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Fachverband Mikrosonden (MI)

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Overview of Invited Talks and Sessions

(lecture rooms MER 02, HSZ 02, and Poster P4)

Invited Talks

MI 1.1	Mon	10:00–10:30	MER 02	**Point-group sensitive interpretation of EBSD patterns, and the impact of channeling-in and channeling-out of electrons** — •Gert Nolze, Aimo Winkelmann
MI 1.8	Mon	12:15–12:45	MER 02	**Microstructural characterization of non-metallic precipitates in silicon crystallization processes for photovoltaic applications** — •Susanne Richter, Martina Werner, Sina Swatek, Christian Hagendorf
MI 4.1	Wed	9:30–10:00	MER 02	**X-ray Microscopy: Imaging the Chemistry Inside** — •Christian G. Schroer
MI 5.3	Wed	12:00–12:30	MER 02	**NanoFrazor Lithography - Revolutionizing nanofabrication** — •Zhengming Wu, Colin Rawlings, Simon Bonanni, Tero Kulmala, Heiko Wolf, Urs Duerig, Armin W. Knoll, Martin Spieser, Philip Paul, Felix Holzner

Invited talks of the joint symposium Novel Functionality and Topology-Driven Phenomena in Ferroics and Correlated Electron Systems (SYCE)

See SYCE for the full program of the symposium.

SYCE 1.1	Mon	15:00–15:30	HSZ 02	**Ferroelectric domain walls: from conductors to insulators and back again** — •Petro Maksymovych
SYCE 1.2	Mon	15:30–16:00	HSZ 02	**Zoology of skyrmions and the role of magnetic anisotropy in the stability of skyrmions** — •Istvan Kezsmarki, Sandor Bordacs, Jonathan White, Vladimir Tsurkan, Alois Loidl, Peter Milde, Hiroyuki Nakamura, Andrey Leonov
SYCE 1.3	Mon	16:00–16:30	HSZ 02	**Magnetic imaging of topological phenomena in ferroic materials** — •Weida Wu
SYCE 1.4	Mon	17:00–17:30	HSZ 02	**Topological skyrmion textures in chiral magnets** — •Markus Garst
SYCE 1.5	Mon	17:30–18:00	HSZ 02	**Learning through ferroelectric domain dynamics in solidstate synapses** — Sören Boyn, Gwendal Lecerf, Stéphane Fusil, Sylvain Saïghi, Agnès Barthélémy, Julie Grollier, Vincent Garcia, •Manuel Bibes

Invited talks of the joint symposium Bioinspired Functional Materials: From Nature's Nanoarchitectures to Nanofabricated Designs (SYBM)

See SYBM for the full program of the symposium.

SYBM 1.1	Tue	9:30–10:00	HSZ 02	**New twists in biological photonics: circular polarisation and beyond.** — •Pete Vukusic, Luke McDonald, Ewan Finlayson
SYBM 1.2	Tue	10:00–10:30	HSZ 02	**Bio-inspired materials and structures for technology and architecture** — •Thomas Speck
SYBM 1.3	Tue	10:30–11:00	HSZ 02	**Cellulose bio-inspired hierarchical structures** — •Silvia Vignolini

SYBM 1.4	Tue	11:15–11:45	HSZ 02	**Strong Flexible Bioenabled Nanocomposites for Sustainable Sensing** — •Vladimir Tsukuruk
SYBM 1.5	Tue	11:45–12:15	HSZ 02	**3D laser nano-printing of rationally designed materials** — •Martin Wegener

Invited talks of the organized joint symposium Nanostructuring Beyond Conventional Lithography (SYNS)

See SYNS for the full program of the symposium.

SYNS 1.1	Wed	15:00–15:30	HSZ 02	**The Limits to Lithography: How Electron-Beams Interact with Materials at the Smallest Length Scales** — •Karl K. Berggren
SYNS 1.2	Wed	15:30–16:00	HSZ 02	**High precision fabrication for light management at nanoscale** — •Saulius Juodkazis, Armandas Balcytis
SYNS 1.3	Wed	16:00–16:30	HSZ 02	**Directed self-assembly of performance materials** — •Paul Nealey
SYNS 1.4	Wed	16:45–17:15	HSZ 02	**Nanometer accurate topography patterning using thermal Scanning Probe Lithography** — •Armin W. Knoll
SYNS 1.5	Wed	17:15–17:45	HSZ 02	**High resolution 3D nanoimprint lithography** — •Hartmut Hillmer

Sessions

MI 1.1–1.9	Mon	10:00–13:00	MER 02	**Analytical Electron Microscopy: SEM and TEM-based Material Analysis**
MI 2.1–2.5	Mon	15:00–18:00	HSZ 02	**Symposium Novel Functionality and Topology-Driven Phenomena in Ferroics and Correlated Electron Systems (DF with MA, KR, MI, TT and DS)**
MI 3.1–3.5	Tue	9:30–12:15	HSZ 02	**Symposium Bioinspired Functional Materials: From Nature's Nanoarchitectures to Nanofabricated Designs**
MI 4.1–4.6	Wed	9:30–11:30	MER 02	**X-Ray Imaging, Holography, Ptychography and Tomography**
MI 5.1–5.6	Wed	11:30–13:15	MER 02	**Session on Nanostructuring Beyond Conventional Lithography**
MI 6.1–6.5	Wed	15:00–17:45	HSZ 02	**Symposium Nanostructuring Beyond Conventional Lithography (MI with DS, DF, HL, MM and VA)**
MI 7.1–7.14	Wed	18:00–20:00	P4	**Poster: Microanalysis and Microscopy**
MI 8.1–8.4	Thu	10:00–11:00	MER 02	**Scanning Probe Microscopy (SPM)**
MI 9.1–9.2	Thu	11:15–11:45	MER 02	**Progress of Instrumentation and Methods for the Surface Analysis (PEEM, LEED)**
MI 10.1–10.2	Thu	12:00–12:30	MER 02	**Positron Annihilation Spectroscopy (PALS)**
MI 11	Thu	15:00–16:00	MER 02	**Annual General Meeting and Celebration of the 50th Anniversary of the Microprobes Division**

Mitgliederversammlung und feierliche Begehung des 50. Jahrestages unseres Fachverbandes Mikrosonden

Donnerstag 15:00–16:00 MER 02

- Bericht des Fachverbandsvorsitzenden
- Planung der DPG-Tagung 2018 in Berlin
- Zukunft des Fachverbandes Mikrosonden
- Diskussion über mögliche Vereinigung thematisch nahestehender Fachverbände
- Abstimmung bzw. Wahl
- Verschiedenes

MI 1: Analytical Electron Microscopy: SEM and TEM-based Material Analysis

Chair: Enrico Langer (TU Dresden) and Hartmut S. Leipner (Martin-Luther-Universität Halle-Wittenberg)

Time: Monday 10:00–13:00 Location: MER 02

Invited Talk MI 1.1 Mon 10:00 MER 02

Point-group sensitive interpretation of EBSD patterns, and the impact of channeling-in and channeling-out of electrons — •Gert Nolze[1] and Aimo Winkelmann[2] — [1]Bundesanstalt für Materialforschung und -prüfung (BAM), Unter den Eichen 87, 12205 Berlin, Germany — [2]Bruker Nano GmbH, Am Studio 2D, 12489 Berlin, Germany

Recent studies contradict the common belief that electron backscatter diffraction follows Friedel's rule. The presentation will demonstrate that entire orientation maps collected under standard acquisition conditions can be processed by pattern matching of experimental with simulated patterns which enables to distinguish between (hkl) and $(\bar{h}\bar{k}\bar{l})$. However, the polarity determination for phases such as GaAs is very difficult since Ga an As have a similar contribution to the backscattered intensity of hkl and $\bar{h}\bar{k}\bar{l}$. We will show that in such case the energy-dispersive X-ray signal can be used, but presently for single orientations only.

It is also frequent practice that an EBSD pattern is mainly reduced to its backscattered diffraction part. This also called *channeling-out* signal is used for the orientation interpretation, phase interpretation etc. The presentation will prove that the *channeling-in* of the electron beam reacts clearly more sensitive regarding orientation variations and is responsible for the orientation contrast in images e.g. collected by a backscattered electron detector. Despite the fascinating misorientation sensitivity a quantitative evaluation seems to be very unlikely.

MI 1.2 Mon 10:30 MER 02

The Complicated Information Depth of EBSD — •Wolfgang Wisniewski — Otto-Schott-Institut, Fraunhoferstr. 6, 07743 Jena, Germany

The information volume of a method enables to estimate which part of a sample actually contributes to the given measurement and establishes boundaries concerning possible measurements. In the case of EBSD, the widespread opinion is that the information depth is limited to 10-40 nm or less. However, recent results show that this information depth depends not only on the material and the available technology, but also on the quality of the pattern being analyzed. In high quality patterns, the evaluated information indeed originates from a very thin layer of material, but the information depth may increase significantly for low quality EBSD-patterns. This aspect e.g. expands the possibilities of EBSD-measurements to materials covered by passivation layers.

MI 1.3 Mon 10:45 MER 02

Quantitative materials characterization at the nanoscale with TKD in SEM — •Laurie Palasse and Daniel Goran — Bruker Nano GmbH, Am Studio 2D, 12489 Berlin, Germany

Characterization of nanostructured materials requires high spatial resolution orientation mapping at large-scale for quantitative results. Because EBSD does not achieve such resolution on bulk samples, these kind of studies are often done using a TEM. However, TEM-based orientation mapping techniques suffer from small field of view. As a result, Transmission Kikuchi Diffraction (TKD) in SEM was developed as a technique capable of delivering the same type of results as EBSD but with a spatial resolution improved by up to one order of magnitude. TKD analysis is conducted on an electron transparent sample using the same hardware and software as for EBSD system. But when using conventional EBSD geometry, the transmitted patterns (TKP) are captured by a vertical phosphor screen with a considerable loss of signal and strong distortions induced by gnomonic projection. The limitations of such sample-detector geometry are overcome by an on-axis detection system. With a horizontal phosphor screen placed underneath the sample, the transmitted signal is captured where it is the strongest and TKPs will have minimal distortions. Using low probe currents, the spatial resolution is increased and the beam-induced specimen drift reduced. The improved stability and high spatial resolution allow the user to conduct large-area TKD orientation mapping, especially when combined with a fast and sensitive EBSD detector.

