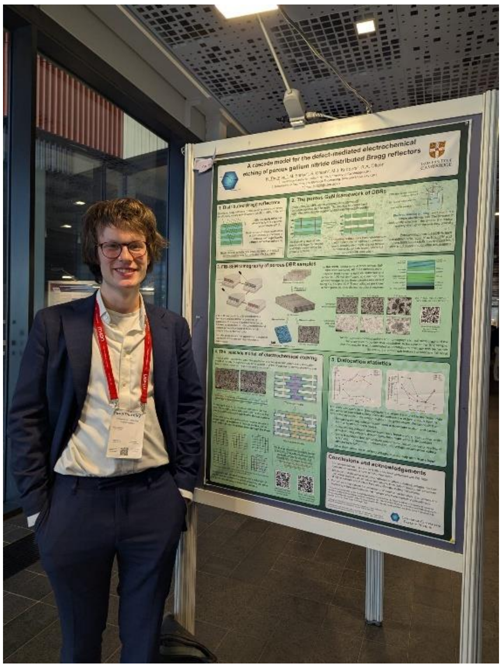
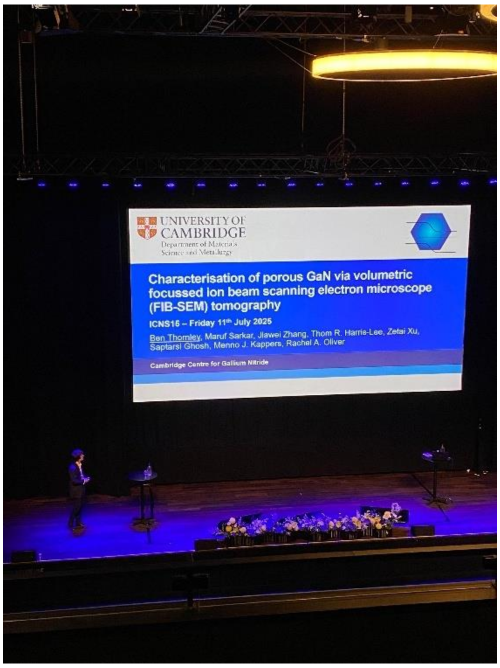
Conference report – ICNS15, Malmö (Sweden), 6-11th July 2025

Introduction

The 15th International Conference on Nitride Semiconductors was held from 6th-11th July 2025 in the Clarion Live hotel in Malmö, Sweden. This represented the 30th anniversary of the founding of the conference, with 8 plenary speakers, 59 invited speakers and over 800 attendees. Works were presented in four concurrent streams, broadly categorized under the topics of growth, physics/characterisation, electronic devices and optical devices, and grouped into sessions based on relevant subjects. Posters, of which there were over 450, were presented throughout the venue over the Monday, Tuesday and Thursday, with dedicated slots for presenting them for two hours on the Monday and Tuesday and one hour on the Thursday. The conference was held in the memory of Professor Bo Monemar, who was an esteemed and beloved researcher in the field and had been instrumental in the bringing of the conference to its host city.

Through the awarding of a Phil Dawson travel bursary on behalf of the UKNC, I was able to travel to the conference and engage with the full duration of the 6 days. I presented a poster titled ‘A cascade model for the defect-mediated electrochemical etching of porous gallium nitride distributed Bragg reflectors’ on Thursday and a contributed talk titled ‘Characterisation of porous gallium nitride via volumetric focussed ion beam scanning electron microscope tomography’ on Friday and received some valuable feedback. This report will cover the overarching themes and hot topics that persisted through the various presentations, the work that was relevant to my research and a selection of the presentations that I found to be most interesting or noteworthy.





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Characterisation of porous GaN via volumetric focussed ion beam scanning electron microscope (FIB-SEM) tomography

ICNS15 – Friday 11th July 2025

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Common topics and themes

Many of the long-standing challenges and discussion points of nitrides research were referenced throughout the conference, but there were new themes that persisted as well. In the context of optical devices, the perennial issue of the ‘green-gap’ was referenced extensively in the context of laser and LED efficiency. This is the low internal quantum efficiency seen in optical devices producing in the wavelength region of visible green light, classically attributed to the presence of non-radiative recombination states that are created by defects resulting from lattice mismatching of materials. There were dozens of researchers presenting data on the causes and solutions for this issue, including different device architectures, growth processes and simulation results. One of the most comprehensive works covering the issue was the invited talk by Dr Aurelien David (Google), titled ‘Disorder and the luminescence of InGaN emitters’. This work compared simulation results and experimental data to understand the effect of alloy disorder on InGaN quantum well-based lasers and LEDs, where the effect is well reported. The presentation covered the controversy as to whether localisation of hole wavefunctions, an effect of alloy disorder, is good or bad for increasing quantum efficiency, concluding ultimately that the peak broadening of emission spectra of green and red LEDs are affected by alloy disorder and the formation of Urbach tails, but that the efficiency drop is ultimately not itself caused by the same effect, which itself is a fascinating claim.

