DS 32: Focus session: Resistive Switching by Redox and Phase Change Phenomena III (Defect and material engineering in oxides)

Time: Wednesday 15:00–16:30 Location: CHE 89

DS 32.1 Wed 15:00 CHE 89

Towards selective ion beam modification of vanadium dioxide — •Jura Rensberg, Ronny Nawrodt, Sebastian Vatterodt, Jana Sommerfeld, Alexander von Müller, and Carsten Ronning — Institut of Solid State Physics, Friedrich Schiller University Jena, Germany

Vanadium dioxide VO_2 undergoes a metal-insulator transition (MIT) at a critical temperature of about 68°C. The MIT induces significant changes in electrical, optical and structural properties making VO_2 thin films promising for integrated devices as switches, sensors, and memories. The critical temperature can be decreased by doping with electron donors like tungsten. However, doping of VO_2 thin films during growth is limited to vertical incorporation of dopant profiles. In contrast, ion beam doping allows also for lateral doping using suitable masking technique. Furthermore, the dopant concentration and implantation depth can be well controlled. The major disadvantage of doping by ion implantation is the creation of irradiation damage, making in-situ or post implantation annealing necessary. Here we report on noble gas ion irradiation of VO_2 thin films. Damage formation was studied using Rutherford backscattering spectrometry. Electrical and optical measurements were performed in order to investigate the change of MIT properties. It was found that damage formation leads to a degradation of MIT properties. Irradiation at higher temperatures utilizing dynamic annealing is not applicable due to oxygen outdiffusion in high-vacuum. Furthermore, post implantation annealing studies will be discussed in this contribution.

DS 32.2 Wed 15:15 CHE 89

Towards forming free switching in HfO_{2-x}/TiN thin films grown by molecular beam epitaxy — •S Ulhas Sharath[1], Thomas Bertaud[2], Jose Kurian[1], Erwin Hildebrandt[1], Christian Walczyk[2], Pauline Calka[2], Peter Zaumseil[2], Malgorzata Sowinska[2], Damian Walczyk[2], Andrei Gloskovskii[3], Thomas Schroeder[2], and Lambert Alff[1] — [1]Materialwissenschaft, Technische Univerität, Darmstadt — [2]IHP, Frankfurt/Oder, Germany — [3]Deutsches Elektronen-Synchroton DESY, Hamburg, Germany

Oxygen deficient thin films of hafnium dioxide (HfO_2) were grown using reactive molecular beam epitaxy on epitaxial and polycrystalline titanium nitride films with varying thicknesses and deposition temperatures. The oxygen content was engineered by controlled oxidation using RF-activated oxygen during growth [1]. The crystallinity of the films was studied using X-ray diffraction. Under oxygen deficient conditions, a mixture of monoclinic and tetragonal or cubic phases of HfO_2 was stabilized whereas close to stoichiometric films were purely monoclinic. The films were further probed using hard X-ray photoelectron spectroscopy (HAXPES) confirming the presence of sub-stoichiometric hafnium oxide and defect states near the Fermi level. Resistive switching in Pt/HfO_{2-x}/TiN stack devices was then studied for different electrode size, thickness and crystallinity of the HfO_2 thin films. Oxygen deficient hafnium oxide thin films show bipolar switching with an electroforming step occurring at voltages less than 2V and slightly higher than the set voltage. [1] E. Hildebrandt et al., Appl. Phys. Lett. 99, 112902 (2011).

DS 32.3 Wed 15:30 CHE 89

Defects behavior in HfO_2-based resistive switching devices — •Małgorzata Sowińska[1], Thomas Bertaud[1], Damian Walczyk[1], Andrei Gloskovskii[2], Pauline Calka[1], Lambert Alff[3], Christian Walczyk[1], and Thomas Schroeder[1,4] — [1]IHP, Im Technologiepark 25, 15236 Frankfurt (Oder), Germany — [2]P09 beamline at Petra III (DESY), Notkestrasse 85, 22607 Hamburg, Germany — [3]Institute of Materials Science, Technische Universität Darmstadt, Alarich-Weiss-Str. 2, 64287 Darmstadt, Germany — [4]Brandenburgische Technische Universität, Konrad-Zuse-Strasse 1, 03046 Cottbus, Germany

In-operando hard X-ray photoelectron spectroscopy (HAXPES)[1,2] is applied to non-destructively study the influence of current compliance and switching cycles on the Ti/HfO_2 interface chemistry and physics of resistive switching Ti/HfO_2/TiN cells. The HAXPES studies confirm theoretical results that current compliance is a crucial parameter to create a critical amount of oxygen vacancies in order to achieve stable resistive switching. Furthermore, HAXPES clearly detects an interface segregation of carbon impurities from the HfO_2 film towards the Ti/HfO_2 interface under electrical stress by current compliance and over the cycling. As carbon impurities may thus alter the oxygen vacancy defect balance in the HfO_2 film during resistive switching, materials engineering approaches need to include all major impurities in the dielectric to achieve reproducible and reliable resistive random access memory performance.

[1] M. Sowinska et al., Appl. Phys. Lett. 100, 233509 (2012).
[2] T. Bertaud et al., Appl. Phys. Lett. 101,143501 (2012).

