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Report:

Due to structural imperfections, the performance of InGaN-based laser diodes still does not reach the predicted values. Surface and interface roughening, dislocations, and indium segregation reduce the optical emission of the multilayer structures on which the devices are based. Ideally, the metal-organic vapor phase epitaxy (MOVPE) grown mulitlayer structures are depostited on single crystalline GaN substrates. However, since high quality GaN substrates are very expensive and do not reach the sizes required for mass production, often Al_2O_3 substrates are used, inducing even more defects due to the lattice mismatch between substrate and film.

In order to study the influence of the In content and the substrate on the quality of $In_xGa_{1-x}N$ layers, several samples have been studied. $In_xGa_{1-x}N$ layers with x=0.08 and x=0.16 and a film thickness of 35 nm have been deposited on 3 substrate types: (1) c-plane GaN grown by Hydride Vapor Phase Epitaxy (HVPE) by UNIPRESS, (2) c-plane GaN(001) grown by HVPE by Lumilog, and (3) a-plane α-Al_2O_3. The 3 films with identical concentration have been deposited simultaneously, in order to ensure identical growth conditions. All films have been grown on a buffer layer consisting of 25 nm GaN grown at low temperatures, 1.5 um GaN and 2.5 um Si doped GaN. As reference sample, a structure consisting only of the buffer layer grown on Al_2O_3 has been used.

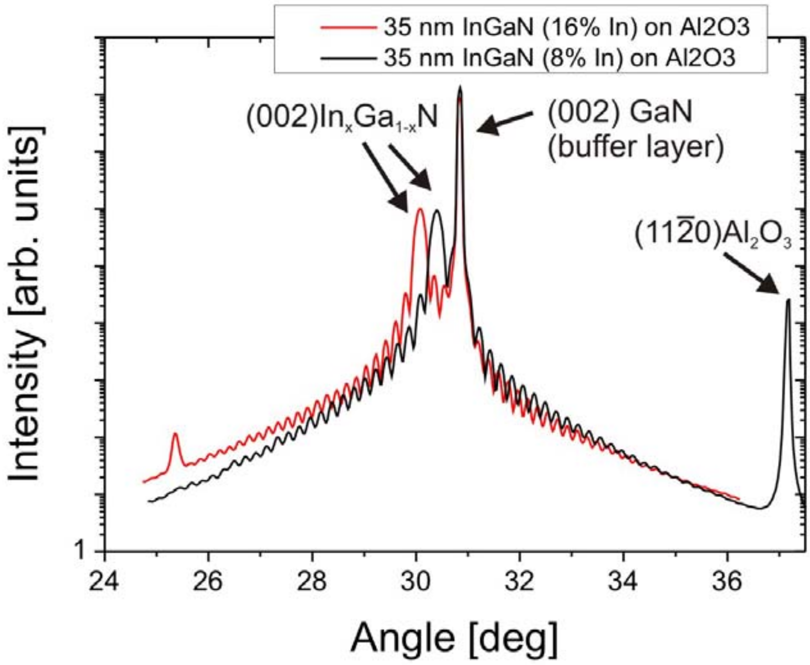

Fig. 1: Radial scans of the specular (002) reflection

X-ray diffraction experiments in specular and grazing incidence geometry have been performed at an X-ray energy of 9 keV. For all samples, the specular (002) reflection and the in plane (10-10) reflection have been measured. As an example, Fig. 1 shows radial scans of the specular (002) reflection for $In_{0.08}Ga_{0.92}N$ (black line) and for $In_{0.16}Ga_{0.84}N$ (red line) deposited on Al_2O_3. The Bragg peaks from film, GaN buffer layer and sapphire substrate are indicated.

The Kiessig fringes are visible over several degrees before damping out. This is related to the high perfection of crystalline structure and interfaces. The high quality of the InGaN films could be verified for all substrate types. While the sapphire substrate showed no visible curvature within the area illuminated by the X-ray beam, the local curvature of the HVPE grown GaN substrates was well visible. These sample had to be permanently readjusted during the measurement, in order to prevent measurement errors such as reduced peak intensities and phase shift of the oscillations.

From Vegards law, the lattice parameter in c-direction of the hexagonal In_xGa_{1-x} N unit cell is expected to be c=5.270 Å for x=0.08 and c=5.228 Å for x=0.16.The measured peak positions of the In_xGa_{1-x} N (002) reflection deviate from the position corresponding to the calculated lattice parameter. Reason for this is the interplay between lattice clamping to the substrate and partial relaxation due to structural defects.

Anomalous scattering experiments have been performed close to the In K edge (E=27.94 keV) for $In_{0.16}Ga_{0.84}N$ on Al_2O_3. The exact position of the In K edge has been verified by measuring the In fluorescence while scanning the energy. The (002) reflection has been measured at various energies close to the absorption edge. No visible changes of the peak shape were observed. A quantitative analysis of the data might be difficult due to the large positioning error of 2 eV of the monochromator angle.

A detailed data analysis, based on the dynamic scattering theory, will be performed, in order to get quantitative information about the structural perfection of the InGaN layers.