



色转换 Micro LED 显示技术

Color Conversion Technology for MicroLED Application

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20190625

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Who we are??



國立交通大學



香港科技大學



Introduction

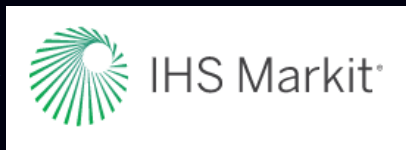
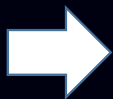
Chin Wei Sher. (Steven Sher) 佘庆威



师承 郭浩中 教授
Professor Hao Chung Kuo



LED Light Source
Manufacture
Manager



LED Backlight and Display
Marketing
Principle Analyst



LED Display System
R&D
Director



MicroLED
Color Conversion Technology
R&D
CTO



Outline

- Why need LED Display
- MicroLED Display Challenge and Future
- Quantum Dots in Micro LED application
- Full color MicroLED - Monolithic MicroLED array + Quantum Dots
- Novel micro scale LED for full color micro display



Why need LED Display

Pure colors

Fast response

High brightness

Great contrast/wide view angle

Real life images, suitable for augmented and virtual reality (AR/VR)

Flexible

Lower Power Consumption

Super expensive ???



Where is the display?

Sony small-pitch large video display
(InfoComm 2016)

- 403 x 453 mm modules of 320 x 360 x RGB resolution
- 1.26 mm pitch.
- 1,000 Cd/m² brightness

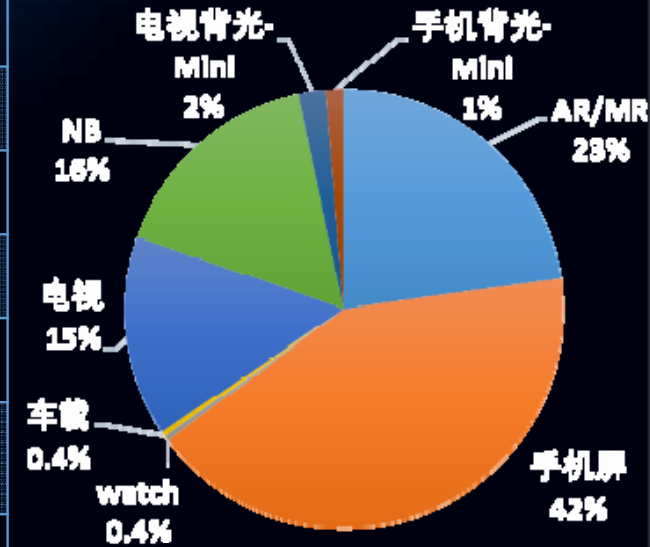
Subpixel size
~30 x 30 μm

Sony CLEDIS (Micro-LED Video Wall)



LED Display Pixel Pitch and Application

应用产品	分辨率 (PPI)	像素 (μm)	子像素长 (μm)	子像素宽 (μm)	预估市场规模 万个/月	预估产值 亿元/年
AR/MR	4000	10*10	9	3	1667	1000
手机屏	500	50*50	10	10	1667	600
watch	333	75*75	25	10	200	24
车载	150	500*200	100	50	21	25
电视	70	800*600	225	125	183	220
NB	150	500*200	100	50	433	260
电视背光-Mini	--	--	225	125	92	44
手机背光-Mini	--	--	50	25	583	21
总计						2194





