Type-II Superlattice Infrared Detectors

Naval Research Laboratory nrl.navy.mil

At a Glance

What is it?

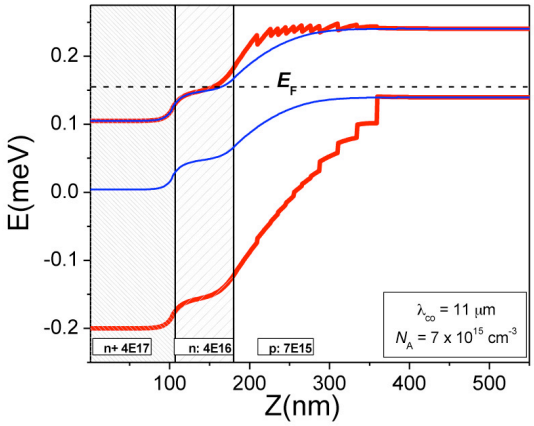
NRL is using bandstructure Engineering with III---V Materials grown on GaSb Substrates to develop. The next generation of high performance infrared (IR) sensors.

How does it work?

III---V based type---II superlattices and bulk alloys lattice matched to 6.1 Å GaSb substrates yield direct bandgap semiconductors with strong absorption over the key IR imaging bands. The key advantage is the large range of band gaps and band--alignments that are available in the 6.1 Å family, which allows for tailoring of the bandstructure to lower dark current.

What will it accomplish?

Lowering dark current using 6.1 Å materials will allow for higher operating temperature and reduced cooling needs, lowering the size weight and power of the overall imaging system. This will help to enable the use of high performance IR imaging systems on low payload weight platforms such as satellites.



NRL is using bandstructure engineering with III-V materials, alloys and superlattices to develop the next generation of high performance infrared (IR) sensors for demanding imaging application is the 3-16 micron wavelength range. Direct bandgap semiconductors with strong absorption over most of the key bands for IR imaging can be synthesized using antimonide based alloys and type-II superlattices lattice matched to 6.1 Å GaSb substrates. A big advantage over material systems currently in use is the much larger range of band gaps and band-alignments that are available in the 6.1 Å family. This allows for tailoring of the band-structure to suppress dark current, such as by gradually increasing the bandgap from the IR absorber, to lower generation within the photodiode junction without impeding the flow of photo-generated minority carriers.

For high performance applications, IR imagers must be cooled to reduce thermally generated dark current (noise) that competes with the photo-generated signal. Typically this is done using heavy, power-intensive cryo-coolers. Using 6.1 Å materials can allow for higher operating temperature, greatly lowering the size, weight, and power of the overall imaging system. This is an essential part of the enabling technologies necessary to get the highest performance IR imaging systems on critical low payload weight platforms such as satellites and unmanned aerial vehicles.

Research Challenges and Opportunities

- Reducing high rates of Shockley-Read-Hall recombination.
- Surface passivation

List of Publications:

Aifer, E. H., J. H. Warner, et al. (2010). "Shallow-Etch Mesa Isolation of Graded-Bandgap "W''-Structured Type II Superlattice Photodiodes." Journal of Electronic Materials **39**(7): 1070-1079.

Canedy, C. L., E. H. Aifer, et al. (2009). "Controlling dark current in type-II superlattice photodiodes." Infrared Physics & Technology **52**(6): 326-334.

Jackson, E. M., E. H. Aifer, et al. (2010). "Radiation Damage in Type II Superlattice Infrared Detectors." Journal of Electronic Materials **39**(7): 852-856.

Nolde, J. A., R. Stine, et al. (2011). Effect of the oxide-semiconductor interface on the passivation of hybrid type-II superlattice long-wave infrared photodiodes. Quantum Sensing and Nanophotonic Devices Viii. M. Razeghi, R. Sudharsanan and G. J. Brown. **7945**.

Vurgaftman, I., C. L. Canedy, et al. (2011). "Analysis and performance of type-II superlattice infrared detectors." Optical Engineering **50**(6).

Yakes, M. K., S. B. Qadri, et al. (2012). "Combined cross sectional scanning tunneling microscopy and high resolution x-ray diffraction study for quantitative structural descriptions of type-II superlattice infrared detectors." Applied Physics Letters **101**(24).