MI 1.4 Mon 11:00 MER 02

Cryo-EBSD on $BaFe_2As_2$ single crystals — •Aurimas Pukenas[1], Paul Chekhonin[1], Ellen Hieckmann[2], Martin Meissner[2], Saicharan Aswartham[3], Jan Engelmann[3], Bernhard Holzapfel[4], Sabine Wurmehl[3], Bernd Büchner[3], and Werner Skrotzki[1] — [1]Institut für Strukturphysik, Technische Universität Dresden, 01069 Dresden, Germany — [2]Institut für Angewandte Physik, Technische Universität Dresden, 01069 Dresden, Germany — [3]Leibniz-Institut für Festkörper- und Werkstoffforschung (IFW) Dresden, 01069 Dresden, Germany — [4]Institut für Technische Physik, Karlsruher Institut für Technologie, 76344 Eggenstein-Leopoldshafen, Germany

$BaFe_2As_2$ belongs to the family of iron-based high temperature superconductors. In previous publications it was reported that superconductivity occurs under certain conditions, e.g. by chemical doping, pressure or epitaxial strain. Undoped $BaFe_2As_2$ orders antiferromagnetically at $T_C \approx 140$ K and simultaneously undergoes a tetragonal $I4/mmm$ to orthorhombic Fmmm structural phase transition. The orthorhombic structure leads to the formation of twin lamellae. Investigations reported so far using transmission electron microscopy and polarized light microscopy show inconclusive results with respect to the domain size. To achieve high spatial resolution (≤ 100 nm) an experimental setup was used consisting of a scanning electron microscope with sample holder on a helium cryostat and electron backscatter diffraction (EBSD) technique. EBSD mappings of domains below T_C and after a cooling-warming cycle will be presented and discussed.

15 min. break.

MI 1.5 Mon 11:30 MER 02

Angle-resolved X-ray fluorescence spectroscopy for elemental depth profiling with nanometer resolution — •Ioanna Mnatouvalou, Jonas Baumann, Veronika Swedowski, Malte Spanier, Steffen Staeck, Daniel Grötzsch, Wolfgang Malzer, and Birgit Kanngiesser — Institut für Optik und atomare Physik, Technische Universität Berlin, Deutschland

X-ray fluorescence (XRF) spectroscopy is a well-established analytical tool for the non-destructive investigation of elemental distributions. Typically, the measured fluorescence intensities are converted to elemental concentrations using tabulated atomic cross sections, thus rendering reference-free quantification feasible. With adapted X-ray lenses lateral micro- or even nano-analysis is possible. Depth information, though, is not readily available. Recent development is directed toward angle-resolved (AR) XRF for the derivation of elemental depth profiles with nm resolution. Here, the angle of incidence or emission is varied, thereby changing the fluorescence information depth. The comparison of measured and simulated angular profiles yields information about the stratigraphy of technologically relevant specimen such as multilayer structures, solar cells or transistor gate stacks. We present our lab-based instrumentation in the soft and hard X-ray range. With a flexible spectroscopy chamber and various sources (X-ray tubes, laser-produced plasma source) and detectors (SDD, CCD) AR and especially grazing emission measurements show the feasibility of the analysis independent on large scale facilities such as synchrotron radiation sources.

MI 1.6 Mon 11:45 MER 02

Analysis on nanostructures and samples with high topography using low acceleration voltages — •Max Patzschke — Bruker Nano, Berlin, Germany

Continuing technological advances require the elemental analysis of increasingly smaller structures in many industrial fields, including biological applications, semiconductors, and nanotechnology in general. This confronts the otherwise well proven electron microscope based energy dispersive spectroscopy (EDS) with new challenges. Most of these challenges are due to physical conditions, such as limited resolution and radiation yield in the low energy range requiring the analysis on bulk samples with low accelerating voltages. The necessary of low probe current would give low X-ray count rates with traditional EDX detectors, and only low to intermediate energy X-ray lines with many peak overlaps can be evaluated.

The XFlash FlatQUAD Silicon Drift Detector (SDD) allowing us to overcome these limitations, and offering additional benefits. Using the

FlatQuad detector with low accelerating voltages, the element distribution of nanometer-sized structures can be displayed in a short time. Peaks with several overlapping elements (e.g. Co-L, Ni-L, Fe-L) can be deconvolved using the improved atomic database with 250 additional L,M and N lines below 4 keV.

Examples for nanotechnological applications will be presented: mapping of nanoparticles down to 4nm, biological application, samples with high topography and specimen where sample preparation like coating is excluded.

MI 1.7 Mon 12:00 MER 02

Identification of laminates in 10 M martensite Ni-Mn-Ga magnetic shape memory single crystals — •Jaromír Kopeček[1], Ladislav Klimša[1], Ladislav Straka[1], Jan Drahokoupil[1], Petr Veřtát[1], Vít Kopecký[1], Hanuš Seiner[2], Martin Zelený[1], and Oleg Heczko[1] — [1]Institute of Physics of the AS CR, Na Slovance 2, Prague, 182 00, Czech Republic — [2]Institute of Thermomechanics ASCR, Dolejškova 5, 182 00 Prague, Czech Republic

Ni-Mn-Ga is the most studied magnetic shape memory alloy and the most effective example of magnetic shape memory effects. Used single crystals with composition Ni50Mn28Ga22 have monoclinic structure at room temperature, nevertheless the monoclinicity is very weak with respect to both monoclinic angle and lattice parameters a and b. Such structure allows two types of mobile twinning boundaries in magnetic field. The Type I with mirror plane symmetry and more complicated, extremely mobile Type II twinning boundary. Generally, thanks to monoclinicity there exists a hierarchy of twinning on different scales: a-c laminate; monoclinic lamellae - compound twinning; a-b laminate. The complex structure of macrotwinning lamellae and monoclinic twinning was observed many times. However, the third level of lamination, i.e. a-b laminate is hard to observe and describe correctly. We observed whole hierarchy of all three types of laminates by particular SEM observation and manage to identify them using our previous knowledge from optical microscopy, X-ray diffraction and theory of martensite. The identification includes the branching of lamellae on twinning boundaries.

Invited Talk MI 1.8 Mon 12:15 MER 02

Microstructural characterization of non-metallic precipitates in silicon crystallization processes for photovoltaic applications — •Susanne Richter, Martina Werner, Sina Swatek, and Christian Hagendorf — Fraunhofer Center for Silicon Photovoltaics CSP, Otto-Eißfeldt-Str. 12, D-06120 Halle (Saale)

During the directional crystallization of silicon the formation of non-metallic precipitates may occur due to enrichment and segregation of carbon and nitrogen. Different types of precipitates lead to different defects in the later processed solar cells. Extensive material analyses were performed to obtain micro structural, chemical and electrical properties of all occurring precipitate types including analyses via IR microscopy, ToF-SIMS, FIB target preparation for TEM combined with nanospot-EDS and SAED. As a result in addition to the previous state of knowledge a precipitate classification is deduced. Selective material properties are correlated to individual precipitate types such as morphology, crystal structure (and polytype) or the presence of certain impurities. These properties can be used for precipitate identification and prediction of expected defect behavior. Especially the correlation between the found impurities, its concentrations within the precipitates analyzed by ToF-SIMS, EDS and ICP-MS, and the resulting crystallographic microstructure investigated by TEM and SAED are presented in detail.

MI 1.9 Mon 12:45 MER 02

Quantitative high-resolution off-axis electron holography of 2D materials — •Florian Winkler[1,2], Juri Barthel[1,3], Sven Borghardt[4], Amir H. Tavabi[1,2], Emrah Yucelen[5], Beata E. Kardynal[4], and Rafal E. Dunin-Borkowski[1,2] — [1]Ernst Ruska-Centre for Microscopy and Spectroscopy with Electrons (ER-C), Forschungszentrum Jülich, D-52425 Jülich, Germany — [2]Peter Grünberg Institute 5 (PGI-5), Forschungszentrum Jülich, D-52425 Jülich, Germany — [3]Gemeinschaftslabor für Elektronenmikroskopie (GFE), RWTH Aachen University, D-52074 Aachen, Germany — [4]Peter Grünberg Institute 9 (PGI-9), Forschungszentrum Jülich, D-52425 Jülich, Germany — [5]FEI Company, Achtseweg Noord 5, Eindhoven 5600 KA, The Netherlands

Usually, phase information in conventional transmission electron microscopy (TEM) is lost. A fully recorded electron wave function with its amplitude and phase would allow for post-acquisition removal of residual aberrations and thus an accurate quantitative description of a material's atomic structure.

Here, we present electron wave functions reconstructed from high-resolution electron holograms of two-dimensional WSe_2. We show that a very precise knowledge of microscope and sample-related parameters, such as image spread, Debye-Waller factor and specimen tilt, can be obtained by comparing experimental wave functions with simulations. Furthermore, we are able to remove residual aberrations from the experimental data, which enables a quantitative description of the atomic structure, including the detection of structural defects.

MI 2: Symposium Novel Functionality and Topology-Driven Phenomena in Ferroics and Correlated Electron Systems (DF with MA, KR, MI, TT and DS)

Time: Monday 15:00–18:00 Location: HSZ 02

Invited Talk MI 2.1 Mon 15:00 HSZ 02

Ferroelectric domain walls: from conductors to insulators and back again — •Petro Maksymovych — Center for Nanophase Materials Sciences, Oak Ridge National Laboratory, Oak Ridge, USA

The root cause of uncertainty around conducting ferroelectric domain walls (DWs) is the contact problem, which may be intrinsic to the polarization topology and may not be resolved by doping ferroelectric films. We revealed how contact effects are responsible for apparent DW conductance in ultrathin BiFeO3, wherein the DW electrostatically gates the interface, but is not itself a conductor. At the same time, we explored AC conductance of DWs to eliminate contact effects. DWs in both BiFeO3 and Pb(Zr0.2Ti0.8)O3 revealed robust conductivity at 3 GHz with remarkably large values of 2-6 S/m. Using the Ginzburg-Landau-Devonshire model for ferroelectric semiconductor, the effect is traced to local charge of nominally straight DWs due to defect-induced roughening and/or an intrinsic flexoelectric effect. Microwave regime opens new opportunities for device integration and carrier-density and dielectric effects at DWs.

Support provided by U.S. Department of Energy, BES, Materials Science and Technology Division. Microscopy experiments performed at the Center for Nanophase Materials Sciences, a DOE Office of Science User Facility.

[1] R. K. Vasudevan, et al., and P. Maksymovych, submitted (2016)
[2] A. Tselev, P. Yu, Y. Cao, L. R. Dedon, L. W. Martin, S. V. Kalinin, and P. Maksymovych, Nat. Comms., 7 (2016) 11630.

Invited Talk MI 2.2 Mon 15:30 HSZ 02

Zoology of skyrmions and the role of magnetic anisotropy in the stability of skyrmions — •Istvan Kezsmarki[1], Sandor Bordacs[1], Jonathan White[2], Vladimir Tsurkan[3], Alois Loidl[3], Peter Milde[4], Hiroyuki Nakamura[5], and Andrey Leonov[6] — [1]Budapest University of Technology and Economics, Budapest, Hungary — [2]Paul Scherrer Institute, Villingen, Switzerland — [3]University of Augsburg, Augsburg, Germany — [4]Technical University of Dresden, Dresden, Germany — [5]University of Kyoto, Kyoto, Japan — [6]University of Hiroshima, Hiroshima, Japan

Skyrmions are nanometric magnetic objects with high stability owing to their topological structures. The internal spin pattern of skyrmions depends on the crystal symmetry of the host materials. While we know many chiral crystals hosting Bloch-type skyrmions, Néel-type skyrmions have only recently observed in polar compounds. On experimental basis, I am going to compare the main characteristics of the two types of skyrmions and discuss the effect of magnetic anisotropy on the thermal stability range of the corresponding Bloch- and Néel-type skyrmion lattices.

