Metamorphic Growth-Related Defects and Electrical Properties in III-Sb Materials for High-Mobility p-MOSFETs

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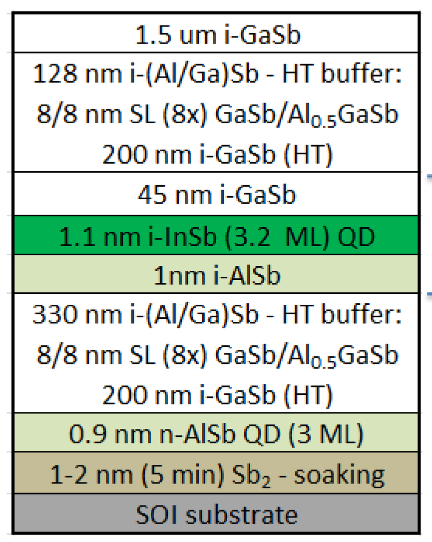
Introduction

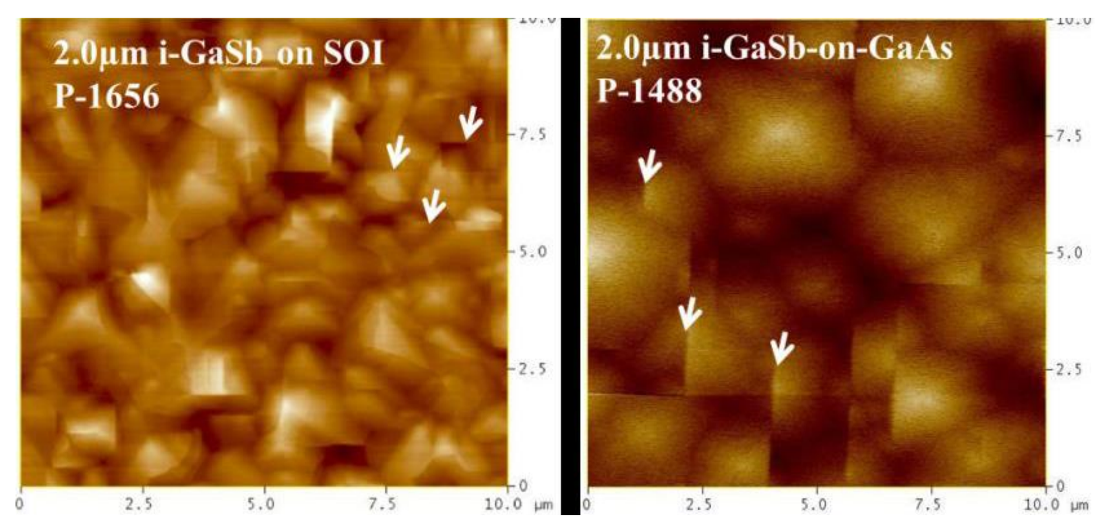
(In)GaSb compound semiconductors are considered as a complimentary PMOS material to n-type InGaAs due to the superior hole transport properties in III-Sb's. Both these materials also have similar chemistry that helps in CMOS process integration. However, the surface/interface electrical properties are in a sense opposite in InGaAs and (In)GaSb: a neutral surface occurs when the Fermi level is close to the conduction band in InGaAs with high In content, and when Fermi level is close to the valence band in (In)GaSb at any In content. Therefore, an (In)GaSb p-MOSFET operates with low interface charge and has lower resistivity p-type source/drain contacts, while InGaAs is better suited for n-MOSFET. In addition to p-type surfaces and interfaces, various intrinsic defects in (In)GaSb introduce dominant acceptor levels. When III-Sb materials are grown on metamorphic substrates, the introduced defects creates unintentional p-type doping, causes additional scattering, increase junction leakages and affects the interface properties. In this abstract, the results on correlations between the defects in various designs of metamorphic superlattice buffers on electrical properties of GaSb and InGaSb QW layers are presented.

