Low-damage Fabrication of InGaN/GaN Nanopillars by Neutral Beam Etching: Towards Directional Micro-LED in Top-down Structure

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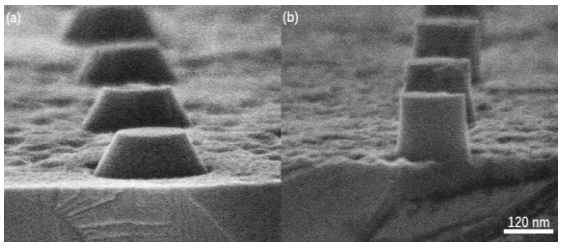
GaN micro-LED (μLED) has great potentials in developing low-power consumption, high-brightness, and high-resolution display for wearable electronics. Usually, highly-directional emission with a small far-field emission angle is a critical factor for high-brightness and high-resolution μLED display. We recently proposed a novel structure to realize highly-directional LED based on the evanescent wave coupling effect in a micron-sized truncated cone [1]. In this device, a small active region with a lateral dimension of about 100 nm is buried at the center of the micron-sized truncated cone. The top-down etching of InGaN/GaN multiple quantum wells (MQWs) is a promising approach to fabricate the small active region required for directional emission. However, the plasma discharge during the process of dry etching brings in damages and defects, which greatly degrades the performance of the device. To solve these issues, neutral beam etching (NBE) has been considered as an effective way [2]. In this work, low-damage nanopillars of InGaN/GaN MQWs with a diameter of about 150 nm were fabricated by NBE and compared with that of inductively coupled plasma (ICP) etching. The results of scanning electron microscopy (SEM) present a smooth and vertical sidewall for nanopillars made by NBE (Fig.1). The internal quantum efficiency (IQE) of nanopillars fabricated by NBE was improved by a factor of about 10, as compared with that of ICP (Fig.2). Our research demonstrates that NBE is a very promising etching technique for low-damage fabrication of nanopillars for directional μLED in top-down structure.



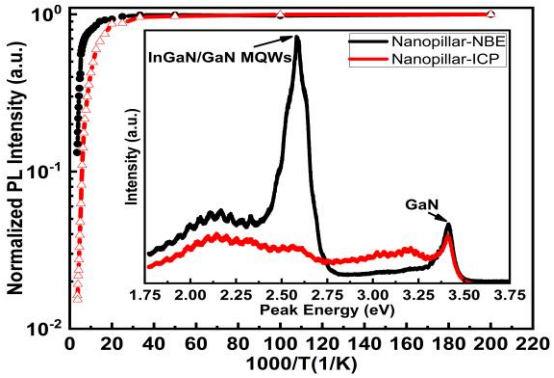


Fig.1. Cross-sectional SEM of nanopillars fabricated by ICP (a) and NBE (b); Fig.2. IQE and room temperature PL (inset) of nanopillars fabricated by ICP and NBE.

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Reference: [1] Xuelun Wang et al., Applied Physics Letters 107.13 (2015): 131112. [2] Yafeng Chen et al., Journal of Applied Physics 123.20 (2018): 204305.