DS 44: Poster III: Focus session: Resistive switching by redox and phase change phenomena

Time: Thursday 16:00–19:00 Location: P1

DS 44.1 Thu 16:00 P1

Memristive operation mode of floating gate transistors for neuromorphic applications — •Martin Ziegler[1], Dietmar Schroeder[2], Wolfgang Krautschneider[2], and Hermann Kohlstedt[1] — [1]Nanoelektronik, Technische Fakultät, Christian-Albrechts-Universität zu Kiel, 24143 Kiel, Germany — [2]Technische Universität der Hamburg-Harburg, Institut für Nanoelektronik, Hamburg, Germany

A memristive operation mode of a single floating gate transistor (MemFlash-cell) is presented. To ensure the memristive operation mode, the three-terminal device is reduced to a two-terminal device in such a way that the device resistance varied accordingly to the charge flow through the device during source-drain voltage application. In particular, we provide evidence that the MemFlash-cell can be used to mimic synaptic functionality. Furthermore, based on Hebbian learning, a synaptic analytical expression for the learning rate of this device is derived. The experimental findings are theoretically supported by a capacitive based model. The presented two-terminal MemFlash-cell can be considered as a potential substitute for any memristive device in neuromorphic circuits, cross bar arrays, or reconfigurable logics, and is compatible with state-of-the-art Si-fabrication technology. — [1] Ziegler, M., Kohlstedt, H., JOURNAL OF APPLIED PHYSICS 114, 194506 (2013). [2] Ziegler, M.; Oberlaender, M.; Schroeder, D.; et al., APPLIED PHYSICS LETTERS 101, 263504 (2012).

DS 44.2 Thu 16:00 P1

High resolution electrocoloration study of Fe:STO single crystals — •Viktor Havel[1], Astrid Marchewka[1], Stephan Menzel[2], Susanne Hoffmann-Eifert[2], and Rainer Waser[1,2] — [1]Institut für Werkstoffe der Elektrotechnik II, RWTH Aachen University, Germany — [2]Forschungszentrum Jülich GmbH, PGI 7, Jülich, Germany

Strontium titanate (STO) single crystals and thin films are utilized as model materials for the understanding of the resistive switching (RS) mechanism of valence change oxides like TiOx, HfOx and TaOx. Prior to the bipolar RS an electroforming step is typically required, which impacts the device performance. A thorough understanding of the physical processes involved in the electroforming step is fundamental for future device optimization.

In this study, the electroforming process in Fe doped STO single crystals is made optically visible. Color changes in the transparent Fe:STO crystals are caused by a valence change of the Fe ions as a result of a local redox processes. Thus, the Fe redox reaction is utilized as an indirect proof of the oxygen vacancy drift-diffusion in the crystal. The custom designed electrocoloration set-up enables to put the samples under temperature and electrical stress, to measure the current and resistance change over time and in parallel to monitor the evolution of the color front by high resolution optical microscopy.

The results are discussed on the basis of 1D drift-diffusion simulations of the temporal evolution of the oxygen vacancy distribution, which represent the initial progress of the virtual cathode region.

This work was supported in part by the DFG (SFB917).

DS 44.3 Thu 16:00 P1

The importance of local temperture for the SET kinetics in valence change memories — •Karsten Fleck[1,2], Stephan Menzel[2,3], Ulrich Böttger[1,2], and Rainer Waser[1,2,3] — [1]Institut für Werkstoffe der Elektrotechnik II, RWTH Aachen — [2]JARA Fundamentals of Future Information Technology — [3]Forschungszentrum Jülich GmbH

Resistive switching random access memories (ReRAM) based on the valence change mechanism (VCM) have gained much attention due to their scalability, endurance and switching speed. By the application of bipolar voltage signals of appropriate amplitude the resistance can be switched between a high resistive (HRS) and a low resistive state (LRS).

Commonly this resistance change is attributed to the modulation of an oxygen vacancy enriched nano-sized filament in the oxide layer. The switching kinetics of VCM cells are highly nonlinear which can be attributed to a positive temperature feedback due to local Joule heating in the filament.

The resistive switching of Ti/SrTiOx/Pt cells is investigated at varying background temperature by pulse measurements and voltage sweeps, both covering several orders of magnitude on the timescale. We found evidence for the importance of local temperature for the switching kinetics.

