Optical Properties of Semipolar (11-22) AlGaN on GaN microrod templates

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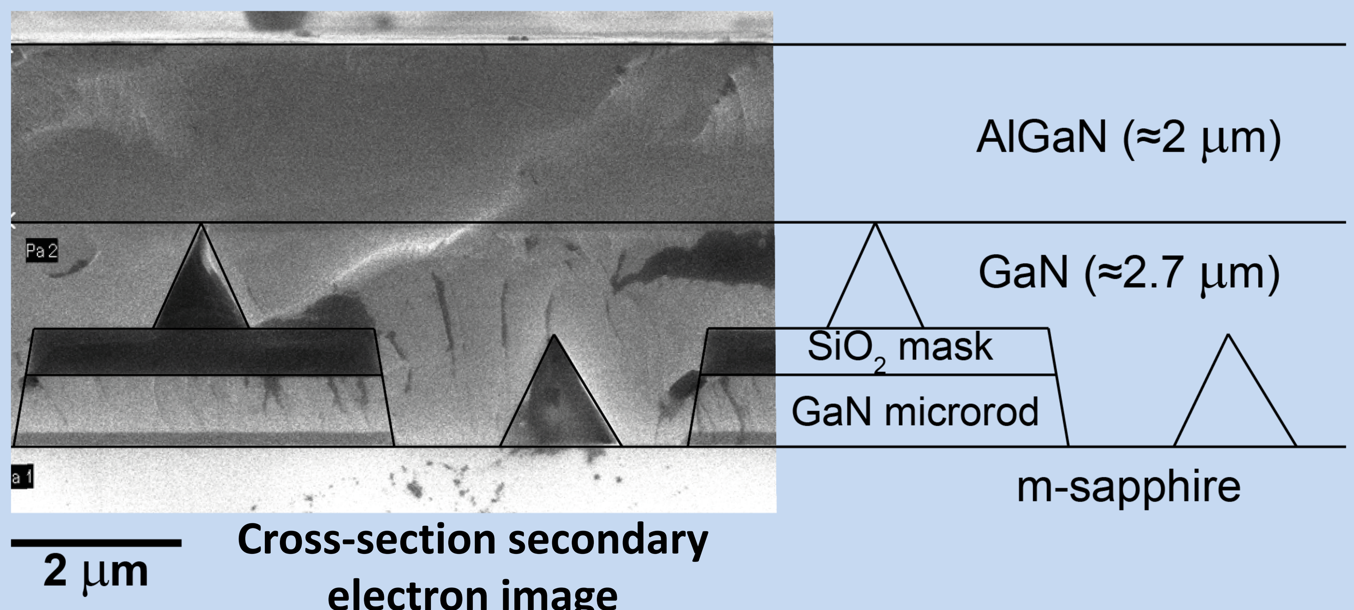
Introduction and motivation

- By alloying GaN with AlN it is possible to shift the emission wavelength into the deep ultraviolet (UV) spectral region
- AlGaN UV light emitters suffer from lower quantum efficiencies and output powers compared with GaN. High densities of extended defects and the quantum-confined Stark effect (QCSE) contribute to this.
- To mitigate these two effects semipolar (11-22) AlGaN layers are grown on semipolar (11-22) GaN templates overgrown on microrod arrays
- The semipolar orientation, however, suffers from a different range of extended defects compared with (0001)-orientated (In/Al)GaN structures
- Applications for UV light-emitting diodes (LEDs) include water purification, sterilisation, and medical treatment (e.g. psoriasis)

