高苑科技大學
Kao Yuan University

LED發光原理和家用照明

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高苑科技大學 綠色能源科技系

綱 要

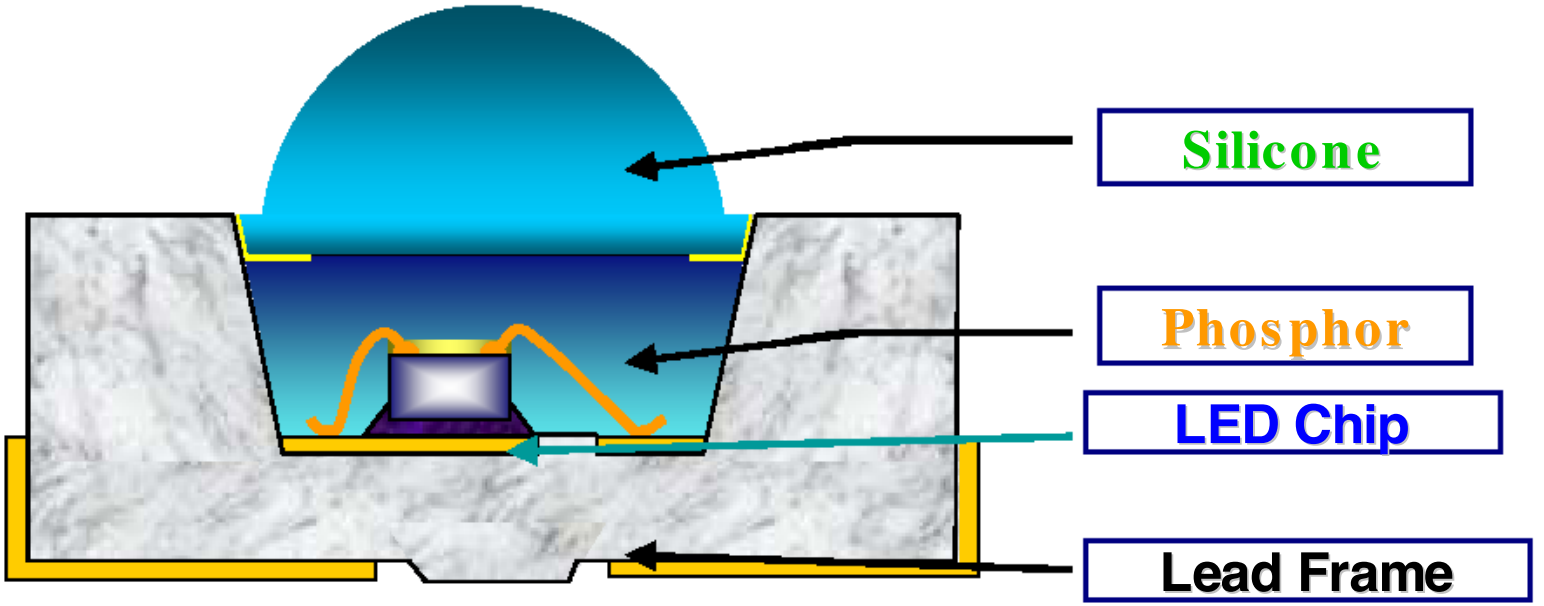
1. LED Applications
2. LED introduction
3. CMLT Advantages
4. LED Epitaxy & Chip
5. PKG & LCD BLU
6. Conclusion

LED簡介 - LED 優點

LED(發光二極體)是一種目前發光效率最高的光源
量產值 > 100 lm/W,理論值 > 263 lm/W

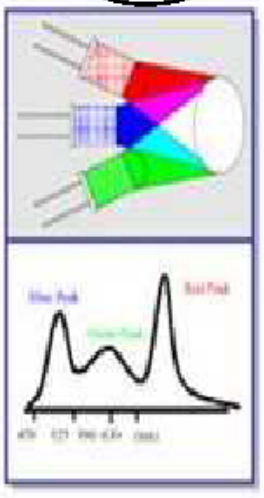
- 高效率, 節能減碳
- 無汞環保, 健康(無UV), 長食物保存期限 (無IR)
- 無閃爍
- 壽命長(>100000Hrs)
- 不易碎, 耐震
- 可調色溫 3000~6000K
- 高演色性 (R,G,B,)

LED結構



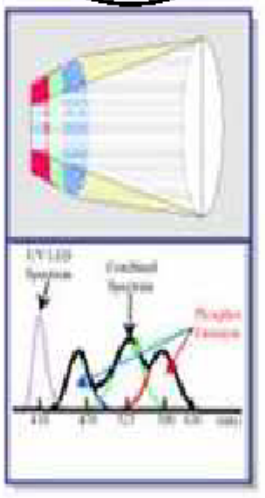
LED 白光種類

R+G+B LED



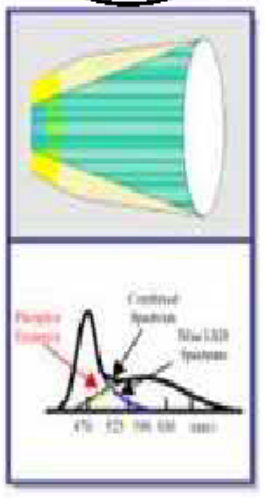
- Dynamic color tuning
- Excellent color rendering
- Large color gamut

UV-LED激發 R,G,B 螢光粉



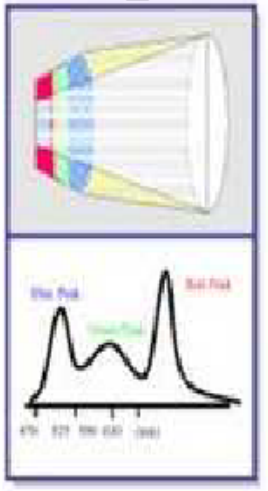
- White point tunable by phosphors
- Excellent color rendering
- Simple to create white

B-LED 激發 Y 螢光粉

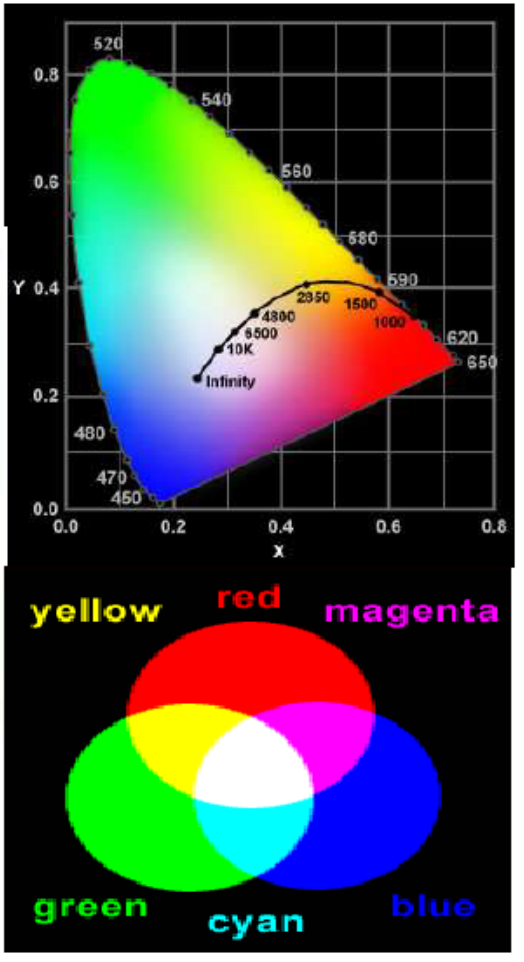


- Simple to create white
- Good color rendering

B-LED 激發 R,G 螢光粉



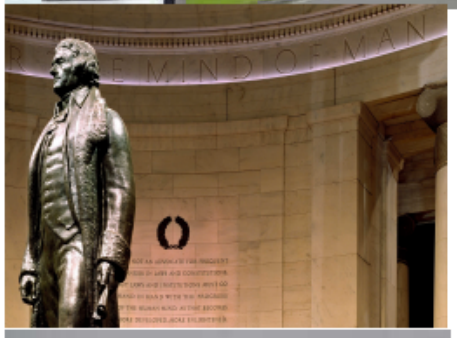
- Dynamic color tuning
- Excellent color rendering
- Large color gamut



目前主要技術 未來可能技術

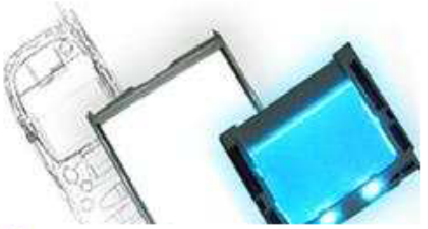
There are various ways to create white light from LEDs, each with specific advantages.

LED 之應用 - 照明



LED 之應用 - 電子產品

螢幕,背光,閃光燈,按鍵



OLPC

LED 之應用 – 汽車&看板

Automotive

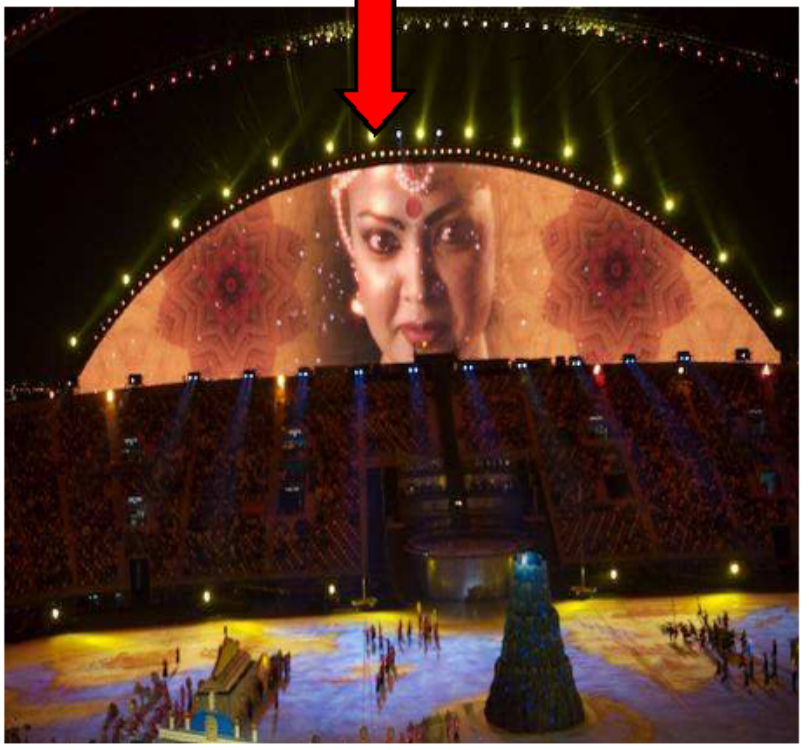
Fig. 3. Audi Le Mans concept car with LED headlamps designed by Ruetz, a German engineering company, using Optis software (see www.sae.org/automag/techbriefs/07-2004/1-112-7-52.pdf).

Audi, BMW, Honda, Toyota, Hyundai…..

