Double dielectric on nitride semiconductor LED boosts output power by 25%

Korean researchers show how a combination of silicon dioxide and aluminum oxide layers offers anti-reflective and passivating effects.

Researchers based in Korea have used double dielectric layers on nitride semiconductor light-emitting diodes (LEDs) to boost output power by up to 25% through anti-reflective and passivation effects [Chung-Mo Yang et al, IEEE Electron Device Letters, published online 2 March 2012]. The research was a collaboration between Kyoungpook National University and Samsung LED Company.

The epitaxial layer structure was grown on patterned sapphire substrates using metal-organic chemical vapor deposition (MOCVD). The active region consisted of indium gallium nitride (InGaN) multi-quantum wells (MQWs) with gallium nitride (GaN) barriers. The region was designed to emit at 460nm (blue) wavelength.

In further processing (Figure 1), the electrodes were then created, first by etching down to the n-type layer and then depositing and annealing (500°C) a 5nm/5nm nickel-gold transparent contact on the p-type layer. Thick bonding pads of titanium/gold were then produced.

The fabrication was then completed by depositing the double dielectric of 5nm aluminum oxide (Al_2O_3) by plasma-enhanced atomic layer deposition (ALD) and 50nm silicon dioxide (SiO_2) by plasma-enhanced CVD. A Fresnel analysis suggested that the optimum layer thicknesses to maximize the output power would have an Al_2O_3 layer of 20nm followed by 50nm SiO_2. However, such a double-layer would suffer from undesirable reverse current effects that increase as the passivation thickness increases. At normal incidence, it is estimated through a Fresnel analysis that the 50nm/5nm SiO_2/Al_2O_3 structure should allow 10% more light to be transmitted compared with a device without dielectric.

The double dielectric layer device benefits from improved light extraction through the index of refraction of the SiO_2 layer widening the angles at which light can emerge from the device, along with improved electrical performance from reduction of competing non-radiative surface recombination of electrons and holes due to the Al_2O_3 passivation

Various passivation layer combinations were tested for LED output power (Figure 2). The double dielectric layer results in about 25% higher output power compared with the unpassivated LED. The double dielectric layer device benefits from improved light

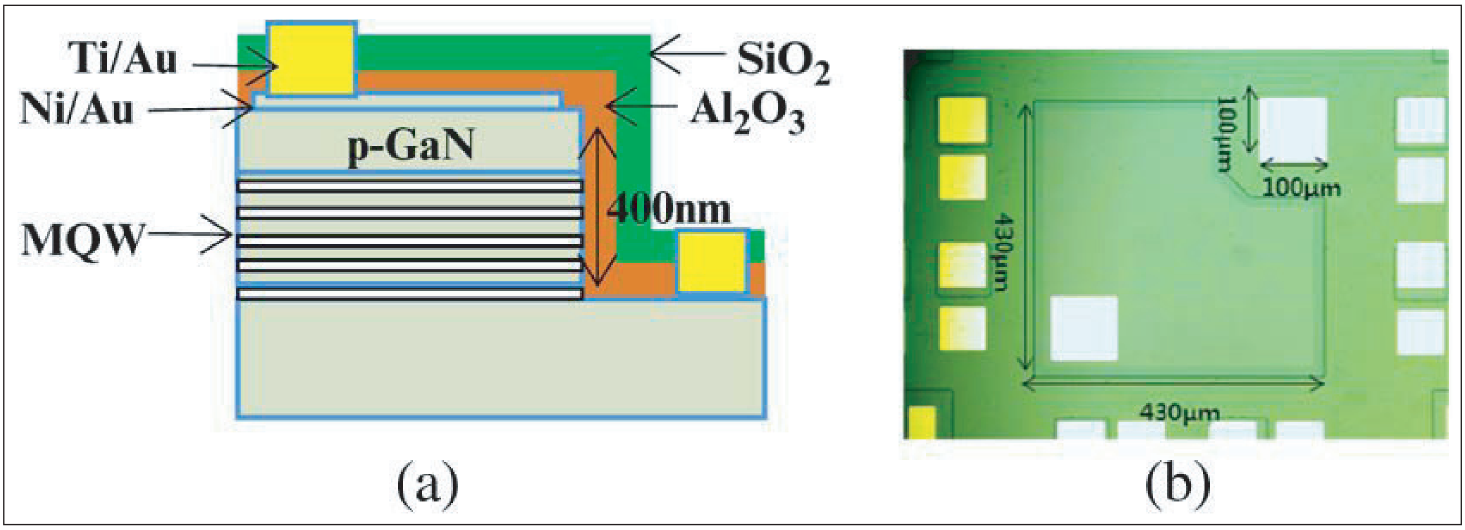

Figure 1. (a) Schematic of the LED configuration. (b) Fabrication of the 430μm x 430μm real LED chip.