Another theme that persisted through the conference is transistor design and the feasibility of nitride CMOS. Since CMOS technology requires highly doped n- and p-type materials, it has been generally restricted in the nitrides by difficulties associated with obtaining highly p-doped GaN. The only seemingly feasible p-type dopant, magnesium, is notoriously difficult to activate in large quantities when prepared by both CVD and ion implantation approaches, and a great deal of presenters discussed treatments such as anneals and growth steps to improve magnesium incorporation and activation in high concentrations. These issues have been known for a long time, so alternative transistor architectures and designs were mentioned a great deal at the conference. A selection of presenters discussed the use of HEMT-like architectures, another long-standing nitride architecture, to prepare devices with 2D hole gas channels, rather than the conventional 2D electron gas. These are relatively undeveloped and suffer for poor mobility, but works at the conference demonstrated impressive sheet carrier density and growth procedures to bring the technology to fruition. Many sessions in the electronic devices category were also devoted to alternative transistors architectures such as the finFET and other vertical structures where development has continued and scaling is improving, whilst breakdown voltage remains a strong consideration throughout the topic.

Many presentations focussed on characterising, modelling and exploiting defects in crystals. The use of positron annihilation experiments to characterise and identify the character and density of states of vacancy complexes was introduced in an invited talk by Professor Akira Uedono (University of Tsukuba), where the focus was the effects of vacancy clustering during the annealing state of Mg activation on the spectra of positron annihilation. This is a very sophisticated method for defect characterisation that was used in a handful of works through the conference. DLTS was utilised through some more works at the conference, as well as it's extremely complex related experiment Laplace DLTS, to assess mid-gap states and energies for a variety of materials and applications. The physical structure of threading dislocations through climb and glide processes was also described in a contributed talk by Han Yang (Peking University). Conventionally research in semiconductor development has focussed on the reduction of defects, but this conference illuminated the promise of point defects in nitride crystals as exploitable emitters of single photons for quantum communications. This was covered in detail in an excellent invited talk by Professor Anthony Bennett (Cardiff University) on the prospects of point defects in AlN being an exploitable platform for single photon emission, presenting good results for Hanbury-Brown Twiss-type experiments carried out at low power on ion implanted samples. Following this was a session on the applications of various nitrides for single photon sources, introducing many at the conference to an uncommon but promising application of the nitrides.

One theme that I anticipated would cast a large shadow was artificial intelligence, which has begun to shape and change almost every scientific discipline already. Despite this, surprisingly few works demonstrated any applications of AI in image processing, signal processing, monitoring or other commonplace uses. It was certainly noteworthy, however, that the power consumption of generative AI which has led to extreme increases in energy demand is a strong motivator for many electronic devices across the board. The final plenary talk of the conference was given by Professor Tomás Palacios (Massachusetts Institute of Technology), titled 'III-Nitride Electronics in the Era of Artificial Intelligence'. This was a very engaging presentation showing that nitride-based devices will be instrumental to the next generation of devices at every scale, for the large range of operating powers seen throughout the complex infrastructure of data centres and power transmission equipment. Ultimately the demand for high-power and ultra high-power devices has grown extremely rapidly and nitride-based devices are well positioned to see mass adoption to replace existing unsuitable silicon devices. This highlighted the importance of breakdown voltage as a pertinent figure of merit for the novel and developing devices shown throughout the conference, but also made clear that diversity in device scale and operating modes is just as important, to fulfil the various needs of different stages power consumption in data centres.

A new session was introduced this year to the conference, titled 'Nitrides go wild'. This was a chance for presentations covering esoteric or cutting-edge applications and research into nitrides and was well attended as a result. Rather than questions for the presenters, the talks were followed by more general discussion by the audience with the speakers. This was a welcome change to the schedule and all of the presenters fit the brief very well, with my personal favourite being the discussion of the prospects for improving red LED efficiency. It would be excellent to see other conferences attempt this style of session as it was well attended and a good chance to see research beyond the four topics on which the conference was run.

My focus area

Porous nitrides occupied a relatively low profile at the conference but there were researchers presenting on relevant work. Professor Rachel Oliver (University of Cambridge) delivered an invited talk on the role of dislocations in electrochemical etching of porous GaN, highlighting the preferred initiation of pores at threading dislocation cores in specific etching conditions. The work also detailed threading dislocation etching in distributed Bragg reflectors, and how the effects of different etching rates of dislocation cores and doped material can be reproduced in simple probabilistic simulations.

