DS 34: Resistive Switching (jointly with DF, KR, HL)

Time: Friday 9:30–12:45 Location: H32

DS 34.1 Fri 9:30 H32

***Ab initio* study of defects in $SrTiO_3$ bulk and (100) surfaces** — •Ali Al-Zubi, Gustav Bihlmayer, and Stefan Blügel — Peter Grünberg Institut (PGI) & Institute for Advanced Simulation (IAS), Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

Oxygen vacancies are believed to play a major role in the conduction mechanisms that enable resistive switching in oxide materials. Employing density functional theory (DFT) and the DFT+U model,we use the full-potential linearized augmented plane wave method as implemented in the `FLEUR` code to study the formation of point defects in the perovskite $SrTiO_3$ with varying coordination. We calculated the formation energy of an O-vacancy in both bulk supercells and (100) surface including different, c(2×2) and p(2×2), in-plane unit cells and different terminations. After performing full relaxation, we found that the bulk and SrO-terminated surface have a nonmagnetic, while TiO_2-terminated surface has a ferromagnetic solution. Using the c(2×2) unit cell, the vacancy formation energy was smaller for the bulk than for the SrO- and even TiO_2-terminated surface. On the other hand, the p(2×2) unit cell shows that TiO_2-terminated surface has the lowest formation energy, more than 1 eV lower than the bulk value. Similar comparisons will be presented when including the the DFT+U model that is used to correct the bulk bandgap and improve the localization of the defect states.

We gratefully acknowledge financial support of the DFG, SFB 917 Nanoswitches–A4 project.

DS 34.2 Fri 9:45 H32

Resistive switching properties in ion beam modified $SrTiO_3$ — •Jura Rensberg, Benjamin Roessler, Christian Katzer, Frank Schmidl, and Carsten Ronning — Institut für Festkörperphysik, Friedrich-Schiller-Universität Jena, Germany

Resistive switching phenomena, which are for instance observed in perovskite-type transition metal oxides, attract intensive attention for their potential application in future nonvolatile memory. Strontium titanate ($SrTiO_3$) exhibits bipolar resistive switching between a high- and a low-resistance state when applying an appropriate electric field. It is often proposed that the underlying mechanism for bipolar resistive switching in $SrTiO_3$ originates from oxygen-vacancy migration along filaments based on extended defects such as dislocations or grain boundaries.

Here we report on well-defined damage formation due to ion irradiation which allows a better control of the lateral and vertical defect arrangements and concentrations. Therefore, we deposited 100 nm single crystalline $SrTiO_3$ thin films with low intrinsic defect concentration on niobium doped $SrTiO_3$ substrates by pulsed laser deposition and implanted these samples with swift heavy gold ions. After irradiation the films were characterized using transmission electron microscopy and Rutherford backscattering spectrometry. Under ion irradiation, the as-deposited crystalline films undergo amorphisation due to the formation and overlap of amorphous tracks. The electrical properties of $SrTiO_3$, i.e. the resistive switching properties are discussed in terms of damage concentration.

DS 34.3 Fri 10:00 H32

Cation defect engineering in SrTiO3 thin films by PLD with Verification and implication on memristive properties — Sebastian Wicklein[1], •Chencheng Xu[1], Alessia Sambri[2], Salvatore Amoruso[2], David Keeble[3], Annemarie Köhl[1], Werner Egger[4], and Regina Dittmann[1] — [1]Peter Grünberg Institut 7, Forschungszentrum Jülich GmbH, Germany — [2]Università degli Studi di Napoli Federico II, Dipartimento di Scienze Fisiche & CNR-SPIN, I-80126 Napoli, Italy — [3]University of Dundee, School of Engineering, Physics and Mathematics, Dundee DD1 4HN, Scotland — [4]University Bundeswehr, D-85577 Munich, Germany

The origin of the c-axis expansion in homoepitaxial STO thin films is investigated by positron annihilation lifetime spectroscopy (PALS): Low laser fluence results in Ti vacancy rich sample while high laser fluence for the Sr vacancy rich sample.

XPS measurement on the ablated spot on the targets shows that increased laser fluence ablates more Ti. The ToF (Time of Flight) data from OES (optical emission spectrometry) indicate a preferred scattering of Ti because of background gas. The two effects together lead to tunable stoichiometry of the film.

In the MIM (metal insulator metal) structure Sr-rich films exhibit the most stable switching behavior and highest on/off ratio, while in the LC AFM (local conducting atomic force microscopy) switching the on/off ratio of Ti is the higest.