DS 44.4 Thu 16:00 P1

Switching processes induced by partial joule heating in vanadium dioxide two-terminal devices — •Danilo Bürger[1], Varun John[1], Kerstin Bernert[2], György Kovacs[2], Ilona Skorupa[2], Oliver Schmidt[3], and Heidemarie Schmidt[1] — [1]Material Systems for Nanoelectronics, Chemnitz University of Technology — [2]Institute of Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf — [3]Institute for Integrative Nanosciences, IFW Dresden

Vanadium dioxide thin films with the reversible semiconductor-metal phase transition at the thermochromic switching temperature of around 340 K have been prepared by pulsed laser deposition on (0001)-sapphire substrates. We fabricated different two-terminal devices and measured the switching properties by time domain reflectometry as well as switching with a pulse generator. We find repeatable switching behavior for billions of voltage pulses and switching times shorter than 50 ns by using a pulse generator. After measurements with time domain reflectometry at higher voltage amplitudes, we observe a local degredation of VO2 between the two metallic contacts. We think that the inhomogenous electrical fields in the VO_2-structure due to the used conventional contact geometry lead to the local degredation. The main consequence is a partial switching due to local joule heating. This is in contradiction with the often used assumption of the homogenous switching of the complete volume of VO_2 in two-terminal devices [1]. [1] Y. Zhou et al., Electron Device Letters, IEEE **34**, 220 (2013)

DS 44.5 Thu 16:00 P1

Thermal stability of VO_2 — •Marcel Hopfe[1], Jura Rensberg[1], Sebastian Vatterodt[1], You Zhou[2], Shriram Ramanathan[2], György J. Kovàcs[3], Ilona Skorupa[3], Heidemarie Schmidt[4], and Carsten Ronning[1] — [1]Institute for Solid State Physics, Friedrich Schiller University Jena — [2]School of Engineering and Applied Sciences, Harvard University — [3]Helmholtz-Zentrum Dresden-Rossendorf — [4]Material Systems for Nanoelectronics, Technical University Chemnitz

Pure vanadium dioxide (VO_2) has a totally reversible metal-insulator transition (MIT) at about 68°C, making it very interesting for photonic and electric applications. It is known that doping reduces the MIT-temperature. One possibility to dope VO_2 thin films is ion implantation. Lattice defects are introduced during ion irradiation, worsening the MIT properties and making annealing indispensable. Thus, our aim was to investigate the thermal stability of VO_2 at a base pressure of around 10^{-6} mbar. The low pressure is necessary for the ion beam doping process. VO_2 thin films were annealed at temperatures ranging from 100°C to 600°C. All samples were optically and electrically characterised in order to investigate possible changes of MIT properties. With increasing annealing temperature the MIT at 68°C vanishes. This is due to oxygen outdiffusion causing a reductoin of VO_2 towards V_2O_3. Same experiments at higher base pressures show, that oxygen outdiffusion can be prevented. Additionally, post-implantation annealing of irradiated VO_2 thin films will be discussed on the poster.

DS 44.6 Thu 16:00 P1

Growth and characterization of free-standing VO_2 nanowires — Matthias Ogrisek, •Tim Barth, Jura Rensberg, and Carsten Ronning — Institut für Festkörperphysik Friedrich Schiller Universität Jena

Recently, Vanadium dioxide has attracted much attention because of its "metal to insulator transition (MIT)" at ≈68°C. This transition causes a significant change of the electrical and optical properties, allowing applications like sensing or switching. The growth of high-quality VO_2 films is challenging due to stress caused by different thermal expansion coefficients and a lattice mismatch between the film and the substrate. For this reason the growth of VO_2 nanowires (NW's) is of particular interest, because stress can quickly relax laterally in NW's. The aim of our study was to grow free-standing VO_2 NW's. The wires have been grown in a 3-zone tube furnace utilizing Vapor-Solid (VS) growth. VO_2 powder was placed in an alumina boat and

heated up to 1325 K to evaporate. The vapor was transported to the substrate by an argon gas flow and grew the wires by self alignment. In-plane grown wires had a length of 200 μm and a diameter of 1-2 μm. Out of plane growth of the nanowires has been achieved by using r-plane sapphire substrates but caused a decrease of the wirelength to 10 μm. EDX-spectrometry revealed only vanadium and oxygen signals and the Raman spectrum measured at RT confirmed the VO_2 nature of the nanowires.

