DS 38: Phase change/ resistive switching

Time: Thursday 15:00–18:45 Location: H 0111

DS 38.1 Thu 15:00 H 0111

Nanosecond laser-induced phase transitions in pulsed laser deposition-deposited GeTe films — •Xinxing Sun, Erik Thelander, Jürgen W. Gerlach, and Bernd Rauschenbach — Leibniz Institute of Surface Modification, Permoserstr. 15, D-04318, Leipzig, Germany

Phase changes in chalcogenide-based alloys have been widely studied in terms of the application in optical data storage and the same class of phase change materials is a promising candidate for further applications in non-volatile memories. In this study, phase transformations between the amorphous and crystalline state in GeTe thin films grown by pulsed laser deposition (PLD) are investigated. The phase transformations are induced by irradiation with nanosecond laser pulses at 248 nm and pulse duration of 20 ns. The structural and optical properties of the GeTe films were studied by x-ray diffraction and optical reflectivity measurements as a function of the number of irradiation pulses between 0 and 30 pulses and of the laser fluence up to 195 mJ/cm2. A reversible phase transition is found by using pulse numbers more than 5 pulses at a fluence above the threshold fluence for crystallization (between 11 and 14 mJ/cm2) and single pulse at a fluence of between 162 and 182 mJ/cm2 for amorphization. The influence of film thickness (6-300 nm) and irradiation with pulse repetition frequency (1-400 Hz) on the crystallization behavior of GeTe films is also discussed. A high optical contrast between the amorphous and crystalline state is achieved, proving that PLD-deposited GeTe films have excellent potential for application in phase change storage.

DS 38.2 Thu 15:15 H 0111

Growth of Germanium Telluride Thin Films on Passivated Silicon Surfaces by Molecular Beam Epitaxy — •Rui Ning Wang[1], Jos Boschker[1], Raffaella Calarco[1], Jamo Momand[2], and Bart Kooi[2] — [1]Paul-Drude-Institut für Festkörperelektronik, Berlin, Germany — [2]University of Groningen, Zernike Institute for Advanced Materials, Groningen, The Netherlands

As a phase change material, and as a ferroelectric semiconductor, germanium telluride is worth investigating both from the fundamental and technological point of view. And especially for fundamental research, the ability to produce GeTe thin films of great crystalline quality is of prime importance.

Epitaxial growth of GeTe on Si(111)-(7x7) by molecular beam epitaxy was first demonstrated by Giussani et al. [1] and it has been recently shown that the crystalline quality of such GeTe thin films can be significantly improved by growing on a passivated Si(111)-($\sqrt{3} \times \sqrt{3}$)R30°-Sb surface [manuscript accepted in J. Phys. Chem. C 19/11/2014].

To better understand the role of the surface passivation in the epitaxy of GeTe, growth on the hydrogen passivated Si(111)-(1x1)-H surface was investigated as well. In this presentation, the growth of GeTe on these different silicon surfaces is reported and compared between each other.

[1] A. Giussani et al., Phys. Status Solidi B, vol. 249, no. 10, pp. 1939-1944, Oct. 2012.

DS 38.3 Thu 15:30 H 0111

Epitaxial and textured Ge-Sb-Te phase-change thin films investigated by Cs-corrected STEM — •Ulrich Ross, Andriy Lotnyk, Erik Thelander, and Bernd Rauschenbach — Leibniz-Institut für Oberflächenmodifizierung e.V. Permoserstr. 15 D-04318 Leipzig

Chalcogenide phase change compounds are under intense scrutiny for emerging data storage and fast switching electronic memory applications. The unique properties of this class of materials are based on the distinct change in electrical conduction and optical reflectivity upon transition between crystalline and amorphous states. Much interest has been focused on compounds from the stoichiometric tie-line $(GeTe)_x$-$(Sb_2Te_3)_{1-x}$ in the Ge-Sb-Te intermetallic system. For the development of phase change memory in particular, oriented, epitaxial and layered thin films have been reported to display significantly enhanced switching properties.

