Correlation among Growth Conditions, Crystal Structures and Optical properties of InN

YASUSHI NANISHI[1], TSUTOMU ARAKI[1], HIROYUKI NAOI[2], MASAHITO KUROUCHI[1], TOMOHIRO YAMAGUCHI[1]

[1]*Dept. of Photonics,* [2]*Center for Promotion of The 21st Century COE Program, Ritsumeikan University*
1-1-1 Noji-higashi, Kusatsu 525-8577, JAPAN
phone: +81-77-561-2679, fax: +81-77-561-3994 , e-mail: nanishi@se.ritsumei.ac.jp

InN is very attractive for future photonic and electronic devices because it has the smallest effective mass, largest mobility, highest peak and saturation velocities and smallest direct bandgap in nitride semiconductors. Extensive studies on InN have been hindered for a long time by the difficulties of growing high-quality crystal because of its high vapour pressure and low dissociation temperature. Properties of InN grown by MOVPE and RF-MBE, however, have been much improved very recently. Especially, quality of InN grown by RF-MBE have improved very quickly within a relatively short period of time. Stimulated by these recent improvements in crystal quality, investigations on physical properties of InN, especially true bandgap energy of InN, have been attracting increased attentions.

Bandgap energy of InN has long been believed to be 1.9 eV. Very recent studies using higher-quality InN grown both by MOVPE and RF-MBE, have demonstrated that the fundamental bandgap of single crystalline InN should be 0.7 ~ 0.8 eV rather than 1.9 eV. However, there are still lots of discussions on true bandgap energy of InN, arguing that 0.7 ~ 0.8 eV luminescence should originate from mid-gap levels associated with crystal defects or interface states.

In this presentation, we would like to discuss true bandgap energy of RF-MBE grown InN correlating with crystal growth conditions, crystal structures and the results on optical and electrical characterizations. The crystal used in this study showed ideal hexagonal wurtzite structure by XRD, TEM, EXAFS and Raman scattering measurements. FWHMs of ω-2θ mode XRD and E_2(high)-phonon-mode Raman scattering were as small as 28.9 arcsec and 3.2 cm^{-1}. PL studies were carefully carried out using PbS as a detector.

PL spectra obtained from various samples grown with different growth conditions are carefully investigated. PL peak energy dependence on carrier concentration can be well explained by Burstein-Moss shift in degenerate semiconductors. Detailed studies on correlation among PL peak energy, mobility, PL intensity, PL-FWHM and XRC-FWHM indicate that the sample with the smallest PL peak energy of 0.67 eV has the highest electron mobility, the strongest PL intensity even with the smallest electron concentration, the sharpest PL and (0002) XRC peaks. All of these results clearly demonstrate that the sample with the smallest PL peak energy has the highest quality in terms of crystal structure, optical and electrical properties. Further PL studies on excitation power dependencies have shown that peak energy do not show any noticeable change and intensity increases almost linearly with the increase in the excitation power over two orders of magnitude. It was further found that PL peak energy and absorption edge were observed at almost the same photon energy.

These experimental results suggest that the PL should originate from fundamental inter-band transitions and not likely from mid-gap levels associated with crystal defects. These results also suggest that true bandgap energy of InN should be less than 0.67 eV and probably around 0.65 eV at room temperature.

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