Bulk GaSb on Si

Schematic Cross-section of GaSb on SOI for bulk electrical measurements



AFM (10x10 μm²) of 2.0 μm GaSb grown on SOI Vs on GaAs substrate (arrows- planar defects)



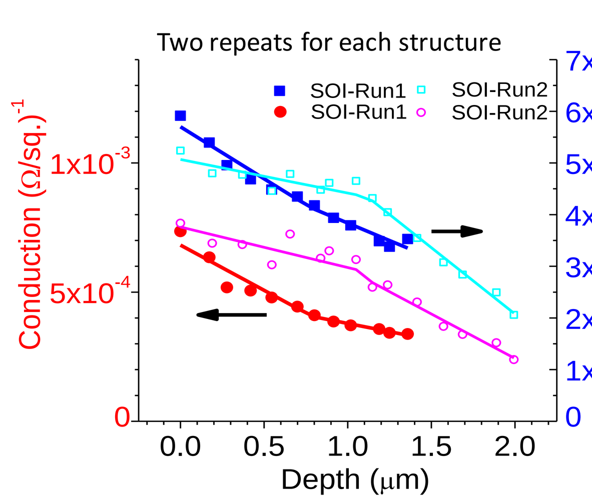
Hole density and mobility vs. depth of the thick i-GaSb layers: (a) i-GaSb on SOI(001), (b) i-GaSb on GaAs(001).

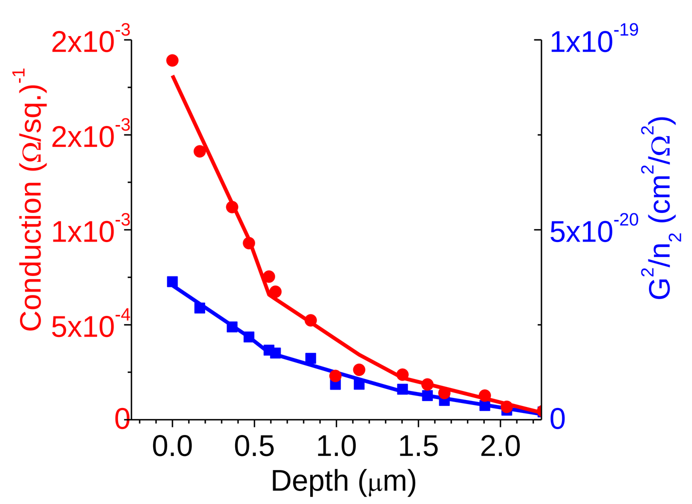
- The averaged curves were analyzed with parallel bi-layer equations for sheet density *p*, layer thickness *d* and sheet conductivity *G*:

