DF 12: Dielectric and ferroelectric thin films and nanostructures II

Time: Thursday 10:00–13:00 Location: EB 107

Invited Talk DF 12.1 Thu 10:00 EB 107

Piezoelectric ceramic materials - a success story — •Dieter Sporn[1], Andreas Schönecker[2], Bernhard Brunner[1], and Horst Beige[3] — [1]Fraunhofer-Institut fuer Silicatforschung, Neunerplatz 2, 97082 Wuerzburg — [2]Fraunhofer-Institut fuer Keramische Technologie und Systeme, Winterbergstrasse 28, 01277 Dresden — [3]Martin-Luther-Universität Halle-Wittenberg, Institut fuer Physik, Friedemann-Bach-Platz 6, 06108 Halle

The development of piezoelectric ceramic materials in the last decade offered a huge number of new applications. This can be shown by market numbers: the world wide market volume doubled from 2001 to 2006! This was driven by growing demands concerning of precise controls of structures and components, monitoring and adaptive systems, control of ignition points in engines, etc.

The success of the piezoelectric ceramics is based by tremendous efforts in material design, new compositions and new shaping opportunities. Beside commonly used buld materials it is evident, that piezoelectric films and fibers opened new applications. The development and the understandig of such structures is based on close cooperations between chemists, material scientists, physicists and engineers. One of the recently important issues is the search of new, lead-free compositions with properties similar to them of so far used lead-containing compositions.

In this contribution the efforts of the last years will be demonstrated on the hand of selected isssues (piezoelectric films, piezoelectric fibers and new compositions).

DF 12.2 Thu 10:40 EB 107

Thickness dependence of leakage current through capacitor stacks with high-k materials for DRAM application — •Herbert Schroeder — IEM im Institut für Festkörperforschung und CNI, Forschungszentrum Jülich GmbH, D-52425 Jülich

According to the International Technology Roadmap for Semiconductors (ITRS) the implementation of high-permittivity thin insulating films as dielectrics in capacitors (charge-based memory) and gates (MOSFET) is indispensable within the near future to achieve the documented goals. One of the most important issues for these applications is the sufficiently low leakage current through the metal/insulator/metal (MIM) capacitor stacks. A large number of experimental data on leakage current through MIM thin film capacitor structures is published for high-k perowskite-type mixed oxides, especially for the model alloys $SrTiO_3$ (STO) and $(Ba,Sr)TiO_3$ (BST). The mechanistic interpretation of these data is rather contradictory and therefore unsatisfactory. This especially holds for the current dependence on dielectric thickness, for which very different and opposite trends have been observed. This contribution reports simulation results of leakage curves within a new model combining current injection/ejection at the interfaces with drift-diffusion current in the film bulk with special emphasis on dielectric thickness. The main result is that the used model is able to describe all kinds of thickness dependencies as the current is dependent on the defect properties in the dielectric, i.e. type (donor and/or acceptor), densities, energy level in the gap, and type and degree of compensation (ionic, electronic), as well as electrode/interface properties.

DF 12.3 Thu 11:00 EB 107

Leakage spot evolution in thin $(ZrO_2)_{0.8}(Al_2O_3)_{0.2}$ -films observed by conductive atomic force microscopy (CAFM) — •Dominik Martin[1], Oliver Bierwagen[2], Matthias Grube[1], Lutz Geelhaar[2], and Henning Riechert[2] — [1]namlab gGmbh, D-01187 Dresden — [2]Qimonda, D-81730 Munich

A change from amorphous to nanocrystalline dielectric layers is necessary to achieve dielectric constants >30 as required for future technology nodes. This often leads to significantly higher leakage currents. These were measured in such inhomogeneous samples with a spatial resolution on the nanoscale. CAFM was used to characterize 20 nm-thin $(ZrO_2)_{0.8}(Al_2O_3)_{0.2}$ -films grown by molecular beam deposition. In nanocrystalline samples, there are hillocks at the surface with typical diameters and heights of 30 nm and 3 nm, respectively. An investigation by transmission electron microscopy implies that these hillocks are crystallites that protrude from the surface. CAFM current maps show leakage spots in which the current is significantly higher than in the surrounding matrix. These leakage spots are strongly correlated with the hillocks on the corresponding morphology images, indicating that the formation of crystallites really leads to leakage paths. To distinguish between different transport mechanisms, multiple images of the same area were taken, while the bias-voltage was changed consecutively. By using the entire set of images, IV-curves can be assigned to each location. These show a hysteretic behaviour for all leakage spots. Also, the voltage at which the strong increase in current occurs varies significantly for different leakage spots, i.e. between -1 V and -4 V.

DF 12.4 Thu 11:20 EB 107

The influence of image potential on defect assisted leakage mechanisms — •Grzegorz Kozlowski and Jarek Dabrowski — IHP, Im Technologiepark 25, 15236 Frankfurt (Oder), Germany

We present the results of numerical simulation of tunneling current through a dielectric film. A carrier inside a dielectric film between metallic plates encounters an additional potential resulting from the interaction with its electrical image in the metal. As a result not only the height of barrier is lowered and the bands are bent downwards in vicinity of the metal electrodes, but also the tunneling length is shortened. Besides causing the well-known Schottky effect, this increases the tunneling leakage. Maybe more interestingly, also leakage due to the presence of defects is affected. This is because carriers must be supplied from the electrode to the defect states. Without the image force, in many cases this supply process limits the current that may flow through defects. This limitation may be partially or completely lifted when the image force is taken into account. The image potential lowers both the energy of defect states in vicinity of the electrode and the energy barrier separating these defects from the electrode. We investigate the influence of this effect on the magnitude of leakage current for various leakage mechanisms including trap assisted tunneling and Poole-Frenkel conduction.