Invited Talk MI 2.3 Mon 16:00 HSZ 02
Magnetic imaging of topological phenomena in ferroic materials — •Weida Wu — Department of Physics and Astronomy, Rutgers University, Piscataway, NJ, 08854 USA

Topology is a pervasive concept in condensed matter physics. Topological phenomena such as vortices, Skyrmions and chiral edge states are mesoscopic textures that are crucial for the physical properties and functionalities. Thus, it is imperative to directly visualize these mesoscopic phenomena. In this talk, I will present our recent discovery of alternating uncompensated magnetic moments at Z6 vortex domain walls in hexagonal manganites, which demonstrates the coupling between ferroelectric and antiferromagnetic orders. Furthermore, magnetoelectric response of the vortex domains were directly visualized by Magnetoelectric Force Microscopy (MeFM), a combination of MFM with in-situ modulating high electric fields. Our MeFM results reveal a giant enhancement of magnetoelectric response of a lattice mediated magnetoelectric effect near a spin-reorientation critical point.

This work is supported by US DOE under grant DE-SC0008147.

30 min. break

Invited Talk MI 2.4 Mon 17:00 HSZ 02
Topological skyrmion textures in chiral magnets — •Markus Garst — Institut für Theoretische Physik, Technische Universität Dresden, Zellescher Weg 17, 01062 Dresden, Germany

A magnetization that spatially varies within a plane can be characterized by a topological skyrmion number specifying how often the magnetization vector covers the unit sphere. Magnetic skyrmion textures with such a non-trivial winding number are endowed with additional functionality as they efficiently couple to magnon- and itinerant spin currents allowing for novel spintronic applications. Such textures arise, in particular, in chiral magnets where the Dzyaloshinskii-Moriya interaction favours a spatially modulated magnetization. This stabilizes magnetic solitons that carry an integer skyrmion charge as well as regular arrangements thereof, i.e., skyrmion crystals. We demonstrate that defects of helimagnetic order can carry half-integer skyrmion numbers. In analogy to cholesteric liquid crystals, such defects can be interpreted as disclinations and dislocations that are instrumental for the magnetic relaxation process in these systems. We also show that an array of such defects might arise in topological domain walls of helimagnetic order permitting an efficient manipulation by spin currents.

Invited Talk MI 2.5 Mon 17:30 HSZ 02
Learning through ferroelectric domain dynamics in solidstate synapses — Sören Boyn[1], Gwendal Lecerf[2], Stéphane Fusil[1], Sylvain Saïghi[2], Agnès Barthélémy[1], Julie Grollier[1], Vincent Garcia[1], and •Manuel Bibes[1] — [1]Unité Mixte de Physique CNRS/Thales, Palaiseau FRANCE — [2]IMS Laboratory, U. Bordeaux FRANCE

In the brain, learning is achieved through the ability of synapses to reconfigure the strength by which they connect two neurons. Artificial hardware with performances emulating those of biological systems require electronic nanosynapses endowed with such plasticity. Promising solid-state synapses are memristors, simple two-terminal nanodevices that can be finely tuned by voltage pulses. Their conductance evolves according to a learning rule called spike-timing-dependent plasticity, conjectured to underlie unsupervised learning in our brains. We will report on purely electronic ferroelectric synapses and show that spike timing-dependent plasticity can be harnessed and tuned from intrinsically inhomogeneous ferroelectric polarisation switching. Through combined scanning probe imaging and electrical transport experiments, we demonstrate that conductance variations in such BiFeO3-based ferroelectric memristors can be accurately controlled and modelled by the nucleation-dominated electric-feld switching of domains with different polarisations. Our results show that ferroelectric nanosynapses are able to learn in a reliable and predictable way, opening the way towards unsupervised learning in spiking neural networks.

MI 3: Symposium Bioinspired Functional Materials: From Nature's Nanoarchitectures to Nanofabricated Designs

Time: Tuesday 9:30–12:15 Location: HSZ 02

Invited Talk MI 3.1 Tue 9:30 HSZ 02
New twists in biological photonics: circular polarisation and beyond. — •Pete Vukusic, Luke McDonald, and Ewan Finlayson — University of Exeter, Exeter, UK.

The evolution of structural colour mechanisms in many biological systems has given rise to many specialised and often highly functional optical effects both in animals and in plants. Recent scientific works yielded several examples that are being developed for use across technology. Among many thousands of biological systems, a distinctive example involving circular polarisation (CP) was described by Michelson himself: the scarab beetle Chrysina resplendens. Its exoskeleton has a bright, golden appearance that reflects both right-handed and left-handed CP light. The chiral nanostructure responsible for this is a helicoid comprising twisted birefringent dielectric planes. This presentation revisits the C. resplendens beetle, correlating details of its CP reflectance spectra directly with detailed analysis of its morphology that includes a chiral multilayer configuration comprising two chirped, left-handed, helicoids separated by a birefringent retarder. The system's optical behaviour is modelled using a scattering matrix simulation, where the optical roles of each component of the morphological substructure are elucidated. The C. resplendens' model is presented here, alongside summaries of other inspirational biological structural colour generation strategies, as a key example of highly adapted optical design.

Invited Talk MI 3.2 Tue 10:00 HSZ 02
Bio-inspired materials and structures for technology and architecture — •Thomas Speck — Plant Biomechanics Group & Botanic Garden, University of Freiburg

Biological structures and materials are typically multi-layered, hierarchically structured, finely tuned and highly differentiated based on the combination of a few basic molecular components. This leads to materials and structures that are characterized by multiple networked functions and (often) possess excellent mechanical properties, a pronounced adaptability to changing environmental conditions and manyfold self-x-properties.

During the last decades biomimetics, i.e. using living organisms as inspiration for technical developments products, has attracted increasing attention as well from basic and applied research as from various fields of industry. Biomimetics has a high innovation potential and offers the possibility for the development of sustainable technical products and production chains. On the one hand, novel sophisticated methods for quantitatively analyzing and simulating the form-structure-function-relationship on various hierarchical levels allow new fascination insights in multi-scale mechanics and other functions of biological structures, materials and surfaces. On the other hand, recent developments in computational design and simulation together with new production methods enable for the first time the transfer of many outstanding properties of the biological role models into innovative biomimetic products for reasonable costs which makes them interesting for applications in many fields of technology and building construction.

Invited Talk MI 3.3 Tue 10:30 HSZ 02
Cellulose bio-inspired hierarchical structures — •Silvia Vignolini — Lensfield Road Cambridge CB2 1EW UK

Nature's most vivid colours rely on the ability to produce complex and hierarchical photonic structures with lattice constants on the order of the wavelength of visible radiation. A recurring strategy design that is found both in the animal and plant kingdoms for producing such effects is the helicoidal multilayers. In such structures, a series of individual nano-fibers (made of natural polymers as cellulose and chitin) are arranged parallel to each other in stacked planes. When distance between such planes is comparable to the wavelength of light, a strong polarised, colour selective response can be obtained. These helicoidal multilayers are generally structured on the micro-scale and macroscopic scale giving rise to complex hierarchical structures.

Biomimetic with cellulose-based architectures enables us to fabricate novel photonic structures using low cost materials in ambient conditions. Importantly, it also allows us to understand the biological processes at work during the growth of these structures in plants. In this talk the route for the fabrication of complex bio-mimetic cellulose-based photonic structures will be presented and the optical properties of artificial structures will be analyzed and compared with the natural ones.

15 min break

Invited Talk MI 3.4 Tue 11:15 HSZ 02

Strong Flexible Bioenabled Nanocomposites for Sustainable Sensing — •Vladimir Tsukuruk — School of Materials Science and Engineering, Georgia Institute of Technology, Atlanta, USA

I discuss recent results from our research group on designing flexible and strong responsive polymer and biopolymer nanocomposite materials and structures for advanced flexible sensing and electronic applications. Ultrathin silk fibroin proteins and chemically modified cellulose nanocrystals were assembled in order to control intimate assembly with graphene oxide sheets with controlled surface chemical composition on planar and curved substrates. We demonstrated flexible laminated bionanocomposites with developed biointerphases that facilitate extremely high elastic modulus, bending flexibility, and toughness. Both experimental and computational methods were undertaken to address silk fibroin adsorption at heterogeneous surfaces of graphene oxide with different degrees of oxidation. Graphene oxide and reduced graphene oxide sheets at various levels of oxidation were compared with silicon dioxide (SiO2) as a benchmark substrate. We concluded that silk fibroin readily forms single molecule proto-nanofibrils with β-sheet structures on oxidized graphene oxide surfaces but aggregated globular structures on the hydrophobic surfaces. Finally, electrochemical-assisted photolithography has been utilized for high spatial resolution conductive patterning of these nanocomposites with high local electrical conductivity, sharp boundaries, and optical transparency. Some peculiar features of these flexible bionanocomposites can be explored for tactile recognition, remote sensing, and low-noise SERS substrates.

Invited Talk MI 3.5 Tue 11:45 HSZ 02

3D laser nano-printing of rationally designed materials — •Martin Wegener — Karlsruhe Institute of Technology, Karlsruhe, Germany

Broadly speaking, 3D structures and materials can be designed by using the human brain, computer-based (topology) optimization, or inspiration from nature. Regardless of how a 3D blueprint has been obtained, it eventually needs to be manufactured. 3D laser printing on the micro- and nanometer scale has become a versatile and reliable workhorse for accomplishing this task. Here, we review recent examples from our group. This includes micropolar metamaterials with behavior beyond ordinary continuum mechanics, metamaterials with effectively negative thermal expansion from positive constituents, and electrical metamaterials with unusual direction and sign of the Hall voltage.

MI 4: X-Ray Imaging, Holography, Ptychography and Tomography

Chair: Ehrenfried Zschech (Fraunhofer IKTS Dresden)

Time: Wednesday 9:30–11:30 Location: MER 02

Invited Talk MI 4.1 Wed 9:30 MER 02

X-ray Microscopy: Imaging the Chemistry Inside — •Christian G. Schroer — Photon Science, DESY, Notkestr. 85, 22607 Hamburg — Institut für Nanostruktur- und Festkörperphysik, Universität Hamburg, Jungiusstr. 11, 20355 Hamburg

One key strength of hard X-ray microscopy is that it can image the inner structures of an object without destructive sample preparation. Exploiting various X-ray analytical contrasts, such as fluorescence, diffraction, and absorption, the elemental, structural, and chemical information can be obtained from inside a sample, e. g., a chemical reactor. Conventional X-ray microscopy is currently limited by X-ray optics to a few tens of nanometers. One way to overcome this limitation is scanning coherent X-ray diffraction microscopy also known as ptychography [1]. It can be combined with spectroscopy to obtain chemical information on a given element of interest [2]. In combination with tomography, the three-dimensional structure of an object can be reconstructed with unprecedented spatial resolution [3]. Here, an overview is given over multimodal X-ray imaging for materials research at modern synchrotron radiation sources.