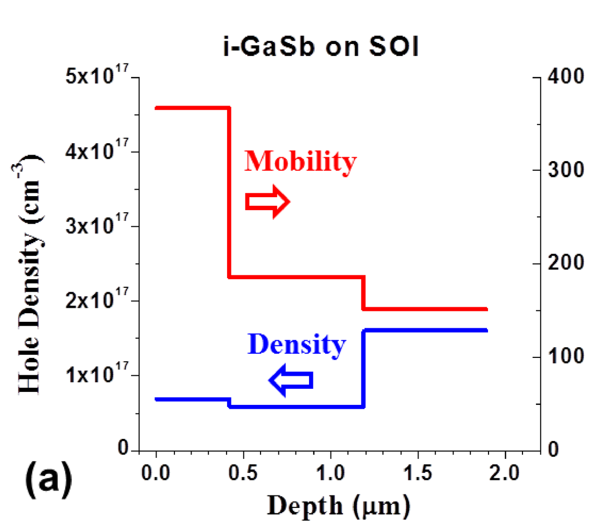
$$G = G_1 + G_2$$

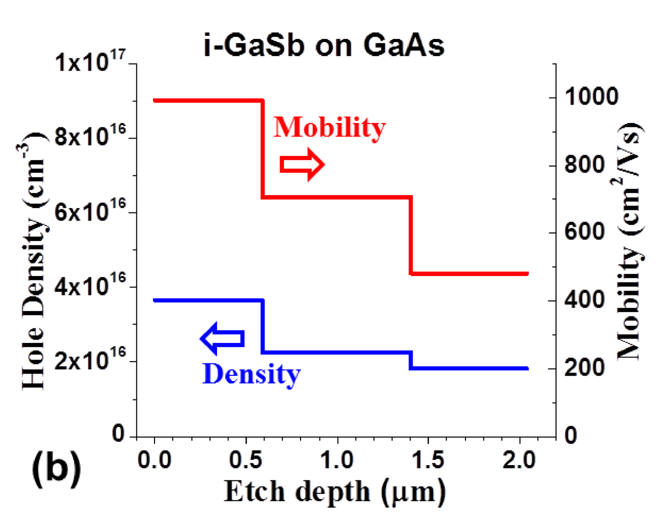
$$\frac{G^2}{pd} = \frac{G_1^2}{p_1 d_1} + \frac{G_2^2}{p_2 d_2}$$

- The hole concentration is increasing with depth as defect density is increasing





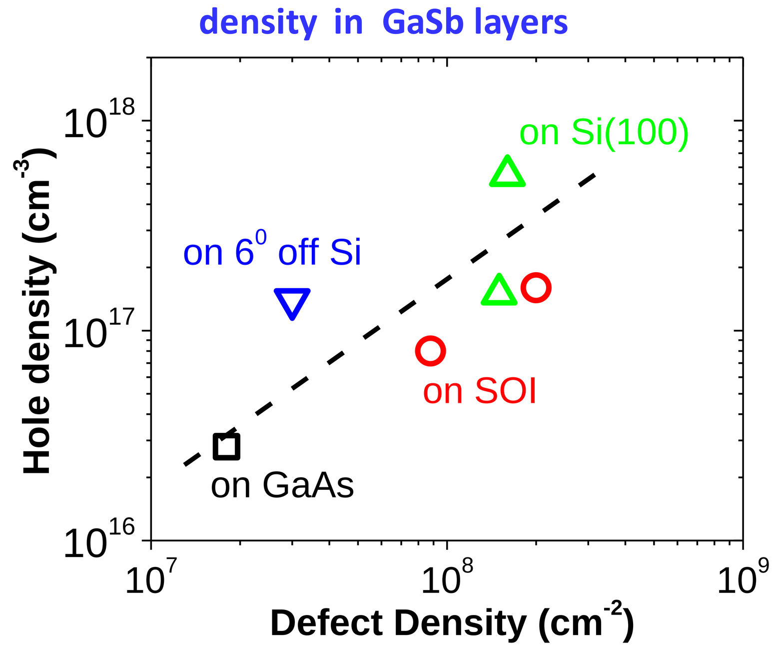




Extracted hole concentration and mobility Vs depth of the GaSb layer

	Conc., (cm^{-3})	μ (cm^2/V-s)
2.0μm i-GaSb-on-SOI	1.2×10^{17}	286
2.0μm i-GaSb-on-GaAs	2.8×10^{16}	813