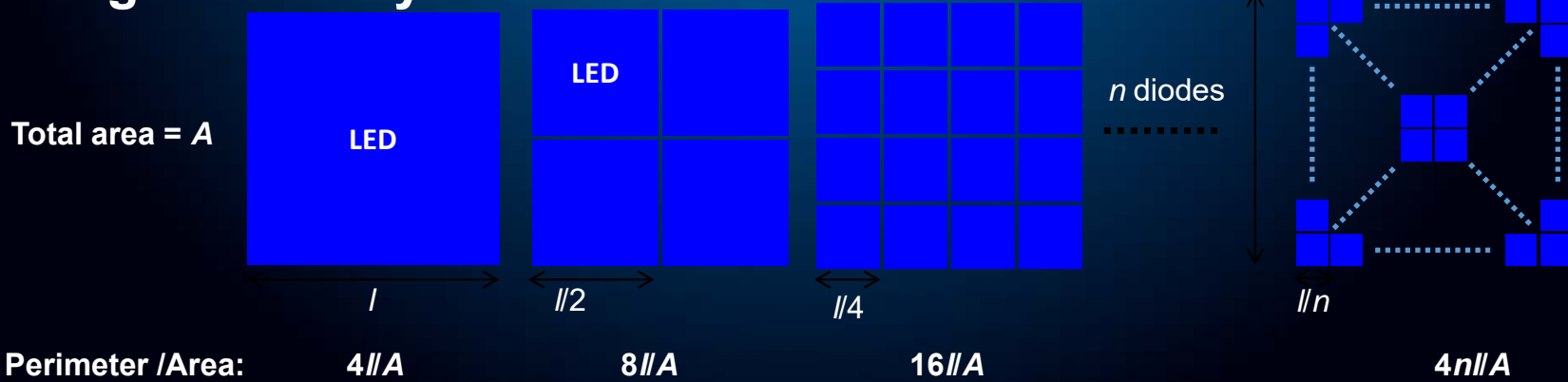
MicroLED Display Industry Status

主要参与企业、研究机构		最近发展
日本	SONY	于2012年公布 (CRYSTAL LED DISPLAY) , 成为Micro-LED产业的试金石 在2016年提出 (CLEDIS) 产品
	Lux View /Apple	Apple在2014年并购Lux View公司
	X-Celeprint	以LED晶片的转移为重点, 以大尺寸Micro-LED的生产技术为导向
欧美	德州技术大学	Micro-LED发明者江红星教授巡讲各地研讨会介绍Micro-LED
	CEA Leti	通过氮化镓LED display与驱动IC的晶圆结合方式, 制作10微米以下的HMO装置
	OSTENDO	针对AR/VR应用, 开发垂直并结构发光单元构造的Micro-LED显示器
	GLO	开发砷化镓纳米线Micro-LED, Google有投资, 计划针对AR glass应用
	其他欧美创投公司	例如Lumiode、Vue Real、mLED、InfiniLED (Oculus收购)。
韩国	Samsung	电影院采用400寸超高4K LED电影荧幕
	LG	2017年10月在韩国电子展中, 展示像素间距为1.5mm的LED显示器
	LUMENS	2017年10月在「IMID Business Forum」, 受邀发表Micro-LED演讲并展示了应用于Pico projector与车用HUD的范例
	韩国光电技术协会	2017年6月在「LED Korea」展览中, 展示Micro LED晶圆与晶片
	韩国机械与材料协会(KIMM)	2017年6月在「LED Korea」展览中, 发表利用ROLL TO ROLL的Micro-LED制程
	首尔国立大学	在SID发表有关在延伸性基板上封装LED的技术
	工业技术研究院 (ITRI)	2016年底成立“巨量微组装产业互动联盟” 开发像素间距小于10微米的Micro Display System
大中华区	鏢创	以在中小尺寸范围内实现直接显示与透明MicroLED
	Mikro Mesa Technology	目标是开发55寸RGB Mini LED电视
	三安光电	从像素间距1mm规格的mini LED慢慢进行微型化, 考虑用现有技术的扩展来完成0.2mm规格
	隆达电子	主要聚焦于车用电子应用进行开发
	夏普/群创 (鸿海)	与美国eLux合作, 进行Micro LED开发
	香港科大 刘纪美团队	最早研发 Micro LED 技术的团队之一
南方科大 刘召军团队	利用硅基板来驱动Micro LED, 与GLO合作, 提供Micro LED 整体方案	
交通大学 郭浩中团队	为了发展Micro LED 的RGB三原色, 利用气溶胶喷涂印刷量子点开发成形技术	



Micro LED Display Problem

• Light intensity



Device scale \downarrow » Total perimeter/Area \uparrow » surface defects \uparrow »

➤ Solution: Annealing, Acid treatment, **Passivation**

{ Reliability & Output emitting \downarrow
Leakage current \uparrow

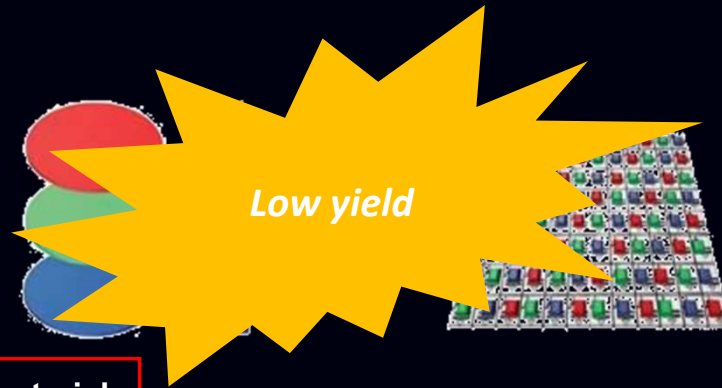
• Color

➤ Challenge:

- ① Mass-transfer technology → Pick & Place
- ② Different operating conditions of RGB LEDs
- ③ Different materials and structure of RGB LEDs