Signs

Display

2006 Asia Games in Doha- 165 m×39m LED Display



LED 之應用 – 裝飾照明

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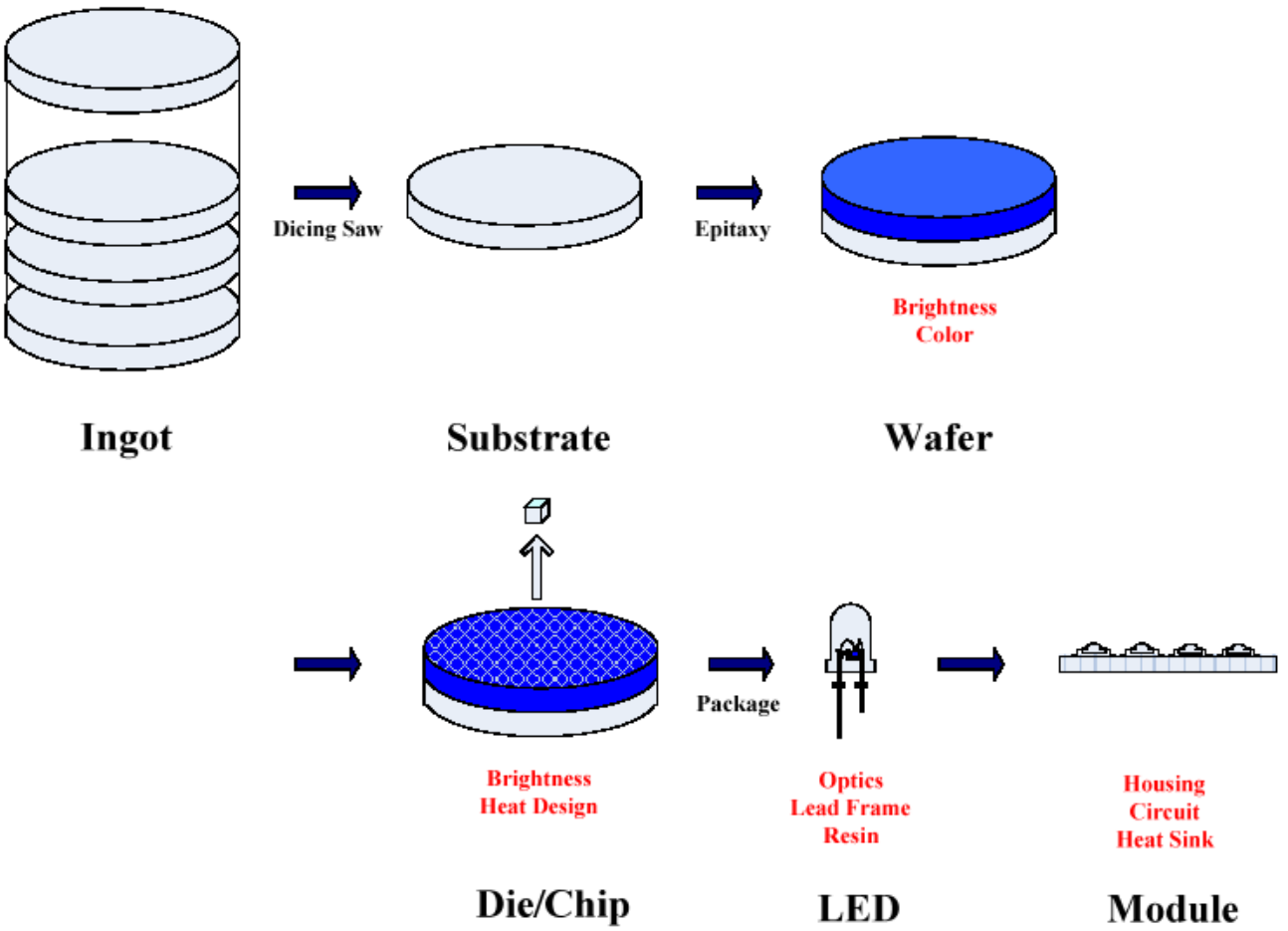
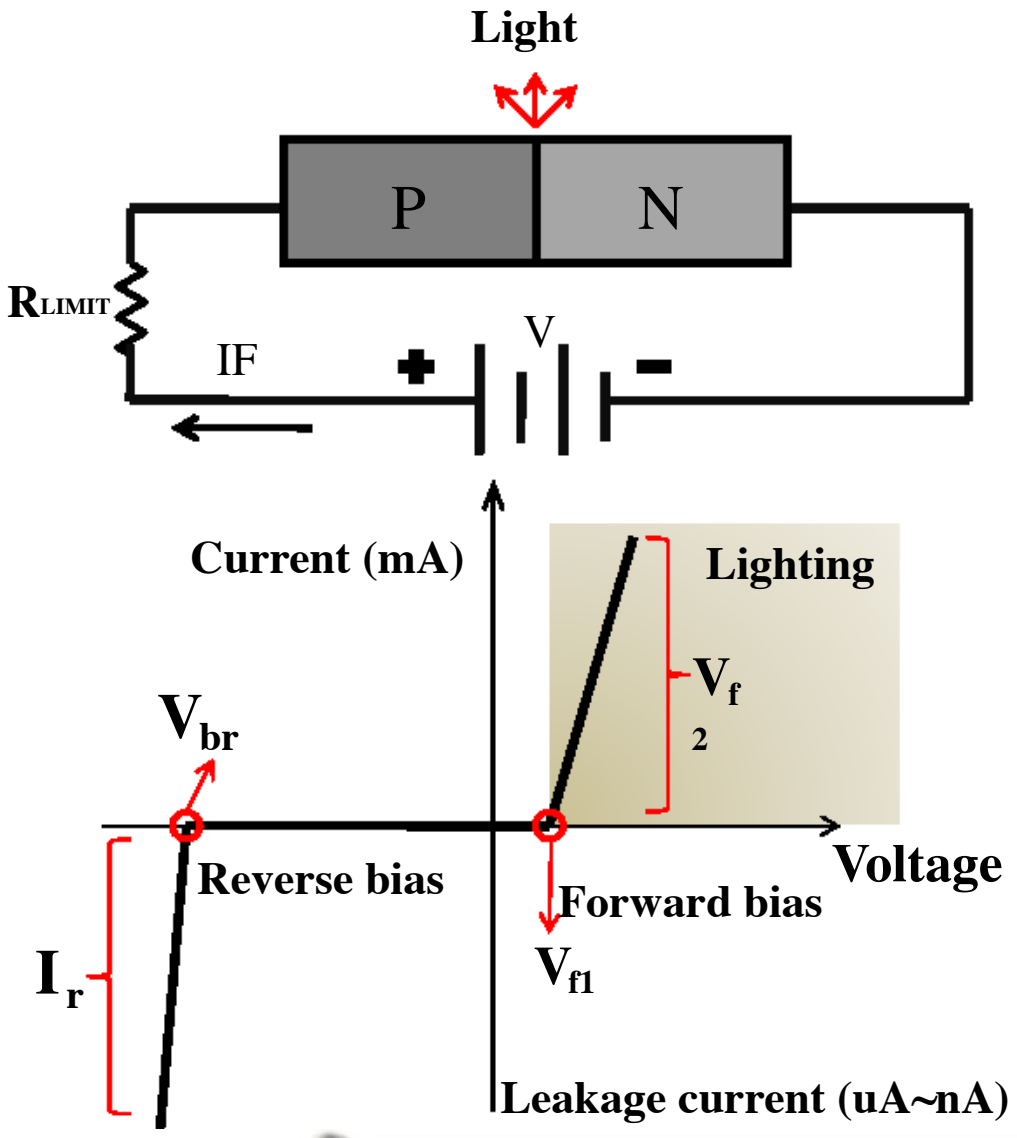
2. LED introduction

Let's Light Up The World

LED Manufacture



Electrical characteristics of LEDs



V_{br}: break bias

I_r: Reverse leakage current

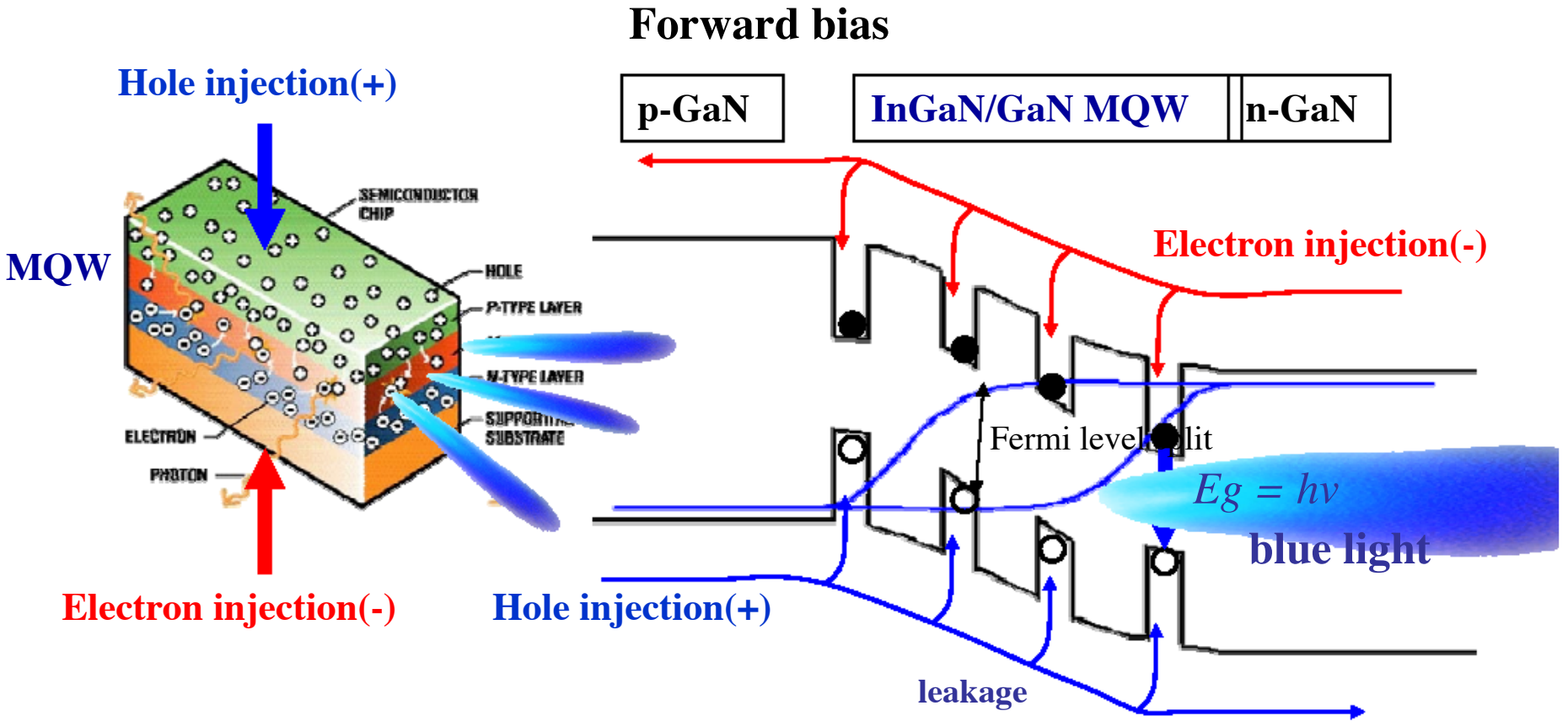
V_{f1} : Starting Voltage

Color	Potential Difference (Vf)	
Infrared	1.6V	AlInGaP
Red	1.8~2.1V	
Orange	2.2V	
Yellow	2.4V	
Green	3.0~3.5V	InGaN
Blue	3.0~.35V	
While(YAG)	3.0~3.5V	
Ultra Violet	3.5V	

V_{f2} : Working voltage

Lighting Zone

LED Basics

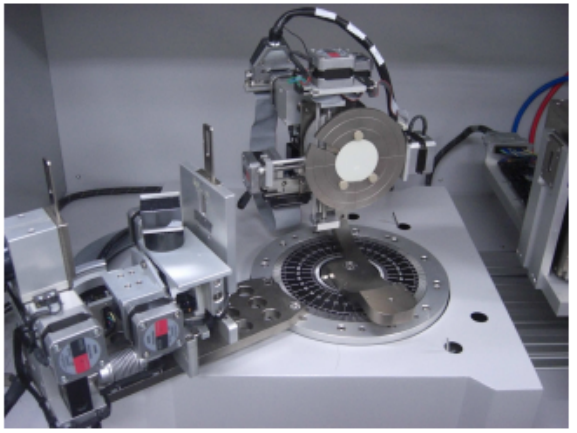

Forward bias
Hole injection(+)
MQW
Electron injection(-)
SEMICONDUCTOR CHIP
HOLE
P-TYPE LAYER
N-TYPE LAYER
SUBSTRATE
ELECTRON
PHOTON
p-GaN
InGaN/GaN MQW
n-GaN
Electron injection(-)
Fermi level
Eg = hv
blue light
Hole injection(+)
leakage

LED Epitaxy設備簡介

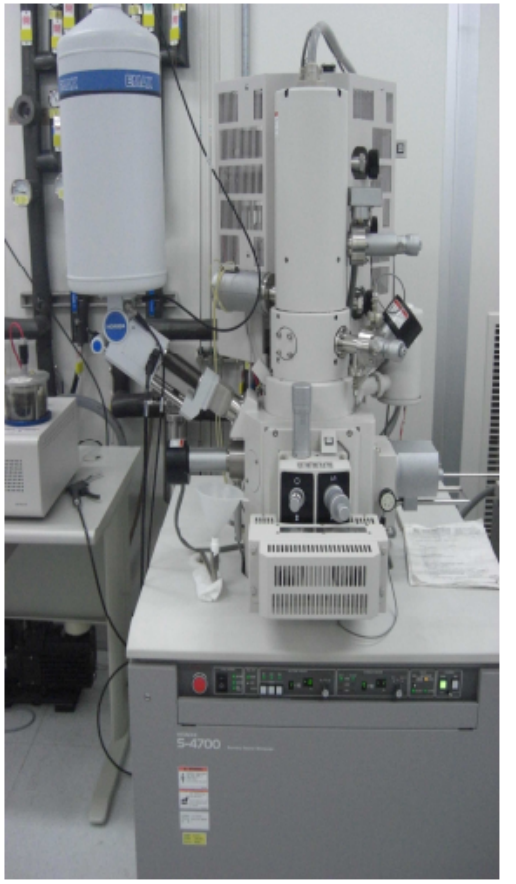
Factory profile

MOCVD

XRD



SEM



HALL

PL

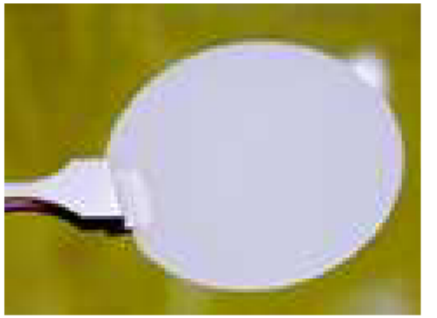
CMLTs LED Wafer Products

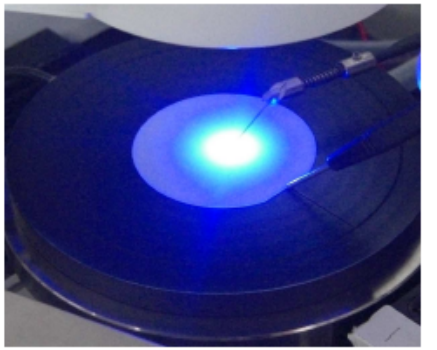
GaN LED wafer

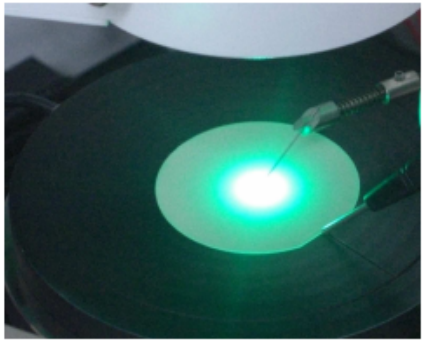
- Epi-wafer Diameter：50.8 mm±0.5mm
- Epi-layer thickness： 4~7 μm
- Total Thickness：430 μm±50 μm

