10th International Conference on Nitride Semiconductors (ICNS-10)

Conference Report

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Introduction

The 10th International Conference on Nitride Semiconductors, ICNS-10, was the 10th edition of a series of biannual international meetings organised by the worldwide community of nitride semiconductors researchers. It was held at the recently built Gaylord National Resort and Convention Centre at National Harbor, minutes from the capital of the United States of America (USA), Washington D.C., one of the world's cultural, government, and historic epicentres. The 10th edition of ICNS was held from the 25th to the 30th of August, 2013, following the previous meeting held in Glasgow, Scotland, United Kingdom and preceding ICNS-11, which is scheduled to take place in Beijing, China in 2015. ICNS-10 was organised and co-chaired by scientists and members of the Materials Research Society (MRS), Jaime A. Freitas Jr., from the U.S. Naval Research Laboratory, USA, and Christian Wetzel, from Rensselaer, USA.

The conference served as a showcase for scientists around the world to converge in Washington D.C. to share ideas, present technical information and contribute to the advancement of nitride semiconductors. The conference presented high-impact scientific and technological advances in materials and devices based on group-III nitride semiconductors.

The six day event featured plenary sessions, parallel topical sessions, poster sessions, and industrial exhibitions. ICNS-10 was grouped into four general categories which were further grouped into twelve topics consisting of 36 different parallel sessions, each focusing on a specific area of nitride semiconductors research. The conference featured over 700 oral and poster presentations and offered a strong program with 36 technical sessions and 5 plenary sessions focused on bulk and film growth, optical devices – both visible and Ultraviolet – and electrical devices.
Due to the vast number of talks which took place during this conference, the author of this report will focus on a few topics related to his research and the talks he found most interesting.

Oral Presentations

The parallel sessions were split into four main categories with each main category consisting of several more specific technical topics. The detailed structure is as follows:

A. Bulk and Film Growth
    1. Planar, Alternative Nitrides and Growth Methods I
    2. Doping and Defects I
    3. Optical Structures and Measurements
    4. Polar and Semi-Polar
    5. Structure Strain and Defects
    6. Bulk
    7. Doping and Defects II
    8. Nanostructures
    9. Planar, Alternative Nitrides and Growth Methods II

B. Optical Devices – Visible
    1. Visible LEDs on Silicon
    2. Nano LEDs and Lasers
    3. High Brightness/Efficiency Visible LEDs
    4. Visible LED Physics and Characterisation
    5. Visible LED Fabrication and Intergration
    6. Solar Cells
    7. Visible Nanostructures
    8. Next Generation Visible LEDs
    9. Visible Lasers
    10. IR Material and Devices
    11. Characterization of Nitrides
    12. Optical Properties of Nitrides
    13. Optical Properties of Quantum Wells
    14. Visible Quantum Dots

C. Optical Devices – Ultraviolet
    1. Mid UV Lasers and Photodetectors
    2. UV Quantum Effects
    3. Mid-UV LEDs
    4. UV Optical Properties
    5. UV Nanostructures

D. Electrical Devices
    1. High-Speed and High-Performance Nitride HEMTs and Modelling
    2. Characterization of Nitride Electronic Devices
    3. Substrates and Epitaxial Integration for Nitride Electronic Devices
    4. Novel Nitride Electronic Devices and Concepts
    5. Novel Electronic Concepts
    6. GaN on Silicon Electronic Devices and Process Innovations

Plenary Sessions

There were five plenary sessions at the conference held on Monday and Friday. On Monday morning, Mike Krames, from Soraa, Inc., started off with his talk on Solid-State Lighting with Native Substrate GaN-based LEDs. This was followed by Miroslav Micovic, from HRL Laboratories, LLC, presenting Highly Scaled GaN Transistor for Sub-millimeter Wave and High Efficiency Applications. This

presentation provided an overview of the development and evolution of high frequency GaN HFET technology for millimetre-wave and sub-millimeter-wave RF applications spanning a period of 15 years. In his talk, Micovic, mentioned that in the late 1990s, solid state RF power sources for frequencies exceeding 2 GHz were realized almost exclusively in GaAs and InP material systems, however, the prospects for realizing a more powerful millimetre-wave and sub-millimeter-wave solid state power source using established GaAs or InP MMIC Power Amplifiers are limited by the fundamental properties of GaAs and InP. Micovic then went on to summarize the key challenges in the development of high frequency GaN transistor and the key technical breakthroughs that have enabled the demonstration of high frequency GaN HFETs.

