

Electronic Supplementary Information

Nanopillar InGaN/GaN Light Emitting Diodes Integrated with Homogeneous Multilayer Graphene Electrodes

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1. Fabrication of nanopillar LED with various diameters

For the fabrication of nanopillar structures with various diameters, Ni metal films with a thickness of 5 nm, 10 nm, and 20 nm were deposited on SiO₂/LED by e-beam evaporator. All samples were treated by rapid thermal annealing to form Ni nanodots. The size of Ni nanodots was controlled by the deposited Ni layer thickness. As the ICP etching gas, we used only Cl₂ to create the nanopillar structure with high verticality. As shown in Fig. S1, the nanopillar LEDs thus fabricated have the diameter with about 150 nm (a, b), 250 nm (c, d), and 400 nm (e, f) for 5 nm, 10 nm, and 20 nm Ni thickness, respectively.

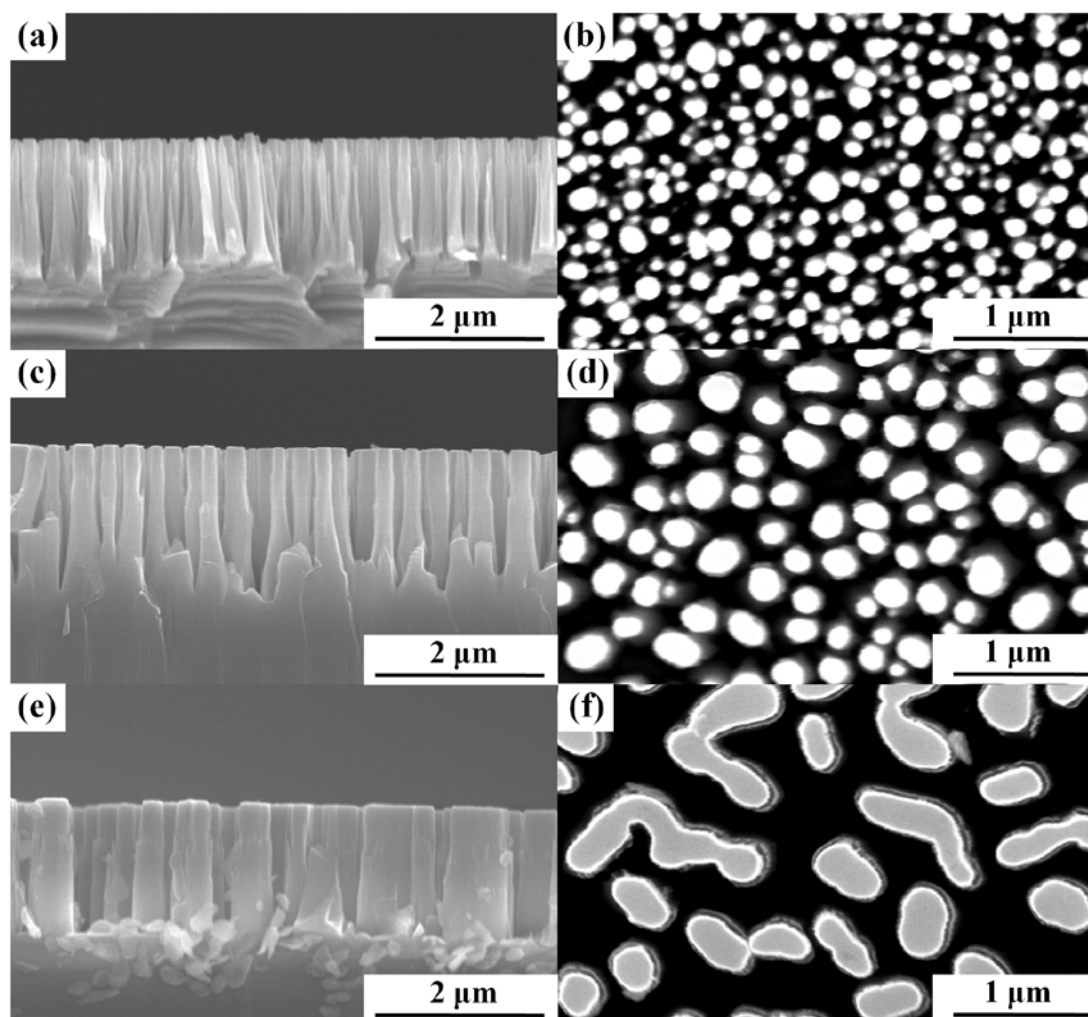


Figure S1. Cross sectional (a, c, e) and plan view (b, d, f) SEM images of nanopillar structures with various diameter

