DS 13: Phase Change/Resistive Switching

Time: Monday 15:00–16:45 Location: CHE 91

DS 13.1 Mon 15:00 CHE 91

Towards Shot Noise Study of Hafnium Oxide Resistive Switching — •Donato Civita[1,2], Carlos Sabater[2], and Jan van Ruitenbeek[2] — [1]Institute of Chemistry, Graz, Austria — [2]Leiden Institute of Physics, Leiden, The Netherlands

The continuous down-scaling of memory devices led to an increased interest in the Resistive Random Access Memory (ReRAM). Such a memory device consists of an ultrathin insulating layer between two metal electrodes where the insulating layer has the resistive switching (RS) properties, i.e. the ability to reversibly change its resistance as a result of an electrical stimulus. The switching mechanism is considered to be based on the formation and dissolution of a conducting filament surrounded by the insulating matrix. However, the nature of the conducting lament is still unclear.

In the present work, we design and produce novel RS nano-devices, consisting of hafnium oxide as insulating material and platinum as material for the metal electrodes. We describe in detail the fabrication procedure and characterization of the nano-devices and their RS behavior. A novel method to investigate the RS system, the Shot Noise measurement, is presented. The Shot Noise experiments will be presented together with the results of conductance measurements, with the goal to obtain insight into the nature of the conducting filaments.

DS 13.2 Mon 15:15 CHE 91

Nonvolatile resistive switching to 10 ^6 OFF/ON resistance ratio in yttrium manganite thin films with downscaled top electrodes — •Venkata Rao Rayapati[1], Agnieszka Bogusz[1,2], Nan Du[1], Danilo Bürger[1], Ilona Skorupa[1,2], Stefan E Schulz[3], Oliver G Schmidt[1,4], and Heidemarie Schmidt[1,3] — [1]Materials systems for Nanoelectronics, Chemnitz University of Technology, 09126 Chemnitz, Germany — [2]Helmholtz-Zentrum Dresden-Rossendorf, Institute of Ion Beam Physics and Materials Research, Bautzner Landstraße 400, 01328 Dresden, Germany — [3]Fraunhofer-Institut für Elektronische Nanosysteme, Abteilung Back-End of Line, Technologie-Campus 3, 09126 Chemnitz, Germany — [4]Institute for Integrative Nanosciences, IFW Dresden, Dresden, Germany

Polycrystalline, hexagonal YMnO3 (YMO) thin films grown by pulsed laser deposition with ceramic target [1] exhibit nonvolatile unipolar resistive switching (RS). In this work, we investigate RS properties of YMO thin films with different chemical compositions on large-scale Pt and Pt/Ti bottom electrodes (BE). Circular Au and Al top electrodes (TE) of different size have been prepared by magnetron sputtering and e-beam evaporation, respectively. SET and RESET bias during RS strongly depend on ceramic target and bottom electrode. Endurance of YMO with Al TE is improved in comparison to Au TE. The observed increasing ROFF/RON ratio with decreasing size of Al TE can be related with increasing ROFF with decreasing size of Al TE due to decreased tendency for local shunting. [1] A. Bogusz et al., AIP Advances 4 (2014)

DS 13.3 Mon 15:30 CHE 91

Characterization of the early stages in the MBE-growth of phase change materials — •Marvin Kaminski[1], Marc Pohlmann[1], Matti Wirtssohn[1], Abderrafii Moktad[1], Peter Jost[1], and Matthias Wuttig[1,2,3] — [1]I. Institute of Physics, Physics of Novel Materials, RWTH Aachen University, 52056 Aachen, Germany — [2]JARA-FIT, RWTH Aachen University, Germany — [3]3JARA-Insitut Energy-efficient information technology (PGI-10), FZ Jülich, 52428 Jülich, Germany

In chalcogenide-based phase-change materials (PCMs), the switching between the amorphous and the crystalline phase is fast, reversible, and concomitant with a prominent contrast in physical properties. PCMs are, therefore, among the most promising candidates for future nonvolatile electronic memory applications. Recent developments such as the concept of interfacial phase-change materials (IPCMs), where thin layers of Sb2Te3 and GeTe are stacked as superlattices, call for highly-textured or even epitaxial films, which can be produced by sputter deposition, MOPVE, and molecular beam epitaxy (MBE). In this work, we study thin MBE-grown chalcogenide layers on Si(111). The combination of in-situ RHEED and ARHEED as well as ex-situ XRD, SEM, and AFM measurements provides insights on the early stages of the growth process. As the early stages of the growth govern the overall quality of the film to a large extent, proper understanding is crucial for further optimization.

