Electronic Supplementary Material (ESI) for Nanoscale.

Supplementary Information

Light-Extraction Enhancement of a GaN-based LED covered with ZnO Nanorod Arrays

Hyun Jeong, Doo Jae Park, Yong, Yeong Hwan Ko, Jae Su Yu, Hong Seok Lee, Sang-Bae Choi , Dong-Seon Lee,Eun-Kyung Suh, and Mun Seok Jeong**

Supporting Information S1

Electroluminescence of GaN-based LED with and without ZnO NRAs:

Figure S1a presents the macro-EL spectra of GaN-based LED with and without ZnO NRAs measured at room temperature. The integrated EL intensity of GaN-based LED with ZnO NRAs is 30% larger than that without ZnO NRAs. Thus, from the confocal scanning EL results, it can be deduced that ZnO NRAs enhance the light output power from the GaN-based LEDs. The far-field radiation patterns of the GaN-based LED with ZnO NRAs were measured (**Figure S1b**) for a chip that was not encapsulated in epoxy. The light output pattern of the conventional GaN-based LED is also shown for comparison. As a result, the GaN-based LED with ZnO NRAs had larger EL intensities than the conventional GaN-based LED in all directions.

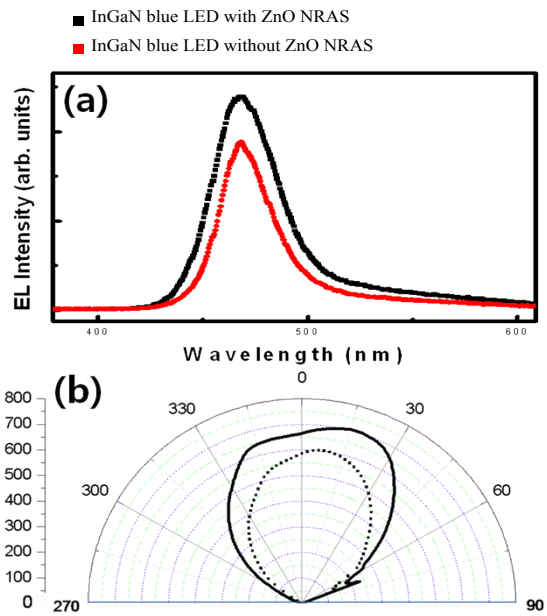

Figure S1: (a) EL spectra and (b) light output pattern of a GaN-based blue LED with and without ZnO NRAs. The solid and dashed lines indicate InGaN blue LED with and without ZnO NRAs, respectively.

Supporting Information S2

Description of patterned sapphire substrate:

Figure S2 presents the optical microscopy image of the *c*-plane patterned sapphire substrate (PSS) for GaN epitaxial growth. The PSS consists of two-dimensional hexagonally arranged hemisphere patterns. The period of patterns on the sapphire substrate is 2 μm. As shown in **Figures 5a** and **b**, such patterns make periodic interference fringes at the top of the LED structure by Bragg's diffraction.

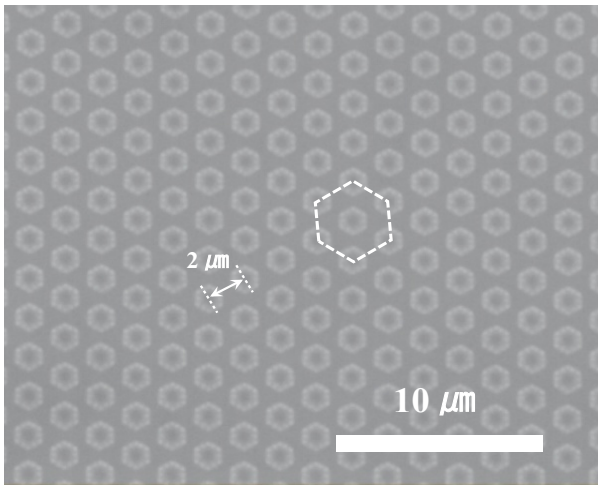

Figure S2: Optical microscopy image of the patterned sapphire substrate.