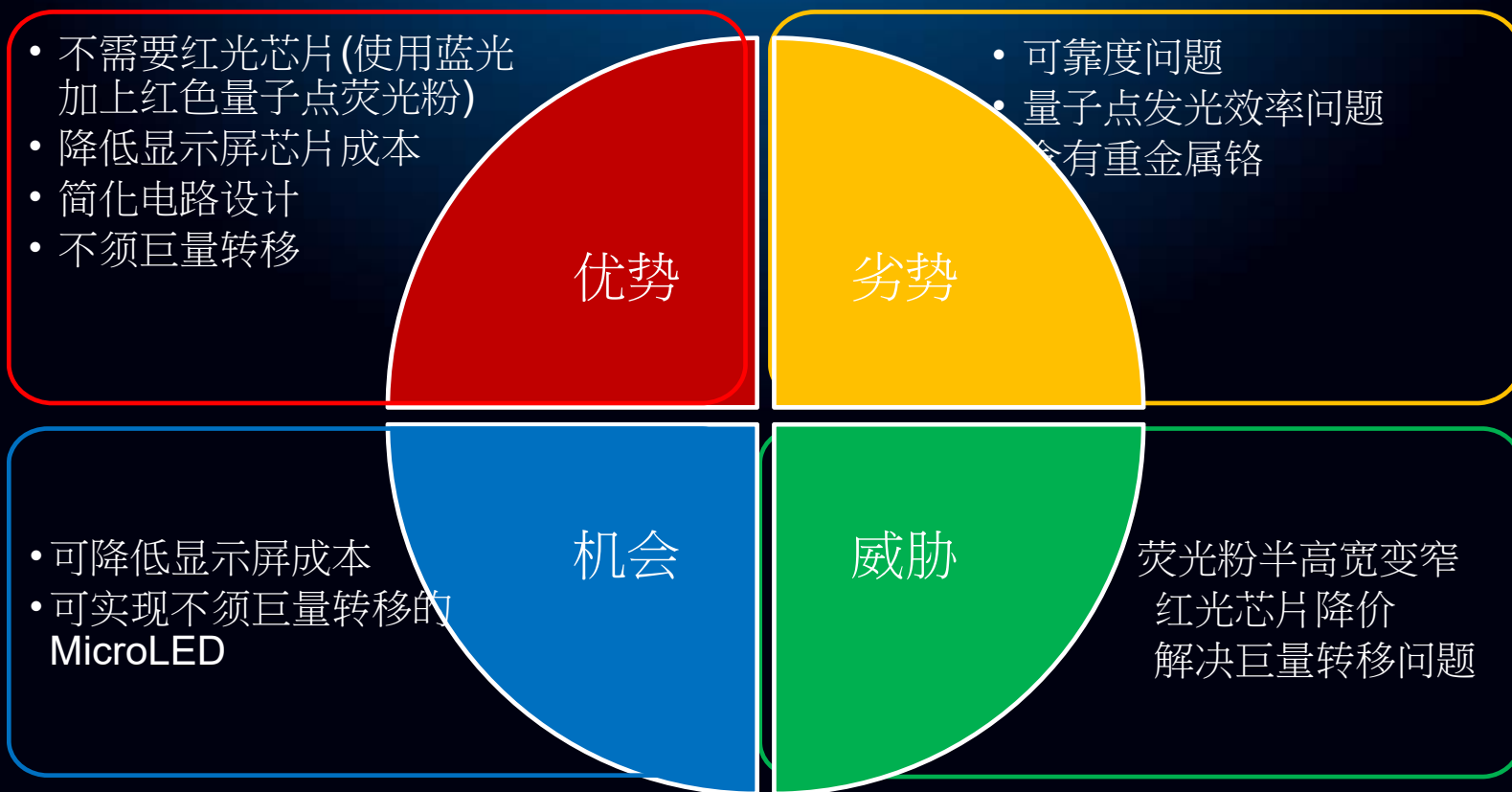
→ **Difficult circuit design**

➤ Solution: Monolithic LED pumping **Quantum Dots materials**



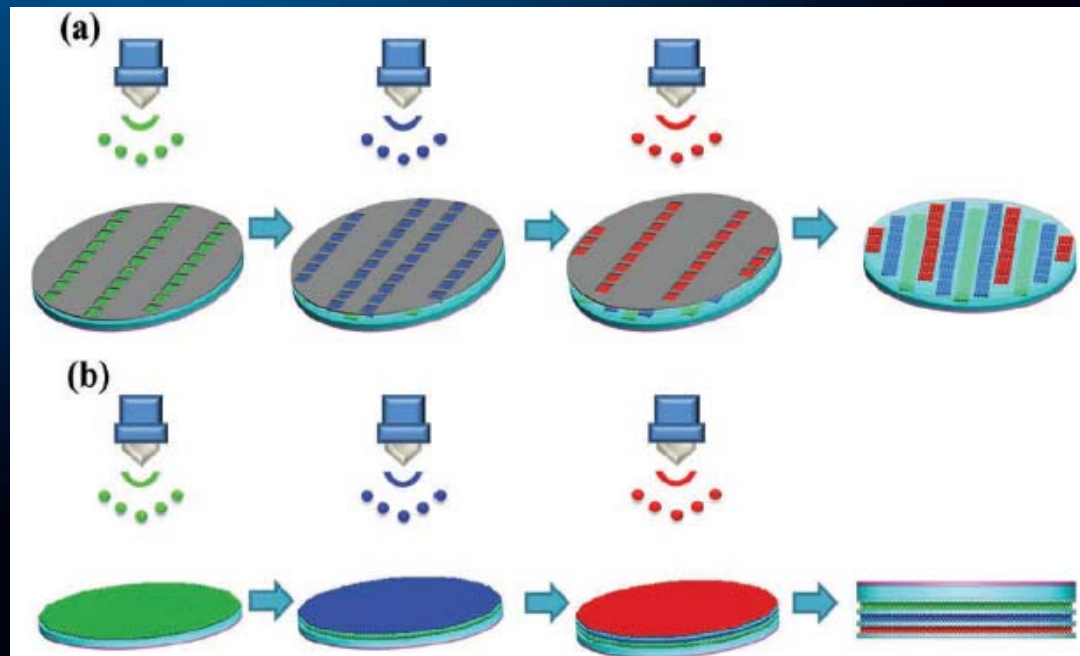
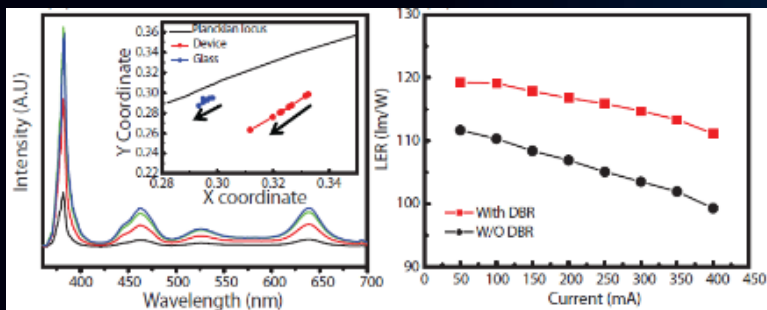
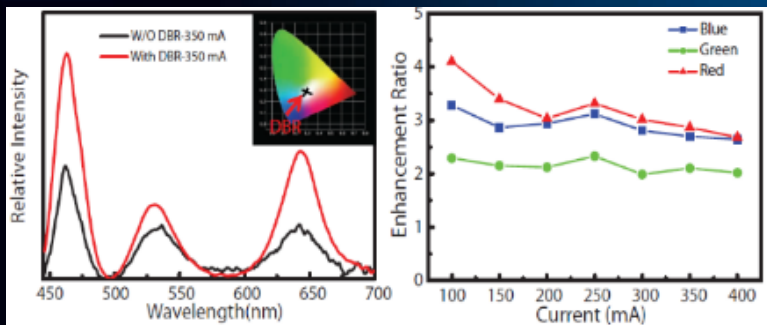


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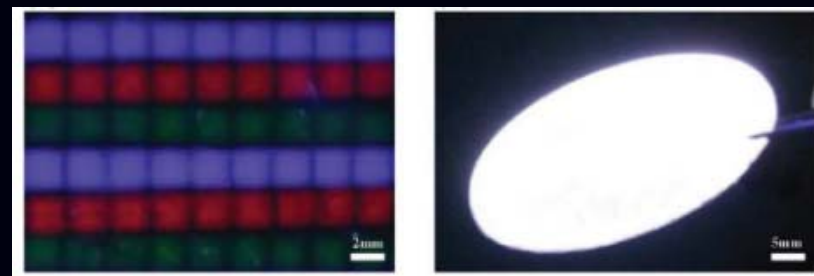
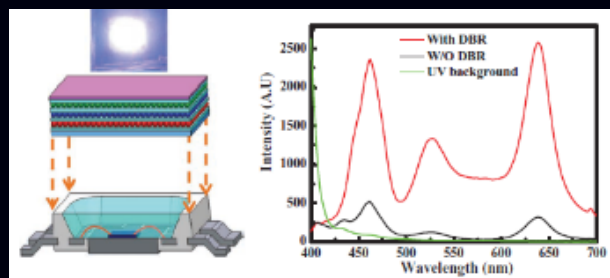


We Start in 2012 with Pulsed Spray Method



Resonant-Enhanced Full-Color Emission of Quantum-Dot-Based Display Technology Using a Pulsed Spray Method