Density of shallow acceptors vs defect density in GaSb layers

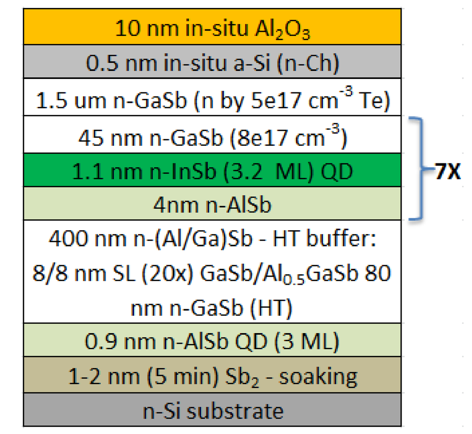


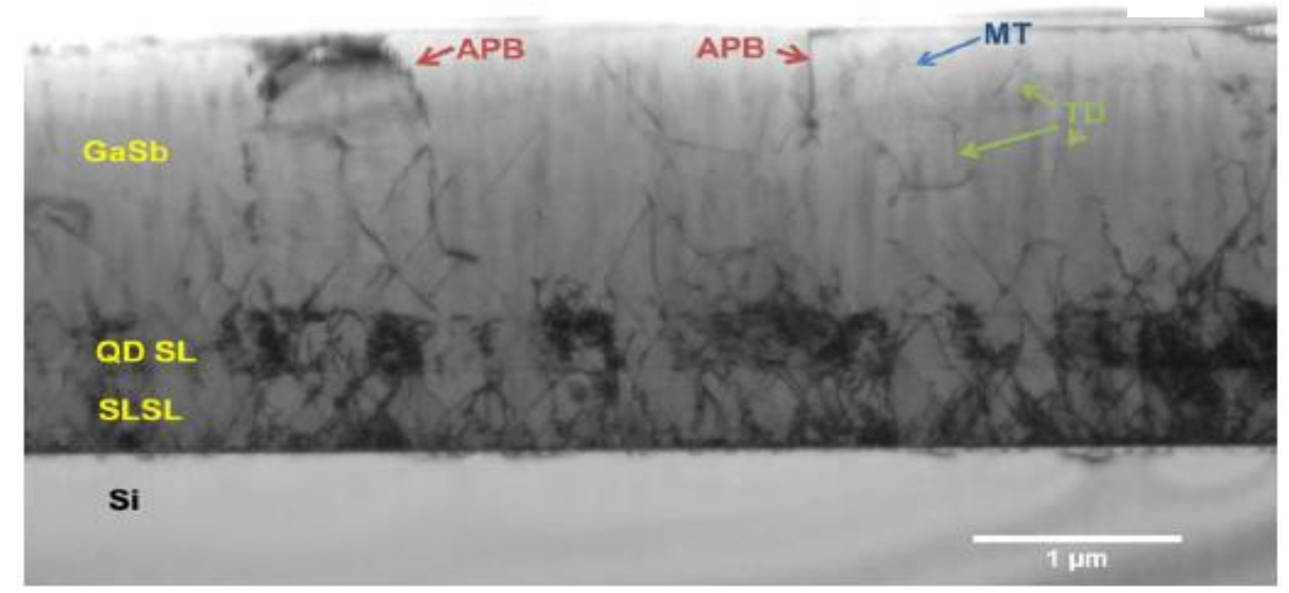
Bulk electrical properties of thick undoped GaSb layers grown on SOI and GaAs

- About 3-5 times higher defect density on Si than on GaAs
- About 1.5-2 times lower mobility on SOI substrate

