Influence of Strain on InAsSb Composition

W.L. Sarney,[1] S.P. Svensson, [1] A.C. Leff, [1] D. Donetsky[2]
[1] US Army Combat Capabilities Command, Army Research Laboratory, Adelphi, MD 20783, USA.
[2] Department of ECE, Stony Brook University, Stony Brook, NY 11794, USA.

A mixed group-V semiconductor's composition results from a complex interaction of each group V element with each other and with the group IIIs. Furthermore, since group V fluxes are controlled thermally and by valves or flow controllers, precise control is overall very difficult in mixed group V alloys compared with mixed group III alloys.

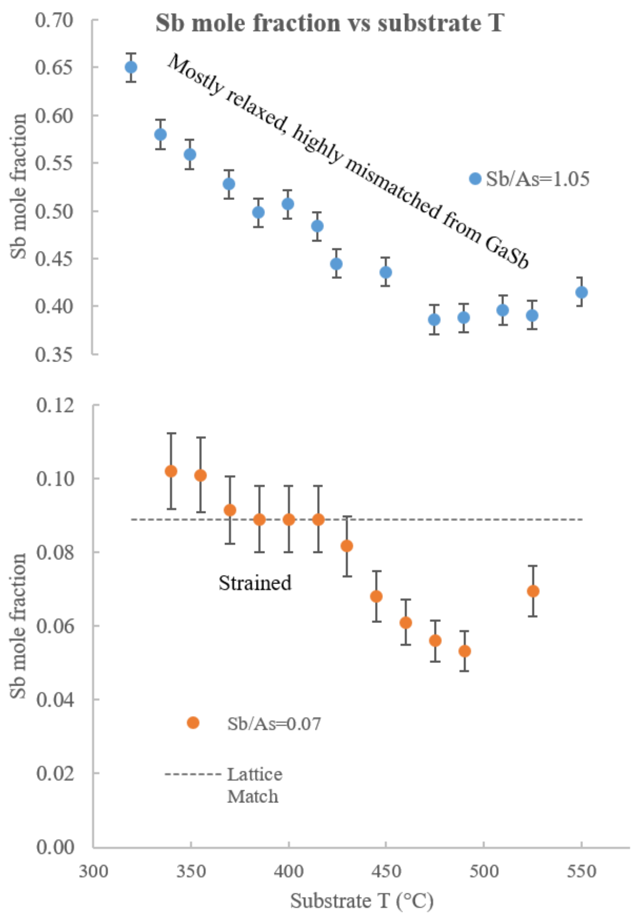

Figure 1. The Sb mole fraction as a function of substrate temperature for two Sb/As ratios. Both graphs share the temperature axis.

MBE growth conditions, such as the group V absolute fluxes and flux ratios, substrate temperature, group III growth rates, and the presence of surfactants all affect the composition of InAsSb [1-4]. The co-dependence of each of these parameters on each other is not well established. The sign and degree of strain also influences incorporation.

In one example, we grew two series of InAsSb samples onto GaSb at a range of temperatures using flux ratios known to produce Sb compositions of ~50% and 9% (near lattice match) at 415° C. The higher composition samples are relaxed and unaffected by strain. The samples grown near lattice match resist the growth temperature-induced changes in composition, as shown in Fig 1, where the composition levels out for a range of ~75° in substrate temperature.

We also observed that the group V incorporation in InAsSb for the same Sb/As ratio varies depending on the degree and sign of the strain.

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+ Author for correspondence: wendy.l.sarney.civ@mail.mil

Supplementary Pages

Additional data – work in progress

Stacked InAsSb layers on GaSb – Strain influenced incorporation study

We grew two samples with three InAsSb layers. The targeted Sb/As BEP ratios were 0.02, 0.04, and 0.06. For k1306 we started with a nearly lattice matched layer and then increased the Sb/As ratio in two steps. The order of the layers was reversed for k1330…i.e. we deposited the highly mismatched, higher Sb content first and then reduced the Sb concentration for the next two layers. We outline the conditions and measured concentrations according to x-ray below in the table and schematically in Fig S1. Each layer was 7500 Å thick. The strain values and the sign of the strain are relative to the underlying layer.