2. PL results of the planar and the nanopillar LED

The optical characteristics of the nanopillar LED were investigated by PL measurements. A HeCd laser with 325 nm wavelength was used as an excitation light source. Figure 2S shows the room temperature PL of the planar and the nanopillar LED for comparison. The nanopillar LED showed 230 % higher PL intensity compared with the planar LED.

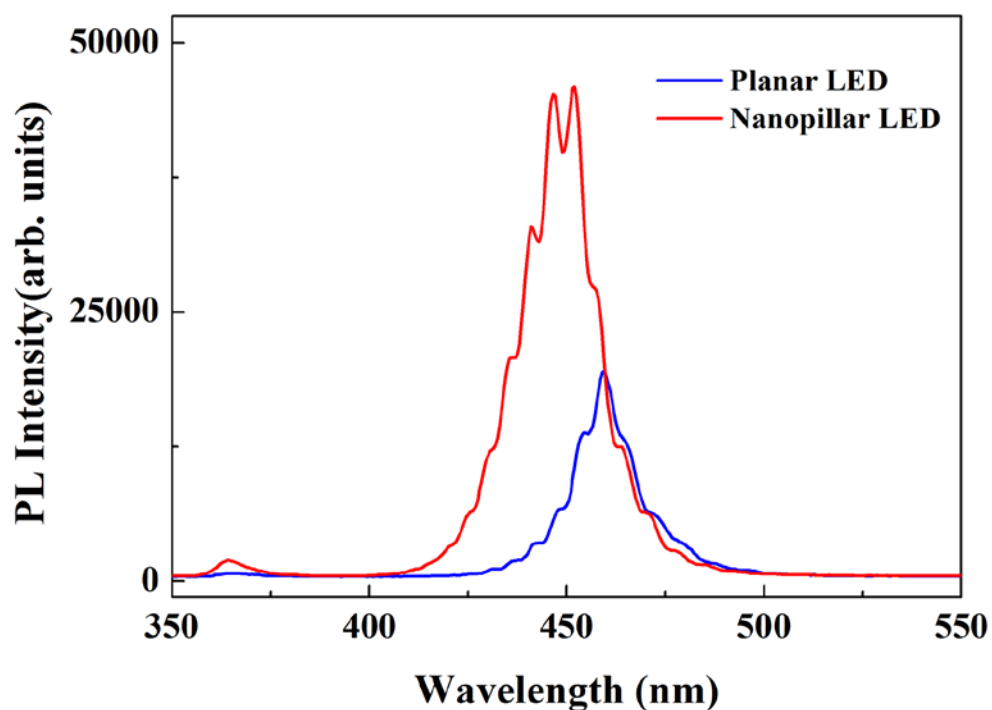


Figure 2S. PL spectra for the planar and the nanopillar LED

3. Moving picture for the electroluminescence (EL) measurement

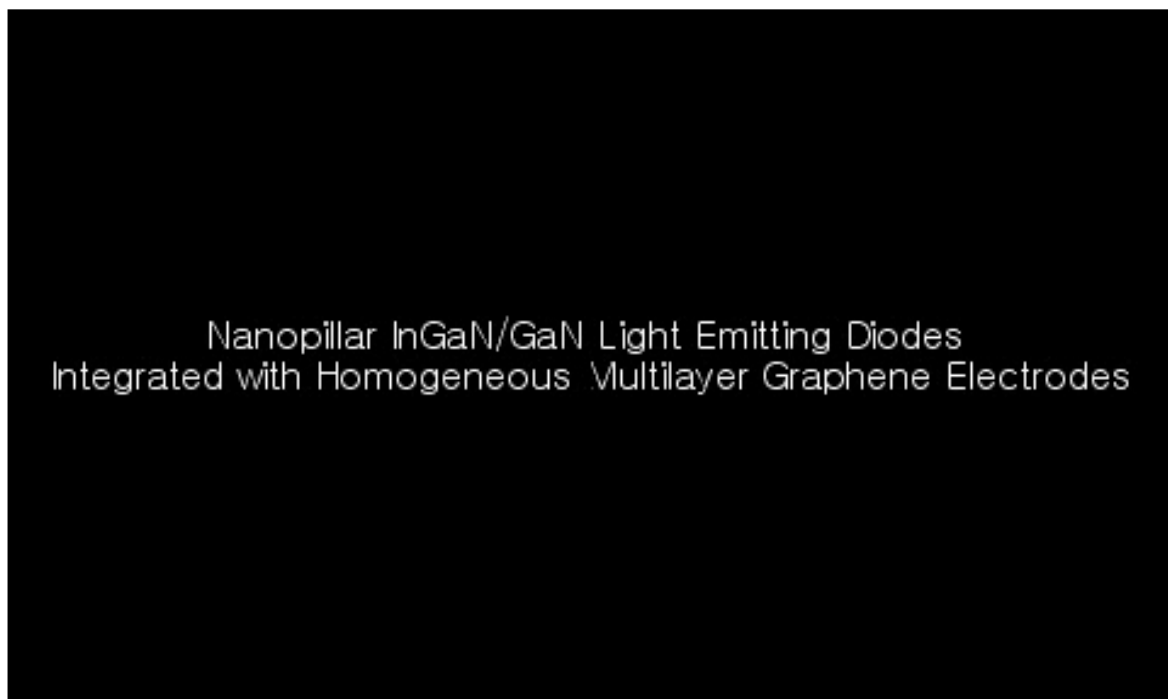


Figure 3S. Moving picture for InGaN/GaN nanopillar LED with homogeneous multilayer graphene electrodes (h-MLG) with injected current from 