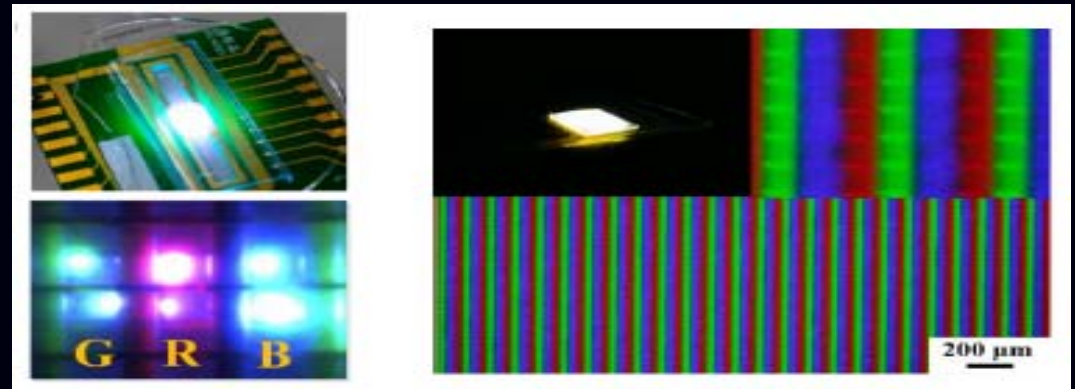
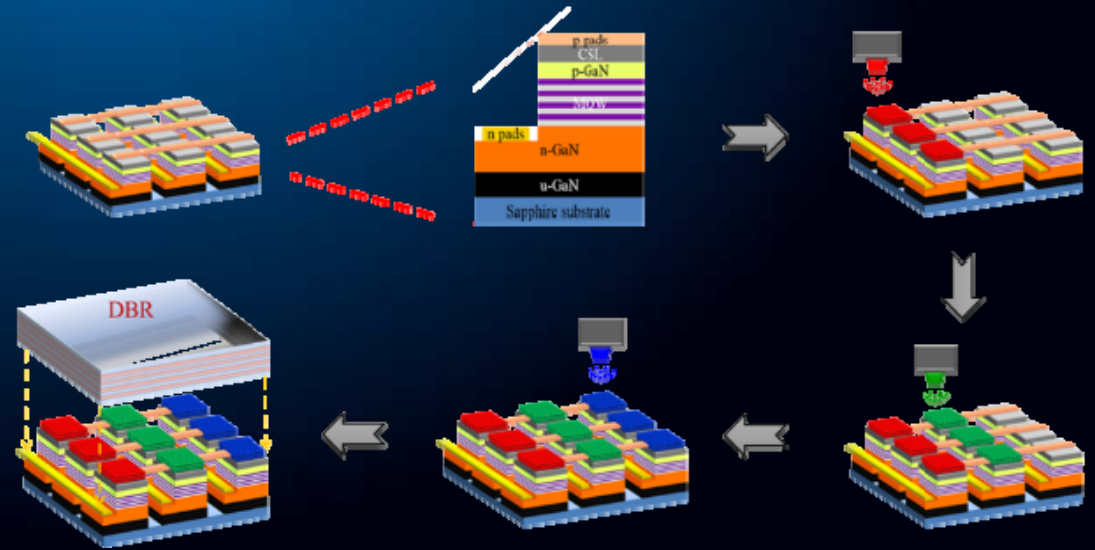
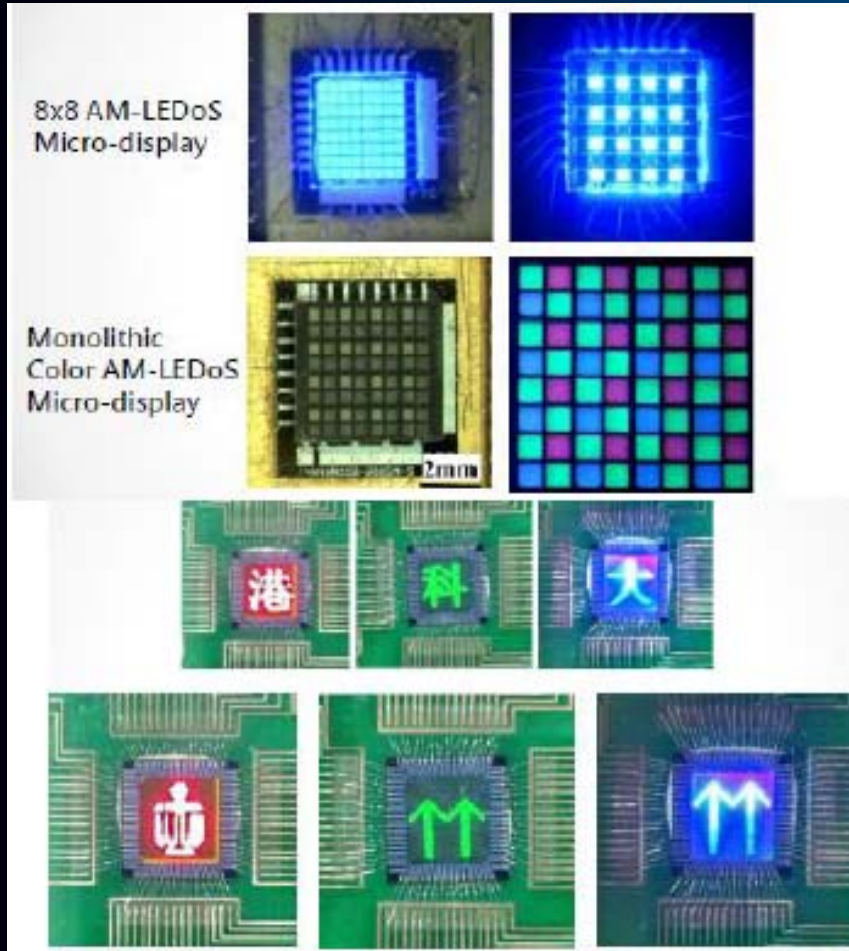
Adv. Funct. Mater. 2012, 22, 5138–5143