Parameter	Symbol	Test condition	Unit	Characteristics		
				Min.	Typ.	Max.
Dominant wavelength	Wd	EL (If= 20mA)	nm	**440**	**460**	**480**
Luminous Intensity	Iv	EL (If= 20mA)	mcd	20	100	200
Forward Voltage	Vf	If= 20mA	volt	2.9	3.2	3.5
Reverse Current	Ir	Vr= 5V	μA	0.01	0.05	1
ESD yield	ESD%	Machine Model 200V	%	---	>80	---

Parameter	Symbol	Test condition	Unit	Characteristics		
				Min.	Typ.	Max.
Dominant wavelength	Wd	EL (If= 20mA)	nm	**500**	**525**	**550**
Luminous Intensity	Iv	EL (If= 20mA)	mcd	400	500	600
Forward Voltage	Vf	If= 20mA	volt	2.8	3.2	3.6
Reverse Current	Ir	Vr= 5V	μA	0.01	0.05	1
ESD yield	ESD%	Machine Model 200V	%	---	>80	---



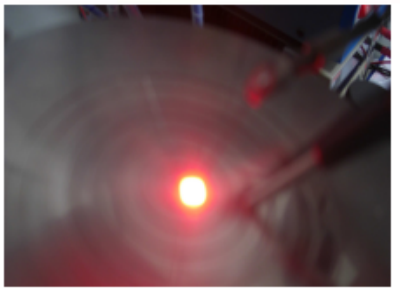




CMLTs LED Wafer Products

• AlGaInP LED wafer

- Epi-wafer Diameter：100.0±0.5 mm
- Epi-layer thickness： 4~20 μm
- Total Thickness：365±30 μm



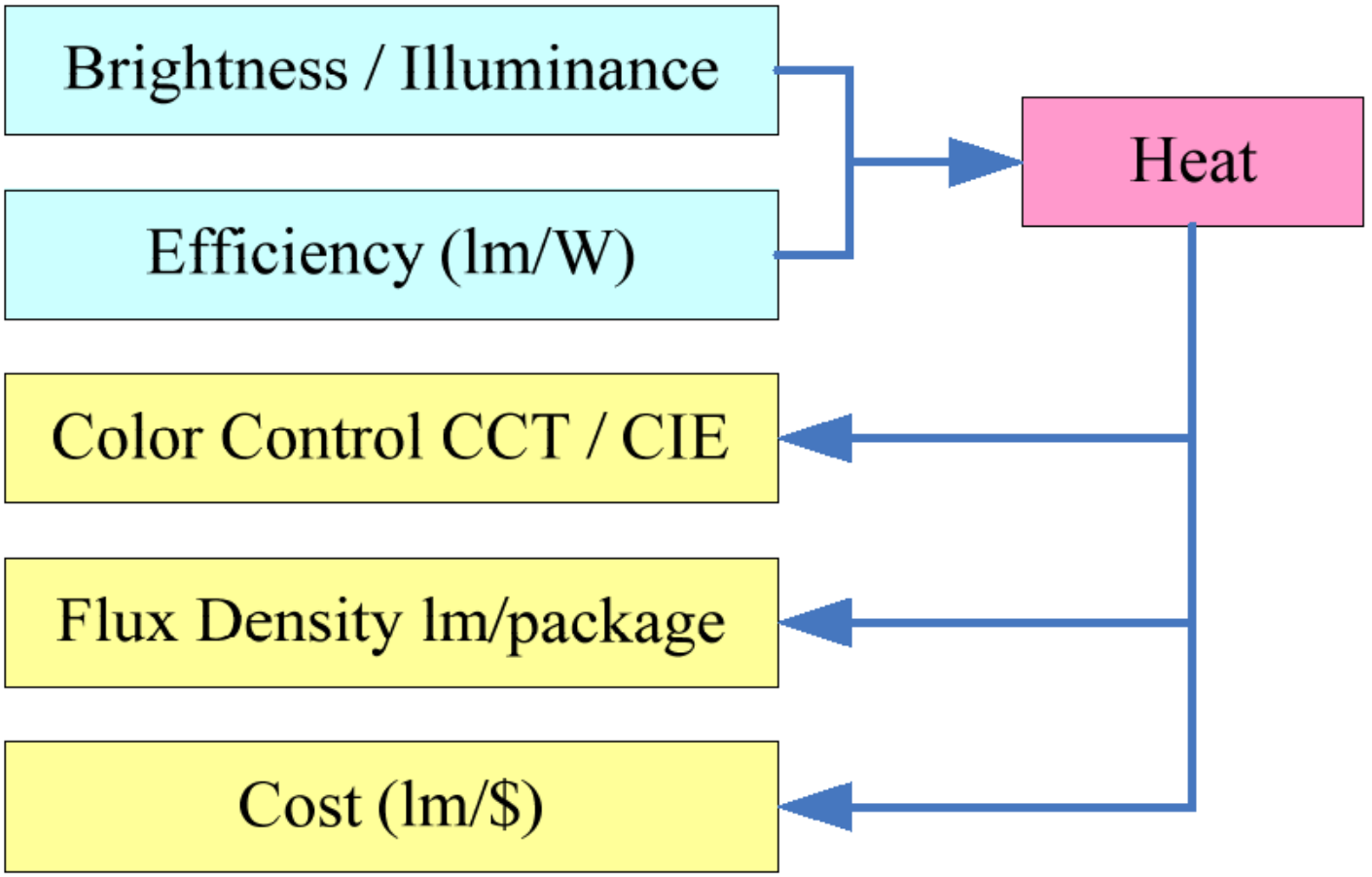
Parameter	Symbol	Test condition	Unit	Characteristics		
				Min.	Typ.	Max.
Dominant wavelength	Wd	EL (If= 20mA)	nm	**560**	**570**	**580**
Luminous Intensity	Iv	EL (If= 20mA)	mcd	10	50	80
Forward Voltage	Vf	If= 20mA	volt	1.8	2.0	2.4
Reliability	LIfe	ΔIAvg＝[(I200 hr－Iinitial)/Iinitial]Avg	%	-25	0	25

Parameter	Symbol	Test condition	Unit	Characteristics		
				Min.	Typ.	Max.
Dominant wavelength	Wd	EL (If= 20mA)	nm	**580**	**590**	**600**
Luminous Intensity	Iv	EL (If= 20mA)	mcd	30	170	200
Forward Voltage	Vf	If= 20mA	volt	1.8	2.0	2.4
Reliability	LIfe	ΔIAvg＝[(I200 hr－Iinitial)/Iinitial]Avg	%	-15	0	15

Trend of LED Technologies

- Epitaxy
  - Patterned Subtrate
  - GaN Substrate
- Chip
  - Surface Roughness
  - Photonics Crystal
  - Laser lift-off
  - Wafer Bonding
- Package
  - High Index Material
  - Hybrid Materials
  - Ceramic Lead FrameModule

Key Issues


Brightness / Illuminance
Efficiency (lm/W)
Heat
Color Control CCT / CIE
Flux Density lm/package
Cost (lm/$)

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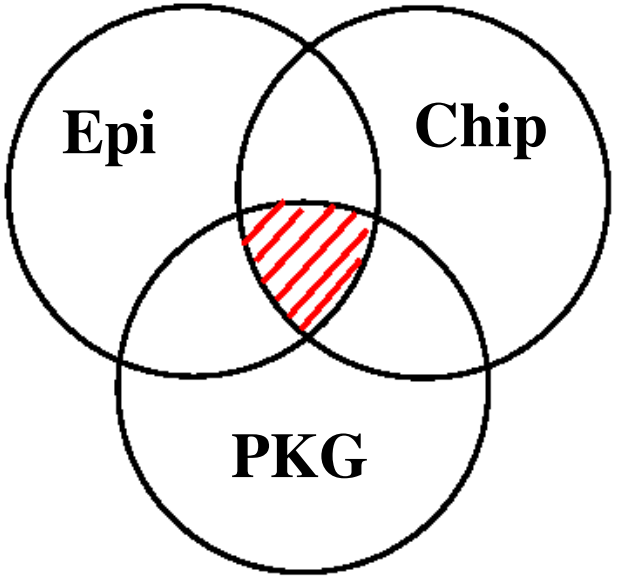
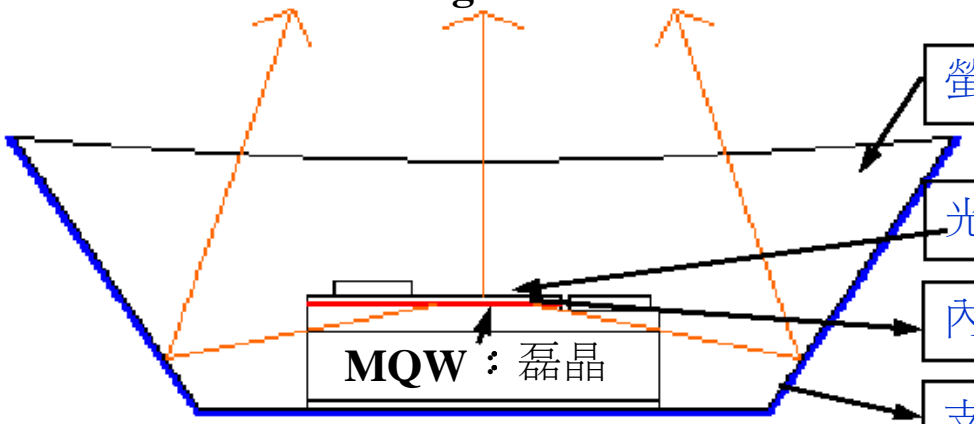
3. Brightness & Life Improvement