0 to 100 mA. This moving picture clearly demonstrates that the emitting area is becoming greater as the forward current increases and that the graphene electrode is allowing emission from a large area of nanopillars and not just directly beneath the probe tip. Click on the image to activate the moving picture. One may need to have Acrobat version 7.0 or higher.

4. EL images

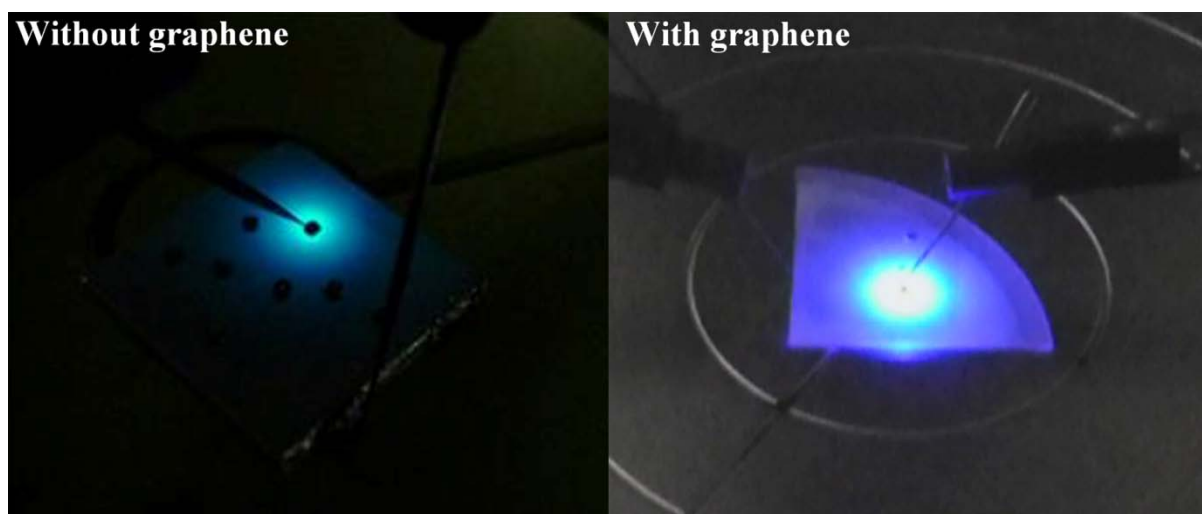


Figure 4S. EL measurement image for the InGaN/GaN nanopillar LED without h-MLG and with h-MLG at a forward current of 20 mA. The graphene-LED exhibits much brighter EL emission compared with the control LED. Note that the EL of the control nanopillar LED tends to suddenly went out at a higher current regime (> 20 mA).