TAIPEI TECH 國立臺北科技大學 National Taipei University of Technology

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世界因為光而豐富 生活因為光而精彩

Evolution of light source

15-20 lm/W

50-80 lm/W

30-50 lm/W
@ 2000

-300 | 1810 | 1879 | 1938 | 1996 | 2008

Home lighting

[Edison 1847-1931]

2012
Flexible Electronics
← Micro LED →Display

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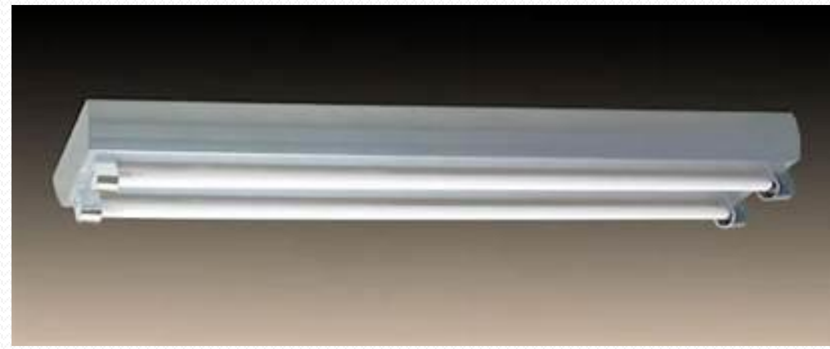
再見了～愛迪生！



省電燈

鹵素燈

2010

2020

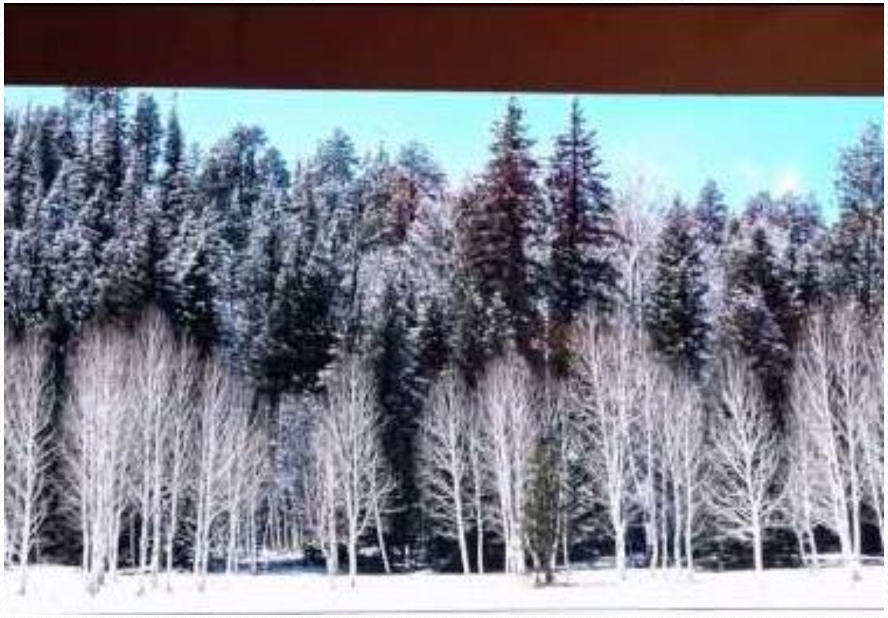
Next wave ....

- 承接在傳統液晶（LCD）、OLED 後，Micro LED被台灣的一些LED廠視為下一波的產業浪潮。作為LED家族的一份子，Micro LED繼承了所有LED的優點基因：低功耗、高亮度、超高解析度與色彩飽和度、反應速度快、超省電、壽命較長、效率較高等，其功率消耗量約為 LCD 的 10%、OLED 的 50%。

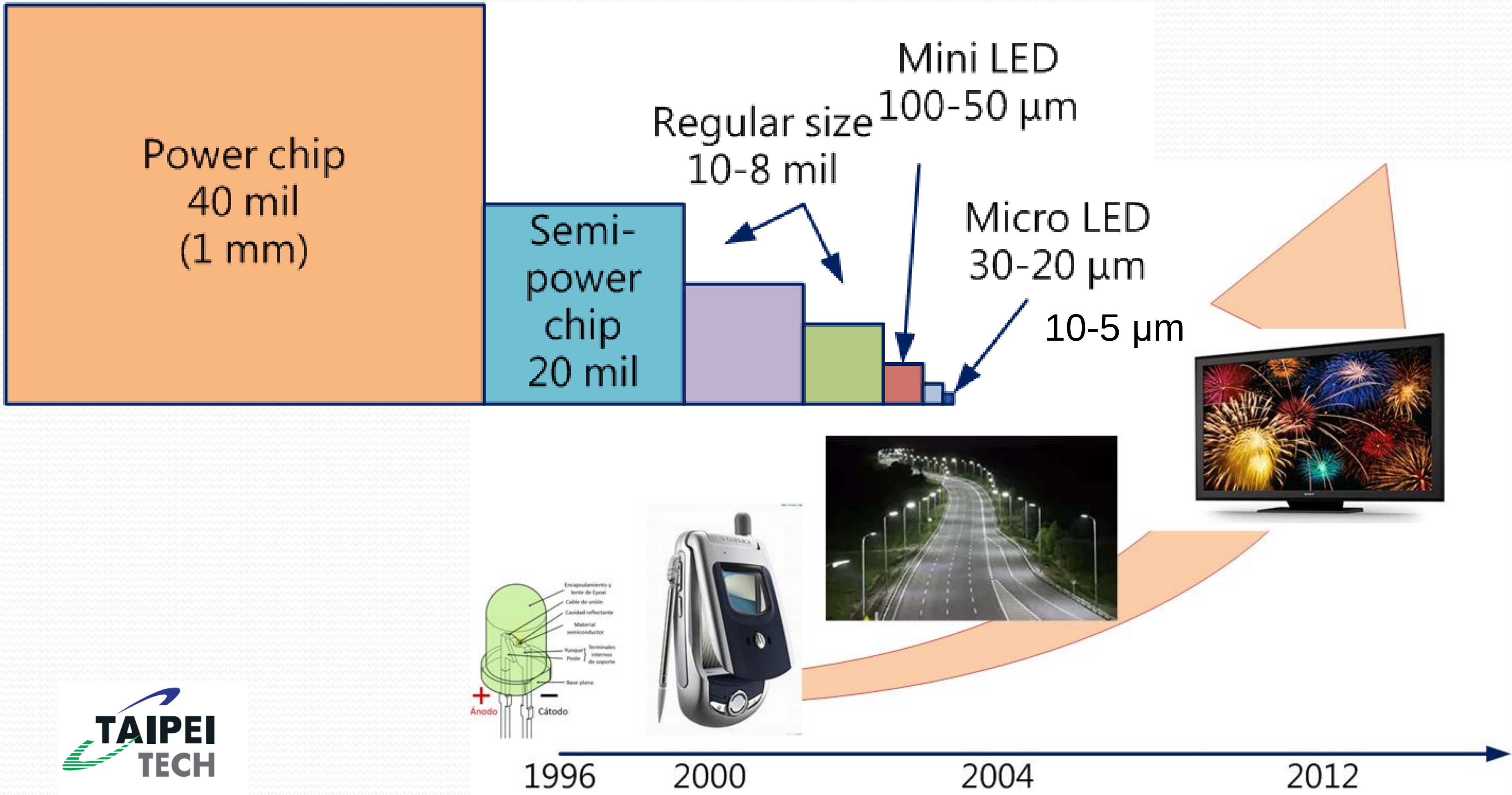
Sony Micro LED TV

- 2012 Crystal LED Display

- 2017 CLEDIS



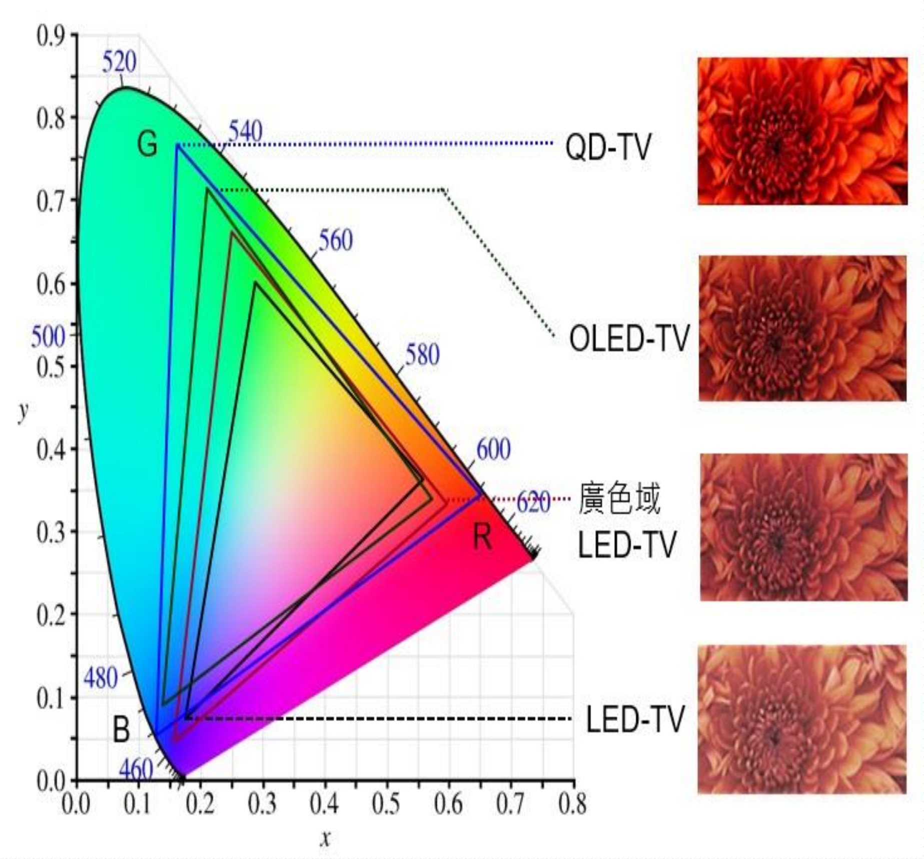
LED applications with different chip sizes