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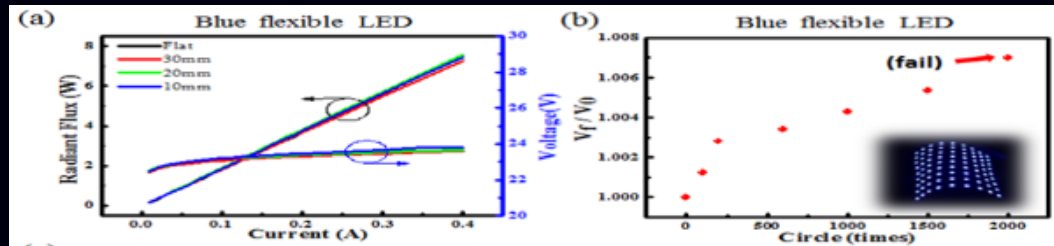
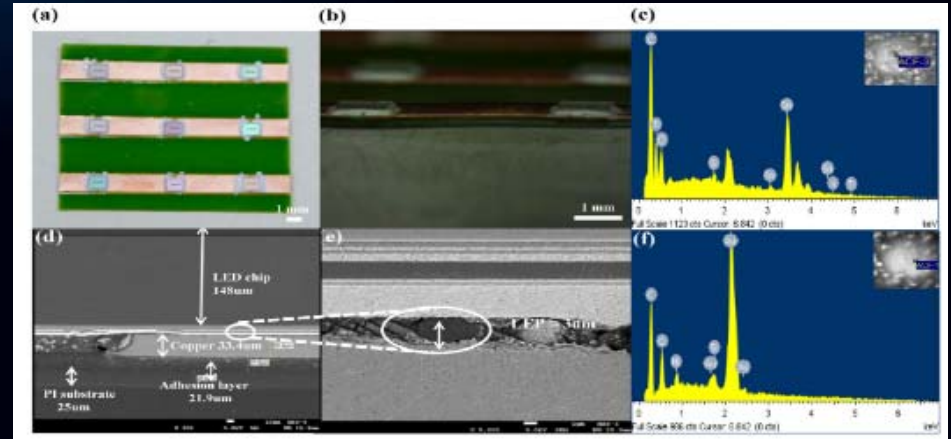
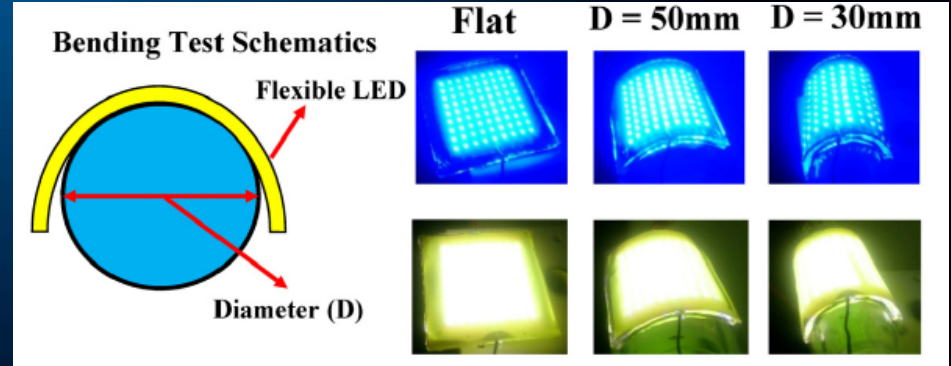
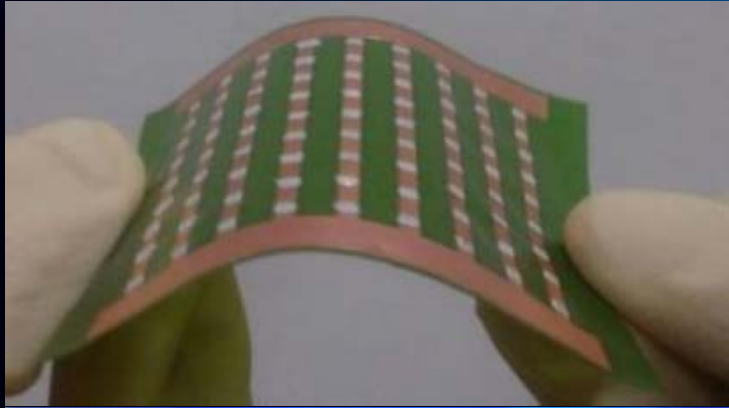


We do Ink-Jet QD MicroLED with HKUST and Prof.Liu in 2015





We do flexible mini LED in 2015





Hot Topic of Optics Express

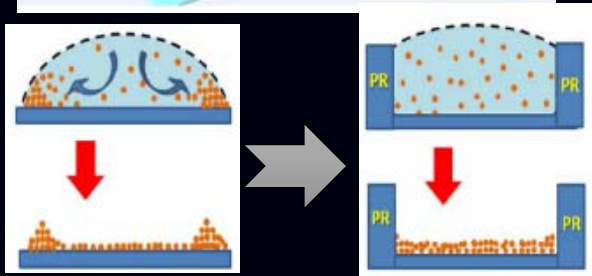
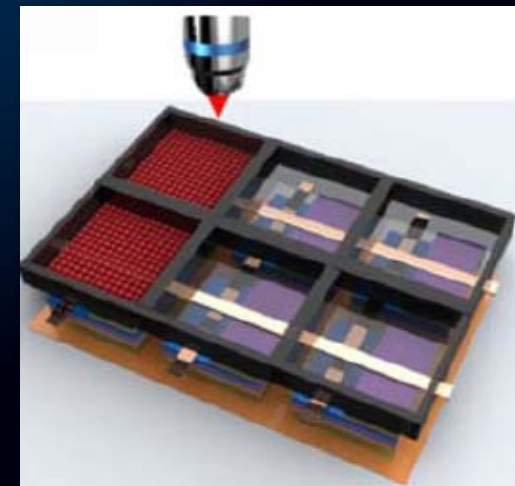
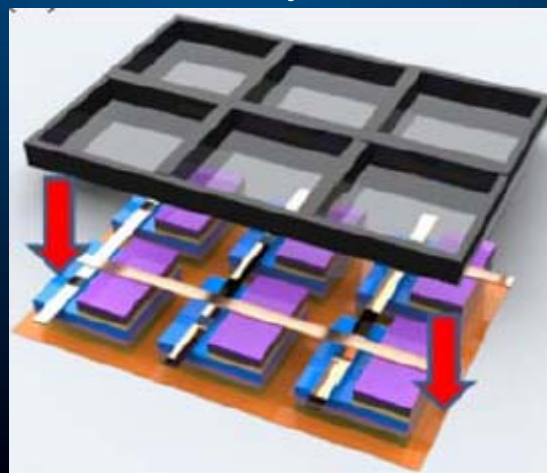
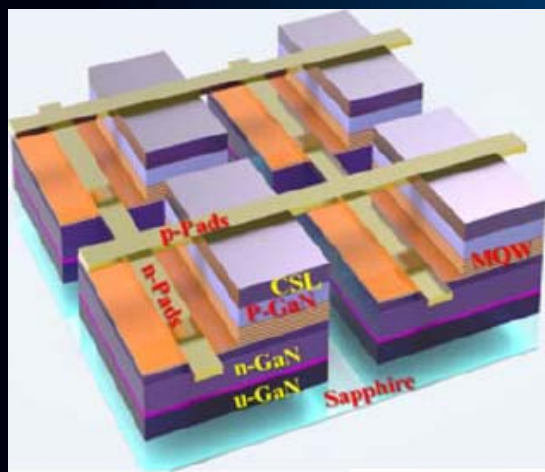
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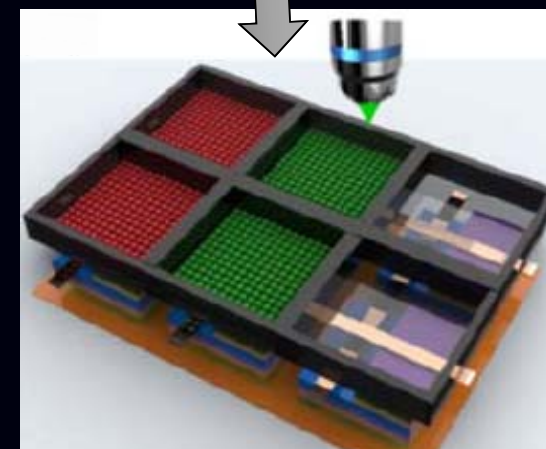
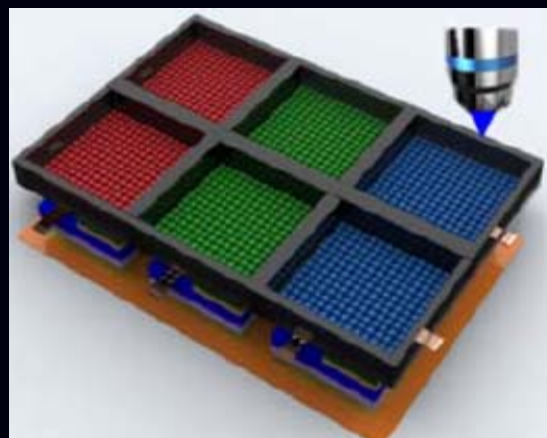


