor-amplifier system. The best sensor performance is predicted for vanishing inactive substrates. If a substrate is needed for mechanical stability it is best to place the active layers on opposite sides of the substrate. This prevents a shift of the neutral plane into one of the active layers and provides the best performance for thin substrates.

A second focus of our research in 2014 was the expansion of our FEM model to include the (empty) space around the sensor and allow for externally applied magnetic fields. This new model allows us to calculated effects of field concentration depending on sensor geometry as well as the evaluation of close spacing of several sensors. With the new model we also evaluated the influence of gaps in the active layers and different magnetic field concentration geometries.

## Personnel

Head of the group: Prof. Dr. M. Gerken; Secretary: S. Thielbörger (50%)
Technical Staff: Dipl.-Ing. J. Buschmann (50%), M. Köpke

Scientific Staff:

| | | |
|---|---|---|
| Dr.-Ing. J. Adam<br>Design of nanostructured surfaces | 01.01.-30.06.2014 | ERC |
| M.Sc. V. Behrends<br>EXIST: System engineering | 08.09.-31.12.2014 | BMWi |
| Dipl.-Wi.-Ing. H. Block<br>Microoptical systems | 01.01.-31.12.2014 | CAU |
| M.Sc. M. Bremer<br>Organic optoelectronics | 01.04.-31.12.2014 | ERC |

| | | |
|---|---|---|
| Dr. rer. nat. P. Glorius<br>EXIST: Biological experiments | 01.04.-31.12.2014 | BMWi |
| Dipl.-Ing. J. L. Gugat<br>Magneto-electric sensors | 01.01.-31.12.2014 | DFG |
| Dipl.-Wi.-Ing. S. Jahns<br>Nanostructured surfaces for biosensing | 01.01.-31.12.2014 | ERC |
| Dr. rer. nat. C. Kallweit<br>Photo-switchable molecules | 01.08.-31.12.2014 | ERC |
| Dipl.-Wi.-Ing. T. Karrock<br>Microoptical systems | 01.01.-31.12.2014 | CAU |
| Dr. M.C. Krantz<br>Magneto-electric sensors | 01.01.-31.12.2014 | DFG |
| Dr.-Ing. P. Metz<br>EXIST: System engineering | 01.01.-15.06.2014 | BMWi |
| Dipl.-Kfm. S. Metz<br>EXIST: Technology transfer | 01.02.-31.12.2014 | BMWi |
| Dr.-Ing. Y. Nazirizadeh<br>EXIST: Project lead and system validation | 01.01.-31.12.2014 | BMWi |
| M.Sc. J. Schmalz<br>Thin-film devices | 04.07.-31.12.2014 | DFG/PP |
| Dipl.-Wi.-Ing. D. Threm<br>Lab-on-a-chip systems | 01.01.-30.06.2014 | CAU |

## Lectures, Seminars, and Laboratory Course Offers

*Winter 2013/2014*

Grundgebiete der Elektrotechnik I, 3 (+ 2) hrs Lecture (+ Exercises)/Week,
M. Gerken (+ staff and student tutors)

Photonic Components, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
M. Gerken

Seminar Integrierte Systeme und Photonik, 2 hrs Seminar/Week,
M. Gerken

Praktikum Optoelektronik, 4 hrs Practical/Week,
Scientific staff

*Summer 2014*

Grundgebiete der Elektrotechnik II, 3 (+ 2) hrs Lecture (+ Exercises)/Week,
M. Gerken (+ staff and student tutors)

Optische Systeme, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
M. Gerken (+ H. Block)

Seminar Integrierte Systeme und Photonik, 2 hrs Seminar/Week,
M. Gerken

Praktikum Optoelektronik, 4 hrs Practical/Week,
Scientific staff

Bachelorpraktikum Mikro-Nano-Optosystemtechnik, 4 hrs Practical/Week,
M. Gerken (+ H. Kohlstedt, W. Benecke, scientific staff)

*Winter 2014/2015*

Grundgebiete der Elektrotechnik I, 3 (+ 2) hrs Lecture (+ Exercises)/Week,
M. Gerken (+ staff and student tutors)

Photonic Components, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
M. Gerken

Seminar Integrierte Systeme und Photonik, 2 hrs Seminar/Week,
M. Gerken

Praktikum Optoelektronik, 4 hrs Practical/Week,
Scientific staff

Quantum Mechanics for Engineers, 3 (+ 2) hrs Lecture (+ Exercises)/Week,
M. Gerken

## Third-Party Funds

DFG, *Mikro-Auge basierend auf Glasoptiken und durchstimmbaren Dünnschichtfiltern herstellbar in waferbasierter Fertigung*, 30.09.2011-30.04.2015 (250.650 EUR)
BMBF, *Multiparametrische Biomarker-Bestimmung auf Wegwerfchips*, 01.04.2012-30.09.2014 (235.539 EUR)
ERC, *Photo-switching of smart surfaces for integrated biosensors*, 01.07.2013-30.06.2018 (1.499.878 EUR)
BMWi, *Instrument für markerfreie Bioanalytik*, 01.08.2013-31.01.2015 (432.000 EUR)
DFG/SFB 855, *Magnetoelektrische Verbundstoffe - biomagnetische Schnittstellen d. Zukunft, Teilprojekt C1*, 01.01.-31.12.2014 (115.000 EUR)

## Diploma, Bachelor's and Master's Theses

M. Mischung, *Herstellung und Charakterisierung eines homogenen und großflächigen photonischen Kristalls für die bildgebende Biosensorik*, 25.02.2014
A. Daßler, *Optische Sensoren in der Robotik: Eignung für Hindernisserkennung und füe Navigationsaufgaben*, 02.04.2014
D. Knoppe, *Entwicklung automatisierter Pumpenantriebe für ein integriertes Biochip-Kartuschensystem für die Point-of-Care Diagnostik*, 15.04.2014
J. Schmalz, *Herstellung und Charakterisierung nanostrukturierter OLEDs auf flexiblem Substrat*, 27.05.2014
R. Reinke, *Entwicklung einer Optik für die Smartphonebasierte Biosensorik*, 15.07.2014
A. Knies, *Simulation und Analyse von magnetischen Flusskonzentratoren für magnetoelektrische Sensoren*, 22.07.2014
H. Lüder, *Modenkopplungsanalyse von Wellenleiterstrukturen mit multiperiodischen Gittern*, 02.09.2014
Ö. Ömür, *Frequenz- und rauschverhalten von magnetoelektrischen Magnetfeldsensoren*, 09.09.2014
R. Kelz, *Degradation von UVB-LEDs*, 01.10.2014
B.-O. Meyer, *Kompaktes Kamerasystem zur abbildenden Auslesung von nanostrukturierten Mikrotiterplatten*, 04.11.2014

C. Behnke, *Einfluss der Geometrieparameter auf die Empfindlichkeit piezoelektrischer Biegebalkensensoren,* 11.11.2014
A. Iwers, *Blue OLEDs with integrated spectral filter,* 11.11.2014
F. Cörek, *Messaufbau zur 3D-Lichtverteilungskurve,* 11.11.2014
H. Winterfeld, *Polymerstrukturierung mit Si3N4 Masken für aktive Mikrooptiken,* 18.11.2014
A. Schönherr, *Resonante Anregung von Molekülen auf Photonischen Kristallen im Blauen Spektralbereich,* 09.12.2014

## Dissertations / Postdoctoral Lecture Qualifications

C. Kluge, *Nanostructures for emission control in organic light-emitting layers,* 16.05.2014
D. Threm, *Integration von organischer Optoelektronik und photonischen Kristallen für Lab-on-a-Chip-Systeme,* 25.06.2014
A. Pradana, *UV nanoimprint lithography for fabrication of 1-D photonic crystal slabs and their application in OLEDs,* 23.07.2014

## Publications

Published in 2014

C. Kluge, J. Adam, N. Barie, P. J. Jakobs, M. Guttmann, M. Gerken, *Multi-periodic nanostructures for photon control,* Opt. Express, **vol. 22, no. S5**, 1363 - 1371 (2014)
U. B. Bala, M. Krantz, M. Gerken, *Electrode Position Optimization in Magnetoelectric Sensors Based on Magnetostrictive-Piezoelectric Bilayers on Cantilever Substrates,* IEEE Trans. Ultrason., Ferroelectr., Freq. Control, **61 (3)**, 392 (2014)
A. Pradana, C. Kluge, M. Gerken, *Tailoring the refractive index of nanoimprint resist by blending with TiO2 nanoparticles,* Opt. Mater. Express, **4 (2)**, 329 - 337 (2014)
P. Metz, J Adam, M. Gerken, B. Jalali, *Compact, transmissive 2D spatial disperser design with application in simultaneous endoscopic imaging and laser microsurgery,* Applied Optics, **Vol. 53, Iss. 3**, 383 - 387 (2014)

## Patent Applications

Y. Nazirizadeh, M. Gerken, P. Metz, T. Karrock, *Mobile photometrische Messvorrichtung und Verfahren zur mobilen photometrischen Messung an Mikrotiti,* Deutsches Patentamt, 27.10.2014, 10 2014 115 564.5

## Presentations

M. Gerken, *Biomedical sensing with photonic crystal slabs,* Applied Physics Seminar, KTH Stockholm, Sweden, 13.-13.02.2014
J. Adam, *Modelling for photonic devices and systems: from integrated photonic devices to high-speed particle screening,* Mads Clausen Institute Seminar, SDU, Alsion, 03.-03.04.2014
S. Jahns, B. Meyer, K. Thilsing-Hansen, S. B. Gutekunst, C. Selhuber-Unkel, Y. Nazirizadeh, M. Gerken, *Multiparametric and Label-free Thrombin Detection with Photonic Crystal Aptasensor,* XII Conference on Optical Chemical Sensors and Biosensors, EUROPT(R)ODE Conference, 13.-16.04.2014
P. Metz, K. Dopf, M. Aichholz, B. Riedel, U. Lemmer, B. Freudig, C. Zimmermann, M. Gerken, *Optical transmission measurements for in-line monitoring of turbid oil-water emulsions,* Micro-Optics, SPIE Photonics Europe conference, 14.-17.04.2014
H. Block, P. Metz, J. Adam, M. Gerken, *Thermally tunable optical aperture based on a segmented thin-film resonator,* Micro-Optics, SPIE Photonics Europe conference, 14.-17.04.2014
J. Adam, A. Mahjoubfar, E. Diebold, B. Buckley, B. Jalali, *Time-stretched spectrally encoded angular light scattering for*

*high-throughput real-time diagnostics,* Biophotonics: Photonic Solutions for Better Health Care, SPIE Photonics Europe conference, 14.-17.04.2014

D. Threm, S. Jahns, Y. Nazirizadeh, J. Adam, M. Gerken, *On the effect of broadband, multi-angular excitation and detection in guided-mode resonance biosensors,* Photonic Crystal Materials and Devices, SPIE Photonics Europe conference, 14.-17.04.2014

T. Karrock, J. Schmalz, Y. Nazirizadeh, M. Gerken, *Fabrication of Flexible Photonic Crystal Slabs,* MRS Spring Meeting, 21.-25.04.2014

A. Pradana, C. Kluge, M. Gerken, *Nanostructured, ITO-free electrodes for OLED emission control,* MRS Spring Meeting, 21.-25.04.2014

C. Kluge, M. Paulsen, L. T. Neustock, N. Barié, P. Jakobs, J. Adam, M. Gerken, *Emission Tailoring for Organic Emitter Layers with Compound Binary Gratings,* Controlling the Interaction between Light and Semiconductor Nanostructures for Energy Applications, MRS Spring Meeting, 21.-25.04.2014

M. Gerken, *Nanotechnologische, optoelektronische Systeme für die Biomedizintechnik,* Fakultätskolloquium Elektrotechnik und Informationstechnik, Karlsruher Institut für Technologie, 20.-20.05.2014

C. Kluge, L. T. Neustock, J. Adam, M. Gerken, *Wavelength dependency of outcoupling peak intensities for emission layers with multi-periodic photonic crystals,* Proc. 16th International Conference on Transparent Optical Networks ICTON, 06.-10.07.2014

M. Bremer, J. Schmalz, T. Karrock, M. Gerken, *Photonic crystals for flexible OLEDs,* Thinface Summer School, Alsion Sonderburg, Denmark, 18.-22.08.2014

S. Jahns, F. v. Oertzen, T. Karrock, Y. Nazirizadeh, M. Gerken, *Photonic Crystal Slabs for Biosensing,* PIERS Proceedings, 25.-28.08.2014

C. Kluge, A. Pradana, J. Adam, M. Gerken, *Multi-Periodic Photonic Crystal Out-Coupling Layers for Flexible OLEDs. In Solid-State and Organic Lighting,* Optical Society of America, 02.-05.12.2014

# Microwave Group

Under new leadership the Microwave Group of the Christian-Albrechts-University of Kiel (CAU) has started research in the area of filters. In the majority of today's communication systems, the rapid increase of the operating frequency and the number of users together with new applications such as broadband internet, satellite high definition TV, telemedicine, and video conferencing, put stringent conditions on the electrical and physical characteristics (size and mass) of the filters, i.e. the components that play a major role in the performance of a communication system. A good example for the rapid increase of the operation frequency is the shift of the satellite communications frequencies from Ka to Q band in the next generation and a good example of stringent conditions on the bandwidth requirements can already been seen in the LTE standards.

The Microwave Group has implemented investigations in millimetre and sub-millimetre waves. For example a metamaterial loaded spatial harmonic magnetron was developed. Molecular spectroscopy is focused not only on spectroscopy itself but also on the development of new spectrometers in the millimetre and sub-millimetre wave region.

Furthermore, research in radars and microwave sensors for medical application continues. In collaboration with the Material Sciences group of the faculty, investigations in the area of magnetoelectric sensors are being continued.

## Results

### Filters with Dielectric Resonators

In response to the above mentioned challenges in modern communication systems, the filter research topics of the Microwave Group of CAU have been focused on dielectric resonators (DR) in different shapes and different modes. One novel approach is the utilization of dielectric resonators in the non-resonating mode regime, taking advantage of these modes. We did some preliminary work in this regards and fabricated two DR filters with the possibility of controlling the transmission zeros near the passband without affecting the passband filter response. Then by considering the modal behaviour of the filter an initial equivalent circuit was proposed. This simple model should be developed in such a way that the effect of higher order modes and the coupling ports are taken into account. Based on this research we defined the challenges and the required improvements. Some initial study regarding the multi-mode DR filters and new resonant structures defined the guide lines for research on this topic. We also considered the new synthesis techniques that can take into account the unwanted effects of the resonators, such as limited unloaded quality factor, and determined a new guideline in this area for future research that will be continued in the group. We established a new course on microwave filters for the first time in our group, which is entitled ''Microwave Filters: Theory, Design, and Realization''. This course is for M.Sc. students and provides them with enough material to join the filter research topics of the Microwave Group.

### A New Simple UWB Ring Filter with Flexible Band-Notch Characteristics

A novel design of an Ultra-Wideband (UWB) bandpass filter in microstrip technology has been proposed (see Fig. 1). This design demonstrates controllable filter characteristics with respect to its passband and band-notch frequencies. The filter is constructed of a single annular ring resonator fed by two orthogonal feed lines connected by a 90° microstrip bend. The filter size, without the input/output transmission lines, does not exceed (11mm x 11mm). The insertion loss of the filter is below 0.33 dB over the whole frequency band. Additionally, it shows a low and flat group delay response. Such a proposed filter structure can be a suitable candidate for new UWB filters required for different UWB systems and applications.

### Realization of a Metamaterial Loaded Spatial Harmonic Magnetron

Latterly, application of metamaterials in modifying the dispersion relation of various vacuum electronic devices, suppressing an unwanted beam-wave interaction or enhancing the desired one, and realizing artificial dielectrics to slow down the wave propagation, has been examined in the literature. In accordance with this approach, the main focus of our research in 2014 was the first practical realization of a metamaterial loaded SHM (see Fig. 3). The theory had been developed in

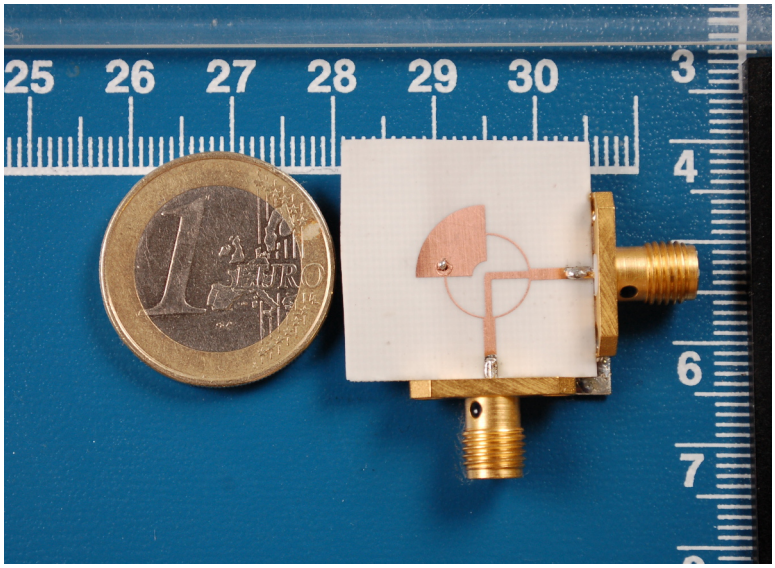


Fig. 1: A photograph of the implemented UWB bandpass filter.

2013. The following figures show the first prototype of a 43 GHz, 10 kW SHM together with its metamaterial unit-cell loaded side resonators. This magnetron shows very interesting properties such as working with very small cathode current densities.

### Pulsed Coherent Radar for Moving Target Detection in Sea Clutter

The radar has been designed within the framework of the PITAS-project (Pirate and Terrorist Aversion System) which was carried out between 2010 to the end of 2013. The aim of the project was the development of a system of warning and protecting the crews of cargo ships in case of pirate attack. Pirate attacks are usually carried out using small motor boats with several armed persons on board. The problem for radar detection of such relatively small targets (about 1 $m^2$) in the near range of a ship is the presence of sea clutter, reflected signal that can be comparable or even stronger than the signal from the pirate boat. Moreover, the traditional navigation radars usually have a large ''dead zone'' at close range that makes them blind up to 150 - 300 m. Therefore, pulsed coherent radar for detection of small moving targets at distances up to 1 - 1.5 km has been designed. The operating frequency of the radar is 34 GHz. The radar antenna, with an antenna gain of 32 dB and power pattern width in the horizontal plane of 1°, in combination with short radiated pulses (50 ns) provides high range and angle resolution, comparable with the size of the target, which allows more effective detection of small boats in sea clutter. The transmitter of the radar is designed using solid-state components and provides average radiation power of 140 mW. The radar receiver has two-stage down-conversion configuration and provides a noise figure of less than 4.5 dB. Signal digitizing is performed in a 12-bit ADC with a sampling rate of 500 MSPS, which requires advanced computational capabilities to provide radar operation in real-time. Consequently the digital signal processing has been realized using modern FPGA technology. Despite the fact that the project has already been completed, the work on radar improvements continues, particularly in signal processing and increasing radar functionality.

### Measurement of biomagnetic signals with magnetoelectric sensors

The aim of this research area is the detection of biomagnetic signals using the magnetoelectric sensors that are being developed in a collaborative research group in this faculty. Since biomagnetic signals are in the picotesla range, extrinsic and intrinsic noise sources are likely to greatly disturb the measured signal. In 2014 the tuning fork approach was further investigated: a tuning fork consists of two identical magnetoelectric sensors that have been connected back- to- back on a clamping point. Due to this orientation, extrinsic noise excites a 180° phase shifted signal with regard to the output signal excited by the magnetic field. With analogue signal processing the noise contributions can then be reduced greatly.

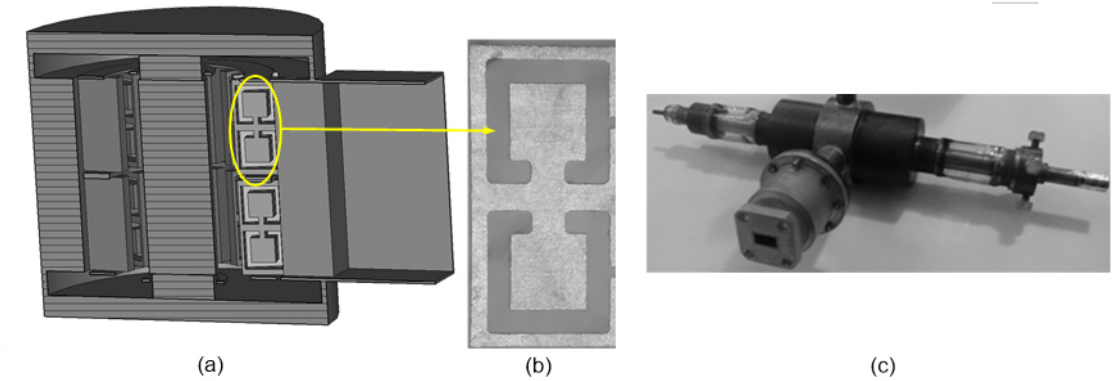


Fig. 2: (a) metamaterial loaded SHM, (b) metamaterial loaded side resonator, and (c) assembled tube.

The assembly and design have been altered to further reduce noise contributions; different noise modes were identified, both in experiment and theory. Investigations with an electrical modulation have been conducted in collaboration with the chair for Functional Materials using piezoelectric materials to convert the frequency of the magnetic signal into the mechanical resonance of the sensor. The use of arbitrary waveforms for the modulation proved to be advantageous in terms of output signal amplitude. For optimal A/D conversion the signals are demodulated by analogue signal processing into the baseband. A new sensor design has been developed that is more convenient and compact. The design yields all possibilities for integration in sensor arrays and use in real sensing applications and combines all designs for tuning forks, noise cancellation setups, single sensors, MEMS sensors, etc. It also provides the bias or modulation coil.

### Implantable blood pressure sensor

With increasing age the risk of heart failure increases. About 10% of men more than 80 years old suffer from this. For proper drug treatment, it is important to know the blood pressure within the pulmonary circulation. However, this information is not accessible with normal blood pressure monitors. It could be measured with catheters but this method has a high effort, is risky, and it is not possible to make continuous measurements. A solution to this problem may be an implantable blood pressure sensor. The idea is that a structure be placed within a blood vessel of the pulmonary circulation. It has to be as small as possible to let the blood pass freely and should work passively so there is no need for batteries and electronics. The possible solution investigated in this project is a microwave sensor. The sensor detunes with mechanical deformations caused by the changing pressure and this information is read out by an external field. The resonator is also stimulated by this external field. The challenge is to produce a small and sensitive sensor using bio-compatible materials and to realize a good coupling between the external fields and the sensors. Once it works, the blood pressure could be monitored continuously and noninvasively without any maintenance.

### Molecular Spectroscopy

Molecular spectroscopy in the range of millimetre and sub-millimetre wavelengths (carried out by Prof. Guarnieri) allows the investigation of free molecules in the gas phase. In this state the molecules are in continuous motion proportional to their thermal energy. A part of this energy is stored as rotational energy. The activity of the lab was concentrated on the improvement of the resolution of the millimetre and sub-millimetre wave spectrometer to allow very precise measurements of transition frequencies between rotational energy states. Astronomical observations in millimetre and sub-millimetre wavelengths have led to the discovery of many different molecules in the interstellar clouds. Laboratory spectra of such molecules in the millimetre and sub-millimetre range measured with a precision $\leq 1$ kHz are therefore needed for modern astrophysical investigations. To this purpose this laboratory's spectrometer has been supplemented with devices that have allowed the observation of absorption lines with Lamb-dip (a result of a saturated absorption process) accuracy. This method allows the measurement of the absorption lines with a precision $\leq 1$ kHz. A corresponding paper was published in 2007 in Astrophysics Letters. Further to increase the sensitivity of the InSb-Detector-chip in the frequency range near

Fig. 3: Excursion with students to Dräger in Lübeck in July 2014.

1 THz (0.3 mm wavelength) a suitable cryostat provided with a neodymium permanent magnet delivering a magnetic field of 1.4 Tesla around the InSb-chip, is under construction in the local workshop of the faculty. Within the scope of the DFG-cooperation project with the Institute of Applied Physics of the Russian Academy of Science (Nizhnii Novgorod), spectra of HCCCN (propyne nitrile), NH3 (ammonia), and various isotopologues of water have been investigated with the goal of obtaining precise transition frequencies in the millimetre and sub-millimetre range (accuracy $\leq$ 1 kHz) for investigation of the dynamics of interstellar clouds.

## Personnel

Head of the group: Prof. Dr.-Ing. M. Höft; Secretary: M. Bork
Technical Staff: Dipl.-Ing. (FH) L. Ngongue, Dipl.-Ing. (FH) W. Taute

Scientific Staff:

| | | |
|---|---|---|
| Dr.-Ing. F. Daschner | 01.01.-31.12.2014 | CAU |
| Resonant stents / Microwave sensors / Early detection of dental pulp in inflammations | | |
| Prof. Dr. A. Guarnieri | 01.01.-31.12.2014 | CAU |
| Molecular Spectroscopy | | |
| Dr.-Ing. M. Kheir | 01.01.-31.12.2014 | CAU |
| Cocoon-PUF | | |
| Prof. Dr.-Ing. R. Knöchel | 01.01.-31.12.2014 | CAU |
| Dr.-Ing. H. Kreft | 01.01.-31.12.2014 | CAU |
| Cocoon-PUF, UWB filter, RFID | | |

| | | | |
|---|---|---|---|
| M.Sc. N. Nasresfahani<br>Metamaterials in microwave structures | 01.01.-31.12.2014 | | TUHH |
| M.Sc. P. Rezaee<br>Microwave filter design with fuzzy logic, Filters with dielectric resonators | 01.01.-31.12.2014 | (50%) | CAU |
| M.Sc. S. Salzer<br>Magnetoelectric sensors | 01.02.-31.12.2014 | | CAU |
| I. Teliban<br>Magnetoelectric sensors | 01.10.-31.12.2014 | | DFG |
| M.Sc. O. Teplyuk<br>Near range radars | 01.01.-31.12.2014 | | DFG |
| Dipl.-Ing. Jonas Wolff<br>Near range radars | 01.01.-28.02.2014 | (50%) | CAU |

## Lectures, Seminars, and Laboratory Course Offers

*Winter 2013/2014*

Leitungstheorie, 2 (+1) hrs Lecture (+ Exercises)/Week,
M. Höft (+ F. Daschner)

Nichtlineare Schaltungen, 2 (+1) hrs Lecture (+ Exercises)/Week,
M. Höft (+ R. Jahns, O. Teplyuk)

Hochfrequenzschaltungen und -systeme: Aktive Schaltungen, 2 (+1) hrs Lecture (+ Exercises)/Week,
R. Knöchel (+ F. Daschner)

Rauschen in Kommunikations- und Messsystemen, 2 (+1) hrs Lecture (+ Exercises)/Week,
R. Jahns (+ R. Jahns)

Project, 3 hrs Practical/Week,
M. Höft

Masterpraktikum Mikrowellen und EMV, 4 hrs Practical/Week,
F. Daschner (+ I. Teliban, J. Wolff, W. Stellmach)

Seminar Hochfrequenztechnik, 2 hrs Seminar/Week,
M. Höft

Hochfrequenz-Messtechnik, 2 (+1) hrs Lecture (+ Exercises)/Week,
F. Daschner (+ F. Daschner)

*Summer 2014*

Radar, 2 (+1) hrs Lecture (+ Exercises)/Week,
M. Höft (+ O. Teplyuk)

Hochfrequenz-Messtechnik, 2 (+1) hrs Lecture (+ Exercises)/Week,
F. Daschner (+ F. Daschner)

Hochfrequenzschaltungen und -systeme: Passive Systeme, 2 (+1) hrs Lecture (+ Exercises)/Week,
R. Knöchel (+ S. Salzer)

Bachelorpraktikum Hochfrequenztechnik, 4 hrs Practical/Week,
F. Daschner (+ O. Teplyuk, I. Teliban, P. Rezaee, N. Nasresfahani)

Project, 3 hrs Practical/Week,
M. Höft

Seminar Hochfrequenztechnik, 1 hrs Seminar/Week,
M. Höft

Hochfrequenztechnik, 2 (+1) hrs Lecture (+ Exercises)/Week,
M. Höft (+ S. Salzer)

*Winter 2014/2015*

Leitungstheorie, 2 (+1) hrs Lecture (+ Exercises)/Week,
M. Höft (+ F. Daschner)

Nichtlineare Schaltungen, 2 (+1) hrs Lecture (+ Exercises)/Week,
M. Höft (+ O. Teplyuk)

Hochfrequenzschaltungen und -systeme: Aktive Schaltungen, 2 (+1) hrs Lecture (+ Exercises)/Week,
R. Knöchel (+ S. Salzer)

Rauschen in Kommunikations- und Messsystemen, 2 (+1) hrs Lecture (+ Exercises)/Week,
M. Höft (+ S. Salzer)

Masterpraktikum Mikrowellen und EMV, 4 hrs Practical/Week,
F. Daschner (+ I. Teliban, P. Rezaee, N. Nasresfahani)

Seminar Hochfrequenztechnik, 2 hrs Seminar/Week,
M. Höft

Radar, 2 (+1) hrs Lecture (+ Exercises)/Week,
F. Daschner (+ F. Daschner, O. Teplyuk)

Radio Frequency Identification and Security, 2 (+1) hrs Lecture (+ Exercises)/Week,
M. Kheir (+ M. Kheir)

Microwave Filters: Theory, Design, and Realization, 2 (+1) hrs Lecture (+ Exercises)/Week,
P. Rezaee (+ P. Rezaee)

## Third-Party Funds

Deutsche Forschungsgemeinschaft, *Sonderforschungsbereich 855, Subproject C3: Sensor Modelling and Electronic Signal Processing*, 01.01.-31.12.2014 (136415 EUR)

Deutscher Akademischer Austauschdienst, *Leonhard-Euler Programm, Zielland: Ukraine*, 01.09.2013-31.08.2014 (6680)

Deutscher Akademischer Austauschdienst, *Leonhard-Euler Programm, Zielland: Russische Föderation*, 01.09.2013-31.08.2014 (7725)

Deutscher Akademischer Austauschdienst, *Leonhard-Euler Programm, Zielland: Ukraine*, 01.09.2014-31.08.2015 (1695)

Deutsche Bundesstiftung Umwelt, *Förderinitiative Nachhaltige Pharmazie: Prozessanalytische Technologie für die Hormon-Granulierung*, 01.11.2013-31.10.2014 (152000)

## Further Cooperation, Consulting, and Technology Transfer

There is close cooperation concerning magnetic nano composites for rf applications with the departments of Multicomponent Materials (Prof. Faupel), and Inorganic Functional Materials (Prof. Quandt), in the **Faculty of Engineering of CAU**.

With the latter department (Prof. Quandt) there is also cooperation with regard to magnetoelectric sensors.

There exists a cooperation concerning radiophysics and radioelectronics, radar technology, and biological effects of electromagnetic waves and fields, with the **Kharkov National University (KNU)**, Kharkov, Ukraine, in association with research institutes of the Ukrainian Academy of Science, the **Institute of Radiophysics (IRE), (Prof. Khlopov) and the Institute of Radioastronomy (IRA), (Prof. Vavriv). There is also some cooperation within the framework of the Leonard Euler Program of the German Academic Exchange Service (DAAD).**

**With the Technische Universität Hamburg Harburg**, (Prof. Dr. A. Jacob), we cooperate in the areas of microwave components, microwave measurements, and radar technology.

With Prof. Dr. K. Schünemann, **Technische Universität Hamburg Harburg** and Prof. G. Khlopov, **Institute of Radiophysics**, Kharkov, Ukraine we cooperate in the area of industrial radar sensors.

Concerning sub-millimetre spectrometers and molecular spectroscopy we work in cooperation with the **Applied Physics Institute** of the **Russian Academy of Science** (Dr. Gera Golubjatnikov and Dr. Vladimir Markov).

Cooperation with industry includes: **AMS - Advanced Microwave Systems**, Hamburg, in the area of microwave sensors for density and moisture determination of materials,

**InnoSenT**, Donnersdorf,

**Thales**, Kiel, in the area of antennas,

and **Bikotronic Industrie-Elektronik GmbH**, Deidesheim.

A collaboration concerning resonant stents and other stent solutions is carried out together with the **Paediatric Cardiology Clinical Centre of the Christian-Albrechts-University (PD Dr. Rickers)**. The project on early detection of dental pulp inflammation is in cooperation with the **Department of Conservative Dentistry of the Christian-Albrechts-University (Prof. C. Dörfer)**.

As in previous years there is cooperation with **Dr. M. Kent**, a UK consultant, in the application of dielectric measurements and multivariate analysis.

## Diploma, Bachelor's and Master's Theses

B. Heßbrüggen, *Messtechnische Bestimmung dielektrischer Eigenschaften von pharmazeutischen Hilfsstoffen*, 18.02.2014

S. Leitsch, *Nichtlineare Hauptkomponentenanalyse zur Verarbeitung dielektrischer Spektren*, 29.04.2014

S. Schmidt, *FPGA-basierte Realisierung eines vektoriellen Netzwerkanalysators*, 19.05.2014

N. Boysen, *Entwicklung eines Systems zur Evaluierung verschiedener Radarfrontends mit Auswertung der Basisbandsignale*, 01.09.2014

T. Conradt, *Untersuchung und Entwicklung von Filtern mit dielektrischen Resonatoren in TE 01-Mode*, 11.06.2014

S. Akyol, *Breitbandige dielektrische Spektroskopie zur frühzeitigen Erkennung von Zahnwurzelentzündungen*, 07.10.2014

## Dissertations / Postdoctoral Lecture Qualifications

P. Rezaee, *Investigation and Development of a Qualitative Approach for Microwave Circuit Design*, 08.04.2014

## Publications

Published in 2014

M. Kheir, H. Kreft, I. Hölken, R. Knöchel, *RF Nanostructured Security*, Modelling, Methodologies and Tools for Molecular and Nano-Scale Communications, (2014)

M. Kheir, H. Kreft, I. Hölken, R. Knöchel, *On the physical robustness of RF on-chip nanostructured security*, Journal of Information Security and Applications, **Vol. 19, Issues 4-5**, 301 - 307 (2014)

M. Kheir, H. Kreft, R. Knöchel, *A novel fingerprinting approach for hardware integrated security*, Journal of Information Security and Applications, **Vol. 19, Issue 2**, 143 - 148 (2014)

B.E. Beck-Broichsitter, F. Daschner, D.W. Christofzik, R. Knöchel, J. Wiltfang, T. Becker, *Using eddy currents for noninvasive in vivo PH monitoring for bone tissue engineering*, Oral Maxillofac Surg., (2014)

M. Kheir, H. Kreft, R. Knöchel, *UWB on-chip fingerprinting and identification using carbon nanotubes*, IEEE International Conference on Ultra-Wideband, 462 - 466 (2014)

M. Kheir, M. Höft, R. Knöchel, *A new simple UWB ring filter with flexible band-notch characteristics*, IEEE International Conference on Ultra-Wideband, 462 - 466 (2014)

N. Wagner, M. Schwing, F. Daschner, A. Scheuermann, *Estimation of the Soil Water Characteristics from Dielectric Relaxation Spectra*, Proc. Sensors Applications Symposium, 242 - 247 (2014)

S. Burger, M. Höft, *Improved Filter Tuning in the Time Domain*, 1st Australian Microwave Symposium, (2014)

G. Khlopov, A. Zorenko, O. Teplyuk, C. Plueschke, J. Wolff, R. Knöchel, *Solid-State Coherent Pulse Radar in Millimetre Waveband for Detection of Low-Profile Surface Vessels*, Telecommunication and Radio Engineering, **vol. 73, no. 8**, 705 - 717 (2014)

## Patent Applications

M. Höft, *Dielectric multimode resonator*, Europäisches Patentamt, 04.06.2014, EP 1 962 369 81

## Presentations

M. Kheir, *A new simple UWB ring filter with flexible band-notch characteristics*, IEEE International Conference on Ultra-Wideband, Paris, France, 01.-02.01.2014

M. Kheir, *UWB on-chip fingerprinting and identification using carbon nanotubes*, IEEE International Conference on Ultra-Wideband, Paris, France, 01.-02.01.2014

# Nanoelectronics

Exciting new opportunities for future information technology arise from unconventional and novel electronic materials, nanoscale phenomena, and advanced processing technologies that start at the atomistic level. It is expected that with the trend of aggressive downscaling of commercial electronic devices into the nanoscale regime, quantum mechanical effects will become steadily more important. This trend will lead to a change of paradigm, i.e. future nanoelectronic devices exploiting electron tunnelling and/or spin transport will rely on the fundamental laws of quantum mechanics rather than on classical electrodynamics. In this context, new materials and material combinations are urgently required in order to develop tunnel junctions with enhanced functionalities. The chair of Nanoelectronics is focusing on medium-term and long-term tasks, on emerging far-reaching concepts, and on issues of physics and technology well ahead of the mainstream development of the nanoelectronics industry. The research platform of the AG Nanoelectronics is supported by three main pillars, i. e. new device concepts based on quantum phenomena, interfacial studies, and novel fabrication routes. For example we explore multiferroic tunnel junctions based on complex oxide materials, superconducting junctions for quantum bits, and lateral tunnel junctions (nanogaps). Therefore, a considerable technological and metrological infrastructure is needed. Part of the equipment such as an electron-beam-writer, a focused ion beam system, as well as a Pulsed Laser Deposition system is available via the Kieler Nanolabor. Various current-voltage acquisition systems, magneto- resistance set-ups, and ferroelectric thin films analyzers for a temperature range between 4.2 K and 300 K are part of our lab. On the system level neuromorphic circuits will lead in the future to parallel computing and low power dissipation. The AG Nanoelectroinic is heading the recently funded DFG Research Group 2093 entitled ''Memristive Devices for Neural Systems''.

## Results

### Ferroelectric tunnel junctions (FTJs): Giant electrode effect

*Rohit Soni, Adrian Petraru, Hermann Kohlstedt*

In solid state electronics, the quantum mechanical phenomenon of electron tunnelling occurs when the thickness of a thin insulating barrier between two electrically conducting materials approaches values of a few nanometres. Typical examples of this being exploited for solid state devices are superconducting tunnel junctions, magnetic tunnel junctions, and tunnel diodes. The insulating barriers used in these devices are usually dielectric materials such as various metal oxides. It is believed that integrating a ferroelectric material instead of normal dielectric barriers could further enhance the functionalities of such tunnel junctions. Ferroelectric materials possess a permanent polarization that can be electrically switched between two possible orientations. Switching the polarization of such ferroelectric barriers could change the potential profile across the barrier due to electrostatics, strain, and interface effects and hence modify the tunnelling probability of electrons. A possible change in the tunnelling probability due to ferroelectric switching could lead to a change in the resistance (commonly known as tunnelling electroresistance, TER, effect) of such a ferroelectric material integrated ferroelectric tunnel junction (FTJ). This would allow the use of FTJs in the future as non-volatile memory and logic devices.

The selection of electrode materials, due to different screening and chemical properties at the metal-ferroelectric interface, should have a prominent influence on the TER effect. Therefore, it is essential to examine the impact of different electrode materials on the TER characteristics of FTJs. Furthermore, the coercive electric field strengths of FTJs fall in the regime where soft breakdown phenomena cannot be excluded for ultrathin tunnel barriers, hence there remain concerns that highly stochastic redox based resistance switching effects might be interpreted as (or interfere with) the ferroelectric induced TER effect in FTJs. Therefore, it is important to investigate both redox based resistance switching effects as well as TER effects in FTJs to absolutely differentiate between them with regard to the realization of future non-volatile FTJs based memory devices.

In order to address these issues, we have investigated asymmetric FTJs comprising $La_{0.7}Sr_{0.3}MnO_3$ bottom electrodes

(BEs), 3 nm thick $BaTiO_3$ (BTO) tunnel barriers, and two different top electrodes (Au and Cu TEs). The ferroelectric behaviour of thin BTO barrier is identified using a piezoresponse force microscopy (PFM) technique. Figures 1a and 1c show the phase of the local out-of-plane piezoresponse for the FTJs with Au and Cu TEs, respectively. The observed reproducible phase change of 180 degrees for the piezoresponse during the voltage sweep indicates that the BTO film retains its ferroelectric state in the presence of the TE. To investigate TER effect, the same FTJs were further characterized by measuring their hysteretic *I-V curves* . Quasi-static voltage sweeps with a sweep rate of 0.05 V/s were applied to the Au and Cu TEs via the C-AFM tip. The BE was grounded, and a compliance current of 1 nA was set during the measurements to avoid soft dielectric breakdown of the junctions. Representative *I-V curves* curves are shown in Figures 1b (FTJ with Au TE) and 1d (FTJ with Cu TE). As can be seen, the TER ratios of the two FTJs differ by more than 2 orders of magnitude in a small voltage range. The revealed *giant electrode effect* on TER ratios is attributed to the microscopic interfacial effect of ferroelectric origin.

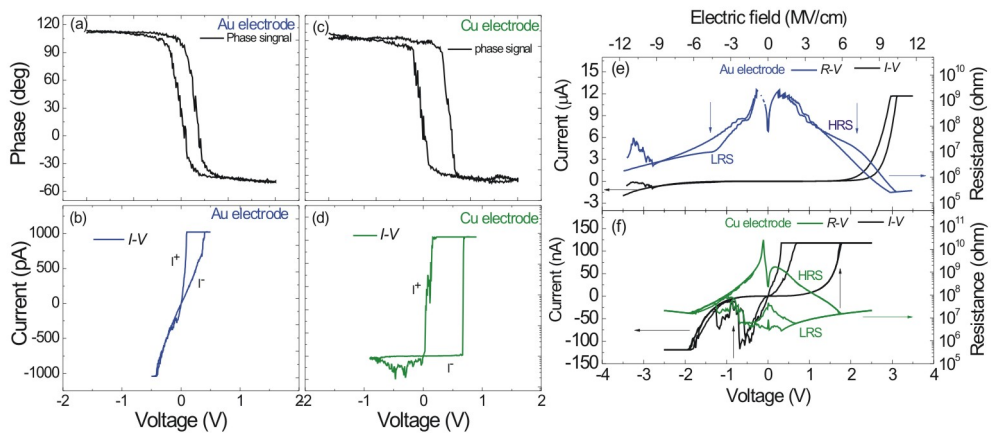


Fig. 1: (a), (c) Hysteretic behaviour of the PFM phase signals plotted as a function of the bias voltage applied to the Au (Cu) TE of the LSMO/BTO/Au (Cu) FTJ. Typical *I-V curves* characteristics of the corresponding FTJs with (b) Au and (d) Cu TEs. Typical redox-based resistance switching characteristics ( *I-V* curves and *R-V* curves ) of LSMO/BTO heterostructures with (e) Au and (f) Cu TEs.

Though the concurrence of the required electric field for tunnel electro-resistance switching with the coercive electric field for BTO barrier in FTJs indicates its ferroelectric origin, nevertheless, as a test of the robustness, we investigated also the redox based resistance switching effects in these ultrathin BTO based FTJs with Au and Cu top electrodes. Figure 1e and 1f show the measured *I-V curves* and corresponding *R-V curves* characteristic for the redox-based resistance switching of the LSMO/BTO/Au and the LSMO/BTO/Cu junctions, respectively. It is clear that, in the case of redox based resistive switching, the voltages required for switching to the low resistance state and back to the high resistance state are 5-10 times higher than the average switching voltages of the FE-TER effect.

**Voltage controlled biaxial strain in $VO_2$ films grown on $0.72Pb(Mg_{1/3}Nb_{2/3})$-$0.28PbTiO_3$ crystals and its effect on the transition temperature**

A. Petraru, R. Soni, and H. Kohlstedt

Vanadium oxide ($VO_2$) exhibits a metal-insulator transition (MIT) near room temperature (transition temperature is about 340K in bulk) showing an abrupt change in resistance of up to five orders of magnitude. The MIT is accompanied by a structural phase transition, from the high-temperature tetragonal (rutile) phase to the low- temperature monoclinic phase. The microscopic origin of the MIT is still a long- standing debate, the recent literature suggesting that the low temperature phase of $VO_2$ could be considered a Peierls-Mott insulator in which electron- electron correlations and dimerization of V

ions along the rutile c axis both contribute to the formation of an insulating gap.

A way to control the phase transition temperature in $VO_2$ is to use doping or chemical substitution. Thus, it was found that electron doping using W, Mo, or Nb- elements with high valence, reduces the transition temperature. W doping (the valence of W being 6+) was found to be the most effective, reducing the transition temperature by 21-28 K/at.%.

Another important aspect is the effect of strain on the MIT in $VO_2$. Lazarovits et al. showed in their theoretical work that besides the Peierls increase in bonding-antibonding splitting, the increase of the bandwidth with compression along the c axis of the rutile phase plays an equally important role in controlling the position of the MIT. Recently, Aetukuri et al. showed, using polarization and temperature- dependent X-ray absorption spectroscopy in combination with X-ray diffraction, that transition temperature and the structural distortion across the MIT depend on the orbital occupancy in the metallic state. Thus, they manipulated the orbital occupancy by strain engineering in thin films of $VO_2$ and succeeded in varying the transition temperature in a controlled manner by over 60 K.

To study the influence of the strain on the transition temperature and conductivity of $VO_2$ films, a *continuous* and *controllable* change in strain would be desirable. This can be achieved by growing the $VO_2$ films on a crystalline piezoelectric substrate; using an external electric field, the lattice parameters of the substrate and film can continuously be modified in a certain range. This approach allows a further tuning of the strain in epitaxial films after deposition. Thus, a relaxor material like (1-x)Pb($Mg_{1/3}Nb_{2/3}$)-x$PbTiO_3$ (PMN-PT), is a good choice due to its huge piezoelectric coefficient : one of the highest yet reported.

We demonstrated the growth of vanadium dioxide films on PMN-PT piezoelectric single crystal substrates of composition $x = 0.28$ using the pulsed laser deposition (PLD) technique. The PMN-PT substrates are (001) cut and the vanadium dioxide films appear to be epitaxial having the (011) orientation in their insulating M1 phase at room temperature, as confirmed by X-ray measurements.

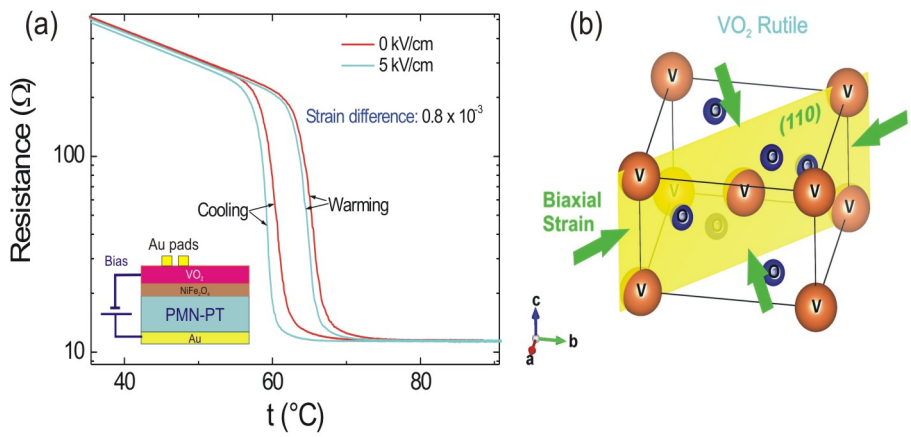


Fig. 2: (a) Shift of the resistance-temperature curves of the $VO_2$ films as a result of applied electric field to the substrate, and consequently, the change of the strain in $VO_2$ films. (b) the rutile unit cell of the $VO_2$ and the (110) plane where the biaxial strain imposed by the piezoelectric PMN-PT crystal is applied.

By applying the electric field along the (001) direction of the PMN-PT crystal, the out-of-plane lattice expands, while the in-plane lattice shrinks accordingly. This deformation of the crystalline lattice of the substrate is transmitted to the epitaxially grown $VO_2$ film, as demonstrated by the X-Ray measurements under bias voltage. Thus, for 100 V applied across the PMN-PT substrate, an additional amount of strain of 0.8 x $10^{-3}$ was induced in the $VO_2$ films.

A sketch of the rutile unit cell and the (110) plane where the biaxial strain is applied is shown in figure 1(b). This differs

from vanadium dioxide films grown on $TiO_2$ (001) substrates where the biaxial strain imposed on the film acts in the (001) plane of the $VO_2$ lattice. In our case we get a change in transition temperature of 1.7 °C per $10^{-3}$ biaxial strain.

Thus, by simply applying an external voltage to the PMN-PT substrate, continuous change in the biaxial strain of the vanadium oxide films is achieved. This opens the opportunity for detailed studies of the metal-to-insulator phase transition in these materials as a function of biaxial strain and temperature. Nonetheless, direct growth of vanadium dioxide films on ferroelectric substrates or films is important in studying the effect of the surface charge on the phase transition in these films.