DF 12.5 Thu 11:40 EB 107

The mechanisms of leakage current in $BaHfO_3$ films — •Grzegorz Kozlowski, Jarek Dabrowski, Grzegorz Lupina, Gunther Lippert, Piotr Dudek, and Hans-Joachim Müssig — IHP, Im Technologiepark 25, 15236 Frankfurt (Oder), Germany

We present the results of theoretical and experimental study of leakage currents through ultrathin dielectric $BaHfO_3$ films in MIM (Metal-Insulator-Metal) capacitor structures. Ab initio calculations have been performed for defects and impurities, and standard electrical measurements have been done in order to reveal the physical processes governing the transport of charge carriers across the film. The dominating leakage mechanism clearly depends on temperature, voltage, and film thickness. Statistical analysis of leakage currents provides further information on the character of the responsible defects, e.g., allowing us to attribute the leakage at given conditions to microscopic or macroscopic defects. We confront the results of this experimental data analysis with the ab initio data and we discuss the implications on the film deposition and processing.

DF 12.6 Thu 12:00 EB 107

On the electronic and dielectric characterisation of thin cubic PrO_2 layers on Silicon — •Olaf Seifarth[1], Christian Walczyk[1], Grzegorz Lupina[1], Jaroslaw Dabrowski[1], Günter Weidner[1], Peter Zaumseil[1], Dieter Schmeisser[2], Peter Storck[3], Hans-Joachim Müssig[1], and Thomas Schroeder[1] — [1]IHP microelectronics, 15236 Frankfurt (Oder), Germany — [2]Brandenburg Technical University, 03046 Cottbus, Germany — [3]Siltronic AG, 81737 München, Germany

For the integration of 100 % Ge onto the Si platform, a buffer oxide approach has been developed recently, using rare earth oxides to tune the lattice constant between the Si and the Ge. Among these buffer oxides, PrO_2 is a prospective candidate with high quality crystalline growth on Si, moderated by an interfacial Pr-silicate between. In order to specify electronic properties of thin PrO_2 and its interface on Si(111), especially the width of the band gap, we performed synchrotron radiation based XPS, UPS and XAS measurements at the U49/2 PGM 2 beamline at BESSY II and correlate the results with our structural characterisation performed by TEM and XRD. In order to evaluate the dielectric properties of thin PrO_2 layers on Si(111), we performed

temperature-, time-, voltage-, and layer thickness-dependent leakage current measurements (J-V). Here, we identified relaxation behaviour in the leakage current, successfully addressed to defect like states inside the Pr-silicate interface layer, corroborated by frequency dependent capacitance versus voltage (C-V) measurements.

DF 12.7 Thu 12:20 EB 107

Transition metal oxide based NVM for IHPs 0.13 micron BiCMOS technology — •Rakesh Sohal, Christian Walczyk, Ioan Costina, Peter Zauseil, Alexander Fox, and Thomas Schroeder — IHP Microelectronics, Im Technologiepark 25, 15236 Frankfurt (Oder), Germany

This Research is targeted to increase the functionality of IHP's 0.13 micron BiCMOS technology by integrating innovative embedded NVM cell concepts. The material of our interest is the tungsten oxide as insulator in metal-insulator-metal (MIM) structure to develop so called back-end-of-line (BEOL) integrated OxRAM cells. In this study, we report on the investigation of the tungsten oxidation process under BEOL constraints (<450°C) by using XPS, XRD, XRR and SEM.

The CVD prepared tungsten layers on TiN covered silicon wafers are thermally oxidised in oxygen environment (with 200 sccm O2 flow rate) in the temperature range of 300-450°C for 15-75 minutes. The tungsten oxide layer thickness estimated by XRR was in the range of 6 nm to 80 nm. The tungsten oxide was in WO3 stoichiometry as confirmed by XPS. The tungsten oxide prepared at higher temperatures (>350°C) show a small shoulder at lower binding energy which corresponds to tungsten sub-oxides. The tungsten oxide starts to crystallise in monoclinic phase at 350°C when it is oxidised for 30 minutes. A (001) oriented growth texture becomes dominant at higher temperatures (>400°C). The tungsten oxide surface was uniform for the layers prepared below 400°C. The tungsten oxide layers were also characterised by analysing the dielectric behaviour (i.e. leakage current).

DF 12.8 Thu 12:40 EB 107

Space charge polarization in solid electrolytes — •Björn Martin and Herbert Kliem — Saarland University, Germany

Thin films of polyethylene oxide are investigated as model systems for a solid electrolyte. Plane parallel capacitance structures of these samples show a pronounced relaxational behaviour with a thickness dependent effective dielectric constant in the low frequency range. This behaviour is attributed to a space charge polarization of mobile ions in the material.

With a three-dimensional discrete hopping model, it is possible to describe the dielectric properties of the systems. Here, mobile charges can fluctuate thermally activated over barriers in a multiwell energy structure. If all interactions in the system, especially the attracting interactions between the ions and their image charges in the electrodes, are considered, it can be shown that electrode effects play an important role. Thus, these effects are responsible for a Kohlrausch behavior of the polarization current in the long time range as well as for an increased accumulation of charges at the electrodes.

The space charge distribution, predicted by simulations of the model system, is determined by measurements of the surface potential with a scanning Kelvin probe contactless [1]. Due to the motion of negative mobile ions after application of an electric field a positive space charge region is found near the negative electrode resulting in a strongly nonlinear surface potential. Additionally a charge injection process is observed.

[1] B. Martin, H. Kliem, acc. by IEEE Trans. Dielectr. Electr. Insul.