TECHNISCHE FAKULTÄT DER CHRISTIAN-ALBRECHTS-UNIVERSITÄT ZU KIEL

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Christian-Albrechts-Universität zu Kiel

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Table of contents

Foreword . . . 5

Computer Science

Institute of Computer Science . . . 7
Discrete Optimization . . . 11
Real Time Systems / Embedded Systems . . . 17
Business Information Technology . . . 25
Algorithmic Optimal Control - CO2 Uptake of the Ocean . . . 29
Communication Systems . . . 35
Multimedia Information Processing . . . 39
Programming Languages and Compiler Construction . . . 47
Computer-Aided Program Development . . . 53
Scientific Computing . . . 59
Software Engineering . . . 63
Technical Computer Science . . . 73
Information Systems Engineering . . . 77
Theoretical Computer Science . . . 89
Theory of Parallelism . . . 93

Electrical Engineering and Information Technology

Institute of Electrical and Information Engineering . . . 97
Automation and Control Engineering . . . 99
Digital Signal Processing and System Theory . . . 105
Technology of Silicon-Based Micro- and Nano-Systems . . . 111
Microwave Laboratory . . . 113
Integrated Systems and Photonics . . . 123
Information and Coding Theory . . . 131
Power Electronics and Electrical Drives . . . 139
Nanoelectronics . . . 151
Communications . . . 159
Circuit and System Theory . . . 167
Computational Electromagnetics . . . 169
Wireless Communications . . . 175

Materials Science

Institute for Materials Science . . . 179
General Materials Science . . . 181
Inorganic Functional Materials . . . 193
Biocompatible Nanomaterials . . . 203
Materials and Processes for Nanosystem Technologies . . . 207
Synthesis and Real Structures . . . 209

Materials Mechanics 221
Multicomponent Materials 223
Functional Nanomaterials 239
Microanalysis of Materials 249
Nanochemistry and Nanoengineering 261
Computational Mechanics 267
CMA Centre for Materialanalytics 269

Organization
Service Centre 273
Deanship 275
Friends of the Faculty of Engineering 277

Preface

Dear Reader,

2010 was a very special year because it was the 20th anniversary of the foundation of the Faculty of Engineering. On February 20th 1990, the federal state government of Schleswig-Holstein made the decision of its formation, but it took approximately another year, until the first three professors started teaching and research. Today the faculty has 28 regular positions for professors, financed by the University, and another 9 positions financed by third parties. After a certain stagnation in the number of enrolled students in Materials Research and Electrical and Information Engineering until the year 2000 (not in Computer Science), the number of first year students is ever increasing and has now reached approximately 600/year and a total number of about 1500 in all disciplines. Approximately half of them are studying Computer Science, 37% Electrical and Information Engineering and 13% Materials Research. The number of female students is around 20% on the average.

Research activities have also reached an impressive level during the last years, which is indicated by a granted third party funding of research projects of 13.1 million euro in 2010. Details of this research together with the work funded via the University budget can be found in this annual report. Among the many excellent projects, some special highlights should be mentioned: in a central position of the third party funded research is the Collaborative Research Centre SFB 855 on magneto-electric nanocomposites for medical applications, where research started in January 2010 and an amount of 11.5 million euros was granted by the German Research Foundation for the first 4 years. Initiated by Prof. Quandt from the Institute of Materials Science, the SFB 855 teamed up colleagues from materials science, electrical engineering, physics, and medicine. A major activity in Computer Science is the competence centre for software systems engineering (KoSSE), which is a collaborative activity with colleagues from the Computer Science Department of the University of Lübeck. The Project PITAS has the goal to develop a concept for a modular system that will give ships the capability to defend themselves against terrorist or pirate attacks and to verify the performance of the main components in a demonstration system. It is a collaboration with the Maritime Cluster North Germany, where from the Faculty of Engineering three groups of Electrical and Information Engineering as well as one of Computer Science are involved.

Due to the retirement of the first generation of professors and their replacement by young colleagues, the Faculty of Engineering is in an ongoing structural change, which is accompanied by increased focusing of science and research. The Faculty is already active in the clusters of excellence "Future Ocean" and "Inflammation at Interfaces". It is strongly involved and is the leading applicant for the new cluster "Materials for Life", where again Prof. Quandt has initiated and is coordinating the work. Meanwhile, as a great success, the first step in the application has been successfully mastered and the final application is under preparation.

Prof. Dr.-Ing. Reinhard Knöchel
Dean of the Faculty of Engineering

Institute of Computer Science

The Institute of Computer Science (*Institut für Informatik*) of the Christian-Albrechts-Universität zu Kiel, was founded in 1971, and is one of the oldest computer science departments in Germany. The research topics, which are described in detail in the subsequent pages, range from theoretical, practical, and technical computer science to applied computer science and applied mathematics.

Results

2009 concluded with the positive funding decision - totaling 2.7 million Euros - for the initial project proposals for the Competence Federation Software Systems Engineering (*Kompetenzverbund Software Systems Engineering*, **KoSSE**). This is an initiative of the departments of computer science in Kiel and Lübeck, jointly led by Prof. Wilhelm Hasselbring (Kiel) and Prof. Martin Leucker (Lübeck), which involves several groups at both universities as well as numerous industrial partners. In 2010, KoSSE and the initial projects have begun operation, including the presentation of KoSSE at the Software Engineering 2010 conference held in Paderborn in February, the KoSSE day for the general public in Kiel in June, and the KoSSE workshop for project participants in Lübeck in November. In 2010, KoSSE has been strengthened with further projects, including two (DynaMod and Xbase, totaling 1.36 million Euros) funded by the Federal Ministry of Education and Research (*Bundesministerium für Bildung und Forschung*, BMBF). The intensive know-how transfer and the vital role of the department for the regional industry is also reflected for example by the *Transferpreis*, awarded by the Innovation Foundation (*Innovationsstiftung*) Schleswig-Holstein, and the Idea Competition for Start-Ups (*Ideenwettbewerb Existenzgründungen*) of the Business Development and Technology Transfer Corporation of Schleswig-Holstein (*Wirtschaftsförderung und Technologietransfer in Schleswig-Holstein*, WTSH) to Prof. Reinhard Koch and his group.

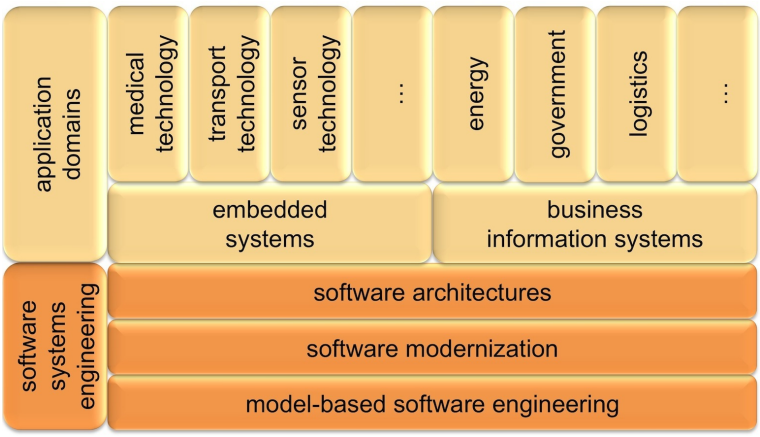

Fig. 1: The structure of the Competence Federation Software Systems Engineering (*Kompetenzverbund Software Systems Engineering*, KoSSE).

In addition to numerous funded projects of individual groups that are detailed in the subsequent sections, the CS department continues to be involved in a number of transversal projects embedded in the university as a whole. As one example, in the graduate school Human Development in Landscapes, Profs. Reinhard Koch and Bernhard Thalheim are involved in the area of algorithms for archaeology and data management, respectively. The CS department is also the initiator and a main contributor of the Computational Science Centre (**CSC**) of the CAU, founded in 2006 and funded by the *Innovationsfonds*. The CSC provides key technologies in numerical mathematics and computer science used for example in the research platform P1 „Numerical Simulation and Data Management" of Kiel's cluster of excellence „**The Future Ocean**" ; investigators involved in P1 include Profs. Steffen Börm, Wilhelm Hasselbring, Klaus Jansen, Reinhard

Koch, Norbert Luttenberger, Thomas Slawig, Anand Srivastav (Lead P1) and Bernhard Thalheim. A particularly positive development in the cluster is the interdisciplinary work between CS, mathematics and maritime sciences with the junior research group „algorithmic optimal control - oceanic CO2-uptake“ , headed since 2007 by **Prof. Thomas Slawig**, now recommended for tenure by the cluster, the university, and the faculty of engineering. The successful work in the CSC and the cluster of excellence is the basis for a new research thrust „Computational Science“ in the newly proposed cluster of excellence „Materials for Life (**M4L**)“ , in which Profs. Steffen Börm, Klaus Jansen, Reinhard Koch, Thomas Slawig and Anand Srivastav (lead) are involved.

In May 2010, we welcomed **Prof. Klaus Tochtermann**, who is now Professor for Computer Media in our department, in addition to his position as director of the German National Library of Economics/Leibniz Information Center for Economics (*Deutsche Zentralbibliothek für Wirtschaftswissenschaften*, ZBW). Prof. Tochtermann is not new to Kiel, as he commenced his studies in Kiel (1985 - 1991) before his career led him to University of Dortmund, Texas A&M University, and the Universities of Ulm and Graz. His research interests include Knowledge Management and Knowledge Transfer, Web 2.0, Semantic Technologies, and the Future Internet. For example, one of his projects - jointly performed with Prof. Hasselbring and Prof. Luttenberger - extends the data management activities in Kiel with a focus on economic research data.

Fig. 2: Prof. Manfred Schimmler, vice dean of the Faculty of Engineering, receives the certificate of accreditation for the Bachelor and Master degree programmes for business information systems engineering from Alexander Kohler, director of the Austrian Agency for Quality Assurance (AQA) [Photo credit: ef6e65 cf2199].

The activities of our department to attract students to computer science include the **Software Challenge**, led by Prof. Manfred Schimmler, where school pupils compete in a series of programming contests. This Challenge is so far restricted to Schleswig-Holstein; however, plans are under way - including committed funding from funding agencies as well as industry - to extend it to a national contest in 2012. In an effort to develop computer science skills among school children, the department also launched a project where art classes at schools all over Schleswig-Holstein are encouraged to use Scratch - „a programming language for everyone“ - for designing computer animations. When classes participate in this project, they are supported by staff from the department.

Perhaps also as a result of these activities, the number of new entrant students has considerably increased during the last years. Alongside increased enrolment, the department has extended its range of degree programmes. The latest addition, launched in the winter term 2010/11, is the degree programme leading to the **M.Sc. in business information systems engineering** (*Wirtschaftsinformatik*). Thus the department now offers bachelor and master programmes in computer science, business information systems engineering, and computer science and education.

A positive development is the steadily increasing proportion of female students. The attraction of women into computer science is the aim of several activities of the department, such as the one-week introductory programming courses dedicated to women (" Schnupperstudium"), or the Girls' Day where female students visit the department from many schools around Schleswig-Holstein.

The good relationship between students and faculty is certainly one of the strengths of the department. There is a substantial, continued effort to provide a high-quality education, reflected for example in the regular teaching report - the *Lehrbericht* - accessible to students and department members- that is jointly edited by lecturers and students. Conversely, the student representatives (*Fachschaft*) present annual „Best Prof Awards" , 2010 for the third time, that honour lecturers of the department.

Fig. 3: Dr. Barbara Langfeld, receiving her award certificate at the annual Best-Prof Award ceremony during the student-organized summer barbecue [Photo credit: *Fachschaften Informatik und Mathematik*].

On December 3rd our traditional computer science day (*Tag der Informatik*) took place, which is a joint event with the „Winterfest" of the Faculty of Engineering. This event, organized by the group of Prof. Norbert Luttenberger, is now an established annual gathering of colleagues, students, employees, alumni, company representatives and friends of our department. This is reflected by the high and still rising attendance - more than 250 participants now - as well as the continued support of our industrial supporters.

Discrete Optimization

Discrete or combinatorial optimization is a branch of mathematical optimization. It is concerned with solving discrete, finite optimization problems efficiently.

The methods and results of modern discrete optimization touch many different areas of mathematics and computer science, as for example combinatorics, graph theory, stochastics, or 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. Particular topics are: approximation algorithms, randomized and de-randomized algorithms, algorithms for multicast-networks, combinatorial and geometric discrepancy theory, combinatorial game theory and discrete geometry.

A major focus of the group is on interdisciplinary research projects within the clusters of excellence „The Future Ocean" and (upcoming) „Materials for Life" , and also on projects with industrial partners.

Results

The group is part of several highly competitive research clusters. Among them are the DFG priority program 1307 Algorithm Engineering, a joint project with the MINT GmbH, Kiel, funded by the technology transfer program HWT (Hochschule-Wirtschaft-Transfer), and the clusters of excellence mentioned above.

Personnel

Head of the group: Prof. Dr. A. Srivastav; Secretary: G. Thiel (50%)

Scientific Staff:

Dipl.-Math. M. El Ouali	01.01.-31.12.2010	(50%)	CAU / DFG
Matching in Hypergraphs			
Dr. M. Gnewuch	01.01.-31.12.2010		DFG
Hochdimensionale numerische Integration			
Dr. G. Jäger	01.01.-14.10.2010		DFG
Exzellenzcluster Future Ocean			
Dr. L. Kliemann	12.01.2010-31.12.2012		CAU
Algorithm Engineering, Game Theory			
Dr. B. Langfeld	01.01.-31.12.2010		CAU
Graph Theory and Discrete Tomography			
Dipl.-Math. V. Sauerland	01.01.-31.12.2010		CAU / HWT
Automatische Lehrgangsplanung (Kooperation mit der MINT GmbH, Kiel)			
G. Wittig-Srivastav	15.10.-31.12.2010		CAU
Projektkoordination			

Lectures, Seminars, and Laboratory Course Offers

Winter 2009/2010

Mathematik für Informatiker A - Grundlagen und Diskrete Strukturen, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
A. Srivastav

Kombinatorische Optimierung - Polynomialität und Optimalität, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
A. Srivastav (+ B. Langfeld)

Probabilistische Kombinatorik, 2 hrs Lecture/Week,
A. Srivastav (+ L. Kliemann)

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

Masterabschlussseminar, 2 hrs Seminar/Week,
A. Srivastav (+ B. Langfeld)

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

Summer 2010

Mathematik für Informatiker IV - Diskrete Strukturen und Wahrscheinlichkeitstheorie, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
A. Srivastav (+ L. Kliemann)

Graphentheorie, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
A. Srivastav (+ B. Langfeld)

Oberseminar Algorithmen, Kombinatorik und Komplexität, 2 hrs Seminar/Week,
A. Srivastav (+ K. Jansen)

Masterabschlussseminar, 2 hrs Seminar/Week,
A. Srivastav (+ B. Langfeld)

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

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

Winter 2010/2011

Kombinatorische Optimierung - Approximation und Randomisierung, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
A. Srivastav (+ B. Langfeld)

Monte-Carlo- und Quasi-Monte-Carlo-Methoden, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
M. Gnewuch

Parallele Algorithmen durch probabilistische Methoden, 2 (+ 2) hrs Lecture (+ Exercises)/Week,
A. Srivastav (+ L. Kliemann)

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

Masterabschlussseminar, 2 hrs Seminar/Week,
A. Srivastav (+ B. Langfeld)

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

Third-Party Funds

DFG SPP 1307, *Engineering randomisierter Algorithmen für Optimierungsprobleme in Hypergraphen,* 01.10.2007-31.12.2011 (134600 Euro)

DFG SPP 1307, *Engineering randomisierter Algorithmen für Optimierungsprobleme in Hypergraphen,* 01.10.2009-30.09.2011 (136000 Euro)

DFG, *Exzellenzcluster 'The Future Ocean' - Numerische Simulation,* 01.01.2009-30.09.2011 (47300 Euro)

DFG, *Hochdimensionale numerische Integration,* 01.04.2009-31.03.2011 (117000 Euro)

DFG, *Internationale Zusammenarbeit: Workshop Discrete Structures and Algorithms,* 01.06.2010-31.01.2011 (57040 Euro)

DFG, *Stipendium für M. Gnewuch als Research Fellow at the Department of Computer Science of Columbia University in the City of New York, USA.,* 01.09.2009-31.08.2010 (36000 Euro)

ISH, *Entwurf effizienter Algorithmen für die Lehrgangsplanung bei Fluggesellschaften,* 01.11.2009-28.02.2011 (71988 Euro)

Further Cooperation, Consulting, and Technology Transfer

Cooperation with:

G. Averkov, Universität Magdeburg. Project: Discrete Covariograms,

J. Dick, University of New South Wales, Sydney, Australia. Project: Fractional discrepancy and numerical integration,

B. Doerr, M. Wahlström, Max-Planck-Institut für Informatik, Saarbrücken. Project: Algorithms to construct small discrepancy samples,

S. Ghorpade, Department of Mathematics, Indian Institute of Technology, Bombay, India,

P. Gritzmann, Technische Universität München. Project: Discrete Tomography.,

R. Möhring, W. Höhn, Technische Universität Berlin. Project: Genetic Algorithms for Sequencing and Scheduling,

C. Patvardhan, Faculty of Engineering, Dayalbagh Educational Institute, Deemed University, Agra, India,

F.-A. Siebert, Universitätsklinikum Kiel. Project: Optimizing therapy planning in particle therapy,

H. Wozniakowski, Columbia University New York, USA, and Department of Applied Mathematics, University Warsaw, Poland. Project: Tractability of multivariate problems and high dimensional numerical integration.

Diploma, Bachelor and Master Theses

S. Preugschat, *δ-Überdeckungen und ihre Anwendungen in der Theorie der Gleichverteilung,* 20.12.2010

Publications

Published in 2010

M. Gnewuch, B. Doerr, M. Wahlström, *Algorithmic construction of low-discrepancy point sets via dependent randomized rounding,* Journal of Complexity, **26**, 490 - 507 (2010)

A. Heinle, A. Macke, A. Srivastav, *Automatic cloud classification of whole sky images,* Atmospheric Measurement Techniques, **3**, 269 - 299 (2010)

G. Jäger, *An Effective SAT Encoding for Magic Labeling,* U. Faigle, R. Schrader, D. Herrmann (EDS.), Proceedings of the 9th Cologne Twente Workshop on Graphs and Combinatorial Optimization (CTW 2010), 97 - 100 (2010)

G. Jäger, C. Ernst, C. Dong, D. Richter, P. Molitor, *Finding Good Tours for Huge Euclidean TSP Instances by Iterative Backbone Contraction*, B. Chen (Ed.), Proceedings of 6th International Computer on Algorithmic Aspects in Information and Management (AAIM), Lecture Notes in Computer Science, **6124**, 119 - 130 (2010)

G. Jäger, W. Zhang, *An Effective Algorithm for and Phase Transitions of the Directed Hamiltonian Cycle Problem.*, Journal of Artificial Intelligence Research, **39**, 663 - 687 (2010)

G. Jäger, W. Zhang, *A SAT based Effective Algorithm for the Directed Hamiltonian Cycle Problem*, F. Ablayev, E.W. Mayr (Eds) Proceedings of 5th International Computer Science Symposium in Russia (CSR 2010), Lecture Notes in Computer Science, **6072**, 216 - 227 (2010)

L. Kliemann, *Brief Announcement: The Price of Anarchy for Distributed Network Formation in an Adversary Model*, Proceedings of the 29th Annual ACM SIGACT-SIGOPS Symposium Principles of Distributed Computing, Zurich, 229 - 230 (2010)

L. Kliemann, *Networks and Distributed Operation: The Price of Anarchy in Non-Atomic Routing and Network Formation*, PhD Thesis, Christian-Albrechts-Universität zu Kiel, Document ID: d811d50d-931a-4413-bffe-1cd6a2e1d84c, (2010)

C. Patvardhan, J. Rückelt, V. Sauerland, T. Slawig, A. Srivastav, B. Ward, *Parameter Optimization and Uncertainty Analysis in a Model of Oceanic CO2-Uptake using a Hybrid Algorithm and Algorithmic Differentiation*, Nonlinear Analysis B Real World Applications (2010), **11**, 3993 - 4009 (2010)

Presentations

M. Gnewuch, *Infinite Dimensional Integration on Weighted Hilbert Spaces*, Seminar on Information-Based Complexity, Columbia University, New York, USA, 29.03.2010

M. Gnewuch, *Fractional Discrepancy*, 2nd Intern. Conference on Uniform Distribution Theory 2010 (UDT 2010), Strobl, Austria, 07.07.2010

M. Gnewuch, *Fractional Discrepancy*, 9th Intern. Conference on Monte Carlo and Quasi-Monte Carlo Methods in Scientific Computing (MCQMC 2010), Warsaw, Poland, 19.08.2010

M. Gnewuch, *Entropy, Randomization, Derandomization, and Discrepancy*, 9th Intern. Conference on Monte Carlo and Quasi-Monte Carlo Methods in Scientific Computing (MCQMC 2010), Warsaw, Poland, 20.08.2010

M. Gnewuch, *Weighted Geometric Discrepancies and Numerical Integration on Reproducing Kernel Hilbert Spaces*, Oberseminar, Arbeitsgruppe Computational Stochastics, Techn. Universität Kaiserslautern, Kaiserslautern, 11.10.2010

M. Gnewuch, *Relation between Geometric Discrepancy and Numerical Discrepancy in the Weighted and Unweighted L_2-Setting*, Kolloquium, Institut für Finanzmathematik, Johannes Kepler Universität Linz, Linz, Austria, 07.12.2010

G. Jäger, *Introduction to the Hamiltonian Circuit Problem and the Traveling Salesman Problem*, Summer School Operational Research with Logistic Applications, University of Nizhny Novgorod, Nizhny Novgorod, Russia, 06.05.2010

G. Jäger, *An Effective SAT Encoding for Magic Labeling*, 9th Cologne-Twente Workshop on Graphs and Combinatorial Optimization (CTW 2010), Köln, 25.05.2010

G. Jäger, *A SAT Based Effective Algorithm for the Directed Hamiltonian Cycle Problem*, 5th International Computer Science Symposium (CSR 2010), Kazan, Russia, 18.06.2010

L. Kliemann, *Streaming Algorithms for Bipartite Graph Matching*, Bi-National DFG Workshop and Round-Table on Discrete Structures and Algorithms, Bonn, 02.06.2010

L. Kliemann, *Streaming Algorithms for Bipartite Graph Matching*, 60. Theorietag der Fachgruppe Algorithmen und Komplexität, Kiel, 15.06.2010

L. Kliemann, *Hypergraph b-Matching and Experimental Studies of Streaming Algorithms for Graph Matching*, DFG SPP 1307 Annual Meeting, Halle, 17.06.2010

L. Kliemann, *Brief Announcement: The Price of Anarchy for Distributed Network Formation in an Adversary Model*, 29th

Annual ACM SIGACT-SIGOPS Symposium Principles of Distributed Computing (PODC 2010), Zurich, Switzerland, 27.06.2010

L. Kliemann, *Optimization in Large Graphs,* DFG SPP 1307 Workshop on Optimization, Köln, 03.12.2010

B. Langfeld, *A note on computing a dither array,* Jahrestagung der DMV 2010, München, 09.03.2010

B. Langfeld, *A note on computing a dither array,* Oberseminar, Institut für Mathematische Optimierung, Universität Magdeburg, Magdeburg, 16.03.2010

B. Langfeld, *Fixing Numbers of Matrices and Polytopes,* DFG German-Indian Workshop/Round-table on Discrete Structures and Algorithms, Bonn, 03.06.2010

B. Langfeld, *Fixing Numbers of Matrices and Polytopes,* 60th Workshop on Algorithms and Complexity, Institut für Informatik, Universität Kiel, Kiel, 15.06.2010

B. Langfeld, *Three Remarks on Uniqueness Issues in Discrete Tomography,* Oberseminar, Institut für Mathematische Optimierung, Universität Magdeburg, Magdeburg, 20.07.2010

A. Srivastav, *Algorithm Engineering for Matching-Problems,* Workshop, Agra, Indien, 13.03.2010

A. Srivastav, *Algorithms and Complexity of Hypergraph Matching,* DFG Indo-German Workshop on Discrete Structures and Algorithms, Bonn, 04.06.2010

A. Srivastav, *Streaming Algorithms,* Workshop on Algorithm Engineering, Shanghai, China, 29.08.2010

Further Activities and Events

M. Gnewuch: Research Fellow at the Department of Computer Science of Columbia University in the City of New York, USA, 01.09.2009-31.08.2010.

M. Gnewuch: Organization of the special session „Discrepancy Estimates" at the 9th International Conference on Monte Carlo and Quasi-Monte Carlo Methods in Scientific Computing (MCQMC 2010), Warsaw (Poland). Organized with Dr. J. Dick.

M. Gnewuch: Invited plenary talk „Entropy, Randomization, Derandomization, and Discrepancy" at the 9th International Conference on Monte Carlo and Quasi-Monte Carlo Methods in Scientific Computing (MCQMC 2010), Warsaw (Poland).

B. Langfeld: Organization of the Minisymposium „Anwendungen der diskreten Optimierung" , DMV-Jahrestagung 2010, with Dr. M. Ritter (TU München), March 2010.

B. Langfeld: Best-Prof-Award 2010 (2. Platz) der Fachschaften Mathematik und Informatik der Universität Kiel in der Kategorie Informatik, Juni 2010.

A. Srivastav: Organization of DFG Indo-German Workshop on „Discrete Structures and Algorithms" , Bonn, 01.06.2010-05.06.2010.

A. Srivastav: Member of Program Committee of Workshop on Algorithms and Computation (WALCOM 2010), Bangladesh.

Real Time Systems / Embedded Systems

The research interest of the RTSYS group is the systematic design and analysis of „computers, which are not perceived as such“ , which is 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, fly-by-wire aircraft. Such systems not only have to provide the correct outputs to the environment, they also have to provide these in time. In other words, these are *real-time systems.* Of particular interest for us are the *reactive systems*, which continuously react 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:

- The model-based design of complex reactive systems,
- Reactive processors, and
- Deterministic concurrency and synchronous languages.

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The activities on the **model-based design of complex reactive systems** concentrate on the *modelling pragmatics*, that is, the practical aspects of creating, maintaining and visualizing graphical system models. 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. Novel developments in 2010 include capabilities for the automatic layout of UML class diagrams, and a new graph editor with a graph analysis framework for assistance of algorithm engineering. KIELER's layout capabilities have also been added to UC Berkeley's Ptolemy system. KIELER is also an integral part of the MENGES project, which aims to develop a model-driven software toolchain for a new type of electronic railway control centre. The project started in January 2010 and will last to December 2012. MENGES is funded by the ZPW (*Zukunftsprogramm Wirtschaft*), a program to support research and development in Schleswig-Holstein. Project partners are Funkwerk Information Technologies GmbH, Kiel, b+m Informatik AG, Melsdorf and the groups for Software Engineering (Prof. Hasselbring) and for Real-Time and Embedded Systems of Christian Albrechts University Kiel. MENGES is one of the initial projects associated with the Competence Federation Software Systems Engineering (*Kompetenzverbund Software Systems Engineering*, KoSSE).

Reactive Processors aim to implement reactive behaviour with deterministic behaviour and minimal resource usage. The Kiel Esterel Processor (KEP) is a reactive processor that supports concurrency through multithreading and offers highly predictable timing at minimal power consumption. In 2010, developments focused on compilation for the Kiel Lustre Processor, a reactive processor for the synchronous data-flow language Lustre.

The major result in the area **deterministic concurrency and synchronous languages** is the development of *Synchronous C (SC)* and *Synchronous Java (SJ)*, which are light-weight mechanisms to embed deterministic concurrency in C and Java. SC and SJ are inspired by the reactive processing paradigm, but are implemented as macros/classes expressed in standard C/Java, available as open-source code. In 2010, the main developments were a first working prototype for SJ, and an improved, more structured syntax for SC (developed in cooperation with UC Berkeley).

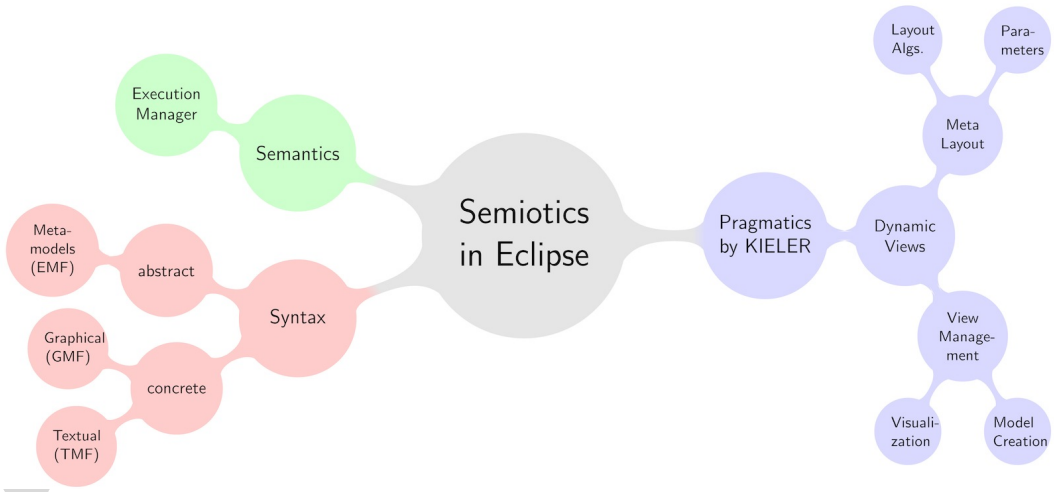

Fig. 1: A mind map illustrating how the KIELER modelling environment is positioned in the Eclipse context [from Fuhrmann/v. Hanxleden, MoDELS'10]. KIELER focuses on pragmatics, which together with syntax and semantics constitutes the field of semiotics.

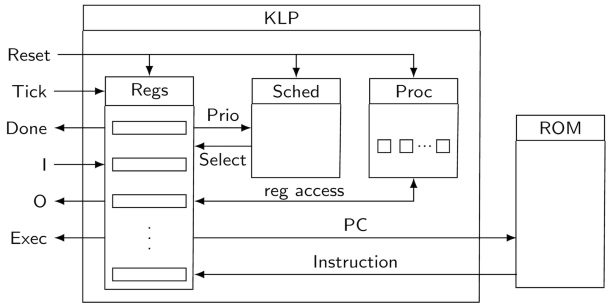

Fig. 2: Architectural overview of the Kiel Lustre Processor [from Traulsen/v. Hanxleden, SAC'10]. A priority-based scheduler interacts with a set of processors, to exploit maximal parallelism while still respecting data dependencies.

Personnel

Head of the group: Prof. Dr. Reinhard von Hanxleden; Secretary: Sandra Lersmacher (50%), Gesa Walsdorf (Elternzeit) (50%)
Technical Staff: Tim Grebien (50%)

Scientific Staff:

Dipl.-Inf. Hauke Fuhrmann	01.01.-30.09.2010	Landesmittel
Dipl.-Inf. Hauke Fuhrmann MENGES	01.10.-31.12.2010	Drittmittel
Dipl.-Inf. Christian Motika MENGES	01.01.-31.03.2010	Drittmittel
Dipl.-Inf. Christian Motika	01.04.-31.12.2010	Landesmittel
Dipl.-Inf. Jens Schönborn	01.-31.12.2010	Landesmittel
Dipl.-Inf. Miro Spönemann	01.01.-31.12.2010	Landesmittel

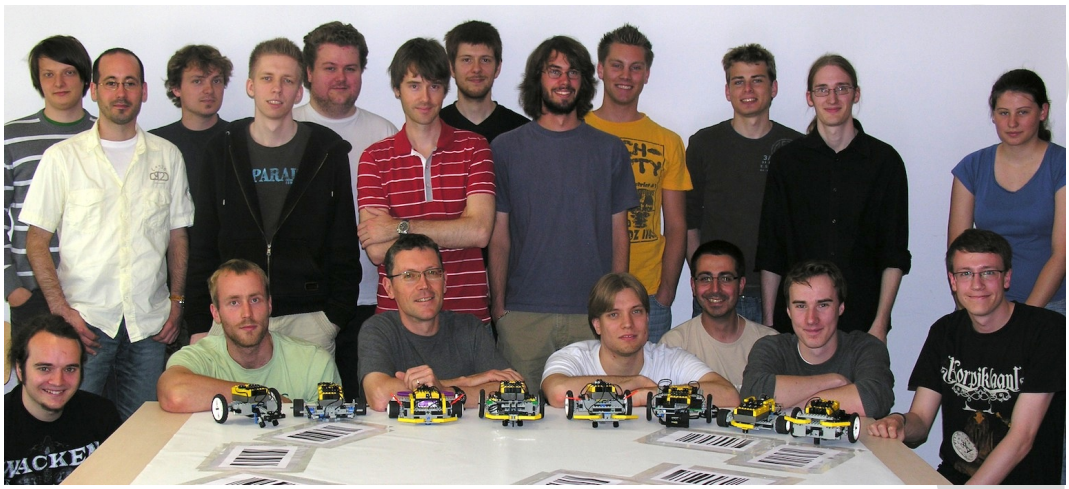

Fig. 3: Final Mindstorms Contest, in the class *Design of Embedded Real-Time Systems* held in the summer semester 2010 (07.07).

Dipl.-Inf. Claus Traulsen	01.01.-31.03.2010	Landesmittel

Lectures, Seminars, and Laboratory Course Offers

Winter 2009/2010

MS1102: - Synchrone Sprachen, 4 hrs Vorlesung/Week,
Reinhard von Hanxleden

Übung zu: Synchrone Sprachen, 2 hrs Übung/Week,
Reinhard von Hanxleden (+ Claus Traulsen)

A5.3.3: Fortgeschrittenenpraktikum - Echtzeitsysteme/Eingebettete Systeme (Modellierung in Eclipse), 4 hrs Exercise/Week,
Reinhard von Hanxleden (+ Miro Spönemann, Hauke Fuhrmann)

MSS1101: Seminar - Echtzeitsysteme/Eingebettete Systeme (Modellierung und Ausführung Nebenläufiger Systeme), 2 hrs Seminar/Week,
Reinhard von Hanxleden (+ Miro Spönemann, Hauke Fuhrmann)

Oberseminar, 2 hrs Seminar/Week,
Reinhard von Hanxleden

Summer 2010

Inf-OAR: Organisation und Architektur von Rechnern, 3 hrs Vorlesung/Week,
Reinhard von Hanxleden (+ Hauke Fuhrmann)

Übung zu: Organisation und Architektur von Rechnern, 2 hrs Übung/Week,
Hauke Fuhrmann (+ Miro Spönemann)

WI20: Entwurf eingebetteter Echtzeitsysteme, 4 hrs Vorlesung/Week,
Reinhard von Hanxleden

Übung zu: Entwurf eingebetteter Echtzeitsysteme, 2 hrs Übung/Week,
Christian Motika

Fortgeschrittenenpraktikum - Echtzeitsysteme/Eingebettete Systeme (Layout-Algorithmen), 4 hrs Praktikum/Week,
Reinhard von Hanxleden (+ Hauke Fuhrmann, Miro Spönemann)

MSP1101: Masterprojekt - Echtzeitsysteme/Eingebettete Systeme (Layout-Algorithmen), 4 hrs Masterprojekt/Week,
Reinhard von Hanxleden (+ Miro Spönemann, Hauke Fuhrmann)

WI24: Wahlpflichtmodul Informatik - Modellbasierter Entwurf (Layout-Algorithmen), 2 hrs Seminar/Week,
Reinhard von Hanxleden (+ Miro Spönemann, Hauke Fuhrmann)

MSS1101: Seminar - Echtzeitsysteme/Eingebettete Systeme (Synchrone Sprachen), 2 hrs Seminar/Week,
Reinhard von Hanxleden (+ Christian Motika)

Oberseminar, 2 hrs Seminar/Week,
Reinhard von Hanxleden

Winter 2010/2011

Inf-BS: Betriebssysteme, 3 hrs Vorlesung/Week,
Reinhard von Hanxleden

Übung zu: Betriebssysteme, 2 hrs Übung/Week,
Reinhard von Hanxleden (+ Hagen Peters, Christian Motika)

MS1101: Modellierung nebenläufiger Systeme, 4 hrs Vorlesung/Week,
Reinhard von Hanxleden (+ Rudolf Berghammer)

Übung zu: Modellierung nebenläufiger Systeme, 2 hrs Übung/Week,
Reinhard von Hanxleden (+ Miro Spönemann)

MSP1101: Masterprojekt - Echtzeitsysteme/Eingebettete Systeme, 4 hrs Übung/Week,
Reinhard von Hanxleden (+ Miro Spönemann, Christian Motika)

MSS1101: Seminar - Echtzeitsysteme/Eingebettete Systeme, 2 hrs Seminar/Week,
Reinhard von Hanxleden (+ Christian Motika)

Oberseminar - Echtzeitsysteme und Eingebettete Systeme, 2 hrs Seminar/Week,
Reinhard von Hanxleden

Third-Party Funds

Zukunftsprogramm Wirtschaft (ZPW), *Modellbasierte Entwurfsmethoden für eine neue Generation elektronischer Stellwerke (MENGES)*, 01.08.2009-31.07.2012 (217.560 EUR)

DAAD Programm des Projektbezogenen Personenaustauschs (PPP) USA, *Model Engineering und Predictable Processing*, 01.01.2010-31.12.2011 (15.318 EUR)

Further Cooperation, Consulting, and Technology Transfer

Cooperation with Edward A. Lee, University of California, Berkeley, on the automatic layout of Ptolemy II diagrams and simulation of SyncCharts (funded by DAAD PPP).

Cooperation with the Software Engineering group (Prof. Hasselbring), b+m Informatik AG and Funkwerk Information Technologies GmbH on the model-based design of railway signalling applications (project MENGES).

Cooperation with ETAS/Bosch, on visual model exploration. Advisorship (R. v. Hanxleden) of a doctoral researcher (Matthias Schmeling, graduate of the CAU) at ETAS.

Cooperation with Michael Mendler, Bamberg University, on worst case reaction time analysis.

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

Cooperation with Partha Roop and Sidharta Andalam, University of Auckland, New Zealand, on reactive processors and timing analysis.

Cooperation with CEA List (Saclay, Paris), on pragmatics of UML2 modelling.

Cooperation with the Daimler Center for Automotive IT Innovations (Berlin), on the automatic layout of Simulink diagrams.

Diploma, Bachelor and Master Theses

Sören Hansen, *(Bachelor Thesis) Configurations and Automated Execution in the KIELER Execution Manager*, 24.03.2010
Michael Matzen, *(Diploma Thesis) A Generic Framework for Structure-Based Editing of Graphical Models in Eclipse*, 26.03.2010
Adriana Lukaschewitz, *(Bachelor Thesis) Transformation von Esterel nach SyncCharts in KIELER*, 30.03.2010
Matthias Schmeling, *(Diploma Thesis) A Graphical Editor for IEC 61499 Function Blocks*, 17.04.2010
Torsten Amende, *(Diploma Thesis) Synthese von SC-Code aus SyncCharts*, 22.05.2010
Joachim Bleidiessel, *(Diploma Thesis) A Domain Specific Language for Railway Control*, 20.09.2010
Ole Claußen, *(Bachelor Thesis) Implementing an Algorithm for Orthogonal Graph Layout*, 29.09.2010
Philipp Döhring, *(Bachelor Thesis) Algorithmen zur Layerzuweisung*, 29.09.2010
Christian Kutschmar, *(Bachelor Thesis) Planarisierung von Hypergraphen*, 29.09.2010
John Carstens, *(Bachelor Thesis) Datenvisualisierung in grafischen Modellen*, 30.09.2010
Mirko Heinold, *(Bachelor Thesis) Synchronous Java*, 30.09.2010
Paul Klose, *(Bachelor Thesis) Beispiel Management in KIELER*, 30.09.2010
Martin Rieß, *(Bachelor Thesis) A Graph Editor for Algorithm Engineering*, 30.09.2010
Niclas Köser, *(Diploma Thesis) SyncCharts in C auf Multicore*, 20.10.2010

Dissertations / Postdoctoral Lecture Qualifications

Claus Traulsen, *Reactive Processing for Synchronous Languages and its Worst Case Reaction Time Analysis*, 26.02.2010

Publications

Published in 2010

H. Fuhrmann, M. Spönemann, M. Matzen, R. von Hanxleden, *Automatic Layout and Structure-Based Editing of UML Diagrams*, Proceedings of the 1st Workshop on Model Based Engineering for Embedded Systems Design, (2010)

C. Traulsen, R. von Hanxleden, *Reactive Parallel Processing for Synchronous Dataflow*, Proceedings of the 25th Symposium On Applied Computing (SAC'10), Special Track Embedded Systems: Applications, Solutions, and Techniques. Sierre, Switzerland, (2010)

C. Traulsen, T. Amende, R. von Hanxleden, *Compiling SyncCharts to Synchronous C*, Technical Report 1006, Christian-Albrechts-Universität zu Kiel, Department of Computer Science, Kiel, Germany, (2010)

C. Motika, H. Fuhrmann, R. von Hanxleden, *Semantics and Execution of Domain Specific Models*, 2nd Workshop Methodische Entwicklung von Modellierungswerkzeugen (MEMWe 2010) at conference INFORMATIK 2010, GI-Edition - Lecture Notes in Informatics (LNI), Bonner Köllen Verlag. Leipzig, Germany, (2010)

M. Spönemann, H. Fuhrmann, R. von Hanxleden, P. Mutzel, *Port Constraints in Hierarchical Layout of Data Flow Diagrams*, Proceedings of the 17th International Symposium on Graph Drawing (GD'09), volume 5849 of LNCS, Springer, 135 - 146 (2010)

X. Li, R. von Hanxleden, *Multi-Threaded Reactive Programming - The Kiel Esterel Processor*, IEEE Transactions on

Computers, preprint, (2010)
H. Fuhrmann, R. von Hanxleden, *Taming Graphical Modeling,* Proceedings of the ACM/IEEE 13th International Conference on Model Driven Engineering Languages and Systems (MoDELS'10), LNCS, Oslo, Norway, Springer, (2010)
H. Fuhrmann, R. von Hanxleden, *Taming Graphical Modeling,* Technical Report 1003, Christian-Albrechts-Universität zu Kiel, Department of Computer Science, (2010)
H. Fuhrmann, R. von Hanxleden, *On the Pragmatics of Model-Based Design,* Foundations of Computer Software. Future Trends and Techniques for Development - 15th Monterey Workshop 2008, Budapest, Hungary, September 24-26, 2008, Revised Selected Papers, volume 6028 of LNCS, (2010)
M. Chimani, C. Gutwenger, P. Mutzel, M. Spönemann, H. Wong, *Crossing Minimization and Layouts of Directed Hypergraphs with Port Constraints,* Proceedings of the 18th International Symposium on Graph Drawing (GD'10), LNCS, Springer, (2010)

Presentations

C. Motika, *KlePto - KIELER Leveraging Ptolemy Semantics - Executing SyncCharts with Ptolemy,* Presentation at the Ptolemy group, Department of Electrical Engineering and Computer Sciences, University of California at Berkeley, Berkeley, USA, 09.03.2010
H. Fuhrmann, M. Spönemann, M. Matzen, R. von Hanxleden, *Automatic Layout and Structure-Based Editing of UML Diagrams,* Proceedings of the 1st Workshop on Model Based Engineering for Embedded Systems Design (M-BED 2010), Dresden, Dresden, Germany, 12.03.2010
H. Fuhrmann, C. Motika, *Metamodeling, Transformation and Code Generation in Eclipse,* Presentation and interactive demo at the Ptolemy group, Department of Electrical Engineering and Computer Sciences, University of California at Berkeley, Berkeley, USA, 16.03.2010
C. Traulsen, R. von Hanxleden, *Reactive Parallel Processing for Synchronous Dataflow,* Proceedings of the 25th Symposium On Applied Computing (SAC'10), Special Track Embedded Systems: Applications, Solutions, and Techniques, Sierre, Switzerland, 22.-26.03.2010
R. von Hanxleden, *Modellieren statt Malen - Ein pragmatischer Ansatz,* Computer Science and Transport Symposium Kiel, Kiel, Germany, 05.05.2010
J. Bleidiessel, *On the Pragmatics of Model-Based Design– The KIELER Approach,* Invited presentation at the Irkutsk State University, Irkutsk, Russia, 26.05.2010
M. Spönemann, *Pragmatik modellgetriebener Systementwicklung,* Modellierung@CAU, Kiel, Germany, 20.07.2010
R. von Hanxleden, *Lightweight and Deterministic Concurrency and Preemption in C and Java,* Robotics and Embedded Systems Seminar, UC Berkeley, Berkeley, USA, 15.09.2010
C. Motika, *Simulating SyncCharts and Actor-Oriented Modeling in KIELER,* Presentation and interactive demo at the Ptolemy group, Department of Electrical Engineering and Computer Sciences, University of California at Berkeley, Berkeley, USA, 21.09.2010
C. Motika, H. Fuhrmann, R. von Hanxleden, *Semantics and Execution of Domain Specific Models,* 2nd Workshop Methodische Entwicklung von Modellierungswerkzeugen (MEMWe 2010) at conference INFORMATIK 2010, GI-Edition - Lecture Notes in Informatics (LNI), Bonner Köllen Verlag, Leipzig, Germany, 29.09.2010
H. Fuhrmann, R. von Hanxleden, *Taming Graphical Modeling,* Proceedings of the ACM/IEEE 13th International Conference on Model Driven Engineering Languages and Systems (MoDELS'10), LNCS, Oslo, Norway, Springer, Oslo, Norway, 03.-08.10.2010
C. Schneider, G. Hoops, W. Goerigk, *Integration von textueller und grafischer Modellierung - Pragmatik in MENGES,* KoSSE-Workshop, Lübeck, Germany, 10.11.2010
R. von Hanxleden, H. Fuhrmann, *Taming Graphical Modeling,* Presentation at the 17th International Open Workshop on Synchronous Programming (SYNCHRON'10), Frejus, France, 29.11.-03.12.2010
C. Motika, *Executing SyncCharts with Ptolemy,* 17th International Open Workshop on Synchronous Programming

(SYNCHRON'10), Frejus, France, 29.11.-03.12.2010

Further Activities and Events

H. Fuhrmann, C. Motika, C. Schneider, M. Spönemann:

reviewer for the *International Conference on Embedded Software* (EMSOFT).

R. von Hanxleden:

member of the *ArtistDesign European Network of Excellence on Embedded System Design*. Program Committee member for the *International Conference on Embedded Software* (EMSOFT) and for the workshop *Methodische Entwicklung von Modellierungswerkzeugen*. Reviewer for the *ACM Transactions on Embedded Computing Systems*, the *Design Automation for Embedded Systems Journal*, and the *European Symposium on Programming* (ESOP).

C. Motika, C. Schneider:

demonstration of the model-railway, Girls'Day 2010 (22.04.) and the Schnupperstudium (20.10.)

J. Schönborn, M. Spönemann: reviewer for the ACM SIGPLAN/SIGBED Conference on Languages, Compilers and Tools for Embedded Systems (LCTES).

C. Traulsen:

reviewer for the *Design Automation for Embedded Systems Journal* and for the *Microprocessors and Microsystems Journal*
.

Atin Ruia (Jadavpur University, India):

DAAD-WISE scholarship, for summer internship at the RTSYS group 01.06. - 31.07.

Business Information Technology

A main focus of the working group is the support of systems integration by improved generation and validation concepts. Integration is a major problem in business information systems. Almost all of these commercial systems are composites, for example an ERP system is connected to an e-commerce system in order to realize a web shop.

Besides the research activities the working group provides courses for the various computer science courses (bachelor, master and diploma). Moreover, the implementation of the new bachelor course in business information systems is the main focus of the working group.

Results

Innovative concepts for system generation support flexible generation. This facilitates an increased degree of re-use. For instance this new concept may be applied in systems integration and the realization of systems communication.

Standard models (business processes) have been enhanced in order to improve the checkability of these models. The new model languages may be used to express both the model to be validated as well as the specification of the basis of the validation.

Personnel

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

Scientific Staff:

Dipl.-Wirt.-Inf. Harm Brandt User Driven Innovation	01.01.-31.12.2010	(50%)
Dipl.-Wirt.-Inf. Sven Feja	01.01.-31.12.2010	
Dipl.Inf. Aneta Lotycz	15.11.-31.12.2010	(50%)
MBA Andreas Rusnjak	01.01.-31.12.2010	
Dipl.-Ing. Sören Witt	01.01.-31.12.2010	

Lectures, Seminars, and Laboratory Course Offers

Winter 2009/2010

WInf-WInf1:-Grundlagen Wirtschaftsinformatik I, 2 (+ 2) hrs Lecture (+ Exercises)/Week,
Andreas Speck (+ Sven Feja, Andreas Rusnjak)

MS0703:-Qualitätssicherungsmanagement, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
Andreas Speck (+ Sven Feja)

S5.1:-Seminar - Architekturen betrieblicher Systeme, 2 hrs Seminar/Week,
Andreas Speck

WBA5.1:- Projektvorbereitung - Modellierung und Entwicklung, 3 (+ 3) hrs Lecture (+ Exercises)/Week,
Andreas Speck (+ Sven Feja, Andreas Rusnjak)

WWIa:-Bertriebliche Standardsoftware, 4 (+ 3) hrs Lecture (+ Exercises)/Week,
Andreas Speck (+ Andreas Rusnjak)

Summer 2010

WG2.2:-Grundlagen Wirtschaftsinformatik II, 3 (+ 1) hrs Lecture (+ Exercises)/Week,
Andreas Speck (+ Sven Feja)

WA4.3:-Proseminar/ Projekt, 3 hrs Seminar/Week,
Andreas Speck

eCommerce Systeme, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
Andreas Speck (+ Sven Feja)

Marktorientierte und betriebliche Anwendungssysteme, 2 hrs Lecture/Week,
Andreas Speck (+ Sven Feja, Andreas Rusnjak)

Winter 2010/2011

WInf-WInf1:-Grundlagen Wirtschaftsinformatik I, 2 (+ 2) hrs Lecture (+ Exercises)/Week,
Andreas Speck (+ Sven Feja, Andreas Rusnjak)

MS0703:-Qualitätssicherungsmanagement, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
Andreas Speck (+ Sven Feja)

S5.1:-Seminar - Architekturen betrieblicher Systeme, 2 hrs Seminar/Week,
Andreas Speck

WBA5.1:- Projektvorbereitung - Modellierung und Entwicklung, 3 (+ 3) hrs Lecture (+ Exercises)/Week,
Andreas Speck (+ Sven Feja, Andreas Rusnjak)

WWIa:-Bertriebliche Standardsoftware, 4 (+ 3) hrs Lecture (+ Exercises)/Week,
Andreas Speck (+ Andreas Rusnjak)

Diploma, Bachelor and Master Theses

Aristide Tchuadjeu, *Strategien zur Erhaltung manueller Modikationenan generierten Zwischenmodellen im EMF,* 28.02.2010

Peter Michelis, *Einsatz digitaler Medien in öffentlichen Schulen,* 27.04.2010

Björn Bornemann, *Mobile Payment,* 27.04.2010

Robin Richter, *Web Service Security Modellierung auf Basis der EPK zur automatischen Erzeugung von Web Service Security Policies,* 01.09.2010

Michael Jöhnke, *Vergleich bestehender Business Modeling Ansätze aus der Perspektive eines eBusiness- Startups,* 27.09.2010

Timur Ercan, *Ziel- und Intentionsorientierte Modellierung von Geschäftsmodellenzur Identifikation von kritischen Erfolgsfaktoren auf Basis des i*Framework,* 30.09.2010

Dissertations / Postdoctoral Lecture Qualifications

Daniel Fötsch, *Adaptive anwendungsspezifische Verarbeitung von XML-Dokumenten,* 15.01.2010

Publications

Published in 2010

A. Speck, E. Pulvermüller, S. Feja, *Developer-friendly verification of process-based systems,* Knowledge Based Systems, **23**, 667 - 676 (2010)

A. Speck, S. Feja, S. Witt, M. Schulz, *Checkable Graphical Business Process Representation*, Advances in Databases and Information Systems - 14th East European Conference (ADBIS 2010), 176 - 189 (2010)

A. Speck, E. Pulvermüller, S. Feja, S. Witt, *ROCESS MODEL VALIDATION - Transforming Process Models to Extended Checking Models*, 5th International Conference on Evaluation of Novel Approaches to Software Engineering (ENASE 2010), 214 - 220 (2010)

A. Rusnjak, *Integration von kritischen Erfolgsfaktoren in das*, 13. GI Tagung, (2010)

A. Speck, A. Rusnjak, M. El Kharbili, H. Hristov, *Managing the Dynamics of e/mCommerce with a Hierarchical Overlapping Business-Value-Framework*, The 6th International Symposium on Web and Mobile Information Services (WAMIS 2010), 461 - 466 (2010)

A. Rusnjak, *Improving IT-Strategy-Alignment with a multidimensional business value*, 16th International Working Conference on Requirements Engineering: Foundation for Software Quality (RefsQ2010), (2010)

A. Speck, S. Feja, S. Witt, A. Brosche, C. Prietz, *Modellierung und Validierung von Datenschutzanforderungen in Prozessmodellen*, Vernetzte IT für einen effektiven Staat - Gemeinsame Fachtagung Verwaltungsinformatik und Fachtagung Rechtsinformatik, FTVI/FTRI 2010, **LNI 162 GI 2010**, 155 - 166 (2010)

Algorithmic Optimal Control - CO2 Uptake of the Ocean

The amount of CO_2 in the ocean is mainly determined by ocean currents and biogeochemical processes. The simulation of these processes is important, e.g. to investigate the future behaviour of the ocean as a CO_2 buffer for increasing emissions into the atmosphere. Models of CO_2 uptake consist of equations for different tracers such as nutrients, phyto- and zooplankton. These models use many parameters that are fitted to measurement data. For this purpose, methods of mathematical optimization, high performance computing, and uncertainty analysis are used. Main challenges are the huge computational effort to spin up 3-D models to steady seasonal cycles in order to optimize them. Among other different optimization techniques, the algorithmic generation of sensitivities, and Newton-like methods for the computation of periodic states are used in the project.

The role of CO_2 in the ocean

CO_2 is a main topic in the discussion about climate change and climate protection strategies. It is one of the main greenhouse gases, i.e. it holds back a part of the radiation reflected from the earth's surface in the atmosphere. Thus, on the one hand, CO_2 is responsible for the comfortable warm climate on earth allowing us to survive at all but on the other hand, the increase of CO_2 emissions in the last 200 years has caused a temperature rise with all its consequences such as sea ice melting, changes in vegetation etc. Climate model simulations indicate that these effects, summarized as global warming, will continue and even become stronger. Even though the atmospheric CO_2 is most discussed, its amount in the oceans is also very important. In fact, much more of this gas is dissolved in the oceans, and two thirds of the emitted CO_2 is taken up from the atmosphere via the sea surface. This effect thus mitigates the greenhouse effect, but, naturally, it also changes the chemical composition of the ocean water, leading for example to acidification. Moreover it is unclear how this mitigation property will change in the future due to global warming.

Modelling the CO_2 Uptake

The amount and distribution of CO_2 in the ocean is determined by the water circulation, by biochemical processes, namely the assimilation of CO_2 by phytoplankton (algae) and its mineralization by zooplankton (animals), and sedimentation. A well-accepted theory describes the relation of the amounts of CO_2 and nutrients that are converted to biomass by photosynthesis. Thus the CO_2 uptake is usually modelled in a system of transport (or advection-diffusion) equations for so-called tracers. The coupling relations between the tracers in these models are more or less empirical, i.e. it is not very clear what the coupling terms look like mathematically, and, moreover, how many tracers have to be taken into account. Many model parameters are used: they are chosen such that the model results remain feasible (i.e. tracer concentrations remain non-negative) and that given measurement data are matched by the model output.

Results

General Optimization and Validation Strategy

We developed a strategy to combine state-of-the-art optimization methods (stochastic and deterministic) to optimize model parameters. Since optima, that lead to a perfect data fit, are hard to find for ecosystem and climate models, we exploit the hardware infrastructure using a so-called random-restart method to prevent the optimization algorithm settling in suboptimal local minima. Based on this method, uncertainty estimates can also be generated without additional linearity assumptions on the models. For a one-dimensional model of NPZD type this was done successfully with respect to model parameters and initial values.

3-D Results

For the more spatially realistic three dimensional models, we currently work with Khatiwala's Transport Matrix Method (TMM) that provides a discretization of the ocean circulation forcing of the ecosystem in matrix form. We study the dependency of the model output with respect to the time discretization from a mathematical viewpoint, and find that the

models' spin-up phase can be significantly accelerated. This was also achieved by applying Newton's method to compute the periodic state. A flexible software framework METOS3D was developed that allows the coupling of the TMM with a wide range of ecosystem models.

One-Shot Optimization

The above mentioned work is a prerequisite for the method of simultaneous analysis and design. It enables already a model improvement during the spin-up phase. The method that was already successful in aerodynamics and for the ocean box model, is currently applied on the full 3-D problem.

Model Predictive Control

Linear-quadratic Control Theory is used to incorporate time varying parameters. For this purpose, linearizations of full nonlinear models are obtained algorithmically by the method of Automatic Differentiation (AD). This control approach extends the models by introducing periodic parameters which, so far at least, lead to a better fit, in the piecewise linearized model.

Surrogate-based Optimization

Working with model hierarchies (in temporal and spatial resolution, number of space dimensions, different numbers of tracers) can be a useful tool if one optimizes a coarse model and uses the results in a fine model. Here 1-D tests lead to computer time reductions up to 95 %. This perspective is even more promising in 3-D.

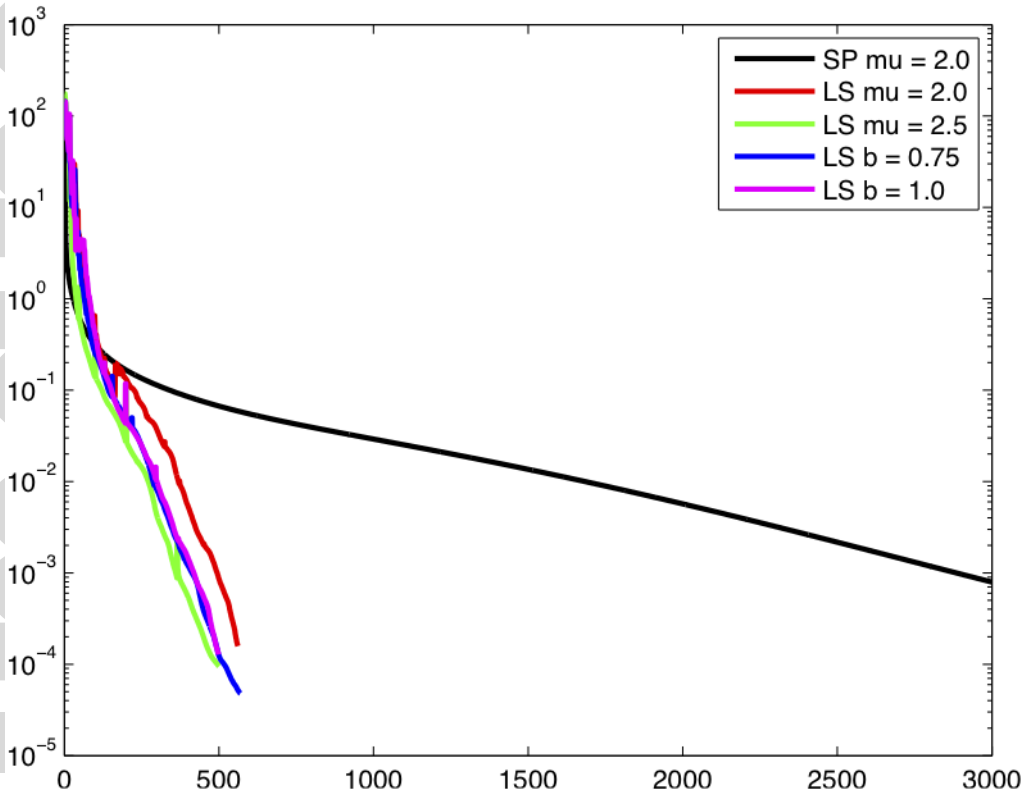

Fig. 1: Acceleration of model spin-up into a periodic state by a Newton iteration (coloured lines for different parameters) compared to the usual pseudo-time-stepping (black line). The Newton method needs less than 500 model-years compared to 3000 to reach the same accuracy.

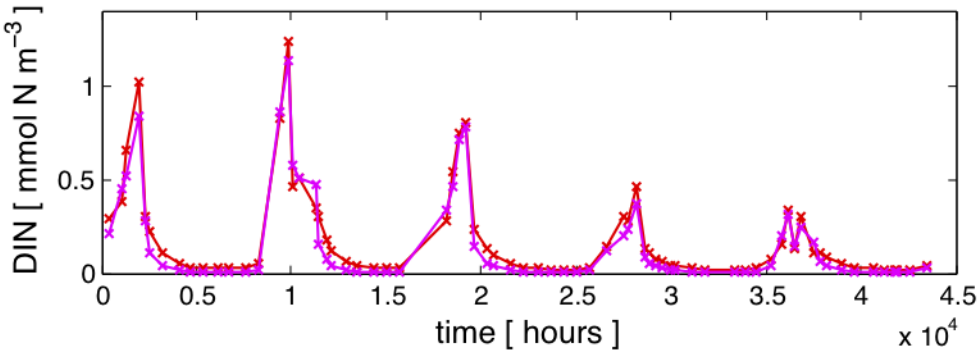

Fig. 2: Comparison of an exemplary ecosystem model output with the original model (red) and a surrogate (magenta) using a 40 times larger time step and needing only 5 % computation time. It is important to guarantee numerical stability of the coarse model.

Personnel

Head of the group: Prof. Dr. T. Slawig;

Scientific Staff:

Dipl.-Math. M. El Jarbi Cluster Future Ocean A3	01.01.-31.12.2010	DFG
Dipl.-Math. A. Heinle Cluster Future Ocean A3	01.01.-31.12.2010	DFG
Dipl.-Math. C. Kratzenstein SPP 1253/Cluster Future Ocean A3	01.01.-31.12.2010	DFG
Dr. H. Mütze Cluster Future Ocean A3	01.01.-31.12.2010	DFG
Dipl.-Math. J. Piwonski Cluster Future Ocean A3	01.01.-31.12.2010	DFG
Dipl.-Phys. M. Prieß Cluster Future Ocean A3	01.01.-31.12.2010	DFG
Dipl.-Math. J. Rückelt Cluster Future Ocean A3	01.01.-31.12.2010	DFG

Lectures, Seminars, and Laboratory Course Offers

Winter 2009/2010

Einführung in die Optimierung, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
T. Slawig (+ M. El Jarbi)

Algorithmische Optimale Steuerung/Klimasimulationen, 2 hrs Masterprojekt/Week,
T. Slawig

Optimierung und Informatik in Meeres- und Klimaforschung, 2 hrs Projektmodul/Week,
T. Slawig

Optimierung und Informatik in Meeres- und Klimaforschung, 2 hrs Praktikum/Week,
T. Slawig

Numerische Mathematik und Optimierung, 2 hrs Seminar/Week,
T. Slawig (+ S. Börm, J. Burmeister)

Numerische Mathematik, 2 hrs Oberseminar/Week,
T. Slawig (+ S. Börm, M. Braack)

ISOS-Course: Introduction to Numerical Modeling, 2 hrs Seminar/Week,
T. Slawig

Summer 2010

Programmierpraktikum, 3 hrs Lab/Week,
T. Slawig (+ J. Piwonski, S. Schulmeister)

Programmierpraktikum für Mathematiker, 3 hrs Lab/Week,
T. Slawig (+ J. Piwonski, S. Schulmeister)

Numerische Mathematik und Optimierung, 2 hrs Seminar/Week,
T. Slawig (+ S. Börm, J. Burmeister)

Numerische Mathematik, 2 hrs Oberseminar/Week,
T. Slawig (+ S. Börm, M. Braack)

Optimale Steuerung, 4 (+2) hrs Lecture (+ Exercises)/Week,
T. Slawig

Optimierung und Informatik in Meeres- und Klimaforschung, 2 hrs Projektmodul/Week,
T. Slawig

Optimierung und Informatik in Meeres- und Klimaforschung, 2 hrs Praktikum/Week,
T. Slawig

Algorithmische Optimale Steuerung/Klimasimulationen, 2 hrs Masterprojekt/Week,
T. Slawig

ISOS Course: MATLAB for PhDs, 2 hrs Seminar/Week,
T. Slawig

Winter 2010/2011

Numerische Mathematik und Optimierung, 2 hrs Seminar/Week,
T. Slawig (+ S. Börm, J. Burmeister)

Klimamodelle und Klimasimulationen, 4 (+2) hrs Lecture (+ Exercises)/Week,
T. Slawig (+ C. Kratzenstein)

Informatik in Meeres- und Klimaforschung, 2 (+1) hrs Lecture (+ Exercises)/Week,
T. Slawig (+ A. Heinle)

Optimierung und Informatik in Meeres- und Klimaforschung, 2 hrs Projektmodul/Week,
T. Slawig

Optimierung und Informatik in Meeres- und Klimaforschung, 2 hrs Praktikum/Week,
T. Slawig

Algorithmische Optimale Steuerung/Klimasimulationen, 2 hrs Masterprojekt/Week,
T. Slawig

Third-Party Funds

DFG, *Personal/Sachmittel,* 01.01.-01.12.2010 (20000 EUR)
DFG, *Personal/Sachmittel,* 01.09.-31.12.2010 (141500 EUR)

Further Cooperation, Consulting, and Technology Transfer

Prof. Dr. Andreas Oschlies, **IfM Geomar**, Kiel.

Dr. Iris Kiest, **IfM Geomar**, Kiel.

Prof. Dr. Anand Srivastav, **Institut für Informatik**, Kiel.

Prof. Dr. Andreas Griewank, **MATHEONandHumboldt-Universität zu Berlin**, Berlin.

Prof. Dr. Nicolas Gauger, **DLR BraunschweigandHumboldt-Universität zu Berlin**, Braunschweig/Berlin.

Ira Neitzel, **Technische Universität Berlin**, Berlin.

Dr. Uwe Prüfert, **MATHEOn**and**Technische Universität Berlin**, Berlin.

Prof. Dr. Slawomir Koziel, **Reykjavik University**, Iceland.

Diploma, Bachelor and Master Theses

J Reimer, *Globalisierung von Quasi-Newton-Verfahren vom Broyden-Typ,* 23.06.2010
J. Meyer, *Implementierung von Basisalgorithmen auf Grafikkarten,* 30.09.2010

Publications

Published in 2010

J. Rückelt, V. Sauerland, T. Slawig, A. Srivastav, B Ward, C. Patvardhan, *Parameter Optimization and Uncertainty Analysis in a Model of Oceanic CO2-Uptake using a Hybrid Algorithm and Algorithmic Differentiation,* Nonlinear Analysis B Real World Applications, (2010)

A. Heinle, A. Macke, A. Srivastav, *Automatic cloud classification of whole sky images,* Atmospheric Measurement Techniques, **3**, 269 - 299 (2010)

M. Prieß, T. Slawig, *Surrogate-based Optimization of Biogeochemical Transport Models,* AIP Conference Proceedings, **1281**, 612 - 615 (2010)

J. Piwonski, T. Slawig, *The Idea and Concept of Metos3D – A Marine Ecosystem Toolkit for Optimization and Simulation in 3-D,* Technische Berichte des Instituts für Informatik, Christian-Albrechts-Universität zu Kiel, **tr1016**, (2010)

M. Prieß, T. Slawig, *Aggressive Space Mapping for the Optimization of a Marine Ecosystem Model,* Technische Berichte des Instituts für Informatik, Christian-Albrechts-Universität zu Kiel, **tr1014**, (2010)

I. Neitzel, U. Prüfert, T. Slawig, *A Smooth Regularization of the Projection Formula for Constrained Parabolic Optimal Control Problems,* Preprint series of the Institute of Mathematics, Technische Universität Berlin, **21**, (2010)

J. Rückelt, A. Oschlies, T. Slawig, *Optimization of Parameters and Initial Values in a Marine NPZD-Type Ecosystem Model,* Technische Berichte des Instituts für Informatik, Christian-Albrechts-Universität zu Kiel, **tr1013**, (2010)

Presentations

M. Prieß, *CO2 Uptake of the Ocean-Junior Research Group A3: Research Challenges and Recent Results,* Invited talk at Engineering Optimization and Modeling Center der Universität, Reykjavik, Iceland, 12.-19.11.2010

T. Slawig, *Marine Ecosystem Models - Optimization and Validation,* Nordcluster Meeting, Hamburg, Germany, 05.-06.10.2010

M. El Jarbi, *Introducing periodic Parameters in a marine biogeochemical Model using Linear Quadratic Optimal Control,* Future Ocean Symposium, Kiel, Germany, 13.-16.09.2010

M. Prieß, *Surrogate-based Optimization of Biogeochemical Models,* 8th International Conference of Numerical Analysis and Applied Mathematics, Rhodes, Greece, 19.-25.09.2010

J. Rückelt, *Sensitivity Analysis and Parameter Estimation for a Marine Biogeochemical Model,* Future Ocean Symposium, Kiel, Germany, 13.-16.09.2010

J. Piwonski, *Equilibrium Sensitivities for Simple Global Biogeochemical Models in 3D,* Future Ocean Symposium, Kiel, Germany, 13.-16.09.2010

M. Prieß, *Surrogate-based Optimization of Biogeochemical Models,* Future Ocean Symposium, Kiel, Germany, 13.-16.09.2010

M. Prieß, *Surrogate-based Optimization of Biogeochemical Transport Models,* 2nd International Conference on Engineering Optimization, Lisbon, Portugal, 06.-09.09.2010

T. Mildner, C. Eden, M. Prieß, D. Nürnberg, *Impact of Last Glacial Maximum wind stress and reduced sea level on heat and freshwater transport into the Gulf of Mexico,* 10th International Conference on Paleoceanography, San Diego, USA, 29.08.-03.09.2010

J. Piwonski, *Analysis and Parameter Optimization of a Marine Biogeochemical Model in 3D,* Summer School and Workshop on Analysis and Numerics of PDE Constrained Optimization, Lambrecht, Germany, 18.-23.07.2010

A. Heinle, *Automatic cloud classification of whole sky images,* 13th Conference on Cloud Physics, Portland, USA, 27.06.-02.07.2010

J. Rückelt, *Sensitivity analysis and parameter estimation for a marine biogeochemical model,* 28th IUGG Conference on Mathematical Geophysics, Pisa, Italy, 07.-11.06.2010

T. Slawig, *Parameter optimization and uncertainty analysis for a biogeochemical model using local and genetic algorithms,* European Geosciences Union, General Assembly 2010, Vienna, Austria, 02.-07.05.2010

T. Slawig, *Parameter Optimization for the Calculation of the Oceanic CO2,* GAMM Workshop on Recent Trends in Mathematics Related to PDE Constrained Optimization 2010, Paderborn, Germany, 22.-23.04.2010

M. Prieß, *Space Mapping Optimization and Model Reduction for Biogeochemical Models,* Invited talk at AG Technomathematik Prof. Rene Pinnau, Kaiserslautern, Germany, 24.-26.03.2010

A. Heinle, *Modelle - Ein Versuch etwas über die Entwicklung unseres Klimas auszusagen,* Girls' Day am Institut für Informatik, Christian-Albrechts-Universität zu Kiel, Kiel, Germany, 22.04.2010

Further Activities and Events

Dipl.-Math. Anna Heinle participated as a tutor during „Girls' Day" (" Modelle - Ein Versuch etwas über die Entwicklungunseres Klimas auszusagen").

Prof. Dr. Thomas Slawig was co-organizer of the 5th Scientific Computing Seminar in Kiel from June, 28-30, 2010.

Dipl.-Phys. Malte Prieß spent research periods at the Engineering Optimization & Modelling Centre, Reykjavik University, Iceland (Prof. Koziel) and the Technomathematics Group of Prof. Dr. Rene Pinnau, Technical University of Kaiserslautern.

Dipl.-Math. Anna Heinle participated in a fieldwork-genome training course in Japan in summer 2010 (exchange with Kyoto University Global Centre of Excellence (COE) Programme).

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 since then has been directed by Prof. Dr.-Ing. Norbert Luttenberger. The AG ComSys performs research work in four different application-oriented areas. These areas will be introduced in the following.

Results

1. Computer science support for marine research

In the context of the European-funded Network of Excellence ESONET (standing for European Sea Floor Observatory Network) AG ComSys closely cooperated with oceanographers from MARUM in Bremen. AG ComSys contributed to the following sub-projects of ESONET: (1) standardization of sensor communication protocols (IEEE 1451), (2) manpower support during the cruise of the research vessel Merian for scientific drilling with the sea floor drill rig MeBo (Elefsina - Valletta, 05.06.2010 - 04.07.2010). Most mentionable is that ComSys staff member Jesper Zedlitz was appointed a position in the IEEE 1451 standards committee.

2. Verification of Railway Infrastructures

In close co-operation with Funkwerk IT GmbH, Kiel, an ontology-based verifier for railway infrastructures was designed and implemented. In 2010, the focus was on the formalization of railway infrastructure design rules in SWRL language (Semantic Web Rule Language) and on gaining practical experience with this new methodology.

3. Parallel Processing on Graphics Cards

This project was set up to find out about enhanced parallel processing methods for XML-coded documents on commercially available and cheap parallel processors, namely high-performance graphics cards. We focussed on NVIDIA's GTX series of cards, because these cards come with a programming environment (called CUDA), that enables the programmer to develop general purpose programs that can run on a graphics card. We enhanced our previous work by concentrating on parallel algorithms for the XML-related technologies XPath and XSLT.

Personnel

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

Scientific Staff:

MSc. Michael Lodemann Railway infrastructure verification	01.01.-31.12.2010	ISH-HWT
Dipl.-Inf. Hagen Peters Massive parallel processing	01.01.-31.12.2010	Land SH
Dipl.-Inf. Jesper Zedlitz CS support for marine research	01.01.-31.12.2010	ESONET

Lectures, Seminars, and Laboratory Course Offers

Winter 2009/2010

Systemorientierte Informatik 3 Betriebssysteme, 3 (+ 2) hrs Lecture (+ Exercises)/Week,
Norbert Luttenberger (+ Hagen Peters)

Internet Communications, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
Norbert Luttenberger (+ Hagen Peters)

Master-Praktikum Kommunikationssysteme, 6 hrs Seminar/Week,
Norbert Luttenberger (+ Hagen Peters)

Summer 2010

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

Computer Networks and Internetworking, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
Norbert Luttenberger (+ Hagen Peters)

Bachelor-Abschlußprojekt Kommunikationssysteme, 6 hrs Seminar/Week,
Norbert Luttenberger (+ Hagen Peters)

Third-Party Funds

ISH-HWT, *RTVE/ITIS*, 01.01.-31.12.2010 (60000 EUR)
ESONET (via MARUM Bremen), *CS Support for Marine Research*, 01.01.-31.12.2010 (60000 EUR)

Further Cooperation, Consulting, and Technology Transfer

Our close cooperation partners were MARUM Bremen and Funkwerk IT GmbH Kiel.

Diploma, Bachelor and Master Theses

Jan Jörke, *Alternativen für die konzeptuelle Modellierung von GML*, 06.12.2010
Amelie Kurland, *Reference Implementation for IEEE 1451*, 21.07.2010
Rita Marnau, *Benutzerdefinierte Constraints für ontologische Wissensbasen*, 20.12.2010
Lukasz Rybinski, *CUDA-based Filtering of Geo-Data on Graphic Cards*, 30.09.2010

Publications

Published in 2010

Hagen Peters, Ole Schulz-Hildebrandt, Norbert Luttenberger, *Parallel external sorting for CUDA-enabled GPUs with load balancing and low transfer overhead*, Proceedings of the 24th IEEE International Parallel and Distributed Processing Symposium, Workshops and Phd Forum, Atlanta, USA, April 2010, (2010)

Michael Lodemann, Norbert Luttenberger, *Ontology-based Railway Infrastructure Verification - Planning Benefits*, International Conference on Knowledge Management and Information Sharing (KMIS 2010), (2010)

Norbert Luttenberger, *Geographische Modellierung mit der Geography Markup Language (GML)*, Praxis der Informationsverarbeitung und Kommunikation (PIK), **33-4**, (2010)

Hagen Peters, Martin Köper, Norbert Luttenberger, *Efficiently using CUDA enabled GPUs as shared resource*, FGC 2010 - The First International Workshop on Frontier of GPU Computing, (2010)

Michael Lodemann, Carsten Gehrke, Norbert Luttenberger, *Beschreibung von Eisenbahninfrastrukturen mit railML und ihre Verifikation*, Signal und Draht, **4**, (2010)

Hagen Peters, Ole Schulz-Hildebrandt, Norbert Luttenberger, *Fast in-place, comparison-based sorting with CUDA: a study with bitonic sort*, CONCURRENCY AND COMPUTATION: PRACTICE AND EXPERIENCE, (2010)

Presentations

Norbert Luttenberger, *XML Language Technology for the Railway Domain,* Workshop and Cluster Meeting CNA e.V. and Cluster Bahntechnik Bayern, Karlsfeld, 01.02.2010

Norbert Luttenberger, *Verification Support for Railway Infrastructure Planning,* VDE-Kongress, Leipzig, 08.11.2010

Multimedia Information Processing

The Multimedia Information Processing group (MIP) is active in research and applications of 3D technology, computer vision and computer graphics. The main focus of the group is on various aspects of 3D data processing from image and video data, and on sensor fusion with range and navigation data. In 2010, 14 scientific researchers were involved in 12 research projects. Project funding was supported by DFG, EU, BMWi, Land Schleswig-Holstein, and Industry (Daimler, Raytheon, SevenCs, IBAK, RealEyes,WISKA, VW).

Results

The Multimedia Information Processing Group MIP has continued its successful research in the field of 3D modelling, 3D metrology and 3D visualization. In the following, research results from two of the twelve active projects in 2010 are discussed.

3D surface models from images as 3D documentation tool in archaeology

Documentation plays an important role in archaeology, because the configuration of finds and features in an archaeological trench is usually destroyed during the progress of an excavation. In order to allow the interpretation in retrospect, archaeologists spend a lot of time and effort on shooting and rectifying photographs and producing computer-aided and hand-made drawings of a site. However, these methods only yield 2D representations and lack any depth information. Furthermore, the viewer is always restricted to the viewpoint the photographer has chosen. To circumvent these limitations, MIP investigates the applicability of state-of-the-art computer vision algorithms in the field of archaeology to produce 3D models of the trenches. Computer vision techniques, and structure-from-motion in particular, are well-suited for this task, because the soil usually contains rich textural information.

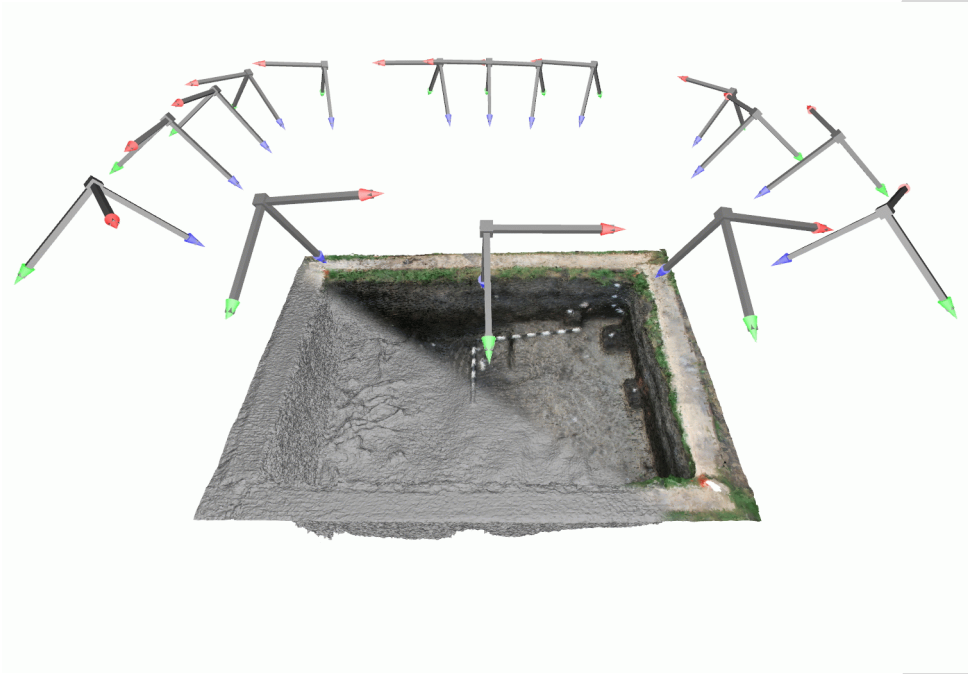

Fig. 1: 3D model of excavation site at Bruszczewo, Poland, 2008, site 5, layer 15006. Left part of model: geometry only, shaded surface. Right part of model: model surface with colours. The model was constructed from a set of 16 images (local coordinate systems, drawn at camera positions, camera optical axes with blue arrows).

The MIP group is working on image-based 3D archaeological reconstructions as part of the Graduate School „Human Development in Landscapes“ . The input to the 3D reconstruction pipeline is a set of photographs taken of a trench from different viewpoints. The following steps are necessary to reconstruct the 3D geometry: first, keypoints are extracted automatically from each input image, and second, the keypoints between all images are matched to establish correspondences. These keypoint correspondences allow the computation of the relative camera positions in the next step. For this a hierarchical algorithm is used, similar to the divide-and-conquer approach: sub-sequences are processed individually and are successively merged until the whole sequence has been processed. Next, the cameras are transformed into the reference coordinate system used at the excavation site. The transformation is based on a small set of measured points in the trench. This transformation is necessary to allow 3D measuring in the final model and to correlate it with other spatial data (e.g. reconstructed models of other trenches). Finally, a dense 3D model is computed represented by a triangular mesh, see fig. 1.

High-Quality large-scale 3D advertisement with lightfield posters

In 2010 a project for visualizing high quality 3D data was successfully finalized. The goal of the project was to produce highly realistic large-scale 3D posters with up to 50,000 separate views from a 2D lens array of 250,000 lenses per square-metre, to achieve unprecedented realism by the use of micro-lens arrays. An observer samples this light field and depending on their position different views are collected from each of the 250,000 lens systems, resulting in the final picture that is seen. Two images of a prototype 3D poster are shown in figure 2, taken from different viewpoints. In order to achieve this goal the industry partners RealEyes GmbH, AutoPan GmbH, Euromediahouse GmbH, Meuser Optik GmbH and Kleinhempel Ink-Jet-Center GmbH together with the research partners Fraunhofer IPM, Fraunhofer IPT and CAU MIP jointly built up a production chain for content generation and assembly of the 3D poster.

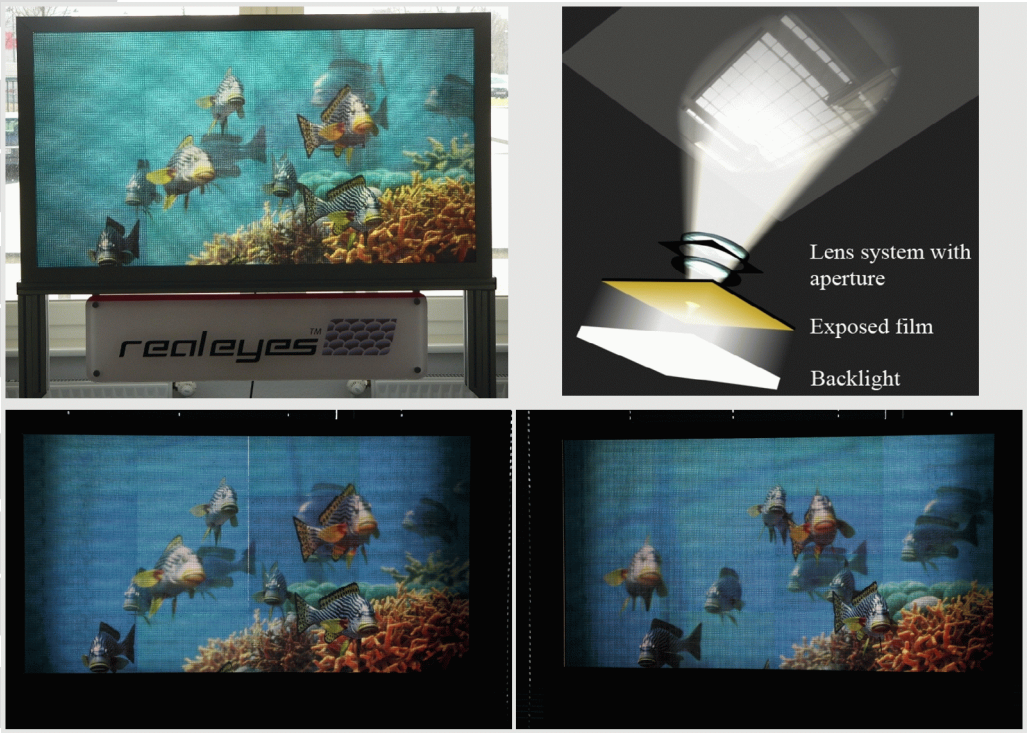

Fig. 2: Top left: Prototype of 3D Display. Top right: design of one of the 250,000 lense images on the display. Bottom: Two snapshots of the prototype 3D display showing a computer generated scene, taken from a distance of about 4.2 metres. The display shows a correct perspective for the left viewpoint (left) and the right viewpoint (right) allowing for an unconstrained 3D viewing experience.

One of the obstacles of such a 3D poster is the huge amount of data, since typically for each square-metre of poster, 250,000 images with different viewpoints are to be rendered and processed, resulting in about 200 GB of image data and a processing time of several months per poster. It can be seen that the content of the poster is dependent on the viewpoint of the observer. Every observer sees a slightly different image, which allows for a true 3D effect that even permits looking behind objects by viewpoint change. This technique allows for a smooth viewpoint transition and a 3D viewing experience of unprecedented quality. For each of the 250,000 lens systems an image of 256x256 pixels has to be rendered for the 3D poster, resulting in about 200 GB of image data. On a single workstation rendering of all images would require several months of rendering time. For this project the MIP group developed a rendering system that achieved the reduction in the rendering time for one display from several months to about two days on a single work station. This was achieved by exploiting the redundancy of the images and the use of highly effective data structures for rendering.

