

Lateral current thinking improves light and voltage in nitride LEDs

Superlattices introduced on n-side of LED increase output power by 13.7% and reduce input power by 6.7%.

LG Electronics Materials and Components Laboratory in South Korea has used aluminium gallium nitride (AlGaN) superlattice structures (SLs) to improve lateral current spreading from the n-side of nitride semiconductor light-emitting diodes (LEDs) [Hooyoung Song et al, Appl. Phys. Lett., vol103, p141102, 2013].

Lateral current spreading is important in nitride semiconductor LEDs for several reasons. For example, these devices are mostly produced with the n-contact to one side of the LED because vertical flow is not possible through insulating substrates such as sapphire. Also, nitride semiconductor LEDs suffer from efficiency droop effects at high current density so that non-uniform flow through the devices leads to avoidable power losses.

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LEDs. "However," the LG researchers say, "n-type conductivity is also an important factor in devices such as LEDs where current spreading still remains as an issue." They thus set out to investigate "methods to enhance transport properties of n-type AlGaN/GaN SLs layers and demonstrate improved LED performance from n-type AlGaN/GaN SLs embedded LED structures".

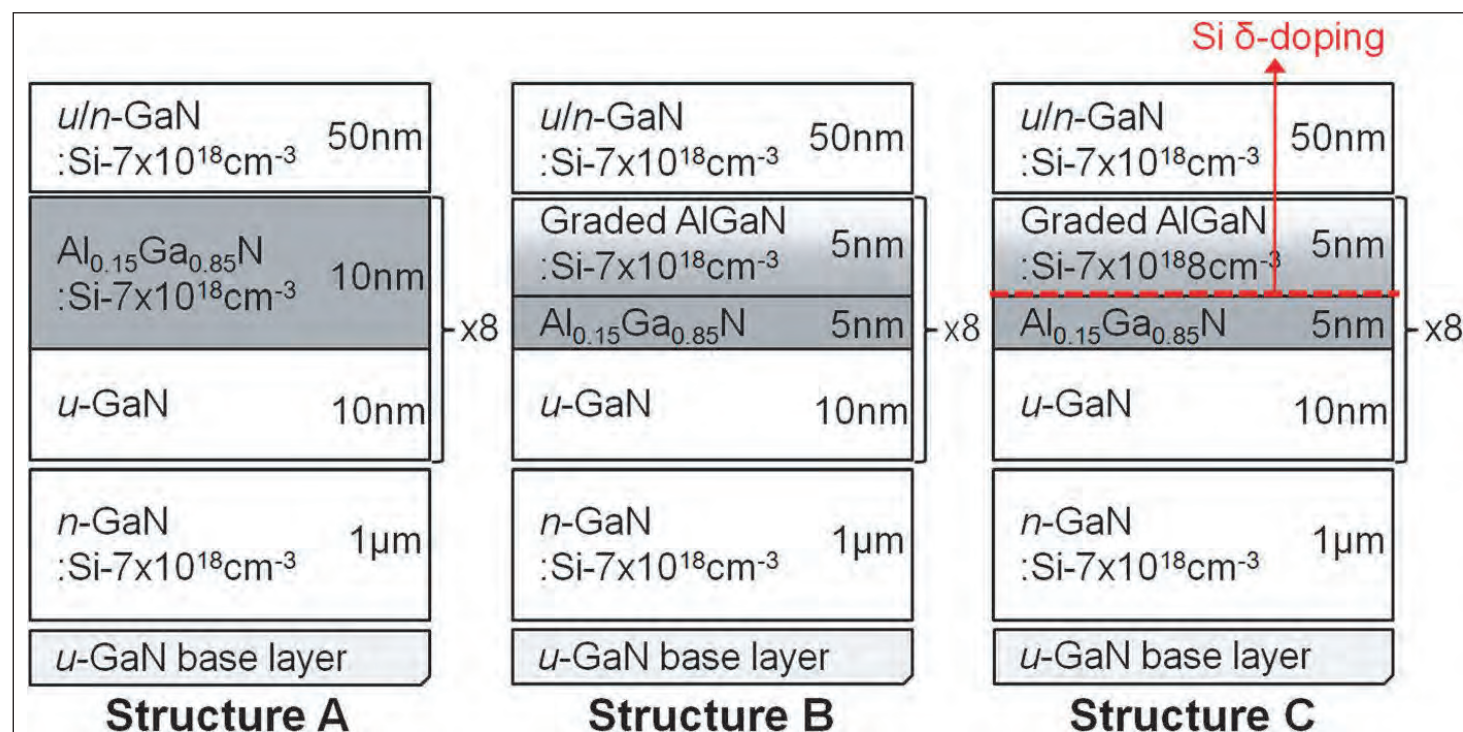


Figure 1. Schematics of structures A, B and C used to explore current-spreading effects of superlattices.

Contact	p-GaN	100nm
Electron blocking	AlGaIn	10nm
Superlattice	InGaIn/GaN	0.6µm/2
Contact	n-GaN	2µm

Figure 2. Schematic of LED layers. Where there was an AlGaIn/GaN superlattice (structures A–C), this was 1µm below the InGaIn/GaN superlattice.

