DF 2 Dielectric and Ferroelectric Thin Films and Nanostructures I

Time: Monday 14:30–17:30 Room: MÜL Elch

Invited Talk

DF 2.1 Mon 14:30 MÜL Elch

Size effects in ferroelectric nanostructures — •Andreas Rüdiger — Center of Nanoelectronic Systems for Information Technology, Institute of Solid State Research, Research Center Jülich, 52425 Jülich, Germany

Ferroelectrics are among the most advanced candidates for non-volatile memory applications. They are also widely used in pyroelectric sensors and piezoelectric actuators. As current integration techniques are driving the dimensions towards 10nm lateral extension and only a few unit cells height, the analogy to ferromagnetism raises the question if a lower size limit also exists for ferroelectrics. Earlier studies on free particles neglected electromechanical constraints imposed by conductive substrates and rather determined a pyroelectric limit (i.e. the size-driven transition into a centrosymmetric phase). Our results of piezoelectric force microscopy on e.g. ferroelectric $BaTiO_3$ nanoislands indicate structural and functional integrity well below the critical volume of free particles. So far, there is no evidence of a size limit in ferroelectric nanoparticles on conducting substrates. We highlight the impact of the aforementioned electromechanical boundary conditions on ferroelectricity and discuss composition and time-scale as possible origins of a critical size below 10 nm.

DF 2.2 Mon 15:10 MÜL Elch

Towards Ferroelectric Tunnel Junctions — •Alexander Kaiser, Adrian Petraru, Ulrich Poppe, Nicholas Pertsev, Hermann Kohlstedt, and Rainer Waser — Institut für Festkörperforschung (IFF-IEM) and Center of Nanoelectronic Systems for Information Technology (CNI), Forschungszentrum Jülich, 52425 Jülich

Experimental results showed evidence that ferroelectric phase is maintained even in a few nanometers thick ferroelectric films. If such an ultra-thin ferroelectric film is placed in between two electrodes, a so-called *ferroelectric tunnel junction* (FTJ) is obtained. Recent theories predict that the direct electron tunneling current through these ultra-thin ferroelectric films may be modified by the polarization state of the ferroelectric [1]. The piezoelectric effect, interface effects and the depolarization field may lead to a giant electroresistance (GER) [2] switching effect. For studying this behaviour we deposited $SrRuO_3$ (electrode)/$BaTiO_3$ (ferroelectric)/$SrRuO_3$ on $SrTiO_3$ (001) substrates by high-pressure sputtering. The film thickness of the ferroelectric $BaTiO_3$ was varied between 200 nm and 3 nm. AFM, XRD and TEM measurements show high cristalline quality with clear epitaxial $BaTiO_3$/$SrRuO_3$ interfaces. P−V and C−V measurements demonstrate ferroelectricity down to $BaTiO_3$ thickness of 5 nm. Tunnel junctions were fabricated in a four point geometry and I-V characteristics were measured between 300 K and 4.2 K. The I−V curves will be discussed in the framework of the I−V characteristics predicted by theory.

[1] Kohlstedt *et al.*, Phys. Rev. B **72**, 125341 (2005)

[2] Zhuravlev *et al.*, Phys. Rev. Lett. **94**, 246802 (2005)

DF 2.3 Mon 15:30 MÜL Elch

GROWTH, MICROSTRUCTURE AND PROPERTIES OF EPITAXIAL, ANTIFERROELECTRIC $PbZrO_3$ FILMS ON $SrRuO_3$ - COVERED $SrTiO_3$ SINGLE-CRYSTAL SUBSTRATES — •Ksenia Boldyreva, Ionela Vrejoiu, Gwenael LeRhun, Lucian Pintilie, Nikolai Zakharov, Marin Alexe, and Dietrich Hesse — Max Planck Institute of Microstructure Physics, Weinberg 2, D-06120 Halle, Germany

Epitaxial, antiferroelectric $PbZrO_3$ (PZO) films have been grown by pulsed laser deposition on $SrRuO_3$-covered $SrTiO_3$ (STO) single crystal substrates. Due to its good lattice match with the STO substrate and due to the possibility to obtain atomically flat surfaces by a layer-by-layer growth mode, epitaxial $SrRuO_3$ was used as bottom electrode allowing electrical measurements. XRD analyses and TEM, HRTEM and SAED investigations revealed a (120) preferred orientation of the PZO films. Since the films were grown above the nominal antiferroelectric Curie temperature of 230°C (to let cubic PZO grow epitaxially on cubic SRO/STO), the cooling after deposition leads to the spontaneous formation of crystallographic domains during the phase transition. As shown by XRD pole figures and TEM images, there are four kinds of domains in the orthorhombic PZO film. These domains also have the character of antiferroelectric domains. The antiferroelectric properties of the films are under study by piezoresponse scanning force microscopy and by macroscopic ferroelectric measurements.

DF 2.4 Mon 15:50 MÜL Elch

GROWTH-MICROSTRUCTURE-PROPERTY RELATIONS IN EPITAXIAL FERROELECTRIC PbZr0.2Ti0.8O3 FILMS — •Ionela Vrejoiu, Gwenael Le Rhun, Lucian Pintilie, Nikolai Zakharov, Dietrich Hesse, and Marin Alexe — Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, D 06120, Halle

Epitaxial PbZr0.2Ti0.8O3 (PZT) films were grown by pulsed laser deposition (PLD) onto vicinal SrTiO3 (001) (STO) single crystal substrates. Step flow-grown SrRuO3 (SRO) fabricated by PLD was employed as bottom electrode, to allow for electrical characterization of the PZT films. The atomically flat surface of the SRO layer may act as a template for layer-by-layer growth of the subsequent layers. It may thus result in very smooth and defect-free PZT layers with remnant polarization values of up to Pr= 1 C/m2. The influence of defects such as threading and misfit dislocations along with formation of 90° domains on the ferroelectric and switching properties of the films is also discussed.

