Semiconductor News

A quarterly publication of the Semiconductor Society (India), www.ssindia.org.in

June 2017

From the Editor's Desk

We are happy to present the third issue of Semiconductor News, an e-newsletter of SSI. In the last issue, the work on vertical standing GaN nanorods based Schottky diodes was reported. GaN is a promising material for power electronics and optoelectronic devices. Recently IIT Delhi and SSI organized a workshop on growth and fabrication of GaN based electronic and optoelectronic devices where scientists from premier institutions and laboratories presented their research work. This year SSPL (DRDO) and IIT Delhi will jointly organize 19th International Workshop on Physics of Semiconductor Devices (IWPSD), which will be a golden opportunity for researchers and scientists to present their work and exchange ideas in the field of semiconductor materials and devices.

In the quest for smaller, faster and energy efficient devices, semiconductor industries are moving towards new device architecture. As the process technology continued towards lower dimensions, it became very difficult to achieve proper scaling of various device parameters. This trade off became unacceptable with very low dimensions. This led to changes in conventional planar device architecture of transistors towards FinFET. The main characteristic of the FinFET is that it has a conducting channel wrapped by a thin semiconductor ófinô. The channel length of device is determined by thickness of the fin. The advantages are channel quantization, reduced short channel effects, high transconductance, high switching speed, low power consumption and many more. The state of the art 10nm node FinFET is already being produced and research is under progress on 7nm node. One of the major challenges for this node is lithography even if we use extreme ultraviolet lithography technique.

In this issue the current trends in infrared imaging detectors are highlighted. The semiconductor based Infrared technology has key applications in security, defence and space. We further invite the members to contribute the scientific writings about Semiconductor research and related activities in their organization to this newsletter.

Kamal Lohani

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Editorial Board

Current Trends in Infrared Imaging Detectors

Infrared detectors not only provide the capability of seeing in reduced visibility due to dark, dust or haze but also serve in a wide variety of important military applications, such as strategic surveillance, thermal weapon sights, aircraft navigation/piloting, fire control, naval self-defense, missile guidance, air-defence systems etc. Other than military applications, these detectors are also employed in several medical, industrial, astronomical, communication and various other civilian applications.

There are some important IR wavelength bands in which the atmospheric absorption is less and radiations can travel to large distances, of the orders of a few kilometers to a few tens of kilometers, without being much attenuated. These bands are near infrared (NIR, 0.7 ï 1.1 µm), short wave infrared (SWIR, 1.5 ï 1.7 µm and 2.0 ï 2.4 µm), medium wave infrared (MWIR, 3 ï 5 µm), long wave infrared (LWIR, 8 ï 12 µm) and very long wave infrared (VLWIR, 14 ï 30 µm). SWIR band is mainly used for low-light level detection in active mode which is based on reflected radiations aided with the significant atmospheric night glow. It provides clearer images and is useful in friend-and-foe detection. MWIR and LWIR radiations are useful in passive thermal imaging of the objects. LWIR is used for imaging terrestrial objects, human/animal body etc., whereas MWIR is used for detection, recognition and identification of high temperature objects such as battle tanks, missiles etc. The VLWIR band is important for strategic missile defense system where a cold object needs to be detected in low background outside the atmosphere.

Infrared detectors are classified as thermal detectors and photon detectors based on the mode of operation. The photon IR detectors in MWIR and LWIR bands are usually cryogenically cooled, whereas thermal detectors need some cooling / heating only for thermal stabilization. Thermal detectors are characterized by slow response time whereas photon detectors exhibit faster response times. Photon detectors can be either photoconductive or photovoltaic. Among various materials that are being used in photon detection, InSb (3-5 µm) and HgCdTe (3-5µm and 8-12 µm) are leading contenders. HgCdTe is preferred over InSb as it has adjustable band gap from 0.7-25 µm with high absorption coefficient.

