Abstract

Due to the high symmetry of the cubic III-nitride crystal unit, physical properties of the cubic III-nitrides were predicted theoretically, which are superior to those of their thermodynamically stable hexagonal counterparts. High quality c-InGaN layers and quantum structures, which form the active layers of optoelectronic devices are indispensable for realization of the highly efficient blue and green emission from c-III nitride based LEDs and Laser diodes. In this thesis, the epitaxy of high quality c-InGaN layers and InGaN/GaN wells (QWs) is optimized and the influence of various growth parameters on their structural and optical properties is investigated.

The Molecular Beam Epitaxy (MBE) of c-GaN, as well as efforts to grow thick c-GaN layers by Metal Organic Chemical Vapor Deposition (MOCVD) on top of MBE grown c-GaN buffer layers are briefly introduced. The influence of the indium and gallium fluxes on the MBE of high quality c-InGaN is studied extensively. Indium is observed to incorporate into the c-InGaN films only when the gallium flux is reduced significantly below the value needed for stoichiometric c-GaN growth. A decrease of the surface roughness of the InGaN layers and an increase of their photoluminescence intensity per unit thickness at the transition from metal-flux limited to active nitrogen-limited growth is observed. A pronounced reduction of the growth rate is observed when indium is involved in the growth. In order to explain these effects, it is supposed that excess indium atoms present on the InGaN surface due In segregation are the reason for the growth rate reduction. Based on these investigations, a recipe for the growth of high quality c-InGaN is proposed. High-resolution X-ray diffraction and Raman measurements show that InGaN layers grown on 3C-SiC substrates have better structural quality than those grown on GaAs substrates. Photoluminescence excitation (PLE) spectroscopy and photoluminescence (PL) measurements reveal that the emission from c-InGaN layers originates from highly localized structures in these layers. The room temperature PL spectra of c-$In_xGa_{1-x}N$ grown on 3C-SiC substrates are dominated by two preferential peaks at around 2.4 eV and 2.6 eV with a slight red shift with increasing x in the range of $0<x<0.2$. Depth resolved cathodoluminescence and PLE demonstrate the existence of In-rich phases, which are found by transmission electron microscopy (TEM) to be oriented along the growth direction. By thermal annealing experiments, stability of these inclusions in the c-InGaN layer is investigated, revealing that they are stable even at annealing temperatures above the growth temperatures, which allows some conclusions on the mechanism of their formation.

The PL emission intensity from c- InGaN/GaN single quantum wells is found to increase with increasing well thickness, which proves the absence of polarization fields in cubic III-nitrides. The InGaN/GaN MQWs were grown with a growth interruption after the InGaN well growth allowing excess In atoms to evaporate yielding sharp InGaN/GaN interfaces. With this growth procedure, highly efficient c-InGaN/GaN MQWs with 515nm room temperature PL emission (FWHM 240meV) and clear superlattice peaks in X-ray diffraction patterns have been realized. Finally, the effect of a c-AlGaN/GaN Bragg-mirror micro-cavity on the 520nm green emission from c-InGaN/GaN MQWs has been demonstrated for the first time.