Ink-Jet QD on MicroLED Display in 2017

Full color MicroLED - Monolithic MicroLED array + Quantum Dots



- Wavelength : 405 nm
- Chip size : 5 x 5 mm²
- Pixel : 128 x 128
- Pixel size : 35 μm
- Pitch : 40 μm



Cooperated with Hong Kong university of science technology



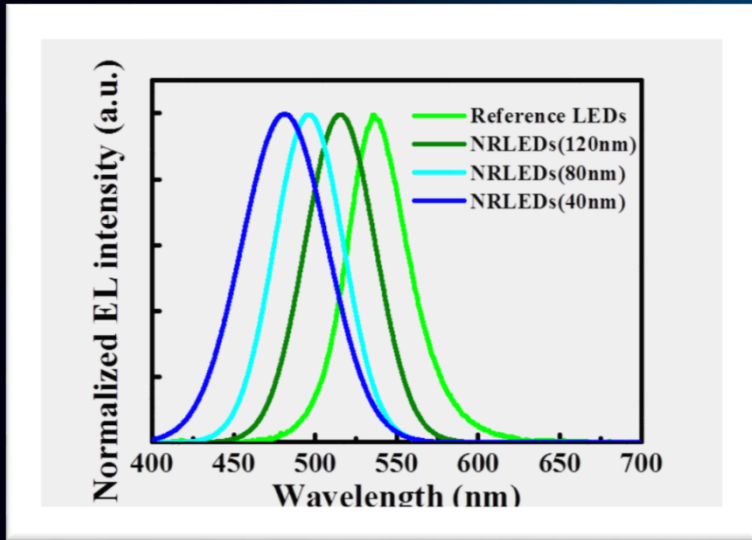
How to reach color conversion goal?

1. Structure change
Nano ring structure and nanoporous structure
2. Use material to reach color conversion
QD material
Ink-jet printing technology



In 2017 Nano-Ring LEDs Innovation

(1)

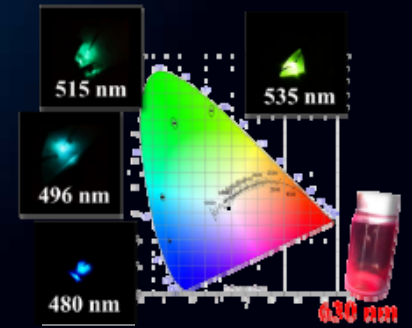


- Through strain-release:

Emission wavelength shifted from 535 nm to 480 nm.

(2)

- Advantage of Nano-structure:
 1. Wavelength tunable
 2. Sub-Micro-pixel ($< 1 \mu\text{m}$)



~ 900 nm



Container

QCSE Issue for GaN-based Materials



GaN LEDs grown on c-plane substrate

- Quantum-confined Stark effect (QCSE)
 - Low internal quantum efficiency
 - Red shift in emission wavelength



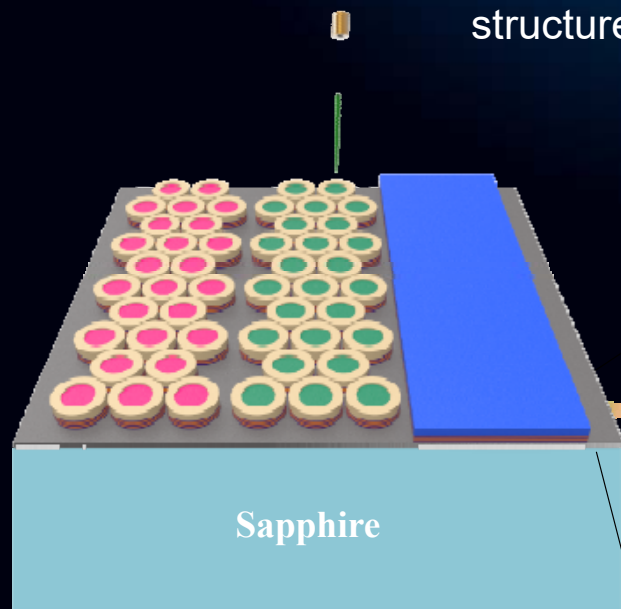
Advance lithography technology to fabricate NR-LEDs

ex. E beam, Nanoimprint etc.

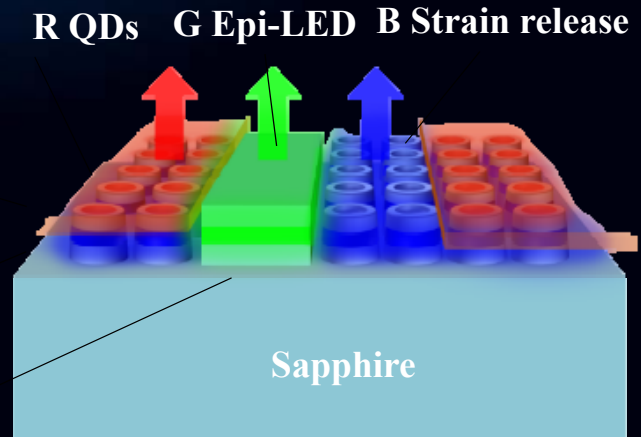
The difficulty of alignment can be solved

→ A single device can be operated individually

RGB quantum dots can be fixed into nano-ring structure separately to achieve sub-micro pixel.