We have performed a detailed high-resolution scanning transmission electron microscopy (STEM) investigation of fast grown $Ge_2Sb_2Te_5$ thin films on native amorphous silicon oxide as well as oriented BaF_2(111) and Si(111) substrates, produced by pulsed laser deposition. Formation of the crystalline phases was induced by deposition at elevated temperatures as well as post-deposition heat treatment. An analytical probe aberration-corrected FEI Titan^3 G2 60-300 S/TEM was used in order to correlate treatment conditions and local structure at the atomic scale. The interplay between grain texture, lattice disorder and local composition variations will be discussed.

DS 38.4 Thu 15:45 H 0111

Optical and structural dynamics of the photoinduced phase transition of GST — •Lutz Waldecker[1], Timothy Miller[2], Roman Bertoni[1], Simon Wall[2], and Ralph Ernstorfer[1] — [1]Fritz-Haber-Institut der Max-Planck-Gesellschaft, Berlin, Germany — [2]ICFO - Institut de Ciències Fotòniques, Castelldefels (Barcelona), Spain

The phase change material $Ge_2Sb_2Te_5$ (GST) exhibits large changes in its optical and electronic properties across the structural phase transition between its amorphous and crystalline states. We use single-shot optical and diffraction measurements to follow the system*s dynamics after initiating the phase transition with a femtosecond laser pulse. We observe large changes in the dielectric function instantaneously after photoexcitation, when the lattice still shows long-range order. Energy transfer from electrons to the lattice heats leads to melting on a few picosecond timescale and the amorphization is achieved by thermal processes on longer timescales.

DS 38.5 Thu 16:00 H 0111

Static and dynamic THz spectroscopy of epitaxially grown GeTe-Sb_2Te_3 alloys — •Valeria Bragaglia[1], Karsten Holldack[2], and Raffaella Calarco[1] — [1]Paul-Drude-Institut für Festkörperelektronik, Berlin, Germany — [2]Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Berlin, Germany

In the last few years, the number of investigations on the dynamics of photo induced effects in GeTe-Sb_2Te_3 alloys increased. Full optical measurements were mostly employed in order to get information on both, the electronic and structural response upon excitation. The films investigated are typically grown by sputtering and result in a polycrystalline structure [1].

In our study we focus on epitaxially grown GST which presents a high degree of structural quality. Static measurements where performed in transmittance and reflectance configuration on crystalline and amorphous GST employing Fourier transform Infrared spectroscopy (THz) which allows to access the spectral range of 20-700 cm^{-1}. Epitaxial crystalline GST shows both free carrier and phonon absorption contributions. In particular, employing a multilayer structure model, we conclude that a Drude model convolved with several Lorentzian contributions arising from soft phonon modes simulate well the experimental data. Ultrafast dynamic measurements of amorphous and crystalline GST under laser excitation are ongoing employing 800 nm fs-laser pump and ps-THz probe in the same spectral range in order to investigate time resolved electronic response upon excitation.

[1] M.J. Shu et al., Appl. Phys. Lett. 102, 201903 (2013).

DS 38.6 Thu 16:15 H 0111

Memristive Hebbian Plasticity: Device requirements for the emulation of Hebbian plasticity based on memristive devices — •Martin Ziegler[1], Mirko Hansen[1], Marina Ignatov[1], Thorsten Bartsch[2], and Hermann Kohlstedt[1] — [1]Nanoelektronik, Technische Fakultät, Christian-Albrechts-Universität zu Kiel — [2]Klinik für Neurologie, Universitätsklinikum Schleswig-Holstein, Christian-Albrechts-Universität zu Kiel

Essential requirements of individual memristive devices for the emulation of Hebbian plasticity in neuromorphic circuits are defined and discussed. Memristive devices based on ionic and exclusively electronic mechanisms are explored. The ionic devices consist of the layer sequence metal/isolator/metal and represent today's most popular devices. The electronic device is a MemFlash-cell. The MemFlash-cell is based on a conventional floating gate transistor with a diode configuration wiring scheme exhibiting a memristive (pinched) I-V characteristic. The electric characteristics of both types of devices are experimentally and theoretically explored with a focus on artificial synaptic plasticity mechanisms. A phenomenological plasticity model suitable for memristive devices is presented, based on advanced novel learning rules, which provide Hebbian plasticity in accordance to the Bienenstock-Cooper-Munro(BCM) rule.

