DF 7: Dielectric and Ferroelectric Thin Films and Nanostructures I

Time: Tuesday 14:30–17:50 Location: H11

Invited Talk DF 7.1 Tue 14:30 H11

Nanosized ferroelectrics — •Izabela Szafraniak — Institute of Materials Science and Engineering, Poznan University of Technology, Poznan, Poland — Institute of Molecular Physics, Polish Academy of Sciences, Poznan, Poland

Among functional materials ferroelectrics are expected to play an important role because they find various applications in a remarkably broad spectrum of advanced electronic, electromechanical and electrooptic components. Future applications require ferroelectric structures with lateral size well below 100 nm. It is well- known phenomena that many materials change or even lose their useful properties as soon as their sizes fall below a certain limit. The ferroelectric size limit has been very important subject of research during last decades. The recent achievements will be discussed. The special emphasis will be put on fabrication ferroelectric nanostructures (including nanowires and nanotubes), multiferroic materials and relations between nanostructure sizes and properties (including role of misfit dislocation on switching behaviour). Financial support: Polish Ministry of Sciences (3TO8A00527, PBZ-MIN-012/KBN/2004, 11/6.PRUE/2005/7).

DF 7.2 Tue 15:10 H11

Ferrroelectric $PbZr_{0.4}Ti_{0.6}O_3$ / $PbZr_{0.6}Ti_{0.4}O_3$ superlattices grown on $SrTiO_3$ (001) by pulsed laser deposition — •Ionela Vrejoiu, Yinlian Zhu, Gwenael Le Rhun, Andreas Schubert, Dietrich Hesse, and Marin Alexe — Max Planck Institute of Microstructure Physics, Weinberg 2, D-06120, Halle, Germany

Artificial heterostructures and superlattices (SLs) involving ferroelectric perovskites have been explored to achieve materials with potentially novel / improved physical properties. Ferroelectric epitaxial superlattices combining tetragonal $PbZr_{0.4}Ti_{0.6}O_3$ and rhombohedral $PbZr_{0.6}Ti_{0.4}O_3$ thin films were grown by pulsed laser deposition (PLD) onto vicinal $SrTiO_3$ (001) single crystal substrates. Step flow-grown $SrRuO_3$ layers fabricated also by PLD were employed as bottom electrodes, to allow for the electrical characterization of these PZT-based superlattices. The SLs were subjected to extensive structural characterization by means of (high resolution) transmission electron microscopy and x-ray diffraction, to atomic- and piezo-force microscopy and to macroscopic ferroelectric and dielectric measurements. The thickness of the individual PZT layers was found to play an important role for the structure adopted by the superlattices, which, in particular cases, grow with a uniform tetragonal structure and form 90° a-c domains.

DF 7.3 Tue 15:30 H11

The impact of interfaces and structural defects on the properties of tetragonal $Pb(Zr,Ti)O_3$ thin film heterostructures — •Ludwig Geske[1,2], Ionela Vrejoiu[1], Lucian Pintilie[1], Marin Alexe[1], and Dietrich Hesse[1] — [1]Max-Planck-Institut für Mikrostrukturphysik Halle — [2]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg

During the deposition of films on substrates with different lattice parameters internal stresses arise. Above a critical thickness h_c dislocations will be introduced. While cooling down from the high deposition temperature, new stresses arise due to the different thermal expansion coefficients of film and substrate, and due to structural phase transitions in PZT. As soon as the temperature is too low to create further dislocations, twin domains will form if the film thickness is above a critical thickness $h_{c,do}$. Heterostructures consisting of bilayers or multilayers of tetragonal $Pb(Zr_{0.2}Ti_{0.8})O_3$ and $Pb(Zr_{0.4}Ti_{0.6})O_3$ thin films were layer-by-layer grown onto vicinal $SrTiO_3$ (001) single crystals by pulsed laser deposition. The thickness of the individual layers, that of the entire PZT structure, and the sequence of layers were varied, to induce or suppress the formation of dislocations and/or ferroelectric twin domains. The ferroelectric and dielectric properties of the samples were studied by the Aixacct TF Analyzer 2000 and by an impedance analyzer. Structural investigations comprising defect analysis were performed by TEM and by AFM. It turns out that the properties of the heterostructures, in particular the dielectric constant and the remanent polarization, are clearly influenced by the defect contents.