DS 32.4 Wed 15:45 CHE 89

Oxygen engineered HfO_{2-x} as a CMOS compatible candidate for resistive switching — •Erwin Hildebrandt[1], S. U. Sharath[1], Jose Kurian[1], Mathis M. Mueller[1], Thomas Schroeder[2], Hans-Joachim Kleebe[1], and Lambert Alff[1] — [1]Institute of Material Science, Technische Universität Darmstadt, Alarich-Weiss-Straße 2, 64287 Darmstadt, Germany — [2]IHP, Im Technologiepark 25, 15236 Frankfurt (Oder), Germany

Reactive molecular beam epitaxy has been applied to grow stoichiometric and oxygen deficient thin films of hafnium oxide. Films as thin as 10 nm were grown epitaxially on *c*-cut sapphire, proven by grazing incidence in-plane X-ray studies and high resolution transmission electron microscopy. As a function of oxygen vacancy concentration, the optical band gap varies by more than 1 eV and a sharp metal-insulator transition occurs. Hall-effect measurements indicate *p*-type conductivity with a mobility of 2 $cm^2/(Vs)$ for highly deficient thin films [1, 2]. The high oxygen vacancy concentrations - which are formed and stabilized *in situ* during the RMBE deposition process - lead to intrinsic resistivities as low as 300 $\mu\Omega$cm. We propose oxygen deficient hafnia thin films driven to the vicinity of the metal-insulator transition as a promising candidate for the functional layer of potentially forming-free and CMOS compatible resistive RAM devices.

[1] E. Hildebrandt, J. Kurian, M. M. Müller, T. Schroeder, H.-J. Kleebe, and L. Alff, Appl. Phys. Lett. **99**, 112902 (2011)
[2] E. Hildebrandt, J. Kurian, and L. Alff, J. Appl. Phys. **112**, 114112 (2012)

DS 32.5 Wed 16:00 CHE 89

Resistive switching of flash lamp crystallized $YMnO_3$ thin films prepared on Pt/Ti/SiO_2/Si substrates by low-temperature pulsed laser deposition — •Agnieszka Bogusz[1,2], Sławomir Prucnal[1], Wolfgang Skorupa[1], Daniel Blaschke[1], Barbara Abendroth[3], Hartmut Stöcker[3], Ilona Skorupa[1], Danilo Bürger[2], Oliver G. Schmidt[2,4], and Heidemarie Schmidt[2] — [1]Institute of Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf — [2]Material Systems for Nanoelectronics, Chemnitz University of Technology — [3]Institute of Experimental Physics, TU Bergakademie Freiberg — [4]Institute for Integrative Nanosciences, IFW Dresden

Use of multiferroic oxides as a switching medium presents an opportunity to add the additional or novel functionalities into the switching device. Typically, the growth temperatures of such oxides are above 600 °C and so far CMOS compatibility has not been achieved. $YMnO_3$ exhibits unipolar resistive switching [1] however its high crystallization temperature (above 750°C) imposes difficulties in preparation of thin films on metal-coated substrates. This work presents the results of electrical and structural characterization of $YMnO_3$ thin films grown on Pt/Ti/SiO_2/Si substrates by pulsed laser deposition at 400 °C and crystallized by flash lamp annealing (FLA). It is shown that the FLA process with optimized parameters allows the preparation of polycrystalline $YMnO_3$ films without deformation of the Pt/Ti electrode and interdiffusion processes in the $YMnO_3$/Pt/Ti/SiO_2 stack.

[1] A. Bogusz et al., IEEE Xplore (2013), DOI:10.1109/ISCDG.2013.656319

DS 32.6 Wed 16:15 CHE 89

Resistive Switching in TiO_2: Comparison of thermally oxidized and magnetron sputtered films — •Daniel Blaschke[1,2], Steffen Cornelius[1], Peter Zahn[1], Sibylle Gemming[1,2], Ilona Skorupa[1], Bernd Scheumann[1], Andrea Scholz[1], and Kay Potzger[1] — [1]Institute of Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf, Germany — [2]Chair of Scalebridging Materials Modeling, Physics Department, Chemnitz University of Technology, Germany

Resistive RAM devices based on TiO_2 are promising candidates for the next generation memory storage devices. We compared TiO_2 thin films from two different preparation methods with respect to crystallinity and resistive switching behavior. While thermal oxidation of 100nm Ti on Pt/Ti/SiO_2/Si substrates leads to polycrystalline rutile TiO_2 layers, dc-magnetron sputter deposition of films on Nb:STO substrates leads to epitaxial anatase TiO_2 structure. In case of the rutile films, unipolar switching occurred, which points to a filamentary mechanism based on the formation of Magnéli phases [1]. The epitaxial anatase films, however, showed bipolar switching, which we correlated with the modification of the metal/oxide interface due to the drift of oxygen vacancies in the applied electric field [2].

The project is funded by the Initiative and Networking Fund of the Helmholtz Association (VI MEMRIOX, VH-VI-422).

[1] Deok-Hwang Kwon et al., Nature Nanotechnology 5, 148 - 153 (2010)

[2] J. Joshua Yang et al., Nature Nanotechnology 3, 429 - 433 (2008)