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From the Editor's Desk

Infrared (IR) Detection technology has major applications in defence such as ground based night vision systems, missile tracking systems, IR countermeasures, range finders, mine detection etc. The technology is one of the most challenging and complex in recent developments of strategic nature. Today most of the military aircrafts are equipped with high performance IR cameras. Apart from this, the technology has many civilian applications in space, medical, astronomy, surveillance, search & rescue, meteorology, climatology etc.

The two main types of IR detectors are thermal and photon detectors, among which, photon IR detectors have high performance but high cost. The early detectors were based on lead sulphide, lead telluride etc. while current detectors have mercury cadmium telluride (MCT) and AlGaAs/GaAs quantum wells. The future of infrared detectors will mostly depend on the development of technologies around quantum dot infrared photodetectors (QDIPs) and Type-II superlattice structures in addition to current materials like MCT and QWIPs. Among the advantages of these material systems, the possibility of large infrared range by virtue of bandgap tailoring. Also, the future IR sensor technology will have photodetectors integrated with highly effective smart algorithms. Advanced growth and fabrication process developments will lead to realization of multi-color IR sensors.

In this issue, we present the recent experimental work at SSPL on development of IR detectors based on T2SL, which includes growth of these superlattice layers and their characterization.

- Kamal Lohani, SSPL Delhi

Executive Committee of SSI

Type II strained Layer superlattices (T2SL) for next generation IR detection

The current third generation infrared photon detectors, which provide enhanced capabilities like large number of pixels, higher frame rates, better thermal resolution as well as multi-colour functionality and other on-chip functions have been based on HgCdTe, Quantum Well (QWIPs) or Quantum Dot (QDIP) based structures. IR sensors based on a new type of material known as type II strained layer superlattice (T2SL) structure are predicted to overcome several difficulties posed by these materials and demonstrate better performance.

These are artificially engineered materials consisting of hundreds of alternate thin layers of InAs and GaInSb/GaSb with perfect interfaces and a unique type-II band alignment, which allows the band gap to be controlled entirely by the thickness of the constituent layers. The preferred technology to achieve this is Molecular Beam Epitaxy (MBE), by which perfect crystalline layers of materials with different composition or doping can be grown with atomic level resolution.

Work has started recently at SSPL, Delhi to develop IR detectors based on T2SL. A MBE system was installed recently for the growth of the T2SL based detector structures. The key to T2SL based IR detector technology is growth of several microns thick perfect strain balanced superlattice layers, which act as the active component of the detector structure. There are several challenges needed to be overcome to achieve this such as controlling interface abruptness, perfect strain balancing through interface engineering to avoid defects, controlling segregation issues and group III and V atoms intermixing. Tight control over the growth conditions is paramount in achieving the desired specifications. Schematic of a basic undoped T2SL structure grown in SSPL using MBE is shown in Figure 1.

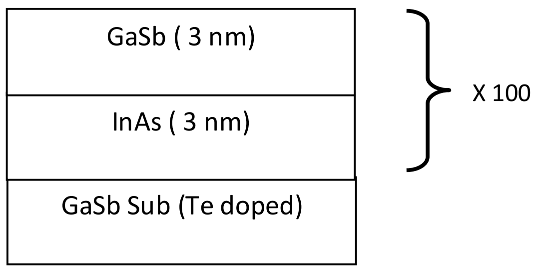

Figure 1: Schematic of a standard T2SL layer

The structure consists of a 100 period strain balanced InAs (3 nm)/GaSb (3 nm) layer on (100) oriented Te-doped GaSb substrate. The grown sample has mirror finish surface and excellent morphology as seen by Atomic Force Microscope (AFM) in Figure 2.

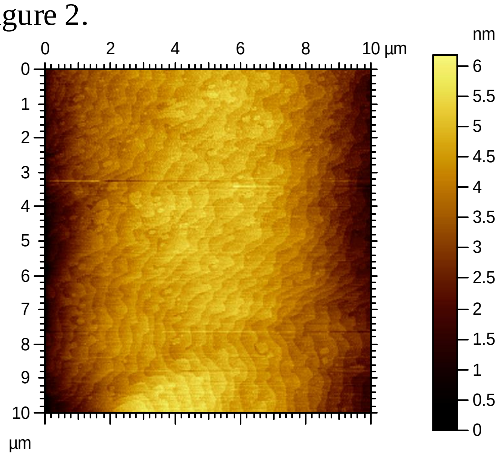

Figure 2: Atomic Force Microscopy image of a 100 period InAs/GaSb Superlattice layer

High resolution X-Ray Diffraction (HRXRD) FTIR and the AFM results are also shown in Figure 3 and 4 indicating excellent sample quality, which is comparable to the best reported results worldwide.

