Analysis of Electrode Structure and Process for High-Power AlGaN-based Deep-Ultraviolet Light-Emitting Diodes

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AlGaN-based deep-ultraviolet light-emitting diodes (DUV-LEDs) are undergoing a rapid evolution in recent years. Several groups reported the external quantum efficiency (EQE) in the 270-280 nm spectral range has exceed 10%.¹,² We recently demonstrated a record output power exceed 90 mW with an emission of 265 nm.³ These are the highest EQE and output power reported to date for DUV-LEDs emission shorter than 280 nm. However, these values are still much lower than that achieved in the visible spectral range, and further improvement is required. Here, we report on a dramatically enhancement in wall-plug efficiency (WPE) with an improvement in the output power and a reduction of the operating voltage by using a well-designed p-electrode and an optimal annealing temperature in LED fabrication process.

The DUV-LEDs emitting at 265 nm were grown on a (0001) sapphire substrate by MOCVD. The LED structures were composed of AlN buffer layers, a Si-doped n-Al0.75Ga0.25N cladding layer, three multiple quantum well active layers, a Mg-doped p-AlN electron blocking layer, a p- Al0.75Ga0.25N cladding layer and a p-GaN layer for ohmic contact formation. The Ti/Al/Au and Ni/Au are used as n- and p- electrodes to form ohmic contact.

Figure 1 shows the I-V characteristics of three DUV-LEDs with the annealing temperatures of 800°C, 900°C, and 1000°C, respectively, for n-Al0.75Ga0.25N ohmic contact formation. It shows that both of the turn-on and operating voltages are lowest when the annealing temperature is 900°C. This is because a lower annealing temperature of 800°C can cause an increasing contact resistance dropped across n-AlGaN/metal contact interface; while a higher annealing temperature of 1000°C could degrade the quality of p-GaN resulting in an increased specific contact resistivity in the p-GaN to Ni/Au contact and an increased resistivity of p-GaN and p-Al0.75Ga0.25N layers.

We then studied the current crowding problem and designed a uniform-current-spreading p-electrode geometry to improve the optical performance of the device. The output power was collected by a Si photodiode from the backside of the device. The comparison of I-L and I-V characteristics between the LED with the new designed p-electrode and the one with a conventional p-electrode are given in Fig. 2. The output power was enhanced by a factor of 40%, and the operating voltage was reduced about 18%, corresponding to an enhancement in WPE by a factor of about 68% at an injection current of 280mA.