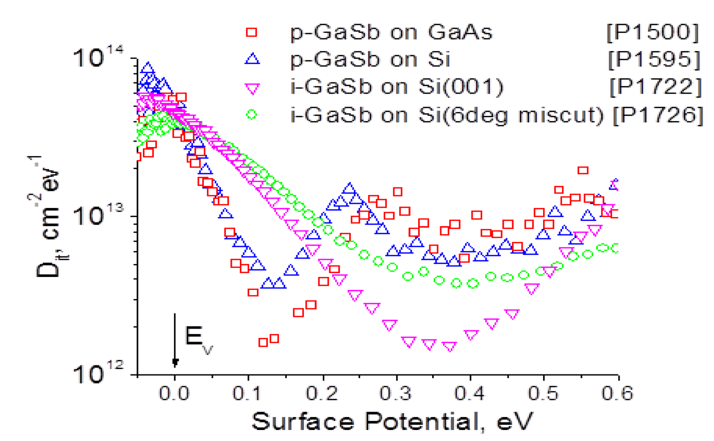
GaSb on Si: Defects and interfaces

Schematic cross-section of GaSb on Silicon with in-situ gate oxide

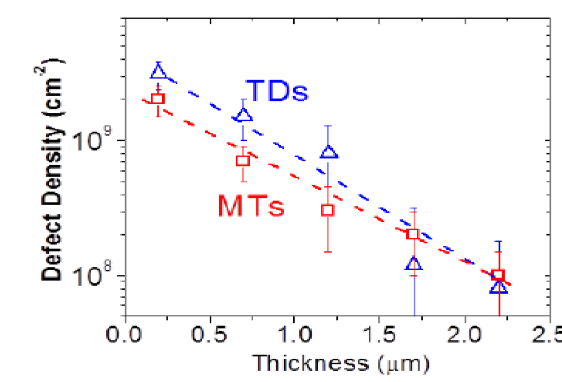




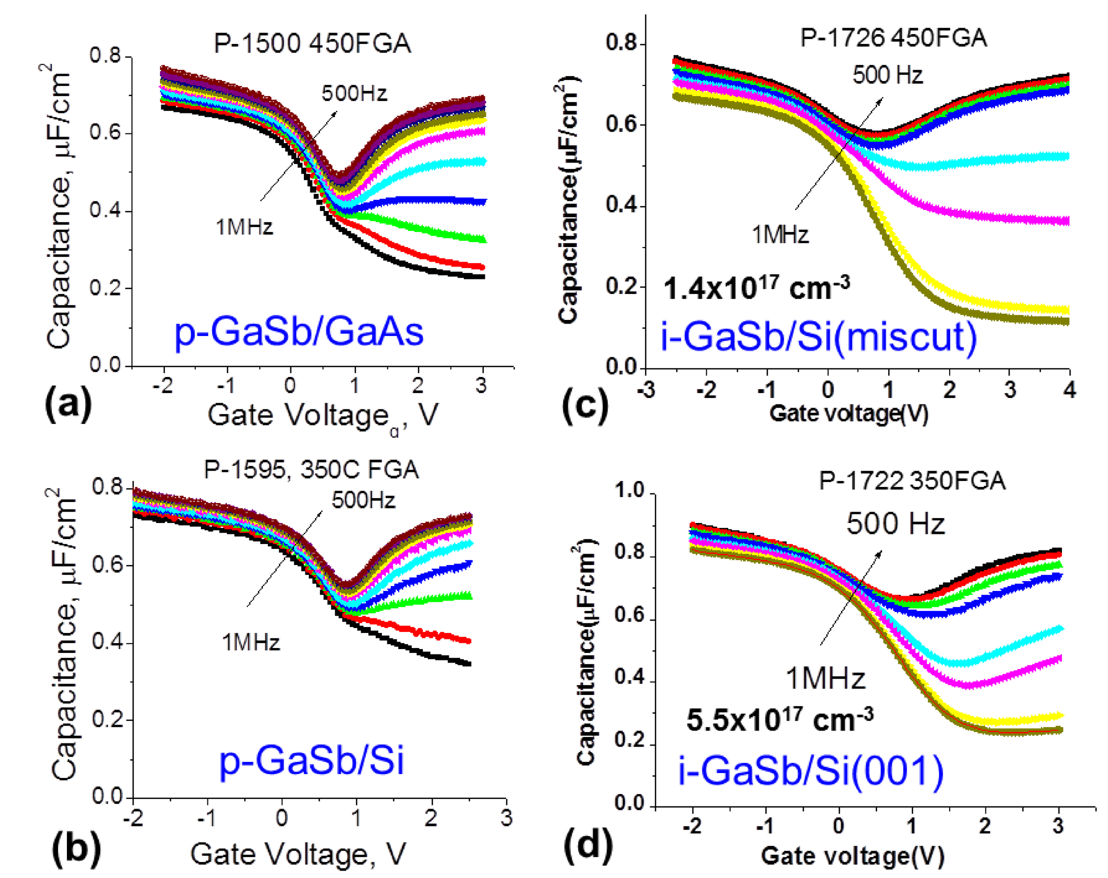
D_{it} by 4-band degenerate Terman method from 1MHz C-V