Micro LED 為何被看好成為新一代顯示技術？

- Micro LED Display 為新一代的顯示技術，結構是微型化 LED 陣列，也就是將 LED 結構設計進行薄膜化、微小化與陣列化，使其體積約為目前主流 LED 大小的 1%，每一個畫素都能定址、單獨驅動發光，將畫素點的距離由原本的毫米級降到微米級。
- 承繼了 LED 的特性:低功耗、高亮度、超高解析度與色彩飽和度、反應速度快、超省電、壽命較長、效率較高等，其功率消耗量約為 LCD 的 10%、OLED 的 50%。而與同樣是自發光顯示的 OLED 相較之下，亮度比其高 30 倍，且解析度可達 1500 PPI（像素密度），相當於 Apple Watch 採用 OLED 面板達到 300 PPI 的 5 倍之多，另外，具有較佳的材料穩定性與無影像烙印也是優勢之一。

NTSC 色域


0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
y
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
x
520
540
560
580
600
620
500
480
460
G
R
B
QD-TV
OLED-TV
廣色域
LED-TV
LED-TV

Micro LED優勢

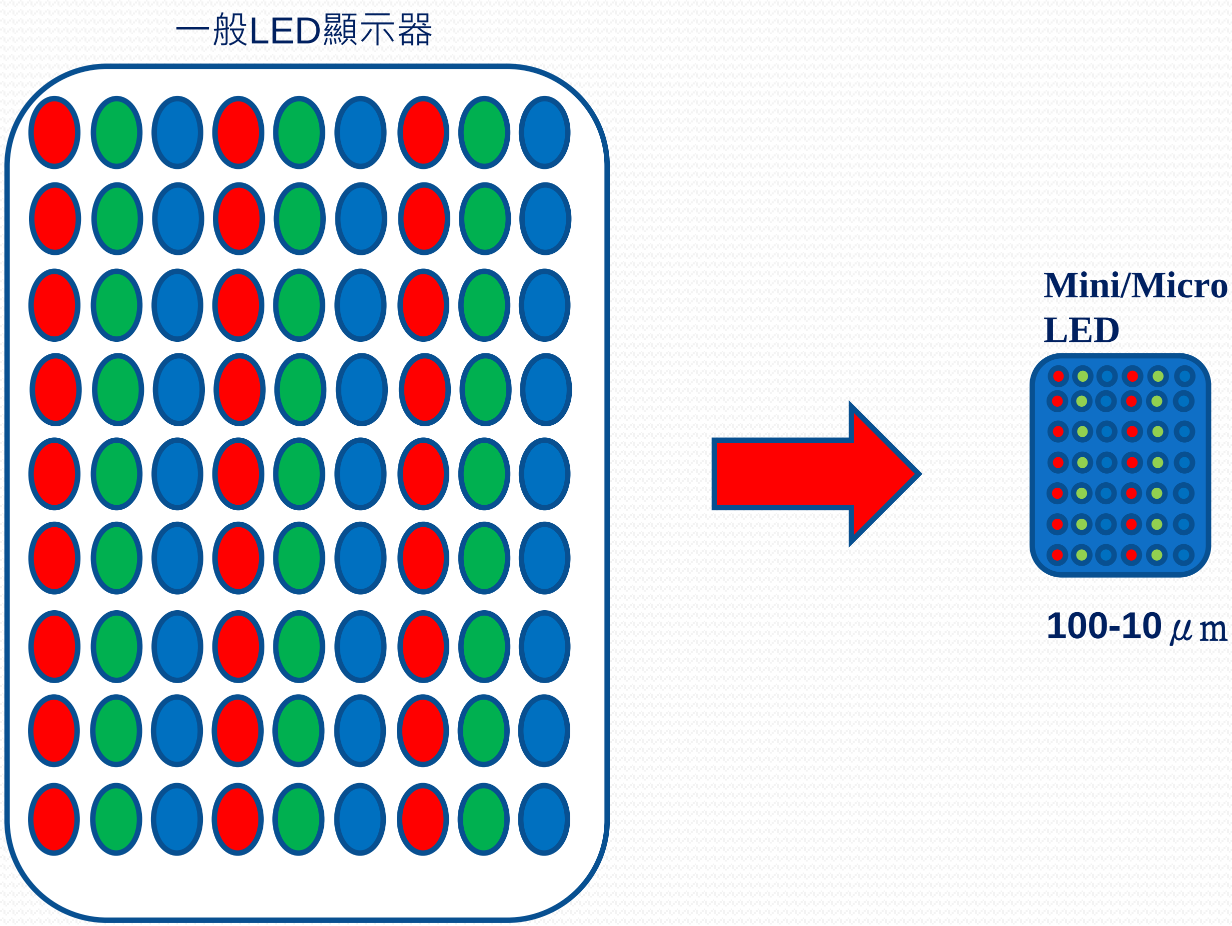
有高發光效率、高解析度、高亮度、高壽命、高可靠度、反應時間快、自發光特性、機構簡易、體積小、薄型等優勢。

顯示技術	LCD	OLED	Micro LED
技術類型	背光板	自發光	自發光
對比率	5000:1	∞	∞
壽命	中	短	長
反應時間	毫秒(ms)	微秒(μs)	奈秒(ns)
運作溫度	-40℃至100℃	-30℃至85℃	-100℃至120℃
成本	低	中	高
能源消耗量	10	2	1
可視角度	中	中	高
PPI 穿戴式	最高250 PPI	最高300 PPI	1500 PPI 以上
PPI 虛擬實境	最高500 PPI	最高600 PPI	1500 PPI 以上

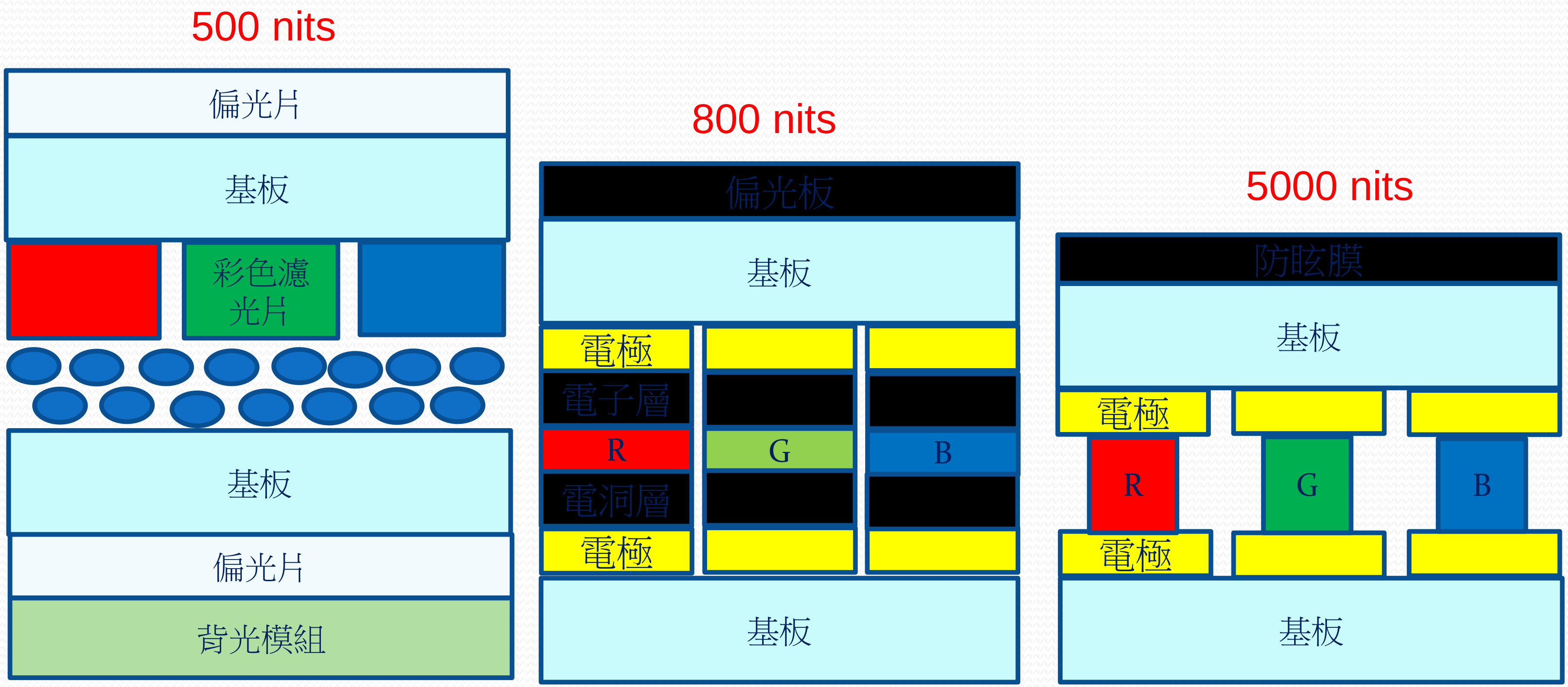
[修改網路資料]

