Conference report: ICNS-12, Strasbourg, 24th-28th July 2017

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The 12th International Conference on Nitride Semiconductors (ICNS-12) was held at the Strasbourg Convention and Exhibition Centre in Strasbourg, France, from 24th-28th July 2017 and featured talks and posters grouped into five symposia: Materials, Optical Devices, Electronic Devices, Other Devices and Theory-Basics. The symposia were further divided into sessions which were each broadly themed around a particular discussion topic, as well as a Late News session. Plenary talks were held on the first and last days of the conference as part of the opening and closing sessions, respectively. I was very grateful to have the opportunity to present my own work to an international audience at this conference in the form of a contributed talk. Below I have summarised selected talks and posters from the conference that I found interesting.

Wide-band-gap semiconductors: present and future

Chris G. Van de Walle, UCSB, California, USA

This was the opening plenary talk and provided an overview of the nitrides materials family and their well-known unique aspects that lead to their high efficiencies in spite of the large defect density and polarisation fields present in quantum well structures. There was a particular focus on work by the group that claims that the current values of the spontaneous polarisation, which are determined for wurtzite nitride materials relative to zincblende material, should in fact be determined using a hexagonal layered structure (layers a two-dimensional graphene or hexagonal BN-like structure) as a reference instead. This is because zincblende material will still produce some contribution to the polarisation due to discontinuities at heterostructure interfaces and these are not usually accounted for. However, the authors also claim that the values for the piezoelectric polarisation which are currently applied to calculations are the “proper” values, when in fact the “improper” values should be used. The former are usually determined by the application of a voltage and the resultant strain measured, but is not sensitive to the change in surface charge density which results from the deformation and is accounted for by the “improper” values. This part of the talk was concluded with the remark that these two errors which are commonly applied together actually cancel each other out almost perfectly, so they do not pose significant problems for previously calculated total polarisations.

The role of random alloy fluctuations in the InGaN/GaN LED

Alessandro Pecchia, CNR-ISMN, Rome, Italy

This was the invited talk opening a session on the topic of modelling carrier localisation. The authors argue that the so-called “green gap” (the difficulty in producing efficient green light emitters) is due, in nitrides, to increased carrier localisation rather than poor material quality in InGaN alloys with the In fractions necessary for green light emission. The authors had modelled quantum wells using an atomistic tight binding approach and found that electrons and holes are localised at potential minima due to In-rich regions, and that the electron and hole wavefunctions are separated due to the strong electric fields that exist across the quantum wells. This results in a large spatial separation of the wavefunctions in 3 dimensions, and the authors claim that this reduction in the electron-hole wavefunction overlap in green LEDs is the main cause of the green gap.

LED based microdisplays with integrated collimating lenses

Kunook Chung, University of Michigan, USA

Micro-LEDs are useful for augmented reality and other heads-up display technologies. This talk described work in which an InGaN quantum well had been etched into an array of nanopillars of different diameters. Following etching, strain relaxation occurred in the quantum well region of the nanopillar which modified the quantum confined Stark effect and so changed the quantum well emission wavelength. Since the degree of strain relaxation is proportional to the diameter of the nanopillar, micro-LEDs of different emission wavelengths could be produced by simply etching the wafer into an array of nanopillars of different sizes. A SiN layer was also grown, etched into a parabola, and then transferred onto the top of each LED to act as a lens which would collimate the light output for near-to-eye displays.

Localisation effects in InGaN/GaN heterostructures evidenced by scanning tunnelling luminescence spectroscopy

W. Hahn, Ecole Polytechnique, Palaiseau, France

Spatially resolved scanning tunnelling luminescence spectroscopy revealed bright regions of a quantum well which were attributed to the preferential recombination of electrons and holes in local potential minima (localised states). The peak emission energy of the luminescence from a particular region of the sample was found to exhibit an anti-correlation with the intensity of that luminescence, and a correlation with the low energy half width at half maximum. This behaviour was attributed to the “hopping down” of electrons which were ejected into the high energy regions of the potential landscape to the lower energy regions where they would experience deeper localisation and therefore be more likely to recombine there.

Carrier dynamics studies of III-nitride materials using photoacoustic and photoluminescence measurements

S. Tomiya, Kanazawa Institute of Technology, Japan

This was the invited talk in a session on characterisation, and it detailed an alternative method for calculating the internal quantum efficiency (IQE) of samples. Usually, the IQE of a sample at room temperature is determined as the ratio of the intensity of the luminescence at room temperature to that at low temperature (around 10 K), where in the latter case the sample is assumed to have an IQE of 100%. However, the authors argue that this assumption is not necessarily valid as a significant portion of the carriers may still diffuse to defects and recombine non-radiatively at low temperatures. Instead, the authors propose a technique whereby a photoacoustic signal is measured using a microphone at the same time as recording the photoluminescence signal. The photoacoustic signal is generated by heat given off as a result of non-radiative recombination, and so the IQE at a particular temperature is given as the ratio of the photoluminescence intensity to the total of the photoluminescence intensity and the photoacoustic intensity. The authors claim that performing these measurements at different temperatures enables a more accurate determination of the radiative and non-radiative recombination rates for a sample under excitation.