## Personnel

Head of the group: Prof. Dr. H. Kohlstedt; Secretary: T. Bittner (50%)
Technical Staff: Dipl.Ing.(FH) N. Röschmann

Scientific Staff:

| | | |
|---|---|---|
| M. Hansen | 01.01.-31.12.2014 | Stipendium |
| MSc Marina Ignatov | 01.01.-31.12.2014 | Landesstipendium |
| Dr. A. Petraru | 01.01.-31.12.2014 | CAU |
| N. Ruppelt | 01.01.-31.12.2014 | DFG |
| KO 1953/11-1, BA 521 | | |
| Dr. R. Soni | 01.01.-31.12.2014 | DFG |
| SFB 855 | | |
| Dr. M. Ziegler | 01.01.-31.12.2014 | CAU |

## Lectures, Seminars, and Laboratory Course Offers

*Winter 2013/2014*

Digital Electronics, 2 (+1) hrs Lecture (+ Exercises)/Week,
H. Kohlstedt

Neuromorphic Engineering, 2 (+2) hrs Lecture (+ Exercises)/Week,
H. Kohlstedt

Physikalsische Grundlagen zur Herstellung elektronischer Bauelemente, 2 (+1) hrs Lecture (+ Exercises)/Week,
H. Kohlstedt

Grenzflächen- und Oberflächenanlytik, 2 (+1) hrs Lecture (+ Exercises)/Week,
M. Ziegler (+ A. Petrau)

Nanoelektronik, 2 hrs Seminar/Week,
H. Kohlstedt

Röntgenstrahlanalyse, 2 (+1) hrs Seminar (+ Exercises)/Week,
A. Petraru

Analyse wissenschaftlicher Texte, 2 hrs Seminar/Week,
H. Kohlstedt

Röntgenstrahlanalyse, 2 hrs Seminar/Week,
A. Petraru

*Summer 2014*

Elektronik, 3 (+ 2) hrs Lecture (+ Exercises)/Week,
H. Kohlstedt (+ A. Petraru)

Sensoren, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
H. Kohlstedt

*Winter 2014/2015*

Digital Electronics, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
H. Kohlstedt

Neuromorphic Engineering, 2 (+ 2) hrs Lecture (+ Exercises)/Week,
H. Kohlstedt

Physikalsische Grundlagen zur Herstellung elektronischer Bauelemente, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
H. Kohlstedt

Grenzflächen- und Oberflächenanlytik, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
A. Petraru (+ M. Ziegler)

Nanoelektronik, 2 hrs Seminar/Week,
H. Kohlstedt

Analyse wissenschaftlicher Texte, 2 hrs Seminar/Week,
H. Kohlstedt

Röntenstrahlanalyse, 2 hrs Seminar/Week,
A. Petraru

Nanoseminar, 2 hrs Seminar/Week,
H. Kohlstedt (+ A. Petraru)

## Third-Party Funds

Bundesministerium für Bildung und Forschung, *Multiferroische Nanokomposite Magnetoelektrische Materialien vom Reissbrett NANO C*, 01.01.-31.12.2014 (23.848 EUR)
Deutsche Forschungsgemeinschaft, *Forschergruppe 2093*, 01.11.-31.12.2014 (272.200 EUR)
Deutsche Forschungsgemeinschaft, *FOR 2093 - Memristive, quantenmechanische Tunnelkontakte und MemFlash-Zellen*, 01.11.-31.12.2014 (367.400 EUR)
Deutsche Forschungsgemeinschaft, *Memristive Bauelemente für neuronale Systeme*, 01.11.-31.12.2014 (191.500 EUR)
Sonderforschungsbereich 855, *Magnetoelektrische Verbundwerkstoffe - biomagnetische Schnittstellen der Zukunft*, 01.01.-31.12.2014 (65.200 EUR)

## Diploma, Bachelor's and Master's Theses

B. Erbe, *Memristive Nachbildung als Informationsverarbeitung und Weiterleitung eines Dendriten*, 15.02.2014
E. Altin, *Simultane Messung resistiver und kapazitiver Eigenschaften von ferroelektrischen Tunnelkontakten mit einem leitfähigen Rasterkraftmikroskop*, 20.02.2014
A. Schoneville, *Serienschaltung von ferroelektrischen Kondensatoren zur Spannungsamplitudenverstärkung von magnetoelektrischen Sensoren*, 14.04.2014
C. Riggert, *Simulation von Floating-Gate Transistoren für den betrieb als MemFlash-Zelle*, 30.04.2014

L. Kolberg, *Entwicklung eines Simulationsmodells zur beschreibung memristiver quantenmechanischer Tunnelbauelemente*, 30.05.2014

S. Gaspar, *Modifikation des Metall-Isolator-Übergangs in VO2 durch kontrollierbare Verspannungsänderungen*, 15.08.2014

R. Günther, *Entwicklung eines MemFlash-Simulationsmodells in PSpice*, 03.10.2014

H. Winterfeld, *Polymerstrukturierung mit Si3N4 masken für aktive Mikrooptiken*, 07.11.2014

## Publications

Published in 2014

M. Ziegler, O. Harnack, H. Kohlstedt, *Resistive switching in lateral juctions with nanometre separated electrodes*, Solid-State Electronics, **92**, 24 - 27 (2014)

C. Riggert, M. Ziegler, D. Schröder, W.H. Krautschneider, H. Kohlstedt, *MemFlash device: floating gate transistors as memristive devices for neuromorphic computing*, Semicond. Sci. Technol, **29**, 104011 (2014)

M. Ziegler, K. Ochs, M. Hansen, H. Kohlstedt, *An electronic implementation of amoeba anticipation*, Appl. Phys., **2**, 565 - 570 (2014)

A. Petraru, R. Soni, H. Kohlstedt, *Voltage controlled biaxial strain in VO2 films grown on 0.72Pb(Mg1/3Nb2/3)-0.28PbTiO3 crystals and its effect on the transition*, Appl. Phys. Lett., **105**, 092902 (2014)

R. Soni, A. Petraru, P. Meuffels, O. Vavra, M. Ziegler, S.K. Kim, D.S. Jeong, N. Pertsev, H. Kohlstedt, *Giant electrode effect on tunnelling electroresistance in ferroelectric tunnel junctions*, Nature Communications, **5**, 5414 (2014)

N. Ruppelt, O. Vavra, H. Sickinger, E. Goldobin, D. Koelle, R. Kleiner, H. Kohlstedt, *Combinatorial sputtering in planetary type systems for alloy libraries with perpendicular gradients of layer thickness and composition realised by a timing approach*, Appl. Phys., **116**, 229 - 232 (2014)

S. Prokhorenko, H. Kohlstedt, N. A.. Pertsev, *Ferroelectric-ferromagnetic multilayers: a magnetoelectric heterostructure with high output charge signal*, J. Appl. Phys., **116**, (2014)

## Presentations

M. Ziegler, M. Hansen, M. Ignatov, H. Kohlstedt, *Building memristive neurons and synapses*, International Symposium on Circuits and Systems (ISCAS), Melbourne, Australia, 01.-05.06.2014

Mirko Hansen, *Memristive Tunnel Junctions*, DPG-Frühjahrstagung, Dresden, Germany, 30.03.-04.04.2014

Marina Ignatov, *Application of the metal-to-insulator transition in VO2 for neuromorphic circuits*, DPG-Früjahrstagung, Dresden, Germany, 30.03.-04.04.2014

Adrian Petraru, *Effect of biaxial strain on the transition temperature of the VO2 films grown on 0.72Pb(Mg1/3Nb2/3)-0.28PbTiO3 crystals*, Electroceramics XIV Conference Bucharest, Bucharest, Romania, 16.-20.06.2014

Martin Ziegler, *Memristive operation mode of floating gate transistors for neuromorphic applications*, DPG-Früjahrstagung, Dresden, Germany, 30.03.-04.04.2014

Hermann Kohlstedt, *Tunnel Junctions for Electroforming-Free Resistive Switching Devices*, International Symposium on Circuits and Systems (ISCAS), Melbourne, Australia, 01.-06.06.2014

Marina Ignatov, *Memristive Neuromorphe Schaltungen TP B1*, DFG-Forschergruppenprojektantrag, Bonn, Germany, 17.-17.06.2014

Hermann Kohlstedt, *Memristive Bauelemente für neuronale Systeme*, DFG-Forschergruppenprojektantrag, Bonn, Germany, 17.-17.06.2014

Martin Ziegler, *Neuronale Systeme, TP C1*, DFG-Forschergruppenprojektantrag, Bonn, Germany, 17.-17.06.2014

# Power Electronics and Electrical Drives

In 2014 the Chair of Power Electronics comprised 15 Ph.D. students and Post-docs from 5 different nations of 3 continents, supervised by two Professors, Prof. Marco Liserre (Head) and Prof. Friedrich W. Fuchs, assisted by a secretary, a project secretary and a technician. The Chair also enjoyed the presence of 11 invited professors, and 2 guest Ph.D. students. Two Ph.D. theses were completed as were 14 B.Sc., M.Sc. and Dipl. theses. Around 150 students benefited from the department´s teaching activities to which two guest lecturers contribute actively: Dr.-Ing. Torsten Leifert (SMA) and Prof. Dr.-Ing. Michael Bierhoff (Fachhochschule Stralsund).

The Chair of Power Electronics has received one Von Humboldt Scholar, one new Project, LIFE-WIND, (with 3 companies involved and co-funded by EKSH), and one CAU internationalization project (from which several Erasmus agreements followed). These projects added to the other 6 existing projects of which the ERC consolidator grant HEART and the Innovation cluster Renewable Energy should receive a particular mention: the first for the international importance and the second for the regional value. Additionally the department worked on the development of a new medium-voltage laboratory, with focus on efficiency and reliability of power electronics in smart grid applications, which should support the HEART project. Two applications for large pieces of equipment (one co-funded by the region and one by the DFG) were successful, receiving a total of 760,000 Euro.

Prof. Marco Liserre was awarded the first IEEE Dr. Bimal Bose Energy Systems Award and he was listed in the ISI-Thomson publication ''The world´s most influential scientific minds''. Nils Hoffmann received the ETG-Literaturpreis 2014 for a journal publication.

The research activity of the Chair of Power Electronics was organized in three areas:

- Power Converters for electric drives, transportation and renewable energies, where most of the interactions with local companies are found with all the Ph.D. projects having at least one industrial partner. This activity was also supported by EU Interreg Program and by EKSH.
- Analysis of the Electric Grid, and New Grid Scenarios, where most of the new challenges for power electronics research are currently found; hence most of the journal publications fall in this area.
- Smart Transformer, related to the already mentioned HEART project, which involves the most international team and most of the international cooperation.

In general the Chair of Power Electronics kept active a strong cooperative link with the Department of Energy Technology of Aalborg University, Denmark, Prof. Marco Liserre being adjunct professor of AAU. Also, he initiated an active cooperation with the National Technical University of Athens, Greece and the École Polytechnique Fédérale de Lausanne, Switzerland. The department published 14 journal papers (6 more are already accepted for 2015) and 26 conference presentations. It also contributed actively to the dissemination of science in society by participating in the initiatives Power Girls and Power Boys and Tec2You.

## Results

### Power Converters for Electric Drives, Transportation and Renewable Energies

The optimal design, in terms of efficiency, volume, and reliability of power converters is investigated for different types of applications. In this research area the Chair of Power Electronics has the most interactions with local companies. In high power wind turbines typical back-to-back converters are used. In a first research project a converter with a power of 1 MW was designed, built, and tested. In contrast, in small wind turbines the power is below 10 kW; instead of a

back-to-back converter, simple rectifiers can be used, which is investigated in a second research project. The third project has the objective of analyzing the effect of parameter variability on performance and reliability of power converters and to develop reliability-orientated design procedures. In a fourth project a drive train of an electric vehicle is investigated. Different drive topologies and especially different topologies for the drive inverter are analyzed in respect to efficiency, volume and cost. Also, attention is given to control of electric drives and issues related to the use of slim-dc-link.

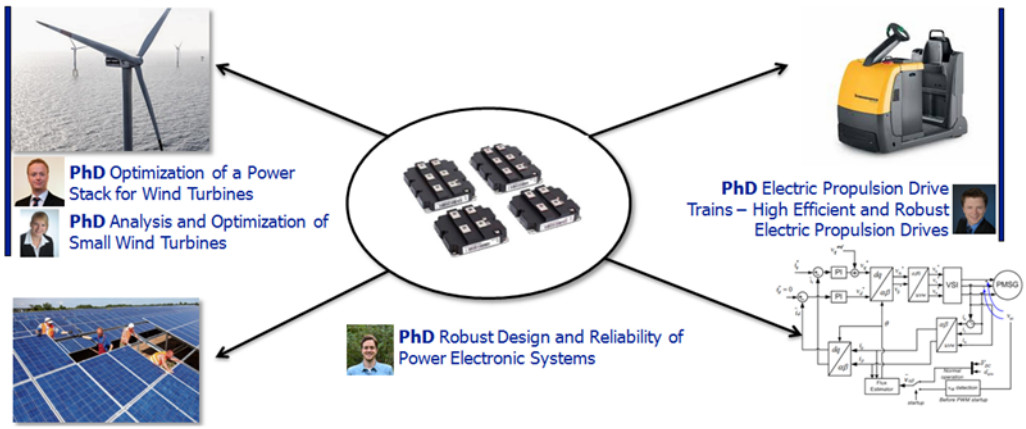


Fig. 1: Projects about Power Converters for Electric Drives, Transportation and Renewable Energies

### Optimization of a 1MW Power Stack for Wind Turbine Application (Benkendorff)

This research project, funded by the innovation cluster Power Electronics for Renewable Energy (Fraunhofer Institute / State Schleswig-Holstein) and industry, is focused on the optimization of an inverter for a wind turbine generator. In addition to space savings in the generator, the improvement of efficiency and the increase of reliability by simplification of maintenance effort has to be addressed. The back-to-back converter is the core element of wind turbine systems. In this project, a 1 MW power inverter is to be designed, built, and tested. The electrical behaviour of a suitable topology for the inverter is selected in respect to efficiency, volume, and cost. The low-inductance design of the inverter and the integration of the driver circuit were designed to improve the performance. Research on active control of the switching behaviour of the power semiconductor is required. A comprehensive study of all components for the development of a compact and modular high power inverter will be carried out. It is planned to put it into operation and make final measurements in 2015.

### Analysis and Optimization of Power Electronic Converter Systems for Small Wind Turbines (Kristina Buchert)

The project is funded by the EKSH and industry. In this project, the power converter for small wind turbines (less than 70 kW) has to be analyzed and optimized. As drive train a small wind turbine with a permanent magnet synchronous generator and simple converters is selected. The system should provide low costs as well as high efficiency over a wide wind speed range. In this project a drive train with a PMSG and a back-to-back converter is investigated. The focus here is on the rectifying part of the converter. Not only are comparison based calculations for the losses made but also efficiency, THD, and different Maximum-Power-Point-Tracking-strategies are investigated. So far, analytical and simulation results due to different rectifier topologies have been finalized and a laboratory setup for five rectifiers has been built. In 2015, different measurements of losses, efficiency and THD will be made and MPPT-strategies will be tested.

### Robust Design and Reliability of Power Electronic Systems (Jedtberg)

Power Electronic Systems (PES) such as converters contain numerous components and are subject to many different mission profiles (applied loads and stresses). Due to both the manufacturing process employed and aging, the parameters

of the components vary, which has an impact on both the performance and the reliability of the PES. Thus, a robust design is essential to minimize the failure rate of the PES and preserve its performance. The objective of this research project is to analyze the impact of parameter variability on performance and reliability of PES as well as to investigate their failure mechanisms in order to achieve mission-orientated design procedures. More specifically, the project focuses on the components of power electronic converters of wind turbine systems (WTS), i.e. the dc-link capacitors and the power modules. Relevant case studies will be set up in order to investigate the parameters which most affect the components, lifetime and reliability. In line with this, electrical and thermal models will be developed which enable lifetime prediction and performance variation with respect to component variability. Laboratory tests will be carried out to verify the simulation findings.

### Electric Propulsion Drive Trains for Working Vehicles and Cars (Stephan Brüske)

The project is financed by Interreg 4a (EU) and the university. Besides robustness high efficiency is a key criterion for the competitiveness of electrically powered vehicles. An optimization of the electric propulsion drive train as the main energy consuming unit especially is necessary and is the focus of this project. The main parts of the electrical drive train are the battery, the motor, and the voltage source inverter (VSI) which is the connecting interface between the battery and the motor. An optional DC/DC converter between the battery and the VSI can decouple the system voltage level from the battery voltage. The design of the VSI is dependent on the design of the whole electrical propulsion drive train. Therefore, detailed analyses of the machine and the possible use of an additional DC/DC converter are necessary and have been conducted. One of the main targets of this working package is the optimisation of the VSI. Two alternative topologies for the commonly used 2-level VSI have been studied and compared by semiconductor power rating and simulation. Both alternative topologies have been tested experimentally. Additionally, new semiconductors based on GaN have been analysed experimentally in the double pulse test circuit. In 2015, final measurements have to be made.

## Analysis of the Electric Grid and New Grid Scenarios

The increasing scale of installation of distributed energy resources has greatly modified the grid scenario. Distributed energy resources constitute active nodes that generate power profiles that are difficult to forecast, since they depend on the weather conditions and may de-stabilize the grid. On top of that, the diffusion of electronic loads that are inherently non-linear causes problems regarding power quality, current/voltage distortion, and resonances. Also, the development of hybrid/electric vehicles will have an impact on the electric grid. In this framework, the investigation of new grid scenarios which could also include storage technologies is of paramount importance to guarantee the grid stability and acceptable levels of power qualities.

### Stability Investigation and Robustness Improvement of Grid Connected Inverters based on Impedance Analysis (Lars Jessen)

This project is funded by industry. Most renewable energy systems such as wind power and solar power are connected to the grid by converters based on power electronics. Hence, as the number of renewable energy sources in the distribution system increases the structure of the electric power system is changing. These changes lead to new challenges for a secure and reliable power system operation. In this research project, the stability of the electric power system with renewable energy sources is analysed. This is done by evaluating the ratio of the frequency-dependent output impedance of a grid connected power converter and the frequency-dependent impedance of the power system at the point of connection. Therefore both impedances are investigated. In addition, the output impedance of a grid connected inverter is shaped by converter control to ensure a stable and robust operation of the power system. Since validation of simulation models is planned for 2015, a laboratory test bed will be constructed.

### Development of a Measurement Current Generator for Low-Voltage Grid Impedance Analysis (Sandro Günter)

This project is funded by the Federal Ministry of Economic Affairs and Energy in cooperation with industry. The number of non-linear loads in the low-voltage grid continues to grow, while the number of big generators directly connected to the

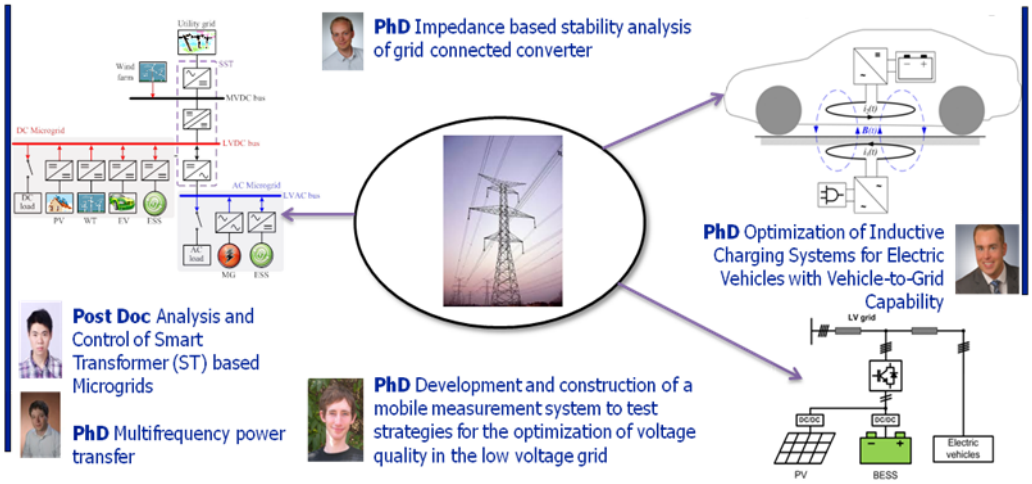


Fig. 2: Projects addressing analysis of the electric grid and new grid scenarios.

grid decreases. Hence the percentage of harmonic voltage producers, as well as of superior controllable systems, increases and the risk of violating allowed voltage levels grows. This new grid must be well defined in performance: standards and limits for harmonics have to be set. By using the steadily growing amount of distributed energy generation systems in the low-voltage grid the harmonic voltages can be reduced but the grid impedance at these frequencies has to be known. To measure the frequency dependant grid impedance a system with monofrequency harmonic current injection has been built, with which, the resultant voltage drop over the grid impedance can be measured for calculating this impedance. This measurement current generator can generate currents with frequencies up to 10 kHz and has been developed and built in this project. It is planned to put it into operation and make final measurements in 2015.

### Multifrequency and Wireless Power Conditioning (Sebastian Brüske)

In power systems, a single frequency is commonly used for power transmission. In the electric grid, this is the line frequency (50/60 Hz). The frequency of isolated grids such as in ships and airplanes is of the order of hundreds of hertz. In systems for contactless, inductive power transfer or within isolated DC/DC converters, the frequency is typically in the kilohertz range. By the use of multiple frequencies, such as in communication engineering, information is transmitted independently within a medium. In power electronics, this principle could be used to split the power flow. In this way for example, a decoupled transfer of conventional and renewable energy can be realized. Another potential use lies in the fact that a power flow control among several senders and receivers can be implemented through the use of multiple frequencies. The senders and receivers can be coupled or decoupled by the selection of different frequencies. The objectives of this work are to investigate the potential of the use of multiple frequencies in a microgrid, transferring power between several renewable energy sources, and within power converters, such as in wireless power transfer. Moreover, the design of power converters to implement multiple frequencies will be investigated.

### Control and Analysis of Smart Transformer (ST) based Microgrids (Zhixiang Zou)

The increasing spread and installation of distributed energy resources (DERs) has imposed severe problems on the distribution network and microgrids, driving the traditional system to change with new structures and scenarios. The ST based microgrid is a promising way to address these issues and meet the requirements of the next-generation grid. This project aims at the modelling, analysis, and control of a ST based microgrid with higher hosting capability, higher efficiency, reliability, and power quality. To achieve these goals, different aspects of ST based microgrids will be completely explored, including architecture design, system modelling, coordinated power control, frequency adaptive control, stability analysis, communication technology, and protection. The proposed solutions will be applicable not only in the proposed

ST based microgrid but also in a traditional microgrid. Germany is leading the implementation of DERs (especially the PV and CHP) and this results in an urgent demand for a microgrid or aggregated DG system with significant hosting capacity of distributed sources. Being able to develop a theory of the ST based microgrid and its operation, as well as control scenarios which solve critical issues brought out by new features of electric system, will be of benefit to the industry, the distribution network, and society in general.

### Optimization of Inductive Power Transfer Systems for Electric Vehicles in Vehicle-to-Grid Applications (Marinus Petersen)

This project is financed by EKSH and industry. Inductive Power Transfer (IPT) Systems are a promising solution for recharging hybrid and electric vehicles. They can contribute to the increase of acceptance of electric vehicles among the population. The objective of this project is further technical development of IPT systems with a focus on Vehicle-to-Grid applications. Several optimization methods (new semiconductor materials, components and topologies) will be analyzed to reach the highest possible efficiency. Comprehensive investigations have been performed concerning the four basic resonant topologies SS, SP, PS and PP. It appeared that especially the SS topology is suitable for the bidirectional IPT system because of its advantages (zero phase angle at resonance frequency, load and coupling independence of primary capacity). Furthermore, a 6 kW prototype was built in the laboratory to investigate the power transfer for various scenarios depending on the misalignment of the vehicle, the power level, and the battery state of charge. A peak efficiency of 93.2 % could be measured (from primary DC link to the battery) for a power level of 6 kW and an air gap of 60 mm. In 2015 final measurements and a practical implementation in a forklift truck for real use will be done.

## Smart Transformer

The increased penetration of renewable energy into the electrical distribution system is causing problems with the transmission and the distribution grids. A promising solution to improve the controllability of the grid is to replace the traditional transformer with one based on power electronics comprising a high frequency transformer and power electronic converters. The ERC consolidator grants HEART, (Highly Efficient and Reliable Smart Transformer) aims to investigate this field. The basis is the analysis of the possible features of the smart transformer for the medium and low voltage sides. A modular smart transformer with fault tolerance capability will be designed and tested. The challenge to compete in terms of efficiency and reliability with the traditional transformer will be addressed by routing the internal energy flows.

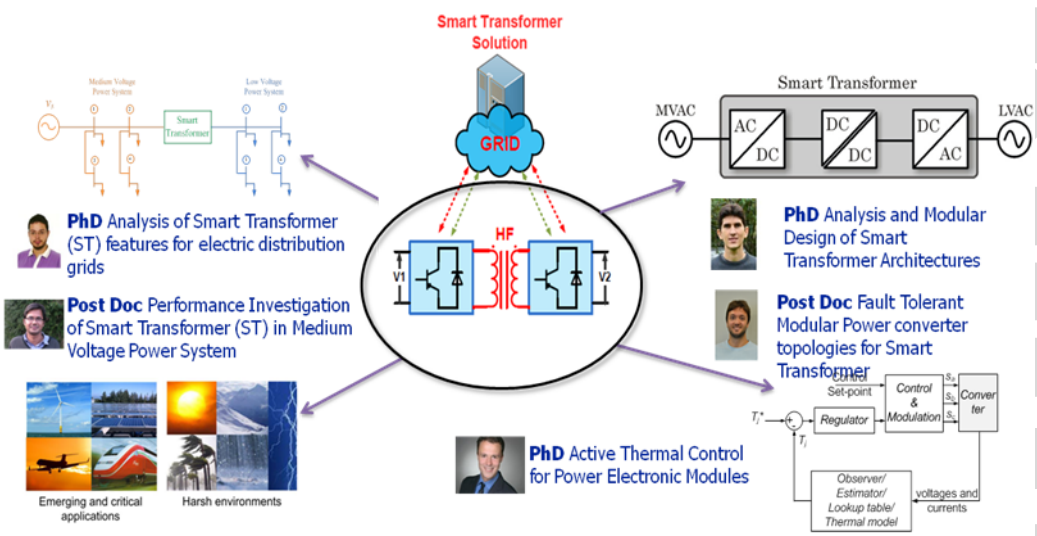


Fig. 3: Smart transformer projects.

### Analysis of Smart Transformer Features for Electric Distribution (Giovanni De Carne)

This project also is funded by the ERC grant HEART. The presence of distributed generators, as well as other renewable resources (batteries, flywheels, etc.), has changed the way energy is supplied to the user. The traditional transformer cannot guarantee anymore optimal performance, in terms of voltage and current profile, when a bidirectional power flux occurs. The Smart Transformer represents a more flexible system that adapts itself as a function of grid requirements and at the same time provides a good power quality to the users. The Smart Transformer could provide several services to the grid concerning on-line voltage profile optimization, current congestion management, and reduction of harmonics magnitude. This project aims to demonstrate the benefits that the implementation of the Smart Transformer in the Low/Medium voltage substations can achieve. The activity has been in researching the grid´s problems and in analysis of optimization actions performed by the Smart Transformer. By the end of this year, these studies will be validated by means of a Real Time Digital Simulator.

### Performance Investigation of Smart Transformer (ST) in Medium Voltage Power System (Chandan Kumar)

The power electronics based smart transformer (ST) is expected to play an important role in future power systems. In addition to providing advantages like voltage transformation and isolation between the medium voltage (MV) and low voltage (LV) sides similar to a traditional power transformer, the ST can provide several additional features like balanced sinusoidal voltage in LV distribution system, balanced sinusoidal unity power factor current in the MV grid side, no effect of MV side disturbances such as sag, swell, transients etc. on the loads, and availability of LV dc link for integration of distributed energy resources (DERs) etc. Moreover, the operational features of the ST in the MV power distribution systems also need to be investigated for maximizing its utilization and making its application more attractive. The objective of this work is to analyze operation of the ST in the medium voltage side under different system conditions e.g. sag, swell, unbalance, overloading, faults, etc . This analysis will be used to develop a suitable control scheme for continuous operation of ST within wide variations in system conditions as well as providing different ancillary services to the medium voltage power system.

### Analysis and Modular Design of Smart Transformer Architectures (Levy Costa)

This is another project funded by the ERC grant HEART. The smart transformer, also known as power electronics transformer or solid-state transformer, is the key element of the future electric distribution system based on a smart grid. This power electronics based transformer should be able to replace the old low frequency one and provide more services to the electric grid. On the other hand, this new technology is still not competitive in term of robustness and efficiency compared to regular transformers. In this context, the project aims to analyze and design a highly efficient and reliable smart transformer. In particular, the main aspect of this project will be to investigate suitable power topologies for it and to evaluate them in terms of efficiency, lifetime estimation, fault tolerance capability, as well as their impact on possible services that the smart transformer should provide to the grid. The final architecture should be based on power electronics modules since the modular concept might enable high reliability, fault tolerance, and easy maintenance of the system.

### Fault Tolerant Modular Power Converter Topologies for Smart Transformer (Giampaolo Buticchi)

This Post-doc work is funded by the Alexander von Humboldt Foundation. The widespread adoption of renewable energy systems and power electronics appliances connected to the grid has affected deeply the electrical distribution, demanding a change of paradigm towards smarter networks: the smart grids. Nowadays, line frequency power transformers constitute the backbone of the distribution grid; in order to comply with the new requirements of the smart grids, researchers have been thinking to substitute this equipment with more flexible power converters which perform the same task while adding further functionalities: these arethe smart transformers. This project aims at the realization of a smart transformer with very high reliability requirements. In particular, the main aspect of this project will be to investigate the architectures of modular power converters, with particular attention to the reliability of the system. The choice of the basic cell for the Smart Transformer was made and the Quadruple Active Bridge (QAB) topology has been selected. A prototype of the basic cell is currently under development.

### Active Thermal Control for Power Electronic Modules (Markus Andresen)

This project also is funded by the ERC grant HEART. The development of the power electronics based smart transformer for the distribution grid demands high reliability from the single component. The main reason for the aging and degradation that finally results in failure is thermal cycling of the power semiconductors. To increase the reliability of the smart transformer, the thermal cycling has to be reduced. This project aims to apply active thermal control for the smart transformer to increase the reliability and lifetime of the system. Depending on the operating conditions, the current can be routed in different paths leading to different efficiency and different estimated remaining lifetime for the components. This can be used to reduce the thermal swing and to maximize the lifetime of the system. On a full bridge converter the first thermal control algorithms have been applied successfully. A prototype is currently under development in cooperation with local industry, on which, the active thermal control will be tested under the operating conditions of a smart transformer.

## Personnel

Head of the group: Prof. Dr.-Ing. Marco Liserre; Secretary: P. Bekendorf, K. Wehring
Technical Staff: B. Doneit

Scientific Staff:

| | | |
|---|---|---|
| M.Sc. M. Andresen | 01.01.-31.12.2014 | ERC-Grant |
| Active Thermal Control for Power Electronic Modules | | |
| Dipl. - Wirtsch.-Ing. B. Benkendorff | 01.01.-31.12.2014 | Zukunftsprogramm SH/Industrie |
| Optimization of a Power Stack for Wind Turbines | | |
| Dipl.-Wirtsch.-Ing. S. Brüske | 15.01.-31.12.2014 | CAU |
| Multifrequency and Wireless Power Conditioning | | |
| Dipl. - Wirtsch.-Ing. St. Brüske | 01.01.-31.12.2014 | Interreg |
| Electric Propulsion Drive Trains - High Efficient and Robust Electric Propulsion Drives including Battery Buffering System for Working Vehicles and Cars | | |
| Dipl. - Wirtsch.-Ing. K. Buchert | 01.01.-31.12.2014 | EKSH/ Industrie |
| Analysis and Optimization of a Small Wind Turbine System | | |
| P.h.D. G. Buticchi | 01.05.-31.12.2014 | Von Humboldt Fellowship |
| Fault Tolerant Modular Power Converter Topologies for Smart Transformer | | |
| M.Sc. Levy Costa | 01.09.-31.12.2014 | ERC-Grant |
| Analysis and Modular Design of Smart Transformer Architectures | | |
| M.Sc. G. De Carne | 01.01.-31.12.2014 | ERC-Grant |
| Analysis of Smart Transformer Features for Electric Distribution | | |
| M.Sc. S Günter | 01.01.-31.12.2014 | BMU |
| Development of a Current Generator to Measure the Frequency Dependent low Voltage Grid Impedance | | |
| Dipl. - Wirtsch.-Ing. H. Jedtberg | 15.01.-31.12.2014 | CAU |
| Robust Design and Reliability of Power Electronic Systems | | |
| M. Eng. L. Jessen | 01.01.-31.12.2014 | Stipendiat |
| Investigation of Interactions between Distributed Generation in Electrical Power Systems with a high Penetration of Converters | | |

| | | |
|---|---|---|
| P.h.D. Chandan Kumar | 01.-31.12.2014 | CAU |
| Performance Investigation of Smart Transformer (ST) in Medium Voltage Power System | | |
| Dipl. - Wirtsch.-Ing. M. Petersen | 01.01.-31.12.2014 | EKSH/ Industrie |
| Inductive Charging for Electric Vehicles | | |
| P.h.D.. ZhiXiang Zou | 01.-31.12.2014 | CAU |
| Control and Analysis of Smart Transformer (ST) based Microgrids | | |

## Lectures, Seminars, and Laboratory Course Offers

*Winter 2013/2014*

Power Electronics I- Basics, 2 (+1) hrs Lecture (+ Exercises)/Week,
F.W. Fuchs (+ M. Petersen)

Power Electronics III- Electrical drives, 2 (+1) hrs Lecture (+ Exercises)/Week,
F.W. Fuchs (+ B. Benkendorff, K. Buchert, St. Brüske, M. Petersen, M. Andresen, S. Günter)

Control of Electrical Drives, 2 (+1) hrs Lecture (+ Exercises)/Week,
Marco Liserre (+ M. Andresen, G. De Carne)

Power Electronics - laboratory course, M.Sc., 4 hrs Lab/Week,
Marco Liserre (+ M. Andresen, B. Benkendorff, K. Buchert, S. Günter, G. De Carne, H. Jedtberg)

Seminar on Power Electronics, 2 hrs Seminar/Week,
Marco Liserre (+ K. Buchert, M. Petersen, St. Brüske, M. Andresen, B. Benkendorff, S. Günter)

Power Electronics - excursion, 1 hrs excursion/Week,
Marco Liserre (+ K. Buchert, B. Benkendorff)

Power Electronic Generator Systems for Wind Turbines, M.Sc., 3 (+1) hrs Study course Wind Engineering in CEwind (+ Exercises)/Week,
F.W. Fuchs (+ St. Brüske, B. Benkendorff, K. Buchert, M. Petersen)

Renewable Energy Systems II, 2 (+1) hrs Lecture (+ Exercises)/Week,
Marco Liserre (+ M. Andresen, G. De Carne, H. Jedtberg, Se. Brüske)

*Summer 2014*

Basics of electrical energy systems and power engineering, 3 (+1) hrs Lecture (+ Exercises)/Week,
Michael Bierhoff (+ M. Andresen)

Design of Power Electronics Converters, 3 (+1) hrs Lecture (+ Exercises)/Week,
M. Liserre (+ St. Brüske, G. Buticchi)

Renewable Energy Systems, 2 (+1) hrs Lecture (+ Exercises)/Week,
M. Liserre (+ G. De Carne, Se. Brüske)

Power Electronics - laboratory course, B.Sc., 4 hrs Lab/Week,
M. Liserre (+ K. Buchert, M. Andresen, S. Günter, Se. Brüske, G. De Carne)

Seminar on Power Electronics, 2 hrs Seminar/Week,
F.W. Fuchs (+ K. Buchert, St. Brüske)

Power Electronics - excursion, 1 hrs excursion/Week,
F. W. Fuchs

Microprocessors for real-time control, 1 (+ 1) hrs Lecture (+ Exercises)/Week,
T. Leifert (+ Se. Brüske)

*Winter 2014/2015*

Power Electronics I- Basics, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
F.W. Fuchs (+ M. Petersen)

Electrical drives, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
M. Liserre (+ B. Benkendorff, M. Andresen, G. De Carne)

Modelling and Control of Power Electronics Converters, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
Marco Liserre (+ L.F. Costa, G. Buticchi, C. Kumar)

Power Electronics - laboratory course, M.Sc., 4 hrs Lab/Week,
Marco Liserre (+ M. Andresen, B. Benkendorff, K. Buchert, S. Günter, G. De Carne, H. Jedtberg)

Seminar on Power Electronics, 2 hrs Seminar/Week,
Marco Liserre (+ K. Buchert, M. Petersen, St. Brüske, M. Andresen, B. Benkendorff, S. Günter)

Power Electronics - excursion, 1 hrs excursion/Week,
Marco Liserre (+ K. Buchert, B. Benkendorff)

Grid Converters for Renewable Energy Systems, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
M. Liserre (+ Se. Brüske, H. Jedtberg)

## Third-Party Funds

European Research Council Consolidator Grant (European Union), *The Highly Efficient And Reliable Smart Transformer (HEART), a new Heart for the Electric Distribution System*, 01.04.2014-31.03.2019 (2000000 EUR)

EKSH/Industry, *LIFEtime-enhanced Components for WIND Turbines (LIFE-WIND)*, 15.01.2015-14.01.2017 (150000 EUR)

Humboldt Research Fellowship for Postdoctoral Researchers, Alexander von Humboldt Foundation, *Fault Tolerant Modular Power Converter Topologies for Smart Transformer*, 01.10.1014-30.09.2015 (41400 EUR)

BMU/Industry, combined project FH Kiel, *Low Voltage Grid Analysis - Power Current Generator for Grid Impedance Measurement*, 01.02.2012-31.01.2015 (326000 EUR)

Fraunhofer/State Schleswig-Holstein/Industry, combined project FH Kiel, FH Westküste, ISIT, *Innovation Cluster Renewable Energy - Optimization of a 1 MW Power Converter for Wind Turbines*, 01.07.2012-31.08.2015 (250000 EUR)

EKSH/Industry, *Analysis and Optimization of Power Converter Systems for Small Wind Turbines*, 15.02.2012-31.03.2015 (178300 EUR)

EKSH/Industry, *Optimization of Inductive Charging for E-Vehicles to Grid Technology*, 01.04.2012-31.07.2015 (160000 EUR)

Industry, *Battery back-up System for E-Vehicles*, 01.01.2013-30.06.2015 (15900 EUR)

Internationalisierungsfonds der Christian-Albrechts-Universität, *Increase in number of ERASMUS students from northern Spain*, 01.01.-31.12.2014 (3240 EUR)

## Diploma, Bachelor's and Master's Theses

D. Lang, *Inbetriebnahme und Untersuchung eines NPC-Umrichters zur Speisung einer permanenterregten Synchronmaschine mit variabler Eingangsspannung für den Einsatz im Elektrofahrzeug*, 29.07.2014

J. Falck, *Aktive thermische Regelung von Leistungshalbleitermodulen zur Erhöhung der Lebensdauer*, 12.12.2014

R. Kühne, *Auslegung, Aufbau, Inbetriebnahme und Untersuchung eines Multilevel-Wechselrichters für den Einsatz in Elektrofahrzeuge*, 07.01.2014

S.T. Walz, *Untersuchung eines NPCs mit variabler Eingangsspannung für den Einsatz im Elektrofahrzeug*, 26.05.2014

M. Wegner, *Auslegung, Aufbau, Inbetriebnahme und Untersuchung eines bidirektionalen Hoch-Tiefsetzstellers für den Einsatz in Elektrofahrzeugen*, 27.05.2014

R. Kulpe, *Auslegung, Aufbau, Inbetriebnahme und Untersuchung eines T-Type-Wechselrichters für den Einsatz im Elektrofahrzeug*, 27.05.2014

F. Thams, *Impact from various Implementations of DC Voltage Droop Control on the Stability of HVDC grids*, 11.11.2014

F. Höhn, *Untersuchung der leitungsgebundenen Störungen und EMV-Optimierungsmaßnahmen für den NPC als Fahrwechselrichter in Elektrofahrzeugen*, 14.05.2014

S. Ha Vu, *Entwicklung eines kostengünstigen, zuverlässigen Messverfahrens für Motorströme*, 02.03.2014

M. Langwasser, *Untersuchung von Regelungsverfahren für einen Diodengleichrichter mit Switch Mode Rectifier im Zwischenkreis beim Einsatz in Kleinwindenergieanlagen*, 21.02.2014

F. Hoffmann, *Verlustanalysen von Gleichrichtertopologien beim Einsatz in Kleinwindenergieanlagen*, 03.09.2014

J. Reichenbächer, *Analyse der dynamischen Netzstützung einer Erzeugungsanlage bei unterschiedlichen Netzverhältnissen*, 11.11.2014

T. Birkoben, *Vergleich von galvanisch getrennten DC/DC-Umrichtern im Ladegerät für Elektrofahrzeuge*, 17.09.2014

N. Weiher, *Evaluating and enhancing lead acid lifetime models*, 14.07.2014

## Dissertations / Postdoctoral Lecture Qualifications

Nils Hoffmann, *Regelung und Aktiv-Filter Funktionalität von Netzpulsstromrichtern in der regenerativen Energieerzeugung*, 01.12.2014

Jens Schröder, *Batterie-Stützung mit DC/DC-Wandler und Doppelschichtkondensatoren für elektrische Fahrantriebe*, 09.01.2014

## Publications

Published in 2014

M. Andresen, M. Liserre, *Impact of active thermal management on power electronics design*, Microelectronics Reliability, **54**, 1935 - 1939 (2014)

Ke Ma, W. Chen, M. Liserre, F. Blaabjerg, *Power controllability of three-phase converter with unbalanced AC source*, Transactions on Power Electronics, **99**, (2014)

Ke Ma, M. Liserre, F. Blaabjerg, T. Kerekes, *Thermal Loading and Lifetime Estimation for Power Device Considering Mission Profiles in Wind Power Converter*, IEEE Transactions on Power Electronics, **99**, (2014)

R. Pena-Alzola, M. Liserre, F. Blaabjerg, M. Ordonez, Y. Yang, *LCL-Filter Design for Robust Active Damping in Grid-Connected Converters*, Industrial Informatics, IEEE Transactions on, **10**, 2192 - 2203 (2014)

R Pena-Alzola, M. Liserre, F. Blaabjerg, F. Sebastián, J. Dannehl, F.W. Fuchs, *Systematic design of the lead-lag network method for active damping in LCL-filter based three phase converters*, Industrial Informatics, IEEE Transactions on, **101**, 43 - 52 (2014)

R. Pena-Alzola, M. Liserre, F. Blaabjerg, M. Ordonez, T. Kerekes, *Self-commissioning Notch Filter for Active Damping in Three Phase LCL-filter Based Grid-tie Converter*, Power Electronics, IEEE Transactions on, **29**, 6754 (2014)

D. Del Puerto-Flores, J.M. Scherpen, M. Liserre, M.M. De Vries, M.J. Kransse, V.G. Monopoli, *Passivity-Based Control by Series/Parallel Damping of Single-Phase PWM Voltage Source Converter*, Control Systems Technology, IEEE Transactions on, **22**, 1310 - 1322 (2014)

Ke Ma, M. Liserre, F. Blaabjerg, *Operating and Loading Conditions of a Three-Level Neutral-Point-Clamped Wind Power Converter Under Various Grid Faults*, Industry Applications, IEEE Transactions on, **50**, 520 - 530 (2014)

W. Wu, Y. Sun, M. Huang, X. Wang, H. Wang, F. Blaabjerg, M. Liserre, H.H. Chung, *A Robust Passive Damping Method*

*for LLCL-Filter-Based Grid-Tied Inverters to Minimize the Effect of Grid Harmonic Voltages,* Power Electronics, IEEE Transactions on, **29**, 3279 - 3289 (2014)

H. Wang, M. Liserre, F. Blaabjerg, P. De Place Rimmen, J.B. Jacobsen, T. Kvisgaard, J. Landkildehus, *Transitioning to Physics-of-Failure as a Reliability Driver in Power Electronics,* Emerging and Selected Topics in Power Electronics, IEEE Journal of, **2**, 97 - 114 (2014)

X. Wang, F. Blaabjerg, M. Liserre, Z. Chen, J. He, Y. Li, *An active damper for stabilizing power-electronics-based AC systems,* Power Electronics, IEEE Transactions on, **29**, 3318 - 3329 (2014)

N. Baker, M. Liserre, L. Dupont, Y. Avenas, *Improved Reliability of Power Modules: A Review of Online Junction Temperature Measurement Methods,* Industrial Electronics Magazine, IEEE, **29**, 17 - 27 (2014)

N. Hoffmann, F.W. Fuchs, *Minimal Invasive Equivalent Grid Impedance Estimation in Inductive-Resistive Power Networks Using Extended Kalman Filter,* Power Electronics, IEEE Transactions on, **29**, 631 - 641 (2014)

J.C. Schroeder, F.W. Fuchs, *General Analysis and Design Guideline for a Battery Buffer System With DC/DC Converter and EDLC for Electric Vehicles and its Influence on Efficiency,* Power Electronics, IEEE Transactions on, **30**, 922 - 932 (2014)

M. Andresen, M. Liserre, G. Buticchi, *Review of active thermal and lifetime control techniques for power electronic modules,* Power Electronics and Applications (EPE'14-ECCE Europe), 2014 16th European Conference on, (2014)

S. Günter, F.W. Fuchs, *Switching Time Prediction for Digital Hysteresis Control for High Frequency Current in Grid Impedance Measurement Application,* Electronics and Applications (EPE'14-ECCE Europe), 2014 16th European Conference on, (2014)

K. Buchert, F.W. Fuchs, *Comparison of Three Phase Rectifier Topologies in Small Wind Turbines,* Power Electronics and Applications (EPE'14-ECCE Europe), 2014 16th European Conference on, (2014)

S. Brueske, F.W. Fuchs, *Efficiency Optimization of a Neutral Point Clamped Inverter for Electric Vehicles by Means of Variable DC Input Voltage and Different Power Semiconductors,* Electronics and Applications (EPE'14-ECCE Europe), 2014 16th European Conference on, (2014)

S. Brueske, F.W. Fuchs, *Comparison of Topologies for the Main Inverter of an Electric Vehicle,* PCIM Europe 2014, (2014)

F. Giuliani, D. Barater, P. Concari, N. Cova, R. Delmonte, R. Menozzi, G. Buticchi, L. Tarisciotti, *Modular Photovoltaic Inverter with High-frequency DC-DC Stage based on Low-voltage FETs,* Proc. IEEE ECCE, (2014)

G. Buticchi, C. Barater, L. Tarisciotti, P. Zanchetta, *High-dynamic Single-phase Hilbert-based PLL for Improved Phase-jump Ride-through in Grid-connected Inverters,* in Proc. IEEE ECCE, (2014)

G. Buticchi, M. Liserre, D. Barater, A. Concari, G. Soldati, G. Francescini, *Frequency-based Control of a Micro-grid with Multiple Renewable Energy Sources,* Proc. IEEE ECCE, (2014)

N. Delmonte, F. Barater, F. Giuliani, P. Cova, G. Buticchi, *Oscillating Water Column Power Conversion: A Technology Review,* Proc. IEEE ECCE, (2014)

D. Barater, c: Concari, G. Buticchi, D. de Gurpinar, A. Castellazzi, *Performance Evaluation of a 3-level ANPC Photovoltaic Grid- connected Inverter with 650V SiC Devices and Optimized PWM,* Proc. IEEE ECCE, (2014)

G. Buticchi, M. Galea, L. Empringham, L. De Lillo, C. Gerada, C. Bianchini, *Enabling Technologies for a Fault Tolerant Linear Actuation Drive,* Proc. IEEE IECON, (2014)

S. Brueske, G. De Carne, M. Liserre, *Multi-Frequency Power Transfer in a Smart Transformer Based Distribution,* Proc. IEEE IECON, (2014)

G. De Carne, M. Liserre, M. Christakou, M. Paolone, *Integrated Voltage Control and Line Congestion Management in Active Distribution Networks by Means of Smart Transformers,* International Symposium on Industrial Electronics (ISIE), (2014)

H. Jedtberg, A. Pigazo, M. Liserre, *Robustness Evaluation of Transformerless PV Inverter Topologies,* Proc. IEEE COMPEL, (2014)

G. Quartarone, M. Liserre, F.W. Fuchs, N. Anglani, G. Buticchi, *Sensitivity Analysis of Transformerless PV Inverter Topologies to Physical Variations of Power Devices,* Proc. IEEE IECON, (2014)

W. Xiongfei, F. Blaabjerg, C.L. Bak, M. Liserre, *An active damper to suppress multiple resonances with unknown frequencies,* Applied Power Electronics Conference and Exposition (APEC), (2014)

R. Beres, X. Wang, F. Blaabjerg, C.L. Bak, M. Liserre, *New optimal design method for trap damping sections in grid-connected LCL filters,* Proc. IEEE ECCE, (2014)

R. Beres, X. Wang, F. Blaabjerg, C.L. Bak, M. Liserre, *A review of passive filters for grid-connected voltage source converters,* In Applied Power Electronics Conference and Exposition (APEC), (2014)

G. Gohil, H. Wang, M. Liserre, T. Kerekes, R. Teodorescu, F. Blaabjerg, *Reduction of DC-link capacitor in case of cascade multilevel converters by means of reactive power control,* In Applied Power Electronics Conference and Exposition (APEC), (2014)

Z. Qin, M. Liserre, F. Blaabjerg, P.C. Loh, *Reliability-oriented energy storage sizing in wind power systems,* Power Electronics Conference (IPEC-Hiroshima 2014-ECCE-ASIA), (2014)

A. Garcia, R. Molina, A. Mastromauro, M. Liserre, *A combined centralized/decentralized voltage regulation method for PV inverters in LV distribution networks,* PES General Meeting Conference and Exposition, (2014)

R.A. Mastromauro, S. Stasi, F. Gervasio, M. Liserre, *A ground power unit based on paralleled interleaved inverters for a More-Electric-Aircraft,* In Power Electronics, Electrical Drives, Automation and Motion (SPEEDAM), (2014)

N. Baker, S. Munk-Nielsen, M. Liserre, F. Ianuzzo, *Online junction temperature measurement via internal gate resistance during turn-on,* In Power Electronics and Applications (EPE'14-ECCE Europe), 2014 16th European Conference on, (2014)

X. Lu, K.S.L. Huang, M. Liserre, F. Blaabjerg, *An active damping method based on biquad digital filter for parallel grid-interfacing inverters with LCL filters,* Applied Power Electronics Conference and Exposition (APEC), (2014)

## Further Activities and Events

**Visiting Professors:**

Prof. Alberto Pigazo, University of Cantabria, Santander, Spain, Dec. 2015
Prof. Inigo Martinez De Alegria, University of the Basque Country, Spain, 12.12.14
Prof. Fernando Briz, University of Oviedo, Spain, Dec. 2014
Prof. Giovanni Franceschini, University of Parma, Italy, Nov. 2014
Prof. Braham Ferreira, Delft University of Technology, The Netherlands, Sept. 2014
Prof. Domenico Casadei, University of Bologna, Italy, May 2014
Prof. Carlo Cecati, University of L´Aquila, Italy, July 2014
Prof. Mario Paolone École polytechnique fédérale de Lausanne, Switzerland, June 2014
Prof. Tamas Kerekes, Aalborg University, Denmark, Nov. 2014
Prof. Frede Blaabjerg, Aalborg University, Denmark, Dec. 2014
Prof. Costas Vournas, National Technical University of Athens, February 2014

**Visiting Researchers**

Giusi Quartarone, Ph.D. student, University of Pavia, Italy, Nov. 2013- Feb. 2014
Massimiliano De Cristofaro, Ph.D. student, University of Salerno, Italy, Sept. 2014- Feb. 2015

# Technology of Silicon-Based Micro- and Nano-Systems

Since October 2008 Prof. Dr.-Ing. Wolfgang Benecke has been Managing Director of the Fraunhofer-Institut für Siliziumtechnologie (ISIT) in Itzehoe.

Fraunhofer ISIT develops and manufactures components in microelectronics and microsystems technology, from the design phase, including system simulation, through prototyping and fabrication of samples, up to series production. Even though components manufactured at Fraunhofer ISIT, such as acceleration sensors, valves, and deflection mirrors are often just a fraction of a millimetre in size, there is a wide range of applications: the devices are implemented in areas like medical care, environmental and traffic engineering, communication systems, automotive industry, and mechanical engineering. Working under contract, ISIT develops these types of components in accordance with customer requirements, also creating the application specific integrated circuits (ASICs) needed for the operation of sensors and actuators. Included in this service is the system integration using miniaturized assembly and interconnection technology.

Together with Vishay Siliconix Itzehoe GmbH, the institute operates a professional semiconductor production line which is up-to-date in all required quality certifications (e. g. ISO 9001, TS 16949). This line is used in parallel for PowerMOS and microsystem production, and for R&D projects developing new devices and technological processes.

Other fields of activity at ISIT focus on assembly and packaging techniques for microsystems, analysis of the quality and reliability of electronic components, and development of advanced power-supply components for electronic systems.

The institute employs a staff of around 150 people.

Further information about Fraunhofer ISIT is available on the web: www.isit.fraunhofer.de.

In addition the Institute publishes an Annual Report which can be ordered at ISIT.

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# Wireless Communications

The research of the Wireless Communications group (CWC) focuses on the physical aspects of wireless communications, i.e. antennas and channel modelling.

Antennas are key components of many rf systems for wireless communications and sensing as they perform the transition from guided waves to free space propagating waves. Antenna design is often seen as an art in applying basic electromagnetic principles to create real structures with the required properties. Nowadays, applications offer limited space for the integration of the wireless modules and therefore, are dominated by obstacles to integration; this is especially true for antenna performance. The group's research activities aim particularly to master this integration challenge. Applications range from reconfigurable multiband antennas for SDR (software defined radio), multiple antenna systems for small MIMO (multiple input multiple output) terminals, UWB (ultra wideband) antennas for combined communication and localization, and antenna implantation into the human body for medical implants and BAN (Body Area Networks).

Detailed knowledge of the electromagnetic propagation channel is essential to gain optimum performance in all wireless communication, sensing, and locating applications. In terms of wireless communications the channel properties set the upper bound of the capacity for a given SNR (signal to noise ratio). While channel models of typical urban or indoor environments are already standardized for common mobile communication systems, such as GSM, UMTS, and IEEE 802.11, more specific environments such as aircraft cabins, or in- and on- the- body wireless channels, become an interesting research topic.

## Results

### UWB Communication and Localization

The Wireless Communications group works on design and integration of UWB antennas for a combined communication and localization system. Application areas range over airborne systems, search and rescue, and implantable medical devices. The antennas designed cover the frequency range from 3.1 GHz to 10.6 GHz. In the framework of a BMWi project grant and in cooperation with Airbus, multiple two antenna systems are integrated into the cabin's ceiling while a miniature mobile device contains a single antenna that is specifically designed to work in close proximity to the human body.

Currently, the CWC evaluates the RF localization of medical implants and surgical instrumentation in cooperation with the Department of Neurosurgery of the Kiel University hospital.

### Reconfigurable MIMO Antenna Integration into Small Terminals

MIMO (Multiple Input Multiple Output) is a technique to utilize multiple antenna systems to increase the capacity of modern communication systems. The integration of multiple low correlated antennas is especially challenging if we look at small terminals such as mobile phones. Our results are well received by both the scientific community and industry. They indicate a relationship between the element correlation and the characteristic modes established on the common finite ground plate. It can already be foreseen that these promising findings will have the potential to derive design rules for the integration of multiple antennas into small terminals. Meanwhile, CWC gained funding for multiple projects in this area including a new focus area of the DFG with emphasis on 100 GBit wireless systems.

Recently the CWC won research grants from the DAAD, DFG, the BMBF and the ENIAC European framework. Furthermore, cooperation with the Fraunhofer ISIT in Izehoe in the area of piezoelectric MEMS for reconfigurable antennas is continuing.

### Implanted Antennas and RF propagation within the human body

A Body Area Network (BAN) is a combination of several electronic applications that are worn on or in the body, preferably having a wireless interconnection with each other or with external peripheral devices. The applications can range over consumer electronic devices, security equipment, medical devices for telemedicine, and electronic implants. In order to allow

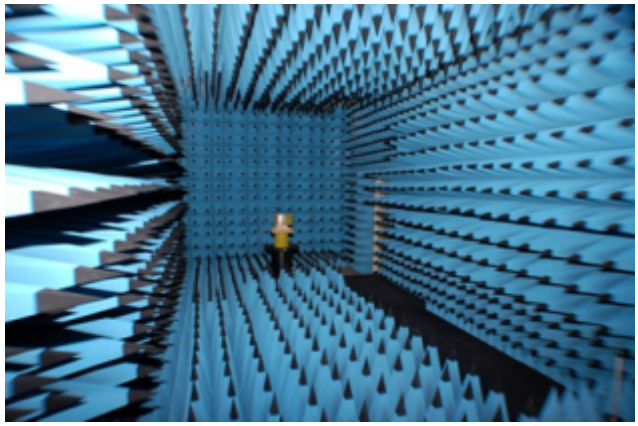

Fig. 1: Shielded absorber room for antenna measurements.

for high data rates, reliable links, and low power consumption, UWB (Ultra Wideband) technology has been considered recently for future BANs. The CWC aims at developing and integrating new miniaturized antennas and channel models for BANs in different applications. The antennas are developed and optimized taking into account realistic integration into the chassis of the application and realistic implantation into the body.