Micro LED介紹

即LED微縮化和矩陣化技術，在一個晶片上集成高密度微小尺寸的LED陣列，可將像素點距離從毫米級降低至微米級，而每個畫素可單獨驅動發光和定址。



TFT-LCD、OLED and Micro LED 顯示技術



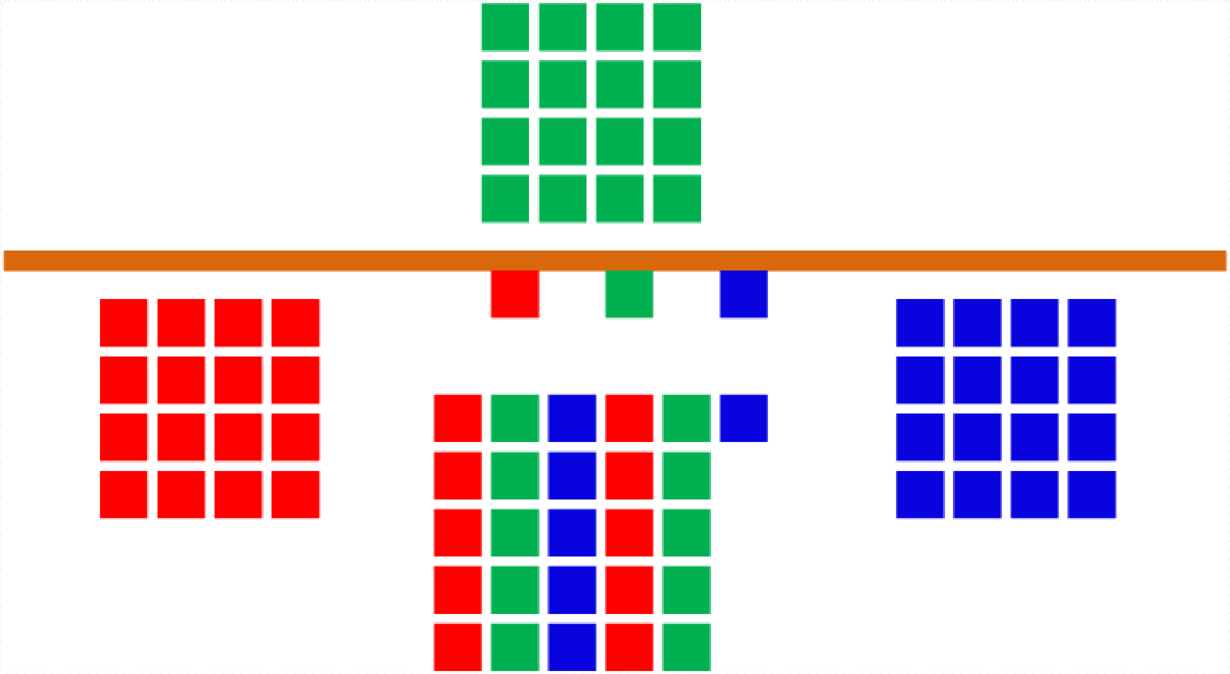
TFT-LCD是透過液晶層通電與分子移轉，搭配彩色濾光片與背光源，讓每個化速含有紅、藍、綠三原色，可混合出各式各樣的顏色光。

OLED是由電流驅動有機薄膜，可自行發出紅、藍、綠光，顏色較LCD鮮豔。

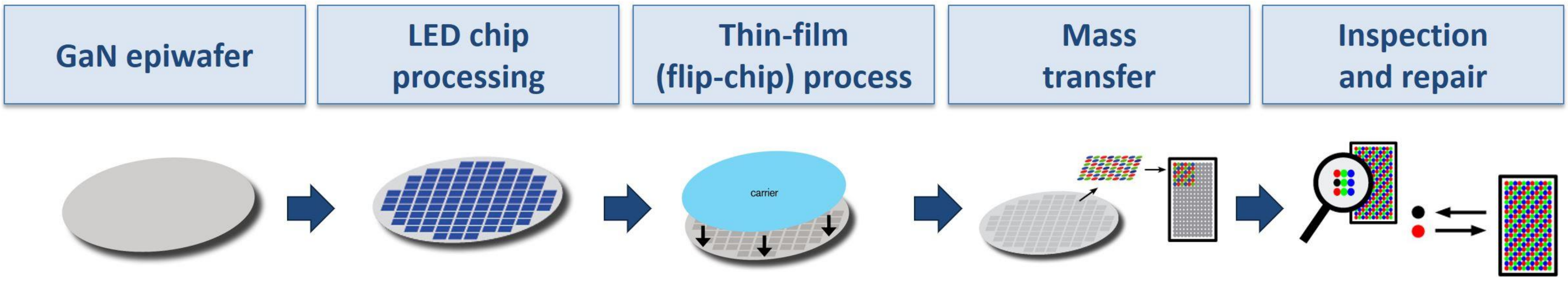
Micro LED陣列微小化，可使亮度、畫質、反應速度提升。

[修改網路資料]

Mini/Micro LED 技術



Micro LED manufacturing process steps

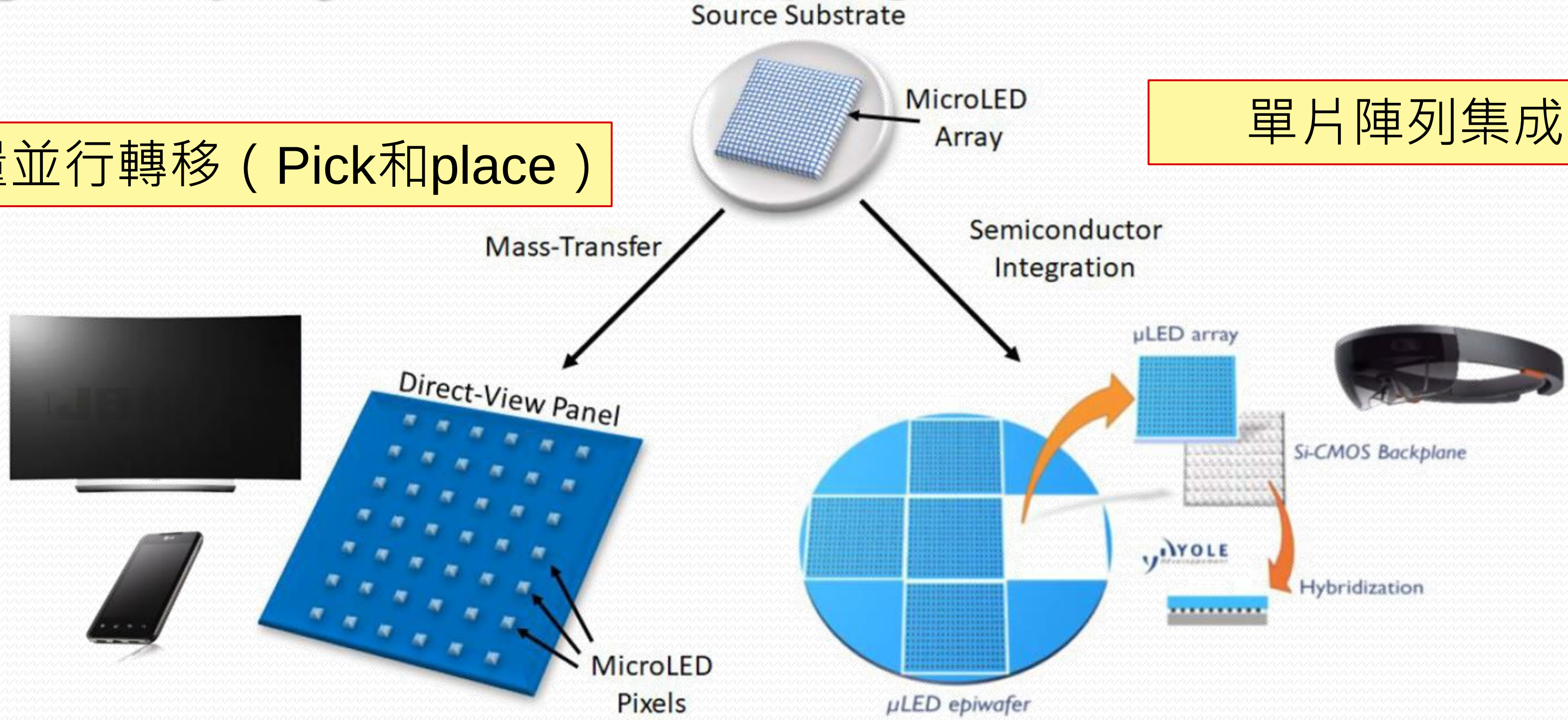


- Micro LED主要生產製程主要包括磊晶片成長，晶片製造，薄膜製程，巨量轉移，檢測與修復。
- 磊晶片成長，Micro LED晶片製造，薄膜製程跟傳統的LED製程比較， 只需對設備稍加改造就可用於Micro LED製造環節。
- 目前的製造難點主要集中在巨量轉移，檢測與修復方面以及驅動IC的設計和製程上。

