DS 40: Resistive switching II (jointly with DF, KR, HL)

Time: Friday 11:00–12:30 Location: H 0111

DS 40.1 Fri 11:00 H 0111

Resistive switching mechanism of Ti/HfO_2/TiN RRAM cells studied by nondestructive hard x-ray photoelectron spectroscopy — •Małgorzata Sowińska[1], Thomas Bertaud[1], Damian Walczyk[1], Christian Walczyk[1], Sebastian Thiess[2], Wolfgang Drube[2], and Thomas Schroeder[1] — [1]IHP, Im Technologiepark 25, 15236 Frankfurt/Oder, Germany — [2]DESY, Notkestrasse 85, 22607 Hamburg, Germany

A variety of different metal-insulator-metal (MIM) multilayered structures reveal reversible changes in resistance upon applying bias voltages across the layers. The physical mechanism of this resistive switching effect in such MIM cells is mostly unknown up to nowadays, although different models depending on the switching behaviour (unipolar or bipolar) and the conducting path type (filamentary or interface) have been proposed. In order to identify whether the resistance variation in the Ti/HfO_2/TiN system is related to local changes in the chemistry or to charge distribution we performed ex-situ and in-situ hard x-ray photoelectron spectroscopy (HAXPES) studies. This technique is well suited for investigating the buried interface of our resistive random access memory (RRAM) cell in a nondestructive way. In result, spectral differences observed between as-deposited and electrically switched devices lead us to the conclusion that the Ti/HfO_2 interface was modified, which can be associated with an interface-type model. Furthermore, we have also better revealed the impact of the current compliance on the HAXPES spectra of our device.

DS 40.2 Fri 11:15 H 0111

Pulse-induced resistive switching of CMOS embedded HfO_2-based 1T1R cells — •damian walczyk, christian walczyk, thomas bertaud, małgorzata sowińska, mindaugas lukosius, steffen kubotsch, thomas schroeder, and christian wenger — IHP, Im Technologiepark 25, 15236 Frankfurt (Oder), Germany.

Low-cost embedded nonvolatile memories (eNVMs) with high-density, high-speed, and low-power are of interest for many different system applications in Si-based CMOS technologies, including consumer electronics, high-end and mobile computing, various sensor and medical health care devices. The rising importance of embedded NVM technologies in recent years has pushed Resistance change Random Access Memory (RRAM) into the spotlight. However, despite numerous integration efforts, the driving mechanism for the resistive switching effect of HfO_2-based RRAM is still under debate [1]. Progress in the development has mainly been delayed due to the lack of control over the switching parameters. To achieve an application relevant endurance, the capability to control the resistance by an access device is addressed in this talk. Moreover, this work considers the pulse-induced resistive switching of memory cells with an area down to 1×1 μm^2. It is observed that the pulse width range for the set process is between 60 ns and 80 ns while the reset encompasses a pulse width range of 10-30 μs. Due to the intrinsic current compliance of the access transistor, low set currents of 10 μA and reset currents of 1 μA are obtained.

[1] C. Walczyk et al., IEEE Trans. Electron. Devices, vol. 58, no. 9, pp. 3124-3131 (2011).

DS 40.3 Fri 11:30 H 0111

Resistive switching on HfO_2-based metal-insulator-metal structures: effects of the top metal electrode and the oxygen partial pressure — •Thomas Bertaud[1], Damian Walczyk[1], Christian Walczyk[1], Steffen Kubotsch[1], Malgorzata Sowinska[1], Thomas Schroeder[1], Christophe Vallée[2], Vincent Jousseaume[3], and Christian Wenger[1] — [1]IHP, Im Technologiepark 25, 15236 Frankfurt Oder, Germany — [2]LTM Université Joseph Fourier, 17 Rue des Martyrs 38054 Grenoble, France — [3]CEA-LETI Minatec, 17 Rue des Martyrs 38054 Grenoble, France

Embedded nonvolatile memories (eNVM) are attractive for a growing number of applications. One promising candidate for next-generation eNVM is based on the electrically switchable resistance change between a high and a low resistive state of a metal-insulator-metal (MIM) structure, called resistance random access memory (RRAM). Due to the cost effectivity and BEOL compatibility with (Bi)CMOS technologies, this approach is highly attractive. In this talk, the resistive switching on HfO_2/bottom TiN based devices will be demonstrated. The work is focused on the impact of the top metal electrode on the switching behavior of the RRAM devices: Al, Hf and Ti (reactive non-blocking), and Cu, Pt and Au (non-reactive blocking) are used and lead to bipolar or unipolar switching, respectively [1]. The current and capacitance characteristics of the MIM diodes are studied by voltage sweeps and retention measurements under different gas ambient in order to highlight the effect of the oxygen partial pressure for a better understanding of the mechanism. [1] T. Bertaud et al., Thin Solid Films (2011).

