Abstract (in Chinese) i	i
Abstract (in English) i	ii
Acknowledgementi	iii
Contents i	iv
List of tables	vi
List of figures	vi
Chapter 1 Introduction	1
Chapter 2 Optical Property of LEDs and Implements	4
2-1 Internal, extraction, external and power efficiencies	4
2-2 The light escape cone	7
2-3 Monte Carlo raytracing	9
Chapter 3 Flip Chip Technology	13
3-1 Development of flip chip technology	13
3-2 Advantages of flip chip technology	13
3-3 Interconnection of flip chip bonding	14
3-4 Principle of ultrasonic flip chip bonding	14
3-5 Advantages of LEDs with flip chip technology	15
Chapter 4 Flip-Chip Light-Emitting-Diodes with Textured Micro Pillar Array	ys
(MPAFC-LEDs)	20
4-1 Fabrication of MPAFC-LEDs	20
4-1.1 Process prcedure	20
4-1.2 SEM images of micro pillar arrays	21
4-2 Characteristics of MPAFC-LEDs	22
4-2.1 L-I-V measurement and efficiency enhancement 2	22
4-2.2 Monte-Carlo ray-tracing calculations	23

Chapter5 Flip-Chip Light-Emitting-Diodes with Geometric Sapphire Shaping
Structure (SSFC-LEDs)
5-1 Fabrication of SSFC-LEDs 38
5-1.1 Process prcedure 38
5-1.2 SEM images and photomicrographs of SSFC-LEDs and
conventional FC-LEDs (CFC-LEDs)
5-2 Characteristics of SSFC-LEDs 40
5-2.1 L-I-V measurement and far-field pattern
5-2.2 Monte-Carlo ray-tracing calculations
Chapter 6 Conclusions and Future Work 56
6-1 Conclusions 56
6-2 Future work 57
Reference

List of tables

Table 4-1 (a) shows the material variable of the models and (b) shows	
the surface variable of the models	33

List of figures

Figure 2-1 Band diagram of active region of LEDs 11
Figure 2-2 Reservoir analogy 11
Figure 2-3 Definition of the escape cone by the critical angle θ_c 12
Figure 2-4 Picture of TracePro software 12
Figure 3-1 Various flip chip technologies 17
Figure 3-2 Diffusion type of metal oxide film 17
Figure 3-3 Principle of Thermo-Ultrasonic bonding process
Figure 3-4 Structure of conventional GaN-based LED
Figure 3-5 Structure of Flip chip GaN-based LED 19
Figure 4-1 Schematic of fabrication steps of GaN LEDs with micro-pillar-
arrays
Figure 4-2 Scanning electron micrographs (SEM) images of Si sub-mount
before flip chip bonding. (a) Top view and (b) Side view 27
Figure 4-3 SEM image of a chip bonding on the Si sub-mount
Figure 4-4 SEM images of micro-pillar-array surface of sapphire backside
with various depth and bevel angle. (a) 1.1 μm MPA, (b) 1.8 μm
MPA, (c) 2.7 μm MPA, and (d) 3.2 μm MPA 30
Figure 4-5 The current-voltage (I-V) characteristics of flat surface FC-LEDs
and MPAFC-LEDs
Figure 4-6 The light output power-current (L-I) curves of flat surface FC-
LEDs and MPAFC-LEDs

Figure 4-7 Light extraction enhancement of experimental results versus
different depth of MPA 32
Figure 4-8 Photons of (a) conventional flat surface FC-LED and (b) micro
pillar-array FC-LED at a dc injection current of 350 mA 32
Figure 4-9 Figure 4-9 (a) shows the structure of the simulated models, (b)
shows the models in the TracePro software, and (c) is a sketch
of the pattern on the backside surface of the sapphire substrate
Figure 4-10 The simulation results by Monte-Carlo ray-tracing. (a) and (b)
show the irradiance maps of conventional flat FC-LEDs and 3.2
µm MPAFC-LEDs, respectively
Figure 4-11 Light extraction enhancement comparison of experimental and
simulation results versus different depth of MDA
Figure 5-1 Schematic of fabrication steps of sapphire shaping FC-LEDs
Figure 5-2 Schematic drawing of the GaN SSFC-LEDs, illustrating the
means by which light may be extracted from the oblique sapphire
sidewall 44
Figure 5-3 SEM images of SSFC-LED. (a) shows the cross view and (b),
(c), (d) show the angle of 60° , 30° and 50° against (0001) c-axis,
respectively 46
Figure 5-4 Scanning electron micrographs of (a) CFC-LED and (b) SSFC
-LED devices 47
Figure 5-5 Photomicrographs of (a) CFC-LED and (b) SSFC-LED chips
(40X40 mil) operating at 20 mA (dc) with an emission wavelength
of $\lambda_p \sim 460$ nm

Figure 5-6 The corresponding current-voltage (I-V) characteristics of SSFC	
-LEDs and CFC-LEDs 49	
Figure 5-7 The light output power and wall plug efficiency as a function of	
injection current for $\lambda_p \sim \!$	
-LEDs 49	
Figure 5-8 The normalized far-field patterns of the SSFC-LED and CFC-	
LED versus two directions ((1-106)-plane to (1-102)-plane, X-axis;	
(11-25)-plane to (11-25)-plane, Y-axis), respectively 50	
Figure 5-9 The normalized three-dimensional far-field patterns of (a) FC-	
LEDs and (b) SSFC-LEDs	
Figure 5-10 The structure of the siumalted model in TracePro software	
Figure 5-11 The candela maps of (a) CFC-LEDs and (b) 100 μm SSFC-	
LEDs	
Figure 5-12 The ray-tracing images of oblique sidewall of (a) CFC-LEDs	
and (b) SSFC-LEDs	
Figure 5-13 The calculated enhancement of the light extraction efficiency	
with the increasing of etching depth of SSFC-LEDs	
Figure 6-1 The schematic structure of flip-chip LEDs with micro-pillar-array,	
geometric sapphire shaping structure and greatly thick sapphire	
window layer	