[1] J. Rodenburg, H. Faulkner, Appl. Phys. Lett. 85, 4795 (2004); P. Thibault, et al., Science 321, 379 (2008); A. Schropp, et al., Appl. Phys. Lett. 96, 091102 (2010); A. Schropp, et al., Appl. Phys. Lett. 100, 253112 (2012); J. Reinhardt, et al., Ultramicroscopy 173, 52 (2017).

[2] R. Hoppe, et al., Appl. Phys. Lett. 102, 203104 (2013).

[3] M. Dierolf, et al., Nature 467, 436 (2010); M. Holler, et al., Scientific Reports 4, 3857 (2014).

MI 4.2 Wed 10:00 MER 02

Imaging with hard X-rays and Nanometer Resolution using Multilayer Zone Plates — •Jakob Soltau[1], Christian Eberl[2], Tim Salditt[1], Hans-Ulrich Krebs[2], and Markus Osterhoff[1] — [1]Röntgenphysik, Uni-Göttingen, Friedrich-Hund Platz 1, 37077 Göttingen — [2]Materialphysik, Uni-Göttingen, Friedrich-Hund Platz 1, 37077 Göttingen

The resolution of zone plates is determined by their smallest zone width. Multilayer zone plates (MZP) can be fabricated using the process of pulsed laser deposition, which allows zone width of 5 nm and less and therefore enabling imaging of X-rays on a nanometer scale [1]. The central challenge in the development of hard X-ray nano-focusing MZPs is the fulfilling of the Bragg condition across the zone plate. To achieve this the individual zones need to be tilted. Latest experiments using tilted-MZPs at synchrotron sources demonstrated successfully a resolution of a few nanometer in a wide X-ray energy range from 7 keV at DESY/Petra III and for the first time with photon energies above 100 keV at ESRF. A new setup and a motorized stage significantly reduced the set-up and measuring time in scanning X-ray microscopy allowing high resolution imaging of soft- and hard-matter samples in a shorter time. In addition to the experiments, 3D simulations have been performed. The propagation of electromagnetic waves inside and behind the MZP proved the advantage of circular MZPs to achieve very high photon flux densities in a single focal point. The simulations were revealing interaction processes like e.g. dynamical diffraction inside the MZPs. [1] Eberl, C. et al. Appl. Surf. Sc

MI 4.3 Wed 10:15 MER 02

The Fluence-Resolution Relationship in Holographic and Coherent Diffractive Imaging — •Johannes Hagemann and Tim Salditt — Institut für Röntgenphysik, Friedrich-Hund-Platz 1, University Göttingen, 37077 Göttingen

The simple question "Which resolution do I get for the invested photon fluence?" is extremely important for x-ray imaging of radiation sensitive specimen, such as biological cells and tissues. This work [1] presents a numerical study of the fluence-resolution behavior for two coherent lens-less x-ray imaging techniques. To this end we compare in numerical experiments the fluence-resolution relationship of inline near-field holography (NFH) and far-field coherent diffractive imaging (CDI). To achieve this, we carry out the phase reconstruction using iterative phase retrieval algorithms on simulated noisy data. Using the incident photon fluence on the specimen as control parameter we study the achievable resolution for two exemplary phantoms (cell and bitmap). A survey based on maximum likelihood estimation [2] of CDI and NFH showed in principle no difference in the encoded information of the measured data for a given fluence. In the current approach we assess the actual reconstructability of the CDI/NFH data via direct phase retrieval. We use then the Fourier Ring Correlation as measure of reconstruction quality i.e. the achievable resolution. Our results indicate a superior performance of holography compared to CDI, for the same fluence and phase reconstruction procedure. [1] J. Hagemann and T. Salditt, Acta Crystallogr. A, (in review) [2] T. Jahn et al., Acta Crystallogr. A, (2017), 73, 1-11

MI 4.4 Wed 10:30 MER 02

Simulations towards high magnification setups in X-ray

Talbot-interferometry — •Andreas Wolf, Veronika Ludwig, Jens Rieger, Max Schuster, Maria Seifert, Georg Pelzer, Thilo Michel, Gisela Anton, and Stefan Funk — ECAP - Erlangen Centre for Astroparticle Physics, Universität Erlangen-Nürnberg, Erwin-Rommel-Str. 1, 91058 Erlangen

Compared with the traditional attenuation contrast, X-ray Talbot-interferometry can yield additional information in terms of the differential phase contrast (DPC) and the dark field contrast (DFC) images.

In this imaging modality, which is primarily pursued in the field of medical diagnostics and soft tissue imaging, the Talbot effect leads to the generation of self images of a grating in the beam path. With respect to the thus created spatial reference pattern and by introducing a second grating, the aforementioned contrast modalities can be retrieved either via a phase-stepping approach or by using Moiré-fringes in a single-shot scheme.

In this contribution, we present simulation studies of Talbot-interferometer-based setups featuring high magnifications towards future applications for imaging at XFEL-beamlines and in the field of laboratory astrophysics where a high magnification of object structures is needed to resolve the generated shocks.

15 min. break

MI 4.5 Wed 11:00 MER 02

X-Ray Phase-Contrast Tomography with Anisotropic Source Conditions — •Malte Vassholz, Leon Merten Lohse, and Tim Salditt — Institute for X-Ray Physics, University of Göttingen, Germany

Hard x-ray tomography offers a unique capability to nondestructively map out the three-dimensional structure of a body or material. A major challenge for high-resolution and/or phase-contrast tomography in the laboratory, is the lack of high-brilliance table-top x-ray sources. By suitable generalization of the tomographic measurement geometry and the reconstruction framework, one can significantly relax the brilliance/coherence condition in one of the two lateral source dimensions [1], opening up new opportunities towards nanoscale resolution with low-brilliance table-top x-ray sources. To this end, the framework of the two-dimensional Radon transform, which is the common basis for most analytical x-ray tomography applications, is replaced by the three-dimensional Radon transform. We show applications for absorption tomography as well as phase-contrast tomography for anisotropic source conditions with aspect ratios larger than two orders of magnitude in the lateral source dimensions.

[1] M. Vassholz, B. Koberstein-Schwarz, A. Ruhlandt, M. Krenkel, and T. Salditt, Phys. Rev. Lett. 116, 088101 (2016).

MI 4.6 Wed 11:15 MER 02

Core-shell-shell nanowires studied by coherent x-ray nanobeam — •Arman Davtyan[1], Vincent Favre-Nicolin[2], Ryan B. Lewis[3], Hanno Küpers[3], Lutz Gelhaar[3], Dominik Kriegner[4], Ali Al-Hassan[1], Otmar Loffeld[1], and Ullrich Pietsch[1] — [1]Faculty of Science and Engineering,University of Siegen,57068 Siegen,Germany — [2]The European Synchrotron,71 Avenue des Martyrs,Grenoble,France — [3]Paul-Drude-Institut für Festkörperelektronik,Hausvogteiplatz 5-7,D-10117 Berlin,Germany — [4]4 Department of Condensed Matter Physics,Charles University, Ke Karlovu 5,121 16 Prague 2,Czech Republic

Core-shell-shell heterostructure nanowires (NWs) with 140nm GaAs core, 10nm In(0.10)Ga(0.90)As inner shell and 30nm GaAs outer shell have been investigated by combining coherent x-ray diffraction imaging (CXDI) and ptychograpy in the Bragg geometry. NWs were grown on a prepatterned substrate. Individual nanowires were measured at the ID01 beamline of the ESRF with coherent x-rays of 9keV energy and 150x200 nm full width half maximum (FWHM). 2D ptychography at GaAs (111) Bragg reflection was applied to investigate the nanowire along the growth axis. Ptychographic reconstruction shows the homogeneous structure of the wire along the growth axis. CXDI was applied to record the 3D reciprocal space maps around the symmetric GaAs (111) reflection at different heights along the NW growth axis.

MI 5: Session on Nanostructuring Beyond Conventional Lithography

Chair: Hartmut S. Leipner (Martin-Luther-Universität Halle-Wittenberg)

Time: Wednesday 11:30–13:15 Location: MER 02

MI 5.1 Wed 11:30 MER 02

X-ray waveguide optics — •Sarah Hoffmann-Urlaub, Mike Kanbach, Hsin-Yi Chen, and Tim Salditt — Institut für Röntgenphysik,Georg-August Universität, Friedrich-Hund Platz 1, 37077 Göttingen

Virtual x-ray sources as provided by channel waveguides exhibit nanoscale sizing [1] as well as a high degree of coherence. We report on imaging experiments and the fabrication process of these hard x-ray waveguides deployed at the synchrotron sources at DESY and ESRF. Among nother techniques e-beam lithography, reactive ion etching and Silicon wafer bonding are involved within the fabrication of two-dimensional, sub-100 nm sized waveguide channels. Both waveguide geometry [2] and material [3] can be adapted to meet the requirements of a specific experiment, such as the photon energy (7.9-17.5 keV), the desired source size, or the application of a reference beam in a holography setup [4].

[1] H. Neubauer et al., J. Appl. Phys. 115, 214305 (2014)
[2] H.-Y. Chen, et al. Appl. Phys. Lett. 106(19), 194105 (2015)
[3] S. Hoffmann-Urlaub, et al. Microelec. Eng. 164: 135-138. (2016)
[4] S. Hoffmann-Urlaub, et al. Acta Cryst. A, 72.5 (2016)

MI 5.2 Wed 11:45 MER 02

Additive Fabrication of Nanostructures with Focused Soft X-Rays — •Andreas Späth[1], Fan Tu[1], Florian Vollnhals[2], Hubertus Marbach[1], and Rainer H. Fink[1] — [1]FAU Erlangen-Nürnberg, Physical Chemistry II, Erlangen, Germany — [2]Luxembourg Institute of Science and Technology (LIST), Materials Research and Technology, Belvaux, Luxembourg

We have developed a novel technique for the deposition of metallic nanostructures by illuminating gas phase precursors with focused soft X-rays in a zone plate based scanning transmission X-ray microscopy (STXM) setup. With this technique we have been able to produce localized Co and Mn nanostructures with growth rates and purity competitive with electron beam induced deposition (EBID) [1]. We demonstrate that our approach exhibits significant selectivity with respect to incident photon energy leading to enhanced growth for resonant absorption energy of the precursor molecule. This finding opens a new field of photon energy selective deposition from precursor mixtures and deposition from various precursors within one production cycle. The impact of several deposition parameters on the growth rate, such as illumination time, precursor pressure and multi-sweep experiments are discussed with respect to a deeper understanding of deposition processes and optimization of the procedure. Furthermore, we discuss routes to the formation of magnetic deposits.

