Chapter 6

Conclusions and Future Work

6-1 Conclusions

In summary, Two types of FC-LEDs including FC-LEDs with micro-pillar-array structure and FC-LEDs with oblique sapphire geometric structure were demonstrated. In the first part, we employ inductively coupled plasma (ICP) to etch micro-pillar-array on the backside surface of sapphire substrate for light extraction enhancement. The etching depth and bevel angle of the micro-pillar-array become larger with the increase of ICP dry etching time. The I-V curve of MPAFC-LEDs present a normal p-n diode behavior with a forward voltage (@350 mA) of 3.4 V, indicating that there is no damages for the fabrication process of micro-pillar-array during ICP etching process. The light output power of the MPAFC-LEDs was increased by 68 % for a 3.2 μm textured micro-pillar-array on the bottom side of the sapphire substrate. The improved light extraction efficiency can be further supported by simulation data. Such an enhancement can be attributed to the top surface roughness and the fact which photons are more likely to be emitted from the surface-roughed device, resulting in an increase of the light output power of the MPAFC-LED.

In the other part, the FC-LEDs with oblique sapphire geometric structure and greatly thick sapphire window layer were fabricated. The H_2SO_4:H_3PO_4 (3:1) solution is employed to etching backside surface of sapphire substrate. The I-V curve of SSFC-LEDs exhibits a normal p-n diode behavior with a forward voltage (@350mA) of 3.5 V, indicating that high temperature sapphire wet etching process dose not appear to adversely affect I-V characteristics of these devices. The light extraction efficiency enhancement of 100μm

SSFC-LEDs has 55% improvement under 350 current injection compared to the CFC-LEDs. The simulated result of 100 μm SSFC-LEDs is similar to experiment performance of 55% and enhancement efficiency gradually converges. The novel FC-LEDs structure could not only reduce the TIR effect but facilitate light emission from the edges of the thicker sapphire windows layer resulting in an increase in the light extraction efficiency of FC-LEDs.

6-2 Future work

In the future, we will demonstrate the novel FC-LEDs structure with micro-pillar-array surface and oblique sapphire geometric sidewalls by the combinations of sapphire dry- and wet- etching techniques to procure higher extraction enhancement as shown in figure 6-1. Moreover, the optimization of MPA surface and sapphire geometric sidewalls will be also demonstrated. We wish to realize the high output power and high light external quantum efficiency (EQE) LEDs to accelerate the actualization of solid state lighting.

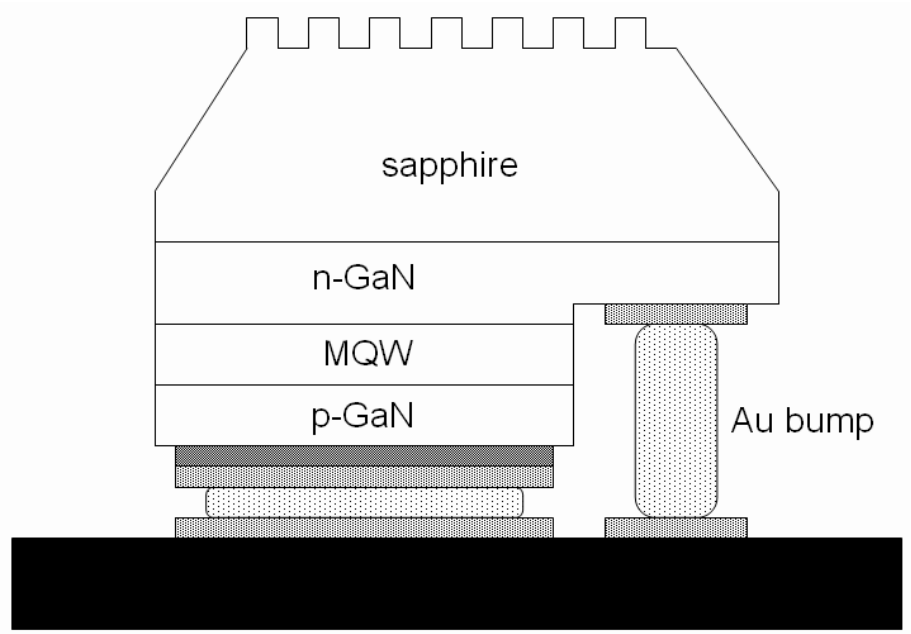

Figure 6-1 The schematic structure of flip-chip LEDs with micro-pillar-array, geometric sapphire shaping structure and greatly thick sapphire window layer.