UV-ozone oxidized high-k dielectrics on Si and Ge substrates

UV-ozone oxidation has been used to fabricate ultrathin metal oxide gate dielectrics on Si and Ge semiconductor substrates.[1, 2] This technique entails depositing a metal film on the substrate by, for example, UHV sputtering or e-beam evaporation, and exposing the film to pure oxygen in the presence of ultraviolet light which creates both atomic oxygen and ozone. These highly activated oxygen species produce enhanced low temperature oxidation kinetics for the metal layer. Kinetics of Zr and Hf oxidation on oxynitride or SiO_2-passivated silicon substrates has been studied using XPS, HRTEM, and NRA. The maximum oxide thickness achievable using this technique are 50 Å and 35 Å for ZrO2 and HfO2, respectively (for oxidation at room temperature in an O_2 pressure of 600 Torr). This represents a significant enhancement over the limiting oxide thickness during room temperature oxidation in pure molecular oxygen at comparable pressure. Electrical results obtained from Pt-electroded MOSCAP structures fabricated on Si substrates indicate an oxide with a high dielectric constant and low leakage current density. Capacitance-derived EOT values of 1.5 nm have been achieved for 2.8 nm UV ozone oxidized ZrO2 on 1.0 nm SiO2. The corresponding leakage current is in the 10^{-4} A/cm^2 range.[3, 4]

As a semiconductor channel material for use in future scaled MOS transistors, Ge has the advantage of enhanced low-field mobility compared to Si. With the expected introduction of deposited high-k dielectrics in MOS technology, the poor quality and stability of GeO_2 may no longer be a significant obstacle to development of Ge-channel field effect transistors. Growth of ZrO_2-based gate dielectrics on Ge (100) substrates is reported in this presentation. HRTEM of UV-ozone oxidized ZrO_2 on Ge indicates a sharp interface between the oxide and the substrate. However conventional TEM is not well-suited for identifying a Ge oxide layer in this system due to the closeness in atomic number of Zr and Ge. XPS spectra suggest the presence of a substoichiometric Ge oxide phase at the ZrO_2/Ge interface. Depth profiling using angle-resolved XPS and MEIS have been performed on multiple ZrO_2/Ge gate stacks. Results indicate that the thickness of the Ge oxide layer is dependent upon the ZrO_2 overlayer thickness, suggesting that the interfacial layer can be controlled through the oxidation conditions. Electrical testing results obtained from ZrO2/Ge MOSCAPS and MOSFET devices will be summarized. A systematic comparison of UV-ozone oxidized dielectrics grown upon Si and Ge will be presented. Key differences including oxidation kinetics and electrical properties will be highlighted.

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