DS 22: High-k Dielectric Materials - Synthesis, Properties, Applications

Time: Wednesday 16:45–18:30 Location: H 2032

Invited Talk DS 22.1 Wed 16:45 H 2032

Development of novel processes for atomic layer deposition of high-k dielectrics — •Jaakko Niinistö, Kaupo Kukli, Mikko Ritala, and Markku Leskelä — Laboratory of Inorganic Chemistry, Department of Chemistry, P.O. Box 55, FI-00014 University of Helsinki, Finland

Atomic layer deposition (ALD) has gained considerable interest in the recent years as a thin film deposition method to overcome many technological problems faced by the semiconductor industry. Deposition of high-k materials for CMOS and DRAM applications are the main application areas for ALD.

The success of ALD is built on chemistry. The unique characteristics of ALD can be achieved and benefited only with precursors that provide the self-limiting film growth through the saturative surface reactions. For high-k materials the leading solutions include the oxides of Hf and Zr. For ALD of these materials, alkylamides have gained wide interest as precursors. However, thermal decomposition of the alkylamides at rather low temperatures prevent the ALD-type growth mode. The need for process development and existing ALD processes of ZrO2 and HfO2 with recent advancements are discussed.

In this presentation, recent research with cyclopentadienyl-precursors, which offer high thermal stability, is reviewed. In addition, we introduce mixed alkylamido-cyclopentadienyl precursors of Zr and Hf. With ozone as the oxygen source, the process yields ZrO2 films with high permittivity cubic phase and low leakage current density. Finally, results of doping the ZrO2 and HfO2 films are presented.

Invited Talk DS 22.2 Wed 17:15 H 2032

Towards a better understanding of the dielectric collapse in high-K BST thin film capacitors — •Regina Dittmann[1], Rafael Plonka[2], Nikolay Pertsev[3], Susanne Hoffmann-Eifert[1], and Rainer Waser[1,2] — [1]Institut für Festkörperforschung, Forschungszentrum Jülich, 52425 Jülich — [2]Institut für Werkstoffe der Elektrotechnik, RWTH Aachen, 52056 Aachen — [3]A. F. Ioffe Physico-Technical Institute, 194021 St. Petersburg, Russia

According to permittivities in the order of 10.000 observed in bulk ceramic samples, the perovskite material BaxSr1-xTiO3 (BST) is a promising candidate for future DRAM storage capacitors. A considerable drawback is that in polycrystalline thin films, the permittivity collapses to values in the order of 100 and decreases strongly with decreasing thickness. We addressed the influence of defects, substrates-imposed strain and the electrode interfaces on the dielectric collapse by investigating fully epitaxial SrRuO3/BST/SrRuO3 thin film capacitors. High resolution transmission electron microscope investigations prove the SrRuO3-BST interfaces to be atomically sharp and free of any defective "dead-layers". These capacitors exhibit bulk-like permittivity in the order 4000 and their thickness dependence can be well described by an extended Ginzburg-Landau-Devonshire model by taking into account plastic strain relaxation in BST thin films and finite screening of depolarizing fields by the SrRuO3 electrodes. We will compare the data to thin film capacitors with noble metal electrodes and discuss which type of interface is superior in terms of its screening ability.

DS 22.3 Wed 17:45 H 2032

From hexagonal Pr2O3 films to lattice matched twin-free PrO2/Si(111) with cubic structure — Thomas Weisemoeller, Andreas Greuling, Sebastian Gevers, Carsten Deiter, and •Joachim Wollschläger — Fachbereich Physik, Universität Osnabrück, Barbarastr. 7, 49069 Osnabrück, Germany

Praseodymiumoxide is a well suited material for epitaxial high-k films on Si due to both its high dielectric constant (k=25-30). Oxide films deposited by molecular beam epitaxy (MBE) on Si(111) have Pr2O3 stoichiometry with metastable hexagonal structure[1]. It is well known that these films can be transformed into a (less lattice matched) cubic phase by annealing at low oxygen pressure [2]. Here we present experiments performed after annealing Pr2O3 films with hexagonal structure at high oxygen pressure. The crystal structure of these films has been investigated by synchrotron based x-ray diffraction (XRD) including grazing incidence (GIXRD). The oxide films have fluorite structure which points to the formation of PrO2 with cubic structure which matches the Si lattice in all directions. The PrO2 films are exclusively B-oriented so that no twins are formed. The structure of both the oxide films and the interface has been investigated by crystal truncation rod (CTR) analysis. Depending on the preparation the oxides films show some oxygen deficiency. In addition, silicate layers are formed at the interface as verified by both XRD and x-ray reflectometry (XRR).

[1] E.J. Tarsa et al., Appl. Phys. Lett. 63 (1993) 539.
[2] T. Schroeder et al., J. Appl. Phys. 99 (2006) 014101.

DS 22.4 Wed 18:00 H 2032

Structural, chemical and electrical characterization of HfNO-HfTiO high-k dielectric stack — Visorian Mikhelashvili[1], Gadi Eisenstein[1], Thangadurai Paramasivam[2], and •Wayne Kaplan[2] — [1]Electrical Engineering Dept. Technion — [2]Material Engineering Dept.Technion

We study the influence of annealing temperature on structural, compositional and electrical characteristics of a MOS structure with a high-k dielectric based on a 5 nm HfNO-HfTiO nanolaminate stack. A common feature of all samples independent on annealing temperature is the observation of two distinct ˜2-2.5 and 2.3-2.5 nm thick layers, respectively for transition (close to Si substrate) and top layers. The transition layer is amorphous, while in the top layer some crystalline inclusions embedded into the amorphous matrix are observed. EDS line-scans and XPS analysis showed that the transition layer is similar to metal-Si-O-N or metal-Si-O. The minimum values of quantum mechanical corrected Effective Oxide Thickness close to 1.29 and 0.86 nm, respectively for structures with Au and Cr electrodes. A large reduction of leakage current density to 1.5X10-8 and 2.9X10-7 A/cm2, respectively for Au and Cr gate electrodes at an electric fields of 2 MV/cm was observed with annealing temperature and breakdown electric filed as high as ˜10-12 MV/cm, was measured independently of the electrodes type.

DS 22.5 Wed 18:15 H 2032

Photoemission and absorption spectroscopy for in situ investigations of the ALD growth — •Massimo Tallarida[1], Konstantin Karavaev[1], Dieter Schmeisser[1], and Ehrenfried Zschech[2] — [1]Brandenburgische Technische Universität Cottbus, Konrad-Wachsmann-Allee 17, 03046 Cottbus, Germany — [2]AMD Saxony LLC & Co. KG, Center for Complex Analysis, Wilschdorfer Landstr. 101, D-01109 Dresden, Germany

We have investigated the growth of Hf-oxide on Si by means of photoemission and X-ray absorption spectroscopy using synchrotron radiation at Bessy, Berlin. The Hf-oxide layers were grown via atomic layer deposition (ALD) using an in-situ ALD reactor attached to the investigation chamber. The XPS and XAS spectra were measured after every deposition cycle by transferring the sample into the investigation chamber without breaking the vacuum. From the experimental data we have obtained information about the early stages of the Hf-oxide growth, concerning in particular the reactivity of the interface with Si. Due to the possibility to study the layers after every cycle and with different oxidation parameters without exposing them to contaminants, the in situ investigation revealed to be a very important method to understand the growth properties of Hf-oxide.