DS 44.7 Thu 16:00 P1

Resistive switching characteristics of $Pr_{0.48}Ca_{0.52}MnO_3$ heterostructures — •Benedikt Arndt[1], Anja Herpers[1], Christian Lenser[1], Regina Dittmann[1], and Rainer Waser[1,2] — [1]Peter Grünberg Institut, Forschungszentrum Jülich GmbH, Jülich, 52425, Germany — [2]Institut für Werkstoffe der Elektrotechnik II, RWTH Aachen University, Aachen, 52074,Germany

Resistive random access memory (RRAM), which is based on hysteretic resistive switching in transition-metal oxides, is believed to be a promising candidate for high-density nonvolatile memory. It has been demonstrated for many oxides, that the resistive switching and its related redox processes take place in a spatially restricted filament region. In contrast, it has been demonstrated that the currents from high and low resistive states in praseodymium calcium manganate (PCMO) RRAM cells scale with the electrode area. The underlying mechanisms in these systems have not yet been fully understood.

We could experimentally prove that resistive switching in PMCO/Ti heterostructures is based on a redox-process, which mainly happens on the side Ti of the PCMO/Ti interface. In particular, the amount of fully oxidized Ti-ions determines the thickness of the insulating TiO_2 tunnel barrier, which forms at this interface.

Furthermore, we compare these devices to cells which comprise an yttria stabilized zirkonia (YSZ) layer at the interface of PCMO and platinum top electrodes. The YSZ is intended as an artificial tunnel barrier whose properties can be influenced by the deposition process. This extra layer allows further to tune the device properties.

DS 44.8 Thu 16:00 P1

Oxygen-vacancy behavior in strontium titanate — •Marcel Schie[1], Roger A. De Souza[2], and Rainer Waser[1] — [1]Institute of Materials in Electrical Engineering and Information Technology, RWTH Aachen University, 52074 Aachen — [2]Institute of Physical Chemistry, RWTH Aachen University and JARA-FIT, 52056 Aachen

We investigate the effect of acceptor-type cation dopants on oxygen-vacancy migration in the perovskite oxide SrTiO3 by static lattice simulation techniques. We focus on two themes: cation dopants modifying the activation energies for vacancy migration, and cation dopants (Ni2+, Fe2+, Co2+, Mn2+ and Al3+) binding oxygen vacancies in binary associates. In both cases a variety of defect configurations exceeding the scope of nearest neighbor (NN) interaction is examined Our results predict that, regardless of the cation dopant, the binding energy of an oxygen vacancy to a dopant is negative at NN sites, but only converges to zero for NNNNN sites. In addition the simulations show that the migration energy of a vacancy is affected by an acceptor dopant cation over a length scale of several unit cells. The results are also used in an analytic three frequency model of ionic conductivity in SrTiO3 to show trends for different dopants and concentrations. For comparison, a simple defect-chemical model containing only dopant-vacancy association at nearest neighbor sites is employed to reconcile literature data. Within this model two major results that are apparently inconsistent with different migration enthalpies are combined.

DS 44.9 Thu 16:00 P1

Influence of Au-nanoparticles on the resistive switching properties of $SrTiO_3$ thin films — •Nicolas Raab[1], Oliver Schmidt[2], Ulrich Simon[2], and Regina Dittmann[1] — [1]Peter Grünberg Institut, Forschungszentrum Jülich GmbH, Jülich, 52425, Germany — [2]Institut für Anorganische Chemie, RWTH Aachen University, Aachen, 52074,Germany

The strong impact of defects on the resistive switching properties of $SrTiO_3$ is generally assumed. Therefore we investigated a method of tailoring defect positions and thereby locally modifying the resistive switching properties of $SrTiO_3$ thin films.

To induce locally defined defects we processed Au-nanoparticles (AuNPs) from solution onto 0.5%wt-Nb:$SrTiO_3$ substrates. We expect the AuNPs to act as defect nuclei for the subsequently PLD-grown $SrTiO_3$ thin films. We investigated the correlation between the topography and the local conductivity by performing *in-situ* LC-AFM measurements with area scanning as well es grid measurements. These measurements combine topography scans with single point spectroscopy, leading to I-V curves correlated with defined positions on the surface.

We measured differences in the resistive switching behavior between the AuNPs, their immediate vicinity and the more distant areas. In the immediate vicinity of the AuNPs the $SrTiO_3$ thin film can be switched, whereas the other areas show no change in the conductivity. We will discuss the influence of defects formed in the vicinity of the AuNPs on the local switching properties.