Personnel

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

Scientific Staff:

B. Bartczak Interreg/3D4YOU/3DPoseMapII	01.01.-31.12.2010	EU/EU/DFG
D. Chen	01.03.-31.12.2010	Chinese Research Council
S. Esquivel Land	01.01.-31.12.2010	CAU
A. Frick 3D4You	01.01.-31.12.2010	EU
K. Haase AR-Fernglas/Land/Interreg	01.01.-31.12.2010	ISH/CAU/EU
A. Jordt 3D4You/Interreg	01.01.-31.12.2010	EU
D. Jung InnoNet/Land	01.01.-31.12.2010	BMWi/CAU
F. Kellner InnoNet/Interreg	01.01.-31.12.2010	BMWi/EU
A. Petersen Land/KoSSE	01.01.-31.12.2010	CAU/EU
C. Rabe InnoNet	01.01.-31.03.2010	BMWi
I. Schiller KoSSE	01.01.-31.12.2010	EU
A. Sedlazeck Modelling of Seafloor Structures	01.01.-31.12.2010	DFG
R. Wulff Graduiertenkolleg Human Landscapes	01.01.-31.12.2010	DFG

Lectures, Seminars, and Laboratory Course Offers

Winter 2009/2010

Computer Graphik, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
R. Koch (+ S. Esquivel, D. Jung)

Vertiefende Übung Visuelle Modellierung, 4 hrs Advanced Seminar/Week,
R. Koch (+ A. Petersen, F. Kellner, A. Frick)

Multimedia Communications, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
R. Koch (+ S. Esquivel, A. Petersen)

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

Oberseminar - Multimediale Informationsverarbeitung, 2 hrs Seminar/Week,
R. Koch (+ S. Esquivel)

Bachelor and Master Thesis Seminar, 4 hrs Advanced Seminar/Week,
R. Koch (+ S. Esquivel, D. Jung, A. Frick, F. Kellner)

Summer 2010

Vertiefende Übung Computer Graphik/Computer Vision, 6 hrs Advanced Seminar/Week,
R. Koch (+ A. Petersen, F. Kellner)

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

Multimediale Informationsverarbeitung, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
R. Koch (+ S. Esquivel, A. Petersen)

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

Masterprojekt - Vertiefende Übung Visuelle Modellierung, 4 hrs Advanced Seminar/Week,
R. Koch (+ D. Jung, F. Kellner, A. Frick)

Multimediale Informationsverarbeitung, 4 hrs Advanced Seminar/Week,
R. Koch (+ D. Jung, F. Kellner, A. Frick)

Masterabschlussseminar Multimediale Informationsverarbeitung, 2 hrs Masterseminar/Week,
R. Koch (+ S. Equivel)

Winter 2010/2011

Computer Graphik, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
R. Koch (+ S. Esquivel, D. Jung)

Vertiefende Übung Visuelle Modellierung, 4 hrs Advanced Seminar/Week,
R. Koch (+ A. Petersen, F. Kellner, A. Frick)

Einführung in die Multimedia-Informationsverarbeitung, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
R. Koch (+ D. Jung, F. Kellner)

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

Fortgeschrittenenenpraktikum - Multimediale Informationsverarbeitung, 2 hrs Seminar/Week,
R. Koch (+ D. Jung, F. Kellner, A. Frick)

Projektmodul Computer Graphik/Computer Vision, 6 hrs Bachelorarbeit/Week,
R. Koch (+ S. Esquivel)

Third-Party Funds

BMWi + Partner, *Entwicklung und Aufbau einer Herstellungskette für hochwertige 3D-Bilder TV: Aufbau eines Renderers für 3D Bilder,* 01.06.2008-30.09.2010 (238.520 EUR)
EU, *3D4YOU,* 01.02.2008-31.01.2011 (438.100 EUR)
ISH + Partner, *AR Fernglas II,* 11.04.2008-30.04.2010 (127.100 EUR)
DFG, *Dynamisches 3D Sehen,* 11.02.2008-31.12.2010 (150.000 EUR)
Daimler AG, *Collision Avoidance,* 01.04.2008-28.02.2010 (145.000 EUR)
Raytheon, *Optimale Zustandschätzung von Navigationsdaten mittels redundanter Sensorik,* 30.04.2008-30.04.2010 (176.600 EUR)
DFG, *Seafloor modeling,* 01.09.2009-31.08.2011 (150.000 EUR)
EU, *InterReg,* 01.09.2009-31.07.2012 (273.000 EUR)
EU, *KoSSE,* 01.08.2009-31.08.2012 (330.000 EUR)
ISH/Fa. Basler, *Transferprämie/Transferpreis,* 04.08.2010 (30.000,00 EUR)
VW, *Konzeptstudie Optical see-through head-mounted Display Kalibrierung,* 01.07.-15.09.2010 (19.800,00 EUR)
WISKA/Verbundprojekt PITAS, *Software für visuelles Detektions- und Reaktionssystem, Bildanalyse und Kamerasteuerung,* 28.09.2010-30.06.2013 (41.000,00 EUR)

Further Cooperation, Consulting, and Technology Transfer

Dr. Hunger, **Fa. IBAK**, Kiel

Dr. Didier Stricker, **IGD - FHG**, Darmstadt

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

Fabian Doil, **VW**, Wolfsburg

Friedhelm Moggert-Kägeler, **Seven Cs**, Hamburg

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

Prof. Hans-Peter Seidel, **MPI für Informatik**, Saarbrücken

Dr. Bodo Rosenhahn, **MPI für Informatik**, Saarbrücken

Jürgen Streufert, **Raytheon Anschütz GmbH**, Kiel

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

Shahriar Negadaripour, **University of Miami** Miami, USA

Soenke Ehlers, **Fa. WISKA** Kaltenkirchen

Diploma, Bachelor and Master Theses

L. Stuckmann, *Genauigkeitsanalyse für ein markerbasiertes Trackingverfahren,* 29.09.2010

N. Majewski, *Verfeinerung von Tiefendiskontinuitäten in Videosequenzen unter Verwendung von Graph-Cut-Farbsegmentierung,* 18.10.2010

J. Falck, *Aufbau eines 3D-Messsystems für Stereokamerasysteme im Unterwasserbereich,* 29.09.2010

B. Angerer, *Modellbasierte volumetrische Rekonstruktion artikulierter Körper aus Tiefendaten mehrerer 3D-Kameras,* 30.09.2010

J. Brünger, *Approximation der Deformation dynamischer Oberflächen aus Tiefendaten,* 14.07.2010

P. Suwito, *Datenstrukturierung und Visualisierung von ENC-Seekarten für ein Augmented Reality System,* 04.06.2010

F. Schulte, *Analyse eines nichtlinearen Kameramodells unter Berücksichtigung der Lichtbrechung aufgrund unterschiedlicher optischer Medien,* 25.10.2010

C. Hiller, *Design and Implementation of a Subtractive Audio Synthesizer,* 31.03.2010

D. Zens, *Filtertechniken fuer subtraktive Audiosynthese,* 31.03.2010

Publications

Published in 2010

A. Frick, B. Bartczak, R. Koch, *3D-TV LDV content generation with a hybrid ToF-multicamera RIG,* Proceedings 3D-TV-conference Tampere Finnland 07.06.10-09.06.10, (2010)

A. Frick, B. Bartczak, R. Koch, *Realtime Preview for Layered Depth Video in 3D-TV,* Proceedings SPIE Realtime-Time Image and Video Processing 12.04.10-16.04.10, (2010)

A. Petersen, R. Koch, *Statistical Analysis of Kalman Filters by conversion to Gauss-Helmert Models with Applications to Process-Noise Estimation,* Proceedings of ICPR2010 August 2010 Istambul Turkey, (2010)

A. Jordt, I. Schiller, J. Brünger, R. Koch, *High Resolution Object Deformation Reconstruction with Active Range Camera,* Proceedings of DAGM Springer Verlag LNCS, **6376**, 543 - 552 (2010)

S. Esquivel, R. Koch, H. Rehse, *3D Reconstruction of Sewer Shafts from Video,* Proceedings of Go-3D '10, 97 - 109 (2010)

R. Wulff, A. Sedlazeck, R. Koch, *Measuring in Automatically Reconstructed 3D Models,* Proceedings of Geoinformatik, (2010)

M. Lindner, I. Schiller, A. Kolb, R. Koch, *Time-of-Flight Sensor Calibration for Accurate Range Sensing,* Journal of Computer Vision and Image Understannding (CVIU), (2010)

I. Schiller, B. Bartczak, F. Kellner, R. Koch, *Increasing realism and supporting content planning for dynamic scenes in a mixed reality system incorporating a time-of-flight camera,* Journal of Virtual Reality and Broadcasting 7, **4**, (2010)

D. Jung, R. Koch, *Efficient Depth-Compensated Interpolation for Fulll Parallax Displays,* Proceedings of the Fifth International Symposium on 3D Data Processing, Visualization and Transmission, (2010)

A. Kolb, E. Barth, R. Koch, R. Larsen, *Time-of-Flight Cameras in Computer Graphics,* Computer Graphics Forum, **29**, 141 - 159 (2010)

S. Esquivel, R. Koch, H. Rehse, *Time Budget Evaluation for Image-Based Reconstruction of Sewer Shafts,* Real-Time Image and Video Processing, Proceedings of SPIE '10, **7724**, (2010)

A. Sedlazeck, K. Koeser, R. Koch, *Supporting Underwater Archaeology by 3D Reconstruction from Unterwater Images,* Skyllis '10, (2010)

R. Koch, K. Haase, *Extension of Electronical Nautical Charts for 3D interactive Visualization via CityGML,* Proceedings of Geoinformatik, (2010)

R. Koch, K. Haase, *Extension of Sea Charts for 3D Visualization,* 3D GeoInfo Conference ISPRS Proceedings, (2010)

C. Menk, R. Koch, *Physically-based Augmentation of Real Objects with Virtual Content under the Influence of Ambient Light,* Proceedings of PROCAMS IEEE Computer Society Conference of Computer Vision and Pattern Recognition Workshops (CVPRW), San Francisco USA, (2010)

R. Koch, A. Kolb, C. Rezk-Salama, *VMV 2010: Vision, Modeling, Visualization,* Proceedings VMV, (2010)

C. Menk, E. Jundt, R. Koch, *Evaluation of Geometric Registration Methodas for Using Spatial Augmented Reality in the*

Automotiv Industry., Proceedings vision, Modeling, Visualisation, EUROGRAPHICS Association, Siegen Germany, (2010)

Presentations

A. Frick, *3D-TV LDV content generation with a hybrid ToF-multicamera RIG,* 3DTV-Conference, Tampere, Finnland, 07.06.2010

A. Frick, *Realtime Preview for Layered Depth Video in 3D-TV,* Real-Time Image and Video Processing (SPIE), Brüssel, Belgien, 16.04.2010

A. Petersen, *Statistical Analysis of Kalman Filters by conversion to Gauss-Helmert Models with Applications to Process-Noise Estimation,* ICPR, Istambul, Türkei, 25.08.2010

A. Jordt, *High Resolution Object Deformation Reconstruction with Active Range Camera,* DAGM, Darmstadt, Deutschland, 24.09.2010

S. Esquivel, *3D Reconstruction of Sewer Shafts from Video,* Go-3D '10, Rostock, Deutschland, 31.08.2010

D. Jung, *Efficient Depth-Compensated Interpolation for Full Parallax Displays,* 3DPVT '10, Paris, Frankreich, 20.05.2010

R. Wulff, *Measuring in Automatically Reconstructed 3D Models,* Geoinformatik 2010, Kiel, Deutschland, 18.03.2010

S. Esquivel, *Time Budget Evaluation for Image-Based Reconstruction of Sewer Shafts,* Real-Time Image and Video Processing (SPIE), Brüssel, Belgien, 15.04.2010

K. Haase, *Extension of Electronical Charts for 3D interactive Visualization via CityGML,* Geoinformatik 2010, Kiel, Deutschland, 18.03.2010

K. Haase, *Extension of Sea Charts for 3D Visualization,* 3d Geoinfo Konferenz 2010, Berlin, Deutschland, 03.11.2010

R. Koch, *3D Scene Reconstruction and Visualisation from Image Data.*, Keynote at the Geoinformatik, Kiel, Deutschland, 18.03.2010

R. Koch, *Hybrid Multicamera Systems with Range and Color Cameras,* Invited Presentation University of Verona, Verona, Italy, 08.05.2010

R. Koch, *Einsatz von ToF-Kameras für 3D-TV und Augmented Reality.*, Time-of-Flight Workshop, Invited Presentation, Heidelberg, Deutschland, 21.09.2010

R. Koch, *3D im Kino und Wohnzimmer - was kommt nach HDTV?*, GI- Lehrervereinigung Norddeutschland, Keynote, Neumünster, Deutschland, 13.01.2010

R. Koch, *3D-TV using Hybrid Color and Range Cameras,* PMDDays, Keynote, München, Deutschland, 18.11.2010

Further Activities and Events

Christoffer Menk was awarded the **Fokusfinderpreis** donated by the ISH and Baseler, Ahrensburg. The award of 1000 Euro was granted for his excellent diploma thesis *Geometrische Registrierung von Mehrprojektor-Systemen am Beispiel der CAVE 2009*.

Dr. Kevin Köser was honoured with the university **Fakultätspreis** for his doctoral thesis *Geometric Estimation with Local Affine Frames and Free-Form Surfaces*. The best thesis of each faculty is granted 1000 Eur.

Prof. Dr.-Ing. Reinhard Koch received the **Transferpreis** , donated by the ISH Schleswig-Holstein for his achievements in the transfer of knowledge in connection with the **Transferprämie** of the ISH. They were endowed with 10,000 and 20,000 Euros.

Johannes Brünger won the second prize 2000 Euro **Preis der Technik** donated by the **Prof.-Dr.-Werner-Petersen Stiftung** for his diploma thesis *Approximation der Deformation dynamischer Oberflächen aus Tiefendaten*.

Robert Wulff's diploma thesis *Image based 3D Documentation in Archaeology* was accepted for presentation at the **DAGM Symposium** and was awarded **outstanding thesis** by the **Young Researcher's Forum**.

Bogumil Bartczak, Anatol Frick and Ingo Schiller won the second prize in the competition **donated by the WTSH** as

a seed and startup fund for the best new ideas. 3000 Euro were awarded for the idea of a capturing system for 3D film production.

Interuniversitäre Gremien

- Vorsitzender des Prüfungsausschusses „Ingenieurinformatik“

Reviews

Member of the programme committee of the following international conferences and workshops:

- 3DTV-Con,
- 3DPVT 2010,
- CVMP 2010,
- CVPR 2010,
- DAGM 2010,
- ECCV 2010,
- ICIP 2010,
- ICME 2010,
- VMV 2010.
- Member of the Technical Committee of the DAGM, and spokesman of the TK since 2009.
- German Representative of the International Association on Pattern Recognition, IAPR, since 2009.
- Co-chair of the conference Vision, Modelling & Visualization VMV 10, Siegen, Germany.
- Co-chair of Asian Conference Computer Vision Workshops, ACCV 10, Christchurch, New Zealand 2010.

Member of the editorial board for the following journals:

- Journal of Realtime Image Processing (JRTIP), Springer, since 2007,
- Journal of Visual Communications and Image Representation (JVCI) Elsevier, since 2008.

Reviewer for the following journals:

- IEEE-IE Transactions IE, Special Issue on Optomechatronics,
- International Journal of Image and Graphics,
- IEEE T-IP: Transactions for Image Processing,
- IEEE T-VCG: Transactions of Visualisation and Computer Graphics,
- IEEE T-PAMI Transactions of Pattern Analysis and Machine Intelligence,
- Journal on CVIU Computer Vision and Image Understanding,
- Journal PFG (Photogrammetrie, Fernerkundung, Geoinformation).

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-oriented design methods and the analysis of concurrent and distributed systems to the implementation and application of declarative programming languages, in particular, in the area of web-based systems.

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 towards the integration of the most important declarative programming paradigms: functional and logic programming. Due to our long-standing research in this area, we were invited to publish a survey on functional logic programming in the Communications of the ACM, the main publication forum of the Association for Computing Machinery, the world's largest educational and scientific society for computing.

In the area of *software technique* related to declarative languages, we collaborated with the Portland State University (Oregon, USA) and developed a transformation tool to support the development of reliable declarative programs. This tool supports the idea of generating implementations from high-level specifications and to use such specifications as assertions for lower-level implementations. Another development in this area is a new approach to combine laziness and faithfulness in the implementation of assertions for functional logic programs.

We also investigated several issues related to the *implementation* of functional logic programming languages. We developed a new compiler that is based on the implementation of nondeterminism in a purely functional language exploiting monads. This monadic approach allows the selection of the concrete search strategy by different monad instances so that various search strategies can be selected and combined at run-time. This also provides a new basis to exploit *parallelism* since one can implement nondeterministic computations by concurrent threads that run on multicores. Furthermore, we also worked in collaboration with the Portland State University (Oregon, USA) on new reduction strategies for the evaluation of nondeterministic operations.

Related to the *application* of declarative languages, we designed and implemented a new framework, called Spicey, to generate complete web applications from a specification of the underlying data as an entity-relationship model. Since the generated implementation is a high-level declarative program, it is easy to adapt this program to various customer requirements. In contrast to other web frameworks, our framework exploits high-level declarative programming techniques so that it yields reliable implementations that avoid data inconsistencies at various levels. Another application area we explored is the matching of regular expressions. We have developed a high-level, but also quite efficient matching algorithm, in the functional language Haskell, which is competitive with matching algorithms implemented in lower-level imperative programming languages.

Our research group was also engaged in activities to train young students. We introduced students from schools in Schleswig-Holstein to basic programming techniques in one-week courses. During this period, the participating students developed a distributed chat program in the concurrent functional language Erlang. This course was organized by Frank Huch (in collaboration with Thomas Wilke).

Personnel

Head of the group: Prof. Dr. Michael Hanus; Secretary: Ulrike Pollakowski
Technical Staff: Dipl.-Ing. (FH) Thomas Heß

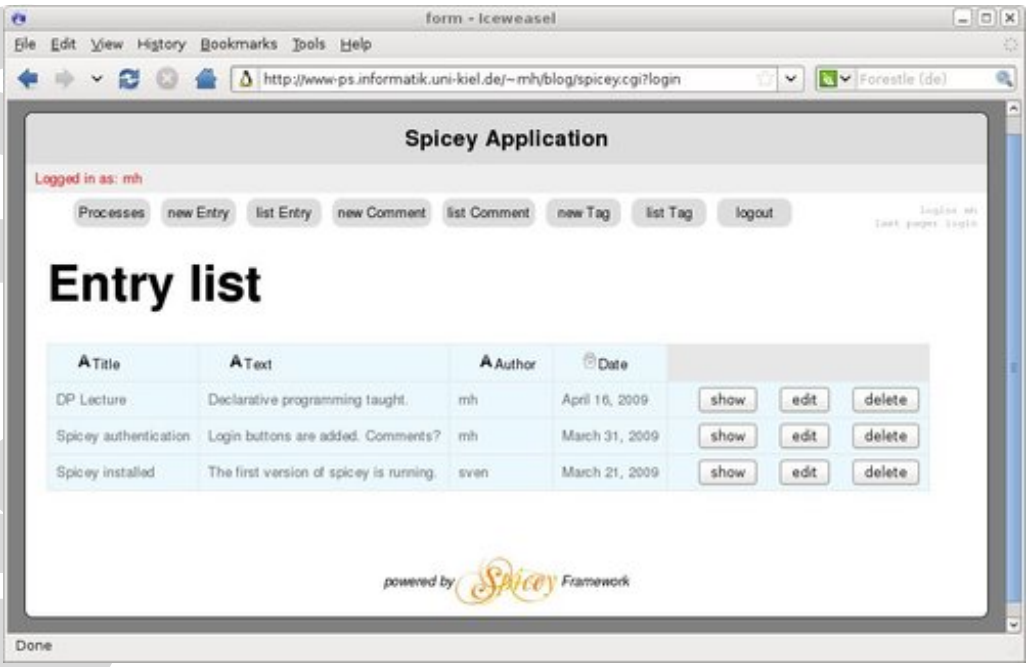

Fig. 1: A simple blog generated by the web framework Spicey

Scientific Staff:

Dipl.-Inf. Sebastian Fischer	01.01.-14.09.2010	CAU
Priv.-Doz. Dr. Frank Huch	01.01.-31.12.2010	CAU
Administration of study programs		
M. SC. Björn Peemöller	01.10.-31.12.2010	
Dipl.-Inf. Fabian Reck	01.01.-31.12.2010	CAU
Dr. Friedemann Simon	01.01.-31.12.2010	CAU

Lectures, Seminars, and Laboratory Course Offers

Winter 2009/2010

Diplomandenseminar, 2 hrs Seminar/Week,
Michael Hanus

Inf-Prog: - Programmierung, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
Michael Hanus (+ Fabian Reck, Christina Otte, Bernd Braßel, Sebastian Eggert)

MS0302: Übersetzerbau, 4 (+ 2) hrs Exercise (+ Exercises)/Week,
Michael Hanus (+ Sebastian Fischer)

NF-Inf-3: Programmiertechniken für die Künstliche Intelligenz für Nebenfächler, 2 (+ 2) hrs Lecture (+ Exercises)/Week,
Friedemann Simon

WI16: Programmiertechniken für die Künstliche Intelligenz, 2 (+ 2) hrs Lecture (+ Exercises)/Week,
Friedemann Simon

Arbeitsgemeinschaft Informatik, Logik und Mathematik, 2 hrs Seminar/Week,
Michael Hanus (+ Rudolf Berghammer)

MSS0302: Seminar - Programmiersprachen und Programmiersysteme, 2 hrs Seminar/Week,
Michael Hanus

MSS0303: Masterabschlusseminar Programmiersprachen, 2 hrs Seminar/Week,
Michael Hanus

NF-Inf-1: Informatik für Nebenfächler, 2 (+ 2) hrs Lecture (+ Exercises)/Week,
Frank Huch (+ Sebastian Fischer, Hauke Furhmann)

Vertiefende Übung zu: Informatik für Nebenfächler, 2 hrs Exercise/Week,
Frank Huch (+ Sebastian Fischer)

Summer 2010

Systematisches Programmieren, 2 (+ 4) hrs Lecture (+ Exercises)/Week,
Friedemann Simon

Diplomandenseminar, 2 hrs Seminar/Week,
Michael Hanus

Arbeitsgemeinschaft Informatik, Logik und Mathematik, 2 hrs Seminar/Week,
Michael Hanus (+ Rudolf Berghammer)

MS0303: - Deklarative Programmiersprachen, 4 (+ 2) hrs Seminar (+ Exercises)/Week,
Michael Hanus (+ Fabian Reck)

MS0306: - Nebenläufige und verteilte Programmierung, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
Frank Huch

MSS0302: Seminar - Programmiersprachen und Programmiersysteme, 2 hrs Exercise/Week,
Michael Hanus

Systematisches Programmieren für Physiker (NF-Inf-2-Phys), 2 hrs Lecture/Week,
Friedemann Simon

WI09: - Fortgeschrittene Programmierung, 3 (+ 2) hrs Lecture (+ Exercises)/Week,
Michael Hanus (+ Frank Huch, Sebastian Fischer)

Winter 2010/2011

MSS0303: Masterabschlusseminar - Programmiersprachen, 2 hrs Seminar/Week,
Michael Hanus

Inf-Prog: Programmierung, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
Michael Hanus (+ Fabian Reck, Lars Prädel)

Arbeitsgemeinschaft Informatik, Logik und Mathematik, 2 hrs Seminar/Week,
Michael Hanus (+ Rudolf Berghammer)

MS0303: Deklarative Programmiersprachen, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
Michael Hanus

MS0306: Nebenläufige und verteilte Programmierung, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
Frank Huch

NF-Inf-1: Informatik für Nebenfächler, 2 (+ 2) hrs Lecture (+ Exercises)/Week,
Frank Huch (+ Sandro Esquivel)

NF-Inf-1v: Informatik für Nebenfächler (vertiefend), 4 (+ 2) hrs Lecture (+ Exercises)/Week,
Frank Huch (+ Sandro Esquivel)

Inf-ObjPro:Objektorientierte Programmierung, 2 (+ 2) hrs Lecture (+ Exercises)/Week,
Friedemann Simon

Inf-ObjProNF: Objektorientierte Programmierung (für Nebenfächler), 2 (+ 2) hrs Lecture (+ Exercises)/Week,
Friedemann Simon

Further Cooperation, Consulting, and Technology Transfer

During the reported period, the research group collaborated with Prof. Sergio Antoy, Portland State University (funded by DAAD).

Diploma, Bachelor and Master Theses

Julia Mangels, *Marketing im E-Commerce*, 06.10.2010
Max Fritzsche, *Declarative Specification of Platform-Independent User Interfaces*, 17.05.2010
Axel Stronzik, *Evolutionsunterstützung von modellbasierter Programmentwicklung*, 02.08.2010
Benjamin Lücke, *Digital Natives - Herausforderungen für die Didaktik wirtschaftlicher Schulfächer*, 31.07.2010
Gabriel Wicke, *ByteMap: Persistent and Locality-Optimized Trie for Disk and Memory*, 01.12.2010
Andreas Baldeau, *Reguläres Ausdrucksmatching in Trie-Strukturen*, 08.11.2010
Stefanie Pelz, *Verwendung endlicher Automaten in der Betriebswirtschaftslehre insbesondere im Controlling*, 02.09.2010
Deniz Okcu, *Betriebswirtschaftsliche Beispiele für grundlegende Konzepte der Informatik*, 13.09.2010
Maike K. Hargens, *Ein Vergleich der Programmiersprachen Groovy und Scala*, 30.09.2010
Florian Micheler, *Extensions to a Haskell based Web-Server*, 30.09.2010

Dissertations / Postdoctoral Lecture Qualifications

Sebastian Fischer, *On Functional-Logic Programming and its Application to Testing*, 27.05.2010
Frank Kupke, *Robust Distributed Software Transaction for Haskell*, 19.11.2010

Publications

Published in 2010

Sebastian Fischer, Frank Huch, Thomas Wilke, *A Play on Regular Expressions (Functional Pearl)*, Proceedings of the 15th ACM SIGPLAN International Conference on Functional Programming, New York, NY, USA, ACM Press, 357 - 368 (2010)

Sergio Antoy, Michael Hanus, *Functional Logic Programming*, Communications of the ACM, **53(4)**, 74 - 85 (2010)

Michael Hanus, Sven Koschnicke, *An ER-based Framework for Declarative Web Programming*, Proc. of the Twelfth International Symposium on Practical Aspects of Declarative Languages, PADL 2010, **Springer LNCS 5937**, 201 - 216 (2010)

Bernd Braßel, Sebastian Fischer, Michael Hanus, Fabian Reck, *Transforming Functional Logic Programs into Monadic Functional Programs*, Proceedings of the 19th International Workshop on Functional and (Constraint) Logic Programming, **WFLP 2010**, 2 - 18 (2010)

Michael Hanus, *Lazy and Faithful Assertions for Functional Logic Programs*, Proceedings of the 19th International Workshop on Functional and (Constraint) Logic Programming, **WFLP 2010**, 50 - 64 (2010)

Sergio Antoy, Michael Hanus, *A Transformation Tool for Functional Logic Program Development*, Proc. of the 24th Workshop on (Constraint) Logic Programming, **WLP 2010**, 23 - 33 (2010)

Michael Hanus, Fabian Reck, *Proc. 27. Workshop der GI-Fachgruppe Programmiersprachen und Rechenkonzepte*, Christian-Albrechts-Universität zu Kiel, **Technical Report 1010**, (2010)

A. Alqaddoumi, S. Antoy, Sebastian Fischer, Fabian Reck, *The Pull-Tab Transformation*, Third International Workshop on Graph Computation Models, 127 - 133 (2010)

Sebastian Fischer, Frank Huch, Th. Wilke, *Reguläres Ausdruckstheater*, Proc. 27. Workshop der GI-Fachgruppe Programmiersprachen und Rechenkonzepte, 34 - 34 (2010)

Bernd Braßel, Sebastian Fischer, Michael Hanus, Fabian Reck, *Transforming Functional Logic Programs into Monadic Functional Programs*, Proc. 27. Workshop der GI-Fachgruppe Programmiersprachen und Rechenkonzepte, 129 - 129 (2010)

Presentations

Michael Hanus, *Lazy and Faithful Assertions for Functional Logic Programs*, 19th International Workshop on Functional and (Constraint) Logic Programming (WFLP 2010), Madrid, Spanien, 17.01.2010

Fabian Reck, *Transforming Functional Logic Programs into Monadic Functional Programs*, 19th International Workshop on Functional and (Constraint) Logic Programming (WFLP 2010), Madrid, Spanien, 17.01.2010

Michael Hanus, *An ER-based Framework for Declarative Web Programming*, Twelfth International Symposium on Practical Aspects of Declarative Languages, PADL 2010, Madrid, Spanien, 19.01.2010

Sebastian Fischer, Frank Huch, *Reguläres Ausdruckstheater*, 27. Workshop der GI-Fachgruppe Programmiersprachen und Rechenkonzepte, Bad Honnef, 03.-05.05.2010

Michael Hanus, *A Transformation Tool for Functional Logic Program Development*, 24th Workshop on (Constraint) Logic Programming (WLP 2010), Cairo, Egypt, 16.09.2010

Sebastian Fischer, *A Play on Regular Expressions*, 15th ACM SIGPLAN International Conference on Functional Programming (ICFP'10), 29.09.2010

Fabian Reck, *Transforming Functional Logic Programs into Monadic Functional Programs*, 27. Workshop der GI-Fachgruppe Programmiersprachen und Rechenkonzepte, Bad Honnef, Germany, 05.05.2010

Fabian Reck, *The Pull-Tab Transformation - An evaluation technique for functional logic programs*, Third International Workshop on Graph Computation Models, Enschede, The Netherlands, 02.10.2010

Further Activities and Events

M. Hanus: organization of the 27th Workshop of the GI-Fachgruppe Programmiersprachen und Rechenkonzepte, Bad Honnef (Germany), May 2010.

M. Hanus: program committee member of WFLP 2010 (19th Workshop on Functional and (Constraint) Logic Programming), Madrid (Spain), January 2010.

M. Hanus: program committee member of FLOPS 2010 (Tenth International Symposium on Functional and Logic Programming) Sendai, April 2010.

M. Hanus: program committee member of TFP 2010 (Eleventh Symposium on Trends in Functional Programming), Oklahoma (USA), May 2010.

M. Hanus: program committee member of LOPSTR 2010 (20th International Symposium on Logic-based Program Synthesis and Transformation), Hagen (Austria), July 2010.

M. Hanus: program committee member of WLP 2010 (24th Workshop on (Constraint) Logic Programming), Cairo (Egypt), September 2010.

M. Hanus: Member of the Editorial Board of the Journal of Functional and Logic Programming.

M. Hanus: chair of the executive committee of the Fachgruppe „Programmiersprachen und Rechenkonzepte“ of the Gesellschaft für Informatik e.V.

M. Hanus: member of the steering committee of the symposia on Logic-based Program Synthesis and Transformation.

M. Hanus: 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).

M. Hanus: member of the advisory board of the GLP (Gesellschaft für Logische Programmierung), German-speaking branch of the Association for Logic Programming (ALP).

M. Hanus: member of the selection committee of the DAAD (German Academic Exchange Service) for the project-related support to scientific cooperation with Spain and Portugal.

M. Hanus: member of the advisory board of the „Berufsakademie an der Wirtschaftsakademie Schleswig-Holstein“ .

M. Hanus: referee of the Ph.d. thesis Karl Klose (title: „On the Expressiveness of Declarative Meta-Languages“), Aarhus University, 2010.

M. Hanus: chair of the managing directorate of the Institute of Computer Science, University of Kiel.

M. Hanus: chair of the examinations board of computer science studies, University of Kiel.

M. Hanus: member of the convent of the Faculty of Engineering, University of Kiel.

M. Hanus: member of the Senate Curriculum Committee, University of Kiel.

M. Hanus: vice-member of the Senate Equal Opportunities Committee, University of Kiel.

M. Hanus: research stay related to „Functional Logic Program Development“ at Portland State University (Oregon, USA) with Prof. Sergio Antoy, February 10-24, 2010.

F. Huch: member of the Steering Committee of Symposia on Implementation and Application of Functional Languages (IFL).

F. Huch: chair of the executive committee of the Fachgruppe „Programmiersprachen und Rechenkonzepte“ of the Gesellschaft für Informatik e.V.

F. Huch: organisation (together with Thomas Wilke) of the „Schnupperstudium Informatik für Schülerinnen und Schüler“ , April 6 - 9, 2010, Kiel, 70 participants. Course on introduction to programming: navigation of a pirate ship by means of the programming language Erlang, final project: development and implementation of a distributed chat.

F. Huch: organisation (together with Thomas Wilke) of the „Schnupperstudium Informatik für Schülerinnen“ , October 18 - 22, 2010, Kiel, 22 participants, course on introduction to programming: navigation of the little ladybird Kara by means of the programming language Erlang, final project: development and implementation of a distributed chat.

F. Simon: participation in seminars for students planning professional careers.

F. Simon: „Computer Museum“ , representative of the Faculty of Engineering in the board of control.

Computer-Aided Program Development

For many years the group has investigated the fundamentals of programming languages and formal methods for problem specification and program development. Also for more than a decade a main topic has been relational methods, especially axiomatic relation algebra in the sense of Alfred Tarski, relational modelling, and the use of relation-algebraic techniques in mathematics and computer science. The latter has always been done in view of computer support and led to the development of the well-known Kiel tool RelView for the manipulation and visualization of relations and for relation-algebraic prototyping and programming. In the course of the ERS project LogICCC, for some years relational techniques and RelView have been combined with binary decision diagrams (BDDs) to solve computational problems from Social Choice Theory and the theory of cooperative games.

Results

With regard to the fundamentals of programming languages, in the last year we mainly concentrated on declarative programming languages, namely functional languages and their extensions to functional-logic ones. We have investigated type-based reasoning in the latter category of programming languages. Type-based reasoning is a very popular technique in functional programming. In particular, so-called parametric polymorphism, a feature that is part of all modern functional programming languages like Haskell, constrains functions in such a way that statements about their behaviour can be derived without consulting the definition of the functions. We have investigated whether the same is also true in a strongly and polymorphically typed functional logic language. To prove our example of driven observations, we started with the development of a functional-style denotational semantics for functional-logic programming languages.

Furthermore, in the context of fundamentals of programming languages and formal methods the group has worked on the semantic foundations of minimally strict sequential functions, again in the context of functional programming languages. In a functional programming language with a non-strict call-by-name semantics functions can differ with regard to their strictness. The less-strict a function is, on average the less storage is needed for its evaluation. We have developed a new technique (leading to the Haskell-based tool Sloth) that allows testing whether a sequential function exists that is less strict than a given one. Our technique is based on an approach to this problem that was developed by Olaf Chitil some years ago. Chitil's technique tries to find least strict functions instead of minimally strict ones. As a consequence, it is not able to consider sequential functions only. Like least strict functions non-sequential functions also may come into play. This is a serious drawback of the approach, since in all existing programming languages (without using dirty tricks) only sequential functions can be implemented.

Regarding the fundamentals of programming languages, in the last year our group also has investigated the possibility to model functional-logic programming languages as equations within a special form of algebra. Doing so, we have used order-sorted algebras as decisive means.

For many years we have combined relation algebra and the tool RelView since this approach turned out to be adequate for solving a lot of discrete problems. That it is appropriate for problems on graphs, orders and lattices is not surprising, since these structures are nothing else than (or closely related to) specific relations. The results of the last year showed that the relational approach also works quite well in the case of problems, which at first glance, seem far from relations. An example is the solution of specific timetabling problems for universities and similar educational institutions. Other applications stem from Social Choice Theory and Game Theory. As a third class of applications of relations and RelView chess problems should be mentioned. In the last year we have investigated independence and domination problems for chess pieces on certain kinds of chessboards. A result is, for example, the proof of the Bishops independence number for strictly rectangular chessboards, that has been found with the help of RelView experiments.

In the area of Social Choice Theory and cooperative games we concentrated again over this last year on simple games. Here the payoff of a group of players is either one (the coalition wins) or zero (the coalition loses). Specific classes of

simple games are weighted voting games and vector-weighted voting games. These play, for example, a decisive role in the analysis of decision-making processes like the formation of political coalitions after elections. We investigated some mechanisms for the formation of alliances and coalitions and the description and measurement of the strength of the single players in a simple game. For the latter there exist different possibilities. Strength can for example, be described by so called power indices (e.g., the well-known Banzhaf power index), by the classification of the set of powers using some key players (like dictators and dummy players), and by the use of the so-called desirability relation that relates two players with respect to the power of forming winning coalitions with other players. Many of the corresponding computational problems are of highly practical relevance, for instance, to analyze the distribution of power in the EU Council of Ministers, the International Monetary Fund, and in some other important organizations and committees, like the World Bank.

Our investigations have covered the application of relation algebra and the BDD-based RelView tool, as well as direct application of binary decision diagrams without the use of the language of relations as an intermediate language. The latter technique led to much faster algorithmic solutions. Binary decision diagrams can seamlessly be integrated into the RelView approach. Beside that, we have developed a standalone application for computing some standard power indices via the Web, that has been released during the last year. At present, we work on an extension of the RelView tool that allows the autosourcing of program logic into so-called plug-ins, and the development of appropriate BDD-based plug-ins for the fast solution of game-theoretic problems.

Finally, in a cooperation with the MIP Saarbrücken evolutionary multi-objective optimization has been investigated. This technique deals with the task of computing a minimal set of search points according to a given set of objective functions. Its application may lead to a cyclic behaviour that, in turn, may lead to worsening with respect to Pareto optimality. We have taken an order-theoretic view on evolutionary multi-objective optimization and have examined the use of indicator functions. This allowed us to prove in which situations well-known binary and unary indicators can help avoid cyclic behaviour.

Personnel

Head of the group: Prof. Dr. Rudolf Berghammer; Secretary: Ulrike Pollakowski

Scientific Staff:

Dipl.-Inf. Stefan Bolus 01.01.-31.12.2010 DFG
SOCIAL SOFTWARE for elections, the allocation of tenders and coalition/alliance formation (SSEAC)

Dr. phil. Bernd Braßel 01.01.-31.12.2010
Semantics of functional-logic programs and methods for debugging

Dipl.-Inf. Jan Christiansen 01.01.-31.12.2010
Investigations concerning strictness and non-strictness in functional languages

Dr. Martin Halfpap 01.01.-31.07.2010 CAU
Technical didactics of computer science

Lectures, Seminars, and Laboratory Course Offers

Winter 2009/2010

TEF-inf-FD2: Planung, Durchführung und Analyse von Informatikunterricht (im Praxismodul 2) (TEF-inf-FD2), 2 (+ 2) hrs Seminar (+ Exercises)/Week,
Martin Halfpap

Arbeitsgemeinschft Informatik, Logik und Mathematik, 2 hrs Seminar/Week,

Rudolf Berghammer (+ Michael Hanus)

MS0402: Ordnungen und Verbände, 4 (+ 2) hrs Exercise (+ Exercises)/Week,
Rudolf Berghammer (+ Bernd Braßel)

Oberseminar für Diplomanden und wiss. Mitarbeiter, 2 hrs Lecture/Week,
Rudolf Berghammer

Übung zu: Mathematik für Informatiker A - Grundlagen und Diskrete Strukturen, 2 hrs Exercise/Week,
Rudolf Berghammer

Vertiefende Übung zu: Planung, Durchführung und Analyse von Informatikunterricht (im Praxismodul 2), 2 hrs Exercise/Week,
Martin Halfpap

Summer 2010

A5.3.8: Fortgeschrittenenpraktikum - Rechnergestützte Programmentwicklung, 4 hrs Exercise/Week,
Rudolf Berghammer (+ Jan Christiansen, Bernd Braßel)

Arbeitsgemeinschaft Informatik, Logik und Mathematik, 2 hrs Seminar/Week,
Rudolf Berghammer (+ Michael Hanus)

BA6.10: Projektmodul - Rechnergestütze Programmentwicklung (iPhone Programmierung), 6 hrs Exercise/Week,
Rudolf Berghammer (+ Jan Christiansen, Bernd Braßel)

Fachdidaktik der Informatik, 2 (+ 2) hrs Seminar (+ Exercises)/Week,
Martin Halfpap

Inf-Math-A: Mathematik für Informatiker A - Grundlagen und Diskrete Strukturen, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
Rudolf Berghammer

Oberseminar, 2 hrs Seminar/Week,
Rudolf Berghammer

MSP0401: Fortgeschrittenenpraktikum - Rechnergestützte Programmentwicklung (iPhone Programmierung), 4 hrs Exercise/Week,
Rudolf Berghammer (+ Jan Christiansen, Bernd Braßel)

TEF-info-FD1: Grundlagen fachbezogenen Lehrens und Lernens im Fach Informatik (TEF-inf-FD1), 2 hrs Seminar/Week,
Martin Halfpap

WI11: Semantik von Programmiersprachen, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
Rudolf Berghammer (+ Jan Christiansen)

Winter 2010/2011

Arbeitsgemeinschft Informatik, Logik und Mathematik, 2 hrs Seminar/Week,
Rudolf Berghammer (+ Michael Hanus)

Oberseminar für Diplomanden und wiss. Mitarbeiter, 2 hrs Lecture/Week,
Rudolf Berghammer

Inf-EinfPP: Einführendes Programmierpraktikum, 2 hrs Exercise/Week,
Rudolf Berghammer (+ Jan Christiansen, Bernd Braßel, K. O. Kürtz, J. Schönborn)

Inf-Math-A: Mathematik für Informatiker A - Grundlagen und Diskrete Strukturen, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
Rudolf Berghammer (+ Barbara Langfeld, Christina Robenek, M. El Ouali)

Third-Party Funds

DFG, *LogiCCC: SOCIAL SOFTWARE for elections, the allocation of tenders and coalition/alliance formation (SSEAC)*, 01.01.-31.12.2010 (54.695,14 EUR)

LogiCCC: Computational Foundations of Social Choice (CFSC), *Reisezuschuss St. Bolus, COMSOC 2010, Düsseldorf*, 12.-17.09.2010 (556,60 EUR)

Further Cooperation, Consulting, and Technology Transfer

Applications of relational methods in computer science, with B. Möller (Augsburg), G. Schmidt (München), R.A. Schmidt (Manchester, UK), G. Struth (Sheffield, UK) and M. Winter (St. Catheriens, Canada).

Social software for elections, aggregation of tenders and coalition formation, with J.L. Garcia-Lapresta (Valladolid, Spain), H. Nurmi (Turku, Finland), A. Rusinowska (Lyon, France) and H. de Swart (Tilburg, The Netherlands).

Evolutionary and approximation algorithms, binary decision diagrams, with F. Neumann and T. Friedrich (Saarbrücken).

Semantic foundations and type-based reasoning for functional logic programming languages with J. Voigtländer and D. Seidel (Bonn)

Guests in the year 2010:

Prof. M. Winter (St.Catheriens, Kanada), 20. - 30. April 2010 Dr. F. Neumann (MPI, Saarbrücken), 26. - 30. Oktober 2010

Publications

Published in 2010

Jan Christiansen, Daniel Seidel, Janis Voigtländer, *Free Theorems for Functional Logic Programs*, Programming languages meets program verification. ACM, 39 - 48 (2010)

Jan Christiansen, Daniel Seidel, Janis Voigtländer, *A Denotational Semantics for Curry*, Provisional Proceedings of Workshop on Functional and (Constraint) Logic Programming. Universidad Politecnica de Madrid, 89 - 90 (2010)

Rudolf Berghammer, Britta Kehden, *Relation-algebraic specification and solution of special university timetabling problems.*, Journal on Logic and Algebraic Programming, **79**, 722 - 739 (2010)

Rudolf Berghammer, Bernhard Möller, Georg Struth, *Special issue on Relations and Kleene Algebra in Computer Science*, Journal on Logic and Algebraic Programming, **79**, **issue B**, (2010)

Agnieszka Rusinowska, Harrie de Swart, *Applying relation algebra and RelView to measures in a social network*, European Journal of Operational Research, **202**, 182 - 198 (2010)

Rudolf Berghammer, Michael Winter, *Embedding mappings and splittings with applications*, Acta Informatica, **47**, 77 - 110 (2010)

Rudolf Berghammer, Stefan Bolus, *On the use of BDDs for solving problems on simple games. algorithm development*, Steinbach B. (ed.: Proc. 9th International Workshop on Boolean Problems. Freiberg, 16.9.-19.7. 2010, TU Bergakademie Freiberg), 113 - 124 (2010)

Rudolf Berghammer, Frank Neumann, Tobias Friedrich, *Set-based multi-objective optimization, indicators and deteriorative cycles*, Pelikan M., Branke J. (eds.): Proc. 15th Genetic and Evolutionary Computation Conference (GECCO 2010), Portland (USA), 7.7.-11.7. 2010, ACM, 495 - 502 (2010)

Rudolf Berghammer, Georg Struth, *On automated program construction and verification*, Bolduc C., Desharnais J., Ktari B. (eds.): Proc. 10th Conference on Mathematics of Program Construction (MPC '10), Quebec (Canada), 21.6.-23.6. 2010, LNCS, Springer: Berlin-Heidelberg-New York, **6120**, 22 - 41 (2010)

Rudolf Berghammer, Stefan Bolus, *Problem Solving on Simple Games via BDDs,* Conitzer V. and Rothe J. (eds.): Proceedings of the 3rd International Workshop on Computational Social Choice, 11 - 12 (2010)

Bernd Braßel, Sebastian Fischer, Michael Hanus, Fabian Reck, *Transforming Functional Logic Programs into Monadic Functional Programs,* Proceedings of the 19th International Workshop on Functional and (Constraint) Logic Programming, WFLP 2010, 2 - 18 (2010)

Rudolf Berghammer, Bernd Braßel, *Functional (Logic) Programs as Equations over Order-Sorted Algebras,* Till Mossakowski (ed.): Proceedings of the 20th International Workshop on Algebraic Development Techniques WADT 2010, (2010)

Bernd Braßel, *Using Haskell's Type Systems to Check Relation Algebraic Programs,* Proceedings of the 27. Workshop der GI-Fachgruppe Programmiersprachen und Rechenkonzepte, (2010)

Presentations

Jan Christiansen, *Minimally Strict Polymorphic Functions,* 27. Workshop der GI-Fachgruppe Programmiersprachen und Rechenkonzepte, Bad Honnef, Germany, 03.-05.05.2010

Rudolf Berghammer, *A functional and successor-based version of Warshall's algorithm,* 27. Workshop der GI-Fachgruppe, Bad Honnef, Germany, 03.-05.05.2010

Rudolf Berghammer, *Combining relation algebra and RelView in formal algorithm development,* SSEAC Workshop, Turku, Finland, 08.-09.06.2010

Rudolf Berghammer, Georg Struth, *On automated program construction and verification,* 10th Conference on Mathematics of Program Construction, Quebec, Canada, 21.-23.06.2010

Rudolf Berghammer, Sebastian Fischer, *Simple functional programs for computing reflexive-transitive closures,* 20th International Symphosium on logic-based program synthesis and transformation, Hagenbarg, Austria, 23.-25.07.2010

Rudolf Berghammer, Stefan Bolus, *On the use of BDDs for solving problems on simple games, algorithm development,* 9th International Workshop on Boolean Problems, Freiberg, Germany, 16.-19.09.2010

Stefan Bolus, *Problem Solving on Simple Games via BDDs,* 3rd International Workshop on Computational Social Choice (COMSOC), Düsseldorf, Germany, 12.-17.09.2010

Stefan Bolus, *Simple games, voting power and binary decisin diagrams,* SSEAC Workshop on Voting and Allocation Systems, Turku, Finland, 08.-09.06.2010

Rudolf Berghammer, Bernd Braßel, *Functional (Logic) Programs as Equations over Order-Sorted Algebras,* 20th International Workshop on Algebraic Development Techniques WADT 2010, Schloss Etelsen, Germany, 01.-04.07.2010

Bernd Braßel, *Using Haskell's Type Systems to Check Relation Algebraic Programs,* 27. Workshop der GI-Fachgruppe Programmiersprachen und Rechenkonzepte, Bad Honnef, Germany, 03.-05.05.2010

Further Activities and Events

Rudolf Berghammer, Stefan Bolus, Bernd Braßel, and Jan Christiansen worked as reviewers for scientific publications.

Rudolf Berghammer is a member of the international working group "Relational Methods in Computer Science. He is the chair of the steering commitee 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". He is a member of the programme committee of RAMiCS 12, held in May 2011 in Rotterdam.

Rudolf Berghammer is a member of the German initiative "Softwarevisualisierung".
For details, see URL http://www.softwarevisualisierung.de.

Scientific Computing

The group focuses on developing fast solvers for mathematical problems. This task includes several aspects:

1. the mathematical problem has to be translated into a form that can be handled by a computer (typically by approximation and discretization),

2. the relevant data has to be represented as efficiently as possible (using suitable compression techniques),

3. the solution has to be computed by a fast method (we currently focus on hierarchical matrices and multigrid iterations), and

4. the algorithms have to be implemented in a way that takes advantage of the properties of the computer architecture that will be used to solve them (e.g., by preparing them for parallelization or vectorization).

Current research topics are the method of hierarchical matrices for treating non-local phenomena and fast solvers for partial differential equations.

Personnel

Head of the group: Prof. Dr. S. Börm; Secretary: D. Scheel (50%)

Scientific Staff:

Dipl.-Math D. Boysen	01.10.-31.12.2010	(50%)	CAU
Dipl.-Math J. Burmeister	01.01.-31.12.2010		CAU
Dipl.-Math J. Gördes	01.01.-31.12.2010		DFG
Separation der Fundamentallösungen elliptischer Differentialgleichungen mit Hilfe von Quadraturverfahren			
Dipl.-Math K. Reimer	01.01.-31.12.2010		CAU

Lectures, Seminars, and Laboratory Course Offers

Winter 2009/2010

Elementare numerische Methoden und ihre Implementierung I (Blockkurs), 2 hrs Lecture/Week,
S. Börm (+ J. Burmeister)

Iterative Verfahren für große Gleichungssysteme, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
S. Börm (+ K. Reimer)

Einführung in die numerische Mathematik, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
S. Börm (+ J. Burmeister)

Oberseminar - Numerische Mathematik, 2 hrs Seminar/Week,
S. Börm (+ T. Slawig, M. Braack)

Seminar - Numerische Mathematik und Optimierung, 2 hrs Seminar/Week,
S. Börm (+ T. Slawig, J. Burmeister)

Summer 2010

Absolventen-Seminar Scientific Computing, 2 hrs Seminar/Week,
S. Börm (+ J. Burmeister)

Elementare numerische Methoden und ihre Implementierung II (Blockkurs), 2 hrs Lecture/Week,
S. Börm (+ J. Burmeister)

Numerische Verfahren für Differentialgleichungen, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
S. Börm (+ K. Reimer)

Hierarchische Matrizen (Mathematisches Praktikum), 2 (+ 4) hrs Lecture (+ Exercises)/Week,
S. Börm (+ K. Reimer, J. Burmeister)

Numerische Behandlung naturwissenschaftlicher Probleme (Numerische Mathematik für Ingenieure), 2 (+ 1) hrs Lecture (+ Exercises)/Week,
S. Börm (+ J. Gördes)

Seminar - Numerische Mathematik und Optimierung, 2 hrs Seminar/Week,
S. Börm (+ J. Burmeister, T. Slawig)

Winter 2010/2011

Absolventen-Seminar Scientific Computing, 2 hrs Seminar/Week,
S. Börm (+ J. Burmeister)

Analysis III, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
S. Börm (+ J. Burmeister, K. Reimer, D. Boysen)

Elementare numerische Methoden und ihre Implementierung I (Blockkurs), 2 hrs Lecture/Week,
S. Börm (+ J. Burmeister)

Iterative Verfahren für große Gleichungssysteme, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
S. Börm (+ K. Reimer)

Seminar - Numerische Mathematik und Optimierung, 2 hrs Seminar/Week,
S. Börm (+ T. Slawig, J. Burmeister)

Third-Party Funds

Deutsche Forschungsgesellschaft, *Separation der Fundamentallösungen elliptischer Differentialgleichungen mit Hilfe von Quadraturverfahren,* 01.02.2010-31.01.2013 (170.500 EUR)

Diploma, Bachelor and Master Theses

M. Franck, *Effiziente numerische Simulation von Teilchensystemen,* 18.08.2010
M. Pfeil, *Numerische Berechnung von Schnittkurven zwischen ausgerollten Flächen und Freiformflächen,* 17.11.2010
U. Schröder, *Das MG-CG-Verfahren zur Lösung elliptischer partieller Differentialgleichungen mit unstetigen Koeffizienten,* 25.03.2010

Publications

Published in 2010

S. Börm, *Approximation of solution operators of elliptic partial differential equations by H- and H^2-matrices,* Numerische Mathematik, **115**, 165 - 193 (2010)
S. Börm, *Efficient Numerical Methods for Non-local Operators,* EMS Tracts in Mathematics, **14**, (2010)

Presentations

S. Börm, *Weighted H^2-Matrix Compression,* GAMM 2010, Karlsruhe, DE, 22.-26.03.2010

J. Gördes, *Eigensolver for Hierarchical Matrices*, GAMM 2010, Karlsruhe, DE, 22.-26.03.2010
K. Reimer, *Using H^2-Matrices to approximate Forces in Particle Simulations*, GAMM 2010, Karlsruhe, DE, 22.-26.03.2010

Further Activities and Events

Steffen Börm is a member of the cluster of excellence **Future Ocean** and the **Computational Sciences Centre**.

Software Engineering

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 continuously provide services with required quality properties is another great challenge. One Goal of the Software Engineering Group is to investigate innovative techniques and methods for engineering and operating continuously operating software systems.

Since October 2008, Prof. Dr. Wilhelm Hasselbring has been head of the Software Engineering Group. Beforehand, he was head of the Software Engineering Group at the University of Oldenburg. Until 2010, Prof. Hasselbring was still associated with the DFG Graduate School TrustSoft (http://trustsoft.uni-oldenburg.de) and the OFFIS institute (http://www.offis.de). Currently, he intends to establish the new KoSSE network together with other colleagues of the Computer Science Institutes in Kiel and Lübeck (https://www.kosse-sh.de). In 2010, the KoSSE projects MENGES and Xbase started, and the project DynaMod (Dynamic Analysis for Model-Driven Modernization) has been acquired to start in 2011. One recent milestone is the establishment of a KoSSE office together with the Cluster Management DiWiSH (http://www.diwish.de/).

Results

BIS-Grid

The BIS-Grid project, as part of the German D-Grid initiative, investigates service orchestration using Grid service technologies to show how such technologies can be employed for information systems integration, especially when crossing enterprise boundaries. Small and medium enterprises will be enabled to integrate heterogeneous business information systems and to use external resources and services with affordable effort. BIS-Grid supports the new orchestration as a Service (OaaS) paradigm. The BIS-Grid workflow engine orchestrates both plain Web services and stateful, WSRF-based Grid services. For more information, refer to http://bisgrid.d-grid.de.

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. Needed for the robust operation are means for effective monitoring of software runtime behaviour. 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 monitoring 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 with a telecommunication customer self-service and a digital photo submission service. Kieker is available as open-source software. For more information on Kieker, refer to http://kieker.sourceforge.net.

MENGES

The objective of the project MENGES is the development of a model-driven software toolchain for a new type of electronic railway control centres. The project started in January 2010 and will last to December 2012. It is associated to KoSSE (Kompetenzverbund Software Systems Engineering, engl. Competence Federation Software Systems Engineering) and

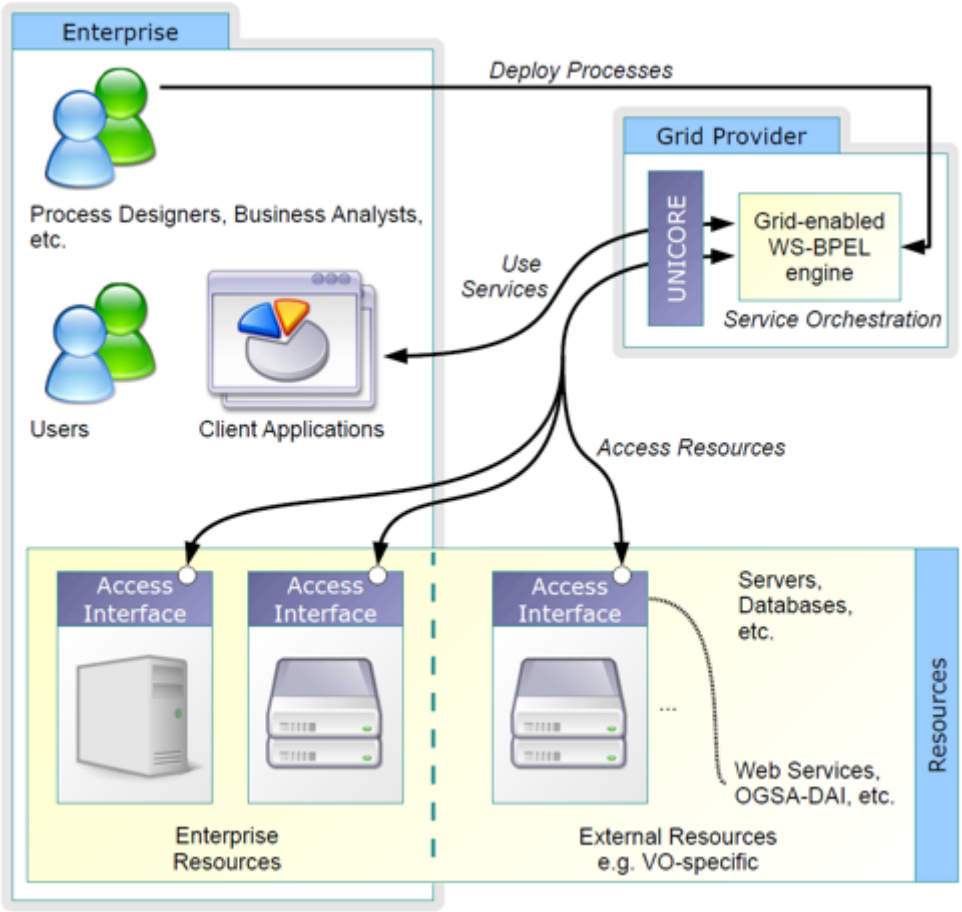

Fig. 1: Orchestration as a Service (OaaS) with the BIS-Grid workflow engine

funded by ZPW (Zukunftsprogramm Wirtschaft), a programme to support research and development in Schleswig-Holstein. Project partners are Funkwerk Information Technologies GmbH, Kiel, b+m Informatik AG, Melsdorf and the groups for Software Engineering and for Real-Time and Embedded Systems of Christian Albrechts University Kiel.

In the first project year, the research focused on engineering the application domain of electronic railway control centres, the technical domain of programmable logic controllers and the development of domain specific languages (DSL) for describing topological and behavioural structures of this application domain. The application domain has (especially in the topological aspect) a wide range of variations, due to topographical and technical specifics, as well as existing components. Therefore, the design of the DSLs and its meta model includes variation points for future extensions. The toolchain is based on Eclipse EMF for meta modelling, Xtext for implementing textual DSLs, Kieler for layout of graphical DSLs, and Kieker for Profiling and Monitoring. Furthermore different techniques of DSL coupling were explored and the findings have been presented to the research community on various conferences and workshops (SEACON, KoSSE-Tag Kiel, Transportforum, MDD-RW Karlsruhe, KoSSE-Workshop) in 2010. For more information on MENGES, refer to https://menges.informatik.uni-kiel.de/

Xbase

In the project Xbase a new base language for the language development framework Xtext will be developed. The project started in May 2010 and will last to April 2012. The project is funded by the BMBF KMU Innovativ initiative and associated with KoSSE. This project is realized in cooperation with itemis AG. Xbase is an open source project and released with Xtext.

In the first eight months of the project, we focused on the Xbase language syntax and its type system. These specifications

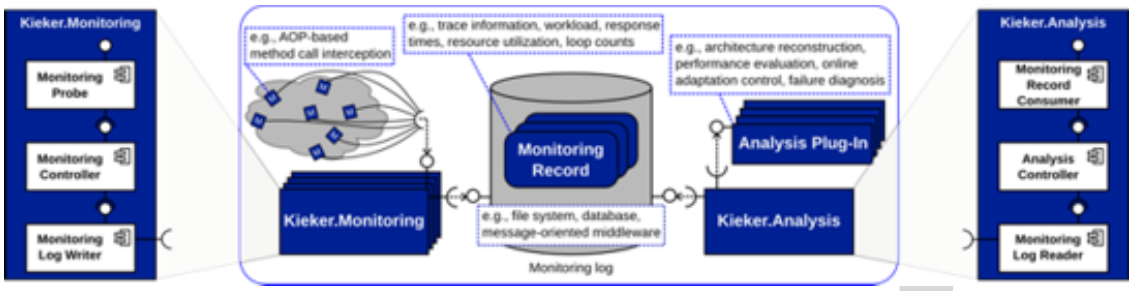

Fig. 2: The Kieker Monitoring Framework Architecture

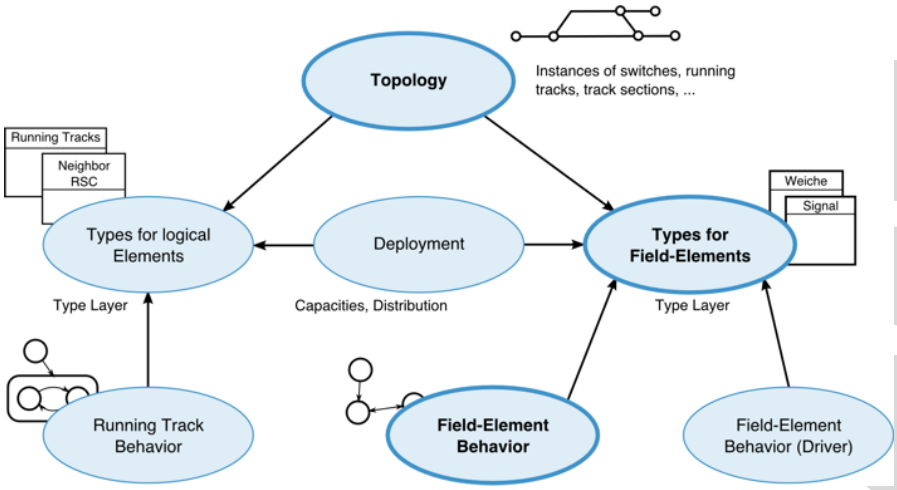

Fig. 3: Current landscape of domain specific languages in MENGES

are essential for the development of a runtime environment, i.e. an interpreter. For proper documentation, the language Xdoc was developed. Featuring concepts that are recurring in many documentation tasks, such as embedding code blocks in various languages or linking to Java classes, Xdoc is able to generate Eclipse help plugins as well as PDF. The Xbase language specification is written in Xdoc and the previous Xtext documentation has been migrated to Xdoc. For more information on Xbase, refer to https://kosse-sh.de/projekte/xbase/.

Personnel

Head of the group: Prof. Dr. W. Hasselbring; Secretary: H. Capell (50%)
Technical Staff: B.Sc. M. Westphal (50%)

Staff:

Prof. Dr. W.-P. de Roever	01.01.-31.12.2010	retired

Scientific Staff:

Dipl.-Wirt.-Inf. J. Ehlers Kieker, eProject	01.01.-31.12.2010	CAU
M.Sc. S. Frey Kieker	01.01.-31.12.2010	CAU

Dipl.-Inform. S. Gudenkauf BIS-Grid	01.01.-31.12.2010	OFFIS, BMBF
M.Sc. I. Gul TrustSoft	01.01.-31.12.2010	DFG
Dipl.-Inform. R. Jung MENGES, Kieker	01.11.-31.12.2010	ZPW
Dipl.-Inform. G. Scherp BIS-Grid	01.01.-31.12.2010	OFFIS, BMBF
Dipl.-Inform. N. Streekmann IF-ModE	01.01.-31.12.2010	OFFIS, BMBF
Dipl.-Inform. A. van Hoorn TrustSoft, Kieker	01.01.-31.12.2010	DFG
Dipl.-Inform. R. von Massow Xbase	01.05.-31.12.2010	BMBF
Dipl.-Inf. J. Waller Kieker	01.01.-31.12.2010	CAU

Lectures, Seminars, and Laboratory Course Offers

Winter 2009/2010

Informatik III - Softwaretechnologie, 4 (+2) hrs Lecture (+ Exercises)/Week,
W. Hasselbring (+ S. Frey, J. Waller, S. Esquivel)

Softwarepraktikum, 3 hrs Exercise/Week,
W. Hasselbring (+ J. Ehlers)

Masterseminar - Software Performance Engineering, 2 hrs Seminar/Week,
W. Hasselbring (+ J. Ehlers, J. Waller, A. van Hoorn)

Masterabschlussseminar - Software Engineering, 2 hrs Seminar/Week,
W. Hasselbring

Summer 2010

Softwarepraktikum, 3 hrs Exercise/Week,
W. Hasselbring (+ J. Ehlers)

Fortgeschrittenenpraktikum - Software Engineering, 4 hrs Exercise/Week,
W. Hasselbring (+ S. Frey, J. Waller)

Projektmodul - Software Engineering, 6 hrs Exercise/Week,
W. Hasselbring (+ J. Waller, S. Frey, J. Ehlers)

Masterprojekt - Software Engineering für parallele und verteilte Systeme, 4 hrs Exercise/Week,
W. Hasselbring (+ S. Frey, J. Waller, J. Ehlers)

Masterseminar - Software Performance Engineering, 2 hrs Seminar/Week,
W. Hasselbring (+ J. Ehlers, J. Waller, S. Frey, A. van Hoorn)

Winter 2010/2011

Softwarearchitektur, 2 (+ 1) hrs Seminar (+ Exercises)/Week,
W. Hasselbring (+ S. Frey)

Softwarepraktikum, 3 hrs Exercise/Week,
W. Hasselbring (+ J. Ehlers)

Softwaretechnik, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
W. Hasselbring (+ S. Frey, J. Waller)

Masterseminar - Software Performance Engineering, 2 hrs Seminar/Week,
W. Hasselbring (+ J. Ehlers, J. Waller, A. van Hoorn, S. Frey)

Masterabschlussseminar - Software Engineering, 2 hrs Seminar/Week,
W. Hasselbring

Third-Party Funds

BMBF, *BIS-Grid: Betriebliche Informationssysteme: Grid-basierte Integration und Orchestrierung,* 01.05.2007-30.04.2010 (379.426 EUR)
DFG, *Graduiertenkolleg TrustSoft (Uni Oldenburg)*, 01.04.2005-30.09.2010 (two Ph.D. scholarships)
Zukunftsprogramm Wirtschaft (ZPW), *MENGES: Modellbasierte Entwurfsmethoden für eine neue Generation elektronischer Stellwerke*, 01.08.2009-31.12.2012 (217.560 EUR)
BMBF, *Verbundprojekt Xbase: Produktivitätssteigerung bei der Implementierung domänspezifischer Sprachen durch effektive Wiederverwendung*, 01.05.2010-30.04.2012 (133.205 EUR)
CAU, *eProject - Einführung von Kooperationswerkzeugen für Softwareprojekte in der Lehre*, 01.06.2010-30.05.2011 (4622 EUR)

Further Cooperation, Consulting, and Technology Transfer

In BIS-Grid, we cooperate via the OFFIS-Institute with CADsys Vertriebs- und Entwicklungsgesellschaft mbH, CeWe Color AG & Co. OHG, Forschungszentrum Jülich, KIESELSTEIN GmbH, Siemens IT Solutions and Services, TU Berlin, and with the Paderborn Centre for Parallel Computing (PC2).

In TrustSoft, we cooperate within the context of the Kieker project with EWE TEL GmbH and CeWe Color AG & Co. OHG.

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

In eProject, we cooperate with eLK.Medien, the CAU service centre for e-learning.

In MENGES, we cooperate with b + m Informatik AG and with Funkwerk Information Technologies GmbH as well as with the group for realtime systems and embedded systems (Prof. Dr. Reinhard von Hanxleden).

In Xbase, we cooperate with itemis AG on extending the Xtext language development framework (http://www.eclipse.org/Xtext/).

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.

Diploma, Bachelor and Master Theses

B. Schnoor, *Modeling Usage and Architecture Metrics for Software Systems Applying OMG's KDM and SMM,* 30.09.2010

D. Zimmermann, *Eigenschaften, Entwurf und Evaluation ressourceneffizienter Softwarearchitekturen*, 30.09.2010

C. Wulf, *Runtime Visualization of Static and Dynamic Architecture Views of a Software System to Identify Performance Problems*, 31.03.2010

F. Fittkau, *Reconstructing Software Architectures using the Code- and Structure Package of the Knowledge Dicovery Meta-Model*, 28.02.2010

R. von Massow, *Performance Simulation of Runtime Reconfigurable Software Architectures*, 01.04.2010

Publications

Published in 2010

W. Hasselbring, A. Brinkmann, *3. Grid Workflow Workshop (GWW 2010)*, Software Engineering 2010 - Fachtagung des GI-Fachbereichs Softwaretechnik, **159**, 242 - 243 (2010)

S. Gudenkauf, *A Coordination-Based Model-Driven Method for Parallel Application Development*, Models in Software Engineering, Springer Lecture Notes in Computer Science, **6002**, 21 - 35 (2010)

W. Hasselbring, *Betriebliche Informationssysteme: Grid-basierte Integration und Orchestrierung*, GITO Verlag, (2010)

S. Bärisch, *Domain-Specific Model-Driven Testing*, Vieweg + Teubner Verlag, (2010)

G. Scherp, W. Hasselbring, *Ein modellgetriebener Ansatz zur Nutzung von WS-BPEL für Scientific Workflows*, Software Engineering 2010 - Workshopband, **160**, 201 - 208 (2010)

N. Streekmann, *Model-Based Architecture Restructuring of a Large Industrial System*, Softwaretechnik-Trends, **2**, 58 - 59 (2010)

S. Frey, W. Hasselbring, *Model-Based Migration of Legacy Software Systems into the Cloud: The CloudMIG Approach*, Softwaretechnik-Trends, **2**, 84 - 85 (2010)

S. Frey, W. Hasselbring, *Model-Based Migration of Legacy Software Systems to Scalable and Resource-Efficient Cloud-Based Applications: The CloudMIG Approach*, Proceedings of the First International Conference on Cloud Computing, GRIDs, and Virtualization, 155 - 158 (2010)

R. von Massow, A. van Hoorn, W. Hasselbring, *Performance Simulation of Runtime Reconfigurable Component-Based Software Architectures*, Proc. International Conference on Architecture-based Software Quality Prediction (Palladio Days 2010), **Institut für Informatik TR-101**, (2010)

J. Matevska, *Rekonfiguration komponentenbasierter Softwaresysteme zur Laufzeit*, Vieweg + Teubner Verlag, (2010)

T. Warns, *Structural Failure Models for Fault-Tolerant Distributed Computing*, Vieweg + Teubner Verlag, (2010)

S. Giesecke, M. Gottschalk, W. Hasselbring, *The ArchMapper Approach to Architectural Conformance Checks: An Eclipse-based Tool for Style-oriented Architecture to Code Mappings*, Tagungsband des 3. Workshops zur Software-Qualitätsmodellierung und -bewertung, 71 - 80 (2010)

G. Scherp, W. Hasselbring, *Towards a Model-Driven Transformation Framework for Scientific Workflows*, 3rd International Workshop on Software Engineering for Computational Science and Engineering, 1513 - 1520 (2010)

I. Gul, W. Hasselbring, *Towards Power Consumption Reduction by User Behavior Monitoring at Application level*, Proceedings of the 23rd International Conference on Architecture of Computing Systems (ARCS 2010), 377 - 386 (2010)

W.-P. de Roever, G. Lüttgen, M. Mendler, *What Is in a Step: New Perspectives on a Classical Question*, Time for Verification, Springer Lecture Notes in Computer Science, **6200**, 370 - 399 (2010)

S. Gudenkauf, G. Scherp, A. Höing, W. Hasselbring, O. Kao, *Workflow Modeling for WS-BPEL-based Service Orchestration in SMEs*, Software Engineering 2010 – Workshopband, **160**, 185 - 192 (2010)

A. Rohr, A. van Hoorn, W. Hasselbring, M. Lübke, S. Alekseev, *Workload-Intensity-Sensitive Timing Behavior Analysis for Distributed Multi-User Software Systems*, Proceedings of the Joint WOSP/SIPEW International Conference on Performance Engineering, 87 - 92 (2010)

R. Jung, *DSL-Konzept-Idee*, MENGES Koordinierungstreffen, Kiel, Germany, 06.01.2010

G. Scherp, *Ein Transformations-Framework zur modellgetriebenen Abbildung von fachlichen zu technischen Scientific Workflows*, Oberseminar (Frank Leymann), Stuttgart, Germany, 02.02.2010

G. Scherp, *Ein modellgetriebener Ansatz zur Nutzung von WS-BPEL für Scientific Workflows*, Grid Workflow Workshop (Software Engineering 2010), Paderborn, Germany, 23.02.2010

W. Hasselbring, *KoSSE: Kompetenzverbund Software Systems Engineering*, Software Engineering Forum der Informatik-Transferinstitute (SE FIT 2010), Paderborn, Germany, 25.02.2010

W. Hasselbring, A. van Hoorn, *Effektives Monitoring im Betrieb von Softwaresystemen*, IT-Anwenderkreis Norddeutschland, Kiel, Germany, 09.03.2010

N. Streekmann, *Model-Based Architecture Restructuring of a Large Industrial System*, 12. Workshop Software-Reengineering (WSR 2010), Bad Honnef, Germany, 05.05.2010

S. Frey, *Model-Based Migration of Legacy Software Systems into the Cloud: The CloudMIG Approach*, 12. Workshop Software-Reengineering (WSR 2010), Bad Honnef, Germany, 05.05.2010

R. Jung, *Vorstellung, Einleitung und Ausblick*, Kieker-Workshop im Rahmen des MENGES-Projekts, Kiel, Germany, 10.05.2010

G. Scherp, *Towards a Model-Driven Transformation Framework for Scientific Workflows*, Third International Workshop on Software Engineering for Computational Science and Engineering (International Conference on Computational Science 2010), Amsterdam, Netherlands, 31.05.2010

W. Hasselbring, W. Goerigk, *Domänenmodellierung und MDSE im Entwurf elektronischer Stellwerke: Wer stellt die Weichen - und wenn ja, wieviele?*, Software Engineering im Norden (SEACON 2010), Hamburg, Germany, 28.06.2010

A. van Hoorn, *Online Capacity Management for Increased Resource Efficiency of Component-Based Software Systems*, Internes Kolloquium des Departments für Informatik der Universität Oldenburg, Oldenburg, Germany, 01.07.2010

R. Jung, *MDSD for Railway Control Centers*, Model-driven Development in the Real World (MDD RW), Karlsruhe, Germany, 27.-28.07.2010

R. Jung, *Model-driven Instrumentation for DSL*, Internes Kolloquium, Kiel, 03.11.2010

R. Jung, R. von Massow, *Erfahrungen mit Xtext zur Entwicklung domänenspezifischer Sprachen und geplante Erweiterungen in Xbase*, KoSSE-Workshop 2010, Lübeck, Germany, 10.11.2010

S. Frey, *Model-Based Migration of Legacy Software Systems to Scalable and Resource-Efficient Cloud-Based Applications: The CloudMIG Approach*, 1st International Conference on Cloud Computing, GRIDs, and Virtualization (Cloud Computing 2010), Lissabon, Portugal, 23.11.2010

R. von Massow, A. van Hoorn, *Performance Simulation of Runtime Reconfigurable Component-Based Software Architectures*, Palladio Days 2010, Karlsruhe, Germany, 25.11.2010

J. Ehlers, *Adaptive Performance Monitoring - The Kieker Monitoring Framework*, IT Operations Management Workshop, Bern, Switzerland, 26.11.2010

R. Jung, *Modellgetriebene Entwicklung für neue elektronische Stellwerke*, Internes Kolloquium, Kiel, Germany, 26.11.2010

R. von Massow, *Monitoring simulated systems using Kieker*, MENGES Kieker-Workshop, Kiel, 10.05.2010

R von Massow, *Xbase – a Base Language for Xtext*, Model-driven Development in the Real World (MDD RW), Karlsruhe, 27.-28.07.2010

Further Activities and Events

W. Hasselbring:

- chairman of the board of GI-Fachgruppe Softwaretechnik,
- board of GI-Fachgruppe Software-Architektur,
- board of GI-Querschnittsfachausschuss Modellierung,
- vice chair of D-Grid-Beirat.
- Reviewer for the following funding agencies:
  - Deutsche Forschungsgemeinschaft (DFG),
  - Natural Sciences and Engineering Research Council of Canada (NSERC),
  - Arbeitsgruppe Innovative Projekte beim niedersächsischen Ministerium für Wissenschaft und Kultur (AGIP).
- Editorial Board of the following journals:
  - Advances in Software Engineering,
  - Datenbank-Spektrum, Special Section ''Programmierung von Datenbankanwendungen'',
  - Enterprise Modelling and Information Systems Architectures - An International Journal,
  - International Journal of Software Architecture,
  - International Review on Modelling and Simulations,
  - Softwaretechnik-Trends.
- Reviewer for the following journals and publishers:
  - Computer Science – Research and Development,
  - dpunkt Verlag,
  - IEEE Software,
  - IEEE Transactions of Software Engineering,
  - Journal of Systems and Software,
  - Science of Computer Programming,
  - Software and Systems Modelling,
  - Software: Practice and Experience,
  - Vieweg + Teubner Verlag.
- Member of the program committee for various conferences and workshops such as:

SE 2010: GI-Fachtagung Software Engineering ,
CSMR 2010: 14th European Conference on Software Maintenance and Reengineering,
EMDT 2010: First International Workshop on Evolution Support for Model-Based Development and Testing,
DFF 2010: 2nd Workshop Design for Future,
TEAR 2010: Trends on Enterprise Architecture Research Workshop,
Informatik 2010:
Workshop Service-Orientierte Architekturen im Gesundheitswesen
, Workshop Servicebasierte Entwicklung und Evolution von Software-Produktlinien
, Workshop Software und Service Engineering für mobile Dienste
, Workshop IT-Governance in verteilten Systemen
, Workshop Integration Engineering,

ECSA 2010: European Conference on Software Architecture,

MODELS 2010: 3rd International Workshop on Non-functional System Properties in Domain Specific Modelling Languages,

SE 2011: GI-Fachtagung Software Engineering,

WI 2011: Development/Architecture of IS track,

IMETI 2010: 3rd International Multi-Conference on Engineering and Technological Innovation,

ESoSyM 2011: Evolutionäre Software- und Systementwicklung - Methoden und Erfahrungen,

CSMR 2011: 15th European Conference on Software Maintenance and Reengineering,

SQMB 2011: Workshop zur Software-Qualitätsmodellierung und -bewertung,

DFF 2011: 3nd Workshop Design for Future,

GWW 2011: 4th Grid Workflow Workshop,

TEAR 2011: Trends on Enterprise Architecture Research Workshop,

ESEC/FSE 2011: European Software Engineering Conference and the ACM SIGSOFT Symposium on the Foundations of Software Engineering Industrial Track.

- Organization of:
  - Grid Workflow Workshop 2010,
  - KoSSE-Tag 2010,
  - workshop Model-Driven Software Migration (MDSM 2011),
  - ECSA 2011 – Tutorial and Workshop Chair.

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 lies on massively parallel systems: particularly systems that can speed up computer intensive operations by the use of special purpose hardware architectures. The activities during 2010 can be subsumed under three headings: first, the ongoing development of the massively parallel architecture RIVYERA, second, the development and implementation of new parallel algorithms for specific, computationally demanding problems in bioinformatics, and third, the deployment of massively parallel algorithms for economic optimisation problems.

Results

Next Generation COPACOBANA

Many problems in scientific computing and crypto analysis are currently intractable due to the limitations of standard pc architectures or clusters of those. Solutions for that lack of performance are problem specific architectures like supercomputers, grid computing or even application specific ASICs. Lately, a new architectural approach has proven its benefits: the field programmable gate arrays. These reconfigurable silicon devices combine the flexibility of general-purpose circuits, like CPUs in computers, with the speed-up of application specific integrated circuits, ASICs.

The research group technical computer science utilizes these reconfigurable devices in a massively parallel architecture called COPACOBANA. The project COPACOBANA, the Cost Optimized COde Breaker and ANAlyser is as yet the only known affordable hardware for breaking DES (data encryption standard). It was developed in collaboration with the university of Bochum between 2005 and 2007.

In order to meet the requirements of modern bio-informatics, a number of additional features for COPACOBANA were desired. In a HWT2-project funded by the ISH (Innovation Society Schleswig-Holstein), the architecture RIVYERA has been designed for this purpose. During 2009 and 2010 this design was implemented in several stages. It uses new versions of the XilinX-Spartan series, the Spartan3-5000. The first complete prototype of the new machine operated in July 2010.

Algorithms in Bio-Informatics

In the area of bio-informatics several projects have been completed and others are in progress. These projects span a variety of different algorithms in bio-informatics, primarily motif finding, sequence alignment, and short read assembly/error correction.

A problem in motif search algorithms in biosequences is to distinguish between so called repeat regions and motifs. We found a new approach to detect motifs by collecting statistical information of the candidates and using it to assign probabilities for real motif occurrences in the sequence. This work was done in collaboration with the Institute for Clinical Molecular Biology of the CAU.

The second main topic was the development of bio-informatic algorithms for the new RIVYERA architecture. One of the most computer intensive tasks in bio-informatics is the alignment of two DNA sequences. Due to this fact, many researchers use heuristics like BLAST which are fast but imprecise. With the RIVYERA architecture it becomes feasible to produce precise results in reasonable time. In this area a new parallel implementation of the Smith-Waterman-Algorithm has been found and implemented on the RIVYERA.

New algorithms for motif search, sequence assembly, and error correction were developed in cooperation with National ICT Australia and RMIT in Melbourne. DNA sequencing is spoken of as one of the most significant techniques of the century. Its relevance to progress in medical and biological research is profound. Sequencing means the process of translating or reading molecular DNA into a digital representation consisting of letters. New technologies to increase speed are being developed and the costs for sequencing DNA are dropping accordingly. The new technologies however demand new

computer techniques to process the raw output from the sequencing machines and since the amount of data produced every day is increasing all the time the requirement for computing resources does so as well. So far the cooperation dealt with correcting errors in the output data of sequencing machines allowing easier processing of the data. Recently a new project partner, the Institute for Clinical Molecular Biology in Kiel, joined this project and the goal is to implement assembly algorithms on massively parallel hardware architectures to speed up the assembly process, hence allowing bigger genomes to be sequenced faster.

Massively Parallel Portfolio Optimization

RIVYERA has turned out to be very suitable for optimization problems in the area of financial mathematics (portfolio optimization, strategy analysis). In 2010 we developed a number of parallel financial mathematics algorithms for the architecture. These algorithms have been implemented in VHDL. The received results are impressive in terms of runtime and energy efficiency. Therefore, the research in this area will be intensified in 2011.

Mobile Client for Workflow Management Systems

The department of Computer Science of the CAU has concentrated on „Software and Systems Engineering" during the last year. Together with the University of Lübeck there has been a funding of seven projects in this context. One of these projects is managed by the research group Technical Computer Science. The goal is the development of a mobile client for workflow management systems. The maintenance of infrastructure and industrial plants requires a high degree of coordination. The software environment is typically heterogeneous. A universal client must therefore integrate different task models and must provide a unified interface to the user. The client is mainly developed for the application field of energy suppliers. Here, a large variety of end devices are currently used. The client must therefore be adaptable to all these end devices. The project started in October 2009 and will be funded for three years.

Personnel

Head of the group: Prof. Dr. rer. nat. M. Schimmler; Secretary: B. Scheidemann (50%)

Scientific Staff:

M. Sc. A. Abbas	01.01.-31.12.2010	University Aleppo
M. Sc. S. Koschnicke	01.01.-31.12.2010	KoSSE
M.Sc. F. Schatz	01.01.-31.12.2010	Getdigital
Dipl.-Inf. Ch. Starke	01.01.-31.12.2010	Land SH
Dipl.-Inf. L. Wienbrandt	01.01.-31.12.2010	Land SH
M. Sc. C. M. Y. Yeo	01.05.-31.12.2010	Land SH

Lectures, Seminars, and Laboratory Course Offers

Winter 2009/2010

Digitale Systeme, 3 (+ 2) hrs Lecture (+ Exercises)/Week,
M. Schimmler (+ Ch. Starke, L. Wienbrandt, M. Schimmler)

Hardwarepraktikum, 3 hrs Practical/Week,
L. Wienbrandt (+ Ch. Starke)

Oberseminar, 2 hrs Seminar/Week,
M. Schimmler

Algorithmen der Bioinformatik, 2 hrs Seminar/Week,
M. Schimmler

Summer 2010

Hardwarepraktikum, 3 hrs Practical/Week,
L. Wienbrandt (+ C. M. Y. Yeo)

Parallele Architekturen und Algorithmen, 2 (+ 2) hrs Lecture (+ Exercises)/Week,
M. Schimmler (+ M. Schimmler)

Rechnergestützter Entwurf digitaler Systeme, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
M. Schimmler (+ C. M. Y. Yeo)

Algorithmen der Bioinformatik, 2 hrs Seminar/Week,
M. Schimmler (+ L. Wienbrandt)

Winter 2010/2011

Digitale Systeme, 3 (+ 2) hrs Lecture (+ Exercises)/Week,
M. Schimmler (+ M. Schimmler, S. Koschnicke, C. M. Y. Yeo)

Hardwarepraktikum, 4 hrs Practical/Week,
M. Schimmler (+ S. Koschnicke, L. Wienbrandt)

Algorithmenentwurf für massiv parallele Hardware, 4 hrs Practical/Week,
M. Schimmler (+ L. Wienbrandt)

Algorithmen der Bioinformatik, 2 hrs Seminar/Week,
M. Schimmler

Third-Party Funds

University of Aleppo, *Stipendium Ayman Abbas,* 01.01.-31.12.2010 (11.094,00)
Innovationsstiftung Schleswig-Holstein, *Transferprämie,* 02.07.2010 (15.000,00)
Digitale Wirtschaft Schleswig-Holstein, *Software-Challenge,* 26.05.2010 (4.945,31)
Prof. Dr. Werner Petersen-Stiftung, *scholarships Software-Challenge,* 30.04.2010 (18.000,00)
Ministerium für Wissenschaft, Wirtschaft und Verkehr, *BLK-Modellversuch,* 01.08.2009-30.06.2010 (35.000,00)
Ministerium für Wissenschaft, Wirtschaft und Verkehr, *BLK-Modellversuch,* 01.09.2010-30.08.2011 (30.000,00)
SCI Engines GmbH, *Bio-Engine,* 01.01.2009-31.03.2010 (25.000,00)
Ministerium für Wissenschaft, Wirtschaft und Verkehr, *Universeller Aufgabenclient zur Unterstützung des technischen Betriebsmanagements bei verteilter Datenhaltung,* 01.10.2009-31.08.2012 (176.233,00)
ESN, *Universeller Aufgabenclient zur Unterstützung des technischen Betriebsmanagements bei verteilter Datenhaltung,* 01.10.2009-31.08.2012 (20.264,36)
GISWORK, *Universeller Aufgabenclient zur Unterstützung des technischen Betriebsmanagements bei verteilter Datenhaltung,* 01.10.2009-31.08.2012 (2.251,60)
Dataport, *Software-Challenge,* 20.01.2010 (4.284,00)
b + m Informatik AG, *Software-Challenge,* 05.02.2010 (9.520,00)
b + m Informatik AG, *Software-Challenge,* 09.12.2010 (11.900,00)

Diploma, Bachelor and Master Theses

A. Abbas, *Implementierung des Smith Waterman Algorithmus auf COPACOBANA,* 04.03.2010
M. Lange, *Implementierung des SMBusses für massiv parallele FPGA-Architekturen,* 11.11.2010

Publications

Published in 2010

M. Schimmler, L. Wienbrandt, *Collecting Statistical Information in DNA Sequences for the Detection of Special Motifs,* BIOCOMP, 274 - 278 (2010)

M. Schimmler, L. Wienbrandt, T. Güneysu, J. Bissel, *COPACOBANA: A Massively Parallel FPGA-Based Computer Architecture,* Book Chapter in 'Bioinformatics: High Performance Parallel Computer Architectures' edited by Bertil Schmidt, CRC Press, (2010)

L. Wienbrandt, C. M. Y. Yeo, M. Schimmler, S. Baumgart, J. Bissel, *Using the reconfigurable massively parallel architecture COPACOBANA 5000 for applications in bioinformatics,* ICCS, Procedia Computer Science, Elsevier, 1 - 8 (2010)

F. Schatz, M. Schimmler, *Boundaries for short-read, low-coverage denovo assembly and resequencing,* 9th European Conference on Computational Biology, ECCB 10, Gent, Belgium, (2010)

F. Schatz, M. Schimmler, *A priori estimation of contig length distribution of short-read sequencing. Research in Computational Molecular Biology,* 14th Annual International Conference, RECOMB , Lisbon, Portugal, (2010)

Presentations

M. Schimmler, *Auftragsforschung und Verbundprojekte zwischen Wissenschaft und Wirtschaft,* Transferforum, Kiel, Deutschland, 02.11.2010

S. Koschnicke, M. Schimmler, Ch. Starke, *Poster Mobiler Aufgabenclient (KoSSE),* Tagung Software Engineering im 'Software Engineering Forum der Informatik-Transferinstitute', Paderborn, 22.-26.02.2010

Further Activities and Events

M. Schimmler: Vicedean of the Faculty of Engineering from 01.01.-31.12.2010

Information Systems Engineering

Research and teaching in the department of Information Systems Engineering concentrates 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, 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

A crystal-chemical approach to superconductivity

We try to complement the physical approach to high-temperature superconductivity by a crystal-chemical one which is based on the notion of structural valency. The structural data of a large amount of cuprates as well as chalcogenides and pnictides have been analyzed using graph-based algorithms. A necessary though not sufficient condition for structural valences could be formulated which has to be fulfilled by a compound in order to become superconducting at low temperatures by doping and/or increased pressure.

