**SYMPOSIUM H**

**H: Materials Science of High-k Dielectric Stack---From Fundamentals to Technology**

March 24 - 27, 2008

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* Invited paper

**TUTORIAL**

**H: High-k and Device Fabrication Properties on Ge and III-V Substrates**

Monday March 24, 2008  
1:00 PM - 5:00 PM  
Room 2008 (Moscone West)

High-k materials on substrate materials other than Si (GaAs, InGaAs, Ge, etc.) are actively researched around the world for continuing the CMOS performance increase and scaling. This is witnessed by the increasing level of research contributions and activities in recent years. Most of the activities so far have focused general material and interfaces optimization, while the integration and device performance part has been rather limited. The purpose of this tutorial is to bridge this gap. The tutorial will begin with a general overview
segregation of Al atoms towards the interface. Importantly, in all cases Al-vacancy complexes at the interface significantly change the band alignment, reducing the valence band offset (or increasing the EWF). Thus, doping the SiO2/HfO2 gate stack with Al atoms offers a consistent way to adjust the alignment. This increase of the EWF can be explained with our previously introduced model that suggests that an oxygen depleted interface provides less effective screening, which in turn increases the interface dipole.

H4.16
Pre-ALD Surface Cleaning and Passivation of (100) InGaAs and Al2O3 Gate Insulator Deposition. Byungha Shin1, Donghun Choi2, James S. Harris2 and Paul C. McIntyre1; 1Materials Science and Engineering, Stanford University, Stanford, California; 2Electrical Engineering, Stanford University, Stanford, California.

Despite extensive efforts in the past to produce high-quality III-V based MOS devices, substantial improvements in device performance are required, mainly due to the poor quality of the interface formed between thermally-grown or deposited gate dielectric layers and the III-V channel surface. In this presentation, we report on a process for removal of native oxides on the III-V surface prior to atomic layer deposition of high k gate insulator. We have developed and tested the efficacy of a method that removes native oxides from the initially group III-rich (100) In0.2Ga0.8As surface and thus provides a clean starting surface for efficient atomic layer deposition of ultra-thin Al2O3 layers. Successive wet etching by aqueous HCl and NH4(OH) solutions and in situ pre-ALD thermal desorption of residual As at a moderate temperature is employed. ALD of Al2O3 with TMA and H2O precursors is carried out. XPS performed on ultra-thin ALD-Al2O3 on InGaAs prepared by this method reveals that the interface is free of In-, Ga-, and As-oxide.

MOS capacitors demonstrate satisfactory C-V and I-V characteristics without any thermal treatments. Annealing under various conditions results in alteration of oxygen and/or hydroxyl group contents in Al2O3 layer as revealed by XPS analysis, which is consistent with the shift of flat band voltage observed in C-V measurements. The effects of ALD growth temperature, the sequence of ALD precursors introduced (i.e., TMA first vs. H2O first), and different metal electrodes on the electrical properties of the resulting MOS capacitors will be discussed.

H4.17
Intense Photoluminescence from Amorphous Nitrogen-doped Zirconium Oxide Films. Anping Huang1,2, Zhisong Xiao3, Lei Wang4 and Paul K Chu1; 1Department of Physics, Beihang University, Beijing, China; 2Physics and Materials Science, City University of Hong Kong, Hong Kong, China.

Due to its high dielectric constant (14-28) and good dielectric breakdown strength, zirconium oxide (ZrO2) is a promising candidate material in many microelectronic devices such as the storage capacitor dielectric in high-density random access memories, decoupling capacitors in high performance electronic packing systems, and gate dielectric layer in future metal-oxide-semiconductor (MOS) devices to substitute for SiO2. In addition, ZrO2 has an optical and gap as large as 5.4 eV, which makes it an attractive material as optical coatings, piezoelectric films, and oxygen sensors. However, an important issue for high-k materials is the thermodynamic stability after high temperature post-deposition annealing. One common way to address this issue is to incorporate nitrogen into the high-k films. Previous approaches to improve the thermal stability include nitridating by post-annealing in NH3 or N2 after metal oxide formation or incorporating nitrogen during sputtering under a N2 flow. Unfortunately, existence of suboxides introduced by nitrogen doping tends to enhance oxygen deficiency in the films and increase the leakage currents thus deteriorating the dielectric properties of the films. On the other hand, the enhanced oxygen deficiency in the film may increase visible light emission, since the first and second ionization energies of the O-vacancy double donor are about 1.2 and 2.1-2.7 eV below the conduction band. It is thus of both theoretical and practical interest to investigate the photoluminescence (PL) behavior of nitrogen-doped zirconium oxide thin films. In this work, we report on the synthesis and room temperature visible PL characteristics of amorphous nitrogen-doped zirconium oxide films prepared by plasma nitridation in conjunction with cathodic arc deposition. The visible light emission can be attributed to ZrOx suboxides that enhance oxygen deficiency in the film. Our results reveal that incorporation of a small amount of nitrogen in ZrO2 enhances its visible photoluminescence significantly. Our study also suggests that plasma nitridation in conjunction with cathodic arc deposition is an effective method to dope ZrO2 with nitrogen and to improve the optical properties of the thin films. The underlying mechanism of intense photoluminescence is also discussed in this paper.

H4.18

For future Gigabit DRAM capacitor application, it is necessary to reduce capacitor cell area