FM 19: Advanced Microscopy and Tomography for Functional Materials

chair: Manuel Zahn (University of Augsburg)

Time: Thursday 10:15–12:45 Location: BEY/0E40

FM 19.1 Thu 10:15 BEY/0E40

Electron Beam-Induced Currents as a Quantitative Probe for Nanoscale Semiconductor Devices — •Sebastian Schneider[1], Sebastian Beckert[1], René Hammer[2], Markus König[3], Grigore Moldovan[2], Darius Pohl[1], and Bernd Rellinghaus[1] — [1]Dresden Center for Nanoanalysis (DCN), TU Dresden, Dresden, Germany — [2]Point Electronic GmbH, Halle (Saale), Germany — [3]Max Planck Institute for Chemical Physics of Solids, Dresden, Germany

Electron beam-induced current (EBIC) mapping in the scanning transmission electron microscope (STEM) enables the direct visualization of charge carrier transport with nanometer resolution. We present a comparative STEM-EBIC study on silicon photodiode lamellae prepared by gallium and xenon focused ion beam milling. The EBIC mapping reveals the p-n junction and allows for the extraction of the effective electron and hole diffusion lengths as a function of local thickness. These values are up to three orders of magnitude smaller than bulk EBIC results, highlighting strong surface recombination and preparation-induced artifacts. Complementary I-V measurements show significant deviations from the expected diode-like behavior, which we attribute to high resistive contacts at the metal-semiconductor interfaces. Our findings emphasize the critical role of sample preparation for quantitative EBIC analysis.

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FM 19.2 Thu 10:30 BEY/0E40

X-ray Stress Tensor Tomography — •Peter Modregger[1,2], Ahmar Khaliq[1,2], and Felix Wittwer[1,2] — [1]Physics Department, University of Siegen — [2]Center for X-ray and Nano science, CXNS, DESY, Hamburg

The possibility for tomographic reconstrution of strain and stress tensor present in poly-crystalline samples has been discussed for nearly two decades. We will demonstrate the successful retrieval of all 6 strain/stress tensor components in martensitic steel samples from experimental data acquired at the ID11 beamline of the ESRF. Compared to established techniques this novel approach for the depth-resolved determination of stress states offers the tantalizing advantages of a simple experimental setup, isotropic gauge volumes and faster scans. In our presentation, we will discuss the possible adverse effects of detector parallax and crystallographic texture. Further, we will provide specific experimental requirements such as the required photon flux or the available scattering angles. With these in mind, we have achieved a strain sensitivity of 10^{-4} and a stress sensitivity of 20 MPa.

FM 19.3 Thu 10:45 BEY/0E40

Developing a resuable optical fiber-based sensing system for in-situ X-ray radiaiton monitoring — Ali Karatutlu[1,2], Esra Kendir Tekgül[2], Zehra Gizem Mutlay[1], Andriy Budnyk[1], Gianluca Iori[3,4], Philipp Hans[5], Fareeha Hameed[5], and •Bülend Ortaç[1] — [1]Bilkent University, Institute of Materials Science Nanotechnology and National Nanotechnology Research Center (UNAM), Ankara, 06800 Turkey — [2]Sivas University of Science and Technology, Department of Engineering Basic Sciences, Sivas, 58100 Turkey — [3]Swiss Light Source, Paul Scherrer Institute, Villigen, Switzerland — [4]GratXray, Villigen, Switzerland — [5]Synchrotron-light for Experimental Science and Applications in the Middle East (SESAME), Allan, 19252, Jordan

Specialty optical fibers doped with rare-earths such as Yb, and Tm are utilized for various applications from medical to high-power beam delivery for materials processing. Nevertheless, radiation-induced defects can occur due to irradiation, causing a degradation of beam quality. In this study, we utilize this type of degradation, referred to as radiation-induced attenuation, as an X-ray sensing and the conditions in the in-situ recovery of color centers. The experiments were conducted at hard X-ray beamline at BEATS, SESAME, using different monochromatic beams such as 10 keV and 20 keV, suggesting the origin of color centers playing role in the RIA and the sensing and recovery behavior that are related to the optical and morphological effects of the X-ray irradiation.

