Radiative and Nonradiative Recombination in AlGaN-based Deep-Ultraviolet Light-Emitting Diodes

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AlGaN-based light-emitting diodes (LEDs) are attracting considerable interest as deep-ultraviolet (DUV) light sources that could be used to replace toxic mercury lamps in various applications including sterilization, air/water purification, medical diagnostics, UV curing, and lithographic microfabrication. We recently demonstrated a DUV-LED with light output power of 90 mW emitting at wavelength of 265 nm by utilizing a novel light-extraction technique, which is the highest light output power reported to date for DUV-LED with emission wavelength shorter than 280 nm.[1] To further improve the performance of DUV-LEDs, a detailed knowledge and reliable evaluation of radiative and non-radiative recombination processes are of considerable importance. The recombination processes are strongly dependent on the exceed carrier density in the active region, which is varied with the injection current. However, there is no way to measure the carrier density directly in contrary to the injection current density. In this report, the variation of carrier density was evaluated based on the rate equation model (sometimes referred to as the ABC model). The Auger recombination coefficients was determined to be about 1.5×10^{-30} cm^6/s. The Shockley–Read–Hall (SRH) non-radiative, radiative and Auger recombination processes and their dependence on injection current density were analyzed. The SRH non-radiative recombination plays an important role on the emission efficiency in low current density, while the Auger recombination becomes dominant in high injection current density region due to the high exceed carrier density in DUV-LEDs. The IQE reduction occurs from about 55 A/cm^2 is attributed to the Auger nonradiative recombination.

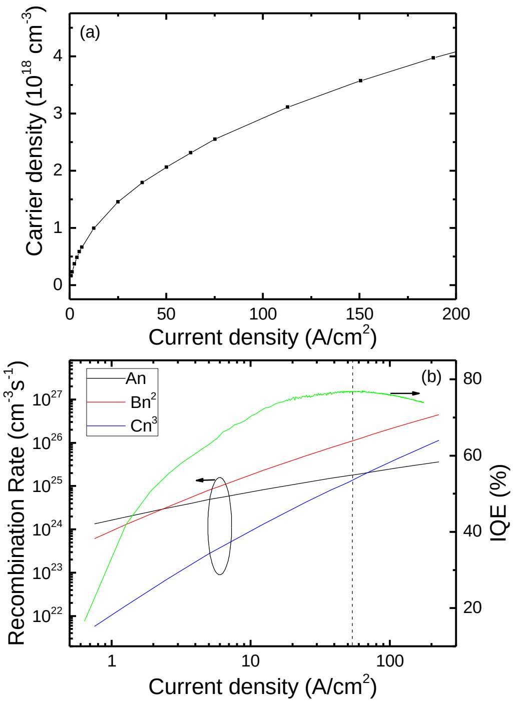

Fig. 1. (a) Carrier density as a function of injection current density. (b) Calculated SRH, radiative, and Auger recombination rates as a function of injection current density.

1. S. Inoue, T. Tamari, T. Kinoshita, T. Obata, and H. Yanagi, Appl. Phys. Lett. **106**, 131104 (2015).