Effect of silicon nitride and silicon dioxide bonding on the residual stress in layer-transferred SOI

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The possibility of bonding two different buried layers (one silicon nitride and one silicon dioxide film) to produce layer-transferred silicon films over a multi-layer insulating structure or SOIM (Silicon On Insulating Multilayers) has been recently demonstrated [1]. Measurements of the bow of different bonded wafers evidenced a variation of the curvature with the oxide and nitride thickness which opens the way to control independently the stress equilibrium in the entire layer structure.

The main limitation of bow measurements is to provide informations on the overall residual strain present in the SOIM wafer and not in the different layers. However SOI materials are not perfectly strain-relaxed systems [2]. They behave more like balanced-strain structures which conform to equilibrium conditions depending on every stage of the technology [3,4].

In this work, we evaluate separately the residual strain in the thin Silicon OverLayer (SOL) and silicon handle wafer. We have used TEM to control the bonding, high resolution X-ray diffraction to evaluate the biaxial strain components in the SOL and micro-Raman spectroscopy to control the strain relaxation in the silicon handle wafer (see figure 1).

We show that thinning the SOL in the case of a standard SOI wafer results in an increased biaxial (tensile) stress in the SOL and underlying silicon handle wafer, while the average oxide compression decreases. In the case of SOIM, the introduction of a third material (Si_3N_4) changes this overall mechanical behavior. Of course, this is because of the opposite difference in thermal expansion coefficients with respect to silicon oxide. Once the relative thickness of the buried layers is properly adjusted, the oxide strain can be internally balanced and this should lead to an (almost) perfectly strain-relaxed system.

Experimentally speaking, this occurs for nitride layer 200 nm thick and 400 nm thick SiO_2. When the nitride is 400 nm thick, the SOL is in compression when thinner than ~0.1 µm (instead of tension for standard bonded SOI material). The thickness ratio 1 for the nitride and 2 for the oxide, balances the two different effects on the thin (active) SOL film and leads to an almost relaxed SOIM material.

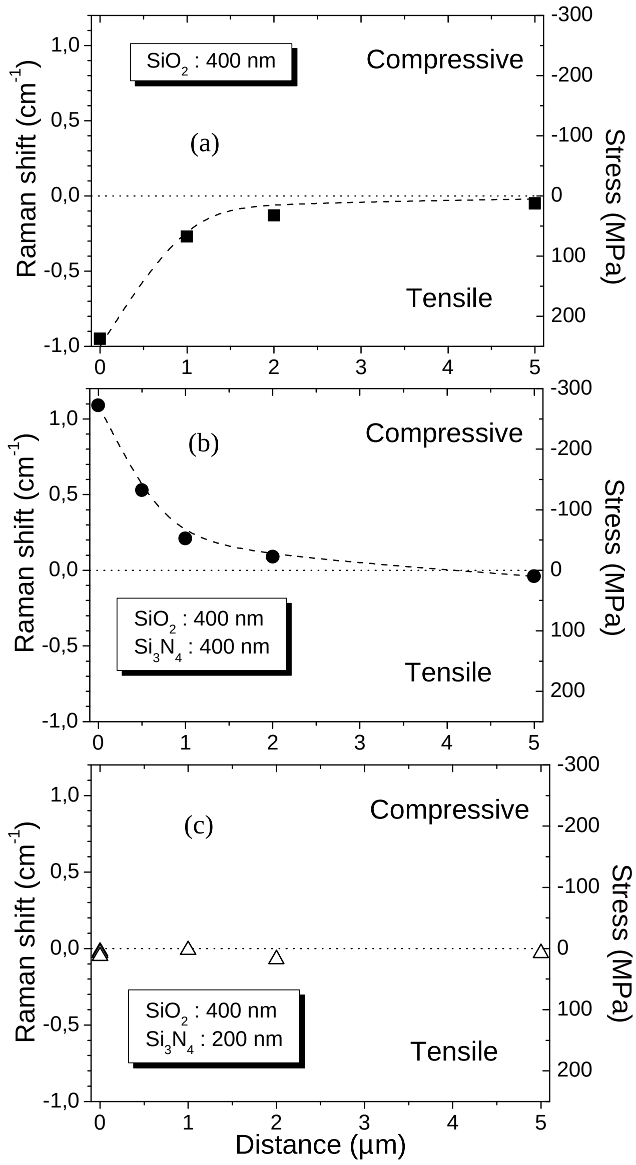

Figure 1 : Raman shift and its corresponding biaxial stress in the silicon handle wafer depending on the distance to the SiO_2/Si interface for a standard bonded SOI wafer (a), a SOIM wafer with a nitride layer 400 nm thick (b) and a SOIM wafer with a nitride layer 200 nm thick (c). The silicon overlayer is 200 nm thick and the buried oxide 400 nm thick.

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