Recently the CWC won a project grant from the DFG in the area of analytic path loss modelling of On-Body wireless propagation.

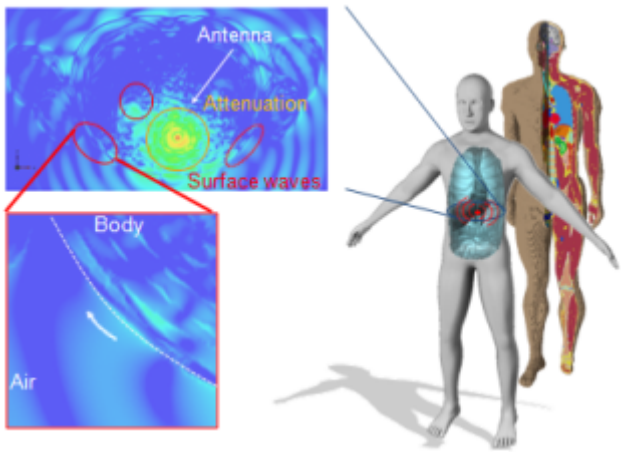


Fig. 2: In and on body radio propagation of wireless medical implants.

## Personnel

Head of the group: Prof. Dr.-Ing. D. Manteuffel; Secretary: M. Bork
Technical Staff: Dipl.-Ing. W. Taute

Scientific Staff:

| | | |
|---|---|---|
| Dipl.-Ing. Y. Chen<br>EPAMO | 01.01.-31.12.2014 | BMBF / EU |
| Dipl.-Ing. M. Grimm<br>MIMO | 01.01.-31.12.2014 | DFG |

| | | |
|---|---|---|
| M.Sc. T. Hadamik<br>Massive MIMO | 01.04.-31.12.2014 | DFG |
| Dipl.-Wirtsch.-Ing. R. Martens<br>EPAMO / MIMO | 01.01.-31.12.2014 | BMBF / DFG |
| Dipl.-Ing. E. Safin | 01.01.-31.12.2014 | CAU |
| Dr. Sc. R. Valkonen<br>KoAMo | 01.01.-31.12.2014 | BMBF |

## Lectures, Seminars, and Laboratory Course Offers

*Winter 2013/2014*

Grundgebiete der Elektrotechnik III, 3 (+ 2) hrs Lecture (+ Exercises)/Week,
D. Manteuffel

Funkbasierte Kommunikation und Sensorik in der Medizintechnik, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
D. Manteuffel

Project, 3 hrs Practical/Week,
D. Manteuffel

Masterpraktikum Mikrowellen und EMV, 4 hrs Practical/Week,
D. Manteuffel

*Summer 2014*

Wireless Communication (RF), 2 (+ 1) hrs Lecture (+ Exercises)/Week,
D. Manteuffel

Antennas, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
D. Manteuffel

Seminar EM Modelling, 3 hrs Seminar/Week,
D. Manteuffel

Project, 3 hrs Practical/Week,
D. Manteuffel

*Winter 2014/2015*

Grundgebiete der Elektrotechnik III, 3 (+ 2) hrs Lecture (+ Exercises)/Week,
D. Manteuffel

Funkbasierte Kommunikation und Sensorik in der Medizintechnik, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
D. Manteuffel

## Third-Party Funds

Bundesministerium für Bildung und Forschung, *ENIAC-Verbundprojekt EPAMO - Teilvorhaben: MEMS basierte rekonfigurierbare Antennen für mobile Terminals,* 01.04.2011-30.09.2014 (353713 EUR)

Deutsche Forschungsgemeinschaft, *Integration von Mehrantennensystemen in kleinen mobilen Endgeräten auf Basis der Theorie der Charakteristischen Moden,* 01.12.2010-28.02.2015 (187440 EUR)

Bundesministerium für Bildung und Forschung, *Numerische 3D-Feldsimulationen für Konzeptentwicklung und Integration der Antennen für Aufbau mobiler Demonstratorplattformen (Verbundprojekt KoAMo)*, 01.03.2012-28.02.2015 (213948 EUR)

Deutsche Forschungsgemeinschaft, *Ultrabreitband-Kommunikation basierend auf ''Massive MIMO'' und Multimode-Antennen für mobile Endgeräte*, 01.04.2014-31.03.2017 (239900 EUR)

## Further Cooperation, Consulting, and Technology Transfer

The Wireless Communications group (CWC) cooperates with several international universities, such as the University of Nice, Helsinki University of Technology, and Loughborough University. Industrial cooperation has been conducted with I2R Singapore, IMST GmbH, Airbus and Draeger. Within the Institute CWC has a strong collaboration with the ICT group. In a joint initiative they recently won a project grant within a newly created DFG focus area with the subject of multi-mode massive MIMO.

## Diploma, Bachelor's and Master's Theses

D. Hunger, *Entwicklung und Evaluierung silikonbasierter Phantomkörper zur Modellierung körperbezogener Funkapplikationen*, 06.04.2014

J. Lengefeld, *Entwicklung und Aufbau einer Referenzantenne*, 06.04.2014

T. Hadamik, *Entwicklung eines massiven Mehrantennensystems für Indoor-Basisstationen*, 18.05.2014

V. Geberlin, *Entwicklung eines Programms zum Generieren von Rüstdaten für eine Produktionslinie*, 02.09.2014

P. Sponagel, *Entwicklung eines Fertigungsverfahrens zur Herstellung silikonbasierter EM-Körperphantome*, 16.09.2014

I. Heilemann, *Analyse und Bewertung von kompakten breitbandigen Antennenkonzepten für Multistandardkommunikation im Automobil*, 16.12.2014

## Publications

Published in 2014

M. Grimm, D. Manteuffel, *Norton Surface Waves in the Scope of Body Area Networks*, IEEE Transactions on Antennas and Propagation, **vol. 62, no. 5**, 2616 - 2623 (2014)

D. Manteuffel, *Towards Analytic Path Loss Models in On-Body Wireless Communications*, 2014 International Workshop on Antenna Technology, (2014)

R. Martens, D. Manteuffel, *Systematic Design Method of a Mobile Multiple Antenna System Using the Theory of Characteristic Modes*, IET Microwaves, Antennas and Propagation, **vol. 8, issue 12**, 887 - 893 (2014)

Y. Chen, R. Martens, R. Valkonen, D. Manteuffel, *A Varactor-Based Tunable Matching Network for a Non-Resonant Mobile Terminal Antenna*, 8th European Conference on Antennas and Propagation, 2225 - 2229 (2014)

E. Safin, D. Manteuffel, *Influence of the Impedance Matching on the Characteristic Wave Modes*, 8th European Conference on Antennas and Propagation, 1323 - 1327 (2014)

M. Grimm, D. Manteuffel, *Far Field Modelling of Body Worn Antennas by the Superposition of Equivalent Electric Sources*, 8th European Conference on Antennas and Propagation, 1754 - 1755 (2014)

R. Valkonen, A. Lehtovuori, D. Manteuffel, *Capacitive Coupling Elements - Changing the Way of Designing Antennas*, 8th European Conference on Antennas and Propagation, 209 - 213 (2014)

R. Martens, D. Manteuffel, *Mobile LTE-A Handset Antenna Using a Hybrid Coupling Element*, IEEE Antennas and Propagation Society International Symposium, 1419 - 1420 (2014)

T. Hadamik, R. Martens, D. Manteuffel, *Systematic Broadband Multiport Antenna Design based on a Characteristic Mode Analysis*, COST IC1 102, 6. WG Meeting and Technical Workshop, (2014)

M. Grimm, D. Manteuffel, *Body Worn Antenna System for Health Care related On- and Off-body Communication*, 4th International Conference on Wireless Mobile Communication and Healthcare, (2014)

R. Martens, Y. Chen, D. Manteuffel, *Tunability Comparsion of a Capacitive Coupling Element and a Planar Inverted-F Antenna,* Loughborough Antennas and Propagation Conference, 667 - 668 (2014)

## Further Activities and Events

Prof. Manteuffel has the following responsibilities:

VDE ITG Fachauschschuss 7.1 ''Antennen'': appointed national committee member,

EurAAP (European Association on Antennas and Propagation): member of the Board of Directors,

EurAAP WG on Small Antennas: chairman of the working group,

IEEE AP-S AdCom member (term 2013 - 2015),

ESoA - European School of Antennas: member of the board of directors,

Standardization: ICES working group TC34 member,

Editor of the IET Proceedings on Microwave, Antennas and Propagation and IEEE Transactions on Antennas and Propagation.

Steering Committees and Technical Programme Committees.

In 2014 Prof. Manteuffel served on the Technical Programme Committees of the following events: chairman, iWAT 2014 (International Workshop on Antenna Technology), member, EuCAP 2014 ( European Antennas and Propagation Conference), member, LAPC 2014 (Loughborough Antennas and Propagation Conference), member, ISAP 2014 (International Symposium on Antennas and Propagation).

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# Institute for Materials Science

The Institute for Materials Science consists of 9 professorships, 2 honorary professorships, and one adjunct professorship. The Institute offers 2 degree programmes, a B.Sc. course ''Materials Science'' (173 students) and an M.Sc. course ''Materials Science and Engineering'' (147 students) with still increasing student numbers and a relatively high percentage of female students (up to 29 % ). The establishment of a new degree programme in ''Business Materials Science'' is planned to start in the autumn term of 2016 in cooperation with the Faculty of Economics. Financial revenue intended to promote university teaching resulted from the funds of the *Hochschulpakt*. In 2014, these essential funds were budgeted for the replacement of scientific equipment used in the basic lab courses, to ensure that in the future the excellent training of students can be continued. Moreover, funds for enhancing the international visibility of the Institute were provided, which supports the marketing of the international M.Sc. Course by developing and designing new advertising for several countries.

Prof. Dr. Helmut Föll retired from his teaching duties at the end of October 2014. Consequently, the focus of this year's summer festival was on his farewell. Prof. Föll was highly active in several leading positions, most notably as the founding and elected dean of the Technical Faculty from 1991-1998. In this context, completely new structures have been created, including the study courses and the global budget of the faculty. This work was fundamental to the success of today's faculty. For his outstanding achievements Prof. Föll received the Golden Badge of Honour of the University. The Institute thanks Prof. Föll for his great and pioneering work over the last twenty-five years, including his great scientific achievements, and for chairing the General Materials Science group.

Prof. Dr. Regine Willumeit-Römer was appointed in September 2014 as Professor for ''Biological Interfaces of Implants''. Her research focus lies on the development of degradable metallic implants based on magnesium. Besides the optimization of the material, a strong emphasis is on the interaction with the biological environment: how does the degrading material stimulate the formation of bone and how do biological parameters influence the degradation? Common projects exist between CAU and the Helmholtz-Zentrum Geesthacht, *Zentrum für Material- und Küstenforschung in Geesthacht (HZG)*, where Prof. Willumeit-Römer is director of the ''Metallic Biomaterials' ' division of the Institute of Materials Research.

In 2014, the members of the Institute for Materials Science were again very successful as indicated by their receiving scientific awards, by scientific networking, and by attracting outstanding third-party funds. Of particular note here are the interdisciplinary projects and awards involving staff of the Institute:

- The package proposal 902 (coordinator (Sprecher): Prof. Dr.-Ing. Eckhard Quandt) is funded by the German Research Foundation. 16 working groups of the CAU, including the University Hospital Schleswig-Holstein (UKSH) and the Fraunhofer Institute for Silicon Technology (ISIT), jointly explore new sensors for medical diagnostics. Particular emphasis is on sensors for magnetoencephalography (MEG) and magnetocardiography (MKG) that do not require cooling and magnetic-field shielding.

- The research unit 2093 ''Memristive Devices and Neuromorphic Circuits'' (coordinator (Sprecher): Prof. Dr. Hermann Kohlstedt) aims to simulate learning and memory processes of the human brain technically. The memristive devices offer an interesting approach to build electronic circuits closer to their biological counterpart than anything ever developed previously. The interdisciplinary collaboration between neurology, systems theory, as well as materials science and nanotechnology includes scientists from the Ruhr-University Bochum, the Technical University of Hamburg-Harburg, the Helmholtz Institute Ulm, and the CAU.

- Prof. Dr. Christine Selhuber-Unkel received a Feodor Lynen fellowship from the Humboldt foundation for a research stay at Cornell University, where she worked on the project ''Biophysical investigation of bacterial symbiosis in a model insect system'' together with Prof. Chris Ober (Materials Science), Prof. Jan Lammerding (Bioengineering), and Prof. Angela Douglas (Entomology).

- Prof. Dr. Rainer Adelung was voted by the Graphene Flagship as an official partner, contributing with a scientific project.
- Prof. Dr. Mady Elbahri was awarded several scientific prizes, particularly the distinction prize of the Ministry of Higher Education (Egypt), the honour certificate of the Egyptian Cultural and Educational Mission at the Egyptian embassy in Berlin, and the Kajal Mallick Memorial Award by the Institution of Civil Engineering (UK).

## Results

The high scientific quality of the Institute's members became visible in 2014 by several excellent high profile scientific results that are briefly summarized below. Further details can be found in the chapters of the respective groups.

- The stability, reliability, and fatigue mechanisms of thermoelectric materials were thoroughly investigated by the group Synthesis and Real Structure headed by Prof. Dr. Lorenz Kienle. In</latex> *situ* and *ex situ* electron microscopy investigations (cf. recent papers in Chemistry of Materials and Dalton Transactions) highlight the impact of thermal fatigue on material performance - an important, yet frequently overlooked aspect of energy-material science.
- The Chair for Multicomponent Materials held by Prof. Dr. Franz Faupel reported very interesting results on the diffusion behaviour of multicomponent glass-forming metallic melts. The group showed that these technologically important melts exhibit marked deviations from the dynamics of ordinary multicomponent melts and liquids, where, according to a widely accepted theory by Einstein, the atoms of all components should diffuse with almost the same velocity. The results were published in Physical Review Letters.
- A major advance in magneto-optical magnetic domain imaging was achieved in the group Nanoscale Magnetic Materials - Magnetic Domains headed by Prof. Dr. Jeffrey McCord. Imaging of magnetic domain and domain wall activity with picosecond time-resolution was demonstrated and used for the direct imaging of domain wall motion and spin waves. The method and results were published in Physical Review B.
- Fast reacting and highly sensitive ZnO UV-sensors were formed in a rapid fabrication process by the group of Prof. Dr. Rainer Adelung. The paper attracted broad interest and was presented as front cover story in the high-impact journal Advanced Materials.
- The Nanochemistry and Nanoengineering group headed by Prof. Dr. Mady Elbahri has developed a new type of ultrathin (15 nm) photo-driven resonant antireflection coating for tuning reversibly the optical properties of a mirror under Vis-UV illumination from reflector to absorber and vice versa. The finding was recently published in Advanced Optical Materials and highlighted as the Frontispiece. Moreover, it was selected as a Highlight in Nature Photonics. Furthermore, plasmonic metamaterials which are intended to be used for optical frequency have been demonstrated here as UV perfect absorbers. This strategy for development of tunable metamaterials for high frequency could pave the way to their application in thermo-photovoltaic, stealth Technology, and UV-protective coating. The Paper published in Applied Physics Letter has drawn the attention of the worldwide press such as "Die Welt".

## Further Activities and Events

Finally, our second joint graduation ceremony of the Institute of Electrical Engineering and Information Technology and the Institute for Materials Science was well recognized. This year the executive director of the Institute for Material Science, Prof. Dr. Lorenz Kienle, honoured the B.Sc. and M.Sc. graduates. For the first time in its research field, Kiel Nano Surface and Interface Science awarded Ph.D. prizes for Electrical Engineering and Materials Science. The candidate from our Institute, Dr. Enno Lage, was honoured for his outstanding work on new sensor concepts that can detect tiny magnetic fields. Before the actual ceremony, Prof. Dr. Jeffrey McCord presented laboratory tours in order to demonstrate to the interested general

public some of the current research topics at the institutes. Following the solemn ceremony, the *Förderverein* and the Institutes were invited to a social gathering in the cafeteria.

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# Biocompatible Nanomaterials

Using an interdisciplinary approach, research in the group "Biocompatible nanomaterials" focuses on investigating cell-material interactions by combining methods from materials science, physics, chemistry, and biology. Our long-term goal is to control living cells with nano- and microstructures on levels ranging from single molecules to many cells. Furthermore, we develop methods to quantitatively investigate cell adhesion mechanobiology. Experiments include force microscopy techniques and optical microscopy. Due to excellent funding from our ERC Starting Grant "Cell-inspired: Mechanotransduction mediating cell adhesion - towards cell-inspired adaptive materials", Hendrikje Neumann and Michael Timmermann started their Ph.D. theses in our group last year. Furthermore, in March 2014, Julia Reverey was the first student in the group to finish her Ph.D. on the topic "Biophysical Studies of Processes Involved in Acanthamoeba Infections: Contact Lens Contamination, Adhesion and Intracellular Dynamics".

## Results

### Influence of PDMS Substrate Stiffness on the Adhesion of *Acanthamoeba castellanii*

An essential mechanism present in all cell types is adhesion. It epitomizes the workings of the immune system and is of major relevance for the operation of biological systems and tissues. Mechanosensing has been investigated comprehensively for mammalian cells, particularly the cellular response to substrates with different elastic properties. So far, no attention has been paid to a mechanosensing mechanism in human pathogens. It is of interest that the main targets of *Acanthamoeba castellanii* infections in the human body are soft environments of lower Young's moduli, i.e. the eyes and brain. To determine the complexity of adhesion, we fabricated polydimethylsiloxane (PDMS) substrates with different elasticities by varying the amounts of crosslinkage. We find that the adhesion area of *Acanthamoeba castellanii* is largest on the softest substrates (Figure 3). Therefore, our study provides first evidence of the relevance of mechanical aspects in the pathogenicity of eukaryotic parasites.

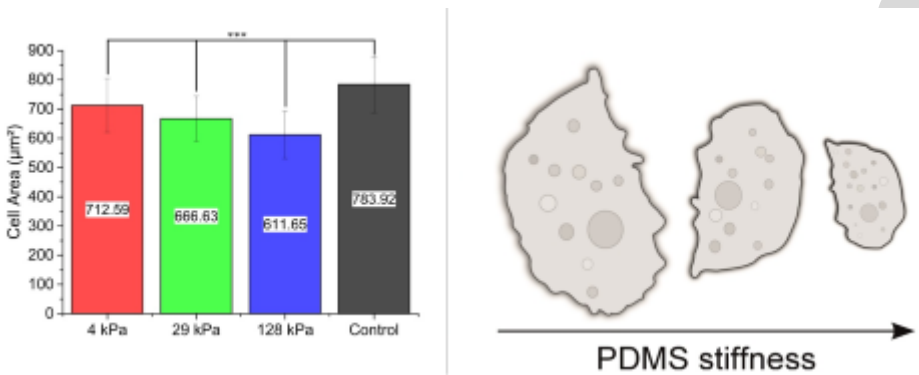


Fig. 3: (left) Cell adhesion area (error bars: standard deviation) of *Acanthamoeba castellanii* as a function of Young's modulus of PDMS substrates in comparison to control tissue culture substrates after 1 h of adhesion. Differences in cell adhesion area are statistically significant (Kruskal-Wallis test; ***, $p < 0.001$). (right) Schematic of *Acanthamoeba castellanii* adhering to substrates of different stiffnesses and their changing adhesion areas.

This project is funding by Emmy-Noether (DFG).

### Carbon nanotubes as tumour targeting photoacoustic molecular imaging agent

Carbon nanotubes (CNTs) have attracted much attention as multimodal platforms in drug delivery and in diagnostics on the molecular level. Having nanoscale dimensions, water soluble CNTs can cross biological barriers, such as cell membranes. Their high surface area facilitates attachment of multiple copies of different agents, such as drugs and targeting molecules.

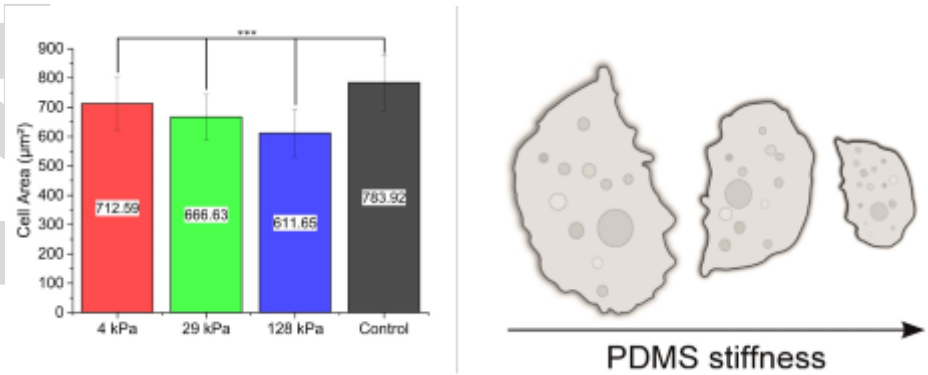


Fig. 3: (right) Schematic of *Acanthamoeba castellanii* adhering to substrates of different stiffnesses and their changing adhesion areas. (left) Cell adhesion area (error bars: standard deviation) of *Acanthamoeba castellanii* as a function of Young's modulus of PDMS substrates in comparison to control tissue culture substrates after 1 h of adhesion. Differences in cell adhesion area are statistically significant (Kruskal-Wallis test; ***, $p < 0.001$).

An intrinsically strong photoacoustic signal renders CNTs as promising candidates as a tumour-targeting photoacoustic contrast agent. In a pilot study we were able to show that CNTs can be visualized validly with a preclinical photoacoustic imaging system. Furthermore we demonstrated selective targeting of $\alpha_v\beta_3$ on human squamous cell carcinoma (SCC9) cells *in vitro* with cRGD functionalized CNTs. The integrin $\alpha_v\beta_3$ is a well-established tumour marker which is highly overexpressed in a number of solid tumours. Currently we are investigating this CNT-based targeting approach for *in vivo* visualization of $\alpha_v\beta_3$ expression in primary and recurrent orthotopic oral carcinomas.

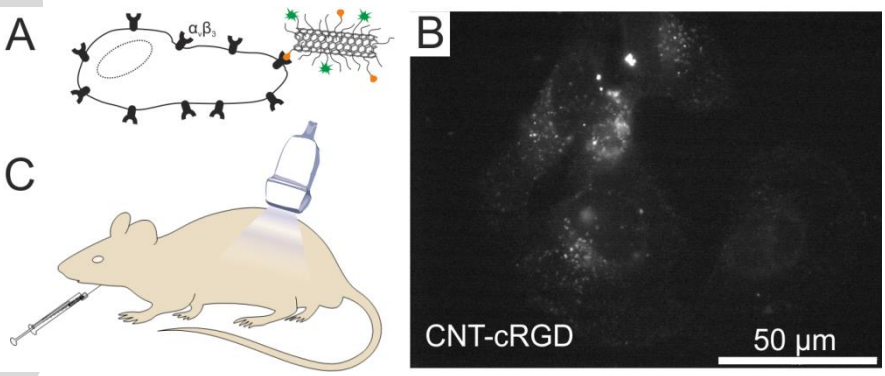


Fig. 2: Figure: (A) Selective binding of Alexa488-cRGD functionalized CNTs to $\alpha_v\beta_3$ integrins on the membrane of SCC9 cells. (B) Fluorescence image ($\lambda$ex = 488nm, $\lambda$em = 512nm) of live SCC9 cells targeted with fluroescntly labeled CNTs. (C) Schematic outlook: for in vivo visualization of tumours in mice using CNTs as tumour targeting photoacoustic imaging agent.

**Improving cardiomyocyte adhesion and proliferation on polyurethane cardiac patches by gold nanowires**

To repair and regenerate heart muscle tissue after myocardial infarction (MI), tissue engineering approaches are desired which provide materials that can improve the adhesion of cardiomyocytes and provide electrical coupling of them. In this study, we produced polyurethane-gold nanocomposites in which gold nanotubes and nanowires (PU-GNT/NW) mimic the electromechanical properties of myocardium and have the potential to improve the interaction of cells due to enhanced conductivity in the micro-environment. H9C2 rat cardiomyocyte cells were seeded onto the composites and electrical stimulation was applied. Cell morphology and proliferation were examined with fluorescence microscopy and scanning electron microscopy. Cells that adhered to PU-GNT/NW and were stimulated electrically, showed a more native morphology and higher proliferation rates. RT-PCR revealed that functional gene expression levels of myocardium are upregulated on

PU-GNT/NW scaffolds after electrical stimulation.

This project was supported by a travel grant from the Boehringer Ingelheim Fonds.

**" Graphite4Med"**

In this project we are testing potential biomedical applications of the ultra-lightweight, porous, carbon-based material Aerographite (AG) with special focus on its feasibility as a substrate for tissue engineering. We were able to overcome the inherent hydrophobicity of AG by proper surface functionalization with amine terminated poly(ethylene glycol) biopolymers that made the material hydrophilic. Exploiting the amine terminus of the biopolymers, we introduced cell adhesion promoting c(-RGDyK-)-peptides onto the AG surface that led to specific attachment of rat fibroblasts (connective tissue) on the scaffold material. Cell growth and multiplication were monitored over the course of 4 days and revealed a progressive invasion of cells into the scaffold. Currently, we are testing and comparing the compatibility of unfunctionalized and biofunctionalized AG with different tissues, including lung epithelial cells, osteoblasts (bone precursor cells), and undifferentiated neuronal cells. Initial results show no cytotoxic effect on lung epithelial and fibroblast cells for short-term contact with properly functionalized AG.

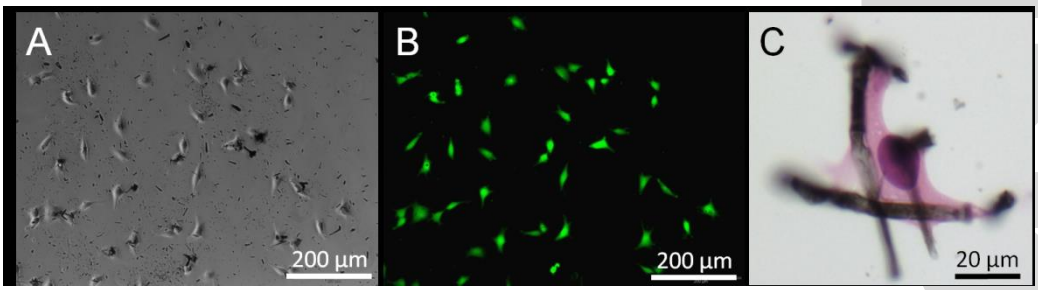


Fig. 1: (A) Brightfield microscopy image of live, human lung epithelial cells after 4 days of exposure to fragmented biofunctionalized Aerographite. (B) Fluorescence image of the same area in A showing strong green fluorescence of viable cells after calcein live/dead staining, indicating short term biocompatibility. (C) Hämalaun/Eosin stained section of a fibroblast cell in contact with filaments of Aerographite, which was functionalized with cell adhesion-promoting c(-RGDyK-)-peptides. The cell body appears in red and the cell nucleus is stained blue.

This project is supported by Marie Curie Actions-Intra-European Fellowships (IEF).

## Personnel

Head of the group: Prof. Dr. C. Selhuber-Unkel; Secretary: E. Riemer (50%)
Technical Staff: Dipl.-Ing. M. Lieb (50%)

Scientific Staff:

| | | |
|---|---|---|
| Dr. C. Grabosch | 01.01.-31.10.2014 | CAU |
| Mechanosensitive polymer materials | | |
| Dipl.-Chem S. Gutekunst | 01.01.-31.12.2014 | DFG |
| A nanobiophysical Approach to Elucidate Target-Cell Killing by amoebic parasites. | | |
| M. Sc. L. Kadem | 01.01.-31.12.2014 | DFG |
| SFB 677, Teilprojekt B11, Schaltbare Zelladhäsion | | |
| Dr. C. Lamprecht | 01.01.-31.12.2014 | Marie Curie Actions-IEF |
| Graphite4Med-Atomic force microscopy on single molecules and live cells/Graphite4Med-Aerographite as scaffold material for regenerative medicine | | |

| | | |
|---|---|---|
| M. Sc. Q. Li<br>CellInspired | 01.01.-31.12.2014 | CAU / EU |
| Dipl.-Chem H. R. Neumann<br>Force sensors for the local analysis of cell adhesion and force spectroscopy | 01.03.-31.12.2014 | EU |
| M. Sc. J. Reverey<br>CellInspired | 01.01.-31.07.2014 | EU |
| Dr. T. Tellkamp<br>CellInspired | 01.11.-31.12.2014 | EU / CAU |
| M. Sc. M. Timmermann<br>CellInspired | 01.-31.12.2014 | EU |
| Dr. S. Viebig<br>Biocompatibility studies | 01.01.-30.04.2014 | CAU |
| Dr. W. Wang<br>CellInspired | 01.05.-31.12.2014 | CAU / EU |

## Lectures, Seminars, and Laboratory Course Offers

*Winter 2013/2014*

Bioinspirierte Materialien, 2 hrs Seminar/Week,
C. Selhuber-Unkel

Cell Mechanics, 2 (+ 2) hrs Lecture (+ Exercises)/Week,
C. Selhuber-Unkel

Chemistry and Physics of Biomaterials, 3 (+ 1) hrs Lecture (+ Exercises)/Week,
C. Selhuber-Unkel (+ C. Grabosch, C. Lamprecht)

Biokompatible Nanomaterialien, 2 hrs Seminar/Week,
C. Selhuber-Unkel

*Summer 2014*

Bioinspired Materials, 2 hrs Lecture/Week,
C. Selhuber-Unkel

Nano Medicine, 2 hrs Lecture/Week,
C. Lamprecht

Biokompatible Nanomaterialien, 2 hrs Seminar/Week,
C. Selhuber-Unkel

*Winter 2014/2015*

Cell Mechanics, 2 (+ 2) hrs Lecture (+ Exercises)/Week,
C. Selhuber-Unkel

Chemistry and Physics of Biomaterials, 3 (+ 1) hrs Lecture (+ Exercises)/Week,
C. Selhuber-Unkel (+ C. Grabosch, C. Lamprecht)

Biokompatible Nanomaterialien, 2 hrs Seminar/Week,
C. Selhuber-Unkel

Materialwissenschaft 1, 3 (+ 1) hrs Lecture (+ Exercises)/Week,
C. Selhuber-Unkel

## Third-Party Funds

DFG, *Sachbeihilfe zur Einrichtung einer Nachwuchsgruppe im Emmy Noether-Programm zum Thema: A nanobiophysical approach to elucidate target-cell killing by amoebic parasites*, 01.06.2010-30.05.2015 (1.244.542 Euro)
DFG, *Schaltbare Zelladhäsion: SFB 677/B11*, 01.07.2011-30.06.2015 (237.600 Euro)
Marie Curie IEF, *Graphite4Med - Aerographite as scaffold material for regenerative medicine*, 01.04.2013-31.03.2015 (161.968,80 Euro)
EU, *CellInspired: Mechanotransduction mediating cell adhesion - towards cell-inspired adaptive materials*, 01.09.2013-31.08.2018 (1.467.483 Euro)
Alexander von Humboldt Stiftung, *Feodor Lynen Research Fellowship*, 01.04.-30.06.2014 (ca. 16.000 Euro)
Wilhelm und Else Heraeus-Stiftung, *Klausurtagung in Aabenraa*, 07.-10.09.2014 (2.074,28 Euro)
DAAD Scholarship, *Research Grant for Doctoral Candidates*, 10.10.2014-30.09.2015 (14.625 Euro)

## Further Cooperation, Consulting, and Technology Transfer

The group has cooperated in work with the following individuals and organizations:

Prof. D. Adam, UKSH: adhesion forces of Jurkat cells on biopolymer surfaces,
Prof. R. Adelung, Universität Kiel, Lehrstuhl für Funktionale Nanomaterialien: Aerographite for medical applications,
Dr. R. Fromme, Wöhlk Contactlinsen, Schönkirchen,
Prof. M. Gerken, Universität Kiel, Lehrstuhl für Integrierte Systeme und Photonik: cell adhesion on photonic crystals,
Prof. S. Gorb, Universität Kiel, Zoologisches Institut: common projects on investigating adhesion with AFM,
Dr. med. C. Heneweer, UKSH, Klinik für Radiologie und Neuroradiologie: Carbon nanotubes as tumour targeting photoacoustic molecular imaging agent,
Prof. R. Herges, Prof. T. K. Lindhorst, Universität Kiel, Otto-Diels-Institut: Switchable cell adhesion (SFB 677 ''Function by switching''),
Prof. M. Leippe, Universität Kiel, Zoologisches Institut: Characterizing Biophysical properties of amoebae,
Prof. R. Metzler, University of Potsdam, Dr. Jae-Hyung Jean, University of Tampere, Finland: diffusion and ageing in cells,
Prof. G. Multhoff, Dr. M. Gehrmann, TU Munich, Klinikum rechts der Isar, Department Radiation Oncology: Role of cell adhesion in highly invasive tumors.
Prof. E. Quandt, Universität Kiel, Lehrstuhl für Anorganische Funktionsmaterialien: NiTi and magnesium thin films.
Prof. K. Schwarz, Dr. Y. Serfert, Dr. J. Keppler Universität Kiel, Institut für Humanernährung und Lebensmittelkunde: AFM characterization and investigation of functional food ingredients.

## Diploma, Bachelor's and Master's Theses

G. Zoch, *The influence of different nanostructures on the adhesive properties of Acanthamoeba castellanii (M.Sc.)*, 14.01.2014
K. Siemsen, *Adhesion of acanthamoeba on microstructured pillar substrates (B.Sc.)*, 04.03.2014
H. Westerhaus, *Einfluss der manuellen hygienischen Aufbereitung auf die Biokompatibilität von Medizienprodukten aus polymeren Werkstoffen (B.Sc.)*, 27.03.2014
B. Spetzler, *Microfluidic investigation of Jurkat cell adhesion (B.Sc.)*, 15.09.2014

B. Groß, *Influence of silver particles and silver ions on adhesion and growth of Acanthamoeba castellani (B.Sc.)*, 28.09.2014

S. Sindt, *Micro- nanostructured surfaces for studying acanthamoeba adhesion (B.Sc.)*, 09.10.2014

A. Möhring, *Synthesis and characterization of microporous hydrogel materials for three-dimensional Traction force microscopy on cells (M.Sc.)*, 16.12.2014

## Dissertations / Postdoctoral Lecture Qualifications

J. Reverey, *Biophysical Studies of Processes Involved in Acanthamoeba Infections: Contact Lens Contamination, Adhesion and Intracellular Dynamics*, 21.03.2014

## Publications

Published in 2014

S. B. Gutekunst, C. Grabosch, A. Kovalev, S. N. Gorb, C. Selhuber-Unkel, *Influence of PDMS Substrate Stiffness on the Adhesion of Acanthamoeba castellanii*, Beilstein J. Nanotechnol., **5**, 1393 - 1398 (2014)

Y. Serfert, C. Lamprecht, C.-P. Tan, *Characterization and use of $\beta$-lactoglobulin fibrils for microencapsulation of lipophilic ingredients and oxidative stability thereof*, Journal of Food Engineering, **143**, 53 - 61 (2014)

J. Reverey, R. Fromme, M. Leippe, C. Selhuber-Unkel, *In vitro adhesion of Acanthamoeba castellanii to soft contact lenses depends on water content and disinfection procedure.*, Contact Lens & Anterior Eye, **37(4)**, 262 - 266 (2014)

C. Lamprecht, P. Hinterdorfer, A. Ebner, *Applications of biosensing atomic force microscopy in monitoring drug and nanoparticle delivery*, Expert Opinion on Drug Delivery, **11(8)**, 1237 - 125 (2014)

C. Lamprecht, B. Plochberger, V. Ruprecht, *A single- molecule approach to explore binding, uptake and transport of cancer cell targeting nanotubes*, Nanotechnology, **25(12)**, 125704 - 125704 (2014)

## Presentations

C. Selhuber-Unkel, *Biophysics of cell adhesion on micro-nanostructures surfaces (invited talk)*, Ringvorlesung, Hamburg, Germany, 08.-08.01.2014

C. Lamprecht, *Aerographit für biomedizinische Anwendungen (invited talk)*, Daimler und Benz Stiftung, Ladenburg, Germany, 16.-16.01.2014

C. Lamprecht, *Investigation of biocompatible nanomaterials and their interaction with cells (invited talk)*, University of Heidelberg, Kirchhoff Institute of Physics, Heidelberg, Germany, 17.-17.01.2014

S. B. Gutekunst, C. Selhuber-Unkel, *Hydrogel based force sensors for 3D traction force microscopy (poster)*, Linz Winter Workshop 2014, Linz, Austria, 30.01.-03.02.2014

C. Lamprecht, Y. Serfert, C.-P. Tan, E. Appel, C. Selhuber-Unkel, K. Schwarz, S. Drusch, *AFM characterization of $\beta$-lactoglobulin fibrils for incorporation in functional foods (poster)*, Annual Linz Winter Workshop, Johannes Kepler Universty Linz, Linz, Austria, 31.01.-03.02.2014

L. Kadem, C. Selhuber-Unkel, *Regulating Cell Adhesion at the Nanoscale on Microtopographic Substrates (talk)*, New Materials and Biosystems, Antholz, Italy, 09.-14.03.2014

S. B. Gutekunst, J. Reverey, C. Selhuber-Unkel, *Influences of Polymer Properties on Cell Adhesion (talk)*, Seminar New Materials and Biosystems, Antholz, Italy, 09.-15.03.2014

Q. Li, D. Adam, C. Selhuber-Unkel, *Modulation of T-lymphocyte adhesion forces by activation with TNF (poster)*, Euro AFM Forum, Göttingen, Germany, 17.-19.03.2014

C. Lamprecht, *Aerographite for biomedical Applications (talk)*, DPG-Frühjahrstagung der Sektion Kondensierte Materie (SKM), Technische Universität Dresden, Dresden, Germany, 30.03.-04.04.2014

Q. Li, D. Adam, C. Selhuber-Unkel, *Modulation of T-lymphocyte adhesion forces by activation with TNF (talk)*, Spring Meeting of DPG, Dresden, Germany, 30.03.-04.04.2014

L. Kadem, J. Purtov, C. Lamprecht, C. Selhuber-Unkel, *Microtopographic Substrates for Controlling Cell Adhesion at the Nanoscale (talk)*, DPG Conference, Dresden, Germany, 30.03.-04.04.2014

S. B. Gutekunst, C. Grabosch, C. Selhuber-Unkel, *Controlling adhesion of Acanthamoeba castellanii by substrate stiffness (poster)*, DPG-Frühjahrstagung der Sektion Kondensierte Materie (SKM), TU Dresden, Dresden, Germany, 30.03.-04.04.2014

C. Lamprecht, *AFM force spectroscopy - From single molecules to cell-cell contact (invited talk)*, TU Munich, Klinikum rechts der Isar, Munich, Munich, Germany, 28.-28.07.2014

L. Kadem, G. Suana, Q. Li, M. Holz, R. Herges, C. Selhuber-Unkel, *Photoswitchable Cell Adhesion on Azobenzene Coated Substrates (poster)*, SFB677 Summer School, Mölln, Germany, 05.-06.08.2014

C. Selhuber-Unkel, *Intracellular motion in Acanthamoeba castellanii (invited talk)*, Condensed Matter Physics, Paris, France, 24.-26.08.2014

L. Kadem, J. Purtov, C. Lamprecht, C. Selhuber-Unkel, *Regulating Cell Adhesion at the Nanoscale on Microtopographic Substrates. (talk)*, Materials Science and Engineering Conference, Darmstadt, Germany, 23.-25.09.2014

C. Lamprecht, *Atomic force microscopy in cancer research (invited talk)*, Seminar of the SFB 850 Control of Cell Motility in Morphogenesis, Cancer Invasion and Metastasis, University Freiburg, Freiburg, Germany, 24.-24.10.2014

C. Selhuber-Unkel, *Investigating dynamic processes in parasitic Acanthamoeba (invited talk)*, 11th Japanese-German Frontiers of Science Symposium, Bremen, Germany, 30.10.-02.11.2014

C. Lamprecht, C. Grabosch, S. Gutekunst, C. Selhuber-Unkel, N. Purcz, C. Heneweer, *Carbon nanotubes as tumour targeting photoacoustic molecular imaging agent (poster)*, MOIN CC Symposium, Christian-Albrechts-University Kiel, Kiel, Germany, 31.-31.10.2014

S. B. Gutekunst, C. Grabosch, J. Reverey, C. Selhuber-Unkel, *Hydrogel based force sensors for 3D traction force microscopy (poster)*, MRS Fall Meeting and Exhibit, Hynes Convention Center, Boston, USA, 29.11.-05.12.2014

L. Kadem, J. Purtov, C. Lamprecht, C. Selhuber-Unkel, *Microtopographic Control of Nanostructure Self-Assembly (poster)*, Materials Research Society Meeting, Boston, USA, 30.11.-05.12.2014

Q. Li, D. Adam, C. Selhuber-Unkel, *Cell adhesion forces and mechanotransduction after TNF stimulation (talk+poster)*, Sixth AFMBioMed Conference, San Diego, USA, 13.-17.12.2014

## Further Activities and Events

C. Lamprecht: Guest lecturer at the seminar ''New Technologies'', M.Sc. programme, Medical Life Sciences, CAU, 30.04.2014

C. Lamprecht: Best Poster Award at MOIN CC, Symposium, Christian-Albrechts-University Kiel, Kiel, Germany, 31.10.2014

C. Selhuber-Unkel: JAGFOS 2014 (Japanese-German Frontiers of Science Symposium, Alexander von Humboldt Foundation): Conference co-chair and Session chair ''Chemistry / materials science'', Bremen, Germany, 30.10.-02.11.2014

C. Selhuber-Unkel: Research Fellowship, Arvo Foundation for Eye Research

C. Selhuber-Unkel: Feodor Lynen fellowship for experienced scientists from the Alexander von Humboldt Foundation for a research stay at Cornell University, Ithaca, NY Project: Biophysics of symbiosis

C. Selhuber-Unkel: Co-coordinator of a proposal for the Graduate school ''Materials for Brain''

Guest in 2014:

L. Stevenson: Blood cell adhesion on biofuntionalized nanostructures, University of Copenhagen, Denmark, 01.-15.06.2014.

Wilhelm-Elise-Heraeus Group Retreat

In the late summer of 2014, the members of our interdisciplinary team got the chance to organize a group retreat to Aabenraa, Denmark, with the kind support of the Wilhelm and Elise Heraeus-Foundation. From the 7th to the 9th of

September, 17 postdocs, Ph.D., M.Sc., B.Sc. students, co-workers, and the group leader travelled to the countryside of southern Denmark for an interdisciplinary and intercultural knowledge exchange to improve team spirit and intragroup collaborations. Every day, during morning and lunchtime sessions, presentations and discussions of current projects led to the development of new projects and future plans of cooperation, while the afternoons were reserved for a group trip to the harbour or a collective stroll through the inner city. A GeoCaching session in the city of Aabenraa served as the main event of our gathering. It was a great chance to solve different tasks in small groups. In a competition to find the GPS-coordinates of an unknown target, we got to know more about our group´s dynamics, structures, and ways of team-building. In our final victory ceremony, the best group was honoured. After a slideshow summary of the previous days, we finished our retreat with new motivation for future projects and a deepened sense of team spirit.

# Electrochemistry of Metallic Biomaterials

Since 01.03.2014 ''Electrochemical of Metallic Biomaterials'' has been a shared professorship with the Helmholtz-Zentrum Geesthacht, Zentrum für Material- und Küstenforschung in Geesthacht (HZG). HZG is a member of the Hermann von Helmholtz-Gemeinschaft Deutscher Forschungszentren (HGF). Prof. Dr. Mikhail Zheludkevich is professor at the Institute of Materials Research.

Prof. Dr. Mikhail Zheludkevich
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Email: mikhail.zheludkevich@hzg.de
http://www.hzg.de/institutes_platforms/materials_research/magnesium_technology/corrosion_and_surface_technology/staff/055052/index.php.de and

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Technische Fakultät, Institut für Materialwissenschaft
Kaiserstr. 2, Geb. F, Rm 101
24143 Kiel

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# Functional Nanomaterials

2014 was a very productive year for the Functional Nanomaterials group as can be seen below. There are contributions from the group members covering findings, research topics, publications, patents, lectures, and technology transfer projects. Several published contributions were very high profile in 2014 both in the international research community and beyond, e.g. the March front cover story in Advanced Materials that reported on the rapid fabrication of fast UV-sensors or the review article in KONA that made it to the front cover in January and reported about the recent findings of the group in the field of flame transport synthesis of ZnO micro/nanoparticles and their application. Overall the group was highly productive; in research this resulted in more than twelve publications in international research journals and in five proposed research projects receiving funding. Those research projects reflect nicely the breadth of the group. Three basic research projects will be carried out in the framework of DFG (''Deutsche Forschungsgemeinschaft'' (German Research Foundation)) funding, which are all included in collaborative projects: firstly in the framework of the new research Unit FOR 2093 ''Memristive Bauelemente für neuronale Schaltungen'' dealing with memresistive elements, and secondly in the framework of the PAK 902 consortium which develops magnetic field sensors. Both consortia are highly interdisciplinary with collaboration between electrical engineering and medical science departments. Technology transfer is the focus of the 2 other new projects, both funded by the BMWi, the federal ministry concerned with economic affairs and energy. Within the project ''Nano-WWZ'', coatings for the bases of offshore wind turbines are being developed, and the project ''Nanomet'' is focused on multifunctional polymer foils.

After the retirement of Prof. Föll, the group fused with the members of the permanent AMAT group which is now officially part of the Chair for Functional Nanomaterials. The group reached its largest expansion of all at the end of the year: 23 members were employed, either by third party or by federal state funds. New office and lab space was found in the former rooms of Prof. Föll in building A. However, due to the large amount of third party funds the office space is insufficient, so consequently, 5 more desks are still located in building F. In 2014, the group expertise was expanded towards biology, especially with Dr. Martina Baum, one of the new researchers that joined the group. This is particularly helpful within the BMWi project ''Nano-WWZ'', dealing with antifouling properties. Further details are given below.

The large size of the group allowed various lectures, lab classes, and seminars to be offered as well as the highest number of supervisions of M.Sc. and B.Sc. theses in the institute. Beside scientific conference contributions several public lectures were given, e.g. during the night of the profs 2014 or the ''Kieler Uni Live'', both with large public participation.

## Results

Only a small selection of the overwhelming total scientific output of the group in 2014 can be given here. In general, the work of the group finds increasing interest by the scientific community: in 2014, its research papers were cited more than 300 times in other publications. Besides the research publications, two patent applications express possibilities in the technology transfer projects; in the following, three selected examples should give a more detailed insight into the research and technology transfer projects carried out by the group. Most importantly, the output of the group is based on its Ph.D., M.Sc., and B.Sc. theses. All the findings and achievements in the research projects are some of the most important parts of student education but this is only possible when up-to-date projects are funded by third parties.

### Advanced Adhesion concepts for polymers by micro interlocking

A very basic problem in materials science is adhesion. Whenever a simple static problem is solved by employing two materials (e.g. one bearing compression, the other tensile loads), or a composite material is created doing the same on the microscale, or a functional layer is added to a static material, an interface between two different materials has to be formed. The strongest bonds that can be formed between materials are covalent, ionic, or metallic but typically such bindings cannot be achieved if two materials are joined that come directly from the shelf because they already have unreactive surfaces consisting of saturated bonds. Furthermore, without vacuum or other protection methods reactive

surfaces with broken bonds would not be storable or processable under ambient conditions; they would tend to passivate themselves. Only by harsh techniques like welding, in which two metals are partially decomposed by a melting process, can strong bonds be formed between the materials. Therefore, conventional standard glues that are used to connect different materials provide only the weak van der Waals bonds to both surfaces. Figure 1 illustrates this. Figure 1a shows that a small surface roughness is enough to effect a gap between two materials allowing no larger adhesion surface and resulting in negligible total van der Waals force between such materials. Figure 1b shows the effect of glue: for standard applications this can be strong enough as a glue levels the roughnesses on both sides, and in such a way, creates a flat surface that finds a large area of effectively acting van der Waals force. By increasing the surface with normal roughening techniques like sand blasting or cutting, larger surface areas are created and higher forces hold both materials together, see figure 1c. However, if much higher strength is required, mechanical interlocking is necessary as illustrated in figure d. Even if the adhesion between the glue and the material is weak, to separate both parts a crack along one of the dashed lines is necessary. This requires an adhesive failure, meaning that covalent bonds have to be broken. In this way a few years ago, it was demonstrated that it is possible to connect Teflon (PTFE) and Silicon (PDMS) with the help of a mechanical interlocking agent, tetrapodal ZnO (see below). Further developments now allow the development of a silicone paint that enables silicone, one of the least adhesive materials of all, to be painted over. Figure 1e shows an optical microscopy image of the interface, where the coloured silicone is deposited on the pure silicone. The coloured zone is approximately 200 $\mu$m micrometre wide, but due to the good interlocking no peeling of the film is possible. This concept and the general considerations about adhesion were published in the magazine Macromolecular Rapid Communication. The same principle can be utilized with surface roughness made by an etching approach, as was done conventionally by the general material science group, and demonstrates how well the different research topics can be brought together. The $AlMg_3$ structures described in the ''General Materials Science'' section of Prof. Föll were subjected to lap shear tests to evaluate the adhesion performance of polyurethanes (PU) on the chemically structured $AlMg_3$ surface. Therefore, chemically structured $AlMg_3$ / polyurethane (PU) sandwich composites were prepared with grit-blasted $AlMg_3$ / PU sandwich composites as reference. These sandwich composites always showed cohesive failure in the PU. The tremendous improvement in adhesion compared to the grit-blasted $AlMg_3$ / PU reference composites is represented by a doubled maximum shear stress before failure and a 10 fold increase transversely before failure. A patent application was made by the PVA in 2014 for the pore etching method . Figure 1f demonstrates the load behaviour; the aluminium plates are deformed before failure of the polymer. From the aluminium plate, only a 30 $\mu$m deep zone was treated. This is approximately the radius of a human hair. A further demonstration is given in figure 1 h. With a 3D printer a plastic hook was printed directly onto the aluminium. Even though the hook had a base plate of just 1 $cm^2$, the image shows that it can hold easily 10 kg of water bottles. It is estimated that such a hook can easily hold more than 150 kg for each square centimetre, meaning a car could be suspended on an Area of 3 cm x 4 cm.

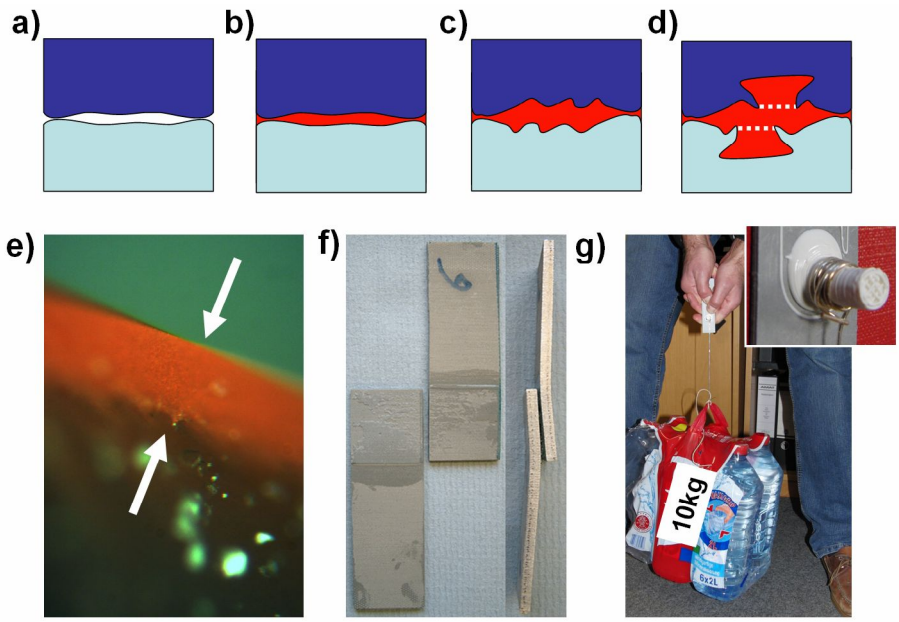


Fig. 1: Illustration for adhesion and interlocking. a) A small surface roughness is enough to effect a gap between two materials leading to almost no adhesion and negligible total van der Waals force between such surfaces will be achieved. b) For standard applications glue can be strong enough because glue levels the roughness on both sides and in such a way creates a flat surface with a large area of effectively acting van der Waals binding force. c) By increasing the effective surface area with normal roughening techniques like sand blasting or cutting, larger surface areas are created and higher forces hold both materials together. d) Only undercuts force a direct fracture of stiff materials; the whole junction system is now only limited by cohesive failure along the dashed white lines. e) Shows an adhesion system between silicones that allows the painting of silicone. At the interface, mechanical interlocking is realized by mixing tetrapod shaped ZnO into it. f) Extreme adhesion can be achieved by a surface treatment that creates undercuts by a directed etching approach (see Almanac section ''General Materials Science''). The photograph shows an Al sample that even bent before cohesive failure in the polymer occurred. g) The photograph shows a polymer hook that is printed on such an etched surface; please note that the depth of etching is approximately only the radius of a hair.

