Conference Report

9th International Workshop on Nitride Semiconductors (IWN 2016)

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Introduction

The 9th International Workshop on Nitride Semiconductors (IWN) was held in Orlando, Florida from 2nd October to 7th October 2016. The conference included over 800 attendees, six plenary talks, 436 oral presentations and 345 posters.

There were six major session categories including: fundamentals of material growth, optical devices, electronic devices, basic material properties, nanostructures, novel materials and devices. Each category was further divided into two to three sub-categories. There were three rump sessions including 'Is There a Suitable Future for Ordered Nanostructures as Real Devices', 'Do We Really Need Better LEDs' and 'The Future of Wide-Bandgap Electronics'.

Optional tours to Kennedy Space Centre and Wild Florida Airboat & Wildlife Park were organised, as well as a conference banquet held in the Epcot theme park at Disneyland. The final two days of the conference were partially disrupted by the category 3 Hurricane Matthew.

Below I outline the content of a range of talks and posters that I found interesting.

Plenary Talks

There were six plenary talks, of which four given by speakers from industry, including Martin Strassburg from OSRAM Opto Semiconductors GmbH, Hideki Hirayama from RIKEN, Thomas Kazior from Raytheon Company and Jy Bhardwaj from Lumileds. The other two academic speakers were Umesh Mishra from University of California, Santa Babara and Takashi Egawa from Nagoya Institute of Technology.

Perspectives of III-N Optoelectronics

Martin Strassburg, OSRAM Opto Semiconducotrs GmbH

Commercial InGaN/GaN LEDs currently have IQEs greater than 85% at room temperature, with operational lifetimes of 10-50k hours. The design of the devices and material choices depend on the application of the device. Problems that commercial InGaN/GaN LEDs have yet to overcome include the efficiency droop problem and super high powered LEDs. In order to overcome the green gap problem, Strassburg suggested moving towards 3D nanostructures and nanowires.

Current Status and Future Directions in GaN-Based Electronics

Umesh Mishra, University of California, Santa Barbara

GaN serves a large market, including kHz for power conversion and GHz for RF amplification and communications. There is a clear roadmap to lower costs and improve performances of GaN-based electronics, paving way for mass adoption. For power electronics, Mishra believes that improvements need to be made to the design of devices, rather than aiming for smaller scales.

Current status and future of III-nitride UV and THz emitters

Hideki Hirayama, RIKEN

UVC LEDs currently have low light extraction efficiencies (LEE) due to a lack of transparent electrodes, and UVC wavelengths are completely absorbed by the p-GaN layer. Hirayama proposed the use of a transparent p-AlGaN layer, reflective electrodes and photonic crystals to improve the LEE. The simulations from his work show that LEE >70% and EQE of ~40% can be achieved.

Selected Talks

Green gap and droop in InGaN/GaN LEDs – the role of random alloy fluctuations

Matthias Auf der Maur, University of Rome Tor Vergata

Auf der Maur presented his work on using a theoretical atomistic approach to investigate the role of In fluctuations in InGaN quantum wells in the 'green gap' problem. It was assumed that alloy followed a uniform spatial distribution, and the random alloy was created by substituting Ga atoms with In atoms using the Monte Carlo technique, with a supercell that was sufficiently large and periodic. A tight-binding and valence force field approach was used. A check ensured that the model fitted with bulk properties obtained from experimental and DFT results. The model was then applied to InGaN quantum wells and simulations were performed with tiberCAD, a multiscale CAD tool for the simulation of modern nanoelectronic and optoelectronic devices developed by his group. The atomistic structure of a single InGaN quantum well sandwiched between two layers of GaN used consisted of 100k atoms, and the number of In atoms was varied to simulate different In content. The model was found to overestimate the efficiency of emitters, especially at increasing In content. Auf der Maur explained this in terms of electrons and holes localising at In rich areas and the spatial separation caused by internal electric fields (quantum-confined Stark effect). He also considered the non-uniformity of In fluctuation caused by temperature fluctuation, which would affect the B coefficient of the ABC model.

Cubic InGaN MQWs for efficient green LEDs

David Wallis, University of Cambridge

Wallis presented work on cubic GaN grown on 3C-SiC on Si substrates for green-wavelength LEDs. Cubic GaN has the advantage of the absence of internal electric fields, which are present in hexagonal crystal structure. The growth of cubic GaN was performed by MOCVD on large area substrates up to 150 mm in diameter, and was compatible with processing on GaN on Si production line (through Plessey Semiconductors), thus presenting a clear route to commercialisation if successful. Photoluminescence data showed that cubic GaN has a smaller band gap of 3.2 eV compared with 3.39 eV for hexagonal GaN. This is beneficial for achieving green wavelengths, possibly with reduced indium concentrations in the InGaN quantum wells. The crystal quality of the cubic GaN films was confirmed using x-ray diffraction, which samples mm^2 areas. The multiple quantum well region emitted green wavelength light at λ = 516 nm, with $\Delta\lambda$ = 108 nm. The thicknesses of the quantum wells were also varied between 2-12 nm and emission wavelengths varied between 470 - 530 nm. The radii of curvature of the substrates were 75 - 100 µm. Since wafer bow can lead to temperature variations on the substrate and problems with In incorporation, work on the control of wafer bow needs to be done, especially when transferring the process to larger 150 mm wafers. Initial growth on 150 mm wafers demonstrated good quality cubic GaN on most of the wafer area.

