

Characterization of strained silicon on insulator (sSOI) substrates using high-resolution X-ray diffraction

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For the past 40 years, tremendous progress has been made by the silicon semiconductor industry in its relentless pursuit of Moore's law. This progress has largely been achieved through lithographic scaling of the traditional CMOS transistor. In recent years, however, the industry has been forced to introduce new materials and processes to maintain the requisite improvements in transistor performance.

Strain engineering to improve the carrier mobility in advanced transistors was introduced at the 90 nm technology node and is now becoming widespread as the industry moves from the 65 nm to the 45 nm nodes. To date, local strain engineering approaches have been used. SiGe embedded in the source/drain regions of the transistor gives impressive mobility enhancements in PMOS devices by introducing compressive uniaxial strain into the channel region. SiN stressor layers deposited over the transistor can be made with compressive or tensile strains and have been used to enhance the mobility in both PMOS and NMOS devices.

As the industry moves forward, a number of companies and consortia are investigating global strain approaches using engineered substrates, such as strained silicon on insulator (sSOI). These substrates comprise a thin, strained layer of silicon bonded to an insulating oxide layer atop a silicon carrier wafer. The manufacturing process is quite complex. A very thin (~10 nm) Si layer is grown strained to a relaxed SiGe buffer layer grown on a donor Si wafer. The Si layer is bonded to an oxide layer atop a carrier wafer and then the SiGe is removed. The process must produce a layer that is free of defects and retains its strain both as delivered and during subsequent device processing.

X-ray diffraction is a well-known technique for measuring the strain in crystalline materials from small shifts in the position of their Bragg diffraction peaks. High resolution X-ray diffraction (HRXRD), employing crystal optics to condition the beam in both angle and divergence, is used to characterize single crystal substrates and epilayers. The conventional, out-of-plane, HRXRD technique has been used previously to characterize silicon on insulator (SOI) and strained SOI wafers. We will first show data from such measurements and describe what information is available together with the drawbacks of the technique for automated, fast measurement. We will then describe the in-plane HRXRD technique that we developed to address these issues. The technique uses the angular separation from two in-plane reflections to directly determine the strain and twist of the thin, strained Si layer with respect to the carrier wafer. Results from four bonded substrates (two SOI wafers and two sSOI wafers) will be presented to illustrate the technique.