DS 38.7 Thu 16:30 H 0111

Memristive Tunnel Junctions — •Mirko Hansen[1], Martin Ziegler[1], Thomas Mussenbrock[2], Sven Dirkmann[2], and Hermann Kohlstedt[1] — [1]AG Nanoelektronik, Technische Fakultät, Christian-Albrechts-Universität zu Kiel, Germany — [2]Lehrstuhl für Theoretische Elektrotechnik, Fakultät für Elektrotechnik und Informationstechnik, Ruhr-Universität Bochum, Germany

We present results on a device which consists of a tunnel barrier and a thin niobium oxide layer in between two metal electrodes.

By using the well established niobium/aluminium technology to fabricate aluminium oxide tunnel junctions with a smooth interface, we are able to fabricate very thin (<3 nm) and highly resistive niobium oxides layers. The homogeneous change in resistance (Roff/ Ron > 100) and RxA vs. A plots suggest an area-dependent and non-filamentary switching mechanism, which is explained by taking the interface effects at the tunnel barrier and the top electrode into account.

The memristive tunnel junctions were optimized for the use in neuromorphic circuits and were fabricated on 4" wafers using standard optical lithography, (reactive) DC sputtering and wet etching.

DS 38.8 Thu 16:45 H 0111

Emulation of neuronal functionality by using a VO_2-based oscillator circuit — •Marina Ignatov, Martin Ziegler, Mirko Hansen, Adrian Petraru, and Hermann Kohlstedt — Nanoelektronik, Technische Fakultät, Christian-Albrechts-Universität zu Kiel, Germany

A negative-differential oscillator circuit based on a vanadium dioxide (VO_2) device is presented. The oscillator circuit allows to emulate basic neuronal functionalities, including spike coding. The obtained results are compared to common spiking neuron models. Additionally, a theoretical analysis of the oscillator circuit is used to gain insight into the functionality of the circuit and to give advice for the device development and the implementation of the circuit. In this respect, important requirements for the strongly correlated electron material VO_2 are presented and discussed in detail. Further, possible modifications of the oscillator circuit model for a better agreement with neuronal spikes are presented.

15 min. break.

DS 38.9 Thu 17:15 H 0111

Effect of oxygen engineering and doping on resistive switching in HfO_2 based RRAM devices grown by MBE — •S.U. Sharath[1], Jose Kurian[1], Erwin Hildebrandt[1], Philipp Komissinskiy[1], Thomas Bertaud[2], Christian Walczyk[2], Pauline Calka[2], Thomas Schroeder[2], and Lambert Alff[1] — [1]Materialwissenschaft, Technische Universität Darmstadt, Germany — [2]IHP, Im Technologiepark 25, 15236 Frankfurt (Oder), Germany

Thin films of titanium nitride (TiN, electrode) and hafnium oxide (HfO_2) were grown using molecular beam epitaxy (MBE). Oxygen engineering using strongly oxygen deficient growth parameters and trivalent doping of HfO_2 thin films has been utilized to stabilize oxygen vacancy concentrations far beyond the thermodynamical equilibrium. Thin films of hafnium oxide grown at 320 °C on TiN crystallize in a monoclinic symmetry (m-HfO_2) at higher oxidation conditions, whereas the oxygen deficient hafnium oxide films showed oxygen vacancy stabilized tetragonal like phase of hafnium oxide (t-HfO_{2-x}) which was verified by X-ray diffraction [1]. A large concentration of oxygen vacancies lead to a defect band at the Fermi-level as observed by X-ray photoelectron spectroscopy (XPS). The electrical switching measurements show that the forming voltage is reduced for oxygen deficient films paving the way for low power devices in future. In oxygen deficient HfO_{2-x} thin films grown on TiN/Si(001), the thickness dependence of the forming voltage is strongly suppressed [2].