Sample details: Growth and fabrication

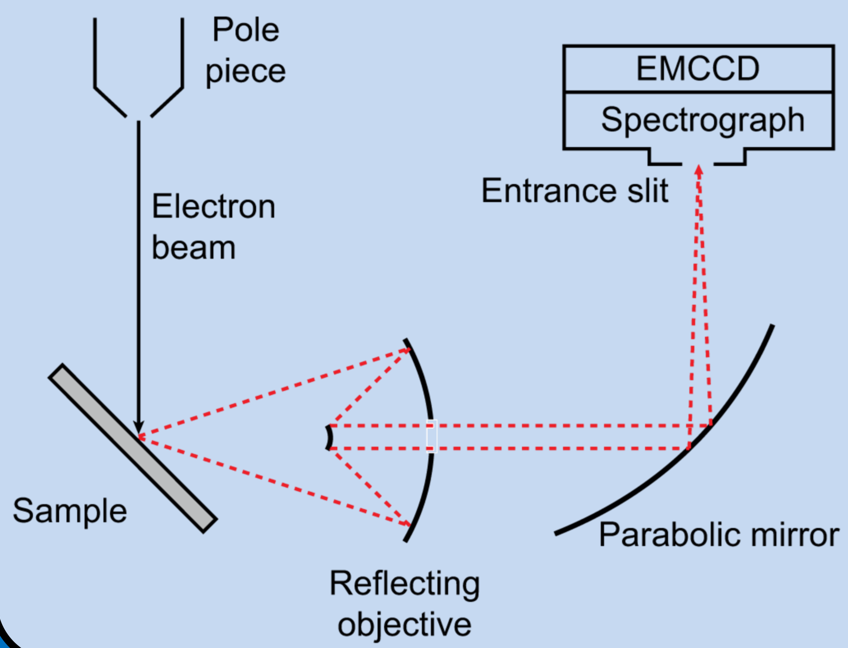
- Growth: Metalorganic chemical vapour deposition (MOCVD)
- Template: regular array of etched GaN microrods on *m*-plane sapphire defined by pitch and diameter of the microrods
- Semipolar AlGaN grown on just coalesced GaN, which has been overgrown on the microrods
- Crystal orientation of GaN and AlGaN layers is (11-22)



Cross-section secondary electron image

Zhang, *AIP Advances* **6**, 025201 (2016)

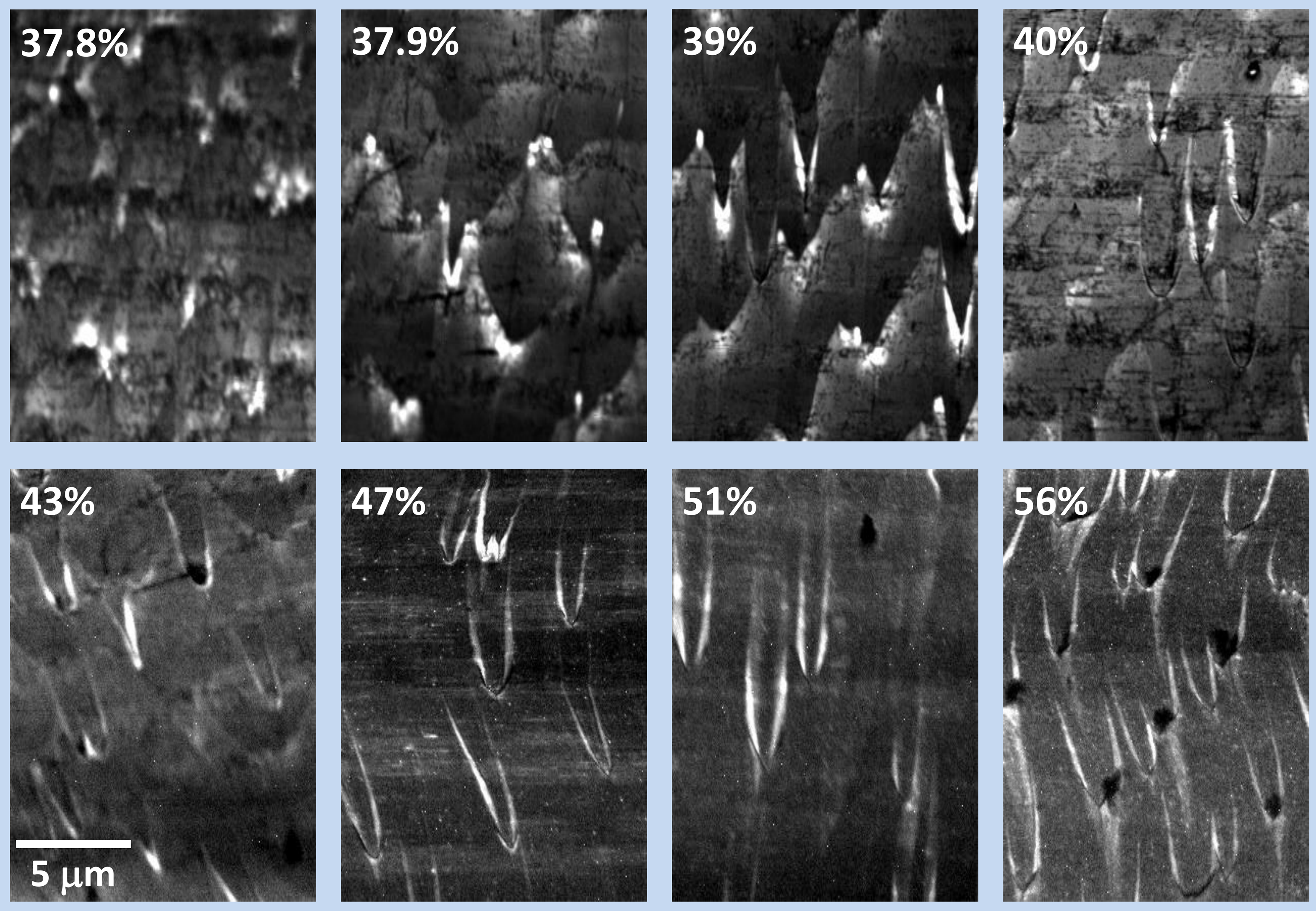
Cathodoluminescence (CL) hyperspectral imaging



