Multi-technique Approach for the Evaluation of the Crystal Phase of Ultrathin High-*k* Gate Oxide Films

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ABSTRACT

High-*k* HfO_2 based gate oxides have recently been put into production in CMOS based integrated circuits, and their use in future integrated circuits depends on how well they can continue to be downscaled. To this end, efforts to increase the dielectric constant (*k*) of HfO_2 based gate oxides have been ongoing..[1] Higher-*k* values (k>30) for HfO_2 occur for the metastable tetragonal/cubic crystal phases, while the thermodynamically preferred monoclinic phase has a lower *k* value (~20).[2] Recent work has shown that by tailoring annealing procedures the higher-k phase can be stabilized.[3] Much of this work, however, has been done on films that are significantly thicker than those used in devices (< 30 Å). In this regard, to evaluate the crystal structure of such thin HfO_2 films which have undergone various annealing treatments, we used a multitude of techniques including grazing incidence X-ray diffraction (GIXRD) in both in-plane and out of plane configurations, spectroscopic ellipsometry (SE), and UV photoelectron spectroscopy (UPS) measurements. SE has shown that the extinction coefficient of the HfO_2 film has a sub-band-gap feature that is associated with crystallinity.[4] UPS measurements of the valence band of HfO_2 have shown a characteristic two peak structure that is also associated with crystallinity.[5] We have analyzed the extinction coefficient and valence band spectra from SE and UPS measurements, respectively, and correlated them with the XRD measurements in an effort to find additional methods to distinguish the crystal phases of the HfO_2 films. **(Keywords: high-κ, higher-κ, crystal phase, grazing incidence X-ray diffraction, spectroscopic ellipsometry, UV photoemission spectroscopy)**

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