Advancements in High Indium Content AlInN Grown Via Metal Modulated Epitaxy and Application Towards Polar/Non-Polar Optical Devices

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AlInN has been a topic of recent study due to its unique property among III-nitrides of lattice matching to GaN at a composition of 18% indium, making it a strong candidate for power electronic and optoelectronic applications. A widely unexplored area is the application of AlInN towards visible/Near-IR optical devices. AlInN has a tunable bandgap, spanning the infrared to ultraviolet range, of 0.7 to 6.1eV. At a composition of about 70% indium AlInN has a perfect bandgap, 1.7eV, for tandem solar cells with silicon and for various optical communications applications. Challenges exist with the growth of AlInN as a result of the large lattice parameter mismatch and differences in growth regimes between the two binary components. At the low temperatures required for the growth of AlInN the aluminum adatoms have a low mobility, often leading to lateral phase separation in the film. Metal Modulated Epitaxy (MME) offers a good solution to the growth issues of AlInN. This flux modulated technique allows for growth under metal rich conditions, increasing surface diffusion lengths of the Aluminum while limiting droplet formation and terminating in a dry surface suitable for devices.

For comparison ~100 nm thick high indium content AlInN samples were grown using nitrogen rich (0.8 III/V ratio) MBE and MME using a III/V ratio of 1.3 with a dose designed to prevent surface segregation (details supplied at the conference). Both films were grown cold at 375 degrees C to limit phase separation The MME sample showed improvement over the MBE sample in crystal quality and surface roughness, with the XRD (0002) reflection FWHM improving from 783 arcsec to 184 arcsec, the XRD (10-15) reflection FWHM improving from 2456 arcsec to 1421 arcsec, and the AFM surface roughness improving from 1.52nm rms to 0.882nm rms between the MBE and MME samples respectively. The carrier concentrations of both samples were found to be about 1E19 cm^{-3} via hall measurement implying that like InN, In-rich AlInN may suffer from excessive residual electron concentrations and/or surface fermi-level pinning. Optical measurements will be presented at the conference.

The same MME growth conditions were used to grow 100nm of indium rich AlInN directly on a (111) p-silicon substrate. Simple indium contacts were used to contact the Si and AlInN. Vertical conduction and rectification between the silicon and AlInN layers were observed in this large area (~0.25x0.25 cm^2) device. Understanding of the limitations of and physics governing this promising vertical polar/non-polar heterojunction will be given at the conference. Additionally, results from various growth conditions will be detailed.

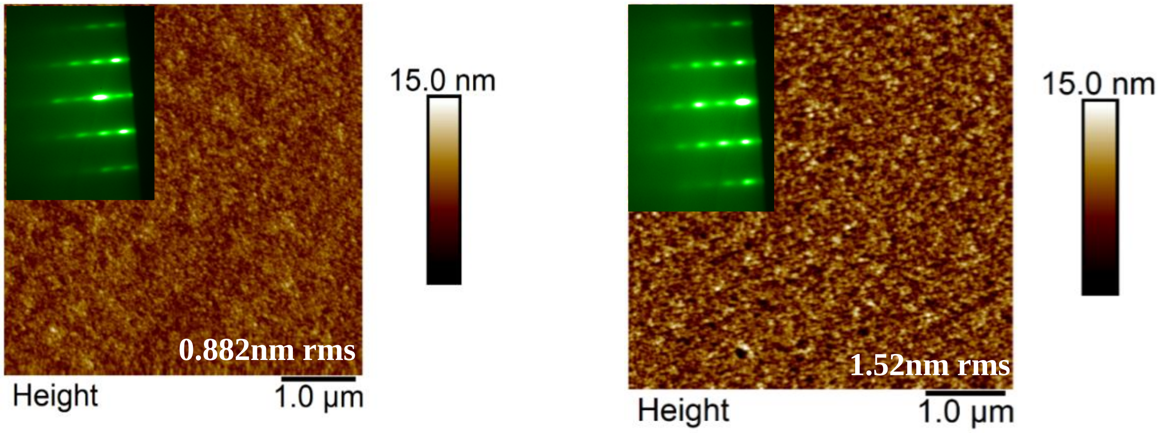

Figure 1: AFM images and corresponding RHEED images of the MME grown sample (left) and the traditional MBE grown sample (right)

