DF 5: Scanning and diffraction methods

Time: Monday 14:30–17:30 Location: EB 407

Invited Talk DF 5.1 Mon 14:30 EB 407

Behaviour of Ferroelectrics Influenced by Nanoscale Morphology — •John Martin Gregg[1], Alina Schilling[1], Liwu Chang[1], Mark McMillen[1], Mohamed Saad[1], Robert Bowman[1], Gustau Catalan[2], James Scott[2], and Finlay Morrison[3] — [1]School of Maths and Physics, Queen's University Belfast, Belfast, U. K. — [2]Department of Earth Sciences, Cambridge University, Cambridge, UK — [3]Department of Chemistry, University of St Andrews, St Andrews, Scotland, U. K.

This talk describes attempts made to simplify the study of nanoscale ferroelectrics by minimizing the influence of defects, microstructure and to some extent boundary-related strain effects by using a Focused Ion Beam Microscope (FIB) to cut thin film sheets and nanowires directly from bulk single crystal ferroelectrics.

Low field permittivity characteristics of FIB-cut thin film $BaTiO_3$ sheets have been investigated, and it has been shown that bulk-like permittivity response persists even in films as thin as $\sim$70nm. This result contradicts decades of previous work done on conventionally grown thin film ferroelectric heterostructures.

In addition the domain characteristics of single crystal thin sheets and nanowires have been characterised as a function of scale and of morphology using Scanning Transmission Electron Microscopy. The domain periodicities and polar orientations observed show a dramatic sensitivity to both size and shape. It has been shown that nanoscale morphology can be used to control polar orientation along the lengths of single nanowires.

DF 5.2 Mon 15:10 EB 407

Fourier analysis of ferroelectric polarization reversal — •Andreas Rüdiger — Institute of Solid State Research, Research Center Jülich, Germany

The detection of nanoscale piezoelectricity is generally achieved by means of lock-in techniques. As the excitation voltage exceeds the coercive field, polarization reversal occurs with a complex fourier spectrum that contains information on the piezoelectric response, the electrostriction and the polarization reversal process. A quantitative spectral analysis in comparison to experimental data shows the potential of the method to cover the dynamic range from cantilever to domain wall dynamics.

DF 5.3 Mon 15:30 EB 407

Complete reconstruction of the piezoelectric tensor in $BaTiO_3$ nanoislands — •Sebastian Albiez, Serge Röhrig, and Andreas Rüdiger — Institut für Festkörperfosrschung, Forschungszentrum Jülich, 52425 Jülich

Due to the advancing miniaturization of non-volatile ferroelectric memories, a better separation of extrinsic and intrinsic contributions becomes mandatory. Piezoresponse force microscopy (PFM) is the favored tool to investigate these phenomena as the third rank-piezoelectric tensor represents the crystallographic structure of the system and thus also allows for the discussion of the polarization. Current PFM systems achieve lateral resolutions of a few nanometers. The piezoelectric tensor describes the three-dimensional displacement of the tip in contact with the surface i.e. three linearly independent orthogonal forces on the tip. The optical lever arm method however only detects a lateral and a vertical displacement the latter one containing the information of vertical bending and vertical buckling while the first one only contains the information of lateral torsion. To disentangle these contributions a 90-degree rotation of the sample underneath the tip is required without losing the area under investigation. We present current experimental data on ferroelectric nanoislands and discuss them in terms of a complete reconstruction of the piezoelectric tensor where all three displacement modes of the cantilever are differentiated.

DF 5.4 Mon 15:50 EB 407

Electromechanical force microscopy as a non-destructive detection of local inhomgeneities with nanoscale — •Serge Röhrig and Andreas Rüdiger — Institute of Solid Research, Research Center Jülich, Germany

Detection of crystallographic defects and inhomgeneities is typically achieved by either non-destructive light or sound scattering with a lateral resolution of the order of the used wavelength or in a destructive way with atomic resolution by means of e.g. TEM. We present a non-destructive approach based on a standard piezoresponse force microscope detecting the second harmonic of the excitation voltage i.e. the electrostrictive response with nanometer resolution. We use the lateral torsion of the cantilever to monitor displacements that stem from any reduction of radial symmetry underneath the tip. While a globally reduced radial symmetry e.g. due to orthorhombic symmetry of the sample generates an undetectable background, any local variation causes a torque on the cantilever that can be monitored without need for any piezoelectric activity. We demonstrate the feasibility of this technique that is generally applicable to all crystalline dielectrics on any lengthscale.

