Growth of Eu-doped GaN using an oxygen-free liquid Eu source bis(*n*-propyltetramethylcyclopentadienyl)europium by organometallic vapor phase epitaxy and its luminescence properties

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1. Introduction

Red emission from GaN-based semiconductors is a key technology to realize a high-resolution monolithic full-color light-emitting display. The successful growth of Eu-doped GaN (GaN:Eu) by organometallic vapor phase epitaxy (OMVPE) and red light-emission from the GaN:Eu under the current injection has been reported [1]. For the Eu doping into GaN by OMVPE, an organometallic Eu source, tris(dipivaloylmethanato)europium [$Eu(DPM)_3$], has been extensively used due to its moderate vapor pressure. However, $Eu(DPM)_3$ has problems with instability of supply rate due to the solid source (melting point of 188°C) and including oxygen in the molecular structure, which is possible to degrade electrical characteristics of matrix materials. Recently, we have succeeded in the first synthesis of a new Eu organometallic source, bis(n-propyltetramethylcyclopentadienyl)europium [$Eu(Cp^{pm})_2$], which is an oxygen-free liquid Eu source at operating temperatures with moderate vapor pressure. In this contribution, we characterized luminescence properties of GaN:Eu grown using $Eu(Cp^{pm})_2$.

2. Experimental Approach and Results

The samples were grown on sapphire (0001) substrates by OMVPE. The $Eu(Cp^{pm})_2$ was used for the Eu source for Eu-doping on GaN. $Eu(Cp^{pm})_2$ was maintained at the temperatures in the range from 115 to 135°C. At the temperatures, the Eu source is liquid and can be supplied by bubbling method. A 300-nm thick GaN:Eu and 10-nm thick GaN capping layers were grown on undoped GaN buffer layer. The GaN:Eu grown using $Eu(DPM)_3$ with the same sample structure was used for comparison. The concentrations of both samples were determined $\sim 1\times10^{19}$ cm^{-3} by fluorescent x-ray intensity compared with standard samples.

X-ray absorption near-edge structure (XANES) spectrum at Eu L_{III}-edge revealed that Eu ions incorporated into GaN using $Eu(Cp^{pm})_2$ were trivalent, while the Eu had a valence of two, *i.e.* divalent, in the $Eu(Cp^{pm})_2$. Therefore, divalent Eu in the $Eu(Cp^{pm})_2$ were oxidized during the growth and doped in GaN as trivalent Eu^{3+} ions.

Room-temperature photoluminescence (PL) spectra of GaN:Eu grown using $Eu(Cp^{pm})_2$ and $Eu(DPM)_3$ are shown in Fig. 1. The emission peaks associated with intra-4*f* shell transition from $^5D_0$ to $^7F_2$ in Eu^{3+} ions are observed in both samples. The GaN:Eu using $Eu(Cp^{pm})_2$ exhibits a significantly broad emission spectrum, which is reflected in inhomogeneous emission lines due to fluctuation of the local structures of Eu^{3+} ions. Regardless of the broad emission spectrum, $Eu(Cp^{pm})_2$ has another advantage in obtaining abrupt doping profile, which improves the device performance electrically.

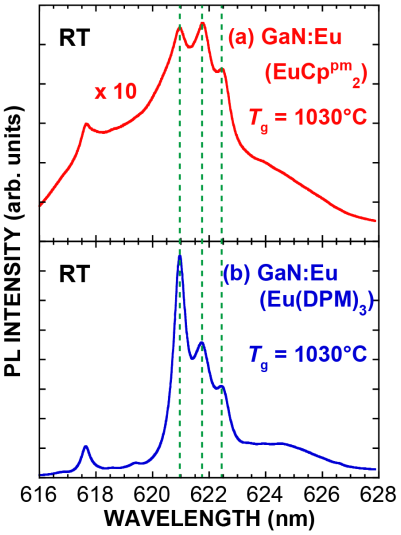

Fig. 1 *Room-temperature PL spectra for the GaN:Eu grown using (a) $Eu(Cp^{pm})_2$ and (b) $Eu(DPM)_3$.*

3. Conclusions

In summary, we have succeeded in growth of GaN:Eu using the oxygen-free liquid Eu source, $Eu(Cp^{pm})_2$, by OMVPE and observed red emission from the Eu^{3+} ions.

4. Open Questions

Open question to be discussed is as follows.

- What is the difference in the local structures between GaN:Eu using $Eu(DPM)_3$ and $Eu(Cp^{pm})_2$?

Acknowledgements

This work was partly supported by a Grant-in-Aid for Scientific Research (S) (Grant No. 24226009) from the Japan Society for the Promotion of Science. The synchrotron radiation experiments were performed at the BL14B2 of SPring-8 with the approval of the Japan Synchrotron Radiation Research Institute (JASRI) (Proposal No. 2012B1865).

References

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