DS 34.4 Fri 10:15 H32

Resistive Switching in thermally oxidized Titanium — •Daniel Blaschke[1], Ilona Skorupa[1], Bernd Scheumann[1], Andrea Scholz[1], Peter Zahn[1], Sibylle Gemming[1], Kay Potzger[1], Agnieszka Bogusz[2], and Heidemarie Schmidt[2] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Institute of Ion Beam Physics and Materials Research, P.O. Box 510119, 01314 Dresden - Germany — [2]Dept. Electr. Eng. & Inf. Techn., TU Chemnitz, 09107 Chemnitz

In recent years the resistive switching of binary transition metal oxides like NiO, Nb2O5 and TiO2 has attracted considerable attention for application in nonvolatile memory storage systems.

For our investigations we used a thin rutile TiO2 film, which was prepared by the thermal oxidation of a 100nm thick e-beam evaporated Ti film. The oxidation temperatures were varied from 500°C to 800°C at an oxygen partial pressure of 1 atmosphere. We will present the dependence of the crystal structure and the switching behavior on the oxidation temperature as well as an interesting feature on the time-dependent evolution of the resistance during the Reset process.

The project is funded by the Initiative and Networking Fund of the Helmholtz Association (VH-VI-422).

DS 34.5 Fri 10:30 H32

Non-volatile resistive switching in multiferroic YMnO3 thin films — •Agnieszka Bogusz[1,2], Ilona Skorupa[1], Andrea Scholz[1], Oliver G. Schmidt[2,3], and Heidemarie Schmidt[2] — [1]Institute of Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf, 01314 Dresden, Germany — [2]Faculty of Electrical Engineering and Information technology, Chemnitz University of Technology, 09107 Chemnitz, Germany — [3]Institute for Integrative Nanosciences, IFW-Dresden, 01069 Dresden, Germany

Intensive research on multiferroic materials [1] is driven by the possibility of creating novel, miniaturized tunable multifunctional devices [2]. This work investigates resistive switching behavior of YMnO3 thin films, which can be utilized in new generation memory devices. Series of YMnO3 films were grown by pulsed laser deposition on Si substrates with Pt bottom electrode at temperatures varying between 500°C and 850°C. Characterization of as-grown samples by X-ray diffraction and scanning electron microscopy was followed by determination of electrical properties of films in metal-insulator-metal (MIM) configuration. Results showed that the YMnO3 films grown at 800°C exhibit the best resistive switching properties with high resistance ratio (>10000) of high over low resistance state. Switching mechanism is ascribed to the structural transitions within the film upon applied current.

[1] A. Bogusz et al., Defect Diffus. Forum 323-325, 115 (2012)

[2] Y. Shuai, H. Schmidt et al., J. Appl. Phys. 109, 124117 (2011); J. Appl. Phys. 111, 07D906 (2012)

DS 34.6 Fri 10:45 H32

Practical guide for validated memristance measurements — •Nan Du[1,2], Yao Shuai[3], Wenbo Luo[3], Christian Mayr[4], Rene Schüffny[4], Oliver G. Schmidt[1,2], and Heidemarie Schmidt[1] — [1]TU Chemnitz, Faculty of Electrical Engineering and Information Technology, 09107 Chemnitz, Germany — [2]Institute for Integrative Nanosciences, IFW Dresden, Helmholtzstraße 20, 01069 Dresden, Germany — [3]Helmholtz Research Center Dresden-Rossendorf, 01328 Dresden, Germany — [4]TU Dresden, Department of Electrical Engineering and Information Technology, 01062 Dresden, Germany

L.O. Chua predicted rather simple charge-flux curves for active and passive memristors and presented active memristor circuit realizations already in the 70s. However, despite the fact that memristors give rise to complicated hysteretic current-voltage curves, memristors are traced in current-voltage curves. Here we give a practical guide how to use normalized charge-flux curves for the prediction of current-voltage characteristics of memristors with stable electrical characteristics in dependence on the shape and amplitude of the input voltage or input current signals. In the case of memristive BiFeO3 thin film capacitor

structures [1] the normalized charge-flux curves superimpose for different numbers of measurement points and a different measurement time per measurement point. Such normalized charge-flux curve can be used for the prediction of current-voltage characteristics of plastic synapses in neuromorphic systems [2]. [1] Y. Shuai et al., J. of Appl. Phys. 109, 124117-124117-4 (2011). [2] C. Mayr et al., NIPS 2012, in press.

