Local-structure Dependent Energy Transfer from the Host to Eu Ions in Eu-doped GaN

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1. Introduction

A GaN-based red light emitter is expected to realize nitride-based monolithic optical devices, which compose the red, green, and blue GaN-based light-emitting diodes (LEDs) for full-color displays and/or lighting technology. Eu-doped GaN (GaN:Eu) has been identified as a promising candidate for the red emitter because it has shown excellent luminescence properties in the red spectral region, resulting from the specific optical properties of rare-earth materials, such as a sharp, intense, and temperature-independent emission peak due to the intra-*4f* shell transitions. We have grown GaN:Eu by organometallic vapor phase epitaxy (OMVPE) and observed successfully bright red emission from a LED using the GaN:Eu as an active layer [1]. By optimizing growth conditions and device structures, the light output power has been growing steadily upto submilli-Watt at 20 mA [2]. In this contribution, preferential energy transfer from the host to Eu ions, depending on local structures, will be demonstrated in GaN:Eu.

2. Experimental Approach and Results

The sample studied was a GaN:Eu layer grown on a freestanding GaN (0001) substrate by atmospheric-pressure OMVPE. Combined excitation-excitation spectroscopy (CEES) using a wavelength-tunable laser revealed that there are at least eight kinds of luminescent Eu sites (OMVPE 1-8) with different local structures. From the comparison of photoluminescence (PL) intensities, OMVPE 4 was clearly dominant in GaN:Eu. However, the excitation and emission probabilities are different among the luminescent sites since each luminescent site has a different symmetry. Therefore, a simple comparison of PL intensities between luminescent sites does not reflect their relative abundance. We calibrated the efficiency of excitation and emission using the excitation cross section and radiative decay time, respectively. The quantitative evaluation of the Eu luminescent sites showed that more than 80% of Eu ions are incorporated into a high-symmetry site (OMVPE4) [3]. However, the PL spectrum under indirect excitation using a He-Cd laser was markedly different from that under resonant excitation (Fig. 1), which indicates that the luminescent site with high symmetry exhibits low-efficiency energy transfer from the GaN host to the luminescent site.

3. Conclusions

We have investigated PL properties in GaN:Eu under resonant and indirect excitation, respectively. The site-selective excitation of Eu ions revealed that more than 80% of Eu ions are incorporated into a high-symmetry site. However, the PL spectrum under indirect excitation was markedly different from that under resonant excitation. The observation indicated clearly local-structure dependent energy transfer from the host to the luminescent sites.

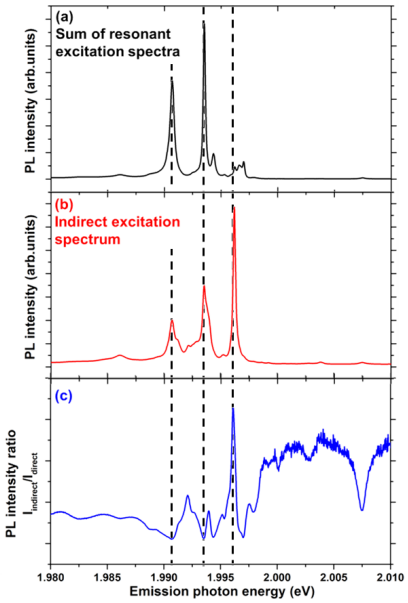

Fig. 1 (a) Constructed PL spectrum under resonant excitation, (b) PL spectrum under indirect excitation, and (c) ratio of (b) to (a).

4. Open Questions

- What are microscopic structures of OMVPE1-8?
- What is the mechanism of preferential energy transfer, depending on local structures?

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