	k1306			k1330		
Layer	1	2	3	1	2	3
Measured Sb/As	0.020	0.039	0.059	0.061	0.040	0.020
Sb (Torr)	1.19E-7	1.19E-7	1.19E-7	1.21E-7	1.21E-7	1.21E-7
As (Torr)	5.98E-6	3.01E-6	2.01E-6	1.99E-6	2.99E-6	6.01E-6
Composition	$InAsSb_{0.09}$	$InAsSb_{0.19}$	$InAsSb_{0.26}$	$InAsSb_{0.27}$	$InAsSb_{0.17}$	$InAsSb_{0.02}$
Relaxation	13%	94%	93%	98%	100%	90%
	compressive	compressive	compressive	compressive	tensile	tensile

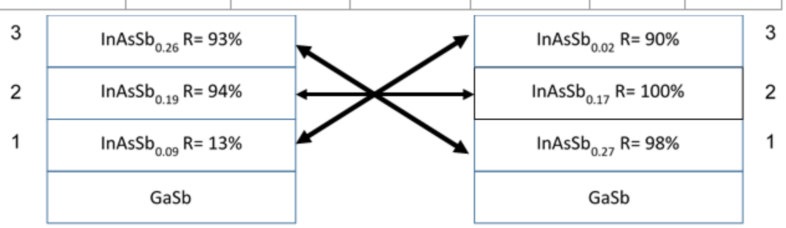

Figure S1. Schematic of the samples.

We can see that the composition in layers presented with the same Sb/As ratios is different, particularly layer 1 in k1306/layer 3 in k1330, which has the largest difference in relaxation (90% vs 13%) The discrepancy in composition between the two samples is greatest for the two layers that are tensile strained.

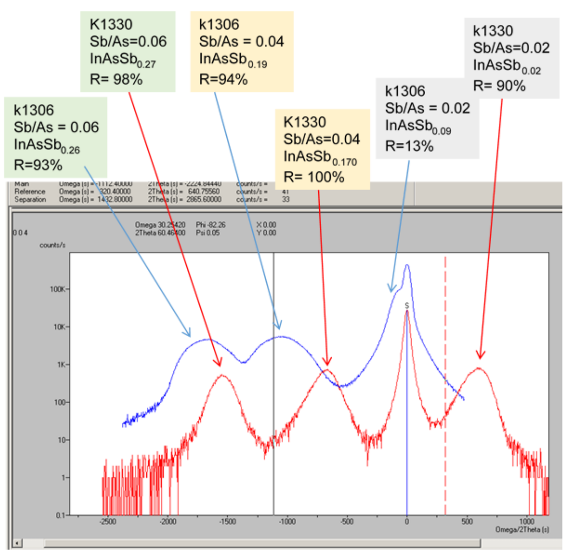

Figure S2. XRD scans from the two samples.

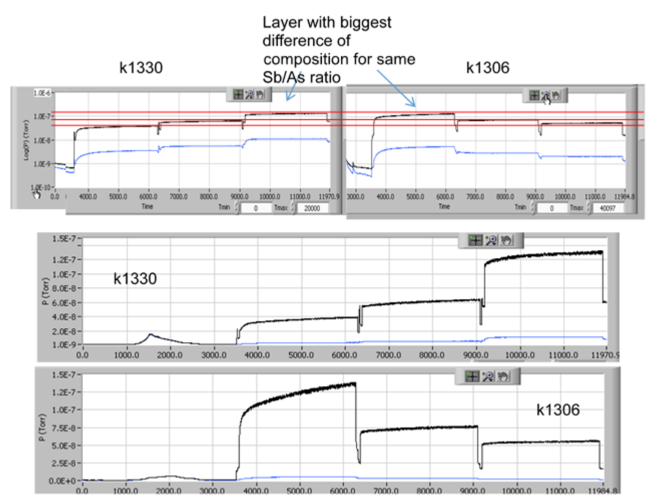

Figure S3. The pressure gauges logged the same overall system pressures vs time corresponding to the same Sb/As ratios.

