DF 9: Focused Session on Ferroic Domain Walls III (DF with MA)

Part of the 3-days focus on ferroic domain walls:

Tutorial, Symposium (SYDW), three Focused Sessions, and Poster Session.

Organizers: Elisabeth Soergel (Universität Bonn) and Dennis Meier (ETH Zürich)

Time: Tuesday 14:00–16:00 Location: EB 107

DF 9.1 Tue 14:00 EB 107

STM imaging of ferroelectric domains of strained $BaTiO_3$ films at the thickness limit — •Maik Christl[1], Klaus Meinel[1], Stefan Förster[1,2], and Wolf Widdra[1,3] — [1]Institute of Physics, Martin-Luther-Universität Halle-Wittenberg, Halle, Germany — [2]Department of Physics, University of Zurich, Zurich, Switzerland — [3]Max Planck Institute of Microstructure Physics, Halle, Germany

Ultrathin ferroelectric films are of increasing interest due to novel oxide based applications. In particular, the domain structure as well as the critical thickness are essential key aspects for ferroelectricity in thin films [1].

In this work, we report on in-situ STM and STS studies to image ferroelectric out-of-plane and in-plane nanodomain structures. $BaTiO_3$(100) ultrathin films have been grown pseudomorphically on Pt(100) and Au(100), which corresponds to 2% lateral compression and 2% expansion, respectively [2]. Films with a thickness of 2 unit cells (uc) show already ferroelectricity at room temperature as verified by reversible domain writing and reading using STM. On Pt(100), an irregular c^+/c^- nanodomain configuration is visible in dI/vV maps that are taken at domain sensitive voltages. With film thickness, the domain width increases from 2 nm for 2 uc to 6 nm for 25 uc. In contrast, for expanded $BaTiO_3$ films on Au(100) a regular structure with domain walls proceeding along [100] directions is observed which evidences an in-plane domain arrangement.

[1] Y. Wang *et al.*, *Materials 7*, 103390 **2014**

[2] S. Förster *et al.*, *J. Chem. Phys. 135*, 104701 **2011**

DF 9.2 Tue 14:20 EB 107

Microscopic perspective of magnetoelectric effect in multiferroic composites — •Harsh Trivedi[1], Vladimir V. Shvartsman[1], Doru C. Lupascu[1], Robert C. Pullar[2], Marcos S. A. Medeiros[2], Andrei L. Kholkin[2], Pavel Zelanovskiy[3], and Vladimir Ya. Shur[3] — [1]Institute for Materials Science and Centre for Nanointegration Duisburg-Essen (CeNIDE), University of Duisburg-Essen, 45141 Essen, Germany — [2]Department of Materials and Ceramic Engineering & CICECO, University of Aveiro, 3810193 Aveiro, Portugal — [3]Institute of Natural Sciences, Ural Federal University, 620002 Ekaterinburg, Russia

An extensive analysis of microscopic studies on bulk multiferroic composites is presented. Piezoresponse force microscopy (PFM) is used as a tool to study magnetoelectric effect in composites at local scale. Indirect influence of the stress, that mediates the ME effect, on the PFM response and local switching parameters is evaluated. Principal component analysis is utilized to extract the valuable data buried under noise and statistical inhomogeneity in order to create a spatial visualization of the effect. The spatial distribution of the intensity of the magnetoelectric coupling reveals interesting phenomena at the interface suggesting a resemblance to Eshelby's solution for elliptical inclusion in a matrix. Spatially resolved Raman spectroscopy mapping reveals a similar dominance of the stress at the interfaces corroborating the PFM findings. Finally, a simplified FEM based theoretical model simulating the realistic polycrystalline microstructure is presented, in order to compare the experimental findings.

DF 9.3 Tue 14:40 EB 107

Domain structure in anisotropically strained $K_{0.75}Na_{0.25}NbO_3$ thin films on $TbScO_3$ — •Dorothee Braun[1], Albert Kwasniewski[1], Philipp Müller[1], Martin Schmidbauer[1], Jan Sellmann[1], Michael Hanke[2], and Jutta Schwarzkopf[1] — [1]Leibniz-Institute for Crystal Growth, Berlin, Germany — [2]Paul-Drude-Institut für Festkörperelektronik, Berlin, Germany

Understanding and controlling of domain formation in ferroelectric thin films at the nanoscale is essential for fundamental research as well as for potential applications. The incorporation of anisotropic in-plane lattice strain has a decisive impact on the stability of ferroelectric phases and is achieved by the deposition on lattice mismatched substrates. In this study 30 nm thick $K_{0.75}Na_{0.25}NbO_3$ films were epitaxially grown on $TbScO_3$ substrates by metal-organic chemical vapor deposition. They experience in average a slight compressive lattice strain of 0.47% and are $(100)_c$ oriented. Our PFM measurement revealed both a lateral and a vertical component of the polarization vector whereby the latter one is less pronounced. The lateral PFM shows regularly arranged 90° domains in two directions with domain walls running along <110> and a periodicity of 50 nm has been observed. According to x-ray measurements, the films are grown fully strained on the substrate. The film unit cell is monoclinically distorted in the vertical direction, but no in-plane monoclinic distortion has been detected. These results indicate the occurrence of monoclinic M_C domains which were not observed in (K,Na)NbO_3 thin films before.

