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TEM Characterization of GaSb growth on GaAs (001) Substrate: Growth Mode and Defect Evaluation

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Exploiting extreme lattice-mismatch of Sb-based epitaxy on GaAs and Si substrates are of considerable interest for III-Sb optoelectronic devices on GaAs substrate such as monolithically integrated lasers, detectors, solar cells and transistors. Recent technical advancements in GaSb substrates have enabled high quality lattice-matched GaSb epitaxy on native substrates, but GaAs substrates are desirable for many applications.

Due to 7.8% lattice mismatch between GaSb epilayer and GaAs substrate, standard approaches involve tetragonal distortion in which the material relieves strain energy through 60˚ misfits and threading dislocations. The vertically propagating defects associated with this growth mode will often jeopardize both their electrical and optical properties of the device structures with non-radiative recombination and carrier leakage.

During the interfacial misfit (IMF) growth mode, the initial strain relaxation of highly mismatched GaSb layers grown on GaAs (001) is governed by the two-dimensional (2D), periodic interfacial misfit (IMF) dislocation array growth mode. Under optimized growth conditions, only pure 90° dislocations are generated along both [110] and [1-10] directions that are located at GaSb/GaAs interface, which leads to very low threading dislocation density propagated along the growth direction. Our experimental results show that this interaction causes Sb to participate in the formation of a periodic IMF array instead of simply giving rise to tetragonal distortion in the evolving GaSb layer.

We through TEM technique analyze the defect formation and measure their dislocation density for IMF growth mode and non-IMF growth mode. The long-range uniformity and subsequent strain relaxation of the 2D and periodic IMF array are demonstrated via transmission electron microscopy and scanning transmission electron microscopy images at GaSb/GaAs interface.

The low-dislocation density, strain-relieved GaSb layers formed by the IMF growth conditions have been demonstrated to be applied in the monolithic integration of semiconductor devices.

References:
[1] S. H. Huang et al., *Appl. Phys. Lett*., **88** (2006) 131911.
[2] S. H. Huang et al., *J. Appl. Phys.*, **105** (2009) 103104.

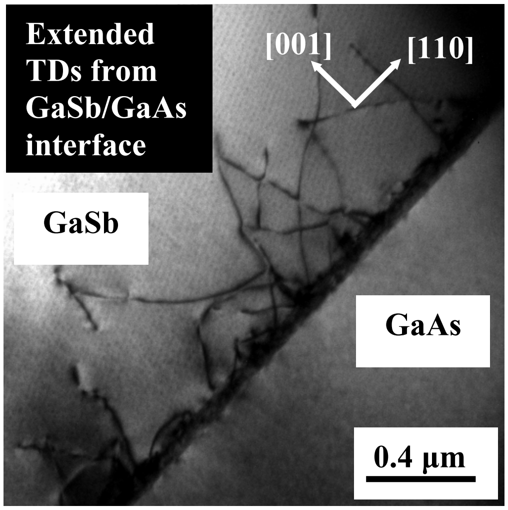

Figure 1: Bright-field cross-sectional TEM images (zone axis [1-10]) of GaSb grown on GaAs under non-IMF growth mode, indicating high threading dislocations are extended from GaSb /GaAs interface.

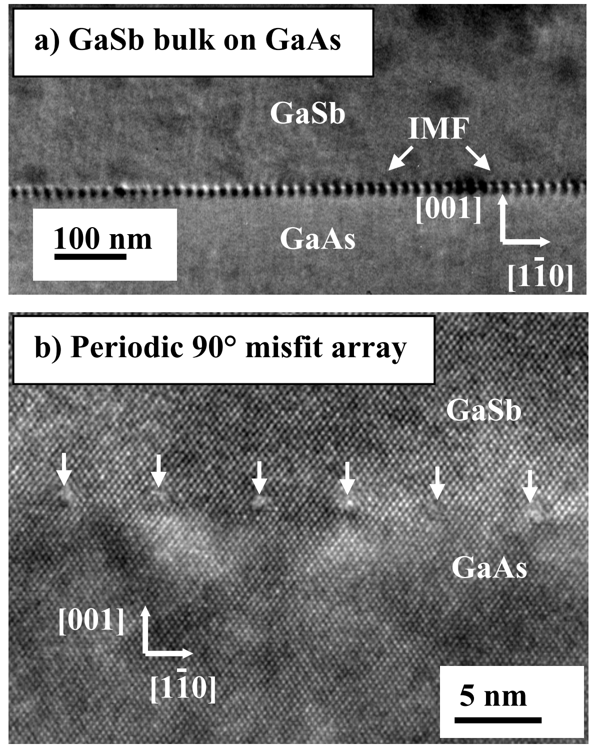

Figure 2: Cross sectional TEM image (zone axis [110]) of GaSb on GaAs under IMF growth mode, a) low magnification, showing a highly periodic array of misfit dislocations at the GaSb/GaAs interface, b) high-magnification, indicating the misfit separation, measured to be 5.6 nm, corresponds to exactly 13 GaSb lattice sites grown on 14 GaAs lattice sites.

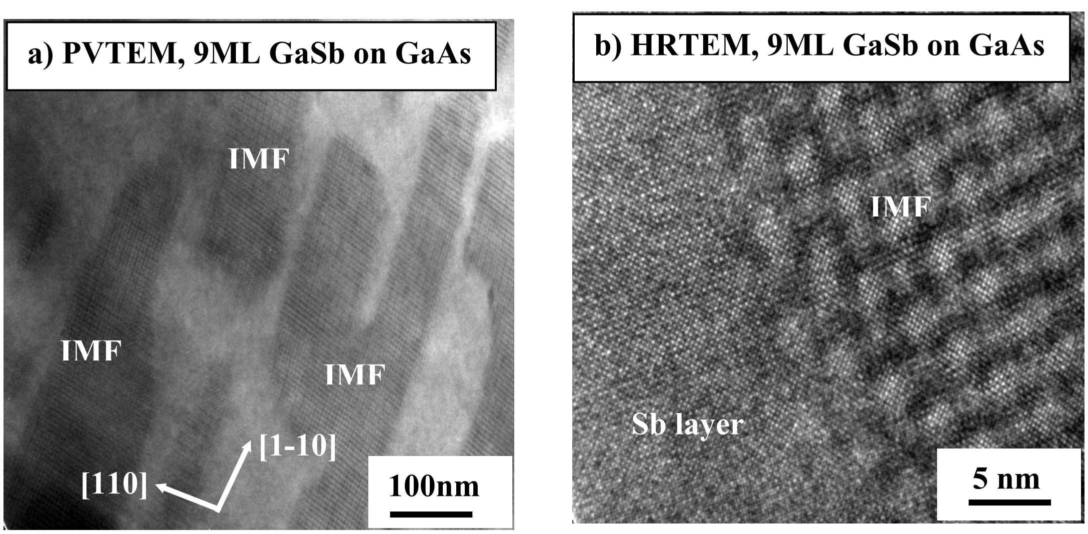

Figure 3: Plan-view bright-field TEM images of 9 ML GaSb grown on GaAs under IMF growth mode, (a) low-resolution image, (b) high-resolution image.

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