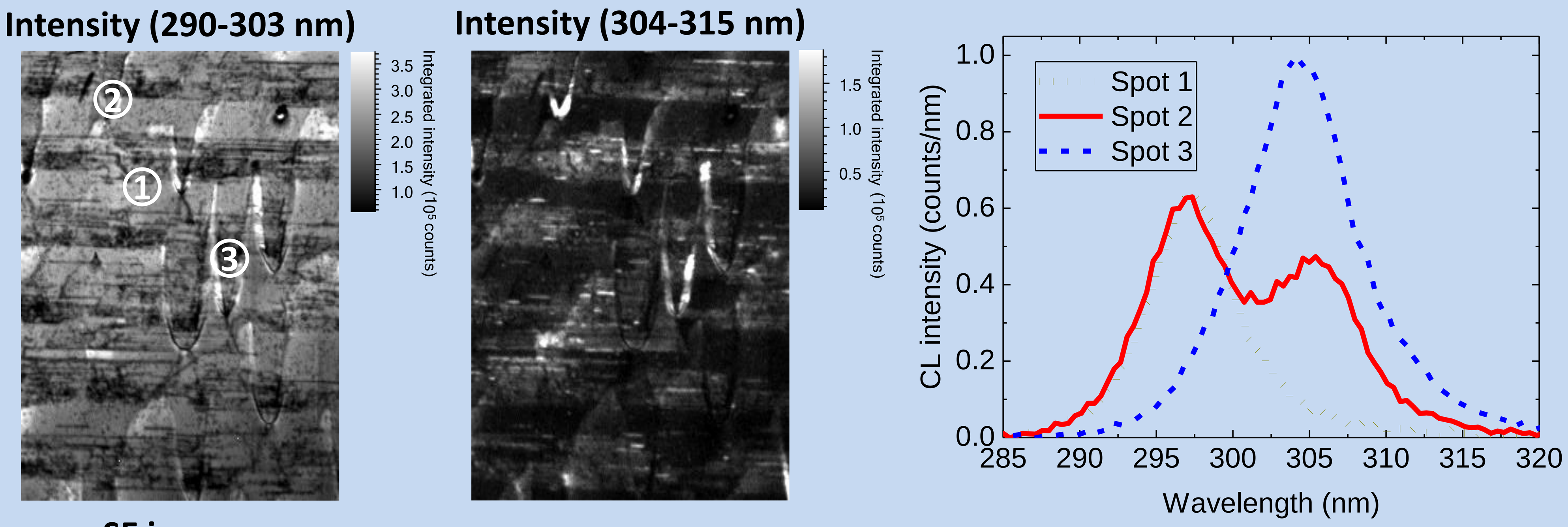
- CL imaging is a powerful technique to investigate the luminescence behaviour of sample features and defects
- The electron beam is scanned across the sample surface while simultaneously acquiring an entire room temperature CL spectrum at each pixel, resulting in a multi-dimensional (hyperspectral) data set
- Numerical peak fitting can be applied to each spectrum in order to extract 2D maps of parameters such as peak energy, peak intensity or line width

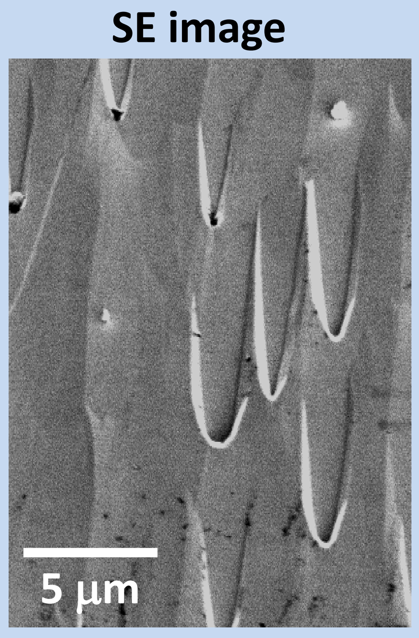
Edwards, *Microsc. Microanal.* **18**, 1212 (2012)

