C | A | U Christian-Albrechts-Universität zu Kiel Technische Fakultät

mikrostrukturanalytik

microanalysis of materials

2010 activities and results

Annual Report

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Ed. Dr. Frank Paul

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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 Center of Materials Analysis (CMA) and the ''Kieler Nanolabor'' of the CAU (see TF almanach 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 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

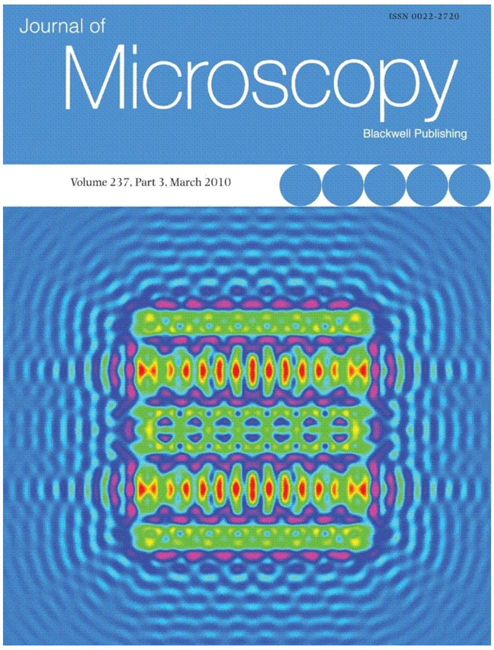

Fig. 1: Advantages of aberration correction for HRTEM investigation of complex layer compounds. From: E. Spiecker, M. Garbrecht, W. Jäger, K. Tillmann: Journal of Microscopy, Vol. 237, 3, 341 - 346, 2010. Selected for Cover Page of Journal Volume.

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 characterisations by scanning transmission electron microscopy (STEM) have focused on developing methods for the assessment of the layer growth, the coating control, and the reflectivity properties of multilayer systems for X-ray optics. More recent investigations focused on characterisations 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 Center 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 member of our Microanalysis of Materials group (See almanach 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 the 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 with nanometer resolution in 3D. In materials science, the use of BF-TEM tomography is limited as BF images of crystalline materials do not fulfill the projection requirement and thus cannot be used for tomography of most crystalline samples. To fulfill 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.

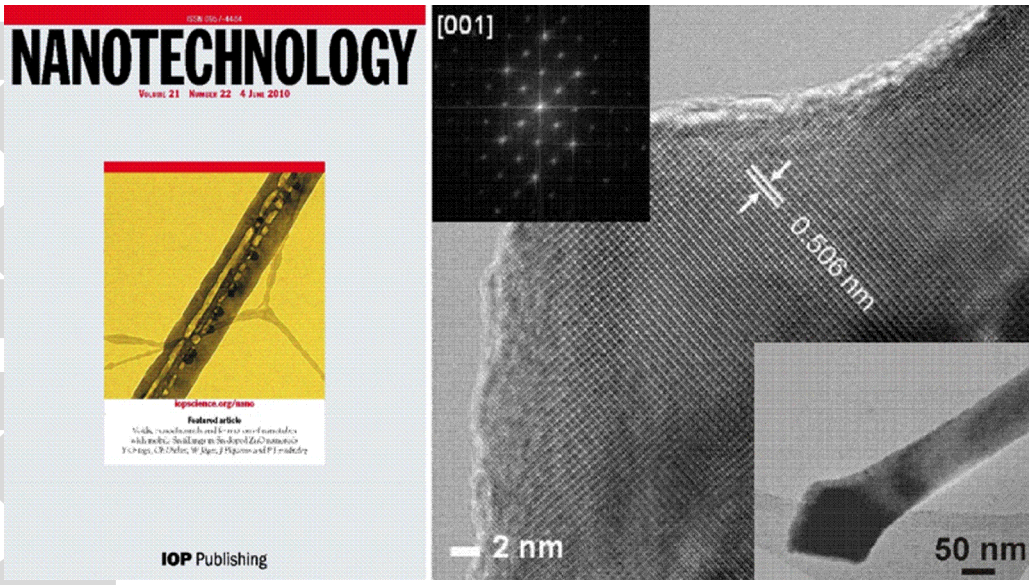

Fig. 3: (a) ∗ DOPED ZINC OXIDE (ZnO) NANOSTRUCTURES. Bright-field TEM micrograph of single Sn-doped ZnO nanorod with distinct core and shell regions. (b) DOPED INDIUM OXIDE (In_2O_3) NANOSTRUCTURES. HRTEM lattice image, related SAD pattern in [001] zone axis orientation, and a bright-field image of a 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 is of interest as functional materials 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 the 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 aim 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 sun light 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 external 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 Center 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 Center 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-Center 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 Dr. C. Morawe, European Synchrotron Radiation Facility, Grenoble, France.

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: 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 Center 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 to repeat this style of symposium in 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 Center 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

21. - 25.06.2010 Prof. Dr. Pierre Stadelmann, CIME-EPFL Lausanne, Switzerland: Tutorials on ''JEMS Computer Simulation Techniques for TEM''

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 Programm ''Uni kommt zur Schule''.