Abstract No. Ulri0188

SXPS Studies of High-k Dielectrics for Si-FET Gate Oxide Applications

M. D. Ulrich (North Carolina State U.), J. G. Hong (North Carolina State U.), R. S. Johnson (North Carolina State U.), D. Kang (North Carolina State U.), D. Niu (North Carolina State U.), T. D. Abatemarco (North Carolina State U.), J. S. Quinton (Rutgers U.), J. E. Rowe (ARO), G. N. Parsons (North Carolina State U.), G. Lucovsky (North Carolina State U.), T. E. Madey (Rutgers U.)

Beamline(s): U4A

Introduction: The continued reduction of the size of microelectronic devices will shortly require the SiO_2 gate dielectric in field effect transistors (FETs) to be replaced with alternative high dielectric constant (high-k) materials. As scaling of these devices becomes smaller, FET performance and reliability depend less on the bulk properties of the dielectric and more on the chemical bonding environment in the locality of the Si-dielectric interface. An understanding of the properties of deposited gate-dielectric systems for Si-FET requires a qualitative and quantitative analysis of the Si-dielectric interfacial electronic structure. The soft x-ray photoelectron spectroscopy (SXPS) instrumentation of beamline U4A is used to examine the Si-dielectric interface of ultrathin films (< 30 Å).

Methods and Materials: Films of Al_2O_3, HfO_2, $(HfO_2)_x(SiO_2)_{1-x}$, Y2O3, ZrO_2 and $(ZrO_2)_x(SiO_2)_{1-x}$ were deposited by remote plasma enhanced chemical vapor deposition (RPECVD) on Si(111) and Si(100) substrates at North Carolina State University. Several HfO_2 films were also prepared by atomic layer deposition on SiO_2 and Si_3N_4.

Results: Figure 1 compares the Si $2p_{3/2}$ single-component spectra of HfO_2 and Al_2O_3 depositions on Si(111) with that of a SiO_2/Si(111) structure. The thickness of SiO_2 in each is about 11 Å. In the SiO_2/Si(111) structure, the three suboxide interface states, Si^{1+}, Si^{2+} and Si^{3+} are clearly distinguished. The Si^{4+} peak has a binding energy relative to the substrate peak of 3.88 eV. In all metal oxide samples, the Si $2p$ data reveals that SiO_2 has formed between the metal oxide and the substrate. This is consistent with other studies of Si-dielectric interfaces formed by RPECVD. Only the Si^{1+} suboxide interface state is clearly resolved. The other suboxide states are inferred based on the known SiO_2/Si(111) interface. The Si^{4+} peak of the HfO_2 sample and Al_2O_3 sample has a relative binding energy of 3.56 eV and 3.57 eV respectively, 0.3 eV lower than for the SiO_2/Si structure. Contributing to this shift are an increase in final-state core-hole screening due to the metal oxide covering the SiO_2 and a Si-O-metal bonding environment. Careful data analysis indicates that core-hole screening is the dominating effect.

Acknowledgments: This research was supported by ARO, NRC, ONR, AFOSR, SRC and the SEMATECH/SRC Front End Process Center.

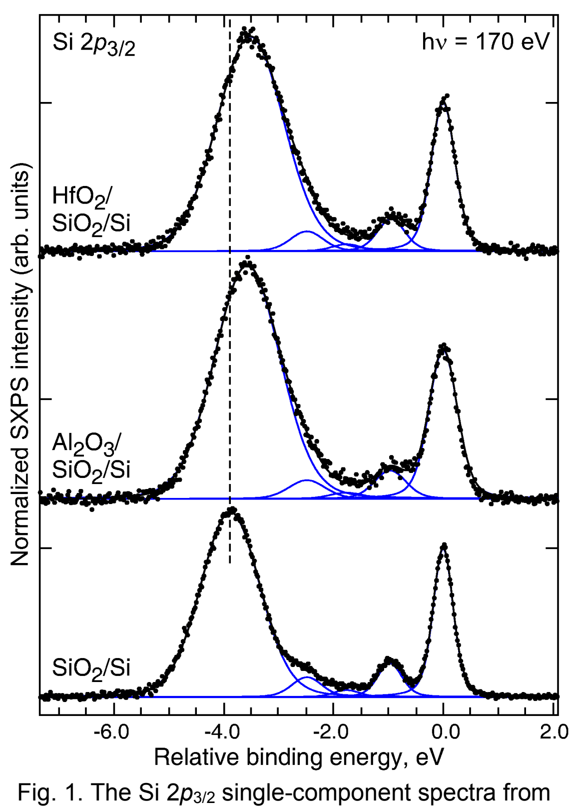

Fig. 1. The Si $2p_{3/2}$ single-component spectra from structures resulting from HfO2 and Al_2O_3 RPECVD compared with that of an SiO_2/Si(111) structure.