Progress in heteroepitaxy of semi-polar GaN on sapphire

Jung Han, Yale University

Han reported on the development of the growth of semi-polar GaN on sapphire substrates. Selected area growth on a-plane GaN annular ring pattern can be used to reveal the natural planes of GaN. Many semi-polar planes occur naturally, although they can also be formed artificially. Since semi-polar bulk GaN substrates are small, expensive and not compatible with commercial processes, semi-polar GaN is usually grown by heteroepitaxy on sapphire substrates. Epitaxial lateral overgrowth (ELO) was first used to reduce the high density of basal-plane stacking faults. Patterned sapphire substrates (PSS) were subsequently developed, where the GaN crystal grows from the side walls of the patterned features and the angle of the side walls can be changed to achieve all different orientations of GaN. His research group demonstrated $(11\bar{2}2)$ and artificial $(20\bar{2}1)$ GaN LEDs on patterned sapphire substrates in 2014. Basal-plane stacking faults could be removed by suppressing the formation of N-polar facets, by ensuring complete two-dimensional growth, controlling growth conditions and using surfactant engineering. The group's most recent interest is the growth of semi-polar $(20\bar{2}1)$ and $(20\overline{21})$ GaN using facet controlled growth on patterned 2-inch sapphire substrates, with support from the company Saphlux.

Impact of substrate temperature on magnesium incorporation in MBE grown Al-rich $Al_xGa_{1-x}N$

S.M. Islam, Cornell University

Deep UV (~250nm) LEDs can be used for imaging, sensing and water purification. The drop in external quantum efficiencies (EQE) of deep UV LEDs arises from poor Mg doping and injection efficiencies of the p-type layer. It is difficult to activate Mg in higher Al content AlN layer that is also transparent to deep UV wavelengths. Islam presented results from a study of substrate temperature on magnesium incorporation in plasma-assisted MBE grown Al-rich $Al_xGa_{1-x}N$. A concentration of ~1 x 10^{20} cm^{-2} of Mg could be achieved at a relatively high temperature of 730°C, which is beneficial for achieving a higher quality crystal.

Carbon doping by propane for the compensation of n-type GaN

Andreas Lesnik, Institut für Experimentelle Physik, Magdeburg, Germany

As-grown GaN n-type conductivity due to point defects and impurities lead to leakage currents in field-effect transistors (FET) buffer structures grown on Si. Lesnik investigated the use of carbon doping by propane to compensate for the unintentional n-type conductivity. High-resolution x-ray diffraction (HRXRD) revealed no structural degradation over the whole C-doped regions, scanning transmission electron microscopy (STEM) results showed no change in dislocation distribution, and the leakage current of the structure decreased by several orders of magnitude.

N.B. Unfortunately, I could not attend the rump sessions due to the hurricane.

Selected Posters

The poster sessions were useful to quickly gain an overview of the different research questions for nitrides, as well as the groups involved in the various areas.

The green gap in biological systems- why green matters

Christian Wetzel, Rensselaer Polytechnic Institute

The 'green gap' needs to be solved for horticultural lighting applications. Wetzel presented data on the quality of lettuce grown under different types of illumination, including cool white fluorescent, red/blue LED, RBG LED, and phosphor-converted LED. The crop quality was lowest for lettuce grown with light from phosphor-converted LEDs, and the best for cool white fluorescent lamps since they emitted a broad range of visible wavelengths including green. Thus green light sources are vital for healthy crop growth and the low efficiency of green LEDs is the limiting their use as horticultural lighting at present. This must be the only poster featuring photos of lettuce in the nitrides conference!

Hybrid white inorganic/organic LEDs using organic colour converters

Jochen Bruckbauer, University of Strathclyde

Bruckbauer reported the use of organic phosphors for blue LEDs to produce white light, with the white to blue emission ratio used as a quality factor. Three different organic molecules with different absorbing and emissive units were deposited on blue LEDs, and their colour rendering properties, emission spectra and efficiencies were compared. The best phosphor was a compound with triphenylamine emissive units and benzothiadiazole absorbing units. Organic phosphors have the potential advantage of being cheaper compared with the YAG phosphors currently used, but their stabilities have yet to be controlled.

Monolithic integration of light-emittng diode and photodetector for self-monitoring of light output

Haitao Lu, University of Hong Kong

Lu presented his work of integrating an LED with a photodetector on the same GaN-on-sapphire wafer. The photodetector would detect the light intensity level produced by the LED, and thus be able to detect any fault of the LED light source, whether the cause of the fault is internal or external.

Direct growth of multilayer graphene as transparent electrode on GaN-based light emitting diode

Jumpei Yamada, Meijo University

Deep UV LEDs require contacts that are transparent to deep UV wavelengths, however the commonly used indium tin oxide (ITO) absorbs such wavelengths. Yamada investigated the use of graphene as the transparent electrode material. Graphene was grown directly on to the p-type layer of a blue LED structure by the precipitation method, where amorphous carbon was annealed with W and Ni catalysts at 700°C for 15 mins to precipitate graphene. The presence of multilayer graphene was confirmed by Raman spectroscopy, and the contact was reported to work.

Improved output power of NUV AlGaN-based light-emitting diodes by using silver nanowires

Byongjun Choi, Korea University

The p-contact for near-UV (385 nm) LEDs should be thin enough for light emission, but thick to reduce its resistance. Choi reported the combination of Ag nanowires with ITO for use as such electrodes, and a 14% increase in light output compared with electrodes made of only ITO.

Conclusion

The exposure to the diverse range of nitrides research was eye-opening. I had the opportunity to hear, meet and speak with members of the nitrides community working on various topics, which will certainly beneficial for my future work and scope of the field. Moreover, I had the chance to present my work in a talk which was a valuable experience.

The next IWN conference will be held in Kanazawa, Japan during the Fall of 2018.

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