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 developed based on the development of a complete formalisation of BPMN 1.0 and 1.1 developed over the last few years in an international collaboration. 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 is structured into requirements analysis and definition, systems design, systems implementation and testing, and systems operation and maintenance. For web information systems the traditional approach suffers from 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 the 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 at 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 can 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 a way that these systems are exception-aware, exception-reactive and provide a management of exceptions in a coherent form.

Modernisation 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 modernisation is an essential component in developing and maintaining truly useful systems that minimise service disruption and down-time, and maximise 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 granted 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 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 to 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 generalisation 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, complicating modelling and extension. A theory of m-objects has been developed that offers powerful techniques for modular and redundancy-free models, for query flexibility, for heterogeneous level-hierarchies, and for multiple relationship-abstraction.

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

A general theory of database transformations defines the background for queries and updates which are two fundamental types of computations in any databases: 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 the 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 and 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.

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 has 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 and 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.

Knowledge bases and knowledge web

The internet and web applications have changed business and human life. Nowadays everybody is used to obtaining data through the internet. Most applications are still Web 1.0 applications. Web 2.0 community collaboration and annotated data on the basis of Web 3.0 technologies support new businesses and applications. The quality dimension of the web is however one of the main challenges. Knowledge web information systems target at high-quality data on safe grounds, with a good reference to established science and technology and with data adaptation to the user's needs and demands. They can be built based on existing and novel technologies.

The knowledge web approach has been applied to management of processes that allow flexible handling of catastrophes. Another application targets delivery of actionable information on demand in a way that users can easily assimilate them to perform their tasks in juristical environments.

Our knowledge web approach is based on advanced content management and on the theory of media types. Content management is the process of handling information within an organization or community. We developed, applied and

implemented a novel data model for content which treats semantic information not only as describing metadata but also incorporates the data itself, the intension behind the data, the usage of data and the origin of data on the same level.

Random databases

We consider stochastic modelling for databases with uncertain data and for some basic database operations (for example, 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

Software and information systems design and development coexist and co-evolve with quality provision, assessment and enforcement. However, most,including modern, 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 whereas 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.

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, their semantics, and their 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 mainly developed 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 among applications and with users, of components of systems, and of 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 of 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 risks, ambiguities and contradictions which normally result from the parallel use of different modelling languages and modelling tools.

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 that 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 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, the wide variety of responses and the 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 utilisation 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, and 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 utilisation 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: M. Sc. S. Gaede

Scientific Staff:

Dipl.-Inf. K. Jannaschk	01.01.-31.12.2010	CAU
apl.-Prof. Dr. H.-J. Klein	01.01.-31.12.2010	CAU
M.Sc. R. Noack	01.01.-31.03.2010	DFG
Adaptives content- und benutzungsgesteuertes generisches Layouting von Web-Anwendungen		
M.Sc. R. Noack	01.04.-31.12.2010 (50%)	
HSP		
Dipl.-Inf. T. Polomski	15.10.-31.12.2010	BMWI
Verbundprojekt: PITAS - Piraterie- und Terrorabwehr auf Seeschiffen		
Dipl.-Inf. O. Sörensen	01.01.-31.12.2010	CAU
Dipl.-Inf. M. Tropmann	01.-31.01.2010	CAU
Risikoforschungspool		

Winter 2009/2010

MS0505: - Datenbanktheorie, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
H.-J. Klein (+ H.-J. Klein)

MS0508: - Fuzzy Methoden, 2 (+ 2) hrs Lecture (+ Exercises)/Week,
A. Salski (+ A. Salski)

MS0509: - Pattern-based information systems development, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
B. Thalheim (+ B. Thalheim, K. Jannaschk)

WBA5.2: Projektvorbereitungsmodul Wirtschaftsinformatik, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
B. Thalheim (+ B. Thalheim)

WI14: - Datenbank-Programmierung, 2 (+ 2) hrs Lecture (+ Exercises)/Week,
B. Thalheim (+ O. Sörensen)

MSS0503 - Seminar Datenbanksysteme, 2 hrs Seminar/Week,
H.-J. Klein, B. Thalheim

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

Summer 2010

MS0507: - Künstliche Intelligenz, 2 (+ 2) hrs Lecture (+ Exercises)/Week,
A. Salski (+ A. Salski)

Inf-IS: Informationssysteme (DB), 4 (+ 2) hrs Lecture (+ Exercises)/Week,
H.-J. Klein (+ K. Jannaschk + C. Starke)

MS0502: Content Management Systeme, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
B. Thalheim (+ O. Sörensen)

WI21: Informationsmanagement (WIInfmanagement) (080122), 2 (+ 1) hrs Lecture (+ Exercises)/Week,
B. Thalheim (+ R. Noack)

MSS0503: Seminar - Datenbanksysteme, 2 hrs Seminar/Week,
H.-J. Klein, B. Thalheim

WInf-Sem2: Seminar Wirtschaftsinformatik (Modelle betrieblicher Informationssysteme, 2 hrs Seminar/Week,
B. Thalheim (+ O. Sörensen)

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

Winter 2010/2011

Inf-DBTech: Datenbanktechnologie, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
H.-J. Klein (+ H.-J. Klein)

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

MS0503: Intelligent Information Systems, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
B. Thalheim (+ K. Jannaschk)

WInf-InfMinKD: Information Mining and Knowledge Discovery, 2 (+1) hrs Lecture (+ Exercises)/Week, B. Thalheim (+ K. Jannaschk)

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

WInf-Proj: Business Information Systems Project, 4 hrs Lecture/Week, B. Thalheim (+ R. Noack)

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

MSP0501: Masterprojekt - Datenbankprogrammierung (FopraDBII), 4 hrs Exercise/Week, K. Jannaschk + O. Sörensen

MSS0503 - Seminar Datenbanksysteme, 2 hrs Seminar/Week, H.-J. Klein, B. Thalheim

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

Third-Party Funds

DAAD, *Projektbezogener Personenaustausch mit Finnland - PPP Finnland*, 01.01.-31.05.2010 (6.100,00 EUR)
DAAD, *Projektbezogener Personenaustausch mit Japan : Knowledge Technology for Next Generation Web*, 01.01.-31.12.2010 (27.850,00 EUR)
DAAD, *Projektbezogener Personenaustausch mit Finnland - PPP Finnland*, 01.07.-31.12.2010 (12.697,00 EUR)
DFG, *Adaptives content- und benutzungsgesteuertes generisches Layouting von Web-anwendungen*, 01.01.-31.03.2010 (79.195,00 EUR)
BMWI, *Verbundprojekt: PITAS - Piraterie- und Terrorabwehr auf Seeschiffen,*, 15.10.-31.12.2010 (11.161,00 EUR)

Further Cooperation, Consulting, and Technology Transfer

University of Antwerp (Jan Paredaens), Free University Berlin (Heinz Schweppe, Hans-Joachim Lenz), Technical University Berlin (Herbert Weber), Humboldt University Berlin (Johann Christoph Freytag, Oliver Günther), Alfred Renyi Institute Budapest (Gyula Katona, Dezső Miklós), Georgia College and State University (Ajantha Dahanayake), MTA SZTAKI Budapest (Janos Demetrovics), University Conception (Marcela Varas), Cottbus University of Technology (Heinrich-Theodor Vierhaus), University of Dortmund (Gabriele Kern-Isberner, Joachim Biskup), Freiburg University (Dietmar Janetzko), Technical University Hamburg-Harburg (Joachim W. Schmidt), Klagenfurt University (Heinrich Mayr), Louisiana State University (Peter P. Chen), Kazakhstan Institute of Management, Economics and Strategic Research KIMEP, Almaty (Roland Kaschek), Information Science Research Centre Palmerston North (Klaus-Dieter Schewe), Lomonossov University Moscow (Elyar Gasonov, Valerij B. Kudrjavcev), Charles University Prague (Jaroslav Pokorny), Microsoft Research Redmond (Yuri Gurevich), Saarbrücken University (Klaus-Peter Jantke), Brigham Young University, Salt Lake City (David Embley), Silicon Valley Lab IBM (Laura Haas, Holger Kache), Tampere University of Technology (Hannu Jaakkola), Tampere University (Hannu Kangassalo), Umea University (Stephen Hegner, Oleg Seleznev), Versailles University (Elisabeth Metais), Portland State University (David Maier), University of Melbourne (James Bailey), University of Otago, Dunedin (Qing Wang), University Vermont (X. Sean Wang), Universita di Pisa (Egon Börger), Victoria University, Wellington (Hui Ma), KEIO University Tokyo (Yasushi Kiyoki), NICT Institut Kyoto (Koji Zettsu).

Diploma, Bachelor and Master Theses

Derya Kisen, *Foundations and Applications of Correlation Algorithms.*, 20.10.2010

Long Ma, *Ein Anfrageeditor für POLYSEARCH*, 15.01.2010
Tsvetelin Polomski, *A Systematic Approach to Cluster Analysis*, 06.10.2010
Claas A. Rathje, *Kompakte Datenbankschemata mit Sichtensuits*, 20.09.2010

Dissertations / Postdoctoral Lecture Qualifications

Qing Wang, *Logical Foundations of Database Transformations for Complex-Value Databases*, 25.04.2010

Publications

Published in 2010

M. Berg, A. Düsterhöft, B. Thalheim, *Integration of Dialogue Patterns into the Conceptual Model of Storyboard Design*, Lecture Notes in Computer Science, ER Workshops, **6413**, 160 - 169 (2010)

M. Berg, A. Düsterhöft, B. Thalheim, *Integration of Natural Language Dialogues into the Conceptual Model of Storyboard Design*, Lecture Notes in Computer Science, NLDB, **6177**, 196 - 203 (2010)

B. Catania, M. Ivanovic,, B. Thalheim, *Advances in Databases and Information Systems - 14th East European Conference, ADBIS 2010, Novi Sad, Serbia, September 20-24, 2010. Proceedings*, Lecture Notes in Computer Science, Springer, **6295**, (2010)

A. Dahanayake, B. Thalheim, *Co-Evolution of (Information System Models*, EMMSAD 2010, 141 - 154 (2010)

A. Dahanayake, B. Thalheim, *Towards a Framework for Emergent Modeling*, Lecture Notes in Computer Science, ER Workshops, **6413**, 128 - 137 (2010)

M. Duzi, H. Jaakkola, K. Jannaschk, Y. Kidawara, Y. Kiyoki, P. Linna, B. Thalheim, K. Zettsu, *Knowledge modeling, management and utilization towards next generation web*, Information MoFrontiers in Artificial Intelligence and Applications, Information Modelling and Knowledge Bases XXI, **206**, 387 - 402 (2010)

H. Jaakkola, B. Thalheim, *Architecture-driven modelling methodologies*, Proc. EJC 2010, 105 - 124 (2010)

H. Jaakkola, B. Thalheim, *Framework for high-quality software design and development: a systematic approach. IET Software 4(2)*, 105 - 118 (2010)

K. Jannaschk, T. Polomski, *A data mining design framework - a preview*, Proceedings of the 14th East European Conference on Advances in Databases and Information Systems, ADBIS, Novi Sad, Serbia. Lecture Notes in Computer Science, Springer, **6295**, 571 - 574 (2010)

K. Jannaschk, T. Polomski, *A data mining design framework*, iDB Tokyo, 1 - 10 (2010)

M. Kirchberg, B. Thalheim, *First International Workshop on Conceptual Modelling of Service (CMS 2010). ER Workshops 2010*, Lecture Notes in Computer Science, ER Workshops, **6413**, 75 - 75 (2010)

H.-J. Klein, F. Liebau, X. Wang, *A crystal chemical approach to superconductivity. I. A bond-valence sum analysis of inorganic compounds*, Zeitschrift für Kristallographie (Online), **226**, (2010)

H. Ma, R. Noack, K.-D. Schewe, B. Thalheim, *Using Meta-Structures in Database Design*, Informatica, **34**, 387 - 403 (2010)

H. Ma, K.-D. Schewe, B. Thalheim, Q. Wang, *A theory of data-intensive software services*, Service Oriented Computing and Applications, **Volume 3, Number 4**, 263 - 283 (2010)

R. Noack, Q. Wang, *Intelligent author identification*, Lecture Notes in Computer Science, Springer, **6413**, 96 - 106 (2010)

B. Neumayr, M. Schrefl, B. Thalheim, *Hetero-homogeneous hierarchies in data warehouse*, CRPIT, **110**, 61 - 70 (2010)

K.-D. Schewe, B. Thalheim, *Pragmatics of Storyboarding - Web Information Systems Portfolios. WEBIST (2) 2010*, INSTICC, **2**, 40 - 47 (2010)

K.-D. Schewe, B. Thalheim, Q. Wang, *A fixed-point query language for xml*, Information Modelling and Knowledge Bases XXI, Frontiers in Artificial Intelligence and Applications, **206**, 226 - 246 (2010)

O. Seleznjev, B. Thalheim, *Random Databases with Approximate Record Matching*, Methodology and Computing in Applied Probability, **12**, 63 - 89 (2010)

M. Skusa, B. Thalheim, *Kohärente Softwareentwicklung - Grundlagen, Arbeitsumgebungen, Vorgehensweisen,* Preprint 1018, Department of Computer Science, Kiel University, (2010)

B. Thalheim, *Model suites for multi-layered database modelling,* Information Modelling and Knowledge Bases XXI, **206**, 116 - 134 (2010)

B. Thalheim, *WEBIST 2010 Proceedings 6th International Conference on Web Information Systems and Technologies,* INSTICC, **2**, 40 (2010)

B. Thalheim, M. Tropmann, *Performance forecasting for perfomance critical huge databases,* In Proc. EJC 2010, 214 - 233 (2010)

B. Thalheim, *NULL value algebras and logics,* In Proc. EJC 2010, 365 - 376 (2010)

B. Thalheim, *Towards a theory of conceptual modelling,* Journal of Universal Computer Science, **16**, 3102 - 3137 (2010)

Presentations

K. Jannaschk, *A Data Mining Design Framework,* Hokkaido University,, Sapporo, Japan, 29.07.2010

K. Jannaschk, *A Data Mining Design Framework,* iDB 2010, Tokyo, Japan, 02.08.2010

K. Jannaschk, *Data Mining and Design,* NICT,, Kyoto, Japan, 09.08.2010

K. Jannaschk, *A Data Mining Design Framework - A Preview,* ADBIS 2010, Novi Sad, Serbia, 22.09.2010

R. Noack, *Intelligent Author Identification,* CMS 2010 - 1st International Workshop on Conceptual Modeling of Services, Vancouver, Canada, 02.11.2010

B. Thalheim, *Supporting Technology for Multi-Cultural Engineering,* Technical University Tampere at Pori, Pori, Finland, 10.03.2010

B. Thalheim, *Pragmatics of Storyboarding,* WebIST 2010, Valencia, Spain, 10.04.2010

B. Thalheim, *Web 2.0,* Schleswig-Holsteinische Universitäts-Gesellschaft, Elmshorn, Germany, 20.04.2010

B. Thalheim, *Web x.0 and virtual societies,* Schleswig-Holsteinische Universitäts-Gesellschaft, Kronshagen, Germany, 20.05.2010

B. Thalheim, *Back to the roots - Healthcare ohne IT?,* NexCon, Elmshorn, Germany, 28.05.2010

B. Thalheim, *NULL Value Algebras and Logics,* EJC 2010, Juväskyllä, Finland, 04.06.2010

B. Thalheim, *Architecture-Ruled Development of Web Information Systems,* EJC 2010, Juväskyllä, Finland, 04.06.2010

B. Thalheim, *Co-Evolution of (Information) System Models,* EMMSAD 2010, Hammamet, Tunis, 08.06.2010

B. Thalheim, *Fundierung von BPMN,* Kolloquium, Dortmund, Germany, 15.06.2010

B. Thalheim, *Anwendungen des Web 2.0 und 3.0,* Schleswig-Holsteinische Universitäts-Gesellschaft, Germany, 05.07.2010

B. Thalheim, *Modellierung und Modelle,* Öffentliche Antrittsvorlesung,Mathematisch-Naturwissenschaftliche Fakultät der Christian-Albrechts-Universität zu Kiel, Kiel, Germany, 06.07.2010

B. Thalheim, *Knowledge Web: The Next Generation Web Beyond Web x.0 - Technology for the Next Generation Web,* Hokkaido University, Colloquium, Sapporo, Japan, 29.07.2010

B. Thalheim, *Semantical Foundations of Databases, Information Systems and Knowledge Bases,,* Hokkaido University,, Sapporo, Japan, 29.07.2010

B. Thalheim, *Architecture-Driven Modelling Methodologies,* iDB2010, Tokyo, Japan, 03.08.2010

B. Thalheim, *Developing a Foundation of BPMN (Business Process Modelling and Notation 1.0, 1.1, 2.0),* NICT Colloquium, Kyoto, Japan, 09.08.2010

B. Thalheim, *Eine allgemeine Theorie der Modelle, ''Modellbildung zwischen Theorie und Anwendung'',* IIftC-Symposium, Kiel, Germany, 01.10.2010

B. Thalheim, *Modellierung von BPMN (Business Process Modelling and Notation) und die Fundierung des Standards,* SCCH Hagenberg, Hagenberg, Austria, 15.10.2010

B. Thalheim, *Web 2.0,* Schleswig-Holsteinische Universitäts-Gesellschaft, Norderstedt, Germany, 26.10.2010

B. Thalheim, *Technology Solutions for the Next Generation Web,* Kolloquium, Clausthal, Germany, 23.11.2010

B. Thalheim, *Conceptual modelling in the large,* Tutorial, Half-Day, ER 2010, Vancouver, Canada, 01.11.2010

Further Activities and Events

H.-J. Klein

Member of Programme Committee:

- ADVCOMP 2010 (Fourth Int. Conf. on Advanced Engineering Computing and Applications in Sciences), Valencia, Spain, 2010,

- DTA 2010 (Int. Conf. on Database Theory and Application), Jeju Island, Korea, 2010.

Reviewer for:

- Annals of Mathematics and Artificial Intelligence.

R. Noack

Member of programme committee:

SDKB 2010 Int. Workshop on Semantics in Data and Knowledge Bases, Bordeaux, France, July 2010.

A. Salski

Editorial board member (since 2005):

The International Journal „Ecological Informatics" , Elsevier.

Member of programme committee:

The 7th International Conference on Ecological Informatics (ISEI7), 13- 16.12.2010, Gent, Belgium.

Reviewer for: „Ecological Informatics" (Elsevier).

B. Thalheim

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

Member of programme committee:

ACM-L2010, November 2010,

APCCM 2010, January 2010,

Baltic DB & IS, July 2010,

CAiSE 2010, June 2010,

ER 2010, November 2010,

EDOC 2010, October 2010,

FP-UML 2010, November 2010,

ICWE 2010, July 2010,

Logic-Based Modelling, November 2010,

MKWI 2010, June 2010,

NLDB 2010, June 2010,

PhD Workshop, ER '10 Workshop, November 2010,

SOFSEM 2010, January 2010,

UDM 2010, April 2010,

WISM 2010, November 2010,

Member of steering committees of international conferences:

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

Vice-Chair of the Steering Committee of the FOIKS Conferences.

Co-Chairman of conferences:

SDKB 2010,

ADBIS 2010.

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.

Editor and Co-Cair of the Conference Proceedings:

SDKB 2010,

ADBIS 2010 (Proceedings bei Springer) Handbook of conceptual modelling, Springer 2010.

Editor of Conceptual Modelling: Handbook, Springer 2010.

Chair:

- of the German group of DAMA International,

- of the Schleswig-Holstein Regional Group of the German Computer Science Society.

Member of the Scientific Advisory Board: with Dataport.

Tutorial: ER 2010, Conceptual modelling in the large, ER 2010, 1. November 2010, Vancouver.

Co-Chairman of workshops:

CMS 2010, Vancouver.

Reviewer for various journals in Mathematic, Computer Science and Engineering.

Theoretical Computer Science

The theory group specializes in logic in computer science, automata theory and formal languages, verification, computational complexity, cryptographic protocols, and computer science education.

Results

Complex Security Properties of Cryptographic Protocols. Part of the work of the theory group focuses on properties of cryptographic protocols that have *strategic* and *epistemic* (i.e. knowledge-related) aspects. One example for such a property is abuse-freeness of contract signing protocols, where it is required that no involved party can „prove" to an outside party (the „verifier") that she has certain strategic abilities, for instance, being able to choose between getting a valid copy of a contract and preventing a potential contracting partner obtaining one. In joint work with the security group at Trier University, a new attack on such a protocol was identified in 2010. The interesting aspect about the attack is that the „verifier" plays a more active part than in prior considerations. As a consequence of the discovery of the attack, a notion of online abuse-freeness was introduced. Part of the joint work with the group in Trier was an analysis of well-known contract signing protocols with respect to the new security property. Additionally, the group worked on a notion of security for two-round authenticated message exchange in a concrete/computational model. This security notion is relevant for the study of web services; it was proved that a new protocol is secure with respect to the new definition.

Computational Complexity of Logic-Related Problems. In joint work with researchers from Hannover, Jena, Lübeck, Marseille, and Rochester, the theory group worked on several algorithmic problems related to applications of logic in computer science. One example is the use of linear temporal logic (LTL) in verification. More precisely, in the joint work the complexity of variations of the corresponding model-checking problem (to determine whether a given system satisfies a given specification) was analyzed with respect to its computational complexity. Similar results were obtained in the context of modal logics (for the related satisfiability problem) and for quantified and non-uniform constraint satisfaction problems.

Computational Social Choice. The group continued to work on computational aspects of manipulating elections, i.e., the question how human or electronic voters can use dishonesty in elections to achieve a strategic advantage. This research was carried out in cooperation with groups in Rochester and Krakow.

Algorithms in Automata Theory. One of the most prominent applications of regular expressions is in text searching: text searching tools are widespread and valuable tools for programmers (and, sometimes, even users). In joint work with the programming languages research group of the department, a purely functional program for regular expression matching was developed. This program is comparable in terms of efficiency with the Google tools released in the same year.

Computer Science Education. The research group increasingly focuses on topics in computer science education. In 2010, two projects began. One of the projects is a study where a class of high school students (6th grade) is taught according to a curriculum designed for the CS curriculum framework of Schleswig-Holstein as established in 2010. The aim of the study is to evaluate this curriculum. The objective of the other project is to find out to which extent it is possible to convey basic programming and algorithmic skills by (simply) using a specifically designed tool for designing computer animations and computer games in art courses. The tool used is Scratch, which was developed at MIT. First findings show that, in contrast to our assumptions, it is easier for children to use message passing (for structuring a distributed program) than to use loops (as a means of abstraction).

Personnel

Head of the group: Prof. Dr. Th. Wilke; Secretary: H. Capell (15 percent, 3 months), F. Lorenz (50 percent)
Technical Staff: Th. Hess (50%)

Scientific Staff:

Dipl.-Math. S. Eggert	01.01.-31.12.2010		CAU
M.Sc. I. Khan	01.01.-31.12.2010		DAAD
Dipl.-Inf. K. O. Kürtz	01.01.-30.09.2010		DFG Trier
Dipl.-Inf. K. O. Kürtz	01.10.-31.12.2010		CAU
Dipl.-Math. T. Radtke	01.02.-30.09.2010	(50%)	CAU
Dipl.-Math. T. Radtke	01.10.-31.12.2010		ISH
Dr. H. Schnoor	01.01.-31.12.2010		CAU
StR S. Schulmeister	01.01.-31.12.2010	(50%)	CAU
Dipl.-Inf. J. Schönborn	01.01.-30.11.2010	(50%)	CAU
Dr. L. Willert	01.08.-31.12.2010		CAU

Lectures, Seminars, and Laboratory Course Offers

Summer 2010

Secure Communications, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
H. Schnoor

Informatik IV - Theoretische Grundlagen der Informatik, 4 hrs Lecture/Week,
Th. Wilke

Automaten, Logiken, Spiele, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
Th. Wilke

Winter 2010/2011

Boolesche Schaltkreise, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
H. Schnoor

IT-Sicherheit, 1 (+ 1) hrs Lecture (+ Exercises)/Week,
Th. Wilke

Theoretische Grundlagen der Informatik, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
Th. Wilke (+ S. Eggert)

Grundlagen fachbezogenen Lehrens und Lernens im Fach Informatik, 2 hrs Seminar/Week,
L. Willert

Planung, Durchführung und Analyse von Informatikunterricht (im Praxismodul 2), 2 hrs Seminar/Week,
S. Schulmeister

Third-Party Funds

DFG, *Automatische Analyse kryptographischer Protokolle mit komplexen Nachrichtenformaten*, 01.01.-30.08.2010 (119500 EUR)

Innovationsstiftung Schleswig-Holstein, *Wenn Bilder laufen lernen, ist Informatik nicht weit!*, 16.06.2010-30.04.2012 (133080 EUR)

Further Cooperation, Consulting, and Technology Transfer

The theory group cooperates with groups in Trier (Prof. Dr. Ralf Küsters), Hannover (Prof. Dr. Heribert Vollmer), Rochester (Prof. Dr. Edith Hemaspaandra), Marseille (Prof. Dr. Nadia Creignou), Paris (Prof. Dr. Arnaud Durand), Krakow (Prof. Dr. Piotr Faliszewski), and Sydney (Prof. Dr. Ron van der Meyden).

Diploma, Bachelor and Master Theses

J. Dahlke, *Papierbasierte digitale Signaturen,* 15.02.2010
S. Schäfer, *Ein Interpreter für Termersetzungssysteme,* 08.11.2010

Dissertations / Postdoctoral Lecture Qualifications

K. O. Kürtz, *Secure Two-Round Message Exchange,* 10.12.2010

Publications

Published in 2010

R. Küsters, H. Schnoor, T. Truderung, *A formal definition of online abuse-freeness,* Security and Privacy in Communication Networks, **2010**, 484 - 497 (2010)
E. Hemaspaandra, H. Schnoor, I. Schnoor, *Generalized modal satisfiability,* Journal of Computer and System Sciences, **76 (7)**, 561 - 578 (2010)
M. Bauland, E. Böhler, N. Creignou, S. Reith, H. Schnoor, H. Vollmer, *The Complexity of Problems for Quantified Constraints,* Theory of Computing Systems, **47 (2)**, 454 - 490 (2010)
N. Creignou, H. Schnoor, I. Schnoor, *Nonuniform Boolean constraint satisfaction problems with cardinality constraint,* ACM Transactions on Computational Logic, **11 (4)**, (2010)
K. O. Kürtz, H. Schnoor, Th. Wilke, *Computationally secure two-round authenticated message exchange,* ACM Symposium on Information, Computer and Communications Security, **2010**, 214 - 225 (2010)
S. Fischer, Frank Huch, Th. Wilke, *A play on regular expressions: functional pearl,* International Conference on Functional Programming, 357 - 368 (2010)
D. Kähler, R. Küsters, Th. Wilke, *Deciding strategy properties of contract-signing protocols,* ACM Transactions on Computational Logic, **10**, 171 - 1742 (2010)

Presentations

K. O. Kürtz, H. Schnoor, Th. Wilke, *Computationally secure two-round authenticated message exchange,* ASIACCS, Beijing, China, 13.-16.04.2010
H. Schnoor, *Strategic planning for probabilistic games with incomplete information.,* AAMAS 2010, Toronto, Canada, 10.-14.05.2010
P. Faliszewski, E. Hemaspaandra, H. Schnoor, *Manipulation of copeland elections,* AAMAS 2010, Toronto, Canada, 10.-14.05.2010
R. Küsters, H. Schnoor, T. Truderung, *A Formal Definition of Online Abuse-Freeness,* Workshop on Foundations of Security and Privacy, Edinburgh, UK, 14.-15.07.2010
R. Küsters, H. Schnoor, T. Truderung, *A Formal Definition of Online Abuse-Freeness,* SecureComm 2010, Singapore, Singapore, 07.-09.09.2010
H. Schnoor, *Deciding epistemic and strategic properties of cryptographic protocols,* GIPSy 2010, Rennes, France, 15.-16.11.2010

Th. Wilke, *Functional Programs for Regular Expression Matching,* Seminar über Automaten, Wadern, Germany, 13.-17.12.2010
Th. Wilke, *Logic in Cryptography and Cryptographic Protocols,* Logic Colloquium, Paris, France, 25.-31.07.2010
Th. Wilke, *Functional Programs for Regular Expression Matching,* Authomatha 2010, Vienna, Austria, 22.-24.11.2010

Further Activities and Events

- Th. Wilke has been a member of the Council of the European Association for Theoretical Computer Science.
- Th. Wilke has been vice speaker of the division »Grundlagen« of the »Gesellschaft für Informatik«.
- Th. Wilke has been a member of the editorial boards of the following journals and series: Fundamenta Informaticae, Formal Methods in System Design, Lecture Notes in Logic.
- Th. Wilke was a member of the programme committee of LATA 2010.
- Consulting for the curriculum »Angewandte Informatik« (Schulmeister, Wilke),
- Organization of a workshop for computer science and art teachers,
- organization of two weeks »Schnupperstudium Informatik«,
- representation of the department at the »Schleswig-Holstein-Tag 2010«,
- organization of part of the Girls' Day 2010.

Theory of Parallelism

Our workgroup 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 workgroup's main areas of interest include: approximate solvers for linear programs (which generate provably good solutions quickly as opposed to solving instances to optimality in excessive time), approximation schemes (which permit a controllable trade-off between efficiency and accuracy), parameterized complexity (where the aim is to obtain better running times for instances with a special structure), scheduling problems (which include problems in industrial production planning), geometrically constrained packing problems (which feature several optimization aspects and model, for instance, the packaging of goods in containers or the loading of trucks with resources), network flow problems (which model the transportation of physical commodities as well as data) and finally timetabling problems (which are fundamental in staff scheduling in administrative systems, educational systems and for medical care).

Personnel

Head of the group: Prof. Dr. K. Jansen; Secretary: U. Iaquinto (50%)
Technical Staff: P. Karimi Massouleh (50%)

Scientific Staff:

K.-M. Klein	01.10.-31.12.2010		CAU
S. Kraft	01.10.-31.12.2010		DFG
C. Otte	01.01.-31.12.2010	(50%)	DFG
C. Otte	01.01.-31.12.2010	(50%)	CAU
Hochschulpakt 20/20			
L. Prädel	01.01.-31.12.2010	(50%)	DFG
L. Prädel	01.01.-31.12.2010	(50%)	CAU
Hochschulpakt 20/20			
Dr. I. Schnoor	01.11.-31.12.2010		CAU
3/4 position			
Dr. U. Schwarz	01.01.-30.09.2010		CAU

Lectures, Seminars, and Laboratory Course Offers

Winter 2009/2010

Vorlesung - Effiziente Algorithmen, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
K. Jansen (+ U. Schwarz)

Vorlesung - Lineare Optimierung, 2 (+ 2) hrs Lecture (+ Exercises)/Week,
K. Jansen (+ L. Prädel)

Fortgeschrittenen Praktikum - Effiziente Algorithmen, 4 hrs Lab/Week,
K. Jansen (+ U. Schwarz)

Masterpraktikum - Vertiefende Übung Effiziente Algorithmen, 4 hrs Exercise/Week,
K. Jansen (+ U. Schwarz)

Seminar - Theoretische Informatik, 2 hrs Seminar/Week,
K. Jansen (+ U. Schwarz)

Seminar - Approximative Algorithmen, 2 hrs Seminar/Week,
K. Jansen (+ U. Schwarz)

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

Summer 2010

Vorlesung - Algorithmen und Datenstrukturen, 4 (+2) hrs Lecture (+ Exercises)/Week,
K. Jansen (+ C. Otte, L. Prädel)

Vorlesung - Applications of Matrix Products to Combinatorial Problems, 2 hrs Lecture/Week,
A. Lingas

Seminar - Approximative Algorithmen, 2 hrs Seminar/Week,
K. Jansen (+ U. Schwarz)

Seminar - Theoretische Informatik, 2 hrs Seminar/Week,
K. Jansen (+ U. Schwarz)

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

Projektmodul - Effiziente Algorithmen, 6 hrs Exercise/Week,
K. Jansen

Fortgeschrittenenpraktikum - Effiziente Algorithmen, 4 hrs Lab/Week,
K. Jansen (+ U. Schwarz)

Winter 2010/2011

Vorlesung - Lineare Optimierung und ganzzahlinge Optimierung, 4 (+2) hrs Lecture (+ Exercises)/Week,
K. Jansen (+ K.-M. Klein)

Vorlesung - Approximative Algorithmen, 4 (+2) hrs Lecture (+ Exercises)/Week,
K. Jansen

Fortgeschrittenen Praktikum - Effiziente Algorithmen, 4 hrs Lab/Week,
K. Jansen (+ S. Kraft)

Seminar - Theoretische Informatik (Ressourcenbeschränkte Algorithmen), 2 hrs Seminar/Week,
K. Jansen (+ K.-M. Klein, S. Kraft)

Seminar - Approximative Algorithmen, 2 hrs Seminar/Week,
K. Jansen

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

Third-Party Funds

DFG-Projekt, Entwicklung und Analyse von approximativen Algorithmen für zwei- und dreidimensionale Packungsprobleme, *Personal, travel, and aquisition,* 01.10.2008-30.09.2011 (203.280 EUR)

DFG-Projekt, Entwicklung von effizienten polynominellen approximationsschemata für Scheduling- und verwandte Optimierungsprobleme, *Personal, travel, and aquisition,* 01.10.2010-30.09.2013 (205.200 EUR)

Further Cooperation, Consulting, and Technology Transfer

Our workgroup cooperates closely with the Max-Planck-Institut für Informatik in Saarbrücken mainly with the researchers Rob van Stee and Rolf Harren and with Roberto Solis-Oba from the University of Western Ontario, Canada. In the summer term 2010 Prof. Andrzey Lingas from the University of Lund was our guest sponsored by the Öresund-Gastdozentur.

Diploma, Bachelor and Master Theses

S. Berndt, *Robust Approximation Schemes for Online Bin Packing,* 29.10.2010
T. Ehlers, *Scheduling with Migration,* 29.10.2010

Dissertations / Postdoctoral Lecture Qualifications

U. Schwarz, *Approximation Algorithms for Scheduling and Two-Dimensional Packing Problems,* 01.07.2010

Publications

Published in 2010

F. Diedrich, K. Jansen, F. Pascual, D. Trystram, *Approximation Algorithms for Scheduling with Reservations,* Algorithmica, **58 (2)**, 391 - 404 (2010)

T. Erlebach, T. Hagerup, K. Jansen, M. Minzlaff, A. Wolf, *Trimming of graphs, with application to point labeling,* Theory of Computing Systems, **47 (3)**, 613 - 636 (2010)

K. Jansen, R. Thöhle, *Approximation algorithms for scheduling parallel tasks,* SIAM Journal on Computing, (2010)

K. Jansen, *An EPTAS for scheduling jobs on uniform processors,* SIAM Journal on Discrete Mathematics, (2010)

G. Muratore, U. Schwarz, G.J. Woeginger, *Parallel machine scheduling with nested job assignment restrictions,* Operations Research Letters, **38 (1)**, 47 - 50 (2010)

K. Jansen, R. Solis-Oba, *Approximation schemes for scheduling jobs with chain precedence constraints,* International Journal of Foundations of Computer Science, **21 (1)**, 27 - 49 (2010)

K. Jansen, R. Solis-Oba, *An OPT + 1 algorithm for the cutting stock problem with constant number of object lengths,* 14. Conference on Integer Programming and Combinatorial Optimization (IPCO XIV), (2010)

K. Jansen, S. Kratsch, D. Marx, I. Schlotter, *Bin packing with fixed number of bins revisited,* 12. Scandinavian Symposium and Workshops on Algorithm Theory (SWAT 2010), (2010)

M. Bougeret, P.F. Dutot, K. Jansen, C. Otte, D. Trystram, *Approximating the non-contiguous multiple organization packing problem,* IFIP International Conference on Theoretical Computer Science (TCS 2010), (2010)

M. Bougeret, P.F. Dutot, K. Jansen, C. Otte, D. Trystram, *A fast 5/2 approximation algorithm for hierarchical scheduling,* International European Conference on Parallel and Distributed Computing (EUROPAR 2010), (2010)

E. Bampis, K. Jansen, *Approximation and Online Algorithms,* 7th International Workshop, WAOA 2009, Springer LNCS, **5893**, (2010)

M. Serna, R. Shaltiel, K. Jansen, J. Rolim, *Approximation, Randomization, and Combinatorial Optimization. Algorithms and Techniques,* 13th International Workshop, APPROX 2010, and 14th International Workshop, RANDOM 2010, Springer LNCS, **6302**, (2010)

Presentations

K. Jansen, *An EPTAS for scheduling jobs on uniform processors,* Vortrag an der École polytechnique fédérale de Lausanne EPFL, Lausanne, Switzerland, 22.-26.02.2010

K. Jansen, *An EPTAS for scheduling jobs on uniform processors,* PMS'10 12th International Workshop on Project Management and Scheduling, Tours, Fance, 26.-28.04.2011

K. Jansen, *A fast approximation scheme for the multiple knapsack problem,* DFG German-Indian Workshop on Discrete Structures and Algorithms, Bonn, Germany, 01.-04.06.2010

K. Jansen, R. Solis-Oba, *An OPT+1 algorithm for the cutting stock problem with a constant number of object lengths,* IPCO 2010 The 14th Conference on Integer Programming and Combinatorial Optimization, Lausanne, Switzerland, 09.-11.06.2010

K. Jansen, R. Solis-Oba, *An OPT+1 algorithm for the cutting stock problem with a constant number of object lengths,* Theorietag der Gesellschaft für Informatik, 60. Workshop über Algorithmen und Komplexität, Kiel, Germany, 15.06.2010

K. Jansen, *A fast approximation scheme for the multiple knapsack problem,* Workshop New Challenges in Scheduling Theory, Frejus, France, 13.-17.09.2010

K. Jansen, *Approximative Algorithmen für Scheduling- und Packungsprobleme,* Kollquiumsvortrag an der Universität Bonn, Bonn, Germany, 06.12.2010

L. Prädel, R. Harren, K. Jansen, R. Van Stee, *A (5/3+epsilon)-Approximation for Strip Packing,* Workshop New Challenges in Scheduling Theory, Frejus, France, 13.-17.09.2010

L. Prädel, R. Harren, K. Jansen, R. Van Stee, *A (5/3+epsilon)-Approximation for Strip Packing,* Theorietag der Gesellschaft für Informatik, 60. Workshop über Algorithmen und Komplexität, Kiel, Germany, 15.06.2010

C. Otte, M. Bougeret, P.-F. Dutot, K. Jansen, D. Trystram, *Approximation Algorithms for Multiple Strippacking/Scheduling in Clusters,* 59. Workshop über Algorithmen und Komplexität, Illmenau, Germany, 24.02.2010

A. Lingas, *The Complexity of Inferring a Minimally Resolved Phylogenetic Supertree,* Theorietag der Gesellschaft für Informatik, 60. Workshop über Algorithmen und Komplexität, Kiel, Germany, 15.06.2010

Further Activities and Events

Prof. Jansen was involved in the organization of the following conferences. He was a workshop chairman at the conference APPROX RANDOM 2010 for the 13th international workshop „Approximation Algorithms for Combinatorial Optimization Problems“ , and the 14th international workshop „Randomization and Computation“ , which took place from 1-3 September 2010 in Barcelona. At WAOA 2010 the 8th „Workshop on Approximation and Online Algorithms“ from 9 - 10 September 2010 in Liverpool he was a programme chairman. In addition he organized the 60th workshop on algorithms and complexity (Theorietag der Gesellschaft für Informatik) on 15 June 2010 at the CAU Kiel. Prof. Jansen was a programme committee member at ICALP 2010 the 37th International Colloquium on Automata, Languages and Programming in Bordeaux.

Institute of Electrical and Information Engineering

The Institute of Electrical and Information Engineering (Institute of ET&IT) of Christian-Albrechts-University is engaged in a great variety of cooperative and interdisciplinary research projects. The Institute of ET&IT has a close collaboration with the Institute for Computer Science (Informatik) with a common research focus of ''Information Engineering''. It also has another collaboration with the Institute for Materials Science and the Physics department covering the topic ''Nanosystems''. Furthermore, the Institute of ET&IT takes part in the Collaborative Research Centre SFB 855 ''Magneto-Electric Composites - Biomagnetic Interfaces of the Future'', which was initiated by Prof. Dr.-Ing. Eckhard Quandt. In addition, the Institute is engaged in the Cluster of Excellence ''The Future Ocean'' of the CAU, the ''Computational Sciences Centre'' as well as in the research network ''CEwind Centre of Competence in Wind Energy''.

There are currently 11 professorships including the position of the Managing Director of the Insitut für Siliziumtechnologie (ISIT) in Itzehoe, Prof. Dr.-Ing. Wolfgang Benecke, who holds an external professorship at the Institute. One of these professorships was reassigned in 2010: in March 2010, Prof. Dr.-Ing. Gerhard Schmidt took over the professorship ''Digitale Signalverarbeitung und Systemtheorie'' (''Digital Signal Processing and System Theory'') as the successor of Prof. Dr.-Ing. Ulrich Heute. In October 2010, Prof. Dr.-Ing. Ludger Klinkenbusch was elected as a new executive member of the board and thereby relieved Prof. Dr.-Ing. Helmut Röck from this office.

In the winter term (semester) 2010/2011 a total of 178 new students enrolled in course programmes offered by the Institute of ET&IT. In the Bachelors programme ''Electrical and Information Engineering'' (7 terms) 58 students started their studies, and 107 enrolled in the Bachelors programme ''Electrical and Information Engineering and Business Management'' (7 terms). The Masters programme ''Digital Communications'' saw 13 new students enrolling, with all courses offered in English (4 terms). Enrolment in the diploma programmes ''Electrical and Information Engineering'', ''Electrical and Information Engineering and Business Management'', as well as the upgrade programme in '''Electrical and Information Engineering for FH-graduates'' are only offered to students in higher classes. In the summer term 2011 the Institute will offer for the first time 3-term Masters programmes in ''Electrical and Information Engineering'' and ''Electrical and Information Engineering and Business Management''.

In spring 2009 the Institute of ET&IT, together with the Institute for Materials Science, founded the ''Centre for Study Services'' in order to effectively manage all matters of interest for both of the institutes in the areas of study, course programme, internships and examinations.

In 2010 the Institute again was very active in the promotion of young talent. The Institute took part in the events ''Girls Day'', ''Schul-AG Technik'' (Study group engineering for pupils), ''Power Girls & Boys'', organized a project week ''Mobile Communications'' for a school in Schleswig-Holstein and participated in the project ''lüttIng'' and ''Stadt der jungen Forscher'' .

Automation and Control Engineering

The department of Automation and Control Engineering focuses on:

- Coriolis Mass Flow Metering,
- Control in Biotechnology and Medicine,
- Control of weakly damped mechanical and/or underactuated mechanical nonlinear systems.

In the Coriolis Mass Flow lab the research in the area of self-calibration and on-line adjustment of zero and sensitivity continues.

In Biotechnology we cooperate with an industrial partner in order to set up optimal conditions for the production of starter cultures for the dairy industry and to predict the optimal time for harvesting the biomass.

In the Mechanical Systems lab we have started a new project for controlling a weakly damped Micromechanical Mirror, which is to become a key element in tomorrow's mobile phones.

In the area of Biotechnical Engineering Joachim Hörrmann finished his PhD examination with a thesis on Control Strategies for Cultivating the Bacteria Streptococcus Thermophilus.

Results

Coriolis Mass Flow Metering (Felix Koschmieder)

To further reduce measurement uncertainties in modern Coriolis Mass Flow Meters adaptive model based correction schemes for self-calibration and adjustment have to be implemented in the measurement device. For controlling the oscillations of the measuring pipe in the 1st and 2nd eigenmode simultaneously, a nonlinear phasor control scheme was developed. The realization of a compensation method i.e. the compensation of the Coriolis forces turned out to be quite simple and resulted in choosing appropriate set points for amplitude control of the 1st and 2nd mode of the measuring pipe.

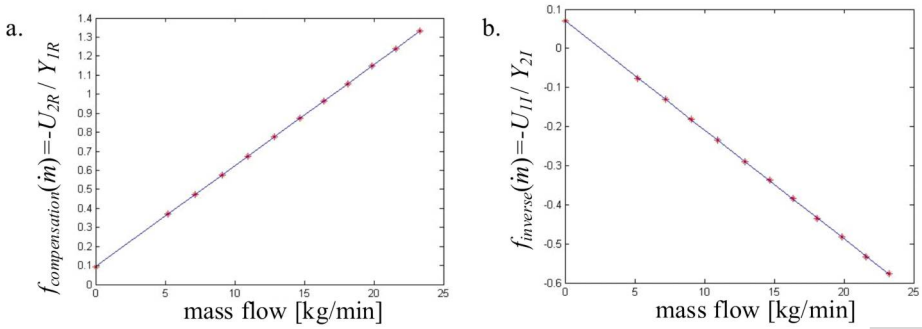

Fig. 1: Measured characteristics of the CMFM: a. Normal Mode, b. Inverse Mode

As both of the eigenmodes are coupled via mass flow two characteristics can be measured. The 1st characteristics i.e. the characteristics exploited by all of the meters available on the market is the 2nd mode oscillation induced by stimulating the 1st mode. In this case the amplitude of the 2nd mode is proportional to mass flow. The 2nd characteristics or inverse characteristics i.e. the oscillation of the 1st mode stimulated by the 2nd mode, has been measured for the first time and proved to be also linearly dependant on mass flow. As the interaction between 1st and 2nd mode according to the inverse characteristics is rather weak, it can nevertheless be used for self-diagnosis and self-calibration. Both characteristics can

be exploited simultaneously when operating the device at two different frequencies. To enhance the signal to noise ratio it is desirable to stimulate the device in both of its eigenfrequencies simultaneously. As the eigenfrequencies change due to ambient conditions, the frequencies of stimulation have to be adjusted by phase control

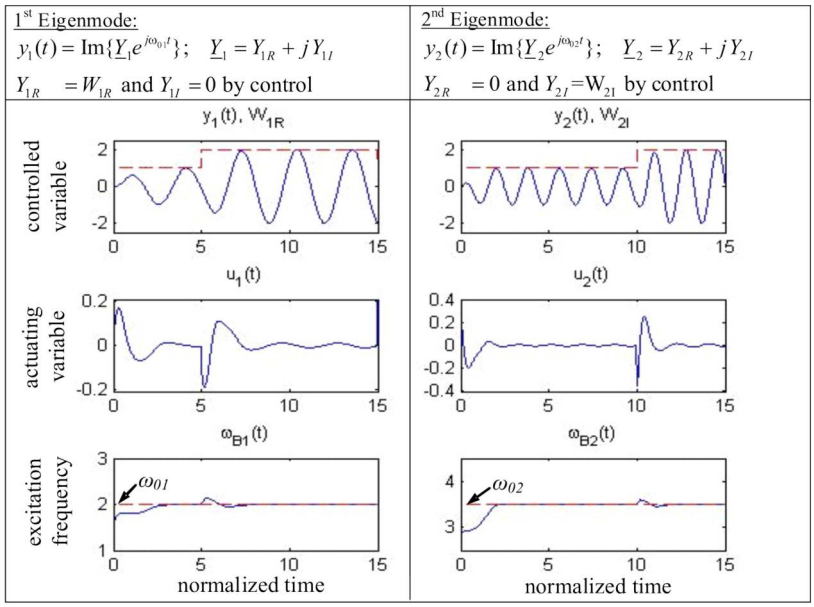

Fig. 2: Simulation results: Simultaneous control of the eigenmodes in their eigenfrequencies. At start-up the excitation frequencies differ by 20 percent from the real eigenfrequencies.

First simulation results (fig. 2) show good performance of the MIMO amplitude and frequency control at two different frequencies. Practical results were presented at the 15th Flow Measurement Conference Flomeko 2010 in Taipei, Taiwan and selected for publication in the Journal of Flow Measurement and Instrumentation (JFMI).

Control in Biotechnology (Eduard Peter, Wei Zhong)

The bacterium Streptococcus thermophilus is often used as a starter culture in the dairy and food industry. The bacterium is cultivated in a batch reactor and should be harvested at its maximum activity i.e. when the acidification rate reaches its maximum. As the pH value is kept constant during the fermentation, the acidification rate is reflected in the added base rate and measured as the control output of the pH controller. Regarding the inflection point of the added base, this point coincides with the point of maximum activity of the biomass.

To predict the inflection point at an early stage of the process, we use soft-sensing techniques based on artificial neural networks (ANN) that provide an efficient way to solve the problem. Using training data provided by our industrial partner and data from our own experiments, we succeeded in providing a tool for predicting the optimal harvesting point for the biomass. The tool is now being extensively tested by our industrial partner. Further developments will combine artificial knowledge together with exact process modelling (PhD-Thesis of Dorothee Barth) in order to further reduce the error in predicting the harvesting time for the biomass.

Control of a Micro Mechanical Mirror (Thomas von Wantoch)

The controlled deflection of a visible/invisible light beam usually referred to as optical or laser scanning, is a well-known and widely spread technology. Typical applications of input and/or output scanning for information handling comprise microscopy, object measuring/triangulation, spectral analysis and image projection.

As small and portable devices become increasingly prevalent in the modern information age, the need grows for ultra-compact systems for collecting, manipulating and visualizing information. Micro Electro Mechanical Systems

(MEMS) technology enables the design and fabrication of micro- mirrors for miniaturized optical scanning systems with lightweight, small aperture size, low-energy consumption, high scan frequencies, high mechanical robustness and reduced manufacturing costs at high volumes. In particular, MEMS scanners are very promising candidates for utilisation in compact laser projection systems for personal and mobile display solutions in infotainment and business.

A typical assembly for miniaturized projection systems involving 2D scanning with a single MEMS mirror is analysed in this research project. It consists of a laser source, a biaxially driven micro scanner and system electronics. Figure 3 demonstrates the optical operation principle of a laser projection system.

The laser beam is directed onto the mirror that oscillates sinusoidally around two perpendicular axes and produces a Lissajous figure on the projection area. By adjusting an appropriate frequency ratio for the two axes, every single point of the screen can be hit within a predetermined time frame. Modulating the laser source synchronously with the driving of the mirror, arbitrary images can be visualized. As there are no optics between the micro-mirror and the projection area the system has „unlimited" depths of focus.

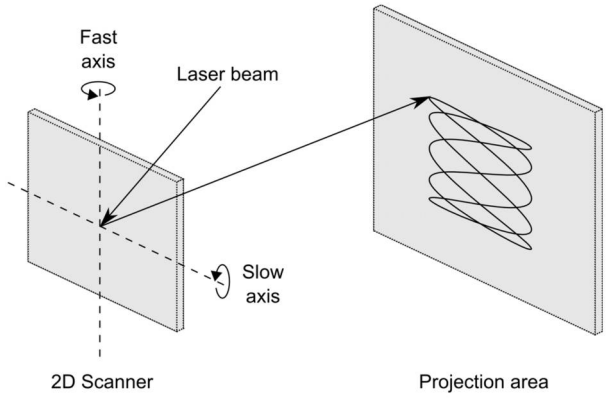

Fig. 3: Optical setup of a laser projection system with a single 2D scanner

The objective of the research project is to design and implement a control algorithm enabling the deflection of a RGB laser beam with a micro-mirror for scanning purposes. In order to guarantee a stable and distortion-free image projection the frequencies as well as the amplitudes of both sinusoidal oscillations must be controlled simultaneously. In addition, long term environmental changes such as temperature fluctuations and differences in the mechanical properties of the mirrors due to manufacturing, have to be compensated during operation. The implementation of the controller in the laboratory apparatus is realized on a FPGA-based DSP development system. In order to apply the controller in a miniaturized system, the feasibility of the digital algorithm in an integrated circuit (ASIC) must be taken into consideration during the design phase.

The MEMS scanners examined are developed and fabricated at the Fraunhofer Institut für Siliziumtechnologie (ISIT). The typical mirror aperture size is about 0.7mm. Mounting the specular surface on gimbals, the scanner can be deflected in two perpendicular axes with resonance frequencies of about 560 Hz and 16 kHz, respectively. As the mirror is packaged in a vacuum, very low damping and an accordingly high quality factor ($Q > 60.000$) can be achieved. To accomplish low power consumption and large mechanical scan angles up to $\pm 60°$ at the same time, the scanner is driven in resonant mode. The actuation of the scanner is realized by electrostatic forces applying stacked vertical comb drives. The position can be detected by capacitive measuring.

In a first step prior to designing a control method, a mathematical model of the system comprising electrostatic actuation, micro-mirror and capacitive position detection is developed. The oscillation of the scanner can be regarded as two coupled, second order differential equations that are characterized basically by the mechanical properties of the mirror. Due to thermomechanical effects and electrostatic forces and momentums nonlinear interactions must be taken into account. In

order to evaluate the mathematical model, a measurement setup to characterize the projection system is employed.

Personnel

Head of the group: Prof. Dr.-Ing. H. Röck; Secretary: S. Marquardt-Hansen (50%)
Technical Staff: Dipl.-Ing (FH) M. Lieb

Scientific Staff:

Dipl.-Ing. F. Koschmieder Coriolis mass flow measurement	01.01.-31.12.2010		CAU
Dipl.-Ing. E. Papazova Control of blood glucose levels	01.01.-31.12.2010		Guest
Prof. Dr. E. Pawluk Nonlinear control	01.01.-31.12.2010		Guest
Dipl.-Wirtsch.-Ing. E. Peter Process control in the dairy industry	01.01.-31.12.2010		CAU
Dipl.-Ing. Thomas von Wantoch Control of a Micro Mechanical Mirror	15.08.-31.12.2010		CAU
Dr. Wei Zhong Process control in the dairy industry	15.04.-31.12.2010	(50%)	Ind.

Lectures, Seminars, and Laboratory Course Offers

Winter 2009/2010

Praktikum Blockkurs Regelungstechnik II, 4 hrs Lab/Week,
H. Röck (+ F. Koschmieder, E. Peter)

Digitale Regelung, 2 (+1) hrs Lecture (+ Exercises)/Week,
H. Röck (+ E. Peter)

Regelungstechnik III, 2 (+1) hrs Lecture (+ Exercises)/Week,
H. Röck

Regelungstechnik I, 3 (+2) hrs Lecture (+ Exercises)/Week,
H. Röck

Ausgewählte Kapitel der Regelgungstechnik, 2 hrs Seminar/Week,
H. Röck (+ E. Peter, F. Koschmieder)

Anleitung zum wissenschaftlichen Arbeiten, 1 hrs Lecture/Week,
H. Röck (+ E. Peter, F. Koschmieder)

Blockkurs Regelungstechnik II, 3 hrs Lecture/Week,
H. Röck

Summer 2010

Praktikum Leistungselektronik und Regelungstechnik, 2 (+1) hrs Lecture (+ Exercises)/Week,
H. Röck (+ F. Koschmieder)

Robuste Regelung, 2 (+1) hrs Lecture (+ Exercises)/Week,
H. Röck (+ F. Koschmieder)

Ausgewählte Kapitel der Regelungstechnik, Anleitung zum wissenschaftlichen Arbeiten, 1 hrs Lecture/Week,
H. Röck (+ E. Peter, F. Koschmieder)

Praktikum Leistungselektronik und Regelungstechnik, 3 hrs Lab/Week,
H. Röck (+ F. Koschmieder, E. Peter, T. von Wantoch)

Ausgewählte Kapitel der Regelungstechnik, 2 hrs Lecture/Week,
H. Röck (+ F. Koschmieder, E. Peter)

Winter 2010/2011

Praktikum Leistungselektronik und Regelungstechnik, 4 hrs Lab/Week,
H. Röck (+ F. Koschmieder, E. Peter, T. von Wantoch)

Digitale Regelung, 2 (+1) hrs Lecture (+ Exercises)/Week,
H. Röck (+ E. Peter)

Regelungstechnik III, 2 (+1) hrs Lecture (+ Exercises)/Week,
H. Röck (+ F. Koschmieder)

Regelungstechnik I, 3 (+2) hrs Lecture (+ Exercises)/Week,
H. Röck (+ T. von Wantoch)

Ausgewählte Kapitel der Regelgungstechnik, 2 hrs Seminar/Week,
H. Röck (+ E. Peter, F. Koschmieder, T. von Wantoch)

Anleitung zum wissenschaftlichen Arbeiten, 1 hrs Lecture/Week,
H. Röck (+ E. Peter, F. Koschmieder, T. von Wantoch)

Praktikum Leistungselektronik und Regelungstechnik, 3 hrs Lab/Week,
H. Röck (+ F. Koschmieder, E. Peter, T. von Wantoch)

Third-Party Funds

Innovationsstiftung Schleswig-Holstein, *Control of biotechnological systems*, 01.01.-31.12.2010 (16.900,00)
Industrie, *Coriolis Mass Flow Measurement*, 01.01.-31.12.2010 (15.000,00)
Prof. Werner Petersen Stiftung, *Travel costs*, 01.-31.08.2010 (1.500,00)

Diploma, Bachelor and Master Theses

T. von Wantoch, *Erstellung eines vollständigen Phasor-Modells eines Coriolis-Massendurchflussmessers (CMD); Nichtlineare, zeitvariante Regelung eines CMD*, 30.09.2010

A. Trost, *Anwendung eines Kompensationsverfahrens zur Bestimmung von Nullpunkt und Empfindlichkeit eines Coriolis-Massendruchflussmessers mit einem geraden Messrohr*, 16.06.2010

Dissertations / Postdoctoral Lecture Qualifications

J. Hörrmann, *Prozessführung eines biotechnologischen Prozesses am Beispiel der Fermentation des Bakteriums Streptococcus thermophilus*, 11.10.2010

P. Weitmann, *Technik als Kunst. Automaten in der griechisch-römischen Antike und deren Rezeption in der frühen Neuzeit als Ideal der Kunst oder der Philosophie und Wirtschaft.*, 02.12.2010

Publications

Published in 2010

H. Röck, F. Koschmieder, *Compensation Method Applied to Coriolis Mass Flow Metering, Flomeko 2010, Taipeh, Taiwan,* 15th International Flow Measurement Conference Flomeko2010, CDROM ISBN 978-986-264-062-3, Taipei, Taiwan, (2010)

Presentations

H. Röck, *Vorstellung der Arbeitsgebiete des Lehrstuhlls ART*, ISIT, Itzehoe, 02.10.2010

H. Röck, *Phasoren Regelung am Beispiel eines Coriolis-Massendurchflußmessung,* Universität Stuttgart, Stuttgart, Deutschland, 15.06.2010

Further Activities and Events

Honorary positions of Prof. Röck:

member of the International Programme Committee IEEE Multi-Conference on System and Control 08.09.-10.09.2010, Yokohama, Japan,

reviewer IEEE Multi-Conference on System and Control 08.09.-10.09.2010, Yokohama, Japan,

member of the „Tönnis Kommission" ,

executive director of the Institute of Electrical and Information Engineering,

member of the GMA Workshop Theoretic Methods in Control Engineering (GMA Arbeitskreis Theoretische Verfahren der Regelungstechnik),

member of the AHMT (Arbeitskreis der Hochschullehrer für Messtechnik),

head of Engineering Branch Library (Fachbibliothek Ingenieurwissenschaften),

member of Examination Committee Industrial Engineering,

member of Honorary Committee „Prof. Lange" , Rostock.

Digital Signal Processing and System Theory

The department of ''Digital Signal Processing and System Theory'', abbreviated DSS in the following, has been in existence since October 1993, with the abbreviation LNS, for ''Lehrstuhl für Netzwerk- und Systemtheorie'', i.e., Chair for Circuit and System Theory. The new name came together with a new professor; On March 1-st, 2010, Dr.-Ing. Gerhard Schmidt took over from Dr.-Ing. Ulrich Heute, who, however, is still actively involved in several projects of DSS.

At the beginning of 2010, there were four scientific co-workers, two paid by the state, two on a project-funding basis, plus the Head of the group with a secretary and a technician (both also working for the group for Information & Coding Theory (ICT) of Prof. Dr.-Ing. P. Höher). In addition, several students helped us, on a short-time job basis, with the everyday work in teaching, research, and administration.

Both of the state-paid scientists and one fellowship holder who had left already in December 2009 had their –very successful – doctoral examinations in the first months of the year. The former fellow joined a team at the neurological university hospital at Kiel, as a post-doc within a large cooperative project which also involves DSS. Of the other two new doctors one left for a job in industry in Bremen, and the other stayed half a year longer and helped to create the new DSS environment.

After the actual start of DSS, i.e., after March 2010, the personnel grew, and since the middle of the year, there have been nine research scientists working with the two professors here at the institute. In addition, five external research scientists are part of the DSS team.

Our cooperations with the Neurology Department of the University Clinics Kiel and with the Federal-Navy Research Institute for Under-Water Acoustics and Geophysics (abbreviated FWG) continued with very good success, the latter based now on two BMV-funded projects, and the former on a huge DFG-funded bundle of 17 scientific projects (''Sonder-Forschungsbereich'', ''SFB-855'') with groups from materials science, physics, electrical and information engineering, and medicine; the DSS part concerns the digital processing of encephalographic signals gained from newly developed magneto-electric sensors.

The cooperation with FWG was strengthened furthermore by another new, large project funded by BMWi, termed PITAS, concerning detection and classification of pirate or terrorist attacks against ships, and involving also, apart from DSS and three other groups of TF, teams from four industrial companies in Schleswig-Holstein. Furthermore, the cooperative work with the Telecom laboratories at TU Berlin was restarted, based once again on a DFG-funded research project.

Speech and audio processing continue to be important research topics of the chair. To be more precise, the investigation of so-called in-car communication systems (systems that support speech communication in passenger compartments) has started in 2010. In addition to that, research on the (real-time) simulation of acoustic environments has started. With this approach, it is possible to simulate the acoustic properties of any location in a semi-anechoic chamber or even in an arbitrary, yet silent location. While the approach of wave field synthesis demands expensive equipment, our goal is to minimize the amount of needed channels.

Results

Ongoing work led to numerous publications and presentations. Prof. Heute published a summary of the ongoing cooperation in tremor research, and he presented an overview of the neurology work at the international conference BIOSIGNAL 2010 in Brno, Czech Republic. The problems and ideas behind the new FWG project concerning detection and classification of marine mammals were presented at an ITG meeting in Erlangen. Prof. Schmidt was mainly focussed on starting the new part of the institute, which will have a strong emphasis on real-time processing of speech and audio signals. In the various fields of DSS, of course, the co-workers presented their results also:

- Speaker characterization: Jan Schwarz finalized his doctoral thesis and defended it successfully in February 2010.

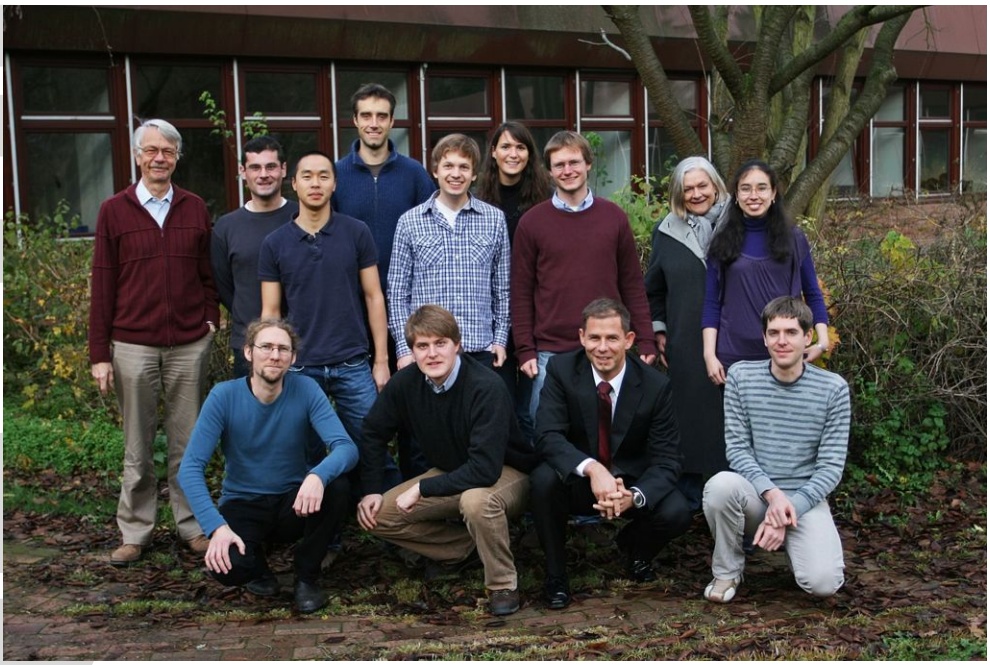

Fig. 1: The DSS team (November 2010).

- Speech quality: As mentioned, this is still a central item of DSS research within a continuous and extremely fruitful cooperation with ''T-Labs'' at TU Berlin, especially the group of Prof. Dr.-Ing. Sebastian Möller. A new DFG project was launched, and Christoph Norrenbrock presented some first ideas at an ITG meeting in Aachen.

- Medical signal processing: ECGs were analyzed with the aim of sleep-stage identification. Halil Özer looked into both common parameters like heart-rate variability and not-so-well investigated morphological details of the ECG itself, based on pattern-matching and filter-bank /wavelet approaches. He finalized his doctoral thesis, which was successfully defended in April 2010.

- Medical signal processing: EEGs and, in the future, MEGs, are analyzed by Muthuraman Muthuraman, cooperating closely with the Neurology group at Kiel's University Clinics. The aim is to find new hints to the sources of Parkinson's disease. The results led to various publications, one at BIOSIGNAL 2010, in Brno, Cz., and one in the journal on Biomedical Signal Processing and Control. Furthermore he also finalized his doctoral thesis and defended it successfully in February 2010.

- Medical signal processing: Noise and artefact reduction in MEGs are the central topic of the DSS part of the above mentioned SFB-855, to be carried out by Alina Santillán Guzmán. She presented the state of her work at an SFB seminar in Salzau, in September 2010.

- Sonar-Signal Processing: Kathrin Seget (now Wilkens) continued to work for a FWG-BMV funded project on active-sonar DSP, with a focus on tracking by means of variants of Kalman filters. The cooperation includes, apart from the FWG team at Kiel, the strong tracking-expert group of FGAN at Wachtberg and practical experiments on research vessels of the Federal Navy. The state of the work was presented at a sonar workshop in Leipzig, and a publication was accepted at the International Conference on Information Fusion, Edinburgh, 2010.

- Sonar signal processing: Dennis Küter started to work for the PITAS system and, especially, for novel concepts of a sonar sensor. His first ideas will be published at DAGA 2011 in Düsseldorf.

- Sonar signal processing: Viet Duc Nguyen started to also work for PITAS, and his part concerns object tracking and sensor fusion. The state of his work is documented in a first report.
- Marine-Mammal Detection and Classification: In close cooperation with FWG and, especially, with Drs. Ludwig, Knoll, and Nissen, a huge database was created and sorted meanwhile by Roman Kreimeyer.

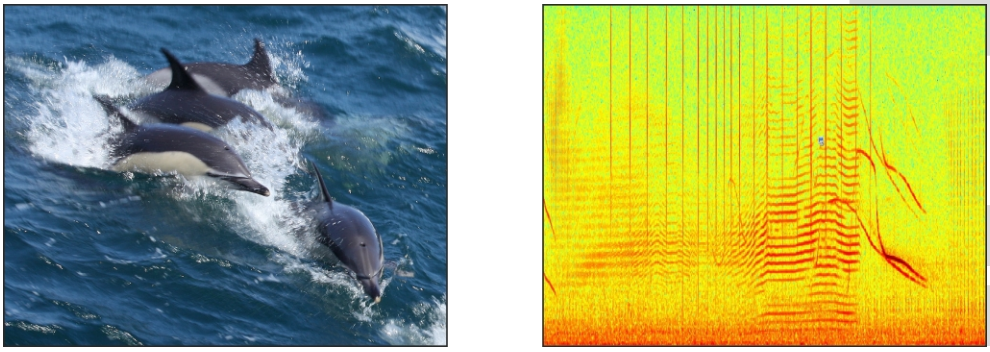

Fig. 2: Dolphins and a time-frequency analysis of their sounds.

- Real-time audio processing: Christian Lüke, Halil Özer, Gerhard Schmidt, and Jochen Withopf started with the development of the "KiRAT" soft- and hardware combination. "KiRAT" stands for Kiel Real-Time Audio Toolkit, and will be the basis for the audio and speech research at the institute.
- Real-time audio processing: Jochen Withopf started to implement an in-car communication system, which improves the communication between front and rear passengers of a vehicle.
- Real-time audio processing: Christian Lüke started to implement an acoustic environment simulation, allowing for reliable and reproducible testing of speech and audio equipment in nearly real environments.

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.-31.12.2010	Lecturer and PhD supervisor
Dr.-Ing. T. Ludwig	01.01.-31.12.2010	Lecturer

Scientific Staff:

Dipl.-Ing. M. Christoph	01.07.-31.12.2010	External PhD student
M.Sc. M. Haide	01.07.-31.12.2010	External PhD student
M.Sc. P. Hannon	01.07.-31.12.2010	External PhD student
Dipl.-Ing. R. Kreimeyer	01.01.-31.12.2010	PhD student
Dipl.-Phys. D. Küter	01.10.-31.12.2010	PhD student
Dipl.-Phys. C. Lüke	01.04.-31.12.2010	PhD student

Dipl.-Ing. D. Nguyen	01.09.-31.12.2010	PhD student
Dipl.-Ing. C. Norrenbrock	01.04.-31.12.2010	PhD student
M.Sc. A. Santillán Guzmán	15.03.-31.12.2010	PhD student
M.Sc. Sebastian Stenzel	01.07.-31.12.2010	External PhD student
Dipl.-Ing. K. Wilkens	01.01.-31.12.2010	PhD student
Dipl.-Ing. J. Withopf	01.04.-31.12.2010	PhD student
M.Sc. A. Wolf	01.07.-31.12.2010	External PhD student
Dr.-Ing. H. Özer	01.01.-31.12.2010	PhD student and postdoc

Lectures, Seminars, and Laboratory Course Offers

Summer 2010

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,
U. Heute (+ C. Norrenbrock)

Signals and Systems I, 3 (+2) hrs Lecture (+ Exercises)/Week,
G. Schmidt (+ J. Withopf)

Statistical Signal Processing, 2 (+1) hrs Lecture (+ Exercises)/Week,
T. Ludwig

System Theory Lab, 3 hrs Lab/Week,
G. Schmidt (+ C. Lüke)

Seminar on Topics in Digital and Optical Communications, 3 hrs Seminar/Week,
G. Schmidt (+ together with several members of the faculty)

Winter 2010/2011

Advanced Digital Signal Processing, 2 (+1) hrs Lecture (+ Exercises)/Week,
G. Schmidt (+ C. Lüke)

Advanced Signals and Systems, 3 (+2) hrs Lecture (+ Exercises)/Week,
U. Heute (+ H. Özer)

Digital Speech Signal Processing, 2 (+1) hrs Lecture (+ Exercises)/Week,
U. Heute (+ C. Norrenbrock)

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)

Third-Party Funds

Industry, *Research on the topics described before,* 01.-31.01.2010 (Adequate payment)
Bundesamt für Wehrtechnik und Beschaffung (BMV):, *New Concepts for Sonar Detection, Classification, and Tracking of Small Moving Targets under Water by DSP,* 01.-31.01.2010 (71800 EUR)
Bundesamt für Wehrtechnik und Beschaffung (BMV), *Detection and Classification of Marine Mammals by means of Speaker-Recognition Methods,* 01.-31.01.2010 (65000 EUR)
DFG, *Synthetic Speech-Signal Quality Measurement,* 01.09.-31.12.2010 (22000 EUR)
DFG / SFB-855, *Digital Signal Processing for New MEG Sensors,* 15.01.-31.10.2010 (50000 EUR)
BMWi, *New Sonar Sensor Concepts, Tracking, and Sensor Fusion (within the project PITAS),* 01.09.-31.10.2010 (30000 EUR)

Diploma, Bachelor and Master Theses

V. D. Nguyen, *Analyse des Einflusses einer variablen Clutterdichte auf das Trackingergebnis,* 04.06.2010
A. R. Anwar, *Partial Directed Coherence between EEG and EMG in Tremor,* 01.12.2010

Dissertations / Postdoctoral Lecture Qualifications

H. Özer, *Untersuchung des Elektrokardiogramms bezüglich eines Zusammenhanges zwischen Herzaktivität und Schlaf,* 30.04.2010
J. Schwarz, *Statistische Stimmenumwandlung in Kombination mit prosodischen Modellen,* 05.02.2010
M. Muthuraman, *Interactions in the Complex Tremor-Related Motor Networks of the Brain,* 12.02.2010

Publications

Published in 2010

P. Hannon, G. Schmidt, M. Krini, A. Wolf, *Reducing the Complexity or the Adaptive Subband Filtering,* Proc. ESSV, Berlin, Germany, 158 - 165 (2010)
A. Wolf, B. Iser, G. Schmidt, *Laufzeitoptimierte Geräuschreduktionsverfahren basierend auf overlap-save-Strukturen mit Projektionsfilternäherungen,* Proc. ESSV, Berlin, Germany, 134 - 141 (2010)
K. Seget, A. Schulz, U. Heute, *Maneuver-Adaptive Multi-Hypothesis Tracking for Sonar Systems,* Proc. IEEE ISIF GI Workshop Sensor Data Fusion, Leipzig, Germany, (2010)
J. Withopf, P. Hannon, M. Krini, G. Schmidt, *Phoneme-Dependent Speech Enhancement,* Proc. ITG-Fachtagung, Bochum, Germany, (2010)
K. Seget, A. Schulz, U. Heute, *Multi-Hypothesis Tracking and Fusion Techniques for Multistatic Active Sonar Systems,* Proc. International Conference on Information Fusion, Edinburgh, Scotland, (2010)
B. Iser, G. Schmidt, *Bandwidth Extension of Telephony Speech,* Haykin (eds.), Adaptive Signal Processing: Next Generation Solutions, Wiley-IEEE Press, New York, USA, 349 - 391 (2010)
M. Buck, E. Hänsler, M. Krini, G. Schmidt, T. Wolff, *Acoustic Array Processing for Speech Enhancement,* S. Haykin, K. J. R. Liu (eds.), Handbook on Array Processing and Sensor Networks, Wiley-IEEE Press, New York, USA, 231 - 268 (2010)
U. Heute, M. Muthuraman, J. Raethjen, G. Deuschl, *Tremor-Erkrankungen: Symptome, Verstaendnis, Hilfe,* Christiana Albertina, **70**, 42 - 53 (2010)
M. Muthuraman, J. Raethjen, G. Deuschl, U. Heute, *Differentiating essential tremor patients form healthy subjects using time-frequency analysis,* BIOSIGNAL 2010, Berlin, Germany, (2010)
M. Muthuraman, A. Galka, G. Deuschl, U. Heute, J. Raethjen, *Dynamical correlation of non-stationary signals in time domain: A comparative study,* Biomedical Signal Processing and Control, **5**, 205 - 213 (2010)

M. Knoll, R. Kreimeyer, S. Ludwig, *Performance of the PASS-MMAD System during Sirena10*, FWG, Technical Report, (2010)

Presentations

U. Heute, *Tremor Diseases – Help via Signal Processing*, BIOSIGNAL 2010, Brno, Cz., 30.06.2010

U. Heute, *Klassifikation von Meeressäugern mit Methoden der Spracherkennung*, ITG-Fachgruppe Algorithmen der Signalverarbeitung, Erlangen, Germany, 26.02.2010

C. Norrenbrock, *Stimmqualitätsbeurteilung für synthetische Sprachsignale*, ITG-Fachgruppe Algorithmen der Signalverarbeitung, Aachen, Germany, 15.10.2010

K. Wilkens, *Multi-Hypothesis Tracking and Data Fusion applied to MSTWG datasets*, 10th Meeting of the Multistatic Tracking Working Group (MSTWG), Edinburgh, Scotland, 26.07.2010

Further Activities and Events

Membership and activities of U. Heute in the following functions:

- Editorial Board of the CAU university journal ''Christiana Albertina'',
- Advisory Committee, European Association for Signal, Speech, and Image Processing (EURASIP),
- Editorial Board,''SIGNAL PROCESSING'',
- Editorial Board, ''Journal of Advances in Signal Processing'',
- Scientific Committee, European Signal Processing Conference (EUSIPCO), and co-organizer of a Special Session on Filter Banks, Aalborg, Dk., September 2010,
- Scientific Committee, International Conference BIOSIGNAL 2010, Brno, Cz.,
- Scientific Committee, International Conference on Speech Processing (INTERSPEECH) 2010, Japan,
- Session Chair, ITG conference ''Speech Communication'', Bochum, October 2010.

Technology of Silicon-Based Micro- and Nano-Systems

Prof. Dr. Wolfgang Benecke is since October 2008 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 - to 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 millimeter 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 applicationspecific 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, analyze the quality and reliability of electronic components, and develop advanced power-supply components for electronic systems.

The institute employs a staff of around 150 people

Further information about Fraunhofer ISIT is available in the web: www.isit.fraunhofer.de.

In addition the Institute publishes an Annual Report, which can be ordered at ISIT.

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Microwave Laboratory

The **Microwave Laboratory** of the Christian Albrechts University of Kiel (CAU) has continued research in the areas of **ultra-wideband technology (UWB)**, **power amplifiers for communication systems**, and **high frequency materials and components**. The working area of **microwave sensors**, where highly recognized research has been carried out during the last few decades, has been further extended to field based sensors, which include for example eddy current sensors, low frequency capacitive sensors and magnetoelectric sensors. Another working area is **molecular spectroscopy**, where work on spectrometer construction continues.

UWB-technology concentrates on sensors for the characterization of condition, composition and history of natural materials. At present the research is focused on non-contacting determination of the properties of dielectric objects, which may be much smaller than the footprint of the interrogating antenna. Over the years the laboratory has acquired considerable expertise in the application of dielectric spectroscopy and in the use of multivariate statistics to analyse the response of UWB signals.

The work on **power amplifier (PA) principles** is mainly concerned with so-called sequential amplifiers and outphasing amplifiers. The concept of sequential amplifiers was investigated with respect to efficiency and linearity and extended to various derivatives with distinct advantages concerning re-configurability and tunability. Some work has been devoted to a novel approach of linearization by predistortion. Outphasing amplifiers have also been investigated for many years in this laboratory. Present work concentrates on special power combiners and PA linearization.

Industrial microwave sensors is an area, where the microwave laboratory has a long established experience. A wide range of sensors has been created in the past. Present work concentrates on millimetre wave doppler radar sensors for the characterization of, for example aerosols, on other radar sensors and on sensors for medical applications. In addition, a novel density independent measurement method was conceived, which is suited for moisture measurements up to very high moisture levels. Significant effort has been devoted to investigations concerning the characterisation of thin film magnetoelectric sensors in collaboration with the materials research at Kiel and to low noise electronic circuits for interrogating such devices.

The working area **Materials and high frequency components** is focused on various characterization methods for the determination of the permeability of magnetic nanocomposites at frequencies up to several GHz. The materials are then applied in components such as inductors or balun transformers at microwave frequencies. Close cooperation exists in this area with the materials research at CAU Kiel.

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.

Results

Non-Contacting Characterization of the Dielectric Properties of Objects of Irregular Shape

The aim of the DFG-project ISOPerm (irregular shaped objects permittivity) is to develop an UWB method for the measurement of the dielectric properties of irregularly shaped bodies by using a non-contacting approach. Industrial processes often require for example, the determination of the water content of bulk materials and other process parameters. There is a strong correlation between many of those quantities and the dielectric properties. Therefore, dielectric measurements are well-suited for material characterization. Existing methods for such measurements require that the samples are regular in shape. They also require that the entire cross section of the electromagnetic field which is used is filled with the material under test. The method under development does not require such restrictions. Unlike existing methods, and as a novel approach, an attempt was made using multivariate analysis, to separate effects caused by the geometry of the object from those caused by its dielectric properties. It was successfully proved with simulations and

measurements of dielectric objects and the use of multivariate analysis methods that the determination of the dielectric properties is possible independent of shape, size and orientation to a certain accuracy. It was also shown that related properties like for example the water content of water-ethanol mixtures or the carbon content of carbon loaded silicons can be determined directly from time domain data. The multivariate analysis methods can be improved by a prior classification algorithm which classifies objects into dielectric classes, e.g. high and low dielectric constant. The statistical models applied for each class are more accurate in comparison to statistical models for the whole dielectric range. Further investigations will focus on the demonstration of a stand-alone sensor system which will form the basis of the development of a prototype practical apparatus capable of working in real time. This will reveal the system performance and accuracy under practical conditions.

Magnetic Nanocomposites for RF-Applications

In cooperation with the Multicomponent Materials department, the Inorganic Functional Materials department and the Nanoelectronics group novel magnetic and magnetoelectric materials were characterized by measurements. Additionally, analytical expressions for modelling these materials were found. The measured permeability spectrum was used to calculate the unknown material parameters by using a nonlinear regression algorithm. Furthermore a new approach for the design of baluns with magnetic cores was introduced. The investigations have the objective to fulfil the demands of small size, wide operation bandwidth, and low loss, required for modern mobile communication and electronic systems. Baluns were designed using HFSS and will be realized in thin-film technology with various core designs to avoid eddy currents and minimize parasitic capacitances.

Heterotopic Bone Induction

When the jaw bone is affected by cancer the diseased areas need to be removed. Today these removed parts are replaced by tissue from the thigh bone. This procedure has the disadvantage that the thigh bone becomes more fragile. In this project another way is pursued: a matrix of calcium apatite is manufactured by a 3D-plotter in such a way that the shape perfectly fits into the gap created by the removed tissue. This matrix is provisionally transplanted into a muscle. Stem cells colonize the matrix which has the structure of a sponge. When growth factors are injected into the matrix a vascularisation process starts and the tissue built by the stem cells is nourished. After a period of 12 to 16 weeks the matrix is permeated by new induced cartilage and bone tissue. The new bone piece is now ready to be transplanted into the gap in the jaw. The advantage of the described method is that the tissue is produced by the patient and therefore there is no rejection by the immune system. A disadvantage of heterotopic bone induction however is that the growth factors may cause cancer. Hence the drug dose should be as small as possible. In order to optimise the ossification a regularly monitoring is needed.

For this purpose an eddy current sensor was developed in the microwave laboratory. The principles of eddy current sensors are well known and they are established in metal detectors. The challenge in this application is that the conductivities of the involved tissues are relatively low in comparison to metals by a factor of a million. Furthermore the difference in conductivity between bone tissue and body fluid (filling the sponge of calcium apatite) is relatively small. Because the sensor works with magnetic fields it can measure tissues behind the skin and therefore being non-invasive causes no injuries. The results of the measurements are available immediately. Hence the progress of the ossification can be monitored continuously without any risks of infections. On the basis of simulations the structure of the sensor was optimised and a suitable frequency was found. A prototype was built and first measurements led to encouraging results. In the future the sensor will be evaluated in animal tests. This project is carried out together with the Department of Oral and Maxillofacial Surgery of the Clinical Centre of the Christian-Albrechts-University.

Collaborative Research Centre SFB 855 ''Magnetoelectric Composite Materials - Biomagnetic Interfaces of the Future''
Subproject C3: Sensor Modelling and Electronic Signal Processing

The aim of the collaborative research centre SFB 855 is the development of a highly sensitive magnetoelectric (ME) detection unit that is able to measure biomagnetic signals in the picotesla region. Previous noise calculations of sensor and readout electronics were verified by noise measurements. A system noise level as low as 7.5 $pT/\sqrt{Hz}$ and magnetic

signals down to 10 pT were measured. Moreover a ME modulation technique was conceived and developed to reach a

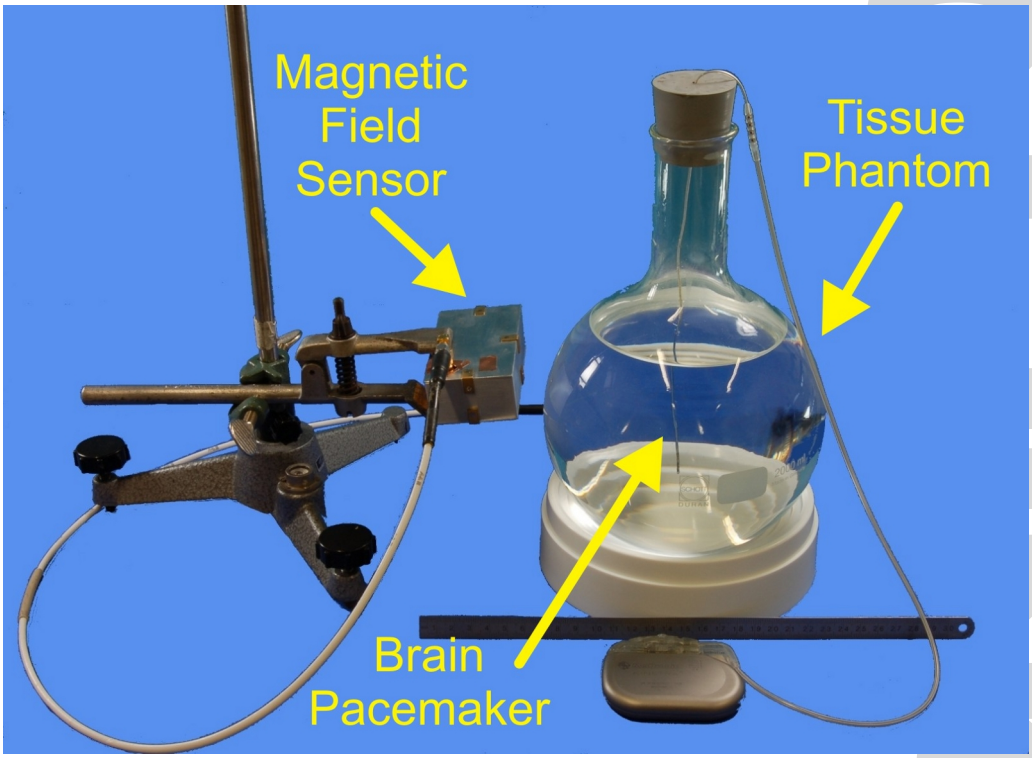

Fig. 1: Measurement of the magnetic field of a brain pacemaker in a phantom head

high system sensitivity outside the sensor resonance. This technique allows sensitive broadband measurements below 100 Hz as required for biomagnetic diagnostics in magnetoencephalography (MEG) and magnetocardiography (MCG). Another task was the detection of magnetic fields caused by pacemaker signals, for which a compact magnetometer was developed and simulations and measurements were carried out. Furthermore a non-magnetic scanner was designed to allow a 3 dimensional movement of the sensor.

