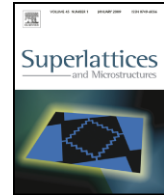




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Enhanced output power for InGaAlP LEDs by contact-transferred and mask-embedded lithography

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ABSTRACT

The authors applied a simple, low-cost, mass-producible contact-transferred and mask-embedded lithography (CMEL) to texture p-GaP window layer for the fabrication of InGaAlP light-emitting diodes (LEDs) emitting at 612 nm. Under 20 mA current injection, it was found that forward voltages were 2.25, 2.24 and 2.25 V for CMEL-400 nm LED, CMEL-2 μ m LED and the conventional LED without CMEL, respectively. It was also found that the 20 mA output powers were 1.43, 1.28 and 1.16 mW for CMEL-400 nm LED, CMEL-2 μ m LED and the conventional LED without CMEL, respectively.

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1. Introduction

Quaternary InGaAlP is an important material that has been widely used for high brightness red, yellow and yellow/green light emitting diodes (LEDs) [1–4]. It is known that light extraction of LEDs depends on the refractive index and morphology of the surface layer. With a large refractive indexed surface layer, a significant amount of light generated in the LED will be reflected at the semiconductor/air interface [5]. To solve this problem, one can texture the sample surface so that

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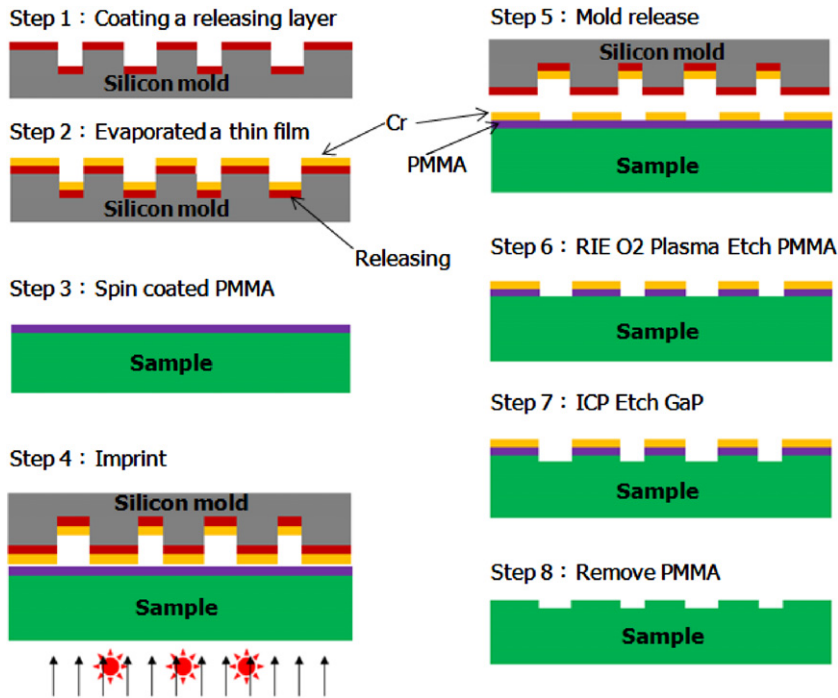


Fig. 1. Detailed proceeding steps for our CMEL.

photons can experience multiple opportunities to find the escape cone [6–8]. It has also been shown that nanometer-sized textures could provide much larger output power enhancement, as compared to micrometer-sized textures [9]. E-beam lithography is a standard method to achieve nano-patterns on semiconductor surface. However, the e-beam lithography system is extremely expensive with a low throughput. Alternatively, one can use imprint methods such as nano-imprinting lithography (NIL) [10], step and flash imprint lithography (SFIL) [11], micro-contact printing (μ CP) [12] and nanotransfer printing (nTP) [13] to transfer nano-patterns. Indeed, some of these methods have already been used to enhance output power of GaN-based LEDs [14–20].

For example, Chang et al. used imprint lithography to pattern indium-tin-oxide (ITO) contact electrode of GaN-based LEDs [19]. Using similar imprint lithography, Bao et al. formed polymer gratings on the sapphire backplane of GaN-based flip-chip LEDs [18]. However, output power enhancement was limited due to the fact that no subsequent etching of the GaN epitaxial layer was performed in these two cases. On the other hand, Huang et al. used imprint lithography to pattern a dried polymer film and then used reactive ion etching (RIE) to transfer the pattern onto a SiO_2 layer [15]. Using the patterned SiO_2 layer as the mask, they subsequently used an inductively coupled plasma (ICP) etcher to etch the GaN epitaxial layer.

Very recently, Lee and Chiu developed a new type of contact imprinting lithography, called contact-transferred and mask-embedded lithography (CMEL) [21]. It utilizes an anti-adhesion layer to release a patterned metal film from a mold to a polymer layer deposited on a substrate. With the anti-adhesion layer, the patterned metal film can serve as the etching mask directly after imprint. Thus, transferring the pattern onto a SiO_2 layer is no longer necessary [15]. It has been shown that CMEL is much easier to implement for micro-/nano-patterning and fabrication in comparison with the other currently existing imprint methods. In this letter, we report the use of CMEL to enhance output power of InGaAlP-based LEDs. Although imprint lithography has already been applied to GaN-based LEDs, it has never been used to enhance output power of AlInGaP-based LEDs to our knowledge. The physical, electrical and optical properties of the fabricated LEDs will also be discussed.

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