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Parallel conduction through unpassivated surfaces lowers the apparent turn-on voltage of devices. The voltages at 20mA forward current were 3.31V, 3.33V, 3.39V and 3.99V for the unpassivated, the Al_2O_3-passivated, the SiO_2-passivated, and the SiO_2/Al_2O_3-passivated LEDs, respectively.

Al_2O_3 passivation also reduced reverse leakage current at −5V by two or three orders of magnitude from -1.9×10^{-8}A (unpassivated) and -7.14×10^{-9}A (SiO_2 passivated) to -3.46×10^{-11}A (Al_2O_3).

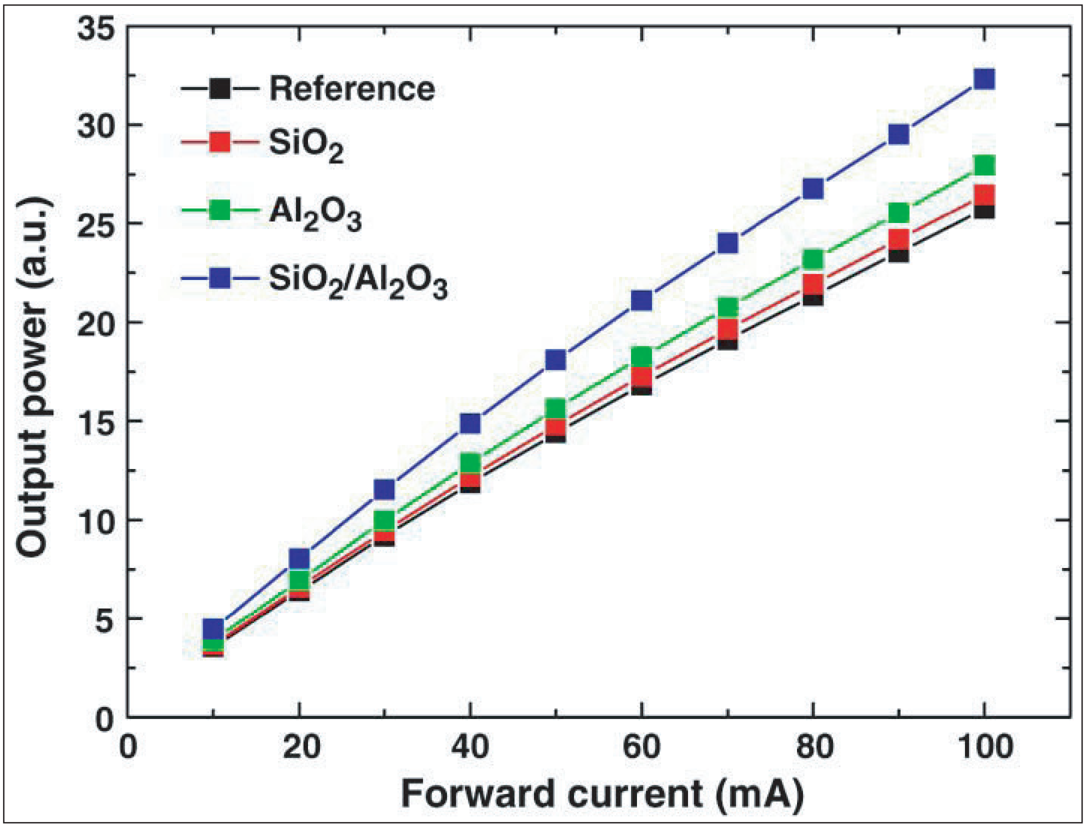

Figure 2. Output power characteristics of unpassivated, SiO_2-passivated, Al_2O_3-passivated, and Al_2O_3/SiO_2-passivated LEDs. The output power of the Al_2O_3/SiO_2-passivated LED is about 25% higher than that of the unpassivated LED.

Another positive effect of Al_2O_3 passivation is reduced trap state densities, which are estimated to be 2.6×10^{11}/eV-cm^2 for the Al_2O_3 passivated device, compared with 6.2×10^{12}/eV-cm^2 for the SiO_2/GaN interface. The lower trap density decreases the amount of competing non-radiative recombination. ■

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Author: Mike Cooke