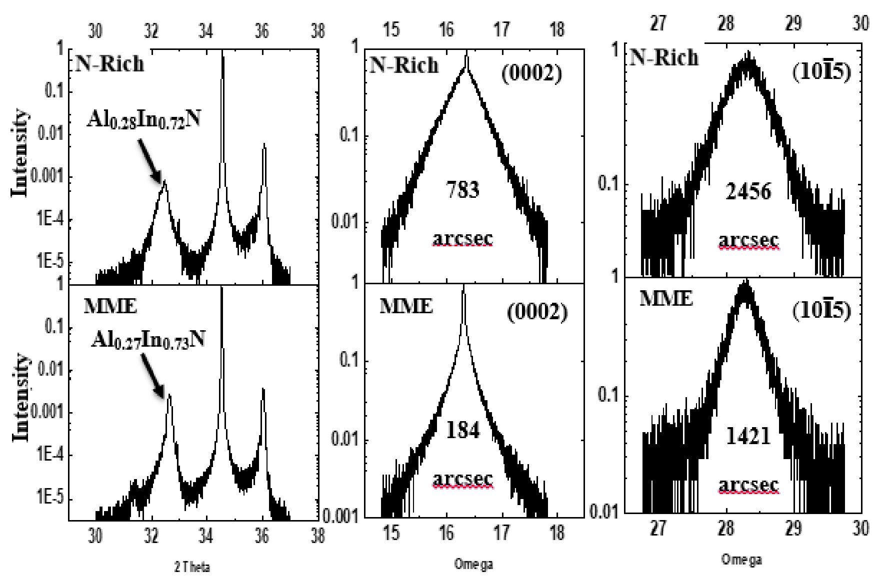

Figure 2: Normalized XRD 2 Theta Omega (left), **(0002)** rocking curves (middle) with FWHM labelled, and (**10-15)** rocking curves (right) with FWHM labelled scans of the MME (bottom) and N-Rich (top) samples. The AlN peak in the 2 Theta-Omega scan is the result of a buffer layer used by the substrate manufacturer.

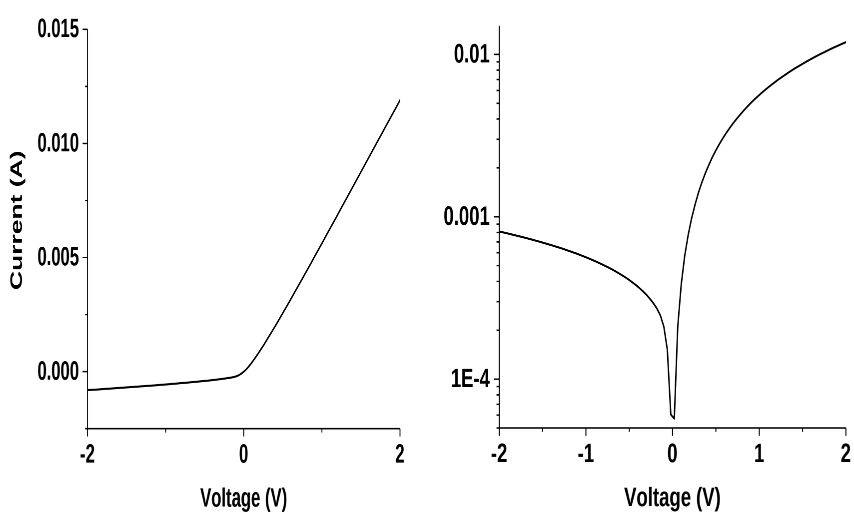

Figure 3: Linear and logarithmic scale IV curves of a large area ($0.0625cm^2$) AlInN/p-Silicon device.