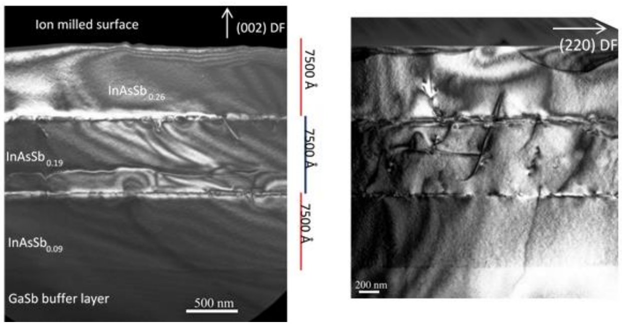

Figure S4. TEM sample k1306 with three compressively strained layers.

Sample k1330 had one compressive layer on the GaSb substrate, followed by two tensile layers. Very low resolution TEM is shown in Fig. S6. The sample relieves strain by cracking. The cracks begin at the second interface (where the structure goes from compressive to tensile) and propagate to the surface. Figure S7 shows a higher magnification bright field image. The compressively strained layer has the dislocations expected for a highly mismatched sample. There also unexpected contrast modulations which may be due to compositional inhomogenities.

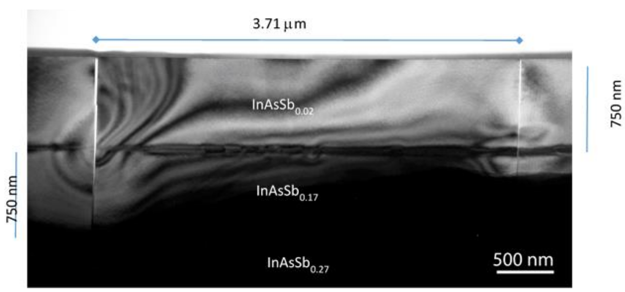

Figure S6 Sample k1330, showing cracking in the tensile InAsSb layers.

Fig S4 shows low-resolution (220) and (002) dark field TEM images of k1306. The defect morphology is consistent with that expected for compressive strain relaxation. The curved lines are thickness fringes. Figure S5 is a high-resolution image of the top layer, with lattice spacings corresponding to the InAsSb of the composition measured by x-ray. Compositional inhomogenities are not observed.

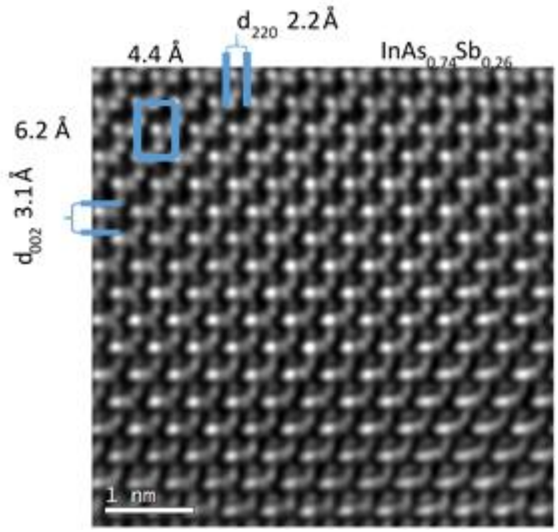

Figure S5. High resolution image of k1306 surface layer.

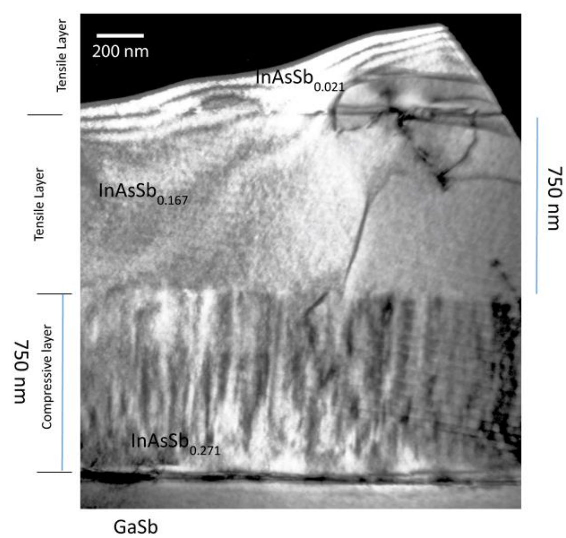

Figure S7. Sample k1330, bright field.