On Friday, there was a presentation on Uncovering and Surmounting Loss Mechanisms in Nitride Light Emitters by Chris Van De Walle, from University of California, Santa Barbara. Then Hiroshi Amano, from Akasaki Research Centre, Japan, gave his presentation on Reduction of Parasitic Reaction and Realization of High-quality In-rich InGaN-based Multiple-Quantum-well Structures by High-pressure Metalorganic Vapor Phase Epitaxy. The Conference was then rounded off on Friday afternoon by Jürgen Christen, from Otto von Guericke University of Magdeburg, Germany, with a presentation on Advanced Luminescence Nano-characterization of III-N Semiconductors.

Parallel Sessions

Due to the scope of my research, I mostly attended talks in the Electrical Devices category of the conference. There were four invited talks for this category of the ICNS-10 conference. The first was given by David J. Meyer, from the Naval Research Laboratory, Washington D.C., detailing Nano-Crystalline Diamond Coated AlGaN/GaN HEMT Pulsed I-V and RF Performance.

The second invited paper was presented by Kevin Chen, from the Hong Kong University of Science and Technology, Kowloon, Hong Kong, who spoke about the Technologies for II-N Heterogeneous Mixed-signal Electronics.

Then came the highly anticipated invited talk on Wednesday morning by Umesh K. Mishra from the Electrical and Computer Engineering Department of the University of California-Santa Barbara, Santa Barbara, California. This presentation focused on Novel Device Concepts in GaN Electronics. In his talk, Mishra indicated that GaN based transistors have entered the commercial markets for high power and high frequency applications and stressed on the fact that GaN based power switching devices based on (Ga, Al)-polar (0001) (Al, Ga) N heterostructures outperform traditional counterparts. However, he then went on to state that for operating frequencies beyond Ka-band, the performances of existing devices rapidly degrades, requiring a re-design of the device structures. Mishra then went on further to introduce attractive devices based on N-polar (Al, Ga, In) N grown on (000-1) GaN. Mishra observed that, due to the opposite direction of the internal electric fields in N-polar heterostructures, the two dimensional electron gas is located on top of the (Al, Ga, In) gating layer, which serves as a back barrier leading to improved electron confinement in these devices. He also stated that, the 2DEG is contacted via the GaN channel, which in combination with re-grown ohmic contacts enables extremely low contact resistances, and values as low as 23 Ω-µm were demonstrated. Mishra also introduced the audience to another alternate transistor approach known as the GaN based Hot Electron Transistor (HET), which operates by the injection of electrons over a first barrier (emitter) into a thin transient region (base) before getting collected over a second barrier (collector). Mishra suggested that, the ballistic carrier transport in these devices potentially allows for extremely high operation frequencies, and that, whilst this technology has been originally demonstrated in traditional compound semiconductors, group-III nitrides are particularly attractive for HET

applications due to the large band off-sets and the strong internal electric fields in (0001) and (000-1) (Al, Ga, In) N heterostructures.

The last invited paper on High-power III-N HFETs on Si Substrates for Millimeter Wave Applications was presented by Farid Medjdoub, from I.E.M.N – CNRS – CSAM, Villeneuve d'Ascq, France.

The parallel sessions also included some very interesting oral presentations throughout the conference. For instance, Xing Lu, from the Department of Electronic and Computer Engineering, The Hong Kong University of Science and Technology, Kowloon, Hong Kong, presented a paper on In-situ SiN_x Gate Dielectric br MOCVD for Low-Leakage-Current Ultra-Thin-Barrier AlN/GaN MISHEMTs on Si. Xing Lu presented work that was carried out on ultra-thin-barrier (1.5 nm) AlN/GaN MISHEMTs on Si devices, employing 7 nm and 3 nm In-situ SiN_x as gate dielectrics. In their group's work, the In-situ SiN_x was deposited using silane and ammonia immediately after the AlN/GaN heterostructures growth in an MOCVD chamber at 1145 °C. They observed from AFM and TEM that the sample with 7 nm In-situ SiN_x showed a smooth surface morphology and good coverage and compared with 3 nm barrier AlN/GaN Schottky diodes fabricated and characterized by the group, the 7 nm and 3 nm In-situ SiN_x had effectively reduced the leakage current at -5 V bias by about 7 and 4 orders of magnitude respectively.