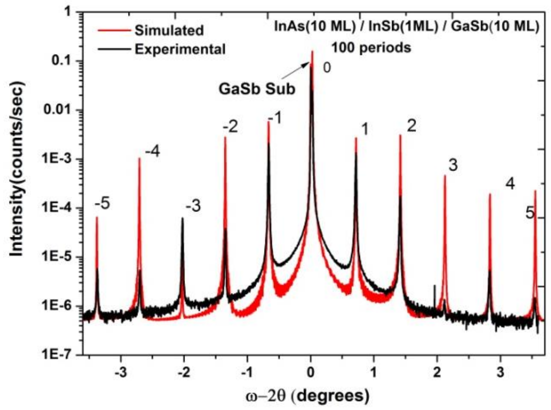

Figure 3 High Resolution X-Ray Diffraction of a 100 period InAs/GaSb Superlattice layer

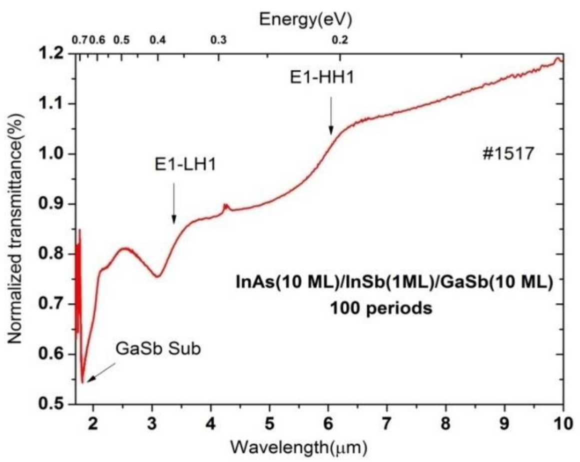

Figure 4. Normaized Transmittance in a 100 period InAs/GaSb Superlattice layer

Complete detector structures having a bariode type design (involving a barrier layer to reduce dark current), which is preferred due to better performance and availability of materials with nearly similar lattice constants and large difference in band offsets have also been successfully grown. The complete detector structure consists of a thick active layer, contact layers and an AlGaSb based barrier layer. The individual layers for the entire detector structure were calibrated by thorough characterization using various techniques.

Dr. Pushpashree Mishra

Recent News/Events in Semiconductors

1. Historically, high-performance infrared (IR) detectors have been fabricated out of materials such as InSb or HgCdTe. These semiconductors have material properties that are isotropic, e.g., the hole mobilities along the in-plane and growth directions are equal. However, IR absorbing materials with anisotropic material properties, such as type-II superlattice (T2SL) materials, based on InAs/GaInSb or InAs/InAsSb, have become increasingly prevalent. Specifically, the hole mobility is much larger along the in-plane direction than the growth direction, which directly impacts detector performance. The impact of utilizing T2SL materials with anisotropic material properties is assessed by simulating the crosstalk and modulation transfer function (MTF) in sequential two-color MW/LW T2SL focal plane arrays. The MTF is a key figure of merit (FOM) in all cameras which describes how well an optical system reproduces an object's contrast in the image at different spatial frequencies. The detector MTF depends on numerous parameters, especially material

transport parameters such as the mobility, and as such the MTF is sensitive to the mobility anisotropy. This dependence, and the MTF already being a valuable FOM, makes the MTF a natural metric to assess the impacts of adopting an absorbing material with anisotropic material properties. (IEEE Transactions on Electron Devices, Volume: 66 , Issue: 3 , March 2019)

2.Visible/extended shortï wavelength infrared photodetectors with a bandstructureï engineered photoï generated carrier extractor based on typeï II InAs/AlSb/GaSb superlattices have been demonstrated. The photodetectors are designed to have a 100% cut-off wavelength of ~2.4 εm at 300K, with sensitivity down to visible wavelengths. The photodetectors exhibit roomï temperature (300K) peak responsivity of 0.6 A/W at ~1.7 εm, corresponding to a quantum efficiency of 43% at zero bias under frontï side illumination, without any antiï reflection coating where the visible cutï on wavelength of the devices is <0.5 µm. With a dark current density of 5.3×10^{ï4} A/cm^2 under ï 20 mV applied bias at 300K, the photodetectors exhibit a specific detectivity of 4.72×10^{10} cm·Hz$^{1/2}$/W. (Arash Dehzangi *Et al. Scientific Reports,* volume 9, Article number: 5003 (2019))

3. Scientists at the National Institute for Materials Science (NIMS) in Japan have succeeded for the first time in visualising at the nanoscale the distribution and optical behaviour of GaN implanted with a small amount of magnesium. They believe this may help in improving electrical performance of GaN based devices. They have also revealed some of the mechanisms by which introduced expedite the identification of optimum conditions for magnesium implantation vital to the mass production of GaN power devices. The results of this research have provided vital guidance for the development of ion-doped p-type GaN layers. The use of these techniques may therefore speed the development of high-performance GaN devices.
The results have been published online in Applied Physics Express on April 2019. magnesium ions convert GaN into a p-type semiconductor.

Forthcoming Conferences:

1. **The International Conference on emerging advancement in Science and technology and 10th India-Japan Science and Technology Conclave** will be organized jointly by Indian JSPS Alumni Association (IJAA) and Solid State Physics Laboratory (SSPL) Delhi during Sep 5th-6th 2019 at New Delhi, India. The details of the conference are available at www.iceast2019.com

2. ***20th International Workshop on the Physics of Semiconductor Devices (IWPSD)***, will be organized by SN Bose National Center for Basic Sciences during December 16-20, 2019, at Kolkata. Prof. S. K. Ray is the Chairman for this edition of the workshop. The details about the workshop can be seen at ***http://newweb.bose.res.in/Conferences/IWPSD2019/***