[1] A. Späth et al., RSC Advances, 2016, 6, 98344.

Invited Talk MI 5.3 Wed 12:00 MER 02

NanoFrazor Lithography - Revolutionizing nanofabrication — •Zhengming Wu[1], Colin Rawlings[2], Simon Bonanni[1], Tero Kulmala[1], Heiko Wolf[2], Urs Duerig[2], Armin W. Knoll[2], Martin Spieser[1], Philip Paul[1], and Felix Holzner[1] — [1]SwissLitho AG, Zurich, Switzerland — [2]IBM Research - Zurich, Rueschlikon, Switzerland

Thermal Scanning Probe Lithography (t-SPL) is an alternative maskless lithography technique which is also commercially available since 2014 under the name NanoFrazor Lithography. It provides similar speed (up to 20 mm/s) and resolution (10 nm half-pitch) as EBL, but without charged particles involved. In addition 3D topographical structures can be written in just one step at better than 2 nm vertical resolution. Here, we present the technology involved and the examples of high resolution and high density nano-structures made by the NanoFrazor for applications like photonics, plasmonics etc. Furthermore, the remaining topography from structures buried under the spin-coated resist is detectable and extremely accurate overlay alignment to these structures (e.g. nanowires & 2D material flakes) is achieved. The capability to write large area pattern is explored. The alternative applications of the heated tip are discussed.

MI 5.4 Wed 12:30 MER 02

Nanopillar with self-assembled Si nanodot for single electron transistor — •Thomas Prüfer, Karl-Heinz Heinig, Wolfhard Möller, and Johannes von Borany — Helmholtz-Zentrum Dresden-Rossendorf, Dresden-Rossendorf, Deutschland

Conventional Lithography allows the fabrication of structures down to ~10 nm, being still too large for single electron transistors (SET) operating at room temperature (RT), which requires a tiny quantum dot (<5nm) embedded in SiO2, with tunnel distances to the source and drain <2nm. Here, we predict a fully CMOS-compatible method of self-assembly of a single Si quantum dot. We assume that 10*20nm thin nanopillars of a layer stack c-Si/6nm SiO2/30nm a-Si are made by conventional lithography. We predict that such a single dot is self-organized and self-assembled between the top and bottom silicon layer by phase separation of metastable SiOx. The SiOx is made by collisional mixing in the layer stack, which is simulated by TRI3DYN [1]. The phase separation of SiOx is described by 3D kinetic lattice Monte Carlo simulations [2]. Our results predict that a single Si nanodot forms if the volume of SiOx is smaller than (10nm)^3. This work has been funded by the European Union's Horizon 2020 research and innovation program under grant agreement No 688072. [1] W. Möller; NIM B, 322, 23*33; [2] M. Strobel, K.H. Heinig, W. Möller, PRB 64, 245422

MI 5.5 Wed 12:45 MER 02

Site-controlled formation of Si nanodots in a buried SiO2 layer via ion-beam implantation and phase separation — •Xiaomo Xu[1], Daniel Wolf[1], Gregor Hlawacek[1], René Hübner[1], Ahmed Gharbi[2], Thomas Prüfer[1], Lothar Bischof[1], Karl-Heinz Heinig[1], Stefan Facsko[1], and Johannes von Borany[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [2]CEA-LETI, Grenoble, France

The single electron transistor (SET) is a promising candidate for low energy-dissipation computing units. However, so far its success is hindered by low-temperature requirements and the lack of CMOS-compatible fabrication route. By combining standard top-down lithography with bottom-up self-assembly of Si nanodots we will overcome this barrier.

In this work, Si nanodots, sufficiently small for RT operation of SETs, are formed in a CMOS-compatible way inside a buried SiO2 layer. This is achieved via ion beam mixing in a geometrical restricted volume and subsequent thermally activated phase separation via RTA. Guided by 3DkMC and TRI3DYN simulations, we perform focused Ne+ beam irradiation with Helium Ion Microscopy (HIM) on planar layers, and Si+ broad-beam irradiation of nano-pillars with embedded SiO2. Both approaches lead to a constrained size of the collision cascade and hence the mixed volume. The as-formed Si nanodots are studied with TEM, SIMS and electrical characterization techniques.

This work has been funded by the European Union Horizon 2020 Research and Innovation Program under grant agreement No. 688072.

MI 5.6 Wed 13:00 MER 02

Transmission Helium Ion Microscopy — Christoph Herrmann and •Karen L. Kavanagh — Dept. Physics, Simon Fraser University, Burnaby, BC V5A 1S6 Canada

The application of a Si p-i-n detector array (Modupix) for the imaging of a coherent helium ion beam (25 keV, Zeiss nanofab) is described. The beam intensity as a function of ion current, aperture size, spot size, focus condition, and gas pressure have been investigated. The transmission through thin films (Si, Al, C and polymers) have been imaged with a lateral resolution of 5 microns, limited by the detector pixel size (55 microns) and distance below the sample (15 cm). The potential for the detection of ion milling rates, diffraction and channeling is discussed.

MI 6: Symposium Nanostructuring Beyond Conventional Lithography (MI with DS, DF, HL, MM and VA)

Time: Wednesday 15:00–17:45 Location: HSZ 02

Invited Talk MI 6.1 Wed 15:00 HSZ 02

The Limits to Lithography: How Electron-Beams Interact with Materials at the Smallest Length Scales — •Karl K. Berggren — Massachusetts Institute of Technology (MIT), 77 Massachusetts Ave., Cambridge, MA, USA

Electron-beam lithography is a ubiquitous tool required by the modern industry and research enterprise. The semiconductor industry relies on it for mask making, while researchers use it for prototyping advanced device concepts and structuring materials to achieve desired form and function. However, surprisingly the impact of the underlying physics of the interaction of electrons with radiolytic materials such as photoresist has been somewhat neglected in describing the limits of lithography. It has been known for some time that, lithographic systems suffer from spatial blurring due to the creation of secondary electrons and the propagation of these secondary electrons in space. What was not as well understood was the role of electro-galvanic effects–plasmons–in the limiting the performance of sub-10-nanometer lithography.

In this talk, I will describe efforts to improve the resolution and performance of sub-10-nm lithographic systems based on enhancement of resist processing. I will then point out the role plasmons (primarily in the bulk) play in limiting the resolution of lithography at the sub-10-nm scale. Finally, I will present some key applications of lithographic patterning at this length scale, and discuss the future implications of the work to related fields such as optical lithography, microscopy, and electromagnetic radiation generation.

Invited Talk MI 6.2 Wed 15:30 HSZ 02

High precision fabrication for light management at nanoscale — •Saulius Juodkazis[1,2] and Armandas Balcytis[1] — [1]Swinburne University of Technology, Melbourne, Australia — [2]Melbourne Center for Nanofabrication, Melbourne, Australia

For control of light-matter interactions occurring on molecular level we need to develop tools with nanoscale precision via nano-fabrication. Recent advances in high precision nanofabrication using 3D approaches and combining standard cleanroom tools with laser direct writing capabilities will be presented. Combination of electron beam lithography (EBL) with post-processing of nanoparticles with Ga-ion milling opens a possibility of sub-20 nm direct write of nano-inscriptions on nanoparticles. Arrays of identical chiral nanoparticles were fabricated with high fidelity and with uniform nano-features. Controlled resizing of ion-milled nanopores over the range of sizes from 100 nm to several nanometers in nano-membranes is achieved using electron beam scanning. Surface charging which is a common problem in applications of ion milling and electron imaging is resolved with co-illumination of deep UV light whose photons have energy larger than the electron work function for a given material. EBL and IBL can be both optimized for a high throughput for simple sample geometries. 3D laser fabrication of micro-optical elements and nano-textured surfaces adds new applications in lab-on-chip and sensing.

Invited Talk MI 6.3 Wed 16:00 HSZ 02

Directed self-assembly of performance materials — •Paul Nealey — University of Chicago and Argonne National Laboratory, Chicago, IL USA

Directed self-assembly (DSA) is arguably the most promising strategy for high-volume cost-effective manufacturing at the nanoscale. Over the past decades, manufacturing techniques have been developed with such remarkable efficiency that it is now possible to engineer complex systems of heterogeneous materials at the scale of a few tens of nanometers. Further evolution of these techniques, however, is faced with difficult challenges in terms of feasibility of implementation at the scale of 10 nm and below, and prohibitively high capital equipment costs. Materials that self-assemble, on the other hand, spontaneously form nanostructures down to length scales at the molecular scale, but the micrometer areas or volumes over which the materials self-assemble with adequate perfection in structure is incommensurate with the macroscopic dimensions of devices and systems of devices of industrial relevance. Directed self-assembly (DSA) refers to the integration of self-assembling materials with traditional manufacturing processes to enhance and augment capabilities. Here I will discuss the use of lithographically-defined chemically patterned surfaces to direct the assembly of block copolymer films for semiconductor manufacturing and ion-conducting membranes, liquid crystal based systems for optoelectronics, and nanoparticles for applications in nanophotonics.

15 min. break

Invited Talk MI 6.4 Wed 16:45 HSZ 02

Nanometer accurate topography patterning using thermal Scanning Probe Lithography — •Armin W. Knoll — IBM Research - Zurich, Switzerland

In thermal Scanning Probe Lithography (t-SPL) [1-5] a heated tip with an apex radius of less than 5 nanometers is used to locally evaporate organic resists and thereby create well defined patterns. Key features of t-SPL are linear patterning speeds of up to 20 mm/s [3] and a resolution of < 10 nm half pitch in resist and < 15 nm after pattern transfer to the substrate [4]. High precision device fabrication is possible due to overlay accuracies of < 5 nm [5]. In addition, 3D topography patterning with ~1 nm (1 sigma) depth accuracy was demonstrated [2].

Examples of unique devices fabricated by t-SPL will be discussed, such as Gaussian shaped mesas in optical micro-cavities for light confinement and Brownian motors for transport and separation of nanoparticles in fluids.

References:

[1] D. Pires et al. Science, 328, 732-735 (2010).
[2] R. Garcia et al. Nature Nanotechnology 9, 577-587 (2014).
[3] P. Paul et al. Nanotechnology, 22, 275306 (2011).
[4] H. Wolf et al. J. Vac. Sci. Technol. B, 33, 02B102 (2015).
[5] C. Rawlings et al. ACS Nano, 9, 6188-6195 (2015).