The nitride structures were grown using metal-organic chemical vapor deposition (MOCVD). Various current-spreading AlGaIn/GaN superlattices were produced based on simulations (Figure 1). These structures were tested using Hall-effect measurements and by incorporation into LEDs (Figure 2). Standard lateral LEDs were fabricated with mesa etch, and the application of indium tin oxide (ITO) transparent conductor on the p-GaN top layer and chromium/nickel/gold n- and p-electrodes.

The Hall-effect measurements (Table 1) showed improved conductivity for the superlattices over a 1.2µm n-GaN layer with target doping concentration of $7 \times 10^{18}/\text{cm}^3$ (‘structure D’). The higher mobility of the superlattice structures ‘B’ and ‘C’ was attributed to “reduced ionized impurity scattering as a result of undoped AlGaIn layer that separates 2DEG channel and Si-doped graded AlGaIn layer”.

In addition to lateral conductivity, superlattices for use with LED structures need to have good vertical conductivity. Tests of the vertical conductivity of the superlattices were in line with simulations with

high conductivity correlated with low barrier height. Thus, structure C had a similar vertical conductivity to the reference structure D. By contrast, structures A and B had reduced current for a given voltage, with the lowest vertical current being that through structure A that had the highest barriers in simulation.

The performance of the LEDs (Figure 3) confirmed the superiority of structure C for giving improved current spreading without impacting the vertical flow. The peak wavelength at 60A/cm² current density was 635nm for all devices. At the same current, the output powers were 73.1mW, 75.3mW, 79.9mW, and 70.1mW for structure A–D, respectively.

The devices with current-spreading superlattices showed increased output power. However, structure A with high barriers to vertical current flow also showed the highest forward voltage, indicating series resistance.

The structure C LED had 13.7% better light output power and 6.7% reduced forward voltage at 60A/cm², compared with the reference LED (structure D). ■

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Table 1. Hall-effect measurements for structure A, B, C, and D.

Sample	Sheet concentration ($\times 10^{13}/\text{cm}^2$)	Mobility ($\text{cm}^2/\text{V}\cdot\text{s}$)	Conductivity ($/\Omega\cdot\text{cm}$)
Structure A	6.61	649	289
Structure B	6.25	960	340
Structure C	1.02	1075	569
Structure D	N/A	237	197

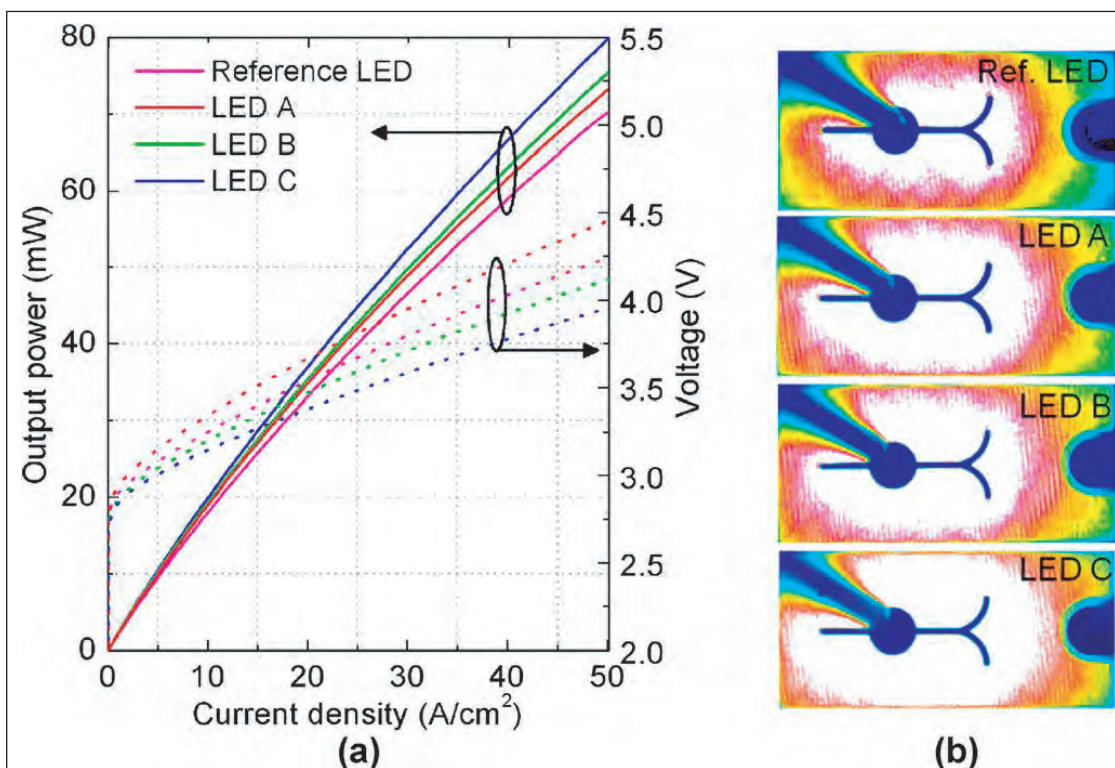


Figure 3. (a) Output power-current-voltage (L-I-V) relations and (b) current-spreading images of LED A, B, C, and reference.