FM 19.4 Thu 11:00 BEY/0E40

Multiscale characterization of porous carbon fibers — •Markus Löffler[1], Mohsen Sadeghi Bogar[2,3], Paul Bertram[3,4], Jan Wolf[2,3], Darius Pohl[1], Thomas Behnisch[2,3], Iris Kruppke[3,4], Chokri Cherif[3,4], Maik Gude[2,3], and Bernd Rellinghaus[1] — [1]Dresden Center for Nanoanalysis (DCN), cfaed, TUD Dresden University of Technology (TUD), Dresden, Germany — [2]Institute of Lightweight Engineering and Polymer Technology (ILK), TUD, Dresden, Germany — [3]Research Center Carbon Fibers Saxony, TUD, Dresden, Germany — [4]Institute of Textile Machinery and High Performance Material Technology (ITM), TUD, Dresden, Germany

Porous carbon fibers (PCF) are valued for structural energy storage because they combine low density, high thermal and electrical conductivity, low thermal expansion, strong mechanical properties, and a large specific surface area. Key pore features - volume, shape, and connectivity - determine their suitability for use as electrodes in batteries, supercapacitors, and as structural materials. A hierarchical pore structure with sizes from 2 nm to over 50 nm is desirable. These PCFs are made by wet-spinning polyacrylonitrile (PAN) with nanocellulose as a pore-forming additive, followed by electron beam irradiation, stabilization, and carbonization. To understand how processing affects pore development, fibers are analyzed at various stages and scales using submicro-XCT, FIB, SEM, and TEM. All fibers show a low density of large pores, while precursor and irradiated fibers also have a high density of nanoscale pores.

FM 19.5 Thu 11:15 BEY/0E40

Tomographic Electron Holography reveals 3D-Potential Variations from Surface Segregation in p-n doped InGaAs Nanowires — •Kai-Luis Jakob[1], Laura Niermann[1], Tore Niermann[1], Frederik Otto[1], Rahel Specht[1], Daniel Wolf[2], Esmaielpour Hamidreza[3], Gregor Koblmüller[1], and Michael Lehmann[1] — [1]TU Berlin — [2]IFW Dresden — [3]TU München

Mapping the three-dimensional electrostatic potential distribution at the nanoscale is crucial for tuning the electrical properties of semiconductor nanostructures, such as InGaAs nanowires utilized in optoelectronics. Off-axis electron holography enables measurement of the projected electrostatic potential with nanoscale spatial resolution; however, the 3D information typically remains inaccessible. In this work, we combine electron holography with tomography to reconstruct 3D potentials, thereby investigating subtle effects such as surface segregation, Fermi-level pinning, and damages induced by Focused Ion Beam preparation. Here, we focus on MBE-grown InGaAs nanowires featuring an axial p-n junction. A tilt series of holograms is acquired over a wide tilt range in a FEI Titan 80-300 TEM. Projected electrostatic potentials are reconstructed individually and aligned for tomographic reconstruction. This approach allows us to access the electrostatic potential and resolve both axial and radial changes from the wire core to its surface. We observed a largely constant potential step across the axial p-n junction of 0.5 V, however, near-surface regions exhibited deviations from it. At the surface of the n-doped segment, we found a thin p-type layer, likely attributable to known surface segregation.

Coffee break

FM 19.6 Thu 11:45 BEY/0E40

Advanced Polymer-Tungsten Nanocomposites for Radiation Shielding and X-ray Computed Tomography Applications — Taylan BAŞKAN[1], Saliha MUTLU[2,3], Bülend ORTAÇ[3], Ali KARATUTLU[3,4], Sevil SAVAŞKAN YILMAZ[2,3], and •Ahmet Hakan YILMAZ[1] — [1]Karadeniz Technical University Physics Department, Trabzon, 61080, Türkiye — [2]Karadeniz Technical University Chemistry Department, Trabzon, 61080, Türkiye — [3]National Nanotechnology Research Center (UNAM) and Institute of Materials Science Nanotechnology, Bilkent University, Ankara, 06800, Türkiye — [4]Sivas University of Science and Technology, Department of Engineering Basic Sciences, Sivas, 58100 Turkey

The growing trend of ionizing radiation in biomedicine and industry has intensified the need for efficient and reliable radiation shielding materials. In our current work, we incorporated W nanoparticles and WO3 nanoparticles with varying proportions in the PMSQ polymer to synthesize dual-functional nanocomposites with simultaneous gamma ray shielding and contrast enhancement in computed tomography imaging. This study will present the three-dimensional microevolutions of biodegraded polymer-metal/polymer-metal oxide composite materials using synchrotron-based X-ray computed tomography methods upon post γ-radiolysis exposure from 0.5 kGy to 5 kGy. The synchrotron-based XCT available at BEATs in SESAME demonstrates the internal structural defects and morphology non-destructively in the vicinity of resolved micro-scales with 650 nm resolution.