Invited Talk MI 6.5 Wed 17:15 HSZ 02

High resolution 3D nanoimprint lithography — •Hartmut Hillmer — Institute of Nanostructure Technologies and Analytics (INA), University of Kassel, Germany

2D nanoimprint technologies have been widely investigated and are well established today, although huge research and development tasks have to be tackled in future since many scientific problems are not yet fully solved. In contrary, studies dealing with 3D nanoimprint technologies are still rare. This talk presents imprints of 3D structures:

1) 3D structures on substrates with very high spatial resolution in the vertical direction on substrates. Mesa arrays of laterally arbitrary shape with nominally perpendicular side walls towards the vertical direction have been fabricated by Substrate Conformal Imprint Lithography (SCIL). The height differences between the mesas are in the range of 2-3 nm and is some cases in the sub-nm range. These structures are embedded between Distributed Bragg Reflectors (DBRs) and define the cavities. These arrays of Fabry-Pérot Filters are applied as spectrometers. Since the entire different cavity heights are implemented by a single nanoimprint step, we label the device a nanospectrometer. The 3D templates have been fabricated using digital lithography. Applications of the imprinted nanospectrometer are demonstrated in food monitoring.

2) Released full 3D micro and 3D nano particles with arbitrary shape have been fabricated using our Self-Aligned NanoShaping (SANS) technology. The technological process involves a dual mold "waffle iron" principle. The novel SANS nanoimprint technology allows arbitrarily shaped 3D nanoparticles with precise size and shape control. Applications are intended in the field of pulmonal drug application in future.

References:

S. Schudy, M. Smolarczyk, H. Hillmer, N. Worpattrakul, F. Pilger, Patent application DE 10 2011 054 789.4
A. Albrecht, X. Wang, H.H. Mai, T. Schotzko, I. Memon, M. Bartels, M. Hornung and H. Hillmer, Nonlinear Optics and Quantum Optics 43, 339-353 (2012).

MI 7: Poster: Microanalysis and Microscopy

Chair: Enrico Langer (TU Dresden) and Hartmut S. Leipner (Martin-Luther-Universität Halle-Wittenberg)

Time: Wednesday 18:00–20:00 Location: P4

MI 7.1 Wed 18:00 P4

Anisotropic X-ray optics for laboratory-based X-ray Imaging — •Toni Schiller, Malte Vassholz, and Tim Salditt — Institut für Röntgenphysik, Georg-August-Universität Göttingen, Friedrich-Hund-Platz 1, Göttingen

Recently, we proposed a technique for high resolution x-ray tomography with anisotropic source conditions [1]. This technique combines higher photon-flux of an extended source in one dimension with high spatial resolution of a point-source in the other. In that way imaging and tomography with a spatial resolution limited to the point-source direction can be achieved, applying modified Radon-Transform for reconstruction.

The content of this work presents technical solutions building and improving such a laboratory-setup. The aim is to push spatial resolution further from 100μm to several microns. Main parts of the setup are a liquid-jet Gallium alloy x-ray-source and a high-performance mirror-optic. The mirror-optic focuses chromatic Ga-Kalpha light at 9.2keV to a focal spot of 70μm FWHM . Within the focal plane a slit aperture of a few microns in height and >100μm in width generates a virtual anisotropic source spot for 3D-Radon-Tomography. Characterizing source parameters as well as mirror-optic performance leads to geometric optimization of the setup applying theoretical models of wave propagation. Furthermore sampling and reconstruction routines are optimized to reduce acquisition as well as processing time.

[1] M.Vassholz, B.Koberstein-Schwarz, A.Ruhlandt, M.Krenkel and T.Salditt; Phys. Rev. Lett. 116, 088101 * Published 24 February 2016

MI 7.2 Wed 18:00 P4

Ultra-narrow Germanium-slits and waveguides for laboratory and synchrotron x-ray applications — •Ferdinand Döring, Sarah Hoffmann-Urlaub, Mike Kanbach, and Tim Salditt — Institute for X-Ray Physics Friedrich-Hund-Platz 1 37077 Göttingen Germany

Modern nano-beam x-ray diffraction and imaging applications are based on accuratly manufactured elements. Recently we developed x-ray waveguides to facilitate coherence beams with flat wavefrontsconfined down to below 20nm. To open a new oppotiunity for beamshaping, we adapted the known processes of waveguide fabrication to slit production. For a larger angular acceptance, the optical thickness has to be reduced while the absorption (in the cladding) needs to stay sufficiently high. Therefore, we replaced silicon by germanium as cladding material. We use a lithographic manufacturing processes at UV 400nm in combination with reactive ion etching and germanium wafer bonding of 500um thick 20mm x 20mm sampels. Along the vertical direction, the slit size is varied from 100nm up to 1000nm, while the horizontal size is in the rage between 1um and 1000um. Germanium slits showed a prominent modification of the challes during cross-section bonding. The growth of an interlayer inside the channels decreases the wall roughness resulting in round boundaries. That is why we applied the improved germaniumprocess to waveguide fabrication with the result of approximately round waveguid channels exhibiting a diameter of 100 nm and a multimodal exit field of hight transmission. The fabrication is guided by finite differences simulation.

MI 7.3 Wed 18:00 P4

Simulation and Reconstruction of Coherent Modes for Near Field Imaging — •Johannes Hagemann and Tim Salditt — Institut für Röntgenphysik, Friedrich-Hund-Platz 1, University Göttingen, 37077 Göttingen

In X-ray near field imaging experiments the probing beam determines the imaging quality in terms of resolution and artifacts. Distortions in the probe from optical elements such as focusing optics can easily spoil quantitative contrast. Thus characterizing the probe is an important issue. In previous work [1] we have reconstructed the probe under the assumption of full coherence. In this contribution we extend the reconstruction scheme to include also the partial coherent case, by extending the ptychography approach proposed for far field detection [2] to the near field. The reconstruction scheme uses the measurements from multiple detection planes. Experimentally this is achieved by moving the detector to different distances. The reconstruction is numerically quite demanding since the modes have to be individually propagated and orthogonalized in each iteration of the reconstruction algorithm. Without the use of GPUs this would be a time consuming process. By numerical simulations and a suitable representation of modes, we show how to take into account partial spatial coherence, both in image formation and in reconstruction. Our results show that the occupation numbers of the modes and the degree of coherence can be reconstructed. [1] J. Hagemann et al., J. Synchrotron Radiat., (in review). [2] P. Thibault, A. Menzel, Nature 494, 68-71(2013).

MI 7.4 Wed 18:00 P4

Improving Holographic Image Reconstruction by Statistical Multi-resolution Estimation — •Stephan Kramer[1] and Johannes Hagemann[2] — [1]Fraunhofer ITWM, Fraunhofer-Platz 1, 67663 Kaiserslautern — [2]Institut für Röntgenphysik, Universität Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen

We study the applicability of statistical multiresolution estimation (SMRE) to the problem of phase reconstruction in X-ray near-field holography. X-ray imaging experiments essentially yield near-field holograms. Despite their high quality they still contain noise and blur due to imaging errors. To get the final image of the object of interest its phases have to be retrieved from the measured hologram. To improve the input to this phase reconstruction we deconvolve and denoise a hologram either with our implementation of SMRE [1,2] or with Matlab's Richardson-Lucy (RL) algorithm, where the latter serves as reference. To assess the quality we study the number of fringes restored and the sharpness of edges after the phase reconstruction. Our results show that, in contrast to RL, our SMRE method is able to improve the holograms and thus the phase reconstruction.

[1] Kramer, S.C., Hagemann, J., Künneke L. and Lebert, J., 2016. SIAM Journal on Scientific Computing, 38(5), pp.C533-C559.

[2] Kramer, S.C. and Hagemann, J., 2015. ACM TOPC, 1(2), p.15.

MI 7.5 Wed 18:00 P4

Pre-Studies towards phase-contrast imaging in the field of laboratory astroparticle physics — •Max Schuster, Veronika Ludwig, Jens Rieger, Maria Seifert, Andreas Wolf, Georg Pelzer, Thilo Michel, Gisela Anton, and Stefan Funk — ECAP - Erlangen Centre for Astroparticle Physics, Universität Erlangen-Nürnberg, Erwin-Rommel-Str. 1, 91058 Erlangen

Laboratory astrophysics is an emerging field in astroparticle physics with the aim to prepare, control and investigate systems which behave similar to those of astrophysical origin.

Shock acceleration, e.g., is a candidate mechanism for the origin of cosmic rays. Therefore, the production of laser-induced shock fronts and the imaging of the resulting density distribution is of great interest.

X-ray phase-contrast Imaging (PCI) is an x-ray imaging method which is sensitive to local variations in the electron density distribution.

PCI of the shock front region with high intensity x-ray beams such as beams from free electron lasers can be used to acquire images of the projected electron density gradients in the shock.

High spatial resolution measurements of shock waves at an X-ray free electron laser have already been performed using propagation-based PCI. Compared to this, grating-based PCI promises better sensitivity to small variations in the densities.

In this contribution we will present a comparison between propagation and grating-based PCI with regard to their requirements on the experimental setup and on the image reconstruction.

MI 7.6 Wed 18:00 P4

Adaption of conventional CCD cameras for grazing-emission X-ray fluorescence spectroscopy in the laboratory — •Steffen Staeck, Veronika Szwedowski, Jonas Baumann, Ioanna Mantouvalou, and Birgit Kanngiesser — TU Berlin

X-ray fluorescence spectroscopy (XRF) is a well-established, non-destructive technique for analyzing the element distribution in a sample. Additional depth information can be gained by introducing an angle variation regarding incident or emitted photons and so changing the information depths. In grazing-incidence and grazing-emission X-ray fluorescence spectroscopy (GI/GEXRF) the angle of the incident beam or the emission angle is varied close to the angle for total reflection. Though these methods have proven to be reliable when analyzing multilayer structures or solar cells, the whole angular range has to be scanned. This can be avoided by using scanning-free GEXRF, where a range of emission angles is recorded simultaneously with a 2D-detector. For this scanning-free approach usually an energy-dispersive pixel camera such as the pnCCD has to be used which is optimized for single-photon counting regarding e.g. read-out noise and sensitivity. As these cameras are high prized, it is of interest to perform such experiments with conventional CCD cameras. In this work we present investigations concerning the understanding of charge cloud formation and transport for the optimization of a conventional CCD camera for GEXRF using laboratory equipment.

MI 7.7 Wed 18:00 P4

Correlative Microscopy and Image Fusion of SIMS and Electron Microscopy data — •Florian Vollnhals, Santhana Eswara, Jean-Nicolas Audinot, David Dowsett, and Tom Wirtz — Advanced Instrumentation for Ion Nano-Analytics (AINA), Luxembourg Institute of Science and Technology (LIST), L-4422 Belvaux, Luxembourg

The investigation of complex micro- and nanostructured samples found in many fields of science like materials research, biology and medicine, pose significant challenges both in terms of microscopy and chemical microanalysis. Often, a combination of different imaging and analysis techniques is required to establish a comprehensive picture of the sample and its properties.

Correlative microscopy of high-resolution techniques like SEM or TEM with chemically sensitive techniques like imaging SIMS, can provide such information. These resulting multimodal data sets are commonly evaluated individually or side-by-side, but it is also possible to combine both types of data in a meaningful way to improve or facilitate their analysis. One such approach is derived from remote sensing, where low resolution spectral images are sharpened via a high-resolution pan-chromatic band. We will present two basic image fusion approaches (EM sharpening using IHS transformation and Laplacian pyramid based) and discuss their applicability, advantages and disadvantages in the context of TEM/SIMS, SEM/SIMS and HIM/SIMS correlative microscopy.

