Asymmetric-Strained InGaAs/GaAsSb Type-II Superlattice Photodiodes for SWIR detection

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The detection of short wavelength infrared (SWIR) optical signals (1-3 µm) is important for sensing applications including remote greenhouse gas monitoring and Light detection and ranging (LiDAR). Commercial SWIR detectors are based on HgCdTe or extended-InGaAs (ex-InGaAs). The former has relatively high costs, requires cryogenic operating temperatures, and faces increasing restrictions on the use of Hg and Cd. Ex-InGaAs photodiodes exhibit competitive dark current densities, but they do not fully cover the SWIR range with a cut-off wavelength of 2.65 um.

InGaAs/GaAsSb Type-II superlattices (T2SL) can be grown lattice matched to InP. T2SLs offer flexibility in the cut-off wavelength, across the SWIR range, by tailoring the well (InGaAs) and barrier (GaAsSb) thicknesses. They can be grown using conventional III-V growth techniques. Characteristics of symmetric and lattice-matched T2SL photodiodes, including cut-off wavelengths [1] and absorption profiles [2], have been successfully modelled using Nextnano, a simulation tool for semiconductor nanostructures. In this work, we report Nextnano simulations to assess if the cut-off wavelength of T2SL photodiodes can cover the SWIR region fully, by using asymmetric-strained T2SL designs.

The validation used an asymmetric 5nm/3nm InGaAs/GaAsSb T2SL which was grown by MBE on n+ InP substrate. X-ray diffraction (XRD), shown in Fig. 1, was performed to check material composition and T2SL period. Mesa diodes were fabricated from the wafer to facilitate temperature dependence measurements of dark current and cut-off wavelength. The experimental results were used to validate the Nextnano simulation tool. Further simulations were carried out for other InGaAs/GaAsSb T2SL designs, including the incorporation of barrier strain, as shown in Fig. 2 below. Simulation results show cut-off wavelengths between 1.8 and 3 µm can be achieved, with increasing wavefunction overlap for lower Sb composition.

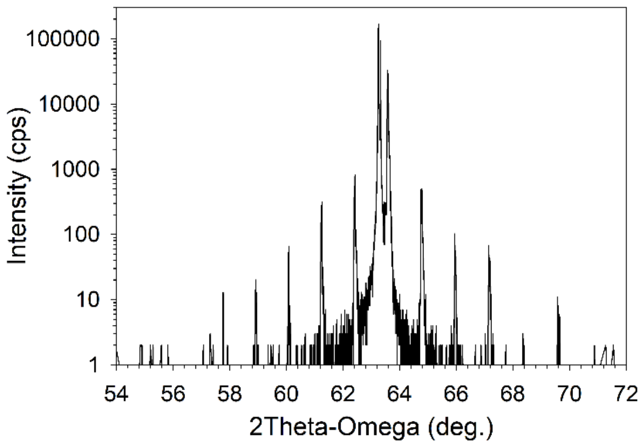

Figure 1: XRD of a strained 5nm/3nm InGaAs/GaAsSb T2SL.

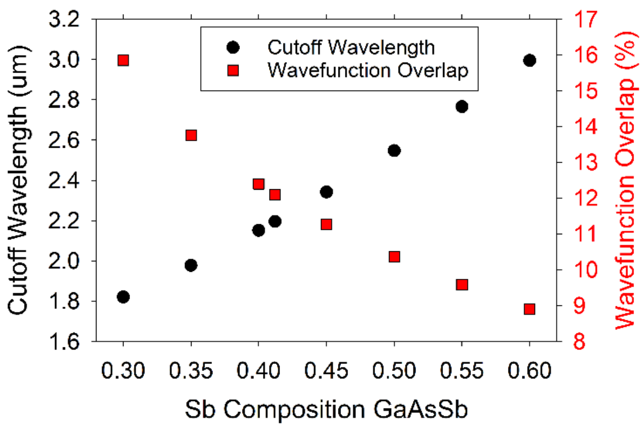

Figure 2: Simulated room temperature cut-off wavelength and wavefunction overlap versus GaAsSb composition on 5nm/3nm InGaAs/GaAsSb T2SL.

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References: [1] Y. Uliel *et al.*, *Infrared Phys. Technol.*, **84**, pp. 67-71. 2017., [2] J. Easley *et al.*, *J. Electron. Mater.*, **48**(10), pp. 6025-6029, 2019.