Enhanced light output power of GaN UV-LED by a simple passivation with graphene oxide

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Abstract

GaN-based ultraviolet (UV) LEDs are widely used in numerous applications, including white light pump sources, high-density optical data storage, medical equipment, and counterfeit bill detection[1,2]. However, low hole injection rate in p-type region due to poorly activated holes and spontaneous polarization leads to insufficient light emission efficiency[3]. Therefore, improving hole injection rate is a key step towards high performance UV-LEDs to expand their uses[4]. Here, we report a new method for enhancing light output power of UV-LEDs by increasing hole injection rate in p-type region. This was achieved by simply passivating graphene oxide (GO) on top of the fully fabricated LED. The dipole field formed by the passivated GO and indium tin oscide (ITO) junction enhanced hole injection rate in p-type region and simultaneously increased hole concentration by about 60%. This not only improved the homogeneity of electroluminescence intensity in active layers but also enhanced light output power to about 60% in linear current region and almost twice in saturated current region due to the delayed hole saturation. Our simple approach of overcoming the limited carrier concentration of p-type GaN using GO passivation method disrupts the current state of the art technology and will be useful for high-efficiency UV-LED technology.

In one sentence summary, we developed a simple passivation method using GO nanosheets to enhance light output power of GaN-based UV-LED by about 60% where the spontaneous polarization in p-type GaN hole injection layer is suppressed by forming a strong dipole layer in GO nanosheets.

References

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Figures

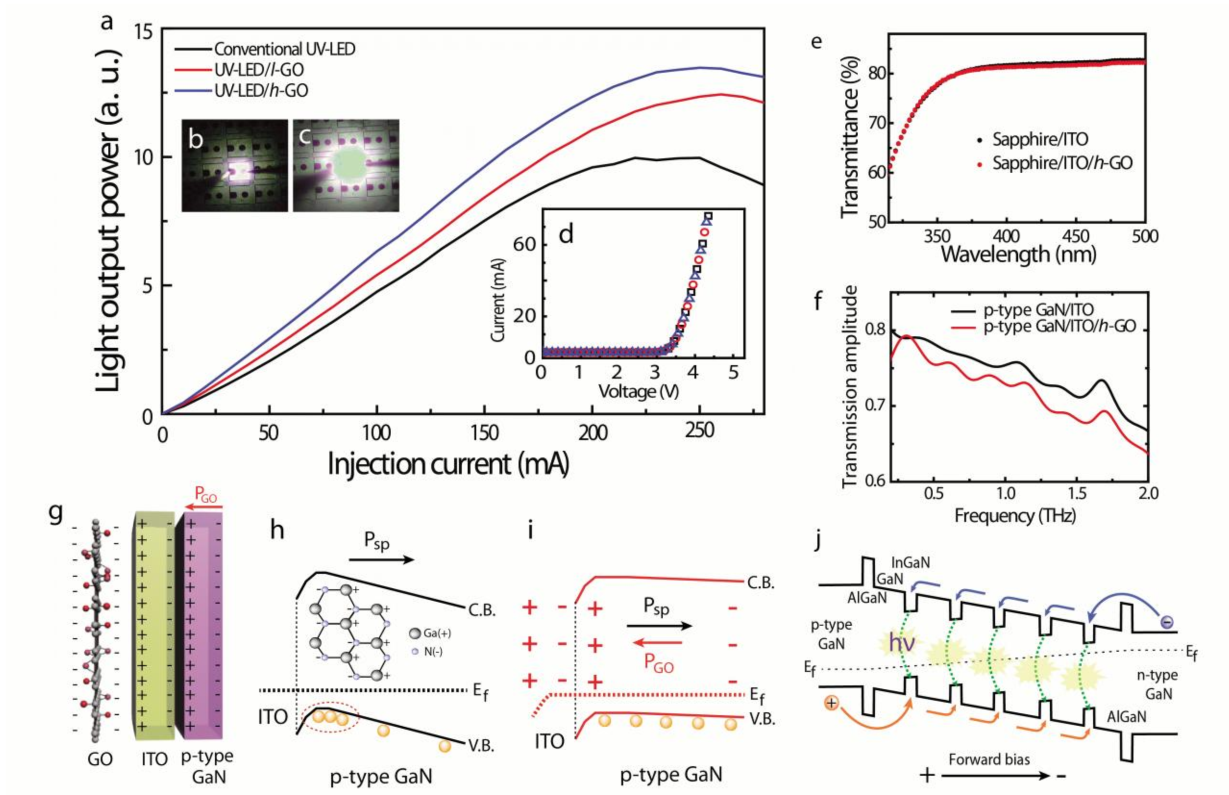

Figure 1. Enhancement of LED performance by GO coating. a, The light output power versus injection current of conventional (black curve), l-GO-coated (red curve), and h-GO-coated (blue curve) UV-LEDs. The light output power increased by approximately 60% when the conventional UV-LED was coated with h-GO. b,c, Photograph of UV-LED/h-GO of the electroluminescence at an injection current of 1 mA (b) and 5 mA (c). d, I-V characteristics of the devices used in a. No significant change in the samples was observed. e, Energy band diagram of active region in UV-LED when device are applied forward bias. f, Transmittance spectra of sapphire/ITO with h-GO (red curve) and without h-GO (black curve). The change in the transmittance between two samples was negligible. g, Schematic diagram of the electric polarization in the ITO and p-type GaN regions induced by the GO nanosheets. h,i, Energy band diagram of p-type GaN (h) without and (i) with h-GO, which schematically explains the relaxation of spontaneous polarization. j, THz transmittance spectra of the p-type GaN/ITO with GO nanosheets (red curve) and without GO nanosheets (black curve).