Let's Light Up The World

LED RD 效能改善



- 高效能、長壽命之**LED** 需要磊晶、晶粒、封裝 3 段工程完整之連結



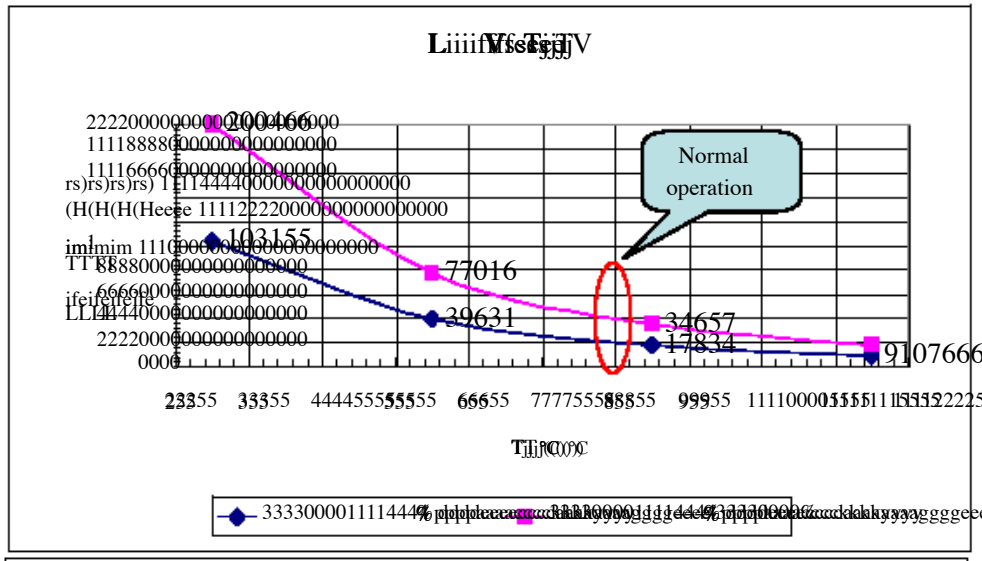
螢光粉&膠材 ：封裝

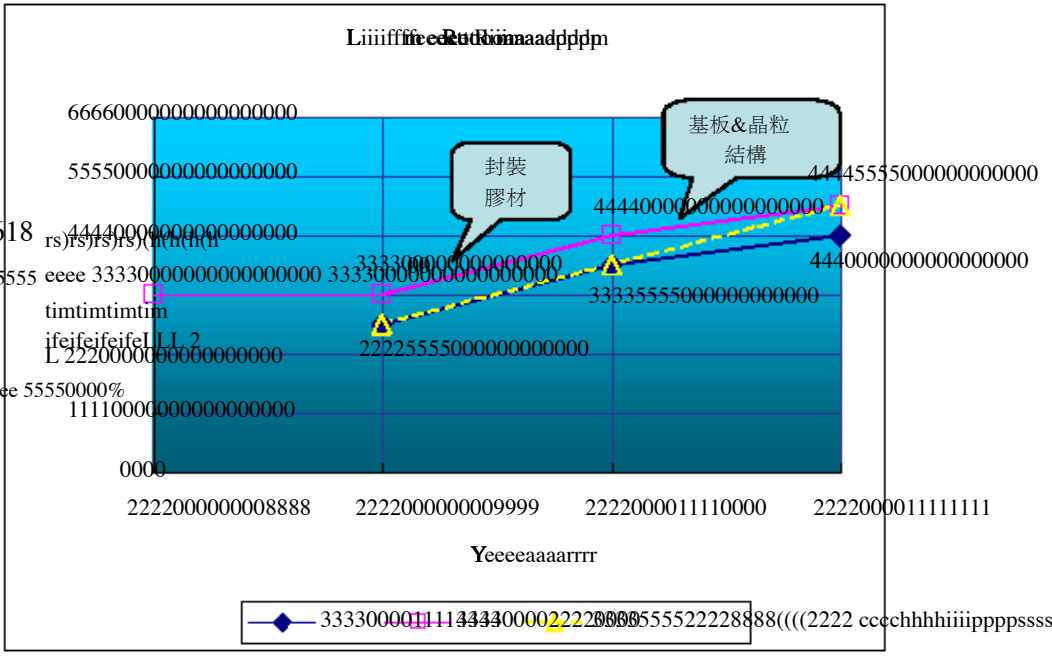
光取出效率 ：磊晶、晶粒表面工程

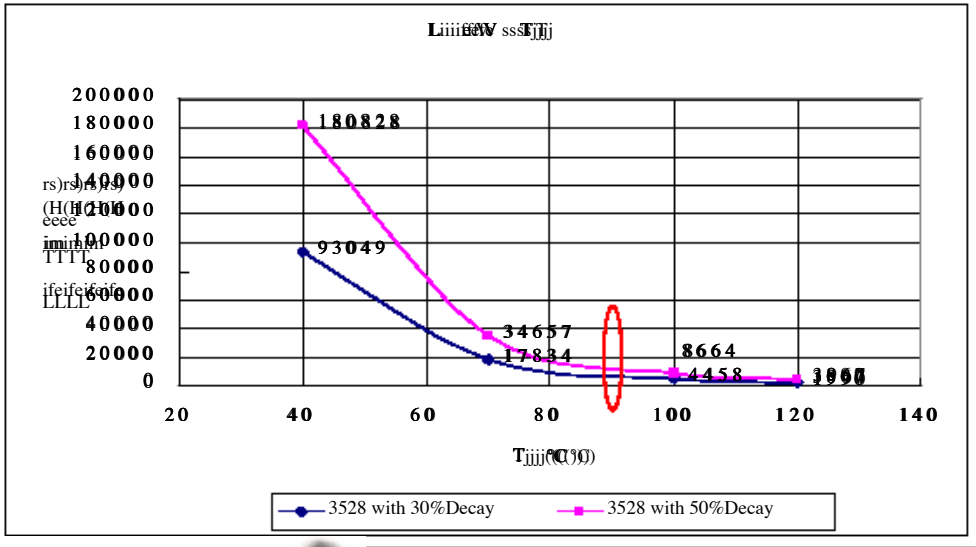
內部量子效率 ：發光層能帶結構設計

支架 ：封裝、機構設計、光學設計

Estimating Life time Roadmap







PS:

1. **Ta=60℃℃ @20mA per chip.**
2. **LED packaged with Yellow phosphor.**

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4. Epitaxy & Chip

Let's Light Up The World

Epitaxy Technologies

- Epitaxy
  - Patterned Subtrate
  - GaN Substrate
  - Si Substrate

1.GaN-LED Epitaxy

Growth temperature: 450(GaN buffer)~11000 °C

Precursors : Ga : TMGa (Ga(CH3)3) or TMAl

Dopant : SiH4, CP2Mg

Purge gas : N_2 + H_2

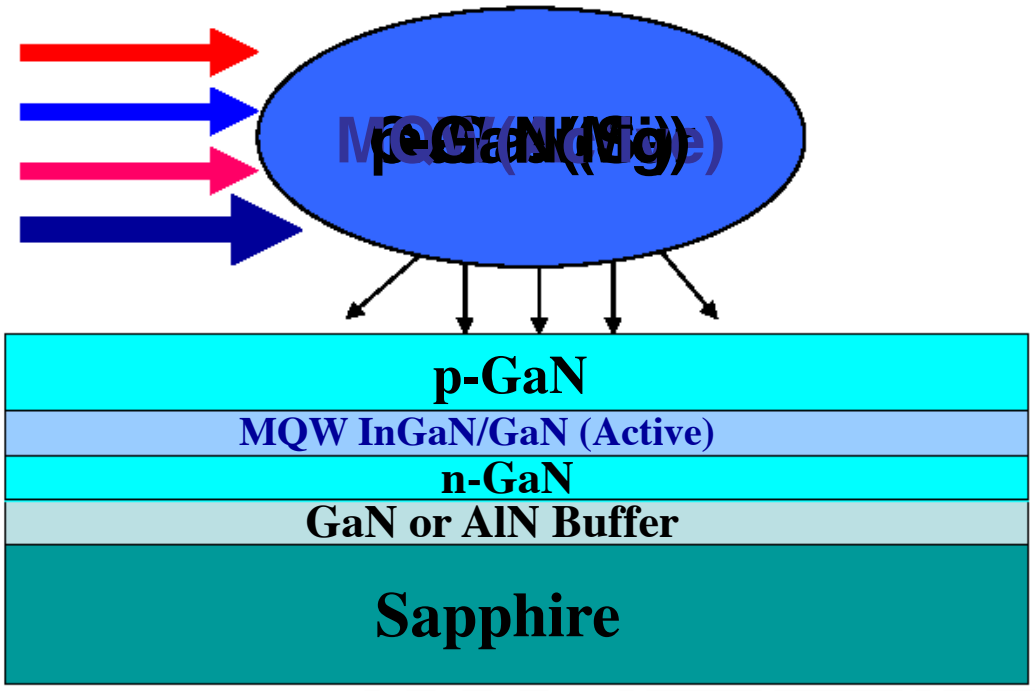
N : NH_3

SiH4 or CP2Mg

TMGa, TMIn or TMAl

N : NH3

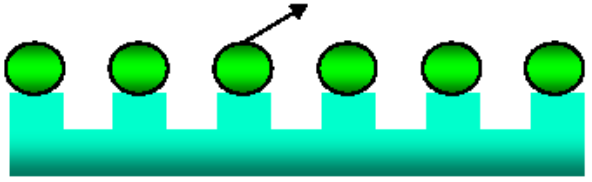
Purge gas : N2 + H2

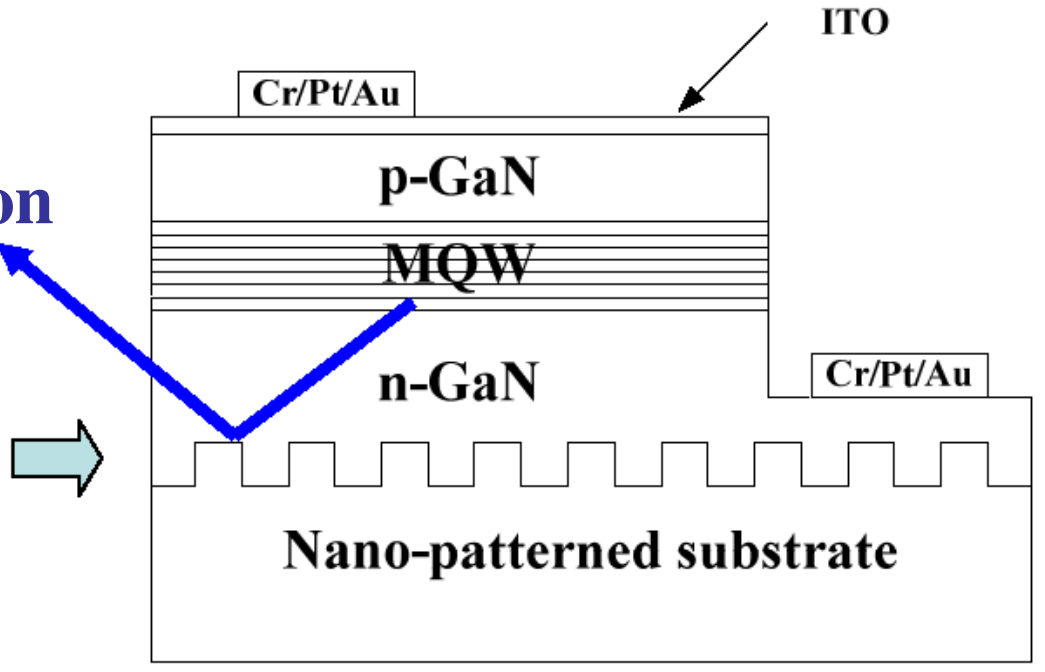


Epi - Patterned Substrate

Enhance Light Extraction

PR or Nano Particle





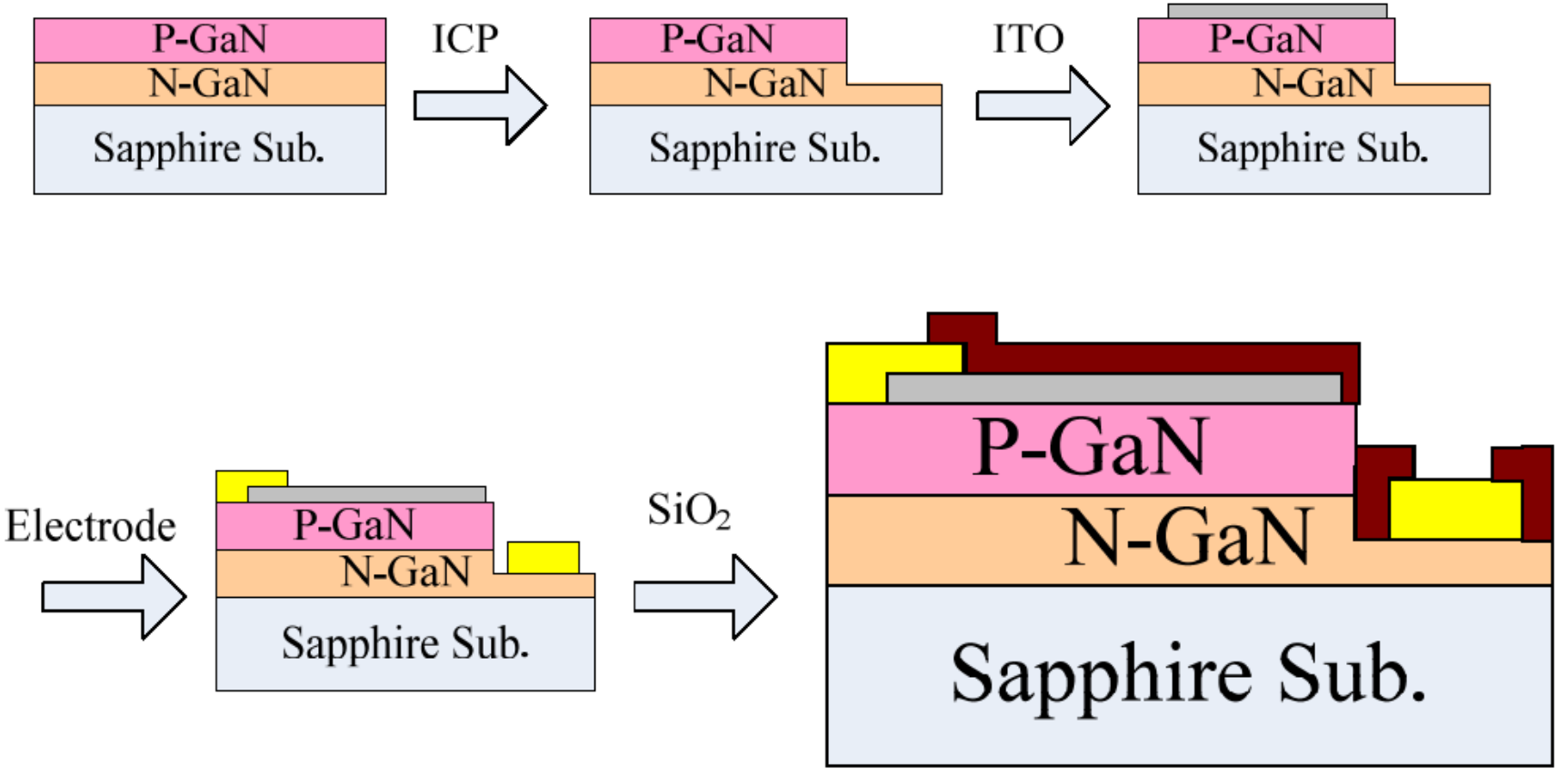
MQW Quality

Chip Technologies

- **Chip**
  - **Current Spreading Layer**
  - **Surface Roughing**
  - **Photonics Crystal**
  - **Laser Lift-off (Thin GaN)**

