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Examination of the Structural Quality of InAsSbBi Epilayers using Cross Section Transmission Electron Microscopy

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Efficient infrared detection and emission is desired for numerous applications, including navigation, night vision, communications, imaging, spectroscopy, and launch detection. Incorporation of bismuth in InAs alloys results in larger bandgap reduction per unit strain than antimony and provides an efficient means of tuning the bandgap while limiting the level of biaxial strain that can introduce defects that reduce optical quality [1]. Pseudomorphic InAsSbBi grown on GaSb is of interest because it permits the designer to independently adjust bandgap and strain by varying the group-V mole fractions as well as providing improved hole confinement over InAsSb alone. This study describes the TEM characterization of 210 nm thick, pseudomorphic InAsSbBi layers grown under various V/III flux ratios and temperatures ranging from 280°C to 430ºC. The changes in microstructure that result from adjusting the growth conditions are reported. Cross sectional TEM samples are prepared for observation along the <110> projection using standard mechanical polishing and dimple grinding, followed by argon-ion-milling (maximum beam energy 2.5 keV) with liquid-nitrogen cooling to reduce ion-beam damage. The electron microscopy was performed using a FEI CM-200 high-resolution electron microscope with an accelerating voltage of 200kV.

The sample set examined consists of InAsSbBi layers grown at 1) 280 ºC with Bi/In flux ratio 0.065, 2) 400 ºC with Bi/In flux ratio 0.050, and 3) 430 ºC with Bi/In flux ratio 0.100. The sample structure cross-section is inset in Figure 1. The structural quality of growths 1 and 2 is examined using high resolution electron microscopy at low magnification (see Figures 1 and 2). The material is observed to be defect free over large lateral distances. The observation of contrast modulation in Figure 2 indicates the presence of composition inhomogeneity in InAsSbBi grown at the higher growth temperature. The upper interfaces are imaged using high resolution electron microscopy and shown in Figures 3 and 4. The interfaces are observed to be smooth and coherent with no misfit dislocations. The high quality interfaces are confirmed by the presence of Pendellösung fringes in X-ray diffraction measurements over large angular ranges (see Figure 6). For growth 3 at the highest temperature and highest Bi flux, the surface morphology significantly changes via the formation of surface droplets, as observed in the electron micrograph shown in Figure 5 [2].

References:

[1] P. T. Webster *et al,* Appl. Phys. Lett. **111** (2017), 082104.
[2] The authors gratefully acknowledge financial support through the National Science Foundation (NSF) award DMR-1410393 and the Air Force Office for Scientific Research (AFOSR) STTR Phase II grant FA9550-16-C-0021, as well as the use of facilities in the LeRoy Eyring Center for Solid State Science at Arizona State University.

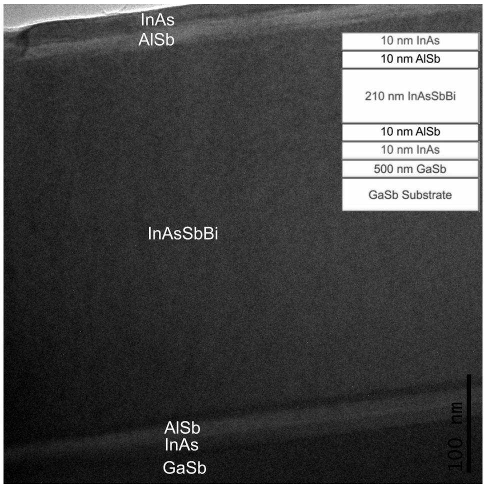

Figure 1. High resolution electron micrograph from sample grown at 280 ºC; cross section inset.

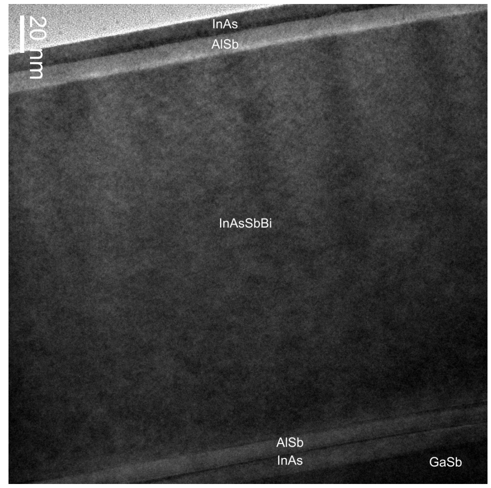

Figure 2. High resolution electron micrograph from sample grown at 400 ºC.