Micro-LED Display Technology
Large Display & Micro display

巨量並行轉移（Pick和place）

單片陣列集成



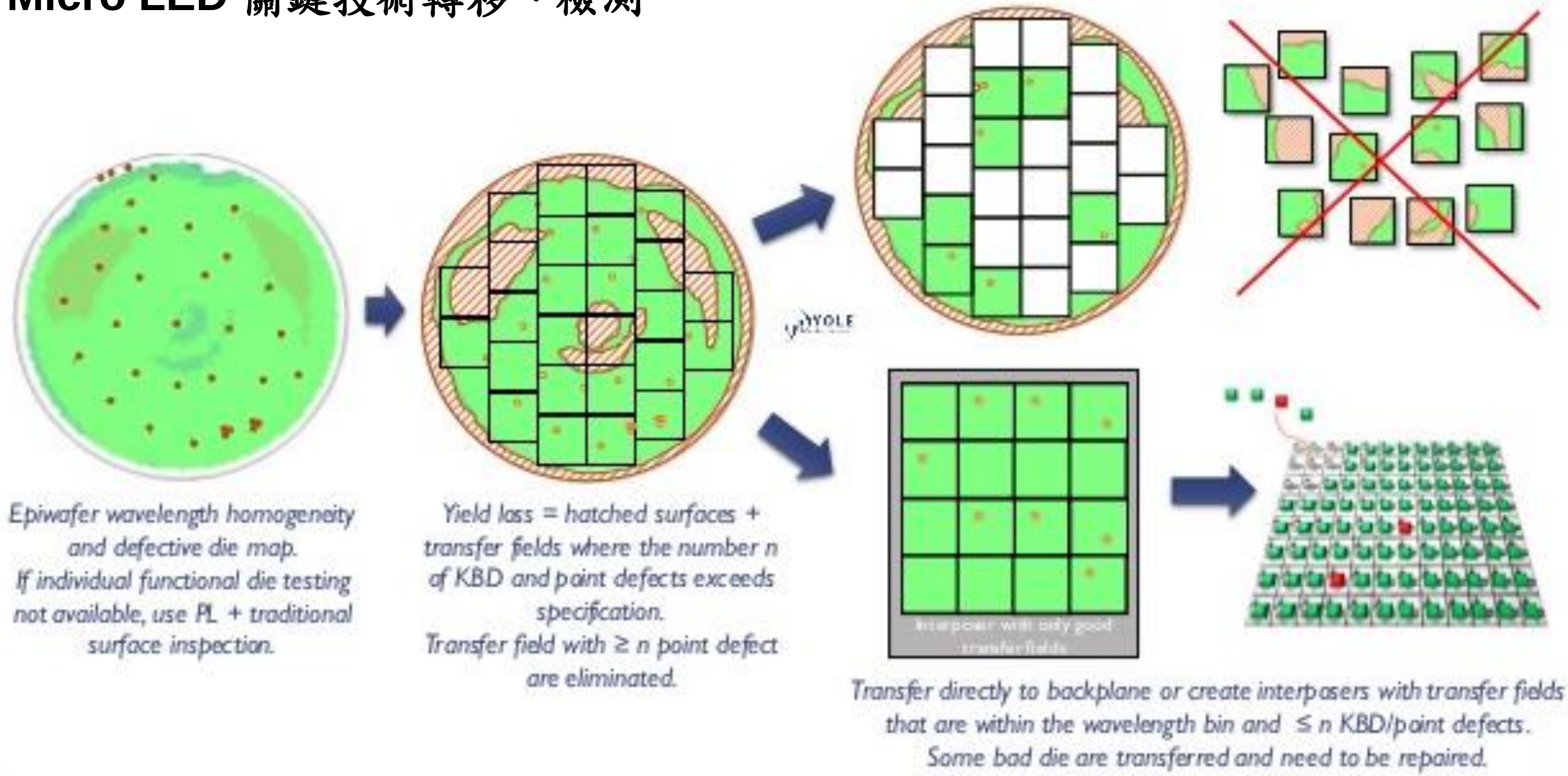
Cellphones, Tablets, Laptops, Monitors, TVs, etc.

AR/VR Micro displays

- Micro LED技術，即LED微縮化和矩陣化技術，指的是在一個晶片上集成高密度微小尺寸的LED陣列。
- Micro LED display，則是底層用正常的CMOS積體電路製成LED顯示驅動電路，然後再用MOCVD在CMOS上製作LED陣列，從而實現了微型顯示屏。