DS 44.10 Thu 16:00 P1

Chemical investigation of buried active layers in resistive switching materials by hard x-ray photoemission electron microscopy (HAXPEEM) — •Christoph Schmitz[1], Marten Patt[1], Carsten Wiemann[1], Alexandra von der Heiden[2], Manfred Martin[2], Andrei Gloskovskii[3], Wolgang Drube[3], and Claus M. Schneider[1,4] — [1]Peter Grünberg Institut PGI-6, FZ Jülich, Jülich, Germany — [2]Institute of Physical Chemistry, Aachen, Germany — [3]Deutsches Elektronen-Synchroton DESY, Hamburg, Germany — [4]Fakultät f. Physik and Center for Nanointegration Duisburg-Essen (CeNIDE), Duisburg, Germany

Energy filtered photoemission electron microscopy (EF-PEEM) offers a lot of valuable insights into chemically driven processes at surfaces. In our work we want to apply this method to resistive switching materials to understand the origin of the different resistive states of such materials by investigating changes of band structure, chemical bonding and composition. However, devices based on resistive switching materials are commonly designed in layered structures where the active material is buried beneath a metal top electrode and usually not accessible by conventional photoemission techniques due to their high surface sensitivity. Here we present a way to increase the probing depth of EF-PEEM up to several nm in a non-destructive manner by using hard x-ray photons (hν=6550eV). Advantages and limitations of this method will be discussed on the basis of recent data of GaOx-based resistive switching devices and a Cr/Au/Si wedge sample collected at PETRA III Beamline P09.

DS 44.11 Thu 16:00 P1

Spectroscopic investigations of resistively switching Ta_2O_{5-x} thin films — •Oliver Peters[1], Katharina Skaja[1], Christoph Bäumer[1], Regina Dittmann[1], and Rainer Waser[1,2] — [1]Peter Grünberg Institut, Forschungszentrum Jülich GmbH, Jülich, 52425, Germany — [2]Institut für Werkstoffe der Elektrotechnik II, RWTH Aachen University, Aachen, 52074,Germany

The subject of resistive switching in metal oxides and its utilisation in resistive random access memory (RRAM) has received abundant research interest during the last years.

Within the valence change memory (VCM) type of RRAM, Tantalum Oxide is one of the materials of choice, recently being introduced to the market. Thus, the proposed physical model of resistive switching in VCM, which is linked to the diffusion of oxygen vacancies and the formation of conducting filaments, has been analysed by different approaches. Although there are several publications dealing with the spectroscopic analysis of stacked structures, such as capacitors, the details of the chemical changes induced by electrical treatments at the electrode/Ta_2O_{5-x} interface are not completely understood so far.

Employing an in-situ electrode delamination technique, the electrode/Ta_2O_{5-x} interface was analysed by means of energy filtered photoelectron emission microscopy (PEEM). We will present characteristics of the low and high resistance state as well as non-switched areas of a Ta/Ta_2O_{5-x}/Pt stacked sample.

DS 44.12 Thu 16:00 P1

TaOx based memristive systems with variable oxygen concentration — •Stefan Niehörster[1], Savio Fabretti[1], Markus Schäfers[1], and Andy Thomas[1,2] — [1]Bielefeld University, Bielefeld, Germany — [2]Mainz University, Mainz, Germany

TaOx based devices show reversible and nonvolatile memristive switching effects for a large number of cycles. This property makes them very interesting for data storage applications or imitating synapses in a neural network. We prepared devices with Pd and Ta electrodes and a TaOx barrier. The electrodes were deposited by magnetron sputtering and the tunnel barrier was fabricated by in-situ oxidation of a thin sputtered Ta film. This approach gives us the possibility to manipulate the oxygen concentration of the barrier compared to sputter deposition of a TaOx target. We varied the bias voltage of the oxy-

gen plasma to regulate the thickness of the barrier by the penetration depth, and we varied the oxidation time to regulate the oxygen concentration. We used optical lithography to define squares of 10x10, 15x15 or 25x25μm^2. The junctions were characterized by transport measurements in two point geometry. The measurements of our devices show memristive switching, where the amplitude and the noise of the switching show a dependence on the oxidation time. In addition, we were able to reach more than two states. The data is compared to our earlier results with MgO based memristive tunnel junctions. Here, the amplitude of the memristive switching was increased by a factor of 3.