UV light pump RGB QDs



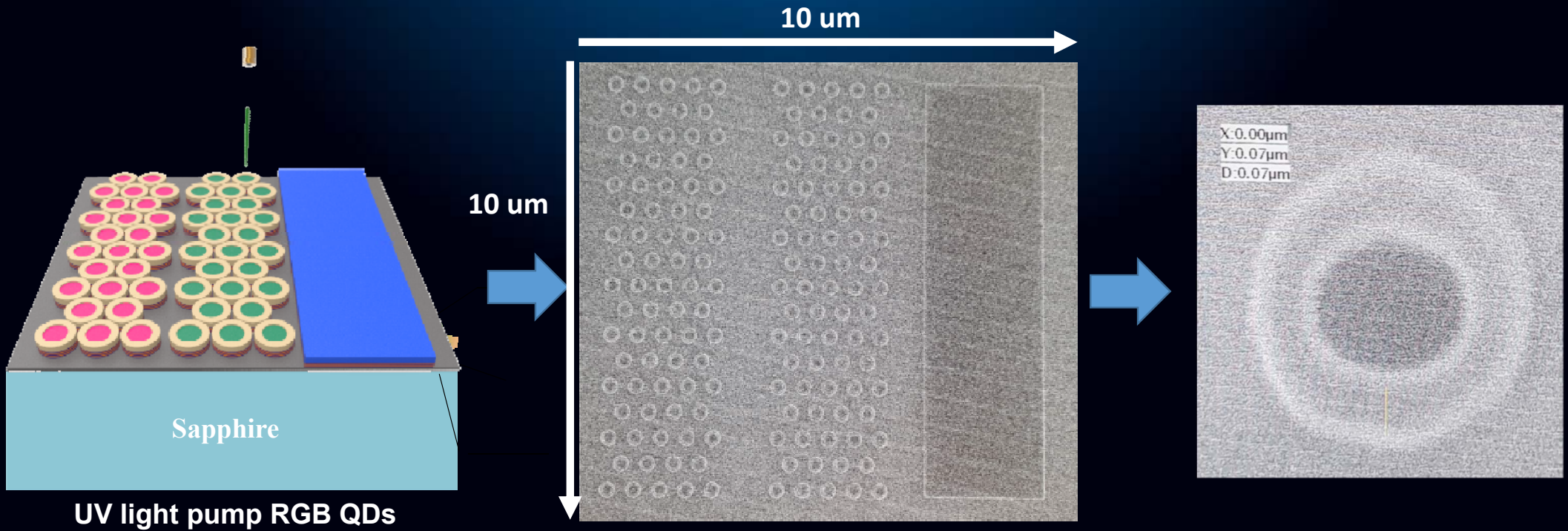
Filter
Nano-ring LED
(p-GaN + MQWs)
n-GaN

Combined with G epi LED, B NR-LED, and R QDs

Create a novel solution for micro-LED with RGB color.



SEM image of NR-LEDs

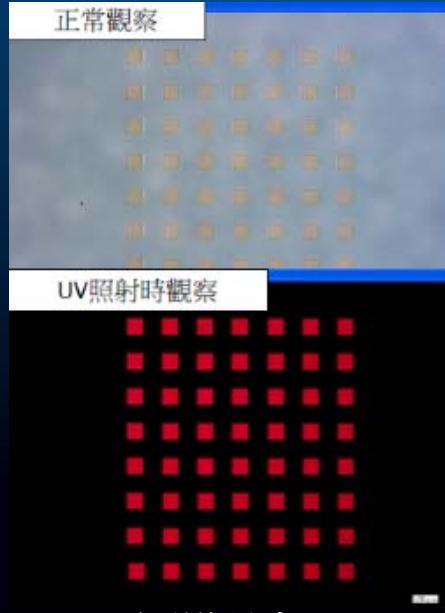




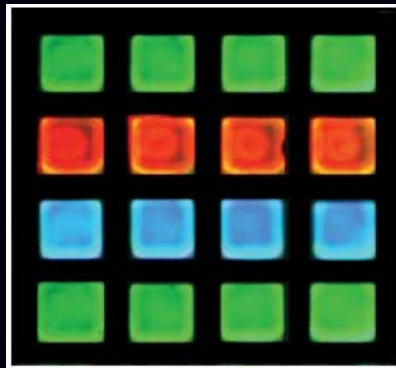
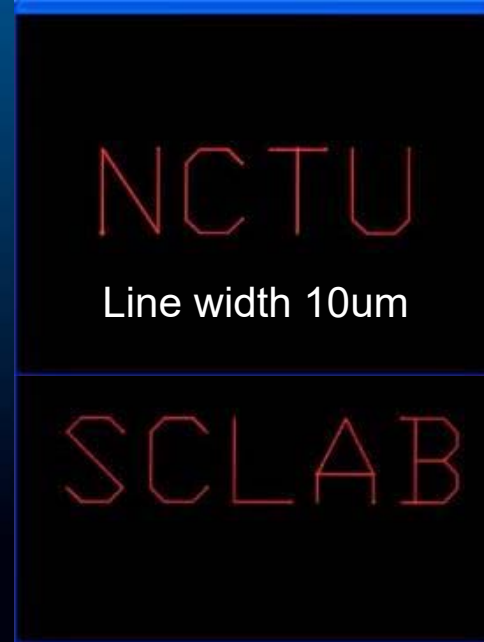
Super Inkjet Printing Technology



点的直径：约 $5\mu\text{m}$



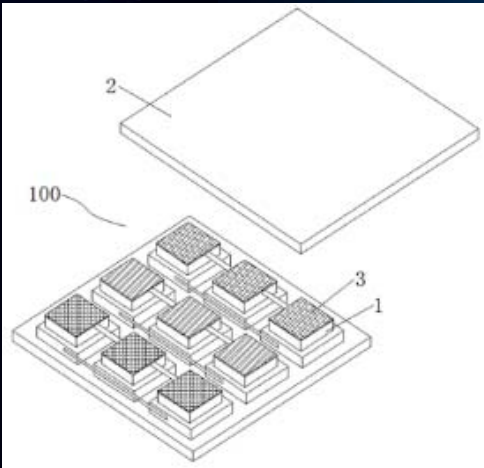
正方形的尺寸： $51\mu\text{m}$
厚度： $0.3\mu\text{m}$



