Atomic Layer Chemical Vapour Deposition of ZrO2 Thin Films: Study of Growth Kinetics and Dielectric Behavior

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One of the problems with scaling MOSFETs beyond the 0.1 μm technology is the increasing leakage current through the gate dielectric. The technology roadmap for semiconductors indicates that the present rate of device scaling will produce 0.1 μm generation devices using an equivalent gate oxide thickness of 1.5-2 nm. ZrO_2, a candidate to replace SiO_2, has a high dielectric constant, large band gap, thermodynamic stability, and may be deposited with predictable thickness by atomic layer deposition (ALCVD) at low temperatures.

In an ALCVD reactor built in-house, we have deposited thin films of zirconium oxide on Si(100) using different β-diketonates of Zr developed in our laboratory as precursors. These films are characterized by x-ray diffraction, transmission and scanning electron microscopies, infrared spectroscopy, and electrical measurements. Analysis shows that x-ray amorphous zirconia films of high dielectric quality may be grown on Si(100) starting at about 400°C. As the growth temperature is raised, the films become crystalline, the phase formed (cubic or monoclinic) and the microstructure depending on precursor molecular structure. IR spectroscopy shows that films grown at low temperature contain carbon, the extent and the chemical nature of the carbon present depending on the precursor. It also depends on whether oxygen or nitrous oxide is used as the reactant gas. C-V measurements show that films grown on Si(100) at 450°C have low interface state density, low leakage current, a hysteresis width of only 100 mV, and a dielectric constant of 22. These data indicate that β-diketonate complexes of Zr are suitable candidates for the ALCVD of zirconia films of device quality. Zirconia films have also been deposited on SIMOX substrates using the same technique. Further details of the ALCVD growth of zirconium oxide thin films using different precursors, their microstructure, and the electrical and optical properties of the films deposited on both Si and SIMOX substrates will be presented.