Coffee break (15 min)

DS 34.7 Fri 11:15 H32

Creating an Oxygen Gradient in Nb_2O_5 by Argon Irradiation for Resistive Switching Memory — •Helge Wylezich[1], Hannes Mähne[1], Daniel Blaschke[2], Stefan Slesazeck[1], and Thomas Mikoljiack[1] — [1]NamLab gGmbH, Nöthnitzer Str. 64, D-01187 Dresden — [2]Helmholtz-Zentrum Dresden-Rossendorf, D-01314 Dresden

It is common knowledge that an oxygen gradient is mandatory for bipolar resistive switching [1]. We confirmed this by investigations of thin films with Nb_2O_5 as switching layer. Samples with two inert Pt electrodes are nearly symmetric and do not show bipolar resistive switching behavior. Replacing one Pt electrode with a reactive one – for example Al or Nb – results in an unsymmetrical device. These samples could be switched reproducible. It is also possible to create an oxygen gradient by depositing a stack of two different niobium oxide layers. While the first layer consists of stoichiometric Nb_2O_5 the second layer is sputtered substoichiometric [2].

A new approach is to get an oxygen gradient by irradiating the oxide layer with argon. Two effects appear: The argon sputters the surface of the Nb_2O_5 layer and so the oxide thickness decreases. Because the Nb-atoms are heavier than the O-atoms, the oxygen sputter rate is higher and the surface becomes niobium rich. The investigated samples consist of a Pt-Nb_2O_5-Pt stack. The oxide layer was irradiated by different Ar-doses before top electrode deposition. At the highest dose Φ = 3e16 cm^{-2} the resulting oxygen gradient enables resistive switching.

[1] Bertaud et al. (TSF 520, 2012)
[2] Mähne et al. (MEMCOM Workshop 2012)

DS 34.8 Fri 11:30 H32

Multilevel resistive switching in Ar+ irradiated BiFeO3 thin films — •Yao Shuai[1], Xin Ou[2], Wenbo Luo[2], Nan Du[3], Danilo Bürger[2,3], Oliver G. Schmidt[3,4], and Heidemarie Schmidt[3] — [1]State Key Laboratory of Electronic Thin Films and Integrated Devices, UESTC, China — [2]Helmholtz-Zentrum Dresden-Rossendorf e.V., Institute of Ion Beam Physics and Materials Research, Germany — [3]University of Technology Chemnitz, Faculty of Electrical Engineering and Information Technology, 09107 Chemnitz, Germany — [4]Institute for Integrative Nanosciences, IFW Dresden, Helmholtzstraße 20, 01069 Dresden, Germany

Low energy Ar+ ion irradiation has been applied to an Au/BiFeO3/Pt capacitor structures before deposition of the Au top electrode. The irradiated thin films exhibit multilevel resistive switching without detrimental resistance degradation, which makes the intermediate resistance states more distinguishable as compared to the non-irradiated thin film [1]. The stabilization of resistance states after irradiation is discussed based on the analysis of conduction mechanism during the resistive switching in BiFeO3 with a rectifying Au top electrode and a nonrectifying Pt bottom electrode [2]. Furthermore, it is shown how the conduction mechanisms change from room temperature to 423 K. [1] Y. Shuai, X. Ou et al., IEEE Device Letters, 2012, in press. [2] Y. Shuai, S. Zhou, D. Bürger, M. Helm, H. Schmidt, J. Appl. Phys. 109 (2011), 124117-4.

DS 34.9 Fri 11:45 H32

Influence of thickness ratio on resistive switching in BiFeO3:Ti/BiFeO3 bilayer structures — •Tiangui You[1], Wenbo Luo[2], Yao Shuai[1,2], Nan Du[1], Danilo Bürger[1,3], Ilona Skorupa[3], Oliver G. Schmidt[1,4], and Heidemarie Schmidt[1] — [1]Chemnitz University of Technology, 09107 Chemnitz, Germany — [2]University of Electronic Science and Technology of China, 610054 Chengdu, China — [3]Helmholtz-Zentrum Dresden-Rossendorf, P.O. Box 510119, 01314 Dresden, Germany — [4]IFW-Dresden, 01069 Dresden, Germany

Nonvolatile resistive switching in BiFeO3 (BFO) [1] has attracted increasing attention; however, the underlying resistive switching mechanism is still controversial which restricts its application in nonvolatile memory devices. BFO:Ti/BFO bilayer structures with a 540 nm thick BFO layer and different thickness of BFO:Ti layer were grown on Pt/Sapphire substrates by pulsed laser deposition using the same growth conditions. Circular Au top electrodes were prepared with magnetron sputtering. Au/BFO/Pt single layer structures show a symmetric I-V curve without hysteresis due to the formation of Schottky contacts at both the top and bottom interface. However, Au/BFO/BFO:Ti/Pt bilayer structures exhibit an obvious resistive switching behavior under both voltage polarities. The influence of the thickness of BFO:Ti on the conduction mechanisms in Au/BFO/BFO:Ti/Pt bilayer structures is discussed to reveal similarities and differences between single and bilayer structures.

