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Cascaded GaN light-emitting diodes with hybrid tunnel junction layers

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GaN-based LEDs are also used for commercial solid-state lighting nowadays. However, GaN-based LEDs are still not cost effective. To further enhance the penetration rate of solid-state lighting, we thus need to reduce the production cost of these devices. One possible way to reduce the production cost is to serially grow two InGaN-GaN multiquantum well (MQW) structures on the same sapphire substrate and connect these two MQW structures with a tunnel junction (TJ). Using this structure, it has been reported the fabrication of GaN-based dual-wavelength blue/green LEDs using two different MQW structures with different InGaN wells [1], [2] . Here, we reported the fabrication of GaN TJ LEDs using p^{++}-GaN/u-InGaN/n^{++}-GaN TJ layers (TJL).

Figures 1(a), 1(b) and 1(c) schematically depict the structures of the conventional LED (i.e., LED1), the LED with p^{+}-GaN/u-InGaN/n^{+}-GaN TJL (i.e., LED2) and the LED with hybrid TJL (i.e., LED3), respectively.

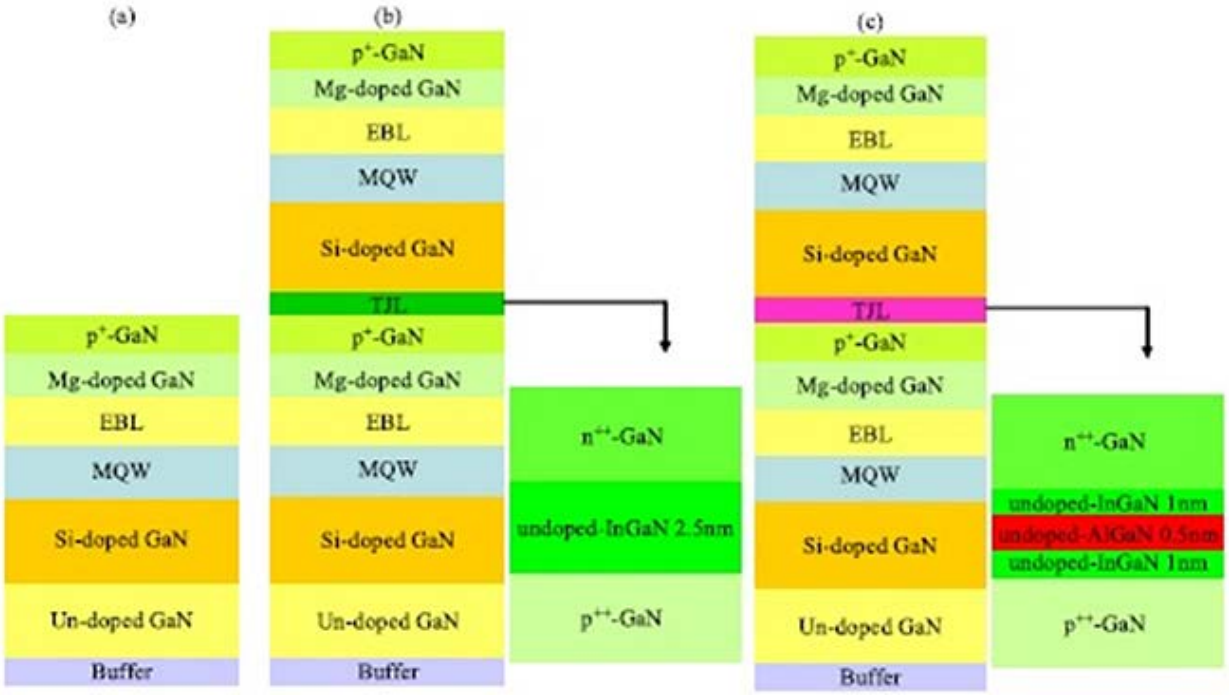

Fig. 1. Schematic diagrams of (a) LED 1, (b) LED 2, and (c) LED 3.