Defect Density vs. GaSb-on-Si thickness from c/s TEM

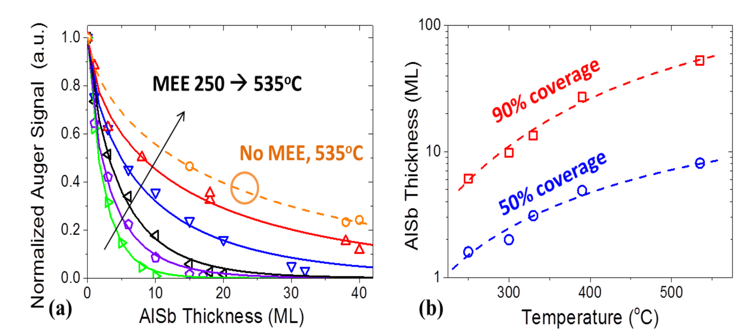


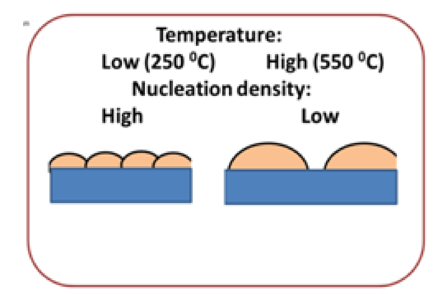
MOSCaps: GaSb/*in-situ* Al_2O_3 on p-Si



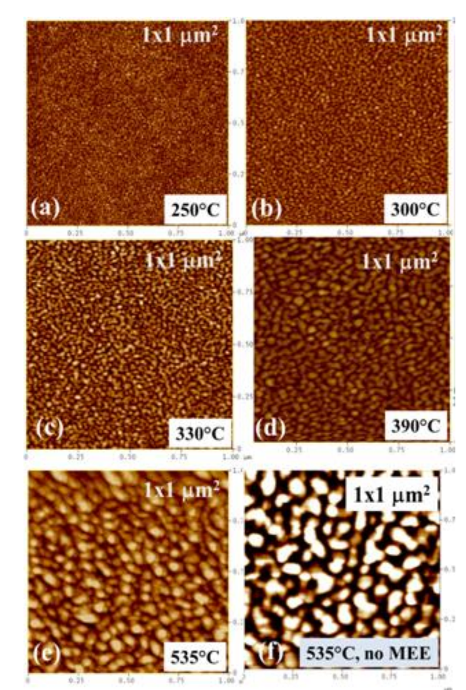
AlSb nucleation layer for Strained InGaSb on SOI

