ICNS 2019: Conference Report

Bozinakis Pavlos

Semiconductor Spectroscopy and Device Group, Department of Physics, SUPA, University of Strathclyde, Scotland

pavlos.bozinakis@strath.ac.uk

The 13th International Conference of Nitride Semiconductors (ICNS) was held in Bellevue, Washington from 7th-12th July 2019. There was a total of 8 plenary talks, 46 invited talks, 370 contributed talks and 353 poster presentations. The plenary talks were held on the first and last day of the conference. The poster presentations were held on the first and second day of the conference. The contributed talks were organized based on 13 broad topics and were held throughout the conference (except the last day) into 5 parallel sessions. Below is the summary of a few talks which I found particularly interesting:

Efficiency of Nitride LEDs - Impact of Point and Extended Defects

Plenary talk, Nicolas Grandjean

This plenary talk gave an overview of the current state of LEDs, particularly blue LEDs with an active region of InGaN/GaN quantum wells (QWs). These QWs have a very high internal quantum efficiency (IQE), above 90% at room temperature, despite the high dislocation density. The epitaxial growth of GaN is usually carried out on foreign substrates such as sapphire. The lattice mismatch between substrates and epilayers is the main culprit for dislocations and other extended defects. The high IQE of InGaN/GaN QWs has been attributed to carrier localization caused by alloy fluctuations and/or the self-screening of threading dislocations but both theories fail to provide a fully satisfactory explanation. An alternative mechanism/explanation for the high IQE was introduced during the talk and it is related to an InGaN underlayer below the active region of the LEDs. This InGaN underlayer which is present in all state-of-the-art blue LEDs was the focus of the talk. Comparative photoluminescence (PL) measurements between samples with and without an underlayer showed huge differences in the intensity of light emission. The suggested mechanism was the following: a) without the InGaN underlayer surface defects are incorporated in the QWs and act as non-radiative recombination centres, b) with the InGaN underlayer these surface defects are trapped there and fail to reach the active region. Underlayers which did not have Indium failed to reproduce this high efficiency, therefore it was suggested that the Indium atoms play a key role in this “trapping” of the defects. What I found entertaining is that this could be the reason commercial LEDs use multiple QWs. Conventional wisdom (trial and error) suggest that multiple QWs are more efficient but if this theory holds true, then the reason for the improved performance of LEDs with multiple QWs is only due to the fact that some of the QWs play the role of the InGaN underlayer.

How do we make AlGaN into a useful semiconductor?

Plenary talk, Zlatko Sitar

The last plenary talk started with a seemingly simple question: What is a semiconductor? The definition I had previously known, the bandgap of a semiconductor must not be too large (how small/wide should the bandgap be?), suddenly seemed vague and incomplete. The answer given during the talk was more satisfactory: a semiconductor is something that can be controllably and usefully doped. During the talk the challenges of doping AlGaN with high Al content were presented and analysed. The main challenge is the formation of point defects such as vacancies with an increasing doping concentration. The formation process was explained with the following example. Doping a semiconductor with donors will move the fermi level towards the conduction band, the material will try to compensate and deep energy levels will appear in the form of vacancies and vacancy complexes. Results showed that the formation energy of vacancy complexes in AlGaN remains almost constant for low concentrations of Si doping, but drops drastically when the concentration of Si is high. This leads to an exponential increase of vacancy complexes which in turn will reduce the carrier density despite the increase in doping. The formation of the defects can be supressed with UV illumination during growth.

Room Temperature Single Photon Emission from Planar GaN/AlN Quantum Dot Samples Grown by MBE

Nanostructures and Nano-Devices session, Gordon Callsen

At the beginning of the talk an overview of the growth of GaN quantum dots (QDs) was given. The GaN QDs were grown with the use of ammonia-MBE and the Stranski-Krastanov technique. The QDs were formed spontaneously as strained induced GaN islands were formed on top of AlN. Subsequent AlN growth embedded the GaN QDs in the AlN film. The density of the QDs was controlled by adjusting the growth conditions/rate of GaN. The density of QDs is very important (must be low enough) because it is necessary that only a single QD is excited during micro-photoluminescence (μ-PL) measurements. The AlN films were grown on bulk AlN and Si(111) subtrates. Even though the growth of AlN on Si(111) contains a high number of threading dislocations, the Si substrate can provide a pathway for on-chip integration of GaN QDs. μ-PL was used to analyse how effiecient are the QDs as single photon emitters. The $g^{(2)}(0)$ value of the single exciton was measured at 0.17±0.03.

Relaxation of AlGaN Epitaxial Layers on Native GaN substrates

Epitaxial Growth session, Seiji Mita

In this talk it was presented how AlGaN layers as thick as 10µm were grown by MOCVD. The Al content in these layers varied up to 50%. The focus of this talk was how to accommodate strain in the AlGaN layer without cracking. To achieve this, facet controlled epitaxial lateral overgrowth (FACELO) was used. Specifically, a GaN substrate was covered by SiO_2 stripes and subsequent GaN growth produced $\{11\overline{2}2\}$ pyramidal facets. AlGaN was grown on those inclined facets and after complete coalescence the thick AlGaN layer was created with the strain relaxed at the interfaces between AlGaN and GaN. What really caught my interest in this talk was the effect the coalescence boundaries had on the dislocation density. The dislocation density was reduced in the area above the coalescence boundaries. The TEM images showed that the dislocations were terminated at the boundaries. The reason for this is that at the boundary the AlGaN has already grown on one side and the dislocations cannot propagate when the growth from the other side reaches the boundary.

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