High In-content InGaN films grown by Plasma-Assisted Molecular Beam Epitaxy for Photovoltaic Applications

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InGaN alloys are a family of semiconductors with a direct bandgap that can span almost the entire solar range, a property that makes them particularly appealing for photovoltaic applications. For device development, however, several challenges have to be overcome: increased structural defects due to the large lattice mismatch between the alloy endpoints as well as phase separation phenomena caused by the immiscibility of the alloy components, especially at high temperatures. The RF-MBE growth of $In_xGa_{1-x}N$ films on GaN(0001) substrates with a wide range of compositions and significant thickness (>300nm) under different growth conditions is considered in the present work. High resolution x-ray diffraction (HR-XRD), high resolution transmission electron microscopy (HR-TEM), scanning electron microscopy (SEM), atomic force microscopy (AFM), photoluminescence (PL) and Hall effect measurements were used to characterized the films.

The growth of high-In-content, single-phase InGaN films is reported. Analysis shows that In incorporation seems to depend on the preferable incorporation of Ga over In, InGaN decomposition, In desorprion for higher growth temperatures especially and the interplay of such kinetic mechanisms.

Both HR-XRD and TEM studies show that phase separation in the films depends greatly on the growth conditions and, in particular, on the substrate temperature during growth: phase separation is more likely to occur at higher growth temperatures, while for lower temperatures it is significantly suppressed. The full width at half maximum (FWHM) of XRD (0002) rocking curves also shows a deterioration of the crystal quality as the temperature increases. Information from TEM suggests phase separation could be related to strain relaxation effects: at low temperatures, films exhibit V-defects, while for higher-temperature samples, stacking faults are observed and samples appear to form a sequestration layer at the base of the InGaN film. AFM shows low-temperature samples having ‘pits’ on the surface that are also consistent with V-defects, while high-temperature samples have much smoother surfaces. Furthermore, optoelectronic properties of the InGaN layers seem to be greatly affected by the substrate temperature: as the temperature rises there appears a redshift in the PL emission and a decrease of the carriers Hall mobility.

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