Enhancement of Light-Emitting Efficiency for GaN-based Light-Emitting Diodes by Nanoscale Bump and Pit ITO Surface

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In recent years, light emitting diodes (LED) have been widely used in varies of applications such as illumination, pilot lamp, and display screens. Although the internal quantum efficiency exceeding 70% has been demonstrated by metalorganic chemical vapor deposition grown GaN-based LED [1], the light extraction efficiency is still very low because of the total internal reflection. Photonic crystal is proved to be a useful way for the light extraction enhancement, and varies of ordered and disordered structures have been fabricated on the ITO layer[2-4]. The GaN has relatively high refractive index, for the light can only escape from ITO to air when the incidence angle is below 23.5°.The textured ITO can improve the extraction efficiency by decrease in total internal reflection. However, nanoscale bumps or pits have not been studied so far.

In this paper, we fabricated nanoscale bump and pit structures on the ITO layer of GaN-based LED by argon ion beam etching method. The sample was placed on an inclined rotated platform, in order for uniformed bombardment [see Figure 1 (a)]. The high energy ion beam has large damage on the corner of the PMMA mask, so that the top of the mask can become smaller than the bottom in the etching process, and we can finally get sloping sidewalls, as shown in Figure 1 (b). The pit structure was etched under PMMA mask, and the bump one under Cr mask. The SEM images were shown in Figure 2. The light emitting intensity was measured by integrating sphere, and over 20% enhancement was obtain compared to the textured LED and original LED.

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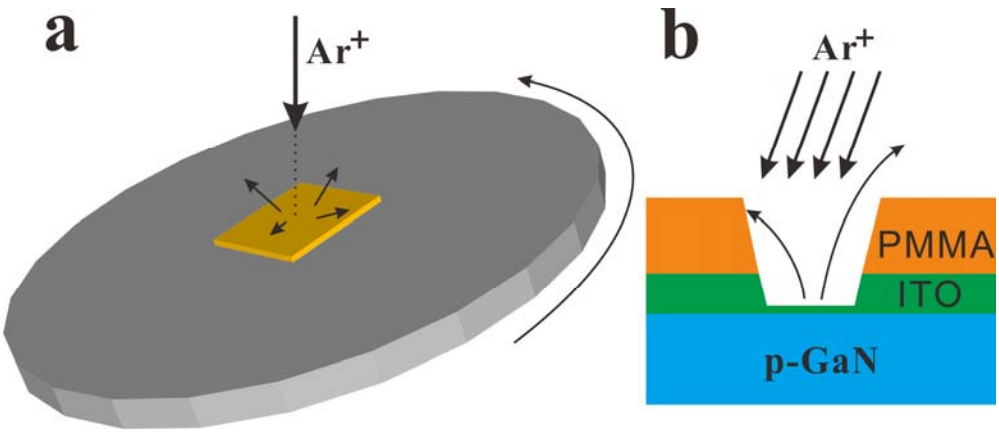

Figure 1: Schematic of argon ion beam etching. (a) The platform was place 20° to the direction of ion beam and kept rotating; (b) ion beam etching lead to inclined sidewall.

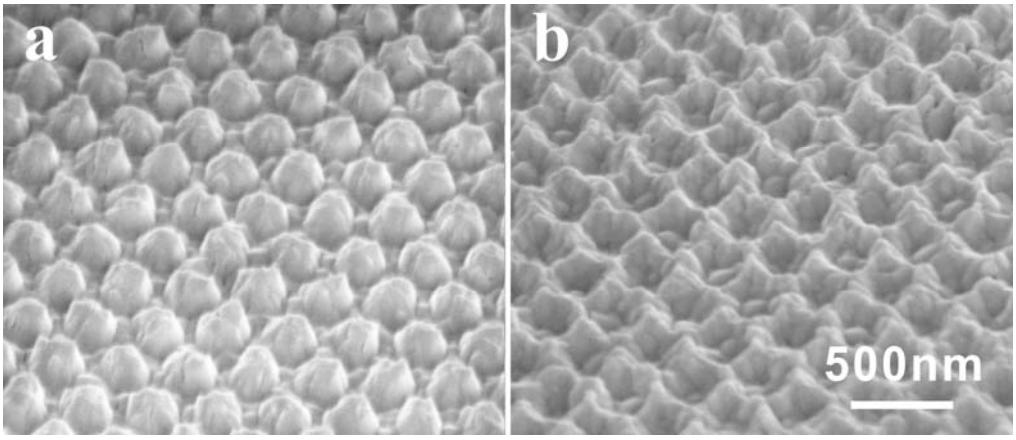

Figure 2: SEM images of bumps and pits in ITO layer. The period of these structures is 350 nm, and the etching depth is 200 nm.