Defect Characterization in Carbon Autodoped GaN: A Multitechnique Approach

Anna Honda[1], Momoko Inayoshi[2], Wakana Takeuchi[2],
Hirotaka Watanabe[1], Yoshio Honda[1, 3], and Takeshi Kato[1, 3]
[1] Institute of Materials and Systems for Sustainability, Nagoya University,
[2] Department of Electrical and Electronic Engineering, Aichi Institute of Technology,
[3] Department of Electronics, Nagoya University
honda.anna.e9@f.mail.nagoya-u.ac.jp

Introduction

Carbon (C) is often unintentionally incorporated into GaN layers, where it acts as a compensating impurity, forming deep acceptor levels such as carbon substituting for nitrogen (C_N). These defects significantly affect carrier compensation and thus the electronic properties of GaN-based devices. Recently, carbon autodoping has emerged as a growth method in which the carbon concentration is controlled by adjusting the growth temperature without external sources. However, systematic experimental studies on how this method modifies carbon-related defects compared to conventional doping are still limited. This work presents a multitechnique study of GaN:C with different carbon concentrations, focusing on the characterization of carbon-related defects and their impact on the material properties.

Experimental Procedures

GaN:C samples were grown on freestanding GaN substrates by metalorganic vapor phase epitaxy (MOVPE). The carbon concentration was controlled by adjusting the growth temperature to 1035, 1015, and 955 °C, corresponding to carbon concentrations of approximately 1×10^{17}, 1×10^{18}, and 1×10^{19} cm^{-3}, respectively. Electrical characterization was performed using capacitance–voltage (C–V), current–voltage (I–V), and optical deep-level transient spectroscopy (ODLTS). In addition, photoluminescence (PL) and electron spin resonance (ESR) measurements were conducted to investigate the optical and paramagnetic properties of carbon-related defects.

Results and Discussion

Figure 1 shows the PL spectra of GaN:C samples. With increasing carbon concentration, changes in each emission band were observed, suggesting the formation of carbon-related deep levels acting as non-radiative recombination centers and a possible shift in dominant defect species [1]. Figure 2 summarizes the series resistance as a function of carbon concentration, both with and without 385 nm LED illumination. The series resistance decreased systematically with higher carbon concentration, and illumination further reduced the resistance, indicating photo-activated carrier generation. In addition, ODLTS measurements revealed multiple trap levels (0.2 to 0.9 eV), possibly related to carbon-related point defects and implying a transition from isolated to more complex configurations. These results clearly demonstrate that carbon autodoping strongly modifies both the optical and electrical properties of GaN:C. A more detailed analysis, including the correlation among PL, ESR, and ODLTS, will be discussed at the conference.

Acknowledgement

This work was supported by the Research Foundation for the Electrotechnology of Chubu (RFEC), Japan, and by the Tatematsu Foundation, Japan. A portion of this research was conducted at the Next-Generation Biomaterials Hub, Nagoya University, supported by the Advanced Research Infrastructure for Materials and Nanotechnology in Japan of the Ministry of Education, Culture, Sports, Science and Technology (MEXT), Japan. This work was performed under the joint usage/research program of the Institute of Materials and Systems for Sustainability (IMaSS), Nagoya University.

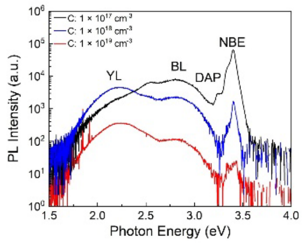

Figure 1 PL spectra of GaN:C samples with different carbon concentrations

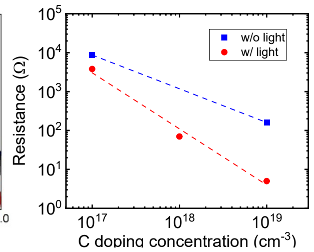

Figure 2 Series resistance as a function of carbon concentration with and without 385 nm LED illumination

References

[1] A. Honda, H. Watanabe, T. Kato, Y. Honda, and H. Amano, Phys. Status Solidi B, in press (2025)