Electrical and Optical Studies on InAs/InGaSb VLWIR Superlattices

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BIOGRAPHY

Gail J. Brown: Principal Physicist with the Electronics and Optical Materials Branch of the Materials and Manufacturing Directorate of the Air Force Research Laboratory. Dr. Brown has worked on developing semiconductor materials for infrared detector applications since 1980. Dr. Brown is the program manager for very long wavelength infrared detector materials and for quantum semiconductor materials. In addition she leads a team of researchers studying the epitaxial growth, theoretical modeling and property characterization of InAs/Ga(In)Sb superlattice materials for infrared detector applications. Dr. Brown has co-authored over 200 journal articles and proceedings papers and given numerous invited talks. She has chaired and co-chaired over 25 conferences and symposia on topics covering a variety of areas such as photodetectors, quantum sensing, semiconductor nanostructures for electronics and optoelectronics, and metamaterials. Dr. Brown is an Air Force Research Laboratory Fellow, A Fellow of the International Society for Optical Engineering and a Fellow of the American Physical Society. Her outstanding contributions in fundamental scientific studies earned her the USAF Basic Research award in 2002.

TECHNICAL ABSTRACT

InAs/InGaSb superlattice (SL) materials are an excellent candidate for infrared photodiodes with cut-off wavelengths beyond 15 µm, i.e. in the very long infrared wavelength (VLWIR) range. There are relatively few options for high performance infrared detectors to cover wavelengths longer than 15 µm, especially for operating temperatures above 15K. There are a variety of possible superlattice designs that will cover the VLWIR wavelength range, including designs with and without indium alloying of the GaSb layers. Transport modeling has shown that alloy scattering should not be a dominant factor in these superlattices so our focus is on designs with 25% indium in the gallium antimonide to achieve energy band gaps less than 50 meV with a superlattice period on the order of 68 Å. Similar to the work reported on InAs/GaSb LWIR and VLWIR superlattices, our designs employ InGaSb layers less than 7 monolayers in width. While the superlattice designs are strain balanced to the GaSb substrate, care was also taken to minimize strain spikes in the interfacial regions. High resolution transmission electron microscope images were analyzed to create strain mapping profiles of the SL layers and interfaces. By focusing on a narrow set of VLWIR SL designs, the deposition parameters for the molecular beam epitaxial SL growth could be carefully optimized.

The electrical and optical properties of the VLWIR superlattices were characterized by both variable temperature and variable magnetic field Hall Effect measurements and by infrared photoresponse spectra. The photoresponse spectra consistently showed a band gap energy of 47 ± 3 meV for the samples studied and a cut-off wavelength at ~ 19 µm at the point where the intensity has dropped by 50% (see Fig 1). The repeatability of these very narrow band gap superlattices over multiple sample depositions, and while some growth parameters were being adjusted, shows the tight control obtainable with molecular beam epitaxy. The narrow band gap designs are very sensitive to small changes in layer widths. The variable temperature Hall effect measurements found that the mobility of electrons in the SL was ~10,000 cm²/Vs below 70 K and was relatively constant in magnitude (see Fig 2). Variable magnetic field results were used to further understand the temperature dependence of the mobility. Additional sample results and modeling of vertical transport in superlattices will be presented.

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Photoresponse (arb. units)

Energy (meV)

Fig. 1 VLWIR superlattice photoresponse spectrum

Fig. 2 VLWIR suprelattice mobility vs. temperature

**Keywords:** Superlattice, InAs/InGaSb, infrared detection, very long wavelength