Panchromatic CL of AlGaN with different AlN content



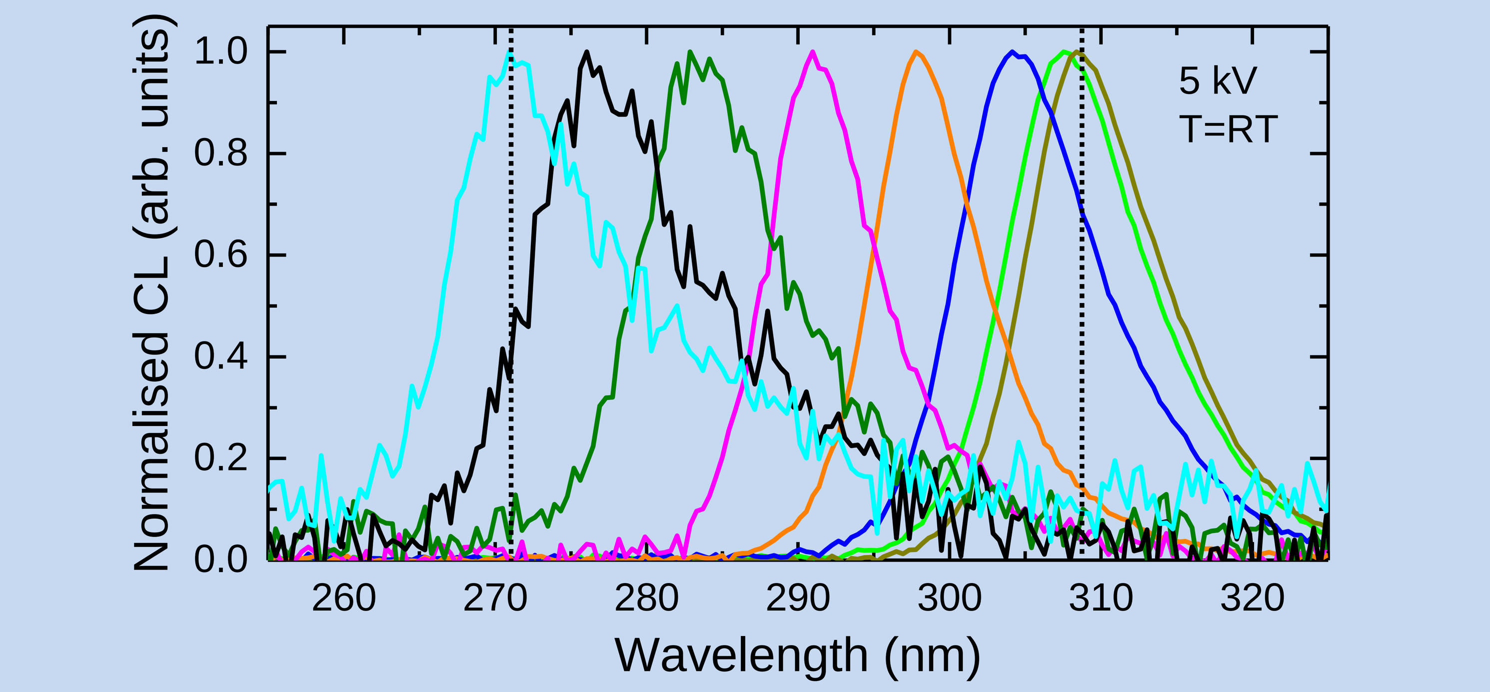
CL imaging of $Al_{0.40}Ga_{0.60}N$: Identification of different emission bands