Chip Manufacture

Example - GaN-based LED



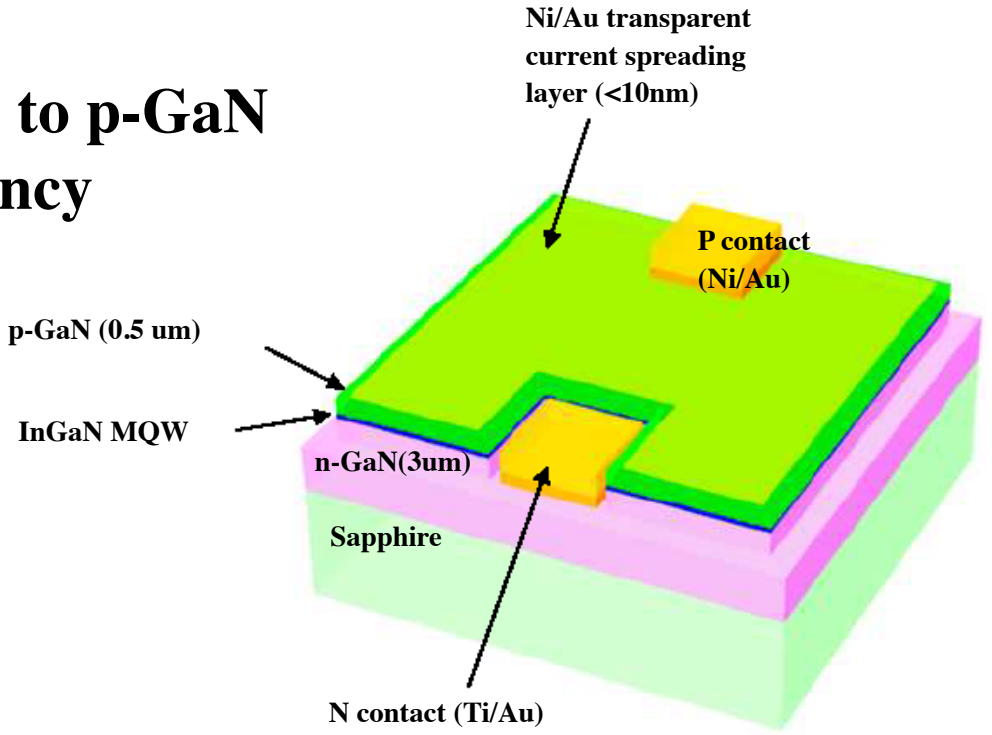
Current Spreading Layer (CSL)

CSL requirements :

1. Low sheet resistance
2. Low contact resistance to p-GaN
3. High optical transparency

Material

1. Ni/Au
2. ITO
3. ZnO

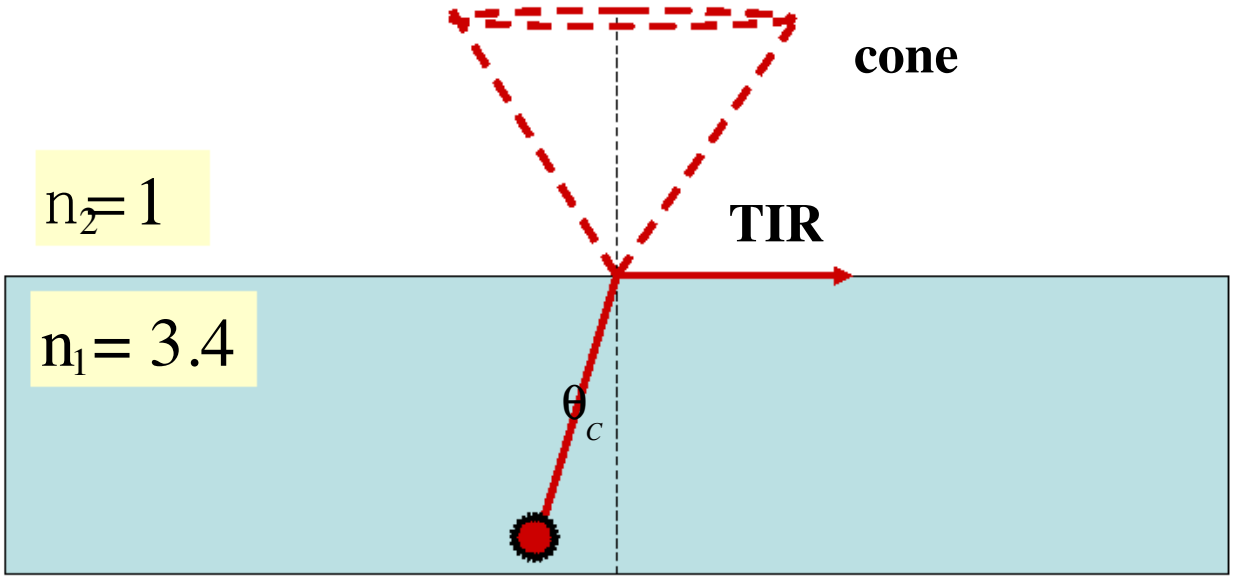


Light Extraction

$n_1 = 3.4$ AlGaInP

$n_2 = 1$ Air

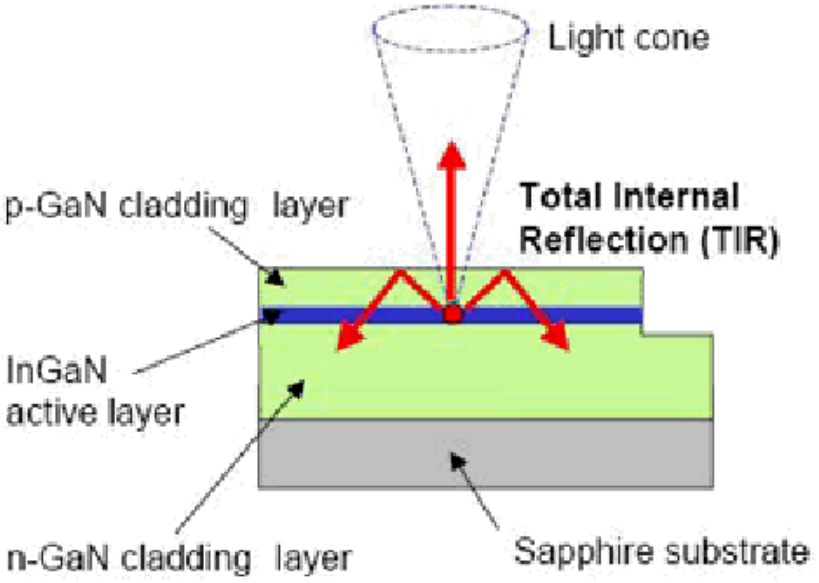
$$\theta_C = \sin^{-1}\left(\frac{n_2}{n_1}\right) \cong 17^{o}$$



Conventional and Photonic Crystal LED

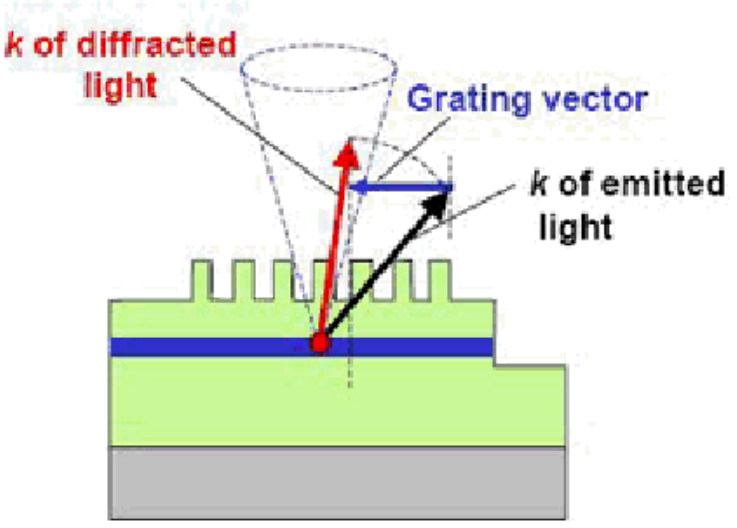
Conventional

Low η_{ex} due to TIR



This work

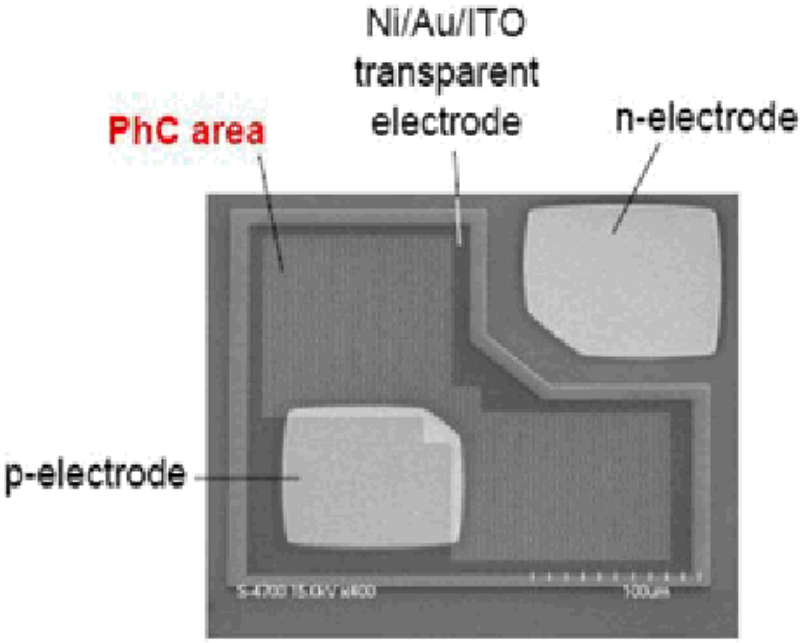
Improvement of η_{ex} by diffraction

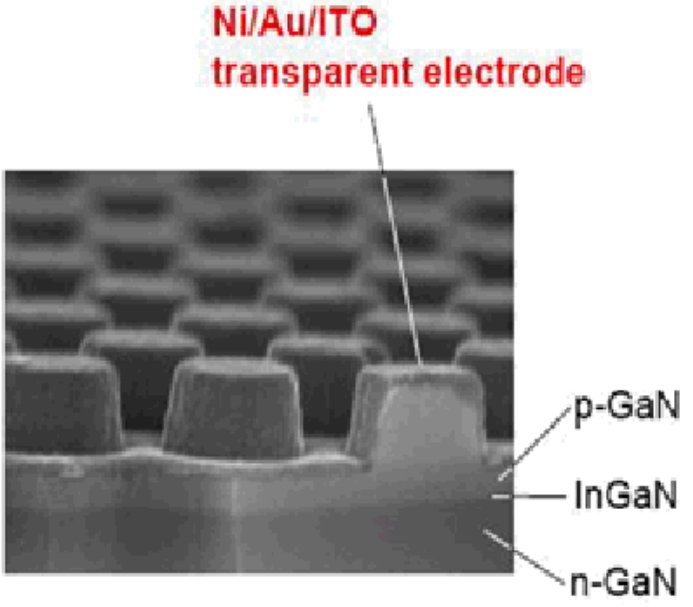


Photonic crystal LED

■Top view of PhC blue LED

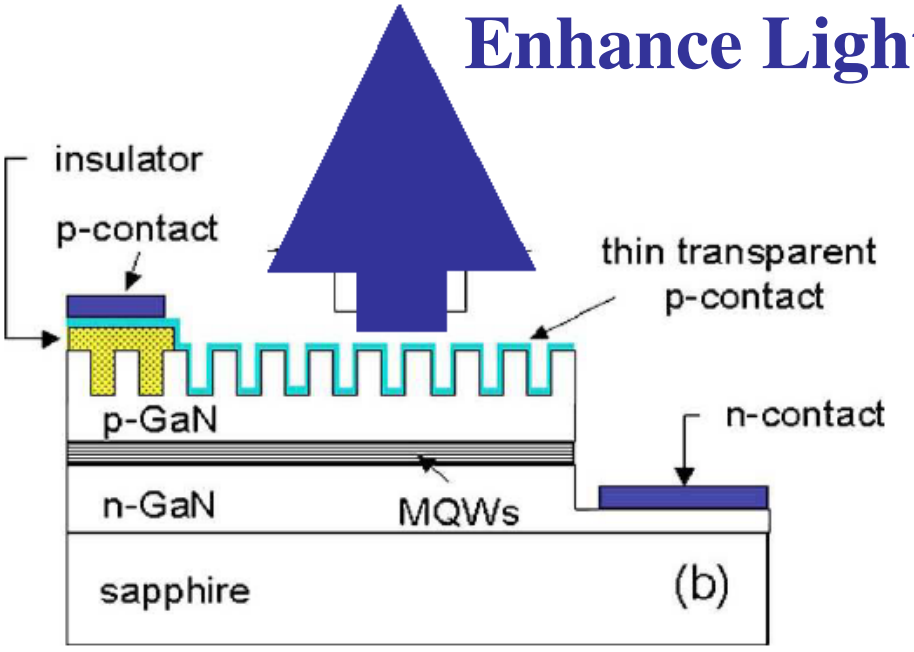
■Cross-sectional view of 2-D PhC



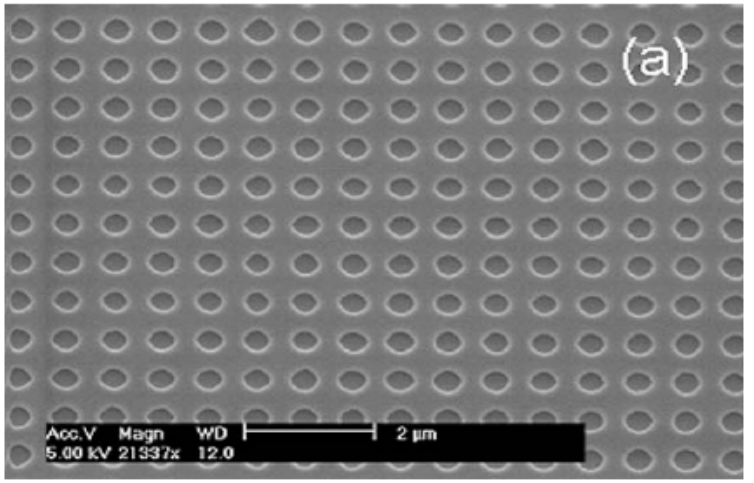


Photonic crystal LED

Enhance Light Extraction



SEM



Applied Physics Letters, vol. 87, 203508, 2005

Thin GaN –Vertical GaN LED ?