[1] S. U. Sharath et al., Appl. Phys. Lett., 104, 063502 (2014).
[2] S. U. Sharath et al., Appl. Phys. Lett., 105, 073505 (2014).

DS 38.10 Thu 17:30 H 0111

BiFeO3-based resistive switching cells with flexible rectifying contact — •Tiangui You[1], Nan Du[1], Stefan Slesazeck[2], Thomas Mikolajick[2,3], Guodong Li[4], Danilo Bürger[1], Ilona Skorupa[1], Hartmut Stöcker[5], Barbara Abendroth[5], Andreas Beyer[6], Kerstin Volz[6], Oliver G. Schmidt[1,4], and Heidemarie Schmidt[1] — [1]TU Chemnitz — [2]NaMLab gGmbH Dresden — [3]TU Dresden — [4]IFW Dresden — [5]TU Bergakademie Freiberg — [6]Philipps-Universität Marburg

Nonvolatile resistive switching in BiFeO3 (BFO) has attracted increasing attention. However, the underlying resistive switching mechanism is still controversial which restricts its application in nonvolatile memory[1] and logics[2]. Here we develop a model on modifiable Schottky barrier height and elucidate the physical origin underlying resistive switching in Au-BFO-Pt/Ti resistive switching cells containing mobile oxygen vacancies.[3] Increased switching speed is possible by applying a large amplitude writing pulse as the migration of mobile oxygen vacancies is tunable by both the amplitude and length of the writing pulse. The local resistive switching has been investigated by conductive atomic force microscopy and exhibits the capability of down-scaling the resistive switching cell to the grain size.

[1] Y. Shuai, et al., J. Appl. Phys. 2011, 109, 124117
[2] T. You, et al., Adv. Funct. Mater. 2014, 24, 3357
[3] T. You, et al., ACS Appl. Mater. Interfaces 2014, 6, 19758

DS 38.11 Thu 17:45 H 0111

Reversible Changes Induced by Liquid Electrolyte Gating in the WO_3 Electronic Structure — •Carlos E. ViolBarbosa[1], Julie Karel[1], Simone G. Altendorf[2], Janos Kiss[1], Yuki Utsumi[1], Mahesh G. Samant[2], Liu Hao Tjeng[1], Claudia Felser[1], and Stuart S. P. Parkin[2] — [1]Max-Planck-Institut für Chemische Physik fester Stoffe, Dresden, Germany 01187 — [2]IBM Almaden Research Center, San Jose, California, USA 95120

Tungsten trioxide (WO_3) is a d0 transition metal oxide that has attracted broad interest due its optical and electrical properties. WO_{3-x} has a rich phase diagram. Many of the studies in this material make use of modifications in the carrier concentration by chemical doping or creation of oxygen deficiencies. In this work, we utilize ionic liquid electrolyte gating in a electric-double-layer transistor device to induce a metallic state in WO_3 films, a process we will show is reversible.

The modifications in the electronic structure (core levels and valance band) resulting from the gating are probed by hard X-ray photoelectron spectroscopy. Electrolyte gating leads to a significant population of W 5d states in the conduction band and an enormous change in the W 4f core levels. Ab initio density functional theory are used to help describe the origin of these modifications in the electronic structure.