PITAS

The PITAS-project is a common activity of the maritime cluster in Kiel and the chairs of „Circuit- and System Theory, (Prof. Heute)“ , „Information and Coding theory, (Prof. Höher)“ ,and „Microwave group, (Prof. Knöchel)“ from the Institute of Electrical Engineering and Information Theory, and the chair of „Information Systems Engineering, (Prof. Klein)“ from the Institute of Computer Science. It addresses attacks of piracy and terrorism on civilian ships. The background of the subproject described is the radar surveillance of the near-range of less than for example one mile around ships, for identifying approaching threats like attacking pirates in order to achieve an early warning to the ship’s crew. Various low cost near-range radar concepts have been investigated with respect to their suitability for use on ships. One of those concepts was near-range surveillance using van Atta arrays. Such radar allows high speed tracking of near -range targets like for example bullets. It turned out, that the van Atta array requires considerable effort in order to offer the required spatial resolution and thus leads to quite complex and costly systems. It has therefore been abandoned for the purpose of tracking swimmers and speedboats. Other system concepts are still under investigation.

Radar-Sensor for the Detection of Dust

A double frequency radar method for remote sensing of disperse streams of solid particles was developed. The method is based on measuring a differential radar cross-section of a moving particle ensemble, and permits the estimation of the parameters of particle size distribution for different types of disperse streams. The method developed was tested on

generated disperse stream of calibrated solid particles using a specially developed double-frequency radar-sensor in the Ka- and W-bands. The

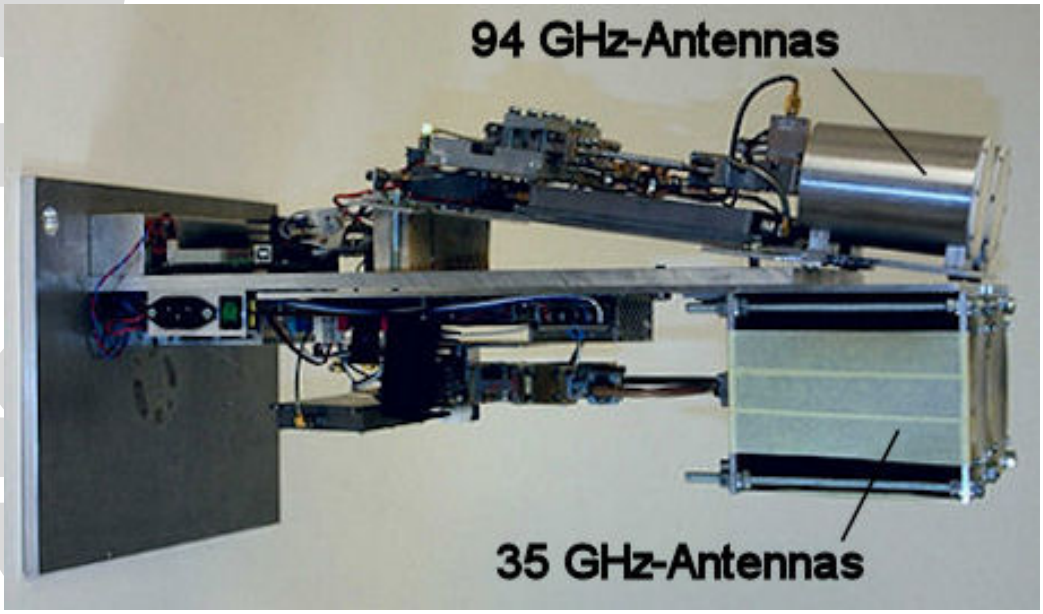

Fig. 2: Double-frequency radar-sensor

experimental data obtained show a good agreement with the simulated results. This allows the method to be used in sensors for industrial emission control, volcano eruption monitoring, dust storm forecast, etc.

Metamaterial Loaded Passive Components

Slow Wave Structures: In order to improve the characteristics of a spatial harmonic magnetron (SHM), the slow wave structure (SWS) of these devices has been loaded by different types of metamaterials. It has been shown that loading the SWS by a negative permeability medium (MNG) can provide the possibility of increasing the efficiency of these devices together with the possibility of increasing the SWS dimensions, which is very important in the millimetre wave range.

Sensors: Solving Maxwell's equations in a cylindrical waveguide which has been filled by anisotropic medium clarifies the possibility of establishing the idea of a virtual short circuit. This virtual short can be used to confine the energy at the open end of a cylindrical TE011 moisture sensor while it blocks only a very small part of the open end. In conventional sensors 75% of the open end should be covered by copper in order to avoid radiation. This has two drawbacks: the first one is a perturbation of the gas flow and the second is a contamination of the end parts, which will affect considerably the quality factor and therefore the accuracy of measurement.

Resonators: In 2002 it has been shown by N. Engheta that loading a slab waveguide with a metamaterial layer can provide the possibility of designing very thin (but only in width) sub-wavelength resonators. Using this idea together with a rigorous analysis of a circular waveguide which has been partially loaded by an anisotropic metamaterial layer, a very small coaxial cylindrical cavity resonator loaded by such a layer(6mm radius and 3.1mm height : resonant frequency 4.9GHz) was realized and simulated. This resonator eliminates the drawback of metamaterial loaded slab waveguide resonators which are small in width but not in length.

Microstrip Filter Design with Fuzzy Logic

Using time consuming full wave simulations and numerical analysis in electromagnetics problems is unavoidable if an exact solution is required. From the perspective of an engineer a trade-off between time and accuracy needs to be found. Sometimes an estimation of the solution with acceptable approximations which have been calculated by a pocket calculator

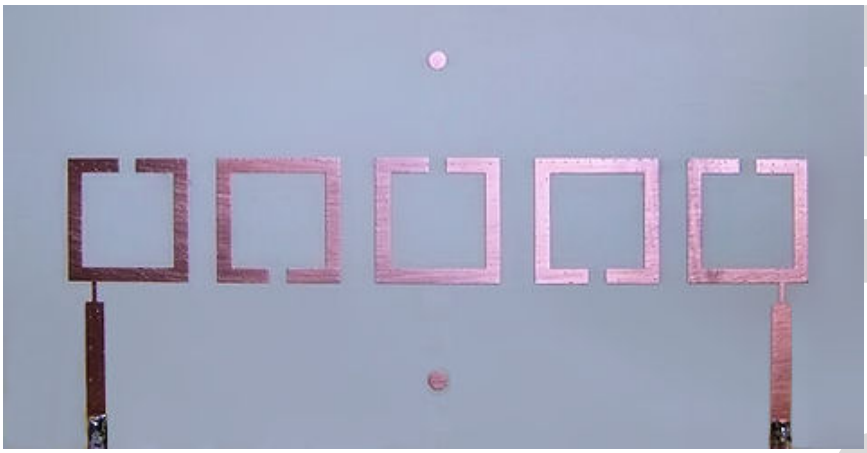

Fig. 3: Open loop resonator filter. The design parameters are extracted using the fuzzy logic method.

is more valuable than a time consuming simulation. This research tries to find a fast and accurate method for the time consuming full wave analysis of a desired filter coupling matrix. This approach makes the filter design process vanishingly short. To reach the above mentioned goal a novel fuzzy logic based approach has been used to overcome the drawbacks of common approaches. The advantage of the method is mimicking the human brain's approach when it encounters a new problem. Therefore a complicated view of the problem is substituted by a simple view of it. Thus the method has a simple formulation and pattern-based processing instead of using complicated models. The approach remains unchanged whether the problem is complicated or simple because it tries to imagine that each multi-input single-output (MISO) system is a combination of some single-input single-output (SISO) one. The behaviour of each SISO system is extracted by the new method and then the total behaviour of the system is extracted by a proper combination rule of inference. The method has been tested in designing open loop microstrip filters with rectangular and triangular structures. The modelling has been completed for two and three independent variables affecting coupling factor and external quality factors. Fabrication and characterization of five different filters (different structures and different filtering characteristics) has confirmed the accuracy and speed of the method. Higher numbers of independent variables affecting coupling factor and external quality factor will be modelled in the next steps. The ability of the method to design other different structures rather than the microstrip open loop resonator filter is currently being investigated.

Architectures of Sequential Power Amplifiers

Various types of sequential power amplifiers have been conceived and analyzed in detail theoretically and experimentally. Sequential amplifiers are somewhat similar to the well-known Doherty power amplifiers, but in contrast to the latter, the main- and peaking- amplifiers are well isolated from each other and can be developed separately, which simplifies the design considerably. In the present project the original concept of sequential power amplifiers has especially been extended concerning reconfigurability and tunability. Thus wideband power amplifiers have been developed which can be tuned over considerable frequency bands while the efficiency under back-off can be adapted to the amplitude probability density of the modulation spectrum used employing directional couplers with switched or tuned coupling ratios.

Microwave Moisture- and Mass- Measurement

The state of the art microwave moisture meters used so far exploited a so-called two parameter measurement approach in order to accomplish an independent determination of moisture content and material density (or mass, if the volume under consideration is fixed). However this approach failed at certain moisture levels, because both measurement values were no longer independent of each other and the combined measurement went into saturation over a certain moisture range. By carefully investigating the dielectric spectra of various moist materials over wide frequency bands and at different moisture levels, it was found that the saturation effect was caused by the dependency of effective relaxation frequencies on the

moisture level. Therefore a new class of moisture meters was conceived, which overcomes the saturation effect and is able to uniquely measure materials with moisture levels from very dry up to high values of 50% and more. The new moisture meters employ at least four parameter measurements, which are for example carried out with wideband ring resonators at two suitably chosen, resonant frequencies. The same approach, however, can also be utilized with wideband antennas.

UWB Through-Wall-Radar

An application of an UWB radar system with a breath simulator (UWBSBS) for remote measurement of the position and respiration of hidden persons in varying positions and angles was finished. A suitable reference system was provided by the breath simulator. The system can control the frequency of simulated human breath and measure it at the same time. The measurements have been done in a given area with 120 measurement points. The whole process of life detection in this case was also carried out automatically. The analysis of these measurements has been accomplished and led to encouraging results.

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 1 THz (0,1 m/m wavelength) a suitable cryostat provided with a superconducting magnet, delivering by 4K a magnetic field of 1 Tesla around the InSb-chip, is under construction in the local workshop of the faculty. Within the scope of the DFG-cooperation project (official ending shifted to 2011) with the Institute of Applied Physics of the Russian Academy of Science (Nizhnii Novgorod) spectra of the HCCCN (propene cyanide), 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 with accuracies $\leq$ 1 kHz for investigation of the dynamics of interstellar clouds.

Personnel

Head of the group: Prof. Dr.-Ing. R. Knöchel; Secretary: M. Bork
Technical Staff: H. Runkowske, Dipl.-Ing. (FH) W. Taute

Scientific Staff:

M.Sc. C.-C. Chao	01.01.-31.12.2010	externally funded
Through wall radar		
Dr.-Ing. F. Daschner	01.01.-31.12.2010	CAU
Resonant stents / Microwave sensors / Heterotopic bone induction		
Dipl.-Ing. W. Gerhard	01.01.-31.12.2010	externally funded
High efficiency amplifiers		
Dipl.-Ing. F. Hettstedt	01.01.-31.12.2010	DFG
Magnetic nanocomposites for RF-applications		

Dipl.-Ing. R. Jahns Magnetoelectric sensors	01.01.-31.12.2010	DFG
Dr. M. Kent Non-contacting characterisation of irregular shaped objects	01.01.-31.12.2010	Contract/ Guest researcher
Dr.-Ing. T. Lehmann High efficiency amplifiers	01.01.-31.12.2010	CAU
Dipl.-Ing. H. Mextorf Non-contacting characterisation of irregular shaped objects	01.01.-31.12.2010	DFG
M.Sc. N. Nasresfahani Metamaterials in microwave structures	01.01.-31.12.2010	DAAD
M.Sc. P. Rezaee Microwave filter design with fuzzy logic	01.01.-31.12.2010	DAAD
M.Sc. O. Teplyuk Radar-sensor	01.01.-31.12.2010	CAU

Lectures, Seminars, and Laboratory Course Offers

Winter 2009/2010

Leitungstheorie, 2 (+1) hrs Lecture (+ Exercises)/Week,
R. Knöchel (+ F. Daschner)

Nichtlineare Schaltungen, 2 (+1) hrs Lecture (+ Exercises)/Week,
R. Knöchel (+ F. Hettstedt)

Radar, 2 (+1) hrs Lecture (+ Exercises)/Week,
R. Knöchel (+ F. Hettstedt)

Hochfrequenz-Messtechnik, 2 (+1) hrs Lecture (+ Exercises)/Week,
R. Knöchel (+ T. Lehmann)

Praktikum Hochfrequenztechnik, 4 hrs Lab/Week,
R. Knöchel (+ F. Daschner, F. Hettstedt, T. Lehmann, H. Mextorf)

Seminar Hochfrequenztechnik, 2 hrs Seminar/Week,
R. Knöchel

Summer 2010

Radar, 2 (+1) hrs Lecture (+ Exercises)/Week,
R. Knöchel (+ F. Daschner)

Hochfrequenzschaltungen für Mobil- und Satellitenfunk, 2 (+1) hrs Lecture (+ Exercises)/Week,
R. Knöchel (+ H. Mextorf)

Hochfrequenz-Messtechnik, 2 (+1) hrs Lecture (+ Exercises)/Week,
R. Knöchel (+ T. Lehmann)

Rauschen in Kommunikations- und Messsystemen, 2 (+1) hrs Lecture (+ Exercises)/Week,
R. Knöchel (+ R. Jahns)

Praktikum Hochfrequenztechnik, 4 hrs Lab/Week,
R. Knöchel (+ F. Daschner, F. Hettstedt, T. Lehmann, H. Mextorf)

Seminar Hochfrequenztechnik, 1 hrs Seminar/Week,
R. Knöchel

Winter 2010/2011

Leitungstheorie, 2 (+1) hrs Lecture (+ Exercises)/Week,
R. Knöchel (+ R. Jahns)

Nichtlineare Schaltungen, 2 (+1) hrs Lecture (+ Exercises)/Week,
R. Knöchel (+ F. Hettstedt)

Radar, 2 (+1) hrs Lecture (+ Exercises)/Week,
R. Knöchel (+ F. Hettstedt)

Hochfrequenz-Messtechnik, 2 (+1) hrs Lecture (+ Exercises)/Week,
F. Daschner (+ F. Daschner)

Praktikum Hochfrequenztechnik, 4 hrs Lab/Week,
R. Knöchel (+ F. Daschner, F. Hettstedt, T. Lehmann, H. Mextorf)

Seminar Hochfrequenztechnik, 2 hrs Seminar/Week,
R. Knöchel

Third-Party Funds

Deutsche Forschungsgemeinschaft, *Magnetic nanocomposites for rf applications in mobile communication (Folgeprojekt)*, 01.10.2008-31.01.2011 (91400 EUR)

Deutsche Forschungsgemeinschaft, *Kontaktlose Bestimmung der dielektrischen Eigenschaften unregelmäßig geformter Objekte (ISOPerm)*, 01.10.2008-31.01.2011 (122300 EUR)

Deutsche Forschungsgemeinschaft, *Aufbau und Optimierung von Spektrometern für den Submillimeterwellen-Bereich sowie Fortsetzung der rotationsspektroskopischen Messungen an interstellaren Spezies*, 01.10.2008-31.03.2011 (53995 EUR)

Deutscher Akademischer Austauschdienst, *Leonhard-Euler-Projekt, Zielland: Ukraine*, 01.09.2010-31.08.2011 (7280 EUR)

Innovationsstiftung Schleswig-Holstein, *''lüttIng.'' - Schüler-Technik- Akademie*, 25.05.2010-22.08.2012 (26140 EUR)

Bundesministerium für Wirtschaft und Technologie, *Verbundprojekt: PITAS - Piraterie und Terrorabwehr auf Seeschiffen; Sensorik und Tracking*, 01.07.2010-30.06.2013 (1029711 EUR)

Deutsche Forschungsgemeinschaft, *Sonderforschungsbereich 855, Subproject C3: Sensor Modelling and Electronic Signal Processing*, 01.01.2010-31.12.2013 (579100 EUR)

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 ''Inorganic functional materials'' 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 and 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) .

Cooperations with industry include; **AMS - Advanced Microwave Systems**, Hamburg, in the area of microwave sensors for density and moisture determination of materials,

Thales, Kiel, in the area of antennas,

Baker Hughes INTEQ GmbH, Celle in the area of high frequency sensors.

A cooperation concerning resonant stents and other stent solutions is carried out together with the **pediatric cardiology clinical centre of the Christian-Albrechts-University (PD Dr. Rickers)** and the measurements regarding heterotopic bone inductions are carried out together with the **Department of Oral and Maxillofacial Surgery of the Clinical Centre of the Christian-Albrechts-University (PD Dr. Dr. Becker)**.

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 and Master Theses

W. Stellmach, *Entwicklung von Baluns mit magnetischen Nanokomposit-Kernen*, 03.02.2010
P. Schluchter, *UWB Antennensystem zur kontaktlosen Materialcharakteristik*, 18.02.2010
L. K. Jensen, *Entwicklung eines Sensors zur berührungslosen und zerstörungsfreien Bestimmung von Materialeigenschaften*, 19.05.2010
R. El Korch, *Streufeldresonator zur Permittivitätsmessung im Mikrowellenbereich*, 02.06.2010
G. Zhao, *Zweimodiger Mikrowellenresonator zur Materialcharakteristik*, 23.08.2010
F. Marx, *Kompakte magnetoelektrische Sensoren zur Messung biomagnetischer Felder*, 15.09.2010
S. Wang, *Hochfrequenzsensor zur Beobachtung einer heterotopen Knocheninduktion*, 10.12.2010
F. Menke, *Detektion von Fremdkörpern mit elektronisch schwenkbarem Antennensystem*, 17.12.2010

Dissertations / Postdoctoral Lecture Qualifications

T. Lehmann, *Sequenzielle Verstärkerarchitekturen für effiziente Leistungsendstufen*, 28.07.2010

Publications

Published in 2010

R. Knöchel, R. Jahns, W. Taute, C. Döscher, *A resonator-based moisture meter for high moisture levels*, Aquametry 2010, 53 - 62 (2010)
F. Daschner, R. Knöchel, *Antennas with Slant Radiation Characteristics for Contactless Material Characterisation at 24GHz*, Aquametry 2010, 90 - 98 (2010)

H. Mextorf, F. Daschner, M. Kent, R. Knöchel, *Non-contacting UWB-characterization of dielectric objects using multivariate calibration,* Aquametry 2010, 136 - 144 (2010)

A. Guarnieri, J. Demaison, H.D. Rudolph, *Structure of Ketene - Revisited re (equilibrium) and rm (mass-dependent) structures,* Journal of Molecular Structure, **969**, 1 - 8 (2010)

F. Daschner, *Breitbandige dielektrische Spektroskopie im Mikrowellenbereich,* Proceedings of the 15th Heiligenstädter Kolloquium, 57 - 65 (2010)

F. Hettstedt, U. Schürmann, R. Knöchel, E. Quandt, *Toroid Microinductors Using Segmented Magnetic Cores,* Proceedings of the International Microwave Symposium 2010, 1348 - 1351 (2010)

H. Mextorf, R. Martens, F. Daschner, R. Knöchel, *Dual polarized UWB antenna for free-space characterization of dielectric objects,* Proceedings of the German Microwave Conference 2010, 162 - 165 (2010)

J. Adam, L. Klinkenbusch, H. Mextorf, R. Knöchel, *Numerical Multipole Analysis of Ultra Wide-Band Antennas,* IEEE Transactions on Antennas and Propagation, **58**, 3847 - 3855 (2010)

H. Mextorf, F. Daschner, M. Kent, R. Knöchel, *Free-space determination of permittivity, size and orientation of rectangular shaped objects using multivariate analysis,* Proceedings of the European Microwave Conference, 152 - 155 (2010)

H. Mextorf, F. Daschner, M. Kent, R. Knöchel, *UWB free-space characterization and shape recognition of dielectric objects using statistical methods,* IEEE Transactions on Instrumentation and Measurement, **59**, **12**, 1 - 8 (2010)

T. Lehmann, R. Knöchel, *Signal Pre-Distortion and Bandwidth Requirements for Sequential Power Amplifiers,* Proceedingsof the International Microwave Symposium 2010, 1056 - 1059 (2010)

P. Rezaee, Nasrin Nasr Esfahani, R. Knöchel, M. Tayarani, *Active Learning Method for Microstrip Filter Design,* Proceedings of the 40th European Microwave Conference, 369 - 372 (2010)

Presentations

H. Mextorf, R. Knöchel, *Kontaktlose Charakterisierung dielektrischer Objekte mittels multivariater Analysemethoden,* UKoLoS-Berichtskolloquium, Ulm, Germany, 22.-23.03.2010

T. Lehmann, R. Knöchel, *Verfahren zur Verbesserung von Linearität und Wirkungsgrad von Leistungsverstärkern,* Kolloquium Hochfrequenztechnik Uni Erlangen, 23.02.2010

Further Activities and Events

Prof. Knöchel served as a Vice-Dean until the beginning of July and thereafter as the Dean of the Faculty of Engineering (Technische Fakultät).

Prof. Knöchel is active in the IEEE-MTT (Microwave Theory and Techniques) Society. He was chairman of subcommittee-29 ''Broadband Microwave Systems'' within the programme committee of the ''International Microwave Symposium'', IMS, which is the biggest conference worldwide in that area. He is also Chairman of the technical committee MTT-16, ''Microwave Systems'', and since 2007, a member of the selection committee for the ''IEEE MTT Distinguished Microwave Lecturers''. He also represents the MTT in the executive committee of the ''International Conference on Ultra-Wideband, ICUWB''. He is a member of the ''editorial board'' of ''Frequenz'' and a reviewer for the journals ''IEEE Transactions on Microwave Theory and Techniques'', ''IEEE Microwave and Wireless Components Letters'' as well as journals of the UK ''Institute of Physics'' (IOP) others. He is also a member of VDE Expert Group 7.3, ''Mikrowellentechnik''. Apart from his membership of the IEEE he is also a member of the ''European Microwave Association, EuMA'' and of URSI, commission A.

Prof. A. Guarnieri, is working in the microwave laboratory and leading the ''molecular spectroscopy''.

Awards: Dipl.-Ing. Robert Jahns received the 2010 Petersen-Award of the Petersen-Foundation for the best Diploma-thesis entitled ''Magnetoelektrische Sensoren für medizinische Anwendungen''.

Dipl-Ing Henning Mextorf reached the 3rd place in the 2010 MTT-S IMS ''ASH Receiver Student Design Competition''.

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. In 2010 we developed with „Surface contrast microscopy" an exciting new microscopy method for enhanced contrast of objects on a nanostructured microscope slide. We advanced our research on lab-on-a-chip systems and integrated optics. Furthermore, we started a new project area on the modelling of magnetoelectric sensors within the framework of the SFB 855 „Magnetoelectric Composites - Future Biomagnetic Interfaces" . Details on the research results are presented below. Particularly important for the fabrication of advanced devices in our group was the installation of a nanoimprint lithography system in the NanoLab Kiel in 2010. This system allows the replication of nanostructured surfaces, which are applied in our group for the efficiency enhancement of organic light emitting diodes as well as for surface contrast microscopy.

The group's activities were marked by the maternity leave of Prof. Gerken between August 2010 and February 2011. During this time Priv. Doz. Dr.-Ing. Thomas Mussenbrock headed the group as substitute director. We started a fruitful cooperation particularly in the area of magnetoelectric sensors.

Results

Surface contrast microscopy

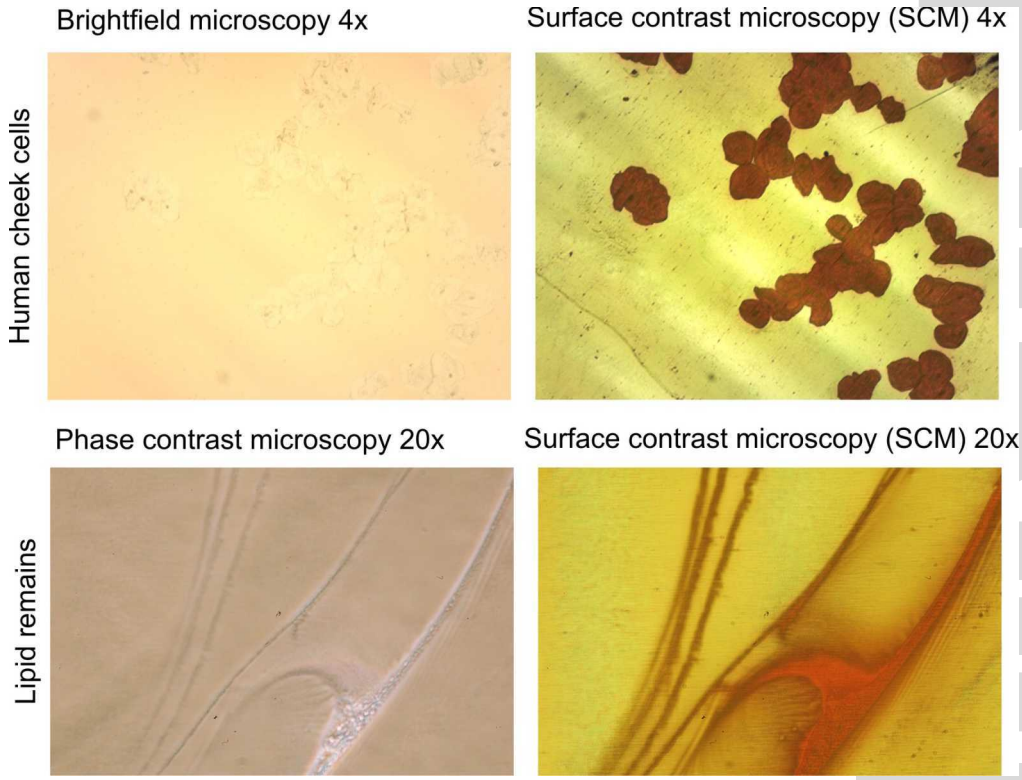

Fig. 1: Comparison of bright field, phase contrast, and surface contrast microscopy

In microscopy the visibility of a specimen depends mainly on its contrast and the magnification of the system. Under conventional microscopes many specimens, in particular cells, appear with a low contrast. We propose to use a photonic crystal slab (PCS) as the microscope slide to enhance the contrast of the image. These structures provide spectrally limited optical modes referred to as guided-mode resonances (GMRs), which can be excited both in transmission or reflection [1].

Using crossed polarization filters before and behind the PCS the direct observation of the GMRs is possible [2] and the PCS appears coloured as a function of the GMRs' spectral position. Any localized refractive index change on the surface of the PCS induces a spectral shift of the GMRs, which results in a colour shift for the human eye. As the human eye is more sensitive to a colour shift than to intensity variations this phenomenon can be used for contrast enhancement of specimens near the surface of the PCS. We refer to this method as surface contrast microscopy (SCM).

In Fig. 1 two examples for the SCM in a transmission setup are shown. The intrinsic colour of this PCS is yellow. In Fig. 1 (upper images) human cheek cells on the surface produce a localized refractive index change and induce a contrast enhancement via a colour shift to red. In Fig. 1 (lower images) lipid remains on the surface are shown. Using SCM the contrast is enhanced compared to phase contrast microscopy.

[1] S. Fan, and J. D. Joannopoulos: Analysis of guided resonances in photonic crystal slabs. Phys. Rev. B 65(23), 235112 (2002).

[2] Y. Nazirizadeh, J. G. Müller, U. Geyer, D. Schelle, E.-B. Kley, A. Tünnermann, U. Lemmer, and M. Gerken: Optical characterization of photonic crystal slabs using orthogonally oriented polarization filters. Opt. Express 16(10), 7153-7160 (2008).

Nanostructured organic light emitting diodes (OLEDs)

Today organic light-emitting diodes (OLEDs) already are found in passive and active matrix displays. As their efficiency increases they are becoming more and more interesting for general lighting applications. While the internal quantum efficiency of state-of-the-art OLEDs is close to 100%, the external quantum efficiency is limited by the poor light extraction. Only about every fifth photon leaves the OLED as useful light, while 80% are absorbed and converted to heat after being trapped as waveguide modes or surface plasmon polaritons in the OLED layer stack or by total internal reflection in the substrate. We investigate light extraction schemes using nanotechnological approaches.

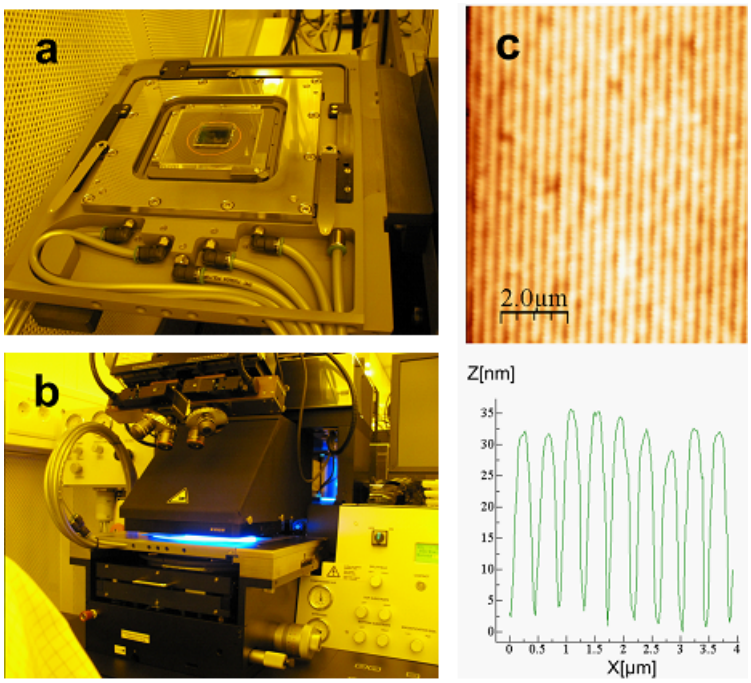

Fig. 2: Nanoimprint lithography (UV-NIL). (a) Substrate holder. (b) System during exposure with UV-light. (c) AFM-measurement of replicated periodic nanostructure.

Using the nanoimprint lithography system (see Fig. 2) newly installed in the NanoLab Kiel, we fabricated substrates

exhibiting a periodic nanostructure. This process is potentially suitable for large area fabrication. On top of these substrates OLEDs based on the polymeric emitter phenylene substituted poly(para-phenylenevinylene) (Ph-PPV; „SuperYellow" purchased from Merck OLED Materials GmbH) are processed. The periodic grating structure causes a coupling of the waveguide modes with leaky modes, thus allowing an enhanced emission. A detailed characterization of the coupling processes was performed.

Lab-On-A-Chip

Integration of organic light emitting diodes (OLEDs) and organic photo detectors (OPDs) on a single substrate is promising for novel applications such as biosensors or optical integrated systems. These optoelectronic devices are advantageous as they are variable in size and inexpensive in fabrication. We realized an optical all-integrated measuring section consisting of two OLEDs as light sources and two OPDs fabricated using the spin-coating technique. Areas of the spin-coated layers that are not required were removed by an oxygen plasma treatment. The functionality of the optoelectronic components after plasma treatment is maintained as the metal cathodes protect the underlying organic layers in this self-aligned structuring process. Light emitted by the OLED propagates through the glass substrate and causes a photo current in the OPD. A change of the index of refraction or the absorption coefficient on top of the glass substrate causes a change in the photo current. Thus, substances on the glass substrate can be analyzed.

Integrated Optics

Our work on spatially dispersive thin film structures has been continued in 2010. We investigated tuneable Fabry-Perot resonators consisting of a polydimethylsiloxane (PDMS) layer which is sandwiched between two partially transparent structured silver electrode layers on a glass substrate. The design allows for two modes of actuation as shown in Fig. 3 (a). Thermal expansion via Joule heating exhibits large tuning effects but rather low response times. Electrostatic actuation exhibits smaller tuning effects but promises fast response times. The device design and fabrication processes are still subject to optimization.

This highly spatial dispersive device may be applied to several fields of microoptics. Besides evaluating tuneable thin film resonators for focus actuation, we concentrate on using the capability of beam shift adjustment to compensate misalignment and thermal drift in free space optical interconnects (OIs). Figure 3 (b) shows a matrix arrangement of active thin film resonators in a free space chip-to-chip optical interconnect offering an individual adjustment of channels. The manipulation of a convergent Gaussian beam (wavelength: 633 nm) passing through the device was quantified by a measurement setup. Transmission properties as well as focus displacement and beam shift were experimentally determined through successively scanning the transmitted beam. Applying thermal actuation of 10K we obtained beam shifts of up to 40 microns, which is in the order of magnitude of misalignment in optical interconnects.

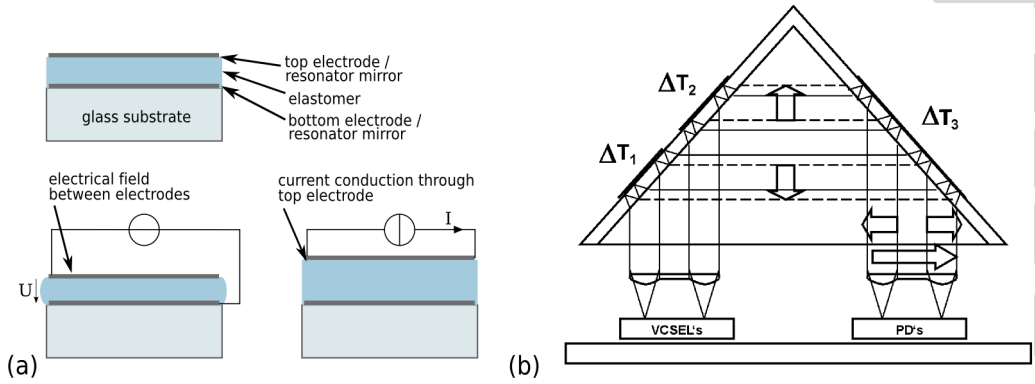

Fig. 3: (a) Device schematic. (b) Device arrangement for thermal drift compensation in free space chip-to-chip optical interconnects.

Modelling and Design

Analytical and numerical methods were employed to investigate electrically actuated elastomers with metal electrodes. These structures are building-blocks for tuneable microoptics, i.e., waveguide modulators and beam steering components. Optimized geometries were developed by the use of finite element simulations with COMSOL Multiphysics.

Enhancing the outcoupling efficiency of OLEDs and integrating organic optoelectronics effectively into Lab-On-A-Chip systems requires knowledge of the lightflow. In 2010 eigenmode extension methods were applied to analyze and design OLEDs coupling into waveguides. A 150 nm thick tantalum pentoxide (Ta2O5) layer brought into the OLED supports a lateral mode. The waveguide facilitates guiding part of the OLED light towards the analyte and further to the detector in a lateral Lab-On-A-Chip system.

Regarding outcoupling efficiency, far-field calculations for OLEDs with a nanostructured indium tin oxide (ITO) anode were carried out in order to support the experimental results. Corresponding two-dimensional far-field calculations were obtained via two-dimensional finite difference time-domain code (2-D FDTD) with integrated 2-D far-field projection. Furthermore, spherical three-dimensional (3-D) far-field calculations were obtained by an efficient multipole-based near-to-far field transformation from three-dimensional FDTD data.

Within the framework of a cooperation with the Laboratory of Physics of Nanostructures, Ecole Polytechnique Federale de Lausanne (EPFL), Switzerland, this near-to-far field transformation technique was further applied to calculate the radiated far field of quantum-wire based photonic-crystal microcavity lasers.

Magnetoelectric Sensors

Within the framework of the SFB 855 we are modelling and optimizing magnetoelectric (ME) sensor structures. The ME effect refers to the change of magnetization on applying an electric field or the appearance of an electric polarization upon applying a magnetic field. The ME response of natural multiferroic materials is too weak for practical applications. On the other hand, ME composite materials exhibit a much larger magnetoelectric response. In order to achieve the maximum possible ME response in composite materials, the optimization of the nanocomposite structure as well as the sensor geometry is necessary. We are modelling ME sensors using analytical as well as numerical methods. As a numerical tool we are employing COMSOL Multiphysics. In 2010 we have focused on modelling composites containing layers of piezoelectric materials and magnetostrictive materials.

Personnel

Head of the group: Prof. Dr. M. Gerken, Priv. Doz. Dr.-Ing. T. Mussenbrock; Secretary: S. Thielbörger (50%)
Technical Staff: Dipl.-Ing. J. Buschmann (50%), J. Greve

Scientific Staff:

M.Sc. A. Abdollahinia Magneto-electric sensors	01.03.-31.12.2010	DFG
Dr.-Ing. J. Adam Design and modelling	01.01.-31.12.2010	BMBF
Dr.-Ing. U. B. Bala Magneto-electric sensors	12.03.-31.12.2010	DFG
Dr.-Ing. U. Geyer Magneto-electric sensors	01.02.-30.06.2010	DFG
Dipl.-Phys. J. Hauss Organic light emitting diodes	01.01.-31.12.2010	BMBF

Dipl.-Ing. C. Kluge Lab-on-a-chip	01.01.-31.12.2010	CAU
Dr. M. Krantz Thin-film devices	01.01.-31.12.2010	BMBF
Dipl.-Ing. P. Metz Microoptical systems	01.01.-31.12.2010	CAU
Dr. J. Mikat Experimental characterization	01.01.-30.09.2010	DFG
Dr.-Ing. Y. Nazirizadeh Nanostructures for analysis and imaging	01.01.-31.12.2010	BMBF/ISH
Dipl.-Ing. M. Nordhausen HSP 2020	01.01.-31.03.2010	CAU
M.Sc. A. Pradana Nanostructured organic optoelectronics	01.01.-31.12.2010	CAU
Dipl.-Phys., MPhys. B. Riedel Organic light emitting diodes	01.01.-31.12.2010	BMBF
Dr. M. Rädler Lab-on-a-chip	01.01.-31.12.2010	BMBF
Dipl.-Wi.-Ing. D. Threm Lab-on-a-chip	01.01.-31.12.2010	BMBF

Lectures, Seminars, and Laboratory Course Offers

Winter 2009/2010

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 (+ A. Pradana)

Seminar Integrierte Systeme und Photonik, 2 hrs Seminar/Week,
M. Gerken

Praktikum Optoelektronik, 4 hrs Exercise/Week,
Scientific staff

Summer 2010

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 (+ P. Metz)

Seminar Integrierte Systeme und Photonik, 3 hrs Seminar/Week,
M. Gerken

Praktikum Optoelektronik, 4 hrs Exercise/Week,
Scientific staff

Winter 2010/2011

Grundgebiete der Elektrotechnik I, 3 (+ 2) hrs Lecture (+ Exercises)/Week,
T. Mussenbrock (+ staff and student tutors)

Grundlagen der Elektrotechnik, 3 (+ 2) hrs Lecture (+ Exercises)/Week,
T. Mussenbrock (+ A. Dochhan)

Seminar Integrierte Systeme und Photonik, 2 hrs Seminar/Week,
T. Mussenbrock

Praktikum Optoelektronik, 4 hrs Exercise/Week,
Scientific staff

Third-Party Funds

BMBF, *Nanostrukturierte optoelektronische Bauelemente*, 01.03.2007-28.02.2012 (1600000 EUR)
DFG, *Entwurf, Herstellung und experimentelle Charakterisierung von aktiven hochdispersiven Dünnschichtfiltern für die Brennweitendurchstimmung*, 01.10.2008-30.09.2011 (213000 EUR)
COST, *Towards Functional Sub-Wavelength Photonic Structures*, 17.12.2007-20.01.2012 (Reisekosten)
DFG/SFB 855, *Magnetoelektrische Verbundstoffe - biomagnetische Schnittstellen d. Zukunft, Teilprojekt C1*, 01.01.2010-31.12.2013 (477000 EUR)
CAU-SDU Seed money funding, *On-chip integration of organic nanofibers - organic photodiode link*, 01.04.-01.10.2010 (3000)

Diploma, Bachelor and Master Theses

Hendrikje Fiedler, *Entwicklung eines zeit- und ortsaufgelösten Spektrometers zur Charakterisierung von OLEDs*, 15.07.2010

Publications

Published in 2010

C. Kluge, N. Galler, H. Ditlbacher, M. Gerken, *Modeling of electrically actuated elastomer structures for electro-optical modulation*, Applied Physics A, **102**, 407 (2010)
B. Riedel, I. Kaiser, J. Hauss, U. Lemmer, M. Gerken, *Improving the outcoupling efficiency of indium-tin-oxide-free organic light-emitting diodes via rough internal interfaces*, Opt. Express, **18**, 631 (2010)
J. Hauss, B. Riedel, M. Gerken, *Nanotechnologie für Licht von morgen*, Nanotechnologie aktuell, **3**, (2010)
Y. Nazirizadeh, U. Bog, S. Sekula, T. Mappes, U. Lemmer, M. Gerken, *Low-cost label-free biosensors using photonic crystals embedded between crossed polarizers*, Optics Express, **18**, 19120 - 19128 (2010)
B. Riedel, J. Hauss, U. Geyer, J. Guetlein, U. Lemmer, M. Gerken, *Enhancing outcoupling efficiency of indium-tin-oxide-free organic light-emitting diodes via nanostructured high index layers*, Applied Physics Letters, **96**, 243302 (2010)
B. Riedel, J. Hauss, M. Aichholz, A. Gall, U. Lemmer, M. Gerken, *Polymer light emitting diodes containing nanoparticle clusters for improved efficiency*, Organic Electronics, **11**, 1172 - 1175 (2010)
M. Stroisch, T. Woggon, C. Teiwes-Morin, S. Klinkhammer, K. Forberich, A. Gombert, M. Gerken, U. Lemmer, *Intermediate high index layer for laser mode tuning in organic semiconductor lasers*, Optics Express, **18**, 5890 - 5895 (2010)
J. Brückner, N. Christ, O. Bauder, C. Gärtner, M. Seyfried, F. Glöckler, U. Lemmer, M. Gerken, *ac excitation of organic light emitting devices utilizing conductive charge generation layers*, Applied Physics Letters, **96**, 041107 (2010)

A. Pradana, D. Threm, M. Rädler, M. Gerken, *Integration of two different spin-coated optoelectronic devices on a single substrate,* Proc. International Symposium Technologies for Polymer Electronics - TPE 10, (2010)

B. Riedel, J. Hauss, I. Kaiser, J. Guetlein, U. Geyer, K. Huska, U. Lemmer, M. Gerken, *Methods to Enhance the Efficiency of Organic Light Emitting Devices,* Proc. International Symposium Technologies for Polymer Electronics - TPE 10, (2010)

Patent Applications

Y. Nazirizadeh, M. Gerken, *Vorrichtung und Verfahren zur Kontrasterhöhung in der Mikroskopie,* Deutsche Patentanmeldung, 26.01.2010, 10 2010 005 860.2

Y. Nazirizadeh, M. Gerken, *Vorrichtung und Verfahren zum Nachweis biologischen Materials,* Deutsche Patentanmeldung, 26.01.2010, 102010 005 859.9

Information and Coding Theory

The **research activities** of the Information and Coding Theory group (ICT) of the University of Kiel are in the general area of wireless digital communications. Simply speaking, ICT is designing new digital transmission schemes and developing corresponding software algorithms. The proposed transmission schemes are motivated by insights from applied information theory. Among our goals is to serve more users in future cellular radio systems, to increase data rates, and to reduce transmission power and signal bandwidth.

The main expertise is in the area of channel coding (Turbo codes, low-density parity check codes, decoding with reliability information, space-time codes), applied information theory, digital modulation schemes (adaptive modulation and channel coding, superposition modulation, orthogonal frequency-division multiplexing), joint communication and navigation, and development of modern receiver algorithms (equalization, channel estimation, synchronisationsynchronization, interference rejection). Among the applications are cellular radio systems (GSM and UMTS enhancements, WLAN, LTE, LTE-Advanced), underwater communications, satellite radio, and terrestrial broadcasting systems.

Concerning **teaching**, we offer lectures and exercises on channel coding, information theory, wireless communications and advanced wireless communications with the emphasis on digital signal processing, partly in English within the international master programme on ''Digital Communications''. A lecture on system identification (with focusfocussed on underwater communications) and a lecture on time series analysis (with focusfocussed on medical applications) are offered in the form of teaching assignments. Furthermore, several seminars and labs are provided for our students.

Results

Joint Communication and Navigation (Rebecca Adam, Kathrin Schmeink). Recently, joint communication and navigation is gaining more and more interest in research. The advantages and applications cover a wide range. In particular, there are many synergy effects that can be exploited. One major application is the automated localization of emergency calls. However, it is a challenging task to combine communication and navigation because the requirements of both techniques are quite different. ICT tries to face this problem with a system concept based on multi-layer interleave-division multiple access (ML-IDMA). The core part of the concept is joint channel and parameter estimation. A maximum-likelihood approach has been investigated, which leads to a nonlinear optimization problem. Different optimization algorithms like the Levenberg-Marquardt method, particle swarm optimization or simulated annealing have been applied. In addition to finding the global optimum of the nonlinear metric, one major task has been to obtain soft information concerning the parameter estimates. Soft information corresponds to the variance of a parameter estimate and is a measure of reliability. The soft information can be exploited in a weighted positioning algorithm in order to improve the positioning accuracy. Different methods to obtain soft information were proposed and analyzed.

Channel Estimation for MIMO-OFDM (Christopher Knievel, Zhenyu Shi). Multi-user multiple-input multiple-output (MIMO) transmission techniques in combination with orthogonal frequency-division multiplexing (OFDM) promise to provide the desired performance of next-generation cellular radio systems. MIMO-OFDM has been selected as a key technology for the IEEE 802.11n wireless local area network (WLAN) standard and for 3GPP Long Term Evolution (LTE), which is the successor of third generation cellular radio systems (such as UMTS). The successor of LTE, called LTE-Advanced (LTE-A), is expected to close the gap between stationary and mobile communications by supporting high data rates.

Channel estimation in multi-antenna scenarios is a challenging task. ICT developed a graph-based iterative receiver, which utilizes correlation in time, frequency, and space in order to improve channel estimation and data detection quality. This graph-based receiver has lower computational complexity, expands the restriction of training symbols, and shows very good performance when compared to iterative as well as non-iterative state-of-the-art algorithms like SAGE and Wiener filtering.

Superposition Modulation (Dapeng Hao, Meelis Noemm, Tianbin Wo). Superposition modulation (SM) is a novel digital modulation scheme that can be used in high-rate mobile communications. The signal points of SM are derived by linearly superimposing binary antipodal symbols with proper power and phase allocation. Unlike conventional PSK/QAM modulation, the signal points of SM are quasi-Gaussian distributed instead of being designed. A special case of SM is interleave-division multiplexing (IDM). IDM can be used as a coded modulation scheme or as a multiplexing scheme. It is particularly suitable for hierarchical signalling.

Power and phase allocation is an important issue for superposition modulation. The constellation diagram and the maximum achievable mutual information are highly influenced by the applied power and phase allocation. Different power and phase allocation schemes were investigated and compared, and we observed that conventional rectangular QAM modulation could be derived by SM with unequal power and orthogonal phase allocation. In the low-to-moderate signal-to-noise region, SM with equal power and uniform phase allocation shows higher potential to achieve the Shannon capacity than other power and phase allocation schemes.

Besides extensive investigations on power and phase allocation of SM, information theoretical properties of SM were investigated. By means of an extensive analysis, the pros and cons of SM have been clarified, and also its potential in the sense of approaching the capacity of the Gaussian channel is now well understood. Theoretical limits for coded as well as uncoded SM systems were derived, which serve as guidelines for practical system design.

The most important result is in finding reasons for the previously known limit on the bandwidth efficiency of coded SM systems. Based on this finding, new coding schemes have been investigated to further improve the system performance. With sophisticated channel coding, we are less than 1 dB away from channel capacity even for large bandwidth efficiencies, which stands currently as the world record.

Graph-based Channel Estimation and Data Detection (Christopher Knievel, Zhenyu Shi, Tianbin Wo). Additional effort has been spent on graph-based soft channel estimation (GSCE) and data detection, as reported in the Almanach 2008. The algorithm is now able to support higher-order modulation formats, such as PSK/QAM. Furthermore, it is found that the most suitable code structure for GSCE is to use a parity-check code as the outer code and a repetition code as the inner code.

Further work includes an extension of the graph-based estimator to MIMO-OFDM systems via multi-dimensional estimation, its performance improvement for higher-order modulation schemes in conjunction with channel coding, and its implementation in a cellular environment. 3GPP LTE-A is treated as a special application.

Time Series Analysis (A. Galka). The work of A.Galka deals with the development and application of new tools for the analysis of time series from neuroscience, such as electroencephalograms (EEG) and functional magnetic resonance imaging (FMRI) data sets. In most cases the analysis is based on state space modelling within a Kalman filtering and maximum likelihood framework. Tasks such as artefact removal, noise reduction, decomposition into physiological components, source analysis, and estimation of task- or stimulus-related activations can be approached by this analysis.

Underwater Communications (Ivor Nissen, Christian Schroeder). In contrast to wireless RF communications, underwater communications (UWC) typically do not use electromagnetic waves as a carrier. This is because of the strong absorption of EM-waves in water. Only for very low frequencies (below 20 kHz) or at optical frequencies may these waves propagate over small distances. Therefore, acoustic waves are used, which are less subject to absorption and can travel further (hundreds of kilometres in the deep sound channel). This leaves only three frequency regions for wireless data transmission (as depicted in the figure).

However, using acoustic waves comes with several drawbacks. One is the lower propagation speed (around 1500 m/s), which varies with temperature, depth and salinity. This causes large latencies and also makes the signals more vulnerable to Doppler influence than in RF transmission, which is determined by the relation of user speed to wave propagation speed. The Doppler effect is induced by the almost inevitable drift of the communication nodes in the water and also

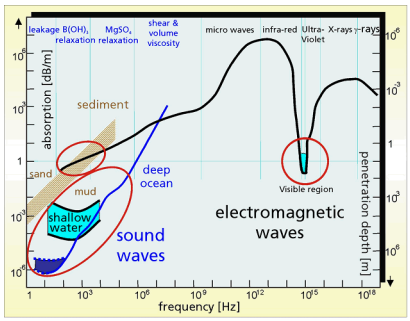

Fig. 1: Absorption of EM and acoustic waves in water.

by the random movement of the reflecting sea surface. Due to the channel geometry there a many reflections from the surface and the seabed resulting in an increasing number of multi-path components at the receiver causing long delay spreads and, hence, inter-symbol interference. The long propagation delay does not allow the assumption of a constant channel during one transmission frame. Moreover, due to the non-constant sound velocity profile in the water column, the propagation is not direct but is affected by refraction. The usable acoustic bandwidth for UWC is rather limited to some tens of kHz (strongly depending on the desired range, which increases with lowering the frequency) and does not allow data rates known from current RF networks.

Since Kiel is a centre for marine research and technology, research in the fields of underwater communications is more than obvious. Hence, there is intensive cooperation with other institutes and companies working on this topic, especially with the *Research Department for Underwater Acoustics and Marine Geophysics (FWG) of the Bundeswehr Technical Centre 71*. In conjunction with this a special lecture on UWC is offered in the international study course on Digital Communications.

Currently, two system approaches are under investigation for underwater acoustic communication, designed for different kinds of application. The first uses a multi-carrier system with non-orthogonal pulse shaping for high data rates (i.e., in the range of some kbps). The second system is designed for small data packets used for example for command & control links to underwater vessels. This uses very short bursts over almost the whole available bandwidth. The benefit is the mitigation of inter-symbol interference due to the short duration and small payload. This might later be used to deploy an underwater network between several mobile nodes or sensors.

The need for underwater mobile communications arises in several fields, from military applications (e.g. communication with submarines) through industrial use (e.g. exploration of natural resources and deep sea-mining) to marine research (geology, oceanography etc.).

Personnel

Head of the group: Prof. Dr.-Ing. P. A. Höher; Secretary: S. Schuchardt (50%)
Technical Staff: Dipl.-Ing. T. Rabsch

Scientific Staff:

Dipl.-Ing. R. Adam Joint Navigation and Communication	01.04.2009-31.12.2010	DFG
Dr. rer. nat. A. Galka Time Series Analysis	01.06.2009-31.12.2010	Lecturer
Dipl.-Ing. M. Gregory Free-space Optical MIMO Communications	01.01.-31.12.2010	External PhD Student

M.Sc. Dapeng Hao	01.01.2007-31.12.2010	DFG
Interleave-Division Multiplexing (IDM), PITAS		
Dipl.-Ing. Ch. Knievel	15.03.2009-31.12.2010	CAU
3GPP LTE-A		
Dr. rer. nat. I. Nissen	01.10.2008-31.12.2010	Lecturer
Acoustical Underwater Communications		
M.Sc. M. Noemm	01.06.2009-31.12.2010	Industry
Interleave-Division Multiplexing (IDM)		
Dipl.-Ing. K. Schmeink	01.04.2007-31.12.2010	CAU
Joint Navigation and Communication		
Dipl.-Ing. Ch. Schröder	01.10.2008-31.12.2010	FWG
Accoustical Underwater Communications		
M.Sc. Z. Shi	01.01.2009-31.12.2010	Industry
3GPP LTE-A		
M.Sc. T. Wo	01.11.2004-31.12.2010	DFG
Superposition Modulation and Graph-based Channel Estimation		
M.Sc. H. Wu	01.12.2006-10.09.2010	External PhD Student
3GPP Long-Term Evolution (LTE)		
Dipl.-Ing. V. Zeiger	01.01.-31.12.2010	External PhD Student
Underwater Navigation		

Lectures, Seminars, and Laboratory Course Offers

Winter 2009/2010

Kanalcodierung, 2 (+1) hrs Vorlesung (+ Exercises)/Week,
P.A. Höher (+ und Mitarbeiter)

Information Theory and Coding I, 2 (+1) hrs Vorlesung (+ Exercises)/Week,
P.A. Höher (+ und Mitarbeiter)

Wireless Communications II, 2 (+1) hrs Vorlesung (+ Exercises)/Week,
P.A. Höher (+ und Mitarbeiter)

System Identification, 2 (+1) hrs Vorlesung (+ Exercises)/Week,
I. Nissen

Communications Lab, 4 hrs Praktikum/Week,
P.A. Höher (+ U. Heute, W. Rosenkranz, und Mitarbeiter)

Advanced Topics Lab, 4 hrs Praktikum/Week,
P.A. Höher (+ U. Heute, W. Rosenkranz, und Mitarbeiter)

Informationstechnik und Codierung, 1 hrs Seminar/Week,
P.A. Höher

Summer 2010

Theoretische Grundlagen der Informationstechnik, 2 (+ 1) hrs Vorlesung (+ Exercises)/Week,
P.A. Höher (+ und Mitarbeiter)

Information Theory and Coding II, 2 (+ 1) hrs Vorlesung (+ Exercises)/Week,
P.A. Höher (+ und Mitarbeiter)

Wireless Communications (DSP), 2 (+ 1) hrs Vorlesung (+ Exercises)/Week,
P.A. Höher (+ und Mitarbeiter)

Digital Communications, 4 hrs Seminar/Week,
P.A. Höher (+ U. Heute, W. Rosenkranz, und Mitarbeiter)

Informationstechnik und Codierung, 1 hrs Seminar/Week,
P.A. Höher

Time Series Analysis, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
A. Galka

Seminar on Topics in Digital and Optical Communications, 2 hrs Seminar/Week,
P.A. Höher (+ und Kollegen)

Projekt, 3 hrs Seminar/Week,
P.A. Höher (+ und Kollegen)

Winter 2010/2011

Grundlagen der Kanalcodierung, 2 (+ 1) hrs Vorlesung (+ Exercises)/Week,
P.A. Höher (+ und Mitarbeiter)

Information Theory and Coding I, 2 (+ 1) hrs Vorlesung (+ Exercises)/Week,
P.A. Höher (+ und Mitarbeiter)

Advanced Wireless Communications (DSP), 2 (+ 1) hrs Vorlesung (+ Exercises)/Week,
P.A. Höher (+ und Mitarbeiter)

System Identification, 2 (+ 1) hrs Vorlesung (+ Exercises)/Week,
I. Nissen

Communications Lab, 4 hrs Praktikum/Week,
P.A. Höher (+ U. Heute, W. Rosenkranz, und Mitarbeiter)

Advanced Topics Lab, 4 hrs Praktikum/Week,
P.A. Höher (+ U. Heute, W. Rosenkranz, und Mitarbeiter)

Informationstechnik und Codierung, 1 hrs Seminar/Week,
P.A. Höher

Third-Party Funds

DFG, *Multi-Antenna Multi-Layer Interleave-Division Multiple Access (HO 2226/10-1)*, 01.07.2007-30.06.2010 (185468 EUR)
DFG, *Joint Navigation and Communication based on Interleave-Division Multiple Access (HO 2226/11-1)*, 15.03.2009-14.03.2012 (180590 EUR)
DFG, *Multi-Layer Interleave-Division Multiple Access (HO 2226/9-2)*, 01.02.2009-30.07.2010 (95704 EUR)
FWG (WTD-71), *Acoustical Underwater Communications*, 01.07.2008-30.06.2011 (270835 EUR)
Industry, *3GPP LTE-A Channel Estimation*, 01.10.2008-30.09.2010 (160000 EUR)
Industry, *Interleave-Division Multiplexing*, 01.11.2009-31.01.2011 (87500 EUR)

Industry, *3GPP LTE-A Interference Cancellation*, 01.10.2010-30.09.2012 (160000 EUR)
BMWi, *PITAS (Pirate Defence)*, 01.09.2010-31.08.2013 (ca. 240000 EUR ICT contingent)

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:

- German Aerospace Research Establishment (DLR), Oberpfaffenhofen,
- DoCoMo Euro Labs, Munich,
- L-3 Communications ELAC Nautik GmbH, Kiel,
- Raytheon Anschütz, Kiel,
- Research Institute of the Armed Forces on Underwater Sound and Geophysics (FWG), Kiel,
- Fraunhofer Institute for Integrated Circuits (IIS), Erlangen,
- Huawei Technologies, Shanghai,
- Nokia Siemens Networks (NSN), Munich,
- Toshiba Telecommunications Research Laboratory (TRL), Bristol.

Diploma, Bachelor and Master Theses

X. Wang, *Channel Coding for Superposition Mapping*, 29.03.2010
Y. Zheng, *Frequency Offset and Phase Noise Compensation for BICM*, 04.05.2010
A. Hafeez, *Channel Modelling and Beamforming for Multi-User MIMO OFDM*, 16.06.2010
S. Ghamari, *Optimization Methods for Joint Channel and Parameter Estimation*, 26.11.2010
R. Odugoudar, *Ad-hoc Network Emulation Framework for Underwater Communication Applications*, 08.11.2010
K. Shahab, *Iterative Soft Decoding of Reed-Solomon Turbo Product Codes*, 17.11.2010
N. Ul Hassan, *Channel Coding for Superposition Modulation*, 18.11.2010

Dissertations / Postdoctoral Lecture Qualifications

H. Wu, *Adaptive Multi-user MIMO Resource Allocation for Uplink DFT-precoded OFDMA*, 10.09.2010

Publications

Published in 2010

T. Wo, M. Noemm, D. Hao, P.A. Hoeher, *Iterative Processing for Superposition Mapping*, Journal of Electrical and Computer Engineering, **vol. 2010, Article ID 706464**, (2010)
T. Wo, P.A. Hoeher, *Low-Complexity Gaussian Detector for MIMO Systems*, Journal of Electrical and Computer Engineering, **vol. 2010, Article ID 609509**, (2010)
C. Schlegel, P.A. Hoeher, O. Axelsson, L. Perez, *Iterative Signal Processing in Communications*, Journal of Electrical and Computer Engineering, **vol. 2010, Article ID 862392**, (2010)
M. Noemm, T. Wo, P.A. Hoeher, *Multilayer APP detection for IDM*, Electronics Letters, **46**, 96 - 97 (2010)
Ch. Knievel, Z. Zhi, P.A. Hoeher, G. Auer, *2D Graph-based Soft Channel Estimation for MIMO-OFDM*, IEEE International Conference on Communications, Capetown, South Africa, (2010)

Z. Shi, T. Wo, P. Hoeher, *Graph-based Soft Iterative Receiver for Higher-order Modulation,* IEEE International Conference on Communication and Technology, Nanjing, China, (2010)

D. Hao, P.A. Hoeher, *Superposition Modulation with Reliability-Based Hybrid Detection,* Proc. International Symposium on Turbo Codes and Iterative Information Processing, Brest, Frankreich, (2010)

Z. Shi, T. Wo, P.A. Hoeher, *Superposition Mapping with Adaptive Bit Loading for BICM-OFDM Systems,* Proc. International Symposium on Turbo Codes and Iterative Information Processing, Brest, Frankreich, (2010)

T. Wo, P.A. Hoeher, *A Universal Coding Approach for Superposition Mapping,* Proc. International Symposium on Turbo Codes and Iterative Information Processing, Brest, Frankreich, (2010)

T. Wo, P.A. Hoeher, *Superposition Mapping with Application in Bit-interleaved Coded Modulation,* Proc. 8th International ITG Conference on Source and Channel Coding, Siegen, (2010)

K. Schmeink, R. Block, Ch. Knievel, P.A. Hoeher, *Joint Channel and Parameter Estimation for Joint Communication and Navigation using Particle Swarm Optimization,* Proc. Workshop on Positioning, Navigation and Communication (WPNC), Dresden, (2010)

Presentations

Ch. Knievel, *2D Graph-based Soft Channel Estimation for MIMO-OFDM,* International Conference on Communication 2010, Cape Town, South Africa, 23.-27.05.2010

Ch. Knievel, *Graph-based Multi-dimensional Channel Estimation for LTE-A,* 5th IEEE Workshop on Advanced Information Processing for Wireless Communication Systems, Copenhagen, Denmark, 14.-15.10.2010

M. Noemm, *Superposition mapping with application in bit-interleaved coded modulation,* 5th IEEE Workshop on Advanced Information Processing for Wireless Communication Systems, Copenhagen, Denmark, 14.-15.10.2010

M. Noemm, *Interleave-Division Multiplexing (IDM),* Huawei Technologies, Shanghai, China, 17.10.2010

K. Schmeink, *Joint Channel and Parameter Estimation for Combined Communication and Navigation using Particle Swarm Optimization,* Int. Workshop on Positioning, Navigation and Communication, Dresden, Germany, 11.03.2010

K. Schmeink, *Particle Swarm Optimization for Channel Parameter Estimation in the Framework of Joint Communication and Positioning,* ITG-Fachgruppe Angewandte Informationstheorie, Rostock/Warnemünde, Germany, 07.10.2010

Z. Shi, Ch. Knievel, *Pilot Design for Multi-User MIMO-OFDM Operating in a Cellular Environment,* DoCoMo Euro Labs, Munich, Germany, 01.10.2010

P.A. Hoeher, *Superpositionsmodulation: Die bessere Alternative?,* University of Erlangen-Nuremberg, Erlangen, Germany, 11.10.2010

Further Activities and Events

Prof. Dr. Peter Adam Hoeher is a director of the Institute of Electrical and Information Engineering, member of the Convention of the Faculty of Engineering, head of the examination board on Digital Communications, member of the examination board on Electrical Engineering, head of the advisory board of the Institute of Electrical and Information Engineering, and the Bafög representative of the Institute. He is a member of the Excellence Cluster "The Future Ocean". He is an IEEE Senior member, vice-chair of the German chapter of the IEEE Communications Society, member of the VDE/ITG Fachausschuss 5.1, and co-founder and managing director of a start-up in telecommunications. He is heading an appointments committee on Control Theory.

Dipl.-Ing. Christopher Knievel is member of the examination board on Electrical & Information Engineering and on Industrial Engineering.

M.Sc. Meelis Noemm is a member of the examination board on Digital Communications.

Dipl-Ing. Kathrin Schmeink is a member of the Convention of the Faculty of Engineering, a member of the study board on doctorate regulations, and a member of the appointments committee on Biocompatible Nano Materials.

Power Electronics and Electrical Drives

In 2010 the institute was able to work again under quite good circumstances. The financial situation with respect to funds from the university for salary and material expenses is regular and the number of university financed research assistants remained unchanged at three. We have good third party funds, obtained in the last few years, for supporting nine research assistants. The problem of a lack of space due to a high number of students and research assistants was solved by intensive and flexible use of our given facilities. Our fields of research are nearly unchanged with respect to the last few years. However, we have expanded into the field of Smart Grid/Smart Feed in which preliminary results have been obtained. The work therefore was as follows:

- novel converter topologies and power semiconductors with control and assembly, including EMC, mains disturbance, and power losses, (also for automotive applications),

- power converters and drives for renewable energies, especially wind energy and photovoltaic, including grid performance,

- modern control methods for power converters and electrical drives,

- condition monitoring and fault tolerance for power converters and drives,

- Smart Grid/Smart Feed In (intelligent feed in of decentralized power sources with converters),

Very good results in research and teaching were obtained from the work of our strong team. We have published 27 papers at conferences and in journals. One of our journal articles from 2009 was honoured this year with the IES Student Best Paper Award of the IEEE Industry Society Award. Most of our research projects are funded and supported by industrial partners, mainly in Northern Germany and Southern Denmark. Moreover we are involved intensively in two research and development centres of excellence: The KLSH Centre of Excellence Power Electronics Schleswig-Holstein, with universities and industrial companies and CEwind e.G. Centre of Excellence for research in wind energy with universities in Schleswig-Holstein. Concerning infrastructure, there are two outstanding results. The two grid voltage emulators developed for investigations of grid-connected inverters have been improved further and used for numerous experiments. The teaching has been carried out as usual with good feedback from the students. We are pleased that Dr. Leifert gave his lecture about *Microprocessors for real-time control* again. Also the course *Power Electronic Generator Systems for Windturbines* within the framework of the CEwind study course Master of Wind-Engineering has been run for the third time. Again a high number of students opted for a diploma or bachelor thesis at our workgroup in the field of power electronics. The masters study course is finally planned and will start in the summer. The workgroup is mainly active in the fields of masters study *Drives and Control* as well as *Renewable Energies*. We continued to have regular meetings with other power electronic institutes in the north of Germany (*Leistungselektronik-Kolloquium Nord*) with technical presentations and a laboratory visit: this year in Hannover. The number of scientific team members is still 12. Mr. Dannehl and Mr. Knop have left; we wish them all the best in industry here in the North; Mr. Reese and Mr. Grunau are new members.

Results

Provision of ancillary services by wind farms and FACTS converters (Wessels)

The electrical behaviour of modern wind turbine systems is being investigated concerning the provision of ancillary services to the grid. Both dominant wind turbine systems, with a doubly-fed induction generator and with a permanent magnet synchronous generator are investigated in the project. The focus of the investigations is on the fault ride-through of the generator systems and the dynamic provision of reactive power to the grid. The investigations are based on standard control methods that are applied in already existing wind turbines as well as different fault ride-through methods and an analysis on active/reactive power capabilities. Furthermore, based on the knowledge of the single wind turbine system, investigations are performed on wind farm structures and on the extension of the wind farm with FACTS converters. For that

purpose simulation models of a realistic power transmission system and of wind farms with different types of generators are investigated.

Condition Monitoring and Fault Tolerance for Power Electronic Converters in Wind Energy Applications (Böttcher)

Wind turbines are increasingly installed in areas which are difficult to access, especially due to the rising number of off-shore applications. Thus maintenance is much more difficult to accomplish and defects can cause breakdowns for a long time, if they are not rectified quickly. In this project different strategies to increase the availability of the power electronic converter are investigated. Fault tolerant converter topologies can maintain operation even in case of a fault. Multi-level converters are very promising in this context. Furthermore Condition Monitoring for early detection of faults and detection of remaining useful life can be used for the most important components of the power electronic converter i.e. the power semiconductors and the DC link capacitors.

Investigation on autonomous controlled inverters in microgrids (Reese)

Due to the constant change towards decentralized power production the density of inverters in the distribution grid will increase in the next decade and therefore the influence of each inverter on other active loads will increase as well. As the voltage quality and stable operation have to be ensured under these conditions, new approaches for the control of each autonomous inverter are required. The aim of this research work is the improvement of the control behaviour of parallel acting, autonomous controlled inverters in microgrids. Therefore positive and negative interactions between parallel acting inverters will be identified and used to enhance the voltage quality and stability of microgrids under stationary and transient grid faults. Conventional and modern control methods for voltage source inverters will be compared. In the year 2011 control methods for parallel acting inverters will be investigated in order to achieve proper results during grid connected operation and the laboratory test bench will be built.

EMC Optimization of Inverters (5kW, 24V) (Mühlfeld)

The optimization of inverters in terms of stray inductance and electromagnetic compatibility is a crucial task in the joint project of the Competence Centre for Power Electronics. A low inductive inverter layout is one of the basic necessities for operating low voltage power modules with short switching times economically and to obtain high efficiency of the power semiconductors. Different inverter hardware setups and power module layouts have been analyzed and compared regarding their overall efficiency, their thermal properties and their fabrication constraints. The simulations allowed the determination of a setup with the best trade-off for the given requirements. Additionally EMC of inverters is investigated and optimized by simulations and measurement, as the inverter has to comply with common standards. The inverter has been fabricated both with a power of 5 kW and 15 kW and is now being tested in the laboratory to validate simulation results.

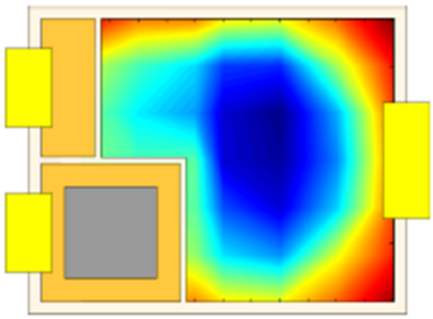

Fig. 1: Simulation result for a combined thermal and electrical optimization of the chip position inside a half-bridge power module

Battery Buffer and Power-management (5kW, 24V) (Schröder)

The design of a battery buffer system and a corresponding power-management for automotive applications is the third part in the project of the Competence Centre of Power Electronics. During strong acceleration, the battery has to deliver high peak currents. Thus, due to the internal serial resistance, the battery voltage drops under high load condition. During regenerative braking, when the battery is charged by a high current, the battery voltage increases significantly. These circumstances cause a strictly load dependent battery voltage. The lifetime of the battery decreases with charging/discharging. These drawbacks can be bypassed by a battery buffer system, which consists of a dc-dc-converter and electric double layer capacitors. This system is able to save the regenerative braking energy with higher efficiency than the battery can during the electrochemical energy transfer. The energy is transferred back to the system during high load conditions. As the maximum battery power is reduced, battery downsizing or lifetime increase is possible. Furthermore, the buffer system stabilizes the on-board voltage. The buffer system has been fabricated and tested. Optimization concerning efficiency and predictive control is now under investigation.

Optimization of Inverters (5kW, 24V) (Wittig)

For the optimization of battery fed inverters for automotive application a modern converter concept has been designed and is being realized. This converter has to be distinguished by a small volume, a high efficiency and a simple method of power multiplication. For these goals it is important to optimize the power losses. The research work is being executed by a project team with up to six members. In the first part of the project, the main focus was on the overall design concept and the electrical dimensioning of the converter, the capacitor bank connection and the development of a driver circuit for control of the power semiconductors. New, for this project the development of MOSFET chips and modules combined with an optimized power module layout and short switching times are the measures to improve the converter's efficiency. A detailed calculation of this efficiency for different layout variants was performed. In the second part, the main focus was on the control of the semiconductor power devices. Besides the development of a suitable driver circuit further additional driver circuits were analyzed to achieve an optimal switching behaviour. Finally in the third part, the converter is being put into operation and a small series of prototypes fabricated and tested in the laboratory.

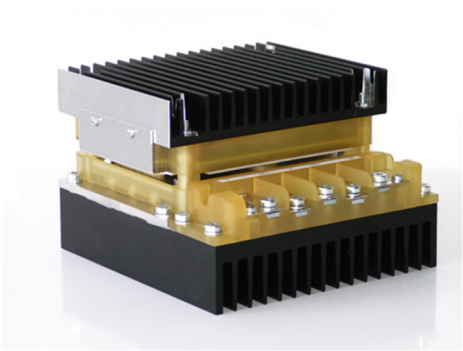

Fig. 2: 24V/5kW converter concept of the Centre of Competence for Power Electronics Schleswig-Holstein

Power electronic generator systems for small wind turbines (Gebhardt)

Small wind turbines (SWT) have a big potential for distributed generation of electrical energy both in remote and in urban areas. The combination of SWTs and photovoltaic installations can produce energy in nearly all weather situations, since the wind usually blows stronger when solar radiation is less and vice versa. Most of the SWTs are in the power range up to 10 kW. There is a big market for SWTs with many manufacturers and many different turbine concepts but most of them show only limited performance. The aim of this research and development project is an optimized SWT. The focus is on the feeding of electrical energy into the grid with energy optimal control and system management. The converter to be developed has to be very efficient over a wide operation range and the costs must be kept down. In order to limit costs the

total count of sensors must be as low as possible, which has to be considered for the control of the turbine. The project has started this year with a detailed literature research concerning actual and completed research work to elaborate further possible working fields. After theoretical and simulative analysis the first prototypes should be developed and tested in the lab in 2011.

High efficiency solar inverters and analysis of modern power semiconductors (Franke)

For feeding the grid with solar energy a high efficiency inverter is necessary. To achieve outstanding efficiency the losses in all components of the inverter, like switches, capacitors and inductors have to be optimized. The idea is to reduce the effort for the passive elements since their losses are proportional to their size. To achieve that the ripple on current and voltage has to be reduced and therefore the switching frequency has to be increased. However increasing the switching frequency leads to higher losses in the switching semiconductor devices so that the total efficiency stays constant. During the last few years new semiconductor devices using silicon carbide (SiC) instead of silicon (Si) as the substrate have been developed. With these devices it was possible to increase the total efficiency of the inverter by 2 %. Moreover the upcoming system services for solar converters have been investigated.

Power Electronic Generator Systems in Wind Energy Applications (Lohde)

Wind energy is one of the fastest-growing ways of electricity generation in the world, having doubled in the three years between 2005 and 2008. This research topic covers control methods for full scaled power converter systems with permanent magnet synchronous generators and partial scaled power converter systems with doubly fed induction generators for wind power plants. The power electronic generator system transfers the wind power to the grid and has to comply with grid codes required by the transmission system operators and tightening standards. The behaviour of the line side converter controlled by means of direct power control (DPC) and voltage oriented control (VOC) was analyzed and the control structure and behaviour were optimized for operation during dynamic grid faults like voltage dips, unbalanced grid voltage, and harmonic distortions. By means of these improved control methods it is possible to ride through low voltages in compliance with the grid codes and with high dynamics. The behaviour of these power converter generator systems is shown by simulation results and measurements taken from a laboratory test bench of a rated power of 30 kVA. There grid connected power converter systems can be tested for voltage sags, overvoltages, unbalanced grid voltages, frequency variations, phase angle jumps, as well as voltage harmonics.

Modern Control of Induction Machines with Resonant Load and Gearbox (Thomsen)

Conventional electrical drive systems consist of an inverter-fed ac motor and a load. The load is connected to the motor via transmission elements which have a non-ideal transmission behaviour like a finite torsional stiffness. This finite stiffness can lead to undesired torsional oscillations. Backlash effects can occur if gearboxes or clutches are located in the drive system and yield to high torque impulses. Torsional oscillations and torque impulses can stress both the mechanical and electrical components and thus can reduce the lifetime of the system significantly. The aim of this research work is to produce a high dynamic speed control with active damping of torsional vibrations, limiting the influence of backlash and the adaption of unknown parameters. The DFG-funded project was continued in 2010. A flatness-based speed control was designed for drive systems with resonant loads. It was analyzed and compared with the conventional PI-control. The dynamic behaviour has been improved significantly using the flatness-based control method. Mechanical oscillations can be damped and the influence of backlash can be reduced.

Modern Control for Active Rectifiers with LCL Filter and Low DC Link Capacitor (Dannehl) Grid-connected PWM converters with DC link capacitors are typically used in regenerative energy systems and industrial drives. Optimization of the converter system for these applications is still in progress. For instance, replacing the electrolytic DC link capacitors by film capacitors improves the system life time and use of LCL filters instead of conventional L filters offers cost reduction as smaller filter elements can used. The DFG-financed project has been concluded in 2010. Control systems based on state-space control as well as sliding mode control concepts for converters with LCL-grid filters have been developed. It was shown that new control approaches provide considerable advantages over the conventional ones.

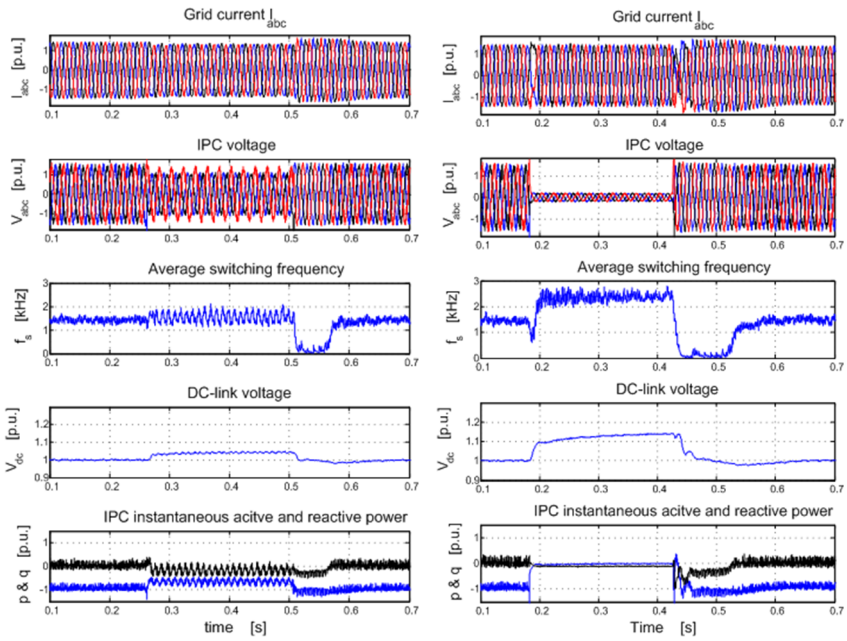

Fig. 3: Measurement results: Behaviour of grid connected voltage source converter during different grid faults with improved Direct Power Control (a) Two-phase (unsymmetrical) voltage dip and (b) Three-phase (symmetrical) voltage dip

Grid-adaptive Control and Active-Filter Functionality of grid-connected PWM-inverters in Wind Energy Applications (Hoffmann) Power electronic generator systems in distributed regenerative power generation applications are used to generate and to inject electrical power into the mains conforming to international standards. By using a grid-connected PWM converter in addition to a proper designed current and voltage control it is possible to affect the mains power quality. Different grid-adaptive and modern control strategies for grid-connected PWM-inverters in wind energy applications are investigated in this project. In 2010 a small power scale (22 kW) laboratory test bench emulating a wind turbine generator with a full rated frequency converter was put into operation. The first control approaches based on conventional PI-control as well as state-space current control have been implemented and tested successfully.