DF 7.4 Tue 15:50 H11

Ferroelectric Thin Films used as Nonlinear Capacitors — •Kay Barz[1], Martin Diestelhorst[1], Horst Beige[1], Ludwig Geske[1,2], Marin Alexe[2], and Dietrich Hesse[2] — [1]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg — [2]Max-Planck-Institut für Mikrostrukturphysik Halle

A simple serial resonance circuit with a ferroelectric bulk material used as capacitance can easily be driven into nonlinear regimes [1]. The response of such a circuit can be explained by the double well potential, introduced by the ferroelectric. Therefore the system can be described with 3 degrees of freedom, thus allowing it to pursue e.g. period doubling sequences into chaos. Recent experiences in ferroelectric thin films suggest, that even more degrees of freedom could be introduced by the semiconductor-like behaviour of ferroelectric thin film structures [2]. Hence, we deployed metal/ferroelectric/metal (MFM) and metal/ferroelectric/silicon (MFS) thin film structures as nonlinear capacitors in the resonance circuit. In the case of MFS, this led to the observation of a torus doubling bifurcation. As this phenomenon depends on the existence of a minimum set of 4 degrees of freedom it supports the previous made assumption. The talk will deal with the problem of separating nonlinear effects known from the pure ferroelectric (MFM and bulk, respectively) structures from those observable in ferroelectric/semiconductor heterostructures.

[1] Diestelhorst, *et al.* 1999 *Int. J. of Bifurcation and Chaos* **9**, 243-250.
[2] Pintillie *et al.* 2005 *Integrated Ferroelectrics* **73**, 37-48

DF 7.5 Tue 16:10 H11

Microstructure and properties of antiferroelectric/ferroelectric $PbZrO_3/Pb(Zr_xTi_{1-x})O_3$ epitaxial multilayers — •Ksenia Boldyreva, Eugene Pustovalov, Lucian Pintilie, Marin Alexe, and Dietrich Hesse — Max Planck Institute of Microstructure Physics, Weinberg 2, 06120 Halle, Germany

Antiferroelectric/ferroelectric multilayers and superstructures represent a topic of interest due to potential coupling phenomena and strain effects. Here, we investigate epitaxial multilayers consisting of alternating antiferroelectric $PbZrO_3$ (PZO) and ferroelectric $Pb(Zr_{80}Ti_{20})O_3$ (PZT80/20) layers. Rhombohedral PZT80/20 was chosen, because its ferroelectric axis lies along the pseudocubic (pc) $[111]_{pc}$-direction, corresponding to the $[111]_{pc}$-direction of the ferroelectric axis in the field-induced ferroelectric state of PZO. PZO/PZT80/20 multilayers were deposited onto STO (100) substrates by pulsed laser deposition (PLD) in oxygen atmosphere. To enable electrical measurements, epitaxial (100)-otiented $SrRuO_3$ (SRO) was used as bottom electrode, because of its atomically flat surface and the low STO/SRO lattice mismatch. SRO deposited on STO shows steps of single unit-cell height due to the layer-by-layer growth mode. XRD analyses and TEM, HRTEM and SAED investigations revealed the preferred $(120)_o$ orientation of the PZO layers and the $(001)_{rh}$ orientation of the PZT layers. (Index „o“ refers to orthorhombic, index „rh“ to rhombohedral indexing). The antiferroelectric properties of the films are under study by macroscopic ferroelectric measurements. Growth-structure-property relations of the PZO/PZT80/20 epitaxial multilayers will be discussed.

DF 7.6 Tue 16:30 H11

Resistive Switching in Ferroelectric Materials — •Hermann Kohlstedt[1], Adrian Petraru[1], Kristoff Szot[1], Valanoor Nagarajan[2], Ulrich Poppe[1], Wolgang Speier[1], and Rainer Waser[1] — [1]Institut für Festkörperforschung (IFF) and CNI, Forschungszentrum Jülich GmbH, Jülich, Germany — [2]School of Materials Science and Engineering, UNSW, NSW 2052, Sydney

We investigated the resistive switching effect in SrRuO3/PbZr0.2Ti0.8O3/Pt ferroelectric capacitors. By using a conductive atomic force microscope the piezoelectric response, the capacitance as well as the resistive current vs. the applied bias voltage was simultaneously measured. The piezoelectric response and the capacitance butterfly loop showed clear indication that the PZT films were ferroelectric. We determined a coercive field of 167 kV/cm in 30 nm thick PZT films. By increasing the bias electric field approximately a factor two larger then the coercive field we observed an electric forming process, i.e. the resistance changed strongly. Hereafter the devices showed bipolar resistive switching. The simultaneously recorded piezoelectric response data showed that after the electric forming procedure the film was ferroelectric. The difference between the coercive field and the resistive switching voltage is explained on the basis of a filament model in which the resistive switching and ferroelectricity are considered as independent phenomena. This model is supported by measurements of the resistance times area (R x A) product. Parasitic effects during the measurements of the piezo response during I-V curve cycling will be discussed.