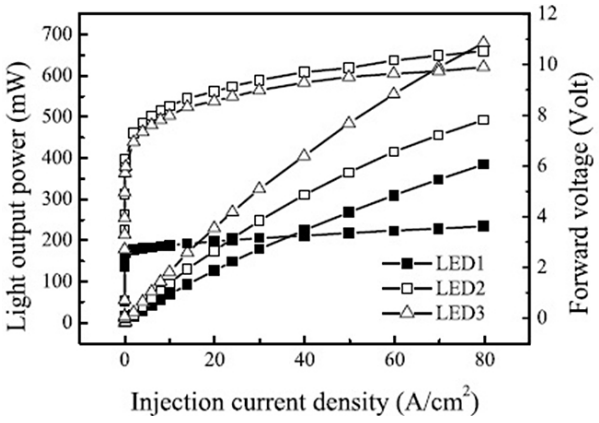

Fig. 2. L-I-V characteristics measured from the three fabricated LEDs.

Figure 2 shows L-I characteristics measured from the three fabricated LEDs. With an injection current density of 20 A/cm^2, it was found that output powers for LED1, LED2, and LED3 were 126.9, 174.3 and 229.5 mW, respectively. In other words, output powers measured from LED2 and LED3 were about 35% and 80% larger than that measured from the conventional LED (i.e., LED1). Compared with the conventional LED (i.e., LED1), the much larger output power observed from the TJ LEDs (i.e., LED2 and LED3) should be attributed to the repeated use of electron and holes for photon generation. As numerically predicted by Tsai et al., the use of hybrid TJ structure could provide larger tunneling current [3]. Thus, we attribute the much larger output power observed from LED3 to the larger polarization charges at the AlGaN/InGaN interface, larger magnitude of the electric field, and thus the enhanced tunneling current due to the use of hybrid TJ structure.

I-V characteristics measured from these devices were also plotted in Figure 2. With an injection current density of 20 A/cm^2, it was found that forward voltages were 3.02, 8.94 and 8.55 V for the LED1, LED2 and LED3, respectively. Compared with LED1, the significantly larger forward voltages observed from LED2 and LED3 should be attributed to the use of two serially connected MQW active regions.

Figures 3(a) and 3(b) shows life-test results for output power and forward voltage, respectively, for LED1 and LED3. During these measurements, we placed these two LEDs in an oven and injected 280 mA burn-in current (B.C) continuously into these devices at 80℃ circumstance temperature (C.T). After a period of time, we took them out from the oven, injected 120 mA test current (T.C) into these devices, and measured the electro-optical properties of these LEDs at room temperature. As shown in figure 3(a), it can be seen that the output power decayed by 2.1% for LED1 and 3.2% for LED3 after 1000 hours. It can also be seen from figure 3(b) that forward voltage increased by 0.4% for LED1 and 1.2% for LED3. The negligibly small variations in output power and forward voltage observed from LED3 suggest the cascaded GaN LEDs with hybrid TJL were also reliable.

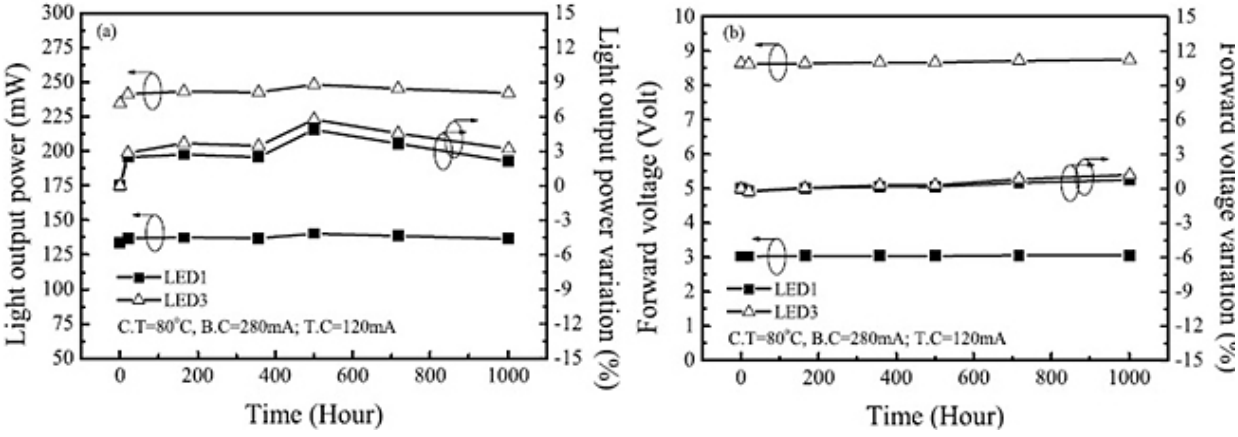

Fig. 3. Life-test results for (a) output power and (b) forward voltage for LED1 and LED3.

Reference :

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