[1] T. Wirtz et al., Nanotechnology 26 (2015), 434001

MI 7.8 Wed 18:00 P4

Source, accelerator and micro-beam line upgrade of the Göttingen proton beam writing facility at MaRPel — •Alrik Stegmaier, Hans Hofsäss, Stefan Niessner, Clemens Beckmann, and Ulrich Vetter — 2. Physikalisches Institut, Georg-August-Universität Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen

The MaRPel (Materials Research Pelletron) accelerator was first used successfully for Nitrogen and Hydrogen depth profiling in RNRA [1,2].

Since then it has undergone many upgrades. It currently consists of a 3 MV NEC-Pelletron, a SNICS (Source for Negative Ions through Cesium Sputtering), a station for ion source development and three beam-lines that can be used for RBS, RNRA, in-air-RBS and PIXE, high energy ion implantation and the micro-beam line.

Here we report on the latest upgrades to the source, the accelerator itself and the micro-beam line that is used for continued development of Proton Beam Writing (PBW).

[1] M. Schwickert et al., Surface and Coatings Techn., 151/152, 222, 2002

[2] M. Uhrmacher et al., J. Alloys. Comp., 307, 404-406, 2005

MI 7.9 Wed 18:00 P4

Positioning planar scanning probes by super-resolution microscopy — •Stefan Ernst and Friedemann Reinhard — Walter Schottky Institut and Physik Department, Technische Universität München, Garching, Germany

Scanning probe microscopy (SPM) is traditionally based on very sharp tips, where the small size of the apex is critical for resolution (STM, AFM, MFM). This paradigm is about to shift, since a new generation of planar probes (SQUIDs, scanning SETs, NV color centers in diamond) promises to image hitherto inaccessible quantities such as very small magnetic and electric fields. So far, much effort is put into fabricating these planar sensors on a tip, to be compatible with traditional SPM techniques and to bring the sensor close to the sample surface. This poses a significant engineering challenge, which is mastered by only a few groups.

Here we propose a novel, tipless, approach – a technique to scan a planar probe parallel to a planar sample at a distance of only a few nanometers. The core element of our scheme is a super-resolution microscopy technique to measure both sensor-sample tilt and distance with high accuracy (mrad/nm). In this project, we aim to use shallow

NV centers at the planar surface of a bulk diamond as scanning probes. This will simultaneously reduce fabrication complexity, improve the sensor quality and reduce the sensor-sample distance compared to existing tip-based schemes [1, 2].

[1] P. Maletinsky, et al., *Nature nanotechnology*, 7(5):320–324, 2012.
[2] G. Balasubramanian, et al., *Nature*, 455(7213):648–651, 2008.

MI 7.10 Wed 18:00 P4

Construction of Ambient Simultaneous Scanning Tunneling /Atomic Force Microscope (STM/AFM) — •Ipen Demirel, Ahmed Uluca, Majid Fazeli Jadidi, and Hakan Özgür Özer — Istanbul Technical University, Istanbul, Turkey

we constructed an ambient simultaneous STM/AFM using a fiber-optic interferometry setup for cantilever deflection detection. Simultaneous measurements of tunnel current, force, force gradient, tunnel barrier height and energy loss with high sensitivity is possible with our specially designed and modified STM/AFM. Our microscope consists of a home-built STM and AFM head, which implements a TiO2 coated fiber attached to a small tube piezo on a commercial micro-positioner, vibration isolation system and SPM control unit. The frequency spectrum was obtained to determine resonance and phase curves on various cantilevers (Si, W) by PLL card besides lock-in amplifier. Since, interference pattern shows power at the signal photo-diode versus cantilever displacement as sensitivity of the interferometer, the fiber is locked by the controller at the most sensitive point. Working in the off-resonance region and using very small lever oscillation amplitudes, we are able to keep the probe in tunneling range during most of the cycle in simultaneous AFM/STM operation. The microscope was tested in STM mode on gold surface and atomically flat terraces has been imaged. We also conducted frequency modulation AFM imaging on the same surface. We are going to study various 2-D surfaces such as graphene, Bi2Te3 by using the microscope in simultaneous mode in which all relevant channels of information are acquired.

MI 7.11 Wed 18:00 P4

An optical setup for focusing THz radiation on a Scanning Tunneling Microscope tip — Mohamad Abdo[1,2], •Steffen Rolf-Pissarczyk[1,2], Jacob Burgess[1,2], Björn Schlie[1,2], and Sebastian Loth[1,2,3] — [1]Max-Planck-Institut für Struktur und Dynamik der Materie, Hamburg — [2]Max-Planck-Institut für Festkörperforschung, Stuttgart — [3]Institut für Funktionelle Materie und Quantentechnologien, Universität Stuttgart

Terahertz (THz) radiation lies between Microwave radiation and Infrared light in the electromagnetic spectrum. It can be generated for example by optical rectification of femtosecond laser pulses in nonlinear crystals. However, the power of the generated THz is typically very weak. This often stands as an obstacle against measurements with weak signal amplitudes, in particular THz-induced tunneling in a scanning tunneling microscope (STM) where the THz electric field couples to the STM tip and enables highly localized transport measurements at picosecond speed [1,2].

Here we show the development of an optical setup that is optimized for THz-induced transport experiments. We also show how to manipulate the THz pulse shape by de-compression of the excitation pulse.

This setup enables studies of ultrafast physical phenomena with the atomic spatial resolution provided by the STM even in tunneling regimes where significantly less than one electron tunnels per THz pulse.

[1] T. Cocker, et al., Nature Photonics 7 620-625 (2013).
[2] T. Cocker, et al., Nature 539, 263-267 (2016).

MI 7.12 Wed 18:00 P4

X-ray crystallography study of Cu-Ga sputter target alloys for Cu(In,Ga)Se_2 thin film solar cells by means of Kossel microdiffraction in the SEM — •Tijani Dmali[1,2], Enrico Langer[1,2], and Siegfried Däbritz[1] — [1]Technische Universität Dresden, Institut für Festkörperphysik, 01069 Dresden — [2]Technische Universität Dresden, Institut für Halbleiter- und Mikrosystemtechnik, 01187 Dresden

Investigation results on polycrystalline Cu-Ga sputter targets by X-ray Kossel microdiffraction will be presented. Materials of this binary system are used for Copper Indium Gallium Diselenide thin film solar cells. The examined specimens are alloys with varied matrix compositions, which has been manufactured by different methods. The observed microstructures showed to be an eutectic phase in this Gallium concentration range. In each case the first X-ray Kossel microdiffraction analyses by means of a CCD area detector proved the existence of an hexagonal close packed lattice, contrary to other measurements and the Cu-Ga phase diagram in certain Ga concentration ranges. The lattice parameters a and c as well as their variation were precisely measured in the micro range. Interestingly in both limiting cases of the lattice constant a the ratio c/a is exactly c/a= 1.620. In combination with EDX measurements it was found that each matrix consists of the ζ phase which can be distinguished in terms of the chemical composition and lattice constants.

We are greatfull to Marian Böhling for the supply of the sample material and his suggestion to investigate this material.

MI 7.13 Wed 18:00 P4

Investigation of biological structures from fossils and simulation of their optical properties — •Ran Zhang, Enrico Langer, Barbara Adolphi, Andreas Voigt, and Andreas Richter — Technische Universität Dresden, Institut für Halbleiter- und Mikrosysteme

Diffraction gratings and photonic crystals play an important role for smart technical applications. The investigation of photonic structures in biology is an interesting scientific endeavor, because it can contribute to a better biological classification and since it may trigger bio-inspired technological developments. In this work, fossil surfaces from crustaceans were investigated by means of both scanning electron microscopy and energy-dispersive X-ray spectroscopy (EDS) in the low-vacuum mode. On the 150 million years old crayfishes "Eryma modestiformis" and "Palaeastacus fuciformis" we discovered structures with different dielectric constants and similar width (about 200 nm) that are arranged periodically on the surface. Moreover, the investigation by EDS allows to draw conclusions on the composition of the original fossil materials. The detected periodic structures can be regarded as 1D and 2D diffraction gratings. Electromagnetic waves would be reflected depending on the wavelength in different directions. We show calculations of these angles by diffraction equations and the reflection of visible light with various colors. Another unusual structure with a finer and more regular arrangement was observed, which was unveiled as a diatom. It can be treated as a photonic crystal slab. With the measured geometric data and material composition, a biological monoclinic photonic crystal model was built. The photonic bands of this structure (which allows conclusions about the reflectance behavior in the horizontal direction) were calculated by the plane wave expansion method [1]. Future work will include the application of the finite difference time-domain method and rigorous coupled wave analysis in order to calculate the transmission and reflection spectra for arbitrary angles of incidence.

[1] S.G. Johnson and J. D. Joannopoulos, Optics Express 8, (2001) 173-190.

MI 7.14 Wed 18:00 P4

Nanokomposit-Kondensatoren - morphologische und dielektrische Charakterisierung — •Till Mälzer[1,4], Tino Band[2], Sandra Wickert[3,4], Frank Apsel[1,4], Hartmut S. Leipner[1], Martin Diestelhorst[2] und Stefan Ebbinghaus[3] — [1]Interdisziplinäres Zentrum für Materialwissenschaften, Martin-Luther-Universität Halle-Wittenberg (MLU), 06120 Halle (Saale) — [2]Institut für Physik, MLU — [3]Institut für Chemie, MLU — [4]enfas GmbH, 86668 Karlshuld

Polymere werden häufig wegen ihrer Vorzugseigenschaften einer hohen Durchbruchfestigkeit und kostengünstigen Produzierbarkeit als dielektrische Materialien für Kondensatoren mit hoher Energiespeicherdichte verwendet. P(VDF-HFP) ist mit seiner relativ hohen Energiedichte ein Kandidat mit großem Potential. Durch Hinzufügen von Nanopartikeln mit hoher Permittivität lässt sich die Energiespeicherdichte bei gleichbleibender Feldstärke weiter steigern. Allerdings auf Kosten höherer Leckströme.

Im Rahmen unserer Forschungsarbeit untersuchen wir Nanokomposit-Folienkondensatoren, bestehend aus verschiedenen Bariumtitanat(BTO)-Nanopartikel-Konzentrationen in einer P(VDF-HFP)-Matrix, genauer den Einfluss u.a. der Verteilung, Größe, Form und Struktur der BTO-Partikel auf die dielektrischen Eigenschaften des resultierenden Komposits. Dafür werden die Folien als Kondensatoren charakterisiert, um Energiedichte, Permittivität, Durchbruchspannung und elektrische Leitfähigkeit zu ermitteln. Andererseits werden strukturelle Untersuchungen mittels XRD, ESEM und FIB durchgeführt.