### Interpenetrating nanostructures for flexible ceramic assisted composite materials

The results from ZnO research again have excited remarkable interest; figure 2 shows three covers from articles that deal mainly with the structural and electronic properties of ZnO. Even though every year thousands of articles are published, the utilization of interpenetration to join individual ZnO structures like tetrapods as basic building blocks is relatively rare. This enables networks to be created from nanostructures that show macroscopic expansion. Most of the published articles in the group are based on the ability to join the individual ZnO structures; an optimization of flame transport synthesis now allows the fabrication of cubic centimetres of nanostructured ZnO networks in a few seconds. This breakthrough allows the material to be used in applications like fire protection. The ZnO sponge structures can handle temperatures above 1000°C and show a very low heat conductivity. It is possible to hold the extremely lightweight wool-like ZnO foam in the hand and heat it from above with a Bunsen burner without any sensible temperature increase in the palm. Applications of this ZnO as filler material in composites are very fruitful: it can be used as a low fouling surface for example.

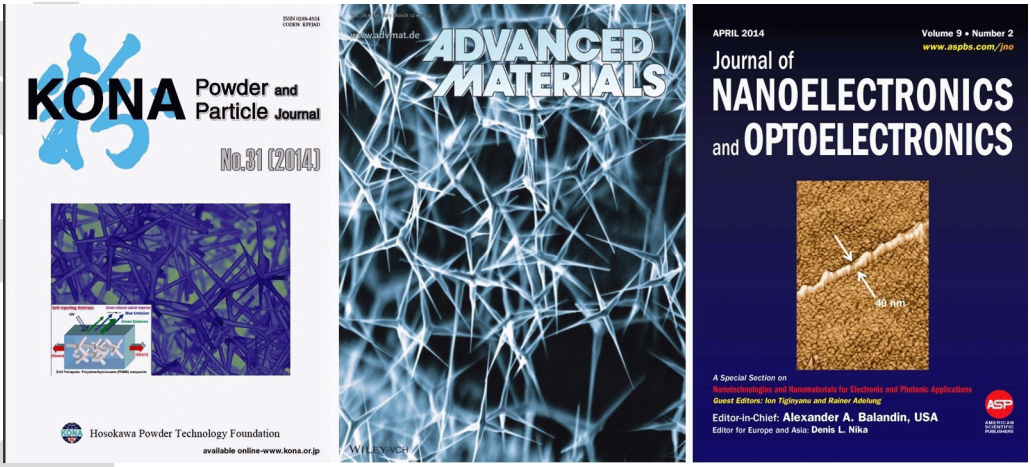


Fig. 2: Cover illustrations in 2014. Left: Cover illustration showing ZnO self-reporting properties. Middle: Cover showing interpenetrating nanowires above a microchip. Right: Nanowire formed with the help of a fracture approach that is integrated in a microchip environment.

### Low fouling surfaces by polymer ZnO composite materials

All surfaces exposed to marine or fresh-water become populated by aquatic organisms; this process is widely known as biofouling. The growth of micro- and macroscopic organisms is accompanied by negative effects for many technical applications, for example increasing surface roughness or the weight gain of ship hulls due to the accumulation of organisms on their surface. This can result in increased fuel consumption of up to 40%, with associated greater greenhouse gas emission as well as increased transport costs. Until 2008 this problem was mostly dealt with using a toxic coating containing tributyltin (TBT) but due to its proven enormously negative environmental effects it has been prohibited globally. Therefore, environmentally sound, mechanically stable, and cost-effective coatings with antifouling properties are demanded for ships and other maritime structures.

Meanwhile, the coatings used, containing Cu- and Zn-compounds, have self-polishing properties or are silicone-based polymer systems. The former is expected to be prohibited within the near future because of its harmfulness to the marine environment, like TBT-coatings. Self-polishing paints are criticized for containing biocides and for their abrasive behaviour without knowing if these particles are environmentally harmful or not. Silicon-based antifouling coatings are known to have strong antifouling effects due to their low surface energy but are known to be mechanically unstable, which makes them unsuitable for most maritime applications.

Therefore there is a need for environmentally friendly, mechanically stable, antifouling coating systems. Experiments were carried out with a novel solvent free polyurethane-based system combined with tetrapodal shaped zinc oxide particles (t-ZnO). This polymer/particle composite offers promising antifouling properties and shows excellent mechanical properties to withstand harsh environmental conditions, see Figure 3. Besides extensive mechanical characterization of this polymer/particle- system, first immersion experiments were conducted at the Aquarium Geomar in Kiel to investigate the antifouling properties of the single polymer as well as of the polymer/particle composite. These experiments showed differences in fouling rates. For example, in the ''Pacific'' environment, there was a strong reduction of fouling organisms on the polymer composite with 5 wt% of t-ZnO (Fig. 3b). Much more growth of sessile marine organisms was found on the uncoated PVC surfaces within this environment as well as a much greater biodiversity (Fig. 3c).

## Personnel

Head of the group: Prof. Dr. Rainer Adelung; Secretary: Katrin Brandenburg (50%), Dipl.-Geol. Beate Minten (50%)
Technical Staff: Dipl.-Ing. Jörg Bahr, Technician Christoph Ochmann

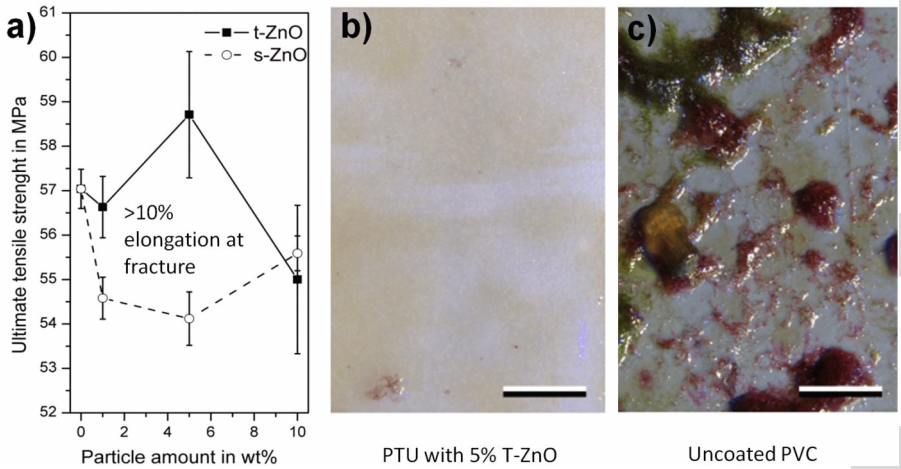


Fig. 3: Mechanical characterization and fouling properties of T-ZnO polymer composites amounts on a) the ultimate tensile strength: highest values are achieved with a filling of 5wt% T-ZnO, where the composite possesses still 10% elongation at fracture. b) and c) Comparison of the different fouling behaviour: surfaces were immersed for 20 weeks in the ''Pacific sea-tank'' at the Kiel Aquarium.

Scientific Staff:

| | | | |
|---|---|---|---|
| Dr. Martina Baum | 01.01.-31.12.2014 | | BMWI, VDI/VDE |
| NanoMarin - Nano-WWZ / Mechanik der Wasserwechselzone | | | |
| M.Sc. Melike Baytekin-Gerngroß | 01.01.-31.12.2014 | (50%) | DFG |
| Nanostructures, toxicity, and surface structuring of metals | | | |
| Dr. Jürgen Carstensen | 01.10.-31.12.2014 | | CAU |
| Characterization of solar cells | | | |
| M.Sc. Stefan Freitag | 01.01.-31.12.2014 | | BMWi |
| Analytics of nanocoatings | | | |
| M.Sc. Dawit Minale Gedamu | 01.01.-28.03.2014 | | DFG, CAU |
| Nanowire electronics | | | |
| Dr. Mark-Daniel Gerngroß | 01.10.-31.12.2014 | | DFG |
| Pore etching and surface structuring of metals | | | |
| M.Sc. Jorit Gröttrup | 01.01.-31.12.2014 | (50%) | EU |
| Graphene like structures | | | |
| Dipl.-Wi.-Ing. Mathias Hoppe | 01.01.-31.12.2014 | | BMWI, VDI/VDE |
| NanoMarin - Nano-WWZ / Mechanik der Wasserwechselzone | | | |
| M.Sc. Iris Hölken | 01.01.-31.12.2014 | | BMWi, CAU |
| Anwendung und Eigenschaften oxidischer Nanomaterialien | | | |
| M.Sc. Xin Jin | 01.01.-31.12.2014 | | DFG, CAU |
| Photoswitchable adhesives (SFB 677) | | | |

| | | | |
|---|---|---|---|
| M.Sc. Victor Kaidas | 01.01.-31.12.2014 | (50%) | CAU, DFG |
| Biomedical research, FOR 2093 Vertikale und horizontale memristive Nanokompositbauelemente ohne Filamentbildung | | | |
| Dipl.-Ing. Sören Kaps | 01.01.-31.12.2014 | | DFG |
| Piezomaterials (SFB 855) | | | |
| PhD Oleg Lupan | 01.01.-31.07.2014 | | AvH Grant |
| ZnO nanostructures | | | |
| Dr. Yogendra Kumar Mishra | 01.01.-31.12.2014 | | CAU |
| Nanowires and nanostructures | | | |
| M.Sc. Sandra Nöhren | 01.01.-31.12.2014 | (50%) | CAU, BMWi |
| Herstellung und Theorie poröser Nanomaterialien, Hochkapazitäts-Lithium-Ionen-Batterien | | | |
| M.Sc. Ingo Paulowicz | 01.01.-31.12.2014 | (50%) | CAU, DFG |
| Synthesis and characterization of nanostructures, FOR 2093 Vertikale und horizontale memristive Nanokompositbauelemente ohne Filamentbildung | | | |
| M.Sc. Arnim Schuchardt | 01.01.-30.09.2014 | | CAU |
| Aeromaterials and electrical properties | | | |
| M.Sc. Fabian Schütt | 01.01.-31.12.2014 | | CAU |
| Composite materials and 3D printing | | | |
| M.Sc. Daria Smazna | 01.01.-31.12.2014 | | EU, BMBF |
| Graphene like structures, Hochkapazitäts-Lithium-Ionen-Batterien | | | |

## Lectures, Seminars, and Laboratory Course Offers

*Winter 2013/2014*

mawi-929: Chemistry and Physics of Biomaterials, 3 hrs Lecture/Week,
R. Adelung (+ C. Selhuber-Unkel, L. Kienle)

mawi-102: Mathematik für Materialwissenschaftler I, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
R. Adelung

mawi-503: Halbleitertechnik und Nanoelektronik, 4 hrs Lecture/Week,
R. Adelung (+ H. Föll)

mawi-503: Halbleitertechnik und Nanoelektronik, 1 hrs Seminar/Week,
R. Adelung (+ H. Föll, Y.K. Mishra)

mawi-907: Semiconductors, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
Y.K. Mishra

Seminar Funktionale Nanomaterialien, 2 hrs Seminar/Week,
Y.K. Mishra

*Summer 2014*

mawi-202: Mathematik für Materialwissenschaftler II, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
R. Adelung (+ J. Gröttrup)

mawi-414: Voraussetzungen und Auswirkungen Nanotechnologie, 2 hrs Lecture/Week,
R. Adelung

mawi-414: Voraussetzungen und Auswirkungen Nanotechnologie, 1 hrs Seminar/Week,
R. Adelung

Seminar Funktionale Nanomaterialien, 2 hrs Seminar/Week,
Y.K. Mishra

*Winter 2014/2015*

mawi-102: Mathematik für Materialwissenschaftler I, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
R. Adelung (+ J. Gröttrup)

mawi-503: Halbleitertechnik und Nanoelektronik, 4 hrs Lecture/Week,
R. Adelung (+ H. Föll)

mawi-503: Halbleitertechnik und Nanoelektronik, 1 hrs Seminar/Week,
R. Adelung (+ Y.K. Mishra)

mawi-505: Quantenmechanische Aspekte in der Materialwissenschaft, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
J. Carstensen

mawi-707: Advanced Mathematics - Computational Mathematics (CompMath), 2 hrs Lecture/Week,
J. Carstensen

mawi-707: Advanced Mathematics - Mathematics for Material Science (MathMatSc), 2 (+ 1) hrs Lecture (+ Exercises)/Week,
J. Carstensen

mawi-907: Semiconductors, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
Y.K. Mishra

mawi-931: Selected Topics in Materials Science (SelTop), 2 hrs Lecture/Week,
R. Adelung

mawi-E007: Grundlagen der Materialwissenschaft, 3 (+ 2) hrs Lecture (+ Exercises)/Week,
M.-D. Gerngroß

mawi-E010: Technologie und Gesellschaft 2, 2 hrs Seminar/Week,
R. Adelung (+ W. Theobald)

Seminar Funktionale Nanomaterialien, 2 hrs Seminar/Week,
Y.K. Mishra

## Third-Party Funds

DFG (SFB 855/1-2010 Teilprojekt IGK), *Magnetoelektrische Verbundwerkstoffe - biomagnetische Schnittstellen der Zukunft: Integriertes Graduiertenkolleg,* 01.01.2010-31.12.2014 (378.272 Euro)

DFG (SFB 855/1-2010 Teilprojekt A5), *Magnetoelektrische Verbundwerkstoffe - biomagnetische Schnittstellen der Zukunft: Herstellung von vertikal freistehenden magnetoelektrischen Kompositen,* 01.01.2010-31.12.2014 (339.840 Euro)

DFG (SFB 855/1-2010 Teilprojekt Z), *Magnetoelektrische Verbundwerkstoffe - biomagnetische Schnittstellen der Zukunft: wiss. Hilfskräfte,* 01.01.2010-31.12.2014 (29.600 EURO)

DFG (SFB 677/2 2011 C10), *Funktion durch Schalten: Photoschaltbare Adhäsive,* 01.07.2012-30.06.2015 (474.240 EURO)

EU (Interreg-Projekt), *Technet Nano (074)*, 29.12.2011-28.03.2014 (112.925 EURO)
BMWi (16KN015421), *Nanobasierte Beschichtungstechnologie für den Erosions- und Vereisungsschutz von Offshore-Windenergieanlagen (DKL:WEA)*, 01.11.2012-31.10.2014 (159.963 EURO)
AvH-Stiftung (3.3-MOL/1148833 STP), *Stipendium an Prof. Dr. Oleg Lupan*, 01.05.2013-30.06.2015 (56.700 EURO)
AvH-Stiftung (3.3-MOL/1148833 STP), *Forschungskostenzuschuss an Gastgeber für 18 Monate*, 01.05.2013-30.06.2015 (14.400 EURO)
BMWi (16KN015428), *NanoMarin / Analysen der DLC Beschichtungen (DLC4marin)*, 01.06.2013-30.11.2015 (173.407 EURO)
DFG (AD 183/10-1), *Differentielle Untersuchungen zur Rolle der Oberflächeneigenschaften und der zellulären Aufnahme von Metalloxiden in ihrer Nanoform für ihre Zytokompatibilität (AOBJ: 602565)*, 17.06.2013-16.06.2015 (87.200 EURO)
EU, *Graphene Flagship (Projekt Nr. 604391)*, 01.10.2013-31.03.2016 (171.500 EURO)
BMWi (16KN015431), *ZIM-KOOP: Nanobasierte Antifoulingbeschichtung von Wasserwechselzonen maritimer Großstrukturen (Nano-WWZ)*, 01.01.2014-31.12.2015 (165755 EURO)
DAAD, *Stipendium für ein Fachpraktikum für Gaurav Modi*, 06.05.-27.07.2014 (2351 EURO)
BMWi AIF (KF2361504SL4), *ZIM-KOOP: NanoMet (Nanomet-Analytik)*, 01.10.2014-30.09.2016 (174 025 EURO)
DFG (AD 183/12-1), *FOR 2093 Memristive Bauelemente für neuronale Systeme, TP A2 Vertikale und horizontale memristive Nanokompositbauelemte ohne Filamentbildung*, 15.10.2014-14.10.2017 (178.200 EURO)

## Further Cooperation, Consulting, and Technology Transfer

The group cooperates with the following individuals and organizations.

*University:*

Prof. Dr. F. Faupel, Institut für Materialwissenschaft - Materialverbunde, CAU Kiel, ForGru 2093 und PAK 902,

Prof. Dr. S. Gorb, Institut für Zoologie, CAU Kiel, Switchable adhesion ,

Prof. Dr. M. Kern, Universitätsklinikum Schleswig-Holstein, Klinik für Zahnärztliche Prothetik, Propädeutik und Werkstoffkunde, CAU Kiel, Chemistry and microscopy of dental materials,

Prof. Dr. L. Kienle, Institut für Materialwissenschaft - Sythesis and Real Structure, CAU Kiel, Transmission electron microscopy,

Prof. Dr. H. Kohlstedt, Institut für Elektrotechnik und Informationstechnik - Nanoelektonik, CAU Kiel, Nanowires, field effect transistors,

Prof. Dr. E. Maser, Institut für Toxikologie, CAU Kiel, Toxicity of nanostructures of ZnO,

Prof. Dr. E. Quandt, Institut für Materialwissenschaft - Anorganische Funktionsmaterialien, CAU Kiel, Magnetoelectric materials,

Prof. Dr. C. Ronning, Universität Jena, Photoluminescence ZnO Nanobridges.

Prof. Dr. D. Shukla, University of Illinois, Chicago, USA, Antiviral properties of ZnO nanostructures.

Dr. F. Spors, Western University of Health Sciences, Pamona CA, USA, Antiviral studies of nanostructures.

Prof. Dr. Anne Staubitz, Institut für Organische Chemie, CAU Kiel, Switchable polymers.

Prof. Dr. H. Steckel, Pharmazeutisches Institut, CAU Kiel, Nanostructured Pharmaceuticals.

Prof. Dr. K. Schulte, TU Hamburg, Aerographite .

Prof. Dr. I. Tiginyanu, TU of Moldova, Galiumnitrite.

Dr. V. Tiwari, Midwestern University, Illinois, USA, Antiviral properties of ZnO nanostructures.

*Research Institutes:*

Prof. Dr. D. Erts, Institute of Chemical Physics, Latvia, Graphene Flagship,

Prof. Dr. N. Pugno, Department of Civil, Environmental and Mechanical Engineering, University of Trento, Italien, Graphene Flagship,

PD Dr. C. Röhl, Bundesinstitut für Risikobewertung, BfR, Berlin, Toxicity of nanostructures of ZnO,

Prof. Dr. H.-G. Rubahn, Mads Clausen Institute, University of Southern Denmark, EU Interreg project: Technet Nano.

*Industry:*

FUMT r&d GmbH, Scharbeutz (Gleschendorf), DKL:WEA, Photocatalytic substances, Forschung und Entwicklung zu Materialsynthese und -analytik,

INPUT - Institute for Polyurethane Technology GmbH, Hr. Klockemann, Hamburg, wwz-Projekt,

IRATEC, Institut für Rohrleitungs- und Apparatetechnik GmbH, Magdeburg, Forschung und Entwicklung zu Materialsynthese und -analytik,

KICKPACK GmbH, Hr. L. Prüss, Durapapp,

Materion thin films and sensors GmbH, Wismar, DLC4marin, Forschung und Entwicklung zu Materialsynthese und -analytik,

OIS, Offshore Industrie Service GmbH, Rostock, Forschung und Entwicklung zu Materialsynthese und -analytik,

Raumedic, Helmbrechts, Siliconeadhesion,

STRYKER, Schönkirchen, Project Proposal,

Tefel Automaten GmbH, Groß Schenkenberg, NanoMet,

## Diploma, Bachelor's and Master's Theses

Alexander Engel, *Entwicklung und Aufbau einer Testanlage zur Untersuchung von Herzklappenprothesen,* 13.01.2014
Robert Veith, *Untersuchung des Resonazverhaltens von 2-1 ME-Sensoren,* 17.02.2014
Chen Rui, *Polymer template-assisted way for synthesizing ZnO nanostructures,* 18.02.2014
Jascha Rohmer, *Charakterisierung von Lithium-Ionen-Akkumulatoren auf NCM Basis,* 18.07.2014
Daniel Hammerich, *Raman- und AFM-Untersuchung an dotierten Kupferoxid-Schichten,* 23.09.2014
Ron-Marco Friedrich, *Modification of processing methods for a two-step Cu deposition onto Si via Cu-gel-matrix,* 26.09.2014
Leonard Siebert, *Die Entwicklung einer kontinuierlichen Synthese für die Produktion von ZnO-Mikrostrukturen,* 30.09.2014
Christian Lasch, *Elektrische Charakterisierung von dreidimensionalen nanostrukturierten Halbleitern mit Fokus auf AeroGaN,* 01.10.2014
Lea K. Jessen, *Untersuchung der chemischen und mechanischen Eigenschaften von variierenden Polythiourethan Stöchiometrien,* 10.10.2014
Katharina Goepfert, *Influence of specific fillers on mechanical properites of polymeric dental materials,* 20.10.2014
Andreas Tonitzki, *Influence of different Zinc-oxyd microstructures to the mechanical and chemical properties of Polythiourethan,* 20.10.2014

Ansgar Olbricht, *Zugfestigkeitsvergleich von Polymerkompositen unter Variation der Verstärkungsfüllstoffe*, 27.10.2014
Florian Ceynowa, *Untersuchungen des Spaltverhaltens von Folienträgern in selbstklebenden Anwendungen*, 31.10.2014
Gerhard Niehus, *Einfluss von tetrapodalem Zinkoxid auf die mechanischen Eigenschaften verschiedener Klebstoffe*, 31.10.2014
Lars Thormählen, *Elektrochemische Untersuchung von Ionenleitermembranen in Siliziummikrodrahtanoden für Lithium-Ionen-Batterien*, 10.11.2014
Seyedeh M. Nojabaee, *FFT-Impedance spectroscopy analysis of anodes for Li ion batteries containing paste Si microwires with different thicknesses*, 12.12.2014
Galina Haidarschin, *Einfluss der Materialwahl und Partikelgeometrie auf die Eigenschaften von Verbundwerkstoffen mit Anwendungspotenzial in der restaurativen Dentaltechnik*, 29.12.2014

## Dissertations / Postdoctoral Lecture Qualifications

D.M. Gedamu, *Nanowires: From microchip integrated synthesis to application examples*, 18.02.2014
X. Jin, *Towards photoswitchable adhesives: Tetrapodal ZnO as joint linker, stress indicator and reinforcement filler for polymers*, 04.07.2014

## Publications

Published in 2014

O. Lupan, V. Cretu, M. Deng, D. Gedamu, I. Paulowicz, S. Kaps, Y.K. Mishra, O. Polonskyi, C. Zamponi, L. Kienle, V. Trofim, I. Tiginyanu, R. Adelung, *Versatile growth of freestanding orthorhombic alpha-Molybdenum trioxide nano- and microstructures by rapid thermal processing for gas nanosensors*, Journal of Physical Chemistry C, **118**, 15068 - 15078 (2014)
O. Lupan, L. Ghimpu, T. Reimer, M. Hoppe, I. Paulowicz, D. Gedamu, Y.K. Mishra, D. Hammerich, S. Chemnitz, V. Cretu, I. Tiginyanu, R. Adelung, *Magnetron sputtering and characterization of doped zinc oxide nanofibrous films and their applications*, Journal of Nanoelectronics and Optoelectronics, **9**, 257 - 264 (2014)
D. Gedamu, O. Lupan, Y.K. Mishra, R. Adelung, *Integration of metal and metal oxide nanowires directly on chip by top-down technology and their electrical characteristics*, Journal of Nanoelectronics and Optoelectronics, **9**, 239 - 246 (2014)
T.H. Reimer, I. Paulowicz, R. Röder, S. Kaps, O. Lupan, S. Chemnitz, W. Benecke, C. Ronning, R. Adelung, Y.K. Mishra, *Single step integration of ZnO nano- and microneedles in Si trenches by novel flame transport approach: Whispering gallery modes and photocatalytic properties*, ACS Appl. Mater. Interfaces, **6**, 7806 - 7815 (2014)
D. Gedamu, I. Paulowicz, S. Kaps, O. Lupan, S. Wille, G. Haidarschin, Y.K. Mishra, R. Adelung, *Rapid fabrication technique for interpenetrated ZnO nanotetrapod networks for fast UV-sensor*, Advanced Materials, Front Cover Story, **26**, 1541 - 1550 (2014)
Y.K. Mishra, S. Kaps, A. Schuchardt, I. Paulowicz, X. Jin, D. Gedamu, S. Wille, O. Lupan, R. Adelung, *Versatile fabrication of complex shaped metal oxide nano-microstructures and their interconnected networks for multifunctional applications*, KONA Powder Technology, Front Cover Story, invited review, **31**, 92 - 110 (2014)
H. Papavlassopoulos, Y.K. Mishra, S. Kaps, I. Paulowicz, R. Abdelaziz, M. Elbahri, E. Maser, R. Adelung, C. Röhl, *Toxicity of functional nano-micro zinc oxide tetrapods: Impact of cell culture conditions, cellular age and material properties*, PLoS ONE, **9(1)**, 84983 (2014)
O. Lupan, V. Trofim, V. Cretu, I. Stamov, N.N. Syrbu, I. Tignyanu, Y.K. Mishra, R. Adelung, *Investigation of optical properties and electronic transitions in bulk and nano-microribbons of molybdenum trioxide*, Journal of Physics D: Applied Physics, **47(8)**, 85302 (2014)
V.S.K. Chakravadhanula, Y.K. Mishra, V.G. Kotnur, D.K. Avashti, T. Strunskus, V. Zaporojtchenko, D. Fink, L. Kienle, F. Faupel, *Microstructural and plasmonic modifications in Ag-$TiO_2$ and Au-$TiO_2$ nanocomposites through ion beam*

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I. Tiginyanu, R. Adelung, *A special section on nanotechnologies and nanomaterials for electronic and photonic applications,* Journal of Nanoelectronics and Optoelectronics, **9**, 193 - 195 (2014)
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R. Wahab, S. Dwivedi, F. Khan, Y.K. Mishra, I.H. Hwang, H.-S. Shin, J. Musarrat, A.A. Al-Khedhairy, *Statistical analysis of gold nanoparticle-induced oxidative stress and apoptosis in myoblast (C2C12) cells,* Colloids and Surfaces B: Biointerfaces, **123**, 664 - 672 (2014)
M. Kumar, C.S. Suchand Sandeep, G. Kumar, Y.K. Mishra, R. Philip, G.B. Reddy, *Plasmonic and nonlinear optical absorption properties of Ag:$ZrO_2$ nanocomposite thin films,* Plasmonics, **9**, **1**, 129 - 136 (2014)

## Patent Applications

M.-D. Gerngroß, J. Carstensen, H. Föll, R. Adelung, *Verzinktes Werkstück mit verbesserter Haftung für Deckschichten,* Deutsches Patent- und Markenamt, 06.05.2015, DE 10 2014 106 276.0
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R. Adelung, *Funktionale mikro- und nanostrukturierte Materialien: Lösungen für extreme Anforderungen,* Forschung erforschen! 2014, Die Innovationstour der Industrie- und Handelskammern, Kiel, Germany, 20.-20.02.2014
M. Baum, I. Hölken, *Präsentation der Ergebnisse zum Thema Windkraft und Antifouling,* Messestand auf der Oceanology, London, UK, 10.-14.03.2014
R. Adelung, *Improving life with micro- and nanotechnology,* Finale Conference Technet-nano-Project, Sonderburg, Denmark, 20.-20.03.2014
R. Adelung, *Von Zinkoxid bis Aerographite: Leichtgewichtige Konzepte intelligenter Materialien,* populärwissenschaftliche Reihe: Wissenschaft für jedermann im Deutschen Museum München, München, Germany, 02.-03.04.2014
O. Lupan, *Chemical sensor and biosensors properties of doped semiconducting oxide nanostructures,* Research at Technical University of Moldova, Chisinau, Moldova, 02.-12.05.2014
R. Adelung, *Funktionale Nanomaterialien,* Nanotechnologie in Schleswig-Holstein (NINa, Technet-nano, WT SH), Kiel, Germany, 10.-10.06.2014
R. Adelung, *Antiviral mit Halbleitermaterial?,* Kieler Woche Vorträge 2014, Kiel, Germany, 29.-29.06.2014
S. Nöhren, *Dependence of the lithiation/delithiation potentials of silicon microwire anodes on their state of charge and sizes,* ECS Conference, Cancun, Mexico, 05.-10.10.2014

Y.K. Mishra, S. Kaps, J. Gröttrup, T.H. Reimer, A. Schuchardt, X. Jin, O. Lupan, R. Adelung, I. Paulowicz, *Flame transport synthesized ZnO nano- and mircrostructures for multifunctional applications: From advance linker elements to 3D hybrid flexible networks,* ICSM 2014 International Conference on Soft Materials, Jaipur, India, 06.-10.10.2014

V. Kaidas, S. Will, M. Kern, *Untersuchungen des Alterungseffektes von eingefärbtem Y-TZP im Vergleich mit ungefärbtem Y-TZP mit Röntgendiffraktion und Raman-Spektroskopie,* Jahrestagung der Deutschen Gesellschaft für Biomaterialien (DGBM), Dresden, Germany, 06.-08.11.2014

R. Adelung, *Verbinden von Leichtbaumaterialien und Verstärkung von Polymeren,* 1. Norddeutsche Luftfahrtforum: Flugzeugmaterialien der Zukunft, Stade, Germany, 20.-20.11.2014

R. Adelung, *10 Minutenvortrag Mathe,* 2. Tag der Lehre: Lehre jeden Tag, Projekt erfolgreiches Lehren und Lernen (PerLe) der CAU, Kiel, Germany, 27.-27.11.2014

Y.K. Mishra, S. Kaps, J. Gröttrup, T.H. Hinrich, D. Smazna, A. Schuchardt, I. Paulowicz, X. Jin, D.M. Gedamu, O. Lupan, R. Adelung, *Flame transport based synthesis of metal oxide nano-microstructures and their 3D interconnected networks: From nanodevices to ultralight aerographite material,* MRS Tagung 2014, Boston, USA, 30.11.-05.12.2014

J. Gröttrup, A. Schuchardt, V. Kaidas, I. Paulowicz, X. Jin, R. Adelung, Y.K. Mishra, *Properties of ultra porous and high temperature stable flexible 3D interconnected nanoceramic networks: Fabrication and characterization,* MRS Tagung 2014, Boston, USA, 30.11.-05.12.2014

Y.K. Mishra, S. Kaps, J. Gröttrup, T.H. Hinrich, D. Smazna, A. Schuchardt, I. Paulowicz, X. Jin, D.M. Gedamu, O. Lupan, R. Adelung, *Flame transport based synthesis of metal oxide nano-microstructures and their 3D interconnected networks: From nanodevices to ultralight aerographite material,* Harvard University, Boston, USA, 06.-06.12.2014

# General Materials Science

The ''Hochschulgesetz'' of Schleswig-Holstein, if memory serves, requests a professor to be active in the following areas: research, teaching, production of young academics, adequate participation within the autonomous administration, and technology transfer. After 24 years of doing this work for the CAU (without much of an infrastructure during the first few years) the time has come for Prof. Föll to take personal stock.

## Research

Research and its associated activities have been as follows:

- about 350 publications (including about 70 from before the CAU time): almost all in refereed journals and books, leading to a ''Hirsch factor'' of 36,
- one of the two initiators and Coordinator of the ''DFG-Schwerpunkt: Photonische Kristalle'',
- successful proposals for about 5.4 Million Euro third party funds, enabling, among many other things, the building of the ''Kieler Nanolab''.

## Teaching

Teaching and related activities were as follows:

- key role in the introduction of the study courses ''Dipl.-Ing. Materialwissenschaft'' in 1992 and ''Master of Materials Science and Engineering'' in 1999. 11 new lecture courses were conceived from scratch and taught most of the time. All lecture courses are augmented by ''hyperscripts'', freely accessible on the Internet, that enjoy considerable international appreciation. (2014: 18 Million requests from 1.5 Million users: 7 TB downloads),
- teaching award of the state of Schleswig-Holstein in 2001,
- special prize from Siemens AG for excellence in teaching engineers in 2001.

## Production of young academics

In the guidance of young academics he has acted for 25 Ph.Ds as first supervisor and for a comparable number as second supervisor. Several post-docs acquired their special knowledge with him: at least 5 are now professors or pursuing an academic career.

## Participation within the autonomous CAU / Science administration

Roles within the administration of the university have been as follows:

- founding Dean and twice elected Dean of the Faculty of Engineering from 1991 - 2000.
- Vice Dean until 2002. Many innovations introduced at the start of the School of Engineering are still in place (e.g. internal financing with a global budget),
- member of the CAU senate and various boards, Chairman of the Materials Science examination board, Executive Director of the Institute for Materials Science, and so on for far more years than I care to remember,
- member or chairman of boards of many science organizations (Technologiestiftung S.-H., ISiT Itzehoe, GKSS Geesthacht, MPI Halle, Forschungszentrum Jülich, ...). Chairman of more than 15 ''Berufungskommissionen'' and many ''Promotionsausschüssen''. DFG ''Vertrauensdozent'' for 12 years.
- founder of the ''Förderverein der Technischen Fakultät'', plus considerable fund raising activities for this entity: e.g. about 15 stipends for foreign M.Sc. students over a period of several years.

### Technology transfer

He has created technology transfer in the following manner:

- 41 Patents and patent applications (including 9 from before the CAU). About 15
- many projects with companies (mostly but not always with public funding),
- a spin-off company (ET and TE GmbH) that markets the unique hard-and software of the group was founded in 2004.

## Results

### Etching research

The pore etching of semiconductors has a new brother: the surface structuring of metals. This topic divides into general surface structuring of metals, and metal pore etching specifically. Pore formation in metals is a very unusual phenomenon and is only found for special metals with very stable metal oxides. The pores in these metals exhibit walls consisting of amorphous metal oxide. In the case of the pores in Zn the resulting pore walls consist only of metallic Zn and not ZnO, which makes this kind of pore formation and growth very special. Figure 1a) presents a top view of the pore structure of polycrystalline Zn. The pores grow at different angles with respect to the surface forming pore domains. Inside each domain the pores grow in the same direction and parallel to each other. The pore density depends directly on the angle between the surface and the pore growth direction. Smaller pores are typically rather hexagonal, while bigger pores tend to have a rhomboidal shape. The typical pore diameter varies between 0.1 $\mu$m and 10 $\mu$m. Figure 1b) gives a top view of the chemically structured $AlMg_3$ surface. The surface contains a multitude of rectangular structures in different sizes with flat faces either in a step-like arrangement or as free-standing structures, so called barbs. Besides the interest in the formation mechanisms in different metals / alloys of the structures presented here, these structures are also of high interest in terms of application (for metal/polymer or metal/metal composites) since they allow for a very efficient mechanical interlocking between the two composite components. This is shown in more detail in the section of the ''Functional nanomaterials'' group of Prof. Adelung.

### Solar cell characterization using luminescence images

A completely quantitative theory for calculating series resistances from luminescence measurements has been developed and published. The variation of global and local series resistance for different injection conditions along the iv-curve has been understood both qualitatively and quantitatively, resulting in a simple ''effective'' parallel arrangement of series and diode resistances (cf. Fig. 2a) and an additional constant offset due to the non-distributed part of the resistance network (cf. Fig. 2b). These concepts allow for a perfect separation of recombination losses (cf. open circuit luminescence map in Fig. 2c) and local distributed series resistances (cf. Fig. 2d). Additionally a detailed ohmic power loss analysis for standard series resistances and lateral balancing currents on inhomogeneous solar cells is possible. These results led to an intensive cooperation with the MPI (Halle) and the ISFH (Hameln) to compare our results with simulation results which will be published in the near future.

### Battery research

The Silicon microwire array anodes fabricated in the AMAT group exhibit superior cycling performance with a high capacity of 3150 mAh/g. They are cycled according to previously optimized capacity and voltage limitations. Those voltage limitations are recorded via cyclic voltammetry measurements.

Experiments showed that not only the external parameters but also the internal ones like length, diameter, and state of charge influence the cycling performance. With optimal sizes, the lithiation and delithiation process could be facilitated. At higher state of charge, the lithiation as well as the delithiation for the analyzed wire dimension show smaller lithiation voltages.

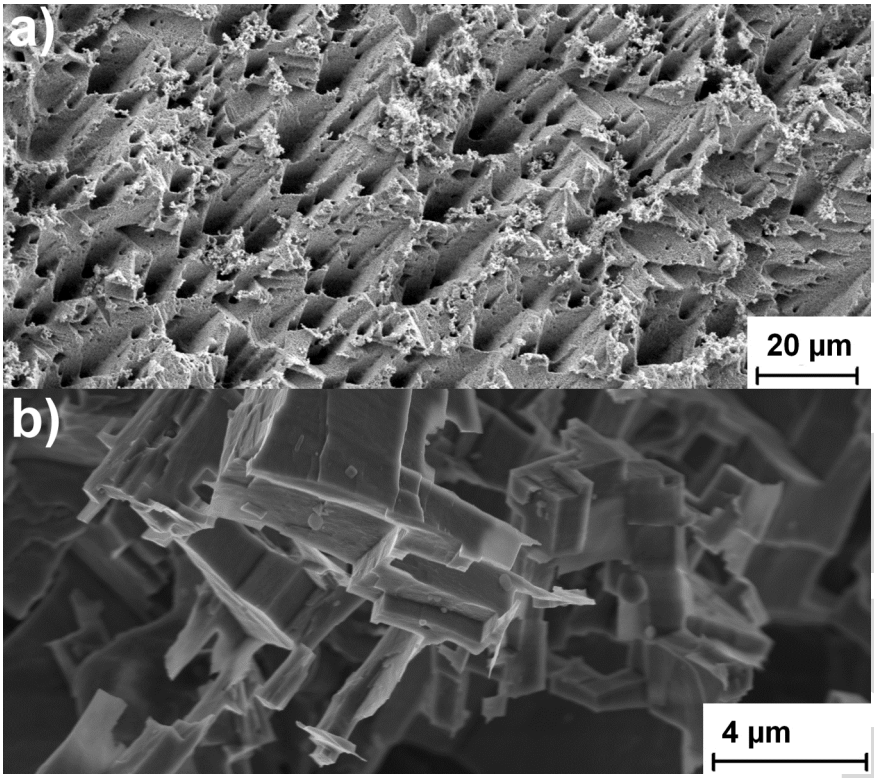


Fig. 1: SEM top view of the respectively electrochemically and chemically etched a) multicrystalline Zn surface with pores and b) nanostructured $AlMg_3$ surfaces with rectangular features.

Not only was the cycling optimized but also the structure of the lithiated anodes was analyzed via synchrotron diffraction measurements at SLAC, Stanford University, USA. In order to obtain a stable long term capacity, the anodes have to be lithiated with C/10 for the first cycles forming a stable solid electrolyte interphase (SEI) which covers the wires evenly. Without this careful prelithiation a rapid capacity fading is always found. After lithiation the wires are mechanically stable even after long term cycling; the SEI especially remains intact.

In Fig. 3, an example of the in-situ synchrotron radiation is presented for analyzing locally resolved crystallinity of the microwires depending on the charging state. The in-situ (synchrotron) diffraction shows that an astonishingly large fraction of crystalline Si exists even after several cycles. Additionally, the diffraction pattern shows the existence not only of copper peaks (resulting from the copper current collector) and polymer peaks (resulting from the pouch cell) but also well peaks from the metallic lithium and the silicon. Results indicate that the end of the silicon wires that are directly in contact with the battery electrolyte starts transforming first while the parts of the wires at the copper current collector remain crystalline, indicating a diffusion limitation for charging the wires.

## Personnel

Head of the group: Prof. Dr. Helmut Föll; Secretary: Katrin Brandenburg (50%)
Technical Staff: Dipl.-Ing. (FH) Jörg Bahr

Scientific Staff:

| | | |
|---|---|---|
| M.Sc. Melike Baytekin | 01.01.-30.09.2014 | Unterauftrag Uni Konstanz |
| 1/5 SolarWinS | | |

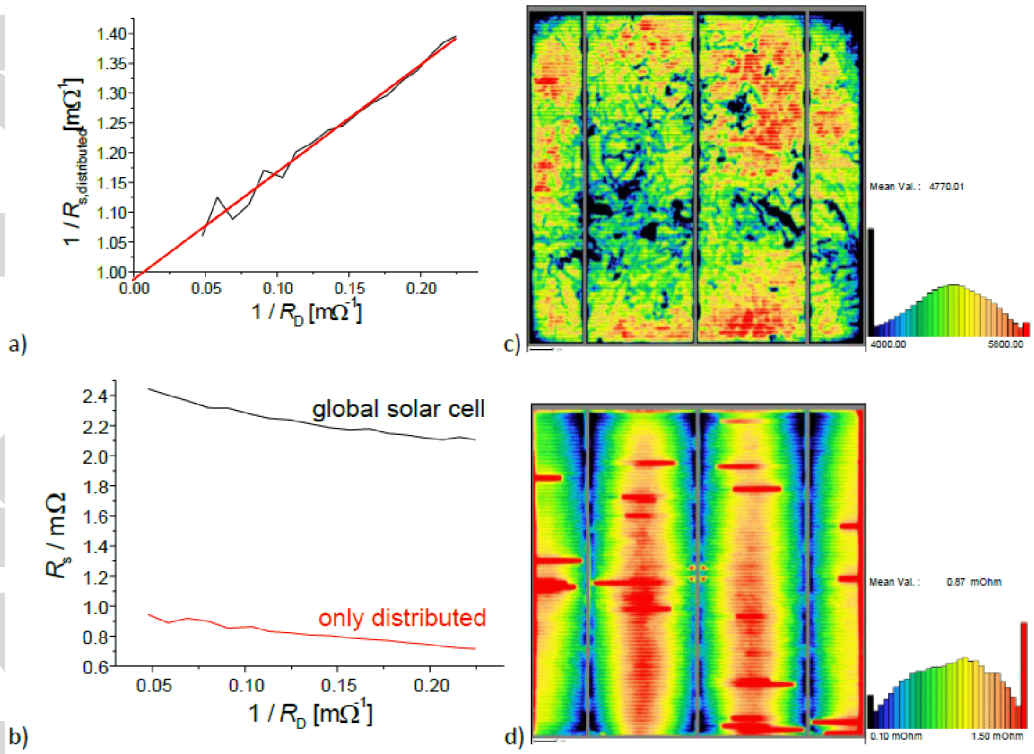


Fig. 2: Quantitative results from luminescence measurements: a) injection level dependence of distributed series resistance, b) constant offset between global and distributed average resistance, c) open circuit luminescence map reflecting local recombination, d) local distributed series resistance map.

| | | | |
|---|---|---|---|
| Dr. Jürgen Carstensen | 01.01.-30.09.2014 | | CAU |
| Theory, software development, supervision of teaching | | | |
| M.Sc. Mark-D. Gerngroß | 01.01.-30.09.2014 | | DFG |
| SFB 855 Magnetoelectric Composites - Future Biomagnetic Interfaces / Elektrochemische und mikrostrukturelle Untersuchung der Prozesse in Anoden für Hochkapazitäts-Lithium-Ionen-Batterien basierend auf Si-Mikrodrahtanordnungen | | | |
| M.Sc. Sandra Nöhren | 01.01.-30.09.2014 | (50%) | BMBF / DFG |
| ''AlkaSuSi'' Si nanowire anode for Li ion battery / Elektrochemische und mikrostrukturelle Untersuchung der Prozesse in Anoden für Hochkapazitäts-Lithium-Ionen-Batterien basierend auf Si-Mikrodrahtanordnungen | | | |
| Dr. Enrique Quiroga-González | 01.-31.01.2014 | | BMBF |
| ''AlkaSuSi'' Si nanowire anode for Li ion battery | | | |
| Dipl.-Ing. Andreas Schütt | 01.01.-30.04.2014 | | EU |
| MOLD-NANONET | | | |

## Lectures, Seminars, and Laboratory Course Offers

*Winter 2013/2014*

Materialwissenschaft I, 3 (+ 1) hrs Lecture (+ Exercises)/Week,
Helmut Föll (+ Mark-D. Gerngroß)

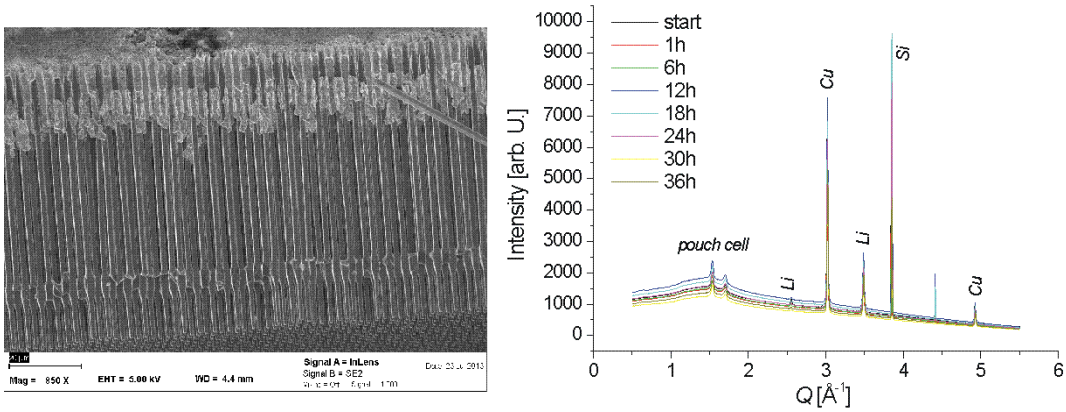


Fig. 3: Results of in-situ XRD measurements of Silicon microwire arrays indicating a high crystalline core.

Quantenmechanische Aspekte in der Materialwissenschaft, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
Jürgen Carstensen

Aktuelle Fragen der Forschung, 2 hrs Seminar/Week,
Helmut Föll (+ Jürgen Carstensen)

Advanced Mathematics - Computational Mathematics (2 groups), 2 hrs Lecture/Week,
Jürgen Carstensen (+ Jan-Martin Wagner)

Basic Laboratory Course for M.Sc. Students, 4 hrs Practical/Week,
Emmanuel Ossei-Wusu (+ S. Nöhren, et al.)

Halbleitertechnik und Nanoelektronik, 4 (+ 1) hrs Lecture (+ Exercises)/Week,
Helmut Föll (+ Rainer Adelung, Yogendra Kumar Mishra)

Grundlagen der Materialwissenschaft, 3 (+ 2) hrs Lecture (+ Exercises)/Week,
Helmut Föll (+ Mark-D. Gerngroß, Jan-Martin Wagner)

Advanced Mathematics - Mathematics for Material Science, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
Jürgen Carstensen

Defects, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
Helmut Föll

Materialanalytik 2, 4 hrs Practical/Week,
Enrique Quiroga-González (+ et al.)

Semiconductors, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
Helmut Föll (+ Yogendra Mishra)

*Summer 2014*

Aktuelle Fragen der Forschung, 2 hrs Seminar/Week,
Helmut Föll

Computergestützte Mathematik, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
Jürgen Carstensen

Advanced Laboratory Course for M.Sc. Students, 4 hrs Practical/Week,
Jürgen Carstensen (+ Sandra Nöhren, et al.)

Materialwissenschaft II, 3 (+ 1) hrs Lecture (+ Exercises)/Week,
Helmut Föll

Statistical Methods in Material Science, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
Jürgen Carstensen

*Winter 2014/2015*

Quantenmechanische Aspekte in der Materialwissenschaft, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
Jürgen Carstensen

Aktuelle Fragen der Forschung, 2 hrs Seminar/Week,
Helmut Föll (+ Jürgen Carstensen)

Materialwissenschaft I, 3 (+ 1) hrs Lecture (+ Exercises)/Week,
Helmut Föll (+ Mark-D. Gerngroß)

Advanced Mathematics - Computational Mathematics (2 groups), 2 hrs Lecture/Week,
Jürgen Carstensen (+ Jan-Martin Wagner)

Basic Laboratory Course for M.Sc. Students, 4 hrs Practical/Week,
Emmanuel Ossei-Wusu (+ S. Nöhren, et al.)

Halbleitertechnik und Nanoelektronik, 4 (+ 1) hrs Lecture (+ Exercises)/Week,
Helmut Föll (+ Rainer Adelung, Yogendra Kumar Mishra)

Grundlagen der Materialwissenschaft, 3 (+ 2) hrs Lecture (+ Exercises)/Week,
Helmut Föll (+ Mark-D. Gerngroß, Jan-Martin Wagner)

Advanced Mathematics - Mathematics for Material Science, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
Jürgen Carstensen

Defects, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
Helmut Föll

Materialanalytik 2, 4 hrs Practical/Week,
Enrique Quiroga-González (+ et al.)

## Third-Party Funds

BMBF, *AlkaSuSi Neue Materialkonzepte für Alkalimetall-Schwefel-Batterien bzw. Alkalimetall-Silizium-Batterien,* 01.05.2011-31.05.2014 (259.769 EUR)

BMBF, *Projektpauschale zu: AlkaSuSi Neue Materialkonzepte für Alkalimetall-Schwefel-Batterien bzw. Alkalimetall-Silizium-Batterien,* 01.05.2011-31.05.2014 (25.976,90)

Unterauftrag BMU-Projekt Universität Konstanz, *SolarWinS, TP 6: Herstellung und Analyse von Solarzellen aus hochreinem kristallinem Silizium,* 01.02.2011-31.01.2014 (87.000 EUR)

EU 7th Framework Programme, *MOLD-NANONET,* 01.12.2011-31.05.2014 (47.658 EUR)

DFG, *Elektrochemische und mikrostrukturelle Untersuchung der Prozesse in Anoden für Hochkapazitäts-Lithium-Ionen-Batterien basierend auf Si-Mikrodrahtanordnungen,* 17.09.2013-16.09.2015 (127.825 EUR)

DFG, *Programmpauschale zu: Elektrochemische und mikrostrukturelle Untersuchung der Prozesse in Anoden für Hochkapazitäts-Lithium-Ionen-Batterien basierend auf Si-Mikrodrahtanordnungen,* 17.09.2013-16.09.2015 (25.600 EUR)

## Further Cooperation, Consulting, and Technology Transfer

Collaboration exists with the following organizations:

- **Bosch AG**, Stuttgart, Germany:

ongoing shared supervision of B.Sc. and M.Sc. theses. Continuous cooperation based on the CELLO technique (measurements on various Bosch specimens): external PhD student.

- **Centrosolar**, Hamburg, Germany:

CELLO investigations of cells and modules (i) regarding the influence of module-making with respect to potential-induced degradation and (ii) for yield engineering issues.

- **Condias**, Itzehoe, Germany:

explorative experiments (based on an AMAT patent) concerning electrochemical processing of large Si wafers.

- **Fraunhofer-Institut ICT**, Pfinztal, Germany / **IWS**, Dresden, Germany:

cooperation within the ''AlKaSuSi'' project (see above).

- **Fraunhofer-Institut ISE** (Solare Energiesysteme), Freiburg / Gelsenkirchen, Germany:

scientific cooperation with Dr. Warta and Prof. Dr. Schindler within the framework of the SolarFocus / SolarWinS project.

- **INFICON GmbH**, Köln, Germany (world market leader for vacuum leak detection):

AMAT produces prototypes of novel sensors based on porous Si. Results are encouraging.

- **Hanwha Q Cells** (formerly Q-Cells), Bitterfeld-Wolfen, Germany:

based on previous CELLO measurements on cells made from different feedstock material and contact via SolarWinS project: evaluation of further collaboration.

- **ISFH GmbH**, Hameln/Emmerthal, Germany:

cooperation within the framework of the SolarFocus / SolarWinS project: informal cooperation with respect to Si nanowire formation and application of porous Si membranes in Li ion batteries.

- **Lund University**, Sweden:

Scientific cooperation with Prof. Christelle Prinz. Samples with different microwire array structures are provided to make biological tests. Especially, growth of optical cells is planned.

- **Max-Planck-Institut für Mikrostrukturphysik**, Halle, Germany

scientific cooperation with Dr. Breitenstein within the framework of the SolarFocus / SolarWinS projects. CELLO and SHALUM measurements in comparison to thermography measurements.

- **CSP Halle (Centre for Silicon Photovoltaic)**, Halle, Germany:

scientific cooperation within the SolarWinS project and bilaterial cooperation with respect to solar cell characterization using the CELLO technique.

- **FUMT GmbH**, Kiel (S.-H. Start-up), Germany:

CELLO measurements for the characterization of novel AR coatings on modules. General cooperation on other topics via Prof. Adelung's group.

