Room temperature electroluminescence of Pr-implanted GaN p-n junction diode

S. Ito[1,2], S.-I. Sato[2], M. Boćkowski[3], M. Deki[4], H. Watanabe[5], S. Nitta[7], M. Kushimoto[1], A. Tanaka[5], K. Yoshida[8], H. Minagawa[8], Y. Honda[4,5,6], H. Amano[4,5,6]

[1]Graduate School of Engineering, Nagoya University, Nagoya, Aichi, Japan
[2]National Institutes for Quantum Science and Technology, Takasaki, Gunma, Japan.
[3]Institute of High Pressure Physics, Polish Academy of Sciences, Warsaw, Poland.
[4]Deep Tech Serial Innovation Center, Nagoya University, Nagoya, Aichi, Japan.
[5]Institute of Materials and Systems for Sustainability, Nagoya, Aichi, Japan.
[6]Institute for Advanced Research, Nagoya University, Nagoya, Aichi, Japan
[7]Innovation Center for Semiconductor and Digital Future, Mie University, Tsu, Mie, Japan.
[8]Ion Technology Center Co.,Ltd., Hirakata, Osaka, Japan.
E-mail: ito.shin.z0@s.mail.nagoya-u.ac.jp

Introduction

The single-photon source (SPS), a quantum device that can generate single photons on demand, is crucial for the development of quantum communication technologies. Isolated rare-earth (RE) ions in semiconductors, whose luminescence transition in the 4f-shell is inherently single photon emission, are a promising candidate for SPS operating at room temperature (RT) because of their stable photon emission with a narrow linewidth even at RT and their potential of electric control (i.e. electroluminescence: EL). In particular, GaN is the suitable host since RE ions do not show significant thermal quenching at RT due to its large bandgap (3.4 eV). Ion implantation technique is used to fabricate electrically driven RE-SPS, ensuring precise RE ion positioning and quantity control. However, limited studies exist on EL characteristics of RE-doped GaN diodes fabricated by ion implantation, which is why this study was conducted.

Experimental Procedures

Here we show that Pr-doped GaN devices were successfully fabricated through crystal growth, ion implantation, annealing, regrowth, and device fabrication. A n^--GaN layer was grown on a GaN substrate, followed by Pr ion implantation at 700 keV with a dose of 1×10^{14} cm^{-2}. Ultra-high-pressure annealing at 1400 °C under 1 GPa N_2 was performed for 10 and 30 minutes, respectively, to regrow the p-GaN layer and form the p-n diode.

Results and Discussion

The I-V measurements showed rectifying behavior. However, irradiation-induced defects at the p-n junction generated by ion implantation caused an increase in series resistance. Figure 1 shows that a sharp emission peak appears at 652 nm as measured by EL. This corresponds to the PL emission of Pr^{3+} in GaN[1]. This fact indicates that the observed EL also originated from the Pr-related transition. Additionally, the I-L characteristics showed a positive correlation between the sharp peak intensity and injection current. These results indicate that the EL in the Pr-doped GaN device is caused by the energy transfer from carrier recombination[2].

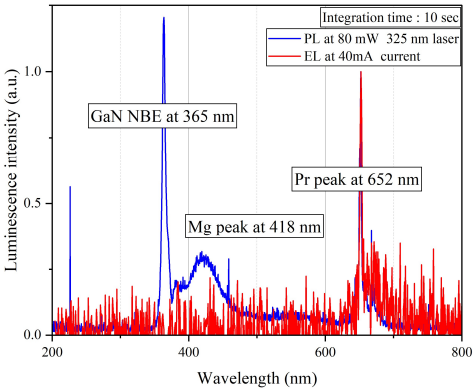

Fig.1. Comparison of RT-PL of a Pr-implanted GaN to RT-EL spectrum of a Pr-implanted GaN pn diode.

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References

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