FM 19.7 Thu 12:00 BEY/0E40

Defects in Materials: Limitations of the Trapping Model - the Influence of Corrupt Components in Positron Lifetime Spectra - cured by a New Spectrometer? — Torsten Staab, •Dominik Boras, and Danny Petschke — LCTM / IFB, Department of Chemistry, University of Wuerzburg, Roentgenring 11, D-97070 Wuerzburg, Germany

Positron lifetime spectroscopy is able to extract densities for defects (e.g. vacancies or dislocations) from the measured spectroscopic data by applying the so-called trapping model, which describes the decomposition of lifetime spectra into two or more components (lifetimes and intensities). Since the procedure of fitting several exponential decays folded by a mimicked instrumental resolution function (IRF) is a so-called ill-posed problem, the goodness of the fit relies heavily on the quality of the recorded data. By our digital twin of a positron lifetime spectrometer we could clearly see the strong influence of back scattered and corrupted coincidences on recorded spectra. Unfortunately, even by physically filtering digitised pulses, those events cannot be removed. One way to reduce their effect are changes in the geometry (90° instead of 180°) of the detector set-up leading to heavy losses in efficiency (about 90%). However, this leads to much more realistic bulk positron lifetimes of light materials (Mg, Al, Si) in accordance with calculations, and enables correct decompositions by the trapping model. We present here a new fully digitised spectrometer with an IRF described by one singe Gaussian and a FWHM of 128ps together with 22-Na sources without positronium having a single lifetime component.

FM 19.8 Thu 12:15 BEY/0E40

Characterising electron vortex beams inside crystalline materials via vorticity — •Christian Bick, Dorothee Hüser, and Tobias Klein — Physikalisch-Technische Bundesanstalt, Braunschweig, Germany

Convergent electron beams with an orbital angular momentum (OAM), also known as electron vortex beams or twisted electrons, have been investigated for multiple applications in material science. Recently, first measurements of vortex electron magnetic circular dichroism (EMCD) in the electron microscope have been reported.

We present a simulation-based study on vortex beam behaviour inside crystalline material utilising vorticity as a local property to characterise the beam. This quantity, which is widely used in fluid mechanics, can be understood as a local measure of OAM . We relate it to commonly used integrated quantities like the total OAM and channelling strength in order to further the understanding of the beams behaviour inside of model crystals and discuss possible measurements.

FM 19.9 Thu 12:30 BEY/0E40

Toward Atomic-scale Imaging of Resistive Switching Mechanisms in Prussian Blue Memristors — •Mohammed Fayis Kalady[1], Johannes Schultz[1], Michael Pohlitz[2], Falk Röder[1], Darius Pohl[3], Daniel Wolf[1], and Axel Lubk[1,4] — [1]Leibniz Institute for Solid State and Materials Research, Dresden, Germany — [2]Faculty of Physical Engineering/Computer Sciences, University of Applied Sciences, Zwickau, Germany — [3]DCN, TU Dresden, Germany — [4]IFMP, TU Dresden, Germany

Prussian blue and its analogues are promising materials for memristive devices based on resistive switching. To obtain a microscopic understanding of the structural and chemical processes responsible for switching, we employed a detailed high-resolution transmission electron microscopy (HRTEM), scanning transmission electron microscopy combined with electron energy loss and energy dispersive x-ray spectrum imaging (STEM-EELS and STEM-EDX) studies on pristine films and on films previously subjected to electrical biasing. The pristine film exhibits a homogeneous distribution of K, Fe, C, N, and O, whereas the electrically biased regions display clear nanoscale modifications, including local changes in elemental distribution and a phase transition from Prussian blue to Prussian white. The electrical measurements on the bulk reveal transitions between low-resistance and high-resistance states, demonstrating bipolar switching behavior across multiple cycles. These results provide the first steps toward in-situ TEM biasing experiments aimed at directly resolving elemental migration pathways and phase evolution under applied voltages.