DS 38.12 Thu 18:00 H 0111

Resistive switching of polycrystalline, multiferroic $YMnO_3$ thin films — •Agnieszka Bogusz[1,2], Sławomir Prucnal[1], Daniel Blaschke[1], Ilona Skorupa[1], Danilo Bürger[2], Oliver G. Schmidt[2,3], and Heidemarie Schmidt[2] — [1]Institute Of Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf — [2]Department of Materials for Nanoelectronics, Chemnitz University of Technology — [3]Institute for Integrative Nanosciences, IFW-Dresden

Resistive switching (RS) phenomena have been widely investigated in the field of materials science, physics, and electrical engineering in the past decade. Recently, multiferroics have been considered as promising candidates for memristive switches. Specific properties of multiferroics might bring additional and/or new functionalities into the memristive switches. This work investigates the RS properties of multiferroic $YMnO_3$ thin films reported as a unipolar resistive switch [1]. $YMnO_3$ was grown at 400°C on $Pt/Ti/SiO_2/Si$ substrates by pulsed laser deposition (PLD) and crystallized by flash lamp annealing (FLA). Film thickness and the concentration of point defects were controlled during the PLD process. Transport and RS properties of $Au/YMnO_3/Pt/Ti/SiO_2$ structures were determined by two-point probe measurements in a top-bottom configuration. Results imply that the filamentary, unipolar RS in $YMnO_3$ originates from the electroredox reactions induced by the Joule heating. [1] A. Bogusz et al.,AIP Advances 4, 107135 (2014)

DS 38.13 Thu 18:15 H 0111

Kinetic Monte-Carlo simulations of resistive switching in silver doped titanium dioxide thin films — Sven Dirkmann[1], Jan Trieschmann[1], Mirko Hansen[2], Martin Ziegler[2], Hermann Kohlstedt[2], and •Thomas Mussenbrock[2] — [1]Ruhr-Universität Bochum, Lehrstuhl für Theoretische Elektrotechnik, 44780 Bochum — [2]Christian-Albrechts Universität zu Kiel, AG Nanoelektronik, 24143 Kiel

Low power consumption, low frabrication costs, fast write and read cycles, and scalability into the nanometer range make resistive switching devices attractive for future non-volatile memory applications and neuromorphic circuits. The majority of devices rely on nano-ionic mechanisms – one of which is electrochemical metallization, where the change in resistance is due to the formation and re-formation of conducting filaments. This contribution is devoted to demonstrate and discuss the formation and re-formation of Ag filaments in an Ag/TiO_2/Pt sandwich-like thin film system at experimental time-scales by means of kinetic Monte-Carlo simulations. It is shown that filamentary electrochemical metalization devices provide distinct and reliable “on” and “off” states, but their dynamic range is limited.

DS 38.14 Thu 18:30 H 0111

Tailoring the electrical properties of a TiO_2 layer by ion-beam irradiation for memristive applications — •Daniel Blaschke[1], Agnieszka Bogusz[1], René Hübner[1], Franziska Nierobisch[1], Vikas Rana[3], Andrea Scholz[1], Sibylle Gemming[1,2], and Peter Zahn[1] — [1]Institute of Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf — [2]Chair of Scale-bridging Materials Modeling, Physics Departement, TU Chemnitz — [3]Peter Grünberg Institut, Forschungszentrum Jülich

Reactively sputtered TiO_2 thin films on $Pt/Ti/SiO_2/Si$ substrates were irradiated with low energy Ar^+ ions of different energies to create surface or bulk modifications in the material. Furthermore, the fluence was varied to optimize the level of the modifications, which are e.g. amorphization, surface smoothing, and preferential sputtering of oxygen. These effects were detected by TEM, AFM and supported by TRIDYN simulations, respectively. The impact of these changes on the electrical properties of the TiO_2 layers was monitored by I-V and C-V measurements in top-bottom geometry with Pt, as well as Ti/Pt top contacts. The results indicate a transition from a Schottky-like behavior of the Pt/TiO_2 interface to an ohmic one with increasing fluence, which is very similar to the behavior of a Ti/TiO_2 interface. Furthermore, the capacity of the complete MIM stack increases with fluence, which points to a reduced effective thickness of the dielectric TiO_2 layer after irradiation.

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