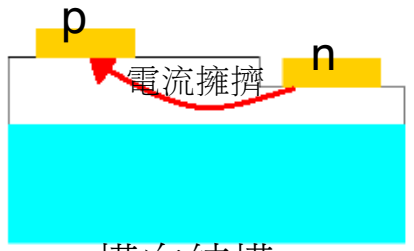
GaN LED使用之sapphire基板由於熱傳導率較差，在高功率使用上易受到限制。

Sapphire基板不導電，橫向結構LED電流傳導較不均勻 。

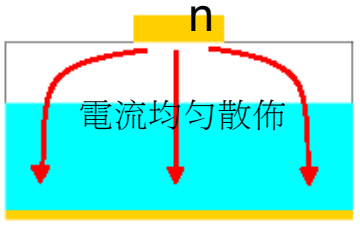
	W / cm · °C
GaN	1.3
InN	0.45
AlN	2.85
SiC	3~3.8
GaAs	0.5
Sapphire	0.35
Diamond	20
Cu	3.93
Al	2.16
Si	1.45
Ag	4.17

移除sapphire基板

垂直結構GaN LED

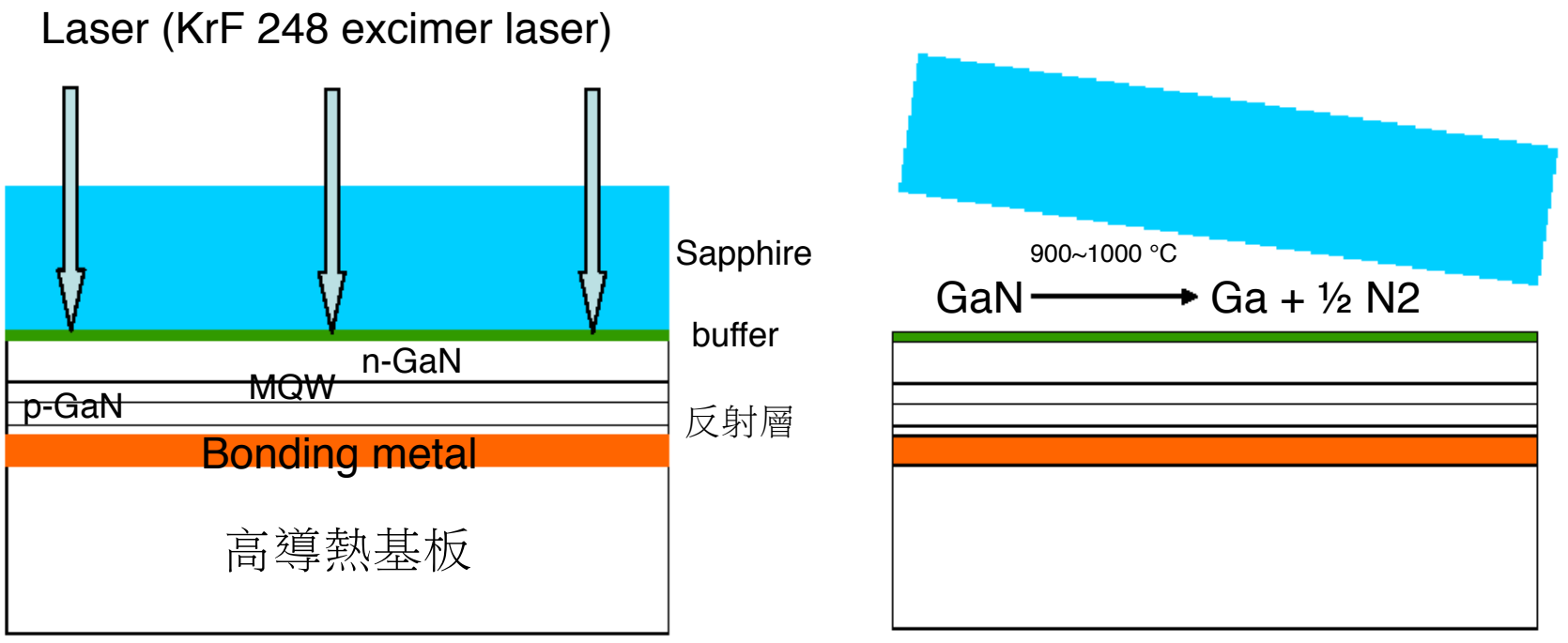


橫向結構



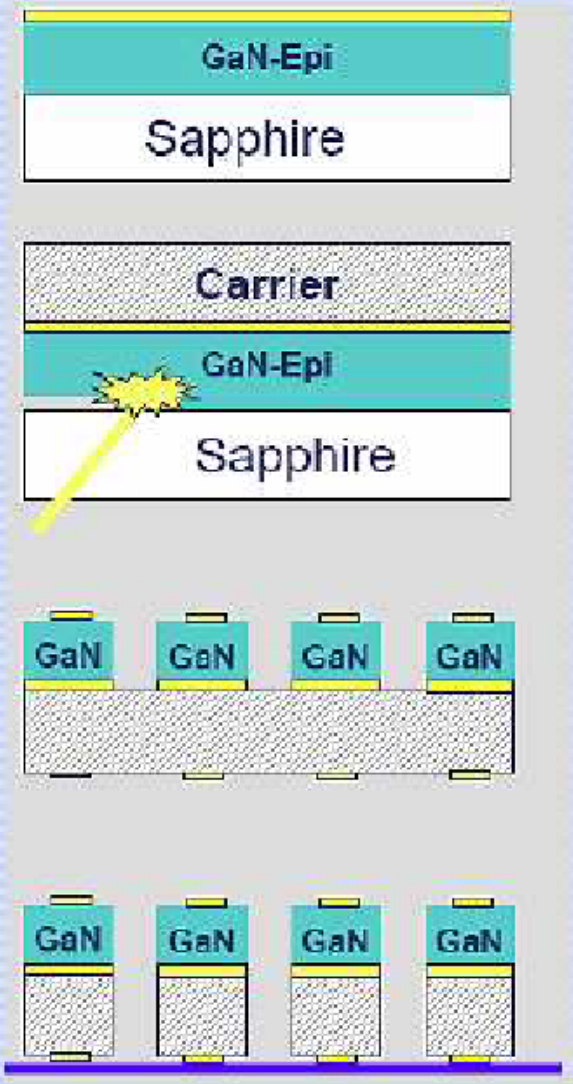
垂直結構

Thin GaN – Laser Lift-off

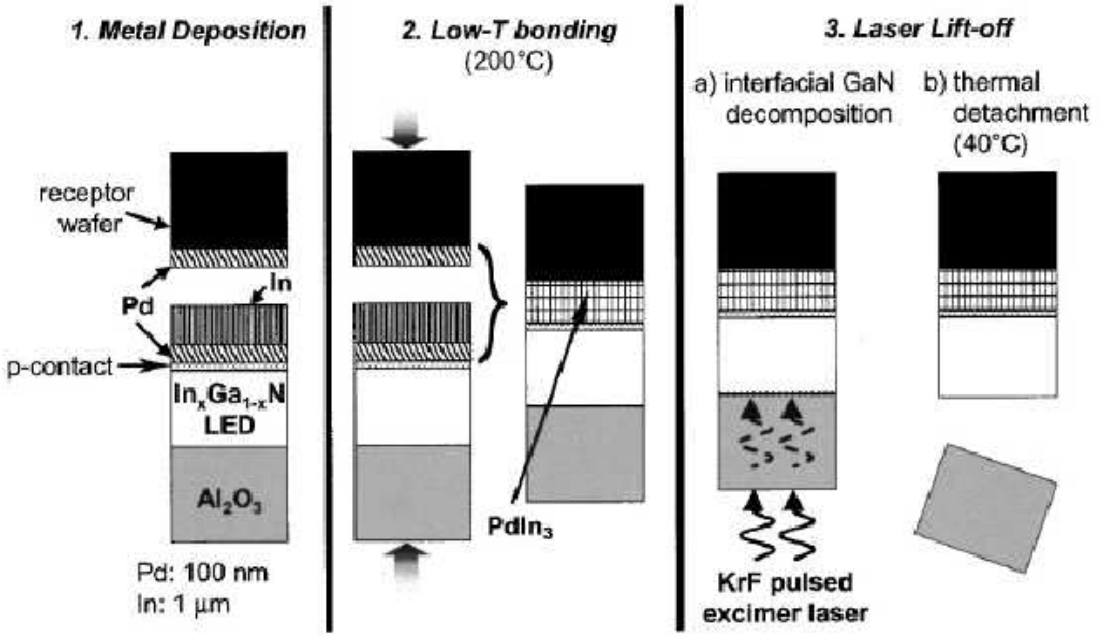


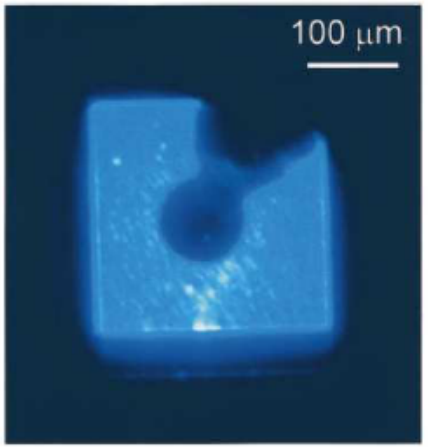
Thin GaN – GaN LED Process

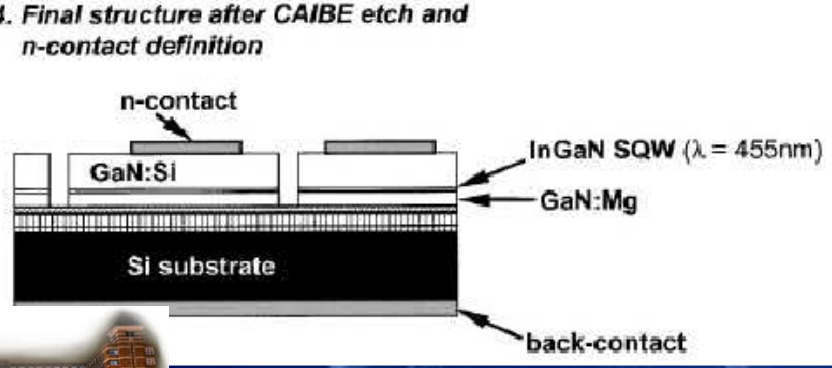
- Epitaxy
- P-mirror metallization
- Bonding on carrier
- LLO of epi
- Contacts
- Chip processing
- Chip dicing



