Semiconductor News

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

December, 2016

From the Chairman's Desk

It gives me immense pleasure to announce the resumption of **Semiconductor News**, an e-newsletter of Semiconductor Society (India). The executive committee of SSI has decided to publish it out quarterly.

The rapid progress in semiconductor technology over a wide spectrum ranging from very high speed processors to small LED's in optoelectronic circuits illustrates the enormous interest of researchers in this field. Very high powers have been achieved for semiconductor lasers and work on energy efficient as well as environment friendly GaN LED's was awarded prestigious Nobel Prize in 2014 to Shuji Nakamura, Hiroshi Amano and Isamu Akasaki from Japan.

In India, we have been viewing significant R&D achievements in the field of Semiconductor Technologies from premier institutes and organizations including IITs, IISc, TIFR, CSIR, DRDO, DAE etc. Realization of high quality III-N based High Electron Mobility Transistors, III-V Qunatum Well lasers/detectors, semiconductor nanowire based sensors and 2D semiconductor based transistors may be mentioned as some of the achievements of recent past. However, there are challenges to develop more efficient and reliable devices that could potentially be commercialized in future.

The purpose of this newsletter is basically to highlight the technological achievements and advancements in the field of semiconductor materials and devices in India. We would also try to cover various events including National/International Conferences related to Semiconductor materials and devices. We are also willing to publish discussions/interviews with/of eminent/landmark achievers in semiconductor technology and contribute towards nation building.

I invite all the researchers in the field of Semiconductor Science and Technology to inform us significant achievements in their field for inclusion in this Newsletter. We wish to boost the exchange of technological knowledge by bringing the scientific and engineering fraternity to a common platform through this newsletter.

We all agree that in spite of a large number of leading research groups working in Semiconductor Technology, India is yet to find its place among frontline nations in semiconductor manufacturing. With the Government initiatives like Make in India, Digital India and Startup India, it is a high time for our community to come forward and expedite the work in making the country capable in indigenous semiconductor product development. I can definitely say that with our sincere efforts and hard work we all together can make this dream come true.

Rajesh K Sharma

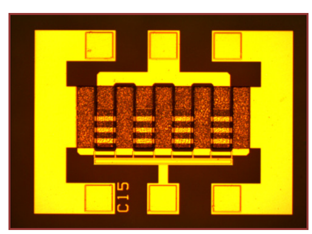
Executive Committee of SSI

Gallium Nitride Power Amplifier: Technology Enabler for the Next Generation RF Systems

Gallium nitride (GaN) is a wide bandgap semiconductor that finds broad area of applications ranging from optoelectronics to microwave electronics. The III-Nitride family of which GaN is also a member covers a very broad range of energies from InN with bandgap of around 0.8 eV to AlN with bandgap of 6.2 eV at room temperature. The presence of such a wide tunable direct bandgap in the III-Nitride material system makes it suitable for applications in optoelectronics covering the spectral range from infrared to the deep ultraviolet. From LEDs for solid state lighting and monochromatic displays to blue laser source for high definition Blu-ray systems, many III-Nitride based optoelectronic devices are ubiquitous in many consumer products.

In the electronic area the application of GaN can be broadly divided into power switching and RF power amplification. The large bandgap of Gallium nitride (GaN) is expected to make high power electronics with much higher efficiency and wider frequency coverage than any other conventional semiconductor technologies. The ability of III-Nitrides to form heterojunction and fabricate high electron mobility transistors (HEMTs) makes them preferable over SiC which is another wide bandgap material possessing similar electronic properties for high frequency applications. Another characteristic of GaN family that puts them in a different league of their own is the strong polarization effect that is well utilized to form a thin sheet of two-dimensional electron gas at the AlGaN/GaN interface whose concentration is almost an order of magnitude higher than GaAs based heterostructure devices. Other than wide bandgap (3.45eV), GaN also exhibits superior electronic properties that include high electron saturation velocity (2.5 x 10^7 cm/sec), high electron sheet density ($\geq 10^{13}$ cm^{-2}) coupled with high carrier mobility (~2000 cm^2/V-sec) in heterostructures making it an ideal choice for high power and high temperature microwave applications. The large bandgap energy of GaN enables it to sustain high peak electric field resulting in high breakdown voltage and carrier concentration coupled with the high electron saturation velocity and current density.

These inherent properties of GaN translate into increased power density with high gain and efficiency suitable for microwave applications. With a continuous improvement in growth quality of AlGaN/GaN heterostructures and device fabrication technology, the power density which is a measure of power output per unit gate periphery has seen a rapid rise through the years. The power density of 8W/mm is a common feature even for commercial devices. GaN devices are also becoming cost competitive to Si laterally diffused metal-oxide-semiconductor (LDMOS) in terms of size, performance and advantage they offer to replace LDMOS based RF power amplifiers for base-station transmitters in cellular networks.