Personnel

Head of the group: Prof. Dr.-Ing. F.W. Fuchs; Secretary: P. Bekendorf, M. Marter
Technical Staff: B. Doneit

Scientific Staff:

Dipl.-Ing. M. Böttcher 01.01.-31.12.2010 Zukunftsprogramm SH/ WTSH

CEwind - Kompetenzzentrum Windenergie S-H Phase II: Condition Monitoring für Frequenzumrichter und Regelung an Generatoren in Windenergieanlagen

Dipl.-Ing. J. Dannehl 01.01.-31.07.2010 DFG/Industry

Modern control of power electronics and electrical drives/ Multivariable control of LCL-filter-based grid-connected PWM converter in wind power applications

Dipl.-Ing. T. Franke 01.01.-31.12.2010 CAU/Stipendium

Investigation of modern Silicon-Carbide semiconductors for high efficient converters for solar applications

Dipl.-Ing. F. Gebhardt	15.02.-31.12.2010	CAU
Power electronic generator systems for small wind turbines		
Dipl. Ing. N. Hoffmann	01.01.-31.12.2010	Zukunftsprogramm S-H/ WTSH
CEwind - Kompetenzzentrum Windenergie S-H Phase II: Netzadaptive Führung der Betriebsverhaltens und der Aktiv-Filter Funktionalität von Netzpulsstromrichtern in Windenergieanlagen		
Dipl.-Ing. A. Knop	01.01.-31.12.2010	Innovationsfonds
Converter for grid impedance measurement		
Dipl.-Ing. R. Lohde	01.01.-31.12.2010	ESF/Land SH/Industry
CEwind Phase I: Power electronics generator systems in wind turbines and its grid behaviour		
Dipl.-Physiker O. Mühlfeld	01.01.-31.12.2010	Frauenhofer ISIT/Land SH
Electromagnetic compatibility of future battery-fed low-voltage converters		
Dipl. Wirtsch.-Ing. J. Reese	01.06.-31.12.2010	CAU
Investigation on autonomous controlled inverters in microgrids		
Dipl.-Ing. J. Schröder	01.02.-31.12.2010	Frauenhofer ISIT/Land SH
Battery Buffer System and Power Management		
Dipl.-Ing. S. Thomsen	01.01.-31.12.2010	DFG
Modern control of electrical drives with oscillatory mechanical loads		
Dipl.-Ing. Ch. Wessels	01.01.-31.12.2010	ESF/Land SH
Power electronics generator systems in wind turbines and their grid behaviour		
Dipl.-Ing. B. Wittig	01.01.-31.12.2010	Frauenhofer ISIT/Land SH
Electrical design and development of future battery-fed low-voltage converters		

Lectures, Seminars, and Laboratory Course Offers

Winter 2009/2010

Power Electronics I- Basics, 2 (+1) hrs Lecture (+ Exercises)/Week,
F.W. Fuchs (+ O. Mühlfeld)

Power Electronics III- Electrical drives, 2 (+1) hrs Lecture (+ Exercises)/Week,
F.W. Fuchs (+ N. Hoffmann)

Control of Electrical Drives, 2 (+1) hrs Lecture (+ Exercises)/Week,
F.W. Fuchs (+ M. Böttcher)

Power Electronics - laboratory course, 4 hrs Lab/Week,
F. W. Fuchs (+ B. Wittig, S. Thomsen, T. Franke, M. Böttcher, C. Wessels, R. Lohde, J. Dannehl, O. Mühlfeld)

Seminar on Power Electronics, 2 hrs Seminar/Week,
F.W. Fuchs

Power Electronics - excursion, 1 hrs excursion/Week,
F.W. Fuchs

Power Electronic Generator Systems for Wind Turbines, 3 (+1) hrs Master Studycourse Wind Engineering in CEwind (+ Exercises)/Week,

F.W. Fuchs (+ S. Thomsen, T. Franke, C. Wessels, J. Dannehl, R. Lohde)

Summer 2010

Basics of energy systems and power engineering, 3 (+1) hrs Lecture (+ Exercises)/Week,
F.W. Fuchs (+ N. Hoffmann, B. Wittig, O. Mühlfeld, T. Franke)

Power Electronics II - Advanced, 2 (+1) hrs Lecture (+ Exercises)/Week,
F.W. Fuchs (+ J. Schröder)

Electrical energy conversion of renewable energy sources, 2 (+1) hrs Lecture (+ Exercises)/Week,
F.W. Fuchs (+ M. Böttcher)

Semiconductor applications, 1 hrs Lecture/Week,
F.W. Fuchs (+ T. Franke, F. Gebhardt, J. Schröder, O. Mühlfeld)

Microprocessors for real-time control, 1 (+1) hrs Lecture (+ Exercises)/Week,
T. Leifert (+ F. Gebhardt)

Power Electronics - labatory course,, 4 hrs Lab/Week,
F.W. Fuchs (+ C. Wessels, S. Thomsen, M. Böttcher, O. Mühlfeld, J. Schröder, N. Hoffmann, B. Wittig, F. Gebhardt)

Seminar on Power Electronics, 2 hrs Seminar/Week,
F.W. Fuchs

Power Electronics - excursion, 1 hrs excursion/Week,
F. W. Fuchs

Winter 2010/2011

Power Electronics I- Basics, 2 (+1) hrs Lecture (+ Exercises)/Week,
F.W. Fuchs (+ J. Reese)

Power Electronics III- Electrical drives, 2 (+1) hrs Lecture (+ Exercises)/Week,
F.W. Fuchs (+ J. Schröder)

Control of Electrical Drives, 2 (+1) hrs Lecture (+ Exercises)/Week,
F.W. Fuchs (+ M. Böttcher)

Power Electronics - laboratory course, 4 hrs Lab/Week,
F. W. Fuchs (+ S. Thomsen, C. Wessels, O. Mühlfeld, F. Gebhardt, J. Schröder, N. Hoffmann)

Seminar on Power Electronics, 2 hrs Seminar/Week,
F.W. Fuchs

Power Electronics - excursion, 1 hrs excursion/Week,
F.W. Fuchs (+ J. Reese, F. Gebhardt)

Power Electronic Generator Systems for Wind Turbines, 3 (+1) hrs Master Studycourse Wind Enegineering in CEwind (+ Exercises)/Week,
F.W. Fuchs (+ T. Franke, C. Wessels, F. Gebhardt, R. Lohde)

Third-Party Funds

DFG, *Regelung elektrischer Antriebe mit aktiver Dämpfung mechanischer Schwingungen und Adaption unbekannter Parameter*, 01.02.2009-31.01.2012 (219.715 EUR)

EU / State SH (CE wind), *Condition Monitoring for frequency converters at wind turbine generators*, 01.10.2008-30.09.2011 (100.000 EUR)

EU / State SH (CE wind), *Grid adapive control of the performance and active filtering ability of active rectifiers in wind turbine generators,* 01.10.2008-30.09.2011 (361.978 EUR)
Frauenhofer ISIT/Land SH, *Power Circuit development and optimization for new converter concepts for battery fed drives,* 01.04.2008-30.03.2011 (541.000EUR + MWSt)
Frauenhofer ISIT/Land SH, *Battery back up for Battery fed drives,* 01.04.2008-30.03.2011 (151.250 EUR + MWSt)
Reiner Lemoin Stiftung, Stipendium, *Solar converters with modern power semiconductors,* 01.01.2009-31.12.2011 (72.000 EUR)
Industry, *Regelung von Synchronmaschinen,* 01.01.2009-31.12.2010 (3.000 EUR + MWSt)
Industry, *Untersuchung der Netzqualität eines Schiffes mit Niederspannungsnetz,* 01.-31.05.2010 (3350 EUR + MWST)
Industry, *Untersuchung zur feldorientierten Regelung für einen Generator mit permanenterregter Synchronmaschine,* 01.01.-31.03.2010 (9.900 EUR + MWST)
Industry, *Characterising of normally off JFETs,* 01.03.-30.04.2010 (5.000 EUR + MWST)
Industry, *Ersatzschaltbild der Elemente eines Leistungshalbleitermoduls,* 01.-31.01.2010 (2.800 EUR + MWST)

Diploma, Bachelor and Master Theses

Nils Oestreich, *Entwurf, Simulation, Aufbau und messtechnische Untersuchung einer neuartigen Umrichtertopologie zur transformatorlosen Einspeisung von Solarenergie ins Netz,* 06.02.2010
Jan Reese, *Untersuchung von direkten Leistungsregelungsverfahren für Netzpulsstromrichter mit LCL-Filter für Windenergieanlagen während transienter Netzfehler und Spannungsharmonischer,* 03.05.2010
Maren Fischer, *Analyse, Vergleich, Auswahl und experimentelle Untersuchung von Methoden zur Bestimmung der Netzqualität in Echtzeit,* 19.05.2010
Stefan Sprenkmann, *Bereitstellung von Systemdienstleistungen mit Hilfe eines StatCom bei einem Windpark mit Asynchrongeneratoren mit Kurzschlussläufer und doppelt gespeisten Asynchrongeneratoren,* 12.07.2010
Stefan Meinl, *Untersuchung der Regelung einer Windenergieanlage mit doppeltgespeistem Asynchrongenerator unter unsymmetrischer Netzspannung,* 31.08.2010
Frederik Mecking, *PI- und PI-Zustandsraumstromregelung sowie die Erweiterung durch selektive Oberschwingungsstromregelung für Netzpulsstromrichter in Windenergieanlagen,* 06.09.2010
Sönke Grunau, *Untersuchung der Regelung eines StatCom Umrichters zum Einsatz an Windenergieanlagen,* 01.10.2010
Hannes Valdiek, *Untersuchung von Systemdienstleistungen zur Reduzierung von armonischen und Asymmetrien im Netz bei gleichzeitiger Anti-Islanding-Erkennung und deren Implementierung in einen Wechselrichter für Photovoltaikanlagen,* 03.11.2010
Midhet Muranovic, *Entwurf, Aufbau und Inbetriebnahme eines Gleichstromstellers zur Speisung von Fahrantrieben,* 05.11.2010
Nils Köhler, *Auslegung, Aufbau, Inbetriebnahme sowie Wirkungsgradoptimierung eines Leistungselektronik-Generatorsystems mit permanenterregter Synchronmaschine,* 25.11.2010
Kevin Neubaumer, *Auslegung, Analyse und Vergleich von Regelungsverfahren zur Drehzahlregelung von elektromechanischen Antriebssystemen mit schwingungsfähiger Last,* 08.12.2010

Publications

Published in 2010

C.H. Benz, W.T. Franke, F.W. Fuchs, *Low voltage ride through capability of a 5 kW grid-tied solar inverter,* Power Electronics and Motion Control Conference (EPE/PEMC), 2010 14th International, Ohrid, Macedonia, (2010)
M. Böttcher, J. Dannehl, F.W. Fuchs, *Interconnection and Damping Assignment Passivity-Based Current Control of Grid-Connected PWM Converter with LCL-Filter,* In Proc. of EPE-PEMC Power Electronics and Motion Control

Conference, Ohrid, Macedonia, (2010)

J. Dannehl, F.W. Fuchs, P.B. Thøgersen, *PI State Space Current Control of Grid-Connected PWM Converters With LCL Filters*, Power Electronics, IEEE Transactions on , vol.25, **9**, 2320 - 2330 (2010)

J. Dannehl, F.W. Fuchs, S. Hansen, P.B. Thøgersen, *Investigation of Active Damping Approaches for PI-Based Current Control of Grid-Connected Pulse Width Modulation Converters With LCL Filters*, Industry Applications, IEEE Transactions on , vol.46, **4**, 1509 - 1517 (2010)

W.T. Franke, C. Kürtz, F.W. Fuchs, *Analysis of Control Strategies for a 3 Phase 4 Wire Topology for Transformerless Solar Inverters*, IEEE ISIE 2010 IEEE International Symposium on Industrial Electronics, Bari, Italien, (2010)

W.T. Franke, N. Oestreich, F.W. Fuchs, *Comparison of Transformerless Converter Topologies for Photovoltaic Application Concerning Efficiency and Mechanical Volume*, IEEE ISIE 2010 IEEE International Symposium on Industrial Electronics, Bari, Italien, (2010)

W.T. Franke, N. Oestreich, F.W. Fuchs, *Comparison of Transformerless Topologies for Solar Application Concerning Efficiency, Leakage Current and Volume*, International Exhibition + Conference for Power Electronics, Intelligent Motion, Power Quality, PCIM 2010, Nürnberg, Germany, (2010)

F. Fuchs, J. Dannehl, F.W. Fuchs, *Discrete sliding mode current control of grid-connected three-phase PWM converters with LCL filter*, Industrial Electronics (ISIE), 2010 IEEE International Symposium on, (2010)

N. Hoffmann, S, Thomsen, F.W. Fuchs, *Model based predictive speed control of a drive system with torsional loads - A practical approach*, In Proc. of Power Electronics and Motion Control Conference, Ohrid, Macedonia, 149 - 156 (2010)

N. Hoffmann, S. Thomsen, F.W. Fuchs, *Appropriate Tuning and Robust Design of a Generalized Predictive Speed Controller for Drive Systems with Resonant Loads*, In Proc. of IEEE Energy Conversion Congress and Exposition, Atlanta, USA, 764 - 771 (2010)

R. Lohde, F.W. Fuchs, *Fulfilling Low Voltage Ride Through Requirements with Direct Power Controlled Voltage Source Converters in Wind Power Applications*, EPE Wind Energy Chapter - 3rd Seminar, Stafford, Großbritannien, (2010)

R. Lohde, F.W. Fuchs, *Improved DPC Method of VSC to Fulfill Low Voltage Ride Through Requirements in Wind Power Applications*, 14th EPE PEMC International Power Electronics and Motion Control Conference, Ohrid, Mazedonien, (2010)

O. Mühlfeld, F.W. Fuchs, *Comprehensive Optimization Method for Thermal Properties and Parasitics in Power Modules*, ECCE IEEE Energy Conversion Congress + Expo, Atlanta, USA, (2010)

O. Mühlfeld, T.W. Franke, F.W. Fuchs, *Design Strategies for Stray Inductance optimized Wire-Bond Power Modules*, PCIM International Exhibition + Conference for Power Electronics, Control, Intelligent Motion, Power Quality, Nürnberg, Deutschland, (2010)

M. Mohr, W.T. Franke, B. Wittig, F.W. Fuchs, *Converter Systems for Fuel Cells in the Medium Power Range-A Comparative Study*, IEEE Transactions on Industrial Electronics, Vol. 57, **6**, 2024 - 2032 (2010)

J.C. Schröder, B. Wittig, F.W. Fuchs, *High Efficient Battery Backup System for Lift Trucks Using Interleaved-Converter and Increased EDLC Voltage Range*, IECON 36th Annual Conference of the IEEE Industrial Electronics Society, Phoenix, AZ, USA, (2010)

S. Thomsen, N. Hoffmann, F.W. Fuchs, *Comparative Study of Conventional PI-Control, PI-based State Space Control and Model Based Predictive Control for Drive Systems with Elastic Coupling*, In Proc. of ECCE IEEE Energy Conversion Congress and Exposition, Atlanta, USA, (2010)

S. Thomsen, F.W. Fuchs, *Flatness Based Speed Control of Drive Systems with Resonant Loads*, In Proc. of IECON IEEE Industrial Electronics Conference, Phoenix, USA, (2010)

C. Wessels, F.W. Fuchs, *Fault Ride Through of DFIG Wind Turbines during symmetrical voltage dip with Crowbar or Stator Current Feedback Solution*, IEEE ECCE Energy Conversion Congress and Exposition, (2010)

C. Wessels, R. Lohde, F.W. Fuchs, *Transformer Based Voltage Sag Generator to perform LVRT and HVRT Tests in the Laboratory*, IEEE ECCE International Power Electronics and Motion Control Conference, (2010)

C. Wessels, F. Gebhardt, F.W. Fuchs, *Dynamic Voltage Restorer to allow LVRT for a DFIG Wind Turbine*, IEEE ISIE International Symposium on Industrial Electronics, (2010)

C. Wessels, F. Gebhardt, F.W. Fuchs, *Dynamic Voltage Restorer to allow LVRT for a DFIG Wind Turbine,* IEEE ISIE International Symposium on Industrial Electronics, July 2010, (2010)

C. Wessels, T. Wehrend, F.W. Fuchs, *Transformer Based Voltage Sag Generator to test Renewable Energy Systems during Grid Faults in the Laboratory,* EPE Wind Energy Chapter Symposium 2010, April 2010, (2010)

B. Wittig, M. Böttcher, F.W. Fuchs, *Analysis and Design Aspects of a Desaturation Detection Circuit for Low Voltage Power MOSFETs,* 14th EPE PEMC International Power Electronics and Motion Control Conference, Ohrid, Mazedonien, (2010)

B. Wittig, F.W. Fuchs, *Current Injection Gate Drive Circuit for Controlling the Turn-Off Characteristic of Low Voltage Power MOSFETs with High Current Ratings,* IEEE ISIE International Symposium on Industrial Electronics 2010, Bari, Italien, (2010)

B. Wittig, F.W. Fuchs, *Analysis and Improvement of the Switching Behaviour of Low Voltage Power MOSFETs with High Current Ratings under Hard Switching Conditions,* IEEE ISIE International Symposium on Industrial Electronics 2010, Bari, Italien, (2010)

B. Wittig, T. Franke, F.W. Fuchs, *Turn-off Active Gate Control of Low Voltage Automotive Power MOSFETs with High Current Ratings,* PCIM Power Electronics, Control, Intelligent Motion, Nürnberg, Deutschland, (2010)

Presentations

M. Böttcher, *Condition Monitoring and Fault Tolerance for Frequency Converters in Wind Turbines,* Industrie, Kiel, 14.-14.10.2010

M. Böttcher, *Condition Monitoring und fehlertoleranter Betrieb für Frequenzumrichter in Windenergieanlagen,* Industrie, Rendsburg, 13.-13.10.2010

W.T. Franke, *Comparison of Transformerless Topologies for Solar Application Concerning Effi-ciency, Leakage Current and Volume,* PCIM, Nürnberg, 04.-06.05.2010

W.T. Franke, *Comparison of Transformerless Converter Topologies for Photovoltaic Application Concerning Efficiency and Mechanical Volume,* ISIE, Bari, Italien, 02.-07.07.2010

W.T. Franke, *Analysis of Control Strategies for a 3 Phase 4 Wire Topology for Transformerless Solar Inverters,* ISIE, Bari, Italien, 02.-07.07.2010

W.T. Franke, *Silicon Carbide for Solar Inverters,* Industrie, 18.-18.10.2010

F.W. Fuchs, *Offshore Windenergy,* Präsentation for the University Association, Wagriem, 31.-31.03.2010

F.W. Fuchs, *Elektrische Systemtechnik des Antriebstrangs von Windenergieanlagen,* 2. Windenergie-Fachtagung, Blickpunkt Antriebsstang, der Firmen gear-tec GmbH und GEO CMC GmbH, Eggebek, 05.-05.05.2010

F.W. Fuchs, *Netzausbaustrategien für Schleswig-Holstein,* 9. Windcommunity Treffen, II. Podiumsdiskussion, Malente, 23.-23.11.2010

F. Gebhardt, *Dynamic Voltage Restorer to allow LVRT for a DFIG Wind Turbine,* IEEE International Symposium on Industrial Electronics, Bari, Italien, 02.-07.07.2010

N. Hoffmann, *Grid-adaptive Control and Active-Filter Functionality of grid-connected PWM-inverters in Wind-Energy applications,* Industrie, 20.-20.10.2010

N. Hoffmann, *Modern control methods for gird-connected PWM converters with active filter functionality, drive system with elastic coupled loads and shunt active power filters,* WEMPEC, University of Wisconsin-Madison, Madison, USA, 10.-10.09.2010

N. Hoffmann, *Appropriate Tuning and Robust Design of a Generalized Predictive Speed Controller for Drive Systems with Resonant Loads,* ECCE 2010, Atlanta, USA, 12.-16.09.2010

N. Hoffmann, *Zeitdiskrete Modellierung und Regelung von Netzpulsstromrichtern in Windenergieanwendungen mit verschiedenen PWM update und Abtastkonzepten und L- bzw. LCL-Netzfiltertopologien,* Industrie, 03.-03.11.2010

R. Lohde, *Improved DPC method of VSC to fulfill Low Voltage Ride Through requirements in wind power applications,* EPE-PEMC2010, Ohrid, Mazedonien, 06.-08.09.2010

R. Lohde, *Fulfilling LVRT Requirements with Direct Power Controlled VSCs in Wind Power Applications,* 3rd EPE-Wind Energy Chapter Seminar, Stafford, Großbritannien, 15.-16.04.2010

R. Lohde, *Untersuchung der feldorientierten Regelung für einen Permanentmagnet erregten Synchrongenerator,* Industrie, 01.-01.03.2010

O. Mühlfeld, *Einführung in die Leistungselektronik am Beispiel eines Elektrofahrzeuges,* Lütt-Ing Projekt, Kiel, 09.-09.12.2010

O. Mühlfeld, *EMV Untersuchungen am KLSH Umrichter,* Kompentenzzentrum Leistungselektronik Schleswig-Holstein, Kiel, 18.-18.10.2010

O. Mühlfeld, *Kombinierte Optimierung der thermischen und elektrischen Eigenschaften von Leistungsmodulen,* Kompentenzzentrum Leistungselektronik Schleswig-Holstein, Kiel, 18.-18.10.2010

O. Mühlfeld, *Optimierung des elektrischen Systems von Umrichtern für batteriegespeiste Fahrantriebe,* 2. KLSH Workshop, Itzehoe, Deutschland, 01.-01.06.2010

O. Mühlfeld, *Design strategies for stray inductance optimized wire-bond power modules,* PCIM Konferenz, Nürnberg, Deutschland, 04.-06.05.2010

J. Schröder, *Batteriestützung in Elektrofahrzeugen,* Leistungselektronisches Kolloquium Nord, Bremen, 03.-03.12.2010

J. Schröder, *Entwurf und Implementierung eines Powermanagements mit Fuzzy-Regler und Optimierung durch genetischen Algorithmus,* Kompetenzzentrum Leistungselektronik Schleswig-Holstein, Kiel, 18.-18.10.2010

J. Schröder, *Vergleich eines Antriebssystems mit und ohne Batteriestützungssystems im Hinblick auf den gesamtenergetischen Wirkungsgrad,* Kompetenzzentrum Leistungselektronik Schleswig-Holstein, Kiel, 18.-18.10.2010

S. Thomsen, *Flatness Based Speed Control of Drive Systems with Resonant Loads,* IECON-2010, Phoenix, USA, 07.-11.11.2010

S. Thomsen, *Comparative Study of Conventional PI-Control, PI-based State Space Control and Model Based Predictive Control for Drive Systems with Elastic Coupling,* ECCE 2010, Atlanta, USA, 12.-16.09.2010

Ch. Wessels, *Fault Ride Through of DFIG Wind Turbines during symmetrical voltage dip with Crowbar or Stator Current Feedback Solution,* ECCE 2010, Atlanta, USA, 12.-16.09.2010

B. Wittig, *Definition der Verfahren zur Ermittlung des Wirkungsgrades - GAK 226.0.9 -Energie- und Ökobilanzen von Leistungselektronik, Schaltgeräte und Antriebssystemen-,* DKE, Kassel, 01.-01.10.2010

B. Wittig, *Active Gate Control,* Kompentenzzentrum Leistungselektronik Schleswig-Holstein, Kiel, 18.-18.10.2010

B. Wittig, *Steuerbarkeit der Stromsteilheit von Leistungs-MOSFETs mittels Hilfssource-Abgriff,* Kompentenzzentrum Leistungselektronik Schleswig-Holstein, Kiel, 18.-18.10.2010

Further Activities and Events

Committee Work (Prof. Fuchs)

Chairman of the Advisory Board of CE wind e.G. Competence Centre for Research in Wind Energy of Universities in Schleswig-Holstein

Convenor of the German standardization committee for power electronics (DKE-K331) and spokesperson for Germany in the international committee (IEC-TC22)

Head of examination committee and students contact person for the study course „electrical and information engineering and business information"

Reviewer, session Chairman, topic co-chairman (PESC-, EPE-, IECON-conferences, IEEE Transactions on Power Electronics-, - on Industrial Electronics)

Infrastructure

- Transformer based voltage generator 30kVA

- STATCOM system 30kVA for laboratory tests

- Test set up with a converter fed salient pole permanent magnet synchronous machine

- Cooling system for power semiconductor test (-40°C)

- EMC measuring autema (30MHZ - 1GHZ)

Contribution to external representation of the Faculty of Engineering

Tech to you (industry fair Hannover, tour for pupils, guided by research assistants, April 2010)

Presentation on two job information events for pupils (January/February 2010)

Information course for the *Kiel University Information Days* (March 2010)

Power Girls and Power Boys (Three days event for 10-11 year old pupils, introduction to technical experiments)

Further Cooperation, Consulting and Technology Transfer We are active member of CEwind e.G. Competence Centre for Wind energy of Universities in Schleswig-Holstein. Actual subjects are combined research and technology transfer as well as a study programme.

In the KLSH Competence Centre for Power Electronics in Schleswig-Holstein we are co-working with some universities of applied science and industry in a combined industry oriented research project.

For most research projects we are accompanied by industry partners for a mutual information exchange.

There is a periodic colloquium of the power electronic institutes of the universities of Bremen, Hamburg, Hannover, and Kiel (Leistungselektronik Nord).

Nanoelectronics

Exciting new opportunities for future information technology arise from unconventional and novel electronic materials, nanoscale phenomena, and advanced processing technologies, which have to be controlled on an 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 , spin transport, or a combination of both 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 and novel transistors with enhanced functionalities and performance. 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 area of the AG Nanoelectronic is defined by three main pillars: (1) new device concepts based on quantum phenomena, (2) interfacial studies, and (3) 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). A considerable technological and metrological infrastructure is an essential precondition for being competitive in science and technology on an international level. Part of the equipment required, such as an electron-beam-writer, a focused ion beam system, as well as a Pulsed Laser Deposition system is available via the recently installed *Kieler Nanolabor*. Various current-voltage acquisition systems, magnetoresistance set-ups and ferroelectric thin films analyzers for a temperature range between 4.2 K and 300 K are part of our lab. Our activities are embedded in the recently founded Collaborative Research Centre SFB 855 on magneto-electric composites and heterostructures for medical sensor applications, as well as in the Focal Point of Support on *Nano and Surface Science* within the CAU Kiel.

Results

Magnetic tunnel junction with an active ferroelectric barrier

As an example of our research activities, we present here our results on multiferroic tunnel junctions. In 2010 our research focused on obtaining experimental evidence to validate our theories concerning magnetoelectric coupling phenomena. We have proceeded by obtaining direct experiment evidence for the ferroelectric mediation of tunnel currents in complex oxide magnetic tunnel junctions in the form of double crossing hysteretic I/V curves and in polarization dependent tunnelling magneto resistance ratios, as published in Advanced Functional Materials.

a) Background

The quantum mechanical phenomenon of electron tunnelling is a process where electrons as particles can penetrate a potential barrier, which classically is forbidden. This can only be accounted for by taking the wave character of the particle into account. In solid state electronics, electron tunnelling is exploited in the operation of devices such as magnetic random access memories (MRAM) and resonant tunnelling diodes. It is expected that, with the trend of aggressive miniaturization 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, spin transport, or a combination of these 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.

One such promising candidate is the ferroelectric tunnel junction (FTJ) and its related devices, upon which we have based our research. We believe that tunnelling through an ultrathin ferroelectric barrier will be strongly dependent on the orientation of electric dipoles in the (switchable) polar material. By reversing the polarization of a ferroelectric, changes in interfacial electronic structure, as well as in the barrier properties, may be created. The ferroelectric barrier then becomes an active component in a tunnel junction, which could be employed as a resistive memory device. It is important first to understand

why FTJs are radically different to prior concepts such as superconducting and magnetic tunnel junctions. Superconducting and magnetic tunnel junctions employ specific properties of the electrodes. Simplistically, the functioning of these tunnel junctions is related to density of states effects in the electrodes (square root singularity of a BCS superconductor or the spin polarization of a ferromagnet). On the other hand, the principal component that drives the notion of an FTJ is associated with the tunnel barrier, implying that the functioning of an FTJ is governed by the ferroelectric barrier alone.

However, this rather simplistic viewpoint is incomplete and hence misleading. Tunnel junctions are interfacial devices. Electrons tunnel from the first few unit cells of the electrodes adjacent to the barrier. Chemical inhomogeneity, strain, and surface reconstruction at an interface can lead to considerable deviation from bulk properties, whilst the phenomenon of orbital reconstruction at ferromagnetic/superconducting complex oxide interfaces introduces further complexity. Therefore, tunnelling through a barrier (be it conventional or ferroelectric) strongly depends on the density of states at the electrode/barrier interface. In the case of FTJs, the situation is even more sophisticated as the remnant polarization at an interface with a metallic electrode can be reversed by an external electric field, which consequently creates subtle changes in interfacial electronic structure due to the polarization reversal.

An additional layer of functionality is present for the special case of ferromagnetic/ferroelectric/ferromagnetic (FM/FE/FM) junctions, where spin dependent screening and novel magnetoelectric effects come into play. Critically, it is believed that the FM/FE/FM junctions may display a tuneable tunnel magnetoresistance (TMR) effect governed by polarization switching induced interface reconstruction. Complex oxide tunnel junctions involving a ferroelectric barrier with a high spontaneous polarization and two ferromagnetic electrodes thus offer an ideal platform for investigating the interplay between electrical polarization and tunnelling magnetoresistance in a controlled manner.

b) Experimental

In our work, we demonstrated experimentally the existence of four resistance states in FM/FE/FM tunnel junctions and provided direct experimental evidence for an interface-mediated magnetoelectric effect in FM/FE/FM junctions, as predicted by Tsymbal and co-workers. We chose $BiFeO_3$ (BFO) as our ferroelectric barrier and $La_{0.7}Sr_{0.3}MnO_3$ (LSMO) as our top and bottom ferromagnetic electrodes. BFO intrinsically possesses one of the highest remnant polarizations and ferroelectric Curie temperatures. Therefore, we expect it to be ferroelectric even down to thickness regimes of a few nm. LSMO is a half-metal perovskite, which has been used previously with considerable success as a ferromagnetic electrode for epitaxial $SrTiO_3$ (STO)-based tunnel junctions. The entire trilayer heterostructure is deposited on a vicinal etched (001)-oriented STO substrate with well-defined steps using pulsed laser deposition and monitored via high-pressure reflection high energy electron diffraction (RHEED). A schematic of the tunnel junction stack depicting the photo-lithographically patterned junction area is shown in figure 1.

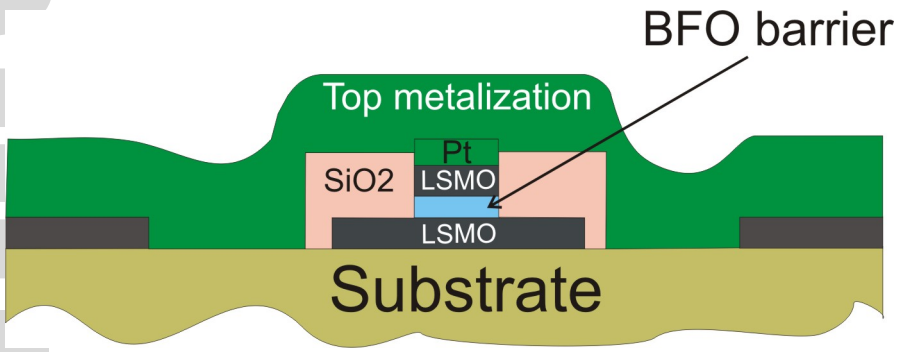

Fig. 1: Schematic representation of a photo-lithographically patterned STO/LSMO/BFO/LSMO multiferroic tunnel junction.

After fabrication, the resistance of the base LSMO electrode was measured as a function of temperature and compared to the junction resistance R. Figure 2 (a) reveals the metallic nature of the electrode, as expected. The presence of a plateau in the junction resistance below approximately 100 K indicates that a temperature-independent conduction

mechanism (e.g., direct or multistep tunnelling) operates in the junction in addition to the thermally activated one (e.g., hopping through oxygen vacancies), which manifests itself as an exponential decrease in resistance at elevated temperatures. Figure 2 (b) shows the TMR of a representative junction measured at 110 K, where the TMR ratio is defined as TMR $= \Delta R/R = (R_{ap} - R_p)/R_p$ with R_p and R_{ap} being the resistances for the parallel and anti-parallel magnetization states of the two ferromagnetic electrodes, respectively. The (positive) TMR ratio is about 80% at 80 K, and the switching magnetic fields are similar to those within the literature for LSMO, which indicates the absence of LSMO magnetization pinning by the anti-ferromagnetic BFO barrier. Interesting features in the TMR curves were observed upon the application of electrical pulses. Figure 2 (c) represents a series of TMR measurements of a different junction on the same film. Here we observe an initial TMR ratio $\sim$50%. The sample was then poled with a $+$200 mV pulse of 0.5 seconds, resulting in an increase of about 62 kOhm and an increase in TMR to $\sim$80%. Finally, the junction was pulsed with -200 mV. Whilst it did not fall back to its initial value, there was a reduction of about 15 kOhm. The corresponding electric (switching) field of about 770 kV/cm is relatively low, which is important to avoid the introduction of possible electrochemical modifications. At the same time, this relatively small electric field may not be sufficient for complete polarization reversal, which might explain the asymmetry in the resistance states after poling seen in figure 2 (c). In figure 2 (d) we present a current-voltage (IV) curve for a similar junction. Here switching (which is accompanied by a sudden change in resistance at approximately 70 mV) is evident in the hysteretic nature of the IV curve. The ratio of the slopes measured for the two branches around the origin was 2.6, which is similar to that observed in figure 2 (c). Obviously, the measured IV curves exhibit increased instabilities (noise) that are more pronounced at around 70 mV.

The TMR curves of figure 2 (c) represent a four resistance state memory cell, which was theoretically predicted by Tsymbal and co-workers for MTJs comprising ferroelectric barriers.

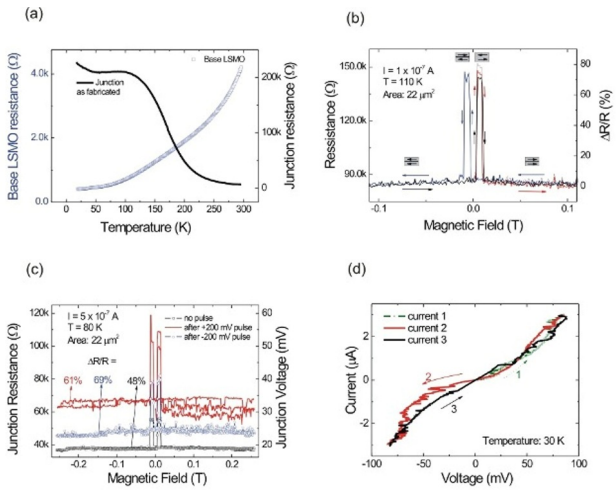

Fig. 2: Electrical characterization of fabricated junctions. (a) Resistance versus temperature plot for both bottom electrode and a junction. The electrode follows the behaviour expected for a metal, whilst the junction data indicates thermally activated conduction mechanisms at temperatures above 100 K. (b) TMR data for a typical junction with R_p x A $=$ 187 MOhm μm^2 (c) TMR from another junction showing the effect of $\pm$200 mV bias pulses. d) Hysteretic current-voltage curve of a similar junction, with the slopes around the origin identifying two distinct resistance states. Here, 1 refers to the initial voltage sweep, which was followed by a second complete voltage sweep in the opposite direction marked 2, and finally 3 indicates the direction of the third voltage sweep.

Our findings are in agreement with this prediction. The observed four resistance states can be related to the mutual orientation of electrode magnetizations and the orientation of ferroelectric polarization states in the barrier (towards the top or bottom electrode). During the TMR measurements, a constant bias current of 5 x10^{-7}A was applied (see figure 2 (c)). Therefore, the bias voltage changed according to the junction resistance R and varied between 17.5 mV and

33 mV. Remarkably, the voltage pulses of ± 200 mV applied across the junction led to a considerable variation of R_p and simultaneously of $R_p - R_{ap}$. As described in the introduction, one would expect the observed experimental facts, i.e., that the spin polarization is influenced by the polarization state of the ferroelectric barrier, which can, in turn, be controlled by the bias voltage. Therefore, our results indicate a (possible) experimental verification of the interface-mediated magnetoelectric effect. Expanding upon this, we propose that the ferroelectric polarization of the barrier, which is controllable by an external electric field, acts as a spin polarization manipulator within the first few unit cells of the adjacent ferromagnetic electrodes. This phenomenon may be explained by changes in the complex band structure at ferromagnetic-ferroelectric interfaces, which result from ionic displacements associated with polarization reversal in the ferroelectric barrier.

We now pay detailed attention to the IV curves shown in figure 2 (d). This hysteretic curve is distinguished by the double-crossing of the branches. We theoretically predicted this feature for weakly asymmetric FTJs, where the ability of electrodes to screen the polarization charges slightly differs. A similar weak asymmetry is expected to be inherent in our junctions, where the electrodes are made of the same material, but the two interfaces likely differ from each other. Secondly, a shaky character of the IV curve is obvious. A pertinent question to ask is if this result is related to the evolution of the polarization reversal on the microscopic scale? So far, the studies of ferroelectric and multiferroic tunnel junctions have assumed that the entire barrier is switched as a single domain once the coercive field is reached. This is a reasonable approximation when the sharp tip of a scanning probe microscope is used as a top electrode. In junctions with extended electrodes, however, simultaneous polarization switching is energetically unfavourable. In bulk ferroelectrics and conventional ferroelectric capacitors, the switching proceeds via the nucleation and growth of multiple 180° domains. The IV curve of figure 2(d) might reflect this fact. Each nucleation event at the interface could modify the tunnel current. Accordingly, the IV curve should reflect the stochastic process of polarization reversal to some extent, with each observed resistance jump being an indicator of an individual switching event. In other words, the IVC measurement could be an analytical tool to gather data on ferroelectric domain growth processes as they happen on the microscopic scale.

Conclusion

In our most current work, we presented strong experimental evidence that the spin polarization of a ferromagnet can be controlled by the remnant ferroelectric polarization, switchable by an applied bias voltage. We observed significant changes in the tunnelling magnetoresistance effect by applying low-voltage pre-pulses to entirely all-oxide LSMO/BFO/LSMO tunnel junctions. The observed phenomenon is attributed to changes in the complex band structure at ferromagnetic-ferroelectric interfaces, which result from ionic displacements associated with polarization reversal in the ferroelectric barrier. We believe our work to be an important step towards the implementation of multistate resistive memory devices based on multiferroic tunnel junctions.

Personnel

Head of the group: Prof. Dr. H. Kohlstedt; Secretary: T. Bittner (50%)
Technical Staff: Dipl.Ing.(FH) N. Röschmann

Scientific Staff:

M. Hambe	01.05.-31.12.2010	DFG
KO 1953/6-1, BA 517		
Dr. habil. N. Pertsev	01.03.-31.12.2010	DFG
Mercator Professur		
Dr. A. Petraru	01.01.-31.12.2010	CAU
N. Ruppelt	01.-31.12.2010	DFG
KO 1953/11-1, BA 521		

Dr. R. Soni SFB 855	01.06.-31.12.2010	DFG
Dr. O. Vavra	01.01.-31.12.2010	CAU
Dr. M. Ziegler	01.04.-31.12.2010	CAU

Lectures, Seminars, and Laboratory Course Offers

Winter 2009/2010

Nanoelectronics, 3 hrs Seminar/Week,
H. Kohlstedt (+ A. Petraru, O. Vavra, M. Ziegler)

Fabrication of Electronic Devices, 2 (+1) hrs Lecture (+ Exercises)/Week,
H. Kohlstedt (+ M. Ziegler)

Summer 2010

Electronics, 3 (+2) hrs Lecture (+ Exercises)/Week,
H. Kohlstedt

Winter 2010/2011

Nanoelectronics, 3 hrs Seminar/Week,
H. Kohlstedt (+ A. Petraru, O. Vavra, M. Ziegler)

Fabrication of Electronic Devices, 2 (+1) hrs Lecture (+ Exercises)/Week,
H. Kohlstedt

Third-Party Funds

DFG, SFB 855, Teilprojekt A4, *Magnetoelektrische Verbundwerkstoffe - biomagnetische Schnittstellen der Zukunft,* 01.01.2009-31.12.2013 (268300 EUR)
DFG, *Transport, Switching and Size Effects in the Lead-Free Ferroelectric BiFeO3,* 12.07.2006-31.12.2010 (210400 EUR)
DAAD, *Interfaces in complex oxide ferroelectric/ferromagnetic heterostructures,* 01.01.2008-31.12.2009 (11870 EUR)
DFG, *Mercator Gastprofessur,* 01.03.2010-28.02.2011 (115600 EUR)
DFG, *Materials World Network: Transport, Switching and Size Effects in the lead-free ferroelectric, BiFeO3,* 01.05.2010-31.01.2011 (54445)
DFG, *Semifluxons in ferromagnetic Josephson junctions,* 01.12.2010-30.11.2013 (211450)

Further Cooperation, Consulting, and Technology Transfer

University of Tuebingen, Germany, Experimentalphysik II and Centre for Collective Quantum Phenomena: Josephson Junctions for Quantum Bits.

University of New South Wales (UNSW), Australia, Department of Material Science: Multiferroic Tunnel Junctions. University of Lincoln, Nebraska, USA, Department of Physics and Astronomy: Ferroelectric polymers for field effect transistors and tunnel junctions.

A.F. Ioffe Physico-Technical Institute, St. Petersburg, Russia: Landau-Theory on strain effect in magnetoelectric heterostructures.

University of California, Berkeley, USA, Materials Science Devision: Multiferroic BiFeO3 Fa. Oerlikon, Leybold, Germany, Cologne: Development of thin film processes.

RWTH Aachen, Germany, Inst. für Werkstoffe der Elektrotechnik II, Muliferroic BiFeO3.

Texas State University, USA, Department of Physics: Devolpment of epitaxially Si-SrTiO3 wafers for magnetoelectric sensors.

Publications

Published in 2010

Soni Rohit, P. Meuffels, A. Petraru, M. Weides, C. Kügler, R. Waser, H. Kohlstedt, *Probing Cu doped Ge0.3Se0.7 based resistance switching memory devices with random telegraph noise,* J. Appl. Phys., **024517**, (2010)

M. Hambe, A. Petraru, N. A. Pertsev, P. Munroe, V. Nagarajan, H. Kohlstedt, *Crossing an Interface - Ferroelectric Control of Tunnel Currents in Magnetic Complex Oxide Heterostructures,* Adv. Func. Mat., **20**, 2436 - 2441 (2010)

N. A. Pertsev, H. Kohlstedt, *Resistive switching via the converse magnetoelectric effect in ferromagnetic multilayers on ferroelectric substrates,* Nanotechnology, **475202**, (2010)

M. Weides, U. Peralagu, H. Kohlstedt, *Critical current diffraction pattern of SIFS Josephson junctions with a step-like F-layer,* Superc. Sci. and Techn., **095007**, (2010)

D. Sprungmann, K. Westerholt, H. Zabel, M. Weides, H. Kohlstedt, *Evidence for triplet superconductivity in Josephson junctions with barriers of the ferromagnetic Heusler alloy Cu2MnAl,* Phys. Rev. B, **060505**, (2010)

T.J. Reece, A. Gerber, H. Kohlstedt, S. Ducharme, *Investigation of state retention in metal-ferroelectric-insulator-semiconductor structures based on Langmuir-Blodgett copolymer films,* J. Appl. Phys., **024109**, (2010)

A. Gerber, M. Fitsilis, R. Waser, T. J. Reece, E. Rije, S. Ducharme, H. Kohlstedt, *Ferroelectric field effect transistors using very thin ferroelectric polyvinylidene fluoride copolymer films as gate dielectrics,* J. Appl. Phys., **124119**, (2010)

S. Scharinger, C. Gurlich, R. G. Mints, M. Weides, H. Kohlstedt, E. Goldobin, D. Koelle, R. Kleiner, *Interference patterns of multifacet 20 x (0-/pi) Josephson junctions with ferromagnetic barrier,* Phys. Rev. B, **174535**, (2010)

C. Gurlich, S. Scharinger, M. Weides, *Visualizing supercurrents in ferromagnetic Josephson junctions with various arrangements of 0 and pi segments,* Phys. Rev. B, **094502**, (2010)

R. Frielinghaus, I. E. Batov, M. Weides, H. Kohlstedt, R. Calarco, Th. Schäpers, *Josephson supercurrent in Nb/InN-nanowire/Nb junctions,* Appl. Phys. Lett., **132504**, (2010)

M. Kemmler, M. Weides, M. Weiler, M. Opel, T. B. Goennenwein, A. S. Vasenko, A. A. Golubov, H. Kohlstedt, D. Koelle, E. Goldobin, *Magnetic interference patterns in 0-pi superconductor/insulator/ferromagnet/superconductor Josephson junctions: Effects of asymmetry between 0 and pi regions,* Phys. Rev. B, **054522**, (2010)

N. A. Pertsev, A. Petraru, H. Kohlstedt, *Nanometer-Sized Ferroelectric Capacitors,* Handbook of nanophysics, CRC Press Taylor and Francis, ed. by Klaus D. Sattler, **Chapter 6**, (2010)

Patent Applications

H. Kohlstedt, *Sensor zur Magnetfelddetektion und Druckdetektion,* München, 12.10.2010, P 5851

Presentations

N. A. Pertsev, H. Kohlstedt, *Voltage-controlled resistive switching in magnetic tunnel junctions and spin valves on ferroelectric substrates,* 19th International Symposium on the Applications of Ferroelectrics and the 10th European Conference on the Applications of Polar Dielectrics, Edinburgh, UK, 09.-12.08.2010

H. Kohlstedt, *Multiferroic Tunnel Junctions (invited),* Seminar, Paris, France, 29.03.2010

A. Petraru, M. Hambe, N. A. Pertsev, P. Monroe, V. Nagarajan, H. Kohlstedt, *Tunnelling magneto resistance in complex oxide heterostructures with active ferroelectric barriers,* Int. Sym. on Integr. Funct. (ISIF 2010), San Juan, USA,

13.-16.06.2010

A. Petraru, H. Kohlstedt, U. Solbach, N. A. Pertsev, M. Heidelmann, U. Klemradt, W. Zander, J. Schubert, R. Waser, *Probing ferroelectricity in ultrathin wedged epitaxial BaTiO3 films*, Int. Sym. on Integr. Funct. (ISIF 2010), San Juan, USA, 13.-16.06.2010

H. Kohlstedt, *Complex oxide heterostructures with active ferroelectric barriers (invited)*, SFB 762 Colloquium, University of, Halle, D, 28.10.2010

H. Kohlstedt, A. Petraru, N. A. Pertsev, V. Nagarajan, M. Hambe, *Crossing an interface: Tuneable spin polarisation by means of electric charge*, Deutsche Physikalische Gesellschaft (DPG), DPG Frühjahrstagung der Sektion Kondensierte Materie, Regensburg, 21.-26.03.2010

M. Hambe, A. Petraru, N. A. Pertsev, P. Munroe, V. Nagarajan, H. Kohlstedt, *Magnetic tunnel junctions with active ferroelectric barriers,* Materials Research Society (MRS) Spring Meeting, San Francisco, USA, 05.-09.04.2010

Further Activities and Events

Organization of the *Drei Koenigstreffen of the Wilhelm-Heraeus Foundation, Bad Honnef, Germany on Magnetoelectric Complex Oxide Heterostructures.*

H. Kohlstedt, Von Baggern und Buergern: Kohletagebau im Rheinland, Night of the Profs, Kiel, 15.01.2010.

Member of the advisor board of the Int. Sym. on Integr. Funct. (ISIF 2010), Puerto Rico, San Juan, USA, conference Organizer of the (Ferroelectric RAM session).

Representative of the ETIT (CAU Kiel) of the Fakultätentag der Elektrotechnik und Informationstechnik (FTIT), 05.06.2010 - 07.06. 2010, Ulm.

H. Kohlstedt, Transistoren: Von der Bastelstube zum Gbit-Chip Saturday Morning Physics, CAU Kiel, 15.10.2010.

Press release: Electron „Pairing" : Triplet superconductivity proven experimentally for first time, http://www.tf.uni-kiel.de/etit/.

Communications

Research Activities:

- Optical communications (measurement, prototyping, and simulation of high speed data communication systems, optical amplifiers for WDM, 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 system level),

- Synchronization in communication systems (clock and carrier synchronization, PLL-applications).

Results

Passive Optical Networks With increasing demand for faster transmission speeds not only the capacity of long haul links but also of the last mile to the end users has to be scaled up. Because the limit of electrical cables is nearly reached, optical communication will play a bigger role in the access area in the near future. Due to cost efficiency, external transmitters and receivers need to be as simple as possible and optical dispersion compensation and optical amplification are to be avoided. Such a passive optical network (PON) consists of an optical line terminal (OLT) at the network side connected via optical fibres and power splitters to multiple optical network units (ONU) at the end user side. In existing PON structures (e. g. GPON) different users share the network with time domain multiple access (TDMA), where every participant has a small time slot for data transmission while all other units are idle. In the next generation optical access networks, wavelength division multiplexing (WDM) will probably be used to allow several parallel data streams on different optical wavelengths, in order to increase the number of end users within the network without reducing the individual data rate. One research topic is the use of orthogonal frequency domain multiple access (OFDMA) to share the channel capacity in the frequency domain. Another research topic is the compensation of channel impairments, as for example dispersion, filter effects and laser chirp, using digital signal processing in the electronic domain. This method allows the use of inexpensive optical components and thus a reduction of costs while increasing the electronic effort only slightly.

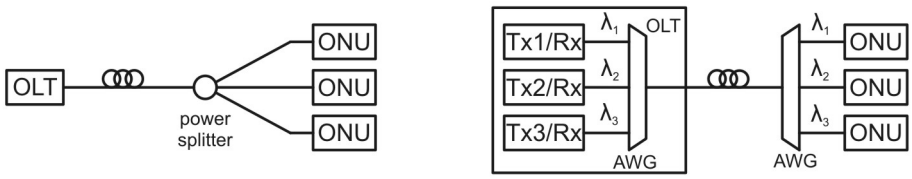

Fig. 1: Left: PON with power splitting (TDMA); right: PON with wavelength splitting (WDMA)

Coherent Detection of Optical Data Signals

Since the invention of the Erbium-doped optical amplifier (EDFA) in the early 1990s, coherent detection of optical data signals had lost attraction since its benefit of increased receiver sensitivity over direct detection did not make up for the additional effort for the local laser and the required carrier recovery. For approximately the last half a decade, however, the interest in coherent detection has returned, as the pressure to achieve high sensitivity and robustness towards transmission impairments has increased dramatically. This is due to the high data rates, beyond 100 Gb/s, that need to be provided in the near future. In recent years, step-by-step the Communications group has updated its laboratory with all the required hardware equipment for the realization of coherent detection. In 2010, in the framework of a diploma thesis, successful coherent detection of an optically phase-modulated orthogonal frequency division multiplexing transmission (OFDM) was achieved. Among the required key components, not only optical components like lasers and couplers were essential for this achievement. The four-channel Real-Time Oscilloscope that was introduced in the 2009 almanac serves as an important

tool that allows storage of up to 200 Million samples per channel. This way, electrical post-processing like carrier recovery and equalization, which is the main technology to enable economic realization of coherent detection, may be carried out afterwards as off-line processing. For 2011, coherent detection is planned also for modulation formats other than OFDM, like for example, quadrature phase-shift keying (QPSK).

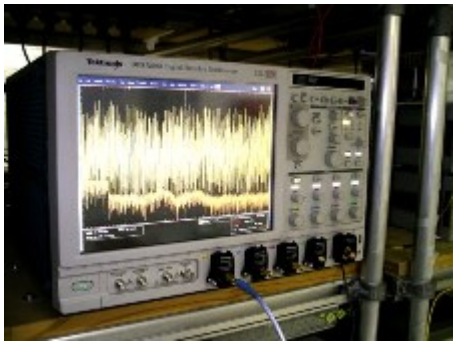

Fig. 2: Left: The four-channel 50 Gsamples/s Real-Time Oscilloscope that was utilized to realize coherent detection of optical data signals

Personnel

Head of the group: Prof. Dr. Werner Rosenkranz; Secretary: Petra Usinger
Technical Staff: Dipl.-Ing. (FH) Sandra Robien

Scientific Staff:

M.Sc. Susmita Adhikari Optical Communication	01.01.-31.12.2010	Industry
M.Sc. Abdulamir Ali Orthogonale Frequenzmultiplextechnik (OFDM)	01.01.-31.12.2010	DFG
Dipl.-Ing. Annika Dochhan Modulationsverfahren	01.01.-31.12.2010	CAU
M.Sc. Ali Emsia	15.01.-03.10.2010	CAU/Industry
Dipl.-Ing. Christina Hebebrand Kohärente Empfänger	01.01.-31.12.2010	Industry
Dr.-Ing. Jochen Leibrich OFDM und Simulationswerkzeuge	01.01.-31.12.2010	CAU
Dipl.-Ing. Christian Ruprecht OFDM-Konzepte für das optische Zugangsnetz	01.10.-31.12.2010	BMBF
Dipl.-Ing. Johannes von Hoyningen-Huene OFDM-Konzepte für das optische Zugangsnetz	01.08.-31.12.2010	BMBF
Dipl.-Ing. Jiani Zhao Optical Communication	01.01.-14.04.2010	CAU

Winter 2009/2010

Nachrichtenübertragung II, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
W. Rosenkranz (+ A. Dochhan)

Optische Kommunikationstechnik II (Hochgeschwindigkeitssysteme und Netze), 2 (+ 1) hrs Lecture (+ Exercises)/Week,
W. Rosenkranz (+ J. Leibrich)

Anleitung zum wissenschaftlichen Arbeiten für Studierende der Elektrotechnik und Informationstechnik, 2 hrs Seminar/Week,
W. Rosenkranz

Seminar über ausgewählte Kapitel der Nachrichtentechnik, 3 hrs Seminar/Week,
W. Rosenkranz und Mitarbeiter/innen

Seminar über Studien- und Diplomarbeiten der Nachrichtentechnik, 2 hrs Seminar/Week,
W. Rosenkranz und Mitarbeiter/innen

Communications Lab, 4 hrs Lab/Week,
W. Rosenkranz (+ J. Zhao)

Digital Communications, 3 (+ 2) hrs Lecture (+ Exercises)/Week,
W. Rosenkranz (+ A. Ali)

High-Speed Systems and Networks, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
W. Rosenkranz (+ J. Leibrich)

Summer 2010

Nachrichtenübertragung, 3 (+ 2) hrs Lecture (+ Exercises)/Week,
W. Rosenkranz (+ A. Dochhan)

Optische Kommunikationstechnik I (Grundlagen und Komponenten, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
W. Rosenkranz (+ J. Leibrich)

Praktikum Nachrichten- und Informationstechnik, 4 hrs Lab/Week,
W. Rosenkranz und Mitarbeiter/innen

Anleitung zum wissenschaftlichen Arbeiten für Studierende der Elektrotechnik und Informatonstechnik, 2 hrs Seminar/Week,
W. Rosenkranz

Seminar über ausgewählte Kapitel der Nachrichtentechnik, 3 hrs Seminar/Week,
W. Rosenkranz und Mitarbeiter/innen

Seminar über Studien- und Diplomarbeiten der Nachrichtentechnik, 2 hrs Seminar/Week,
W. Rosenkranz und Mitarbeiter/innen

Optical Communicatons, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
W. Rosenkranz (+ J. Leibrich)

Winter 2010/2011

Numerische Simulation analoger und digitaler Nachrichtensysteme, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
J. Leibrich (+ J. Leibrich)

Optische Kommunikationstechnik II (Hochgeschwindigkeitssysteme und Netze), 2 (+ 1) hrs Lecture (+ Exercises)/Week,
W. Rosenkranz (+ J. Leibrich)

Seminar über ausgewählte Kapitel der Nachrichtentechnik, 3 hrs Seminar/Week,
W. Rosenkranz und Mitarbeiter/innen

Seminar über Studien- und Diplomarbeiten der Nachrichtentechnik, 2 hrs Seminar/Week,
W. Rosenkranz und Mitarbeiter/innen

Anleitung zum wissenschaftlichen Arbeiten für Studierende der Elektrotechnik und Informationstechnik, 2 hrs Seminar/Week,
W. Rosenkranz

Communications Lab, 4 hrs Lab/Week,
W. Rosenkranz

Digital Communications, 3 (+ 2) hrs Lecture (+ Exercises)/Week,
W. Rosenkranz (+ A. Ali)

High-Speed Systems and Networks, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
W. Rosenkranz (+ J. Leibrich)

Third-Party Funds

BMBF, *OFDM-Konzepte für das optische Zugangsnetz*, 01.08.2010 (504.954 EUR)
Industrie, – , 01.04.-31.12.2010 (77.500 EUR)
Deutsche Forschungsgemeinschaft (DFG), *Orthogonale Frequenzmuliplextechnik (OFDM) in der leitungsgebundenen optischen Hochgeschwindigkeitsübertragung*, 01.01.-30.11.2010 (76.000 EUR)
Industrie, *Untersuchungen zur Identifikation der optimalen Takt- und Trägerrückgewinnung eines kohärenten Epfängers mit Polarisationsmultiplex*, 01.01.-31.10.2010 (95.000 EUR)
BMBF, *Übertragungskonzepte mit Parallelisierung für 100Gbit/s Ethernet Metronetze*, 01.01.-31.12.2010 (87.000 EUR)
Industrie, *ADVAntage-PON*, 01.07.-31.12.2010 (89.250 EUR)

Further Cooperation, Consulting, and Technology Transfer

The chair is a partner in the project CELTIC OPTRONET (optimized transponders for durable optical networks) with the following partners: Siemens S.A. (Portugal), CIVCOM Inc.,

(Israel), CoreOptics GmbH (Nürnberg), Instituto de Telecommuncoes Aveiro (Portugal).

The chair is member of the contact group which annually arranges the Workshop **Optical Communications**:

- TU Munich(Prof. N. Hanik),

- „Reseach Centre COM" , TU Kopenhagen (Prof. P. Jeppesen),

- FhG Heinrich Hertz Institut, Berlin,

- Deutsche Telekom T-Systems, Berlin, Darmstadt.

Diploma, Bachelor and Master Theses

Johannes von Hoyningen-Huene, *Untersuchung neuer Konzepte für optische OFDM-Übertragung mit kohärentem Empfänger*, 10.06.2010
Mechtildis Cerisnanda, *Signal Processing in Optical 112 Gbit/s Polarization-multiplexed PQSK Systems with Coherent Receiver*, 03.12.2010
Setareh Maghsudi, *Direct-Detection Optical OFDM with 100 Gb/s Data Rate Based on Square and Non-Square Digital Modulation Formats*, 21.10.2010

Muhammad Panhwar, *Electronic Mitigation of Transmission Impairments in Optical Communications Using Full-Field Detection*, 20.10.2010

Mohammad Rezania, *Transmission Performance for Wavelength-Division-Multiplexed (WDM) Systems in Standard-Single-Mode Fiber (SSMF) Using Direct-Detection Optical-OFDM*, 12.11.2010

Publications

Published in 2010

M. Eiselt, A. Dochhan, W. Rosenkranz, *OSNR Sensitivity of Multi-Level Modulation Formats*, ACP, 08.-12. December 2010, Shanghai, China, **FA3**, (2010)

V.A.J.M. Sleiffer, M.S. Alfiad, D. van den Borne, S.L. Jansen, M. Kushnerov, S. Adhikari, H. De Waardt, *A Comparison of 43-Gb/s POLMUX-RZ-DPSK and POLMUX-RZ-DQPSK Modulation for Long-Haul Transmission Systems*, ECOC, 19.-23.09.2010, Turin, Italy, **Mo.2.C.4**, (2010)

B. Inan, S. Randel, S.L. Jansen, A. Lobato, S. Adhikari, N. Hanik, *Pilot-Tone-based Nonlinearity Compensation for Optical OFDM Systems*, ECOC, 19.-23.09.2010, Turin, Italy, **Tu.4.A.**, (2010)

S. Adhikari, S.L. Jansen, M. Alfiad, B. Inan, A. Lobato, V.A.J.M. Sleiffer, W. Rosenkranz, *Experimental investigation of Self Coherent Optical OIFDM Systems Using Fabry-Perot Filters for Carrier Extraction*, ECOC, 19.-23.09.2010, Turin, Italy, **Tu.4.A.1**, (2010)

C. Hebebrand, A. Napoli, A. Bianciotto, S. Calabro, B. Spinnler, W. Rosenkranz, *Digital Clock Recovery with Adaptive Loop Gain to Overcome Channel Impairments in 112 Gbit/s CP-QPSK Receivers*, ECOC, 19.-23.09.2010, Turin, Italy, **P3.06**, (2010)

W. Rosenkranz, S. Schöllmann, *Optical MIMO-Processing and Modemultiplexing: Experimental Achievements and Future Perspectives*, Optoelectronics and Communications Conference (OECC), 05.-09.07.2010, Sappro, Japan, **6B2-3**, (2010)

W. Rosenkranz, A. Ali, J. Leibrich, *Design Considerations and Performance Comparison of High-Order Modulation Formats using OFDM*, ICTON, 27.06.-01.07.2010, Munich, **Tu.D1-3**, (2010)

C. Hebebrand, A. Napoli, A. Bianciotto, S. Calabro, B. Spinnler, W. Rosenkranz, *Clock Recovery with DGD-Tolerant Phase Detector for CP-QPSK Receivers*, SPPCom, 21.-24.06.2010, Karlsruhe, Germany, **SPWB3**, (2010)

S.L. Jansen, S. Adhikari, B. Inan, D. van den Borne, *Application scenarios for optical OFDM*, SPPcom, 21.-24.06.2010, Karlsruhe, Germany, (2010)

A. Dochhan, W. Rosenkranz, *Minimization of the Receiver Sensitivity of Cost Efficient Multlevel ASK Modulation Formats for Metro Networks by Filter Optimization*, SPPCom, 21.-24.06.2010, Karlsruhe, Germany, **SPTuA3**, (2010)

J. Leibrich, A. Ali, W. Rosenkranz, *Single Polarization Direct Detectin Optical OFDM with 100 Gb/s Throughput: A Concept Taking into Account Higher Order Modulation Formats*, SPPCom, 21.-24.06.2010, Karlsruhe, Germany, **SPTuA3**, (2010)

S. Randel, S. Adhikari, S.L. Jansen, *Analysis of RF-Pilot-based Phase Noise Compensation for Coherent Optical OFDM Systems*, IEEE Photonics Technology Letters,, **Vol. 22**, **No. 17**, 1288 - 1290 (2010)

J. Leibrich, W. Rosenkranz, *Frequency Domain Equalization with Minimum Complexity in Coherent Optical Transmission Systems*, OFC, 23.-25.03.2010, Sand Diego, California, USA, **OWV1**, (2010)

S. Adhikari, S.L. Jansen, D van den Borne, A.G. Striegler, W. Rosenkranz, *PDM-OFDM for Upgrade Scenarios: An Investigation of OFDM-Induced XPM on 42.8-Gb/s DPSK over SSMF and LEAF*, OFC, 23.-25.03.2010, San Diego, Califonia, USA, **OTuL5**, (2010)

A. Dochhan, M.O. Al-Dwairi, W. Rosenkranz, *Optimization of Cost Efficient Multilevel-ASK Modulation Formats under the Constraint of Chromatic Dispersion*, OFC, 23.-25.03.2010, San Diego, California, USA, **OMJ7**, (2010)

A. Ali, H. Paul, J. Leibrich, W. Rosenkranz, K.-D. Kammeyer, *Optical Biasing in Direct Detection Optical-OFDM for Improving Receiver Sensitivity*, OFC, 23.-25.03.2010, Sand Diego, California, USA, **JThA12**, (2010)

A. Dochhan, J. Leibrich, W. Rosenkranz, *Multilevel ASK Amplitude Level Optimization in the Presence of Chromatic*

Dispersion and PMD, 11. ITG-Fachtagung Photonische Netze, 03.-04.05.2010, Leipzig, Germany, 215 - 219 (2010)

Patent Applications

C. Hebebrand, S. Calabro, B. Spinnler, *Clock Recovery with Adaptive Loop Gain Conrol,* PVA SH, 15.07.2010, –

Presentations

M. Eiselt, A. Dochhan, W. Rosenkranz, *OSNR Sensitivity of Multi-Level Modulation Formats,* ACP, Shanghai, China, 08.-12.12.2010

W. Rosenkranz, A. Ali, J. Leibrich, *Electronics for Orthogonal Frequency Division Multiplexing (OFDM) in Optical Communications for Access and Metro Networks,* SODC, Berlin, Germany, 04.-07.10.2010

V.A.J.M. Sleiffer, M.S. Alfiad, D. van den Borne, S.L. Jansen, M. Kushnerov, S. Adhikari, *A Comparison of 43Gb/s POLMUX-RZ-DPSK and POLMUX-RZ-DQPSK Modulation for Long-Haul Transmission Systems,* ECOC, Turin, Italy, 19.-23.09.2010

B. Inan, S. Randel, S.L. Jansen, A. Lobato, S. Adhikari, N. Hanik, *Pilot-Tone-based Nonlinearity Compensation for Optical OFDM Systems,* ECOC, Turin, Italy, 19.-23.09.2010

S. Adhikari, S.L. Jansen, M. Alfiad, B. Inan, A. Lobato, V.A.J.M. Sleiffer, W. Rosenkranz, *Experimental investigation of Self Coherent Optical OIFDM Systems Using Fabry-Perot Filters for Carrier Extraction,* ECOC, Turin, Italy, 19.-23.09.2010

C. Hebebrand, A. Napoli, A. Bianciotto, S. Calabro, B. Spinnler, W. Rosenkranz, *Digital Clock Recovery with Adaptive Loop Gain to Overcome Channel Impairments in 112 Gbit/s CP-QPSK Receivers,* ECOC, Turin, Italy, 19.-23.09.2010

W. Rosenkranz, S. Schöllmann, *Optical MIMO-Processing and Modemultiplexing: Experimental Achievements and Future Perspectives,* Optoekectronics and Communications Conference, OECC, Sapporo, Japan, 05.-09.07.2010

W. Rosenkranz, A. Ali, J. Leibrich, *Design Considerations and Performance Comparison of High-Order Modulation Formats using OFDM,* ICTON, Munich, Germany, 27.06.-01.07.2010

C. Hebebrand, A. Napoli, A. Bianciotto, S. Calabro, B. Spinnler, W. Rosenkranz, *Clock Recovery with DGD-Tolerant Phase Detector for CP-QPSK Receivers,* SPPCom, Karlsruhe, Germany, 21.-24.06.2010

S.L. Jansen, S. Adhikari, B. Inan, D. van den Borne, *Application scenarios for optical OFDM,* SPPCom, Karlsruhe, Germany, 21.-24.06.2010

A. Dochhan, W. Rosenkranz, *Minimization of the Receiver Sensitivity of Cost Efficient Multlevel ASK Modulation Formats for Metro Networks by Filter Optimization,* SPPCom, Karlsruhe, Germany, 21.-24.06.2010

J. Leibrich, A. Ali, W. Rosenkranz, *Single Polarization Direct Detectin Optical OFDM with 100 Gb/s Throughput: A Concept Taking into Account Higher Order Modulation Formats,* SPPCom, Karlsruhe, Germany, 21.-24.06.2010

J. Leibrich, W. Rosenkranz, *Frequency Domain Eyualization with Minimum Complexity in Coherent Optical Transmission Systems,* OFC, San Diego, California, USA, 23.-25.03.2010

S. Adhikari, S.L. Jansen, D. van den Borne, A.G. Striegler, W. Rosenkranz, *PDM-OFDM for Upgrade Scenarios: An Investigation of OFDM-Induced XPM on 42.8-Gb/s DPSK over SSMF and LEAF,* OFC, San Diego, California, USA, 23.-25.03.2010

A. Dochhan, M.O. Al-Dwairi, W. Rosenkranz, *Optimization of Cost Efficient Multilevel-ASK Modulation Formats under the Constraint of Chromatic Dispersion,* OFC, San Diego, California, USA, 23.-25.03.2010

A. Ali, H. Paul, J. Leibrich, W. Rosenkranz, K.-D. Kammeyer, *Optical Biasing in Direct Detetction Optical-OFDM for Improving Receiver Sensitivity,* OFC, San Diego, California, USA, 23.-25.03.2010

A. Dochhan, J. Leibrich, W. Rosenkranz, *Multilevel ASK Amplitude Level Optimization in the Presence of Chromatic Dispersion and PMD,* 11. ITG-Fachtagung Photonische Netze, Leipzig, Germany, 03.-04.05.2010

Further Activities and Events

Mitgliedschaft von Prof. Rosenkranz in folgenden Gremien:

* 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 ist Mitglied im Programmkomitee folgender internationaler Konferenzen:

* *" IEEE/OSA Optical Fibre Communication (OFC)"*

* *" 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)"*

LNT-Mitarbeiter wirken mit im „Arbeitskreis Übertragungstechnik" im Rahmen des BMBF Verbundprojektes „100GET" .

Der Lehrstuhl wirkte mit an:

* *Projektwoche „Mobilfunk"* des Gymnasiums Bad Oldesloe * *Technik AG*

Awards

Herr Johannes von Hoyningen-Huene erhielt den Alumni-Preis der Christian-Albrechts-Universität für seine 2010 abgeschlossenen Studienleistungen.

Circuit and System Theory

Personnel

Head of the group: Prof. Dr.-Ing. U. Heute; Secretary: S. Schuchardt (50%)
Technical Staff: Dipl.-Ing. T. Rabsch (50%)

Scientific Staff:

Dipl.-Ing. R. Kreimeyer	01.01.-30.04.2010	WTD 71
Klassifikation der Signaturen von Meeressäugern mit Methoden der Spracherkennung		
M.Sc. M. Muthuraman	01.01.-31.12.2009	LNS / Neurology
EEG- and EMG Analysis of Tremor Patients		
Dipl.-Ing. J. Schwarz	15.09.2009-31.03.2010	CAU
Speaker Charact. and Transformation		
Dipl.-Ing. K. Wilkens	01.01.-31.12.2010	BMV
Sonar-Signal Processing		
Dipl.-Ing. H. Özer	01.01.-31.12.2009	CAU
Bio-Medical / ECG Signal Processing		

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 (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 aim 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, and fields and waves in biological systems.

Results

a) Efficient near-field far-field transformation for the FDTD-method

Multipole analysis is a classical technique to analytically describe electromagnetic (and acoustic) fields using series expansions. It is an orthogonal decomposition of the field into the (canonical) dipole, quadrupole, octopole etc. fields with respect to a chosen origin. The method has been successfully employed to solve several classical boundary value problems in the frequency domain. Applications of spherical symmetry include diffraction at a perfectly conducting or dielectric sphere (Mie solution) and diffraction at a perfectly conducting cone. This DFG-sponsored project uses the extraordinary features of multipole analysis to evaluate and post-process numerically obtained near-fields. Within the FDTD-method, a near-field far-field transformation utilizes an equivalence principle: the sources of the field are replaced by electric and magnetic currents on a closed surface surrounding all actual sources. Conventionally for each far-field point of interest a numerical integration over this whole surface used to be required. As has been shown for the frequency-domain and later for the time-domain, the new approach avoids that problem. In addition, the analytical multipole expansion of the far-field obtained allows for an enhancement of the numerically obtained results using a spatial frequency low-pass filter.

In this research project a novel technique has been developed, which is perfectly adjusted to the problem. It allows for a very efficient calculation of the Legendre polynomials needed here. As an application of this technique the calculation of the far-fields of UWB antennas for an entire frequency range by just one single FDTD-run has been achieved. The promising multipole interface for computational electromagnetics is still being developed and extended. Particularly the efficiency of numerical convolution in the time-domain is to be improved.

b) 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 mechanical constraints and on the frequency range of the anticipated disturbances. A quantitative measure of a shield's impact on electric and magnetic disturbances at low frequencies is the electrical and magnetic shielding effectiveness. However, these measures are not applicable for high frequency disturbances or pulsed (transient) disturbances.

This research project concentrates on the evaluation of the adequacy of definitions regarding shielding effectiveness. This is done by simulated and experimental examination of specific shielding enclosures. We are particularly interested in the results of a near-field source of interference as compared to incoming plane waves.

c) Statistical EMC

Statistical EMC is an important part of statistical electromagnetics, as many parameters in EMC (frequencies, amplitudes,

waveforms, and geometry) are known only by means of their statistics. The 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 only the amplitudes are described through statistical moments.

d) Multipole analysis of diffraction coefficients

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.

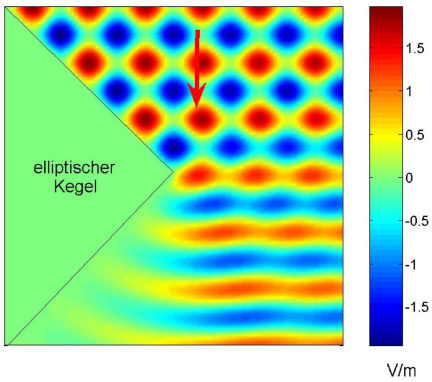

Fig. 1: Snapshot of the electric field strength in the plane of symmetry of a semi-infinite elliptic cone with a plane wave incident from above. Interference in the region of reflection can be identified, as well as an almost undisturbed plane wave in the region of transmission and a spherical-wave-like diffracted field in the shadow region.

In this DFG sponsored research project we managed to determine diffraction coefficients from solutions for the sector and the elliptical cone. These structures have peaks and the associated diffraction coefficients are obtained by numerical evaluation of a series expansion of the field in elliptic conical coordinates, using series transformations for improved convergence. Possible applications may include more precise calculations of the fields scattered by airport constructions to improve instrument landing systems.

e) Multipole antennas

Antennas are renowned as key elements in wireless digital communications. In multipath propagation scenarios, like in the field of mobile devices, multiple antennas (MIMO systems) could improve crucial parameters such as SNR or channel capacity. In this project a novel approach to implement such systems in small devices (e.g. mobile phones) is examined. Instead of the usual approach of several separate antennas, only one antenna is fed trough N inputs. By feeding different currents, N virtual antennas with orthogonal directional characteristics (multi-modes) can be achieved.

f) 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" founded 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.

g) Modelling and localization of cardiomagnetic sources

The project is part of the Collaborative Research Centre (SFB) 855 on „Magnetoelectric Composites - Future Biomagnetic Interfaces" funded by the Deutsche Forschungsgemeinschaft (DFG). The goal of this project is to model physiological and pathological currents in the heart by means of a minimal number of unknowns.

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. F. Argin	01.04.-31.12.2010	DFG
SFB855 - D1: Multipole-based reconstruction schemes		
Dipl.-Ing. M. Kijowski	01.04.-31.12.2010	DFG
Scattering by semi-infinite structures		
Dipl.-Phys. K. Körber	01.01.-31.12.2010	CAU
Statistical EMC		
Dr.-Ing. V. Motrescu	15.03.-31.12.2010	DFG
SFB 855 -D4: Magnetocardiographic modelling and localization		
Dipl.-Ing. Ch. Möller	01.01.-30.09.2010	CAU
HS2020		
Dr.-Ing. L. Radic-Weißenfeld	01.04.-31.12.2010	DFG
SFB855 - D1: Multipole-based reconstruction schemes		

Lectures, Seminars, and Laboratory Course Offers

Winter 2009/2010

Elektromagnetische Felder 2, 3 (+1) hrs Lecture (+ Exercises)/Week,
L. Klinkenbusch (+ K. Körber)

Felder und Wellen in biologischen Systemen, 2 (+1) hrs Lecture (+ Exercises)/Week,
L. Klinkenbusch (+ K. Körber)

Intensivübung Elektromagnetische Felder, 1 hrs Exercise/Week,
L. Klinkenbusch (+ C. Möller, K. Körber, M. Kijowski)

Summer 2010

Elektromagnetische Verträglichkeit, 2 (+1) hrs Lecture (+ Exercises)/Week,
L. Klinkenbusch (+ K. Körber)

Seminar Feldtheorie, 1 hrs Seminar/Week,
L. Klinkenbusch

Elektromagnetische Felder 1, 3 (+1) hrs Lecture (+ Exercises)/Week,
L. Klinkenbusch (+ C. Moeller)

Mathematische Methoden in der Feldtheorie, 2 (+1) hrs Lecture (+ Exercises)/Week,
L. Klinkenbusch (+ M. Kijowski)

Projekt, 3 hrs Exercise/Week,
L. Klinkenbusch (+ K. Körber)

Winter 2010/2011

Elektromagnetische Felder 2, 3 (+1) hrs Lecture (+ Exercises)/Week,
L. Klinkenbusch (+ K. Körber)

Felder und Wellen in biologischen Systemen, 2 (+1) hrs Lecture (+ Exercises)/Week,
L. Klinkenbusch (+ K. Körber)

Intensivübung Elektromagnetische Felder, 1 hrs Exercise/Week,
L. Klinkenbusch (+ C. Möller, K. Körber, M. Kijowski)

Projekt, 3 hrs Lecture/Week,
L. Klinkenbusch (+ K. Körber)

Third-Party Funds

DFG, *Semi-infinite Strukturen*, 01.01.-31.12.2010 (1/1 E13 + 1 WiMi + Sachmittel)
DFG, *URSI EMTS2010 - 16-19. August 2010, Steigenberger Hotel Berlin*, 16.-19.08.2010 (30000 EUR)
DFG, *SFB 855 TP D1*, 01.01.-31.12.2010 (2 E13 + Sachmittel)
DFG, *SFB 855 TP D4*, 01.01.-31.12.2010 (1 E13 + Sachmittel)

Further Cooperation, Consulting, and Technology Transfer

1. Prof. Dr. H. Chaloupka, Bergische Universität Wuppertal, Subject: multimode atennas.

2. Prof. Dr. M. Popovic, McGill University, Montreal (Canada), Subject: bioelectromagnetic fields.

3. Prof. Dr. R. Sikora, Westpommeranian University Szczecin (Poland), Subject: non-destruction evaluation, ERSASMUS partnership.

4. Prof. Dr. E. Cardelli, University Perugia (Italy), ERASMUS partnership.

5. Prof. Dr. Paul Urbach, TU Delft und Philips Eindhoven (Netherlands), Subject: scattering theory, FDTD-Simulation.

6. Prof. L. Pichon, University Paris-Sud (XV), Paris (France) Subject: EMC of complex systems, ERASMUS partnership.

7. Prof. G. Manara, University of Pisa (Italy), ERASMUS partnership.

Publications

Published in 2010

J. Adam, *Analyse und Verarbeitung numerisch berechneter elektromagnetischer Felder mittels Multipolentwicklungen*, Shaker Verlag Aachen, (2010)

L. Klinkenbusch, *Spherical-Multipole Based Time-Domain Near-Field to Near-Field Transformation*, Proc. 2010 URSI Commission B International Symposium on Electromagnetic Theory, Berlin, August 16-19, 782 - 785 (2010)

J. Adam, L. Klinkenbusch, H. Mextorf, R. Knöchel, *Numerical Multipole Analysis of Ultrawideband Antennas*, IEEE Trans. on Antennas and Propagation, **58**, 3847 - 3855 (2010)

Patent Applications

L. Klinkenbusch, *Method an arrangement for reconstructing the source of an electromagnetic field*, Munich, 14.07.2010, PCT/DE2010/000824

Presentations

M. Kijowski, L. Klinkenbusch, *Eigenmodal Analysis of the Field Scattered by an Elliptic Cone*, Kleinheubacher Tagung 2011, Miltenberg, 05.10.2010

L. Klinkenbusch, *Ansätze zur Lokalisation und Modellierung elektrischer Hirnströme*, Neurobiologisches Kolloquium, Kiel, 14.04.2010

L. Klinkenbusch, *Spherical-Multipole Based Time-Domain Near-Field to Near-Field Transformation*, URSI EMTS 2010, Berlin, 18.08.2010

Further Activities and Events

Prof. Klinkenbusch was chairman of the Local Organizing Committee of the URSI International Symposium on Electromagnetic Theory (EMT-S) successfully held in Berlin, Germany in August 2010. Since 2009 he has been a committee member of the German Academic Exchange Service (DAAD) for the region Near-East/ North Africa. Prof. Klinkenbusch was chairman of the examining board (until October 2010) and is academic adviser for the departmental programs in electrical and information engineering (dploma and bachelor). Since October 2010, he serves as the managing director of the Institute of Electrical and Information Engineering. He also is representative of the Faculty of Engineering in the Schleswig-Holsteinische Universitätsgesellschaft.

Prof. Klinkenbusch is member of VDE, elected member of URSI Commission B, and a Fellow of IEEE. He serves in the IEEE Antennas and Propagation Education Committee. He currently is guest editor for the ISTET'09 special issue of COMPEL and an associate editor of RADIO SCIENCE.

Wireless Communications

The research of 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: 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 the antenna performance especially is dominated by the integration impairments. The group's research activities especially aim 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,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. The system is intended for integration into an aircraft cabin. The designed antennas cover the frequency range from 3.1 GHz to 10.6 GHz. Multiple two antenna systems are integrated into the cabin's ceiling while a miniature mobile device contains a single antenna which is specifically designed to work in close proximity to the human body.

MIMO Antenna Integration into Small Terminals

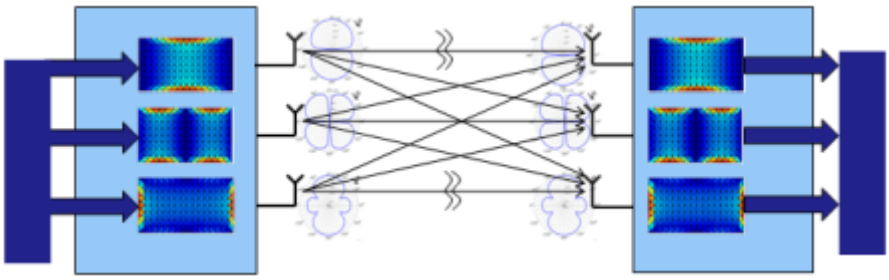

Fig. 1: Concept for de-correlated antenna modes in small terminals.

MIMO (Multiple Input Multiple Output) is a technique to utilize multi-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. As part of his PhD thesis Robert Martens investigates the coupling between multiple antenna elements on small terminal platforms and its influence on the element correlation. First results indicate a relation 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 for deriving design rules for the integration of multiple antennas into small terminals. As a short term prospective such rules are valuable e.g. for the design of LTE (Long Term Evolution) mobile terminals and WLAN IEEE802.11.n devices.

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 periphery devices. The applications can range over consumer electronic devices, security equipment , medical devices for telemedicine, and electronic implants. In order to allow 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 of different applications. The antennas are developed and optimized taking into account realistic integration in the chassis of the application and realistic implantation into the body.

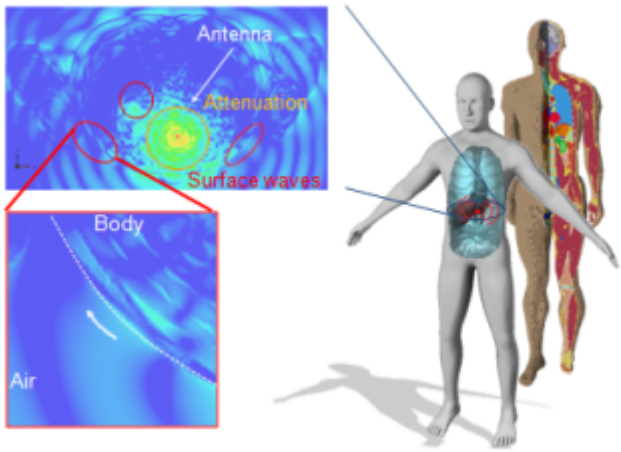

Fig. 2: RF propagation (f = 2.45 GHz) excited by an implanted antenna inside the body.

Personnel

Head of the group: Prof. Dr.-Ing. D. Manteuffel; Secretary: M. Bork
Technical Staff: Dipl.-Ing. W. Taute

Scientific Staff:

Dipl.-Ing. M. Grimm UWB BAN	01.10.-31.12.2010	DFG
Dipl.-Wirtsch.-Ing. R. Martens MIMO	01.01.-31.12.2010	CAU
Dipl.-Wirtsch.-Ing. F. Marx Localization	01.10.-31.12.2010	CAU

Lectures, Seminars, and Laboratory Course Offers

Winter 2009/2010

Grundgebiete der Elektrotechnik III, 3 (+2) hrs Lecture (+ Exercises)/Week,
D. Manteuffel (+ R. Martens, Ch. Möller, M. Nordhausen)

Entwurf von Antennen, 4 hrs Lab/Week,
D. Manteuffel (+ R. Martens)

Summer 2010

Antenna Design, 2 (+1) hrs Lecture (+ Exercises)/Week,
D. Manteuffel (+ R. Martens)

Communication Devices II: RF Communication, 2 (+1) hrs Lecture (+ Exercises)/Week,
D. Manteuffel (+ R. Martens)

Hochfrequenztechnik, 2 (+1) hrs Lecture (+ Exercises)/Week,
D. Manteuffel (+ R. Martens)

Seminar on Topics in Digital and Optical Communications, 2 hrs Seminar/Week,
D. Manteuffel

BSc ETIT, 4 hrs Project/Week,
D. Manteuffel

Winter 2010/2011

Grundgebiete der Elektrotechnik III, 3 (+2) hrs Lecture (+ Exercises)/Week,
D. Manteuffel (+ R. Martens, F. Marx)

Advanced Topics Lab, 6 hrs Lab/Week,
D. Manteuffel (+ M. Grimm)

Third-Party Funds

Deutsche Forschungsgemeinschaft, *Antennen und Wellenausbreitung für am und im Körper betriebene Funkanwendungen basierend auf ultra breitbandiger Technologie (Schwerpunktprogramm UKoLoS)*, 01.10.2010-30.09.2012 (124960 EUR)

Deutsche Forschungsgemeinschaft, *Integration von Mehrantennensystemen in kleinen mobilen Endgeräten auf Basis der Theorie der Charakteristischen Moden*, 01.12.2010-30.11.2011 (187440 EUR)

Industry cooperation, *UWB Antennas and Propagations for a combined communication and localization systems inside an aircraft cabin*, 01.02.2009-30.06.2010 (EUR non-disclosed)

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, Loughborough University. Industrial cooperations have been conducted with I2R Singapore, IMST GmbH, Airbus and Draeger.

Diploma, Bachelor and Master Theses

M. Grimm, *Antennen und Wellenausbreitung für Body Area Networks (BAN)*, 18.06.2010
B. Klinke, *Entwicklung und Aufbau einer dual-polarisierten ultra-breitbandigen Hornantenne*, 24.06.2010
Ch. Friedt, *Ocular integrated wireless video transmission*, 03.09.2010

Publications

Published in 2010

R. Martens, E. Safin, D. Manteuffel, *On the Relation between the Element Correlation of Antennas on Small Terminals and Characteristic Modes of the Chassis*, Proceedings of the Loughborough Antennas and Propagation Conference, 457 - 460 (2010)

M. Grimm, D. Manteuffel, *Electromagnetic Wave Propagation on Human Trunk Models excited by Half-Wavelenghth Dipoles*, Proceedings of the Loughborough Antennas and Propagation Conference, 493 - 496 (2010)

D. Manteuffel, M. Grimm, R. Martens, *Optimization of UltraWideBand Bow-Tie Antennas for Cable based Operation,* Proceedings of the Loughborough Antennas and Propagation Conference, 585 - 588 (2010)

D. Manteuffel, T. Ould, T. Kempka, *Antenna and Propagation impairments of UWB localization system integrated into an aircraft cabin,* Proceedings of the Loughborough Antennas and Propagation Conference, 589 - 592 (2010)

R. Martens, D. Manteuffel, *Element Correlation of MIMO antennas on small terminals,* Proceedings of the Fourth European Conference on Antennas and Propagation, 1 - 5 (2010)

C. Luxey, D. Manteuffel, *Highly-efficient multiple antenna-systems for small MIMO devices,* Proceedings of the International Workshop on Antenna Technology, 1 - 6 (2010)

H. Mextorf, R. Martens, F. Daschner, R. Knöchel, *Dual polarized UWB antenna for free-space characterization of dielectric objects,* Proceedings of the German Microwave Conference, 162 - 165 (2010)

Further Activities and Events

VDE ITG Fachauschschuss 7.1 ''Antennen'': Prof. Manteuffel became a member of this national committee of experts in February.

Standardization: Prof. Manteuffel is a member of the ICES working group TC34. Prof. Manteuffel is an editor of the IET Proceedings on Microwave, Antennas and Propagation.

ESoA - European School of Antennas: Prof. Manteuffel is a member of the board of the European School of Antennas ESoA, which is a geographically distributed post-graduate school offering courses in selected topics on antennas.

Conferences chaired: In 2010 Prof. Manteuffel was the general chairman of the Loughborough Antennas and Propagation Conference LAPC 2010 with more than 150 delegates.

Technical Program Commitees: In 2010 Prof. Manteuffel served on the TPC of the following international conferences: ICUWB 2010 - International Conference on Ultra Wideband Technology, EuCAP 2010 - European Antennas and Propagation Conference, LAPC 2010 - Loughborough Antennas and Propagation Conference, iWAT 2010 - International Workshop on Antenna Technology. Short course ''Industrial Antenna Design'' at IEEE AP-S, Toronto, Canada. TAE (Technische Akademie Esslingen) seminar ''Technik der Antennen'': Lectures on ''EM Modelling'' and ''Mobile Communication Antennas''.

Institute for Materials Science

General Development of the Institute for Materials Science

The Institute for Materials Science enjoyed a successful year but became increasingly aware of the limits to growth. A still increasing number of third-party funded Professors, together with an increasing number of Institute members and a rapidly rising number of students, strained the available basic and finite infrastructure to its utmost limit. The CAU conducted a large survey in 2009 with the aim to find out how students evaluate the new Bachelor courses. The results, published in early 2010, were gratifying: The Materials Science Bachelor study course enjoyed first place out of 40 courses. Rumours are that we could defend the top position in 2010 but final results are not yet in.

Work on the Collaborative Research Centre SFB 855 (''Magnetoelectric Composites - Future Biomagnetic Interfaces'') started in January. Prof. Eckhardt Quandt is the speaker for this SFB. The CAU decided to submit a proposal for a ''cluster of excellence'' to the DFG and established Prof. Quandt as the responsible person coordinating the effort. A proposal entitled ''Materials for Life'' was sent to the DFG in Sept 2010. A decision will be made in March 2011. Two ''Research Unit'' (Collaborative Research Centre) proposals with participation of Institute members were submitted in 2010 / 2011 to the DFG. Topics are research on periimplantitis proposed in the dental clinic (with Profs. from Materials Science Faupel and Adelung) and interocular sensor and actor technology (with Profs. from Materials Science Selhuber-Unkel and Adelung).

Other outstanding events were:

Our ''Heisenberg Prof.'' Dr. Rainer Adelung received an offer for a W3 Professorship from the Technical University Hamburg-Harburg (TUHH) in February 2010. With the much-appreciated help of the CAU president, we were able to induce him to stay in Kiel. Prof. Adelung will take over Prof. Helmut Föll's group after his retirement in 2014; in the meantime special funds supply the base for his work as a full-time member of the Institute.

The Institute welcomed Prof. Christine Selhuber-Unkel on July 1st 2010 as its newest member. Prof. Selhuber-Unkel's group is entitled ''Biocompatible Nanomaterials'' and works on the basis of a large grant from the Emmy-Noether program of the DFG awarded for the proposal ''A nanobiophysical approach to elucidate target-cell killing by amoebic parasites''.

The DFG approved a proposal for a third Heisenberg Professorship to be established in the institute for Jeff McCord. Internal procedures were duly started, and Jeff McCord received an official offer in January 2011. Negotiations have not been completed at the end of 2010.

Prof. Volker Abetz, one of our two ''GKSS professors'', received a call from the Saarland University for a W3 professorship in ''Chemical Materials Science'' in combination with a Scientific Director position at the INM Leibniz-Institute for New Materials in Saarbrücken. No decision has been made in 2010.

Prof. Wolfgang Jäger succeeded in bringing an international conference concerning electron microscopy to Kiel (Microscopy Conference MC 2011, Kiel; Organized by the DGE - German Society for Electron Microscopy e.V.). The conference, co-sponsored by microscopy societies of many nations, will take place in the autumn of 2011; for details see www.mc2011.de.

Prof. Helmut Föll was elected executive director of the Institute in Nov. 2011 for a third consecutive period. However, after one year of service, Prof. Lorenz Kienle, who was appointed as permanent professor in Dec. 2010 after his Heisenberg professorship expired, will take over.

The proposal (drawn up by Prof. Adelung) to acquire a much-needed High-Resolution REM for the central services of the institute was approved by the DFG. The microscope might be in service by the second half of 2011.

Dr. Oliver Riemenschneider, already known from prior research work in the AMAT group, was named the leader of the (Teaching) Service Centre and the Centre for Materials Analysis (CMA), replacing Dr. Kai Dolgner who is now a member of

parliament. Dr. Riemenschneider now organizes the R&D work of the CMA for institutional and industrial third partners. Within the newly founded Service Centre he is responsible for accreditation and development of study courses and the examination office as part of the Service Centre. He also mentors students in all topics relating to our study courses and is directly involved in teaching undergraduates.

The Master Study course was successfully re-accredited in May; the new structure was implemented in the winter term. Re-accrediting of the Bachelor study course has started but will be finished in 2011.

Publications

Published in 2010

Profs. Institute, *Much more than just sailing,* PS Public Service Review: Sciene and Technology, **8**, 40 - 41 (2010)

General Materials Science

The existing projects with partners (topics: ''Thermoelectricity'' and ''Si Solar cell technology'') are running well and producing results. Three new projects with third party funding have been started, concerning pore etching in ZnSe, high-capacity Li ion batteries, and a magneto-electric sensor based on piezoelectric porous InP.

The whole process chain for Si nanowire anode fabrication for high capacity Li ion batteries is now established in Kiel; the process has been substantially simplified and stabilized for future low-cost production. General work aiming at a better understanding of electrochemical pore etching in semiconductors and the concomitant self-organization processes is progressing satisfactorily. The new paradigm introduced by the group in this context (known under the catchword ''current burst model'') is enjoying increasing acceptance by the scientific community.

CELLO has mutated to what one could call ''FC CELLOplus'' (Four Colour CELLO plus Impedance) and is now used routinely for the most demanding solar cell characterizations in cooperation with most major players in the German solar cell establishment. The new SHALUM technique (short for ''SHAded LUMinescence'') has overcome the problems encountered in 2009 and started to produce good results.

With the beginning of 2011 the chair has reached its zenith. The remaining 3 years until Prof. Föll's retirement will be dedicated to finishing running projects, transfering the technology developed, and to familiarizing Prof. Adelung, the successor of Prof. Föll, with the research activities of the group with the aim of starting common projects. ***Technology Transfer and Research Projects in General***

Results

Three new projects have been started. First, the Alexander von Humboldt Foundations approved a partnership with the National Centre for Materials Study and Testing of the Technical University of Moldova; the topic is ''electrochemical pore etching in ZnSe and related new properties''. The objective is to explore pore etching in ZnSe single crystals for the purpose of elaborating wide-band-gap semiconductor nanotemplates for nanofabrication, and to obtain a better understanding of pore etching in II-VI compounds. Work has begun.

Second, together with the Fraunhofer Institutes for Chemical Technology (ICT) and Material and Beam Technology (IWS) a proposal (''Neue Materialkonzepte für Alkalimetall-Schwefel-Batterien bzw. Akalimetallsulfid-Silizium-Batterien (AlkaSuSi)'') has been sent to the BMBF-Fördermaßnahme ''Schlüsseltechnologien für die Elektromobilität (STROM)''; the proposal was generally approved in Dec. 2010, and work on the project will commence in 2011. The objective is to establish a ''proof of concept'' for a high capacity Li ion battery with a Si nanowire anode and a sulphur based cathode.

Third, experimental work concerning the SFB 855 (magneto electric compound materials) has started and shown that porous InP can indeed be used as a novel piezo electrical material.