Transfer Fields and Interposers

Micro LED 關鍵技術轉移、檢測

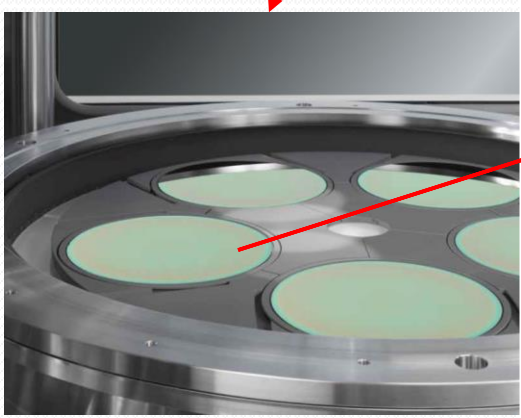


利用PL mapping進行表面檢測波長均勻性和是否有缺陷的晶粒，
將好的晶粒直接轉移至背板，一些壞的晶粒需轉移並維修。

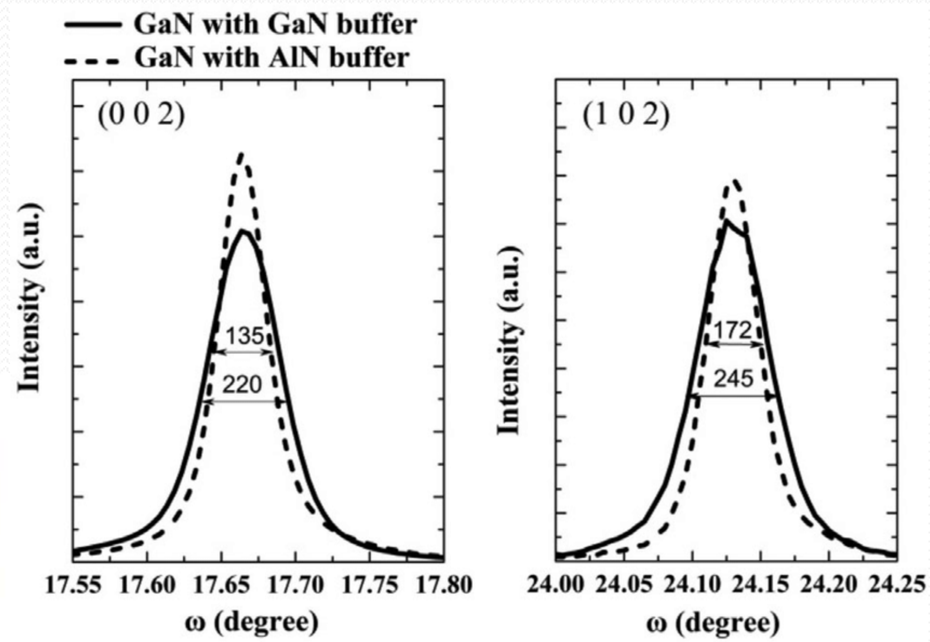
LED epi-wafer 檢測

XRD

AIX G5+ C



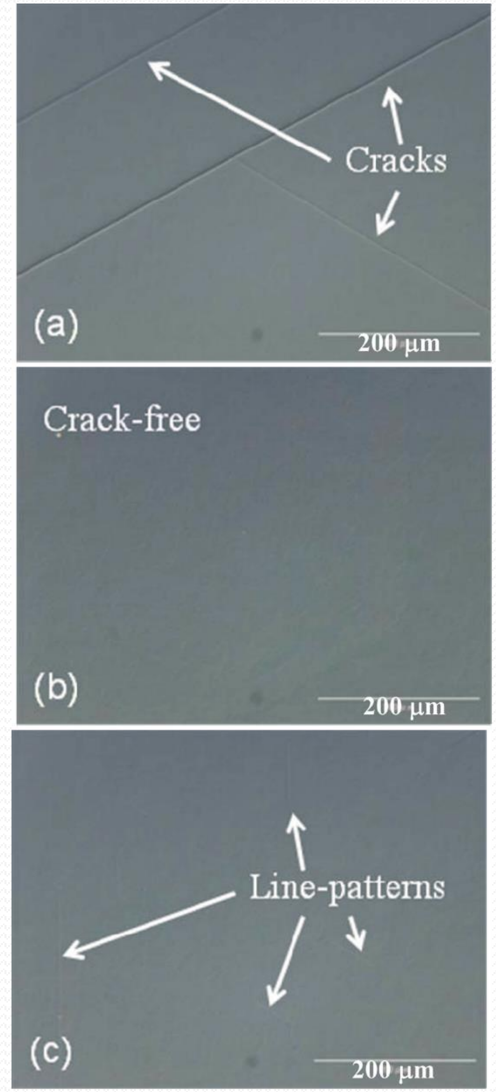
Panalytical X'Pert³ MRD



- 生產Micro-LED其波長一致性高、缺陷密度較低的高品質磊晶片是重要的。
- 透過XRD可以判斷磊晶片品質。

LED epi-wafer 檢測

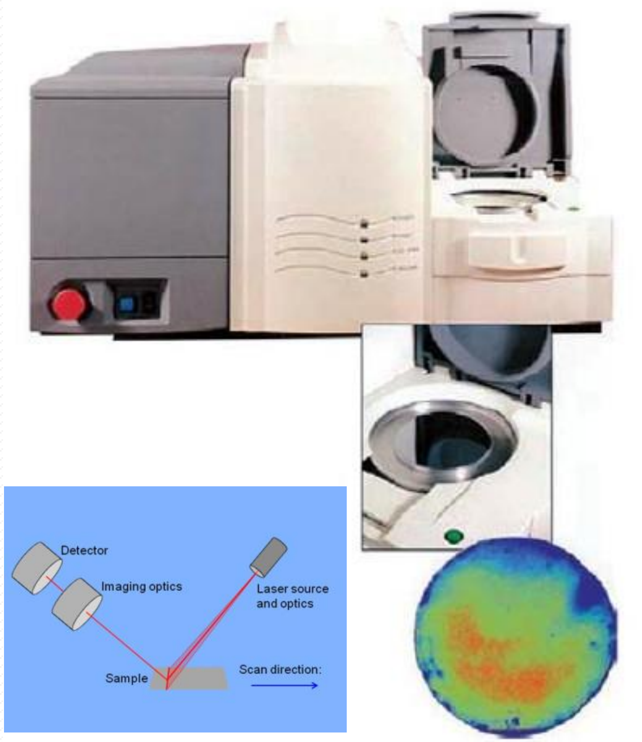
OM crack



- 透過OM顯微鏡判斷磊晶片是否有裂紋(crack)的圓，提高磊晶品質的良率與降低晶粒製程失敗的機率。

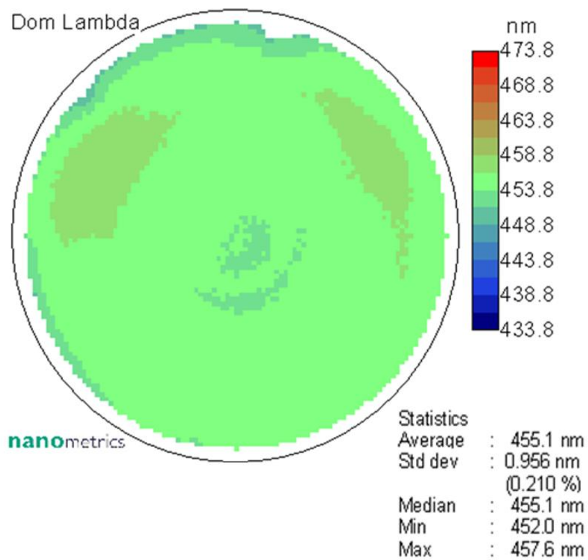
LED epi-wafer 檢測

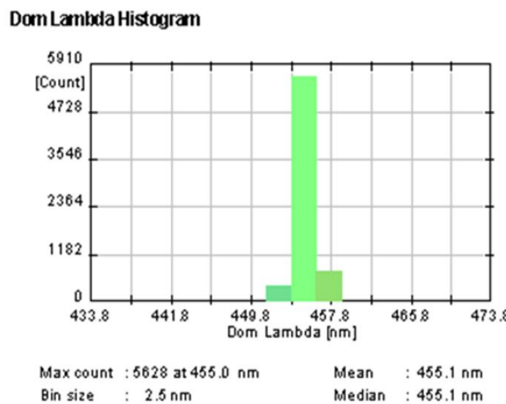
Wavelength mapping



PL Mapping System

Emission uniformity < 1 nm on 200 mm epiwafer

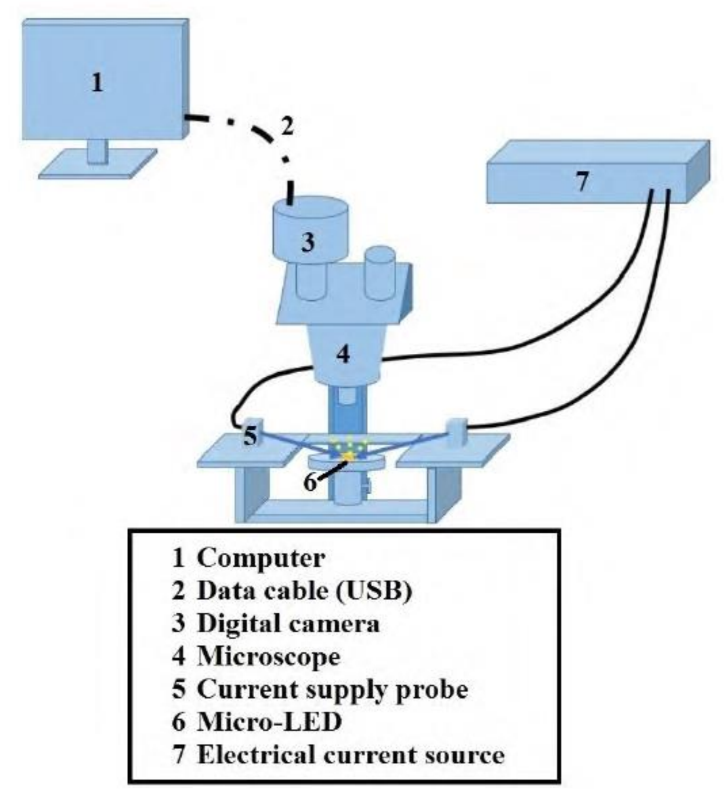


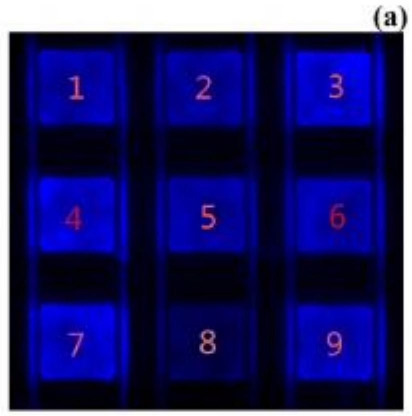


82.7% in 2.5 nm bin
99.0% in 5.0 nm bin

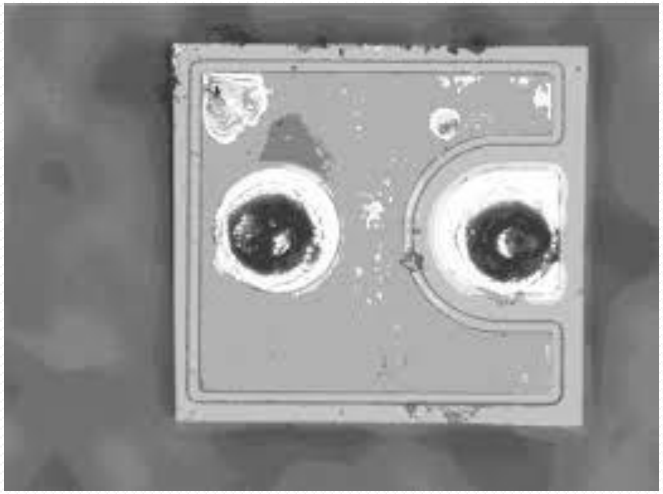
- 由於Micro LED晶片非常小，所以磊晶片的波長均勻性和缺陷密度對於後續生產過程都至關重要。
- 透過PL Mapping System檢測磊晶片波長範圍是否均勻，整體波長範圍要小於4 nm。

OM inspection





IEEE Access 6(2018)51329



製程技術

製程種類	Chip Bonding	Wafer bonding	Thin film transfer
描述	將LED直接進行切割成微米等級的Micro LED chip，利用SMT技術或COB技術，將微米等級的Micro LED chip一顆一顆鍵接於顯示基板上。	在LED的磊晶薄膜層上用感應耦合等離子離子蝕刻(ICP)，直接形成微米等級的Micro LED結構，，再將LED晶圓(含磊晶層和基板)直接鍵接於驅動電路基板上形成顯示畫素。	剝離LED基板，以一暫時基板承載LED磊晶薄膜層，再形成微米等級的Micro LED磊晶薄膜結構。將Micro LED磊晶薄膜結構進行批量轉移，鍵接於驅動電路基板上形成顯示畫素。
顯示畫素種類	Micro LED chip	Micro LED matrix	Micro LED thin film array
顯示基板尺寸	無尺寸限制	小尺寸/可擴充	小尺寸/可擴充
轉移間距是否可調	可	不可	不可
批量轉移能力	不可	可	可
成本	高	低	中

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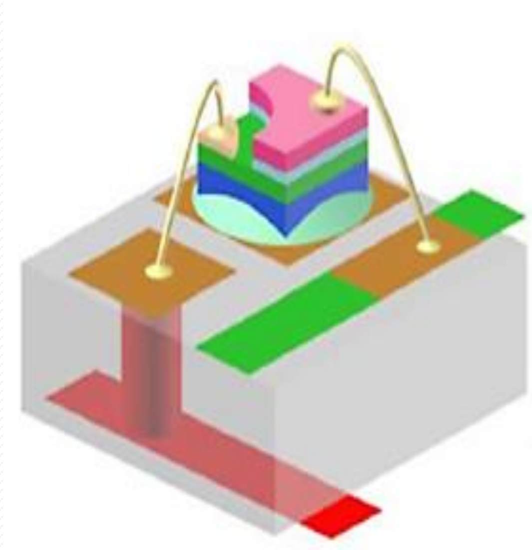
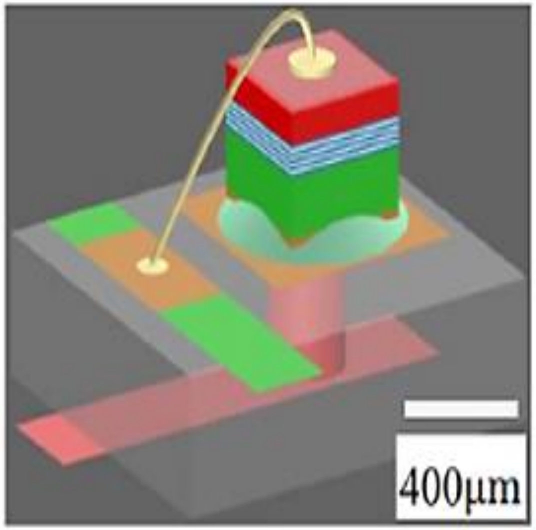
Lateral micro LED and vertical micro LED





Lateral micro led

- Additional interconnection
- Low power
- High heat
- Complex
- Medium-resolution

vertical micro LED

- Transfer and interconnection
- High power
- Low heat
- Simple wiring
- High resolution(400-1300ppi)

IEEE Journal of the Electron Devices Society VOLUME 5, NO. 1, JANUARY 2017

Electrical, spectral and optical performance of yellow–green and amber micro-pixelated InGaN light-emitting diodes

