CHAPTER VI

CONCLUSIONS

In this thesis, the author has described a detailed study of structural and optical properties of the high-N containing GaAsN bulk layer and GaAsN/GaAs MQWs grown by MOVPE. Special emphasis has been placed on (i) the influence of high N concentration on the physical properties such as bandgap energy, strain state, (ii) physical mechanism of temperature dependence of PL spectra, (iii) effects of post-growth thermal annealing on the structural and optical properties, and (iv) discussion on the type of fundamental band alignment of GaAsN/GaAs QWs structure. The main results and conclusions obtained in this study are summarized as follows:

(1) The structural quality of high N-containing GaAsN bulk layer and GaAsN/GaAs MQWs for both the as-grown and annealed samples were investigated. For as-grown GaAsN bulk layer and as-grown MQWs, the structural properties showed high quality strained layer without any structural defects (such as dislocations) at the interface. However, after post-growth thermal annealing, the strained relaxation and defect generation at the interface were only occurred in annealed bulk layer. On the other hand, the structural investigation of GaAsN/GaAs MQWs revealed that the annealed MQWs showed high quality strained QWs without any defects formation at the hetero-interface. Comparing with GaAsN bulk layer, this result showed that the QWs structure can prevent the strain-relaxation due to the post growth thermal annealing treatment.

(2) The optical quality of GaAsN bulk layer was investigated. It is found that the emission of PL peak intensity cannot be observed from as-grown GaAsN bulk layer, indicating highly non-radiative recombination centers. After annealing the PL peak energy can be observed due to removal of non-radiative defects. The PL peak position showed emission at 0.96 eV for annealing time 2 min at 650°C, corresponding to the long-wavelength emission around 1.3 μm. However, the PL peak position blue shifted after increasing annealing time. In general PL peak blue-shift is due to (i) N-out diffusion, (ii) strain relaxation, (iii) improvement of alloy uniformity. In case of high N-containing GaAsN bulk layer, HRXRD, optical microscopy image

and Raman scattering results showed that the blue-shift of PL peak position is caused by (i) the strain relaxation in GaAsN layer, which is induced by the increase of N concentration and (ii) the improvement of alloy distribution fluctuation corresponding to the reduction of full width at half maximum (FWHM) after annealing. The temperature dependence of PL spectra has been examined to know the transition energy states and bandgap energy of GaAsN alloy. It is found that the PL spectra is related to localized exciton states at low-temperature and near band edge emission at higher temperature. The localized exciton states are caused by the conduction band edge fluctuation due to the local composition distribution fluctuation.

(3) For optical property of GaAsN/GaAs MQWs, the PL peak emission can be observed at 1.04 eV for as-grown MQWs. Comparing with the as-grown bulk layer, the QW structure can improve optical quality of the GaAsN alloy. The PL peak intensity of as-grown MQWs is much higher than that of the as-grown bulk layer, indicating the higher PL efficiency. However, after annealing, the PL peak position also exhibited blue-shift due to the diffusion of N atoms out of the well and the improvement of alloy uniformity in the well. Moreover, the PL peak intensity is significantly increased after annealing.

(4) Based on our band alignment calculation of GaAsN/GaAs QWs, we can conclude that the band alignment of GaAsN/GaAs QWs is a type-I band lineup. The temperature dependence of PL spectra demonstrated that the optical transition in QW structure is also attributed to the localized exciton states. In case of GaAsN/GaAs MQWs, the localized exciton states are mainly originated from the alloy composition fluctuation, resulting in the conduction band edge fluctuation and well width fluctuation at the same time. The large conduction band offset ($\Delta E_C \sim$ 550 meV) was fabricated in our sample, giving the higher efficient of laser emission at higher temperature.