DF 2.5 Mon 16:10 MÜL Elch

Nonlinear phenomena in ferroelectric thin films — •Kay Barz[1], M. Diestelhorst[1], H. Beige[1], M. Alexe[2], and D. Hesse[2] — [1]Martin Luther-Universität Halle-Wittenberg, Germany — [2]Max Planck Institute of Microstructure Physics, Germany

Ferroelectric thin films have proven to be an interesting subject to investigate into numerous nonlinear effects. Some of these effects are discussed based on experimental data from a $Bi_4Ti_3O_{12}$ Metal-Ferroelectric-Semiconductor (MFS) structure. Firstly the high frequency capacitance-voltage characteristic is compared with simple model derived from a conventional MOS (Metal-Oxide-Semiconductor) structure. From this one can conclude to the influence of interface trap density when measuring a MFS at high frequencies. Secondly the MFS structure is used as capacitor in a LCR resonance circuit. Increasing the driving voltage of the circuit shifts the resonance frequency according to the nonlinearity of the MFS. Finally the investigated specimen shows a torus doubling bifurcation. This nonlinear phenomenon is seldom observable in experiments. A comparison with the behaviour of Metal-Ferroelectric-Metal structures may clarify which of these effects originate from the ferroelectric layer or MOS-typical behavior, respectively.

DF 2.6 Mon 16:30 MÜL Elch

Influence of layer defects in ferroelectric thin films — •Thomas Michael[1], Julia Wesselinowa[2], and Steffen Trimper[1] — [1]Fachbereich Physik, Martin-Luther-Universität, Friedemann-Bach-Platz, 06108 Halle — [2]University of Sofia, Department of Physics, Blvd. J. Bouchier 5, 1164 Sofia, Bulgaria

Based on a modified Ising model in a transverse field we demonstrate that defect layers in ferroelectric thin films, originated by layers with impurities, vacancies or dislocations, are able to induce a strong increase or decrease of the polarization. The change is affected strongly by the variation of the exchange interaction within the defect layers. The applied Greens function methods enables us to calculate the polarization, the excitation energy and the critical temperature of the material with structural defects. Moreover, we find likewise the damping of the elementary excitation. The damping is increased due to interaction. The results are in qualitatively good agreement with experimental data for ferroelectric thin films. The model can be modified to discuss the polarization of ferroelectric nanoparticles. The nanoparticle is composed of layers with spherical and cylindrical geometry.

J. M. Wesselinowa, S.Trimper, and K.Zabrocki: Impact of layer defects in ferroelectric thin films, J.Phys.: Condens. Matter 17, 4687 (2005). J.M Wesselinowa,T.Michael,S.Trimper,and K.Zabrocki: Influence of layer defects on the damping in ferroelectric thin films, Phys. Lett.A in press. T.Michael, J.M.Wesselinowa, and S.Trimper: Ferroelectric nanoparticles (in preparation)

DF 2.7 Mon 16:50 MÜL Elch

Praseodymium silicate high-k dielectric layers on Si(100) — •Grzegorz Lupina, Thomas Schroeder, Jarek Dabrowski, Christian Wenger, Anil Mane, Gunther Lippert, and Hans-Joachim Müssig — IHP, Im Technologiepark 25, 15236 Frankfurt (Oder)

Praseodymium silicate dielectrics were investigated as potential replacement for SiO_2 gate insulator in complementary metal-oxide-semiconductor (CMOS) applications. Physical characterization by applying TEM and SR-XPS indicate that the prepared dielectrics have a bilayer structure: an SiO_2-rich Pr silicate at the interface to Si substrate and an SiO_2-poor Pr silicate on top of the dielectric stack. Photoemission studies point to a reasonably high valence and conduction band offsets of $\sim$ 3 eV and $\sim$ 2 eV, respectively. Electrical characterization of the dielectrics was accomplished by capacitance-voltage and current-voltage measurements providing insight into the interface state density, fixed charge concentration, and the dominating conduction mechanisms. Based on the results of ab-initio calculations, the most probable fixed charge formation mechanisms in Pr silicates are discussed. Thermal treatments prove that Pr silicate / Si (100) system is compatible with the conventional CMOS processing.

DF 2.8 Mon 17:10 MÜL Elch

Intrinsic tunneling in perovskite derivatives: switching of resistive states and negative differential resistance — •P. Müller[1], F. Chowdhury[1], Y. Koval[1], V. Dremov[1], F. Lichtenberg[2], and J. Mannhart[2] — [1]Physikalisches Institut III der Universität Erlangen-Nürnberg, Erwin-Rommel Str. 1, 91058 Erlangen, Germany — [2]Experimentalphysik VI der Universität Augsburg, 86135 Augsburg, Germany

In many cases, perovskite related compounds with excess of oxygen can be described as materials with alternating conducting and insulating layers. Electric transport across these layers can be considered as tunneling between the conducting layers. We investigated several materials of the family $A_nB_nO_{3n+2}$, like $LaTiO_{3.41}$ and $SrNbO_{3.41}$, which can be considered as a stacking of blocks consisting of 5 perovskite layers. We measured I-V characteristics at different temperatures. Switching between different resistive states has been found in some of these materials. The resistive states have long-term stability, which makes them interesting for memory applications. Furthermore, our materials show negative differential resistance at low temperatures. We present a summary of our recent results.