Ongoing third-party funded projects were: ''Macroporous Si for ultra-thin single crystalline wafer based photovoltaics'' (MACPSI) together with the ''Institute for Solar Energy Research GmbH'', Hameln/Emmerthal (ISFH), funded by the BMU; and ''Porous Si as a thermoelectric material (Positem)'' together with the MPI ''Microstructure Physics'' in Halle, funded by the BMBF.

The novel SHALUM (short for ''SHAded LUMinescence'') technique (in cooperation with Fa. Basler AG and funded by the ''Innovationsstiftung Schleswig-Holstein'' (ISH)) experienced severe technical problems that were caused by the extremely low (optical) signal to noise ratio. As we had to learn, optical data of LEDs, filters and materials in general are not reliable at this level. Meanwhile solutions have been found and SHALUM has started to live up to its promise.

The results from ongoing internal projects are quite satisfactory. In particular, dedicated work with respect to Si nanowire anodes resulted not only in the establishment of a complete process chain, including pre-structuring and etching 150

mm wafers plus Cu deposition in Kiel (using the ''Kieler Nanolab'' facilities) but also in much more production friendly key processes. The close cooperation with the ISIT in all aspects of battery research continued. Several companies are interested in the Si nanowire anode and are ready for joint projects as soon as some proof of principle based on sufficient numbers of real batteries can be demonstrated.

AMAT also supported a new start-up company in Halle (SmartMembranes GmbH) by lending it some key etching equipment for evaluation. If the company succeeds with its first products based on porous Si, a close cooperation in the future is envisioned.

Continuation of the solar cell work resulted in a final rugged and reliable ''FC CELLOplus'' (Four Colour CELLO plus Impedance) system that is ahead of most other solar cell characterization techniques. The system is now routinely used for the most demanding solar cell characterizations in cooperation (via BMBF projects or directly) with most German solar cell companies; two units are also at present being tested by well-known companies. A cooperation based on CELLO with the FhG ''Solar Energy Systems'' (ISE) and ''Labor- und Servicecenter Gelsenkirchen'') culminated in the PhD examination of Sinje Keipert-Colberg in Dec. 2010.

The BMU-supported SolarFocus Project finished in April 2010. AMAT will participate in the subsequent project ''SolarWinS'' (Starting in Jan. 2011), where nearly all (11) of the major German silicon solar cell manufacturers and a number of research institutes are integrated.

Research Details

Our task within the ''MACPSI'' project was to establish large area etching techniques for the desired structures. Process recipes were developed and demonstrated. An important milestone was reached; a 20 μm thick structure of specified low porosity followed by high porosity could be produced within 12 min. Currently the facilities for a 6 inch lithography on n-Si wafers in the ''Kieler Nanolab'' are tested for an intensified cooperation and the transfer of the existing etching recipes to 6 inch wafers is in progress.

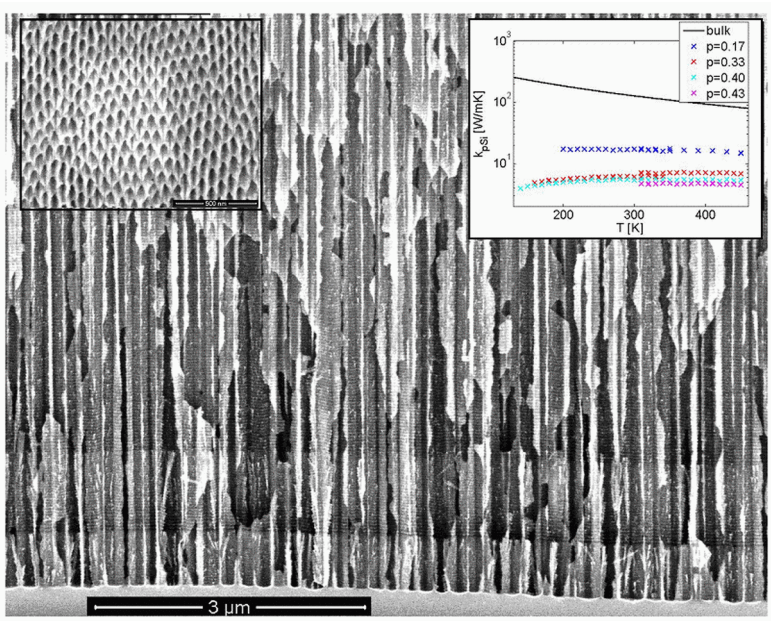

Fig. 1: Pore structure in Si:3%Ge suitable for thermoelectric applications. The inset on the left shows a top view of the pore: the inset on the right thermal conductivity measurements (done in Halle) for (similar) samples with different porosities (p parameter).

The ''PoSiTeM'' project has met its major goals (despite the fact that our principal investigator, Dr. A. Cojocaru, gave birth

to a daughter in December and accordingly was not allowed to work in the laboratory from May 2010 onwards and was completely off work for 3 months). In essence, the task was to develop etching methods for Si and Si:Ge alloys that allowed the fast production of rather thick (several 100 μm) and uniform porous layers with average distances between pores of $\sim$50 nm. The scientific challenge was to emulate pore structures known from InP in Si and Si:Ge alloys. The challenge could be met; **Fig. 1** shows a pore structure that meets most requirements (in particular pore size and depth) and provides for thermal conductivities up to two orders of magnitude below that of solid Si:Ge. The specimen was actually a Si-3%Ge alloy and it was not clear that pore etching know-how from pure Si could be used. **Fig. 1** not only shows a pore structure that comes close to what was desired but also an almost perfect ''clone'' to the self-organized, fast-growing current line pores in InP with self-induced diameter oscillations that so far could not be reproduced in other semiconductors. The work was based on a ''meta'' theory for pore growth that the group had developed and published in recent years. This ''meta'' theory is based on the observation that an increasing number of pore related features, mostly centred on self-organization issues, are common to pores in most semiconductors obtained under a wide range of chemically different conditions. Logic then dictates that a common underlying principle must exist that does not depend on the detailed (electro)chemistry of the dissolution process. This principle has been identified and condensed in the catchword ''current burst model''.

Porous InP (not unlike in appearance to the porous Si sample in **Fig. 1**) was expected to be an insulator that would show the full potential of the inherent piezoelectric behaviour of III-V semiconductors. As it turned out in first experiments aimed towards the development of magneto-electric compound materials within the SFB 855, this is not really true. However, suitable post treatments of porous InP samples produced insulating samples with piezoelectric coefficients far larger (factor of $\sim$30) relative to literature values. The next step will be to fill the pores with a magnetorestrictive material.

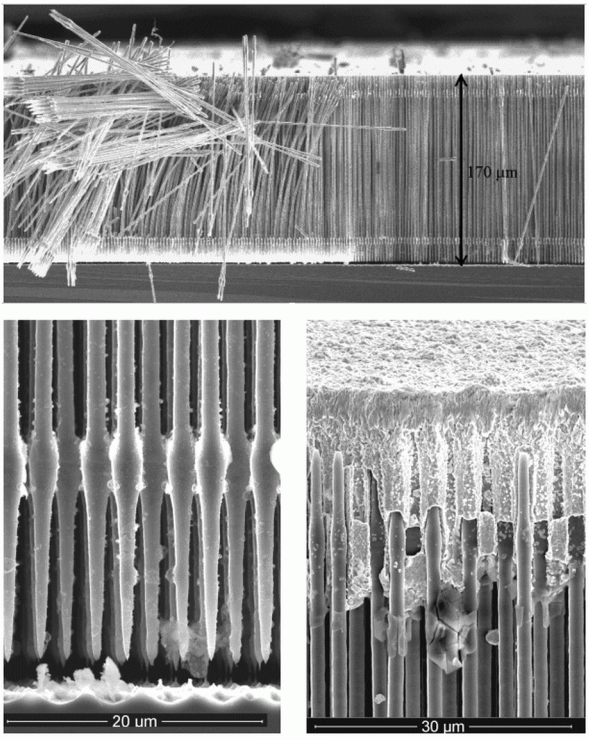

Fig. 2: Si nanowires for Li ion battery. Top: Stiction-stabilized nanowire array with maximum density and thus capacity. The ''loose'' nanowires result from cleaving the sample. Bottom left: Bottom end of nanowires showing detachment from the substrate and stabilizing layer. Bottom right: Top of nanowire array embedded in Cu.

The whole process chain for making Si nanowire anodes is now established at AMAT, including pre-structuring of 150 mm wafers by lithography in the ''Kieler Nanolab'' facilities. The bulk of the work done was dedicated to the development of a

production-friendly process.

Key features are: i) etching pores with a sophisticated diameter vs. depth profile resulting in nanowires stabilized against stiction effect and easily detachable from the (reusable) substrate, ii) development of an anisotropic over-etch procedure that is far faster and has a larger process window in comparison to standard acidic etchants, iii) avoidance of slow and unreliable Cu galvanics at the bottom of the nanowires in favour of fast electrodeless Cu plating on the nanowire tops followed by a simple galvanic Cu deposition. Some results are shown in **Fig. 2**. Nanowire, or more correctly microwire anodes made in this way have the highest achievable capacity in comparison to other ''nano'' Si anodes and can be produced at relatively low costs (a few € including a 200 mm Si wafer).

The ongoing systematic study of the formation of crystallographic pores and current-line pores in InP and intrinsic growth mode transitions, augmented with an increasing number of relevant data, in particular in-situ FFT impedance spectra, yielded detailed insights into pore formation processes in InP and on the meta level discussed above. One invited presentation of the results had to be cancelled, however, because of air travel problems related to the Eyjafjalla-Jökull volcano eruption in spring.

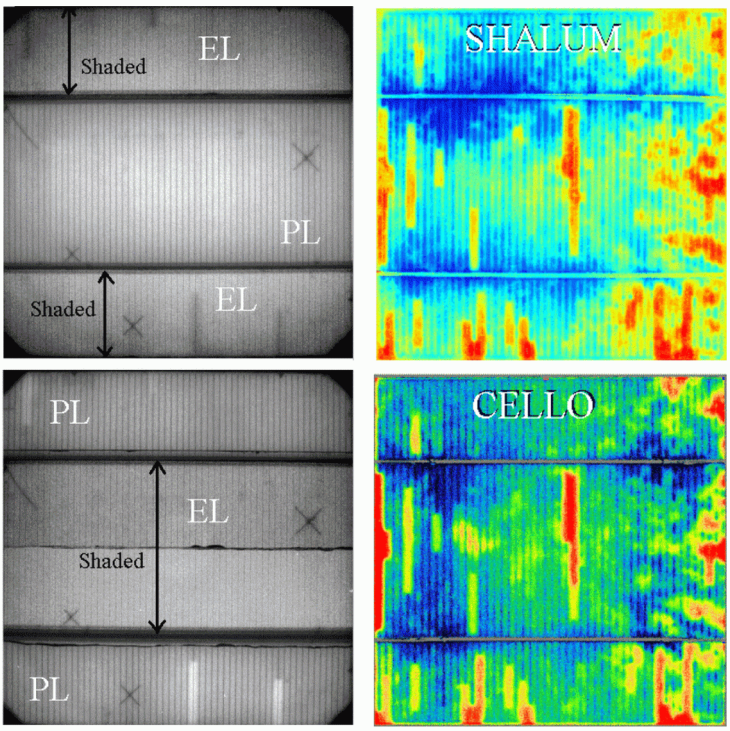

Fig. 3: SHALUM results. On the left: The two sets of raw SHALUM data from a mono-crystalline Si solar cell (EL = electro-, PL = photoluminescence). Note the contrast reversal at broken grid fingers; the ''crosses'' show dislocation piles from surface damage. On the right: Series resistance data for a multi crystalline solar cell calculated from the two sets of raw data. For comparison the independently obtained CELLO results are shown at the bottom.

The CELLO technique has overcome the last technical problems and proved its unsurpassed power for characterizing solar cells with tiny (< 1 cm^2) and extremely poor efficiency ($\eta < 1$ %) organic solar cells as well as with huge (> 200 cm^2) high-efficiency ($\eta > 15$ %) Si cells. Three (out of four) lasers with different penetration depth confocally scan at high speed across a solar cell held at an arbitrary fixed working point including global illumination. All lasers can be modulated with several superimposed but well-defined frequencies. Three amplitude and phase pictures result for any frequency. With, for example, two angular frequencies $\omega_1(L_i)$ and $\omega_2(L_i)$ (i = 1,2,3) per laser L (all different), 12 maps are produced in real time; each one contains information about parameters of interest.

In addition, a number of second-harmonic maps (e.g. for $\omega = \omega_1(L_1) + \omega_2(L_2)$) can be generated from the digital data that contain highly relevant local information, e.g. about the so-called ''current matching'' in multi junction cells, information not accessible at present by any other method. Evaluation of the data requires involved theory; at present, models exist and are implemented in the CELLO software for standard (fronts side contact) Si solar cells. The theory for non-harmonic responses is non-trivial and under development.

Development of the SHALUM technique suffered from the (somewhat unexpected) finding that nearly everything luminesces at the ''Si line'' (around 1.1 eV) with intensities comparable to that of Si under intense red illumination. This is especially true for the LEDs providing the red illumination and for the filters needed to block the global illumination. Only a frustrating and time consuming intensive search for suitable materials and filters finally yielded working hardware. At the end of 2010 the first and very promising results could be achieved. In essence, part of the globally illuminated solar cell is shaded with a filter that blocks the incoming radiation but transmits the luminescence signal. The non-shaded part then will provide a photoluminescence picture (PL) and produce a photocurrent that flows into the shaded part that acts as a load. In the shaded part the photocurrent induces electroluminescence (EL) that is also recorded by the IR camera. Changing the shaded area produces two pictures showing PL and EL from all areas. It can be shown theoretically that in a first approximation the difference between the two pictures produces a series resistance map, whereas the sum produces a so-called J_0 map that contains lifetime and mobility information. This is demonstrated in **Fig. 3**. Note that SHALUM is much faster than CELLO (a luminescence picture can be obtained in about 1 s, corresponding to about a 1000 pixels for CELLO) while CELLO is not only fully quantitative but can access more solar cell properties. In other words, CELLO is a research tool while SHALUM is a production tool.

Teaching

Even though some of the major Hyperscripts have not been updated for years, they are still quite prominent in the Net as shown by a few numbers:

2007: 20.3 million hits, 1,510 GByte downloads; 2008: 19 million hits, 1,692 GByte downloads; 2009: 18.5 million hits, 2,240 GByte downloads; 2010: 20.6 million hits, 2,341 GByte downloads.

Equally gratifying is the Google ranking of all relevant search strings (e.g. chapter and sub-chapter headings) where the AMAT Hyperscripts usually are found on first or second place (then after Wikipedia). Some examples: Defects in Crystals: 1/11 Mio; Hard Soft Magnets: 1/26 Mio, MOS Transistor 3/1,4 Mio, Production Chip 1/119 Mio, Laser Condition 1/169 Mio, 2. Hauptsatz 2/140.00, Reziprokes Gitter 2/13.500. More details concerning Hyperscript statistics can be found under http://www.tf.uni-kiel.de/matwis/amat/generalinfo_en/statistics_hyperscripts.html

Personnel

Head of the group: Prof. Dr. Helmut Föll; Secretary: Katrin Brandenburg (50%)
Technical Staff: Dipl.-Ing. (FH) Jörg Bahr

Scientific Staff:

Dr. Jürgen Carstensen	01.01.-31.12.2010	CAU
Theory, software development, supervision of teaching		
Dr. Ala Cojocaru	01.01.-31.12.2010	BMBF
Porous Si and SiGe for thermoelectrics		
M.Sc. Mark-D. Gerngroß	16.08.-31.12.2010	DFG
SFB 855 Magnetoelectric Composites - Future Biomagnetic Interfaces		
Dipl.-Ing. Dirk Kaden	01.01.-31.03.2010	FhG-ISiT
PZT layers in MEMS technology		

Dipl.-Ing. Malte Leisner	01.01.-31.12.2010		CAU
Modelling pore growth in semiconductors			
M.Sc. Emmanuel Ossei-Wusu	01.01.-31.12.2010		BMBF
Macroporous Si for solar cell uses; optimization of pore etching			
Dipl.-Ing. Anselm Pape	01.01.-31.12.2010		ISH
Quantitative Photolumineszenzanalyse von Siliziumsolarzellen			
Dr. habil. Georgi Popkirov	01.01.-31.12.2010	(50%)	ISH / Firma Basler
Hardware development for photoluminescenc, CELLO, electrochemistry			
Dr. Enrique Quiroga-González	01.06.-31.12.2010		CAU
Si nanowire anode for Li ion battery			
Dr. Jan-Martin Wagner	01.07.-31.12.2010		1) DFG, 2) third party funds
Theory and development for multi-color CELLO (incl. impedance and non-linear behaviour) and for shaded luminescence techniques			

Lectures, Seminars, and Laboratory Course Offers

Winter 2009/2010

Electronic Materials, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
Helmut Föll (+ Malte Leisner)

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 (+ Malte Leisner)

Laboratory Course: Scientific Methods, 4 hrs Lab/Week,
Anselm Pape (+ Ala Cojocaru, Mohammed Qasim Shaik, Seid Jebril, Dietrich Häußler, Vladimir Zaporojtchenko, Andriy Lotnyk, Kai Dolgner)

Mathematics for Material Scientists, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
Jürgen Carstensen

Basic Laboratory Course for Master Students, 4 hrs Lab/Week,
Emmanuel Ossei-Wusu (+ Mohammed Qasim Shaik, Amit Kulkarni, Sönke Kaps, Christina Pakula, Marlies Schwitzke)

Halbleitertechnik und Nanoelektronik, 4 (+ 1) hrs Lecture (+ Exercises)/Week,
Helmut Föll (+ Rainer Adelung)

Praktikum: Analytische Methoden, 4 hrs Lab/Week,
M. Leisner (+ Marlies Schwitzke, Klaus Rätzke, Dirk Meyners, Mady Elbahri, Dietrich Häußler)

Grundlagen der Materialwissenschaft, 3 (+ 2) hrs Lecture (+ Exercises)/Week,
Helmut Föll (+ Anselm Pape, Malte Leisner)

Summer 2010

Materialwissenschaft II, 3 (+1) hrs Lecture (+ Exercises)/Week,
Helmut Föll (+ Malte Leisner)

Statistical Mechanics, 2 (+1) hrs Lecture (+ Exercises)/Week,
Jürgen Carstensen

Aktuelle Fragen der Forschung, 2 hrs Seminar/Week,
Helmut Föll (+ Jürgen Carstensen)

Laboratory Course: Functional Materials, 4 hrs Lab/Week,
Malte Leisner (+ Mohammed Qasim Shaikh, Amit Kulkarni, Dietrich Häußler)

Semiconductors, 2 (+1) hrs Lecture (+ Exercises)/Week,
Helmut Föll

Computergestützte Mathematik, 2 (+1) hrs Lecture (+ Exercises)/Week,
Jürgen Carstensen

Defects, 2 (+1) hrs Lecture (+ Exercises)/Week,
Helmut Föll (+ Andriy Lotnyk)

Winter 2010/2011

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 (+ Malte Leisner)

Laboratory Course: Scientific Methods, 4 hrs Lab/Week,
Anselm Pape (+ Enrique Quiroga González, Ala Cojocaru, Andriy Lotnyk, Christiane Zamponi, Vladimir Zaporojtchenko, Dawit Gedamu, Thomas von Hofe)

Advanced Mathematics - Computational Mathematics, 1 (+1) hrs Lecture (+ Exercises)/Week,
Jürgen Carstensen (+ Jan-Martin Wagner)

Basic Laboratory Course for Master Students, 4 hrs Lab/Week,
Emmanuel Ossei-Wusu (+ Mohammed Qasim Shaik, Amit Kulkarni, Sören Kaps, Marlies Schwitzke, Christina Pakula)

Halbleitertechnik und Nanoelektronik, 4 (+1) hrs Lecture (+ Exercises)/Week,
Helmut Föll (+ Rainer Adelung)

Praktikum: Analytische Methoden, 4 hrs Lab/Week,
Malte Leisner (+ Dirk Meyners, Mady Elbahri)

Grundlagen der Materialwissenschaft, 3 (+2) hrs Lecture (+ Exercises)/Week,
Helmut Föll (+ Anselm Pape)

Advanced Mathematics - Mathematics for Material Science, 2 (+1) hrs Lecture (+ Exercises)/Week,
Jürgen Carstensen

Third-Party Funds

BMWi (BEO Jülich), *SolarFocus, TP5: Charakterisierung der Wechselwirkung zwischen Defekten und ihres Einflusses auf die elektrischen Eigenschaften unter besonderer Berücksichtigung der Synchrotron-Mikroskopie,*

01.03.2007-28.02.2010 (87000 EUR)

Fraunhofer Institut für Siliziumtechnologie (FhG ISiT), Itzehoe, *Erstellung einer Studie zum Thema: Untersuchungen zur Herstellung von piezoelektrischen Bauelementen mit Dünnfilm-PZT-Schichten,* 15.11.2007-14.11.2010 (228757 EUR)

DFG, *Schnelle quantitative und ortsaufgelöste Komplettcharakterisierung von Solarzellen durch Kombination von ''CELLO'' auf FFT Impedanzspektroskopie,* 01.06.2008-31.05.2010 (172000 EUR)

DFG, *Programmpauschale zu Schnelle quantitative und ortsaufgelöste Komplettcharakterisierung von Solarzellen durch Kombination von ''CELLO'' auf FFT Impedanzspektroskopie,* 01.06.2008-31.05.2010 (34.400 EUR)

ISH, *Quantitative Photolumineszenzanalyse von Siliziumsolarzellen,* 01.01.2009-31.12.2010 (125588 EUR)

Industrie, *Industriebeteiligung zu Quantitative Photolumineszenzanalyse von Siliziumsolarzellen,* 01.01.2009-31.12.2010 (35416 EUR)

BMBF, *Poröses Silizium als Thermoelektrisches Material (PoSiTeM),* 01.07.2009-30.06.2011 (165139 EUR)

Alexander von Humboldt-Stiftung, *Institutspartnerschaft mit der TU Moldova,* 01.07.2010-31.12.2012 (55000 EUR)

BMBF F+E-Vertrag mit Institut für Solarenergieforschung (ISFH) GmbH, *Macroporöses Silicium für ultradünne monokristalline Waferphotovoltaik (MacPSI) TP: Optimierung des Ätzprozesses,* 01.03.2010-31.08.2011 (107100 EUR)

DFG, *SFB 855, TP A3 Magnetoelektrische 1 - 3 Komposite,* 01.01.2010-31.12.2013 (350700 EUR)

Further Cooperation, Consulting, and Technology Transfer

Technical University of Moldova, Chisinau, Moldova: Scientific cooperation with Prof. Dr. I.M. Tiginyanu.

Max-Planck-Institut für Mikrostrukturphysik, Halle, Germany: Scientific cooperation with Dr. Breitenstein within the framework of the SolarFocus project.

Max-Planck-Institut für Mikrostrukturphysik, Halle, Germany: Scientific cooperation with Dr. Schmid on ''Porous Si for thermoelectric applications''.

ISFH, Hameln/Emmerthal, Germany: Cooperation within the framework of the SolarFocus project and application of electrochemical pore formation for solar cell production within the MacPSI-project.

Fraunhofer-Institut für Solare Energiesysteme, Freiburg, Gelsenkirchen, Germany: Scientific cooperation with Dr. Warta and Prof. Dr. Schindler within the framework of the SolarFocus project; CELLO-measurements in connection with the shared supervision of a Ph.D. student.

Fraunhofer-Institut für Siliziumtechnologie, Itzehoe, Germany: Shared supervision of Ph.D. students and Bachelor-Thesis. Scientific cooperation with respect to Li-Ion Batteries.

Dispatch Energy Innovations GmbH, Itzehoe, Germany: Scientific cooperation with respect to Li-Ion Batteries.

BetaBatt, Inc., U. S. A.: Discussion of a joint project in cooperation with Fraunhofer Institute for Silicon Technology (ISIT), Itzehoe.

CaliSolar, Inc., Berlin / U. S. A.: Cooperation concerning interpretation and discussion of CELLO measurements.

RWE Schott Solar GmbH, Alzenau, Germany, Deutsche Solar GmbH, Freiberg, Germany, Deutsche Cell GmbH, Freiberg, Germany, Shell-Solar GmbH, München, Germany, ERSOL, Erfurt, Germany, Sunways, Konstanz: Cooperation within the framework of the SolarFocus project for solar cell characterization and single measurements.

Helmholtz-Zentrum für Materialien und Energie, Berlin, Germany: Shared supervision of a Ph.D. student.

Bosch AG, Stuttgart, Germany; Shared supervision of Bachelor- and Master-Thesis and PhD-work: cooperation concerning CELLO-characterization of solar cells.

Bosch Solar Industries, Erfurt, Germany: CELLO-characterization of industrially produced solar cells and advanced solar cell concepts.

CSP, Halle, Germany: CELLO characterization of CSG solar cells.

FhGs ICT and IWS, Germany: Common proposal ''AlKaSuSi'' for BMBF; approved Dec. 2010.

Diploma, Bachelor and Master Theses

Hemanth K. Venkat, *Examination of highly-selective, cexia based sluxxies for oxide chemical mechanical planaxization,* 26.02.2010

Hauke Hartz, *Herstellung und Nutzung von Silizium-Nanowires als negatives Elektrodenmaterial für Lithium-Ionen-Batterien,* 30.03.2010

Muhammad Tayyib, *Angular Dependent Measurements of the Quantum Efficiency of Silicon Thin Film Solar Cells,* 30.07.2010

Timo Koenen, *Hazebildung bei lösemittelprozessierten TCOs,* 15.09.2010

Mark-D. Gerngroß, *Characterization and optimization of electrochemically etched porous InP structures for possible piezoelectric applications,* 28.09.2010

Anselm Pape, *Testen und Optimierung der CELLO-Impedanzanalyse zur Verbesserung von Solarzellenmessungen,* 16.12.2010

Dissertations / Postdoctoral Lecture Qualifications

Julian Tornow, *Trennung und Rekombination von Ladungsträgern in Solarzellen mit nanostrukturierter ZnO-Elektrode,* 02.03.2010

Sinje Keipert-Colberg, *Multikristalline Siliziumsolarzellen mit Siliziumoxid-Siliziumnitrid-Rückseitenpassivierung,* 01.12.2010

Publications

Published in 2010

H. Föll, H. Hartz, E.K. Ossei-Wusu, J. Carstensen, O. Riemenschneider, *Si nanowires arrays as anodes in Li ion batteries (One of 18 articles selected to be featured in a special issue ''Best of pss'')*, phys. stat. sol. RRL, **4(1)**, 4 - 6 (2010)

H. Föll, M. Leisner, A. Cojocaru, J. Carstensen, *Macroporous semiconductors (invited review)*, Materials, **3**, 3006 (2010)

M. Leisner, J. Carstensen, H. Föll, *Pores in n-type InP - a model system for electrochemical pore etching,* Nanoscale Res. Lett., **5(7)**, 1190 (2010)

M. Leisner, A. Cojocaru, E.K. Ossei-Wusu, J. Carstensen, H. Föll, *New applications of electrochemically produced porous semiconductors and nanowire arrays,* Nanoscale Res. Lett., **5(9)**, 1502 (2010)

J. Carstensen, A. Schütt, A. Pape, H. Föll, *CELLO measurements for local and global characterization of grid finger, contact, and emitter resistance losses of large area solar cells,* Proceedings of the 25th European Photovoltaic Solar Energy Conference, 2CV.3.19, Valencia, Spain, (2010)

J. Carstensen, A. Schütt, G. Popkirov, H. Föll, *CELLO FFT impedance analysis of solar cells with a strong injection level dependence*, Proceedings of the 25th European Photovoltaic Solar Energy Conference, 2CV.3.27, Valencia, Spain, (2010)

Presentations

H. Föll, *Solarzellen und Materialwissenschaft (talk)*, Night of the Profs., Christian-Albrechts-University Kiel, Kiel, Germany, 15.01.2010

Jürgen Carstensen, A. Schütt, H. Föll, *Charakterisierung von Siliziumscheiben und Solarzellen mit ELYMAT und CELLO (talk)*, SolarFocus Abschlusstreffen, Fulda, Germany, 23.-25.02.2010

J. Carstensen, A. Schütt, H. Föll, *Erste CELLO-Ergebnisse an Solarzellen dotiert mit 0.05 % Ge und Cr (talk)*, SolarFocus Abschlusstreffen, Fulda, Germany, 23.-25.02.2010

J. Carstensen, A. Schütt, H. Föll, *CELLO-Ergebnisse zur großen Varianz in der Mobilität und der Injektionslevel-Abhängigkeit an Solarzellen aus kompensiertem mc-Si und CZ-Si (talk)*, SolarFocus Abschlusstreffen, Fulda, Germany, 23.-25.02.2010

H. Föll, *Materialwissenschaft (talk)*, Studieninformationstage, Christian-Albrechts-University Kiel, Kiel, Germany, 10.03.2010

H. Föll, *Ulrich Gösele (invited talk)*, 7th International Conference Porous Semiconductors - Science and Technology (PSST) 2010, Valencia, Spain, 14.-19.03.2010

E. Ossei-Wusu, H. Hartz, A. Cojocaru, J. Carstensen, H. Föll, *Silicon nanowires made via macropore etching for superior Li ion batteries (talk, outstanding contribution award)*, 7th International Conference Porous Semiconductors - Science and Technology (PSST) 2010, Valencia, Spain, 14.-19.03.2010

A. Cojocaru, M. Leisner, J. Carstensen, H. Föll, *Comparison of currentline pore growth in n-type InP and in n-type Si (poster)*, 7th International Conference Porous Semiconductors - Science and Technology (PSST) 2010, Valencia, Spain, 14.-19.03.2010

M. Leisner, J. Carstensen, H. Föll, *Quantitative analysis of curro pore growth on n-type InP (poster)*, 7th International Conference Porous Semiconductors - Science and Technology (PSST) 2010, Valencia, Spain, 14.-19.03.2010

M. Leisner, D. Dorow-Gerspach, J. Carstensen, H. Föll, *Influence of the doping concentration on crystallographic pore growth on n-type InP and GaAs (poster)*, 7th International Conference Porous Semiconductors - Science and Technology (PSST) 2010, Valencia, Spain, 14.-19.03.2010

E. Garralaga Rojas, J. Hensen, J. Carstensen, H. Föll, R. Brendel, *Mesoporous germanium multilayers (talk)*, 7th International Conference Porous Semiconductors - Science and Technology (PSST) 2010, Valencia, Spain, 14.-19.03.2010

J. Carstensen, A. Schütt, G. Popkirov, H. Föll, *CELLO investigation for local characterization and optimization of (organic) solar cells (SOLAR CELL LOCAL CHARACTERIZATION) (talk)*, Visit from Bosch AG, Kiel, Germany, 14.05.2010

Helmut Föll, *Solarik und Wissenschaft (invited talk)*, ECO Forum 2010, Strom aus der Sonne - Perspektiven für Schleswig-Holstein, Rendsburg, Germany, 17.06.2010

J. Carstensen, A. Schütt, G. Popkirov, H. Föll, *CELLO measurement technique for local identification and characterization of various types of solar cell defects (talk)*, BIAMS 2010, Halle, Germany, 04.-08.07.2010

J. Carstensen, A. Schütt, G. Popkirov, H. Föll, *CELLO FFT impedance analysis of solar celss with a strong injection level dependence (poster)*, 25th European Photovoltaic Solar Energy Conference, Valencia, Spain, 06.-10.09.2010

J. Carstensen, A. Schütt, A. Pape, H. Föll, *CELLO measurements for local and global characterization of grid finger, contact, and emitter resistance losses of large area solar cells (poster)*, 25th European Photovoltaic Solar Energy Conference, Valencia, Spain, 06.-10.09.2010

M.-D. Gerngroß, *Magnetoelectric 1-3 composites (talk)*, Fall-Workshop of the collaborative research center 855, Salzau, Germany, 01.-01.10.2010

M.-D. Gerngroß, *Magnetoelectric 1-3 composites (poster)*, Fall-Workshop of the collaborative research center 855, Salzau, Germany, 01.-01.10.2010

H. Föll, J. Carstensen, *Pattern formation during anodic etching of semiconductors (invited talk)*, 218th ECS Meeting, Las Vegas, U. S. A., 10.-15.10.2010

H. Föll, J. Carstensen, E. Ossei-Wusu, A. Cojocaru, G. Neumann, *Optimized Cu contacted Si nanowire anodes for Li ion batteries made in a production near process (talk)*, 218th ECS Meeting, Las Vegas, U. S. A., 10.-15.10.2010

A. Cojocaru, J. Carstensen, J. Boor, D.S. Kim, V. Schmidt, H. Föll, *Production and investigation of porous Si-Ge structures for thermoelectric application (talk)*, 218th ECS Meeting, Las Vegas, U. S. A., 10.-15.10.2010

H. Föll, *Remembering Ulrich Gösele (invited talk)*, 218th ECS Meeting, Las Vegas, U. S. A., 10.-15.10.2010

E. Garralaga Rojas, J. Hensen, J. Carstensen, H. Föll, R. Brendel, *Porous germanium layers by electrochemical etching for layer transfer processes of high-efficiency multi-junction solar cells (talk)*, 218th ECS Meeting, Las Vegas, U. S. A., 10.-15.10.2010

E. Qiroga González, *Optimized Cu Contacted Si Nanowire Anodes for Li-Ion Batteries Made in a Production-Near Process (talk)*, German-Moldova Workshop on Electrochemical Nano-Structuring of Materials, Kiel, Germany, 12.-12.11.2010

A. Corduneanu, *Etching GaAs Materials Using Surface Charge (talk)*, German-Moldova Workshop on Electrochemical Nano-Structuring of Materials, Kiel, Germany, 12.-12.11.2010

M. Leisner, *Simulating Crystallographic Pore Growth on III-V Semiconductors (talk)*, German-Moldova Workshop on Electrochemical Nano-Structuring of Materials, Kiel, Germany, 12.-12.11.2010

M.-D. Gerngroß, *Porous InP for Piezoelectric Applications (talk)*, German-Moldova Workshop on Electrochemical Nano-Structuring of Materials, Kiel, Germany, 12.-12.11.2010

M. de Souza Sikora, *Investigation of Titanium Oxide Films Obtained by Galvanostatic Anodization (talk)*, German-Moldova Workshop on Electrochemical Nano-Structuring of Materials, Kiel, Germany, 12.-12.11.2010

A. Cojocaru, *Production and Investigation of Porous Si Structures for Thermoelectric Materials Application (talk)*, German-Moldova Workshop on Electrochemical Nano-Structuring of Materials, Kiel, Germany, 12.-12.11.2010

H. Föll, *Solarzellen und Materialwissenschaften (invited talk)*, Deutsches Museum, Vorträge im Ehrensaal ''Wissenschaft für jedermann'', München, Germany, 17.11.2010

J. Carstensen, A. Schütt, G. Popkirov, J. Bahr, H. Föll, *CELLO investigation for local characterization and optimization of solar cells (SOLAR CELL LOCAL CHARACTERIZATION) - Stress investigation on Solar Cells (invited talk)*, Invited talk for members of Bosch AG, Schillerhöhe / Stuttgart, Germany, 25.11.2010

Further Activities and Events

Our paper ''Si nanowire arrays as anodes in Li ion batteries'', H. Föll, H. Hartz, E. Ossei-Wusu, J. Carstensen, and O. Riemenschneider, Phys. Status Solidi RRL **4**, 4 - 6 (2010) is one of 18 articles selected to be featured in the special issue ''Best of PSS''.

Prof. Dr. H. Föll is the executive director of the Institute for Materials Science, Faculty of Engineering, Christian-Albrechts-University Kiel.

Prof. Dr. H. Föll is a member of the scientific advisory board of the Max-Planck-Institut für Mikrostrukturphysik, Halle, Germany.

Prof. Dr. H. Föll is a member of the curatorship of the Fraunhofer-Institut für Siliziumtechnologie, Itzehoe, Germany.

Prof. Dr. H. Föll is a member of the executive board of the ''Förderverein der Technischen Fakultät'' at Christian-Albrechts-University Kiel.

Prof. Dr. H. Föll is the ''Vertrauensdozent für Angelegenheiten der Deutschen Forschungsgemeinschaft'' at Christian-Albrechts-University Kiel.

Guests Scientists in 2010

26.08.2010 - 31.12.2010 Guest scientist: Mariana de Souza Sikora, Universidade de Sao Carlos, Departamento de Quimica, Sao Carlos, Brazil: Use of ''current burst'' mode for TiO_2.

01.09.2010 - 31.12.2010 Guest scientist: Alexandru Cordunenau and Veaceslav Sprincean, Technical University of Moldova, Chisinau, Moldova: Pore etching and pore filling.

Guests in 2010

19.04.2010 Dr. Matthias Boehringer, Robert Bosch GmbH, Gerlingen, Germany, Colloquium of the Faculty of Engineering „Poröses Silizium im Umfeld einer Halbleiterfertigung“ .

Inorganic Functional Materials

The department „Inorganic Functional Materials“ concentrates on research and development of smart and multiferroic thin film materials and their applications in micro- or nanosystems. As an inherent property these materials directly transduce electrical into mechanical energy and vice versa and are based on the physical phenomena magnetostrictive, piezoelectricity and shape memory effects. Thus they are very attractive for the realization of miniaturized actuators or sensors.

These small and easy-to-integrate, „intelligent“ micro-actuators and -sensors are essential for a high number of application areas in automotive, information, biochemical, and medical technology. Selected examples are discussed in more detail in the following chapters.

Results

Magnetoelectric Composite Future-Biomagnetic Interfaces

The Collaborative Research Centre SFB 855 „Magnetoelectric Composite Future- Biomagnetic Interfaces“ began work at the beginning of 2010. Besides being deeply involved in this SFB with two scientific sub-projects A1 and C2, the central analysis project Z1 and the administrative project Z2, Prof. Quandt is also the speaker of the SFB.

The objective of project A1 is the development of magnetoelectric thin film 2-2 composites based on a magnetostrictive and highly soft magnetic layer and a piezoelectric layer. Here the optimization of the film and interface properties is of key interest. The films are prepared by different techniques. On the one hand PVD processes like magnetron sputtering and pulsed laser deposition are used, and on the other complex oxide films like the lead-free ferroelectric BCT-BZT are prepared by the sol-gel technique. The results of project A1 are directly applied in project C2, a cooperative project with the group of Prof. Wagner of the Fraunhofer Institute for Silicon Technology. The goal of C2 is to integrate these functional layers in sensors based on microelectromechanical systems (MEMS) processes.

In 2010 the most remarkable result was the fabrication and characterization of cantilever-type thin film magnetoelectric (ME) sensors [1, 2]. Thin films of piezoelectric AlN and the magnetostrictive alloy FeCoSiB were deposited on silicon cantilever structures (Fig. 1 a)). By special design of the cantilevers ME coefficients up to 1800 V/cmOe in resonance were achieved (Fig. 1 b)). This is the highest ME coefficient reported so far. Sensors of this type are also investigated in the project C3 of Prof. Knöchel.

[1] H. Greve, E. Woltermann, R. Jahns, S. Marauska, B. Wagner, R. Knöchel, E. Quandt, Low damping resonant magnetoelectric sensors, Appl. Phys. Letters, 97, 3497277 (2010). [2] H. Greve, E. Woltermann, H. J. Quenzer, B. Wagner, E. Quandt, Giant Magnetoelectric Coefficients in $Fe_{90}Co_{10}$(78)$Si_{12}B_{10}$-AlN Thin Film Composites, Appl. Phys. Lett., 96, 182501 (2010).

Non-contact Magnetic Sensors

In the form of interdisciplinary research (Physics, Material Science), the priority program „HAUT“ (SPP 1299) funded by the Deutsche Forschungsgemeinschaft(DFG) is concentrated on the development and investigation of adapting surfaces for high temperature applications. The main contribution of the Inorganic Functional Material research group is to develop contact-free sensors to monitor thickness, temperature or induced strain of thin hard or protective coatings by measuring their magnetic properties. For this purpose a sensing method based on frequency mixing has been developed. The technique has been adapted to be employed in two projects within the „HAUT“ research program:

I. Nano-structured magnetic thin layer-composites for application in high temperature sensor systems

In this project in collaboration with the KIT (Dr. Stüber) and the Ruhr University Bochum (Prof. Ludwig) new nano-structured magnetic thin film composites for application in high temperature sensors are developed. For the first time a combination

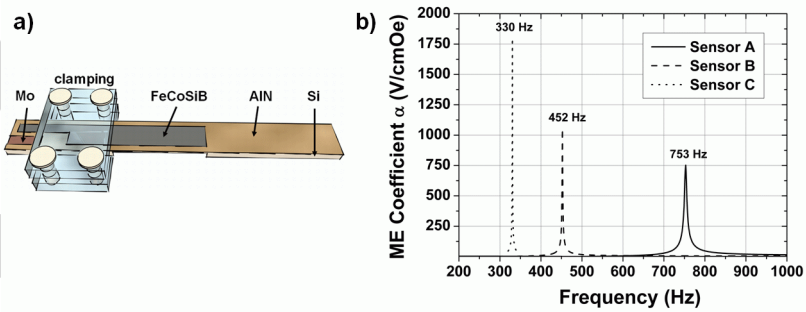

Fig. 1: a) A schematic view of the cantilever sensor layout. b) ME coefficient α of three sensors with different geometries: dependence on the frequency of the measured magnetic field.

of different thin film materials, nano-scaled wear resistant hard coatings and ferromagnetic functional films, will be integrated in new structures and used as sensor components. The functionality is realized by a high temperature activation process in which the films form special multiphase microstructures. For those multifunctional systems the sensor, which is based on the inverse magnetostrictive effect is applied for the measurement of temperature and stress [1].

II. Depletion sensor for in-situ detection of the degradation state of protective high temperature coatings.

In this project in collaboration with Dechema (Prof. Schütze) and FZ Jülich (Dr. Quadakkers) magnetic reservoir phases are integrated into high temperature protective coatings in order to measure their degradation upon use. Suitable magnetic Al- and/or Cr-rich reservoir phases for the formation of a protective oxide layer are identified and characterized, then protective diffusion coatings containing these phases are developed. As a second concept magnetic garnets (Fe_3O_4, $Fe_{19}Ni_{81}$) are integrated in common protective coatings consisting of paramagnetic MCrAlY. Both coating systems containing these phases are developed by the project partners. Here, the sensor system is employed to measure the magnitude of magnetic moments and implicitly the thickness of these coatings [2]. As a challenge in the second stage of the project, a further development of the measurement technique is provided in order to separate between quantity (thickness) and the spatial distribution of the magnetic phase in metallic protective coatings.

[1] C. Bechtold, I. Teliban, C. Thede, S. Chemnitz, E. Quandt, Non-contact strain measurements based on inverse magnetostriction, Sensors and Actuators A: Physical, Volume 158, Issue 2, 2010 [2] I. Teliban, S. Chemnitz, C. Thede, C. Bechtold, W.J. Quadakkers, M. Schütze, E. Quandt, Magnetic Moment Investigation by Frequency Mixing Technique, Rev. Sci. Instr., 80, 115106, 2009

Magnetic Shape Memory Thin Films and Sensors

Magnetic shape memory (MSM) materials are a promising material class for both actuator and sensor applications due to their unique physical properties, namely the large length changes that these materials can undergo and their high magnetocrystalline anisotropy energy. In combination, these two properties on one hand lead to high magnetic field induced strains and on the other to strong changes in magnetic properties when the material is mechanically strained The high strains that this material can endure are caused by a structural redistribution of differently oriented martensitic twin variants by twin boundary motion. The redistribution of variants leads at the same time to the inverse magnetostrictive effect (the change in magnetic properties while the material is subjected to external stress) since the magnetocrystalline anisotropy energy of the MSM material is high. This effect can be used for the development of novel sensors that can detect strains in the range of several per cent.

As part of the DFG priority programme SPP 1239 „Modification of microstructure and shape of solid materials by external magnetic fields“ the ongoing research aims at the development of adequate MSM thin films for strain sensing applications. Ferromagnetic shape memory thin films are therefore deposited by magnetron sputtering in the Kieler Nanolab on single crystalline M_gO substrates in order to obtain an epitaxial film growth. Cr, Au or Mn_3Ir buffer layers can be used as

intermediate layers to influence the amount of epitaxial strain stored in the FePd layer. The soft mechanical properties of the MSM material $Fe_{70}Pd_{30}$ allows growth of epitaxial films with very large thicknesses that in the case of some buffer materials can be released from the substrate by wet chemical etching processes[1]. Subsequent annealing of these freestanding films leads to films with the desired fcc structure, which is important for MSM activity, and to films with a highly textured microstructure. This is therefore a promising fabrication route towards the development of freestanding $Fe_{70}Pd_{30}$ films showing a stress-induced, martensitic reorientation that can be exploited for the novel sensor applications mentioned above.

[1]Bechtold, C., Buschbeck, J. Lotnyk, A., Erkartal, B., Hamann, S., Zamponi, C., Schultz, L., Ludwig, A., Kienle, L., Fähler, S. and Quandt E.: Artificial Single Variant Martensite in Freestanding Fe70Pd30 Films Obtained by Coherent Epitaxial Growth, Advanced Materials 22, 2010, 2668-2671

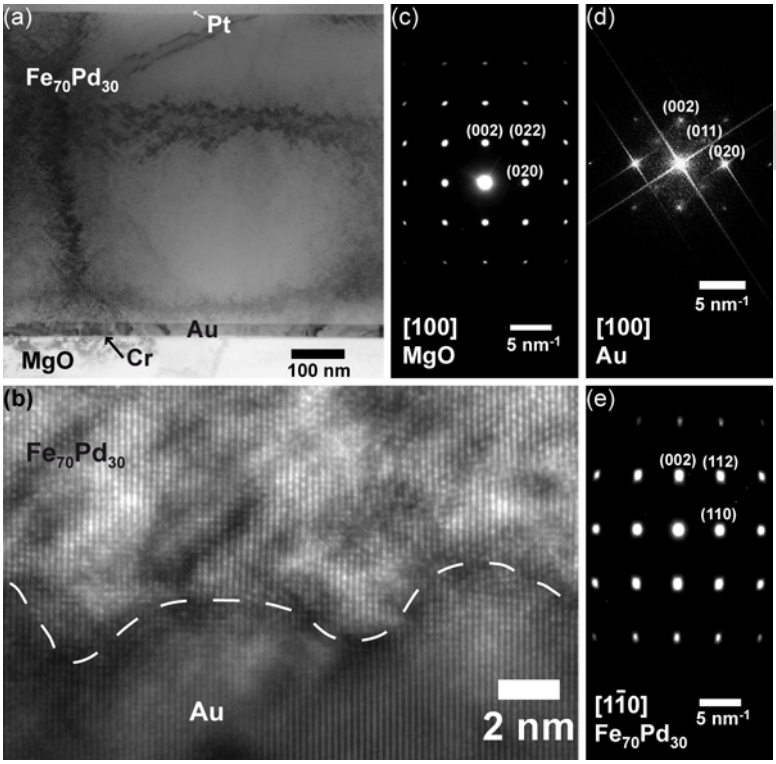

Fig. 2: (a) Overview over the stacking sequence in bright-field mode (b) HRTEM-image of the Au/$Fe_{70}Pd_{30}$-interface: Lattice planes of the Au intermediate layer continue in the $Fe_{70}Pd_{30}$ layer. (c) Electron diffraction pattern of the MgO substrate (d) FFT of the HRTEM image of the Au layer (e) The electron diffraction image in 600 nm distance to the interface shows a single crystalline $Fe_{70}Pd_{30}$ microstructure with a defined orientation relationship towards the Au layer.

Biodegradable Magnesium-Stents

Stents are devices used to scaffold or brace the inside of tubular passages or lumens, e.g. oesophagus, biliary duct and, most importantly, a series of blood vessels, e.g. coronary, carotid, iliac, aorta, femoral arteries, etc. The major part of the stents implanted nowadays consists still of non-degradable materials such as stainless steel or the shape memory alloy NiTi. Stents made of these materials often lead to a restenosis and because of this are a permanent source of irritation. In addition for most therapies the stent is no longer necessary after a few months so that the development of biodegradable stents is of special interest. Magnesium-stents dissolve after a certain time, which can be influenced by the choice of the used alloy. So with this material the medical therapy of children with stents also becomes possible. Up to now this was impossible due to the continuing growth of the children and the dangers involved in restenosis. The project focuses on the investigation of the biodegradation of sputtered magnesium alloys as a function of their microstructure and chemical

composition. In addition the investigations of bi- and multilayer systems as well as films, exhibiting a vertical or lateral gradient in chemical composition are carried out to precisely control the temporal and spatial degradation of the implant.

Compared to cast bulk samples of the same chemical composition thin film samples exhibit superior corrosion properties. The deposited thin films show a reduced tendency to localized corrosion.[1] In addition an influence on the mechanical behaviour of the deposited thin films by a variation of the sputter parameters is possible without a negative influence on the degradation behaviour.

[1] Schlüter, K., Zamponi, C., Piorra, A. and Quandt, E. : Comparison of the corrosion behaviour of bulk and thin film magnesium alloys, Corrosion Science 52, 2010, 3973-3977.

Personnel

Head of the group: Prof. Dr.-Ing. E. Quandt; Secretary: G. Schroeder
Technical Staff: Dipl.-Ing. (FH) T. Metzing, J. Ziese

Staff:

B. Gudschun SFB 855, Z2 und IGK	01.02.-31.12.2010		DFG
E. Riemer SFB 855 Programmpauschale	01.07.-31.12.2010	(50%)	SFB 855

Scientific Staff:

Dr. C. Bechtold SPP 1239	01.01.-31.12.2010		DFG
Dr. A. Büttner SFB 855, Z2 und IGK	01.01.-31.12.2010		DFG
Dr. Ing. S. Chemnitz SPP 1299	01.01.-31.12.2010		DFG
Dr. C. Dietz Nanosecure	01.01.-31.12.2010		EU
Dr. H. Greve SFB 855 , Teilprojekt C2	01.01.-31.12.2010		DFG
Dipl.-Ing. E. Lage SFB 855, Teilprojekt Z1	01.01.-31.12.2010		DFG
Dr. R. Lima de Miranda	01.01.-31.12.2010		CAU
Dr. A. Malavé	01.02.-31.12.2010		CAU
Dr. D. Meyners	01.01.-31.12.2009		CAU
Dipl.-Ing. A. Piorra SFB 855, Teilprojekt A1	01.01.-31.12.2010		DFG
Dipl.-Ing. K. Schlüter PRO INNO II, SFB 677, SPP1239	01.01.-31.12.2010		BMWi/DFG

Dr. I. Teliban SPP 1299	01.01.-31.12.2010	DFG
M.Sci. F. Thajudin FeGa-based Nanoelectronic Strain Sensor	01.01.-31.12.2010	ONR/NICOP
Dipl.-Phys. C. Thede SPP 1299	01.01.-31.12.2010	DFG
Dr. T. von Hofe Magnetic Nanocomposites	01.01.-31.12.2010	DFG
Dipl.-Ing. E. Woltermann SFB 855, Teilprojekt A1	01.10.-31.12.2010	DFG
Dr. C. Zamponi Mg Stents	01.01.-31.12.2010	DFG
MSc. A. Zayed TiNi Stents	01.07.-31.12.2010	BMWi

Lectures, Seminars, and Laboratory Course Offers

Winter 2009/2010

Ceramics and Glasses, 2 (+1) hrs Lecture (+ Exercises)/Week,
E. Quandt (+ A. Malavé)

Werkstoffe (Keramik), 2 hrs Lecture/Week,
H. Greve

Smart Materials, 2 (+1) hrs Lecture (+ Exercises)/Week,
E. Quandt

Anorganische Funktionsmaterialien, 2 hrs Seminar/Week,
E. Quandt

Micro/Nanosystems Technology and Processes, 2 (+1) hrs Lecture (+ Exercises)/Week,
D. Meyners

Laboratory Course: Basic Lab - Praktikum, 4 hrs Lab/Week,
D. Meyners (+ K. Schlüter, H. Greve, A. Piorra)

Laboratory Course: Analytikpraktikum - Praktikum, 4 hrs Lab/Week,
D. Meyners (+ C. Zamponi)

Laboratory Course: Scientific Methods- Praktikum, 4 hrs Lab/Week,
D. Meyners (+ Th. von Hofe, R. Lima de Miranda, S. Jhamb)

Summer 2010

Sensors, 2 (+1) hrs Lecture (+ Exercises)/Week,
E. Quandt

Anorganische Funktionsmaterialien, 2 hrs Seminar/Week,
E. Quandt

Laboratory Course: Functional Materials - Praktikum, 4 hrs Lab/Week,
D. Meyners (+ A. Piorra, E. Woltermann, F. Thajudin)

Winter 2010/2011

Ceramics and Glasses, 2 (+1) hrs Lecture (+ Exercises)/Week,
E. Quandt (+ A. Malavé)

Werkstoffe (Keramik), 2 hrs Lecture/Week,
H. Greve

Smart Materials, 2 (+1) hrs Lecture (+ Exercises)/Week,
E. Quandt

Anorganische Funktionsmaterialien, 2 hrs Seminar/Week,
E. Quandt

Micro/Nanosystems Technology and Processes, 2 (+1) hrs Lecture (+ Exercises)/Week,
D. Meyners

Laboratory Course: Basic Lab - Praktikum, 4 hrs Lab/Week,
D. Meyners (+ K. Schlüter, E. Lage, A. Piorra, Ch. Dietz)

Laboratory Course: Analytik- Praktikum, 4 hrs Lab/Week,
D. Meyners (+ C. Zamponi)

Laboratory Course: Scientific Methods - Praktikum, 4 hrs Lab/Week,
D. Meyners (+ Th. von Hofe, F. Thajudin)

Third-Party Funds

DFG, *SPP 1299 HAUT, Nanostrukturierte magnetische Dünnschicht-Komposite für Anwendungen in der Hochtemperatur-Sensorik*, 01.09.2010-31.08.2013 (184.143,20 EUR)

DFG, *SPP 1299 HAUT, Sensorfunktion für Hochtemperatur-Schutzschichten zur in situ Erfassung des Degradationszustands*, 01.07.2010-30.09.2012 (184.143,20 EUR)

DFG, *Magnetic Nanocomposites for rf Applications in Mobile Communication*, 01.07.2009-31.12.2010 (100.000 EUR)

DFG, *SPP 1239, Änderung von Mikrostruktur und Form fester Werkstoffe durch äußere Magnetfelder, Teilprojekt: Exploitation and Transfer of Results of the SPP 1239*, 01.07.2008-30.06.2010 (65,000 EUR)

DFG, *PAK 1: Fe-Pd-X Thin Film-Polymer Composites for Sensor Applications*, 01.01.2009-31.12.2010 (144.020,00 EUR)

DFG, *Herstellung v. bioresorbierbar. Dünnschicht Gefäßstützen (Stents) aus Magnesiumlegierungen durch Magnetron-Sputter-Technologie*, 01.09.2009-01.08.2012 (236.783,00 EUR)

DFG, *SFB 677, Funktion durch Schalten, Teilprojekt C07: Komposite aus Polymermatrix und ferromagnetischen Formgedächtnis-Nanopartikeln als magnetische Schalter*, 01.07.2007-30.06.2011 (192.400 EUR)

DFG, *SPP 1239, Änderung von Mikrostruktur und Form fester Werkstoffe durch äußere Magnetfelder, Teilprojekt: Exploitation and Transfer of Results of the SPP 1239*, 15.07.2010-30.06.2012 (100.900,00 EUR)

DFG, *Magnetoresistive Tunnelstrukturen mit magnetostriktiven Elektroden als Sensor für die Rastermikroskopie*, 01.02.2011-31.12.2012 (174.969,00)

EU, *Nanosecure: Advanced nanotechnological detection and detoxification of harmful airborne substances for improved public security*, 01.01.2008-28.02.2011 (220.821,21 EUR)

BMWi, *PRO INNO II, Kooperationsprojekt: Entwicklung eines neuartigen Stentsystems zur endoluminalen Therapie instabiler Plaques (Softplaques), Teilprojekt: Umhüllung eines Stents mittels Magnetronsputterns*, 01.06.2008-31.03.2010 (125.000 EUR)

BMWi, *ZIM, Entwicklung eines Implantats mit selektriver Abdeckung*, 01.07.2010-01.06.2012 (175.000,00)
Office of Naval Research (ONR,USA), NICOP, *FeGa-based Nanoelectronic Strain Sensor*, 01.07.2008-30.06.2011 (165.232 EUR)
Industrie, *Industrieprojekt Formgedächtnistechnik*, 01.09.2008-31.08.2011 (255.000 EUR)
SFB 855, *Magnetoelektrische Verbundstoffe - biomagnetische Schnittstellen d. Zukunft , Teilprojekt A 1*, 01.01.2010-31.12.2013 (603.200,00)
SFB 855, *Magnetoelektrische Verbundstoffe - biomagnetische Schnittstellen d. Zukunft, Teilprojekt C2*, 01.01.2010-31.12.2013 (289.200,00)
SFB 855, *Magnetoelektrische Verbundstoffe - biomagnetische Schnittstellen d. Zukunft, Teilprojekt Z1*, 01.01.2010-31.12.2013 (557.600,00)
SFB 855, *Magnetoelektrische Verbundstoffe - biomagnetische Schnittstellen d. Zukunft, Teilprojekt Z2*, 01.01.2010-31.12.2013 (1.185.000,00)

Further Cooperation, Consulting, and Technology Transfer

Prof. Dr. F. Faupel, CAU

Prof. Dr. H. Gatzen, Universität Hannover

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. A. Ludwig, RUB

Prof. P. Muralt, EPFL, CH

Prof. Dr. M. Schütze, Dechema

Dr. M. Stüber, KIT

Dr. W. J. Quadakkers, FZ Jülich

Prof. D. Viehland, Virginia Tech, USA

Prof. Dr. M. Wuttig, University of Maryland, USA

Diploma, Bachelor and Master Theses

J. Reverey, *Mechanische und elektrochemische Charakterisierung der Magnesiumlegierungen WE(Gd)43 und WE(Nd)43*, 06.08.2010

Dissertations / Postdoctoral Lecture Qualifications

C. Bechtold, *Entwicklung von $Fe_{70}Pd_{30}$-Dünnschichtsensoren zur Bestimmung von Dehnung mittels des inversen magnetischen Formgedächtniseffektes*, 17.12.2010

Publications

Published in 2010

K. Schlüter, C. Zamponi, A. Piorra, E. Quandt, *Comparison of the corrosion behaviour of bulk and thin film magnesium alloys,* Corrosion Science, **52**, 3973 - 3977 (2010)

H. Greve, E. Woltermann, R. Jahns, S. Marauska, B. Wagner, R. Knöchel, E. Quandt, *Low damping resonant magnetoelectric sensors,* Appl. Phys. Letters, **97**, 3497277 (2010)

S. Hamann, M. E. Gruner, S. Irsen, J. Buschbeck, C. Bechtold, I. Kock, S. G. Mayr, A. Savan, S. Thienhaus, E. Quandt, S. Fähler, P. Entel, A. Ludwig, *The ferromagnetic shape memory system Fe-Pd-Cu,* Acta Materialia, **58**, 5949 - 5961 (2010)

C. Bechtold, J. Buschbeck, A. Lotnyk, B. Erkartal, S. Hamann, C. Zamponi, L. Schultz, A. Ludwig, L. Kienle, S. Fähler, E. Quandt, *Artificial Single Variant Martensite in Freestanding Fe70Pd30 Films Obtained by Coherent Epitaxial Growth,* Advanced Materials, **22**, 2668 - 2671 (2010)

H. Greve, E. Woltermann, H. J. Quenzer, B. Wagner, E. Quandt, *Giant Magnetoelectric Coefficients in* $(Fe_{90}Co_{10})_{78}Si_{12}B_{10}$*-AlN Thin Film Composites,* Appl. Phys. Lett., **96**, 182501 (2010)

C. Bechtold, J. Teliban, C. Thede, S. Chemnitz, E. Quandt, *Non-contact Strain Measurements based on Inverse Magnetostriction,* Sensors and Actuators A-Physical, **158**, 224 - 230 (2010)

C. Bechtold, J. Buschbeck, A. Lotnyk, B. Erkartal, S. Hamann, C. Zamponi, A. Ludwig, L. Kienle, S. Fähler, E. Quandt, *Development Towards MSM Active FePd Thick Films,* Actuator 10 Conference Proceedings, 299 - 302 (2010)

H. Schmidt, E. Quandt, *Magnetically Induced Shape-Change in Solids and its Use in Actuators,* Actuator 10 Conference Proceedings, 289 - 294 (2010)

T. Schied, A. Lotnyk, C. Zamponi, L. Kienle, J. Buschbeck, M. Weisheit, B. Holzapfel, L. Schultz, S. Fähler, *Fe-Pd thin films as a model system for self-organized exchange coupled nanomagnets,* Journal of Applied Physics, **033902**, (2010)

H. Greve, E. Quandt, R. Jahns, D. Meyners, E. Woltermann, E. Lage, R. Knöchel, *Measurement of biomagnetic fields with magnetoelectric thin film sensors,* Biomed Tech 2010, **55**, (2010)

Presentations

E. Quandt, *Magnetostriktive TMR Drucksensoren,* Kolloquium KIT, Karlsruhe, 28.-28.01.2010

S. Chemnitz, A. Jhamb, A. Malavé, E. Quandt, H. Sigrist, H. Gao, K. Kugelbrey, T. Stadthagen, *Surface Acoustic Wave Sensors for Cocaine Detection (Poster),* 21st Seminar News in Solid State Physics, Klosters, Schweiz, 06.-11.02.2010

C. Bechtold, E. Quandt, J. Buschbeck, S. Weiß, S. Fähler, S. Hamann, A. Ludwig, M. Gruner, *FE-Pd-X Thin Film-Polymer Composites for Sensor Applications,* SPP 1239 Renewal Proposal, Dresden, 04.-04.03.2010

H. Greve, E. Woltermann, H.-J. Quenzer, B. Wagner, E. Quandt, *Riesen-Magnetoelektrischer Effekt in dünnen FeCoBSi-AlN Kompositfilmen,* DBG Frühjahrstagung, Regensburg, 21.-26.03.2010

J. Teliban, S. Chemnitz, C. Thede, C. Bechtold, E. Quandt, *Investigation of depletion state of high temperature protective coatings (Poster),* DPG Frühjahrstagung, Regensburg, 21.-26.03.2010

E. Quandt, *Smart Materials in der Sensorik,* Kolloquium FH Regensburg, Regensburg, 04.-04.05.2010

E. Quandt, *Magnetoelektrische Dünnschichtkomposite als hochempfindliche Magnetfeldsensoren,* Siemens AG CT, Erlangen, 05.-05.05.2010

E. Quandt, H. Greve, E. Woltermann, H.-J. Quenzer, B. Wagner, *Giant Magnetoelectric Coefficients in Metglas-AlN Thin Film Composites,* Workshop on Acoustic Transduction Materials and Devices, US Navy, State College, USA, 12.-12.05.2010

S. Teliban, S. Chemnitz, C. Thede, C. Bechtold, E. Quandt, *Measurement of Magnetic Moment in Protective Coatings using Frequency Mixing Techniques (Poster),* Sensoren und Messsysteme 2010, Nürnberg, 18.-19.05.2010

H. Greve, E. Woltermann, E. Quandt, *Magnetoelectric FeCoSiB-AlN thin film composites for magnetic Field sensor applications,* ITG/GMA Fachtagung, Nürnberg, 18.-19.05.2010

H. Schmidt, E. Quandt, *Magnetically Induced Shape-Change in Solids and its Use in Actuators,* Actuator 2010, Bremen, 14.-16.06.2010

C. Bechtold, J. Buschbeck, A. Lotnyk, B. Erkartal, S. Hamann, C. Zamponi, A. Ludwig, L. Kienle, S. Fähler, E. Quandt, *Development Towards MSM Active FePd Thick Films,* Actuator 2010, Kiel, 14.-16.06.2010

J. Teliban, E. Quandt, M. Schütze, K. Aleksandrov, *High temperature protective coatings with sensor function,* 1st International Conference on Materials for Energy, Karlsruhe, 04.-08.07.2010

C. Bechtold, J. Buschbeck, A. Lotnyk, B. Erkartal, S. Hamann, C. Zamponi, A. Ludwig, L. Kienle, S. Fähler, E. Quandt, *Development of freestanding, martensitic, single variant* $Fe_{70}Pd_{30}$ *Thin Films for Strain Sensor Applications (Poster),* MSE Conference, Darmstadt, 24.-24.08.2010

C. Zamponi, J. Reverey, K. Schlüter, E. Quandt, *Sputtered Thin Films of Biodegradable Mg Alloys (Poster),* MSE, Darmstadt, 24.-26.08.2010

H. Greve, E. Woltermann, H.-J. Quenzer, B. Wagner, E. Quandt, *Magnetoelectric FeCoSiB-AlN thin film composites for magnetic field sensor applications,* Materials Science and Engineering 2010, Darmstadt, 24.-26.08.2010

C. Bechtold, E. Quandt, *Development of FSMA Thin Film / Polymer Composite Sensors unsing Micro/Nano-Techniques,* SPP 1239 Convention, Tutzing, 28.09.2010

E. Quandt, H. Greve, R. Jahns, D. Meyners, E. Woltermann, E. Lage, R. Knöchel, *Measurement of biomagnetic fields with magnetoeletric thin film sensors,* BMT 2010, Warnemünde, 06.-06.10.2010

C. Dietz, A. Malavé, S. Jhamb, S. Chemnitz, H. Gao, T. Etterer, H. Sigrist, K. Kugelbrey, *Polyhaptens Coated Surface Acoustic Wave Sensors for Cocaine Detection,* Nanosmat 5, Reims, Frankreich, 18.-21.10.2010

D. Meyners, E. Lage, R. Jahns, E. Woltermann, H. Greve, R. Knöchel, E. Quandt, *Highly Sensitive Magnetoelectri Sensors based on Resonant Cantilevers,* 55th Annual Conference on Magnetism and Magnetic Materials, Atlanta, USA, 14.-18.11.2010

E. Quandt, *Smart Materials in Mikro- und Nanotechnik,* Universitätsgesellschaft Schleswig-Holstein, Melsdorf/Kiel, 19.-19.11.2010

E. Quandt, H. Greve, E. Woltermann, R. Jahns, St. Marauska, B. Wagner, R. Knoechel, M. Wuttig, *Giant Magnetoelectric Cantilever Sensors Based on FeCoSiB/AlN Thin Film Composites,* MRS Fall 2010, Boston, USA, 29.11.-01.12.2010

E. Quandt, *Giant Magnetoelectric Coefficients in (Fe90Co10)78Si12B10-AlN Thin Film Composites,* Fakultätskolloquium, Maryland, USA, 03.-03.12.2010

Further Activities and Events

E. Quandt: Speaker of the DFG Collaborative Research Centre (SFB 855) „Magnetoelectric Composites - Biomagnetic Interfaces of the Future“ .

E. Quandt: Member of the Materials Science and Engineering Expert Committee (MatSEEC) of the European Science Foundation (ESF).

E. Quandt: Speaker of the Research Focus „Nano and Surface Science“ of the Christian-Albrechts-University of Kiel.

E. Quandt: Member of the Executive Board and spokesperson of the Advisory Board of the Deutsche Gesellschaft für Materialkunde (DGM).

E. Quandt: Member of the Scientific Advisory Board of the Acandis GmbH and Co. KG, Pfinztal.

E. Quandt: Coordinator of the Draft Proposal for a Cluster of Excellence „Materials for Life“ .

Biocompatible Nanomaterials

The group "Biocompatible Nanomaterials" was newly established in 2010. We are using an interdisciplinary approach that is based on bringing together Materials Science, Physics, Biology and Chemistry in order to systematically investigate the interaction between biological systems and surfaces. Important methods are force spectroscopy (Fig. 1) in combination with high-resolution imaging techniques that allow the investigation of cellular properties at the molecular and nanoscopic level. The long-term goal of our work is to control living cells with artificial nanostructures and to understand the biophysical mechanisms causing this behaviour. For example, it is known that not only biochemical cues control cells, but also surface structures. In particular, structures at the nanometer scale influence parameters such as cell adhesion, proliferation and differentiation. The perspective of our research is to tailor cellular properties by biocompatible nanomaterials in order to design novel materials for medical and biotechnological purposes.

Results

Adhesion-dependent reactions in cells

Entamoebae are parasitic amoebae that can cause severe diseases, such as human amoebiasis. They destroy target cells by an extracellular killing mechanism that is induced by the formation of adhesion between amoeba and target cell and the subsequent transport of membrane-active proteins to the adhesion site between amoeba and target cell. This mechanism is similar to the one used by immune cells to kill cancer cells for example. For a deeper understanding of this mechanism, we investigate the contact between amoebae and bio-functionalized carbohydrate particles and living target cells using AFM-based single-cell force microscopy and optical tweezers (Fig. 2). Both techniques allow the recording of cellular forces with piconewton and nanometer precision. This project is funded by an Emmy Noether grant from the DFG.

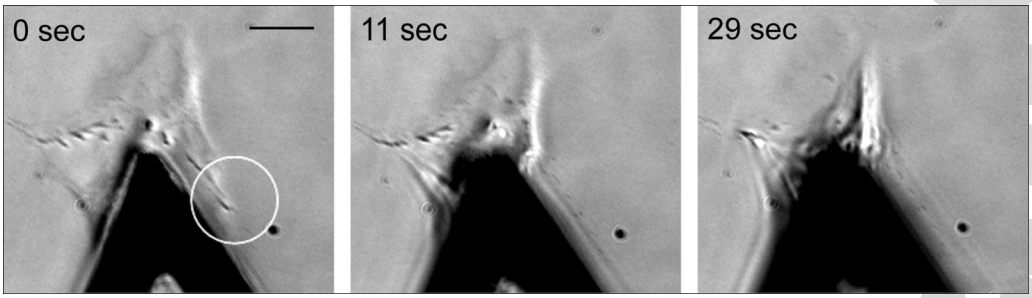

Fig. 1: Detachment of a cell (REF 52 wt fibroblast) from a glass surface after 24 hours of adhesion. The AFM cantilever is continuously retracted while the cell is released from the cell in a step-wise manner. It is clearly observed that the strongest points of cell attachment are located at the cell edge and that the cell body is stretched during pulling. Scale bar = 20μm.

Switchable cell adhesion

For a large number of cell types it is essential to culture them on bio-adhesive substrates. Detaching cells from such substrates is a problem for many cell types, because the typically used mechanical and enzymatic detachment methods kill a high percentage of these cells. The goal of our project is to develop novel biocompatible surface coatings based on functionalized azobenzene molecules, which allow cell adhesion to be switched with light and thus allow a gentle detachment of the cells from substrates.

Diffusion in living cells

The intracellular motion of particles plays an essential role in controlling drug delivery processes for example. We track intracellular particles with high temporal and spatial resolution in order to investigate their diffusion properties. Typically,

the majority of such particles undergoes subdiffusive motion. Interestingly, a comparison of our data with complementary analytical results has shown evidence for anomalous diffusion and ageing. This result implies that basic concepts of statistical physics must be reconsidered for understanding and controlling transport processes in cells.

This project is supported by the "Nationale Akademie der Wissenschaften Leopoldina".

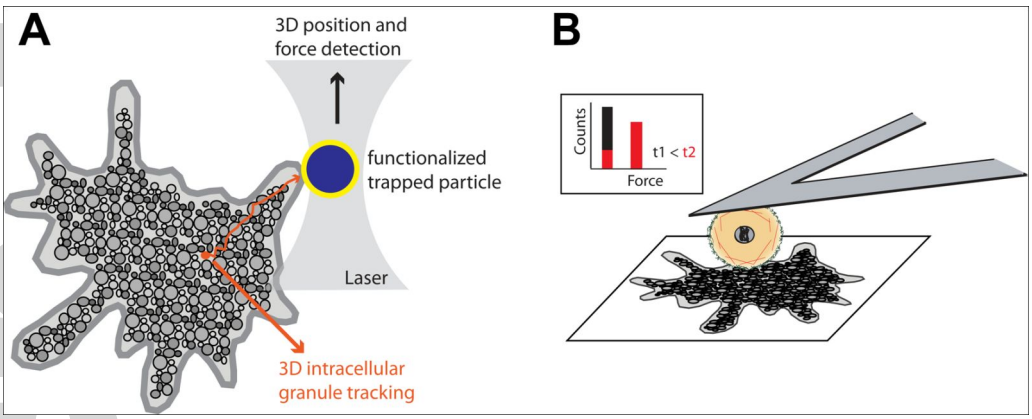

Fig. 2: (A) Experiment studying correlations between the forces acting at functionalized target nanoparticles and intracellular transport processes in amoebae. (B) Sketch of an AFM experiment where a target cell is brought into contact with an amoeba using a cantilever. The inset shows the expected mean forces in rupture events if a cooperative reinforcement of adhesion occurs with increasing contact time.

Personnel

Head of the group: Prof. Dr. C. Selhuber-Unkel; Secretary: N. Gühlke (50%), Dipl.-Chem. S. Kastaun (50%), Dipl.-Geol. B. Minten (50%)
Technical Staff: Dipl.-Ing. R. Kloth, C. Ochmann, Dipl.-Ing. S. Rehders

Scientific Staff:

Dr. J. Kopparty	01.09.-31.12.2010	Stipend
Biocompatability of ZnO and SnO		
M.Sc. J. Reverey	15.09.-31.12.2010	DFG
Granule motion in pathogenic amoebae studied with particle-tracking methods		

Lectures, Seminars, and Laboratory Course Offers

Winter 2010/2011

Cell Mechanics, 2 (+2) hrs Lecture (+ Exercises)/Week,
C. Selhuber-Unkel (+ C. Selhuber-Unkel)

Biokompatible Nanomaterialien, 2 hrs Seminar/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, *Funktion durch Schalten: SFB 677/1-2007 Pauschale Mittel für Selhuber-Unkel,* 01.06.2010-30.06.2011 (17.000 Euro)

Deutsche Akademie der Naturforscher Leopoldina, *Unterstützung für die Teilnahme am 54. Meeting of the Biophysical Society,* 20.-24.02.2010 (1.500 Euro)

Further Cooperation, Consulting, and Technology Transfer

Prof. R. Adelung, Universität Kiel, Lehrstuhl für Funktionale Nanomaterialien, project on the biocompatibility of ZnO

Prof. E. Quandt, Universität Kiel, Lehrstuhl für Anorganische Funktionsmaterialien, PDMS pillar structures from photolithography

Prof. R. Herges, Prof. Th. Lindhorst, Universität Kiel, Otto-Diels-Institut, Switchable cell adhesion (SFB ''Function by switching'')

Prof. S. Gorb, Universität Kiel, Zoologisches Institut, common projects on investigating adhesion with AFM

Prof. M. Leippe, Universität Kiel, Zoologisches Institut, Characterizing biophysical properties of amoebae

Dr. C. Röhl, UKSH, Toxikologie, and Prof. J. Spatz, MPI for Metal Research, Stuttgart, Toxicity of silver nanoparticles

Prof. R. Metzler, TU München, Diffusion and ageing in cells

Assoc. Prof. Lene Oddershede, Niels Bohr Institute, University of Copenhagen, Endothelial cell migration

Prof. M. Gerken, Universität Kiel, Lehrstuhl für Integrierte Systeme und Photonik, Cell adhesion on photonic crystals

Publications

Published in 2010

C. Selhuber-Unkel, T. Erdmann, M. López-García, H. Kessler, U.S. Schwarz, J.P. Spatz, *Cell adhesion strength is controlled by intermolecular spacing of adhesion receptors,* Biophysical Journal, **98**, 543 - 551 (2010)

V. Tejedor, O. Bénichou, R. Voituriez, R. Jungmann, F. Simmel, C. Selhuber-Unkel, L. Oddershede, R. Metzler, *Quantitative analysis of single particle trajectories: mean maximal excursion method,* Biophysical Journal, **98**, 1364 - 1372 (2010)

Presentations

C. Selhuber-Unkel, *Cellular forces and adhesion (Invited talk),* Physical sciences Seminar, Gothenborg, Sweden, 28.-28.04.2010

C. Selhuber-Unkel, *Cell-nanomaterial interactions (Invited talk),* Indo-German Frontiers of Engineering Symposium, Potsdam, Germany, 24.-27.06.2010

C. Selhuber-Unkel, *Zelluläre Wechselwirkungen auf bio-inspirierten Nanomaterialien (Invited talk),* Fakultät für Physik, Tübingen, Germany, 05.-05.07.2010

C. Selhuber-Unkel, *Quantifying cell-nanomaterial interactions with force microscopy (Invited talk),* RWTH Aachen, Aachen, Germany, 08.-08.07.2010

C. Selhuber-Unkel, *Controlling cell functions with nanomaterials (Invited talk),* Nanoseminar at the SDU (Syddansk Universitet), Sonderborg, Denmark, 04.-04.11.2010

Further Activities and Events

25.10.2010 Inaugural lecture of C. Selhuber-Unkel, Title: ''Zelladhäsion auf Nanomaterialien''

Guests in 2010:

Ravi Kumar, IIT Madras, India, 6.10.-12.10.2010, lecture title: ''Unraveling the shell and adhesive plaque of Balanus reticulatus-a barnacle specie from Indian waters''

Constanze Lamprecht, JKU Linz, Austria, 17.10.2010 - 19.10.2010, lecture title: ''Binding of functionalized CNTs to cells and delivery into the cell: A microscopic view''

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 - to 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 millimeter 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 applicationspecific 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, analyze the quality and reliability of electronic components, and develop advanced power-supply components for electronic systems.

The institute employs a staff of around 150 people

Further information about Fraunhofer ISIT is available in the web: www.isit.fraunhofer.de.

In addition the Institute publishes an Annual Report, which can be ordered at ISIT.

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Synthesis and Real Structures

The group "Synthesis and Real Structures" and the TEM centre at the Nanolab Kiel serve as a foundation for many interdisciplinary and third party funded projects. An increasing number of scientists took the opportunity to broaden their analytical capabilities by state of the art electron microscopy, thus substantiating their activities within the funding priority "Kiel Nano Sciences" of the CAU. This year's research projects, both in-house and joint cover a broad range of materials and topics and some keywords are as follows.

- Synthesis, linear magnetoresistance, and real structure of nanodisperse semiconductors: first synthesis of heterogeneous matrix crystals with linear magnetoresistance.

- Investigation of Phase Change Materials by high resolution imaging and electron crystallography: particular focus on the observation of structural changes responsible for metal-insulator transitions via in-situ TEM.

- Structure solution and refinement of complex tellurides, including research on multilayer thermoelectrics (SPP 1386) and mineral samples (collaborative project with the University Sankt Petersburg). We were glad to welcome Dr. Sergey Britvin several times in Kiel.

- Optimization of composite materials for LASER applications: collaborative project with the University of Zhejiang. Dr. Xusheng Qiao worked as a guest scientist for six months in the group.

- Real structure of magnetic thin films and bulk materials with in-situ observations on ferromagnetic shape memory alloys (AiF, SPP 1239).

- Structure of MoS_2 based materials for hydrodesulphurization: collaborative project with the group of Prof. Bensch (Inorganic Chemistry, CAU).

- Electron microscopy on oxide-based nanostructures and composite materials:SFB 855, collaborative project with JLU Giessen and KIT, Prof. Janek.

- High resolution imaging and electron crystallography of complex intermetallics: PAK 19 and collaborative projects with MPI Stuttgart.

Results

a) Precession Electron Diffraction studies on Phase Change Materials: in Cooperation with: Prof. Bensch, CAU Kiel and MPI for Solid State Research, Stuttgart

In recent years precession electron diffraction (PED) has been established as a technique for the advanced characterization of materials at the nanoscale. The PED technique uses an incident beam which is tilted from the zone axis orientation to some so-called precession angle (up to 3°). The superior capabilities of PED are anchored in its ability to reduce multiple scattering. Based on this feature an unambiguous determination of the space group and the ab-initio structure determination of unknown and nanoscale crystals are possible. A second improvement over selected area electron diffraction (SAED) is the significant resolution enhancement achievable with PED. Recently, we demonstrated the advantages of PED in combination with High Resolution Transmission Electron Microscopy (HRTEM) on bulk samples of Phase Change Materials (PCM) with the nominal compositions $Ge_8Sb_2Te_{11}$ and $Ge_8Bi_2Te_{11}$. Thin films of these materials are most commonly used in rewritable recording media like Bluray disks. Their function critically depends on characteristic changes of the structure which are not evident for all orientations of the crystals.

In this regard, another superior feature of PED was demonstrated for the first time, which stands in particular contrast to projective methods like HRTEM and SAED: see Fig. 1 for $Ge_8Bi_2Te_{11}$. The HRTEM micrograph of Fig. 1a and the SAED pattern of Fig. 1b were recorded along the zone axis [100] (according to the rhombohedrally distorted rock salt type

fundamental structure, primitive setting). The SAED pattern shows clearly the distortions of the cubic metrics indicated by the deviations from rectangularity of the lattice, but neither the HRTEM micrograph or its Fourier transform (not shown) nor the SAED pattern (Fig. 1b) refer to any further structural complexity. However, the PED pattern of Fig. 1c contains a set of higher order Laue zone (HOLZ) contributions forming streaks with closely spaced superstructure reflections. These streaks are running along one of the [111] directions, only for PED, the streaks are cut partially by the Ewald sphere and are extended along [110]. The PED patterns depicted in the Figs. 1c and 1d were recorded on two different complex variants. The differences in complexity are well seen by the distinct distances between adjacent superstructure reflections: cf. the enlarged but equally scaled sections in Fig. 1e.

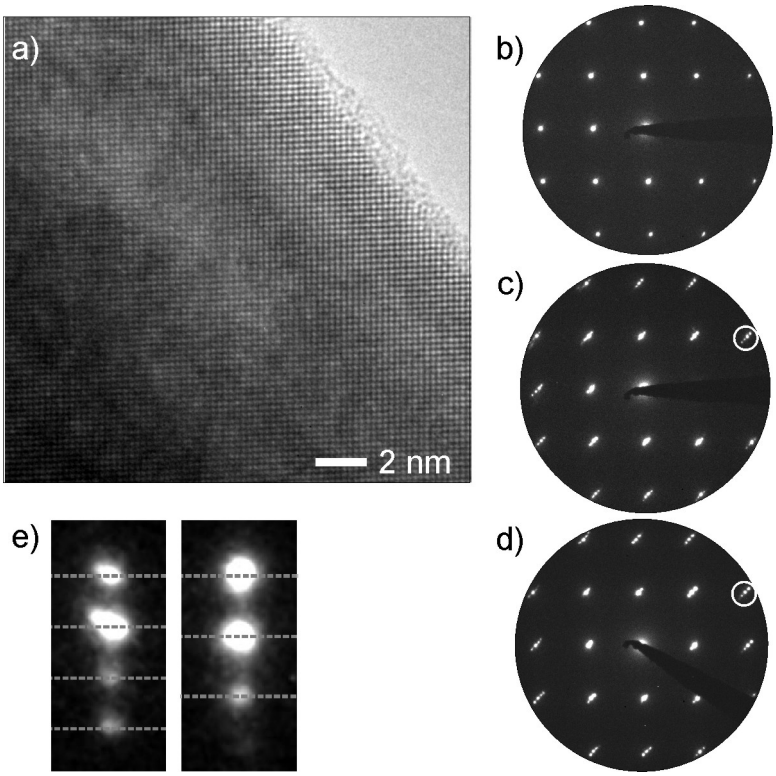

Fig. 1: Electron microscopy of the sample $Ge_8Bi_2Te_{11}$, zone axis [100]. (a) HRTEM micrograph. (b) SAED and (c) PED patterns recorded on the crystallite of a). (d) PED pattern recorded on a complex variant of $Ge_8Bi_2Te_{11}$. (e) Enlarged but equally scaled sections of the superstructure reflections of c) and d).

b) Bi_2Te_3/Sb_2Te_3 Superlattices with high Thermoelectric Figure of Merit (in Cooperation with Prof. Bensch, CAU Kiel and Fraunhofer Institute IPM, Freiburg)

Twenty years ago after a long intermission, research in the field of thermoelectrics received attention again due to concepts that the thermoelectric efficiency could be highly enhanced by nanostructural engineering. Venkatasubramanian et al. [Appl. Phys. Lett. 75, 1999, 1104] reported a ZT value of ~2.4 ~1.7 for p/n-V2VI3-superlattices. Although this report was groundbreaking for the field of thermoelectrics no verification of the data could be provided. To clarify these results and the mechanisms behind the high thermoelectric performance of these materials similar structures are developed at the Fraunhofer Institute IPM in Freiburg and are characterized with regard to the nanostructure by means of HRTEM in the Synthesis and Real Structures group. Multilayers as a pre-stage of the superlattice structures were deposited by nanoalloying using the molecular beam epitaxy (MBE) technique. These multilayers were analyzed with HRTEM and EDX elemental mapping to check the integrity of the superlattice structure. Scanning EDX measurements show clearly the alternating layers of Bi_2Te_3 and Sb_2Te_3. After heating the multilayer material to 150 °C and 250 °C respectively a grain growth is observable in TEM while in the centre of the grains residual layer structures are still visible. The formation of the

large grains might lead to higher charge carrier mobility.

c) 3D Twinning Simulations for SnO_2 and ZnO (in Cooperation with Prof. Adelung from CAU Kiel and MPI for Solid State Research, Stuttgart)

Since defects induced by twinning affect significantly the microstructure and therefore the physical properties of nanomaterials, twin boundaries of SnO_2 with rutile and ZnO with wurzite type structures were studied under the scope of our work in the collaborative research program SFB 855. It has to be noted that specific information about the location and direction of a particular twin boundary is required for in-depth simulations, which can be obtained only by a combined approach of HRTEM and PED. Based on these electron microscopic observations, three dimensional structure models of twinned regions are derived for the material as depicted in Fig. 2a for SnO_2 and in Fig. 2d for ZnO, respectively. Both simulations rely on a supercell approach, however, starting from different observation phenomena. For SnO_2, the HRTEM micrograph (Fig. 2b, zone axis [010]) shows the coherent twin boundary (CTB) edge-on and aligned parallel to the (-101) plane. In contrast to this, the computationally obtained model for ZnO is based on a superposition of twinned domains and the interrelated lamellar fringes in high resolution contrast (Fig. 2e). As illustrated in Fig. 2d, the superposition is based on two single domain structures with the twin boundary (2-1-11) nearly perpendicular to the [2-1-13] zone axis. Hence, the twin boundary is not seen in the HRTEM micrograph of Fig. 2e. With these models, details of twinning can be quantified, thus enabling convincing simulations of PED (Fig. 2c), multiple scattering intensity and HRTEM micrographs (Fig. 2f).