Si AES signal vs. AlSb/Si coverage

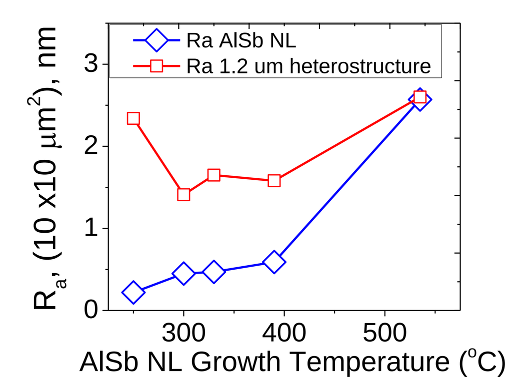


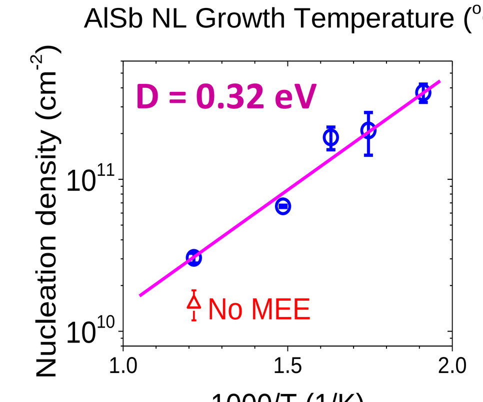


AFM images (1x1 mm²) of AlSb nucleation layer grown by MEE



AlSb seed layer roughness and nucleation density

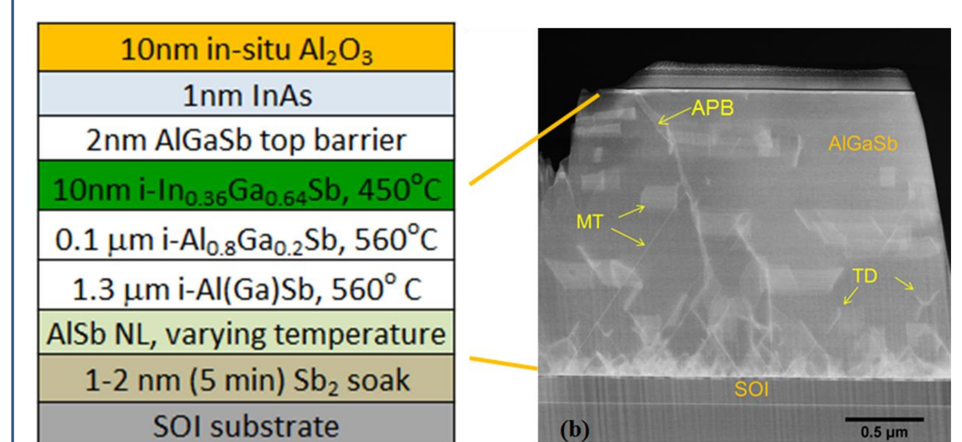




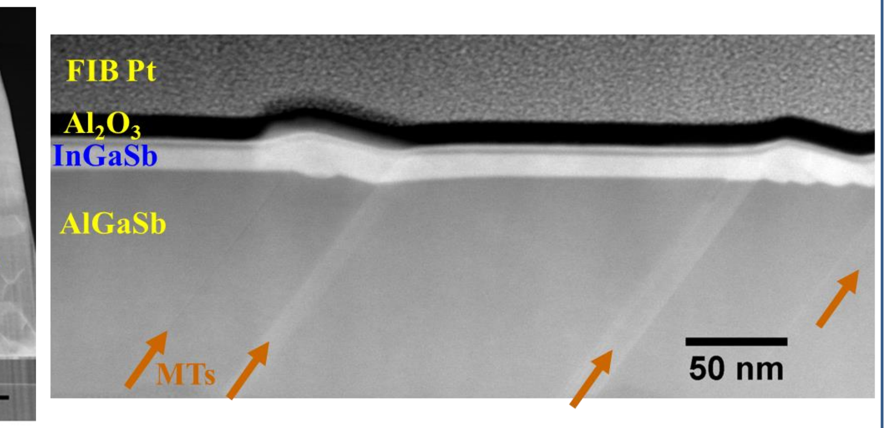
- MEE of AlSb NL- optimum growth temperature at around 300°C

Strained InGaSb on SOI

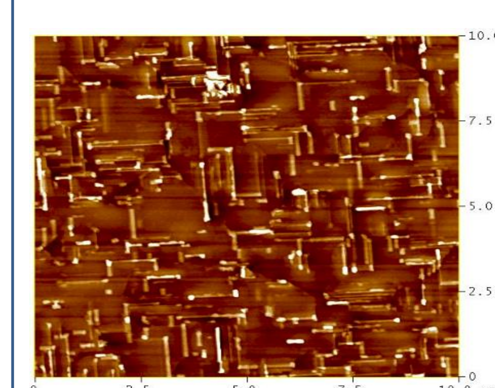
Schematic cross-section & TEM of GaSb on SOI