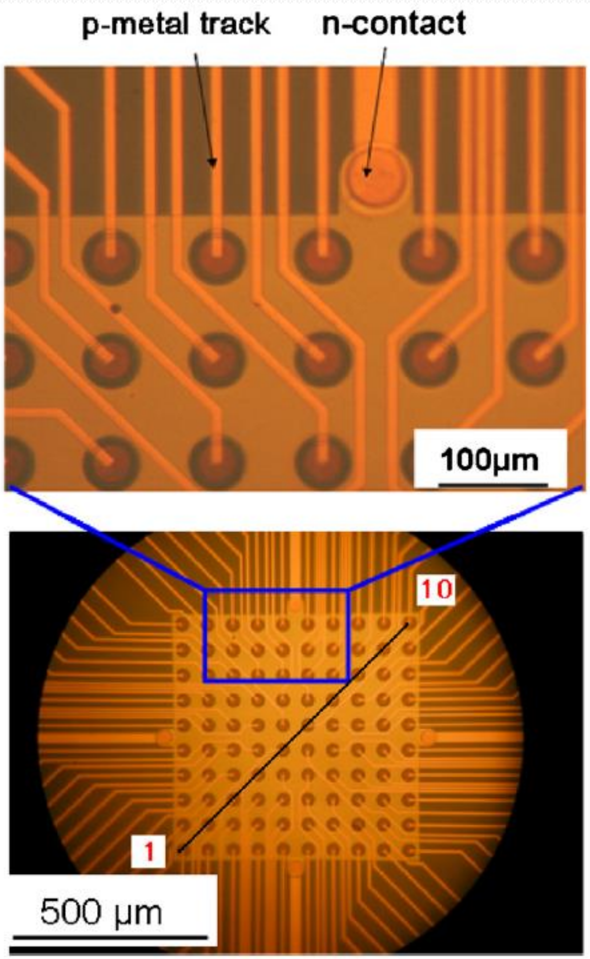
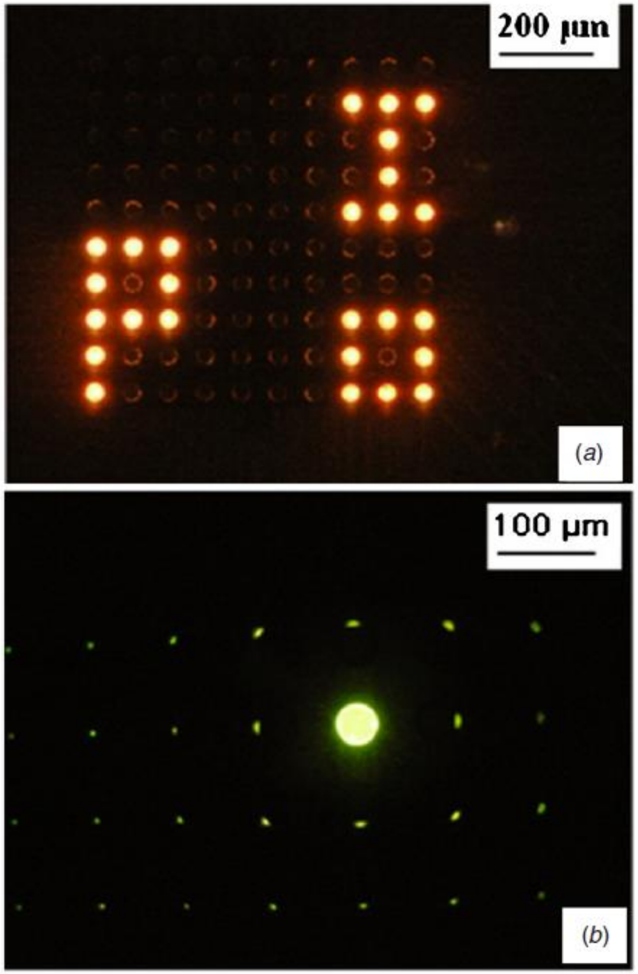
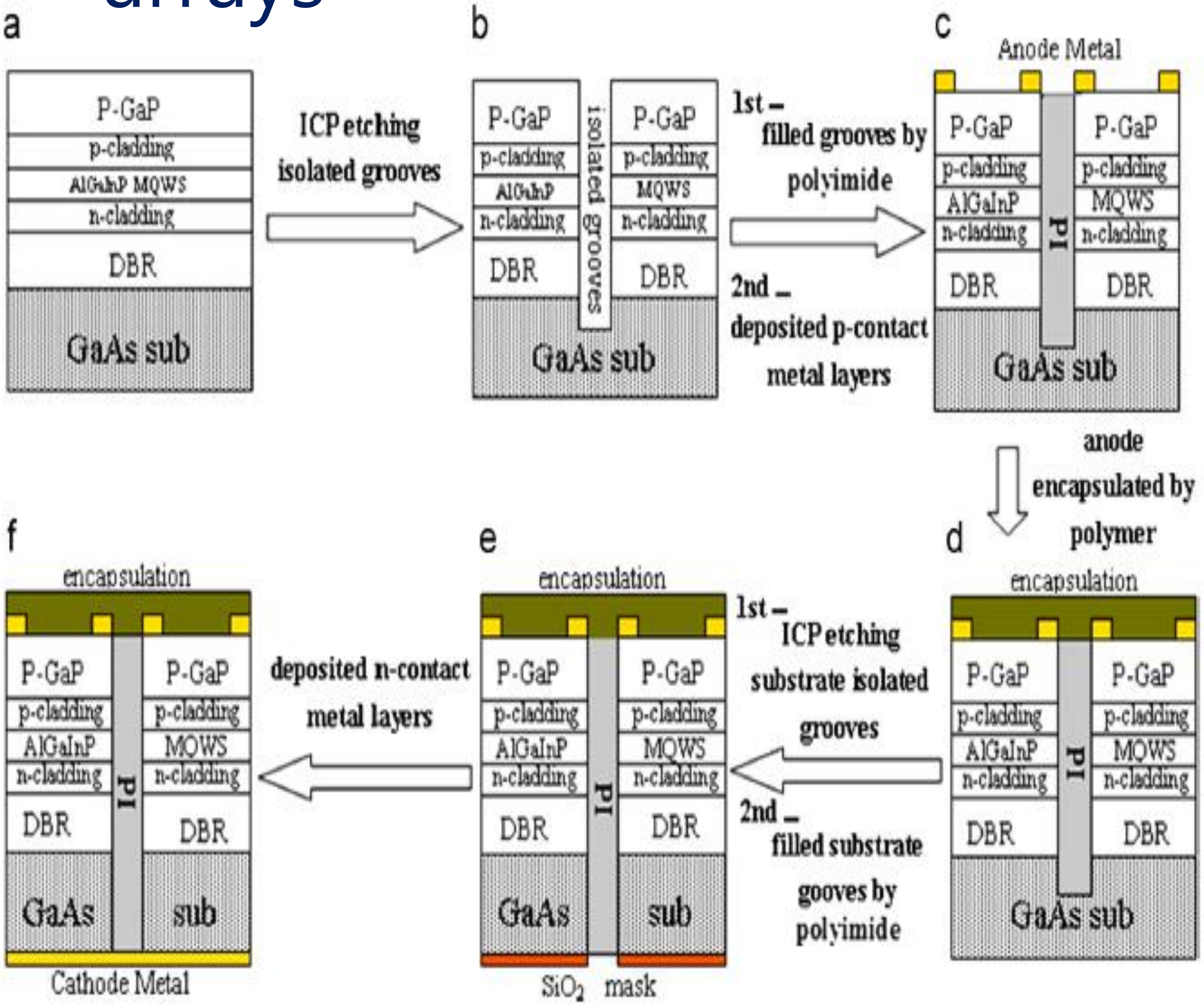


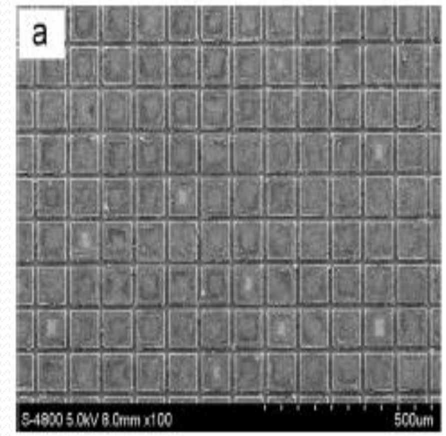
Figure 2. Top-view optical micrograph of a 10 × 10 individually-addressable LED array. Number labels in the lower image correspond to the measurement sequence for figure 3(*b*).

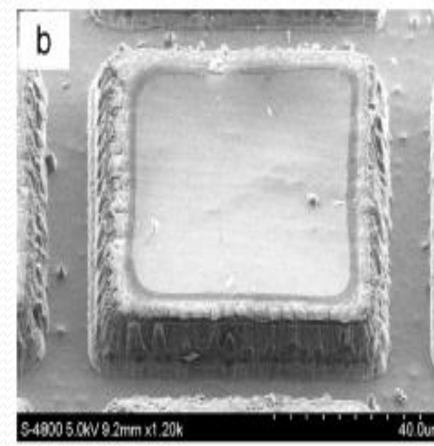


Semicond. Sci. Technol. **27** (2012) 015003 (7pp)

Fabrication process for AlGaInP-Micro LED arrays







Optics &LaserTechnology78(2016)34–41

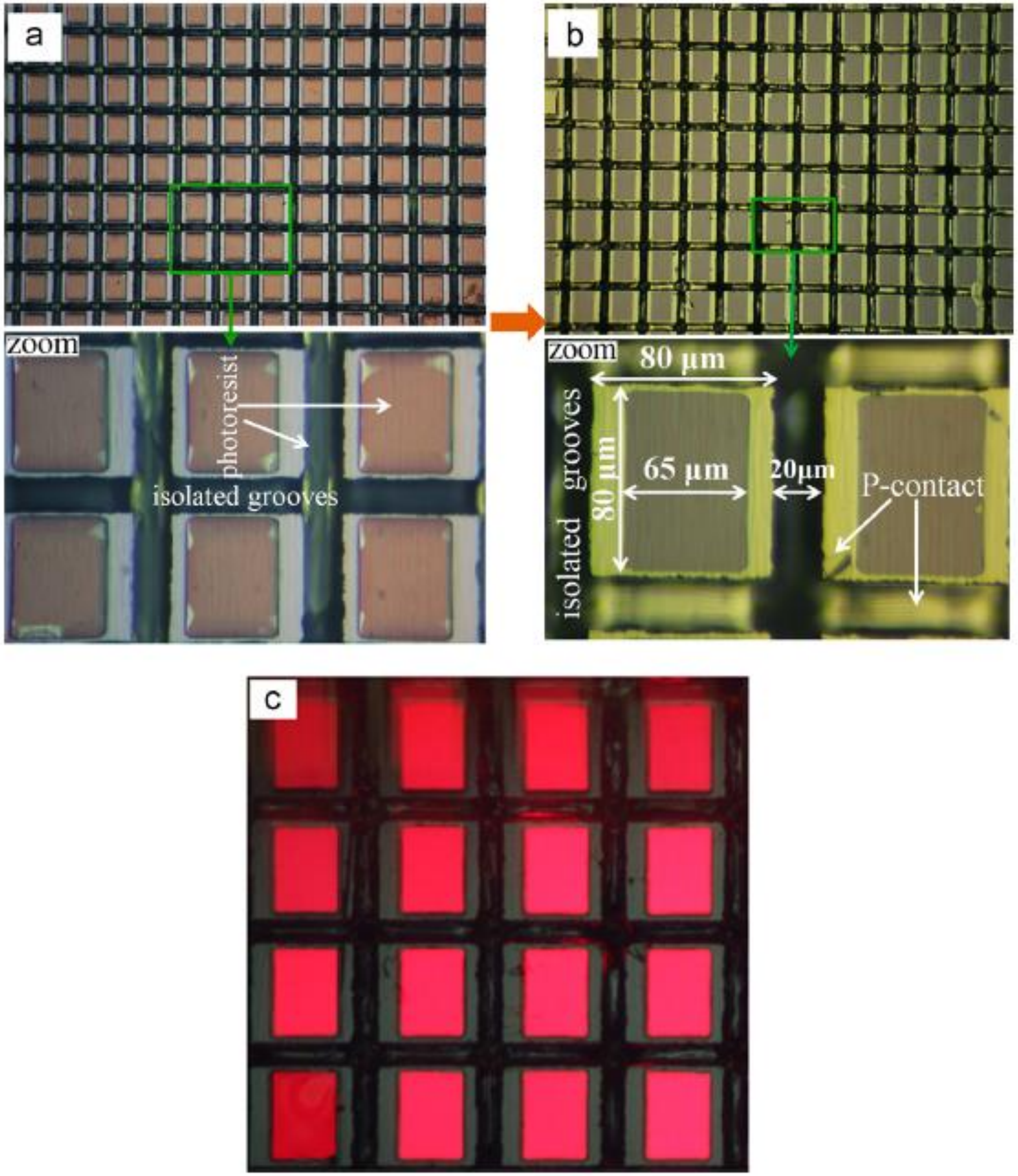


Fig. 11. (a) Image of array before the p-contact was deposited. (b) Magnified image of a segment of an AlGaInP µLED array chip showing µLED pixels and the deposited p-contact, as viewed from the GaP side. (c) The magnified image of 4 × 4 µLED pixels were driven.