DS 44.13 Thu 16:00 P1

Setup for optical switching of single antenna resonances in the mid-infrared using phase-change materials — •Thomas Kalix, Ann-Katrin Ursula Michel, Martin Salinga, and Thomas Taubner — Institute of Physics (IA), RWTH Aachen University, 52056 Aachen, Germany

Metallic nanostructures become more important in the field of plasmonics and metamaterials, since they locally enhance electromagnetic fields. For example the resonance frequency of rod-like shaped nanoantennas depends on the geometry, the material they are fabricated of and the refractive index n of the surrounding media [1].

Phase-change materials (PCM) are characterized by a fast phase transition between the amorphous and crystalline state. The structural change is accompanied by a huge modulation of n, which allows us to tune the resonance frequency of nanoantennas which are embedded in a PCM thin film [2]. The switching between the amorphous and crystalline phase can be realized reversibly for example by an optical pulse [3]. We built a laser setup which allow us the local switching of single nanostructures which are fabricated on the PCM $Ge_3Sb_2Te_6$ with single nanosecond pulses.

[1] F. Neubrech *et al.*, J. Appl. Phys. 89, 253104 (2006).
[2] A. Michel *et al.*, Nano Lett., 13(8), pp 3470-3475 (2013).
[3] J. Siegel *et al.*, J. Appl. Phys. 103, 023516 (2008).

DS 44.14 Thu 16:00 P1

Sputter Deposited Chalcogenide Superlattices (CSL) for Energy Efficient Data Storage — •Felix R. L. Lange[1], Enrico Varesi[2], Andrea Redaelli[2], Luigi Avaro[2], Jamo Momand[3], Bart J. Kooi[3], Stefan Jakobs[1], and Matthias Wuttig[1,4] — [1]1. Physikalisches Institut (IA), RWTH Aachen University, Germany — [2]Micron Semiconductor Italia, Process R&D, Agrate Brianza, Italy — [3]Zernike Institute for Advanced Materials, University of Groningen, The Netherlands — [4]JARA - FIT, RWTH Aachen, Germany

Phase change materials (PCM) are a unique sub-class of chalcogenides where both, an amorphous and a crystalline state are stable at ambient conditions. Since the phase transition can proceed on a nanosecond timescale PCM are already exploited in rewritable optical data storage solutions (CD-RW, Blu-ray-RW) and first solid state memories are commercially available. The phase transition in both cases is induced via melt quenching and crystallizing of the material, respectively. Only recently a very different mechanism was proposed for highly textured multilayers of GeTe and Sb_2Te_3. Here, a change of the coordination number of Ge atoms at the interface was argued to be responsible for the pronounced electrical contrast between these two states [1]. These superlattices furthermore exhibit rather low switching powers as compared to ordinary PCM which makes this novel stack design highly valuable for future 'green' data storage solution. Here we explore the feasibility to grow highly textured thin alternating layers of GeTe and Sb_2Te_3 using DC magnetron sputter deposition.

[1] R. E. Simpson *et al.*, Nat. Nanotechnol. **6**, 501-505 (2011)

DS 44.15 Thu 16:00 P1

Analysis of the switching behaviour of Phase Change Materials using s-SNOM — •Martin Lewin, Benedikt Hauer, Ann-Katrin U. Michel, and Thomas Taubner — Institute of Physics (IA), RWTH Aachen University, 52056 Aachen, Germany

Phase Change Materials (PCM) show at least two stable states in the solid phase: One amorphous and one crystalline state. These two states have significantly different dielectric functions. The fact that the two states can be switched reversibly by optical or electrical means (laser-, voltage-pulses) makes PCM very interesting for storage applications (Re-Writable-Discs, Phase-Change-RAM) or even logical photonic devices [1]. PCM are often characterised by TEM, AFM or far-field reflection measurements (diffraction-limited).

Scattering-type scanning near-field optical microscopy (s-SNOM) is based on an illuminated metal coated tip being scanned over a sample. The backscattered light is measured in a detector yielding the near-field optical amplitude and phase signals which depend on the dielectric function of the sample. Due to the local detecting approach the lateral resolution is no longer wavelength-dependent (here: approx. 25 nm). S-SNOM does not rely on thin samples as TEM does and yields subsurface information in contrast to AFM.

