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Improvement of Light Extraction Efficiency of GaN-Based Vertical LED with Microlens Structure

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Vertical LED (VLED) has been recognized as a way to obtain the high-power LED due to their advantages [1]. However, approximately 4% of the light generated from the active region is extracted, if the light extraction from side walls and back side is neglected because of Fresnel reflection (FR) and total internal reflection (TIR) [2,3]. In this study, the optical simulation of the VLED with the various microstructures was performed. Among them, the microlens having the diameter of 3 μm and the height of 1.5 μm shown the best result was chosen, and then, optimized microlens was formed on a GaN template using conventional semiconductor process. Various microstructures were proposed to improve the light extraction efficiency (LEE) of the VLED for the simulation. The LEE was simulated using LightTools based on a Monte Carlo ray tracing. The microstructures with hemisphere, cone, truncated and cylinder pattern having diameter of 3 μm were employed on the top layer of the VLED respectively. The improvement of the LEE by using the microstructure is 87% for the hemisphere, 77% for the cone, 53% for the truncated, 21% for the cylinder, compared with the LEE of the flat surface at the reflectance of 85%. The LEE was increased by 88% at the height of 1.5 μm, compared with the LEE of the flat surface. We found that the microlens on the top layer is the most suitable for increasing the LEE. In order to apply the proposed microlens on n-GaN surface, we fabricated microlens on a GaN template. A photoresist array having hexagonal-closed packed microlens was fabricated on the GaN template. Then, optimization of etching the GaN template was performed using a dry etching process with ICP-RIE. The dry etching carried out using a gas mixture of Cl2 and Ar, each having a flow rate of 16 sccm and 10 sccm, respectively with RF power of 50 W, ICP power of 900 W and chamber pressure of 2 mTorr was the optimum etching condition as shown in Fig. 2(a).

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References

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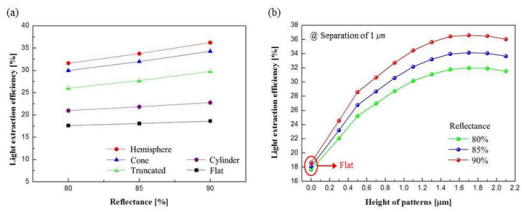

Fig. 1. Light extraction efficiency of GaN-based vertical (a) various micro structures and (b) function of various heights of microlens. LED with

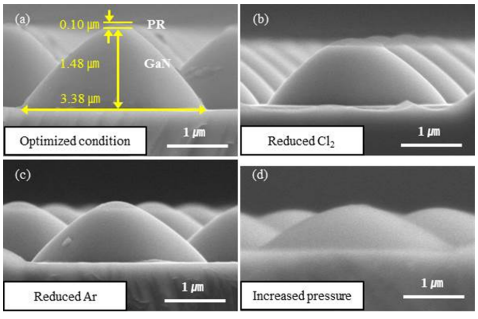

Fig. 2. SEM images of the microlens structure on GaN template fabricated by various condition.