MI 8: Scanning Probe Microscopy (SPM)

Chair: Michael Hietschold (TU Chemnitz)

Time: Thursday 10:00–11:00 Location: MER 02

MI 8.1 Thu 10:00 MER 02

Machine Learning in Spectroscopic Scanning Probe Microscopy: a Magnetoelectric Composite Case Study — •Harsh Trivedi[1], Vladimir V. Shvartsman[1], Doru C. Lupascu[1], and Robert C. Pullar[2] — [1]Institute for Materials Science and Center for Nanointegration Duisburg-Essen (CENIDE), University of Duisburg-Essen, 45141, Essen, Germany — [2]CICECO, University of Aveiro, 3810-193, Aveiro, Portugal

Recent years have seen a tremendous growth in the spectroscopic Scanning Probe Microscopy (SPM) modes, where spectra against various principle variables like voltage (Piezoresponse/Current), distance (force), frequency (amplitude) etc. are collected over a 2-dimensional grid. In certain cases however, the variable in concern is time dependent, and a point by point variation is not ideal. In such cases a convenient alternative is the sequential SPM, where a sequence of SPM images is generated as a function of the principle variable. However, such a method suffers from the absence of a concrete correlation between the consecutive images, and also the nature of each individual spectra differs with the spatial location. In the absence of a universal physical model that fits the data, a proper application of unsupervised machine-learning to such problems could lead to fast extraction of qualitative components of the spectra, which can conveniently be used to device the necessary physical models. Presented in this work is a case study of application of simple unsupervised machine-learning to variable magnetic field Piezoresponse Force Microscopy (PFM) of BaTiO3 based magnetoelectric composites.

MI 8.2 Thu 10:15 MER 02

Potential dependent tunneling barrier-height measurements at the interface of gold(111) in an ionic liquid — •Marcel Lang, Jeannette Lindner, and Rolf Schuster — Karlsruhe Institute of Technology, Germany

The behavior of ionic liquids at charged surfaces is fundamentally different from diluted electrolytes. For example ionic liquids form different multi-layered structures depending on the polarization of the gold electrode.

We employed distance-current spectroscopy in a room temperature electrochemical-STM under ambient atmosphere to study the tunneling barrier heights in [BMP][TFSA] on gold(111). We found that the tunneling barrier vanishes at moderately positive potentials. We attribute this to the formation of ion layers at the interface, which may exhibit high intrinsic conductance.

MI 8.3 Thu 10:30 MER 02

Scanning Microwave Microscopy and its application to nanoscale dopant density determination — •Arne Buchter[1], Johannes Hoffmann[1], Dimitri Hapiuk[2,3], Christophe Licitra[2,3], Kevin Louarn[4,5], Guilhem Almuneau[4], and Markus Zeier[1] — [1]Federal Institute of Metrology, METAS, Lindenweg 50, CH-3003 Bern-Wabern — [2]Univ. Grenoble Alpes, F-38000 Grenoble — [3]CEA, LETI, MINATEC Campus, F-38054 Grenoble — [4]LAAS-CNRS, Université de Toulouse, CNRS, UPS, Toulouse — [5]LNE, 29 avenue Roger Hennequin, F-78197, Trappes

In Scanning Microwave Microscopy (SMM) an atomic force microscope (AFM) is interfaced with a vector network analyzer (VNA) allowing to simultaneously measure topography and complex material properties on the nanoscale. Depending on the impedance forming at the tip-sample interface, a fraction of the microwaves is reflected and detected by the VNA in terms of scattering parameter S11. Operation in the microwave regime with fields confined to the tip's apex allows for spatial resolution down to 50 nm as well as subsurface sensing.

To enable extraction of dopant densities from semiconductor samples we present a fast and versatile algorithm based on classical VNA calibration. This algorithm models the influence of dopant density on tip-sample capacitance thus allowing nanoscale determination of dopant concentrations. As a proof-of-principle we present SMM results on an MBE-grown n-doped GaAs multilayer structure with dopant densities ranging from (1e16 - 6e18) cm^-3 which are then compared to Secondary Ion Mass Spectroscopy (SIMS) data.

MI 8.4 Thu 10:45 MER 02

A Quantitative Model for the Ion Current vs. Distance Behavior in Scanning Ion Conductance Microscopy — •Johannes Rheinlaender and Tilman E. Schäffer — Institute of Applied Physics, Eberhard Karls University Tübingen, Germany

Scanning ion conductance microscopy (SICM) is an emerging scanning probe microscopy technique in biophysical and electrochemical research. It is based on raster-scanning an electrolyte-filled nanopipette across the sample, while the ion current through the nanopipette serves as a measure for the tip-sample distance. However, so far there is no quantitatively validated model for the ion current vs. distance behavior in SICM, although it is the central functional principle of the technique. To quantitatively predict the ion current vs. distance behavior, we here provide two theoretical models: (1) an analytical model to investigate the dimensional dependencies and (2) a numerical model for even higher accuracy based on finite element modeling (FEM). We verified the models using experimental data recorded with nanopipettes of known geometry and opening radii between 30 and 300 nm. The new models therefore allow, for the first time, to quantify the tip-sample distance in SICM. Furthermore, as the ion current vs. distance behavior directly depends on the tip geometry of the nanopipette, the models can also vice versa be used to quantify the tip geometry from experimental ion current data. This provides a unique, non-destructive way of calibrating the nanopipettes tip geometry within the running SICM experiment.

MI 9: Progress of Instrumentation and Methods for the Surface Analysis (PEEM, LEED)

Chair: Barbara Adolphi (TU Dresden)

Time: Thursday 11:15–11:45 Location: MER 02

MI 9.1 Thu 11:15 MER 02

In-situ electrochemistry in photoemission microscopy — •Slavomir Nemsak[1], Claus M. Schneider[1], and Andrei Kolmakov[2] — [1]PGI-6, Forschungszentrum Juelich, 52425 Juelich, Germany — [2]Center for Nanoscale Science and Technology, NIST, Gaithersburg, MD, USA

Until recently, photoemission electron microscopy (PEEM) could not be used in studies of solid/liquid interfaces due to major instrumental and experimental difficulties. The usual technique of differential pumping, which allows photoelectrons to reach the detection in ambient pressure photoemission spectroscopy, cannot be simply realized in PEEM, mostly due to the presence of high potential difference between a specimen and extractor lens. One of the ways to overcome this problem is to use a sample capped with electron transparent molecularly impermeable membrane, which would leave the vacuum conditions between the lens and the sample unaffected [Kolmakov, A et al., Nature Nanotechnol. 6, 651 (2011)]. Application of different potentials at various points on the sample is another ingredient, which would enable doing spectromicroscopy with electrochemistry.

We present a working concept of electrochemical cell inside a photoemission microscope. Our demonstration uses a capping membrane made of a few-layer graphene. In this configuration, the graphene membrane acts also as a top electrode Kolmakov, A et al., Topics in Catalysis 59, 448 (2016)]. A liquid contained in the cell is then imaged primarily with secondary or Auger photoelectrons under operating conditions.

MI 9.2 Thu 11:30 MER 02

Development of an ultrafast miniaturized low-energy electron gun — •Gero Storeck, Simon Vogelgesang, Murat Sivis, Sascha Schäfer, and Claus Ropers — 4th Physical Institute - Solids and Nanostructures, University of Göttingen, Germany

Ultrafast low-energy electron diffraction was recently shown to be a promising approach to access ultrafast structural dynamics in 2D systems [1]. In order to realize ULEED in a backscattering geometry, we developed several designs of miniaturized pulsed electron guns based on a nanometric tungsten photocathode. Specifically, we fabricate downscaled electron sources with an outer diameter of about 80 μm that allow for a working distance from the sample below several hundred micrometers. A photolithographic process and focused ion beam etching are used to construct the electrostatic gun assembly hosting a nanotip photocathode and a lens for electron beam collimation.

We characterize the low-energy electron pulses by the transient electric field effect and achieve pulse durations down to 1 ps at electron energies as low as 50 eV. This enables us to conduct time-resolved measurements in reflection geometry for the study of ultrafast structural transformations and phase transitions at surfaces.

[1] M. Gulde et al., Science 345, 200 (2014).

MI 10: Positron Annihilation Spectroscopy (PALS)

Chair: Hartmut S. Leipner (Martin-Luther-Universität Halle-Wittenberg)

Time: Thursday 12:00–12:30 Location: MER 02

MI 10.1 Thu 12:00 MER 02

Positron Annihilation Spectroscopy for Materials Science — •Andreas Wagner[1], Wolfgang Anwand[1], Reinhard Krause-Rehberg[2], Maciej Oskar Liedke[1], Kay Potzger[1], and Thu Trang Trinh[1,3] — [1]Helmholtz-Zentrum Dresden-Rossendorf — [2]Martin-Luther-Universität Halle — [3]Technische Universität Dresden, Germany

Positron annihilation lifetime spectroscopy serves as a tool for studies of open-volume defects in solid materials such as vacancies, vacancy agglomerates, dislocations, pores and voids. The intense mono-energetic positron beam MePS installed at the superconducting electron accelerator ELBE allows for depth-dependent positron lifetime measurements and Doppler-broadening spectroscopy of thin films. Offline experiments using a radioisotope-based beam called SPONSOR complement those investigations. Here, in-situ modifications of the samples under study can be performed using a new setup called AIDA which allows for thin film growth by molecular beam epitaxy, ion-beam irradiation and sputtering in a temperature-controlled environment reaching from 50 K to 1200 K.

Selected experiments on open and closed porosity in thin films, positron chemistry in fluids, defect characterizations of semiconductors and metals will be presented.

The MePS facility has partly been funded by the Federal Ministry of Education and Research (BMBF) with the grant PosiAnalyse (05K2013). The initial AIDA system was funded by the Impulse- und Networking fund of the Helmholtz-Association (FKZ VH-VI-442 Memriox).

MI 10.2 Thu 12:15 MER 02

Microstructural Changes in Welded AlCuLi-Alloys by Positron Annihilation Spectroscopy (PALS), SAXS and DSC — •Danny Petschke, Frank Lotter, and Torsten Staab — University Wuerzburg, Department of Chemistry, LCTM Röntgenring 11, 97070 Wuerzburg, Germany

We follow changes in the microstructure at several distances from the weld nugget of friction stir welded AlCuLi-alloy (AA2198) plates occurring due to the tool movement and the created heat by employing different methods: Small Angle X-ray Scattering (SAXS), giving information on type, size and density of precipitates, Differential Scanning Calorimetry (DSC), giving information on formed precipitates by their dissolution signal, and positron annihilation lifetime spectroscopy (PALS), being sensitive to vacancies and dislocations as well as to the formation and growth of precipitates. We start by characterizing the base material as a reference and proceed via the heat-affected zone to the weld nugget. By the use of complementary methods, we obtain information on structure, kind and distribution of precipitates and correlate this with hardness measurements.

MI 11: Annual General Meeting and Celebration of the 50th Anniversary of the Microprobes Division

Time: Thursday 15:00–16:00 Location: MER 02

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