- **Nanotechnology Research Centre**, Cairo, Egypt:

proposal to A. v. Humboldt foundation concerning 2-year stay of senior researcher Dr. Osama Tobail at AMAT: Dr. Tobail was a guest in 2012 and in 2013. The common research topic is nanostructuring of materials by electrochemical means for Li ion battery electrodes.

- **SolarWorld**, Freiberg, Germany:

CELLO measurements in respect to some special questions concerning high-efficiency solar cells.

- **Technical University of Moldova**, Chisinau, Moldova:

scientific cooperation with Prof. Dr. I.M. Tiginyanu for more than 10 years. Joint EU project (€ 48,000.– ).

- **University College Cork**, Ireland:

Scientific cooperation with Dr. Colm O'Dwyer: Different kinds of Si porous membranes and porous pieces with different structures have been supplied to Cork with the aim to test their application in thermoelectrics and antireflection coatings, and to make some Raman microscopy studies.

- **University Konstanz**, Germany:

Partner within the ''SolarWinS'' project: possible new direct cooperation concerning large-area pore etching.

- **University New South Wales**, Australia (Prof. Green):

participation in ''round robin'' concerning quantitative solar cell characterization.

- **University of Stanford**, USA, California:

application for synchrotron beam time for characterization of silicon nanowires for Li-ion batteries: in this common project first measurements in Stanford have been performed and are now under evaluation.

- **Institut für Verbundwerkstoffe GmbH**, Kaiserlautern, Germany:

scientific cooperation with Prof. Dr. Ulf Breuer and Dipl.-Ing. Sebastian Nissle: Surface treatment of NiTi-wire smartflex and NiTi-wire alloy for SMA-FRP composites.

- **Stryker GmbH**, Schönkirchen, Germany:

surface treatment and analysis of Stryker titanium nail implants.

- **Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR)**, Köln, Germany:

In most cases, the cooperation is motivated because there is either some interesting research or because the partially unique methods and processes of AMAT could be beneficial to a partner. In many first encounters with companies, ''proof of principle'' is the first goal, typically without direct remuneration. Instead, partners might supply specimens and technologies that are not available elsewhere. In this context it is necessary to point out that no university or research organization (short of large ''national centres'') is capable of producing solar cells that could rival the ones mass-produced by industry. State-of-the-art research with solar cells thus is only possible by cooperation with industry.

First cooperation with companies concerning possible novel products are always hoped to blossom eventually into fully-fledged funded projects. That happens, but not too often. Instead, the rewards are scientific insights and publications. Projects concerning prototypes invariably rely on the possibility of some technology transfer, and that needs ''interface'' companies like ET&TE. Since the CAU administration is opposed to this concept, many of the projects above are doomed to fail.

## Diploma, Bachelor's and Master's Theses

Jan-H. Morjan, *Metallographische und mikrostrukturanalytische Untersuchungen an Artefakten aus dem Nydam-Schatz,* 04.04.2014

Arne Krudoppp, *Charakterisierung des Serienwiderstand-Netzwerkes großflächiger Si-Solarzellen mittels Lumineszenz-Messungen: Anlagen- und Modellvalidierung,* 03.07.2014

Muhammad Omer Farooq, *Study of electrodeless mesoporosification of lightly doped p-type silison by different methods,* 16.07.2014

Sören Nielsen, *Biocompatibility of porous InP,* 20.10.2014

Roderich von Thun, *Charakterisierung einer Sauerstoffmesssonde anhand Impedanz-, Raman- und REM-Untersuchung,* 15.10.2014

Maike Schon, *Validation of a two-point probe for the characterization of deposited diamond layers,* 17.10.2014

## Dissertations / Postdoctoral Lecture Qualifications

Mark-D. Gerngroß, *Fabrication and characterization of single-crystalline InP membranes for several applications,* 14.05.2014

## Publications

Published in 2014

M. Hagen, E. Quiroga-González, S. Dörfler, G. Fahrer, J. Tübke, M.J. Hoffmann, H. Althues, R. Speck, M. Krampfert, S. Kaskel, H. Föll, *Studies on preventing Li dendrite formation in Li-S batteries by using pre-lithiated Si microwire anodes,* J. Power Sourc., **248**, 1058 (2014)

E. Quiroga-González, J. Carstensen, C. Glynn, C. O'Dwyer, H. Föll, *Pore size modulation in electrochemically etched macroporous p-type silicon monitored by FFT impedance spectroscopy and Raman scattering,* Phys, Chem. Chem. Phys., **16**, 255 (2014)

J. Carstensen, J.-M. Wagner, A. Schütt, H. Föll, *Relation Between Local and Global I-V Characteristics: Restrictions for and by Series Resistance Averaging,* Proc. 29th European Photovoltaic Solar Energy Conference, 2BV.8.21, Amsterdam, (2014)

J. Carstensen, J.-M. Wagner, A. Schütt, A. Krudopp, H. Föll, *Ohmic loss analysis for lateral balancing currents by CELLO and photoluminescence measurements,* Proc. 29th European Photovoltaic Solar Energy Conference, 2BO.2.6, Amsterdam, (2014)

M.-D. Gerngross, J. Carstensen, H. Föll, *Electrochemical growth of Co nanowires in ultra-high aspect ratio InP membranes: FFT-impedance spectroscopy of the growth process and magnetic properties,* Nanoscale Research Letters, **9:316**, (2014)

M.-D. Gerngroß, *Fabrication and characterization of single-crystalline InP membranes for several applications,* Dissertation, (2014)

E. Quiroga-González, J. Carstensen, H. Föll, *Scalable processing and capacity of Si microwire array anodes for Li ion batteries,* Nanoscale Res. Lett., **9**, 5 (2014)

M.-D. Gerngross, J. Carstensen, H. Föll, *Electrochemical growth of Co nanowires in ultra-high aspect ratio InP membranes: FFT-impedance spectroscopy of the growth process and magnetic properties,* Nanoscale Res. Lett., **9**, 316 (2014)

## Patent Applications

M.-D. Gerngroß, J. Carstensen, H. Föll, R. Adelung, *Verzinktes Werkstück mit verbesserter Haftung für Deckschichten,* Deutsches Patent- und Markenamt, 06.05.2014, DE 10 2014 106 276.0

M. Baytekin-Gerngroß, M.-D. Gerngroß, J. Carstensen, R. Adelung, *Metallisches Werkstück mit poriger Oberfläche, Verfahren zu seiner Herstellung und Verwendung ...*, Deutsches Patent- und Markenamt, 01.08.2014, DE 10 2014 110 922.8

S. Nören, J. Bahr, J. Carstensen, *Verfahren zur Herstellung einer Flächenableiterelektrode und Halbzeug zur Durchführung d. Verfahrens*, Europäisches Patentamt, 09.09.2014, EP14184103

## Presentations

J. Carstensen, A. Schütt, J.-M. Wagner, H. Föll, *CELLO analysis of ohmic losses induced by lateral balancing currents: a mayor efficiency limiting factor for mc-Si solar cells*, SolarWins project meeting, Ochsenfurt, Germany, 28.-30.01.2014

J. Carstensen, A. Schütt, J.-M. Wagner, H. Föll, *Summary: CELLO-Investigation within the SolarWinS-Project; Limitation when using block cast MC-Si compared to mono-Si*, SolarWins project meeting, Ochsenfurt, Germany, 28.-30.01.2014

M.-D. Gerngroß, *Magnetic metal deposition in ultra-high aspect ratio InP membranes - FFT-IS of the growth process and magnetic properties*, PSST - Porous Semiconductor Science and Technology, Benidorm, Spain, 09.-14.03.2014

S. Nöhren, *Dependency of the lithiation/delithiation susceptibility and cycling stability of Si microwire anodes on their state of charge (poster)*, Kraftwerk Batterie, Münster, Germany, 25.-26.03.2014

J. Carstensen, J.-M. Wagner, A. Schütt, A. Krudopp, H. Föll, *Ohmic loss analysis for laterial balancing currents by CELLO and photoluminescence measurements*, 29th European Photovoltaic Solar Energy Conference and Exhibition, Amsterdam, The Netherlands, 22.-25.09.2014

J. Carstensen, J.-M. Wagner, A. Schütt, H. Föll, *Relation between local and global I-U characteristics: restrictions for and by series resistance averaging*, 29th European Photovoltaic Solar Energy Conference and Exhibition, Amsterdam, The Netherlands, 22.-25.09.2014

## Further Activities and Events

### Special Colloquium on May 28, 2014

Prof. Dr. Ion Tiginyanu, Vice-President of the Academy of Sciences of Moldova gave a talk ''Kiel, Germany - Chisinau, Moldova: 15 years of collaboration in materials science''.

He was proud to hand over the ''Dimitrie Cantemir-Medal'' to Prof. Dr. Helmut Föll for his long standing cooperation with research centres in the Republic of Moldova.

# Inorganic Functional Materials

The research of the Chair of "Inorganic Functional Materials" concentrates on smart and multifunctional thin film materials and their applications in micro- and nanotechnology. Examples include research on:

- superelastic shape memory films for medical implants and for elastocaloric applications,
- magnetostrictive films, multilayers and structures for mechanical sensing applications,
- magnetoelectric composites: a combination of magnetostrictive and piezoelectric thin films for highly sensitive magnetic field sensors, and
- biodegradable Mg- or Fe-based films for medical implants.

The films and devices are fabricated in the cleanroom facility "Kieler Nanolabor" that provides thin film technologies such as magnetron sputtering, pulse laser deposition, and lithography as well as different dry and wet-etching techniques.

## Results

### NiTi thin film technology

The application of NiTi thin film microsystem technology in the field of endovascular devices, such as filters, stents, heart valves, and grafts, has been hampered by the limitation of film thickness and the lack of mechanical and fatigue performance data. Recent data confirmed that NiTi thin films technology can produce patterned films up to 80 $\mu$m thickness with superior mechanical properties, allowing the fabrication of innovative smart implants. This novel technology which is the combination of magnetron sputtering, UV lithography, and chemical etching opens up new ways of designing miniaturized medical devices with the following benefits (Figure 1):

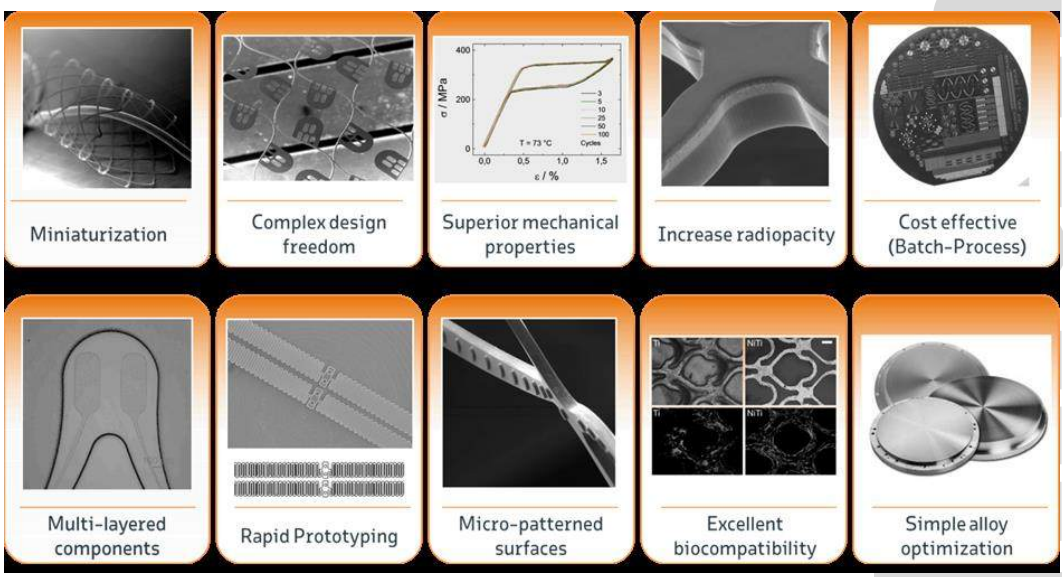


Fig. 1: Benefits and features of NiTi thin film technology

Acquandas GmbH is a medical device OEM supplier founded in 2012 with its headquarter at the Faculty of Engineering in Kiel, Germany. Acquandas produces, on behalf of medical implant and industry manufactures, the new generations of smart implants and instruments for minimally invasive treatments, and smart devices based on state-of-the art microsystem technology processes.

## Magnetoelectric Composites - Future Biomagnetic Interfaces

The chair of Inorganic Functional Materials is part of the Collaborative Research Centre „SFB 855 Magnetoelectric Composites - Future biomagnetic Interfaces“ . Using the Kiel Nanolab cleanroom facility (inaugurated in August 2008) magnetoelectric sensors, featuring composites of magnetostrictive and piezoelectric materials, are developed and optimized for high sensitivity in very low AC magnetic fields in the Picotesla range

One encouraging result this year is the lowering of the limit of detection (LoD), a measure for the minimal detectable field, in the 10 Hz measurement by applying frequency conversion technique to the magnetoelectric (ME) sensors featuring exchange bias. This additional magnetic anisotropy contribution originates from the exchange coupling at antiferromagnetic-ferromagnetic interfaces in the magnetic multilayers and allows control, to a certain extent, of the magnetic domain configuration in the magnetostrictive metglas. Figures 2a) and 2b) provide a comparison between the LoD of cantilevers with and without exchange bias. The increase of noise level in the 10 Hz measurements with frequency conversion is far lower for the ME sensor with exchange bias. The achieved LoD equals 180 pT/$\sqrt{Hz}$.

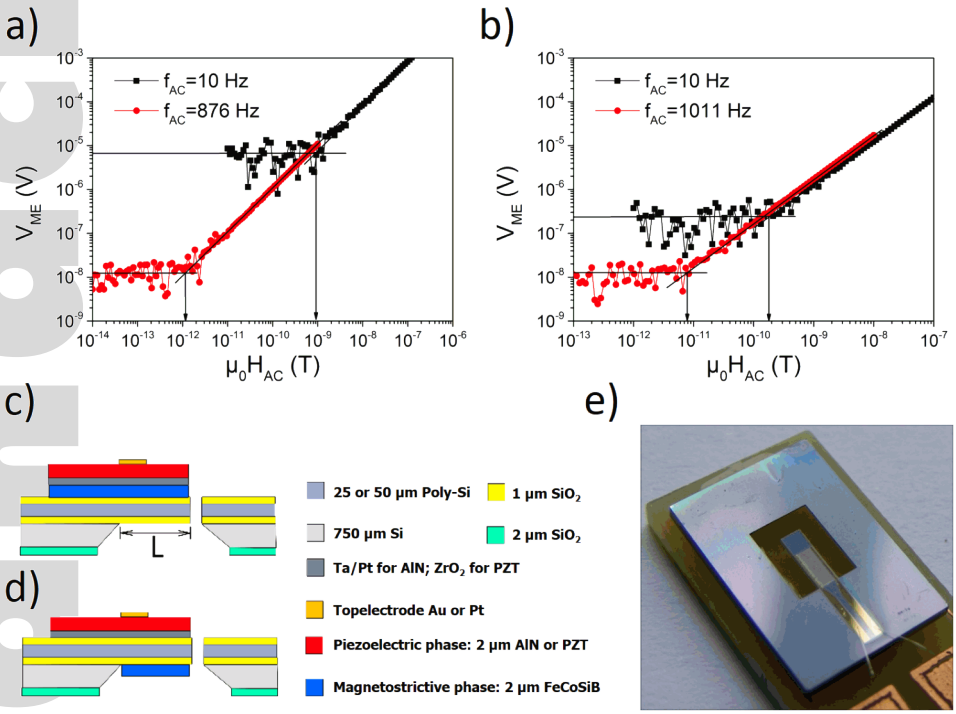


Fig. 2: a) ME response for an AC magnetic field with $f_{AC}$ = 10 Hz (black) and the resonance $f_{RES} = f_{AC} =$ 876 Hz (red) for an ME sensor without exchange bias, b) ME voltage versus AC magnetic field with $f_{AC}$ = 10 Hz (black) and $f_{RES} = f_{AC} =$ 1011 Hz (red) for an ME sensor with exchange bias. c) and d) Cross section of the MEMS processed magnetoelectric sensor with c) FeCoSiB and AlN on top of the cantilever, d) with AlN or PZT on top and FeCoSiB on the lower side of the cantilever: length L of the cantilever 3 mm, width 1 mm. e) . Photo of the finished sensor with PZT and interdigital electrodes (cross section as in d)).

Furthermore a new MEMS process has been developed in the clean room facilities to design magnetoelectric sensors on the chip scale. The unique feature is, that the temperature sensitive magnetostrictive phase based on FeCoSiB can be deposited on the back of a 25 $\mu$m or 50 $\mu$m thick Silicon cantilever, micro machined from an SOI Wafer (Fig. 2d)). This allows a great freedom in the preparation of the piezoelectric material, where high temperatures can be necessary (e.g. 700°C crystallization of PZT). Recent progress in the deposition of a low temperature AlN allows also a layer structure as shown in Figure 2c). Both structures have the advantage that the structure of the top electrode can be optimized according to the

electrical read-out and that the magnetostrictive phase can be optimized according to its magnetic domain configuration, without being affected by roughness or deposition temperature of the piezoelectric phase.

### Biodegradable materials

Biodegradable materials have been the subject of intense scientific research in recent years, in particular, for their application as temporary medical implants. The two most important metallic materials in this respect are magnesium and iron. Whereas the bio-corrosion of magnesium in the human body proceeds under the high rate formation of hydrogen leading to premature device failure, bio-corrosion of iron proceeds too slowly. However, corrosion as well as mechanical properties of these materials can be tuned by alloying additional elements with them.

Within the DFG project ZA748/2-1 several Fe alloys like Fe-Au, FeMn, Fe-Ag and pure Fe were fabricated and tested. It could be shown that the addition of Au results in a strain hardening and an increase of the corrosion. The addition of Mn results in an antiferromagnetic behaviour. Fe-Ag is a non-compound forming system with no solubility of the components in each other. However Ag is known for its antibacterial properties.

Within the DFG project QU149/9-2, structured foils of Mg5X (X = rare earth elements) were fabricated for medical applications like stents. These foils are deposited and structured using magnetron sputtering and microsystem technology processes, respectively. Since mechanical properties and corrosion behaviour are critical factors, the main aim is to reduce corrosion rate by alloying different elements and by surface finishing. A surface finishing procedure was developed to remove the columnar growth at the sample edges.

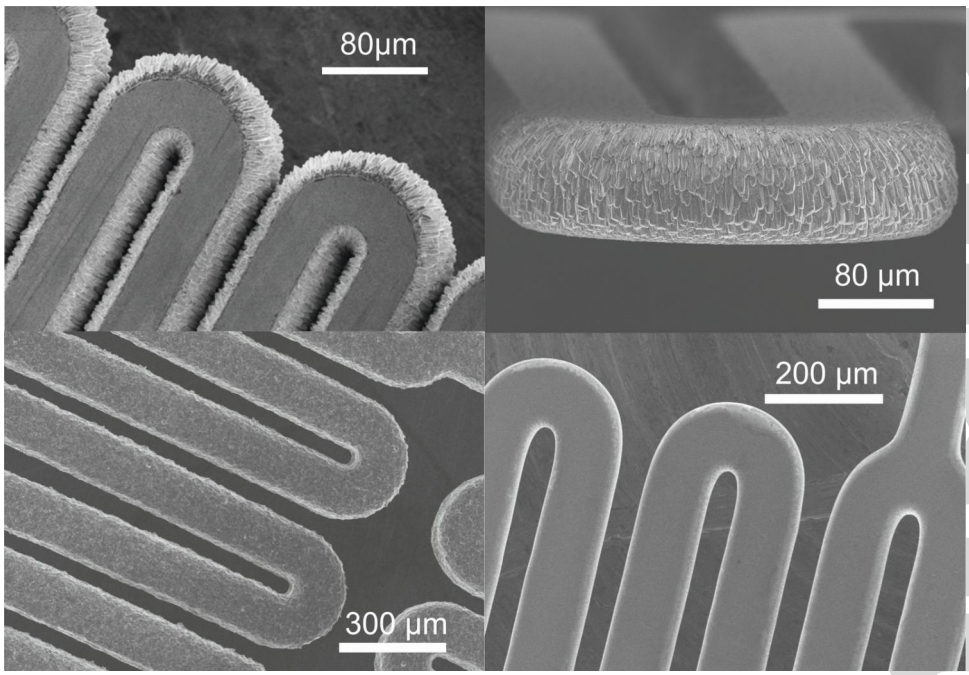


Fig. 3: Bildunterschrift für Bild 3

Due to the fact that the samples fabricated by magnetron sputtering deposition are in a metastable state, sputtered Mg films have no precipitates. Hence the corrosion rate is slower compared to Mg bulk material with the same composition. To combine the mechanical properties of bulk material with the improved corrosion behaviour of sputtered films, bulk material samples were coated by sputtering Mg alloys.

### Piezoelectric Thin-film Hydrophones

Water flow over a surface or around an object can lead to the formation of a turbulent boundary layer. In the case of underwater microphones or hydrophones, the noise generated by the vortices in the boundary layer constitutes a significant portion of the acquired signal and is therefore a matter of interest for fundamental research on hydroacoustics. For experimental investigation of turbulent boundary layer noise, flush-mounted hydrophones are used in order to eliminate other sources of turbulence. At the usual flow velocities, the total thickness of the boundary layer, and therefore also the diameter of the vortices in the layer, is in the millimetre or centimetre range, while the propagation speed of the vortices along the surface is limited by the flow velocity. Therefore, hydrophones for turbulent noise measurement require both high spatial resolution and good sensitivity at low frequencies. Traditional flush-mounted hydrophones provide high sensitivity over a broad frequency range but lack the ability to be placed in close proximity to each other due to their physical dimensions. To overcome this drawback, a closely spaced array of piezoelectric thin-film hydroacoustic sensors has been developed and tested in a laboratory setting. Additional outdoor tests have been performed in Sognefjord, Norway using a submersible test rig towed by the R/V ''Elisabeth Mann Borgese'' and provided by the project partner, the Research Department for Underwater Acoustics and Marine Geophysics (FWG). The recorded data was evaluated using Fourier transformations for the correlation of signals from different elements of the sensor array.

This analysis allows the separation of emissions from different sources, thus demonstrating the capability of thin-film hydrophones for the measurement of low-frequency noise from the turbulent boundary layer.

## Personnel

Head of the group: Prof. Dr.-Ing. Eckhard Quandt; Secretary: Gislinde Schroeder
Technical Staff: Dipl.-Ing. (FH) Thomas Metzing, M.Sc. Nicole Schneidewind

Staff:

| | | |
|---|---|---|
| Boris Gudschun | 01.01.-31.12.2014 | DFG |
| SFB 855, Z2 | | |

Scientific Staff:

| | | |
|---|---|---|
| M.Sc. Christoph Chluba | 01.01.-31.12.2014 | DFG |
| Elastocaloric Ti-Ni based Films and Devices - Materials | | |
| M.Sc. David Haffner | 01.01.2014-31.12.2914 | DFG |
| Herstellung von Bioresobierbaren Dünnschicht Gefäßstützen | | |
| M.Sc. Patrick Hayes | 01.01.-31.12.2014 | DFG |
| SFB Teilprojekt A1 | | |
| M.Sc. Till Jurgeleit | 15.-31.12.2014 | DFG |
| Fe-based biodegradable materials | | |
| M.Sc. Christine Kirchhof | 01.01.-31.12.2014 | DFG |
| SFB 855, Teilprojekt C2 | | |
| Dr.-Ing. Rodrigo Lima de Miranda | 01.01.-31.12.2014 | CAU |
| Dipl.-Phys. Klaas Loger | 01.01.-31.12.2014 | DFG |
| TiNi Dünnschicht Herzklappen | | |
| Dr. Antonio Malavé | 01.01.-31.12.2014 | CAU |

| | | |
|---|---|---|
| Dr. Dirk Meyners | 01.01.-31.12.2014 | CAU |
| M.Sc. Emmanuel Ossei-Wusu<br>Kompetenzzentrum Nanosystemtechnik | 01.01.-31.12.2014 | EFRE |
| Dipl.-Ing. André Piorra<br>SFB 855, Teilprojekt Z3 | 01.01.-31.12.2014 | DFG |
| M.Sc. Volker Röbisch<br>SFB 855, Teilprojekt A1 | 01.01.-31.12.2014 | DFG |
| M.Sc. Ali Tavasollizadeh<br>Magnetoresistive Tunnelstrukturen | 01.02.-31.12.2014 | DFG |
| Dipl.-Phys. Claas Thede<br>Machbarkeitsstudie zu piezoelektrischen Dünnschicht-Wasserschallsensoren | 01.05.-31.12.2014 | WTD 71 Bundeswehr |
| M.Sc. Erdem Yarar<br>SFB 855, Teilprojekt A1 | 01.01.-31.12.2014 | DFG |
| Dr. Christiane Zamponi<br>Fe-based biodegradable materials | 01.01.-31.12.2014 | DFG |

## Lectures, Seminars, and Laboratory Course Offers

*Winter 2013/2014*

Analytics 1, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
E. Quandt (+ E. Quandt)

Smart Materials, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
E. Quandt (+ Ch. Kirchhof)

Anorganische Funktionsmaterialien, 2 hrs Seminar/Week,
E. Quandt

Micro/Nanosystems Technology and Processes, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
D. Meyners (+ D. Meyners)

Laboratory Course: Analytik, 4 hrs Lab/Week,
D. Meyners (+ D. Haffner)

Laboratory Course: Basic Lab Course for M.Sc. Students, 3 hrs Lab/Week,
D. Meyners (+ K. Loger, E. Yarar, A. Piorra)

*Summer 2014*

Analytics 2, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
A. Piorra (+ A. Piorra)

Anorganische Funktionsmaterialien, 2 hrs Seminar/Week,
E. Quandt

Advanced Lab Course for M.Sc. Students, 4 hrs Lab/Week,
D. Meyners (+ K. Loger, V. Röbisch, A. Tavasollizadeh)

*Winter 2014/2015*

Analytics 1, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
E. Quandt (+ A. Piorra)

Smart Materials, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
E. Quandt (+ Ch. Kirchhof)

Anorganische Funktionsmaterialien, 2 hrs Seminar/Week,
E. Quandt

Micro/Nanosystems Technology and Processes, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
D. Meyners (+ D. Meyners)

Laboratory Course: Analytik, 4 hrs Lab/Week,
D. Meyners (+ Ch. Chluba)

Laboratory Course: Basic Lab Course for M.Sc. Students, 3 hrs Lab/Week,
D. Meyners (+ P. Hayes, E. Yarar, T Jurgeleit)

## Third-Party Funds

DFG, *Herstellung von bioresorbierbaren Dünnschicht Gefäßstützen (Stents) aus Magnesiumlegierungen durch Magnetron-Sputter-Technolgogie*, 09.11.2012-08.11.2015 (231.214 EUR)
DFG, *SPP 1599 - Elastocaloric Ti-Ni based Films and Devices - Materials*, 15.11.2012-14.11.2015 (281.234 EUR)
DFG, *TiNi Dünnschicht-Herzklappen*, 01.02.2012-31.01.2015 (239.748 EUR)
SFB 855, *Magnetoelektrische Verbundstoffe - biomagnetische Schnittstellen d. Zukunft , Teilprojekt A 1*, 01.01.-31.12.2014 (127.600 EUR)
SFB 855, *Magnetoelektrische Verbundstoffe - biomagnetische Schnittstellen d. Zukunft, Teilprojekt C2*, 01.01.-31.12.2014 (125.100 EUR)
SFB 855, *Magnetoelektrische Verbundstoffe - biomagnetische Schnittstellen d. Zukunft, Teilprojekt Z3*, 01.01.-31.12.2014 (72.000 EUR)
SFB 855, *Magnetoelektrische Verbundstoffe - biomagnetische Schnittstellen d. Zukunft, Teilprojekt Z2*, 01.01.-31.12.2014 (63.600 EUR)
Industrie, *Forschungs- und Entwicklungsvertrag*, 01.09.2012-31.08.2015 (180.000 EUR)
EFRE, *Kompetenzzentrum Nanosystemtechnik*, 01.03.2013-30.09.2015 (1.297.300,00 EUR)
DFG, *Biodegradierbare eisenbasierte Schichten für medizinische Anwendungen*, 01.04.2013-31.03.2016 (435.700,00 EUR)
Bundeswehr WTD 71, *Piezoelektrischer Dünnschicht-Wasserschallsensor*, 01.09.2013-30.11.2014 (90.000 EUR)
Industrie, *Forschungs- und Entwicklungsvertrag*, 19.12.2014-31.12.2015 (30.678 EUR)
Helmholtz-Institut Geesthacht, *Virtuelles Institut mit MetBioMat*, 01.01.-31.12.2014 (10.000 Euro)

## Further Cooperation, Consulting, and Technology Transfer

The group cooperates with the following individuals and organizations:

Prof. Dr. F. Faupel, CAU,

PD Dr. H. Hölscher, KIT, Karlsruhe,

Dr. N. Hort, Helmholtz-Zentrum, Geesthacht,

Prof. Dr. K.U. Kainer, Helmholtz-Zentrum, Geesthacht,

Prof. Dr. R. Knöchel, CAU,

Prof. Dr. M. Kohl, KIT, Karlsruhe,

Prof. Dr. G. Lutter, UKSH,

Prof. Dr. J. McCord, CAU,

Dr. K. Seemann, KIT, Karlsruhe,

Prof. Dr. C. Selhuber-Unkel,CAU,

Dr. M. Stüber, KIT, Karlsruhe,

Prof. Dr. B. Wagner, FHI ISIT,

Prof. Dr. R. Willumeit, Helmholtz-Institut Geesthacht,

Prof. Dr. M. Wuttig, University of Maryland, USA.

## Diploma, Bachelor's and Master's Theses

Fabian Janus, *Einfluss von Wärmebehandlung auf freitragende, gesputterte Magnesiumlegierungen*, 02.10.2014
Jan Johannsen, *Mechanische Charakterisierung freitragender eisenbasierter, biodegradierbarer Filme*, 29.10.2014
Victor Schell, *Herstellung und Charakterisierung von Schichtsystemen mit Exchange Bias durch Magnetfeldabscheidung*, 01.10.2014
Abraham Tesfamical, *Fabrication and Characterization of Complex 3 D Structured Shape Memory Thin Films*, 11.07.2014
Sultan Muhammad, *Softening of a highly magnetostrictive Material for ME-Sensors*, 10.03.2014
Alexander Dennissenko, *Investigation of Ni-Ti-Cu-Pd sputtered thin films for elastocaloric applications*, 01.11.2014
Hanna Lewitz, *Experimentelle Untersuchung zu Wasserschallsensoren auf Basis piezoelektrischer Dünnschichten*, 17.12.2014

## Dissertations / Postdoctoral Lecture Qualifications

Enno Lage, *Magnetoelektrische Dünnschichtkomposite mit integriertem Exchange Bias*, 20.03.2014
André Piorra, *Ferroelektrische Schichten für magnetische Komposite*, 27.03.2014

## Publications

Published in 2014

K. Schlüter, Z. Shi, C. Zamponi, F. Cao, E. Quandt, A. Atrens, *Corrosion performance and mechanical properties of sputter-deposited MgY and MgGd alloys*, Corrosion Science, **78**, 43 - 54 (2014)

E. Lage, N.O. Urs, V. Röbisch, I. Teliban, R. Knöchel, D. Meyners, J. McCord, E. Quandt, *Magnetic domain control and voltage response of exchange biased magnetoelectric composites*, Appl. Phys. Lett, **104**, 132405 (2014)

G. Siekmeyer, A. Schüßler, R. Lima de Miranda, E. Quandt, *Comparison of the fatigue performance of commercially produced nitinol samples versus sputter-deposited nitinol*, JMEPEG, **23**, 2437 - 2445 (2014)

A. Krasimir, M.C. Galetz, G. Schmidt, F. Depentory, M. Schütze, J. Teliban, E. Quandt, *Protective high temperature coatings with intrinsic depletion sensor*, Surface & Coatings Technology, **245**, 117 - 124 (2014)

H. Ossmer, F. Lambrecht, M. Gültig, C. Chluba, E. Quandt, M. Kohl, *Evolution of temperature profiles in TiNi films for elastocaloric cooling*, Acta Materialia, **81**, 9 - 20 (2014)

V. Hrkac, E. Lage, G. Köppel, J. Strobel, J. McCord, E. Quandt, D. Meyners, L. Kienle, *Amorphous FeCoSiB for exchange bias coupled and decoupled magnetoelectric multilayer systems:real-structure and magnetic properties*, J. Appl. Phys., **116**, 134302 (2014)

K. Loger, R. Lima de Miranda, A. Engel, M. Marczynski-Bühlow, G. Lutter, E. Quandt, *Fabrication and evaluation of Nitinol thin film heart valves,* Cardiovasc. Eng. Technol., **2014**, 308 - 316 (2014)

## Presentations

E. Quandt, A. Piorra, R. Jahns, E. Lage, C. Kirchhof, E. Yarar, V. Röbisch, D. Meyners, R. Knöchel, *Giant Magnetoelectric Thin Film Composites,* DPG Spring Meeting 2014, Dresden, Germany, 30.03.-04.04.2014

E. Quandt, *Materialwissenschaft für die Neuromedizin,* Symposium Neurohorizonte 2025 Medizinische Fakultät CAU, Kiel, Germany, 05.04.2014

E. Quandt, *Superelastic TiNi Thin Film Medical Implants,* Faculty colloquium, University of Maryland, Maryland, USA, 25.04.2014

E. Quandt, A. Piorra, R. Jahns, E. Lage, C. Kirchhof, E. Yarar, V. Röbisch, D. Meyners, R. Knöchel, *Giant Magnetoelectric Thin Film Compositess,* 2nd Seminar of Mechanics of Multifunctional Materials, Bad Honnef, Germany, 06.05.2014

C. Bechtold, R. Lima de Miranda, C. Zamponi, E. Quandt, *Capability of Sputtered Micropatterned NiTi Thick Films,* SMST 2014, Pacific Grove, USA, 12.-16.05.2014

R. Lima de Miranda, C. Bechtold, C. Zamponi, E. Quandt, *Shape Memory Alloy Thin Film Technology for Actuator Applications,* Actuator 2014, Bremen, Germany, 23.-25.05.2014

R. Lima de Miranda, *Von der Materialforschung bis zur Firmengründung,* WTSH Nanotechnologie in Schleswig-Holstein, Kiel, Germany, 10.06.2014

E. Quandt, A. Piorra, R. Jahns, E. Lage, C. Kirchhof, E. Yarar, V. Röbisch, D. Meyners, R. Knöchel, *Giant Magnetoelectric Thin Film Composites,* 7th International Conference on Thin Films 2014, Chongqing, China, 13.-18.07.2014

C. Chluba, R. Lima de Miranda, L. Kienle, M. Wuttig, E. Khachaturyan, *On the Role of Precipitates for the Functional Fatigue in TiNiCu Films,* ICOMAT 2014, Bilbao, Spain, 06.-10.07.2014

E. Quandt, André Piorra, R. Jahns, E. Lage, C. Kirchhof, E. Yarar, V. Röbisch, D. Meyners, R. Knöchel, *Giant Magnetoelectric Thin Film Composites,* 5th International Congress on Ceramics, Peking, China, 16.-23.08.2014

C. Kirchhof, A. Piorra, E. Yarar, V. Röbisch, D. Meyners, E. Quandt, *Thin Film Magnetoelectric Composites as Biomagnetic Sensors,* PIERS 2014, Guangzhou, China, 25.-28.08.2014

R. Lima de Miranda, *Potential der Dünnschicht-Technologie zur Herstellung neuartiger, NiTi-basierter Komponenten,* Bokomat 2014, Bochum, Germany, 18.-19.09.2014

C. Chluba, R. Lima de Miranda, C. Zamponi, H. Ossmer, M. Kohl, E. Quandt, *Sputtered Freestanding NiTi-Based Thin Films for Elastocaloric Cooling Applications,* MSE 2014, Darmstadt, Germany, 23.-25.09.2014

K. Loger, R. Lima de Miranda, A. Engel, M. Marczynski-Bühlow, G. Lutter, E. Quandt, *TiNi thin film heart valve for transcatheter aortic valve replacement,* MSE 2014, Darmstadt, Germany, 23.-25.09.2014

V. Röbisch, E. Lage, N.O. Urs, I. Teliban, R. Knöchel, J. McCord, D. Meyners, E. Quandt, *Magnetoelectric Sensors with Exchange Bias for Biomagnetic Sensing - Oral Poster,* MSE 2014, Darmstadt, Germany, 23.-25.09.2014

E. Yarar, I. Teliban, Y. Hrkac, L. Kienle, R. Knöchel, E. Quandt, *Detection of pT Magnetic Fields at Room Temperature: Inverse-Bilayer and Sandwich-Type Magnetoelectric Thin Film Sensors - Oral Poster,* MSE 2014, Darmstadt, Germany, 23.-25.09.2014

E. Quandt, E. Lage, N.O. Urs, V. Röbisch, I. Teliban, R. Knöchel, D. Meyners, J. McCord, *Magnetic Domain Control of Exchange Biased Magneto-Electric Thin Film Composites,* ECS Fall Conference, Cancun, Mexico, 05.-10.10.2014

R. Lima de Miranda, C. Bechtold, C. Zamponi, E. Quandt, *Sputtered micropatterned Nitinol thick films,* BMT 2014, Hannover, Germany, 08.-10.10.2014

C. Zamponi, T. Jurgeleit, U. Schürmann, L. Kienle, E. Quandt, *Mikrostruktur gesputterter Eisen-Gold Dünnschichtfilme für biologisch abbaubare Implantatmaterialien,* Jahrestagung der Deutschen Gesellschaft für Biomaterialien, Dresden, Germany, 06.-08.11.2014

T. Jurgeleit, C. Zamponi, E. Quandt, *Herstellung und Charakterisierung von hochreinen, freitragenden biodagradierbaren Eisenschichten,* Jahrestagung der Deutschen Gesellschaft für Biomaterialien, Dresden, Germany, 06.-08.11.2014

D. Meyners, V. Röbisch, E. Lage, E. Yarar, N.O. Urs, I. Teliban, R. Knöchel, J. McCord, E. Quandt, *Exchange biased magnetoelectric composites for magnetic field sensor application by frequency conversion,* 59th Annual Magnetism & Magnetic Materials Conference, Honolulu, USA, 03.-07.11.2014

E. Quandt, E. Lage, N.O. Urs, V. Röbisch, I. Teliban, R. Knöchel, D. Meyners, J. McCord, *Magnetic Domain Control of Exchange Biased Magneto-Electric Thin Film Composites,* Colloquium North Eastern University, Boston, USA, 02.-02.12.2014

## Further Activities and Events

E. Quandt has had the following posts and responsibilities:

Dean of the Faculty of Engineering (since 01.04.2014),

Coordinator (Sprecher) of the DFG Collaborative Research Centre (SFB 855) ''Magnetoelectric Composites - Biomagnetic Interfaces of the Future'',

member of the Materials Science and Engineering Expert Committee (MatSEEC) of the European Science Foundation (ESF),

member of ''Deutsche Akademie der Technikwissenschaften (acatech)'',

member of the Executive Board and Coordinator (Sprecher) of the Advisory Board of the Deutsche Gesellschaft für Materialkunde (DGM),

member of the Review Board of the DFG,

member of the Advisory Board of the Fraunhofer Institute ISIT.

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# Materials and Processes for Nanosystem Technologies

Prof. Dr. Bernhard Wagner is the Deputy Director of the Fraunhofer-Institute für Siliziumtechnologie (ISIT) in Itzehoe.

Fraunhofer ISIT develops and manufactures components in microelectronics and microsystems technology, from the design phase (including system simulation), through prototyping and fabrication of samples, up to series production. Even though components manufactured at Fraunhofer ISIT, such as acceleration sensors, valves, and deflection mirrors, often measure just a fraction of a millimetre in size, there is a wide range of applications: the devices are implemented in areas like medical care, environmental and traffic engineering, communication systems, automotive industry, and mechanical engineering. Working under contract, ISIT develops these types of components in accordance with customer requirements, also creating the application specific integrated circuits (ASICs) needed for the operation of sensors and actuators. Included in this service is system integration using miniaturized assembly and interconnection technology.

Together with Vishay Siliconix Itzehoe GmbH, the institute operates a professional semiconductor production line which is up-to-date in all required quality certifications (e. g. ISO 9001, TS 16949). This line is used in parallel for PowerMOS and microsystem production and for R&D projects developing new devices and technological processes.

Other fields of activity at ISIT focus on assembly and packaging techniques for microsystems, analysis of the quality and reliability of electronic components, and development of advanced power-supply components for electronic systems.

The institute employs a staff of around 150 people.

Further information about Fraunhofer ISIT is available on the web: www.isit.fraunhofer.de.

In addition the Institute publishes an Annual Report which can be ordered at ISIT.

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# Metallic Biomaterials

Since 01.09.2014 ''Biological Interfaces of Implants'' has been a shared professorship with the Helmholtz-Zentrum Geesthacht, Zentrum für Material- und Küstenforschung in Geesthacht (HZG). HZG is a member of the Hermann von Helmholtz-Gemeinschaft Deutscher Forschungszentren (HGF). Prof. Dr. Regine Willumeit-Römer is director at the Institute of Materials Research and responsible for the division ''Metallic Biomaterial''.

The ''Metallic Biomaterials'' division examines and develops new implant materials based on titanium and magnesium.

Magnesium provides optimal properties for use as an absorbable implant material in medical applications such as orthopaedics, traumatology and paediatrics.

Magnesium possesses characteristics similar to bone, is an essential element required by the human body, and probably stimulates new bone formation. In order to establish magnesium as a marketable implant material, an array of factors must be examined: the properties of the base material must be considered among other factors in regards to the mechanical characteristics and degradation behaviour. It is equally important to understand what impact the material exerts on the cells that grow on its surface, and ultimately, the impact on the organism. Furthermore, researchers must ensure that the steps in processing, from the base material to implant prototypes, do not cause significant property alterations.

The Magnesium Innovation Centre (MagIC) supplies the base material: the magnesium alloy. The ''Metallic Biomaterials'' division examines factors that lead to magnesium degradation under physiological conditions. The scientists also test magnesium alloy properties in the cell culture. In cooperation with MagIC, the processing of the material is optimised.

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Email: regine.willumeit@hzg.de
Homepage: http://www.hzg.de/metallic_biomaterials
and

Christian-Albrechts-Universität zu Kiel
Technische Fakultät, Institut für Materialwissenschaft
Biologische Grenzflächen von Implantaten
Kaiserstr. 2, Geb. F, Rm 101
24143 Kiel

## Lectures, Seminars, and Laboratory Course Offers

*Winter 2014/2015*

M.Sc. - Chemistry and Physics of Biomaterials, 3 (+ 1) hrs Lecture (+ Exercises)/Week,
Regine Willumeit-Römer

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# Multicomponent Materials

Last year, the Chair for Multicomponent Materials, headed by Prof. Franz Faupel, celebrated its $20^{th}$ anniversary: in January 1994, the Chair for Multicomponent Materials started its work from scratch. To celebrate this $20^{th}$ anniversary a big celebration took place in July attended by former group members and guests from all over the world.

Concerning the scientific output, the group can now look back to 277 publications listed in the Web of Science and more than 5000 citations. The latter number is increasing rapidly with 550 citations in 2014 alone. (The numbers at Google Scholar are even higher). The average number of citations per publication is as high as 21. We are particularly pleased that the early work still attracts a very high number of citations; indeed, some of that work has also found its way into materials science text books.

In addition to numerous diploma, M.Sc. and B.Sc. students, Prof. Faupel and his group supervised more than 40 Ph.D. theses. This would have been impossible without a constantly high number of third parties providing funds. Several of the Ph.D. graduates received prizes, among which were the Young Scientist Award of the German Materials Research Foundation (DGM), and the Faculty of Engineering Award for the best Ph.D. thesis. Moreover, four ''Habilitationen'' emerged from the Chair for Multicomponent Materials here: Klaus Rätzke and Nicolas Stolwijk are now extraordinary professors at the Chair for Multicomponent Materials here in Kiel and at the University of Münster, respectively. Rainer Adelung first became Heisenberg professor and subsequently took over the full professorship of Prof. Föll at the Institute of Materials Science after rejecting an external offer. The name of the group is now ''Functional Nanomaterials''. Dirk Schubert, a former employee of Freudenberg, who cooperated closely with the Chair for Multicomponent Materials, now holds the full professorship in ''Polymer Physics and Processing'' at the University of Erlangen-Nürnberg. Finally, Mady Elbahri is another scholar of the Chair for Multicomponent Materials, who still cooperates closely with the group. He currently holds an assistant professorship at the Institute of Materials Science and is head of the Helmholtz-University Young Investigator Group ''Nanochemistry and Nanoengineering''. Having passed the very successful evaluation of his group, he is now expecting to become a tenured associate professor.

The work of the group during the last 20 years is documented in the abovementioned publications and on our website at http://www.tf.uni-kiel.de/matwis/matv/. Here in this Almanac, only a few aspects of last year's research can be discussed. More information on the different research topics are also given in previous Almanac editions which can be downloaded from our website. The achievements of the group would have been impossible without the work of all the former group members, the continuous administrative support by our secretaries, the server uptime achieved by our computer experts, the many intelligent technical designs by Stefan Rehders, and in particular the valuable contributions over the years of Prof. Klaus Rätzke,the late Dr. Vladimir Zaporojtchenko, who passed away in 2012, and Dr. Thomas Strunskus.

As in the year before, working in three Collaborative Research Centres (SFBs), the group strongly benefited from joint interdisciplinary work with partners ranging from fundamental physics and organic chemistry to electrical engineering and medicine. The Collaborative Research Centre SFB 677 ''Function by Switching'' continued its very successful work of the earlier years and now prepares for a second extension. Here our group benefits strongly from a close cooperation with the group of Prof. Elbahri from the Institute of Materials Science in the field of plasmonic nanocomposites (see Prof. Elbahri's Almanac chapter). Many new results on formation of nanoparticles in plasmas were obtained in our joint project ''Plasma Processes for the Deposition of Nanostructured Composite Materials''; the work on complex plasmas was done both within the Collaborative Research Centre SFB TR 24 and the group of Prof. Kersten from the physics department of the CAU. In 2013, the SFB TR24 was very successfully evaluated and is now in its third funding period. Although the Collaborative Research Centre SFB 855 on magneto-electric nanocomposites for medical applications can also look back to a very productive first funding period and a very positive evaluation, its funding was nevertheless extended by the DFG for only one more year. Much research of the Chair for Multicomponent Materials was also performed outside the three collaborative research centres, e.g. within the DFG priority programme „Polymer-solid contacts: Interfaces and Interphases" , and several other projects. The group also performed investigations at large scale facilities: the storage rings BESSY II in

Berlin and PETRA III at DESY in Hamburg, the positron beam facility of the Research Reactor Garching, and the positron beam at Tsukuba in Japan. As the group is strongly involved in positron spectroscopy for materials characterization, we also hosted a two day workshop in February 2014 on positron physics and materials science with 25 scientists from Germany and Austria.

Over the years, members of the Chair for Multicomponent Materials have been strongly involved in teaching and made great efforts in various ways, including visits to schools in Schleswig-Holstein, to inspire pupils to study materials science and engineering.

Concerning technology transfer, Prof. Faupel founded the society „North German Initiative Nanotechnology Schleswig-Holstein e.V." which aims at bringing together nanotechnology stakeholders in Schleswig-Holstein with partners from industry research institutes and academics in North Germany and the Baltic region.

## Results

### a) Metallic glasses, glass forming melts and organic glass formers

Metallic glasses and glass forming melts have always been one of the key research topics of the Chair for Multicomponent Materials. Metallic glasses can be employed in a vast range of applications from soft-magnetic components, through ultra-thin electronic housings, to biodegradable implants. Although the appearance of metallic glasses resembles that of ordinary metals, their atomic structure differs completely. While the atoms in a conventional metal arrange in a periodic lattice, there is no such long range order in metallic glasses. This disordered state, which is similar to a frozen liquid, can be created by rapid quenching of a melt. However, only for certain mixtures of elements will the glassy state be accessible with technically reasonable cooling rates. Latterly, we have investigated the diffusion behaviour, the glass forming ability, and the glass transition from the undercooled melt to the glassy state. Details were reported in previous Almanac editions. For our early work, we also refer to an invited paper by Faupel et al. in ''Review of Modern Physics'' [75 (2003) 237], a journal with an impact factor far above that of ''Nature'' or ''Science''.

Last year, we reported very interesting deviations of the diffusion behaviour of glass-forming Zr-Cu-Ni-Ti-Be melts from that of ordinary melts or liquids as described by a theory of Einstein. The results were published in the renowned journal „Physical Review Letters" (see list of publications). According to the Stokes-Einstein relation, all atoms in an equilibrium melt far above the melting point are expected to participate in the Brownian motion with approximately the same mobility. In contrast, the majority component Zr, which is also the largest atom of the alloy, proved to have a much lower mobility compared to the other components. This was attributed to the ability of the Zr to form temporary solid-like bonds even in the melt (see Fig. 1). These results give important clues to the excellent glass forming ability of this technologically important bulk glass forming alloy. Some of our findings on the diffusion behaviour of metallic glasses meanwhile have found their way into materials science textbooks.

Over the years, we also have carried out much work on diffusion and the dynamics of organic glass formers. In particular, we investigated diffusion of metals in polymers and organic semiconductors (related to applications in microelectronics), and the glass transition in thin polymer films at polymer surfaces and polymer-solid interfaces. The recent work is discussed below. For the earlier work, we refer to our website and previous Almanac editions.

### b) Metal-polymer interfaces and polymer-solid contacts

The Chair for Multicomponent materials always has been interested in metal-polymer interfaces which play an important role in microelectronics and other fields. Early work focused mainly on polymer metallization, diffusion, interface formation, chemical interaction, and adhesion. This work still continues in a joint project, funded by the DFG, on interface formation during sputter deposition of metals on polymers. Together with Prof. Peter Müller-Buschbaum from the TU Munich and Dr. Stephan Roth from DESY in Hamburg, we use mainly synchrotron based techniques to investigate the early stages of interface formation. The project also involves polymers used in organic electronics.

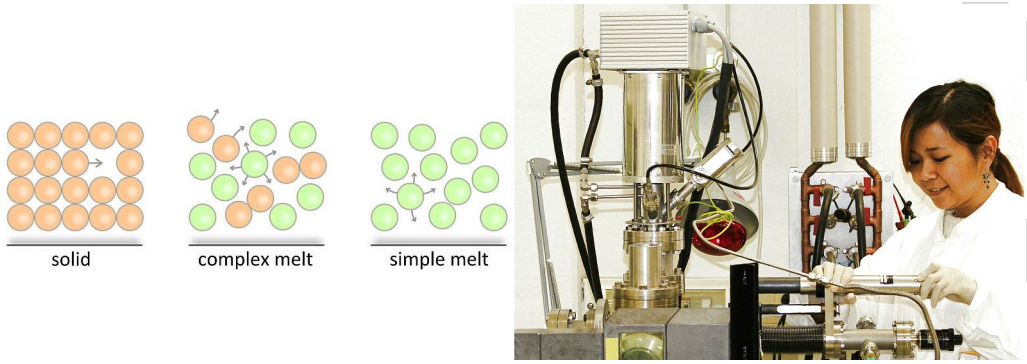


Fig. 1: (left) Highly schematic sketch of the diffusion behaviour in crystalline solids, simple melts, and glass forming melts. In crystalline solids, the atoms form permanent bonds and diffusion only occurs locally via defects in the form of vacancies. In simple melts, all atoms diffuse simultaneously by uncorrelated binary collisions. In complex glass forming melts, some atoms form solid-like temporary bonds which reduce their mobility. (right) The Ph.D. student Sri Wahyuni Basuki preparing a diffusion experiment.

In addition, within the DFG priority programme ''Polymer-solid contacts: Interfaces and Interphases'' which was co-initiated by Prof. Faupel, we studied the structure and formation of interfaces between polymers and solid materials like metals and ceramics, which are important in many applications including polymer nancomposites, where solid nanoparticles are embedded in a polymer matrix. Key questions are how the properties of the polymer change near a solid interface, and over what distance these changes extend. Recently, we succeeded in probing with high resolution the free volume, i.e. the packing density of the polymer chains, at the interface between the fluoropolymer Teflon AF and silicon nitride, using the moderated positron beam at the positron facility in Tsukuba in Japan (see Fig. 2). We found a marked increase in the packing density of the polymer near the interface over a distance of only about 10 nm. While this interface extension is quite small, it may significantly alter the properties of highly filled particulate nanocomposites. The results are reported in ''Macromolecules'' in 2015.

**c) Nanocomposites for functional applications** A main activity of our group during recent years has centred on functional nanocomposites that consist of metallic nanoparticles embedded in an insulating matrix, either polymeric or ceramic in nature. The size of the nanoparticles is between that of atoms and macroscopic materials and thus gives rise to new properties, not observed in conventional materials, which are explored in a broad range of applications ranging from high frequency magnetic materials, through plasmonic metamaterials, to antimicrobial coatings. The nanocomposites are mostly deposited as thin films by vapour phase deposition methods, in particular evaporation and sputtering from solid targets.