DF 7.7 Tue 16:50 H11

Impedance spectroscopy of thin ($d \approx 4\,(nm)$) tantalum oxide films: Temperature and Field dependence — •Katrin Bruder[1], Achim Walter Hassel[1], Beate Mildner[2], and Detlef Diesing[2] — [1]Max-Planck-Institut für Eisenforschung, Max-Planck-Str. 1, 40237 Düsseldorf — [2]Institut für physikalische Chemie, Universität Duisburg-Essen, 45141 Essen

Impedance spectroscopy of tantalum oxide films was accomplished in thin film capacitors (tantalum–tantalum oxide–noble metal). With investigations from $f = 10^{-2}$ Hz to 10^{+6} Hz it is possible to determine the capacitance, the metals resistivities and the tunnel resistivity of the oxide. The latter one is a function of the bias voltage while the capacitance and the metals resistivities remain unchanged. The tunnel resistivity was found to have a maximum at a bias U_{max} slightly different from 0 V. Within single band tunneling models $U_{max} \equiv 0\,V$ is expected whereas two band tunneling models were found to deliver $U_{max} \neq 0$ V as function of the barrier asymmetry and the oxides band gap. For a further investigation the bias dependence of impedance spectra was characterised in the temperature range from $T = 58$ K to 350 K. U_{max} was found to vary with T. A comparison with theory points to a temperature dependent barrier asymmetry of the oxide.

DF 7.8 Tue 17:10 H11

Wachstum und elektrische Eigenschaften von dünnen $SrTiO_3$-Schichten auf $YBa_2Cu_3O_{7-x}$ — •Veit Grosse[1], Frank Schmidl[1], Ingo Uschmann[2] und Paul Seidel[1] — [1]Institut für Festkörperphysik, Friedrich-Schiller-Universität Jena, Helmholtzweg 5, D-07743 Jena — [2]Institut für Optik und Quantenelektronik, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, D-07743 Jena

Dünne Strontiumtitanat (STO)-Schichten wurden mittels gepulster Laserdeposition (PLD) epitaktisch auf mit $YBa_2Cu_3O_{7-x}$ (YBCO) beschichteten STO-Einkristallen abgeschieden. Röntgen-Untersuchungen zeigen eine sehr gute (001)-Orientierung der YBCO- und STO-Schichten. Oberflächenrauhigkeiten von 10 nm (YBCO) bzw. 2 nm (STO) konnten erreicht werden.

Zur elektrischen Charakterisierung diente das YBCO als untere Elektrode. Die obere Elektrode bildete eine zusätzlich aufgesputterte Gold-Schicht. In diesem YBCO/STO/Au-System zeigt sich in Abhängigkeit von der Schichtdicke und Temperatur unterschiedliches Leitungsverhalten von Raumladungslimitierung, Variable Range Hopping bis hin zu resistiven Schalteffekten. Es werden Einflüsse der Sauerstoffstöchiometrie auf das Leitungsverhalten diskutiert. Weiterhin werden Ergebnisse zu den dielektrischen Eigenschaften in Abhängigkeit von der Temperatur, Schichtdicke und zusätzlichem elektrischen Feld vorgestellt.

DF 7.9 Tue 17:30 H11

Size and strain effects in ultrathin epitaxial $BaTiO_3$ films grown by high pressure sputtering — •Adrian Petraru[1], Hermann Kohlstedt[1], Nikolay Pertsev[1], Ulrich Poppe[1], Axel Solbach[2], Uwe Klemradt[2], and Rainer Waser[1] — [1]Institut für Festkoerperforschung and CNI, Forschungszentrum Jülich GmbH, Jülich, Germany — [2]II. Physikalisches Institut B, RWTH Aachen University, 52074 Aachen

High quality epitaxial $BaTiO_3$ films with thicknesses ranging from 2.8 nm to 175 nm were grown epitaxially on $SrRuO_3$-covered $SrTiO_3$ (001) substrates by high-pressure sputtering. The film structure was studied by conventional and synchrotron x-ray diffraction. The amount of the compressive strain in the $BaTiO_3$ films was measured by x-ray reciprocal space mapping (X-RSM)around the asymmetric ($\bar{1}03$) Bragg reflection. Ferroelectric capacitors were then fabricated by depositing $SrRuO_3$/Pt top electrodes, and the polarization-voltage hysteresis loops were recorded at the frequency 1 KHz. The observed thickness effect on the lattice parameters and polarization in $BaTiO_3$ films was analyzed in the light of strain and depolarizing-field effects using the nonlinear thermodynamic theory. The theoretical predictions are in reasonable agreement with the measured thickness dependencies, although the maximum experimental values of the spontaneous polarization and the out-of-plane lattice parameter exceed the theoretical estimates markedly (43 μC/cm^2 vs. 35 μC/cm^2 and 4.166 Åvs. 4.143 Å). Possible origins of the revealed discrepancy between theory and experiment are discussed.