Chapter 5 Conclusions

In this thesis, InN epilayers and InN nano-dots were grown by MOVPE. InN dot sizes were controlled by tuning the TMIn deposition times and changing the substrate temperatures. The morphology of InN dots was studied by AFM. Optical properties of InN epilayers and dots were investigated by temperature dependent PL spectra.

AFM studies show that the dot height of InN increases from 18 nm , 28 nm to 32 nm, and the dot density decreases from 8.4×10^{9}, 1.6×10^{9} to 8.9×10^{8} cm^{-2} with increasing growth temperatures from 650 ^{o}C, 625 ^{o}C to 600^{o}C, respectively. Moreover, the shape of the InN dot is hexagonal.

PL spectra of InN epilayers show the PL peak shifts to higher energy with higher carrier concentration. It indicates that a convolution between thermally distributed electrons and the hole states localized near the acceptors is needed to analyze PL spectra. Therefore, the PL peak position can not be used to describe the energy position of the true band gap. We ascribe our dominant PL peak (I_{sh}) of the epilayer at low temperature is the transition from degenerate electrons to shallow acceptors with an activation energy of 5-10 meV, and the shoulder at the low-energy side of PL emission (I_{da}) is the transition from the degenerate electrons to deep acceptors with an activation energy of 50-55 meV.

PL spectra of InN dots reveal that the deep acceptor emission is suppressed due to the improved crystal quality of InN dots. PL spectra of InN dots exhibit larger energy blue-shift for smaller dot sizes. It is due to the size effect in the grown direction. The blue-shift energies are 5, 20 and 32 meV with respect to the emission energy of the InN epilayer for the dot height of 32 nm, 28 nm and 18 nm, respectively.

Temperature-dependent PL spectra of InN dots show that the emission energy does not depend strongly on temperature. The reasons for no energy red-shift and/or energy blue-shift of the PL emission with increasing temperature could be attributed to an increase in the kinetic energies of carriers, temperature-induced pushing up of non-equilibrium holes located in the valence-band tails, an increase in the quasi-Fermi level due to non-equilibrium photo-generated carriers or the difference of the polarization-induced electric field at low and room temperature.

PL spectra of InN dots at room temperature show a high-energy shoulder (I_H), and it becomes more pronounced with increasing dot size. The separation energy between this shoulder (I_H) and the dominant PL peak (I_{sh}) is about 100 meV for InN dots.

From the integrated PL intensity versus the inverse temperature plot, two activation energies dominant at the low and high temperature were obtained. The smaller activation energies (E_{a1}) are about 10meV for the InN epilayer and dots, and this energy matches the binding energy of shallow acceptors. The larger activation energy (E_{a2}) of the epilayer is 61 meV, and it is approximate to the required energy for the transition of holes from deep acceptor states to the valence band. But respectively larger activation energies (E_{a3}) of the dots are 81, 90 and 89 meV for the 18 nm- , 28 nm- and 32 nm-dots and larger than E_{a2} of the epilayer. These activation energies (E_{a3}) are equal to the energy separation between I_{sh} and I_H, so the energies (E_{a3}) activate carries from I_{sh} state to I_H state.