Thin GaN – GaN LED Process

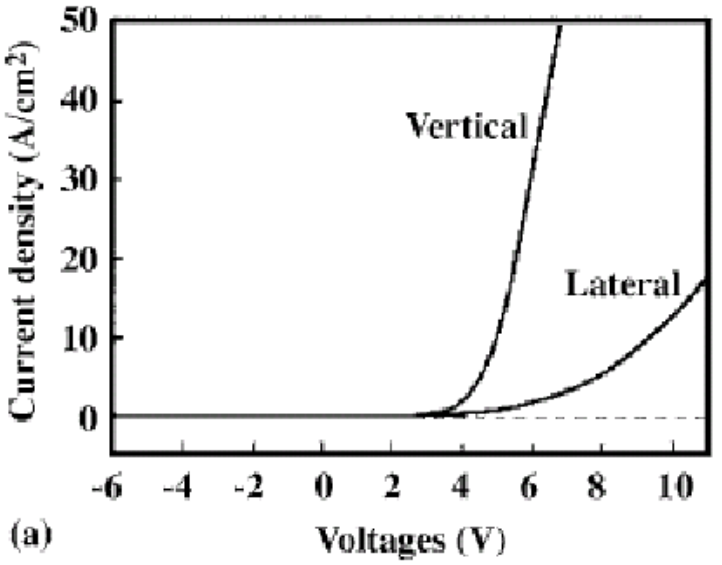


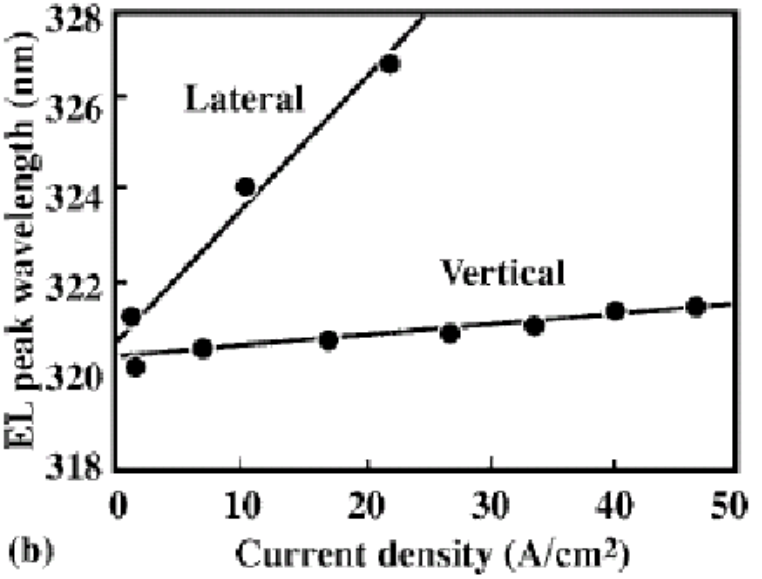




W. S. Wong, APL vol. 77, pp. 2822, 2000

Thin GaN - Performance





1. 較高的操作電流及操作功率
2. 電壓隨電流增加趨勢較緩慢
3. 波長隨電流增加較不明顯

K. Kawasaki, APL vol. 89, 261114, 2006

LED 效能改善方向

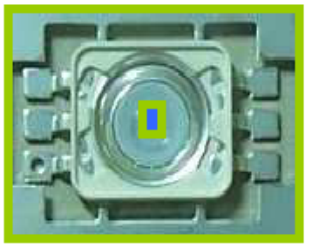
	方法	亮度提升	可靠度改善	靜電防護能力增加
Epi	圖案化磊晶基板最佳化	V		
	MQW磊晶結構調整	V	V	V
	n & p層最佳化	V	V	V
	磊晶表面狀況改善	V		
Chip	表面糙化製程	V		
	光子晶體	V		
	Flip-Chip LED	V	V	V
	thin GaN LED	V	V	
	電鍍銅製程		V	
	電流散佈能力改善		V	V
	雷射切割技術	V		
Package	支架優化	V	V	V
	螢光粉	V	V	
	膠材改善	V	V	
	共金(Eutectic)製程		V	

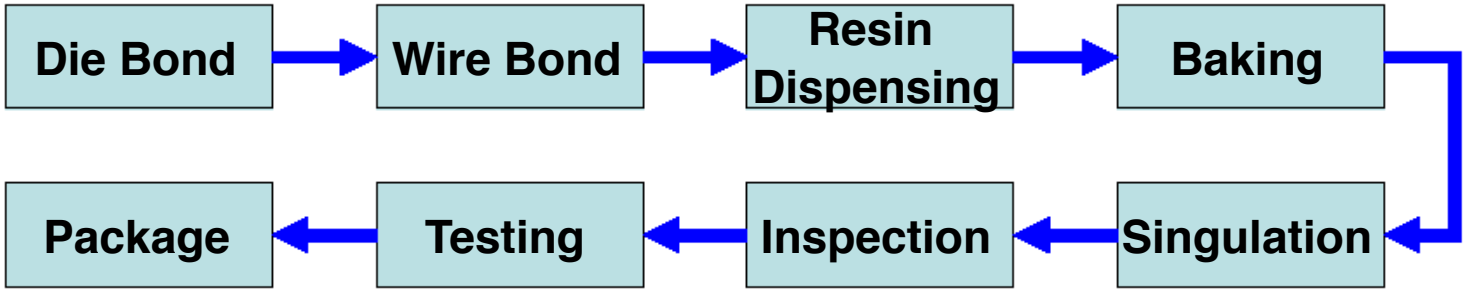
5. Package

Package

- **Package**
  - **High Index Material**
  - **High Thermal Conductivity**
  - **High Stability Materials(Silicone)**
  - **Ceramic Lead Frame**
  - **Si Lead Frame**

LED Package

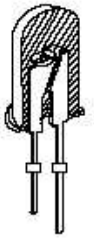



Die Bond
Wire Bond
Resin Dispensing
Baking
Singulation
Inspection
Testing
Package

R_{th} Requirement

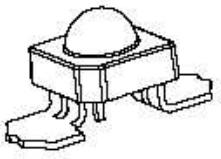
1962

First Indicator LED



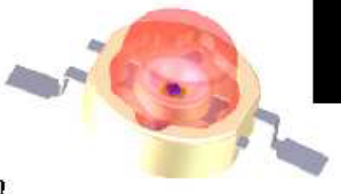
P_{max}~0.1W
Rth=150-200 K/W
1970

Indicator LED



P_{max}~0.2-0.4W
Rth=50 K/W
1994

Indicator LED II



P_{max}~0.6-5.0W
Rth=8-15 K/W
1998

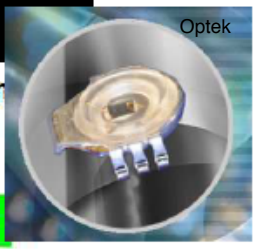
Illuminator LED

P_{max} ~3.7W
R_{th}=8K/W

???