The photon detection based infrared imaging began with the single photoconductive detector. An array of linear photoconductive detectors was termed as first generation Infrared detectors. Due to limit on the number of detectors available for image detection in first generation detectors, photovoltaic detectors came into existence in mid1970s. The second generation IR detectors are based on photovoltaic mode which use p-n junction to generate photo-voltage. The photovoltaic detection is preferred due to advantage in gain by having large number of pixels (array of detectors) and high sensitivity. The photovoltaic detectors can be configured in two types depending upon the combination of detector with read out integrated circuit (ROIC) ï monolithic or hybrid. In hybrid configuration a detector array is coupled with an ROIC for signal processing and multiplexing on the focal plane to capture the image. The configuration of a typical hybrid IR focal plane array (IRFPA) is shown in Fig.1.

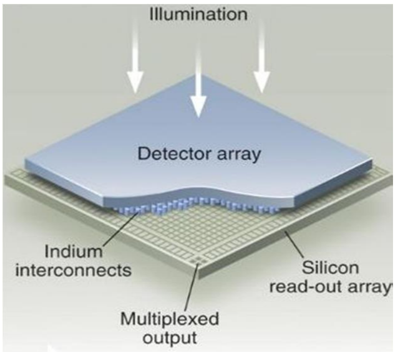


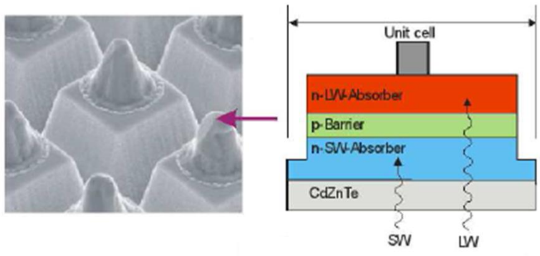
Fig.1. Configuration of hybrid IR Focal Plane Array detector

Such a configuration helped in overcoming the limitation on number of pixels by design of larger format detector array and large format ROIC, which also led to enhancements in sensitivity of these new IRFPAs. The second-generation detectors were primarily based on cooled photovoltaic diodes to reduce noise related to thermally generated carriers and also to reduce power dissipation per pixel.

The future infrared detectors are required to achieve reduced size, weight, power consumption, and cost for various spectral bands. These are being implemented by fabricating detectors in megapixel formats with smaller pixel size and high operating temperatures. The detectors with high resolution imaging capability by exploring various materials technologies and device design are termed as third generation detectors. These are

- Two Color detectors
- Avalanche photodiodes
- HOT (high operating temperature) detectors

Two color detectors are fabricated with a stack of two detector layers separated by a common electrode which can be a p-type layer for nPn-configuration, shown in Fig. 2, where two n-type layers for SW and LW bands are separated by



wide gap p-type layer.

Fig.2. Top view and schematic of a dual colour detector

Avalanche photodiodes use the band structure property of HgCdTe alloy composition with an optical band gap of 0.9eV. For this composition, the energy required to excite electron from valence band to conduction band is almost same as is required for an electron to transit from split off valence band to the top of valence band. This mechanism in the high field region allows multiplication of carriers by avalanche gain, which raises the signal level.

High Operating Temperature (HOT) detectors are based on suppression of Auger recombination mechanism by modifying the device design where an intrinsic layer is inserted between p and n layers.

In addition, detectors based on III-V materials technology are being explored due to their well established growth technology. Two important detector technologies are quantum well infrared photo detectors (QWIP) and type-II super lattices (T2SL)

In QWIP detectors based on GaAs/GaAlAs layered structure, IR absorption and detection is achieved by transitions between conduction bands of these layers by dimensional quantization. GaAlAs layers act as barrier layer which provide confinement and hence quantization of carriers. QWIPs are photoconductive devices.

