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Fabrication of High Light-Extraction Efficiency LED Using Nanostructures by UV Nanoimprint Lithography and Electrodeposition

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1. Introduction

Light emitting diodes (LEDs) are expected to be widely used for illumination and lighting. Increment of the LED luminescence is indispensable for this purpose. Light-extraction efficiency is an important factor for higher luminescence LED. The light-extraction efficiency is increased by reducing the reflection of light on the surface. There are a lot of reports that nanostructures on the LEDs surface prevent the reflection [1][2][3].

We are able to make the metal nanoscale mask for etching in a large area by using ultraviolet nanoimprint lithography (UV-NIL) in combination with electrodeposition, nanostructures of GaN for antireflection are fabricated by reactive ion etching (RIE) using this mask.

2. General Instructions

The fabrication process consists of 5 steps as shown in Figure 1. First, the replicated patterns were formed with the photocurable resin having resistance to electrodeposition by UV-NIL. The mold has dots of 225nm in depth, 200nm in diameter with 500nm pitches. Next, Ni nano patterns were electrodeposited to the holes using the seed layer. Ni was used as an etching mask because Ni has high resistance to Cl_2 RIE. The photocurable resin was removed. Figure 2 indicates the SEM image fabricated Ni nano patterns. Subsequently, GaN substrate was etched by Cl_2-based inductive coupled plasma (ICP) RIE. Figure 3 shows the SEM image of the fabricated GaN nanostructures. Finally, the Ni mask and the seed layer were removed. The nanostructures of 600nm in depth, 300nm in diameter, and 500nm pitches were formed on the surface of GaN substrate.

After forming the electrodes on the LEDs as illustrated in Figure 4, the light-output from the front surface was measured by a photodiode. The light-output of the LEDs increased by 1.5 times compared with conventional LED as shown in figure 5.

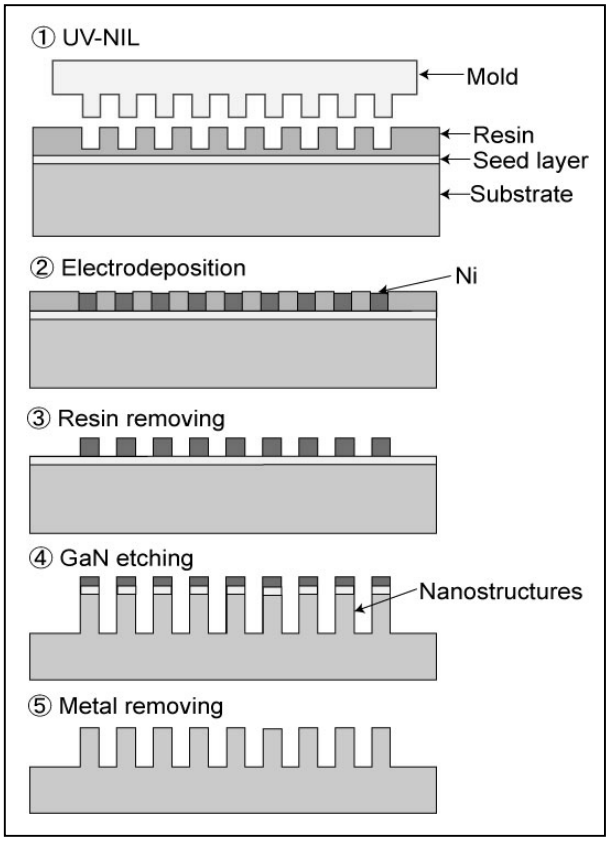

Fig. 1 Fabrication process of the GaN nanostructures.

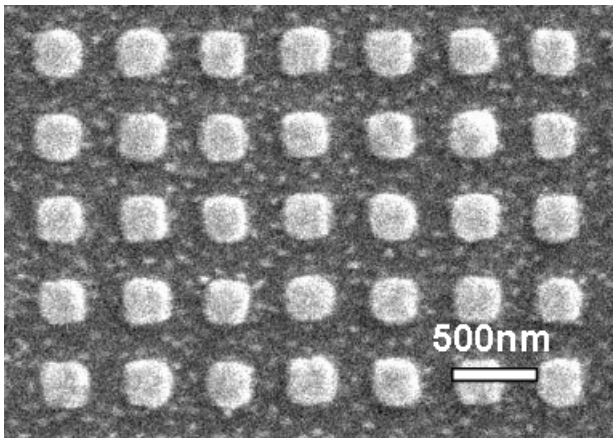

Fig. 2 SEM image of the Ni nano patterns as an etching mask.

