Growth and Characterization of InN grown by RF-MBE

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This is a doctoral thesis, which is summarized about crystal growth technique of InN and characterization of the physical properties. Among nitride semiconductors, InN has the smallest effective mass and the highest electron drift velocity. Therefore, it is expected as a material for high-speed and high-frequency electronic devices. However, the growth of InN is very difficult because of low dissociate temperature and the lack of suitable substrate materials that are matched with InN in terms of both lattice constants and thermal expansion coefficients. In this study, sapphire substrates were used because of low cost, thermally stability, and well developed growth processes such as a nitridation. And InN films were grown by RF-MBE method. The growth methods by MOVPE, HVPE and NH_3 source MBE, however, have inherent disadvantages because it must satisfy conditions for both NH_3 pyrolysis and InN dissociation, which impose conflicting temperature requirements. In contrast, MBE equipped with an RF plasma source has essential advantages over MOVPE for obtaining high quality InN. In this growth method, neutral and ionized excited state nitrogen atoms and molecules can be generated separately by the plasma sources, which enable us to grow InN even at low-temperatures. Therefore, we believe that RF-MBE is the most suitable growth method for obtaining high quality InN. However, InN tends to grow three-dimensionally because of large lattice mismatch of 29 % between InN and the sapphire substrate, and its electrical properties are worse than those of GaN. We found that using low-temperature growth technique at around 300°C and consecutive annealing at 550°C was a very effective way to obtain a smooth surface of InN. Using the low-temperature-grown InN film as a buffer layer, various properties of InN such as crystallinity, carrier density and mobility were dramatically improved. We also discuss about the physical properties and growth mechanism of InN; effective mass, band gap energy, dependence of substrate polarity, and so on, which was realized by successful growth of high quality InN in this study. Thus, this doctoral thesis gives us scientific and industrial information for the high-quality InN growth and its applications.