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Luminescence enhancement of green InGaN/GaN nanopillar LEDs

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In recent years, III-nitride compound semiconductors have been widely explored for their applications in light-emitting diodes (LEDs) and great progress has been achieved [1]. However, LEDs with further improved efficiency are expected in order to replace the conventional light sources. One fundamental limit in LEDs is the low internal quantum efficiency (IQE) caused by the large internal strain in multiple quantum wells, known as the quantum confined Stark effect (QCSE) [2]. In this work, nanopillar structure has been demonstrated on InGaN/GaN green LEDs. A significant IQE enhancement was observed due to the alleviated QCSE. Meanwhile, light extraction efficiency (LEE) was also increased because of the increased scattering and reduced reflection at the nanopillar structures.

To fabricate nanopillar structure, a thin SiO_2 layer was first deposited as an interlayer on the LED sample, followed by a thin Au film. Subsequently the sample was subjected to rapid thermal annealing process to form the self-assembled Au nanoparticles. Reactive-ion etching was then conducted to etch the SiO_2 using Au nanoparticles as etch mask. The LED structure was further etched down to n-GaN layer to transfer the nanopattern from SiO_2 to LED structure. Finally, the residual SiO_2 was removed and nanopillar LEDs were treated in HCl to cure the etching damages on nanopillar sidewall.

Due to the strain relaxation, QCSE was relieved and IQE was then enhanced. The strain relaxation was confirmed by the blue shift of photoluminescence peak and Raman spectra. It is found that IQE enhancement was mainly dependent on the size and density of the nanopillars. Furthermore, the height of nanopillar could affect the LEE of LEDs. At last, a luminescence enhancement with a factor of 4.6 was achieved from nanopillar LED compared to the as-grown one. The promising results suggest that nanopillar structure fabricated by this method is an effective way to enhance the emission efficiency of green LEDs.

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[1] S. Pimputkar, et al.: “Prospects for LED lighting,” Nat. Photonics, vol. 3, 180-182 (2009).
[2] S. F. Chichibu, et al.: “Origin of defect-insensitive emission probability in In-containing (Al,In,Ga)N alloy semiconductors,” Nat. Materials, vol. 5, 810-816 (2006).

Supplementary information

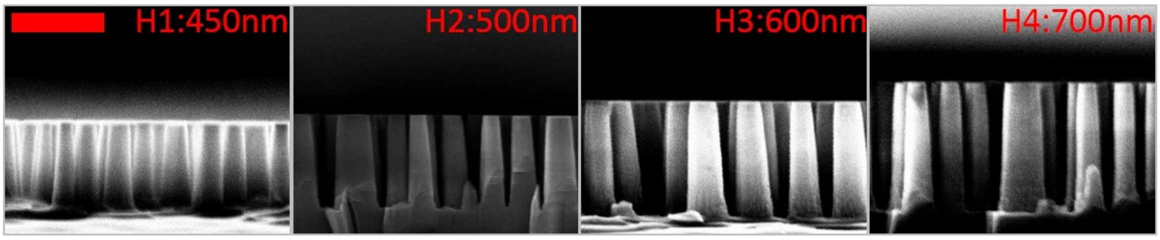

Fig.1 Cross-sectional SEM images of nanopillar LED structures with different height. Scale bar represents 500nm for all.

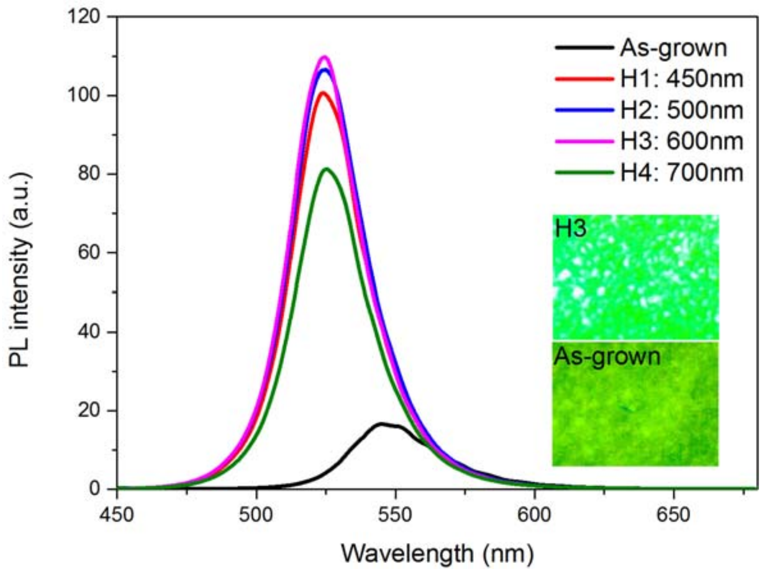

Fig.2 PL intensity spectra of as-grown and nanopillar LEDs with different height (inset: microscope photoluminescence images).

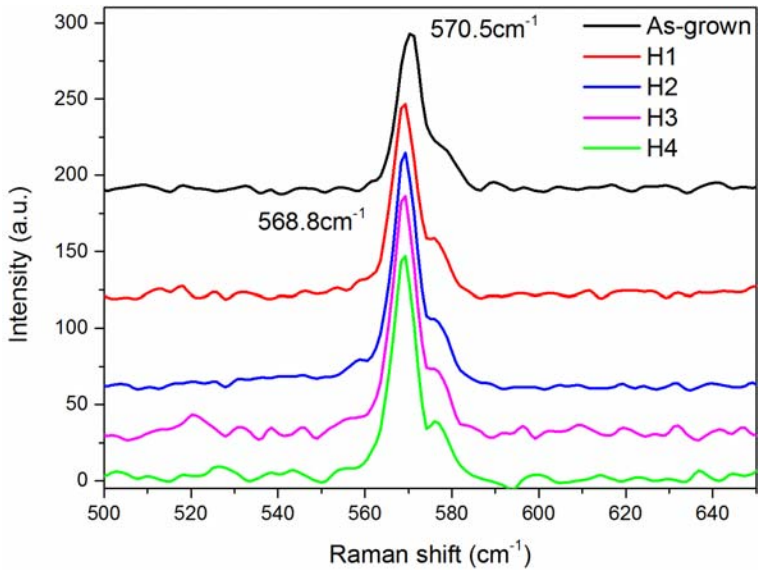

Fig.3 Raman spectra of as-grown and nanopillar LEDs with different height.