Photoluminescence and time-resolved luminescence of quaternary InAlGaN alloys

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The ternary AlGaN alloys are promising materials for blue-UV optical devices, such as LEDs, LDs and photo detectors, since they have the variable direct bandgaps which cover the energy region from 6.2 to 3.4 eV. However, the low efficiency of UV photoluminescence (PL) in AlGaN alloys at room temperature (RT) is one of the severe problems to realize UV emission devices. This is mainly due to the thermal quenching of the dominant component of UV emission band, because the UV emission band mainly consists of a decaytime component with low thermal activation energy, which is much slower than that of GaN RT PL. Incorporation of indium into AlGaN alloy is one of the possibilities to obtain good RT PL efficiency, and in fact the enhanced luminescence in InAlGaN quaternary alloys has been reported [1]. However, there are few studies about basic optical properties of InAlGaN alloys [2]. Then, in this study, we have been performing reflectance (PR), luminescence, excitation (PLE) and time resolved decay (TRD) curve measurements.

Samples were made by MOCVD method. $Al_{0.2}Ga_{0.8}N$ buffer layers were grown on SiC (0001) substrates by 400 nm, and the 80 nm InAlGaN layers were grown on the AlGaN buffer layers. The cation fraction ratios among In, Al and Ga of samples are in the range of 0.04~0.09, 0.12~0.40, 0.61~0.83, respectively. PL peaks under laser excitation are ranging from 328 to 370 nm. All measurements have been performed at the beamline BL7B of UVSOR (IMS, Okazaki, Japan) by using of synchrotron radiation (SR) as a visible – UV light source. A monochromator for luminescence measurements is the conventional 30 cm type with a CCD detector, and decay curve measurements have been performed under single bunch operation mode (SR pulse period : 177 ns, width : 0.5 ns) with TAC method.

Figure 1 shows PR (a), PLE spectrum with 3.64 eV PL peak (b), and PL spectrum at 4.68 eV excitation (c) of $In_{0.05}Al_{0.20}Ga_{0.75}N$ at 17K. The end part of long period interference, which is caused by surface and interface between InAlGaN and AlGaN buffer layers, is shown in lower energy side of Fig. 1 (a). PL spectrum has the peak at 3.64 eV with a small shoulder of higher energy side. The excitation peak is found at 4.68 eV, which may reflect the band structure of this material. Figure 2 shows TRD curve of $In_{0.05}Al_{0.20}Ga_{0.75}N$ at each temperature. The characteristic point of TRD curve is that the ratio of fast decaytime components to slow ones is much higher than that of AlGaN alloy. The existence of first decay components contributes to PL efficiency at RT, though the intensity at longer time side is decreasing rapidly with increasing temperature in similar to the case of AlGaN.

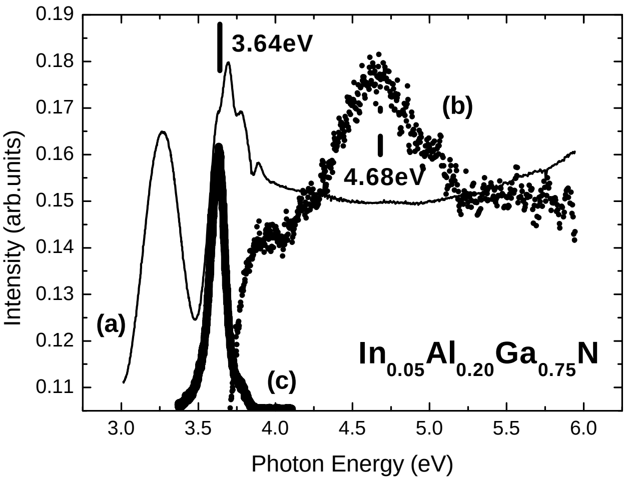

Fig.1. Reflectance (a), excitation (b) and photoluminescence (c) spectra of $In_{0.05}Al_{0.20}Ga_{0.75}N$ at 17 K.

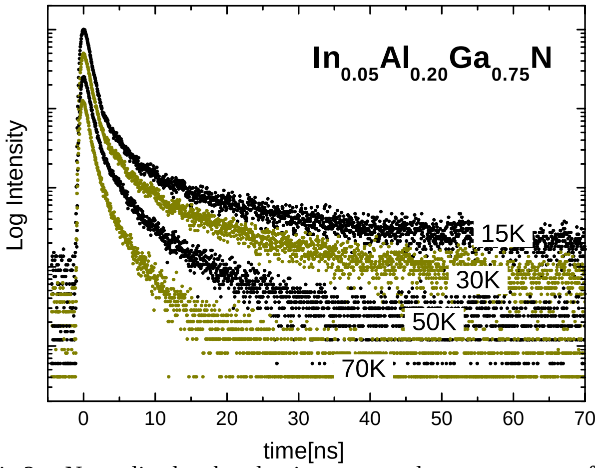

Fig.2. Normalized photoluminescence decay curves of $In_{0.05}Al_{0.20}Ga_{0.75}N$ from 15 K to 70 K. Each spectra is shifted vertically for convenience.

References

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