During the last year, plasma polymerization and plasma enhanced chemical vapour deposition (PECVD) have also been employed in a joint project of the above mentioned Collaborative Research Centre SFB TR 24. This trans-regional Collaborative Research Centre of the universities of Greifswald and Kiel addresses fundamentals of complex plasmas and their applications to nanoscience. As mentioned above, the TR 24 very successfully passed its evaluation after the second funding period and is now in its last period. Within the TR 24, our group established a joint project with Prof. Kersten from the department of physics of CAU, focusing on the use of plasma processes for the deposition of nanostructured composite materials. Details on the activities of our group within the TR 24 were reported in the Almanacs of 2011, 2012 and 2013. In the new funding period, an additional joint project with Prof. Kersten was launched by Dr. Thomas Strunskus. This project aims at exploring the early stages of nanoparticle nucleation and growth using synchrotron based X-ray scattering and spectroscopy techniques at the large scale facilities DESY in Hamburg and BESSY in Berlin. Within the framework of the SFB TR 24, our group also cooperates with the group of Prof. Michael Bonitz from the Institute of Theoretical Physics and Astrophysics on computer simulations of nanoparticle formation in the gas phase and on a substrate.

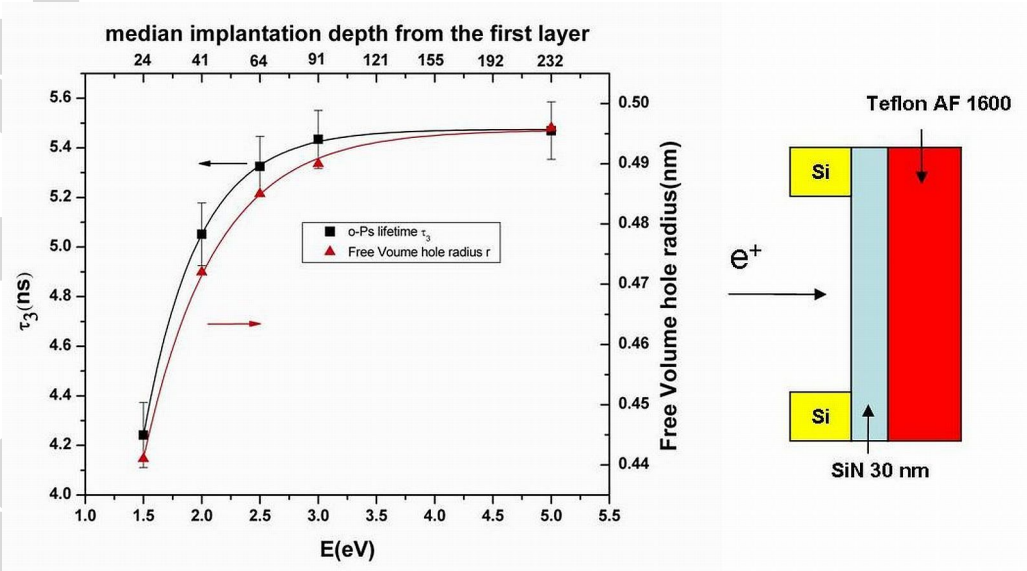


Fig. 2: (left) Depth profile obtained at a Teflon AF-silicon nitride interface using the positron beam facility in Tsukuba in Japan. A marked drop is noted of the positron lifetime near the interface, which corresponds to an increased polymer density of about 7 %. (right) Sketch of the experimental setup. The positron beam impinges on the sample through an etched opening in the silicon wafer coated with a ultra-thin SiN film, which ensures a narrow implantation profile of the positrons.

Nanocomposites also play a key role in our projects within the Collaborative Research Centre SFB 677 ''Function by Switching'' which, now in the second funding period, are carried out jointly with Prof. Elbahri from our Institute of Materials Science (see also recent Almanac editions and his report). Here, the nanocomposites are combined with photoswitchable molecules. These so-called chromophores change their properties reversibly upon irradiation with light of two different wavelengths. Very interesting new electro-optical properties arise through interactions between chromophores and the so-called surface plasmon resonance of the metallic nanoparticles. These resonances are collective oscillations of the conduction electrons in the electrical field vector of electromagnetic radiation. Recently, we also developed new photoswitchable devices which contain carbon nanotubes (CNTs) instead of metallic nanoparticles and allow light-induced conductivity switching. Meanwhile, these investigations were extended from multi-walled carbon nanotubes to single-walled CNTs, where the switching mechanism turned out to be different.

Concerning the Collaborative Research Centre SFB 855 on magneto-electric nanocomposites for medical applications, our work has shown that, in this area, layered composites are much more promising than particulate composites. As reported in previous Almanac editions, we developed a novel magnetic field sensor that was presented to a wide readership in a ''Nature Research Highlight''. The sensor, which is robust against mechanical impact and provides broad-band sensitivity down to the DC range, is based on the so-called giant Delta-E-Effect, i.e. the huge change of Young's modulus of special magnetostrictive alloys in a magnetic field. Currently, various approaches ranging from new materials, through alternative read out and operation principles, to active control, are explored together with partners within the SFB 855. Meanwhile, along with Prof. Bernd Wagner from the Fraunhofer Institute for Silicon Technology (ISIT) and Dr. Robert Jahns from the Department of Electrical and Information Engineering (group of Prof. Reinhard Knöchel), a fully integrated sensor with a largely improved sensitivity was developed. Moreover, we continued our work on magnetoelectric layered composites involving piezoelectric polymers. For details we refer to the Almanac of 2013 and the attached list of publications.

In several projects we explore the large specific surface area of finely dispersed nanoparticles and the strong influence of the surface or interfacial energy on the material's properties. This is particularly the case in antibacterial coatings with nanoparticles of silver and other noble metals, where a high metal ion release rate is strived for because the

antimicrobial activity originates from the released metal ions. Here, research has been carried out in cooperation with Prof. Podschun from the Institute of Infection Medicine of the University Hospital Schleswig-Holstein/Campus Kiel. The toxicity of nanoparticles was investigated in cooperation with PD Röhl from the Institute for Toxicology and Pharmacology for Natural Scientists of the CAU. In addition, among other partners, we cooperate with Prof. Grundmeier from the Chemistry Department of the University of Paderborn in a joint DFG project addressing fundamental issues of silver ion release from nanocomposites. Details are reported in previous Almanac editions and the listed publication on controlling the release behaviour on reactively sputtered Ag-$TiO_2$ nanocomposites.

For many years, the Chair for Multicomponent materials also has explored the plasmonic properties of noble metal nanoparticles in dielectric matrices, which have already been mentioned above in connection with the activities within the SFB 677. During recent years, this work has been boosted by a close cooperation with Prof. Mady Elbahri, a former member of the group. He initiated some exciting new applications of metal-dielectric nanocomposites as so-called plasmonic metamaterials, which were pursued together with our group. Examples include transparent plasmonic conductors and perfect plasmonic absorbers. We refer to the recent Almanac chapters of Prof. Elbahri and the joint publications.

**d) North German Initiative Nanotechnology Schleswig-Holstein e.V.**

Last year, the North German Initiative Nanotechnology Schleswig-Holstein e.V., ( NINa SH e.V.), a society aiming at the advancement of science and research in the field of nanotechnology in Schleswig-Holstein, was registered. NINa's mission is to connect parties from Schleswig-Holstein involved in nanotechnology with relevant stakeholders from all across northern Germany and the Baltic region countries.

NINa SH e.V. was founded in August 2013. The list of founding members, in addition to individual members and companies, includes the big universities in Schleswig-Holstein, the Fraunhofer-Institutes ISIT (Itzehoe) and IFAM (Bremen), the Helmholtz-Centre Geestacht (HZG), as well as several public institutions. The society continues the activities of its successor, the North German Initiative Nanomaterials (NINa), which was founded in 2005 by the Innovationsstiftung Schleswig-Holstein (ISH) and coordinated over the years by Prof. Faupel. Prof. Faupel is now First Executive Director of NINa SH e.V. As a registered society, NINa SH e.V. is able not only to continue NINa's operations in the long term but also to widen its range of activities to the whole field of nanotechnology. In addition, NINa SH e.V. now serves the whole northern part of Germany and the Baltic region countries.

NINa SH e.V. provides the framework for the frequent exchange of up-to-date knowledge and experience between researchers, companies, political institutions and other organizations. Thereby, new contacts are made and innovative ideas and strategies in the field of nanotechnology are cooperatively developed.

Furthermore, the society establishes a supra-regional nanotechnology competence network between all involved stakeholders from northern Germany and the Baltic Sea countries. Recently, the society obtained funding from the Ministry of Economic Affairs, Employment, Transport and Technology in Schleswig-Holstein to set up a „Coordination Centre Nanotechnology in Schleswig-Holstein" . More information is provided at http://www.nina-sh.de.

## Personnel

Head of the group: Prof. Dr. F. Faupel; Secretary: N. Gühlke (50%), Dipl.-Chem. S. Kastaun (50%)
Technical Staff: Dipl.-Ing. (FH) R. Kloth (on leave), Techn. C. Ochmann (DFG, BMBI), Dipl.-Ing. (FH) S. Rehders, Dipl.-Inf. P. Sommer

Scientific Staff:

| | | |
|---|---|---|
| M.Sc. A. M. Ahadi | 01.01.-31.12.2014 | Fellowship Iran, CAU, DFG |
| Nanoparticles from plasmas | | |

Fig. 3: The board of directors of the North German Initiative Nanotechnology Schleswig-Holstein e.V. (from left.) Olaf Jacobs (FH Lübeck), Jens Urny (HSU Hamburg, Treasurer) , Werner Kässens (Wissenschaftszentrum Kiel), Franz Faupel (CAU Kiel, First Executive Director), Joachim Bergmann (WTSH), Rainer Döhl-Oelze (GITZ, 2. Executive Director) and Eckhard Quandt (CAU Kiel), Photo Schimmelpfennig/CAU)).

| | | |
|---|---|---|
| M.Sc. S. W. Basuki<br>Diffusion in complex melts | 01.01.-31.12.2014 | DFG |
| M.Sc. Ana Corres<br>free volume membranes | 15.04.-15.06.2014 | Fellowship DAAD |
| M.Sc. B. Henkel<br>Functional nanocomposites | 01.01.-31.08.2014 | CAU |
| M.Sc. A. Hinz<br>Nanoparticle Formation | 01.01.-31.12.2014 | SFB TR24 |
| M.Sc. T. Koschine<br>Positron beam, polymers | 01.01.-31.12.2014 | CAU |
| M.Sc. A. Kuzminova | 15.08.-15.09.2014 | Visiting scientist |
| Dipl.-Ing. K. Meurisch<br>Magneto-electric nanocomposites | 01.01.-22.09.2014 | CAU, SFB 855 |
| M.Sc. C. Ohrt<br>Polymer-Solid-Interphases | 01.01.-31.12.2014 | DFG SPP 1369, CAU |
| Dr. O. Polonskyi<br>Nanoparticles from plasmas | 01.01.-31.12.2014 | SFB TR24, CAU |
| Prof. Dr. K. Rätzke<br>Supercooled melts, positron annihilation | 01.01.-31.12.2014 | CAU |
| Dipl.-Phys. V. Schneider<br>Photoswitchable nanocomposites | 01.01.-31.12.2014 | SFB 677 |

| | | |
|---|---|---|
| Dr. T. Strunskus<br>Functional nanocomposites | 01.01.-31.12.2014 | SFB 855, CAU |
| M.Sc. J. Xiong<br>Functional nanocomposites | 01.01.-15.08.2014 | Fellowship China |
| Dipl.-Phys. S. Zabel<br>Magneto-electric sensors | 01.01.-31.12.2014 | SFB 855 |

## Lectures, Seminars, and Laboratory Course Offers

*Winter 2013/2014*

Advanced Organic Materials, 2 hrs Seminar/Week,
F. Faupel

Übungen zur Physik I, 2 hrs Seminar/Week,
K. Rätzke

Thin Films, 4 (+ 1) hrs Lecture (+ Exercises)/Week,
K. Rätzke (+ V. Schneider)

Einführung in die Materialwissenschaft 1, 2 hrs Lecture/Week,
K. Rätzke

Werkstoffe - Metalle, 2 hrs Lecture/Week,
F. Faupel

Solid State Physics 1, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
F. Faupel

Advanced Materials A - Polymers, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
F. Faupel (+ T. Strunskus)

Seminar for Members Group of Rätzke, 2 hrs Seminar/Week,
K. Rätzke

Seminar for Members of the Chair for Multicomponent Materials, 2 hrs Seminar/Week,
F. Faupel

*Summer 2014*

Einführung in die Materialwissenschaft II, 2 hrs Lecture/Week,
K. Rätzke

Advanced Metallic Materials, 2 hrs Seminar/Week,
F. Faupel

Seminar for Members of the Chair for Multicomponent Materials and interested guests, 2 hrs Seminar/Week,
F. Faupel

Übungen zur Physik II, 2 hrs Exercise/Week,
K. Rätzke

Seminar for Members Group of Rätzke, 2 hrs Seminar/Week,
K. Rätzke

Solid State Physics 2, 2 (+1) hrs Lecture (+ Exercises)/Week,
F. Faupel

*Winter 2014/2015*

Advanced Organic Materials, 2 hrs Seminar/Week,
F. Faupel

Übungen zur Physik I, 2 hrs Seminar/Week,
K. Rätzke

Thin Films, 4 (+1) hrs Lecture (+ Exercises)/Week,
K. Rätzke (+ O. Polonskyi)

Einführung in die Materialwissenschaft 1, 2 hrs Lecture/Week,
K. Rätzke

Werkstoffe - Metalle, 2 hrs Lecture/Week,
F. Faupel

Solid State Physics 1, 2 (+1) hrs Lecture (+ Exercises)/Week,
F. Faupel

Advanced Materials A - Polymers, 2 (+1) hrs Lecture (+ Exercises)/Week,
F. Faupel (+ T. Strunskus)

Seminar for Members Group of Rätzke, 2 hrs Seminar/Week,
K. Rätzke

Seminar for Members of the Chair for Multicomponent Materials, 2 hrs Seminar/Week,
F. Faupel

## Third-Party Funds

Scholarship Council of China, *Stipendium für Jian Xiong für 4 Jahre*, 15.11.2010-15.11.2014 (48.000 Euro)
Iranian Government, *Stipendium für Amir Mohammad Ahadi für 3,7 Jahre*, 25.11.2010-25.07.2014 (45.000 Euro)
DFG, *Polymer-Solid contacts: Interfaces and Interphases: Verteilung des freien Volumens an Polymer-Festkörper Grenzflächen*, 25.02.2011-30.11.2014 (257.800 Euro)
DFG, *Structural Arrest in Multicomponent Glass-forming Zr-melts*, 06.04.2011-06.04.2014 (278.450 Euro)
DFG SFB 677/2, *Function by Switching: Photoswitchable Metal-Polymer Nanocomposites*, 01.07.2011-30.06.2015 (363.220 Euro)
DFG, *In-situ Untersuchungen zu Kondensation, Nukleation und Wachstum von Metallfilmen und Nanostrukturen auf organischen Oberflächen während Sputterbeschichtung*, 05.06.2013-05.06.2016 (328.050 Euro)
DFG, SFB TR24/3, *Fundamentals of Complex Plasmas: Plasma processes for the deposition of nanostructured composite materials*, 01.07.2013-30.06.2017 (305.450 Euro)
DFG, SFB TR24/3, *Fundamentals of Complex Plasmas: Investigation of nucleation and growth of nanoparticles in plasmas*, 01.07.2013-30.06.2017 (313.375 Euro)
DFG SFB 855, *Magnetoelectric Composites - Future Biomagnetic Interfaces: Gasphasenabscheidung von magnetoelektrischen 0-3 Nanokompositen*, 01.01.2010-31.12.2014 (703.120 Euro)
DFG SFB 855, *Magnetoelectric Composites - Future Biomagnetic Interfaces: Geregelte Magnetfeldsensoren basierend auf dem $\Delta$E-Effekt (Auslauffinanzierung)*, 01.01.-31.12.2014 (59.640 Euro)
DAAD, *scholarship for Ana Corres*, 01.04.-15.06.2014 (3.950 Euro)
DFG, *Vertical and horizontal memristrive nanocomposite devices without filament formation*, 07.10.2014-06.10.2017 (178.200 Euro)

## Further Cooperation, Consulting, and Technology Transfer

The Chair cooperates with the following individuals and organizations:

*Universities:*

Prof. Dr. R. Adelung, Functional Nanomaterials, Memristive Materials and magnetic field sensors,

Prof. M. Bauer, F. Tuczek, O. Magnussen, Prof. W. Herges, combination of switchable molecules and nanocomposites close to the percolation threshold (SFB "Function by Switching"),

Prof. Dr. M. Bonitz, Theoretical Physics, Kiel University, theory and simulation of formation of nanostructured materials,

Prof. Dr. R. Busch, Dr. Z. Evenson, Uni Saarland. relaxation in bulk metallic glasses,

Prof. Dr. G.Dollinger, Dr. W. Egger, Bundeswehr University, Munich, PLEPS at FRM II,

Prof. Drusch, Food Processing Technology and Materials Science, TU Berlin, encapsulation of food products,

Prof. Dr. M. Elbahri, Institute for Material Science, several topics with hybrid organic/inorganic materials,

Prof. Dr. M. Es-Souni, FH Kiel, characterisation of functional materials,

Prof. Dr. M. Gerken, Integrated Systems and Photonics, simulation of magnetoelectric sensors,

Prof. Dr. G. Grundmeier, Paderborn University, polymer based nanocomposites,

Prof. Dr. H. Herges, Organic Chemistry, Prof. Dr. F. Tuczek, Inorganic Chemistry, Kiel University, and other partners, NEXAFS investigations at the Berlin storage ring BESSY, Berlin,

Dr. Chr. Hugenschmidt, TU Munich and FRM II, NEPOMUC,

Dr. Stuart James, U. Belfast,UK, free volume in porous liquids,

Prof. Dr. M. Kern, Dental Clinic, Kiel University, zirconia ceramics for dental applications,

Prof. Dr. H. Kersten, Atom and Plasma Physics, Kiel University, Formation of nanostructured materials in complex plasmas,

Prof. Dr. L. Kienle, Synthesis and Real Structure, TEM analysis of nanoparticles and nanocomposites,

Prof. Dr. H. Kohlstedt, Nano Electronics, memristive materials,

Prof. Dr. E Kovacevic, University of Orleans, France, Formation and investigation of carbon nanoparticles from plasmas,

Prof. Dr. T. Meurer, Automatic Control, nonlinear $\Delta$E Sensors,

Prof. Dr. P. Müller-Buschbaum, Technical University Munich, growth of sputtered metal on organic surfaces,

Prof. Dr. R. Podschun, Institute for Infection Medicine, Kiel University, Antibacterial Coatings,

Prof. Dr. E. Quandt, Inorganic Functional Materials, Faculty of Engineering, functional magnetic nanocomposites,

Dr. Tobias Vossmeyer, Institut für Physikalische Chemie, Universität Hamburg, free volume in polymer-gold nanocomposites.

*Research Institutes:*

Prof. Dr. V. Abetz, Dr. V. Filiz, HZG, free volume in aged PIM-CNT Membranes,

Dr. D. K. Avasthi, Materials Science Group, Nuclear Science Centre New Delhi, India, high energy ion beam effects in polymer-metal nanocomposites,

Priv. Doz. Dr. M. Lackinger, Deutsches Museum München, NEXAFS and XPS investigations of covalent networks on surfaces,

Prof. Dr. A. Meyer, Dr. Fan Yang, DLR, Köln, diffusion in glass forming metallic melts,

Dr. Thomas Neubert, Dr. Michael Vergöhl Fraunhofer-Institute for Surface Engineering and Thin Films (IST), Braunschweig, sputtered titania layers for photocatalysis,

Dr. Nagayasu Oshima (AIST), focussed positron lifetime beam for interphase analysis,

Dr. Stephan Roth (DESY), Hamburg, x-ray scattering investigation of growing nanoparticles.

*Industry:*

KHS Plasmax GmbH, Hamburg, coatings on PET samples ,

Impreglon Materials Technology GmbH, coatings for dental implants,

BioTeSys GmbH, Esslingen, biocompatible antibakterielle Beschichtungen,

Spiegelberg, Hamburg, antibakterielle Beschichtungen,

Fraunhofer Institute for Environmental, Safety and Energy Technology (UMSICHT), Oberhausen, partner in BMBF project Nanopurification,

Enviro Chemie GmbH, Roßdorf, partner in BMBF project Nanopurification,

Kryschi Wasserhygiene, Kaarst, partner in BMBF project Nanopurification,

Cornelsen Umwelttechnologie GmbH, Essen, partner in BMBF project Nanopurification,

Gelsenwasser AG, Gelsenkirchen, partner in BMBF project Nanopurification,

Ferdinand Braun-Institut, Berlin, partner in BMBF project Nanopurification.

## Diploma, Bachelor's and Master's Theses

K. Faliya, *Advanced Supercapacitors Based On Microscale Carbon Structures,* 13.01.2014
B. Grun, *Optimierung von bioabbaubaren Mg-Ca Legierungen für medizinische Anwendungen,* 29.01.2014
M. Uptmoor, *Einfluss einer plasmonischen Anregung auf die Leitfähigkeit von Nanokompositen nahe der Perkolationsschwelle,* 21.02.2014
J. Jakobeit, *Hydrophile Beschichtungen von extrem hydrophoben Silikonkautschukmaterialien in Anwendung als Kontaktlinsen,* 21.03.2014
B. Bossen, *Charakterisierung und Analyse einer gesinterten, lotfreien und hermisch dichten Titan-Keramik Verbindung,* 01.04.2014
M. Terasa, *Untersuchung der Homogenität von $CaF_2$-$BaF_2$- Mischkristallen in Abhänigkeit von der Abkühgeschwindigkeit während der Züchtung,* 13.05.2014
E. Vasiliauskaite, *Nanoparticle deposition by pulsed direct current magnetron sputtering magnetron sputtering in a reactive gas admixture,* 25.06.2014
F. Ellermann, *Plasmonisch verstärkte Photokatalyse in Al/$TiO_2$-Nanokompositen,* 15.07.2014
W. Reichstein, *Untersuchung von Gasbildung bei der Lamination eines Kartenkörpers aus Verbundmaterial,* 12.09.2014
L. Lehmann-Matthaei, *Analysemethoden zur Charakterisierung von Kupfermaterial als Funktionsoberfläche für die Niedertemperatur-Verbindungstechnik,* 30.09.2014
A. Vahl, *Photocatalysis topics with $TiO_2$,* 04.11.2014

## Dissertations / Postdoctoral Lecture Qualifications

M. Bauhuber, *Entwicklung einer Messzelle auf Siliziumbasis mit langer Wegstrecke für die UV/VIS-Spektroskopie,* 04.07.2014

J. Xiong, *Controlling surface segregation and tuning silver ion release property of reactively sputtered Ag/$TiO_x$ nanocomposites,* 08.07.2014

## Publications

Published in 2014

C. Ohrt, T. Koschine, K. Rätzke, F. Faupel, L. Willner, G. J. Schneider, *Free volume in PEP-silica nanocomposites with varying molecular weight,* Polymer, **55**, 143 - 149 (2014)

A. Kulkarni, K. Meurisch, I. Teliban, R. Jahns, T. Strunskus, A. Piorra, R. Knöchel, F. Faupel, *Giant magnetoelectric effect at low frequencies in polymer-based thin film composites,* Applied Physics Letters, **104**, 022904 (2014)

W. Yan, Z. J. Han, B. T. Phung, F. Faupel, K. Ostrikov, *High-Voltage Insulation Organic-Inorganic Nanocomposites by Plasma Polymerization,* Materials, **7**, 563 - 575 (2014)

M. Keshavarz Hedayati, A. U. Zillohu, T. Strunskus, F. Faupel, M. Elbahri, *Plasmonic tunable metamaterial absorber as ultraviolet protection film,* Applied Physics Letters, **104**, 041103 (2014)

C. Etrich, S. Fahr, M. Keshavarz Hedayati, F. Faupel, M. Elbahri, C. Rockstuhl, *Effective Optical Properties of Plasmonic Nanocomposites,* Materials, **7**, 727 - 741 (2014)

M. Keshavarz Hedayati, F. Faupel, M. Elbahri, *Review of Plasmonic Nanocomposite Metamaterial Absorber,* Materials, **7**, 1221 - 1248 (2014)

M. Keshavarz Hedayati, S. Fahr, C. Etrich, F. Faupel, C. Rockstuhl, M. Elbahri, *The hybrid concept for realization of an ultra-thin plasmonic metamaterial antireflection coating and plasmonic rainbow,* Nanoscale, (2014)

J. Xiong, M. Z. Ghori, B. Henkel, T. Strunskus, U. Schümann, L. Kienle, F. Faupel, *Controlling surface segregation of reactively sputtered Ag/$TiO_x$ nanocomposites,* Acta Materialia, **74**, 1 - 8 (2014)

L. Rosenthal, T. Strunskus, F. Faupel, J. W. Abraham, M. Bonitz, *Kinetic Monte Carlo Simulations of Cluster Growth and Diffusion in Metal-Polymer Nanocomposites,* Complex Plasmas, Springer Series on Atomic, Optical, and Plasma Physics, **82**, 321 - 370 (2014)

V. S. K. Chakravadhanula, Y. K. Mishra, D. K. Avashti, T. Strunskus, V. Zaporojtchenko †, S. Fink, L. Kienle, F. Faupel, *Microstructural and plasmonic modifications in Ag-$TiO_2$ and Au-$TiO_2$ nanocomposites through ion beam irradiation,* Beilstein Journal of Nanotechnology, **5**, 1419 - 1431 (2014)

S. W. Basuki, A. Bartsch, F. Yang, K. Rätzke, A. Meyer, F. Faupel, *Decoupling of component diffusion in a glass forming $Zr_{46.75}Ti_{8.25}Cu_{7.5}Ni_{10}Be_{27.5}$ melt far above the liquidus temperature,* Physical Review Letters, **113**, 165901 (2014)

R. Jahns, S. Zabel, S. Marauska, B. Gojdka, B. Wagner, R. Knoechel, R. Adelung, F. Faupel, *Microelectromechanical magnetic field sensor based on $\Delta E$ effect,* Applied Physics Letters, **105**, 052414 (2014)

M. Keshavarz Hedayati, M. Javaheri, A. U. Zillohu, H. J. El-Khozondar, M. S. Bawa'aneh, A. Lavrinenko, F. Faupel, M Elbahri, *Photo-driven Super Absorber as an Active Metamaterial with a Tuneable Molecular-Plasmonic Coupling,* Advanced Optical Materials, **2**, 705 - 710 (2014)

R. Konietzny, T. Koschine, K. Rätzke, C. Staudt, *POSS-hybrid membranes for the removal of sulphur aromatics by pervaporation,* Separation and Purification Technology, **123**, 175 - 182 (2014)

J. Eichhorn, T. Strunskus, A. Rastgoo-Lahrood, D. Samantha, M Schmittel, M Lackinger, *On-surface Ullmann polymerization via intermediate organometallic networks on Ag(111),* Chem. Commun, **50**, 7680 - 7682 (2014)

C. K. Akkan, M. E. Hammadeh, A. May, H. W. Park, H. Abdul-Khaliq, T. Strunskus, O. C. Aktas, *Surface topography and wetting modifications of PEEK for implant applications,* Lasers in Medical Science, **29**, 1633 - 1639 (2014)

T. Sirtl, M. Lischka, J. Eichhorn, A. Rastgoo-Lahrood,, T. Strunskus, W. M. Heckl, M. Lackinger, *From Benzenetrithiolate Self-Assembly to Copper Sulphide Adlayers on Cu(111): Temperature-Induced Irreversible and Reversible Phase*

*Transitions*, Journal of Physical Chemistry C, **118**, 3590 - 3598 (2014)

H.J. Butt, H. Duran, W. Egger, F. Faupel, V. Harmandaris, S. Harms, K. Johnston, K. Kremer, F.Y. Lin, L. Lue, C. Ohrt, K. Raetzke, L. Ravelli, W. Steffen, S.D.B. Vianna, *Interphase of a polymer at a solid interface*, Macromolecules, **47**, 8459 - 8465 (2014)

C. Ohrt, T. Koschine, S. Harms, F. Faupel, K. Rätzke, W. Egger, L. Ravelli, L. Willner, G.J. Schneider, *Interphases in Polymer Solid-Contacts and Nanocomposites Probed by Positron Annihilation Lifetime Spectroscopy*, Soft Materials, **12**, 135 - 141 (2014)

A.U. Zillohu, R. Abdelaziz, S. Homaeigohar, I. Krasnov, M. Müller, T. Strunskus, M. Elbahri, *Biomimetic Transferable Surface for a Real Time Control over Wettability and Photoerasable Writing with Water Drop Lens*, Scientific Reports, **4**, 7407 (2014)

T. Labbaye, A. Canizares, M. Gaillard, T. Lecas, E. Kovacevic, C. Boulmer-Leborgne, T. Strunskus, N. Raimboux, P. Simon, G. Guimbretiere, M.R. Ammar, *In situ Raman spectroscopy for growth monitoring of vertically aligned multiwall carbon nanotubes in plasma reactor*, Applied Physics Letters, **105**, 213109 (2014)

H. Jacob, S. Ulrich, U. Jung, S. Lemke, T. Rusch, C. Schütt, F. Petersen, T. Strunskus, O. Magnussen, R. Herges, F. Tuczek, *Monitoring the reversible photoisomerization of an azobenzene-functionalized molecular triazatriangulene platform on Au(111) by IRRAS*, Physical Chemistry Chemical Physics, **16**, 22643 - 22650 (2014)

W. Metzger, B. Schwab, M. Miro, S. Grad, A. Simpson, M. Veith, G. Wennemuth, V. Zaporojtchenko †, S. Verrier, J. Hayes, M. Bubel, T. Pohlemann, M. Oberringer, C. Aktas, *Induction of Osteogenic Differentiation by Nanostructured Alumina Surfaces*, Journal of Biomedical Nanotechnology, **10**, 831 - 845 (2014)

## Presentations

F. Faupel, *Business potential of nano/micro in the BSR-bringing companies and nanotechnology into touch (best practices) (Invited Talk)*, Technet-nano Workshop, Sonderborg, Denmark, 16.-16.01.2014

F. Faupel, *Functional nanocomposites prepared by vapour phase deposition (Invited Talk)*, 8th International Symposium on Nanostructured Materials and Nanocomposites, Daytona Beach, USA, 28.-30.01.2014

T. Strunskus, *Plasma based deposition of nanoparticles and nanocomposites (Invited Talk)*, DPG-Frühjahrstagung 2014 der Sektion AMOP (SAMOP) (Plasmaphysik), Berlin, Germany, 17.-21.03.2014

O. Polonskyi, A. Ahadi, A. Hinz, E. Vasiliauskaite, T Strunskus, F. Faupel, *Metal and metal oxide nanoparticles generated in gas phase by pulsed DC sputtering in a reactive gas admixture (Talk)*, DPG-Frühjahrstagung 2014 der Sektion AMOP (SAMOP) (Plasmaphysik), Berlin, Germany, 17.-21.03.2014

T. Koschine, K. Rätzke, V. Abetz, T. Emmler, M. Khan, V. Filiz, L. Ravelli, W. Egger, F. Faupel, *Characterization of carbon nanotube containing polymer membranes (Talk)*, DPG-Frühjahrstagung der Sektion Kondensierte Materie (SKM) 2014, Dresden, Germany, 30.03.-04.04.2014

T. Strunskus, A. Kulkarni, K. Meurisch, R. Jahns, J. Teliban, A. Piorra, S. Zabel, E. Quandt, R. Knöchel, F. Faupel, *Giant magnetoelectric effect at low frequencies in polymer based thin film composites composites (Talk)*, DPG-Frühjahrstagung der Sektion Kondensierte Materie (SKM) 2014, Dresden, Germany, 30.03.-04.04.2014

S. Zabel, R. Jahns, S. Marauska, B. Gojdka, B. Wagner, R. Knöchel, R. Adelung, F. Faupel, *Integrated MEMS magnetic field sensor based on $\Delta E$-effect (Talk)*, DPG-Frühjahrstagung der Sektion Kondensierte Materie (SKM) 2014, Dresden, Germany, 30.-30.03.2014

A. Hinz, O. Polonskyi, T. Strunskus, M. Schwartzkopf, G. Santoro, J. Perlich, E. Metwalli, Y. Yao, F. Faupel, S. Roth, P. Müller-Buschbaum, *Growth of Gold on P(VDF-TrFE) during RF-Sputter Deposition (Poster)*, DPG-Frühjahrstagung der Sektion Kondensierte Materie (SKM) 2014, Dresden, Germany, 30.03.-04.04.2014

A. Hinz, E. von Wahl, M. Fröhlich, T. Strunskus, H. Kersten, *Investigation of Nanoparticle Growth in a Dusty Acetylene Plasma (Poster)*, DPG-Frühjahrstagung der Sektion Kondensierte Materie (SKM) 2014, Dresden, Germany, 30.03.-04.04.2014

O. Polonskyi, *Metal and metal oxide nanoparticles generated in gas phase by pulsed DC sputtering in a reactive gas*

*admixture (Talk)*, DPG-Frühjahrstagung der Sektion Kondensierte Materie (SKM) 2014, Dresden, Germany, 30.03.-04.04.2014

F. Faupel, *Functional nanocomposites - preparation and physical properties (Invited Talk)*, Nanotechnology: Research and Development, Vilnius, Lithuania, 15.-16.05.2014

O. Polonskyi, *Highly efficient transition metal nanoparticle generation in the gas phase by reactive pulsed DC magnetron sputtering (Talk)*, German-Czech-Seminar, Prague, Czech Republic, 22.-25.05.2014

T. Strunskus, A. Hinz, E. von Wahl, H. Kersten, F. Faupel, *Investigating Dusty Plasmas by a Novel Particle Collection Concept (Talk)*, German-Czech-Seminar, Prague, Czech Republic, 23.-24.05.2014

T. Strunskus, O. Polonskyi, A. Ahadi, T. Peter, F. Faupel, *Influence of reactive gas admixtures on transition metal nanoparticles deposition by gas aggregation cluster source (Talk)*, German-Czech-Seminar, Prague, Czech Republic, 23.-24.05.2014

F. Faupel, *Neue Werkstoffe durch Nanotechnologie (Invited Talk)*, Universitätsgesellschaft Schleswig-Holstein, Sektion Norderstedt, Norderstedt, Germany, 27.-27.05.2014

A. Hinz, E. von Wahl, M. Fröhlich, T. Strunskus, H. Kersten, *Investigation of Nanoparticle Growth in a Dusty Acetylene Plasma (Poster)*, Bunsentagung 2014, Hamburg, Germany, 29.-31.05.2014

F. Faupel, *Functional nanocomposites: from controlled self-assembly to tailored properties (Keynote Lecture)*, Cluster Surface Interaction Workshop 2014, Varese, Italy, 02.-04.06.2014

K. Rätzke, F. Faupel, *Positronenvernichtung und freies Volumen in Polymeren (Invited Talk)*, Universität Würzburg, Würzburg, Germany, 12.-13.06.2014

F. Faupel, *Helmut Föll: Ein Manager formt die Materialwissenschaft (Invited Talk)*, Wissenschaftliches Abschiedskolloquium für Prof. Dr. Helmut Föll, Kiel, Germany, 13.-13.06.2014

T. Strunskus, *Nanocomposites for Functional Applications (Invited Talk)*, Deutsch-Türkischer Workshop, Ankara, Turkey, 23.-25.06.2014

T. Strunskus, *Carbon based materials and their characterization using synchrotron radiation (Invited Talk)*, Deutsch-Türkischer Workshop, Ankara, Turkey, 23.-25.06.2014

F. Faupel, A. Bartsch, S. Basuki, K. Rätzke, A. Meyer, *Dynamic arrest in multicomponent glass forming alloys (Invited Talk)*, 10th international Conference on Diffusion in Solids and Liquids (DSL 2014), Paris, France, 24.-25.06.2014

T. Strunskus, M. Elbahri, M Keshavarz Hedayati, F. Faupel, *Tailoring functional nanocomposites by vapour phase deposition processes (Talk)*, Nanofair 2014, Dresden, Germany, 01.-03.07.2014

T. Strunskus, *Nanoparticles and Nanocomposites by plasma based processes (Invited Talk)*, summer school TR24, South Orange, USA, 30.07.-08.08.2014

A. Hinz, E. von Wahl, M. Fröhlich, T. Strunskus, H. Kersten, *Collecting Nanoparticles from a Dusty Plasma by Means of Neutral Drag (Talk)*, summer school TR24, South Orange, USA, 31.07.-08.08.2014

F. Faupel, *Functional nanocomposites - from fabrication to function (Invited Talk)*, Seminar of the Colloid and Interface Division of the Chemical Society of Japan, Kobe, Japan, 01.-01.08.2014

F. Faupel, *Functional nanocomposites - from fabrication to function (Invited Talk)*, Fuel Cell Nanomaterials Centre of the University of Yamanashi, Kofu, Japan, 08.-08.08.2014

K. Rätzke, F. Faupel, A. Bartsch, S. Basuki, F. Yang, A. Meyer, *Diffusion in glass forming metallic melts (Talk)*, The International Conference on Diffusion in Materials (DIMAT 2014), Münster, Germany, 17.-22.08.2014

O. Polonskyi, A. Ahadi, A. Hinz, E. Vasiliauskaite, T. Strunskus, F. Faupel, *Highly efficient nanoparticle generation in the gas phase by pulsed DC magnetron sputtering in reactive gas admixture (Poster)*, 14th International Conference on Plasma Surface Engineering, Garmisch-Patenkirchen, Germany, 14.-19.09.2014

O. Polonskyi, T. Peter, A. Hinz, T. Strunskus, F. Faupel, *Silver/$SiO_xC_yH_z$-polymer nanocomposite thin film prepared by a high rate deposition system (Poster)*, 14th International Conference on Plasma Surface Engineering, Garmisch-Patenkirchen, Germany, 14.-19.09.2014

O. Polonskyi, T. Strunskus, F. Faupel, *Nanoparticles and Nanocomposite Thin Films Prepared by Gas Aggregation Source (Talk)*, The 5th international conference on plasma nanoscience (iPlasmaNano-V), Torremolinos, Spain,

28.09.-02.10.2014

K. Rätzke, F. Faupel, *Free Volume and Positron Annihilation in Membrane Materials (Invited Talk)*, International Conference on Soft Materials (ICSM2014), Jaipur, India, 06.-10.10.2014

F. Faupel, *Functional Nanocomposites - From Fabrication to Function (Invited Talk)*, International Conference on Soft Materials (ICSM2014), Jaipur, India, 06.-10.10.2014

F. Faupel, *Functional Nanocomposites - From Fabrication to Function*, International School on Ion Beams in Materials Science, New Dehli, India, 11.-11.10.2014

K. Rätzke, F. Faupel, *Ageing and Free Volume in Thin Polymer Membranes (Invited Talk)*, 11th International Workshop on Positron and Positronium Chemistry (PPC-11), Goa, India, 09.-14.11.2014

F. Faupel, *Eine bessere Welt durch neue Materialien - Träume eines Materialwissenschaftlers (Talk)*, Night of the profs, CAU, Kiel, Germany, 21.-21.11.2014

F. Faupel, *Functional nanocomposites - from fabrication to function (Invited Talk)*, Fraunhofer IST, Braunschweig, Germany, 25.-25.11.2014

F. Faupel, *Neue Werkstoffe durch Nanotechnologie (Invited Talk)*, Gymnasium Kronshagen, Kronshagen, Germany, 04.-04.12.2014

## Further Activities and Events

**Selected Honorary Activities of Prof. Faupel:**

Chairman of *North German Initiative Nanotechnology Schleswig-Holstein e.V. (NINa SH e.V.)*,

Principle Editor of the *Journal of Materials Research, Materials Research Society* (MRS),

Editor of the *encyclopaedia RÖMPP online, Thieme Chemistry*,

Member of the Advisory Board of *Diffusion and Defect Data*,

Member of the DGM Scientific Advisory Board, *German Material Research Society*,

Member of the Minerva-Weizmann Committee of the *Max-Planck Society*,

Member of the Programme Committee of the DFG SPP 1369 Priority Programme *''Polymer-Solid Interfaces, Thin Films, and Interphases - from Molecular View to Continuum''*,

Member of the International Advisory Committee for the *International Conference on Soft Materials (ICSM 2014)*,

Chairman of the Steering Committee of the Centre of Competence Nanosystems Eingineering of the CAU Kiel.

In addition to the activities listed above, Prof. Faupel was involved in many evaluations for the German Science Foundation (DFG), scientific journals, and other Institutions in Germany and abroad.

# Nanochemistry and Nanoengineering

The Nanochemistry and Nanoengineering group research activities encompass various topics from membrane development, materials with smart surface wettability, fabrication of innovative solar absorbers, and UV detectors. In membrane [Materials 2014, 7, 1017-1045] and metamaterial absorbers [Materials 2014, 7, 1221-1248], two reviews have been published wherein all the achievements of the group in these subjects are summarized. We refer the interested readers to these reviews for further details. In the following, the main results of the research activities of the group are summarized.

## Results

### 1. Plasmonic materials

#### 1.1. Plasmonic Anti-reflector: Hybrid concept

Anti-reflective coatings are the materials demanded for reducing the reflection loss of optical elements and devices. Here, in analogy to our earlier works on plasmonic nanocomposite, we have established a new anti-reflective coating based on a plasmonic metamaterial and a dielectric (Figure 1a). Promoted by the strong optical dispersion of the plasmonic metamaterial, this new idea combines two conceivable arrangements for layers in an anti-reflection coating into a single structure, albeit at two different wavelengths. This strategy enables us to realize a broadband reduction of reflection that is marginally sensitive to angle of incidence when compared to traditional antireflective coatings (Figure 1b). Also, we demonstrated that the current metamaterial on a metal reflector can be used for the visualization of different colourations, such as a plasmonic rainbow, despite its sub-wavelength thickness (Figure 1c). The results were published in Nanoscale [Nanoscale 2014, 6, 6037-6045].

#### 1.2. Plasmonic Metamaterials: theoretical simulation

Our research activities on plasmonic metamaterials, in particular the design of the system, was progressively supported by theoretical involvement of the group of Carsten Rockstuhl from the Karlsruhe Institute of Technology; Carsten Rockstuhl is one of the prominent theoreticians in the field of plasmonics. Computational electrodynamic is mainly applied for simulation in the frame of the powerful finite-difference time-domain (FDTD) technique. Despite the complex nature of our nanocomposite in which the ultrafine nanoparticles are randomly dispersed in a thin matrix, our collaboration with the group of Rockstuhl allowed us, for the first time, to simulate with FDTD a near-percolating nanocomposite. In this work, we could extract the optical properties of the nanocomposite theoretically. For instance, calculation of the field distribution within the composite is done with the FDTD method, as is shown in Figure 1d. Moreover, this theoretical calculation enables us to quantitatively analyze the system and extract its optical constant [Materials 2014, 7, 727-741].

#### 1.3. Plasmonic Metamaterials: Perfect UV absorber

Plasmonic metamaterials that are intended to be used for optical frequency, have to be miniaturized to a few $10^{th}$s of nanometres, which makes their manufacturing burdensome. In one of our recent works, we moved the performance of a metamaterial down to the ultraviolet (UV) using an ultrathin nanocomposite made with co-sputtering as a tunable plasmonic metamaterial. It creates the possibility of realizing a plasmonic metamaterial absorber for UV frequency with negligible angle sensitivity (Figure 1e). Its resonance frequency and intensity can be tuned by alteration of the thickness and filling factor of the composite. This strategy for development of tunable metamaterials for high frequency could pave the way to their application for thermo-photovoltaics, stealth technology, and UV-protective coatings.

UV radiation is classically classified into 3 bands in sequence of rising energy: UV-A (320-400 nm), UV-B (280-320 nm), and UV-C (100-280 nm). This division was proposed by the Commission Internationale de l'Eclairage (CIE), and corresponds broadly to the effects of UV radiation on biological tissue. Almost 5% of the ground-level solar radiation is ultraviolet radiation, generally in the UV-A range. So, a useful UV coating layer must be more absorbing in UV-A frequencies. In our group, following our recent work on a highly reflecting substrate, we designed and constructed a tunable

silver-$SiO_2$ nanocomposite by co-sputtering to create a plasmonic metamaterial super absorber (PMSA) that functions from visible up to UV-A frequency. $SiO_2$ film is used as a dielectric to separate the composite from the base mirror. In this design, a huge absorption of light in a wide range of frequency (in visible and UV) is achieved, which exceeds the absorption intensity of silver absorbers recently reported in the literature. The absorption of this metamaterial is nearly insensitive to the angle of incidence and its broadband peak can be adjusted throughout the UV-visible frequencies, which displays also its pronounced potential in sensing applications. For further improvement of the unprecedented performance of this absorber, we compared absorption of this metamaterial with an organic compound base UV absorber. For that purpose, a dye-molecule incorporated in a polymer matrix film was deposited on an optically thick silver film as UV absorber; the absorption intensity and bandwidth of the both films were collated. The results showed that the absorption intensity of the PMSA system is double that of the organic one. Note that not only is the absorption intensity of silver base absorber higher but also the bandwidth covers a broader range of frequency than the single-band dye absorber, which further shows the advantage of this metamaterials absorber to organic counterparts [Applied Physics Letters 2014, 104, 041103].

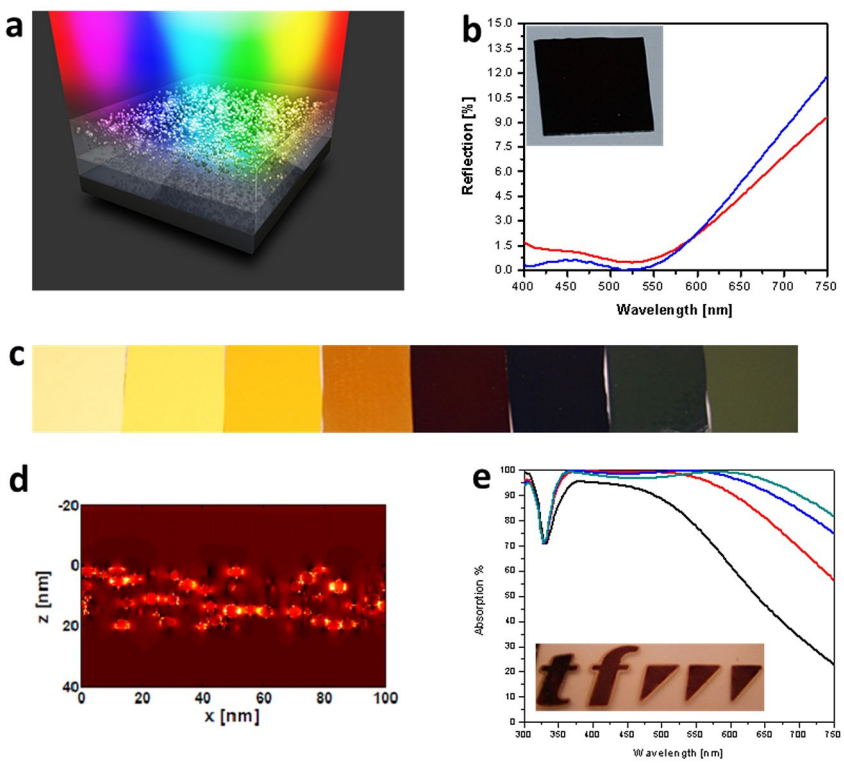


Fig. 1: (a) Geometry of the designed anti-reflective coating. (b) Reflection spectrum of a typical plasmonic anti-reflector coating deposited on silicon substrate. (c) True photograph of 25 nm $SiO_2$ coated gold film covered by 20 nm Au-$SiO_2$ nanocomposite with different filling factor. From left to right the filling factor of the nanocomposite increased (13%, 20%, 30%, 40%, 50% and 60%, correspondingly), while the first and second samples are bare gold and 45 nm $SiO_2$ coated gold respectively. (d) Amplitude of the electric field in a cross section through the plasmonic nanocomposite. The incident linearly polarized plane wave propagates in the $+z$-direction. The amplitude is shown at an incident wavelength of 430 nm. (e) Absorption spectra of silver base metamaterial absorber with various thickness (15-30nm). Inset shows the true colour photograph of the perfect absorber coated on transparent polymeric substrate, presenting the logo of the Faculty of Engineering (TF) of University of Kiel.

## 2. Molecular plasmonic: switching of coupling

### 2.1. Photoswitchable absorber based on chromophore-surface plasmon coupling

By using a very similar system to that which has been used for fabrication of the photo-responsive transparent conductive metal, we substituted the metal nanoparticles in the nanocomposites by chromophores (photoswitchable molecules) but on a 100 nm thick metal film (optically thick), aiming to obtain a photoswitchable super absorber. To this end we focused on the absorbing character of molecules and tried to intensify the absorption intensity to achieve a performance similar to that of the inorganic nanocomposites.

Here, inspired by the fact that the optical properties of the molecules are highly influenced when they are placed in proximity to a conductive mirror, we tried to position these molecules in front of a reflective surface to intensify this influence. Therefore, by depositing a PS (SPO) film with different concentrations on gold and silver mirrors (100 and 200nm thick, respectively), we showed a new active perfect absorber system; deposited samples possess very high absorption in the blue to green part of the visible spectrum (Figure 2a). As soon as the sample is exposed to UV irradiation, its bandwidth and absorption intensity can be enhanced considerably by UV irradiation leading to more than 150 nm bandwidth broadening. Moreover, our results showed that both the filling factor of the dipoles and the type of the mirror play a substantial role in determining the properties of the system. Accordingly, substituting the gold film with a silver base metal film, we further showed how the role of the plasmonic coupling depends on the metal substrate (Figure 2b). We observed that a photo-driven absorber still can be created, but not a broadband super absorber as in the case of gold.

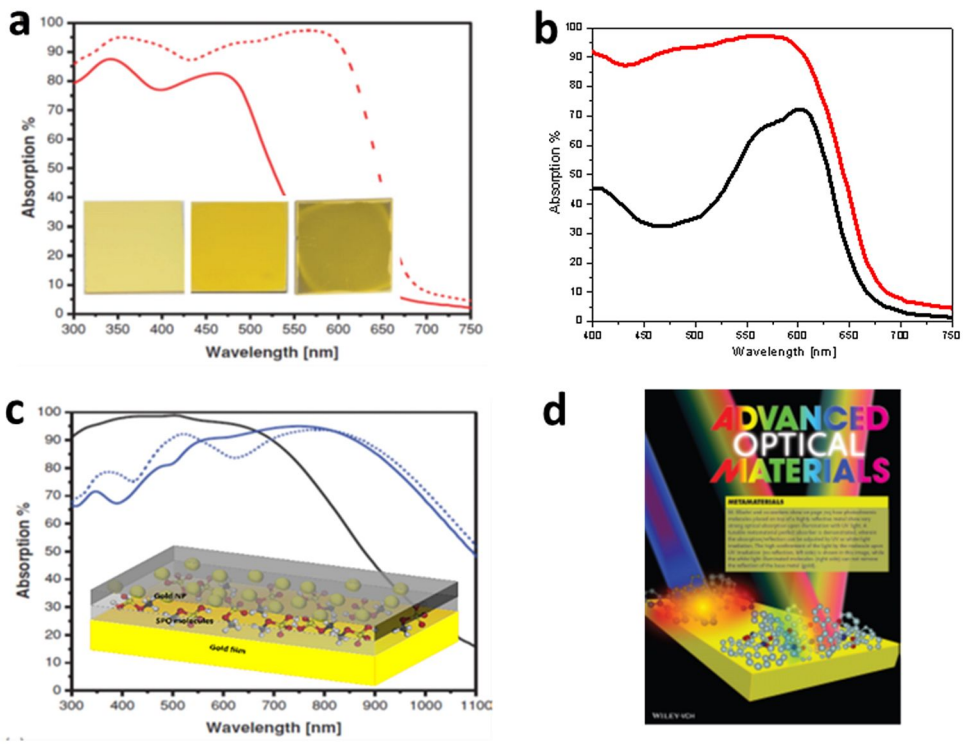


Fig. 2: (a) Absorption spectra of PS-SPO composite deposited on 100 nm gold: as deposited (solid line), and upon UV irradiation (dashed line). The inset shows the photograph of: (left) a bare gold film, (middle) PS-SPO coated gold film before, and (right) after UV irradiation. (b) Comparative absorption spectra of UV illuminated PS (SPO) films on a gold (red) and silver (black) mirror. (c) Absorption spectra of a multi-stack of 20 nm Au-PTFE composite (40%) separated from a 100 nm gold film by a 40 nm highly concentrated PS-SPO composite deposited on a glass substrate before (solid blue) and after (dashed blue) UV illumination. The black curve shows the same stack but with a pure PS as spacer layer for reference. The inset shows the schematic of the geometry of the photo-driven super absorber consisting of three layers, from top to bottom, nanocomposite, SPO doped PS spacer, and metal film. (d) Frontispiece of Advanced Optical Materials highlighting our finding of a photo-driven super absorber.