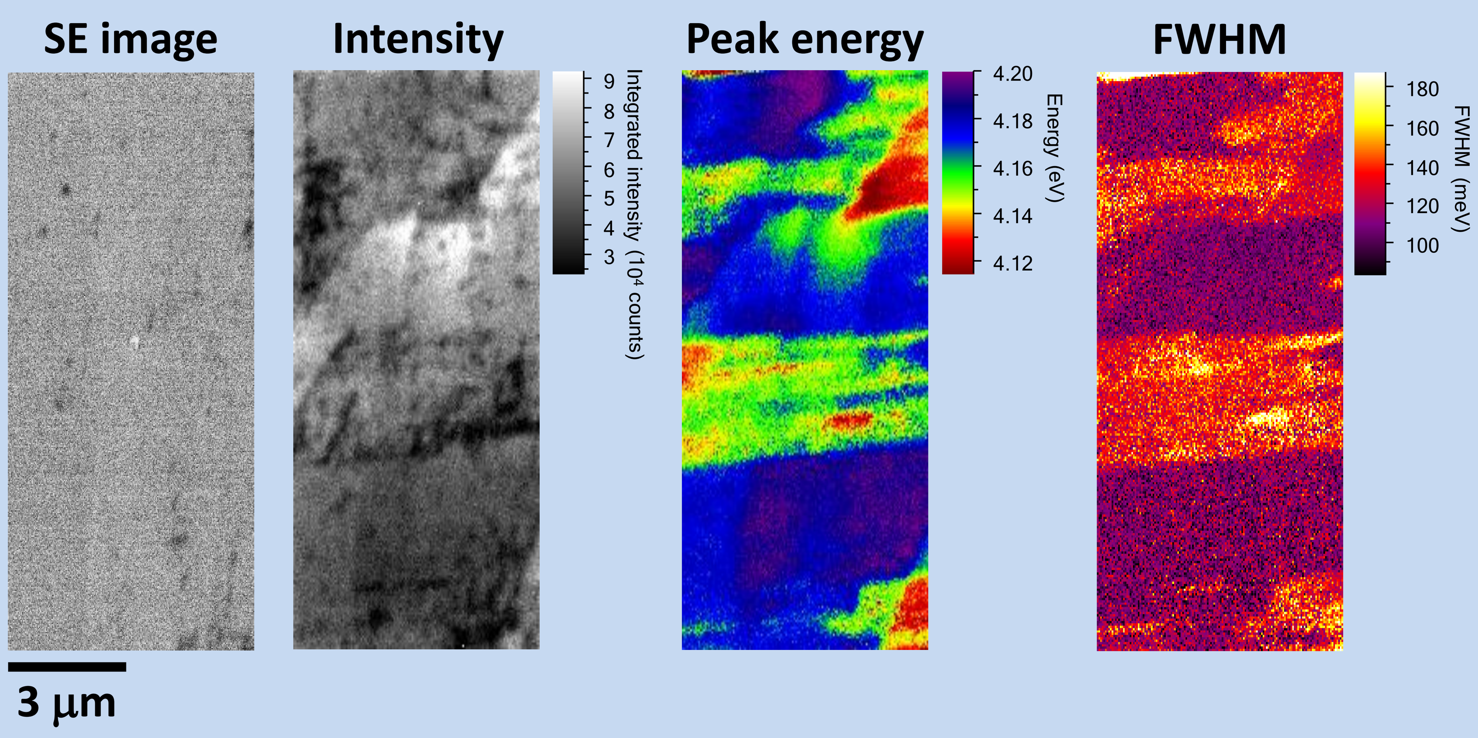
- Surface morphology strongly influences the emission characteristics
- Two dominant emission peaks can be observed: the short wavelength peak is emitted from the majority of the area (spot 1), whereas the longer wavelength peak is located on and around the chevrons (spot 3)
- The chevrons are observed to have an influence on the growth conditions and the AlN incorporation leading to different concentrations on the facets as seen in the CL spectrum taken from spot 2
- The CL images also show dark and bright stripes indicating regions with higher and lower densities of extended defects
- These stripes correlate with regions of increased basal-plane stacking fault density as seen in TEM images from the GaN template

