Chapter 1

Introduction

WIDE BANDGAP light-emitting diodes (LEDs) that are III-Nitride, ranging from ultraviolet to the short-wavelength part of the visible spectrum have been intensely developed in the past ten years [1, 2]. Recently, as the brightness of GaN-based LEDs has increased, applications such as traffic signals, backlight for cell phone, and LCD-TV have become possible [3]. However, as for the replacement of conventional fluorescent lighting source with solid-state lighting, it still needs a great effort for improving the light extraction efficiency as well as internal quantum efficiency of LEDs.

There are many methods to improve extraction efficiency such as p-type GaN surface roughening process [4], n-type GaN surface roughening process with laser lift-off technique [5, 6], texturing surface using double transferred and sapphire wet etching [7], chip shaping using undercut sidewall to vary light direction and path achieving better light extraction [8], photonic crystals [9], and omnidirection reflector techniques [10, 11, 12].

The conventional LEDs are inherently inefficient because photons are generated through a spontaneous emission process and emitted in all directions. A large fraction of light emitted downward toward the substrate does not contribute to useable light output. In addition, there is an inherent problem associated with conventional nitride LEDs, i.e., the poor thermal conductivity of the sapphire substrate. It has been shown that the flip-chip techniques are an effective way to further enhance light extraction and heat dissipation [13]. Therefore, the flip-chip LEDs were always used in high current and high power operation to alleviate the thermal budget problem. The FC-LEDs configuration has high extraction efficiency compared to conventional LEDs due to the thicker light extraction windows layer and lower refraction index contrast between sapphire substrate (n=1.76) and air (n=1). This leads critical angle of light output to become larger and let total internal reflection reduce. Furthermore, metal contact including n- and p- metal of FC-LEDs wouldn't baffle light output and can be served as a reflective mirror to reflect the light and extract through transparent sapphire substrate [14, 15].

However, FC-LEDs still have total internal reflection effect between the sapphire substrate and air, reducing the extraction efficiency of transparent windows layer. The surface roughness technique is an approach for light output enhancement has been proved due to the scattering of photons from the textured semiconductor surface and the probability of photons escaping from semiconductor to can be increased [16, 17]. Another approach is chip shaping technique to decrease the mean photon path-length within the crystal and reduce the effects of internal loss mechanisms [18].

In this thesis, we fabricate two structures of GaN-based flip-chip light emitting diodes (FC-LEDs) including FC-LEDs with micro-pillar-array structure and FC-LEDs with geometric sapphire shaping on the bottom side of sapphire substrate. The formation of micro-pillar-arrays on the bottom side of sapphire surface can be a better way to improve the probability of photons escape through the textured sapphire surface. The fabrication of sapphire shaping on the bottom side of sapphire surface can decrease the mean photon path-length within the crystal and increase light output power. The voltage versus current and the light output power versus current characteristics can be discussed to understand the mechanism of physics. Finally, the TracePro software is used to simulate two different structures of this thesis and verify our experiment results by the Monte-Carlo ray tracing methods. In the future, we will try to combine the micro-pillar-array and geometric sapphire shaping structure on the bottom side of sapphire surface.