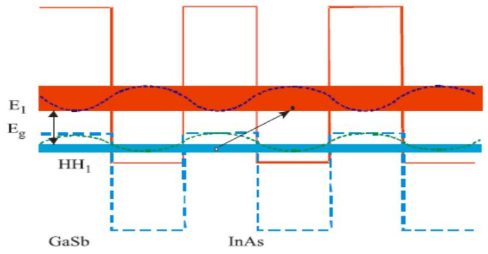


Fig.3. Band diagram of GaSb-InAs T2SL structure

T2SLs consist of alternating layers of InAs/GaSbwith appropriate compositions or ternary alloys of InAsSb. They can be band gap engineered to operate at specific wavelength and also offer the advantage of Auger suppression which reduces dark currents allowing operation at higher temperature.

The InAs/(In,Ga)Sb T2SL material system is characterized by a type-II alignment as shown in Figure 3 with electron and hole wave functions having maxima in InAs and GaSb layers respectively. The overlap of electron or hole wave functions between adjacent InAs or GaSb layers result in the formation of an electron or hole minibands in the conduction or valence band. IR radiation is detected using carrier transition between the highest hole (heavy-hole) and the lowest conduction minibands. The operating wavelength in T2SLs can be tailored from 3-30εm by varying thickness of one or two T2SL layers. Leuven (Belgium) based Xenics, Europe's leading developer and manufacturer of advanced infrared detectors has announced XEVA-2.35-320 TE4 thermo-electrically cooled infrared camera which features T2SL based infrared detection and delivers superb performance in the 1.0 to 2.35 µm wavelength region for hyperspectral imaging.

IR detectors based on III-V materials like QWIP and T2SL offer advantages of operation at higher temperatures. HgCdTe based detectors still have edge over III-V based detectors due to superior material properties.

References:

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Dr. Shiv Kumar

Recent news in semiconductors

1. One day meeting on III-nitrides for electronic and optoelectronic devices was organized jointly by IIT Delhi and Semiconductor Society (India), at IIT Delhi on Friday, 12 May 2017. The objective of the meeting was to exchange ideas, discuss about possible collaborative work, and to plan joint project proposals in the area of III-nitrides for electronic and optoelectronic devices. In the meeting, ten invited talks and two oral presentations were delivered by various prominent speakers from SSPL Delhi, CEERI Pilani, NPL Delhi, Delhi University, SCL Mohali, and IIT Delhi. The convener of the meeting was Dr. Rajendra Singh, Department of Physics, IIT Delhi and co-convener was Dr. Uday Dadwal, Nanoscale Research Facility (NRF), IIT Delhi.

2. Researchers in the USA and Germany have claimed the first radio frequency (RF) measurements on β-crystal gallium oxide (β-Ga_2O_3) metal-oxide-semiconductor field-effect transistors (MOSFETs) (Andrew J. Green et al., *IEEE Electron Device Letters*, 19 April 2017, Published Online). The researchers have claimed

high transconductance and frequency characteristics. The epitaxial Ga_2O_3 layers were grown by metal-organic vapour phase epitaxy (MOVPE) on 2-inch semi-insulating (100) β-Ga_2O_3. This research work paves the way for Ga_2O_3 applications for high frequency, high power transistors.

3. Researchers based in Singapore and USA claim to have developed the first monolithic integration of indium gallium arsenide (InGaAs) field-effect transistors (FETs) and electrically pumped InGaAs/GaAs multiple quantum well (MQW) laser diodes on germanium (Ge) substrate using direct epitaxial growth [Annie Kumar et al, Optics Express, vol 25, p5146, 2017]. This research will facilitate in the development of low power and high speed opto-electronic integrated circuits (OEICs).

4. Sun Yat-Sen University in China has been developing a metal-organic chemical vapor deposition (MOCVD) indium tin oxide (ITO) process with a view to creating ultraviolet transparent conductive electrodes for aluminium gallium nitride (AlGaN) light-emitting diodes (LEDs) [Zimin Chen et al, Appl. Phys. Lett., vol110, p242101, 2017]. Although ITO is one among many possibilities for visible light transparent conductive layers, these materials, including ITO, tend to become less transparent at shorter ultraviolet wavelengths. The Sun Yat-Sen team has managed to widen the optical bandgap to 4.7eV through MOCVD growth.