Growth and Optimization of Opto-electronic performance of InGaAsSb Photodetectors using Molecular Beam Epitaxy

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The quaternary alloy, $In_xGa_{1-x}As_ySb_{1-y}$, grown lattice-matched to GaSb substrates, is a promising alternative to extended InGaAs for Short-Wave Infrared (SWIR) detection due to its tunable wavelength range from 1.7 µm to 3 µm. This flexibility is essential for advanced imaging and sensing applications, positioning InGaAsSb as a key material for next-generation infrared devices. However, GaSb based devices often face challenges such as high background doping and surface leakage. To mitigate these issues, various growth techniques and device architectures, including unipolar barrier designs, have been explored in the literature. Developing an optimal InGaAsSb-based structure requires a comprehensive understanding of the material's properties and key device performance metrics [1]. This work presents the molecular beam epitaxial (MBE) growth and characterization of the nominal composition $In_{0.29}Ga_{0.71}As_{0.25}Sb_{0.75}$ on a GaSb substrate. The growth temperature was estimated to be in the range of 450°C–460°C. Reflection High-Energy Electron Diffraction (RHEED) patterns confirmed that the InGaAsSb layer grows with a (4×2) surface reconstruction. Following MBE growth, the surface and structural properties of the alloy were characterized using high-resolution X-ray diffraction (HR-XRD), atomic force microscopy (AFM), Nomarski imaging, and photoluminescence (PL). Two structures were fabricated: a bulk structure with a 500 nm thick InGaAsSb layer and a homojunction p-i-n structure with a 1 µm thick intrinsic layer. The bulk InGaAsSb exhibited a lattice mismatch of 0.164% and a surface roughness of 1.02 A, indicating good crystalline quality. The PL peak was observed at approximately 2.33 µm. However, HR-XRD scans of the p-i-n structure revealed evidence of spontaneous superlattice formation in the active region, which is currently under investigation. This behavior may be attributed to growth near the miscibility gap (x~0.3). PL measurements showed no detectable peak shift despite the presence of the superlattice. Ongoing studies focus on optoelectronic properties like minority carrier lifetime and background doping to assess the superlattice's impact on performance.

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Supplementary figures:

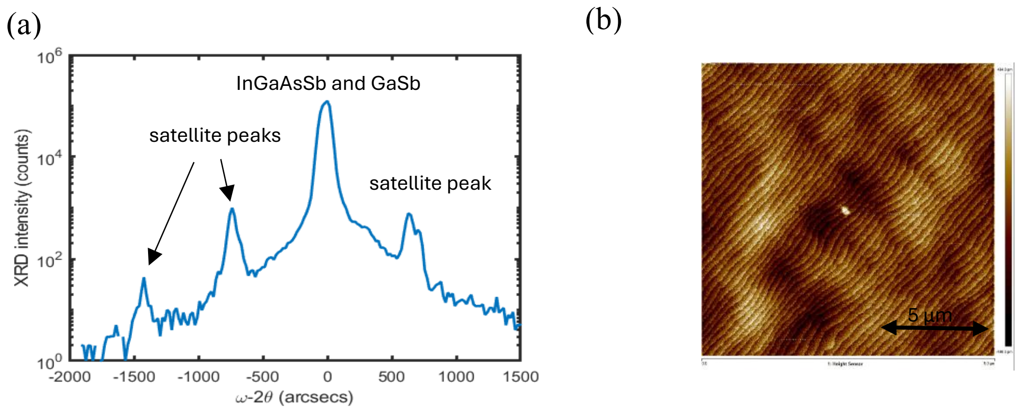

FIG. 1. (a) HR-XRD of the InGaAsSb p-i-n structure, (b) AFM of the InGaAsSb p-i-n structure.