GaN HEMT device fabricated at SSPL

GaN devices can produce 5x higher output power density than GaAs and Si technology enabling systems with lower form factor. In high power amplifiers (HPAs), many amplifiers in parallel are combined at the output to achieve the desired level of output power. The power amplifier block is the most power hungry part in any RF system and major part of the input power is dissipated at the power combining stage which directly translates into higher power consumption and heat generation. GaN devices owing to their higher operating power density requires lesser number of amplifier stages to achieve the desired power output and thus minimizes the combining loss of the FETs in Solid State Power Amplifier (SSPA) leading to increased linearity and efficiency of the system. The high operating voltage and higher power densities of GaN HEMT devices also lead to high device impedance and their smaller sizes leading to lower intrinsic capacitance making broadband matching easier and simpler than other technologies. GaN SSPA is expected to slowly wade through areas dominated by Vacuum Electronic Devices (VEDs) making direct competition in terms of power levels at higher frequencies. However, a major limiting factor in exploiting the full potential of GaN devices is the heat dissipation per unit die area which can severely limit the reliability of the device without proper thermal management. A major area of research pertaining to GaN devices therefore lies in addressing thermal challenges associated with high power devices. The worldwide market for GaN based devices and systems are expected to grow enormously in the coming years. Clearly GaN is becoming the technology-of-choice for RF electronics and will continue to invade more and more niche areas to emerge as the next big thing of the RF technology.

Robert Laishram, SSPL, Delhi

Recent news in semiconductors

1. Silicon monoxide passivation for gallium nitride transistors

Researchers from Shandong University, China and University of Manchester, UK have reported room-temperature thermally evaporated silicon monoxide (SiO) passivation for AlGaN/GaN HEMTs [G. Zhu *et al*, Appl. Phys. Lett. 109 (2016) 113503]. The passivation reduced leakage currents and increased breakdown voltages compared with unpassivated and silicon nitride (SiNx) passivated devices. The researchers have explained that because of its simple preparation technique, low cost and minimal damage characteristics, the thermally evaporated SiO is a promising candidate as a passivant for GaN-based HEMTs.

2. Transistor with record 1nm-long gate

A research team at the US Department of Energy's Lawrence Berkeley National Laboratory (Berkeley Lab) has created a transistor with a gate length of 1nm, which is the smallest reported till date (“MoS_2 transistors with 1-nanometer gate lengths”, Science 354 (2016) 99-102). For conventional semiconductors, the laws of physics set a 5nm threshold on the size of transistor gates (about a quarter the size of high-end 20nm-gate transistors currently in the market). However, the 1nm-gate transistor show that "with the choice of proper materials, there is a lot more room to shrink our electronics," says Ali Javey, lead principal investigator of the Electronic Materials program in Berkeley Lab's Materials Science Division. The key was to use carbon nanotubes and molybdenum disulphide (MoS_2).

Dr. Rajendra Singh, IIT Delhi

International Year of Light celebration

One day seminar was organized in the Solid state physics laboratory on 20th Nov 2015 to celebrate International year of Light 2015 event in view of the United Nations proclaim 2015 as the International Year of Light and Light-based Technologies, 2015 (IYL 2015) to raise awareness of the achievements of light science and its applications; and its importance to humankind. Dr. K. D. Nayak, DG (R&D), MED & COS was the Chief Guest and Dr. Krishan Lal, Ex-President, INSA and Ex-Director, National Physical Laboratory presided over the function and delivered an inaugural lecture on “Challenges in Structural Characterization of Single Crystals and Thin Layers used for Fabrication of Photonic Devices”. Professor AK Ghatak delivered a popular lecture on “Einstein: His equation $E=mc^2$ & his light quantum” along with an Industry Lecture on “LED lighting” by Dr. Manish Prasad from Moser Baer, India.

National Conference on Semiconductor Materials and Devices (NSSMD)

The National Conference on “Semiconductor Materials and Devices” was jointly organized by IIT Jodhpur, Defence Lab Jodhpur and Semiconductor Society of India during 4-6 March 2016 at IIT Jodhpur. The conference was attended by about 200 participants. During the conference a number of invited talks were delivered by many prominent speakers and poster sessions were also held. Best poster awards were also given to PhD students. The conference was financially supported and sponsored by IIT Jodhpur, DRDO and some private companies."

National Seminar on Solid State Devices for Quantum Computing Applications

One day National Seminar on “Solid State Devices for Quantum Computing Applications” (SSDQCA) was organized by Solid State Physics Laboratory (SSPL), Delhi, on 26th Nov. 2016. Dr. R.K. Sharma, Director SSPL welcomed the guests and enumerated the role of solid state devices for quantum computing (QC) applications. Sh. CVS Sastry, Director Anurag and chief guest inaugurated the seminar and stated about the potential applications of Quantum computers for specific problems.

The lectures on Quantum technologies with photons and atoms for QI applications, Superconducting circuits & Solid state devices for QC, Role of coherence and entanglement in Quantum search algorithm, Optical quantum computation, Semiconductor charge qubit devices, Superconducting nanowire based single photon detectors, Experimental implementations of QC devices were delivered during the seminar. This was followed by the brainstorming session. Eighty participants from SSPL Delhi, ANURAG Bangalore, IIT Delhi, NPL Delhi, SAG Delhi, and GAETEC Hyderabad attended the seminar. The speakers were invited from various institutes such as TIFR Mumbai, IIT Delhi, HRI Allahabad, IGCAR Kalpakkam and NPL Delhi.