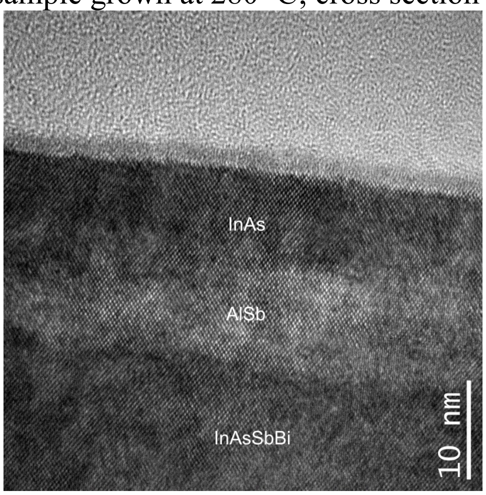

Figure 3. High resolution electron micrograph from top interface of sample grown at 280 ºC.

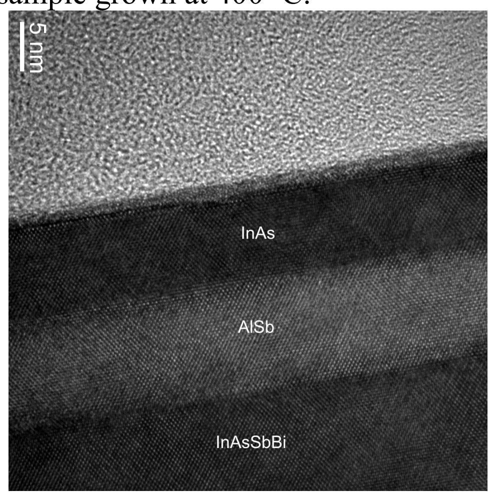

Figure 4. High resolution electron micrograph from top interface of sample grown at 400 ºC.

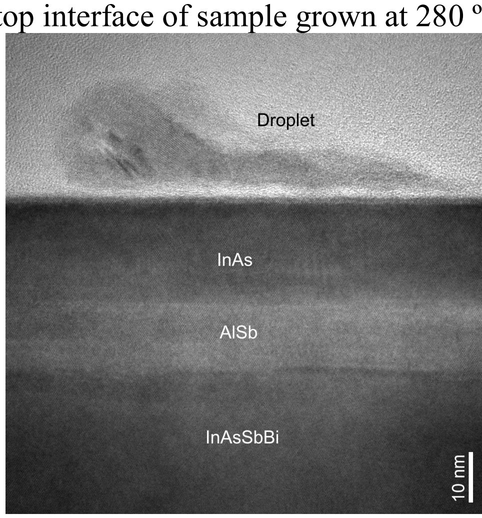

Figure 5. High resolution electron micrograph from sample grown at 430 ºC showing a surface droplet.

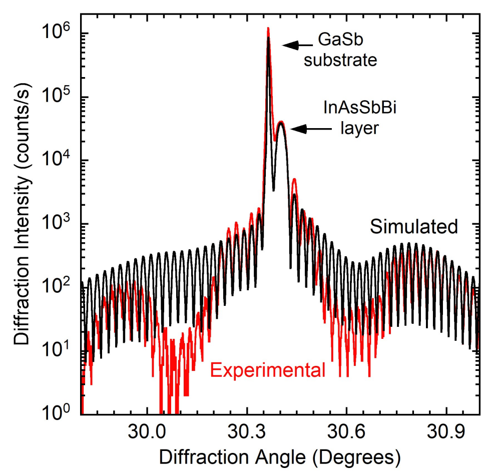

Figure 6. X-ray diffraction pattern from sample grown at 280 ºC.

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