Porous GaN distributed Bragg reflectors were also discussed by Dr Frederik Lüßmann (Technische Universität Braunschweig) in a contributed talk discussing experimental pore morphologies and the suitability of different refractive index approximations for optimising and modelling porous distributed Bragg reflectors. His colleague Dr Florian Meierhofer (Technische Universität Braunschweig) presented a poster detailing feasible routes to in-plane patterning of porous nitrides based on germanium ion implantation, showing the extent of lateral confinement of etch fronts and the issues associated with introducing conductivity this way.

Despite porosity being scarcely mentioned throughout, the electrochemical etching procedure for porosification is being explored by many groups as a route to device lift-off and substrate reuse. Dr Artem Shushanian and colleagues at Chalmers University of Technology exploit electrochemical etching to entirely delaminate prepared UV-LEDs for flip-chip processing and device integration. The procedure requires precise tuning of excitation wavelength and aluminium content to ensure excitation of carriers for etching takes place only in the desired layer of the device. Despite the fact that our research did not directly overlap, it was very insightful to discuss and exchange knowledge on the shared interests.

Highlighted works

Asif Khan (University of South Carolina) – ‘III-Nitride research: a historical perspective’

The conference opened with a plenary talk given by Asif Khan who was awarded the Isamu Akasaki Memorial lecture. This was an excellent way to begin the proceedings, and the talk set the stage very well for the conference to follow. Major contributions to the optimisation of growth and processing were detailed in a fast-paced and engaging run through of the history of the field.

Kensuke Sumida (Nagoya University) – ‘Ultra-high-pressure annealing with a carbon capping layer for activation of Mg ion-implanted GaN’
This talk opened the ‘Heterostructures and implantation’ session and explained an interesting method for ensuring activation of magnesium ions in p-GaN ion-implanted layers. The conventional high-pressure high-temperature anneal is needed to take GaN above its stable temperature in order for magnesium dopants to activate. As opposed to the conventional use of GaN powder on the surface, this work demonstrated the addition of a carbon capping layer. Following the annealing process, this prevents thermal decomposition of the GaN but does not create the poor uniformity seen with GaN powder. The carbon can then be removed by an oxygen treatment that leaves a uniform gallium oxide layer and a high magnesium activation fraction.

Izabella Grzegory (Polish Academy of Sciences) – ‘Phase diagram of GaN — where is its wurtzite-rocksalt-liquid triple point?’
Perhaps a surprising unanswered question in GaN is the precise nature of the pressure-temperature phase diagram. This work combined ab initio molecular dynamics simulations with experimental data to identify the triple point in P/T space, a seemingly basic but extremely important contribution to the understanding of high pressure/high temperature processing of GaN films

Okhyun Nam (Tech University of Korea) – ‘Epitaxy of AlGaN channel HEMT for extreme environmental electronics: challenges and solutions’
Design of HEMT structures with Al-rich AlGaN channels demonstrate higher thermal stability and breakdown voltage, making them more suitable for extreme conditions, but reduce the extent of polarisation doping, leading to reduced carrier density, and cause more alloy scattering. This work demonstrated the use of a superlattice of alternating AlGaN/AlN for low surface roughness in HEMT structures. This causes a blueshift of the photoluminescence spectra of the devices and a reduction in C/V hysteresis, showing a reduction in the activation of deep-level traps.

Jia Wang (Nagoya University) – ‘Magnesium Intercalation in Gallium Nitride with Different Polarities’
This work discussed the properties of magnesium ions when incorporated into GaN lattices via intercalation. Interstitial magnesium atoms were demonstrated to form clusters named ‘pyramidal inversion domains’, where the magnesium remains electronically inactive and repels nearby gallium ions to large strains. These clusters were then demonstrated to form energetically favourable stacks, where overlying clusters will reduce the polarity reversal space if they line up together (with a minimal separation distance of 5-layer pairs). The consequences of this upon electronic properties and the physical mechanics of annealing defects was discussed.

Kentaro Hayashi (Sony) – 'Addressable 2D Array of GaN-based VCSELs with Curved Mirrors'

Arrays of VCSELs can suffer from diffusion/diffraction losses of resonant light due laterally outside the cavity. For arrays of VCSELs, this creates loss of brightness. In this work, the use of curved DBRs at the bottom of cavities was discussed, preventing diffusion losses laterally due to the curvature of the surfaces. The work also addressed the isolation of devices grown in arrays on these curved mirrors, typically done by reaction ion etching down to the substrate to avoid electrical shorting between adjacent devices. Here, the use of a semi-insulating GaN interlayer onto a n-GaN-on-sapphire template was used as a means to prevent electrical leakage and lower lateral current, resulting in the successful demonstration of a 7x7 array of devices that could be operating individually.