Study on efficiency droop behaviors of AlGaN deep-ultraviolet light-emitting diodes with varying MQWs structure

NICT, ◦Guo-Dong Hao and Shin-ichiro Inoue

E-mail: gd.hao@nict.go.jp; s_inoue@nict.go.jp

AlGaN-based deep ultraviolet (DUV) light-emitting diodes (LEDs) have attracted an increasing attention as an effective method for disinfection and sterilization. We have made significant developments in 265 nm DUV-LEDs based on hybrid photonic crystals and uniform current distribution with light output power over 500 mW.[1] Today, DUV-LEDs still suffer from a low wall-plug efficiency (WPE) (typical value < 5%). One major limitation to achieving high WPE is the low internal quantum efficiency (IQE) and its rapidly efficiency droop problem.

In this talk, we theoretically study on the influence of the multiple quantum well (MQW) structure on the efficiency droop. The contributions of radiative recombination efficiency (RRE) and current injection efficiency (CIE) are separately discussed in detail. A one-dimensional drift diffusion model was used for the carrier transport simulations when taking the strain-induced piezoelectric effects into account. The conventional ABC model was adopted for carrier recombination simulations. The results show that a smaller difference of Al fraction between the quantum well and the quantum barrier could significantly reduce the droop and improve the overall performance of devices. This is attributed to the improvement of the CIE and the consequently RRE due to the enhanced hole concentration in the QWs. It is reported that the efficiency droop can be drastically reduced by increasing the quantum well thickness in GaInN-based blue LEDs.[2] However, the results show that it is very different in AlGaN-based DUV-LEDs. The RRE droop could be much more slowly for a narrower QW thickness. Nevertheless, the CIE is significantly degraded when the QW thickness became too narrow, e.g., narrower than 1.5 nm, which is owning to the hole leakage out of the active region caused by the disparity between electron and hole concentrations and mobilities in n-AlGaN and p-AlGaN. As a result, the IQE (=RRE×CIE) achieves a peak value at the well thickness of 2.0 nm in high current region, as shown in Fig. 1. The emission wavelength is shifted from 274 to 286 nm under an injection current density of 7 A/cm^2 when increasing the well thickness from 1.5 to 3.0 nm. More details will be present at the conference.

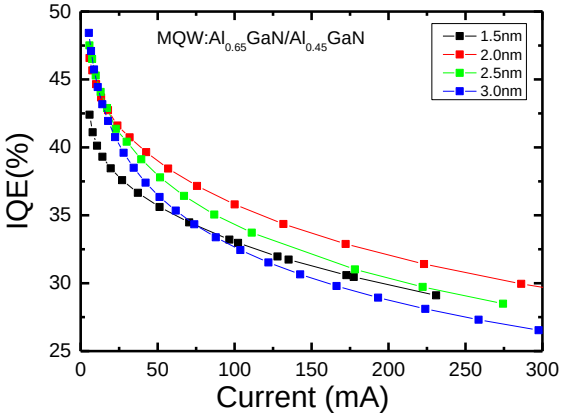

Fig. 1. Internal quantum efficiency as a function of injection current for DUV-LED with different QW thickness.

[1] S. Inoue, Oyo Buturi **88,** 663 (2019).

[2] Y. L. Li, Y. R. Huang, and Y. H. Lai, Appl. Phys. Lett. **91,** 181113 (2007).