Here we present our progress in resolving the state of switched PCM (both thermally and by laser-pulse sequences) on a nm-scale using s-SNOM.

[1] Simone Raoux and Matthias Wuttig. In Nanoelectronics and Information Technology. Rainer Waser (ed.). Wiley-VCH Verlag, 2012.

DS 44.16 Thu 16:00 P1

Textured growth of pulsed laser deposited Ge2Sb2Te5 thin films — •Erik Thelander, Ulrich Ross, Xinxing Sun, Andriy Lotnyk, and Bernd Rauschenbach — Leibniz Institute of surface modification, Leipzig, Germany

Phase change materials based on the material system Ge-Sb-Te have been widely used for optical storage for decades and are gaining more interest as a candidate for storage class memory. Pulsed laser deposition (PLD) is a deposition method with hyper-thermal species that could have a large influence on the film and crystal growth and hence also on the phase change properties. Although a number of groups have studied PLD-deposited phase change films, until now no investigations of the growth of the material has been presented. This investigation show that it possible to synthesize high quality thin films of Ge2Sb2Te5 using a stoichiometric compound target and a pulsed laser deposition process. X-ray diffraction (T-2T, RC and pole figure measurements) was employed to determine the crystalline quality of the samples and selected samples was investigated with HRSTEM using a probe corrected FEI Titan* G2 60-300kV transmission electron microscope. As substrates, HF-dipped Si (100) and freshly cleaved KCl (100) have been used. Thermally annealed as-deposited films show a polycrystalline nature whereas films that are deposited at elevated temperature show a preferred 111-growth direction independent of substrate. This could have implications for the switching behavior of the material and for further studies on epitaxial growth.

DS 44.17 Thu 16:00 P1

Laser-induced phase transitions of PLD-deposited GeTe films — •Xinxing Sun[1], Erik Thelander[1], Hongbing Lu[2], Jürgen W. Gerlach[1], and Bernd Rauschenbach[1] — [1]Leibniz Institute of Surface Modification, Permoserstr. 15, D-04318, Leipzig, Germany, — [2]Hubei University, Wuhan 430062, China

Phase change memory materials based on chalcogenides can rapidly and reversibly be switched between an amorphous and a crystalline phase. Since both phases are characterized by very different optical and electrical properties, there materials can be employed for rewritable optical and electrical data storage. In this letter, phase transformations in Ge-Te thin films (grown using pulsed laser deposition system) are induced by irradiation with nanosecond laser pulse at 248 nm has been investigated. The influence of laser fluence between 20- 300 mJ/cm2 on the structure and properties of Ge-Te phase-change films were studied by X-ray diffraction and reflectivity measurements. The results show that switching is possible under irradiation with nanosecond pulses using single pulses for amorphization and multiples pulses for crystallization. For comparison, the large structural differences between the laser irradiated and thermally annealed films are also revealed, in between those of the crystalline and amorphous.

DS 44.18 Thu 16:00 P1

An alternative route for crossing the metal-insulator transition in GeTe-Sb_2Te_3-alloys — •Annika Poitz, Hanno Volker, Peter Jost, Peter Zalden, Tobias Schäfer, and Matthias Wuttig — I. Physikalisches Institut (IA), RWTH Aachen, 52056 Aachen

Phase-change materials (PCMs) are outstanding materials: Besides a fast transition between the amorphous and the crystalline state, these materials show a high contrast in their optical and electrical properties. Due to these properties PCMs can be employed in optical and electrical memory technologies.

Recently it has been demonstrated[1] that the resistivity in the crystalline phase in some PCMs such as $Ge_1Sb_2Te_4$ depends on the annealing temperature. Higher annealing temperatures lead to smaller resistivities and even a change from non-metallic to metallic behavior. This is explained by a reduction of disorder upon annealing, which leads to a disorder-driven metal-insulator transition (MIT). This MIT

has been proven to be independent of structural transitions[1]. However $Ge_1Sb_2Te_4$ shows a cubic to trigonal transition near the MIT, which hampers a clear distinction between the influences of disorder and crystalline structure.
In this study we report an MIT in PCMs without such a structural change. Instead of annealing, we control disorder by varying the stoichiometry of $(Sb_2Te_3)_{1-x}(GeTe)_x$-alloys with $0.75 \leq x \leq 1$. In this study we employ low- and high-temperature resistivity, Hall-effect and XRD measurements for a characterization of the samples.
[1] T. Siegrist et al., Nat. Mat. 10, 202 (2011)

