DS 24: Focus Session: Resistive Switching by Redox and Phase Change Phenomena I (Memristive devices and new circuit concepts)

The focussed session will give a comprehensive introduction into the physical mechanisms of redox based and phase change based resistive switching phenomena observed in oxides and higher chalcogenides. These phenomena have developed into a mega-trend in nanoelectronics in recent years because of their potential application in energy-efficient high-density memory devices. Methods for the accurate crystallographic determination of the involved defect structures and experimental proves for field-induced crystallographic and valence changes will be reviewed, and issues concerning the integration of such elements within a nanoelectronics environment and the assessment of the device properties will be discussed. In addition, cells based on these phenomena may possibly offer application opportunities which reach into logic and neuromorphic computational concepts. (Organizers: Rainer Waser, RWTH Aachen / FZ Jülich, Matthias Wuttig, RWTH Aachen / FZ Jülich)

Time: Wednesday 9:30–11:00 Location: CHE 89

Invited Talk DS 24.1 Wed 9:30 CHE 89

Scaling limits and future prospects of resistive switching devices: From materials to systems — •Victor Zhirnov — Semiconductor Research Corp., Durham, NC, USA

Device scaling and energy consumption during computation has become a matter of strategic importance for modern Information and Communication Technologies (ICT). The central question addressed in this talk is: What is the smallest volume of matter needed for ICT devices, such as memory or logic? The scaling limits of electron-based devices, such as transistors are˜5-7 nm due to quantum-mechanical tunneling. Smaller devices can be made, if information-bearing particles are used whose mass is greater than the mass of an electron. Therefore the new principles for ICT devices, scalable to ˜1 nm, could be 'moving atoms' instead of 'moving electrons', for example using nanoinonic structures. The nanoionic resistive switching devices may offer a promising path to replace the foundation of today's computing technologies. Examples include memory (ReRAM) and logic (atomic/ionic switches). A related concept, the memristor, is currently being actively explored for different information processing tasks. As will be discussed in this presentation, biological computation is extensively based on heavy particles to represent and process information. Based on the biological computing analogy, future 'neuromorphic' computational architectures could be implemented by using nanoionic devices.

DS 24.2 Wed 10:00 CHE 89

BiFeO3 bilayer structures for implementing beyond von-Neumann computing — •Tiangui You[1], Yao Shuai[2], Wenbo Luo[2], Nan Du[1], Danilo Bürger[1], Ilona Skorupa[3], René Hübner[3], Stephan Henker[4], Christian Mayr[4], René Schüffny[4], Thomas Mikolajick[5], Oliver G. Schmidt[1,6], and Heidemarie Schmidt[1] — [1]TU Chemnitz, Chemnitz — [2]UESTC, Chengdu, China — [3]HZDR, Dresden — [4]TU Dresden, Dresden — [5]NaMLab gGmbH, Dresden — [6]IFW Dresden, Dresden

The conventional von-Neumann architecture, which physically separates processing and memory operations, is limited in so much as the processor cannot execute a program faster than instructions and data can be fetched from and returned to memory[1]. Resistive switching devices[2] are considered as one of the most promising candidates for carrying out the processing and storage simultaneously and at the same device cell. In this work, we present a BiFeO3:Ti/BiFeO3 bilayer structure which shows stable and nonvolatile resistive switching behaviour under both positive and negative bias. With the same writing bias, the bilayer structure shows different resistance state for the different polarity of reading bias. The resistance states are distinguishable and stable enough for the practical applications. For the logic applications, the polarity of reading bias can be used as an additional logic variable, which makes it feasible to program and store all 16 Boolean logic functions simultaneously and into a same single bilayer structure cell in three logic cycles. [1] C. D. Wright, et al., Adv. Funct. Mater., 2013, 23, 2248 [2] A. Bogusz, T. You, et al., accepted in Proc. IEEE (2013)

DS 24.3 Wed 10:15 CHE 89

Application of the metal-to-insulator transition in VO_2 for neuromorphic circuits — •Marina Ignatov, Martin Ziegler, Mirko Hansen, Adrian Petraru, and Hermann Kohlstedt — Nanoelektronik, Technische Fakultät, Christian-Albrechts-Universität zu Kiel, Germany