DF 9.4 Tue 15:00 EB 107

Ferroelectric Domains of partially relaxed $NaNbO_3$ films under tensile strain — •Jan Sellmann, Dorothee Braun, Albert Kwasniewski, Martin Schmidbauer, and Jutta Schwarzkopf — Leibniz-Institute for Crystal Growth, Max-Born-Str. 12489, Berlin

Lead-free alkaline niobates have recently attracted much attention due to their promising piezoelectric properties like high Curie temperatures. In thin film form they exhibit large densities of ferroelectric domains so that the domain walls are expected to contribute significantly to electrical and electromechanical responses of the material. In the present work, epitaxial $NaNbO_3$ films have been grown by Pulsed Laser Deposition under optimized growth conditions yielding 2D growth and nearly stoichiometric films. Tensile lattice strain was induced by the use of $TbScO_3$ substrates. Increasing the film thickness above the critical thickness the formation of misfit dislocations resulted in partial plastic lattice relaxation and thus a reduction of the effective in plane strain. Concurrently, the ferroelectric domain pattern changes at the critical thickness from lateral 1D a1/a2/a1/a2 stripes domains with exclusive in-plane polarization to a periodic stripe domain pattern with both vertical and lateral polarization components. The latter can be described as a1c/a2c domains with head-to-head configuration in some cases possibly resulting in charged domain walls. Similar results with regard to the domain structure have been found for $NaNbO_3$ thin films on $DyScO_3$ substrates. However, it is in contrast to NaNbO3 thin films grown on DyScO3 and $TbScO_3$ by MOCVD where in-plane domains are exclusively found well beyond the onset of plastic strain relaxation.

DF 9.5 Tue 15:20 EB 107

Investigation of second order nonlinear susceptibility tensor elements at the transition of ferroelectric domains — •Alex Widhalm[1], Kai Spychala[1], Moritz Grothe[1], Gerhard Berth[1,2], and Artur Zrenner[1,2] — [1]Department Physik, Universität Paderborn, 33098 Paderborn, Germany — [2]Center for Optoelectronics and Photonics Paderborn (CeOPP), 33098 Paderborn, Germany

Second harmonic (SH) microscopy is an established method for characterizing periodically poled ferroelectric materials. This work focusses on mapping the second order susceptibility tensor elements in ferroelectric domain structures using spatially resolved second harmonic analysis with respect to a focused laser beam. Our novel nondestructive technique allows for a nonlinear confocal scanning probe microscopy as well as for a basic analysis of occurring point spread functions with respect to a fixed excitation point. The resulting complex distribution of polarization states of excitation and generated SH light, allows a prediction about the detectable nonlinear response of the whole system. Here the experimental results obtained by this method are in good agreement with the expected theoretical occurrence of the nonlinear field distributions. In our spatially resolved experiments we found, that in the transition region of contrarily poled domains and its immediate environment some susceptibility tensor elements disappear whereas other elements appear. This results strongly contribute to a deeper understanding of the occurring physics at domain walls and corresponding contrast mechanisms in ferroelectric domains respectively.

DF 9.6 Tue 15:40 EB 107

Visualization of ferroelectric domain structures in KTP by confocal Raman imaging — •Peter Mackwitz[1], Michael Rüsing[1], Gerhard Berth[1,2], and Artur Zrenner[1,2] — [1]Department Physik, Universität Paderborn, 33098 Paderborn, Germany — [2]Center for Optoelectronics and Photonics Paderborn (CeOPP), 33098 Paderborn, Germany

The nonlinear optical material Potassium titanyl phosphate (KTP) unifies several outstanding material properties. Its distinguished features contain a high damage threshold compared with the considerable well known further ferroelectrics, exalted electro-optical coefficients and especially high nonlinear coefficients. The achieving of periodically poled structures in this material represents one of the significant deployments of KTP in integrated optics. Within the common effects of nonlinear implementation frequency conversion is one of the central uses. In order to achieve a highly efficient frequency conversion it is required to supply a nearly ideal surrounding for quasi-phasematching. Periodically poled materials like PPKTP provide this condition. Confocal Raman imaging depicts a noninvasive technique for visualizations of poled structures which is the premise for a characterization. In this work the confocal Raman imaging was achieved in due consideration of different incident polarizations. The measurements were performed as well in y-cut geometry as in z-cut samples. For this purpose numerous phonon modes have been identified as a continuation of previous work. The fundamental result of this work can be outlined as the designation of PPKTP as a proper candidate for domain imaging.