DS 44.19 Thu 16:00 P1

Nanodiffraction and fluctuation electron microscopy of phase-change material — Manuel Bornhöfft[1,2], Paul Voyles[3], Tobias Saltzmann[4], •Ulrich Simon[4], and Joachim Mayer[1,2] — [1]Gemeinschaftslabor für Elektronenmikroskopie, RWTH Aachen University, Ahornstraße 55, 52074 Aachen, Germany — [2]Ernst Ruska-Centre, FZ Jülich and RWTH Aachen, Forschungszentrum Jülich GmbH, 52425 Jülich, Germany — [3]Department of Materials Science and Engineering, University of Wisconsin, Madison, Madison, Wisconsin 53706, USA — [4]Institute of Inorganic Chemistry and JARA - Fundamentals of Future Information Technology, RWTH Aachen University, Landoltweg 1, 52074, Aachen, Germany

We studied phase-change materials in a scanning transmission electron microscopy (STEM) dedicated Titan transmission electron microscope (TEM) by nanodiffraction and fluctuation electron microscopy. In both techniques the samples are investigated by a coherent and parallel electron probe in the nanometer scale by STEM. This is in contrast to the normal STEM, which is executed with a convergent beam. The coherent and parallel illumination enables us to image the diffraction patterns of probe size (1-11nm) limited regions. Nanodiffraction is used to get nanometer scale information of the phase of phase-change materials and its structures. Fluctuation electron microscopy is sensitive to the medium-range order of materials. The grade of order can influence the crystallization kinetics of the materials, which are important for the application as memories.

DS 44.20 Thu 16:00 P1

Resistive Switching Properties of Chemically Synthesized Metal Oxide and Higher Chalcogenide Nanoparticles — •Tobias Saltzmann[1], Oliver Schmidt[1], Michael Noyong[1], and Ulrich Simon[1,2] — [1]Institut für Anorganische Chemie, RWTH Aachen University, 52074 Aachen, NRW, Germany — [2]JARA - Fundamentals of Future Information Technologies

We apply chemical approaches for the fabrication of metal oxide and higher chalcogenide nanoparticles (NPs) as resistively switching nanostructures. By varying size, crystallinity, morphology as well as composition, we aim to explore structure-composition-property relations.

As a model phase change material we studied the narrow band gap semiconductor Sb2Te3. Its highly anisotropic crystal structure consists of quintuple Te Sb Te Sb Te layer stacks, with covalent bonding in ab-, but v. d. Waals bonding in c-direction. Synthesized via a solvothermal route, Sb2Te3 is formed as single crystalline hexagonal platelets (HPs) with sizes of 1 to 10 *m in ab-direction and with a few tens up to 250 nm in c-direction. We electrically addressed single HPs in situ in a SEM in ab- and c-direction, respectively, and monitored switching between two differently conducting states in both directions.

As model valence change material we synthesized TiO2. Via a sol-gel process amorphous TiOx NPs are formed and subsequently calcined to form crystalline TiO2. To study the influence of defect concentration and crystallinity on the resistive switching behavior, amorphous as well as NPs calcined in oxidizing or reducing environments are electrically characterized in situ in a SEM.

DS 44.21 Thu 16:00 P1

Simulation of nucleation and growth in crystallization of phase change metrials — •Fatemeh Tabatabaei[1], Markus Apel[2], and Efim Brener[1] — [1]Peter Grünberg Institut (PGI-2), Forschungszentrum Jülich, 52428, Jülich — [2]Access e.V., RWTH Aachen, 52072 Aachen

Chalcogenide materials like GeSeTe and AgInSbTe showing phase change properties suitable for the use in non-volatile rewritable memory devices. Their crystallization mechanism in the course of switching is known to be nucleation dominated or growth dominated, respectively [1]. The phase field simulation technique is applied in order to study crystallization of the amorphous state to the crystalline state. We extended our work by adding a nucleation model to the simulation of crystallization. The impact of different model parameter like critical radius for nucleation or maximum nucleation frequency has been investigated as a function of process parameter, e.g. the substrate temperature, for non-isothermal and transient conditions. Results of the simulations are grain size, temperature evolution and the crystallization rate.
[1] Raoux S. and Wuttig M., (2010) *Phase Change Materials, Science and Application*, New York, NY: Springer