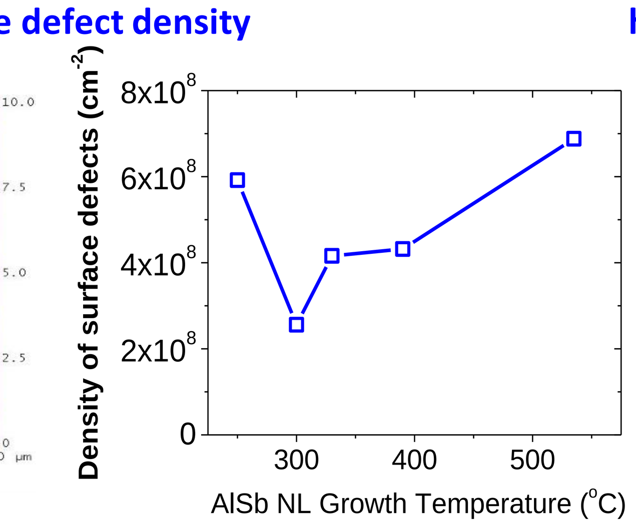


TEM of the surface features: microtwins

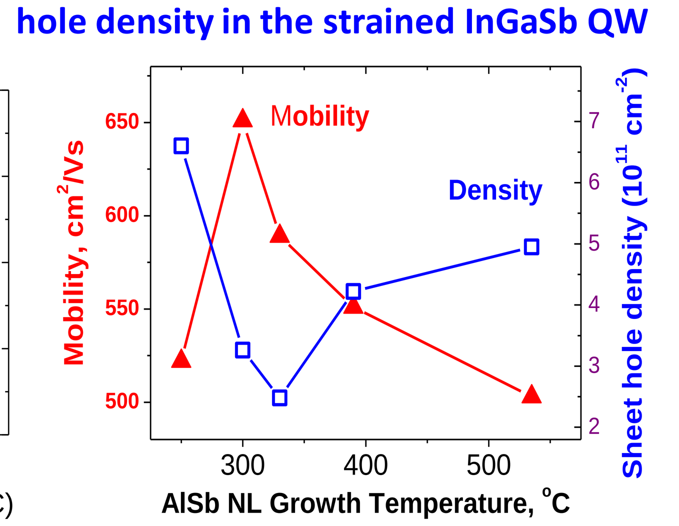


AFM images (10x10 μm²) of InGaSb structure and surface defect density





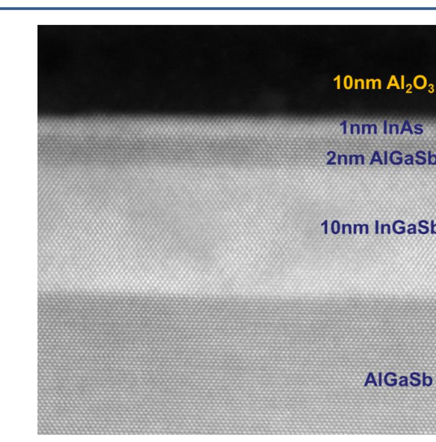
Room temperature Hall mobility and sheet hole density in the strained InGaSb QW

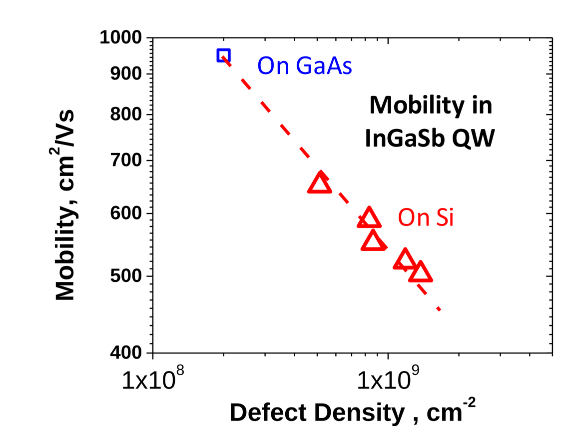


- Major surface features are due to MTs
- Other defects (TD and APB) are not prominent on surface

Summary

- Growth related defects of InGaSb are of p-type; defect density is about 5 times higher on SOI compared to GaAs substrate for 2.0 um thick GaSb
- MEE employed for AlSb NL growth- Optimum temperature around 300C which corresponds to ~650 cm^2/V-s mobility





Acknowledgements

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