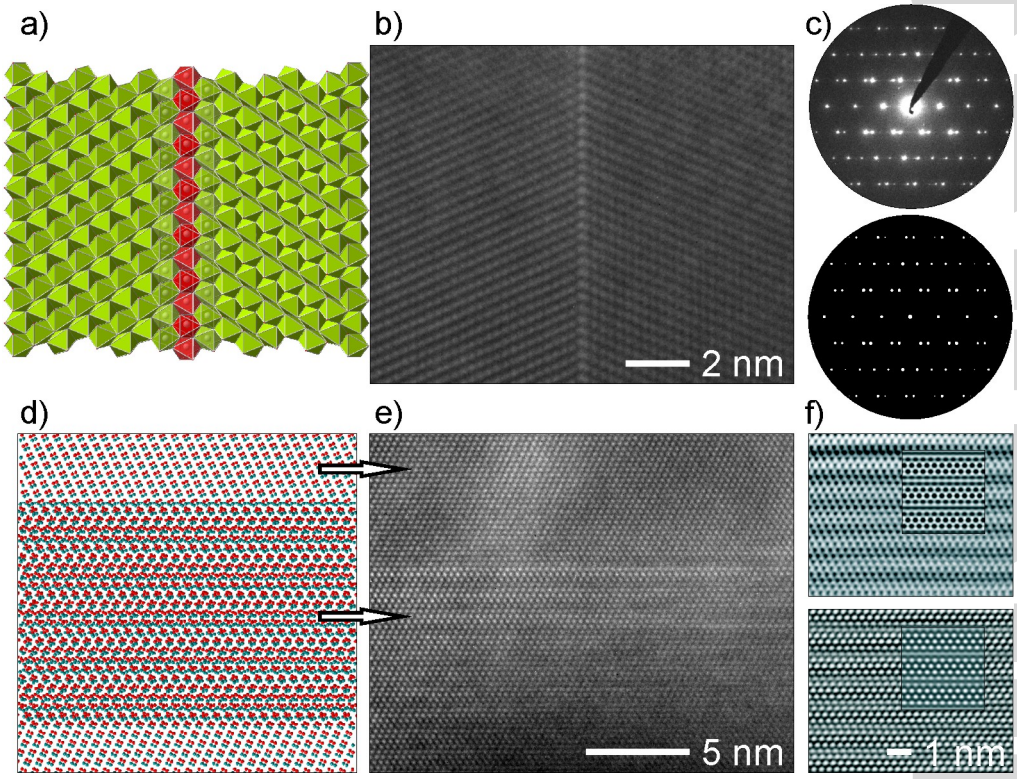

Fig. 2: CTB at (-101) along [010] for SnO_2 with rutile type structure: (a) Model with twin interface (red) vs. (b) HRTEM micrograph. (c) Experimentally obtained PED pattern (top) vs. simulation (bottom). Lamellar fringes caused by superposition of twinned domains for ZnO with wurzite type structure in the [2-1-13] zone axis. (d) Simulation of two superimposed single domains corresponds with the experimental observations (e). (f) Filtered HRTEM micrographs for different focus values (top: -50 nm, bottom -75 nm) with respective simulation insets.

d) TEM Investigations on Fe-Pd and NiMnInCo Ferromagnetic Shape Memory Alloys (in Cooperation with Dr. Fähler from IFW Dresden and Prof. Quandt from CAU Kiel)

NiMnInCo alloys were investigated by advanced transmission electron microscopy (TEM) techniques in the frame of the DFG priority programme SPP 1239. These alloys have recently attracted scientific attention due to their interesting properties such as the magnetocaloric effect. For TEM analyses the NiMnInCo sample was sputtered onto a (001) oriented MgO substrate. An additional Cr buffer layer was deposited between the substrate and the sample as an adhesion promoter. Cross-sectional TEM sample preparation was carried out by focused ion beam (FIB) milling. PED patterns and HRTEM micrographs indicate the presence of modulated martensites (6M, 7M and 8M), non-modulated tetragonal phases and the austenitic parent phase with Heusler type ordering. Furthermore EDX elemental maps recorded from cross section provide evidence for columnar regions with higher Co content and defects inside the Cr adhesion layer. Further interest was concentrated on the Fe-Pd system, which offers a broad range of applications depending on Fe concentration and morphology. For instance, thin films of $Fe_{50}Pd_{50}$ alloys are used as magnetic recording media while thicker films of $Fe_{70}Pd_{30}$ are known for their potential in sensor and actuator applications. For both of these major fields of application a transition from single phase to a nanostructured multiphase material promises a significant improvement of magnetic properties, such as combining a phase of high uniaxial magnetocrystalline anisotropy energy ($Fe_{50}Pd_{50}$) with a phase of high saturation polarization (Fe rich phase). Three Fe-Pd samples were selected for TEM investigations, which were co-sputtered on SiO_2 substrates with a linear thickness gradient from each target across the wafer. It was shown that under appropriate conditions, self-organized, magnetically homogenous Fe/FePd nanostructures can be prepared.

e) Electron microscopic analysis of the Al-rich Al-Ti alloys (within the framework of PAK 19)

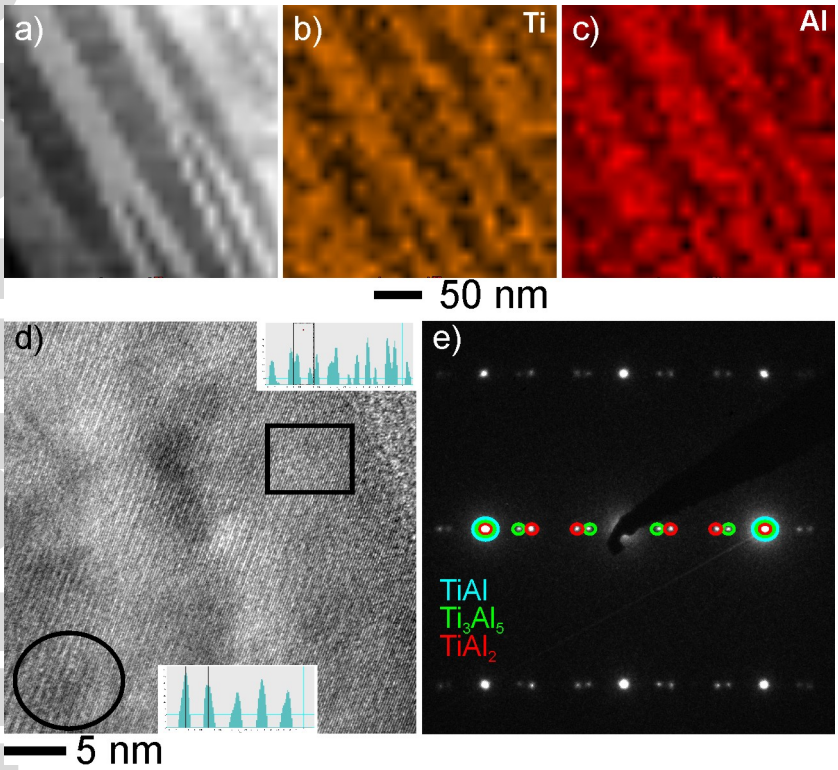

Fig. 3: (a)-(c) STEM image and the elemental maps of Ti, Al (while Nb remains uniform), highlighting the interrelation of Z-contrast and chemical composition of the lamellae. (d) HRTEM micrograph with clear visualization of domains of Ti_3Al_5 and h-$TiAl_2$ by circles and squares (with the corresponding line profiles), respectively. The parallel lines inside the squared and the circled areas correlate with the expected differences in the distances of the lattice fringes. (e) Corresponding SAED pattern with superposition of h-$TiAl_2$ (zone axis [012]) and Ti_3Al_5 (zone axis [118]) showing the characteristic splitting of the superstructure reflections.

Titanium aluminides rich in Aluminium are considered as promising structural materials for high temperature applications.

While it is possible to produce lamellar microstructures in Al-rich Ti-Al alloys comparable to those in near γ-TiAl alloys which are nowadays entering technical applications, their mechanical properties remain unsatisfactory. Refractory elements like Nb improve creep resistance as well as tensile ductility of the Ti-Al alloys. Moreover, besides the beneficial effect of lamellar microstructures in improving mechanical properties, the fracture toughness, temperature strength and oxidation resistance are furthermore enhanced by the addition of Nb.

The bulk alloy for the present study was produced by the collaboration partners through centrifugal casting in a wheel caster. Thinning to electron transparency was done by electropolishing the prepared small discs at -20 °C using a mixture of methanol, n-butanol and perchloric acid as electrolyte.

The effect of the addition of Nb to Al-rich Ti-Al alloys has been studied for $Ti_{36}Al_{62}Nb_2$ by a combined approach of TEM techniques for unravelling the structure and composition at the nanoscale. The phases γ-TiAl, h-$TiAl_2$ and Ti_3Al_5 have been observed in the as-cast alloy through structural and chemical analysis (Figs. 3a-c). An intergrowth of h-$TiAl_2$ (orthorhombic), Ti_3Al_5 (tetragonal) and γ-TiAl was identified by electron diffraction. Additionally, HRTEM micrographs (Fig. 3d) confirm the presence of h-$TiAl_2$-type and Ti_3Al_5 - type structures. The coexistence of h-$TiAl_2$- and Ti_3Al_5-type structures in the γ-TiAl matrix (as-cast state) can be observed by a characteristic superposition of the superstructure reflections in the selected area electron diffraction pattern (Fig. 3e). Further examinations were concentrated on changes of microstructure and composition at the nanoscale, where samples were heated ex-situ, while in-situ experiments are scheduled.

Personnel

Head of the group: Prof. Dr. Lorenz Kienle; Secretary: Katrin Brandenburg (50%)
Technical Staff: Christin Szillus

Scientific Staff:

M.Sc. V.S. Kiran Chakravadhanula 01.01.-31.12.2010 DFG
Elektronenmikroskopische Untersuchung der Mikrostruktur und der lokalen chemischen Zusammensetzung im Rahmen des Paketantrags PAK 19

M.Sc. R. Burak Erkartal 01.08.-31.12.2010 DFG
SPP 1239 Änderung von Mikrostruktur und Form fester Werkstoffe durch äußere Magnetfelder, TP Characterization of the micro- and naostructure of magnetic shape memory materials by Transmission Electron Microscopy

Dipl.-Phys. Viktor Hrkac 01.01.-31.12.2010 DFG
SFB 855 Magnetoelektrische Verbundwerkstoffe - biomagnetische Schnittstellen der Zukunft, TP Z1 Hochauflösende Transmissionselektronenmikroskopie und magnetoelektrische Materialcharakterisierung

Dr. Andriy Lotnyk 01.01.-31.12.2010 CAU

Dr. Xusheng Qiao 06.04.-31.10.2010 CAU, International Center
Guest Scientist

Dr. Ulrich Schürmann 01.01.-31.12.2010 DFG
Comprehensive clarification of the physical background of the breakthrough of ZT-2.4/1.7 for p/n-V2V13-Superlattices

Lectures, Seminars, and Laboratory Course Offers

Winter 2009/2010

Thermodynamics and Kinetics I, 2 (+1) hrs Lecture (+ Exercises)/Week,

L. Kienle

Practical TEM, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
A. Lotnyk (+ L. Kienle)

Solid State Chemistry, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
L. Kienle

Application of TEM for the Characterization of Inorganic Materials, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
L. Kienle

Seminar Synthese und Realstruktur, 2 hrs Seminar/Week,
L. Kienle

Biomaterials, 2 hrs Lecture/Week,
L. Kienle (+ R. Adelung)

Laboratory Course: Scientific Methods, 4 hrs Lab Course/Week,
A. Lotnyk (+ V. Zaporojtchenko, M. Qasim Shaik, S. Jebril, A. Cojocaru, D. Häußler, A. Pape)

Summer 2010

Fundamentals of Solids, 3 hrs Lecture/Week,
L. Kienle

Thermodynamics and Kinetics, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
L. Kienle

Hochauflösende Transmissionselektronenmikroskopie: Prinzipien und Anwendungen, 2 hrs Lecture/Week,
L. Kienle

Mikro- und Nanocharakterisierung von Festkörpern mittels TEM, 2 hrs Lecture/Week,
A. Lotnyk

Praktische Aspekte der Mikro- und Nanocharakterisierung von Festkörpern mittels TEM, 1 hrs Practical Work/Week,
A. Lotnyk

Seminar Synthese und Realstruktur, 2 hrs Seminar/Week,
L. Kienle

Exercises in Defects, 2 (+ 1) hrs Exercise (+ Exercises)/Week,
H. Föll (+ A. Lotnyk)

Cluster 3: Mobility, Innovation and Change, 1 hrs Seminar/Week,
L. Kienle (+ A. Lotnyk)

Winter 2010/2011

Thermodynamics and Kinetics I, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
L. Kienle

Practical TEM, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
A. Lotnyk

Solid State Chemistry, 3 (+ 1) hrs Lecture (+ Exercises)/Week,
L. Kienle

Application of TEM for the Characterization of Inorganic Materials, 2 hrs Lecture/Week,
L. Kienle

Seminar Synthese und Realstruktur, 2 hrs Seminar/Week,
L. Kienle

Biomaterials, 2 hrs Lecture/Week,
L. Kienle (+ R. Adelung)

Laboratory Course: Scientific Methods, 4 hrs Lab Course/Week,
A. Lotnyk (+ C. Zamponi, A. Cojocaru, A. Pape, D. Gedamu, T. von Hofe, V. Zaporojtchenko)

Cluster 3: Mobility, Innovation and Change, 1 hrs Seminar/Week,
L. Kienle (+ A. Lotnyk)

Third-Party Funds

DFG, *Elektronenmikroskopische Untersuchung der Mikrostruktur und der lokalen chemischen Zusammensetzung,* 01.04.2008-31.03.2011 (117800 EUR)

DFG, *Fortführung der Heisenbergprofessur zum Thema: Synthese und Analytik von Festkörpern mit ungewöhnlichen Realstrukturen,* 01.02.2009-31.01.2011 (163200 EUR)

DFG, *Programmpauschale zu: Fortführung der Heisenbergprofessur zum Thema: Synthese und Analytik von Festkörpern mit ungewöhnlichen Realstrukturen,* 01.02.2009-31.01.2011 (32600 EUR)

DFG (SPP 1386), *Comprehensive clarification of the physical background of the breakthrough of ZT-2.4/1.7 for p/n-V_2VI_3-Superlattices (im Rahmen des SPP 1386: Nanostrukturierte Thermoelektrika: Theorie, Modellsysteme und kontrollierte Synthese)*, 01.06.2009-31.05.2012 (138225 EUR)

DFG (SPP 1386), *Programmpauschale zu: Comprehensive clarification of the physical background of the breakthrough of ZT-2.4/1.7 for p/n-V_2VI_3-Superlattices (im Rahmen des SPP 1386: Nanostrukturierte Thermoelektrika: Theorie, Modellsysteme und kontrollierte Synthese)*, 01.06.2009-31.05.2012 (28900 EUR)

DFG (SPP 1239), *Characterization of the micro- and nanostructure of magnetic shape memory materials by Transmission Electron Microscopy (im Rahmen des SPP 1239: Änderung der Mikrostruktur und Form fester Werkstoffe durch äußere Magnetfelder)*, 15.07.2010-14.07.2012 (144000 EUR)

DFG (SPP 1239), *Programmpauschale zu: Characterization of the micro- and nanostructure of magnetic shape memory materials by Transmission Electron Microscopy (im Rahmen des SPP 1239: Änderung der Mikrostruktur und Form fester Werkstoffe durch äußere Magnetfelder)*, 15.07.2010-14.07.2012 (28800 EUR)

DFG, *SFB 855, TP Z1 Hochauflösende Transmissionselektronenmikroskopie und magnetoelektrische Materialcharakterisierung,* 01.01.2010-31.12.2013 (784000EUR)

CAU, International Center, *Guest Scientist Dr. Xusheng Qiao,* 06.04.-31.10.2010 (9000 EUR)

NanoSYD, *Growth and Characterization of Li Ni Nanocrystals for Energy Harvesting and Nonlinear Optical Application,* 01.04.-01.10.2010 (2200 EUR)

Further Cooperation, Consulting, and Technology Transfer

- Multicomponent Materials - Prof. Dr. F. Faupel, CAU Kiel.

- Functional Nanomaterials - Prof. Dr. R. Adelung, CAU Kiel.

- General Materials Science - Prof Dr. H. Föll, CAU Kiel.

- Inorganic Functional Materials - Prof. E. Quandt, CAU Kiel.

- Inorganic Chemistry - Prof. Dr. W. Bensch, CAU Kiel.

- Institute of Physical and Theoretical Chemistry - Prof. Dr. W. Kunz, University of Regensburg.

- Thermoelektrische Systeme - Dr. H. Böttner, Fraunhofer Institut für Physikalische Messtechnik, IPM Freiburg.

- Quantentheorie des Festkörpers - Prof. Dr. I. Mertig, Istitut für Physik, Martin-Luther-Universität Halle-Wittenberg.
- Institute of Polymers and Composites - Prof. Dr. K. Schulte, Technische Universität Hamburg-Harburg.
- Transmission Electron Microscopy - Institute of Nanotechnology - Dr. C. Kübel, Karlsruhe Institute of Technology.
- Geochemistry Division - Dr. M. Chakravadhanula, National Geophysical Research Institute, India.
- Inorganic Materials - Dr. T. Söhnel, University of Auckland, New Zealand.
- Inorganic Chemistry - Prof. Dr. Deiseroth, University of Siegen.
- Materials Science Division - Dr. D. K. Avasthi, Inter University Accelerator Centre, India.
- Laserzentrum Hannover e.V. - Dr. S. Barcikowski, Hannover.
- Department of Physics - Dr. A. K. Tyagi, Banaras Hindu University, India.
- NanoMEGAS SPRL - Dr. S. Nicolopulos, Brussels, Belgium.
- Physical Chemistry of Solids - Prof. Dr. J. Janek, Justus-Liebig-University, Giessen.
- Institut für Chemie und Biochemie - Prof. Dr. S. Schlecht, Freie Universität Berlin, Berlin.
- Electron Microscope and Elemental Analysis - Prof. Dr. Dr. h. c. M. Jansen, MPI for Solid State Research, Stuttgart.
- Simon Department - Prof. Dr. Dr. h. c. A. Simon, MPI for Solid State Research, Stuttgart.
- Crystallography - Prof. Dr. Dr. h. c. W. Depmeier, CAU Kiel.
- Crystallography - Dr. S. N. Britvin, CAU Kiel.
- Nanoelektronik - Prof. Dr. H. Kohlstedt, CAU Kiel.
- Superconducting Materials - Dr. S. Fähler, IFW Dresden.
- Magnetism and Superconductivity - PD Dr.-Ing O. Gutfleisch, IFW Dresden.
- Nanomagnetism - Dr. J. McCord, Helmholz-Zentrum Dresden-Rossenhof.
- Werkstoffe der Mikrotechnik - Prof. Dr.-Ing. A. Ludwig, Ruhr-Universität Bochum.
- Angewandte Wissenschaften, Prof. Dr. S. Jendrzejewski, FH Lübeck.

Diploma, Bachelor and Master Theses

Burak Erkartal, *Transmission Electron Microscopy Studies of $Fe_{70}Pd_{30}$ Ferromagnetic Shape Memory Alloys,* 12.05.2010

Publications

Published in 2010

B. Erkartal, C. Bechthold, A. Lotnyk, E. Quandt, L. Kienle, *Real and Magnetic Structure Investigation of FSMAs via TEM,* Z. Anorg. Allg. Chem., DOI: 10.1002/zaac.201009063, **2080**, (2010)

C. Bechthold, J. Buschbeck, A. Lotnyk, B. Erkartal, S. Hamann, C. Zamponi, A. Ludwig, L. Kienle, S. Fähler, E. Quandt, ..., Proc. Actuator 2010, Conf. on New Actuators, Bremen, Germany, (2010)

C. Bechthold, J. Buschbeck, A. Lotnyk, B. Erkartal, S. Hamann, C. Zamponi, A. Ludwig, L. Kienle, S. Fähler, E. Quandt, *Artificial Single Variant Martensite in Freestanding $Fe_{70}Pd_{30}$ Films Obtained by Coherent Epitaxial Growth,* Advanced Materials, **22**, 2668 - 2671 (2010)

S. Britvin, O.I. Siidra, A. Lotnyk, S.V. Krivovichev, W. Depmeier, *Niobate and Tantalate Pyrochlores: Soft Synthesis by the Fluoride Route,* Eur. J. Inorg. Chem., **2010**, 1082 - 1088 (2010)

S.N. Britvin, D.V. Spiridonova, O.I. Siidra, A. Lotnyk, L. Kienle, S.V. Krivovichev, W. Depmeier, *Synthesis, structure and properties of hydrazinium germanate pharmacosiderite, $(N_2H_5)_3Ge_7O_{15}(OH)2.5H_2O$,* Microporous and Mesoporous Materials, **131**, 282 - 288 (2010)

Z.D. Huang, W. Bensch, A. Lotnyk, L. Kienle, S. Fuentes, J. Bocarando, G. Alonso, C. Ornelas, *SBA-15 as support for NiMo HDS catalysts derived from sulfur-containing molybdenum and nickel complexes: Effect of activation mode,* Journal of Molecular Catalysis A: Chemical, **323**, 45 - 51 (2010)

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L. Kienle, *Real and magnetic structure investigation of ferromagnetic shape memory alloys (FSMAs) with the aid of TEM (talk)*, Evaluation SPP 1239, Dresden, Germany, 03.03.2010

V. Hrkac, *Characterization and imaging magnetic nanostructures using TEM - Principles of Lorentz Microscopy and Electron Holography (talk)*, SFB 855 Auftaktveranstaltung, Leck, Germany, 12.-13.03.2010

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B. Erkartal, A. Lotnyk, C. Bechtold, E. Quandt, L. Kienle, *Real and Magnetic Structure investigation of $Fe_{70}Pd_{30}$ FSMAs with the Aid of TEM (poster)*, MSE Congress, Darmstadt, Germany, 24.-26.08.2010

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B. Erkartal, A. Lotnyk, L. Kienle, *Characterization of the micro- and nanostructure of magnetic shape memory materials by Transmission Electron Microscopy (talk)*, SPP 1239 Convention, Tutzing, Germany, 28.10.2010

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Materials Mechanics

Prof. Dr.-Ing. Wolfgang Brocks retired in 2007 but he still publishes results of his former research activities at the „Helmholtz Zentrum Geesthacht“ . These publications are listed below to demonstrate his successful work.

Publications

Published in 2010

W. Brocks, P. Anuschewski, I. Scheider, *Ductile tearing resistance of metal sheets,* Engineering Failure Analysis, **17**, 607 - 616 (2010)

R. Falkenberg, W. Brocks, W Dietzel, I. Scheider, *Simulation of stress-corrosion cracking by the cohesive model,* Key Engineering Materials, Advances in Fracture and Damage Mechanics VIII, Malta, September 2009, **417-418**, 329 - 332 (2010)

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D. Steglich, H. Wafai, W. Brocks, *Anisotropic Deformation and Damage in Aluminium 2198 T8 Sheets,* Int. J. Damage Mechanics, **19**, 131 - 153 (2010)

W. Brocks, *Computational Fracture Mechanics,* Encyclopedia of Aerospace Engineering, Wiley, (2010)

Presentations

W. Brocks, *Parameteridentifikation in der Werkstoffmechanik*, 42. Tagung des DVM-Arbeitskreises Bruchvorgänge, Paderborn, Germany, 23.-24.02.2010

R. Falkenberg, W. Brocks, W. Dietzel, I. Scheider, *Coupling aspects in the simulation of hydrogen-induced stress-corrosion cracking,* ECF 18, Dresden, Germany, 30.08.-03.09.2010

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Multicomponent Materials

After his deanship, Prof. Faupel took a sabbatical in the winter semester 2010/2011, and the Multicomponent Materials group (formerly Chair for Multicomponent Materials) commenced various new projects supported mainly by external sources. Currently, the group participates actively in three Collaborative Research Centres (SFBs) and has third party funds of about 3 million euro from the German Research Foundation (DFG), the BMBF (Ministry for Education and Research), the AIF (Working Group Industrial Research) and others. As a consequence, the group's size increased considerably and now comprises 15 PhD students, for instance. Concerning the scientific output, more than 20 publications were accepted in international peer reviewed journals during the last year. Here, only a few aspects of the present research can be discussed. For more details we refer to our website http://www.tf.uni-kiel.de/matwis/matv/ and the papers listed below.

A special highlight of the last year was the strong feedback on our investigation of glass formation in so-called metallic glasses. The report was published in the renowned journal ''Physical Review Letters'' and has been referred to in several news-stickers and even newspapers. Another hot topic of great technological potential was transparent metallic coatings. This work, which involves the activities of the group on metal-polymer nanocomposites, was initiated by the former group member Prof. Elbahri and will be described in his Almanac chapter. A joint paper was just accepted in the top journal ''Advanced Materials''.

Working in three Collaborative Research Centres, the group strongly benefited from joint interdisciplinary work with partners ranging from fundamental physics and organic chemistry to electrical engineering and medicine. The activities within the Collaborative Research Centre SFB 677 - Function by Switching - were particularly successful last year as reflected in several new publications. Following the very positive evaluations of our joint project ''Plasma Processes for the Deposition of Nanostructured Composite Materials'' within the Collaborative Research Centre SFB TR 24 on complex plasmas a strong and fruitful cooperation has been established with the group of Prof. Kersten from the physics department of the CAU. First results are also already available in our new project within the Collaborative Research Centre SFB 855 on magneto-electric nanocomposites for medical applications. Our research performed with partners within the DFG priority program ''Polymer-solid contacts: Interfaces and Interphases'', which was co-initiated by Prof. Faupel, also led to several publications; our understanding was enlarged of the formation and structure of interfaces between polymers and solid materials, which are important in many technical applications. The group also performed investigations at large scale facilities particularly at the Electron storage ring BESSY in Berlin and at the positron beam facility of the Research Reactor, Garching.

In addition, various projects were carried out with industry. Besides direct cooperation with companies, joint work with industry was performed within projects of the BMBF and the AIF.

From July 2008 to June 2010 Prof. Faupel was Dean of the Faculty of engineering and still serves as Vice Dean. His main concern was to strengthen the cooperation within the Faculty of Engineering and to promote further interdisciplinary research with partners from other Faculties of the Christian-Albrechts University.

Irrespective of Prof. Faupel's sabbatical during the winter semester 2010/2011, the group was strongly involved in teaching and took great effort to inspire pupils for materials science and engineering in various ways, including visits to schools in Schleswig-Holstein.

Results

a) Mechanism of glass formation in undercooled metallic melts

Metallic glasses are mixtures of metals and non-metals which can be employed in a vast range of applications from 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 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. A strategy to reduce the necessary cooling rate is called the ''confusion of atoms''. The mixture is chosen to crystallize in a complex lattice, thus hindering the atoms moving into place. In this scheme the individual mobility of the constituents, which is called diffusivity, is decisive in whether the cooling melt crystallizes or not.

So far it was not known, which of the constituents determines viscosity. In the equilibrium melt all constituent diffusivities are equal and inversely related to the viscosity. However, up to now, no experiment has investigated how the diffusivities of the individual components behave upon cooling and how structure and dynamics are correlated during glass formation. We measured the diffusivities of all constituents of the representative glass forming alloy Pd-Cu-Ni-P in the temperature range from the glass transition up to the melting temperature. Our findings reveal that in the low temperature range the diffusivities of the individual species decouple and differ by up to four orders of magnitude. At higher temperatures the diffusivities of the constituents were found to be equal, indicating a homogeneous dynamic behaviour. However, the majority constituent Pd, the atoms of which are the largest in the alloy, follows the temperature behaviour of the viscosity over 14 orders of magnitude. We deduce from these data that the Pd-atoms form a network of low mobility within the alloy at decreasing temperature which hinders the crystallization of the melt. Thus our results, which aroused much international attention and were published in the prestigious journal ''Physical Review Letters'', provide a universal mechanism for the formation of metallic glasses.

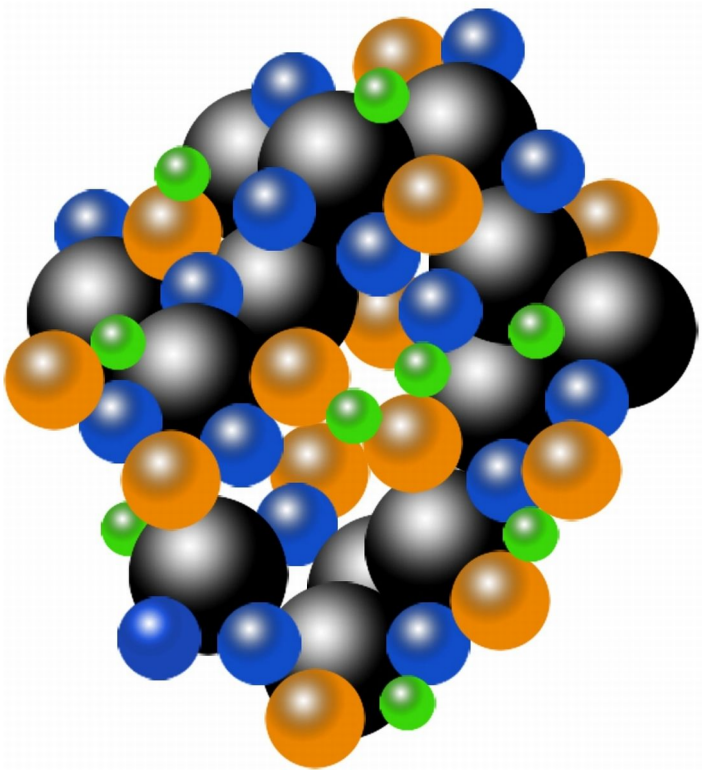

Fig. 1: In a mixture of Palladium, Copper, Nickel and Phosphorous the relatively large Palladium atoms form an immobile framework before the melt solidifies. Thus the other atoms are restricted to cages within the framework.

b) Polymer-solid contacts

Within the DFG priority program ''Polymer-solid contacts: Interfaces and Interphases'', which was co-initiated by Prof. Faupel, we studied the structure and formation of interfaces between plastics and solid materials like metals and ceramics. Such interfaces are important in many technical applications including polymer nanocomposites in which solid

nanoparticles are embedded in a polymer matrix.

In particular, we probed the distribution of the unoccupied space across the polymer-solid interface. This so-called free volume strongly affects many physical properties like viscosity, diffusivity, and brittleness. With the technique of positron annihilation lifetime spectroscopy, the average hole size in a material can be directly determined at the atomic scale. A moderated beam of positrons with well-defined implantation energy, available at the Research Reactor, Garching, can even probe thin films and interphases, which are extended interfacial regions with properties different from the bulk polymer. We systematically examined the interphase of planar Teflon AF/Si samples, for instance. As expected, for thermally evaporated films we found no significant interphase. However, for spin coated samples the free volume was reduced within the polymer-substrate interphase. This finding enabled us to determine the width of the interphase to be of some ten nm. This phenomenon has to be taken into account especially in polymer-nanocomposites, in which the properties of the polymeric matrix are significantly affected by the contribution of the interphase around the solid nanoparticles.

A separate project revealed that the influence of a functionalized layer on the surface of nanoparticles, which is generally used in commercial nanocomposites to obtain a uniform dispersion of the nanoparticles, seemingly can be similar to that of an interphase. Our results provide evidence that these two effects need to be strictly separated, a result which has not so far appeared in the literature.

c) Structural investigation of super sticky barnacle glue

Positron annihilation lifetime spectroscopy with a moderated beam was also applied to the adhesive layer of barnacles. The latter stick on every material, even on Teflon-coated ship hulls. Understanding the mechanisms of this extraordinary adhesion might help to develop new glues. Our investigations showed that the structure of the barnacle adhesive is highly porous up to the sub-nm scale. We suppose that the flexibility and the fracture behaviour of the adhesive originate in this pronounced porosity.

d) Nanocomposites for functional applications

The nanocomposites investigated in our group 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. These new properties are explored for a broad range of applications ranging from high frequency magnetic materials 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 physically enhanced chemical vapour deposition (PECVD) have also been employed in a joint project of the above mentioned Collaborative Research Centre SFB TR 24 with Prof. Kersten's group from the physics department. The central idea is to combine the complimentary know-how of the Kersten group on advanced plasma diagnostics and the expertise of the Faupel group on nanostructured materials to develop new tailored nanomaterials by understanding the correlation between plasma parameters and resulting nanostructure. In this context, we also developed two new cluster sources for the deposition of nanoparticles. In a cluster source, the nanoparticles form in the gas phase and not on the surface of the growing composites. This, among other advantages, allows chemical reactions between the metallic component and the matrix to be widely eliminated. Moreover, the source also allows the deposition of highly porous films made up of aggregated nanoparticles, which are currently being investigated. One of the sources is shown in Fig. 2.

A cluster source was also employed for the deposition of magnetic particles which will be used in our project within the new Collaborative Research Centre SFB 855 on magneto-electric nanocomposites for medical applications. The main idea of the project is to embed magnetostrictive nanoparticles, which change their shape in a magnetic field, in a piezoelectric matrix. The change in shape of the particles can be measured as a voltage change via elastic coupling to the piezoelectric material.

Nanocomposites also play a key role in one of our projects within the Collaborative Research Centre SFB 677 ''Function

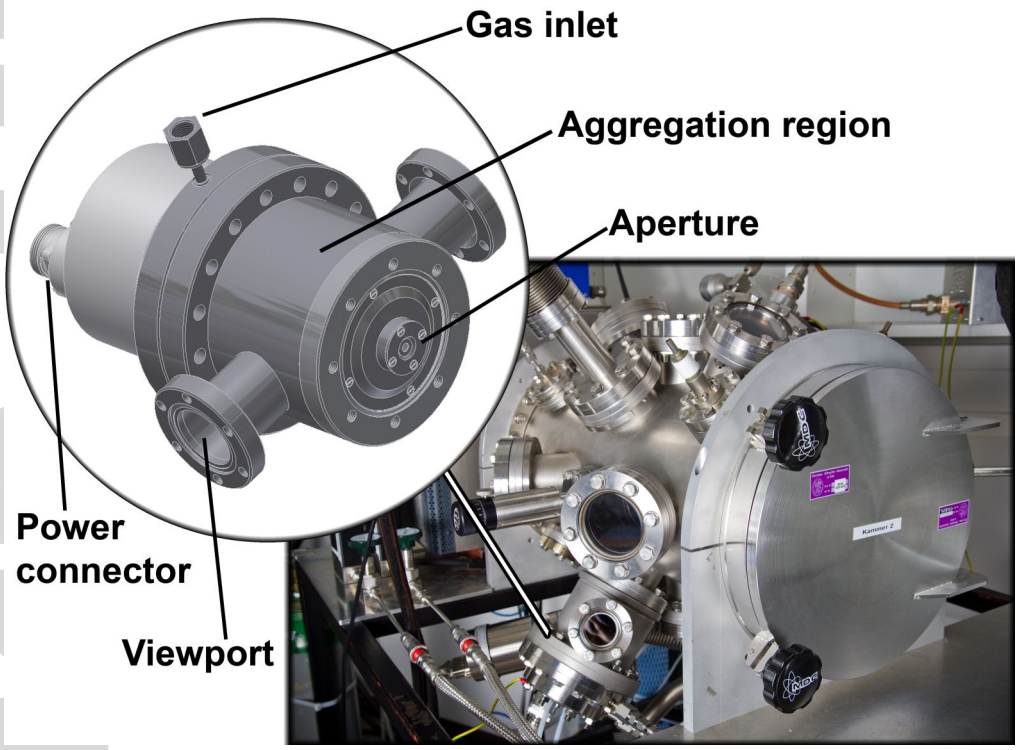

Fig. 2: One of the newly developed cluster sources for the deposition of nanoparticles from the gas phase.

by Switching". Here, the nanocomposites are combined with photo-switchable 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. As described in the Almanac 2006 these resonances are collective oscillations of the conduction electrons in the electrical field vector of electromagnetic radiation. Our recent major progress in this field is reported in many listed publications.

In a second joint project in the SFB 855 together with the group of Prof. Quandt we developed a new type of magnetic field sensor by combining a magnetostrictive material with a nanocomposite near the percolation threshold. Here, the dimensional change in the magnetostrictive material causes a change in the separation between the nanoparticles and thus changes the tunnelling current between the particles.

In several projects we explore the large specific surface area of the 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 since the antimicrobial activity originates from the released metal ions. This research has been supported by the World Gold Council and is carried out in cooperation with Prof. Podschun from the Institute of Infection Medicine of the University Hospital Schleswig-Holstein/Campus Kiel. Toxicity of nanoparticles is studied in cooperation with PD Röhl from the Institute of Toxicity of the CAU. In addition, among other partners, we cooperate with Prof. Grundmeier from the Chemistry Department of the University at Paderborn in a joint DFG project.

Recently, emphasis has been put on noble metal-titania composites. A key point is the control of the ion release behaviour via tailored nanoparticle filling factor profiles and diffusion barriers which ensure long-term release. In this connection, we discovered segregation of silver on the titania surface as an important issue which also affects the release behaviour. Much effort has been invested in order to understand the segregation mechanism. Here high resolution transmission electron

microscopy in conjunction with advanced tomography turned out to be very helpful. This work was performed in the group of Prof. Kienle (see his Almanac chapter). Fig.3 shows an example.

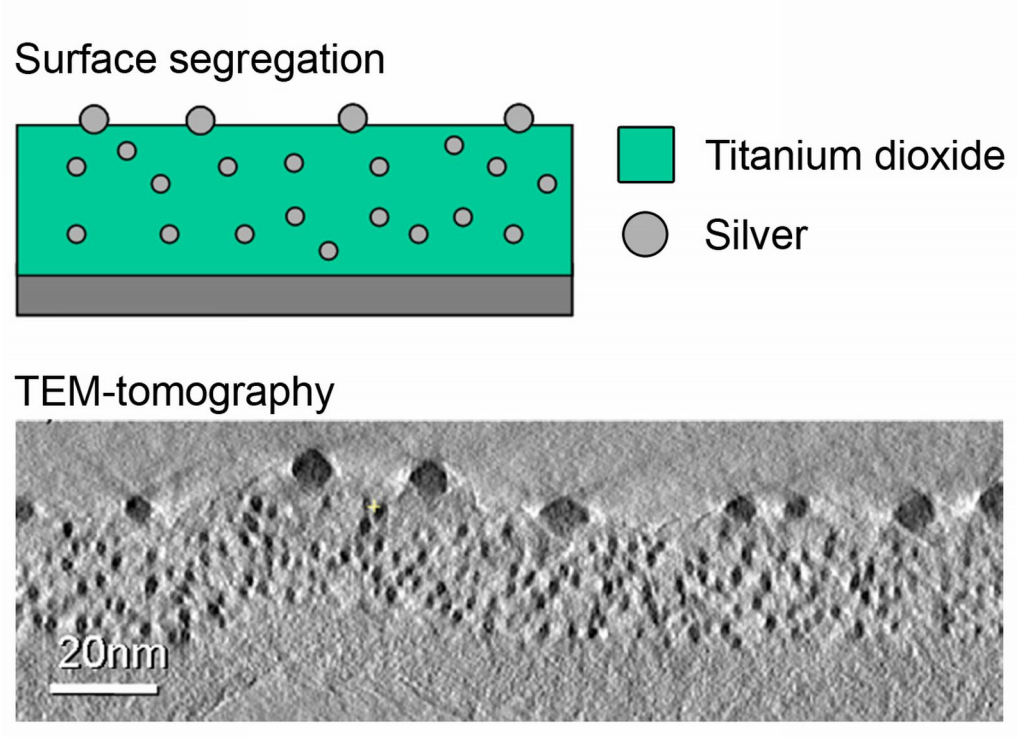

Fig. 3: Sketch of silver segregation on a titania surface and corresponding electron microscopy micrograph obtained in the group of Prof. Kienle by the advanced tomography technique.

The group also investigates various other functional properties of nanocomposites with metallic nanoparticles and an organic or ceramic matrix. Interested readers are referred to the attached list of publications and earlier Almanac editions. Concerning optical and plasmonic properties and so-called metamaterials, we refer to the Almanac chapter of Prof. Elbahri who initiated some exiting new applications pursued together with our group.

Personnel

Head of the group: Prof. Dr. F. Faupel; Secretary: N. Gühlke (50%), Dipl.-Chem. S. Kastaun (50%), Dipl.-Geol. B. Minten (50%)
Technical Staff: Dipl.-Ing. (FH) R. Kloth, C. Ochmann, Dipl.-Ing. (FH) S. Rehders

Scientific Staff:

M.Sc. M. Ahadi Functional nanocomposites	25.11.-31.12.2010	Fellowship Iran
M.Sc. N. Alissawi Ag-ion transfer	01.03.-31.12.2010	DFG
Dipl.-Phys. B. Gojdka Magneto-electric nanocomposites	01.01.-31.12.2010	SFB 855, CAU
Dipl.-Ing. C. Hanisch Functional nanocomposites	01.01.-14.03.2010	Tutech, World Gold Council

Dipl.-Phys. S. Harms Polymer-solid interfaces	01.01.-31.12.2010	DFG SSP 1369
M.Sc. B. Henkel Functional nanocomposites	01.10.-31.12.2010	BMBF
Dipl.-Phys. T. Hrkac Functional materials	01.01.-31.12.2010	BMWI
Dr. S. Jebril PolyMet	01.02.-31.12.2010	BMWI
M. Sc. M. Keshavarz Hedayati Optical nanocomposites	01.08.-31.12.2010	CAU with Prof. Elbahri
M.Sc. T. Koschine Positron beam, polymers	01.10.-31.12.2010	BMBF
M.Sc. A. Kulkarni High-frequency magnetic nanocomposites	01.01.-31.12.2010	DFG SFB 677
M.Sc. Q. Ma Magnetoelectric nanocomposites	01.04.-31.12.2010	Stipendium China, SFB 855
Dipl.-Ing. K. Meurisch Magneto-electric nanocomposites	01.01.-31.12.2010	CAU, SFB 855
Dipl.-Chem. C. Pakula Functional nanocomposites	01.01.-31.12.2010	DFG SFB 677
Dipl.-Phys. T. Peter Nanoparticles from plasmas	01.01.-31.12.2010	SFB TR24
Prof. Dr. K. Rätzke Supercooled melts, positron annihilation	01.01.-31.12.2010	CAU
M.Sc. M.Q. Shaikh Free volume in epoxies	01.01.-31.12.2010	BMBF, CAU
Dr. T. Strunskus Functional nanocomposites	01.01.-31.12.2010	SFB 855
M.Sc. J. Xiong Functional nanocomposites	15.01.-31.12.2010	Fellowship China
Dr. V. Zaporojtchenko Functional nanocomposites	01.01.-31.12.2010	CAU

Lectures, Seminars, and Laboratory Course Offers

Winter 2009/2010

Werkstoffe (Metalle), 2 (+ 1) hrs Lecture (+ Exercises)/Week,
F. Faupel

Thin Films II, 2 (+ 1) hrs Lecture (+ Exercises)/Week,

K. Rätzke (+ T. Hrkac)

Seminar for Members of the Chair for Multicomponent Materials and interested guests, 2 hrs Seminar/Week,
F. Faupel

Metals, 2 (+1) hrs Lecture (+ Exercises)/Week,
F. Faupel (+ M. Keshavarz Hedayati)

Einführung in die Vakuumtechnik, 2 hrs Lecture/Week,
V. Zaporojtchenko

Advanced Organic Materials, 2 hrs Seminar/Week,
T. Strunskus

Übungen zur Physik I, 2 hrs Exercise/Week,
K. Rätzke

Solid State Physics I, 1 hrs Exercises/Week,
S. Jebril

Einführung in die Materialwissenschaft I, 2 hrs Lecture/Week,
K. Rätzke (+ K. Dolgner)

Summer 2010

Solid State Physics II, 1 hrs Exercise/Week,
S. Jebril

Thin Films I, 2 (+1) hrs Lecture (+ Exercises)/Week,
K. Rätzke (+ T. Peters)

Einführung in die Materialwissenschaft II, 2 hrs Lecture/Week,
K. Rätzke (+ D. Dolgner)

Vacuum Technology and Materials, 2 hrs Lecture/Week,
V. Zaporojtchenko

Advanced Metallic Materials, 2 hrs Seminar/Week,
F. Faupel

Functional Nanocomposites, 2 hrs Seminar/Week,
V. Zaporojtchenko

Polymers I, 2 hrs Lecture/Week,
F. Faupel (+ D. Gedamu)

Seminar for Members of the Chair for Multicomponent Materials and interested guests, 2 hrs Seminar/Week,
F. Faupel

Special Problems of Soft Matter Physics, 2 hrs Lecture/Week,
K. Rätzke

Übungen zur Physik II, 2 hrs Exercise/Week,
K. Rätzke

Winter 2010/2011

Werkstoffe (Metalle), 2 (+1) hrs Lecture (+ Exercises)/Week,
M. Keshavarz Hedayati

Einführung in die Vakuumtechnik, 2 hrs Lecture/Week,
V. Zaporojtchenko

Advanced Organic Materials, 2 hrs Seminar/Week,
T. Strunskus

Übungen zur Physik I, 2 hrs Seminar/Week,
K. Rätzke

Advanced Materials A - Metals, 2 (+1) hrs Lecture (+ Exercises)/Week,
K. Rätzke (+ N. Alissawi)

Advanced Materials A - Polymers, 2 (+1) hrs Lecture (+ Exercises)/Week,
T. Strunskus (+ D. Gedamu)

Thin Films II, 2 (+1) hrs Lecture (+ Exercises)/Week,
K. Rätzke (+ T. Peters)

Einführung in die Materialwissenschaft 1, 2 hrs Lecture/Week,
K. Rätzke (+ O. Riemenschneider)

Third-Party Funds

DFG, DST, *Formation of metallic nanostructures in organic matrix by vapour and plasma phase deposition and its modification by swift heavy Iron Irradiation,* 01.03.2006-12.01.2010 (77.130 Euro)

DFG, *Diffusion in glasbildenden Metallschmelzen vom Gleichgewichtszustand bis zum kalorischen Glasübergang,* 15.09.2006-30.03.2010 (130.295 Euro)

DFG SFB 677, *Funktion durch Schalten: Kombination von schaltbaren Polymeren und Nanokompositen nahe der Perkolationsschwelle,* 01.07.2007-30.06.2011 (237.600 Euro)

DFG SFB 677, *Funktion durch Schalten: Komposite aus Polymermatrix und ferromagnetischen Formgedächtnis-Nanopartikeln als magnetische Schalter,* 01.07.2007-30.06.2011 (211.640 Euro)

DFG, *Einfluss der Verhinderung der Kollagen-Degradation durch MMPs auf den Dentin-Klebeverbund,* 04.10.2007-31.01.2011 (25.944 Euro)

DFG, SFB TR24, *Verteilung des Freien Volumens an Polymer-Festkörper-Grenzflächen,* 04.04.2008-04.04.2011 (245.970 Euro)

DFG, *Magnetic nanocomposites for rf applications in mobile communication,* 15.09.2008-30.09.2010 (129.566 Euro)

DFG, *Grundlagen komplexer Plasmen: Plasmaprozesse zur Abscheidung von nanostrukturierten Kompositmaterialien,* 01.07.2009-30.06.2013 (287.640 Euro)

China Scholarship Council, *Stipendium für Qian Ma, PhD-Student für 1 Jahr,* 01.09.2009-31.08.2010 (12.000 Euro)

AIF, *PolyMet-Polymer-Metalloxid-Compositschichten für flexible optische Schichtsysteme,PolyMet-Kiel: Polymer-Metalloxid-Schichtabscheidung und Charakterisierung,* 01.11.2009-31.10.2011 (175.000 Euro)

DFG SFB855, *Magnetoelektrische Verbundwerkstoffe-biomagnetische Schnittstellen der Zukunft: Gasphasenabscheidung von magnetoelekrtischen 0-3 Nanokompositen,* 01.01.2010-31.12.2013 (635.280 Euro)

DFG, *Ion transfer reactions at Ag-nanoparticle/polymer interfaces,* 17.02.2010-17.02.2012 (190.424 Euro)

Fraunhofer-Institut für Siliziumtechnology ISIT, *Untersuchungen mittels Photoelektronenspektroskopie von Elektrodenoberflächen,* 09.-09.03.2010 (780 Euro)

BMBF, *Nano-Purification - Entwicklung fortschrittlicher Materialien und Verfahren zur Wasser- und Abwasserbehandlung mittels funktioneller Nanokomposite,* 01.05.2010-30.04.2013 (202.489 Euro)

DAAD, *Forschungsstipendium im Rahmen des Programms GERSS (German Egyptian Research Short-term Scholarships) für Frau Dr. Rania Mohammed Ahmed Khalil,* 21.05.-21.11.2010 (11.565 Euro)

AvH, *Stipendium für Prof. Dr. Amita Chandra für 1 Monat,* 29.05.-27.06.2010 (2.300 Euro)

BMBF, *Verbundprojekt POSIMETHOD: Teilprojekt 5: ''Charakterisierung nanoskopischer Leerstellen in dünnen Polymerfilmen mittels Positronenlebensdauerspektroskopie''*, 01.07.2010-30.06.2013 (213.300 Euro)
Dräger Safety AG und Co. KGA, *Untersuchung von 4 Proben mit Hilfe der Photonenelektronenspektroskopie*, 05.-19.07.2010 (357 Euro)
China Scholarship Council, *Stipendium für Jian Xiong für 4 Jahre*, 15.11.2010-15.11.2014 (48.000 Euro)
KHS Plasmax GmbH, *XPS-Messungen: Komposition-Tiefenprofil von einer Beschichtung auf PET Proben mit Hilfe der Photonenelektronenspektroskopie*, 17.-17.11.2010 (1.100 Euro)
Iran Government, *Stipendium für Amir Mohammad Ahadi für 3 Jahre*, 25.11.2010-25.03.2014 (45.000 Euro)

Further Cooperation, Consulting, and Technology Transfer

University:

Prof. M. Bauer, F. Tuczek, O. Magnussen, Prof. W. Herges: Kombination von schaltbaren Molekülen und Nanokompositen nahe der Perkolationsschwelle (SFB „Funktion durch Schalten"),

Prof. W. Bensch, Institut für Anorganische Chemie: Komposite aus Polymermatrix und ferromagnetischen Formgedächtnis-Nanopartikeln als magnetische Schalter (SFB „Funktion durch Schalten"),

Dr. Peter Budd, Manchester School of Chemistry, The University of Manchester, Manchester UK, Polymermenbranen,

Prof. Dr. S. Deki, Kobe, Japan, Optische Nanokomposite,

Dr. G. Dlubek, ITA Institute for Innovative Technologies, Universität Halle, Positronenvernichtung in nichtmolekularen Substanzen,

Prof. Dr. G.Dollinger, Dr. W. Egger, Universität der Bundeswehr, München, PLEPS am FRM II,

Prof. Dr. M. Es-Souni, FH Kiel, Ferroelektrische Schichten und Grenzflächen zu Metallen,

Dr. Chr. Hugenschmidt, TU München und FRM II, NEPOMUC,

Prof. Dr. M. Kern, Zahnmedizin, Universität Kiel, AFM, XPS und Kontaktwinkelmessungen an Zähnen,

Prof. R. Knöchel, Inst. f. Elektrotechnik und Informationstechnik, magnetische HF-Materialien (DFG-projekt),

Prof. Dr. R. Podschun, Institut für Infektionsmedizin, Universität Kiel, antibakterielle Beschickung,

Prof. Dr. W. Possart, Universität Saarbrücken, BMBF-Projekt, Nanomodule,

Prof. Dr. E. Quandt, Anorganische Funktionsmaterialien, CAU, Komposite aus Polymermatrix und ferromagnetischen Formgedächtnis-Nanopartikeln als magnetische Schalter (SFB „Funktion durch Schalten"),

Dr. C. Röhl, Prof. Dr. J. Sievers, Anatomisches Institut, Toxikologische Auswirkung von metallischen Nanopartikeln auf menschliche Zellen,

Prof. Dr. V. Shantarovich, N.Semenov Institute of Chemical Physics, Russian Academy of Sciences, Moskau, Positronenvernichtung und Membranpolymere,

Prof. Dr. C. Staudt, Düsseldorf, Blockcopoymere,

Prof. Dr. F. Tuczek, Institut für Anorganische Chemie, CAU Kiel, Self-assembled monolayers,

Prof. Dr. Y. Yampolskii, A.V. Topchiev Institute of Petrochemical Synthesis, Laboratory of Membrane Gas Separation, Russian Academy of Sciences, Moskau, Positronenvernichtung und Membranpolymere

.

Research Institutes:

Dr. D. K. Avasthi, Materials Science Group, Nuclear Science Centre New Delhi, India, High energy ion beam effects in polymer-metal nanocomposites,

Prof. Dr. Dietmar Fink, Hahn-Meitner-Institut, Berlin, High energy ion beam effects in polymer-metal nanocomposites,

Dr. D. Fritsch und Prof. Dr. V. Abetz, Institut für Polymerforschung, GKSS-Forschungszentrum Geesthacht, Freies Volumen in Polymeren mit intrinsischer Mikroporosität,

Prof. Dr. G. Grundmeier, Max-Planck Institut, Düsseldorf, Antibakterielle Beschichtungen,

Prof. Dr. A. Meyer, Dr. A. Griesche, DLR, Köln, Diffusion in Pd-Cu-Ni-P Legierungen,

Dr. M. Noeske, Fraunhofer-Institut für Fertigungstechnik und Angewandte Materialforschung, IFAM Bremen, BMBF-Projekt, Nanomodule und PALS an Polymer-Kompositen,

Prof. Dr. K.V. Peinemann, GKSS, Geesthacht, Freies Volumen und Permeabilität in Spezialpolymeren,

Prof. Schwarz, Dr. Drusch, Lebensmitteltechnologie, Kiel, Verkapselung von Lebensmitteln,

Dr. Thomas Neubert, Fraunhofer Institut für Schicht- und Oberflächentechnik (IST), Braunschweig, Polymer-Metalloxid-Kompositschichten für flexible optische Schichtsysteme.

Industry:

o.m.t. Lübeck, Photoaktive Schichten,

Sennheiser Electronic KG Wedemark, Elektrete,

Wöhlk, Schönkirchen, Oberflächenmodifikationen von Kontaktlinsen,

World Gold Council, G.R.O.W., Improvement of antibacterial coatings by incorporation of gold nanoparticles.

Partners in AIF-Projekt Polymet:

Wohlrab Aufdampftechnik GmbH, Langenzenn,

Rolf Schäfer Beschichtungskomponenten, Münchweiler,

plastic-design GmbH, Bad Salzuflen.

Partners in BMBF-Projekt Umsicht:

Fraunhofer Institut für Umwelt-, Sicherheits- und Energietechnik, Oberhausen,

Hans-Huber AG, Berching,

Kryschi Wasserhygiene, Kaarst,

Evers-Wassertechnik, Hopsten,

Gelsenwasser AG, Gelsenkirchen.

Diploma, Bachelor and Master Theses

A. Al Zayed, *Electro-optica properties of gold/platinum polymer nanocomposite films doped with azobenzene ethers,* 18.05.2010

S. Dollinger, *Freies Volumen mit PALS in leitfähigen Polymernanokompositen,* 31.05.2010

B. Henkel, *Combined Quasi-Magnetoresistive Magnetic Field Sensor - utilizing Magnetostriction and Quantum Tunneling*, 01.10.2010

S.W. Basuki, *Photo-induced capacitance modulation in chromophore/PMMA blends and DC conductance modulation in MWCNT based resistorss*, 01.10.2010

H. Jebril Mahammud, *Study of electrical and optical porperties of polymer/spiropyrane blends with embeded noble metal nanoparticles*, 22.12.2010

M. Wegner, *Investigation of the preparation of nanocomposites by plasmapolymerization an high pressure magnetron sputtering*, 13.09.2010

C. Wang, *Photocatalysis Studies on Silver-modified Titania Nanocomposites and Sandwiched Cells prepared by Magnetron Co-sputtering*, 26.08.2010

H. Aboulfadl, *Investigation of the Portevin-Le Chatelier effect by Atom Probe Tomography*, 09.12.2010

D. Haffner, *Charakterisierung und Optimierung des Feedstock beim MIM von Ti6A14V*, 19.10.2010

P.H. Möseler, *Eutectic cells in cast iron and their influence on thermomechanical properties*, 22.09.2010

V. Röbisch, *Auswahl und Charakterisierung von wasserlöslichen Bindern für die Herstellung von Anoden in Lithium-Ionen-Batterien*, 08.10.2010

N. Alemayehu Zerihun, *Optimization of the morphology of Volatile Organic Compound (VOC) Sensors based on Polymer-metal Nanocomposites*, 08.02.2010

S. Mohammadzadeh Polami, *Stress Analysis during Welding of LTT Alloys under Defined Restraint Intensity*, 22.02.2010

A. Tavassolizadeh, *Investigation of Piezoelectricity of Corona Poled Vacuum-Deposited Nylon 11 Films*, 29.09.2010

M.S. Mohajerani, *Deposition and patterning of superconductor yttrium-barium-copper oxide thin films*, 05.11.2010

Dissertations / Postdoctoral Lecture Qualifications

M.Q. Shaikh, *Free Volume and Storage Stability of one component Epoxy Nanocomposites*, 11.11.2010

Publications

Published in 2010

K. Rätzke, M.Q. Shaikh, F. Faupel, P.-L.M. Noeske, *Shelf stability of reactive adhesive formulations: A case study for dicyandiamide-cured epoxy systems*, International Journal of Adhesion and Adhesives, **30**, 105 - 110 (2010)

G. Dlubek, Q.. Shaikh, K. Rätzke, M. Paluch, F. Faupel, *Free volume from positron lifetime and pressure-volume-temperature experiments in relation to structural relaxation of van der Waals molecular glass-forming liquids*, Journal of Physics, **22**, 235104 - 235114 (2010)

M. Quitzow, M. Wolter, V. Zaporojtchenko, H. Kersten, F. Faupel, *Modification of polyethylene powder with an organic precursor in a spiral conveyor by hollow cathode glow discharge*, Eur. Phys. J. D, **58**, 305 - 310 (2010)

V. Zaporojtchenko, V.S.K. Chakravadhanula, F. Faupel, S. Tamulevicius, M. Adrulevicius, A. Tamulevicien, L. Angulis, *Residual stress in polytetrafluoroethylene-metal nanocomposite films prepared by magnetron sputtering*, Thin Solid Films, **518**, 5944 - 5949 (2010)

G. Dlubek, M.Q. Shaikh, K. Rätzke, J. Pionteck, M. Paluch, F. Faupel, *Subnanometre size free volumes in amorphous Verapamil hydrochloride: A positron lifetime and PVT study through Tg in comparison with dielectric relaxation spectroscopy*, European Journal of Pharmaceutical Science, **41**, 388 - 398 (2010)

H. Takele, V.S.K. Chakravadhanula, C. Hanisch, M. Elbahri, T. Strunskus, V. Zaporojtchenko, L. Kienle, F. Faupel, *Preparation and plasmonic properties of polymer based composites containing Ag-Au alloy nanoparticles produced by vapor phase co-deposition*, Journal of Material Science, **45**, 5865 - 5865 (2010)

F. Faupel, K. Rätzke, B. Gojdka, *Metallische Gläser - hart im Nehmen und extrem vielseitig*, Welt der Physik, www.weltderphysik.de/de/8475.php, 25.10.2010, (2010)

Y.K. Mishra, S. Mohapatra, V.S.K. Chakravadhanula, N.P. Lalla, V. Zaporojtchenko, D.K. Avasthi, F. Faupel, *Synthesis and*

characterization of Ag-polymer nanocomposites, Journal of Nanoscience and Nanotechnology, **10**, 2833 - 2837 (2010)

A. Bartsch, K. Rätzke, A. Meyer, F. Faupel, *Dynamic Arrest in Multicomponent Glass-Forming Alloys,* Physical Review Letters, **104**, 195901 - 195901 (2010)

S. Harms, K. Rätzke, W. Egger, L.. Ravello, A. Laschewsky, W. Wang, P. Müller-Buschbaum, *Free volume and swelling in thin films of poly(N-isopropylacrylamide) end-capped with n-butyltrithiocarbonate,* Macromolecular rapid communications, **31/15**, 1364 - 1367 (2010)

B. Wunderle, E. Dermitzaki, O. Hölck, J. Bauer, H. Walter, M.Q. Shaikh, K. Rätzke, F. Faupel, B. Michel, H. Reichl, *Molecular dynamics approach to structure-property correlation in epoxy resins for thermo-mechanical lifetime modeling,* Microelectronics Reliability, **50/7**, 900 - 909 (2010)

T. Emmler, K. Heinrich, D. Fritsch, P.M. Budd, N. Chaukura, D. Ehlers, K. Rätzke, F. Faupel, *Free Volume Investigation of Polymers of Intrinsic Microporosity (PIMs): PIM-1 and PIM1 Copolymers Incorporating Ethanoanthracene Units,* Macromolecules, **43(14)**, 6075 - 6084 (2010)

C. Pakula, V. Zaporojtchenko, T. Strunskus, D. Zargarani, R. Herges, F. Faupel, *Reversible light-controlled conductance switching of azobenzene-based metal/polymer nanocomposites,* Nanotechnology, **21(46)**, 465201 - 465201 (2010)

M. Marschall, J. Reichert, K. Seufert, W. Auwarter, F. Klappenberger, A. Weber-Bargioni, S. Klyatskaya, G. Zoppellaro, A. Nefedov, T. Strunskus, C. Woll, M. Ruben, J.V. Barth, *Supramolecular Organization and Chiral Resolution of p-Terphenyl-m-Dicarbonitrile on the Ag(111) Surface,* Chemphyschem, **11(7)**, 1446 - 1451 (2010)

K. Rajalingam, L. Hallmann, T. Strunskus, A. Bashir, C. Woll, F. Tuczek, *Self-assembled monolayers of benzylmercaptan and para-cyanobenzylmercaptan on gold: surface infrared spectroscopic characterization,* Physical Chemnistry Chemical Physics, **12(17)**, 4390 - 4399 (2010)

S. Harms, K. Rätzke, F. Faupel, G.J. Schneider, L. Willner, D. Richter, *Free volume of interfaces in model nanocomposites studiend by positron lifetime spectroscopy,* Macromolecules, **43**, 10505 - 10511 (2010)

S. Harms, K. Rätzke, V. Zaporojtchenko, F. Faupel, W. Egger, L. Ravelli, *Free Volume distribution at the teflon af/silicon interfaces probed by a slow positron beam,* Poylmer, **52(2)**, 505 - 509 (2010)

K. Rätzke, M. Wiegemann, M.Q. Shaikh, S. Harms, R. Adelung, W. Egger, P. Sperr, *Open volume in bioadhesive detected by positron annihilation lifetime spectroscopy,* Acta Biomaterialia, **6**, 2690 - 2694 (2010)

F. Faupel, V. Zaporojtchenko, T. Strunskus, M. Elbahri, *Metal-Polymer nanocomposites for functional applications,* Advanced Engineering Materials, **12(12)**, 1177 - 1190 (2010)

C. Hanisch, N. Ni, A. Kulkarni, V. Zaporojtchenko, T. Strunskus, F. Faupel, *Fast electrical response to volatile organic compounds of 2D Au nanoparticle layers embedded into polymers,* Journal of Material Science, **46(2)**, 438 - 445 (2010)

B. Gojdka, *Einzigartig dank Unordnung. Aussichtsreiche Zukunft für metallische Gläser,* Spektrumdirekt, http://www.wissenschaft-online.de/artikel/1053339, (2010)

S.V. Merzlikin, N.N. Tolkachev, L.E. Briand, T. Strunskus, C. Wöll, I.E. Wachs, W. Grünert, *Anomalous Surface Compositions of Stoichiometric Mixed Oxide Compounds,* Angewandte Chemie, **49(43)**, 8037 - 8041 (2010)

S. Stepanow, R. Ohmann, F. Leroy, N. Lin, T. Strunskus, C. Wöll, K. Kern, *Rational Design of Two-Dimensional Nanoscale Networks by Electrostatic Interactions at Surfaces,* ACS Nano, **4(4)**, 1813 - 1820 (2010)

S. Harms, K. Rätzke, C. Pakula, V. Zaporojtchenko, T. Strunskus, F. Faupel, W. Egger, P. Sperr, *Free Volume Changes on Optical Switching in Azobenzene-Polymethylmethacrylate Blends Studied by a Pulsed Low-Energy Positron Beam,* Journal of Polymer Science, part B Polymer Physics, **49(6)**, 404 - 404 (2010)

A. Bartsch, V. Zollmer, K. Rätzke, A. Meyer, F. Faupel, *Diffusion and viscous flow in bulk glass forming alloys,* Journal of Alloys and Compounds, DOI: 10.1016/j.jallcom.2010.11.123, (2010)

Patent Applications

M. Elbahri, R. Adelung, F. Faupel, K. Hirmas, *Verfahren zur Nanostrukturerzeugung mittels spinodaler Entnetzung,* Deutsches Patentamt, 26.08.2010, EP2206153

Presentations

F. Faupel, *Metal-Polymer nanocomposites for functional applications (Invited talk)*, INM (Leibnitz-Institut für neue Materialien), Saaarbrücken, Germany, 13.-13.01.2010

K. Rätzke, *Materialwissenschaften in Kiel (Talk)*, Beruftsinformationstag Helene Lange Gymnasium, Rendsburg, Germany, 16.-16.02.2010

K. Rätzke, *Free volume and structure in polymeric membranes. PALS and XRD (Invited talk)*, AG Prof. Staudt, Düsseldorf, Germany, 01.-02.03.2010

S. Harms, *Free Volume in Polymers Position Annihilation Lifetime Spectroscopy (Talk)*, Interphases and faces: Programm spring school Fulda, DFG project SPP 1369, Fulda, 08.-11.03.2010

F. Faupel, A. Bartsch, K. Rätzke, A. Meyer, *Dynamic Arrest in Multicomponent Glass Forming Alloys (Invited talk)*, DPG-Frühjahrstagung 2010, Regensburg, Germany, 21.-26.03.2010

B. Gojdka, V. Zaporojtchenko, T. Strunskus, F. Faupel, *Vapour Phase Deposition of Ceramic-based Granular Nanocomposites for Magnetoelectric Applications (Poster)*, DPG-Frühjahrstagung 2010, Regensburg, Germany, 21.-26.03.2010

S. Harms, K. Rätzke, F. Faupel, W. Egger, L. Ravelli, A. Laschewsky, W. Wang, P. Müller-Buschbaum, *Free Volume and Swelling in Thin Films of Poly(N-Isopropylacrylamide) End-capped with n-Butyltrithiocarbonate (Talk)*, DPG-Frühjahrstagung 2010, Regensburg, Germany, 21.-26.03.2010

C. Pakula, C. Hanisch, T. Strunskus, D. Zargarani, V. Zaporojtchenko, R. Herges, F. Faupel, *Photo-switchable sensors based on azomolecule containing nanocomposites (Talk)*, DPG-Frühjahrstagung 2010, Regensburg, Germany, 21.-26.03.2010

T. Peter, S. Bornholdt, M. Wolter, T. Strunskus, V. Zaporojtchenko, H. Kersten, F. Faupel, *Nanocompsite thin films prepared by co-sputtering and via deposition from a cluster source (Poster)*, DPG-Frühjahrstagung 2010, Regensburg, Germany, 21.-26.03.2010

A. Kulkarni, V. Zaporojtchenko, T. Strunskus, F. Faupel, E. Quandt, V.S.K. Chakravadhanula, L. Kienle, *Magnetic and structural properties of TiO2-FeCo nanocomposite (Talk)*, DPG-Frühjahrstagung 2010, Regensburg, Germany, 21.-26.03.2010

T. Hrkac, V.S.K. Chakravadhanula, N. Wohner, V. Zaporojtchenko, T. Strunskus, D. Garbe-Schönberg, F. Faupel, *Ag-TiO2 nanocomposites for antibacterial and photocatalytic applications (Poster)*, DPG-Frühjahrstagung 2010, Regensburg, Germany, 21.-26.03.2010

K. Meurisch, V. Zaporojtchenko, T. Strunskus, F. Faupel, *Polymer-Based Magnetoelectric Composites (Poster)*, DPG-Frühjahrstagung 2010, Regensburg, Germany, 21.-26.03.2010

V.S.K. Chakravadhanula, A. Lotnyk, T. Hrkac, A. Kulkarni, H.T. Beyene, T. Strunskus, V. Zaporojtchenko, C. Kuebel, R. Podschun, F. Faupel, L. Kienle, *Synthesis and characterization of functional metal-polymer and metal-oxide nanocomposite thin films (Invited talk)*, ICN 2010 (International Conference on Nanomaterials: Synthesis, Characterization and Applications)), Kottayam, Kerela, India, 27.-29.04.2010

F. Faupel, *Metal-Polymer nanocomposites for functional applications (Invited talk)*, Kolloquium TU Chemnitz, Institut für Physik, Chemnitz, Germany, 28.-29.04.2010

V. Zaporojtchenko, C. Pakula, T. Strunskus, R. Herges, F. Faupel, *Reversible electro-optical switchable effects in azomolecule containing nanocomposites (Talk)*, The international Workshop"Electronic, transport and optical properties of low-dimension systems"(WS10-ETOLDs), Valencia, Spain, 31.05.-02.06.2010

K. Rätzke, F. Faupel, A. Bartsch, A. Meyer, *Dynamic Arrest in Multicomponent Glass Forming Alloys (Invited talk)*,

International Wokshop DSS-2010 "Grain Boundary Diffusion, Stresses and Segregation", Moskau, Russia, 01.-04.06.2010

K. Meurisch, V. Zaporojtchenko, T. Strunskus, F. Faupel, *Polymer-Based Magnetoelectric Composite Films (Talk)*, E-MRS Spring Meeting 2010, Straßburg, France, 07.-11.06.2010

T. Peter, C. Bornholdt, V.S.K. Chakravadhanula, A. Kulkarni, T. Hrkac, C. Hanisch, M. Wolter, T. Strunskus, V. Zaporojtchenko, H. Kersten, F. Faupel, *Nanocompositedeposition by plasmas (Invited talk)*, 24th Symposium on Plasma Physics and Technology, Prag, Czech Republic, 14.-17.06.2010

F. Faupel, A. Bartsch, K. Rätzke, A. Meyer, *Dynamic Arrest in Multicomponent Glass Forming Alloys (Invited talk)*, Konferenz "Emerging Concepts in Glass Physics", Santa Barbara, USA, 21.-24.06.2010

F. Faupel, *Dynamic Arrest in Multicomponent Glass Forming Alloys (Invited talk)*, 17th International Symposium on Metastable, Amorphours and Nanostructured Materials (ISMANAM 2010), Zürich, Switzerland, 05.-07.07.2010

V. Zaporojtchenko, T. Strunskus, A. Kulkarni, T. Hrkac, V.S.K. Chakravadhanula, E. Quandt, R. Podschun, F. Faupel, *Nanocomposites for Functional Applications by Physical Vapor Deposition Processes (Talk)*, Nanofair 2010 (8th International Nanotechnology Symposium - New Ideas for Industry), Dresden, Germany, 06.-07.07.2010

K. Rätzke, S. Harms, F. Faupel, *Free volume distribution at polymer-solid interfaces (Talk)*, 2. Jahrestreffen SPP 1369 (Polymer-Festkörperkontakte), Dechema, Frankfurt, Germany, 09.-09.07.2010

V. Zaporojtchenko, *Surface modifiction of polymers by low energy ions and plasmas (Talk)*, 2nd Graduate Summer Institute, Greifswald, Germany, 11.-13.08.2010

V. Zaporojtchenko, T. Hrkac, T. Strunskus, V.S.K. Chakravadhanula, N. Alissawi, R. Podschun, C. Röhl, D. Garbe-Schönberg, F. Faupel, *Tuning of the Silver Ion Release from Antibacterial Nanocomposite Coatings (Talk)*, International NanoBio Conference 2010, Zürich, Switzerland, 24.-27.08.2010

T. Strunskus, T. Hrkac, V.S.K. Chakravadhanula, N. Wohner, V. Zaporojtchenko, R. Podschun, D. Garbe-Schönberg, F. Faupel, *Nanocomposite Films with Embedded Silver Nanoparticles for Antimicrobial Applications (Poster)*, Materials Science and Engineering, Darmstadt, Germany, 24.-26.08.2010

A. Kulkarni, V. Zaporojtchenko, T. Strunskus, F. Faupel, E. Quandt, F. Hettstedt, R. Knöchel, V.S.K. Chakravadhanula, L. Kienle, *Magnetic nanocomposite preparation, characterization and applications (Poster)*, Materials Science and Engineering, Darmstadt, Germany, 24.-26.08.2010

F. Faupel, *Metal-Polymer nanocomposites for functional applications (Plenary talk)*, Materials Science and Engineering, Darmstadt, Germany, 24.-26.08.2010

K. Meurisch, V. Zaporojtchenko, T. Strunskus, F. Faupel, *Piezoelectricity in Thermally Evaporated Thin Films of Nylon 11 (Poster)*, Materials Science and Engineering, Darmstadt, Germany, 24.-26.08.2010

K. Rätzke, F. Faupel, *Free Volume in high free volume polymeric membranes investigated by positron annhiliation lifetime spectroscopy (Talk)*, 14th International Conference "Polymeric Materials", Halle (Saale), Germany, 15.-17.09.2010

B. Gojdka, *Towards 0-3 dimensional ceramic based magnetoelectric composites (Talk)*, SFB 855 Herbstworkshop und Sommerschule des integrierten Graduiertenkollegs, Salzau, Germany, 29.09.-01.10.2010

F. Faupel, H. Kersten, R. Peter, V. Zaporojtchenko, T. Strunskus, C. Bornholdt, M. Fröhlich, *Deposition of nanostructured composite materials (Talk)*, SFB-Kolloquium des TR24, Wismar, Germany, 30.09.-01.10.2010

V. Zaporojtchenko, T. Hrkac, T Strunskus, V.S.K. Chakravadhanula, T. Peter, R. Podschun, C. Röhl, D. Garbe-Schönberg, F. Faupel, *Tunable Anibakterial Nanocomposites Coatings (Poster)*, Nanosmat: 5th international Conference on Surfaces, Coatings and Nanostructured Materials, Reims, France, 19.-21.10.2010

F. Faupel, *Metal-Polymer nanocomposites for functional applications (Invited talk)*, Physikalisches Kolloquium Uni Göttingen, Göttingen, Germany, 01.-01.11.2010

F. Faupel, *Metal-Polymer nanocomposites for functional applications (Invited talk)*, 2nd ZUM-HASYLAB Colloquium "The metal-polymer interface", DESY, Hamburg, Germany, 02.-02.11.2010

M. Keshavarz Hedayati, V.S.K. Chakravadhanula, V. Zaporojtchenko, M. Elbahri, F. Faupel, *Transparent conductors based on metal-polymer nanocomposites(Talk)*, Materials Science and Engineering, Darmstadt, Germany, 24.-26.08.2010

F. Faupel, *Neue Materialien durch Nano-Technologie (Invited talk)*, Gothaer Allgemeine Versicherung AG, Köln, Germany, 03.-04.11.2010

F. Faupel, *Metal-Polymer nanocomposites for functional applications (Invited talk)*, Metal Kokkola 2010, Kokkola, Finland, 16.-17.11.2010

K. Rätzke, F. Faupel, *Free Volume and Positron Annihilation in Polymers and Polymer Electrolytes (Invitited talk)*, ICEP2010 (4th International Conference on Electroactive Polymers: Materials and Devices), Dehli, India, 22.-27.11.2010

Further Activities and Events

Selected Honorary Activities of Prof. Faupel:

Dean of the Faculty of Engineering from July 2008 until July 2010(Technische Fakultät der CAU),

Coordinator of the *North German Initiative Nanomaterials (NINa)*,

Principle Editor of the *Journal of Materials Research, edited by the Materials Research Society* (MRS),

Editor of the *encyclopedia RÖMPP online, Theme Chemistry*,

Member of the des Advisory Board of *Diffusion and Defect Data*,

Member of the DGM Scientific Advisory Board, *German Material Research Society*,

Member of the Program Commitee of the DFG Priority Program *''Polymer-Solid Interfaces, Thin Films, and Interphases - from Molecular View to Continuum"* ,

Vice Speaker of the SFB 677 ''Function by switching'',

Member of the managing committee of the SFB855 „Magnetoelectric composites - biomagnetic interfaces of the future,

Member of the *Societas Christiana Albertina*,

Member of the HWT (Hochschule-Wirtschaft-Transfer)-Jury of the ISH (Innovation Foundation Schleswig-Holstein),

Member of the Steering Commitee of the Focal Point of Support „Nano and surface science" ,

Member of the Steering Commitee Quality Management of the CAU,

Member of KARE, *(Kiel Alliance of Research and Education)*,

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.

Functional Nanomaterials

The group ''Functional Nanomaterials'' has grown significantly in 2010. Two more research assistant positions could be obtained for the group and filled in October, as well as half a technician and a secretary position. This offer from the University, the Institute and the Faculty of Engineering was a reaction to the group leader considering a W3 position at the Technical University Hamburg-Harburg (TUHH). Furthermore, the Heisenberg Professorship was prolonged in 2010 on the basis of a positive mid-term evaluation. The scientific focus of the group shifted further to the characterization and understanding of the properties of nanostructures as well as towards large scale synthesis to generate amounts of nanostructures of dimensions on the macroscopic scale. In contrast to the earlier years of nanostructure research, the research focused on even more applied aspects as the basics and elementary synthesis became more widely understood. This aspect is visible in the projects started in 2010: a project financed by the BMBF (Federal Ministry of Education and Research) and carried out together with the company Nanoproofed in Gleschendorf, Schleswig-Holstein, is on the development and examination of a novel anti-fouling paint for ships. Bio-fouling occurs to almost every material inserted into natural water, no matter if freshwater or seawater. This means that within a short time surfaces are covered by algae, bacteria or barnacles. The solutions to such problems were called anti-fouling paints, which previously were based on the wide range toxicity of tributyltin. Lately, those marine paints have been banned by the International Maritime Organization due to the drastic effects on the marine population, especially fish. The BMBF project has the goal to develop an ecologically friendly and effective anti-fouling paint based on the multifunctionality of nanostructures. More details are described below. Furthermore, the SFB 855 ''Magnetoelectric Composites - Future Biomagnetic Interfaces'' started in January. The group Functional Nanomaterials is involved in two projects; apart from the graduate school a research project has been funded that develops magnetic field sensors, the main topic of the SFB, based on piezoelectric and magnetostrictive materials in a novel geometry. The nano-technological material aspects are included and applied in this project. Several contributions were started in the framework of coordinated programmes, two new research units are planned together with the dental and the ophthalmic clinic, inspired in the year 2010 by the proposed cluster of excellence ''Materials for life'' led by Prof. Dr. Eckhard Quandt (see chapter Inorganic Functional Materials). In addition, the group leader of the Functional Nanomaterials group is currently proposed as principle investigator in the planned cluster and contributed to the proposal. Beside the initiation and the start of new projects, three new PhD students started in this year, Xin Jin, Ingo Paulowicz, and Arnim Schuchardt joined the group. All three performed their master theses in the group: it should be stressed that Arnim Schuchardt won the award for the best master in materials science in Kiel, after he already received the award for the best bachelor. In total 5 students performed their master thesis and 8 bachelor theses were carried out in the group. Frank Spors, already Assistant Professor in the Western University of Health Sciences, California, U.S.A., completed his PhD in Spring 2010. His findings include novel optics for contact lenses based on photon sieve technology, in collaboration with the physics department. In terms of teaching at the University, a novel seminar together with Priv. Doz Dr. Phil. Werner Theobald from the Centre for Ethics was established in 2010. This interdisciplinary seminar experiment was successful; it will be continued in 2011. Beside the invited talks at other Universities (see list below) talks for a broader audience were also given. Several were held in the framework of the SHUG (four talks in Schleswig-Holstein) and at the ''Lange Nacht der Profs'' but also in other communities. Worth mentioning here are two talks, one in the framework of the ''Schüler- und Kinderuniversität'' (children's university); the video of the talk and a booklet are available on the University homepage. The other was a lecture for the opening of the University's Graduate Centre with contributions from the mayor of Kiel and politicians from Schleswig-Holstein as well as the University president and chancellor. Furthermore, the group organized a symposium at the spring meeting of the German physical society with many invited and contributed talks including a lecture from Prof. Dr. Dwight Viehland from Virginia Tech, one of the international experts in magneto-electrical composites materials.

Results

Metal Oxide Nanostructures:

Ceramics or semiconductors are typically ridged and brittle materials. We found that this can be changed by interconnecting nanostructures in a three dimensional manner. As nanostructures are much more flexible than their bulk counterparts, the novel materials synthesized from interconnected nanostructures transport these features to the macroscopic dimensions. While in the last year, the prime example of nanostructures, ZnO was the focus, this year further metal oxide ceramics and semiconductors were investigated with surprisingly successful results. A patent for the approach is pending in 2010. SnO_2 especially turned out to be a material which is amenable to this approach and, as a three dimensional network material, can show flexibility and elasticity on the macroscale. Figure 1 shows a sequence of images illustrating the aspect of flexibility. The first part in figure 1a-c shows an indentation and relaxation of the nanostructured material. Parts d-f of figure 1 show the bouncing of a screw on the flexible ceramics, revealing the elastic properties of the nano networks. Even temperatures above 1000°C can be withstood by the material, which also cools significantly fast. Figure 1h shows a photograph where an elastic ceramic sample is heated in a flame as a test for its stability and lack of reactivity. The material has a remarkably low heat capacity; it could be touched only a second after heating. A fascinating aspect is the electronic properties of the flexible SnO_2 which are still semiconducting, as the whole network is interconnected by interpenetrating joints. Besides SnO_2, V_2O_5, Al_2O_3 and Fe_3O_4 nanostructures and their mixtures were successfully synthesized in macroscopically expanded amounts. These materials also reveal interesting properties; Fe_3O_4 is magnetic and, as a ferrimagnetic material, exhibits a permanent magnetic moment. All the structures are well examined in optical and electron microscopy. In situ mechanical tests were carried out inside the scanning electron microscope, where a custom made tool holder allowed cutting, sliding and bending tests inside the microscope at high magnifications. This enables the macroscopic mechanical properties to be explained by relating them to the microscopic behaviour now visible down to the nanoscale. In the framework of a close collaboration with the group of Prof. Dr. Lorenz Kienle (see chapter Synthesis and Real Structure) many oxide nanomaterials synthesized here are characterized in detail inside the Transmission Electron Microscope.

Another main objective for further exploration is also the synthesis of ZnO crystals for the SFB 855 project. Here high quality single crystalline hexagonal ZnO columns promise the best performance. Already single crystals of several mm lengths could be formed; their hexagonal shape indicates a high crystal quality. For this project another VLS-setup was built during 2010. Arrays of dimensions of several millimetres could be formed with similar types of micro- and nanostructures. However, for a mass fabrication the reproducibility must be understood. Some of the obtained crystal structures are shown in figure 2.

Semiconductor Composite Materials:

One of the focuses of research was the combination of the above described novel metal oxide nanomaterials with a polymer matrix to form interpenetrating compounds. A part of that research is in the framework of the BMBF anti-fouling project. For this project nanoscale sea urchin like nanospiked micro particles were embedded in a polymer used to cause an anti-fouling effect based on the surface structure and piezoelectricity of the materials. The difficulties of mixing the so called core spike filler particles with the matrix material means that care had to be taken with optimization. After such optimization, it was possible to create an effective anti-fouling paint. The anti-fouling effect already has been successfully tested in collaboration with the company Nanoproofed. In a side-by-side comparison with a commercial anti-fouling paint lasting over a month in a water basin test setup, designed and developed by the company, the newly developed paint showed significantly less fouling on the surface. During the BMBF project it turned out that there is also a strong modification of the mechanical behaviour of the polymer matrix. While the individual core spike particles already reinforce the matrix material, first experiments were carried out with the interconnected networks of nanostructures described above. Experiments with PDMS (Polydimethylsiloxane, known as silicone rubber) showed a very interesting compound behaviour: the mechanical and wetting properties could be changed in a wide range depending on the filling factor and type of

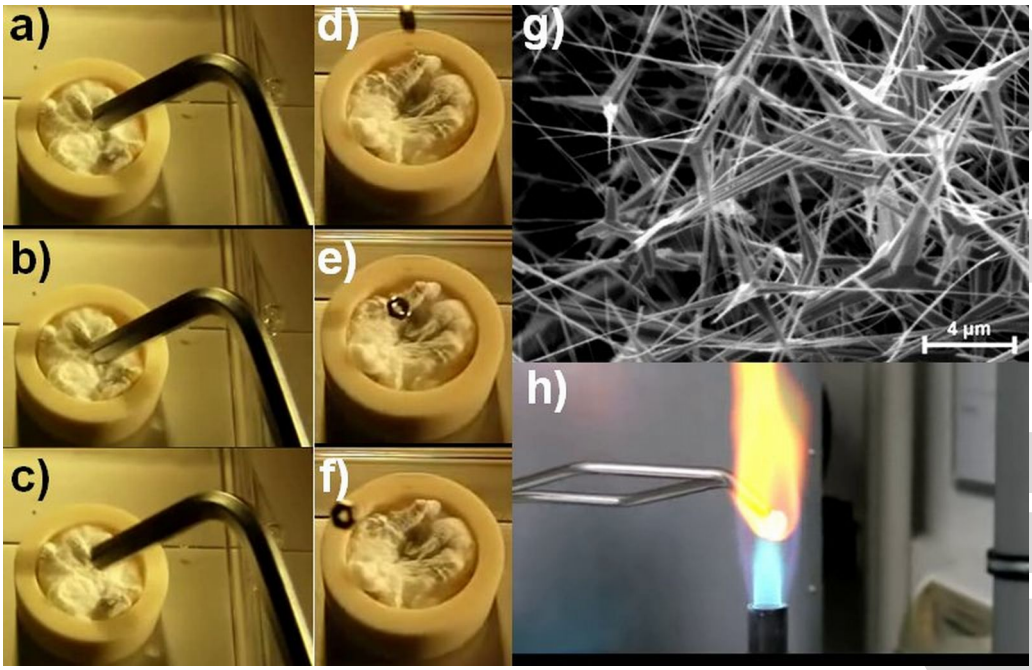

Fig. 1: Flexibility and elastic properties of nanostructures. Photographs a)- c)show a sequence of touching the elastic network with an Allen wrench. Photographs d)-f) show the rebound of a screw on the flexible network acting like a trampoline. The electron micrograph g) reveals a typical network showing macroscopic flexibility and elasticity. The photograph h) shows that the material can withstand the heat of a flame even though it is flexible

nanostructure used for filling. The wetting contact angle could be change from hydrophobic to ultra-hydrophobic, see figure 3a. The mechanical behaviour of the PDMS changed drastically, e.g., the fracture resistance could be significantly increased. The reason for that can be observed in figure 3b and c. In the optical microscopy images a semiconductor micro-needle as part of the micro/nanostructure network can be seen inside the PDMS. In figure 3c the result of an elongation of the crack that is already visible in figure 3b can be seen. The elongation effects a bending of the flexible inorganic filler, meaning a further storage of energy. At higher filling factors, the same crack elongation experiment is repeated as shown in figure 3d and e. Here only a further splitting of the sidewalls of the ruptured area can be seen, but there is now further crack propagation. These interesting material properties led to a joint proposal in the framework of the SFB 677 ''Function by Switching''. Together with Prof. Gorb from the biology department and Prof. Dr. Anne Staubitz from the chemistry department, a light switchable adhesion could be realized. The project mimics the feet structure of geckos or beetles in order to realize adhesion, the composite approach playing a central role in fortifying the soft switchable polymer structures for the adhesive forces. The nanostructure networks in the polymer matrix have the advantage that they maintain the flexibility of the polymer. Another interesting use of the nanostucture polymer composites are dental materials. Mixing the networks with a dental polymer, very high filling factors can be observed without any chemical adoption between the polymer and the filler due to the interlocking of the particles. This promises to form interesting hybrid materials between ceramics and polymers: interesting in applications such as dental filling materials for teeth.