DS 40.4 Fri 11:45 H 0111

A model for a non-volatile memory material: First principles study of Cu diffusion in α-cristobalite and α-quartz — •Martin Zelený[1], Jozsef Hegedüs[1], Adam. S. Foster[2], David. A. Drabold[3], Stephen. R. Elliott[4], and Risto. M. Nieminen[1] — [1]COMP/Dept. of Applied Physics, Aalto University School of Science, Espoo, Finland — [2]Dept. of Physics, Tampere University of Technology, Tampere, Finland — [3]Dept. of Physics and Astronomy, Ohio University, Athens, USA — [4]Dept. of Chemistry, University of Cambridge, Cambridge, UK

The switching mechanism of a new type of non-volatile memories can be based on electrochemical metallization occurring due to the migration of Ag or Cu ions in oxide glasses as for example SiO_2. In order to clarify this mechanism, we have performed simulations of Cu diffusion in the different modifications of SiO_2. All calculations in our study were carried out based on first-principles density-functional theory using the Vienna Ab initio Simulation Package (VASP).

We present a total-energy calculation of the barrier along a diffusion path of Cu between two equivalent interstitial positions in α-cristobalite and α-quartz. Our results for α-cristobalite show that the shape of the path strongly depends on the charge of the system, but the height of the migration barrier stays between 0.15-0.2 eV. On the other hand, the height of the barrier in α-quartz varies between 0.1 and 0.6 eV and depends on the directions of Cu motion. We also present results of molecular dynamics simulations of the drift of a Cu atom driven by an external electric field.

DS 40.5 Fri 12:00 H 0111

Transient Processes in Response to Electronic Excitation of Phase Change Materials — •Martin Salinga and Martin Wimmer — 1. Institut of Physics, RWTH Aachen University, Germany

In recent years a strong interest in phase change materials has been aroused by their potential for being utilized as the core element of a promising novel electronic memory technology. For such an application it is crucial to understand the characteristic switching mechanisms. Especially the electronic properties of the amorphous phase are of paramount importance. Thus, the strong non-linearity in the current-voltage-dependence of the amorphous phase, often referred to as threshold-switching, has drawn much attention.

In this work the transient current response of vertical Ge2Sb2Te5 devices to controlled voltage excitations is experimentally studied down to a time-scale of a few nanoseconds and analyzed with a particular focus on the delay-time before threshold switching and its dependence on the applied voltage. The results are compared to both experimental and theoretical studies in the literature and their implications for this field of research are discussed.

DS 40.6 Fri 12:15 H 0111

Nonvolatile resistive switching in Au/BiFeO3 rectifying junction — •Yao Shuai[1,2], Chuangui Wu[2], Wanli Zhang[2], Shengqiang Zhou[1], Danilo Bürger[1], Stefan Slesazeck[3], Thomas Mikolajick[3], Manfred Helm[1], and Heidemarie Schmidt[1] — [1]Institute of Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf, P. O. Box 510119, Dresden 01314, Germany — [2]State Key Laboratory of Electronic Thin Films and Integrated Devices, Chengdu, China — [3]Namlab gGmbH, Nöthnitzer Strasse 64, 01187 Dresden, Germany

BiFeO3 thin films have been grown on Pt/Ti/SiO2/Si substrates with pulsed laser deposition. RF sputtered Au has been used for the top electrode. The transport properties of the BiFeO3 thin films have been previously demonstrated to be sensitive to the interface [1]. In the present work, an interface-related resistive switching behavior with large switching ratio up to 4500 has been observed in the Au/BiFeO3/Pt structure [2]. The different polarities of the external voltage induce an electron trapping or detrapping process, and consequently change the depletion layer width below the Au Schottky contact, which is revealed by capacitance-voltage measurements and by long-term low/high resistance state capacitance transient measurements at zero bias [3]. [1] Y. Shuai et al., Appl. Phys. Lett., 98, 232901 (2011). [2] Y. Shuai et al., Appl. Phys. Express. 4, 095802 (2011). [3] Y. Shuai et al., J. Appl. Phys. 109, 124117 (2011).