Theoretical simulation of metal mesh structure with graphene for transparent conductive layers of GaN-based light-emitting diodes

Sang-Bae Choi[1], Jung-Hong Min[1] and Dong-Seon Lee[1]
[1]Department of Information and Communications, Gwangju Institute of Science and Technology, Gwangju, 500-712, Korea
Tel.:82-62-715-2248, E-mail: dslee66@gist.ac.kr

GaN-based LEDs have recently been focused in the various fields such as solid-state lighting, automobile and back-light units, which are required with longer lifetime, higher efficiency and better energy savings. [1] Commonly, transparent conductive layers (TCLs) are essential for GaN-based LEDs due to the lower conductivity of *p*-GaN layers. Indium tin oxide (ITO) is one of the commonly used material for TCLs because it shows surpassing transparency, sheet resistance and so on. Nevertheless, the increase of the indium price by lack of resource, alternative materials and structures for TCLs such as graphene layer with a metal mesh structure are suggested to replace the ITO TCLs. [2] In this paper, we performed a theoretical simulation of the metal mesh structure combined with graphene for TCLs of GaN-based LEDs. Using COMSOL Multiphyics with finite-element method, we solve the continuity equation for vertical-type GaN-based LEDs as below

$$\nabla(\sigma\nabla V) = 0$$

where σ is the conductivity and V is the potential. The conductivity of *n*-GaN, active layer and *p*-GaN layer was 10^4 S/m, 10^3 S/m and 33.3 S/m, respectively. Figure 1 (a) shows a schematics of simulated LED structures. We compared the current density distribution of four types of TCLs: (1) a 200 nm-thick ITO layer, (2) graphene layer, (3) metal mesh structure on graphene, and (4) metal mesh structure covered with graphene. The metal mesh structure has a 150 μm gap with 5 μm width and 200 nm height as shown in Fig 1 (b). In addition, the nonlinear *I-V* characteristics of LEDs was applied for the simulations. By the theoretical simulation, the current spreading property and current vector of the TCL layer, *p*-GaN layer, n-GaN layer were investigated for each TCLs. Figure 1 (c) displays the simulated results of the metal mesh structure on the graphene layer.

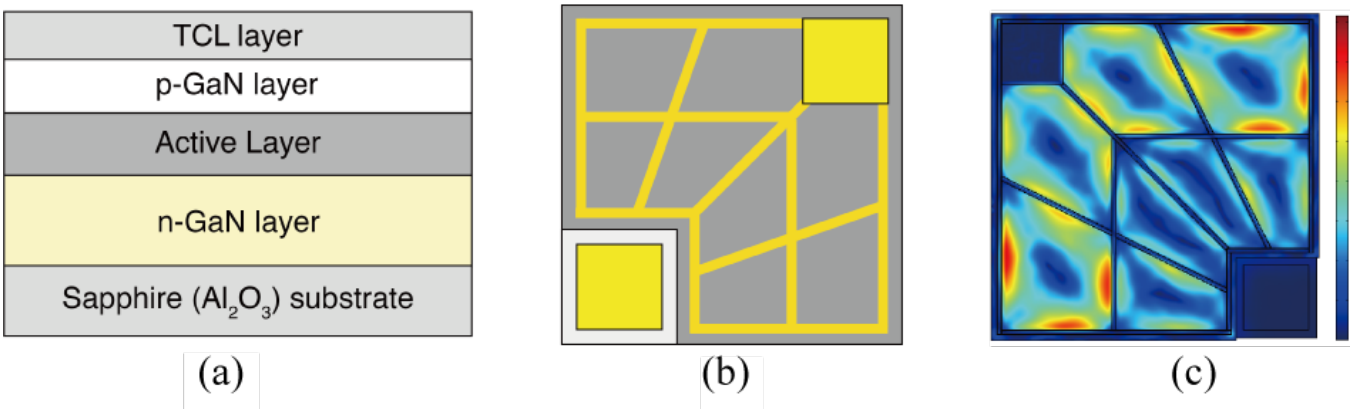

Fig. 1. (a) Device schematics of simulated LED structures. (b) The metal mesh structure having 150 μm for the simulations and (c) the simulated results of the metal mesh structure on the graphene layer.

References

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