Ultrafast spectroscopy of III-nitride heterostructures under high injection: from fundamental properties to device

Gwénolé Jacopin, Ecole Polytechnique Fédérale de Lausanne, Switzerland

The authors reported on power dependent photoluminescence measurements of *c*-plane InGaN/GaN and GaN/AlGaN quantum well structures. At high excitation power densities, both types of structure exhibited a broadening of the quantum well photoluminescence peak on the high energy side. Time-resolved photoluminescence studies showed that the luminescence in this excitation regime narrowed and redshifted with time. This broadening was attributed to an optically induced Mott transition, whereby a supposed “insulating excitonic gas” at low powers transitioned into a “conducting electron-hole plasma” at high powers. Spectrally integrated photoluminescence time decay curves showed a fast component at early times for the InGaN/GaN quantum well, which was attributed to Auger recombination. The decay for the GaN/AlGaN quantum well was exponential. The authors claimed that Auger recombination would be affected by localisation effects and the built-in electric fields across polar quantum wells, so the experiments were repeated on two *m*-plane InGaN/GaN quantum well samples: one with flat well/barrier interfaces and one with a rough interface between the well and the top barrier. The latter sample exhibited a broader photoluminescence peak than the former. This was attributed to the increased localisation due to quantum well width fluctuations. The sample with smooth interfaces showed a monoexponential photoluminescence decay, while the one with the rough interface featured a fast component at the start of the decay. The work across all the samples studied led the authors to conclude that Auger recombination is enhanced at high excitation power densities in samples with a high degree of carrier localisation, namely *c*-lane InGaN/GaN quantum wells and the *m*-plane quantum well with pronounced quantum well width fluctuations. During the questions following the talk, the speaker was asked why the group believed that excitonic localisation occurs in *c*-plane InGaN/GaN quantum wells when it is widely accepted that electrons and holes are localised separately in this system. In response, power dependent photoluminescence excitation data were shown which featured absorption peaks at low powers which were attributed to the formation of excitons. However, this data related to the GaN/AlGaN sample and, while the speaker claimed that the same had been observed for the InGaN/GaN sample, no data was presented for that case.

Suppression of the quantum confined Stark effect in polar III-nitride heterostructures for efficient UV emitters

M. R. Wagner, Technical University Berlin, Germany

The polarisation-induced electric field across *c*-plane GaN/AlN quantum wells embedded in nanowires was mitigated by the inclusion of GaN layers above and below the AlN barrier layers. This technique was dubbed the Internal-Field-Guarded-Active-Region-Design (IFGARD). These layers led to additional polarisation-induced sheet charges forming at the interfaces between the GaN layers and the AlN barriers, which gave a reduced resultant electric field across the quantum well. In some cases, the field was reduced to almost zero. Power dependent photoluminescence showed that the blueshift of the quantum well luminescence peak with increasing power, often attributed to the screening of the electric field by the build-up of electrons and holes at opposite quantum well interfaces leading to a reduced quantum confined Stark effect, was reduced for samples where the electric field was calculated to be almost zero. The photoluminescence decay times were also faster for these samples, which was attributed to an increased electron-hole wavefunction overlap as a result of the reduced electric field.

POSTER: Transformation of localising potential in InGaN MQWs as the emission shifts from blue to amber spectral region

J. Mickevičius, Vilnius University, Lithuania

The authors claim that spatially-resolved photoluminescence studies on multiple quantum well structures emitting in the blue, green and amber spectral ranges showed that the localising potential landscape changes as the quantum well In fraction is increased. For the blue-emitting (low In fraction) sample, the majority of the luminescence had relatively low intensity, but there were some randomly scattered regions of high intensity which had redshifted emission energies. The low intensity regions were said to be weakly localised, while the higher intensity, lower energy regions were more strongly localised. For the green-emitting sample, the highest intensity regions emitted at the median emission energy for that sample; there were randomly scattered lower intensity regions emitting at higher and at lower energies. The amber-emitting (high In fraction) sample showed emission biased towards the low energy side of the distribution of energies, with some randomly scattered blueshifted emission regions which were of higher intensity. A “double-scaled” localising potential profile was proposed, where both large-scale and small-scale potential fluctuations are present. The large-scale fluctuations are responsible for the high and low energy regions of luminescence that were presented, while the small-scale fluctuations cause the spectral broadening of the light detected at a single pixel. The authors suggest that the high energy tail observed in the distribution of emission energies for the amber-emitting sample is due to the large scale potential fluctuations, and that these cause a greater potential difference between individual localised states for this sample which leads to less efficient radiative recombination. In contrast, the emission in blue and green-emitting samples was said to be governed mainly by the small-scale potential fluctuations.

POSTER: Potential barrier formed around dislocations in InGaN quantum well structures by spot cathodoluminescence

Satoshi Kurai, Yamaguchi University, Japan

V-pits were observed in scanning near-field optical microscopy (SNOM) measurements of an InGaN quantum well structure. These are known to occur at the surface due to threading dislocations. Spatially resolved cathodoluminescence measurements showed a high energy shoulder on the quantum well emission peak at the sites of V-pits, which were attributed to recombination from the potential barrier formed by the thinner {10-11} facets which form there. However, the height of this barrier was thought to have been underestimated in this and previous cathodoluminescence studies due to the detection of luminescence from carriers which diffuse away from the intended electron beam target. Instead, the authors suggest that SNOM-photoluminescence measurements would be more accurate, where photoluminescence is detected by a fibre probe with a higher spatial resolution than the cathodoluminescence method.

Concluding remarks

I would like to thank the UKNC for giving me the opportunity to attend this conference and present my work there. It was an eye-opening experience and I am grateful to have had the chance to meet and discuss my work with the international nitrides community.