Type II InAs/GaSb/AlSb superlattice photodiodes for shortwavelength infrared detection

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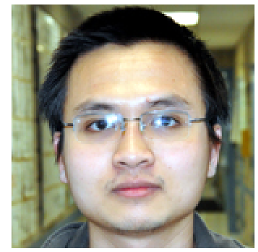
BIOGRAPHY



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TECHNICAL ABSTRACT

One of the requirements of the third generation infrared imager is multiple spectral detections with wider bandwidth. With unique advantages over thermal and visible band owning to its ability to offer infrared radiation detection in both active and passive modes, the shortwavelength infrared (SWIR) band finds its applications in many important sectors. Combining SWIR and longer regimes are of particular interest since SWIR regimes enables imaging conditions close to visible perspective while a longer detection channel operates in passive mode with no additional illumination. Type II superlattice (SL) [1] has been proving itself as good candidate for mid-wave to very long wavelength infrared detections with comparable performance to the state-of-the-art technologies [2-4]. However, in the SWIR regime, Type II SL detectors haven't been able to achieve great performance. In this work, we presented strategies to overcome design and material growth challenges and demonstrated high performance SWIR detector based on Type II SL.

From the great tunability of the M-structure[5] SLs, a new material structure matched to GaSb substrate was proposed and experimentally demonstrated for the SWIR detection. By reducing the InAs and GaSb layer thicknesses and using a thick AlSb layer, we have been able to create high quality material capable of operating at the SWIR regime. As shown in fig 1, due to its high carrier effective mass and high energy band gap, the AlSb layer plays a significant role in changing the band structure of both conduction band and valence band, resulting in a high band gap for SWIR absorption. Different M-structure based designs for SWIR absorbing layer were proposed and calculated using the empirical tight binding modeling (ETBM). With guaranteed lattice match condition, these M-structure SLs would be able to theoretically go down to a cut-off wavelength as short as 1.5 μm.

N-i-p homojunction with superlattice design aiming for 2 μm cut-off wavelength was grown on an n-type (001) GaSb substrate using the state-of-the-art Molecular Beam Epitaxy (MBE). The structural characterizations using Atomic Force Microscopy (AFM) and High resolution X-ray diffraction (HRXD) showed excellent material quality. The surface roughness was 1.12 Å over a $5x5\mu m^2$ area whereas the X-ray exhibited high ordered diffraction peaks with full width at half maximum at zero order of ~44 arcsec and the mismatch of only 480ppm. From this material, mesa-photodiodes were fabricated and characterized. Shown in Fig 2 and 3 are the electrical and optical performance of the sample as a function of temperatures. At 150 K, the photodiodes exhibited a dark current density of 5.6×10^{-8} A/cm^2 and a front-side-illuminated quantum efficiency of 40.3%, resulting in an associated shot noise detectivity of 1.0×10^{13} Jones. With a dark current density of 2.2×10^{-3} A/cm^2 and a quantum efficiency of 41.5%, the photodiodes can operate at room temperature.

The research extended the detection range of the GaSb based type-II SL material system and opened the possibility of incorporating the SWIR channel to multispectral detection and imaging.

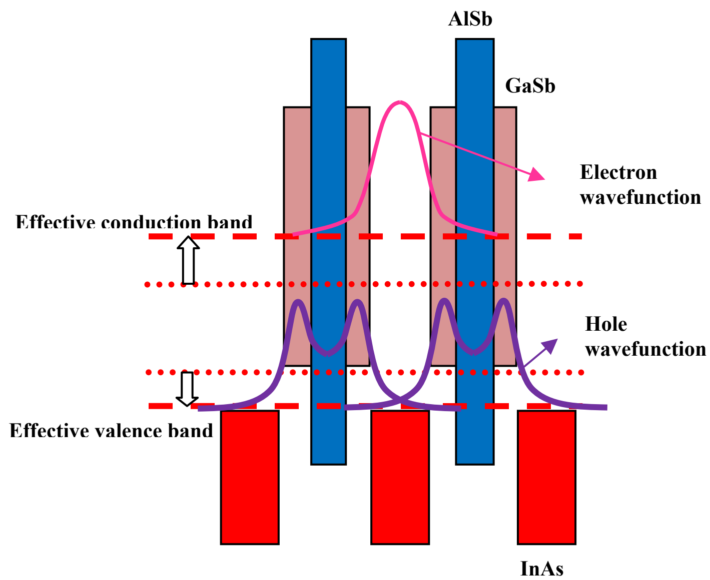

Figure 1: M-structure superlattice and the creation of effective band gap. Colored rectangles represent the prohibited band gap of the materials

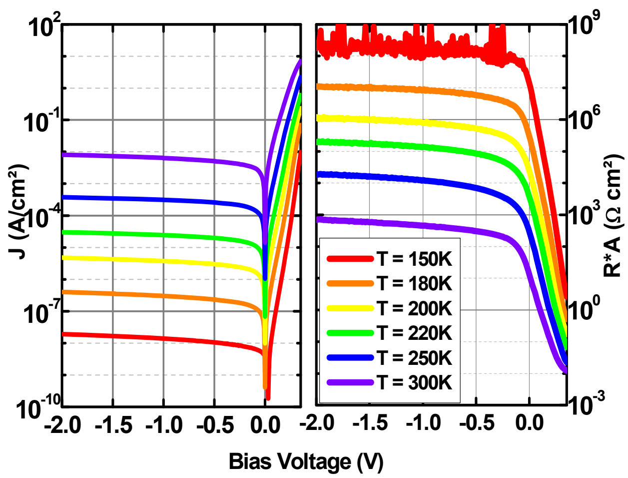

Figure 2: I-V characteristics as a function of temperatures

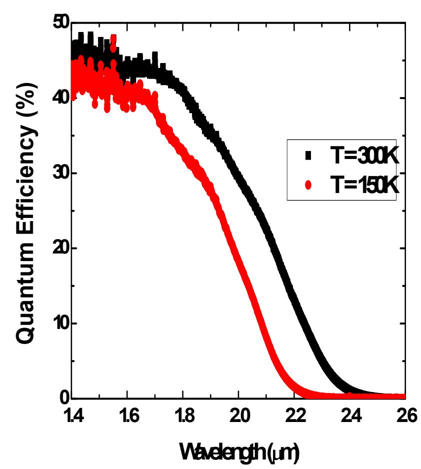

Figure 3: Quantum efficiency at 150K and 300K

Keywords: Shortwavelength infrared, Type II, M-structure, photodiodes, multispectral detection

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