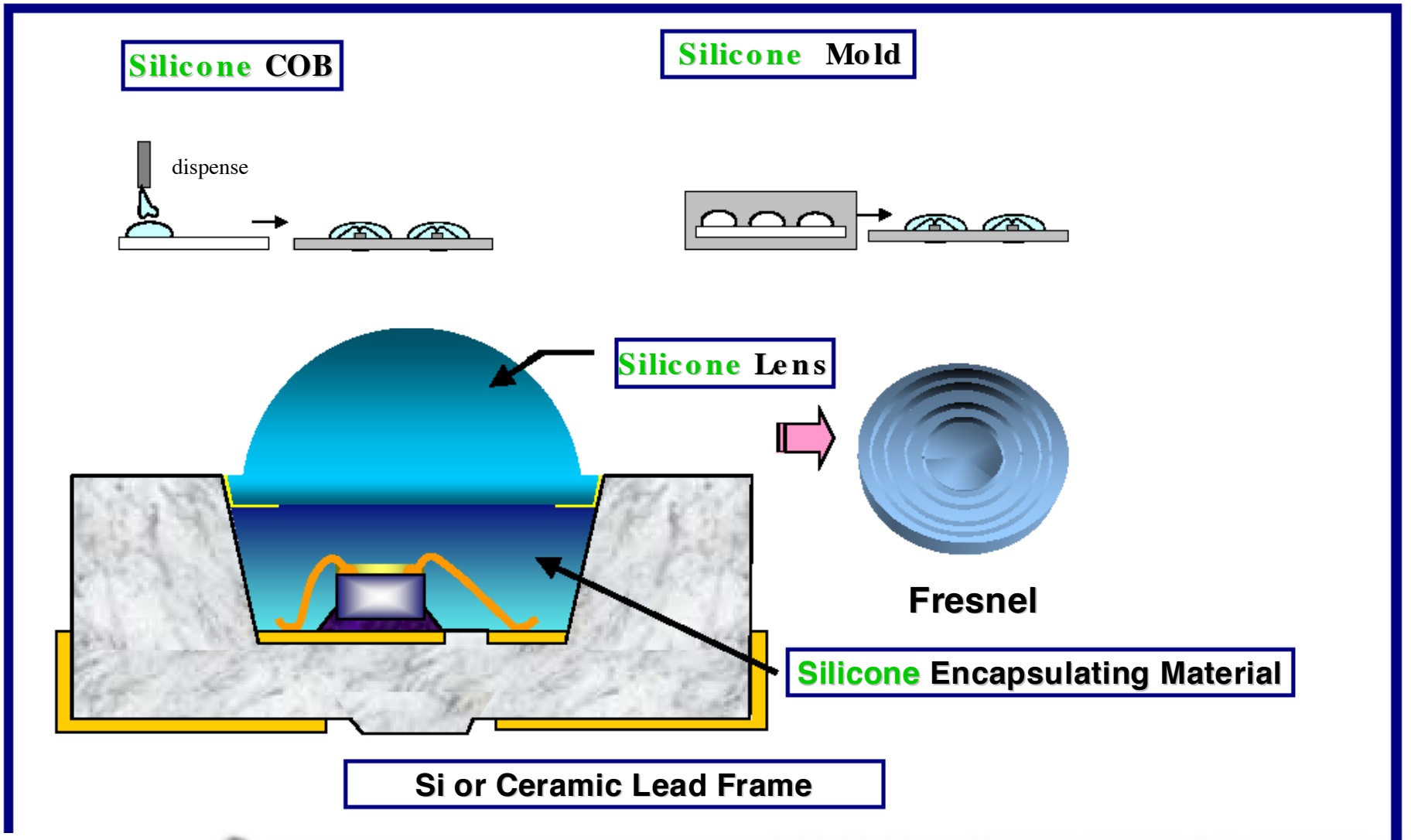
$P_{density}$>4W/mr
Rth<5 K/W

Projector LED



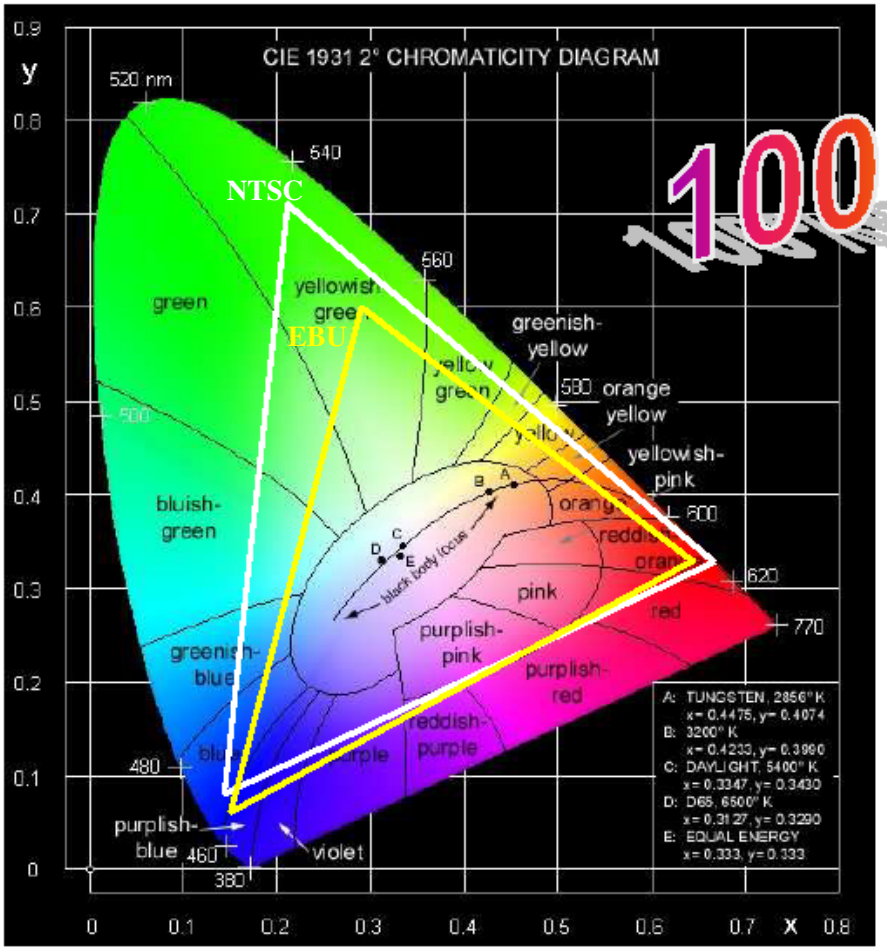
P_{max} ~1.2W
R_{th}=2K/W

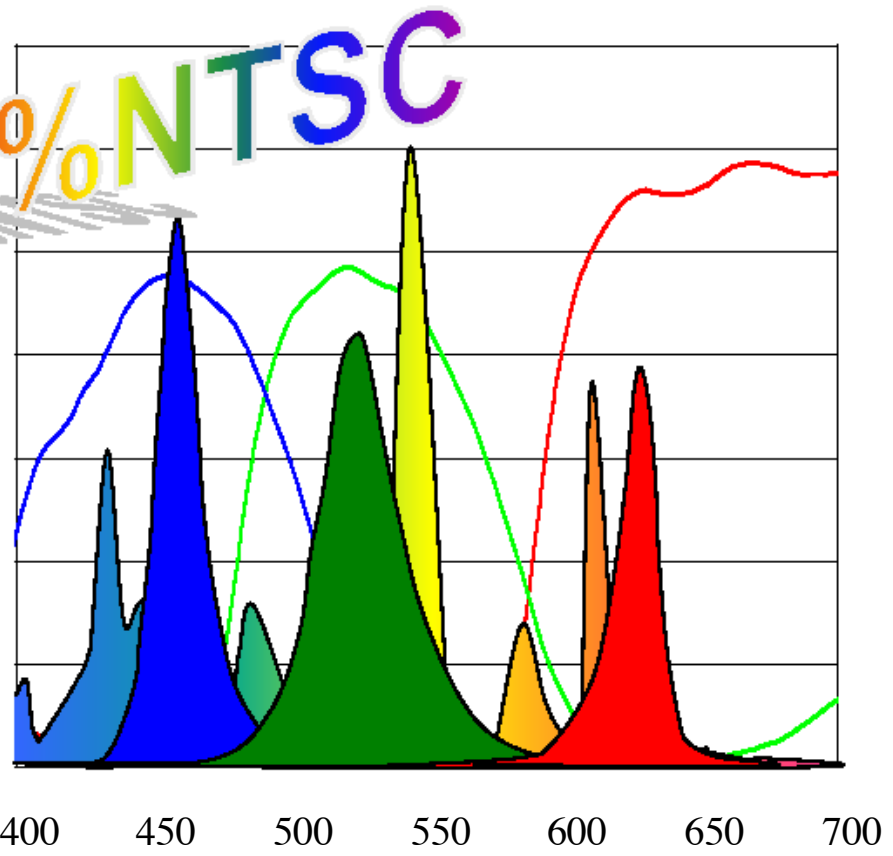
Silicone for LED Application



6.LCD – LED BLU

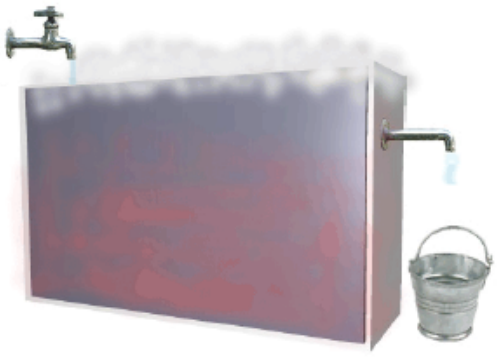
LED Backlight





LED BLU Revolution

2003 → 2004 → 2009

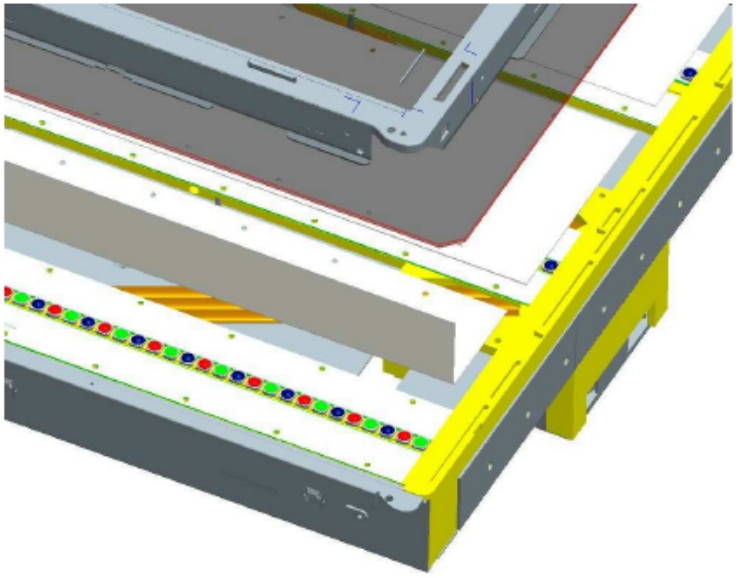


100mm

16mm

2003	2004	2009
20”, 500W, water cooling	32”, 320W, 100mm heat sink / fans	32”, 96W, 16mm no heat sink / no fans

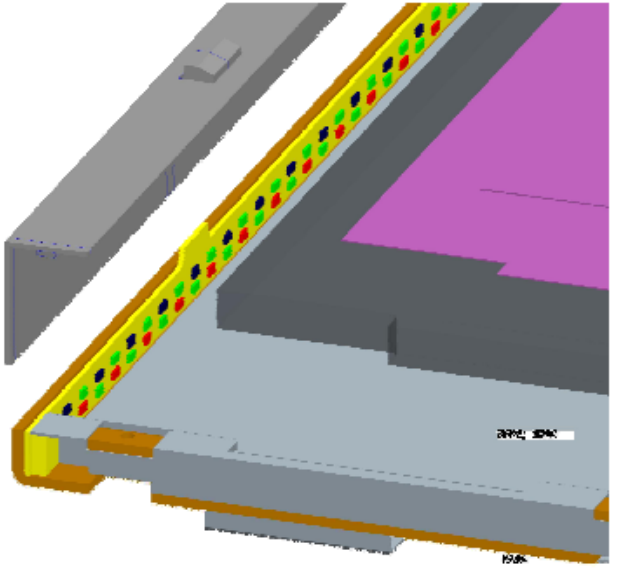
Direct Type and Edge Type



Direct type LED BLU

優點：散熱佳

缺點：厚度厚



Edge type LED BLU

優點：厚度薄

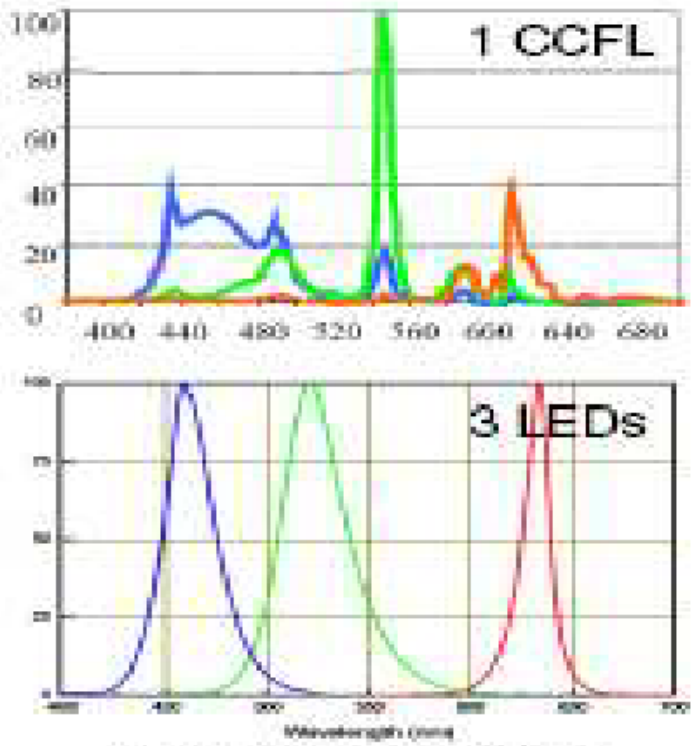
缺點：散熱差

CCFL vs LED

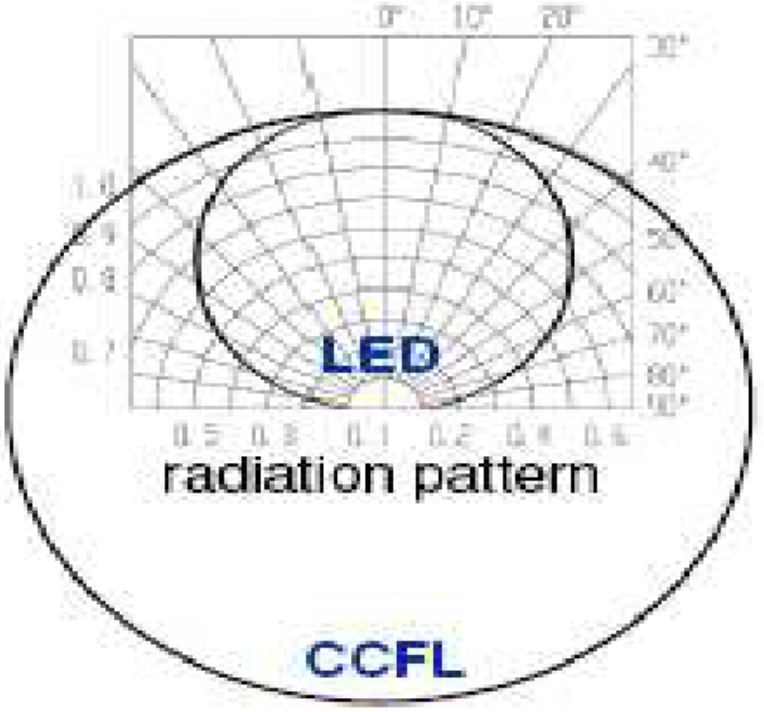
Fluorescent Lamp vs. LED

CCFL

LED



radiation spectrum

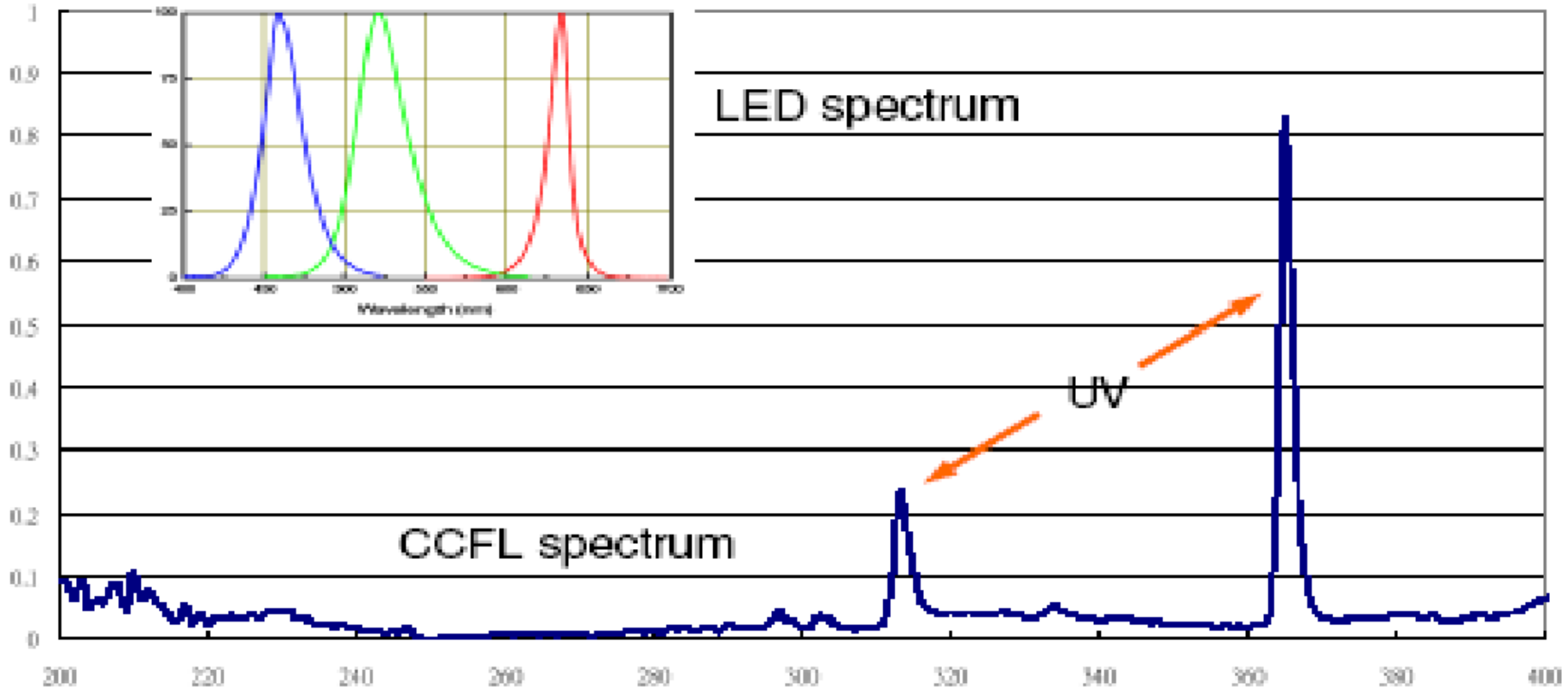


radiation pattern

Spectrum – CCFL vs LED

UV Avoidance

Anti-UV solutions ⟹ **Cost !!**



競爭廠商優劣與應用分析

廠商	Epitaxy	Chip	應用	量產品質	優勢	劣勢
Nichia	GaN/PSS	水平結構	NB背光 TV背光	2500mcd (130 lm/w)	lm/w高	大芯晶 lm/w 小芯晶 Cost
TG	GaN/PSS	水平結構	NB背光 TV背光	2300mcd (120 lm/w)	lm/w高	大芯晶 lm/w 小芯晶 Cost
Cree	GaN/Sic	垂直結構	照明	大芯晶 110 lm/w 小芯晶 2100mcd	大芯片 lm/w高	小芯晶 Cost 小芯晶 lm/w
晶電	GaN/Al_2O_3	水平結構	NB背光 TV背光	2200mcd (115 lm/w)	lm/w高	IP 大芯晶 lm/w
奇力	GaN/PSS	水平結構	NB背光 TV背光	2200mcd (115 lm/w)	lm/w高	IP 大芯晶 lm/w

Conclusion

- LED 磊晶為核心技術
- LED 技術朝更高lm/W 、更長壽命之方向
- LED 技術朝更高功率方向
- LED 提供LCD 技術改善如為色彩品質、訊號處理….
- LED 提供更薄、更省電、更佳色彩品質之LCD BLU

Thank You