Optics &LaserTechnology78(2016)34–41

Journal of Luminescence 191 (2017) 112–116

Influence of size-reduction on the performances of GaN-based micro-LEDs for display application

François Olivier*, Sauveur Tirano, Ludovic Dupré, Bernard Aventurier, Christophe Largeron, François Templier

University Grenoble Alpes, CEA-LETI, Minatec Campus, Grenoble, France and III-V Lab, Grenoble, France

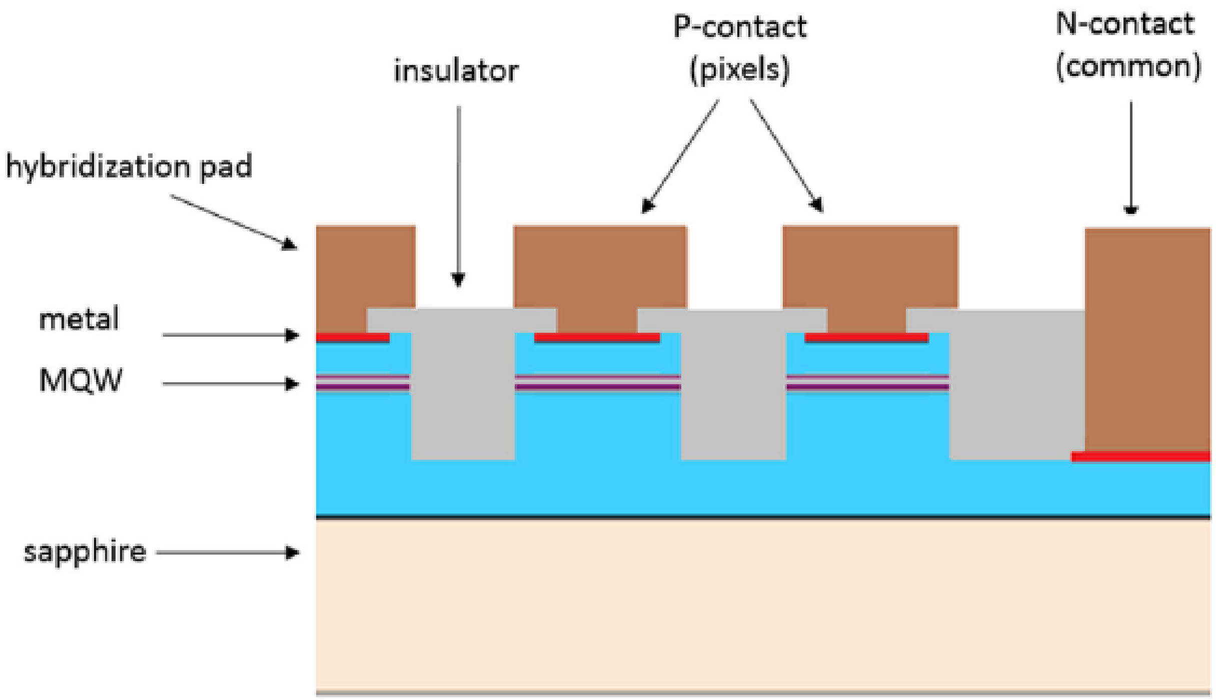


Fig. 1. Schematic cross-section of the final device.

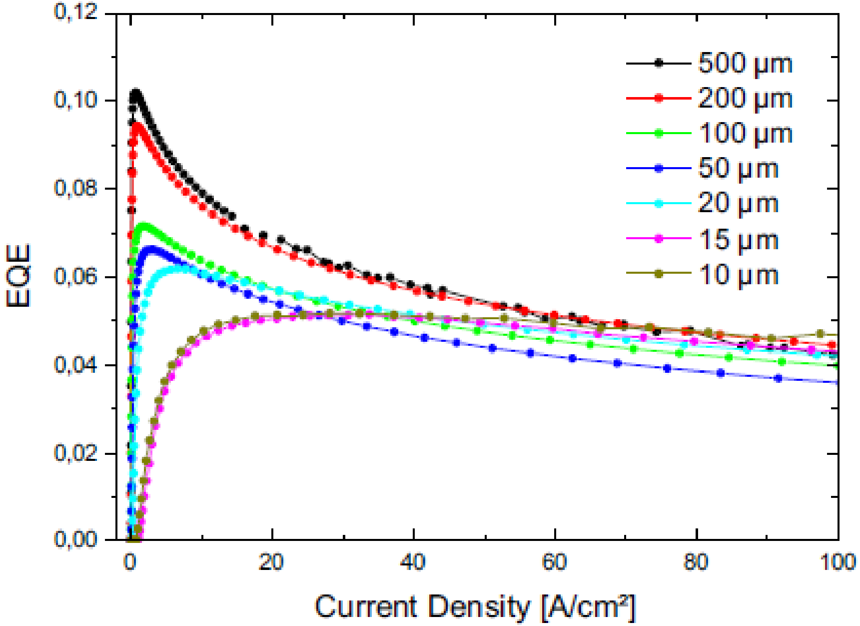


Fig. 4. EQE as a function of current density for different LED sizes.

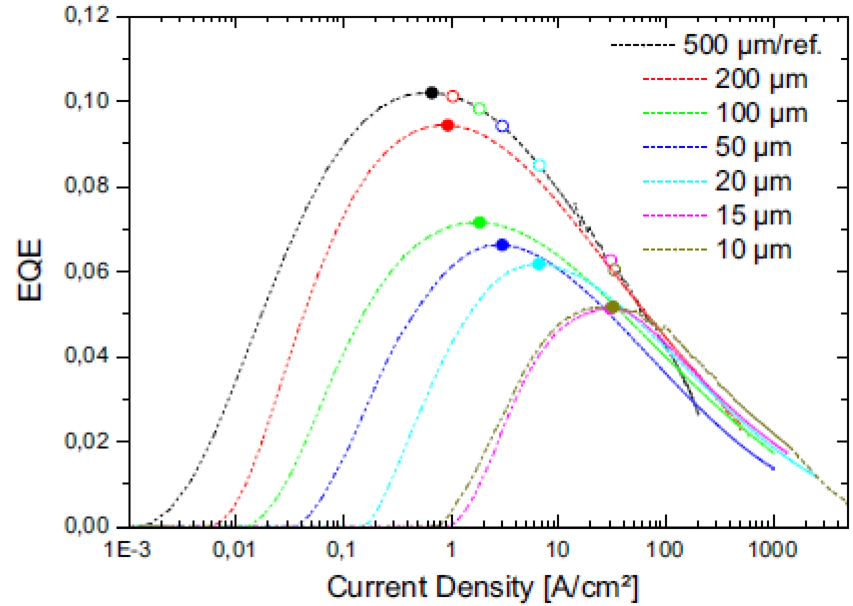


Fig. 5. EQE curves showing experimental (solid circles) and expected maximum (empty circles).

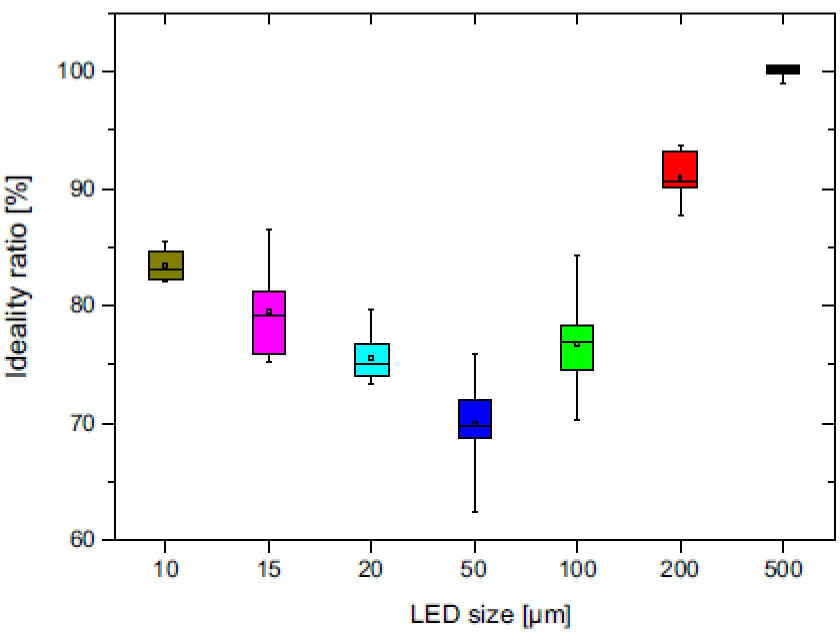


Fig. 6. Calculated ideality ratio.