Yuhao Zhang, from the Department of Electrical Engineering and Computer Science, Massachusetts Institute of Technology, Cambridge, Massachusetts, also presented his group's work on a Normally-off GaN MOS-HEMT with High Threshold Voltage, No Current Collapse and High-Temperature Stability. The group demonstrated E-mode fluorinated MOS-HEMTs with a V_{th} higher than 3 V, no current collapse and long-term stability at 250 °C using a dual-gate structure and an Al_2O_3 gate oxide deposited be atomic layer deposition. The group observed that, the V_{th} of the fluorinated MOS-HEMTs increase with increasing oxide thickness, and went on to explain that, this was due to the existence of negative fluoride-induced bulk charge in the oxide revealed by their modelling work.

The author of this report also presented his group's work on A Novel High Performance AlGaN/GaN Based Enhancement-Mode Metal-Oxide-Semiconductor High Electron Mobility Transistor.

Poster Sessions

ICNS-10 had around 515 posters on display during the conference of which 101 posters were in the Electrical Devices category with authors available for in-depth discussions on their work. The quality of materials on display were highly impressive, and amongst these was a poster by Ye Wang, from Hong Kong University of Science and Technology, Hong Kong, China, displaying a High Performance Normally-off AlGaN/GaN MOSFET with Al_2O_3 High-k Dielectric Layer Using a Low Damage Recess Technique. Her group's poster showed the use of a low damage digital etching process using pre-oxidation and following oxide wet etching to recess the AlGaN barrier to achieve normally-off operation for AlGaN/GaN MOSFET with Al_2O_3 high-k dielectric. The group demonstrated that, the wet etching process eliminates the large damages induced by plasma bombardment with chemical and physical interactions in conventional inductively coupled plasma (ICP) etching process and atomic smooth surface morphology could be reserved using this wet etch process.

Also on display during the poster sessions was work from Ting-Hsiang Hung, from The Ohio State University, Columbus, Ohio, showing Interface Charge and Electron Transport in GaN-Based MIS-

HEMTs. The group investigated experimentally and theoretically, the effect of interfacial charges on transport by varying the charge density (through post-metallization anneal, PMA) and interface-2DEG distance. The group observed that, mobility at low 2DEG density decreases with increasing recess depth due to larger remote impurity scattering at deeper recess depths. However, the group demonstrated that, after PMA, interface charges decrease, and as expected from theory, the mobility increases at low 2DEG density for all cases.

Rump Sessions

Rump sessions addressing key challenges in the field of nitride semiconductors were held on Wednesday evening. These sessions started with short talks by panellists intended to frame the problem statement, followed by and open discussion with all attendees. Amongst the topics discussed in the Electrical devices sessions were:

- Can GaN power devices augment silicon power devices?
- Can GaN challenge and compete with SiC power devices?
- In what operating range are the GaN power devices most competitive?
- What are the main obstacles for large-scale GaN power device commercialization (cost, reliability, avalanche capability)?
- What are the potentials and challenges for monolithic integration (with Si CMOS, GaN photonic and rf devices)?

Exhibit

The industrial and device-oriented focus of the ICNS series in general and of ICNS-10 in particular was emphasised by the strong presence of companies exhibiting their work in 33 exhibit booths during the conference. Amongst these were organizations such as Laytec, Aixtron SE, CrystAl-N, Dow Electronic Materials, IQE, Nitride Crystals Inc., NTT Advanced Technology Corporation, Oxford Instruments-Plasma Technology, SVT Associates and others.

Overall, ICNS-10 featured 893 attendees from 31 countries. There were 320 attendees from the Americas, 297 from Asia, 6 from Australia and 235 attendees from Europe. The conference was concluded with a banquet on Thursday evening where the host of the upcoming ICNS-11 was announced to be Beijing, China.

Conference Proceedings

In continuation of the ICNS tradition, the ICNS-10 proceedings will be published as a special volume of Physica Status Solidi (C). For further information on the scientific and technical highlights of ICNS-10, readers are referred to the conference proceedings.

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I would like to thank the U.K Defence Science and Technology Laboratory (DSTL), Engineering and Physical Sciences Research Council (EPSRC) and UK Nitride Consortium for financially helping make this trip possible. This conference has given me the opportunity to see the scope of research being carried out on nitride semiconductors and the crucial role this technology has to play in the

future of electronics. The experience gained from discussing my work with other leading researchers in my field has also been second to none.