Tuning of emission wavelength



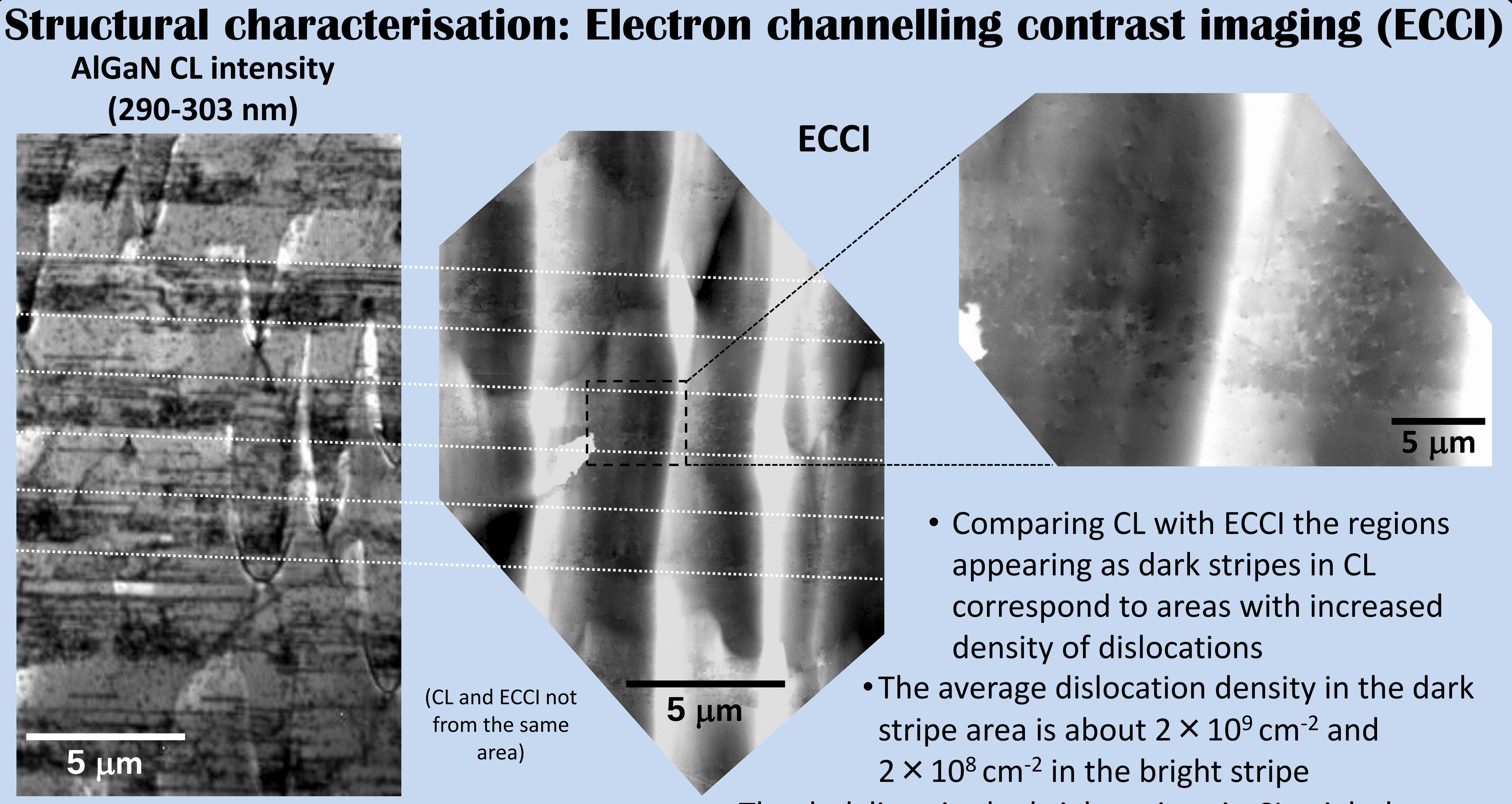
Emission wavelength can be adjusted from 309 nm (AlN content: 38%) to 271 nm (56%) by varying the growth parameters (flow rates and V/III ratio).

Higher resolution CL imaging



- Higher resolution CL maps between the chevrons reveal a redshift of the AlGaN NBE peak in the dark stripes where an increased density of basal-plane stacking faults (BSFs) is observed
- Low-temperature photoluminescence shows the presence of a BSF-related peak on lower energy side of the AlGaN NBE peak
- The higher density of BSFs may lead to a stronger contribution to the overall RT CL emission leading to a broader emission and an apparent redshift

Structural characterisation: Electron channelling contrast imaging (ECCI)



- Comparing CL with ECCI the regions appearing as dark stripes in CL correspond to areas with increased density of dislocations
- The average dislocation density in the dark stripe area is about 2×10^{9} cm^{-2} and 2×10^{8} cm^{-2} in the bright stripe
- The dark lines in the bright stripes in CL might be related to lines of dislocations, misfits or stacking faults

Naresh-Kumar, *Mat. Sci. Semicon. Proc.* **47**, 44 (2016)

Summary

- Semipolar AlGaN has been grown on overgrown GaN microrods with an emission as low as 271 nm
- The AlN content has a strong influence on the emission characteristics with high defect density regions showing a redshift and reduction in emission, which may be associated with BSFs
- Dislocation density in bright stripes is one order of magnitude lower compared with dark stripes

Acknowledgements

SUPA

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