Atomic Layer Deposition of Novel Multifunctional Nanostructures

A major challenge facing the silicon micro- and nano-electronics industry is the requirement to replace the SiO$_2$ gate of transistors with high dielectric constant (k) nanostructures in future processes. The use of high-k materials is essential to reduce overall power dissipation and leakage currents in future devices. The current lack of understanding of process – structure – functionality relationships of high-k/semiconductor nanostructures and interfaces during and after deposition as well as during post-deposition thermal treatments are primary obstacles to the successful incorporation of high-k nanostructured materials into mainstream micro- and nano-electronic processes.[1-4]

The proposed project will focus on atomic layer deposition (ALD) of HfTiO$_x$ using tetrakis-diethylamino hafnium and tetrakis-diethylamino titanium as metal precursors and ozone and water as oxidizers. ALD temperature windows of these two precursors are found to overlap between 200 and 300 °C which is critical for ALD of composite HfTiO$_x$ films. The film composition will be studied with the number of cycles of alternating titania and hafnia. Structure - properties relationships of the resulting HfTiO$_x$ films will also be studied.

We will also investigate the effectiveness of atomic layer deposited (ALD) aluminum oxide barrier layer in controlling the interfacial reaction between ALD HfO$_2$ film and Si substrate.[5] The HfO$_2$ is observed to form silicate and silicide at its interface with Si during 5 min post deposition annealing in Ar at 800 and 1000 °C. Variable thickness Al$_2$O$_3$ barrier layers will be grown in order to study interfacial reactions between HfO$_2$ and Si during annealing at 600 - 1000 °C. Chemical analytical techniques as well as electron microscopy will be used in these studies. And lastly, incorporation of rare earth elements into the composite oxide film using similar techniques is to be examined in future work as a means to further enhance desired properties. The REU students will be involved with the ALD of these nanostructures and their physico-chemical characterization.

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