

**EPITAXIAL OXIDE GROWTH ON Si(001) FOR
FLOATING EPITAXY, A NOVEL PROCESS FOR
SILICON-ON-INSULATOR WAFER PRODUCTION**

By

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As scaling continues in the semiconductor industry, silicon-on-insulator (SOI) wafers are increasingly becoming the substrate of choice, due to higher channel mobility, effective device isolation, reduced short channel effects, minimized parasitic capacitance, and therefore higher speed, compared to a regular silicon wafer. Current methods of SOI wafer production, however, will have difficulty achieving the desired silicon device layer and buried oxide insulator layer thicknesses and eliminating interface roughness as scaling proceeds. We propose “Floating Epitaxy SOI” as a novel method of SOI production utilizing an all *in-situ* growth process. Floating Epitaxy SOI involves Molecular Beam Epitaxy deposition of an epitaxial template oxide, oxidizing through the epitaxial template layer to establish the insulation layer, and silicon growth on top of the epitaxial template oxide layer (which is now “floating” on top of an amorphous oxide layer). The key to this process is the epitaxial oxide template layer; the growth and thermal stability of this layer are discussed, as well as brief results for through-oxidation “floating” of the template oxide layer and silicon growth experiments.

BaO, SrO, CaO, $\text{Ba}_{1-x}\text{Sr}_x\text{O}$, SrTiO_3 , CaTiO_3 , and $\text{Ca}_{1-x}\text{Sr}_x\text{TiO}_3$ were successfully epitaxially deposited on Si(001) substrates. A 64:36 Ba:Sr ratio was used for the solid solution of $\text{Ba}_{1-x}\text{Sr}_x\text{O}$, in order to achieve close lattice matching with silicon; a 50:50 Ca:Sr ratio was used initially for the $\text{Ca}_{1-x}\text{Sr}_x\text{TiO}_3$ solid solution, an attempt to mediate SrTiO_3 's 2% lattice mismatch with silicon and CaTiO_3 's orthorhombic structure. Reflection High Energy Electron Diffraction patterns of both $\text{Ba}_{1-x}\text{Sr}_x\text{O}$ and $\text{Ca}_{1-x}\text{Sr}_x\text{TiO}_3$ indicated high quality 2D epitaxial films. A thin (3 monolayer) film of $\text{Ba}_{1-x}\text{Sr}_x\text{O}$ is stable on silicon to 535°C in vacuum, while a 5 monolayer $\text{Ca}_{1-x}\text{Sr}_x\text{TiO}_3$ film survives to 740°C in vacuum, but roughens from a 2D toward a 3D surface above ~650°C. Of the epitaxial oxides studied, the solid solution $\text{Ca}_{1-x}\text{Sr}_x\text{TiO}_3$ would be the best choice for Floating Epitaxy SOI, based on epitaxial growth quality and stability.

High-resolution TEM indicates the presence of an amorphous interfacial layer at the SrTiO_3/Si interface, as grown. X-ray diffraction confirms an epitaxial film, with a lattice parameter larger than that of bulk SrTiO_3 , likely due to oxygen deficiency in the film. Annealing 17.5nm $\text{SrTiO}_3/\text{Si}(001)$ at 800°C in 5.5 Torr of oxygen for 30 minutes results in an equivalent oxide thickness of 10.3nm, sufficient for scaling to 2020. X-ray diffraction after annealing reveals a still-epitaxial SrTiO_3 film, with sharper 2θ and χ peaks and a lattice parameter closer to that of bulk SrTiO_3 . These results validate the “floating” epitaxy approach: an epitaxial film remains on top of an amorphous insulator, after through-oxidation of the substrate. Direct deposition of epitaxial silicon on $\text{Ca}_{1-x}\text{Sr}_x\text{TiO}_3$ and solid-phase epitaxy of silicon on a CaTiO_3 film are promising.