Workshop on Epitaxial Growth of Infrared Materials
Room Cummings Ballroom - Session WEG1-SuM

Workshop on Epitaxial Growth of Infrared Materials: IR Superlattices I
Moderator: Stephanie Tomasulo, U.S. Naval Research Laboratory

8:45am **WEG1-SuM-1 Welcome & Sponsor Thank Yous*,***

9:00am **WEG1-SuM-2 A Brief Review of InAs/InAsSb Type-II Superlattice: Its Electronic Properties and Applications in IR Photodetectors*, Yong-Hang Zhang,*** Arizona State University **INVITED**

The study of InAs/InAsSb T2SL on GaSb and its application to IR lasers and photodetectors was started in the early 90's. The observation of a 412 ns long carrier lifetime in a long-wavelength infrared (LWIR) InAs/InAsSb T2SL in 2011 triggered extensive research on the fundamental materials properties and device applications worldwide. Pressure-dependent photoluminescence experiments revealed some underlying material physics of these long carrier lifetimes. Its applications in devices, such as nBn, C-BIRD, and PIN photodetectors, and their commercialization have also achieved impressive accomplishments. Many of these devices are currently used in real applications and available commercially.

9:30am **WEG1-SuM-4 MBE Based Superlattice Photodetectors*, Philip Klipstein,*** Semiconductor Devices, Israel **INVITED**

Type II superlattices (T2SLs) based on layers of InAs and GaSb are ideal for absorbing photons in the high transmission long-wave and mid-wave infrared (LWIR and MWIR) windows of the atmosphere. They provide a useful and easier alternative to the legacy HgCdTe infrared material.

Before 2000, all high end MWIR and LWIR photodetectors were based on a simple photodiode architecture. This began to change in 2003 with the invention by the author of XB*n* and XB*p* barrier detectors, based on *n*-type and *p*-type photon absorbing materials respectively. The nearly lattice matched family of InAs/GaSb/AlSb has a unique arrangement of band offsets which allows the engineering of a tall barrier for majority carriers while minority carriers remain unobstructed. The depletion layer is confined completely within the wide bandgap barrier material, leading to suppression of the Generation-Recombination contribution to the dark current. Hence MWIR focal plane array (FPA) detectors based on InSb and traditionally operating at around 80K started to be superseded by XB*n* FPAs which operate between 120-150K. In the LWIR, XB*p* FPAs exhibit excellent and stable image quality, providing a realistic alternative to HgCdTe. The FPA resolution has also increased, with pitches today down to 5μm and formats up to 5 Megapixel in the MWIR.

A major effort has gone into T2SL band-structure simulation, based on an extended version of the **k·p** model. The quantum efficiency and diffusion limited dark current of a detector can also be simulated, agreeing well with experiment. Significant differences with bulk materials have been found, such as an intrinsic carrier concentration for a given band gap that has a weak dependence on the T2SL period and a high sensitivity of the XB*p* dark current to the acceptor binding energy. Holes and electrons are on opposite sides of the metal/insulator transition, which has a strong influence on detector design.

Finally, an intriguing aspect of type II InAs/GaSb quantum wells is that they can exhibit the quantum spin Hall effect at low temperatures, where the current flows only along the sample edges and is both quantized and spin polarized. Topological properties tend to be associated with infrared materials because both involve atoms of high atomic number. In the first case a high atomic number imparts a large spin-orbit coupling which is necessary for robust topological properties, and in the second, it reduces the semiconductor band gap to a value that matches the infrared photon spectrum.

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