Medical Projects:

It turned out that metal oxide semiconductors are also interesting biomaterials. The interactions with cells, bacteria and viruses were examined in different projects. In a collaborative research project with toxicology, the toxic concentration of nanospiked particles could be found. As is known, the shape of nanostructures determines the properties. In addition we found that the cytotoxicity of the structures depends on the chemical surface state that we could tune by an external stimulus. Such a switchability offers a chance to control cell growth over nanostructured surfaces. To shed more light into

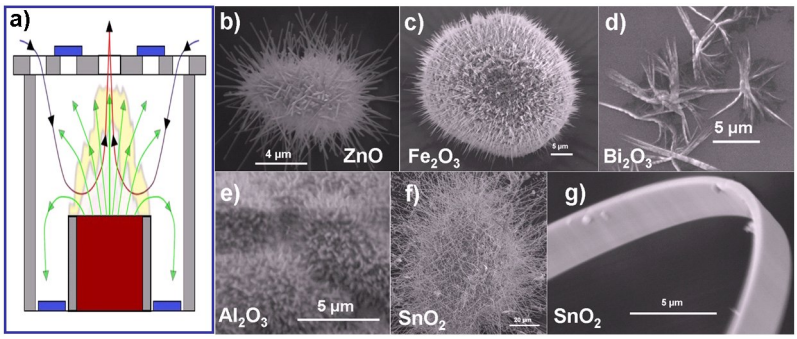

Fig. 2: Sketch of the growth setup (a) and several oxide microparticles containing nanostructures fabricated in the flame transport synthesis developed here (b-g)

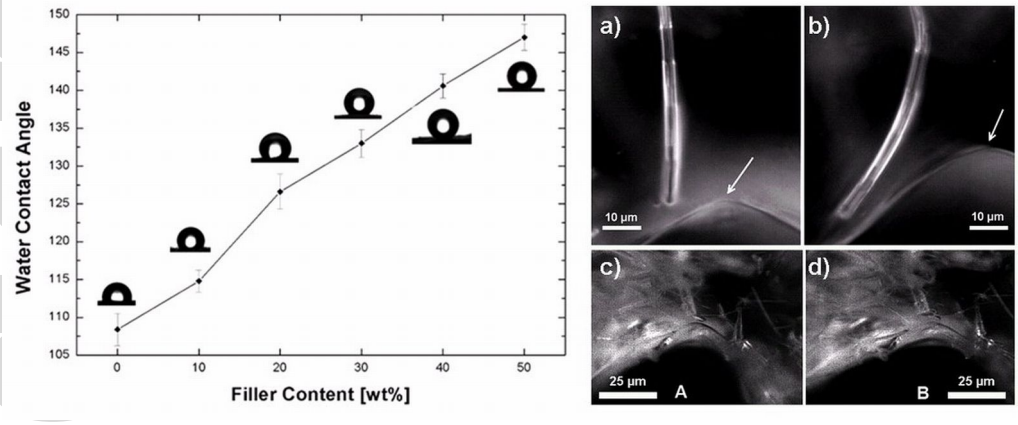

Fig. 3: ZnO/PDMS composites. The diagram on the left shows different water droplets in the profile ranging from hydrophobic to superhydrophobic. The plot shows the contact angle of the droplet in dependence of the filling factor with ZnO. The image on the right shows some interesting features of the composite under an optical microscope. Part a) and b) show the bending of a ZnO rod in the composite due to an increased crack tip nearby: the material adsorbs energy elastically. A higher density of fillers can even stop the crack propagation through the material, see figure c) and d).

the kinetics of such mechanisms, a collaboration with Prof. Christine Selhuber-Unkel, who is an expert in cell movements on surfaces, was established. A joint project with the University of Western Health Care initiated by Prof. Dr. Frank Spors showed very impressive results on the interaction of nanostructures with viruses. Further details cannot yet be revealed due to a joint running patent application. Another very promising approach is the vacuum deposition of pharmaceuticals. Together with the group of Prof. Dr. Hartwig Steckel, several tests on the effect of vacuum deposited drugs were carried out. It turned out, that the dissolution can be controlled in a wide range; an interesting result is the increase in solubility due to vacuum deposition.

Personnel

Head of the group: Prof. Dr. R. Adelung; Secretary: N. Gühlke (50%), Dipl.-Chem. S. Kastaun (50%), Dipl.-Geol. B. Minten (50%)
Technical Staff: Dipl.-Ing. R. Kloth (50%), C. Ochmann (50%), Dipl.-Ing. S. Rehders (50%)

Scientific Staff:

M.Sc. D.M. Gedamu 01.01.-31.12.2010 DFG, CAU
Nanowire electronics

M.Sc. X. Jin Piezo composites	01.01.-31.12.2010	DFG, CAU
Dipl.-Ing. S. Kaps Piezomaterials	01.01.-31.12.2010	DFG
M.Sc. Harminder Kaur Biocompatibility of ZnO	01.-31.12.2010	Grant CAU
Dr. Y.K. Mishra Nanowires and nanostructures	01.01.-31.12.2010	AvH Grand
M.Sc. I. Paulowicz Synthesis and characterization of nanostructures	01.10.-31.12.2010	CAU
M.Sc. A. Schuchardt Aeromaterials and electrical properties	01.10.-31.12.2010	CAU
Dr. S. Wille Anti-fouling	01.01.-31.12.2010	BMBF, TuTech
M.Sc. E.S.E.S.A. Zarie Drug evaporation	01.01.-31.12.2010	Grant Government Egypt and CAU

Lectures, Seminars, and Laboratory Course Offers

Winter 2009/2010

Biomaterials, 2 hrs Lecture/Week,
R. Adelung

mawi-102: Mathematik für Materialwissenschaftler I, 4 hrs Lecture/Week,
R. Adelung (+ S. Wille, T. Strunskus)

Solid State Physics I, 2 (+1) hrs Lecture (+ Exercises)/Week,
R. Adelung (+ S. Jebril)

Nanoelektronik, 4 hrs Lecture/Week,
R. Adelung

Nanoelektronik, 1 hrs Seminar/Week,
R. Adelung

Summer 2010

Mathematik für Materialwissenschaftler II, 4 (+2) hrs Lecture (+ Exercises)/Week,
R. Adelung (+ S. Harms, T. Strunskus)

Solid State Physics II, 2 (+1) hrs Lecture (+ Exercises)/Week,
R. Adelung (+ S. Jebril)

Voraussetzungen und Auswirkungen Nanotechnologie, 2 hrs Lecture/Week,
R. Adelung

Voraussetzungen und Auswirkungen Nanotechnologie, 1 hrs Seminar/Week,
R. Adelung

Winter 2010/2011

Biomaterials, 2 hrs Lecture/Week,
R. Adelung

mawi-102: Mathematik für Materialwissenschaftler I, 4 (+ 2) hrs Lecture (+ Exercises)/Week,
R. Adelung (+ S. Wille, B. Gojdka)

Solid State Physics I, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
Y.K. Mishra (+ A. Schuchardt)

mawi-503: Halbleitertechnik und Nanoelektronik, 4 hrs Lecture/Week,
R. Adelung

mawi-503: Halbleitertechnik und Nanoelektronik, 1 hrs Seminar/Week,
R. Adelung

Nano Ethik Technologie, 2 hrs Seminar/Week,
R. Adelung (+ W. Theobald)

Third-Party Funds

DFG (Ad183/5-1), *Heisenberg-Professur: Interdisziplinäre anwendungsnahe Forschung mit nanostrukturierten Materialien,* 01.07.2007-30.06.2010 (160.286,26 Euro)
DFG (Fa 234/16-1), *Einfluss der Verhinderung der Kollagen-Degradation durch MMPs auf den Dentin-Klebeverbund,* 04.10.2007-31.01.2011 (25.944 Euro)
DFG (Ad 183/4-3), *Fabrication and characterization of functional nanowire and tube devices,* 01.08.2008-31.10.2010 (155.647,30 Euro)
DFG (SFB 677/1-2007 PM02), *Funktion durch Schalten: Anschubfinanzierung für Projekt,* 01.01.2009-30.06.2011 (14.080 Euro)
AvH, *Hildegard Maier Forschungsstipendium Mishra,* 01.02.2009-28.02.2011 (73.200 Euro)
Botschaft der Arabishen Republik Ägypten, *Ägyptisches Regierungsstipendiat in Long Term Mission System für Zarie für 4 Jahre,* 07.03.2009-06.03.2013 (66.000 Euro)
DFG (SFB 855/1-2010 Teilprojekt IGK), *Magnetoelektrische Verbundwerkstoffe - biomagnetische Schnittstellen der Zukunft: Integriertes Graduiertenkolleg,* 01.01.2010-31.12.2013 (378.272 Euro)
DFG (SFB 855/1-2010 Teilprojekt A5), *Magnetoelektrische Verbundwerkstoffe - biomagnetische Schnittstellen der Zukunft: Herstellung von vertikal freistehenden magnetoelktrischen Kompositen,* 01.01.2010-31.12.2013 (339.840 Euro)
DFG (SFB 855/1-2010 Teilprojekt Z), *Magnetoelektrische Verbundwerkstoffe - biomagnetische Schnittstellen der Zukunft: wiss. Hilfskräfte,* 01.01.2010-31.12.2013 (29.600 EURO)
BMBF, *Anti-fouling - Entwicklung, Analyse und Wirksamkeitstests neuartiger Beschichtungen auf ZnO Nanostrukturbasis,* 01.03.2010-29.02.2012 (140.784 Euro)
DAAD, *Working Interships in Science and Engineering (WISE) Hochschulpraktika für indische Studierende 2010 für Herrn Prashant Goyal,* 01.06.-31.07.2010 (1.847 Euro)
University Kiel, *Beihilfe Exzellenzcluster: Unterstützung Fortbildung von Clusterdokteranden,* 01.03.2010-31.10.2012 (5.000 EURO)
DFG (Ad 183/5-2), *Heisenberg-Professur: Interdisziplinäre anwendungsnahe Forschung mit nanostrukturierten Materialien,* 01.07.2010-30.06.2012 (227.400 Euro)

Further Cooperation, Consulting, and Technology Transfer

University:

Dr. D. K. Avasthi, Materials Science Group, Nuclear Science Centre New Delhi, India, Experiments with ZnO,

Prof. Dr. T. Bosch, Zoologisches Institut und Museum (Sektion Biologie), Allgemeine Zoologie, CAU Kiel, Antibacterial properties of nanostructures,

Prof. Dr. F. Faupel, Institut für Materialwissenschaft - Materialverbunde, CAU Kiel, Various projects ranging from nanostructures to ultrahydrophobicity,

Dr. Größner-Schreiber, Dental materials,

Prof. Dr. M. Kern, Prof. Dr. K. Ludwig, Zahnmedizin, CAU Kiel, Chemical and microscopy on dental materials,

Prof. Dr. L. Kipp, Experimentelle und Angewandte Physik, CAU Kiel, Diffractive optics for contact lenses,

PD Dr. C. Ronning, Universität Jena, ZnO Nanobridges,

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, Carbon nanostructures of macroscopic expansion.

Research Institutes:

Prof. Dr. H.-G. Rubahn, Mads Clausen Institute, University of Southern Denmark, Interreg projects.

Industry:

Nanoproofed, Gleschendorf, BMBF-Projekt Anti-fouling,

Wöhlk, Schönkirchen, Examination of contact lenses.

Diploma, Bachelor and Master Theses

Torge Behrendt, *Influence of an electric field on the electrical properties of nanowires,* 08.06.2010
Victor Kaidas, *Untersuchung des Einflusses einer Co-Evaporation von Edelmetallen auf das Wachstumsverhalten von TeTraCain-HCl und Indometacin auf verschiedenen Substraten,* 14.06.2010
Christoph Chluba, *Optimierung des Batch-Prozesses zur Synthese von ZnO - Tetrapoden,* 03.08.2010
Stefanie Schlüter, *Kontrollierte Synthese von Nanostrukturen auf Eisenpartikeln,* 04.08.2010
Jannis Lemke, *Untersuchung zur Wasseraufnahme von nicht imprägnierten und imprägnierten Aktivkohlen, Ableitung von Kennlinien und Charakterisierung der Morphologie,* 02.09.2010
Sandra Nöhren, *Charakterisierung der Rissbildung von Epoxiharz-CNT-Kompositen,* 14.09.2010
Arnim Schuchardt, *Elektrische und piezoelektrische Charakterisierung von durch Flammentransport hergestellten Zinkoxidstrukturen,* 22.09.2010
Ingo Paulowicz, *Synthesis and characterization of SnO_2 micro- and nanostructures,* 27.09.2010
Stefan Freitag, *Synthese verschiedener ZnO-Microstrukturen,* 04.10.2010
Xin Wie Zhu, *Fabrication, characterization of multfunctional tetrapod-ZnO/PDMS composites for bioinspired applications,* 12.10.2010
Akash Bhatnagar, *Synthesis and study of ZnO micro- and nanostructures,* 18.10.2010
Iris Hölken, *Carbon Nano Tubes (CNT) in Titan: Optimierung verschiedener Herstellunsgvarianten zum Einbringen von CNTs in Titan über pulvermetallurgische Verfahren,* 19.10.2010
Tönjes Koschine, *A new method for the fast production of ZnO nanoparticles and their characterization,* 22.10.2010

Dissertations / Postdoctoral Lecture Qualifications

F. Spors, *Entwurf und Erzeugung neuartiger diffraktiver Optiken durch die Mikrostrukturierung von Kontaktlinsenoberflächen,* 10.06.2010

Publications

Published in 2010

S. Jebril, Y.K. Mishra, M. Elbahri, L. Kienle., H. Greve, E. Quandt, R. Adelung, *Using thin film stress for nanoscaled sensors,* Materials Science Forum, **638-642**, 2028 - 2033 (2010)

K. Rätzke, M. Wiegemann, M.Q. Shaikh, S. Harms, R. Adelung, W. Egger, P. Sperr, *Open volume in bioadhesive detected by positron annihilation lifetime spectroscopy,* Acta Biomaterialia, **6**, 2690 - 2694 (2010)

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Y.K. Mishra, S. Mohapatra, V.S.K. Chakravadhanula, N.P. Lalla, V. Zaporojtchenko, D.K. Avasthi, F. Faupel, *Synthesis and characterization of Ag-polymer nanocomposites,* J. Nanosci. and Nanotech., **10**, 2833 (2010)

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D.M. Gedamu, M. Kassab, S. Jebril, R. Adelung, *Nanowire-based sensors for chemical species (talk),* DPG-Frühjahrstagung 2010, Regensburg, Germany, 21.-26.03.2010

Y.K. Mishra, S. Kaps, V.S.K. Chakravadhanula, S. Jebril, L. Kienle, *Synthesis of different ZnO and other nanostructures by modified-VLS approach (talk),* DPG-Frühjahrstagung 2010, Regensburg, Germany, 21.-26.03.2010

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E.S.E.S.A. Zarie, S. Kaps, X. Jin, S. Wille, Y.K. Mishra, R. Adelung, *Fabrication of ZnO structures as templates for interaction with micoroorganisms (Poster)*, Third International Nanobio Conference 2010, Zürich, Schweiz, 24.-27.08.2010

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R. Adelung, *Nanomaterialien, Beispiele aus der Forschung (invited talk)*, Kolloquium FH-Flensburg, Flensburg, 02.11.2010

R. Adelung, *Simple integration of nanowires in devices (invited talk)*, Kolloquium TU-Clausthal, Clausthal, 24.-25.11.2010

Microanalysis of Materials

Research Focus and Methods: Our research projects aim at the understanding of microstructure-property relationships of functional materials and the synthesis of fundamental research, quantitative methodological approaches, and their applications in technology-oriented material developments. Particular emphasis is put on:

- microstructure research of thin film systems, interfaces, defects, and nanomaterials,

- quantitative methods of high-resolution and analytical transmission electron microscopy,

- nanoanalytics with electrons in materials and surface science.

The Centre of Materials Analysis (CMA) and the ''Kieler Nanolabor'' of the CAU (see TF almanac 2008) provide access to a number of methods for the nanoanalysis of materials. Techniques predominantly used in our research projects are the advanced high-resolution imaging (HRTEM, STEM/HAADF, EFTEM) and spectroscopic (EELS/ELNES, EDXS) methods of transmission electron microscopy (TEM), state-of-the-art image simulation, digital image analysis methods, as well as dual-beam FIB / SEM / EDX methods for focussed ion beam (FIB) TEM specimen preparation. The central instrument of the central TEM laboratory - coordinated by Dr. Andriy Lotnyk - is a FEI TECNAI F30 analytical transmission electron microscope, equipped with a GATAN GIF / TRIDIEM 863 Imaging Energy Filter with Multi-Scan CCD Cameras, and with specimen holders for temperature control and electron tomography for 3D object reconstruction. Software packages for state-of-the-art image simulation, digital image analyses, spectral data analyses, and exit-wave reconstruction from focal series, assist in the evaluation of the experimental data. Furthermore, a conventional Philips CM30 transmission electron microscope CTEM, a FEI XL 30 scanning electron microscope, and laboratories for conventional TEM specimen preparation - coordinated by Ms. C. Szillus - are available.

Course Teaching and Research Thesis Projects: study courses for bachelor and master students (teaching languages English, German) in the subject areas Materials Science, Analytical Methods in Materials Science, and Advanced Methods of Transmission Electron Microscopy, offers for thesis projects for Bachelor and Master students, and for dissertation projects.

Collaboration Offers for Research and Technology: R&D collaboration with research institutions and with industry, consulting and expert advice, funded project research and transfer of technology, continuing education ''Analytics of Materials for Research and Industry / Materialanalytik für Forschung und Industrie'' (Prof. W. Jäger, teaching languages German / English), www.uni-kiel.de/wiss-weiterbildung.

Results

We have applied advanced high-resolution imaging and spectroscopic techniques of transmission electron microscopy (conventional and aberration-corrected high-resolution TEM, electron diffraction, high-resolution STEM, and spectroscopic EDXS and EELS analyses) in comprehensive and quantitative research on interfaces, surfaces, and nanomaterials. The topics are as follows:

- quantitative TEM of multilayers for commercial synchrotron optics: methodological development oriented towards technology support,

- TEM of nanoparticle materials: quantitative nanoanalytics of metallic core-shell nanoparticles, nanocrystalline diamond, and embedded nanoparticles,

- oxide semiconductor nanostructures: fundamental research for growth and doping phenomena,

- TEM for improved high-efficiency solar cells: studies for concepts of defect and strain engineering.

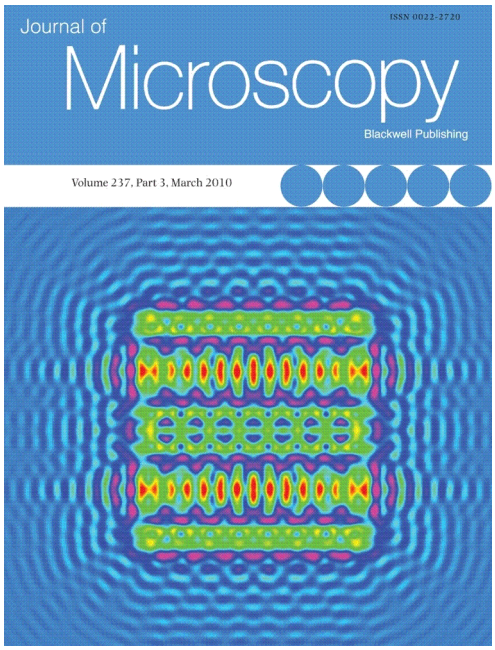


Fig. 1: Advantages of aberration correction for HRTEM investigation of complex layer compounds. From: E. Spiecker, M. Garbrecht, W. Jäger, K. Tillmann: Journal of Microscopy, Vol. 237, 3, 341 - 346, 2010. Selected for Cover Page of Journal Volume.

A. QUANTITATIVE STEM OF MULTILAYERS FOR COMMERCIAL SYNCHROTRON OPTICS

Dr. D. Häußler CAU. Diploma thesis project: Ulrich Roß. Cooperations: Dr. M. Störmer, Institute of Materials Research, Helmholtz-Zentrum Geesthacht, Germany. Dr. J. Wiesmann, F. Hertlein, U. Heidorn, Incoatec GmbH, Geesthacht, Germany. Dr. C. Morawe, ESRF Grenoble, France.

Our quantitative characterizations by scanning transmission electron microscopy (STEM) have focused on developing methods for the assessment of layer growth, coating control, and the reflectivity properties of multilayer systems for X-ray optics. More recent investigations focused on characterizations for developing state-of-the-art thin film X-ray optical multilayer coatings for advanced X-ray analytical equipment and for conventional synchrotron beam lines and FEL sources. The multilayer systems were fabricated by the INCOATEC GmbH Geesthacht and the GKSS Helmholtz-Centre Geeshacht, Institute for Materials Research. The development and fabrication of multilayer coatings for X-ray optics are an excellent example of nanotechnology with a large interdisciplinary scope addressing new products for advanced applications in materials science, semiconductor industries, as well as in life science (please consult, for instance, the website www.incoatec.de for more details on products and applications).

Aperiodic multilayer systems are used as advanced X-ray optical components for large spectral bandwidth synchrotron applications. The recent work focused on high-angle annular dark-field scanning TEM (HAADF-STEM) for cross-section imaging of periodic and aperiodic tungsten-carbon multilayer systems and their interfaces and the quantitative assessment of reflectivity properties.

B. TEM OF NANOPARTICLE MATERIALS - Metallic Nanoparticles

Dr. D. Häußler CAU. Cooperation: Dr. B. Schaffer, Dr. F. Hofer, Institute for Electron Microscopy, Graz University of Technology, Graz, Austria and SuperSTEM Facility Daresbury, UK., M.Sc. Fu Liu, Prof. X. Zhang, Dept. Materials Science and Engineering, Zhejiang University, Hangzhou, China.

Fig. 2: E-MRS Symposium Q Quantitative electron microscopy for research and industry, E-MRS Spring Meeting in Strasbourg, France, June 7 - 11, 2010 (Meeting Report inside): E-MRS Graduate Student Award Winners Vasfi Burak Özdöl ∗, Stuttgart Centre for Electron Microscopy, Max Planck Institute for Metals Research, Stuttgart (right) and Marina Pfaff, Karlsruhe Institute of Technology, Karlsruhe, Germany (left) receiving their awards from Thomas Lippert, Conference Chairman (left), and Francesco Priolo, E-MRS President (centre). Pictures courtesy of Wolfgang Jäger and E-MRS.
∗ V. Burak Özdöl graduated successfully from the Faculty of Engineering with a master degree in Materials Science and Engineering. He worked on his master thesis as a member of our Microanalysis of Materials group (See almanac 2006).
From: Wolfgang Jäger (Kiel), Rafal Dunin-Borkowski (Copenhagen-Lyngby), Paul A. Midgley (Cambridge) and Etienne Snoeck (Toulouse): E-MRS Spring Meeting in Strasbourg, France, June 7 - 11, 2010, Meeting Report E-MRS Symp Q Quantitative electron microscopy for research and industry. Published in: MICROSCOPY AND ANALYSIS, SEPTEMBER 2010, 29.

Metallic core-shell nanoparticles for applications in catalysis and as data storage materials offer the possibility to tailor macroscopic properties generally not obtained by single-component particles. Pd-Sn core-shell nanoparticles fabricated by a solution-impregnation method on multi-wall carbon nanotubes were characterized by a combination of spectroscopic and nanodiffraction methods and by imaging high-resolution and scanning transmission electron microscope (TEM) methods. This extensive methodological approach is directed towards demonstrating the feasibility to precisely analyse and map structure, morphology, and chemical composition of nanoparticles.

For metallic tin-palladium particles with diameters as small as 20 nm our analyses reveal that even for complex polycrystalline particles a semi-quantitative analysis of structure and composition on the nanometer scale appears to become possible.

C. TEM OF NANOPARTICLE MATERIALS - Nanocrystalline Diamond

Dipl.-Ing. Ch. Dieker CAU. Cooperation: Dr. O. Williams, Prof. Ch. Nebel, Fraunhofer Institute for Applied Solid State Physics FHG-IAF. Dr. K. Tillmann, ERC Helmholtz-Zentrum Jülich.

Diamond foam from Nano-Crystalline Diamond (NCD) films is promising for demanding applications such as fuel cells, water purification systems, and molecular traps where chemical stability, biocompatibility and longevity are required. Nano-crystalline diamond prepared by chemical vapour deposition (CVD) consists of diamond crystals (sp3 bonding of carbon) surrounded by non-diamond carbon (sp2 bonding). The ratio of sp2/sp3 is controlled by variation of the ratio CH_4/H_2 during the CVD growth. Thermal annealing in air is applied to remove graphite and amorphous carbon and to generate a porous foam structure with sub-nanometer voids in the film.

The microstructure of particles of so-called ultrananocrystalline diamond suspensions with sizes in the nanometer range can be characterized by high-resolution TEM. With a number of experiments, the potential of aberration-corrected high-resolution TEM for atomic scale imaging of such low atomic number materials has been explored in collaboration with Dr. K. Tillmann, Ernst Ruska-Center Jülich.

D. 3D ELECTRON TOMOGRAPHY OF NANOPARTICLES

Dipl.-Ing. Ch. Dieker. Cooperation: Dr. Ch. Kübel, Group Leader Transmission Electron Microscopy, Karlsruhe Institute of Technology (KIT), Institute of Nanotechnology (INT). D. Esser, H.J. Penkalla, Institute of Energy Research IEF-2, Helmholtz-Zentrum Jülich. Dr. U. Dahmen, NCEM National Center for Electron Microscopy, LBL Berkeley, CA, USA.

Electron tomography is now established as a powerful tool to image complex structures in 3D with nanometer resolution. In materials science, the use of BF-TEM tomography is limited as BF images of crystalline materials do not fulfil the projection requirement and thus cannot be used for tomography of most crystalline samples. To fulfil the projection criterion, alternative imaging techniques have been explored for use in tomography. The most universal approach for tomography in materials science is high-angle annular dark field (HAADF) imaging in a scanning transmission electron microscope (STEM). In addition to the advances in tomography acquisition, new reconstruction algorithms are also significantly improving tomography results.

We perform a methodologically oriented study aiming at the high-resolution analyses of nanometer-scale particles and inclusions formed by diffusion doping in III-V compound semiconductor materials by applying HAADF-STEM tomography on carefully prepared specimens fabricated by focused ion beam (FIB) preparation techniques. Our first investigations reveal that a complete 3D characterization of structure, morphology and composition of complex nanoinclusions can be performed successfully when HAADF-STEM tomography is combined with spatially resolved energy-dispersive X-ray spectroscopy.

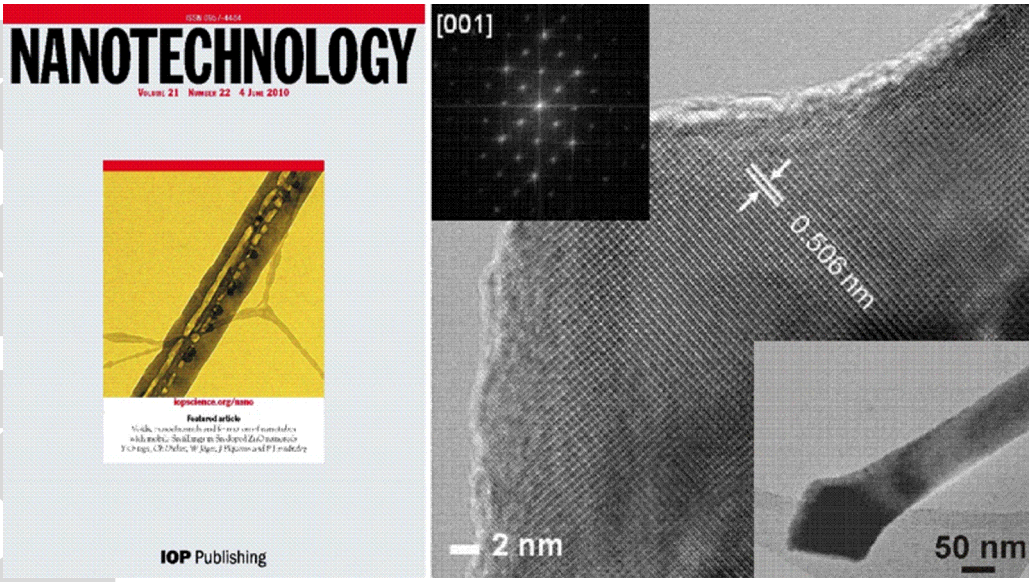


Fig. 3: (a) ∗ DOPED ZINC OXIDE (ZnO) NANOSTRUCTURES. Bright-field TEM micrograph of single Sn-doped ZnO nanorod with distinct core and shell regions. (b) DOPED INDIUM OXIDE (In_2O_3) NANOSTRUCTURES. HRTEM lattice image, related SAD pattern in [001] zone axis orientation, and a bright-field image of a nanorod.

∗ From: Y. Ortega, Ch. Dieker, W. Jäger, J. Piqueras, P. Fernández: Voids, nanochannels and formation of nanotubes with mobile Sn fillings in Sn-doped ZnO nanorods. Nanotechnology 21, 225604 (2010). Selected for Cover Page of Journal Volume.

E. OXIDE SEMICONDUCTOR NANOMATERIALS

Dipl.-Ing. Ch. Dieker, Dr. Dietrich Häussler CAU. Cooperation: Prof. Dr. J. Piqueras, Prof. Y. Ortega Villafuerte, Dr. D. Maestre Varea, Physics Department, Universidad Complutense de Madrid, Spain.

Advanced imaging and spectroscopic techniques of electron microscopy play a crucial role in characterizing the

microstructure and the structure-property relationships of nanostructured functional materials and interfaces. Oxide semiconductor nanostructured materials, such as ZnO, In_2O_3, or SnO_2 nanostructures, grown by catalyst-free vapour solid growth from different precursors show various morphologies and spatially varying cathodoluminescence (CL) properties. We investigated the microstructure and the interface phenomena for a variety of rod-like nanostructures by bright-field, dark-field, high-resolution TEM imaging and scanning TEM in the HAADF (so called Z-contrast) mode, combined with composition analyses by energy-dispersive x-ray microanalysis (EDX). ZnO functional materials are of interest for transparent windows in solar cells, in ultra-violet (UV) lasers and light emitting diodes, or as field emitters in flat-panel displays. Doping of In_2O_3 with Sn is of interest for use as ITO (indium tin oxide) and, when combined with the small dimensions of nanostructures, may possess improved electronic properties for potential applications in nanoelectronics and in optoelectronics.

The TEM investigations reveal that, for the case of Sn-doping, the ZnO rod-like nanostructures are characterized by distinct core and shell regions, with the core regions frequently containing either voids or other defects (Fig. 3a). Various growth phenomena are observed for In_2O_3. Fig 3b shows results of a high-resolution TEM investigation of the tip region of an arrow-shaped nanorod of In_2O_3.

F. TEM FOR IMPROVED HIGH-EFFICIENCY SOLAR CELLS

Dipl.-Ing. Ch. Dieker. Cooperation: Dr. F. Dimroth, Dr. A. Bett, Fraunhofer Institute for Solar Energy Systems FhG-ISE Freiburg.

Our investigations aimed at the development of new concepts for defect engineering and at the control of strain in heteroepitaxial crystal layer growth for high-efficiency solar cells were continued. Highest efficiencies for solar energy conversion are currently achieved for so-called metamorphic solar cell structures which consist of crystalline layer stacks based on III-V compound semiconductor materials on germanium and on silicon substrates. A prerequisite for achieving the highest efficiencies are active regions of the solar cell that remain relatively free of defects. Concentrating the sunlight onto the small area of such solar cells by an appropriate lens system leads to even higher efficiencies. This technique is applied in photovoltaic concentrator systems and is of interest for solar energy power stations in countries with high solar radiation and for power generation in satellites. By using a GaInP/GaInAs layer structure on a Ge substrate and by concentrating the sunlight by a factor of 454 onto a small 5 mm^2 multi-junction solar cell made from this system, the researchers at the Fraunhofer Institute for Solar Energy Systems ISE have achieved an efficiency of 41.1 % for the conversion of sunlight into electricity. This represented a world record in efficiency (as of Jan14, 2009) reached for multi-junction solar cells. Our microstructure research focused on concepts of defect engineering with buffer layer systems based on GaInNAs layers and on GaInP layers.

Personnel

Head of the group: Prof. Dr. Wolfgang Jäger; Secretary: Katrin Brandenburg (50%)

Scientific Staff:

Dipl.-Ing. Christel Dieker	01.01.-31.12.2010	CAU
TEM of layer systems and nanomaterials and preparation for TEM		
Dr. Dietrich Häußler	01.01.-31.12.2010	CAU
Analytical TEM of layer systems and nanomaterials		
Dr. David Maestre Varea	01.01.-04.05.2010	Ministerio de Ciencia e innov.
Guest scientist, Facultad de Ciencias Fisicas, UCM - Universidad Complutense Madrid, Spain		
Dr. Yanicet Ortega Villafuerte	16.10.-15.12.2010	Ministerio de Ciencia e innov.
Guest scientist, Facultad de Ciencias Fisicas, UCM - Universidad Complutense Madrid, Spain		

M.Sc. Burcu Ögüt 01.01.-31.12.2010

Investigations of metallic nanomaterials by energy-filter TEM (co-supervision of external Dissertation research work by Prof. W. Jäger, in collaboration with Max-Planck-Institut für Metallforschung, Stuttgart, Dr. P. Van Aken)

M.Sc. V. Burak Özdöl 01.01.-31.12.2010

Transmission electron microscopy of Si-Ge heterostructures (co-supervision of external Dissertation research work by Prof. W. Jäger, in collaboration with Max-Planck-Institut für Metallforschung, Stuttgart, Dr. P. Van Aken)

Lectures, Seminars, and Laboratory Course Offers

Winter 2009/2010

Analytics I, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
Wolfgang Jäger

Transmission Electron Microscopy I, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
Wolfgang Jäger

Analytical Methods in Materials Research, 2 hrs Seminar/Week,
Wolfgang Jäger

Materialwissenschaft III, 3 (+ 1) hrs Lecture (+ Exercises)/Week,
Wolfgang Jäger

Praktikum: Analytische Methoden, 4 hrs Lab/Week,
N. N. (+ Marlies Schwitzke, Klaus Rätzke, Dirk Meyners, Mady Elbahri, Malte Leisner, Dietrich Häußler)

Summer 2010

Analytics II, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
Wolfgang Jäger

Transmission Electron Microscopy II, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
Wolfgang Jäger

Microstructure Research of Thin Films and Nanostructures, 2 hrs Seminar/Week,
Wolfgang Jäger

Einführung in die Materialanalytik, 2 hrs Lecture/Week,
Wolfgang Jäger

Laboratory Course: Functional Materials, 4 hrs Lab/Week,
N. N. (+ Mohammed Qasim Shaikh, Amit Kulkarni, Malte Leisner, Dietrich Häußler)

Winter 2010/2011

Analytics, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
Wolfgang Jäger

Transmission Electron Microscopy I, 2 (+ 1) hrs Lecture (+ Exercises)/Week,
Wolfgang Jäger

Analytical Methods in Materials Research, 2 hrs Seminar/Week,
Wolfgang Jäger

Materialwissenschaft III, 3 (+ 1) hrs Lecture (+ Exercises)/Week,
Wolfgang Jäger

Third-Party Funds

EU, *MACAN - Merging Atomistic and Continuum Analysis of Nanometer Length-Scale Metal-Oxide Systems for Energy and Catalysis Applications*, 01.07.2009-30.06.2013 (29158 EUR)

DAAD, *Reisekostenzuschuss zur Teilnahme von Herrn Prof. Dr. Wolfgang Jäger an dem 17th International Microscopy Congress, Rio de Janeiro, Brasilien*, 19.-24.09.2010 (1517 EUR)

Ministerio de Ciencia e Innovacion, Madrid, Spain, *Gastwissenschaftler Aufenthalt, Dr. Yanicet Ortega Villafuerte*, 16.10.-15.12.2010 (x EUR)

Ministerio de Ciencia e Innovacion, Madrid, Spain, *Gastwissenschaftler Aufenthalt, Dr. David Maestre Varea*, 05.05.2009-04.05.2010 (x EUR)

Further Cooperation, Consulting, and Technology Transfer

Technology-oriented collaborations with industry and other research institutes:

continued collaboration in the application of advanced TEM methods for the development of nanomaterials for high-capacity hydrogen storage (Dr. M. Dornheim, Dr. U. Bösenberg, GKSS Helmholtz Centre Geesthacht, Dept. Nanotechnology),

continued collaboration in the application of advanced TEM methods for the development of commercial X-ray optical components with Incoatec GmbH Geesthacht and with the GKSS Helmholtz Centre Geesthacht, Institute of Materials Research, (Dr. M. Stoermer),

continued collaboration with Fraunhofer Institute for Solar Energy Systems ISE, (Dr. F. Dimroth, Dr. A. Bett, Prof. E. Weber), on the development of concepts for defect engineering for high-efficiency solar cells,

collaboration in the application of advanced TEM methods for the development of nanoparticle materials for solar energy harvesting,(Prof. Ch.-H. Fischer), Helmholtz-Centre Berlin for Materials and Energy, Berlin.

continued collaboration with Fraunhofer Institute for Applied Solid State Physics IAF,(Dr. O. Williams, Prof. Ch. Nebel), on the development of nanocrystalline diamond.

Further Collaborations with research institutions:

continued research collaboration on quantitative TEM characterisations of nanolayer systems for X-ray optics with, European Synchrotron Radiation Facility, Grenoble, France (Dr. C. Morawe),

continued research collaboration (started in 2008) with Physics Department, Universidad Complutense de Madrid, Spain, (Prof. Dr. J. Piqueras, Prof. Y. Ortega Villafuerte, Dr. D. Maestre Varea) on TEM characterisations of oxide semiconductor nanomaterials.

Collaborations with Universities:

continued research collaboration (CAU funding support) with Materials Science and Engineering and State Key Laboratory for Silicon Materials, Zhejiang University, Hangzhou, China, (Prof. Dr. X. Zhang, M.Sc. Fu Liu) on TEM characterisation for processing of nanoparticle composites,

co-supervision (Prof. W. Jäger) of PhD theses research work at the Max-Planck-Institute for Metal Research, Stuttgart, Germany (Stuttgart Centre for Electron Microscopy),(Dr. P. van Aken, Dr. F. Philipp, Dr. W. Sigle), on TEM characterisations of semiconductor heterostructures and of metal nanoparticles,

DFG Graduate School Human Development in Landscapes at the CAU (Coordination Prof. J. Müller CAU) - member of the board of directors, lecture offers on methods of electron microscopy and materials analysis (Prof. W. Jäger).

Publications

Published in 2010

D. Häußler, U. Roß, B. Ögüt, E. Spiecker, W. Jäger, C. Morawe, F. Hertlein, U. Heidorn, J. Wiesmann, *Aperiodic W/B4C Multilayer Systems for X-Ray Optics: Quantitative Determination of Layer Thickness by HRTEM, HAADF-STEM, and X-Ray Reflectivity*, Surface and Coatings Technology, **204**, 1929 - 1932 (2010)

Y. Ortega, Ch. Dieker, W. Jäger, J. Piqueras, P. Fernández, *Voids, nanochannels and formation of nanotubes with mobile Sn fillings in Sn-doped ZnO nanorods (Selected for Cover Page of Journal Volume)*, Nanotechnology, **21**, 225604 (2010)

E. Spiecker, M. Garbrecht, W. Jäger, K. Tillmann, *Advantages of aberration correction for HRTEM investigation of complex layer compounds (Selected for Cover Page of Journal Volume)*, Journal of Microscopy, **237**, **3**, 341 - 346 (2010)

C. Kübel, Ch. Dieker, D. Esser, H.J. Penkalla, W. Jäger, *Electron Tomography of Nanoparticles in Zn-doped GaAs Semiconductors*, Proc. IMC17 17th International Microscopy Congress, Rio de Janeiro, **I7526**, (2010)

D. Häussler, U. Ross, E. Spiecker, W. Jäger, Ch. Morawe, F. Heidorn, J. Wiesmann, *Quantitative HAADF-STEM Characterizations of Layer Thickness and Interface Roughness of W-C Multilayer Systems for X-ray Optics*, Proc. IMC17 17th International Microscopy Congress, Rio de Janeiro, **M3502**, (2010)

Y. Ortega, Ch. Dieker, W. Jäger, J. Piqueras, P. Fernández, *TEM Investigation of ZnO nanorods with voids and with Sn core fillings fabricated by catalyst-free growth*, Proc. IMC17 17th International Microscopy Congress, Rio de Janeiro, **M5537**, (2010)

D. Maestre, D. Haeussler, A. Cremadas, J. Piqueras, W. Jäger, *Nanopipe Formation in In_2O_3 Nanorods*, Proc. IMC17 17th International Microscopy Congress, Rio de Janeiro, **M5526**, (2010)

Md.N.K. Bhuiyan, M. Menghini, Ch. Dieker, J.W. Seo, J.-P. Locquet, R. Vitchev, Ch. Marchiori, *Epitaxial Dy2O3 Thin Films Grown on Ge(100) Substrates by Molecular Beam Epitaxy*, MRS Symposium Proceedings, (2010)

W. Jäger, R. Dunin-Borkowski, P.A. Midgley, E. Snoeck, *Meeting Report E-MRS Symp Q Quantitative electron microscopy for research and industry*, MICROSCOPY AND ANALYSIS, September 2010, 29 (2010)

Y. Ortega, Ch. Dieker, W. Jäger, P. Fernández, J. Piqueras, *Nanorod networks and core-shell structures of doped ZnO*, Proc. 6th Nanoscience and Nanotechnology Conference (NanoTR-VI), June 15 - 18, 2010, Izmir, Turkey, 74 (2010)

D. Maestre, D. Häussler, A. Cremades, W. Jäger, J. Piqueras, *Nanopipes in In_2O_3 nanorods grown by a thermal treatment*, Crystal Growth and Design, online version http:// pubs.acs.org/doi/full/10.1021/cg101350f, (2010)

O.A. Williams, J. Hees, Ch. Dieker, W. Jäger, L. Kirste, C.E. Nebel, *Size-Dependent Reactivity of Diamond Nanoparticles*, ACS NANO, **4**, **8**, 4824 - 4830 (2010)

Presentations

Y. Ortega, Ch. Dieker, W. Jäger, P. Fernández, J. Piqueras, *Defects and nanochannels in doped zinc oxide nanorods grown by thermal methods (oral presentation)*, FMNT Conference Functional Materials and Nanotechnologies, Riga, Latvia, 16.-19.03.2010

W. Jäger, *Transmission Electron Microscopy of Diffusion and Interface Phenomena of Functional Materials (Plenary Talk)*, DSS 2010 International Workshop Grain Boundary Diffusion, Stresses and Segregation, www.dss.misis.ru, Moscow, Russia, 01.-04.06.2010

D. Häußler, U. Ross, U. Heidorn, F. Hertlein, J. Wiesmann, W. Jäger, *Quantitative Transmission Electron Microscopy of W/C Multilayer Coatings for X-ray Optics (oral presentation)*, E-MRS 2010 Spring Meeting, Strasbourg, France, 07.-11.06.2010

D. Häußler, B. Schaffer, F. Liu, F. Hofer, X.B. Zhang, W. Jäger, *Analytical STEM investigations of Sn-Pd Nanoparticles with Core-Shell Structures (poster)*, E-MRS 2010 Spring Meeting, Strasbourg, France, 07.-11.06.2010

D. Maestre, D. Häussler, A. Cremades, J. Piqueras, W. Jäger, *TEM study of In2O3 and Sn doped In2O3 nanostructures grown by thermal treatment (oral presentation)*, E-MRS 2010 Spring Meeting, Strasbourg, France, 07.-11.06.2010

Y. Ortega, Ch. Dieker, W. Jäger, J. Piqueras, P. Fernández, *TEM Investigation of Sn-ZnO nanorod heterostructures (oral presentation)*, E-MRS 2010 Spring Meeting, Strasbourg, France, 07.-11.06.2010

W. Jäger, Y. Ortega, Ch. Dieker, D. Maestre, D. Haeussler, P. Fernández, A. Cremades, J. Piqueras, *TEM of Defects and Interfaces in Oxide Semiconductor Nanostructures*, E-MRS 2010 Spring Meeting, Strasbourg, France, 07.-11.06.2010

W. Jäger, Y. Ortega, Ch. Dieker, D. Maestre, D. Haeussler, P. Fernández, A. Cremades, J. Piqueras, *TEM of Defects and Interfaces in Oxide Semiconductor Nanostructures (Invited)*, PICS 2010 Workshop on Interfaces in Materials, CINaM, Université de la Méditerranée, Marseille, France, 13.-17.06.2010

D. Häußler, U. Roß, U. Heidorn, F. Hertlein, J. Wiesmann, W. Jäger, *A Scanning TEM Method to Locally Determine Layer Dimensions and Interface Roughness for Multilayer Coatings with Ultimate Accuracy (poster)*, MSE 2010 Materials Science and Engineering Congress, Darmstadt, Germany, 24.-26.08.2010

W. Jäger, D. Häußler, U. Roß, E. Spiecker, E. Janocha, B. Ögüt, V.B. Özdöl, U. Heidorn, F. Hertlein, J. Wiesmann, M. Störmer, C. Morawe, *Multilayer Coatings for X-ray Optics (Invited)*, 12th Annual Conference YUCOMAT 2010, www.mrs-serbia.org.rs, Herceg Novi, Montenegro, 06.-10.09.2010

D. Maestre, D. Häußler, A. Cremades, J. Piqueras, W. Jäger, *Nanopipe Formation in In_2O_3 Nanorods (poster)*, 17th International Microscopy Congress, Rio de Janeiro, Brazil, 19.-24.09.2010

D. Häußler, U. Roß, E. Spiecker, W. Jäger, C. Morawe, U. Heidorn, J. Wiesmann, *Quantitative HAADF-STEM Characterizations of Layer Thickness and Interface Roughness of W-C Multilayer Systems for X-ray Optics (oral presentation)*, 17th International Microscopy Congress, Rio de Janeiro, Brazil, 19.-24.09.2010

C. Kübel, Ch. Dieker, D. Esser, H.J. Penkalla, W. Jäger, *Electron Tomography of Nanoparticles in Zn-Doped GaAs Semiconductors*, IMC17 17th International Microscopy Congress, Rio de Janeiro, Brazil, 19.-24.09.2010

Y. Ortega, Ch. Dieker, W. Jäger, J. Piqueras, P. Fernández, *TEM Investigation of ZnO nanorods with voids and with Sn core fillings fabricated by catalyst-free growth*, IMC17 17th International Microscopy Congress, Rio de Janeiro, Brazil, 19.-24.09.2010

W. Jäger, *Transmission Electron Microscopy of Interface and Defect Phenomena of Functional Materials*, Fraunhofer Institute for Solar Energy Systems ISE, Freiburg, Germany, 03.12.2010

W. Jäger, *Transmission Electron Microscopy of Interface and Defect Phenomena of Functional Materials*, Max-Planck-Institut für Metallforschung und Institut für Theoretische und Angewandte Physik der Universität Stuttgart, Seminar zur Physik der Kondensierten Materie, Stuttgart, Germany, 21.12.2010

D. Maestre, D. Häussler, A. Cremades, W. Jäger, J. Piqueras, *Nanopipes in Thermally Grown Indium Oxide Nanowires (poster)*, MRS Fall Meeting 2010, Boston, U.S.A., 29.11.-03.12.2010

Further Activities and Events

E-MRS Spring Meeting in Strasbourg, France, June 7 - 11, 2010, Symposium Q: Quantitative electron microscopy for research and industry

Meeting Report

A symposium on quantitative electron microscopy for research and industry was held during the E-MRS 2010 Spring Meeting in Strasbourg, France, June 7 - 11, 2010. The symposium was organized by Wolfgang Jäger, Univ. of Kiel, Germany, Rafal Dunin-Borkowski, Technical Univ. of Denmark, Lyngby, Paul Midgley, Univ. of Cambridge, UK, and Etienne Snoeck, CEMES-CNRS Toulouse, France.

The symposium provided a forum for researchers interested in applying quantitative methods of electron microscopy and spectroscopy to materials research in different technology fields, such as electronics, optics, magnetics, energy and environment, engineered materials, nanosystems, soft matter and bioscience. This symposium was the first of its kind, with more than 60 contributions received from 19 countries, including Brazil, Israel, Japan, and the USA. Many participants of the symposium explicitly expressed their positive opinion about the scientific quality and the topical subject areas

of this symposium: some suggested repeating this style of symposium at regular intervals within the series of E-MRS meetings. Numerous excellent contributions by scientists from industry, research institutions, and universities demonstrated convincingly the importance of quantitative electron microscopy methods in materials research, in applications dedicated to the development of new materials, and for the advanced analysis of materials in current areas of technology.

Part of the broad spectrum of topical areas was reflected by the invited speakers with their excellent contributions: 3D imaging for nano-electronics (Hugo Bender, IMEC Leuven, Belgium); 3D EBSD tomographic orientation microscopy (Dierk Raabe, Max-Planck-Institut für Eisenforschung, Düsseldorf, Germany); In-situ electron microscopy in an aberration-corrected STEM (Florian Banhart, Université de Strasbourg, France); Materials science applications with a new electron energy-loss spectrometer (Gerald Kothleitner, FELMI, Graz University of Technology, Austria); Magnetic imaging in a TEM on materials for future high density media (Pascale Bayle - Guillemaud, CEA-Grenoble, France); Transmission electron microscopy studies of aluminium alloys (John C. Walmsley, SINTEF Materials and Chemistry and Norwegian University of Science and Technology, Trondheim, Norway); Using electron microscopy to measure interface energy (Wayne D. Kaplan, Technion Israel Institute of Technology, Haifa, Israel); and Quantitative electron microscopy to characterize solid oxide fuel cell degradation (Aicha Hessler-Wyser, CIME and Laboratory of Industrial Energy Systems, Ecole Polytechnique Fédérale de Lausanne, Lausanne, Switzerland).

During the symposium two graduate student awards were made for outstanding achievements of quantitative electron microscopy in materials science. The awards went to Marina Pfaff, Karlsruhe Institute of Technology, Karlsruhe, Germany, for her presentation entitled ''Semi-empirical equation for electron scattering at low energies in thin films consisting of light elements'' and to Vasfi Burak Özdöl ∗, Stuttgart Centre for Electron Microscopy, Max Planck Institute for Metals Research, Stuttgart, Germany, for his research on „Strain Mapping by Dark-Field Inline Electron Holography" in the characterization of novel semiconductor devices.

Wolfgang Jäger (Kiel), Rafal Dunin-Borkowski (Copenhagen-Lyngby), Paul A. Midgley (Cambridge) and Etienne Snoeck (Toulouse): E-MRS Spring Meeting in Strasbourg, France, June 7 - 11, Meeting Report E-MRS Symp Q Quantitative electron microscopy for research and industry. Published in: MICROSCOPY AND ANALYSIS, SEPTEMBER 2010, 29

∗ V. Burak Özdöl graduated successfully from the Faculty of Engineering with a master degree in Materials Science and Engineering. During his master thesis he has been member of our Microanalysis of Materials group (See almanach 2006).

Selected Further Activities Prof. Wolfgang Jäger:

chairman of Microscopy Conference MC 2011 Kiel, August 28 - September 2, 2011, Organised by the DGE - German Society for Electron Microscopy e.V. in collaboration with European Microscopy Society EMS, Nordic Microscopy Society SCANDEM, Polish Microscopy Society PTMi, Scientists from Research Institutions in Estonia, Latvia, Lithuania, and St. Petersburg, Russia, conference Topics: Instrumentation and Methods, Materials Science, Life Sciences, www.mc2011.de,

expert consultant for a National Research Program of the FNSNF Swiss National Science Foundation, Berne, Switzerland,

expert consultant for National Research Project Proposals for the Ministry of Science and Technological Development, Republic of Serbia, Belgrade, Serbia,

expert consultant for research funding agencies in Germany (DFG and others) and abroad,

guest Editor of Springer Journal of Materials Science,

reviewer for several international scientific journals,

member of board of directors DFG CAU Graduate School ''Human Development in Landscapes'',

E-MRS 2010 European Materials Research Society E-MRS Spring Meeting 2010, Strasbourg, France, June 7 - 11, 2010: Organization of a symposium on ''Quantitative Electron Microscopy for Research and Industry'', Co-chairs: R.

Dunin-Borkowski, CEN Technical University, Kongens Lyngby, Denmark, P. A. Midgley, University of Cambridge, UK, E. Snoeck CEMES-CNRS Toulouse, France, www.emrs-strasbourg.com,

MACAN Conference 2010, Bohinj, Slovenia, July 25 - 28, 2010: Conference on ''Merging Atomistic and Continuum Analysis of Nanometer Length-Scale Metal-Oxide Systems for Energy and Catalysis Applications (FP7-NMP-2009-CSA-233484 MACAN)''and MACAN Partner Meeting,

IMC-17 2010 17th International Microscopy Congress, Rio de Janeiro, Brazil, 19 - 24 September 2010: Organisation of Session M-5 Semiconductors and LSI Device Materials, Co-Chair: Dr. Se Ahn Song, Samsung Electronics Co., Korea, www.imc17.com,

E-MRS 2011 Spring Meeting, Nice, France, May 9 - 13, 2011, Symposium A : MACAN11: Reconciling atomistic and continuum approaches to interfaces - member of the scientific committee, www.emrs-strasbourg.com,

IUMAS-V 2011 5th Congress International Union of Microbeam Analysis Societies, Seoul, Korea, May 22 - 27, 2011 - Co-organisation of Session AM5 on Thin Film Analysis, www.iumas5.org,

EM2011 International Conference on Electron Microscopy of Solids, Wisla, Poland, June 26 - 30, 2011 - Member of the International Advisory Committee, http://em2011.us.edu.pl,

YUCOMAT 2011 13th Annual Conference of Materials Research Society Serbia, Herceg Novi, Montenegro, 05-09 September, 2011 - Member of the International Advisory Committee, www.mrs-serbia.org.rs/firstannouncement11.html,

Guests in 2010

Dr. Frank Dimroth, Fraunhofer-Institut für Solare Energiesysteme, Freiburg, Germany, Colloquium of the Faculty of Engineering „Entwicklung von höchsteffizienten III-V Mehrfachsolarzellen am Fraunhofer ISE" , 26.04.2010

Dr. Christian-Herbert Fischer, Helmholtz Zentrum Berlin, Berlin, Germany, Colloquium of the Faculty of Engineering „ILGAR (Ion Layer Gas Reaction) und Sprühpyrolyse - zwei vielseitige low-cost Methoden zur konformen Abscheidung dünner Halbleiter- und Isolatorschichten" , 03.05.2010

Prof. Dr. Pierre Stadelmann, CIME-EPFL Lausanne, Switzerland: Tutorials on ''JEMS Computer Simulation Techniques for TEM''21. - 25.06.2010

Offers for the general public and for schools

Prof. Wolfgang Jäger ''Faszination Nanokosmos - Mit Elektronen zu den Grenzen des Sichtbaren'' and ''Good vibrations - mit Elektronen Musik Sehen'', SHUG Schleswig-Holsteinische Universitätsgesellschaft and CAU Programme ''Uni kommt zur Schule''.

Nanochemistry and Nanoengineering

The research group Nanochemistry and Nanoengineering is based in the Material Science Institute of the engineering faculty of the Christian Albrechts University of Kiel as well as the Institute of Polymer Research at Helmholtz Zentrum Geesthacht (HZG), a division of the Helmholtz Association (HGF). Our research interests include the design, synthesis, patterning and self-assembly of nanoscale materials for applications in optics, electronics, photonics, sensing, separation, biology, and medicine. Current research activities are concentrated on controlled fabrication and spatial distribution of nanoscale materials which are the foundational principles of multifunctional and smart nanoengineered technologies. We applied several methods including wet chemical, physical, and electrospinning approaches.

Results

Wet Chemical

For fabrication of nanoparticles we applied our patented technique, namely the Leidenfrost approach. This technique is the first to use liquid interfaces at Leidenfrost conditions as a chemical reactor specialized for nanoproducts from solution. The results are very promising and control over the morphology of several nanomaterials i.e. ZnO, TiO_2, Au and Ag has been achieved. However, the minimum size of these nanomaterials is still around 100 nm and further research is needed to further lower their dimensions. The planned functionalization of nanoparticles has also started. Preliminary experiments using functionalized and nonfunctionalized nanoparticles for biomedical applications (i.e. cancer therapy, immunotherapy) have also been initiated. Our main attention in 2010 was given to the synthesis of nanoparticles and nanopatterning of polymers aiming to develop flexible and cost effective photonic, electronic and sensoric devices. For instance, fabrication of highly monodispersed polystyrene nanoparticles in the range of 50 nm up to 600 nm has been successfully achieved using an emulsion technique. Fig. 1a shows one of our fabricated photonic latexes where an optical image of irradiance colour of 3D photonic materials is shown in Fig.1b.

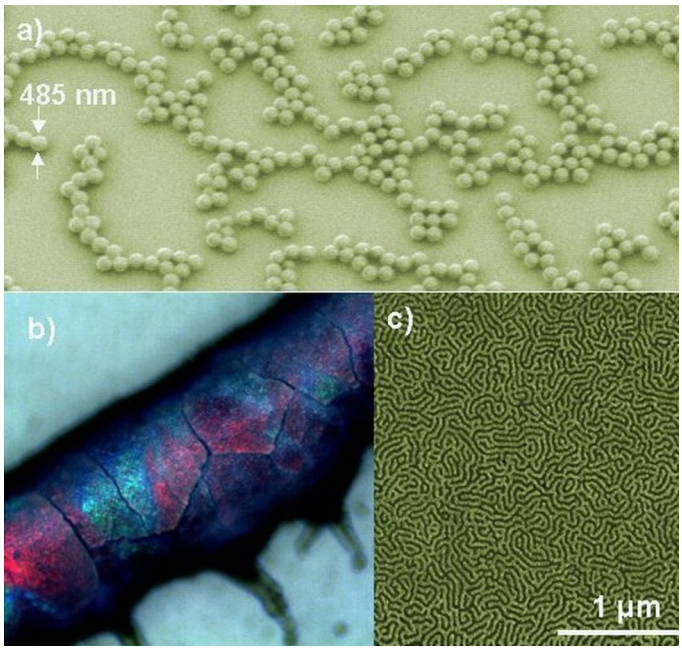


Fig. 1: a) Coloured SEM of monodispersed PS Latex, b) Optical image of 3D photonic latex, C) Coloured phase AFM of block copolymer thin film patterning.

An attractive ''unconventional'' lithographic technique to pattern periodic, sub-100nm features using self-assembled block copolymer thin films, which can be used among other applications such as etch masks, has been started. Unfortunately, as-cast films lack the orientational and positional order of the microphase-separated domains that are necessary for many desired applications. A systematic study is underway and will continue to obtain better control over the pattern. Preliminary results of patterned lamella are shown in Fig1c

Electrospinning

Here we concentrate on understanding the electrospinning process and the variables affecting the fibre's size, morphology and distribution as those parameters ultimately influence the fibre properties. Fibre diameter and shape regularity were found to be dependent on several parameters like viscosity of the polymer solution, applied voltage, distance between the collector and electrodes, humidity, pressure, and the evaporation rate of the solvents. Fabrication of a 3D nanofibre mat in the form of interconnected 1D wires was completed successfully in our laboratory. Random nanofibres, aligned nanofibres, fibres with nanoscale surface topologies, and shaped fibres of different materials including polymer and semiconductor were fabricated by tuning the electrospinning parameters. Fibres with different arrangements (i.e., disordered, aligned or crossed fibres) will enable us to switch isotropic as well as anisotropic properties, as shown in Fig. 2. Highlights of our work here are: a) design of new collectors and electrospinning procedures to fabricate highly aligned monodispersed nanofibrous yarns, and b) fabrication of a ceramic/polymer composite nanofibrous mat with superior mechanical properties (tensile and elastic moduli enhancement of 120%), along with enhancement of water filtration by an order of magnitude. A patent for this breakthrough has been applied for.

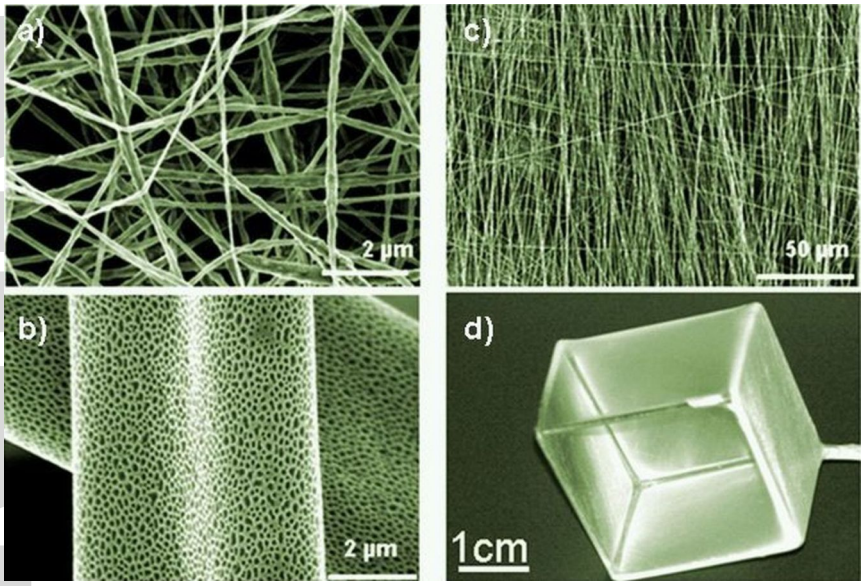


Fig. 2: Coloured SEM Pictures of: a) Random fibres, b) Nanostructured fibres, c) Aligned fibres and d) Shaped fibres.

Physical Deposition

Polymer/metal nanocomposites have recently been the subject of extensive research as multifunctional materials. A breakthrough in this field was realized in our group and in cooperation with Prof. F. Faupel's group (multicomponent materials) where a new transparent conductor based on metal polymer nanocomposite coating was developed. We designed a new transparent plasmonic device based on a system traditionally known as a good light absorber/scatterer. Our omni-directional transparent conducting metal (''TCM'') based on a plasmonic metamaterial, Fig 3., exhibits optoelectronic properties potentially superior to ITO. Already we achieved a transmittance of 80 % over an extended range, not yet encompassing the full visible spectrum, combined with a conductivity exceeding that of a typical ITO layer by an order of magnitude. A patent for this development has also been applied for.

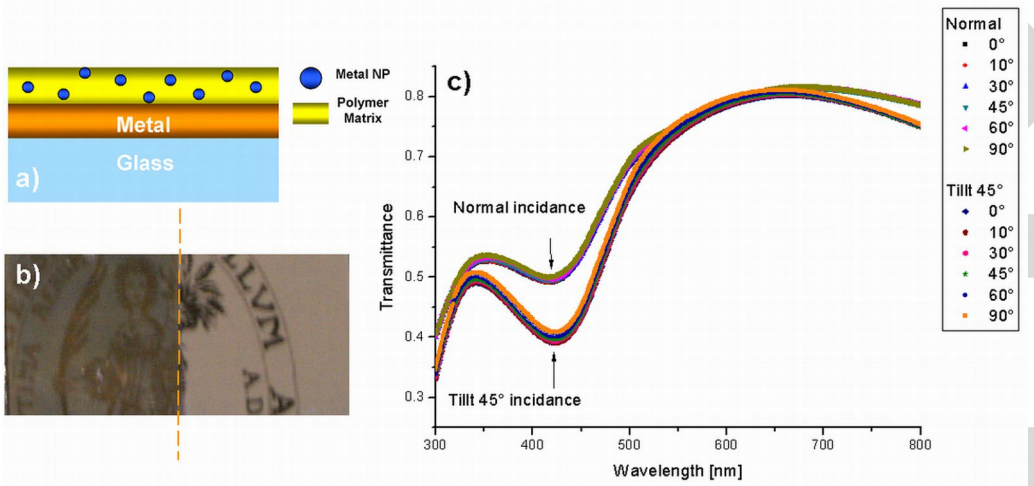


Fig. 3: a) Schematic of the TCM system which was fabricated by sputtering, consisting of a glass substrate, a thin gold film and a metal/polymer nanocomposites, b) Photo of the Christian- Albrechts University logo taken through a glass piece coated with gold film (left) and nanocompsite 25nm gold film (right), c) Angle dependency of the transmission spectra of TCM where the sample surface is normal and 45 degrees tilted relative to the plane of incidence

Personnel

Head of the group: Prof. Dr. -Ing. M. Elbahri; Secretary: N. Gühlke (50%), Dipl.-Chem. S. Kastaun (50%), Dipl.-Geo. B. Minten (50%)
Technical Staff: Dipl. -Ing. (FH) R. Kloth, C. Ochmann, Dipl.-Ing. (FH) S. Rehders

Scientific Staff:

M. Sc. R. Abdelaziz Nanofabrication	01.01.-31.12.2010	CAU, Grant
M.Sc. T. Dai Nanofibers for Catalyst	01.01.-31.12.2010	HZG, HGF
M.Sc. D. Disci Nanofabrication for Bio.	30.09.-31.12.2010	CAU, DFG
Dr. K. Ganesan Smart Materials	23.08.-31.12.2010	CAU, SFB 677
M.Sc. S.S. Homaeigohar Nanofibers for Filtration	01.01.-31.12.2010	HZG, DAAD
M.Sc. M. Jamali Photoswitchable materials	01.02.-31.12.2010	CAU, SFB 677
M.Sc. M. Keshavarz Hedayati Plasmonic materials	01.01.-31.12.2010	CAU, DFG
Dr. R. Khalil Nanocomposites	21.05.-31.12.2010	CAU, DAAD

M.Sc. M. Rakib Polymeric optoelectronic	01.04.-31.12.2010	HZG, HGF
M.Sc. J. Worley Bionanotechnology	01.01.-31.12.2010	CAU, HGF
M.Sc. A.U. Zillohu Photonic nanomaterials	01.04.-31.12.2010	HZG, (HG)

Lectures, Seminars, and Laboratory Course Offers

Winter 2009/2010

Nanochemistry for Nanoengineering, 2 hrs Lecture/Week,
M. Elbahri

Nanochemistry for Nanoengineering Seminar, 1 hrs Seminar/Week,
M. Elbahri

Summer 2010

Polymer based Smart and Multifunctional Devices, 2 hrs Lecture/Week,
M. Elbahri

Polymer based Smart and Multifunctional Devices, 1 hrs Seminar/Week,
M. Elbahri

Winter 2010/2011

Nanochemistry for Nanoengineering, 2 hrs Lecture/Week,
M. Elbahri

Nanochemistry for Nanoengineering - Seminar, 1 hrs Seminar/Week,
M. Elbahri

Werkstoffe (Metalle), 2 hrs Lecture/Week,
M. Keshavarz Hedayati

Third-Party Funds

GKSS, *Einrichtung einer gemeinsamen Helmholtz-Hochschul-Nachwuchsgruppe*, 01.03.2009-28.02.2015 (2.100.000 Euro)
DFG, *Nanosynthesis and Nanopatterning based on ''Drop-on-a-hot-Plat''*, 01.08.2009-27.09.2012 (280.370 Euro)
DAAD, *Stipendium für Shahin Homaeigohar zur Promotion für 3 Jahre*, 01.04.2009-31.12.2010 (45.618 Euro)
Uni Kiel, *Stipendium für Ramzy Abdelaziz für 1 Jahr*, 01.08.2009-31.07.2010 (12.200 Euro)
DAAD, *Stipendium zur Promotion für Ahnaf Usman Zillohu*, 01.04.2010-01.04.2011 (12.096 Euro)
DFG, *Funktion durch Schalten: Anschubfinanzierung für Projekt ''Photoschaltbare multifunktionale Nanofaser''*, 01.07.-31.12.2010 (35.600 Euro)

Further Cooperation, Consulting, and Technology Transfer

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. L. Kienle, Institute for Material Science: transmission electron microscopy.

Prof. Dr. V. Abetz, GKSS Geesthacht: blockcopolymers.

Dr. A. Boschetti-de-Fierro, GKSS Geesthacht: transparent conductors based on CNT/polymer.

Prof. Dr. Eich, TU Hamburg: photonic crystal.

Prof. Dr. sc.hum. Rainer Podschun,Institut für Infektionsmedizin, Christian-Albrechts-Universität.

Priv.-Doz. Dr. C. Röhl, Institut für Toxikologie und Pharmakologie für Naturwissenschaftler, Christian-Albrechts-Universität.

Prof. Dr. rer. nat. S. N. Gorb, Spezielle Zoologie, Christian-Albrechts-Universität.

Dr. Vanessa Witte, Institut für Molekulare und Klinische Immunologie, Otto-von-Guericke-Universität Magdeburg.

Diploma, Bachelor and Master Theses

M. Jamali, *Designing a New Plasmonic Coating for Optical Application,* 15.07.2010
D. Disci, *Biological Aspects of Metaloxide Nanostructures,* 11.08.2010
M. Kassab, *Multifunctional Photonic Glass,* 17.09.2010

Publications

Published in 2010

H.T. Beyene, V.S.K. Chakravadhanula, C. Hanisch, M. Elbahri, T. Strunskus, V. Zaporojtchenko, L. Kienle, F. Faupel, *Preparation and plasmonic properties of polymer-based composites containing Ag-Au alloy nanoparticles produced by vapor phase co-deposition.*, Journal of Material Science, **45**, 5865 - 5865 (2010)

S. Jebril, Y.K. Mishra, M. Elbahri, L. Kienle, H. Greve, E. Quandt, R. Adelung, *Using thin film stress for nanoscaled sensors,* Materials Science Forum, 638 - 642 (2010)

D. Gedamu, S. Jebril, A. Schuchardt, M. Elbahri, S. Wille, Y.K. Mishra, R. Adelung, *Examples for the integration of self-organized nanowires for functional devices by a fracture approach,* Physica status solidi(b), **247**, 2571 - 2571 (2010)

F. Faupel, V. Zaporojtchenko, T. Strunskus, M. Elbahri, *Metal-Polymer Nanocomposites for Functional Applications,* Advanced Engineering Materials, **12**, 1177 - 1177 (2010)

Patent Applications

M. Elbahri, R. Adelung, D. Paretkar, *Verfahren zur Herrstellung von Nanostrukturen auf einem Substrat,* Deutsches Patentamt, 25.02.2010, EP1960309

M. Elbahri, R. Adelung, F. Faupel, K. Hirmas, *Verfahren zur Nanostrukturerzeugung mittels spinodaler Entnetzung,* Deutsches Patentamt, 26.08.2010, EP2206153

M. Elbahri, *Metall-Komposit-Beschichtung mit hoher optischer Transmissivität im visuellen Spektrum,* Patentanmeldung am Deutschen Patentamt, 24.10.2010, DE 10 2010 050 110.7

Presentations

M. Elbahri, *Hybrid Materials as Templates for Development of Multifunctional Materials (Talk)*, SPP 1659, Stuttgart, Germany, 25.-25.10.2010

M. Elbahri, *From Synthesis to Function (Invited talk)*, Nanosyd Seminar an University of Southern Denmark, Sonderborg, Denmark, 18.-18.11.2010

R. Abdelaziz, *Peroxide Nanoparticles for Biomedical Applications (Talk)*, 4th International Conference of Chemical Industries Research Division, Kairo, Egypt, 30.11.-02.12.2010

M. Elbahri, *Nanochemnistry and trends (Invited Pleanary Lecture)*, 4th International Conference of Chemical Industries Research Division, Kairo, Egypt, 30.11.-02.12.2010

Further Activities and Events

Mitglied in der Gesellschaft Deutscher Chemiker e. V.

Mitglied in der Deutschen Gesellschaft für Materialkunde e.V.

Computational Mechanics

Prof. Dr.-Ing. habil. Jörn Mosler, Head of Department Simulation of Solids and Structures, Helmholtz-Zentrum Geesthacht.

Prof. Mosler became professor of the Faculty of Engineering in 2008. Information about his scientific work is available on the Website of Helmholtz-Zentrum Geesthacht: http://www.hzg.de/.

CMA Centre for Materialanalytics

Executive board: Prof. Dr. F. Faupel, Prof. Dr. H. Föll, Prof. Dr. B. Wagner, Prof. Dr. W. Jäger, Prof. Dr. E. Quandt.

Within the Institute for Materials Science the groups and chairs possess advanced equipment for preparation and analysis including electron microscopy, photoelectron spectroscopy and others in the recently established Nanolab.

The main tasks of the CMA include, but are not restricted to:

- materials characterization,
- structure and properties of thin films, surface topography and spectroscopy, 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,
- support of scientific cooperation, service and consulting for industry and research institutes,
- extension of the available experimental methods by resource sharing with other institutions within suitable cooperations,
- support of students (bachelor, master and PhD) 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. O. Riemenschneider; Secretary: M. Wallisch (75 percent)
Technical Staff: Dipl.-Ing. K. Rath (85 percent)

Scientific Staff:

Dipl.-Min. M. Schwitzke	01.01.-31.12.2010	(50%)

Lectures, Seminars, and Laboratory Course Offers

Winter 2009/2010

Tutorium for Junior Students, 1 hrs Seminar/Week,
K. Dolgner

Tutorium for Senior Students, 1 hrs Seminar/Week,
K. Dolgner

Basic Lab Course, 4 hrs Lab/Week,
Marlies Schwitzke (+ S. Kaps, C. Pakula, M.Q. Shaikh, Emmanuel Ossei-Wusu, A. Kulkarni)

Einführung in die Materialwissenschaft I, 2 hrs Lecture/Week,
K. Rätzke

Lab Course Scientific Methods, 4 hrs Lab/Week,
V. Zaporojtchenko (+ M.Q. Shaikh, S. Jebril, Ala Cojocaru, Anselm Pape)

Tutorium für Bachelorstudierende, 1 hrs Seminar/Week,
K. Dolgner

Grundpraktikum für Ingenieure I, Dienstagskurs, 4 hrs Lab/Week,
Kirstin Scholz (+ L. Wienbrandt, M. Nordhausen)

Grundpraktikum für Ingenieure I,Mittwochskurs, 4 hrs Lab/Week,
Kirstin Scholz (+ L. Wienbrandt, M. Nordhausen)

Grundpraktikum für Ingenieure I, Montagskurs, 4 hrs Lab/Week,
Kirstin Scholz (+ L. Wienbrandt)

Summer 2010

Grundpraktikum für Ingenieure II, Dienstagskurs, 4 hrs Lab/Week,
K. Scholz (+ L. Wienbrandt)

Einführung in die Materialwissenschaft II, 2 hrs Lecture/Week,
K. Rätzke

Lab Course: Functional Materials, 4 hrs Lab/Week,
O. Riemenschneider (+ scientific staff of the Inst. f. Materials Science)

Tutorium for Junior Students, 1 hrs Seminar/Week,
O. Riemenschneider

Tutorium for Senior Students, 1 hrs Seminar/Week,
O. Riemenschneider

Grundpraktikum für Ingenieure II, Mittwochskurs, 4 hrs Lab/Week,
K. Scholz (+ L. Wienbrandt, O. Riemenschneider)

Tutorium für Bachelorstudierende, 1 hrs Seminar/Week,
O. Riemenschneider

Grundpraktikum für Ingenieure II, Montagskurs, 4 hrs Lab/Week,
K. Scholz (+ L. Wienbrandt, O. Riemenschneider)

Winter 2010/2011

Tutorium for Junior Students, 1 hrs Seminar/Week,
O. Riemenschneider

Tutorium for Senior Students, 1 hrs Seminar/Week,
O. Riemenschneider

Basic Lab Course, 4 hrs Lab/Week,
O. Riemenschneider (+ Emmanuel Ossei-Wusu, A. Kulkarni, C. Pakula, M.Q. Shaikh, S. Kaps)

Einführung in die Materialwissenschaft I, 2 hrs Lecture/Week,
O. Riemenschneider (+ K. Rätzke)

Lab Course Scientific Methods, 4 hrs Lab/Week,
O. Riemenschneider (+ Th. von Hofe, A. Cojocaru, V. Zaporojtchenko, A. Pape, A. Lotnyk, C. Zamponi, D. Gedamu, E.Q. González)

Tutorium für Bachelorstudierende, 1 hrs Seminar/Week,
O. Riemenschneider

Grundpraktikum für Ingenieure I, Montagskurs, 4 hrs Lab/Week,
K. Scholz (+ K. Scholz, L. Wienbrandt)

Grundpraktikum für Ingenieure I,Mittwochskurs, 4 hrs Lab/Week,
O. Riemenschneider (+ K. Scholz, L. Wienbrandt)

Grundpraktikum für Ingenieure I, Freitagskurs, 4 hrs Lab/Week,
K. Scholz (+ O. Riemenschneider, L. Wienbrandt)

Third-Party Funds

contract work, *maintenance and expansion of equipment*, 01.01.-31.12.2010 (10285,44)

Further Cooperation, Consulting, and Technology Transfer

Cooperation with Industry:

1. Tijet Medizintechnik GmbH, Kiel,

2. Empa, Dübendorf, Schweiz,

3. HDW, Thyssen Krupp, Kiel.

Cooperation with Institutes:

1. Graduiertenschule,

2. Leibnizlabor,

3. Rheologie.

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.

Service Centre

The Service Centre was launched at the Faculty of Engineering in spring 2009. It is a joint corporation of the Institute of Electrical and Information Engineering and the Institute for Materials Science. Figure 1 illustrates the integration of the Service Centre in the organizational structure of the Faculty of Engineering. The Service Centre is managed by assistants of 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 one employee 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 programs of both institutes. In case of vacation or illness the employees can replace each other so that service continuity is guaranteed. The following tasks belong to the above-named fields:

Studies

- accreditation and re-accreditation of all study courses,
- design and development of study and examination regulations,
- capacity calculation,
- public relations, e.g. information days and hosted programs at schools,
- advertisement for the different study courses,
- collecting and evaluating applications for the study courses of Materials Science,
- 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 the rooms for all lectures of the two institutes,
- coordination of UnivIS entries,
- organization and administration of the joint basic laboratory courses.

Lab support:

- centralized buying of gas,
- Management of laboratory keys.

Examinations:

- 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. In May the new assistant of the Institute of Materials Science, Dr. Oliver Riemenschneider, started his work in the Service Centre.

Results

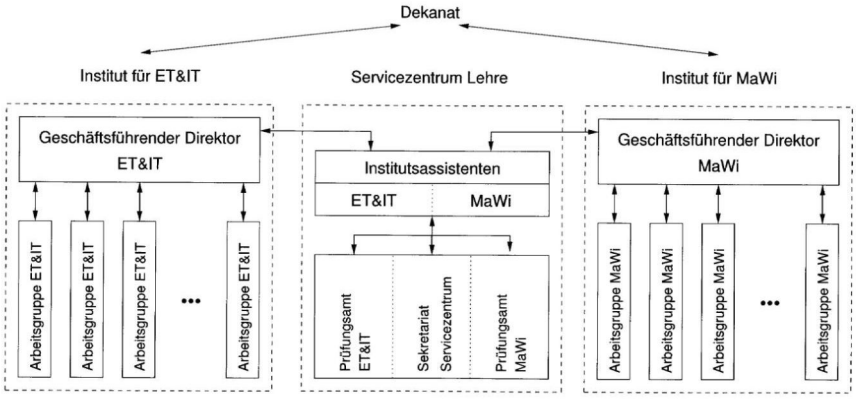


Fig. 1: Integration of the Service Centre into the faculty's organizational structure

Fig. 2: The new logo

Personnel

Head of the group: Dr. Oliver Riemenschneider, Dr.-Ing. Kirstin Scholz; Secretary: Maren Wallisch (75 percent)
Technical Staff: Dipl.-Ing. (FH) Kay Rath (85 percent)

Staff:

Vera Nilsson	01.01.-31.12.2010	(50%)
Christiane Otte-Hüls	01.01.-31.12.2010	(50%)
Lars Struwe	01.01.-31.12.2010	

Scientific Staff:

Dipl.-Min. Marlies Schwitzke	01.01.-31.12.2010	(50%)

Deanship

Results

The Dean´s office is the central administration of the Faculty of Engineering and therefore responsible for managing the complete budget including running expenses, investments, and the finances for the staff. Concerning the part of the Faculty located in Kiel-Gaarden, the Dean's office is also in charge of the computer operating services, the building services and the mechanical workshop. The Dean´s office is managed by Dr. Frank Paul the head of the administration of the Faculty.

To fulfil all these tasks there are about 17 persons in the Dean's office. In 2010 the deanship of Prof. Dr. Franz Faupel expired and in July a new dean ws elected. Prof. Dr.-Ing. Reinhard Knöchel began his deanship for a period of two years while Prof. Dr. Manfred Schimmler and Prof. Dr. Franz Faupel became Vicedeans.

Worth mentioning are the successful negotiations with several newly appointed professors. In 2010 Dr.-Ing. Gerhard Schmidt and Dr. Christine Selhuber-Unkel became professors of the faculty.

Besides the impressive scientific work of the different groups which is reflected in this Almanac, the raising of a respectable amount of third party funds has to be mentioned.

Finally it should be noted that the Dean's office once more agaein successfully organised the contest ''Jugend forscht - Schüler experimentieren'' in Schleswig-Holstein. After participation in the regional contest about 50 young participants were guests of the Faculty of Engineering in Spring 2010. Later, in Essen one group was successfully placed on fourth position on the ranking of the federal contest of ''Jugend forscht'' in Mathematics/Computer Science. However, the main aim of supporting ''Jugend forscht'' is to recruit well educated young scientists for the Faculty of Engineering and the Christian-Albrechts University in general.

Personnel

Head of the group: Dr. F. Paul (Managing Director);

Staff:

S. Anders	01.01.-31.12.2010	(50%)
Head Adminstrator for Staff and Budget Department		
U. Bruse	01.01.-31.12.2010	
Division Manager of Building Services		
M. Burmeister	01.01.-31.12.2010	
Division Manager of the Mechanical Workshop		
R. Doose	01.01.-31.12.2010	
Caretaker		
M. Firnau	01.01.-31.12.2010	
Division Manager of Computer Service Department		
S. Fischer	01.01.-31.12.2010	
Trainee		
M. Hacker	01.01.-31.12.2010	
Secretary of Budget Department		

C. Hinrichsen Aministrator Deans Office	01.01.-30.09.2010	(50%)
S. Johnsen Employee of the Mechanical Workshop	01.01.-31.12.2010	
H. M. Kruse Trainee	01.01.-31.12.2010	
M. Kulling Employee of the Mechanical Workshop	01.01.-31.12.2010	
J. Marienfeld Trainee	01.01.-31.12.2010	
C. Martin Administrator Deans Office	01.01.-31.12.2010	
S. Moeller Secretary of Staff Department	01.01.-31.12.2010	
B. Neumann Vice Devision Manager of the Mechanical Workshop	01.01.-31.12.2010	
C. Newe Administrator Computer Service Department	01.01.-31.12.2010	
M. Quedens Electrician	01.03.-31.12.2010	
T. Wengler Secretary Deans Office	01.10.-31.12.2010	(50%)
M. Willer Clerk	01.01.-05.12.2010	

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. Helmut Föll (Vice-president),

Prof. Dr. Dr. Marcus Porembski (Treasurer),

Dr. Frank Paul (Secretary),

Prof. Dr. Franz Faupel (Assessor),

Prof. Dr. Reinhard von Hanxleden (Assessor),

Herbert Jacobs (Assessor).

Auditors: Prof. Dr. Michael Hanus, Prof. Dr.-Ing. Eckard Quandt.

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 network the faculty with its finances and institutions on the one hand, and with the students, graduates, and alumni on the other.

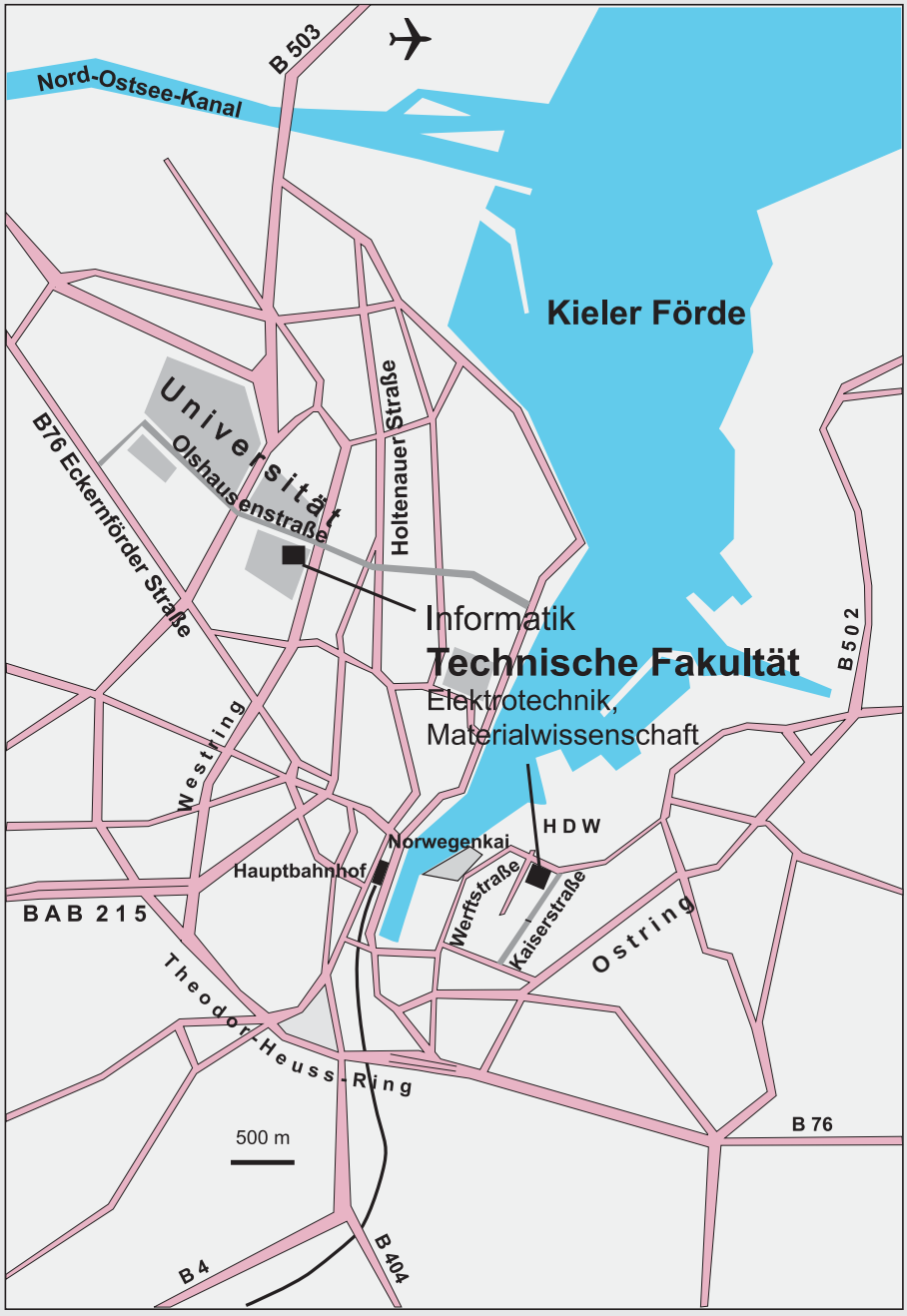
The Friends of the Faculty present a forum for the exchange of ideas between the different disciplines of technology, science, philosophy, social science and the economy.

Members are companies, institutions and persons who support and encourage the faculty with its aims and its tasks.''

During 2010 the Friends of the Faculty were active concerning the basic ideas above. Many different projects were supported and prizes awarded for the best diploma, bachelor, master and doctoral 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 most important industrial fair, the ''Hanover fair'', of organizing the ´Girls' day´ and many other activities of the faculty´s students. Also festivities like the „Sommerfest" and the „Winterfest" were made possible by the help of the Friends of the Faculty.

Fig. 1: Dr. Philipp Murmann, Dipl.-Ing. Enno Lage, Dipl.-Ing. Johannes von Hoyningen-Huene, Dipl.-Ing. Robert Jahns, Dr. Rodrigo Lima de Miranda

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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