Above all, we found that the thickness of the PS (SPO) film does not play any major role in the resulting optical properties. However, our recent finding, where we observed the controllable reflectivity of photochromic molecules, helped us to have better insight of the phenomenon. Based on that, we developed a photoswitchable absorber that works by combination of coupling and interference of the light (Figure 2c). This system is indeed the first demonstration of ultrathin film coating (only 15 nm of PS (SPO)) which performs as a new type of photo-driven ''resonant antireflection coating'' for tuning reversibly the optical properties of a mirror from reflector to absorber and vice versa under Vis-UV illumination. Our finding was recently published in Advanced Optical Materials and was highlighted as the Frontispiece (Figure 2d) [Advanced Optical Materials 2014, 2, 705-710]. Moreover, it was selected as a ''Highlight of literature'' in Nature Photonics.

### 2.2. Active Plasmonics: Switching the coupling regime

Besides what we observed in the system of photoswitchable film over optically thick metallic film was the application of the idea of molecule-plasmon coupling for realization of an active plasmonic system: tuning and switching the coupling between the weak and strong regimes by Vis-UV irradiation. It is well-known that controlling dynamically the coupling between the NPs (dipoles) and the metal film (dipole image) is a fascinating subject that could pave the way for the creation of new properties and applications. As outlined above, we have placed PS (SPO) film as the inter-layer in the perfect absorber system (cf. Figure 2c). This is equivalent to the insertion of photoswitchable doped film into a cavity of a strongly absorbing system wherein light is highly confined. Such a combination allows us to control the refractive index of the spacer layer by irradiation (UV or visible) and hence provide the opportunity to regulate the strength of coupling between the dipoles (NPs) and the images dynamically. It was observed that the non-illuminated sample (before UV exposure) has a weak molecule-plasmon coupling, while UV illumination results in a strong coupling that splits the absorption peak into two parts. The energy difference between the two peaks exceeds 700 meV which is one of the largest illumination induced splitting of peaks reported so far. Our observations and findings, which were also published in the abovementioned Advanced Optical Materials paper, provide new insights into the field of optical cavities and show a great potential for optical applications [Advanced Optical Materials 2014, 2, 705-710].

## 3. Biomimetic Transferable Surface for a Real Time Control over Wettability and Photoerasable Writing with Water Drop Lens

This part of the activity of the group is devoted to studying the effect of photochromic compounds on the wetting properties of the matrix polymer. For material, PVDF was selected as the host matrix because it is usually the material of choice for wetting applications due to its moisture and chemical resistance. Initially, the wettability of the polymer without any inclusion (i.e. chromophore) was analyzed to assess the effect of the geometry and morphology on the properties. Hence, blade cast films and electrospun fibres of PVDF were analyzed. Although PVDF is assumed to be a hydrophobic polymer, it possesses a net dipole moment (i.e. polarity) and hence we observed that its contact angle is around 80°. More interestingly, we could change considerably the surface wettability when we made fibre out of this polymer. The fibrous PVDF showed relatively super-hydrophilic properties in which the contact angle of the surface reached 130°.

Though the contact angle measurement provides us a very useful quantitative value of the surface wettability, we need to know the droplet-surface interaction in dynamic conditions. In other words, not only a high contact angle is essential for hydrophilic surfaces but also the water drop should be able to slide on its surface to make the surface more practical for application. We observed that while a drop slides gently on the polymer film, it does not move at all on the polymer fibremat. Indeed, even turning the mat upside-down, the drop does not fall (Figure 3a). The latter shows an artificial rose petal surface, i.e. a surface which is highly hydrophobic but still sticky towards the drop because of the pinning of the drop in the holes of the fibrous polymer.

Interestingly, one could change the surface properties (into a highly hydrophobic and slippery surface (grass leaf effect)) by adjusting the morphology of the substrate. For that, we rolled the fibres into the form of thicker yarns which were then laid side by side on the random fibre mat. Over the surface of the yarn, the water drop could start to move at the tilt angle

of around 45° (Figure 3b). This happened because it has a minimum contact with the fibres and floats on the air pockets between the yarns under this condition. One of the advantages of this approach is that the yarn structure is movable and can be detached from one surface and positioned on any other. That means, one could make any surface hydrophobic slippery without causing any permanent change to its surface structure (Figure 3c).

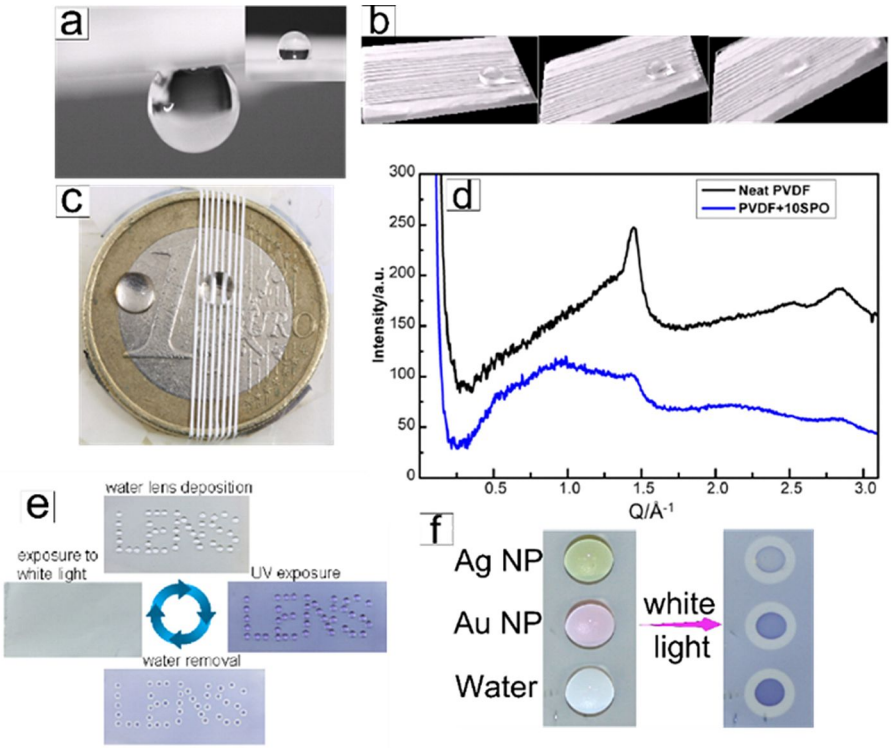


Fig. 3: (a) Drop sticks to the loose nanofibres (as in inset) and does not fall even when upside down. (b) Drop runs on the yarn made from the same fibres as used in (a), when tilted at about 45°. (c) The device was mobile and could turn many surface (here a coin) to a hydrophobic, slippery surface. Here the water drop spreads on the coin but experiences a hydrophobic slippery state on yarn. (d) After adding SPO in PVDF, the resulting electrospun fibres lost their crystallinity (WAXS results). (e) Water drops used as lenses to (erasably) write over a photochromic fibrous surface. (f) Water lens used as a qualitative indicator of any UV absorbing species suspended in water.

Furthermore, the inter-yarn gap can be adjusted in real time, which enables us to switch reversibly the surface wettability from hydrophobic slippery to hydrophobic sticky. In order to see the effect of SPO addition on the wetting properties of the polymer matrix, a blend of PVDF with SPO was electrospun. These fibres were twisted into yarns and placed on the random fibre mat for wettability analysis. Despite other reports in the literature, in which SPO is generally known to increase the hydrophilicity of the host polymer matrix (upon UV exposure), our results showed that the surface affinity to water was reduced (by about 12° decrease in the sliding angle) when SPO was added. We explained this difference by considering the change of the crystal structure of the host matrix when the SPO is added. Wide angle X-ray spectroscopy (WAXS) analysis showed that the PVDF fibre which was initially semicrystalline with $\beta$-conformation lost its crystallinity by inclusion of SPO (Figure 3d). This loss was attributed to the intercalating SPO molecules that hindered regular arrangement of PVDF chains needed for a crystalline structure. In other words, the random chain arrangement in an amorphous structure diminishes the net polarity of the polymer, which corresponds to a low affinity towards water.

We implement the concept of a water drop lens on the sticky hydrophobic fibrous mat under UV exposure, where the drop of water intensifies and focuses the UV light like a lens, in the use of water as a removable template for patterning and erasable writing on the fibre mat (Figure 3e). This concentration of the UV happens beneath the drop, therefore such a

method can be used for UV driven local reactions without unwanted damage to the neighbouring material. Furthermore, the colour contrast of the blue spot made under the drop can be used as a visual indicator of any UV absorbing species suspended in the drop (Figure 3f) [Scientific Reports 2015, 4, Article Number 7407, doi:10.1038/srep07407].

## Personnel

Head of the group: Prof. Dr. -Ing. M. Elbahri; Secretary: N. Gühlke (50%), Dipl.-Chem. S. Kastaun (50%)
Technical Staff: Dipl. -Ing. (FH) R. Kloth (on leave), Techn. C. Ochmann (DFG, BMBI), Dipl.-Ing. (FH) S. Rehders, Dipl.-Inf. P. Sommer

Scientific Staff:

| | | |
|---|---|---|
| M.Sc. M. Abdelaziz<br>Harvesting of energy by plasmonic structures | 01.01.-31.12.2014 | Fellowship CAU |
| M. Sc. R. Abdelaziz<br>Nanofabrication | 01.01.-31.12.2014 | SFB 677, DFG |
| M.Sc. D. Disci<br>Nanofabrication for Bio. | 01.01.-31.12.2014 | Fellowship HZG |
| Dr. S.S. Homaeigohar<br>Nanofibres for Filtration | 01.01.-31.12.2014 | HZG, DAAD, HGF |
| Dr. M. Keshavarz Hedayati<br>Plasmonic metamaterials | 01.01.-31.12.2014 | SFB 677, DFG, CAU |
| Dr. R. Khalil<br>Nanocomposite | 07.06.-07.12.2014 | Fellowship DAAD |
| M.Sc. A.U. Zillohu<br>Photonic nanomaterials | 01.03.-31.05.2014 | Fellowship CAU |

## Lectures, Seminars, and Laboratory Course Offers

*Winter 2013/2014*

Nanochemistry for Nanoengineering, 2 hrs Lecture/Week,
M. Elbahri

Nanochemistry for Nanoengineering - Seminar, 1 hrs Seminar/Week,
M. Elbahri

Werkstoffe - Polymere, 2 hrs Lecture/Week,
M. Elbahri

Nanochemistry and Nanoengineering, 2 hrs Seminar/Week,
M. Elbahri

*Summer 2014*

Einführung in die Makromolekulare Chemie, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
M. Elbahri

Nanochemistry and Nanoengineering, 2 hrs Seminar/Week,
M. Elbahri

Makromolekulare Chemie und Polymerwerkstoffe, 5 hrs Lecture/Week,
M. Elbahri

*Winter 2014/2015*

Nanochemistry for Nanoengineering, 2 hrs Lecture/Week,
M. Elbahri

Nanochemistry for Nanoengineering - Seminar, 1 hrs Seminar/Week,
M. Elbahri

Werkstoffe - Polymere, 2 hrs Lecture/Week,
M. Elbahri

Nanochemistry and Nanoengineering, 2 hrs Seminar/Week,
M. Elbahri

Makromolekulare Chemie und Polymerwerkstoffe, 5 hrs Lecture/Week,
S. Homaeigohar

## Third-Party Funds

GKSS, *Einrichtung einer gemeinsamen Helmholtz-Hochschul-Nachwuchsgruppe*, 01.03.2009-28.02.2015 (2.100.000 Euro)
DFG SFB 677, *Function by Switching: Photoswitchable Metal-Polymer Nanocomposites,* 01.07.2011-30.06.2015 (228.470 Euro)
DFG SFB 677, *Function by Switching: Multifunctional Photoswitchable Polymer Fibres,* 01.07.2011-30.06.2015 (261.720 Euro)
DAAD, *scholarship for El-Khozondar,* 15.03.2013-31.01.2014 (6.575 Euro)
CAU, *PhD scholarship for Moheb Abdelaziz Mahmoud Abdelaziz,* 01.10.2013-30.09.2014 (13.200 Euro)
DAAD, *Forschungsaufenthalt für Frau Dr. Rania Mohammed Ahmed Khalil 2013,* 01.11.2013-31.01.2014 (6.575 Euro)
Egyptian Cultural and Educationa Bureau / Centre, *scholarship for Dr. Rania Mohammed Ahmed Khalil 2014,* 07.06.-07.12.2014 (11.664 Euro)
Christian-Albrechts-Universität zu Kiel, *scholarship for Moheb Abdelaziz Mahmoud Abdelaziz, 3rd year,* 01.10.2014-30.09.2015 (13.200 Euro)

## Further Cooperation, Consulting, and Technology Transfer

The group cooperates with the following individuals and organizations:

Prof. Dr. F. Faupel, Institute for Material Science, several topics with hybrid organic/inorganic materials,

Prof. Dr. R. Adelung, Institute for Material Science, several topics nanostructures, biomaterials i.e. submitted DFG joint project for conductive polymer nanowires,

Prof. Dr. Dieter Adam, Institut für Immunologie, Christian-Albrechts-Universität Kiel,

Prof. Dr. L. Kienle, Institute for Material Science, Transmission electron microscopy,

Prof. Dr. V. Abetz, Helmholz Zentrum Geesthacht, Zentrum für Material- und Küstenfoschung GmbH, Blockcopolymers,

Prof. Dr. Eich, TU Hamburg, Photonic crystal,

Prof. Dr. Martin Müller, Helmholz Zentrum Geesthacht, Zentrum für Material- und Küstenfoschung GmbH,

Prof. Dr. sc.hum. Rainer Podschun, Institut für Infektionsmedizin, Christian-Albrechts-Universität Kiel,

Prof. Dr. Carsten Rockstuhl, Photonik, Uni Jena,

Prof. Dr. Selhuber-Unkel, Biocompatible Nanomaterials, Faculty of Engineering,

Prof. Dr. rer. nat. S. N. Gorb, Spezielle Zoologie, Christian-Albrechts-Universität Kiel,

Dr. Thomas Emmler, Helmholz Zentrum Geesthacht, Zentrum für Material- und Küstenfoschung GmbH,

Dr. Wolfgang Reinert, Fraunhofer ISIT,

Prof. Dr. Peter Müller-Buschbaum, Institute of Physics, TU München,

Prof. Dr. Stefan Linden, Institute of Physics, Bonn University,

Prof. Dr. Horst-Günter Rubahn, NanoSYD, Mads Clausen Institute, Denmark,

Prof. Dr. Andrei Lavrinenko, Department of Photonics, TU Denmark,

Prof. Dr. Abhijit Biswas, Electrical Engineering, Notre Dame, USA,

Prof. Dr. Alexander Govorov, Physics Department, Ohio University, USA,

Prof. Dr. Hala Jarallah El-Khozondar, Electrical Engineering Department, Islamic University of Gaza, Palestine,

Dr. Muhammad Bawa'aneh, Khalifa University of Science, Technology & Research (KUSTAR), Sharjah, UAE.

## Diploma, Bachelor's and Master's Theses

T. Rahman, *Synthesis and Charactorization of nano coatings produced by touch at Leidenfrost temperature*, 13.01.2014

## Dissertations / Postdoctoral Lecture Qualifications

M. Keshavarz Hedayati, *Tunable Plasmonic Metamaterials*, 27.06.2014

## Publications

Published in 2014

C. Etrich, S. Fahr, M. Keshavarz Hedayati, F. Faupel, M. Elbahri, C. Rockstuhl, *Effective Optical Properties of Plasmonic Nanocomposites*, Materials, **Volume: 7 Issue: 2**, 727 - 741 (2014)

S. Homaeigohar, M. Elbahri, *Nanocomposite Electrospun Nanofibre Membranes for Environmental Remediation*, Materials, **Volume: 7 Issue: 2**, 1017 - 1045 (2014)

M. Keshavarz Hedayati, F. Faupel, M. Elbahri, *Review of Plasmonic Nanocomposite Metamaterial Absorber*, Materials, **Volume: 7 Issue: 2**, 1221 - 1248 (2014)

M Keshavarz Hedayati, A. U. Zillohu, T. Strunskus, F. Faupel, M. Elbahri, *Plasmonic tuneable metamaterial absorber as ultraviolet protection film*, Applied Physics Letters, **Volume: 104 Issue: 4**, (2014)

H. Papavlassopoulos, Y. K. Mishra, S. Kaps, I. Paulowicz, R. Abdelaziz, M. Elbahri, E. Maser, R. Adelung, C. Roehl, *Toxicity of Functional Nano-Micro Zinc Oxide Tetrapods: Impact of Cell Culture Conditions, Cellular Age and Material Properties*, Pols One, **Volume: 9 Issue: 1**, (2014)

A. U. Zillohu, N. Alissawi, R. Abdelaziz, M. Elbahri, *Thermo-Plasmonics for Localized Graphitization and Welding of Polymeric Nanofibres*, Materials, **Volume: 7 Issue: 1**, 323 - 332 (2014)

A.U. Zillohu, R. Abdelaziz, S. Homaeigohar, I. Krasnov, M. Müller, T. Strunskus, M. Elbahri, *Biomimetic Transferable Surface for a Real Time Control over Wettability and Photoerasable Writing with Water Drop Lens*, Scientific Reports, **4**, 7407 (2014)

M. Keshavarz Hedayati, M. Javaheri, A. U. Zillohu, H. J. El-Khozondar, M. S. Bawa'aneh, A. Lavrinenko, F. Faupel, M. Elbahri, *Photo-driven Super Absorber as an Active Metamaterial with a Tunable Molecular-Plasmonic Coupling*, Advanced Optical Materials, **2**, 705 - 710 (2014)

M. Keshavarz Hedayati, S. Fahr, C. Etrich, F. Faupel, C. Rockstuhl, M. Elbahri, *The hybrid concept for realization of an ultra-thin plasmonic metamaterial antireflection coating and plasmonic rainbow*, Nanoscale, **6**, 6037 - 6045 (2014)

M. Keshavarz Hedayati, F. Faupel, M. Elbahri, *Review of Plasmonic Nanocomposite Metamaterial Absorbers*, Materials, **7**, 1221 - 1248 (2014)

M. Keshavarz Hedayati, A. U. Zillohu, T. Strunskus, F Faupel, M. Elbahri, *Plasmonic tunable metamaterial absorber as ultraviolet protection film*, Applied Physics Letters, **104**, 041103 (2014)

## Presentations

R. Abdelaziz, *Established and Emerging Nanocolloids: From Synthesis & Characterization to Applications (Talk)*, E-MRS Spring Meeting, Lille, France, 26.-30.05.2014

M. Elbahri, *Nanofabricated Devices under Leidenfrost Condition (Invited Talk)*, TRAMP2014, Marrakech, Morocco, 04.-06.06.2014

M. Elbahri, *Nanotechnologie Made Simple (Invited Talk)*, Kulturabteilung und Studienmission: Elbahri: Nanotechnology Made Simple, Berlin, Germany, 20.-20.11.2014

M. Elbahri, *(Invited Talk)*, Cooperation at the Aalto-University Helsinki, Helsinki, Finland, 07.-09.12.2014

## Further Activities and Events

**Selected Honorary Activities of Prof. Elbahri:**

Distinction Prize of the Ministry of Higher Education (Egypt),

Honour certificate of the Egyptian Cultural and Educational Mission at the Egyptian embassy in Berlin,

Kajal Mallick Memorial Award by the Institution of Civil Engineering (UK).

**Prizes and awards:**

March 2014: Ramzy Abdelaziz, Special prize in „Nanoerleben" presentation competition,

May 2014: Ramzy Abdelaziz, Young scientist award, E-MRS spring meeting, Lille, France,

December 2014: Mehdi Keshavarz Hedayati, DGM-Nachwuchspreis (German Materials Society Young Award).

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# Nanoscale Magnetic Materials - Magnetic Domains

The focus of research in the department of ''Nanoscale Magnetic Materials - Magnetic Domains'' is on magnetic heterostructures with tailored magnetic properties. Nano-structuring and -layering by various methods are used to modify the magnetic microstructure, enabling us to design magnetic materials and specifically control the magnetic domains, as well as applying and optimizing magnetic structures for various types of applications. The effective magnetic properties are influenced using different magnetic interaction effects. Magnetic properties are analyzed by probing the magnetic response laterally on time-scales from DC down to the picosecond range. Therefore, a main task within the department is the methodical advancement of magnetic domain investigation tools with high lateral and temporal resolution.

In general, the scientific emphasis of the research group is on micro- and nanostructured magnetic thin films. The magnetization behaviour of structured and layered magnetic thin films is illuminated from a fundamental point of view as well as from the perspective of application related scientific questions. We are investigating new fundamental concepts based on magnetic domain engineering for the design of the properties of nanostructured and multilayered magnetic film systems. A central goal is the improvement of existing magnetic material systems with respect to their functionality. Another field of interest is the use of structured magnetic thin films for the spatial and controlled manipulation of magnetic particles and objects.

In addition, a strong methodological emphasis of the department is on the optimization, development, and application of optical and microscopic techniques for the investigation of magnetic domain behaviour with high spatial and temporal resolution. The methods are essential for achieving the intended research goals.

## Results

### Magneto-optical imaging of magnetization dynamics in magnetic films

We used time-resolved magneto-optical Kerr microscopy with picosecond time resolution and phase-locked harmonic excitation to image the fundamental dynamic modes of magnetic domains, like spinwave modes and domain wall states, in soft-magnetic thick film elements. As an example, domain wall oscillations and local domain response are visualized below, at, and above the resonance frequency of the magnetic elements (Fig. 1). By analyzing mirrored domain states, we were able to extract the pure in-plane and out-of-plane dynamic magnetic response simultaneously under a continuous microwave excitation. Starting from the magnetic ground state, the lateral magnetic flux paths in the magnetic element are identified for different frequencies under continuous microwave magnetic field excitation. Areas of differing high-frequency permeability are clearly distinguished. Despite in-plane microwave field excitation, we find out-of-plane contributions of magnetization precession and dynamic magnetostatic coupling between individual magnetic domains. The highest amplitude of precession is found at the dominating precession frequency mode which is in agreement with comparative microwave measurement. For the first time, a phase shift between magnetic field application and induced domain wall motion is identified by means of direct imaging.

Overall, our data demonstrates the relevance of detailed magnetic domain knowledge and precise magnetodynamical imaging for the understanding of the dynamic behaviour, beyond the elementary adjustment of the high-frequency property of the material.

### Origin of hysteretic magnetoelectric response in 2-2 composite sensors

We compared the local magnetization behaviour of the magnetostrictive phase of ferromagnetic/piezoelectric magnetoelectric (ME) composites to the hysteretic response using advanced magneto-optical imaging. We were able to show that local magnetoelastic relaxation leads to the formation of magnetization modulated branched domain structures in the magnetic phase. This results in a complex field response governed by interlocking domain processes. Lateral magnetostrictive response images $\lambda_y$(x,y) are calculated directly from the magneto-optical images M(x,y), under the assumption that

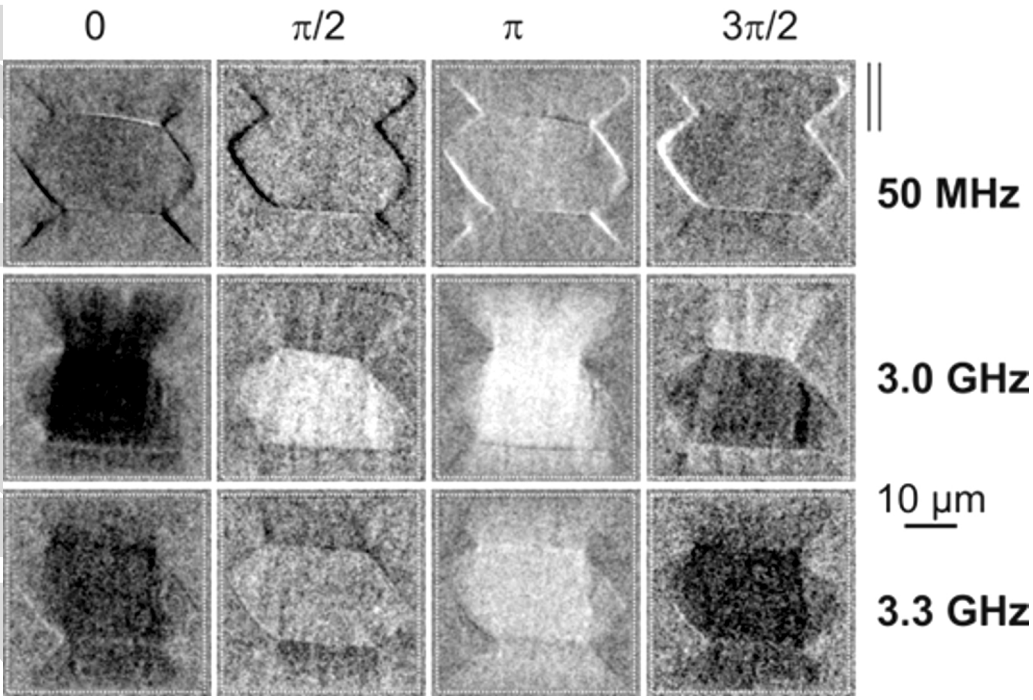


Fig. 1: Examples of laterally resolved magnetic response images for oblique plane of incidence at (a) 50 MHz, (b) 3 GHz (resonance frequency), and (c) 3.3 GHz. The phase of the excitation field is shown in steps of $\pi/2$ (as indicated).

$\lambda_y(x,y) \sim M(x,y)$ ^ 2. A comparison of exemplary magnetic domain and magnetostrictive response images in the edge regions is displayed in Fig. 5. Despite the millimetre-sized structures, local magnetoelastic effects dictate the overall magnetic domain formation even in extended magnetic structures. A unique modulated, internally folded and fanned out magnetic quasi-closure non-Landau domain structure develops. The entire magnetization reversal is then dominated by the hysteretic domain rearrangement processes. Interacting magnetic domain walls induce a local reduction of the effective magnetic susceptibility, leading to variation and reduction of ME sensitivity and to a magnetic field history dependent position of the working point of the ME sensor. The micromagnetic effects found will be even more relevant for smaller sized ME devices.

An interrelation of magnetic domain formation and piezomagnetic response was derived, revealing the origin of the hysteretic magnetoelectric response. As a result, domain wall induced effects lead to a reduction of magnetoelectric signal. Our results show that the understanding of magnetic domain arrangements is imperative for the optimization of 2-2 ME composite magnetic field sensors. Controlling the magnetic domain formation processes is the foundation for reversible magnetoelectric behaviour.

**Uniaxial in-plane magnetization of iron nanolayers grown within an amorphous matrix**

In cooperation with partners we determined the magnetic ground state at zero magnetic field of monolayer thick amorphous iron layers as part of a CoFeB-Fe multilayer stack. An easy in-plane axis of the embedded amorphous Fe layer is verified, which is collinear to the uniaxial anisotropy axis of the neighbouring amorphous CoFeB. Despite the soft magnetic character of the Fe layers, external fields up to several Tesla applied perpendicular to the film plane are insufficient to completely align the embedded Fe moments parallel to the magnetic field due to a local disorder of the magnetic moments of the Fe atoms. From this, the amorphous nature of the sandwiched Fe layers is confirmed, so amorphous iron films are possible.

**Magnetization dynamics of magnetic domain wall imprinted magnetic films**

We investigated the influence of micromagnetic objects on the dynamic magnetic excitation in magnetic thin films by

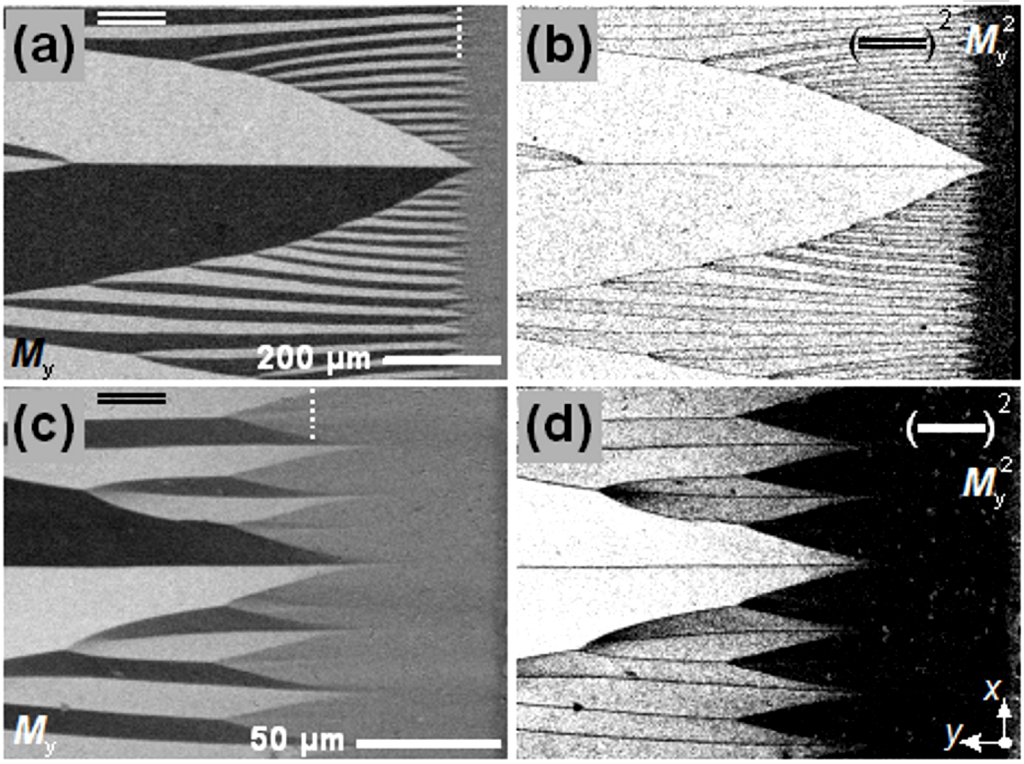


Fig. 2: High resolution regular (a), (c) M(x,y) and corresponding lateral magnetostrictive [M(x,y)] ^ 2 response images (b) and (d).

imprinting periodic domain wall patterns through selective ion irradiation in exchange biased NiFe/IrMn structures. By this, an increased precessional frequency is achieved for high domain wall densities. The zero field resonance of the domain wall state hereby depends directly on the stripe period, showing a pronounced increase with decrease of domain wall spacing. We found that with the abrupt annihilation of magnetic domain walls with an applied bias field a jump-like decrease in precession frequency takes place.

Our experimental data and micromagnetic simulations prove that the characteristic collective dynamic mode for the domain wall configurations is attributed to a strongly coupled and tilted magnetization structure. We show that the controlled introduction of high density frozen-in micromagnetic objects is a novel way to control the dynamic magnetic properties of continuous magnetic thin films.

### Superparamagnetic beads on a merry-go-round

An intricate spatial and temporal control of magnetic microbeads during their motion is significantly important for the successful transport of labelled chemical and biological species in microfluidic cells. Especially, monodisperse microbeads with a superparamagnetic particle-loaded shell and a diameter of a few micrometers act as a model system for biological cell manipulation.

The multi-regime motion of superparamagnetic beads on circular magnetic structures has been analyzed. We studied bead entrapment and its phase-delayed continuous motion by a periodic rotation of external magnetic field. External magnetic field rotation induces a magnetic stray field gradient and, as a result, a frequency modulated local displacement around a disk-shaped magnetic model structure, as shown in Fig. 3. Comparing modelling and experimental results, we investigated the role of superparamagnetic susceptibility, external magnetic field strength, and particle mass for the maximum particle velocity. Examples of the data are shown. As can be seen, the magnetic microsphere completes one revolution around a

curved path with four excursions. Even so, we found that the bead excursions are tunable.

The bead response determined provides guidance for the design of future devices with different sizes and shapes of magnetic structures, which will result in an optimized platform. A precise adjustment of the number of excursions by tuning the applied field and rotational frequency is possible. A path to selected bead transport over larger areas and sorting of bead populations with dissimilar effective susceptibilities is possible by this mechanism.

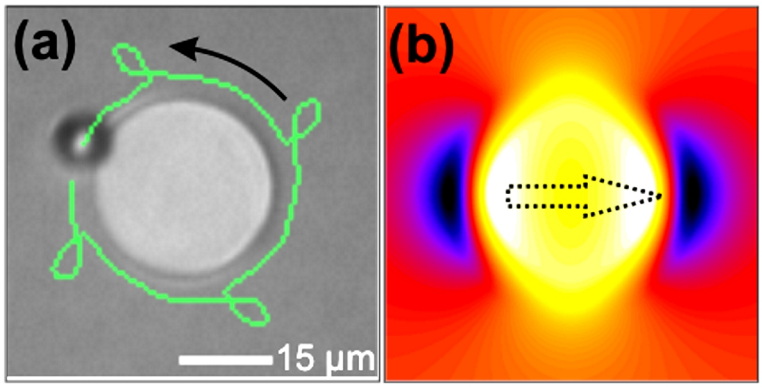


Fig. 3: Fig. 3: Optical image of an 8 micrometre diameter bead moving around a circular ferromagnetic structure with tracked path. (b) Potential energy distribution calculated by integrating the stray field over bead volume.

## Personnel

Head of the group: Prof. Dr. J. McCord; Secretary: E. Riemer
Technical Staff: Dipl.-Ing. (FH) T. Metzing

Scientific Staff:

| | | |
|---|---|---|
| M. Sc. Rasmus Holländer | 01.07.-31.12.2014 | DFG |
| Magnetic surfaces for the controlled manipulation of superparamagnetic microbeads | | |
| M.Sc. B. Mozooni | 01.01.-14.11.2014 | DFG |
| Domain configurations and magnetization dynamics | | |
| M. Sc. Umer Sajjad | 01.07.-31.12.2014 | DFG |
| Magnetic surfaces for the controlled manipulation of superparamagnetic microbeads | | |
| Dipl.-Phys. J. Trützschler | 01.01.-14.06.2014 | DFG |
| Hybrid magnetic materials | | |
| M.Sc. N. O. Urs | 01.01.-31.12.2014 | DFG |
| SFB 855, Magnetoelektrische Verbundwerkstoffe - biomagnetische Schnittstellen der Zukunft, Teilprojekt B05 | | |

## Lectures, Seminars, and Laboratory Course Offers

*Winter 2013/2014*

Werkstoffe - Keramiken, 2 hrs Lecture/Week,
J. McCord

Advanced Materials A - Metals, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
J. McCord

Magnetic Materials: Physics and Applications, 2 (+1) hrs Lecture (+ Exercises)/Week,
J. McCord

Nanoskalige Magnetische Werkstoffe, 2 hrs Seminar/Week,
J. McCord

*Summer 2014*

Magnetische Materialien, 2 (+1) hrs Lecture (+ Exercises)/Week,
J. McCord

Advanced Materials B, 4 (+2) hrs Lecture (+ Exercises)/Week,
J. McCord

Nanoskalige magnetische Werkstoffe - magnetische Domänen, 2 hrs Seminar/Week,
J. McCord

*Winter 2014/2015*

Werkstoffe - Keramiken, 2 hrs Lecture/Week,
J. McCord

Advanced Materials A - Metals, 2 (+1) hrs Lecture (+ Exercises)/Week,
J. McCord

Magnetic Materials: Physics and Applications, 2 (+1) hrs Lecture (+ Exercises)/Week,
J. McCord

Nanoskalige Magnetische Werkstoffe, 2 hrs Seminar/Week,
J. McCord

## Third-Party Funds

DFG, *Heisenberg-Professur*, 01.07.2011-30.06.2014 (189.000 EUR)
DFG, *Heisenberg-Professur*, 01.07.2014-30.06.2016 (186.400 EUR)
DFG, *Einstellbare und schaltbare Hochfrequenzeigenschaften - Domänenkonfiguration und Beobachtung von Magnetisierungsdynamik*, 01.10.2011-30.09.2014 (311.231 EUR)
DFG, *Einstellbare und schalbare Hochfrequenzeigenschaften - Domänenkonfiguration und Beobachtung von Magnetisierungsdynamik nanostrukturierter ferromagnetischer Schichten*, 01.07.2014-30.06.2016 (331.335 EUR)
DFG, *Hybride Magnetische Materialien - mikroskopische Modifikationen, makroskopische Wirkungen*, 15.02.2012-14.06.2014 (184.870 EUR)
DFG, *SFB 855 - Magnetoelektrische Verbundwerkstoffe - biomagnetische Schnittstellen d. Zukunft, Teilprojekt B05*, 01.04.2012-31.12.2013 (6.200 EUR)
DFG, *Magnetische Oberflächen zur kontrollierten Manipulation superparamagnetischer Mikroperlen*, 01.07.2014-30.06.2017 (284.816 EUR)
DFG, *Magnetostriktive Multilagen für magnetoelektrische Sensoren - Schichaufbau und Domänen*, 01.01.2014 (298.600 EUR)
TF, *Transfer einer Sputteranlage*, 01.01.2014 (30.000 EUR)
Schwerpunkt KINSIS, *Transfer einer Sputteranlage*, 01.01.2014 (46.000 EUR)
Petersen-Stiftung, *Transfer einer Sputteranlage*, 01.01.2014 (44.000 EUR)

## Further Cooperation, Consulting, and Technology Transfer

The department has cooperated with the following individuals and organizations:

Dr. A. Berger, nanoGUNE, San Sebastian,

Dr. Daniel Bürgler, Forschungszentrum Jülich - Peter Grünberg Institute,

Prof. J. Fassbender, Helmholtz-Zentrum Dresden-Rossendorf,

Dr. D. Gardner, Intel Corp., USA,

Dr. M. Ghafari, Karlsruhe Institute of Technology,

Prof. R. Grechishkin, Tver State University, Russia,

Dr. J. Grenzer, Helmholtz-Zentrum Dresden-Rossendorf,

Prof. H. Hu, Arizona State University, USA,

Prof. L. Kienle, CAU Kiel,

Prof. R. Knöchel, CAU Kiel,

Dr. M. Kustov, Imperial College, London, UK,

Prof. S. Mangin, Institute Jean Lamour Nancy, France,

Prof. O. Magnussen, CAU Kiel,

Dr. R. Mattheis, IPHT Jena,

Prof. A. Maziewski, Faculty of Physics, University of Białystok, Poland,

Dr. D. Meyners, CAU Kiel,

Prof. I. Mönch, IFW Dresden,

Dr. B. Murphy, CAU Kiel,

Prof. E. Quandt, CAU Kiel,

Prof. R. Schäfer, IFW Dresden,

Dr. H. Schmidt, TU Chemnitz,

Prof. L. Schultz, IFW Dresden,

Prof. A. Wawro, Institute of Physics, Polish Academy of Sciences, Warsaw, Poland,

Prof. S. Visnovsky, Charles University in Prague, Faculty of Mathematics and Physics, Czech Republic.

## Diploma, Bachelor's and Master's Theses

Rameez S. Malik, *Advanced dual wavelength magneto-optical methods for magnetic thin films,* 01.04.2014
Hafiz Ali Raza, *Magnetic domains and magnetization dynamics of structured thin films,* 25.04.2014
Qaisar Latif, *Controlled manipulation of superparamagnetic beads using permalloy magnetic thin film microstructures,* 03.07.2014
Niels Gauter, *Analysis and recovery of materials from hard disc drives in waste electronic and electrical equipment,* 16.07.2014
Finn Klingbeil, *Simulation of magneto-electric response,* 22.09.2014
Rashid Haris, *Development of magneto-optical magnetometer and microscope for imaging of magnetic domains,* 16.10.2014

## Publications

Published in 2014

N. O. Urs, I. Teliban, A. Piorra, R. Knöchel, E. Quandt, J. McCord, *Origin of hysteretic magnetoelastic behaviour in magnetoelectric 2-2 composites,* Applied Physics Letters, **105**, 202406 (2014)

V. Hrkac, E. Lage, G. Köppel, J. Strobel, J. McCord, E. Quandt, D. Meyners, L. Kienle, *Amorphous FeCoSiB for exchange bias coupled and decoupled magnetoelectric multilayer systems: real-structure and magnetic properties,* Journal of Applied Physics, **116**, 134302 (2014)

B. Mozooni, T. von Hofe, J. McCord, *Picosecond wide-field magneto-optical imaging of magnetization dynamics of amorphous film elements,* Physical Review, **B 90**, 054410 (2014)

M. Ghafari, R. Mattheis, J. McCord, H. Hahn, R. A. Brand, W. A. A. Macedo, *Uniaxial in-plane magnetization of iron nanolayers grown within an amorphous matrix,* Applied Physics Letters, **105**, 073102 (2014)

C. Hengst, M. Wolf, R. Schäfer, L. Schultz, J. McCord, *Acoustic-domain resonance mode in magnetic closure-domain structures:a probe for domain-shape characteristics and domain-wall transformations,* Physical Review, **B 89**, 214412 (2014)

O. D. Roshchupkina, T. Strache, J. McCord, A. Mücklich, C. Bähtz, J. Grenzer, *Structural modifications of thin magnetic Permalloy films induced by ion implantation and thermal annealing: a comparison,* Acta Materialia, **74**, 278 (2014)

E. Lage, N. O. Urs, V. Röbisch, I. Teliban, R. Knöchel, D. Meyners, J. McCord, E. Quandt, *Magnetic domain control and voltage response of exchange biased magnetoelectric composites,* Applied Physics Letters, **104**, 132405 (2014)

J. Trützschler, K. Sentosun, M. Langer, I. Mönch, R. Mattheis, J. Fassbender, J. McCord, *Optimization of magneto-resistive response of ion-irradiated exchange biased films through zigzag arrangement of magnetization,* Journal of Applied Physics, **115**, 103901 (2014)

C. Hamann, R. Mattheis, I. Mönch, J. Fassbender, L. Schultz, J. McCord, *Magnetization dynamics of magnetic domain wall imprinted magnetic films,* New Journal of Physics, **16**, 023010 (2014)

M. Langer, A. Neudert, I. Mönch, R. Mattheis, K. Lenz, J. Fassbender, J. McCord, *Magneto-optical analysis of stripe elements embedded in a synthetic antiferromagnet,* Physical Review, **B 89**, 064411 (2014)

E. Jakubisova-Liskova, S. Visnovsky, A. Wawro, L. T. Baczewski, P. Mazalski, A. Maziewski, M. O. Liedke, J. McCord, J. Fassbender, *Effect of Ga+ irradiation in molecular-beam epitaxy grown Pt/Co/Pt thin films studied by magneto-optic spectroscopy,* Journal of Applied Physics, **115**, **17C106**, (2014)

## Presentations

J. McCord, M. Kustov, B. Mozooni, N. O. Urs, *Advanced magneto-optical imaging of magnetic domains and beyond (invited),* Physikalisches Kolloquium der Universität Byalystok, Byalystok, Poland, 16.-19.03.2014

N. O. Urs, I. Teliban, A. Piorra, R. Jahns, R. Knöchel, E. Quandt, J. McCord, *Irregular magnetic domain effects in composite magnetoelectric sensors,* IEEE International Magnetism Conference - Intermag 2014, Dresden, Germany, 03.-08.05.2014

M. Kustov, R. Grechishkin, M. Gusev, N. Mamkina, J. McCord, *Pyromagnetic-based thermal microimaging with magneto-optical indicator films,* IEEE International Magnetism Conference - Intermag 2014, Dresden, Germany, 03.-08.05.2014

B. Mozooni, J. McCord, *Picosecond magneto-optical imaging of magnetization dynamics of magnetic film elements (Poster),* IEEE International Magnetism Conference - Intermag 2014, Dresden, Germany, 03.-08.05.2014

J. Trützschler, K. Sentosun, M. Langer, R. Mattheis, J. Fassbender, J. McCord, *Configurational anisotropy effects in 90° domain wall imprinted thin films - statics and dynamics,* IEEE International Magnetism Conference - Intermag 2014, Dresden, Germany, 03.-08.05.2014

J. McCord, R. Sahid Malik, *Dual path multi-component magneto-optical imaging of magnetic thin films,* IEEE International Magnetism Conference - Intermag 2014, Dresden, Germany, 03.-08.05.2014

R. Mattheis, W. B. Karunnapallil, M. Kuehn, J. McCord, M. Zeisberger, *Peculiarities in domain wall movement in polygonal shaped GMR nanowires,* IEEE International Magnetism Conference - Intermag 2014, Dresden, Germany, 03.-08.05.2014

P. Mazalski, N. O. Urs, W. Dobrogowski, J. Ferre, J. Gierak, L. T. Baczewski, A. Wawro, J. McCord, A. Maziewski, *Multicomponent magnetooptical domain structure imaging in a Pt/Co/Pt film driven by FIB irradiation,* Moscow International Symposium on Magnetism - MISM 2014, Moscow, Russia, 30.-30.06.2014

J. McCord, *Magnetism seen by optics - from DC to picoseconds (invited),* Physikalisches Kolloquium der Universität Kassel, Kassel, Germany, 10.-10.07.2014

J. McCord, *Magneto-optical imaging of magnetic domains... and beyond (invited),* PGI Kolloquium - FZ Jülich, Jülich, Germany, 17.-18.07.2014

J. McCord, *Magnetic materials as seen by magneto-optics (invited),* Seminar of the Institute of Physics Prague, Prague, Czech Republic, 21.-21.07.2014

V. Röbisch, E. Lage, N. O. Urs, I. Teliban, R. Knöchel, J. McCord, D. Meyners, E. Quandt, *Magnetoelectric sensors with exchange biasing for biomagnetic sensing (Poster),* MSE - Materials Science Engineering, Darmstadt, Germany, 24.-24.09.2014

C. Kirchhof, I. Teliban, D. Meyners, J. McCord, R. Knöchel, E. Quandt, *Magnetoelectric low noise composites for quasi static magnetic field measurements,* MSE - Materials Science Engineering, Darmstadt, Germany, 25.-25.09.2014

N. O. Urs, A. Piorra, E. Quandt, J. McCord, *Irregular magnetic domain formation in magnetoelectric composites,* MSE - Materials Science Engineering, Darmstadt, Germany, 25.-25.09.2014

E. Quandt, E. Lage, N. O. Urs, V. Röbisch, I. Teliban, R. Knöchel, D. Meyners, J. McCord, *Magnetic Domain Control of Exchange Biased Magneto-Electric Thin Film Composites (invited talk),* ECS and SMEQ Joint International Meeting, Cancun, Mexico, 05.-10.10.2014

V. Röbisch, E. Lage, E. Yarar, N. O. Urs, I. Teliban, R. Knöchel, J. McCord, E. Quandt, D. Meyners, *Exchange biased magnetoelectric composites for magnetic field sensor application by frequency conversion,* Annual Conference on Magnetism and magnetic materials, MMM 2014, Honolulu, USA, 05.-05.11.2014

H. Wu, U. Sajjad, D. S. Gardner, J. McCord, H. Yu, *Eliminating closure domains in laminated Co-Zr-Ta-B films for on-chip inductor applications,* Annual Conference on Magnetism and magnetic materials, MMM 2014, Honolulu, USA, 07.-07.11.2014

# Synthesis and Real Structures

Transmission Electron Microscopy, the most relevant and well established characterization tool of the group ''Synthesis and Real Structure'', is essential for conducting applied research and modern teaching at CAU. The TEM centre, listed as a core facility of the DFG, develops a broad range of nanoscale characterization techniques, thus enabling nearly all nanostructural challenges of material science to be tackled. The collaboration with almost all other groups in the Institute for Materials Science was further substantiated in 2014, and the already strong links to the Institute of Electrical Engineering and Information Technology were strengthened. Particularly, two new third-party funded interdisciplinary projects were started:

● Together with cooperation partners from KIT Karlsruhe, *in situ* and *ex situ* electron microscopy will provide insights into the switching mechanisms of so called memristive devices. The interdisciplinary research conducted as a sub-project within the research unit FOR 2093 (spokesman: Prof. Kohlstedt) is funded for three years.

● The package proposal PAK 902 (spokesman: Prof. Quandt) and with it the joint application of Prof. Adelung, Prof. Kienle, and Dr. Murphy focusing on piezotronic devices was positively evaluated by DFG. The major scientific challenge for electron microscopy is to find quantitative means for the measurement of strain at interfaces. Moreover innovative new tools for *in situ* straining piezotronic nanostructures are developed in close collaboration with industry partners.

Being part of national and international networks became very valuable in 2014. For instance, scientists from Israel (Dor Amram from the Technion in Haifa) and the United States (Jeff Ditto and Duncan Sutherland from the University of Oregon, Eugene) were long-term guests of the group. Moreover, within the framework of a DFG priority programme, together with partners from Kiel, Freiburg, and the USA (Prof. D.C. Johnson as Mercator Professor) the reliability of thermoelectric bulk- and nanostructures was examined. Our results demonstrate that the details of material production and long-term operation could be of unexpectedly great importance for thermoelectric efficiency. As a consequence, one may assume that the widely discussed spread of thermoelectric characteristics reported by different groups for the same material is due to missing information about such pre- and post-treatments. Meanwhile, we demonstrated a much more reliable benchmarking process for thermoelectric efficiency, which is based on the material integration into prototype thermoelectric power generators.

## Results

### a) Cooperation in the Framework of the TEM Centre

Many projects concerning a broad field of nanostructural problems are submitted to the TEM Centre of the Faculty of Engineering. Here an extract of the cooperation with internal and external partners is given:

- *Evaluation of the oxidation state of Zirconium oxide layers (in cooperation with the Justus-Liebig-University, Giessen)*.

Deposited amorphous layers of Zirconium oxide (cross-sectional preparation with Focussed Ion Beam (FIB)) were crystallized during *in situ* heating in the TEM. The layer was analyzed before, during, and after heating by means of electron diffraction (ED), high resolution TEM (HRTEM), energy dispersive X-ray analysis (EDX), and electron energy loss spectroscopy (EELS) and changes in the distribution, structure, and the oxidation state of the Zirconium (e.g. $ZrO_2$ as well as $Zr_2O$) were detected.

- *Studies on spinel-type materials for Li insertion (in cooperation with the Institute of Inorganic Chemistry, CAU Kiel)*.

Structural, morphological, and chemical properties of spinel ($AB_2O_4$) nanoparticles with different metal ion compounds (Mg, Fe, Mn, Co) as new Li ion battery material were analyzed to study effects of the conversion reaction during Li insertion.

- *High temperature reliability of diffusion barriers (in cooperation with the Group ''Materials and Processes for Nanosystem Technologies'' of Prof. Wagner, Faculty of Engineering, CAU Kiel)*.

Tantalum- and Titanium-Tungsten-based diffusion barriers in MEMS devices prepared by physical vapour deposition techniques were examined cross-sectionally with EDX in the high angle annular dark field (HAADF) scanning TEM (STEM) mode. The distributions of Ni and Au, deposited on the top of the barriers, were monitored with EDX maps, point measurements, and profiles for samples before and after an annealing step of 24 h at 600 °C. As a result, the barriers are impermeable for pure Ni but in the presence of Au both elements, Ni and Au, diffuse through the barriers and form big crystals underneath the barrier.

- *Visiting guest scientist Dor Amram from Technion, Haifa, Israel.*

Magnetic properties of FeAu nanoparticles were studied with Lorentz microscopy (LTEM) in cooperation with the visiting scientist Dor Amram from the Technion - Israel Institute of Technology in Haifa.

- *Micro- and nanostructure of sputtered Fe-Au thin films (in cooperation with Dr. C. Zamponi of the group ''Inorganic Functional Materials'', Faculty of Engineering, CAU Kiel).*

Freestanding films of iron and gold multilayers for biodegradable materials were analyzed with HAADF-STEM and EDX mapping to reveal the micro- and nanostructure distribution before and after *ex situ* annealing steps. After heating the samples the gold layers dissolved along the Fe grain boundaries and new nanostructures such as ring-like gold structures were found inside the Fe grains. (Fig. 1a) and b)).

- *Element and grain distribution after temperature induced decomposition of Kyanite $Al_2SiO_5$ (in cooperation with the Institute of Geoscience, CAU Kiel).*

Elemental EDX maps were performed on cross-sectional FIB lamellae of primarily $Al_2SiO_5$ decomposed at different temperatures to show the difference in the nano-sized distribution of $Al_2O_3$ and $SiO_2$ grains. The study shows that the grain size correlates with the annealing temperature with very small sizes down to a few nanometres at 1300 °C. The grain sizes also correspond to promising mechanical properties of the material.

- *Challenging cross-sectional sample preparation for ZnO nanospikes (in cooperation with the group of ''Functional Nanomaterials'', CAU Kiel and Prof. D.C. Johnson, University of Oregon).*

- Defects like twin and anti-phase boundaries, stacking faults, dislocations, and vacancies play an important role for the structural as well as the electronic properties of wurtzite-type Zinc oxide nanospikes. To display these defects by means of TEM the sample preparation is crucial. By embedding these nanostructures in carbon and subsequent FIB preparation on this configuration it was possible to cut a disc out of the needles on which several defects can monitored by means of HRTEM (Fig. 1c)).

