

### THIN COMPLIANT SiGe FOR RELAXED SiGe AND STRAINED Si GROWTH

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Development of relaxed SiGe layers on Si is sought as a means for creating strained Si layers. Devices fabricated from strained Si benefit from enhanced hole and electron mobilities, which are desired to advance integrated circuit designs without a significant change in technology. Primarily, relaxed SiGe layers are obtained by growing thick ( $> 1\mu\text{m}$ ) compositionally graded buffer (CGB) layers, where the Ge concentration in the film increases over the thickness of the layer so that few threading dislocations form to relieve stress<sup>1</sup>. In so doing, the CGB forms a high density of misfit dislocation lines (commonly referred to as crosshatch) that result in a large surface roughness. Success has been reported where the CGB are chemically mechanically polished and regrown to reduce the surface roughness from the crosshatch<sup>2,3</sup>. However, the thickness of the films creates problems due to the poor thermal properties of the SiGe layer. For these reasons, thin relaxed SiGe films are sought.

We report a new method for the creation of a thin relaxed SiGe film based on the concept of first creating a thin, compliant SiGe film through the formation of dislocations. Obtaining the compliant SiGe film is a challenge, because it is difficult to get sufficient dislocation nucleation formation in the film without growing thick films. During high growth temperatures, SiGe films undergo surface undulations to relieve stress without the formation of dislocations. We observed, however, that a low temperature SiGe alloy growth, subsequently capped with a Si layer, could be annealed at higher temperatures to induce defect formation and propagation without causing surface undulations. Under the proper growth conditions, a SiGe film with a Si cap can form threading dislocation dipoles<sup>4</sup> that result in defect propagation along the top and bottom interfaces such that defect annihilation can occur at the interfaces. This defective SiGe film becomes a plastic compliant layer for the subsequent growth of the relaxed SiGe film.

We grew 100 nm SiGe alloys of 20, 30, and 40% Ge at 400 °C with 100 nm Si caps by molecular beam epitaxy (MBE) and then annealed them at 800 °C *in vacuo*. The Si capping layer was removed with tetramethyl ammonium hydroxide, and then the relaxed SiGe layer was grown by MBE. Shown in Fig.1 is the Nomarski contrast image of the 30% alloy growth after performing a defect etch. The area on the left was masked during growth and represents the compliant layer surface, and the area on the right is the relaxed layer surface. We observe a large density of defects, on the order of  $10^9\text{ cm}^{-2}$ , in the compliant alloy, which are not present in the relaxed alloy. Fig. 2 is a cleaved planview transmission electron microscopy (TEM) image of the 30% alloy sample. We can clearly see the large density of threading and misfit dislocations in the buried SiGe layer and that the top SiGe layer has at least an order of magnitude reduction in dislocations. Preliminary cross-sectional TEM shows that

dislocation confinement occurs within the compliant SiGe layer and that dislocations do not propagate into the top SiGe film. X-ray rocking curves, using  $\text{CuK}\alpha_1$  radiation, for the 30% alloy sample has separate peaks for the compliant and relaxed layers. Setting the Si (004) peak at  $34.564^\circ$ , the compliant layer has a peak at  $33.8695^\circ$  and is nearly fully strained, while the top layer at  $34.0307^\circ$  is nearly fully relaxed. AFM measurements of the surface roughness for both the compliant and relaxed layers were found to be 1.5 nm over  $10\mu\text{m} \times 10\mu\text{m}$  areas. Work continues in improving and developing the relaxed and compliant alloys for device purposes. Results from the compliant 20% and 40% alloys, as well as a discussion of the various growth conditions used to create these compliant and relaxed layers, will be presented in the talk.

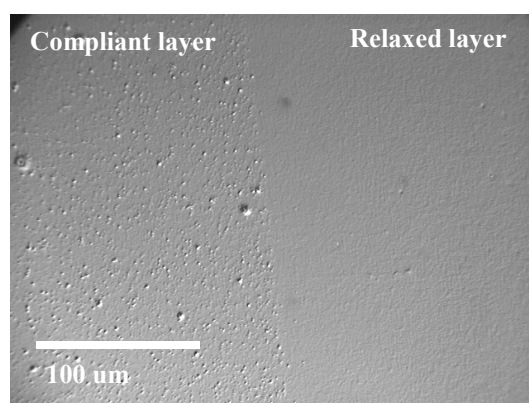


Fig. 1. Nomarski contrast image after etching defects on the surface of a  $\text{Si}_{0.7}\text{Ge}_{0.3}$  alloy sample.

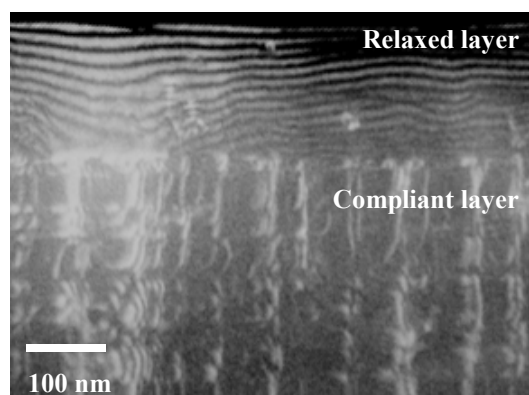


Fig. 2. Cleaved planview transmission electron micrograph of the  $\text{Si}_{0.7}\text{Ge}_{0.3}$  alloy sample showing the top relaxed layer and the bottom defective compliant layer.

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