The negative differential resistance of two-terminal vanadium dioxide (VO_2) devices are investigated for possible applications in neuromorphic circuit architectures. VO_2 was deposited by Pulse Laser Deposition on TiO_2 and Al_2O_3 single crystal substrates. The VO_2 film thickness ranged between 50 nm to 100 nm. Lateral electrodes with a seperation-width ranging from 1 μm to 4 μm were patterned by optical lithography. The observed negative differential resistance is a result of the reversible insulator to metal phase transition in vanadium dioxide due to local Joule heating. In particular, structural and electrical characteristics of different VO_2 devices are discussed in detail. Further, by adding a capacitor in parallel to those devices electrical oscillations at room-temperature were obtained, which enable the emulation of the all-or-nothing spiking behavior of neurons.

DS 24.4 Wed 10:30 CHE 89

High On/Off ratio in ReRAM cells from $TiN/TiO_x/Al_2O_3/Pt$ by atomic layer deposition — •Hehe Zhang, Nabeel Aslam, Rainer Waser, and Susanne Hoffmann-Eifert — Forschungszentrum Juelich, PGI-7 und JARA-FIT, 52425 Juelich, Germany

The bilayer of TiO_x/Al_2O_3 was integrated into micro-cross point TiN/bilayer/Pt devices and investigated for resistive switching memory application. Liquid injection Atomic Layer Deposition (ALD) was used for the deposition of Al_2O_3 and TiO_x in this work. Amorphous Al_2O_3 films with thickness in the nano meter range were prepared using DMAI[$(CH_3)_2AlOCH(CH_3)_2$] and water as oxide source. Al_2O_3 thin films grown on Pt/Si substrates under optimized parameters have sharp interface, low roughness, low impurity level and high insulating properties. Integrated into the $TiN/TiO_x/Al_2O_3/Pt$ micro-cross point structures, the insulting behaviour of Al_2O_3 improved the resistive switching behaviour of the cells. The variation of TiO_x thickness has a significant effect on the R_{off}/R_{on} ratio during switching, whereas the change of Al_2O_3 thickness mainly affects the forming and reset voltage. Bilayer-cells with about 3 to 4 nm Al_2O_3 and 5 to 10 nm TiO_x exhibited a stable bipolar type resistive switching behaviour with resistance ratios of about 10^4 to 10^5.

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DS 24.5 Wed 10:45 CHE 89

Higher harmonics generation using Au/BiFeO3/Pt metal-insulator-metal (MIM) structure — •N. Du[1], N. Manjunath[1], T. You[1], Y. Shuai[2], W. Luo[2], D. Bürger[1,3], I. Skorupa[3], R. Schüffny[4], C. Mayr[5], M. Di Ventra[6], O. Schmidt[1,7], and H. Schmidt[1,3] — [1]Faculty of Electrical Engineering and Information Technology, TU Chemnitz — [2]State Key Laboratory of Electronic Thin Films and Integrated Devices, UESTC — [3]Institute of Ion Beam Physics and Materials Research, HZDR — [4]Department of Electrical Engineering and Information Technology, TU Dresden — [5]Computational Systems Biology Group, ETH Zürich — [6]Department of Physics, University of California — [7]Institute for Integrative Nanosciences, IFW Dresden

Memristive systems can be used for the generation of higher harmonics [1]. We investigated the second and higher harmonics generation by means of a passive circuit with a sinusoidal input voltage source in series with a load resistor and a single memristor (Au/BiFeO3/Pt) that exhibits nonvolatile bipolar resistive switching. We found that a single memristor in high resistance state and in low resistance state can be used to generate two clearly distinguishable sets of second and higher harmonics. The power conversion efficiencies (PCEs) for higher harmonics generation can be derived from the normalized charge-flux curves of the single memristor [2]. The PCEs can be possibly used in neuromorphic computing. [1] G.Z. Cohen et al., Appl. Phys. Lett. 100, 133109 (2012) [2] N. Du et al., Rev. Sci. Instrum. 84, 023903 (2013)