Low Temperature Plasma-enhanced Atomic Layer Deposition for SiO_2 Using Carbon Dioxide

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SiO_2 grown by atomic layer deposition (ALD) is a widely used material for the fabrication of microelectronic devices, due to its precise thickness control, high conformality, and excellent dielectric properties. Expanding the applications of ALD SiO_2 to thermally sensitive materials requires the development of low-temperature (T< 100˚C) processes. Catalyzed ALD [1,2] and plasma-enhanced ALD (PEALD) [3,4] have been applied as effective solutions. However, the commonly used oxidants, H_2O and O_2, potentially degrade moisture/oxygen sensitive materials, thereby limiting the applications of low temperature SiO_2.

In this work, we report the successful deposition of high-quality SiO_2 films by low temperature PEALD using an oxidant, which is compatible with moisture/oxygen sensitive materials. CO_2 and Bis(tertiary-butylamino)silane (BTBAS) were used as ALD precursors. The processes were carried out in a Beneq TFS 200 reactor at 90 ˚C. A thorough analysis was conducted on both growth characteristics and film properties. The CO_2-based PEALD SiO_2 films with a saturated growth-per-cycle of 1.15 Å/cycle, a refractive index of 1.45 (at 632.8 nm) and a density of 2.1 g/cm^3 were obtained. The films showed low impurity levels with bulk concentrations of ~ 3 and ~ 0.15 at. % for hydrogen and nitrogen, respectively, whereas the carbon content was found to be below the measurement limit of TOF-ERDA. A low residual stress of 30 ± 10 MPa (tensile) was measured on 50 nm-thick SiO_2 films. Furthermore, good optical properties, high transparency and zero extinction coefficient, were obtained on sapphire substrates at wavelength range of 400-800 nm. In addition, the highest deposition speed of 62 nm/h was achieved, and we concluded that an increase of the deposition speed above 180 nm/h is potentially reachable by further optimization of process parameters.

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