

Growth and characterization of Tb doped GaN

Hyungjin BANG*, Shinichi MORISHIMA, Katsuhiko AKIMOTO, Masaharu NOMURA
Institute of Applied Physics, University of Tsukuba, 1-1-1 Tennodai, Tsukuba 305-8573, Japan,
Tel +81-298-53-6177, Fax +81-298-55-7440, E-mail: s993503@ipe.tsukuba.ac.jp
Photon Factory, Institute of Materials Structure Science, High Energy Accelerator Research
Organization, Oho, Tsukuba 305-0801, Japan

Rare Earth ions generally show sharp and intense luminescence originating from intra atomic f-f transitions, and the peak position and intensity of the luminescence is not so affected by chemical environment.¹⁻²⁾ We have reported that the luminescence from Eu doped GaN shows sharp peak at 623 nm due to $^5D_0 - ^7F_2$ transition of Eu^{3+} , and the luminescence peak position, intensity and full width at half maximum are extremely stable with temperature.³⁻⁵⁾ So rare earth ions doped GaN can be regarded as a promising material in application for novel optical devices.

In this study, we report the single crystalline growth of Tb doped GaN, substitutional incorporation of Tb into Ga site determined by extended x-ray absorption fine structure (EXAFS) analysis, and PL properties indicating intra atomic f-f transitions of Tb^{3+} ions.

Tb doped GaN films were grown on sapphire (0001) substrates by gas source molecular beam epitaxy using uncracked ammonia for nitrogen source. Tb was evaporated from conventional Knudsen effusion cell. The growth temperature was 700°C and Tb cell temperature was varied from 1200°C-1300°C. *In-situ* reflection high-energy electron diffraction (RHEED) patterns were observed during growth.

The EXAFS measurements were carried out at beam line 12C in High Energy Accelerator Research Organization (KEK) to study the atomic structure around Tb atom. Fourier filtering technique was applied to the first nearest atoms and the EXAFS oscillation function are curve-fitted using the parameters calculated with FEFF 8 program.

RHEED pattern of Tb doped GaN grown on Al_2O_3 substrate shows spotty pattern with no extra spot through out the growth, suggesting single crystalline growth. To investigate the incorporation site of Tb in GaN, we carried out EXAFS measurements and the radial distribution function are shown in Figure 1. The analytical results are listed in Table . The nearest neighbor atoms were confirmed to be nitrogen, and bond length was 2.20Å. Therefore, we can suppose that Tb atoms are incorporated into Ga site and bond length was made larger compared with that of Ga-N (1.9Å).

Figure 2. shows PL spectrum of Tb doped GaN measured at room temperature excited by He-Cd laser. The spectrum is very similar to that of Tb ion implanted GaN.⁶⁾ Though the spectrum shows near band edge emission of GaN at around 360 nm and deep level emission around 500-750 nm, sharp two peaks were observed at 540 nm and 580 nm which can be tentatively assigned as $^5D_4 - ^7F_5$, $^5D_4 - ^7F_4$ transitions of Tb^{3+} ion, respectively.^{1, 2, 6)}

In case of the luminescence of Eu doped GaN, no luminescence related with GaN was observed and the intensity of Eu related luminescence was two orders of magnitude larger than that of Tb. This difference in luminescence between Eu doped GaN and Tb doped GaN may be caused by the difference of energy transfer from GaN to rare earth ions. The poor luminescence of Tb doped GaN may be caused by low reactivity of Tb with nitrogen, so it is necessary to study the growth conditions more detail to improve the luminescence properties.

Table . Analytical results of Tb- EXAFS measurements.

Coordination number	3.76
Bond length	2.20Å
Debye-Waller Factor	0.1738Å ²

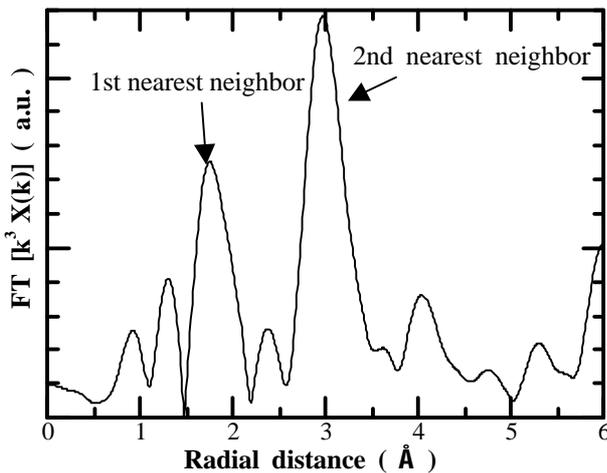


Fig.1. The radial distribution function of Tb doped GaN.

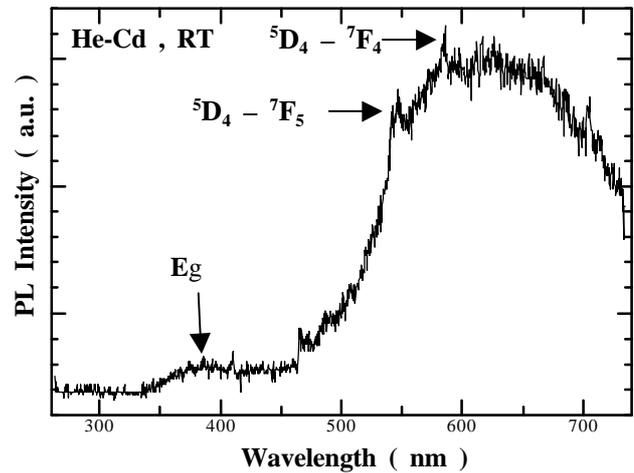


Fig.2. PL spectrum of Tb doped GaN measured at room temperature.

References

- 1) G.H Dieke, in: H.M. Crosswhite, H. Crosswhite (Eds.), Spectra and Energy Levels of Rare Earth Ions in Crystals, Wiley, New York, 1968.
- 2) M.J.Weber, Phys. Rev.171 (1968) 283.
- 3) T.Maruyama, H.Sasaki, S.Morishima, and K. Akimoto, Phys. Stat. Sol (b) 216 (1999) 619.
- 4) S.Morishima, T.Maruyama, M.Tanaka, Y.Masumoto, and K.Akimoto Phys. Stat. Sol (a) 176 (1999) 113.
- 5) S.Morishima, T.Maruyama, K.Akimoto, Journal of Crystal Growth 209 (2000) 378.
- 6) H.J.Lozykowski and W.M.Jadwisieniczak, Appl. Phys. Lett. 76 (2000) 861.