**b) Investigations on the microstructural origin of ultra-low fatigue during superelastic cycling of NiTiCu-based shape memory alloys (in cooperation with: Prof. E. Quandt, CAU Kiel and Prof. M. Wuttig, University of Maryland).**

Shape memory alloys (SMAs) in general, and NiTi-based SMAs in particular, have gained a lot of interest due to their unique capability of reversible deformation. Numerous applications have been established since their discovery, among them cardio-vascular stents and orthodontic wires. However, the implementation of superelastic cycling in devices has been rendered impossible by pronounced fatigue mechanisms. The emphatic search for SMAs has led to ternary NiTi-based compounds which showed ultra-low fatigue during mechanical cycling even after millions of load cycles.

Extensive microstructural *in situ* and *ex situ* TEM analysis have led to the discovery of epitaxial interfaces between the phase-changing matrix and secondary precipitates: the stabilization of cubic austenite (space group: *Pm-3m*) and orthorhombic martensite (*Pmmb*) variants via epitaxial coupling by $Ti_2Cu$-type grains (*I4/mmm*) has been observed and is found responsible for the supreme mechanical cycling capability of these compounds. SAED and PED investigations revealed the characteristic relations between both phases forming distinctive interfaces. (Fig. 1d) and f)).

The interfaces have been analyzed (Fig. 1h) and i)) and a geometric model based on the different misfit strain values between $Ti_2Cu$ and B2/B19 has been developed and confirmed by HRTEM. It involves a nanoscopic B2 transition layer between B19 and $Ti_2Cu$ at interfaces of specific orientations,; which serves as a seed for the transformation of the rest of the grain after mechanical load. This ensures the complete back transformation and hence complete reversion of the stress induced phase change. This mechanism safeguards the repeatability and allows for the high number of cycles now with basically measureable fatigue behaviour as shown by our cooperation partners.

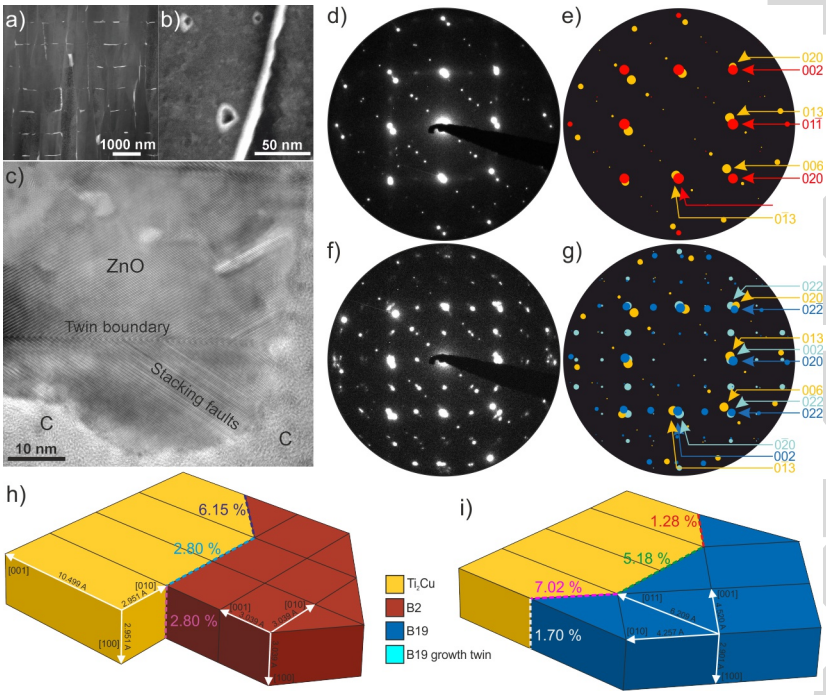


Fig. 1: HAADF-STEM images of a) Au-Fe multilayer after annealing at 685 °C: Au diffusion along the Au grains. b) Nano-sized ring-like Au structure in the Fe. c) HRTEM micrograph of a cross-sectional cut through a ZnO nanospike. The ZnO is embedded in a carbon matrix (labeled C). Inside the ZnO a twin boundary and stacking faults are observable. TEM generated and simulated diffraction patterns of the B2/$Ti_2Cu$ and B19/$Ti_2Cu$ interfaces. The experimental patterns d) and f) have been recorded at both elevated and room temperature, respectively. d) SAED pattern recorded at the B2/$Ti_2Cu$ interface, zone axes [100]. e) Simulation of the pattern in d), showing that 020 $Ti_2Cu$ nearly coincides with 002 B2. f) SAED pattern recorded at the B19/$Ti_2Cu$ interface, zone axes: [100]. g) Simulation of the pattern in f) demonstrating near-overlap of the 020 $Ti_2Cu$ and 02-2 B19 / 022 B19 twin diffraction spots. The patterns confirm the proposed epitaxies at high and low temperatures (010) B2/(001) $Ti_2Cu$ red/yellow in (h), (0-11) B19/(001) $Ti_2Cu$, dark blue/yellow in (i) and (011) B19 twin/(001) $Ti_2Cu$, light blue/yellow. Proposed interfaces between $Ti_2Cu$ (yellow) and B2 (red, h) and B19 (blue, i) in unit cell representation. Dashed lines and corresponding colour coded percentages indicate the misfit strain between both phases at the particular interfaces. h) Interface between B2 and $Ti_2Cu$, dark purple line (6.15 %) indicates an interface as shown in (d). i) Interface between B19 and $Ti_2Cu$, green line (5.18 %) indicates an interface as shown in (f).

**c) Aero-GaN: TEM structural and chemical studies of a 3D interconnected nano-/micro-hollow tubes of GaN network (in cooperation with: Prof. R. Adelung, CAU Kiel, and Prof. I. Tiginyanu, Academy of Science of Moldova).**

GaN is a direct bandgap semiconductor with a wide bandgap of ~3.4 eV and its nano-/micro-structures are promising materials for the electronic, photonic, and piezotronic nano-devices. In this study, a novel 3D interconnected nano-/micro-hollow tubular structure of GaN, i.e. Aero-GaN, was synthesized by the group of Prof. Dr. *Ion Tiginyanu*. This

method is believed to overcome the lattice matching issue occurring in the case of epitaxial growth of GaN with crystalline substrates, which is so far the most viable method for obtaining GaN nanocrystals. Moreover, the high flexibility of the Aerographite-like GaN network also ensures it can be integrated readily into any microdevice with various length scales.

Two variants of the Aero-GaN are synthesized by depositing GaN on the interconnecting ZnO tetrapod network via the hydride vapour phase epitaxy (HVPE) approach at two different temperatures:

(1) Aero-GaN prepared at 850 °C results in microtube structures consisting of a continuous layer without any hole (Fig. 2a)). The layer shows a high transparency to the electron beam, as another film of GaN is visible through this microtube. The bend contour on the surface also indicates the tube structure is formed with a curved, thin, single crystalline layer. A statistical EDX study from several different microtubes shows an average amount of 7 at. % of Zn remaining on/in the structure. A localized EDX elemental mapping (Fig. 2b and c)) revealed the spatial distribution of the residual Zn: Zn and Ga seem to be uniformly incorporated together, without any preferential aggregations on the microtube.

Furthermore, SAED structural analysis confirmed the single crystallinity of the sample. Figure 2d) demonstrates the SAED pattern along the [100] zone axis assuming the structure of GaN. However, when the projection is along the [100] axis, ZnO has a very similar pattern as GaN, e.g. the d-value of the ZnO (010) plane is only ~0.7 Å larger than GaN. In the higher order reflections on the SAED pattern, there are noticeable splittings of the Bragg intensities, shown marked with a yellow box in Figure 2e). An enlarged section at the bottom shows that the d-spacing of the inner and outer circles correspond to ZnO and GaN respectively. Further simulated pattern is calculated by assuming the GaN and ZnO phases are epitaxially growing along the [100] direction. The enlarged green boxed region also shows a reasonable matching with the experimental data. This observation can be explained by assuming the residual ZnO is a stabilizing layer for the deposited GaN to grow with a similar lattice parameter. In this way it achieves a highly crystalline epitaxial growth in a three dimensional manner.

(2) A structure of Aero-GaN obtained at 950 °C is demonstrated in Figure 2f). The TEM image revealed an almost complete GaN tetrapod. Unlike variant 1, the microtubes are more porous. However, SAED Investigation performed on several positions on the tetrapod confirmed the single crystallinity of the porous structure. As compared with variant 1, another difference is that there is no splitting of the reflections on the SAED (Fig. 2f)), where all the d-values are close to GaN. This result implies that the Zn phase could be more reduced, leaving fewer residues within the sample. Further EDX measurements verify an average remaining Zn of only 3~4 at. %. EFTEM elemental maps are shown in Figure 2g) and h). The Ga and N are well incorporated within the structure. Moreover, a thin layer of Zn is clearly revealed in the inner wall of the microtube (marked out with arrows in Fig. 2g) and h)). The second variant of Aero-GaN shows that the reduction of the ZnO template can be probably more complete with higher synthesize temperature, and thus, result in unclosed porous walls.

**d) Synthesis and analysis of various compositions in the system Cu-In-S**. The abandonment of the use of nuclear and fossil-fuel energy sources is not yet possible but it is an unavoidable step for a clean environment in the future. Photocatalysis is, among other techniques, a promising and clean energy source. Hydrogen can be released and harvested by exposing water to sunlight, avoiding either $CO_2$-producing combustion or radioactivity. For this purpose ternary compounds in the copper indium sulphur system prepared by cooperation partners from the Inorganic Chemistry Department were investigated. Multiple compositions, being pseudobinary mixtures of CuS and $In_2S_3$, were obtained by controlled solvothermal syntheses of stoichiometric amounts of the pure elements in organic solvent. Different temperatures and pressures yield three different phases: $CuInS_2$ (C1), $CuIn_3S_5$ (C2) and $CuIn_7S_{11}$ (C3). For composition determination as well as micro- and nanostructural investigations XRD and EDX measurements, in addition to SEM and TEM techniques, were employed. As observed at lower temperatures the C1 phase appeared black consisting of nanoplates. Higher temperatures induce the formation of C2, a red compound of agglomerated nanowalls and C3, an orange fluff-like phase containing nanobelts. C2 and C3 especially, the copper poor phases, show unique nanostuctural features. Tilting experiments in the TEM showed that C2 nanowalls exhibit a bending with a tendency to roll up. C3 nanobelts show a lamellar structure with some degree of bending along the belt. As C2 and C3 tend to appear next to each other C3 is possibly a product of C2 as

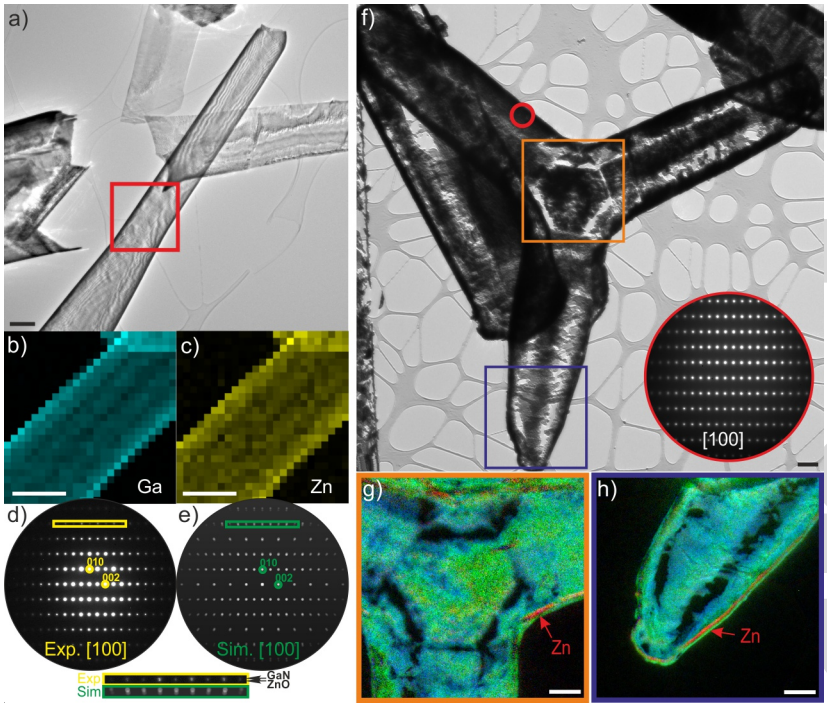


Fig. 2: A combined TEM chemical and structural analyses of Aero-GaN hollow microtubes. (a) TEM bright-field image of the first variant of Aero-GaN microtube with an amount of residual Zn around 7 at. %. EDX elemental maps from the red boxed region in (a): (b) Gallium map; (c) Zinc map. (d) SAED pattern from the marked region in (a), showing a projection along the [100] zone axis of GaN or ZnO (space group: $P6_3mc$). (e) Computer simulated SAED pattern assuming an exact overlapping of the same [100] zone axis of both GaN and ZnO phases. In the bottom a comparison is shown of two enlarged sections from the marked higher order reflections in the experimental and simulated patterns. (f) TEM bright-field image of a second variant of porous Aero-GaN tetrapod with remaining Zn 3-4 at. %. Inset shows the SAED pattern recorded from the red circled area of the tetrapod. (g) A combined EFTEM elemental map from the yellow box region in (f). The elements of interests are represented with different colours. (h) A combined EFTEM elemental map from the blue box region in (f). Colour code: Green: Gallium,Red: Zinc, Blue: Nitrogen. Scale bar is 500 nm.

enrolled edges separate to nanobelts. This has to be proved by further experiments involving EDX and HRTEM.

**e) Effect of real structure changes on highly performing thermoelectric power generators based on GeTe doped with $Bi_2Se_{0.2}Te_{2.8}$ (in cooperation with Fraunhofer IPM (Freiburg) and Prof W. Bensch, CAU Kiel).**

Thermoelectric generators (TEGs) are highly relevant to increase efficiency of heat producing systems by converting a heat flux into an electrical current when long term stability and small scales are decisive. Thus, TEGs have been used as radioisotopic power systems for space explorations since the 1960s. However, reports about high performance TEGs are rare and most of the scientific community is focused on finding materials with high ZT (figure of merit for the efficiency of a thermoelectric material) neglecting electrical contact formation and effects of thermal cycling on the structure. The aim was to produce a highly efficient TEG with low ohmic contact resistance based on GeTe doped with $Bi_2Se_{0.2}Te_{2.8}$ (also known as phase change materials PCMs) and to investigate the stability of these systems against thermal cycling. Therefore 0.0962[GeTe] 0.038[$Bi_2Se_{0.2}Te_{2.8}$] and 0.0937[GeTe] 0.063[$Bi_2Se_{0.2}Te_{2.8}$] powder samples have been synthesized and compacted by spark-plasma sintering (SPS). For 0.0937[GeTe] 0.063[$Bi_2Se_{0.2}Te_{2.8}$] an extraordinary high ZT of $\sim$2.2 at 500 °C was measured. After several heating cycles the ZT dropped to a moderate value of $\sim$1 due to a degradation of the electrical conductivity. X-ray diffraction (XRD) and transmission electron microscopy (TEM) measurements showed significant changes of the nano- and microstructure before sintering (Figure 3c)), after sintering

(Figure 3b)), and after thermal cycling of the sinter body (Figure 3a)). High resolution TEM micrographs showed the formation of stripe like Moiré fringes directly after synthesis and before heat cycling. These fringes can be understood as structural deviations from the cubic metric resulting from agglomerations of vacancies. Consequently, simulations showed that these fringes can be rationalized as an overlap of low and high temperature phase of GeTe. After sintering XRD measurements showed a broadening of the (211) Bragg reflection which can be attributed to the formation of high temperature phase GeTe as a result of the fast cooling process. After heat cycling the sinter body the stripe like Moiré fringes completely disappeared and the formation of so called vacancy layers was observed.

Samples with composition of 0.0962[GeTe] 0.038[$Bi_2Se_{0.2}Te_{2.8}$] showed neither the formation of fringes nor the formation of vacancy layers and consequently no increase in resistivity. TEGs produced from this material resulted in an output power of 0.97W/cm$^2$ at 500 °C using strongly degenerated SnTe as electrical contacts and PbTe doped with Bi (ZT ~0.9) as n-type material.

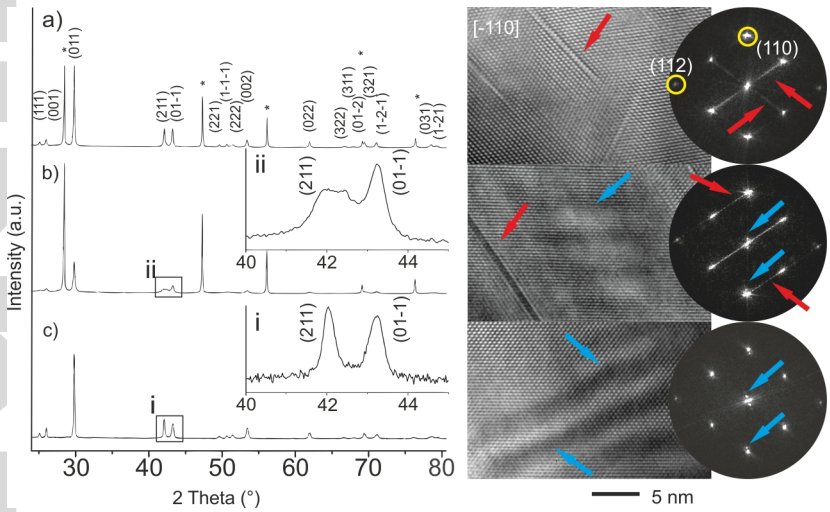


Fig. 3: Powder diffraction pattern and high resolution micrographs including corresponding FFTs of 0.937 (GeTe) 0.063 ($Bi_2Se_{0.2}Te_{2.8}$) of the three different processing stages. Figure a, b and c represent XRD and TEM data of the sample after heat cycling, after SPS, and in the pristine state, respectively. The reflections in the powder diffraction pattern (* mark the reflections of the internal Si standard) and the FFTs were indexed according to the rhombohedral setting of the space group R3m. The insets i and ii represent enlarged sections of the (111) and (001) reflections of the powder diffraction pattern in b and c, respectively. Red and blue arrows in the HRTEM micrographs and the FFTs mark planar defects with corresponding diffuse intensities and the fringes with corresponding additional reflections in the FFTs, respectively.

## Personnel

Head of the group: Prof. Dr. Lorenz Kienle; Secretary: Katrin Brandenburg (50%)
Technical Staff: Christin Szillus

Scientific Staff:

M.Sc. Torben Dankwort 01.01.-31.12.2014 DFG

SPP 1386 Nanostrukturierte Thermoelektrika: Theorie, Modellsysteme und kontrollierte Synthese, TP Nanostructure, thermoelectric properties and transport theory of V2VI3 and V2VI3/IV-VI superlattices

M.Sc. Mao Deng 01.01.-31.12.2014 DFG

Synthese und Realstruktur-Eigenschaftsbeziehungen von katalytisch aktiven Nanoteilchen auf der Basis von Übergangsmetallsulfiden

Dr. Viktor Hrkac 01.01.-31.12.2014 DFG
Elektrochemische und mikrostrukturelle Untersuchung der Prozesse in Anoden für Hochkapazitäts-Lithium-Ionen-Batterien basierend auf Si-Mikrodrahtanordnungen

Dr. Dietrich Häußler 01.01.-31.12.2014 CAU
Disordered chalcogenides, advanced microscopy with aberration correction

M.Sc. Gero Neubüser 01.01.-31.12.2014 DFG
SFB 855, TP Z1 Hochauflösende Transmissionselektronenmikroskopie und magnetoelektrische Materialcharakterisierung

Dr. Ulrich Schürmann 01.01.-31.12.2014 CAU
TEM-Zentrum

M.Sc. Julian Strobel 01.-31.12.2014 DFG
FOR 2093, TP B2 Nanostruktur von Materialien für memristive Schaltvorgänge

## Lectures, Seminars, and Laboratory Course Offers

*Winter 2013/2014*

Thermodynamics and Kinetics I, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
L. Kienle

Solid State Chemistry and Crystallography, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
L. Kienle (+ U. Schürmann)

Solid State Chemistry and Crystallography, 1 hrs Seminar/Week,
U. Schürmann

Electron Microscopy, 3 (+ 2) hrs Lecture (+ Exercises)/Week,
L. Kienle

Materialwissenschaft 3, 3 (+ 1) hrs Lecture (+ Exercises)/Week,
L. Kienle (+ U. Schürmann)

Seminar Synthese und Realstruktur, 2 hrs Seminar/Week,
L. Kienle

Hochauflösende Transmissionselektronenmikroskopie: Prinzipien und Anwendungen, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
L. Kienle

Analytische Methoden for B.Sc. Students, 4 hrs Practical/Week,
D. Häußler (+ et al.)

*Summer 2014*

Thermodynamics and Kinetics 2, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
V. Hrkac (+ L. Kienle)

Mikro- und Nanocharakterisierung von Festkörpern mittels TEM, 2 hrs Lecture/Week,
U. Schürmann

Materialanalytik 1, 2 hrs Lecture/Week,
L. Kienle

Seminar Synthese und Realstruktur, 2 hrs Seminar/Week,
L. Kienle

Praktische Aspekte der Mikro- und Nanocharakterisierung von Festkörpern mittels TEM, 2 hrs Seminar/Week,
U. Schürmann (+ M. Deng, C. Szillus)

Advanced Laboratory Course for M.Sc. Students, 4 hrs Practical/Week,
D. Häußler (+ et al.)

*Winter 2014/2015*

Thermodynamics and Kinetics 1, 2 (+1) hrs Lecture (+ Exercises)/Week,
L. Kienle (+ V. Hrkac)

Electron Microscopy, 3 (+2) hrs Lecture (+ Exercises)/Week,
L. Kienle

Materialwissenschaft 3, 3 (+1) hrs Lecture (+ Exercises)/Week,
L. Kienle (+ U. Schürmann)

Seminar Synthese und Realstruktur, 2 hrs Seminar/Week,
L. Kienle

Analytische Methoden for B.Sc. Students, 4 hrs Practical/Week,
D. Häußler (+ et al.)

## Third-Party Funds

DFG, *SFB 855, TP Z1 Hochauflösende Transmissionselektronenmikroskopie und magnetoelektrische Materialcharakterisierung*, 01.01.2010-31.12.2014 (835.700 EUR)

DFG, *Synthese und Realstruktur-Eigenschaftsbeziehungen von katalytisch aktiven Nanoteilchen auf der Basis von Übergangsmetallsulfiden*, 16.04.2012-15.04.2015 (144.501 EUR)

DFG, *Programmpauschale zu: Synthese und Realstruktur-Eigenschaftsbeziehungen von katalytisch aktiven Nanoteilchen auf der Basis von Übergangsmetallsulfiden*, 16.04.2012-15.04.2015 (28.900 EUR)

DFG (SPP 1386), *Synthesis, theoretical investigation and properties of nanocomposite thermoelectric materials*, 01.10.2013-30.09.2016 (12.000 EUR)

DFG (SPP 1386), *Programmpauschale zu: Synthesis, theoretical investigation and properties of nanocomposite thermoelectric materials*, 01.10.2013-30.09.2016 (4.800 EUR)

DFG, *SPP 1386 Nanostrukturierte Thermoelektrika: Theorie, Modellsysteme und kontrollierte Synthese. Nanostructure, thermoelectric properties and transport theory of V2VI3 and V2VI3 IV-VI based superlattices*, 01.03.2013-29.02.2016 (148.800 EUR)

DFG, *Programmpauschale zu: SPP 1386 Nanostrukturierte Thermoelektrika: Theorie, Modellsysteme und kontrollierte Synthese. Nanostructure, thermoelectric properties and transport theory of V2VI3 and V2VI3 IV-VI based superlattices*, 01.03.2013-29.02.2016 (29.800)

DFG, *Elektrochemische und mikrostrukturelle Untersuchung der Prozesse in Anoden für Hochkapazitäts-Lithium-Ionen-Batterien basierend auf Si-Mikrodrahtanordnungen*, 17.09.2013-16.09.2015 (127.825 EUR)

DFG, *Programmpauschale zu: Elektrochemische und mikrostrukturelle Untersuchung der Prozesse in Anoden für Hochkapazitäts-Lithium-Ionen-Batterien basierend auf Si-Mikrodrahtanordnungen*, 17.09.2013-16.09.2015 (25.600 EUR)

DFG, *FOR 2093 Forschergruppe ''Memristive Bauelemente für neuronale Systeme'', Teilprojekt B2 ''Nanostruktur von Materialien für memristive Schaltvorgänge''*, 01.12.2014-30.11.2017 (148.500 EUR)

DFG, *Programmpauschale zu: FOR 2093 Forschergruppe ''Memristive Bauelemente für neuronale Systeme'', Teilprojekt B2 ''Nanostruktur von Materialien für memristive Schaltvorgänge''*, 01.12.2014-30.11.2017 (29.700 EUR)

## Further Cooperation, Consulting, and Technology Transfer

The group cooperates with the following subjects, individuals, and organisations: - Functional Nanomaterials - Prof. Dr. R. Adelung, CAU Kiel,

- Multicomponent Materials - Prof. Dr. F. Faupel, CAU Kiel,

- Inorganic Functional Materials - Prof. Dr. E. Quandt, CAU Kiel,

- General Materials Science - Prof. Dr. H. Föll, CAU Kiel,

- Nanoelectronic - Prof. Dr. H. Kohlstedt, CAU Kiel,

- Materials and Processes for Nanosystem Technologies - Prof. Dr. B. Wagner, CAU Kiel,

- Inorganic Chemistry - Prof. Dr. W. Bensch, CAU Kiel,

- Inorganic Chemistry - Prof. Dr. N. Stock, CAU Kiel,

- Klinik für Neurologie - Prof. Dr. T. Bartsch, CAU Kie,l

- Institute of Polymers and Composites - Prof. Dr. K. Schulte, Technische Universität Hamburg-Harburg,

- Elektronenmikroskopie - Dr. Andriy Lotnyk, Leibniz-Institut für Oberflächenmodifizierung,

- Thermoelektrische Systeme - J. König, Fraunhofer Institut für Physikalische Messtechnik, IPM Freiburg,

- Solid State Chemistry, Inorganic Chemistry, Electrochemistry and Materials Science - David C. Johnson, University of Oregon,

- Transmission Electron Microscopy - Institute of Nanotechnology - Dr. V.S.K. Chakravadhanula und Dr. C. Kübel, KNMF Karlsruhe,

- Department of Materials Science and Engineering - Prof. Dr. M. Wuttig, University of Maryland,

- Physical Chemistry - Prof. Dr. J. Janek, Justus Liebig University of Giessen,

- Lehrstuhl für Anorganische Chemie mit Schwerpunkt Neue Materialien - Prof. Dr. T. F. Fässler, Technische Universität München,

- Physikalisches Institut (IA) - Prof. Dr. M. Wuttig, RWTH Aachen,

- Acquandas GmbH - Dr. Rodrigo Lima de Miranda, Kiel,

- NanoMEGAS SPRL - Dr. S. Nicolopoulos, Brussels,

- Technical Chemistry - Prof. Dr. Barcikowski, Duisburg-Essen,

- Superconducting Materials - Dr. S. Fähler, IWF Dresden,

- Chemistry - Prof. Dr. Dr. h. c. M. Jansen, Max Planck Institute for Solid State Research, Stuttgart,

- Laboratory of Industrial Chemistry - Prof. Dr. W. Grünert, Ruhr-Universität Bochum,

- Prof. A.M. Klonkowski, University Gdansk (Poland),

- Quantentheorie des Festkörpers - Prof. Dr. I. Mertig, Institut für Physik, Martin-Luther-Universität Halle-Wittenberg,

- Institute of Physical and Theoretical Chemistry - Prof. Dr. W. Kunz, University of Regensburg,

- Institute of Chemical Physics - Dr. Donats Erts, University of Latvia,

- Electron Microscopy for Materials Science - Joke Hadermann, University of Antwerpen,

- Lehrstuhl für Theoretische Elektrotechnik - Dr. T. Mussenbrock, Ruhr-Universität Bochum,

- Institut für Nano- und Medizinelektronik - Prof. Dr. W. Krautschneider, TU Hamburg-Harburg.

- In 2014, Dr. Dietrich Häussler CAU performed some final investigations on the development of concepts for defect engineering of high-efficiency solar cells as part of the earlier collaboration between the Microanalysis of Materials Group, the Fraunhofer Institute for Solar Energy Systems ISE, Dr. F. Dimroth, Dipl. Phys. S. Essig, and the Ernst Ruska Centre for Microscopy and Spectroscopy with Electrons, Research Centre Juelich GmbH, Dr. L. Houben.

## Diploma, Bachelor's and Master's Theses

Marius Kamp, *Improvement, calibration, and testing of a measuring apparatus for time-resolved logging of gas production rate in lithium-polymer-batteries,* 29.09.2014

Julian Strobel, *Microstructural Analysis of Novel NiTiCu-based Shape Memory Alloys for Superelastic Cycling,* 14.10.2014

Lena Nolte, *Real structure of new phases Cu-In-S for water splitting,* 18.11.2014

Cai Müller, *Diffuse Elektronenstreuung in* $K_2Ga_{12}Te_{19}$, 19.12.2014

## Dissertations / Postdoctoral Lecture Qualifications

Viktor Hrkac, *Nanocharacterization of materials for biomagnetic sensing using TEM,* 06.02.2014

## Publications

Published in 2014

J. Eiblmeier, U. Schürmann, L. Kienle, D. Gebauer, W. Kunz, M. Kellermeier, *New insights into the early stages of silica-controlled barium carbonate crystallization,* Nanoscale, **6(24)**, 14939 - 14949 (2014)

O. Falkenbach, A. Schmitz, T. Dankwort, G. Koch, L. Kienle, E. Müller, S. Schlecht, *Influence of mechanochemical syntheses and compacting methods on the thermoelectric properties of nanostructured* $AgSn_mSbTe_{2+m}$ *(TAST-m),* Semicon. Sci. Tech., **29(12)**, (2014)

A.L. Hansen, T. Dankwort, M. Winkler, J. Ditto, D.C. Johnson, J.D. König, K. Bartholome, L. Kienle, W. Bensch, *: Synthesis and Thermal Instability of High-Quality* $Bi_2Te_3/Sb_2Te_3$ *Super Lattice Thin Film Thermoelectrics,* Chem. Mater. (DOI: 10.1021/cm5031574), **26(22)**, 6518 - 6522 (2014)

M. Zeilinger, L.A. Jantke, L.M. Scherf, F.J. Kiefer, G. Neubüser, L. Kienle, A.J. Karttunen, S. Konar, U. Häussermann, T.F. Fässler, *Alkali Metals Extraction Reactions with the Silicides* $Li_{15}Si_4$ *and* $Li_3NaSi_6$*: Amorphous Si versus allo-Si,* Chem. Mater., **26(22)**, 6603 - 6612 (2014)

V.S.K. Chakravadhanula, Y.K. Mishra, V.G. Kotnur, D.K. Avasthi, T. Strunskus, V. Zaporojtchenko, D. Fink, L. Kienle, F. Faupel, *Microstructural and plasmonic modifications in Ag-*$TiO_2$ *and Au-*$TiO_2$ *nanocomposites through ion beam irradiation,* Beilstein of Nanotechnology, **5**, 1419 - 1431 (2014)

J. Xiong, M.Z. Ghori, B. Henkel, T. Strunskus, U. Schürmann, L. Kienle, F. Faupel, *Controlling surface segregation of reactively sputtered Ag/TiOx nanocomposites,* Acta Mat., **74**, 1 - 8 (2014)

O. Lupan, V. Cretu, M. Deng, D. Gedamu, I. Paulowicz, S. Kaps, Y.K. Mishra, O. Polonskyi, C. Zamponi, L. Kienle, V. Trofim, I. Tiginyanu, R. Adelung, *Versatile Growth of Freestanding Orthorhombic alpha-Molybdenum Trioxide Nano-*

*and Microstructures by Rapid Thermal Processing for Gas Nanosensors,* J. Phys. Chem. C, **118(27)**, 15068 - 15078 (2014)

V. Hrkac, E. Lage, G. Koeppel, et al., *Amorphous FeCoSiB for exchange bias coupled and decoupled magnetoelectric multilayer systems: real-structure and magnetic properties,* J. Appl. Phys., **116(13)**, 134302 (2014)

## Presentations

M. Winkler, J.D. König, A.L. Hansen, T. Dankwort, H. Böttner, K. Bartholomé, W. Bensch, L. Kienle, *Stability, structure and properties of $Sb_2Te_3$-$Bi_2Te_3$ intergrowths and superlattices,* CIMTEC 6th Forum on New Materials, Montecatini, Italy, 15.-20.06.2014

M. Winkler, J.D. König, H. Böttner, X. Liu, W. Bensch, T. Dankwort, U. Schürmann, L. Kienle, *Stability, structure and properties of $Sb_2Te_3$-$Bi_2Te_3$ intergrowths and superlattices,* 33rd International Conference on Thermoelectrics, Nashville, U.S.A., 06.-10.07.2014

D. Häussler, L. Houben, S. Essig, R. Dunin-Borkowski, F. Dimroth, W. Jäger, *Analyses of Interfaces in Wafer-Bonded GaInP-GaAs-Si Multiple Junction Solar Cells by Aberration-Corrected STEM and EELS,* M&M Microscopy and Microanalysis, Hartford, U.S.A., 04.-08.08.2014

D. Häussler, T. Dankwort, I. Barg, V. Duppel, M. Schlosser, A. Pfitzner, L. Kienle, *New approach to diffuse Scattering in Complex Chalcogenides,* M&M Microscopy and Microanalysis, Hartford, U.S.A., 04.-08.08.2014

M. Winkler, A.L. Hansen, T. Dankwort, J.D. König, H. Böttner, K. Bartholomé, W. Bensch, L. Kienle, *Stability, Structure and Properties $Sb_2Te_3$-$Bi_2Te_3$ Superlattices Grown by Molecular Beam Epitaxy and the Nanoalloying Method,* MRS fall meeting, Boston, U.S.A., 30.11.-05.12.2014

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# CMA Centre for Materialanalytics

Executive board: Prof. Dr. F. Faupel, Prof. Dr. H. Föll, Prof. Dr. B. Wagner, Prof. Dr. E. Quandt, Prof. Dr. J. McCord, Prof. Dr. R. Adelung, Prof. Dr. C. Selhuber-Unkel, Prof. Dr. L. Kienle.

Within the Institute for Materials Science the various groups and chairs possess advanced equipment for preparation and analysis, including electron microscopy and photoelectron spectroscopy among others, in the recently established Nanolab.

The main tasks of the CMA include, but are not restricted to:

- support of scientific cooperation, service and consulting for industry and research institutes,
- materials characterization, e.g. structure and properties of thin films, surface topography and spectroscopy, and materials testing, in particular testing of mechanical properties,
- allocation of modern equipment and scientific knowledge with respect to materials testing and analysis of modern materials for internal and external users,
- extension of the available experimental methods by resource sharing with other institutions within suitable cooperations,
- support of students (B.Sc., M.Sc. and Ph.D.) within their respective theses,
- support during study courses by various lectures and experimental courses in modern analytical methods, materials testing,and investigations with transmission electron microscopy,
- support of students during job-seeking through various contacts to (local) industry and research institutes.

## Personnel

Head of the group: Dr. Oliver Riemenschneider; Secretary: Maren Wallisch (75 percent)
Technical Staff: Dipl.-Ing. Kay Rath (85 percent)

Scientific Staff:

| | | |
|---|---|---|
| Dipl.-Min. Marlies Schwitzke | 01.01.-31.12.2014 | (50%) |

## Third-Party Funds

contract work, *maintenance and expansion of equipment,* 01.01.-31.12.2014 (9.343,09 EUR)

## Further Cooperation, Consulting, and Technology Transfer

The Centre cooperates with the following external organizations:

Cooperation with Industry:

1. Draeger Medical GmbH, Lübeck,
2. Sommerschmied GmbH, Neumünster,
3. Condias GmbH, Itzehoe,
4. Fa. Element22, Kiel,

5. ThyssenKrupp Marine Systems, Kiel,

6. Zahnarztpraxis Stange, Tornesch

7. M & M Fräsdienstleistungen GmbH, Kappeln

Industrial and Academic cooperation includes:

- inquiries and consulting regarding damage analysis, material selection and surface treatment,
- general consulting,
- single and serial analysis of damage analysis of material characteristics, of compounding techniques and material application,
- material analysis on the micro and macro scale.

# Deanship

## Results

The Dean's office is the administrative centre of the Faculty of Engineering and therefore responsible for managing the total budget including current costs, investments, and personnel costs. For the two institutes of the faculty that are located in Kiel-Gaarden, the Dean's office is also responsible for the computer operating services, the building services, and the mechanical workshop. The Dean's office is directed by Dr. Frank Paul the head of the administration of the faculty.

To fulfil all these tasks there are 18 persons in the Dean's office. Beginning in April 2014 the deanship was led by Prof. Dr.-Ing. Eckhard Quandt as successor to the former dean Prof. Dr. Wilhelm Hasselbring. The vice deans since July 2014 are Prof. Dr. Hermann Kohlstedt and Prof. Dr. Dirk Nowotka.

As new professors of the faculty, Prof. Dr. Ansgar Scherp who as been working at the *German National Library of Economics* since the beginning of 2014, Prof. Dr. Prof. Dr. Mikhail Zheludkevich and Prof. Dr. Regine Willumeit-Römer who have been doing their scientific work at the *Helmholtz-Zentrum Geesthacht* since April 2014 and September 2014 respectively, were welcomed into the faculty. Whereas three new professors began their work, two remarkable members of the faculty retired: Prof. Dr. Helmut Föll and Prof. Dr. Wolfgang Hackbusch. Prof. Hackbusch is the only laureate of the *Leibniz-Preis* of the faculty. Prof. Föll was the first dean of the faculty and was responsible for the successful start of the newly founded faculty. The university as well as the faculty paid tribute for his outstanding work by awarding him the ''Golden Badge of Honour'' of the Christian-Albrechts University Kiel.

Fig. 2: Prof. Dr. Helmut Föll was awarded by the *Golden Badge of Honour* in July 2014

Besides the impressive scientific work of the different groups that is reflected in this Almanac, the acquisition of a respectable amount of third party funding has to be mentioned. Two projects are worth mentioning: Prof. Kohlstedt as the main responsible person was successful in acquiring a *DFG-Forschergruppe* ''Memristive Bauelemente für neuronale Schaltungen'' and the collaboration of different professors of the faculty in ''PAK 902''. Third party funding has been for many years an essential part of the faculty's budget.

Besides the scientific work, the teaching and the recruitment of students is also extremely important for the faculty. Whereas the faculty was actually planned to teach about 1450 students, about 2300 students now are enrolled in the different study courses. As a visible example of the different projects to attract more female students, once again the nationwide Girls' Day was organized in April 2014 by Dr. Ina Pfannschmidt, the equal opportunities officer of the faculty. Different groups from our three institutes for Electrical Engineering and Information Technology, Material Science, and Computer

Science gave the girls some first impressions of the study programmes and work at the faculty. Nearly 100 girls from all parts of Schleswig-Holstein took the chance to visit the different projects.

Anyway, for astronomers 2014 was a notable year worldwide. For the first time in the history of space flight the European Space Agency (ESA) successfully landed instrumentation on the comet *67P/Churyumov-Gerasimenko*. The faculty of engineering was notably present in the media since the landing gear was made 14 years ago in the mechanical workshop of the faculty. Thus, a part which was made in Kiel was deposited on an extraterrestical body more than 500 million km away from the earth.

Finally, the skilful organization by the Dean's office, of the contest "Jugend forscht - Schüler experimentieren" in Schleswig-Holstein should be noted. After participating in the regional contest, in April 2014 about 60 young participants were guests of the Faculty of Engineering. In fields which are covered by these contests (e.g. biology, chemistry, computer science, engineering, geoscience, mathematics, and physics), many of the young people who have participated later begin and are successful in their university studies.

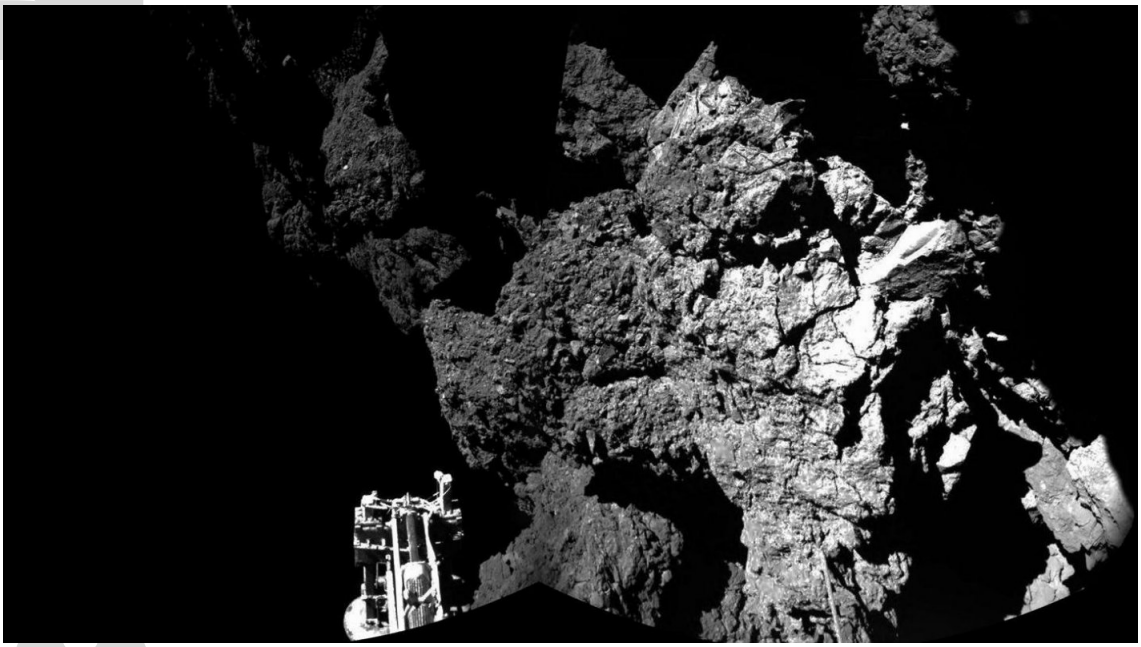

Fig. 1: The lander Philae on the surface of Comet 67P/Churyumov-Gerasimenko. One of its three feet which were made in our mechanical workshop can be seen in the foreground.

## Personnel

Head of the group: Dr. F. Paul (Managing Director);

Staff:

S. Anders 01.01.-31.12.2014
Head Adminstrator for Staff and Budget Department

U. Bruse 01.01.-31.12.2014
Division Manager of Building Services

M. Burmeister 01.01.-31.12.2014
Division Manager of the Mechanical Workshop

| | | |
|---|---|---|
| R. Doose<br>Caretaker | 01.01.-31.12.2014 | |
| M. Firnau<br>Division Manager of Computer Service Department | 01.01.-31.12.2014 | |
| M. Hacker<br>Secretary of Budget Department | 01.01.-31.12.2014 | |
| S. Keller<br>Apprentice | 01.01.-31.12.2014 | |
| M. Kulling<br>Employee of the Mechanical Workshop | 01.01.-31.12.2014 | |
| C. Martin<br>Administrator Deans Office | 01.01.-31.12.2014 | |
| S. Moeller<br>Secretary of Staff Department | 01.01.-31.12.2014 | |
| B. Neumann<br>Vice Devision Manager of the Mechanical Workshop | 01.01.-31.12.2014 | |
| C. Newe<br>Administrator Computer Service Department | 01.01.-31.12.2014 | |
| K. Prehn<br>Apprentice | 01.08.-31.12.2014 | |
| M. Quedens<br>Electrician | 01.01.-31.12.2014 | |
| A. Schaper<br>Apprentice | 01.08.-31.12.2014 | |
| T. Wengler<br>Aministrator Deans Office | 01.01.-31.12.2014 | (50%) |
| E. Wetendorf<br>Apprentice | 01.01.-31.12.2014 | |

## Further Activities and Events

The members of the Deans office are involved in different activities:

Frank Paul is a member of the JURY ''Lütt-Ing'' and is a representative for the companies which organize ''Jugend forscht'' in the ''Kuratorium'',

The ''Jahr der Technik'' organized by the VDI,

The faculty contributes to the ''Gaardener Kulturtage''; that organization is assisted in different manners, mainly advertising.

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# Service Centre

The Service Centre at the Faculty of Engineering was launched in Spring 2009. It is a joint corporation of the Institute of Electrical and Information Engineering and the Institute for Materials Science. The Service Centre is managed by assistants from the two institutes who are subordinated to the managing directors of the institutes. In addition, the examination offices of the two institutes, with three employees and a secretariat with two employees, belong to the Centre. The task of the Service Centre is to organize centrally (as far as it is possible) all issues related to studies, teaching and laboratory courses as well as examinations for the study programmes of both institutes.

The following tasks belong to the above-named fields:

Studies:

- accreditation and re-accreditation of study courses,
- design and development of study and examination regulations,
- capacity calculation,
- public relations, e.g. information days and hosted programmes at schools,
- advertisement for the different study courses,
- collecting and evaluating applications for the M.Sc. degree programmes of both institutes,
- mentoring and supervising students, not only in topics related to study courses but also for foreign students with respect to daily life in Germany.

Teaching and laboratory courses:

- coordination of schedules for all study courses of the two institutes,
- coordination of rooms for all lectures of the two institutes,
- coordination of UnivIS entries,
- organization and administration of the joint basic laboratory courses,
- holding lectures, exercises, lab courses, and tutorials (see below).

Lab support:

- centralized purchasing of gas.

Examination offices:

- administration of student matters,
- administration of examination matters,
- preparation of transcripts.

The Service Centre, together with the Centre of Material Analysis, is located in building G on the East Shore Campus of the Faculty of Engineering.

Fig. 1: Team Service Centre

## Results

## Personnel

Head of the group: Dr. Oliver Riemenschneider, Dr.-Ing. Kirstin Scholz; Secretary: Margit Marter (25 percent), Maren Wallisch (75 percent)
Technical Staff: Dipl.-Ing. (FH) Kay Rath (85 percent)

Staff:

| | | |
|---|---|---|
| Vera Nilsson<br>Examination Office | 01.01.-31.12.2014 | (50%) |
| Christiane Otte-Hüls<br>Examination Office | 01.01.-31.12.2014 | (50%) |
| Lars Struwe<br>Examination Office | 01.01.-31.12.2014 | |

Scientific Staff:

| | | |
|---|---|---|
| Dipl.-Min. Marlies Schwitzke | 01.01.-31.12.2014 | (50%) |

## Lectures, Seminars, and Laboratory Course Offers

*Winter 2013/2014*

Tutorial for Junior Students, 1 hrs Seminar/Week,
O. Riemenschneider

Tutorial for Senior Students, 1 hrs Seminar/Week,
O. Riemenschneider

Fig. 2: Sample Preparation

Basic Lab Course, 3 hrs Practical/Week,
O. Riemenschneider (+ E. Ossei-Wusu, E. Lage, S. Kaps, M. Schwitzke, A. Piorra)

Allgemeine Chemie I, Übungen, 1 hrs Exercise/Week,
O. Riemenschneider

Tutorial für Bachelorstudierende Junior, 1 hrs Seminar/Week,
O. Riemenschneider

Tutorial für Bachelorstudierende Senior, 1 hrs Seminar/Week,
O. Riemenschneider

Grundpraktikum für Ingenieure I, Montags-, Dienstags-, Mittwochskurs, 3 hrs Practical/Week,
K. Scholz (+ O. Riemenschneider, L. Wienbrandt)

Materialanalytik 2 Praktikum, 4 hrs Practical/Week,
O. Riemenschneider (+ M. Schwitzke)

Grundlagen der Elektrotechnik, 3 (+2) hrs Lecture (+ Exercises)/Week,
K. Scholz (+ D. Threm)

*Summer 2014*

Grundpraktikum für Ingenieure II, Montags-, Dienstags-, Mittwochskurs, 3 hrs Practical/Week,
O. Riemenschneider (+ L. Wienbrandt, K. Scholz)

Advanced Lab Course, 3 hrs Practical/Week,
O. Riemenschneider (+ Scientific Staff of the Inst. f. Materials Science)

Tutorial for Junior Students, 1 hrs Seminar/Week,
O. Riemenschneider

Tutorial for Senior Students, 1 hrs Seminar/Week,
O. Riemenschneider

Übungen Physikalische Chemie 1 für Materialwissenschaftler, 1 hrs Exercise/Week,
O. Riemenschneider

Tutorial für Bachelorstudierende Junior, 1 hrs Seminar/Week,
O. Riemenschneider

Tutorial für Bachelorstudierende Senior, 1 hrs Seminar/Week,
O. Riemenschneider

Übungen zur Chemie für Materialwissenschaftler, 1 hrs Exercise/Week,
O. Riemenschneider

*Winter 2014/2015*

Tutorial for Junior Students, 1 hrs Seminar/Week,
O. Riemenschneider

Tutorial for Senior Students, 1 hrs Seminar/Week,
O. Riemenschneider

Basic Lab Course, 3 hrs Practical/Week,
O. Riemenschneider (+ E. Ossei-Wusu, M. Schwitzke)

Allgemeine Chemie I, Übungen, 1 hrs Exercise/Week,
O. Riemenschneider

Tutorial für Bachelorstudierende Junior, 1 hrs Seminar/Week,
O. Riemenschneider

Tutorial für Bachelorstudierende Senior, 1 hrs Seminar/Week,
O. Riemenschneider

Grundpraktikum für Ingenieure I, Montags-, Dienstags-, Mittwochskurs, 3 hrs Practical/Week,
K. Scholz (+ O. Riemenschneider, L. Wienbrandt)

Materialanalytik 2 Praktikum, 4 hrs Practical/Week,
O. Riemenschneider (+ M. Schwitzke)

Grundlagen der Elektrotechnik, 3 hrs Lecture/Week,
K. Scholz

Tutorial für Bachelorstudierende Sophomore, 1 hrs Seminar/Week,
Oliver Riemenschneider

# Friends of the Faculty of Engineering

Friends of the Faculty of Engineering

**Executive Council:**

Dr. Philipp Murmann (President),

Dr. Jörn Biel (Vice-president),

Prof. Dr. Jeffrey McCord (beginning from 11.12.2013)(Vice-president),

Prof. Dr. Dr. Marcus Porembski (Treasurer),

Dr. Frank Paul (Secretary),

Prof. Dr.-Ing. Reinhard Knöchel (till 11.12.2013) Prof. Dr. Wilhelm Hasselbring (beginning from 11.12.2013) (Assessor)

Prof. Dr. Franz Faupel (till 11.12.2013), Prof. Dr. Christine Selhuber-Unkel (beginning from 11.12.2013) (Assessor),

Prof. Dr. Reinhard von Hanxleden (Assessor),

Herbert Jacobs (Assessor).

Auditors: Prof. Dr. Michael Hanus, Prof. Dr.-Ing. Gerhard Schmidt.

## Results

*''Zweck des Vereins ist die Förderung von Wissenschaft und Forschung, Studium und Lehre durch Unterstützung der Technischen Fakultät.*

*Der Verein pflegt die Beziehungen zwischen der Technischen Fakultät einerseits, der Wirtschaft und ihren Organisationen, den Studierenden, den Absolventen sowie ehemaligen Fakultätsangehörigen andererseits.*

*Er bietet dazu ein Forum für den Gedankenaustausch zwischen den Wissenschaftsdisziplinen Technik, Naturwissenschaft, Geistes-, Sozial- und Gesellschaftswissenschaften sowie der Fakultät und der Wirtschaft.*

*Mitglieder des Vereins sind Unternehmen, Institutionen und Personen, die die Technische Fakultät in ihren Zielen und ihrem Wirken unterstützen und begleiten.''*

*''The purpose of the Friends of the Faculty is the encouragement of science and research, study, and teaching, by supporting the Faculty of Engineering.*

*The Friends of the Faculty support the faculty with its finances and institutions on the one hand, and with the students, graduates, and alumni on the other.*

*The Friends of the Faculty present a forum for the exchange of ideas between the different disciplines of technology, science, philosophy, social science, and industry and commerce.*

*Members are companies, institutions, and persons who support and encourage the faculty with its aims and its tasks.''*

During 2013/14 the Friends of the Faculty were active concerning the basic ideas above. Many different projects were supported and prizes awarded for the best diploma, B.Sc., M.Sc., and Ph.D. theses. These prizes should help the young scientists to make successful careers within the economy as well as in the scientific community.

Further activities covered the financial support of a visit by young students to the ''Hanover fair'' (the most important industrial fair in Germany if not Europe), of organizing the ''Girls' day'', and many other activities of the faculty's students. Also events like the ''Sommerfest'' and the ''Winterfest'' were made possible by the help of the Friends of the Faculty.

A very important task was the financing of the important competition ''Jugend forscht - Schüler experimentieren''. Using good contacts to different companies, donations were collected to help the faculty organize this important contest of young scientists. The intention is to cover the costs of the contest for the following years and to get more talented young students for the engineering and computer science study courses. In the recent past many former participants finished their study courses at Kiel University successfully.

The current number of members leaves room to welcome new recruits. Although some have left the Friends of the Faculty the overall number of members could be increased slightly.

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