Reference [1] Y. Shuai et al., J. Appl. Phys., 109, 124117(2011)

DS 34.10 Fri 12:00 H32

Nanoscale resistive switching in epitaxial and polycrystalline BiFeO3 thin films — •Yao Shuai[1], Wenbo Luo[1], Chuangui Wu[1], Wanli Zhang[1], Oliver G. Schmidt[2,3], and Heidemarie Schmidt[2] — [1]State Key Laboratory of Electronic Thin Films and Integrated Devices, UESTC, China — [2]University of Technology Chemnitz, Faculty of Electrical Engineering and Information Technology, 09107 Chemnitz, Germany — [3]Institute for Integrative Nanosciences, IFW Dresden, 01069 Dresden, Germany

Nonvolatile [1], bipolar, and multilevel [2] resistive switching has been observed in ca. 500 nm thick polycrystalline BiFeO3 thin films with rectifying, circular Au top electrodes and a nonrectifying Pt bottom electrode. The diameter of the Au top electrodes amounts to ca. 0.5 mm. By scanning a positionable top contact with a diameter of only 10 nm over polycrystalline BiFeO3 thin films under a constant applied dc voltage, the high and low resistance state can be locally written and afterwards read. It has been observed that for thinner polycrystalline BiFeO3 films with a thickness below 300 nm, no resistive switching can be observed either with large or with small scale top contacts. Bipolar resistive switching can also be realized in ca. 50 nm thick epitaxial BiFeO3 films on SrRuO3/SrTiO3 with a positionable top contact. This resistance is mainly determined by the ferroelectric polarization and the barrier height of the top and bottom contact. For thicker epitaxial BiFeO3 films the unique relation between ferroelectric polarization and resistance state is diminished. [1] Y. Shuai et al., J. Appl. Phys. 109 (2011). [2] Y. Shuai et al., IEEE Device Letters (2012) in press.

DS 34.11 Fri 12:15 H32

An electronic implementation of amoeba anticipation — •Mirko Hansen[1], Karlheinz Ochs[2], Martin Ziegler[1], and Hermann Kohlstedt[1] — [1]Faculty of Engineering, Christian-Albrechts-Universität zu Kiel, 24143 Kiel, Germany — [2]Ruhr-Universität Bochum, 44780 Bochum, Germany

In nature, the capability to memorize environmental changes can already be observed in unicellular organisms like amoebas[1]. An amoeba changes its locomotive speed when it is exposed to unfavorable conditions. If a series of unfavorable conditions is applied, the amoeba later on behaves similarly on a single incident. Pershin et al.[2] are able to emulate this behavior using a simple resistive switching circuit model consisting of an inductor, a capacitor and a resistive switching device. We experimentally implement this model using a resistive switching device. A theoretical analysis of the circuit is presented to gain further insight into the functionality of this model and to give advice for the implementation of resistive switching devices in LC-circuits.

[1] T. Saigusa, A. Tero, T. Nakagaki, Y. Kuramoto, Phys. Rev. Lett. **100**, (2008) 018101

[2] Y. V. Pershin, S. La Fontaine, M. Di Ventra, Phys. Rev. E **80**, (2009) 021926

DS 34.12 Fri 12:30 H32

Lattice dynamics in Sb- and Te-based phase-change materials — •Ronnie Ernst Simon[1,2], Ilya Sergueev[3], and Raphaël Pierre Hermann[1,2] — [1]Jülich Centre for Neutron Science JCNS and Peter Grünberg Institut PGI, Jara-FIT Forschungszentrum Jülich GmbH, D-52425 Jülich, Germany — [2]Faculté des Sciences, Univer- sité de Liège, B-4000 Liège, Belgium — [3]Deutsches Elektronen- Syn- chrotron, D-22607 Hamburg, Germany

Phase-change materials exhibit a significant change of the optical reflectivity and electrical resistivity upon crystallization which renders these materials applicable for optical storage devices and non-volatile electronic memories. In order to understand the switching kinetics between the amorphous and the metastable crystalline states a detailed

knowledge of the lattice dynamics of the different phases is crucial. A suitable technique for the investigation of lattice dynamics is nuclear inelastic scattering (NIS) which gives access to the element specific density of phonon states (DPS). We performed NIS measurements in Sb- and Te-based phase-change materials in the amorphous and crystalline phases. We have recently extended the experimental possibilities by demonstrating the feasibility of high pressure NIS measurements, up to 75 GPa, in Sb_2Te_3 . The ESRF is acknowledged for the provision of synchrotron radiation beamtime at ID18.