DF 5.5 Mon 16:10 EB 407

Growth of C_{60} islands on TiO_2(110) — •Felix Loske, Frank Ostendorf, Michael Reichling, and Angelika Kühnle — Department of Physics, University Osnabrück, Germany

We have investigated the interaction of C_{60} molecules with a dielectric substrate, namely rutile TiO_2(110). Non-contact atomic force microscopy was used to study the adsorption structure and surface mobility in situ at room temperature. At submonolayer coverage the molecules adsorb preferencially at substrate step edges. Upon increasing coverage, islands grow from the decorated step edges on the lower terraces in an island growth mode. Simultaneous imaging of the substrate's bridging oxygen rows and the C_{60} island structure revealed that the C_{60} molecules are arranging in a rhombic supercell, with the molecules lying centered in the troughs between the bridging oxygen rows of the substrate. Domain boundaries were determined to run parallel to the supercell's basis vectors and are characterized by a single strand of protruding C_{60} molecules along the junction.

DF 5.6 Mon 16:30 EB 407

Atomic scale evidence for faceting stabilization of a polar oxide — •Frank Ostendorf, Stefan Torbrügge, and Michael Reichling — Fachbereich Physik, Universität Osnabrück, Barabarastr. 7, 49090 Osnabrück

Polar metal oxide surfaces are of highest importance for various applications like catalysis, sensor technology and optoelectronic devices. In matters of industrial applications and merit these surfaces represent a research field of general scientific interest. With this study we corroborate new aspects in the basic understanding of one of the most prominent polar surfaces, namely zinc oxide (ZnO). With respect to nanoelectronic devices the surface properties of zinc oxide and zinc oxide compounds are of greatest importance. By highest resolution dynamic scanning force microscopy (SFM) operated in the non-contact mode (NC-AFM), we reveal the complex stabilization mechanism of polar zinc terminated ZnO(0001). The nanoscopic and atomic structures unveiled corroborate a model of stabilization via triangular structures. High temperature preparation ($T > 1300$ K) yields a novel phase with an additional stabilization by faceting in the form of highly ordered step arrays. The terraces between steps are partly covered with triangular reconstructions exhibiting exclusively {1010} nano-facets on step edges. The combination of both mechanisms allow a complete stabilization of the surface without involvement of adsorbates.

DF 5.7 Mon 16:50 EB 407

Phonon resonances in ferroelectrics probed with scattering scanning near-field optical microscopy (s-SNOM) using a free-electron laser — •Lukas Eng[1], Susanne Schneider[1], Stefan Grafström[1], Stephan Winnerl[2], and Manfred Helm[2] — [1]Institute of Applied Photophysics, TU Dresden — [2]Forschungszentrum Dresden-Rossendorf

s-SNOM is based on the interaction between an optically scattering nanoparticle (AFM tip) and a dielectric sample. The size of the scatterer defines the resolution of the microscope, which is on the order of a few nanometers. We use here sample-enhanced phonon resonances to study the local optical properties of such anisotropic ferroelectrics.

We present the spectroscopic near-field examination of optically anisotropic ferroelectrics, namely lithium niobate ($LiNbO_3$) [1] and barium titanate ($BaTiO_3$). In these samples we excite phonon resonances in the IR regime. As we need to tune the incident wavelength exactly to the sample resonance, we use a free-electron laser at the Forschungszentrum Dresden-Rossendorf as a precisely tunable light source in the IR with a wavelength range 4-200 μm. Furthermore, we show near-field images of ferroelectric domains of $BaTiO_3$ representing a purely anisotropic near-field contrast. We are presenting the first tunable IR near-field measurements on ferroelectric single crystals, which are furthermore in excellent accordance with recent calculations of optical anisotropy in such systems [2].

[1] S.C. Schneider et al., Appl. Phys. Lett. 90, 143101 (2007)
[2] S.C. Schneider et al., Phys. Rev. B 71, 115418 (2007).

DF 5.8 Mon 17:10 EB 407

Time-resolved X-ray diffraction studies of piezoelectric actuators — •Florian Rödl, Peter Wochner, Ralf Weigel, and Helmut Dosch — Max-Planck-Institut für Metallforschung, Stuttgart, Germany

Piezoelectric materials play an important role in different applications ranging from nanoscale positioners to diesel engine fuel injectors. The internal structure of most devices is highly inhomogeneous and consists of stacks of ceramic layers with asymmetric electrode configurations. It is crucial to understand the structural response to the electrical excitation on the level of the individual grains especially in view of their highly inhomogeneous environment. One of the open questions is how does the local dynamic response of these materials influence the switching and fatigue behavior. Here we present an experimental strategy to perform real-time X-ray experiments on bulk PZT actuators during switching.

In this talk I will discuss the experimental setup we used at different synchrotron beamlines and first in-situ results. Depending on different parameters, like e.g. excitation profile, preloading and grain location, the dynamic response of the crystal lattice will be presented. A microbeam setup was used to study single grains.