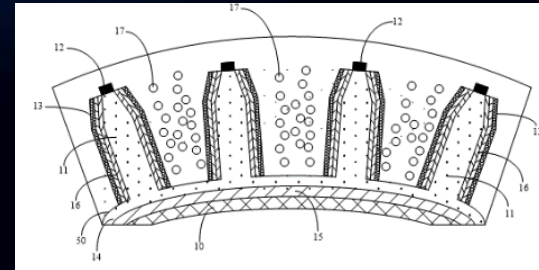
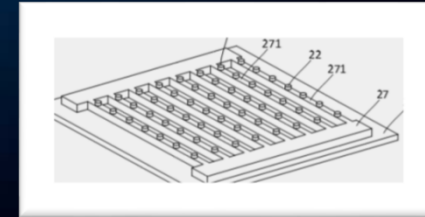
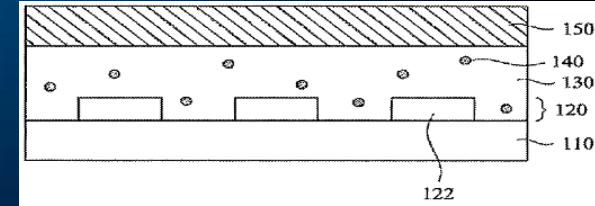
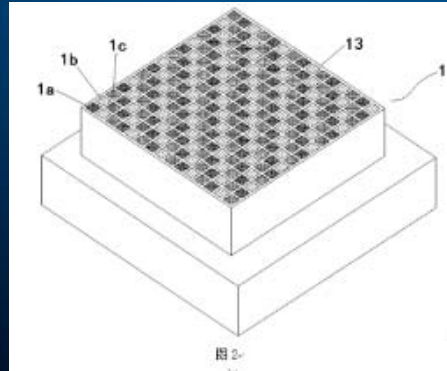
QDs with blue LED
(Chip size $38\text{ um} \times 38\text{ um}$)



Award and Patent in Flexible Micro LED Display



一种微发光显示器数组结构
CN207664059U



奈米柱发光二极管制程及其结构
CN207517719U

可挠性发光二极管结构
CN207517681U



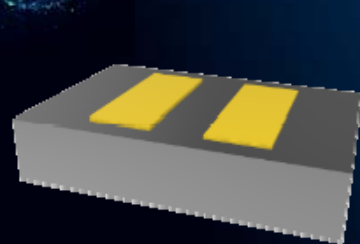
SID 2018 Distinguish Paper Award



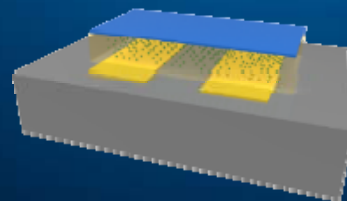
柔性紫外线光装置
CN207517719U



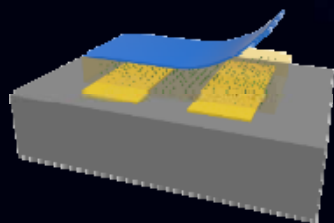
What is next ? Flexible and Transparent MicroLED



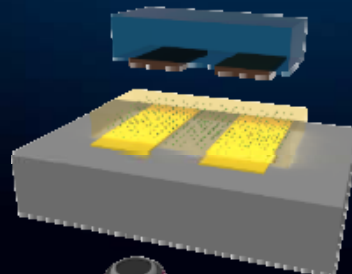
(1) *Cleaning*



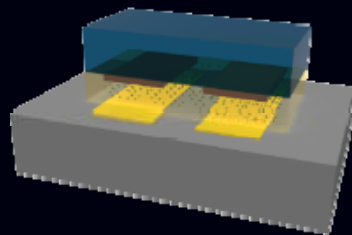
(2) *ACF attachment*



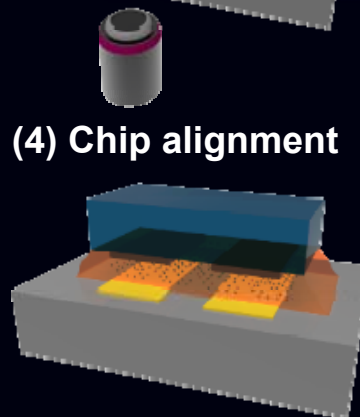
(3) *Remove of a cover film*



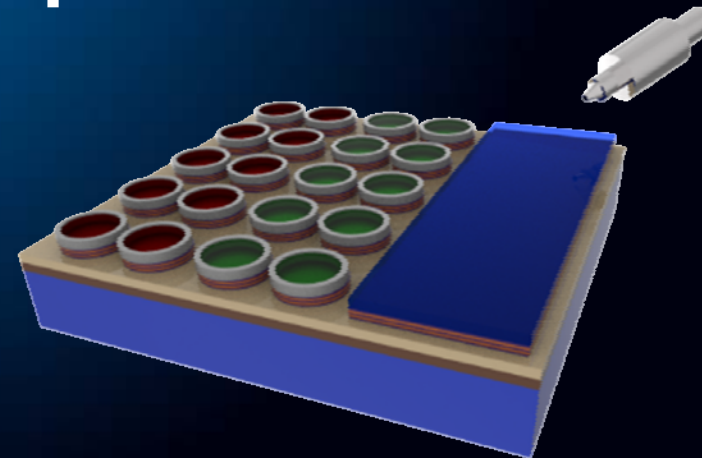
(4) *Chip alignment*



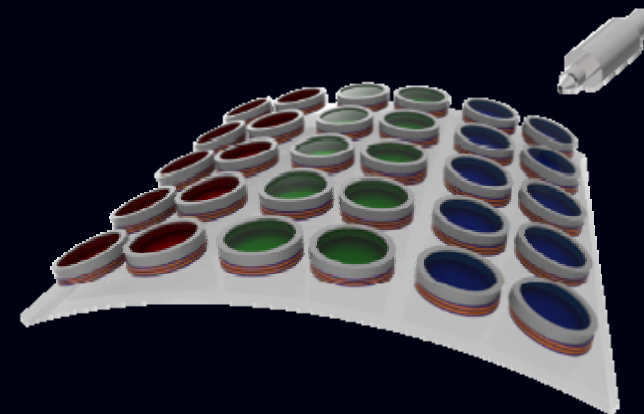
(5) *Pre-bonding*



(6) *Main-bonding*



Basic structure



Flexible structure



Acknowledgement

- HKUST – Prof. KM Lau, Prof. Ricky Lee, Prof. Enboa Wu
- SAPILUX – Prof. Han, Dr. Chen
- ETEB – Dr. Huang
- ITRI – Prof. CC Lin
- SUSTC – Prof. ZJ Liu,
- Playnitride – Dr. Charles Lee



Flex Photonics Co. Ltd

Industrial Collaborations