DS 13.4 Mon 15:45 CHE 91

Accurately controllable phase transitions in pulsed laser deposition-deposited GeTe films for multi-level memory applications — •Xinxing Sun[1], Andriy Lotnyk[1], Martin Ehrhardt[1], Pierre Lorenz[1], Jürgen W. Gerlach[1], and Bernd Rauschenbach[1,2] — [1]Leibniz Institute of Surface Modification, Permoserstr. 15, D-04318, Leipzig, Germany — [2]Institute for Experimental Physics II, Leipzig University, Linnéstr. 5, D-04103 Leipzig, Germany

Multi-level storage techniques are promising for increasing storage density and for reducing energy consumption in the application of phase-change materials based memory devices. However, accurately controlling the phase transitions as well as understanding the underlying switching mechanisms are still unsolved. In this study, non-volatile optical multi-level switching in single-layer GeTe phase-change films prepared by laser ablation are demonstrated to be feasible and accurately controllable at a timescale of nanoseconds. For this purpose, an ns UV laser pump-probe setup was adapted for the investigations. This system is capable to vary the laser parameters with broad ranges. Moreover, the optical switching process and the phase transformation are correlated on the microscopic scale for understanding of the switching mechanism. It is found that each 20 ns laser pulse (wavelength: 248 nm) with a fluence of 26 mJ/cm2 excitation induced a partial crystallization, and complete crystallization was achieved by a succession of 5 such pulses. In the reverse process, a single pulse excitation at a fluence of 112 mJ/cm2 leads to re-amorphization of the film.

DS 13.5 Mon 16:00 CHE 91

Investigation of oxygen vacancy formation and migration in HfO_2 from density functional theory — •Marta Gibertini, Daniel Wortmann, Gustav Bihlmayer, Shigeru Tsukamoto, and Stefan Blügel — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, D-52425 Jülich, Germany

Among the investigated storage devices, resistive random access memory (ReRAMs) are currently considered relevant because of the high-speed/high-density properties and the low energy required for the writing/rewriting cycles. A deeper understanding of the role played by point defects and dopants in the used materials is important for an optimization of those devices.

We present a density functional theory (DFT) study aimed at the investigation of the formation energies and the migration energy barriers of oxygen vacancies in Y-doped and undoped monoclinic HfO_2. We look at these properties in bulk and film systems where the formation energy is calculated also at the surface, and the dependence on the magnitude of an external electric field is studied. The nudged elastic method is applied and the DFT calculations are performed with the electronic structure code jüRS, a real-space finite-difference implementation of the projector augmented wave (PAW) method. The real-space formalism is chosen because it allows a flexible treatment of the boundary conditions and therefore it is favorable for the implementation of an external electric field. – Work is supported by DFG - SFB 917 (Nanoswitches).

DS 13.6 Mon 16:15 CHE 91

Effect of heavy ion radiation on resistive switching in HfOx based RRAM devices grown by MBE — •Stefan Vogel[1], S. U. Sharath[1], J. Lemke[1], E. Hildebrandt[1], C. Trautmann[2], and L. Alff[1] — [1]Institute of Materials Science, Technische Universität Darmstadt, 64287 Darmstadt, Germany — [2]Materials Research Department, Gesellschaft für Schwerionenforschung (GSI), 64291 Darmstadt, Germany

Recently, resistive random access memory (RRAM) gained a lot of attention due to its promising performances: fast switching times, high endurance, and low power consumption. RRAM devices are non-volatile memories based on switching between a stable low resistance state (LRS) and a high resistance state (HRS) by conducting filaments which are formed and disrupted by applying voltages of different polarities. RRAM devices usually have a simple metal-insulator-metal stack structure. Hafnium oxide (HfO_2) is promising for embedded RRAM due to its established CMOS compatibility. Also, its simplicity and the possibility of 3D-stacks makes RRAM being an attractive technology for increased device density, potentially overcoming existing limitations and following Moore‘s law for floating gate metal oxide semiconductor field effect transistors. In-situ stacks of TiN/HfO_x with deficient oxygen stoichiometry were deposited by molecular beam epitaxy (MBE) using radical sources with different gases (oxygen and nitrogen). Device stacks of Pt/HfO_x/TiN were investigated towards their switching characteristics before and after heavy ion radiation utilizing Au-ions with energies of 48 MeV and fluences up to 10^{12} ions/cm^2.

DS 13.7 Mon 16:30 CHE 91

Reducing variability by introduction of thin TiO_2-layers into HfO_2 switching cells — •Alexander Hardtdegen[1], Camilla La Torre[2], Stephan Menzel[1], Rainer Waser[1,2], and Susanne Hoffmann-Eifert[1] — [1]Peter Grünberg Institute and JARA-Fit, Forschungszentrum Jülich GmbH, Jülich, Germany — [2]Institut für Werkstoffe der Elektrotechnik II, RWTH Aachen University, Aachen, Germany

Non-volatile resistive random access memory (ReRAM) cells are interesting for storage class memories, where for industrial purpose HfO_2 is typically used as oxide switching layer. The main challenge of HfO_2 is the slightly increased variability.

By designing bilayer cells combining HfO_2 with TiO_2, improvements of switching behavior can be observed. The devices switch more stable and a gradual SET with self-limiting behavior becomes visible. In contrast to this, the RESET becomes more abrupt when switching with higher current compliances. This behavior can be explained by an intrinsic stack-dependent series resistance, which can be quantified by a numerical method and also verified by physics-based compact model simulations.

In this study, the influence of the HfO_2/TiO_2 ratio is investigated in respect to the switching stability and the series resistance.