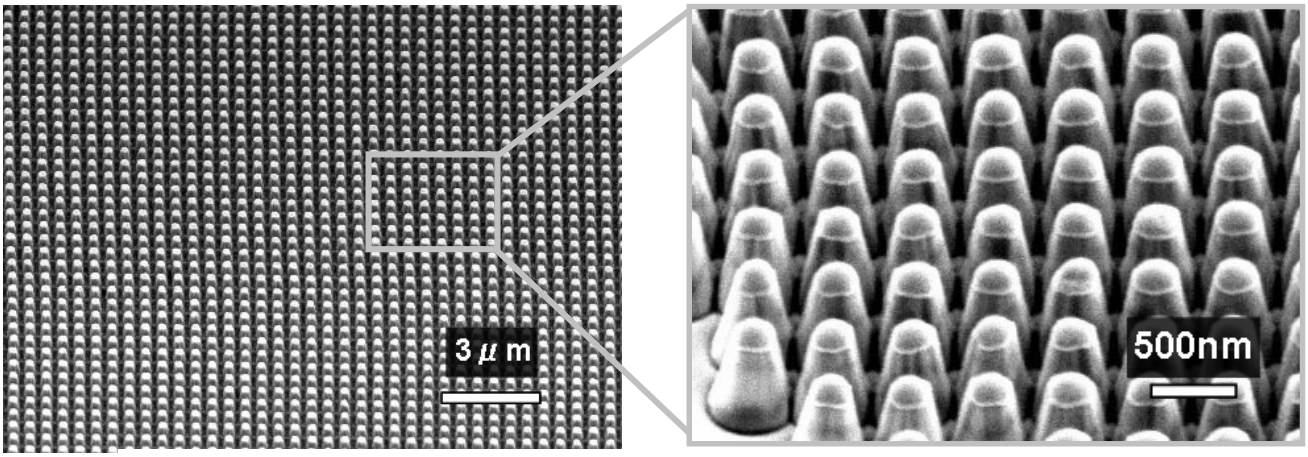

Fig. 3 SEM image of the nanostructures after GaN etching.

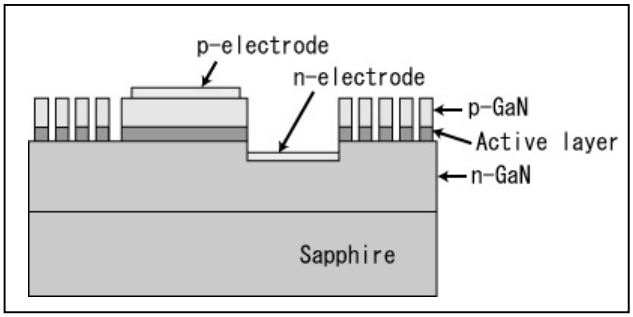

Fig. 4 Cross-section of the LED with nanostructures.

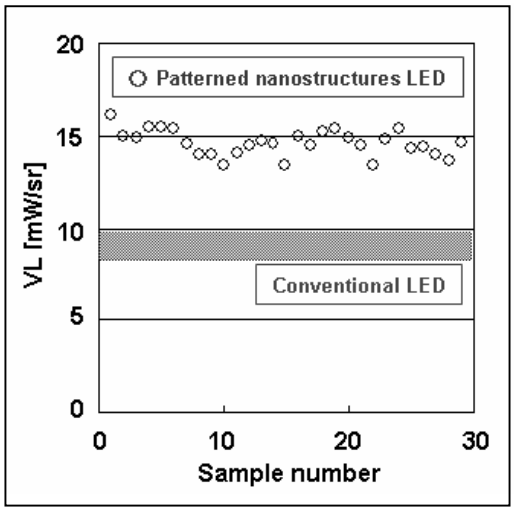

Fig. 5 Light-output from the LED front surface.

3. Conclusions

Nanostructures for antireflection on the GaN LEDs substrate surface were fabricated by RIE using Ni as an etching mask. The Ni mask was formed by the electrodeposition process in combination with UV-NIL. The nanostructures of 600nm in depth, 300nm in diameter, and 500nm pitches were fabricated on the GaN substrate. The light-output of the LEDs increased by 1.5 times compared with conventional LED.

In this work, the patterned Ni mask for GaN etching in a large area was realized by using UV-NIL and electrodeposition. It indicates the possibility of low cost fabrication of nanostructures on the GaN substrate.

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