Study of growth processes of In-rich InGaN alloy by RF-MBE and their properties

Masahito Kurouchi

This doctoral thesis focuses on the growth process of In-rich InGaN alloys and their properties. III-nitride semiconductors, which include GaN, AlN, InN and these alloys, have excellent physical properties. Because it is difficult to grow bulk crystal of III-nitrides, III-nitrides require hetero-epitaxial growth. However, there are no substrates with good thermal expansion coefficients and lattice constants for nitride growth. Thus, hetero-epitaxial growth of III-nitrides has been difficult. GaN and Ga-rich InGaN alloys have been investigated extensively. Today, blue light emitting diodes and laser diodes consisting of these materials have been commercialized. On the other hand, the studies of InN and related materials have been hindered for long time because of the low dissociation temperature. The properties of InGaN with high In-composition have not been understood well. Recently, crystal growth technology for these InN and related materials have been developed, and high quality InN growth has become possible predominantly by RF-MBE. In this doctoral thesis, the growth of In-rich InGaN alloys their properties are presented first. Then trial growth of InN based quantum well structures and their properties are presented.

At first, In-rich InGaN films were grown on (0001) sapphire substrate by RF-MBE, which enables low temperature growth of III-nitride. InGaN films were successfully grown without phase separation. Optical properties of In-rich InGaN films are investigated. Absorption edge and photoluminescence peak energy of InGaN films exhibit a monotonic and smooth decrease with the increase in the In-composition, approaching to $\sim$0.7 eV of InN film. This result supports recent reports of narrower bandgap of InN than the previously accepted 1.9 eV. Bowing parameter of bandgap energy of InGaN is also discussed.

Secondary, Growth studies for better crystalline quality InGaN were carried out. High-quality epitaxial InN films grown on LT-InN buffer layers have been employed as underlying templates for the growth of In-rich InGaN. As compared with In-rich InGaN films grown directly on the LT-InN buffer layers, the In-rich InGaN films grown on the InN templates showed excellent crystallinity. It was found that the insertion of the InN template was very effective in improving the crystalline quality of In-rich InGaN.

Thirdly, InN/InGaN quantum well structures have been successfully fabricated on InN templates grown on sapphire substrates for the first time. From InN/InGaN quantum well structures, photoluminescence emission from the well layers was observed at low temperature. The photoluminescence peak energy lowered with decreasing well width, reflecting quantum size effect.

Thus, this doctoral thesis provides scientific and technical information on growth of In-rich InGaN and its application.