Self-heating and current crowding effects on efficiency droop in 280 nm AlGaN-based deep ultraviolet light-emitting diodes

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We have demonstrated a record light output power of 150 mW of deep ultraviolet (DUV) light-emitting diodes (LEDs) emitting at wavelength of 265 nm by utilizing a large-area nano-photonic light-extraction structure.[1] Much higher output power requires the level of injection current in a single chip to be increased. However, the efficiency droop becomes a major problem at high injection current in AlGaN-based DUV-LEDs.

There have been many studies concerning the efficiency droop in GaN-based LEDs. Almost all the reported temperature-dependent electroluminescence showed that the efficiency droop had little relation to the heat in GaN-based LED.[2,3] We have reported the severe current crowding phenomenon in AlGaN-based DUV-LEDs due to the poor conductivity and limited critical thickness of the n-AlGaN current spreading layer with a high Al fraction. In this work, we reported the heat and current crowding effects on efficiency droop in 280 nm DUV-LEDs. The flip-chip configuration was used in this study. Two types of electrode patterns were fabricated. One used a conventional square *p*-electrode as a reference of current crowding situation, the other used a multiple-narrow-line *p*-electrode to provide a uniform current distribution. The Al fraction and thickness were about 0.7 and 1.0 μm for the *n*-AlGaN lateral current spreading layer. The current uniformity in each LED was finally confirmed by near field pattern. We operated the device under a continue wave (cw) current, the EQE reduction was much more quickly for the current-crowding device than that in the current-uniform one, as shown in Fig. 1(a). However, the EQE reductions were almost same in both LEDs (light-extraction contribute 8% enhancement) when we used a pulsed mode injection current to eliminate the self-heating effects, as shown in Fig. 1(b). These phenomenon is in contrast to the results in GaN-based LEDs, in which the droop behaviors seem almost the same under cw and pulsed injection. These results clearly indicated that the self-heating in DUV-LEDs played an important role in the marked decrease of EQE in high injection current when current crowding is present. The physical mechanism of efficiency droop was also theoretically investigated based on the rate equation model. More details will be present at the conference.

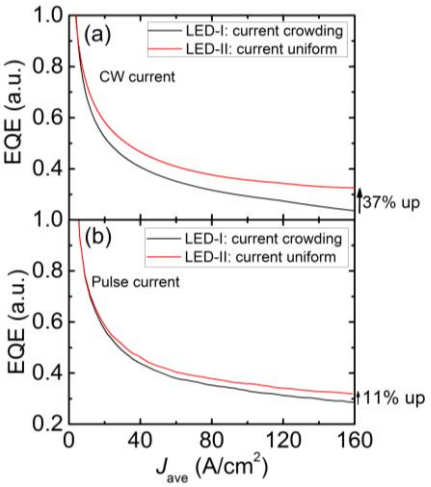

Fig. 1. Measured EQE as a function of injection current density under (a) continuous-wave current and (b) pulse current operation.

1. S. Inoue, et al., Appl. Phys. Lett. **110**, 141106 (2017).
2. L. Wang, et al., Materials, **10**, 1233 (2017).
3. M. H. Kim, et al., Appl. Phys. Lett. **91**, 183507 (2007).