Comparing Droplet Formation and Phase Separation in Post-Saturation GaSbBi and GaAsBi

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III-V semiconductors alloyed with dilute amounts of bismuth have been shown to have dramatically reduced bandgaps, making them well suited for optoelectronic applications in the mid- and far-infrared. Given that GaSb has a bandgap already in the near-IR range (E_g = 0.726 eV), $GaSb_{1-x}Bi_x$ has great potential for pushing out to these long wavelength regimes. Unfortunately, bismuth tends to surface segregate and form droplets at sufficiently high Bi flux rather than incorporate into the growing film. The highest Bi content $GaSb_{1-x}Bi_x$ reported to date had x=0.14, and only x=0.11 has been achieved without droplets forming on the film surface [1]. We have recently observed that droplets are also likely to form upon reaching some critical thickness for a given Bi content in GaAsBi films, and these droplets can lead to significant lateral and vertical phase separation in the GaAsBi system.

We have found the solubility of Bi in GaSb to be different than the solubility of Bi in GaAs. The same Bi flux that leads to x=0.0315 in $GaAs_{1-x}Bi_x$ (grown at 250°C) leads to negligible Bi incorporation in GaSb(Bi) (grown at 285°C). A comparison of the GaSb(Bi) and GaAsBi surfaces is shown in Fig. 1. This work seeks to determine the effect of increasing bismuth flux and film thickness on surface morphology and film homogeneity in GaSbBi films as compared to GaAsBi. Samples were grown on GaSb substrates in a Veeco GENxplor MBE system using a valved Sb cracker and solid source effusion cells for Ga and Bi, with growth monitored in-situ via RHEED. Bismuth content was determined via HRXRD and confirmed for select samples with Rutherford backscatter spectrometry. The presence/absence of droplets was determined via optical microscopy and SEM imaging, while cross-sectional film homogeneity and phase separation was examined via TEM.

[1] O. Delorme, L. Cerutti, E. Tournie, J.-B. Rodriguez. *J. Cryst. Growth*, **447** (2017)

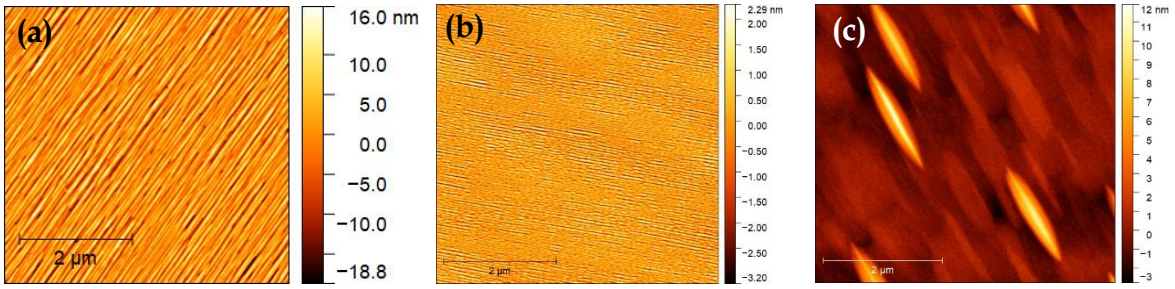

Fig. 1 – AFM scans of (a) GaSb grown without Bi present, giving an RMS roughness of 4.8 nm; (b) GaSb(Bi) grown with Bi:Ga = 0.156. Sample shows negligible Bi incorporation via XRD, but displays a significantly smoother surface than (a) with RMS roughness of 0.77 nm, implying bismuth acted as a surfactant at this low concentration; (c) GaAsBi sample with to same Bi:Ga flux ration (0.16) as (b). However, unlike (b), film has a measured Bi fraction of x=0.0315, and shows no smoothing effect (RMS roughness = 1.58 nm with larger islands present).

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