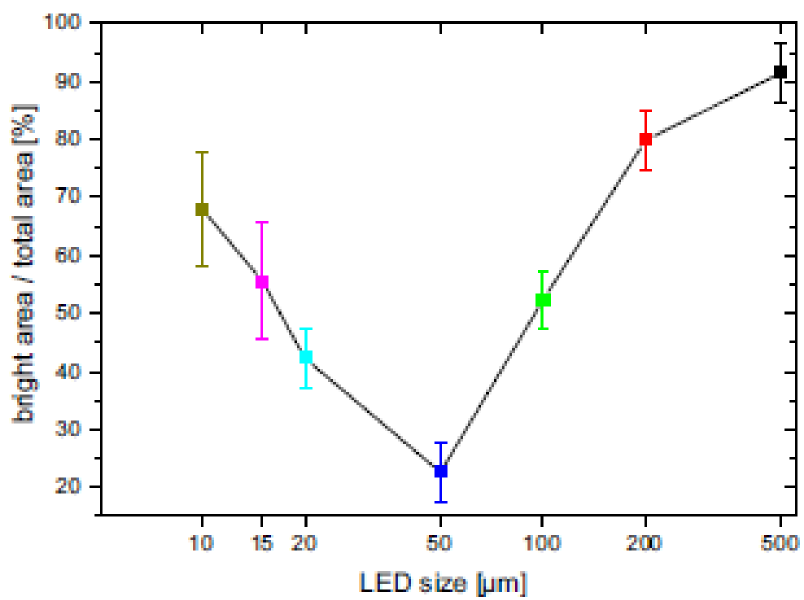
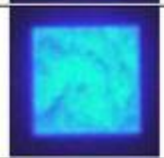
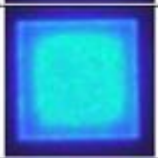
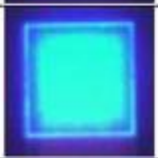
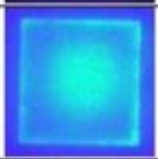
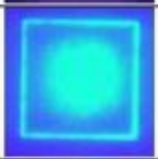
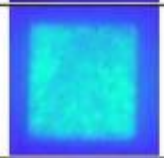
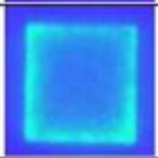
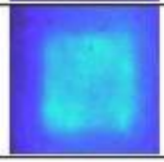
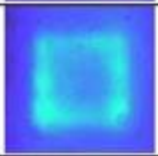
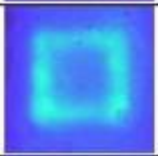
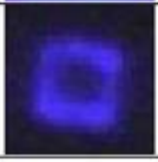


Fig. 7. Ratio of bright area (in droop region) vs. LED size.

Table 1
EL optical photographs of LEDs at various current densities.

LED size	Near onset of light emission	Near maximum efficiency	Droop region
500*500µm²			
200*200µm²			
100*100µm²			
50*50µm²			
20*20µm²			
15*15µm²			
10*10µm²	Below sensitivity of CCD camera		

III-N Micro emitter arrays

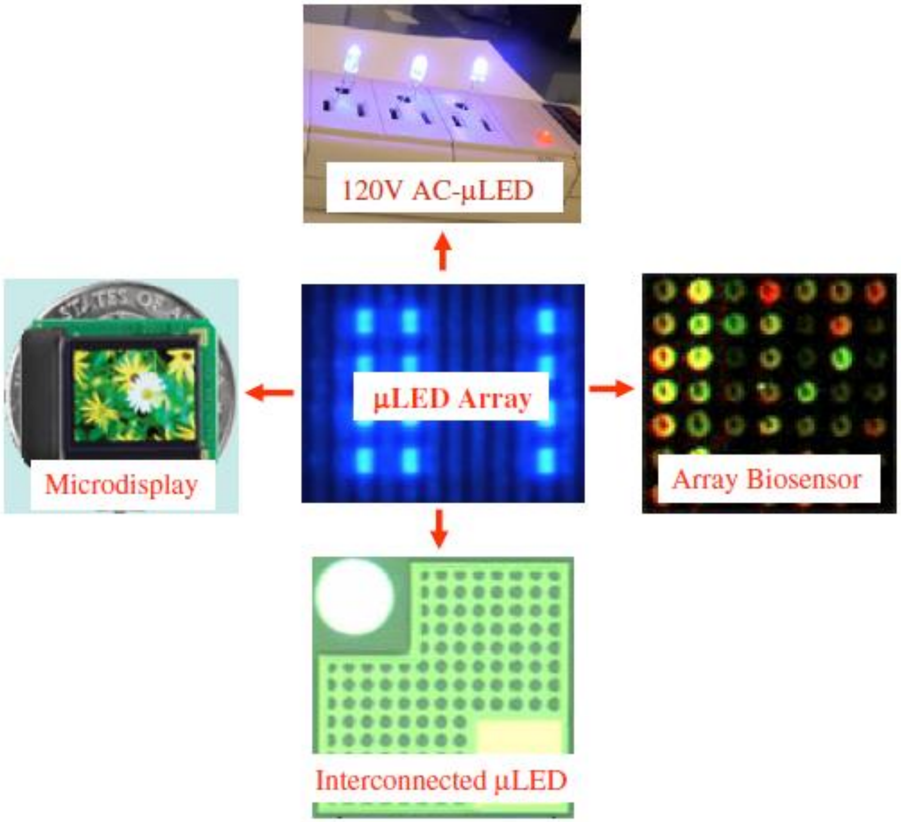


Figure 1. New devices evolved from III-nitride μ-emitter array technology, including single-chip ac-LEDs that can be plugged directly into standard high ac voltage power outlets, parallel interconnected μLEDs for boosting the extraction efficiency of LEDs, matrix addressable μLED array for emissive microdisplays and III-nitride μLED array based biosensors.

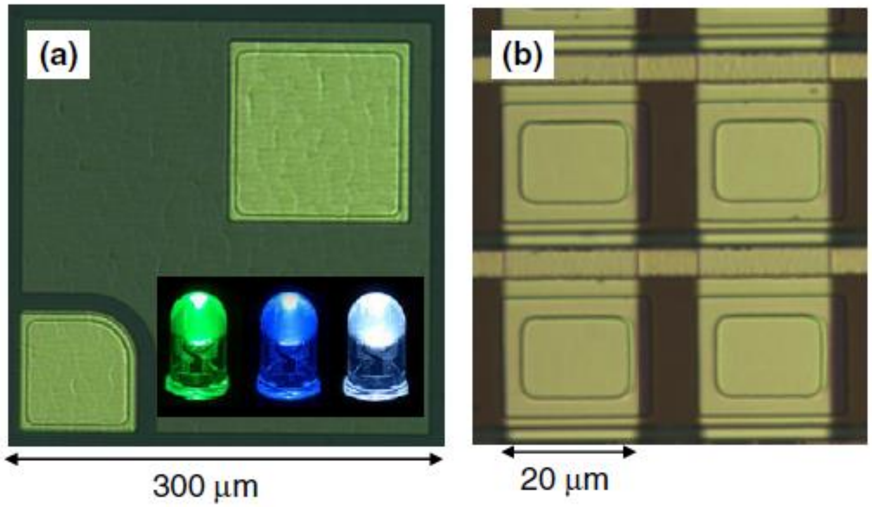


Figure 2. Comparison of conventional LEDs and μLEDs. Microscope images of (*a*) a conventional broad-area LED with a device size of 300 μm × 300 μm (inset shows the encapsulated LED lamps) and several μLEDs with a device size of 20 μm × 20 μm fabricated by the authors' group.

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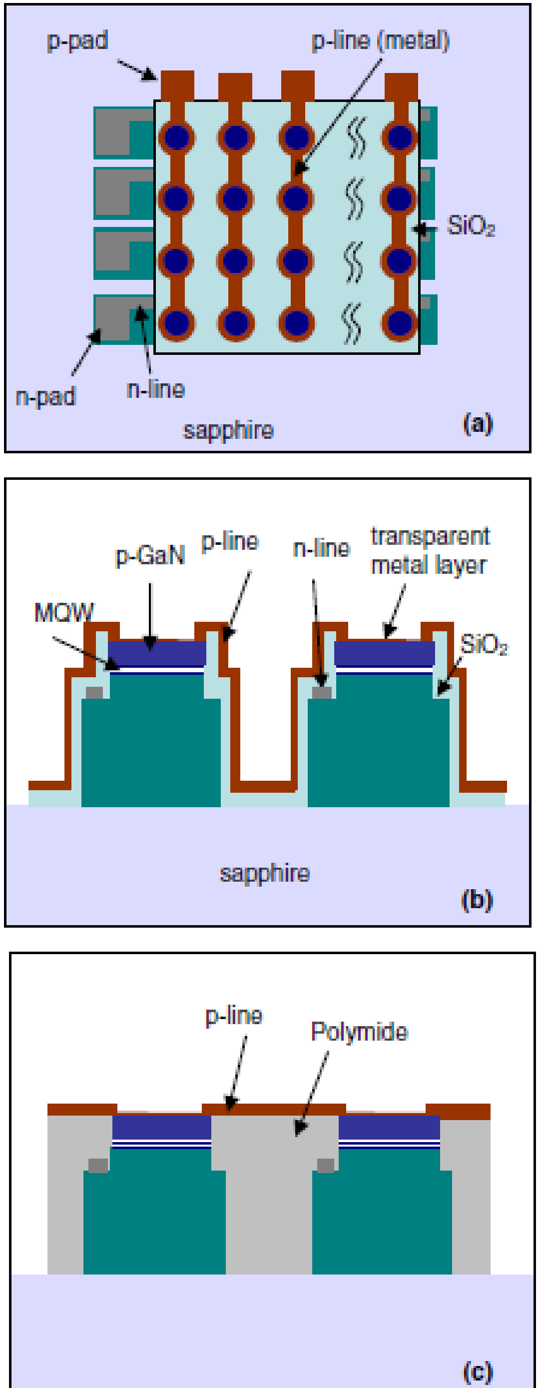
Microdisplay device



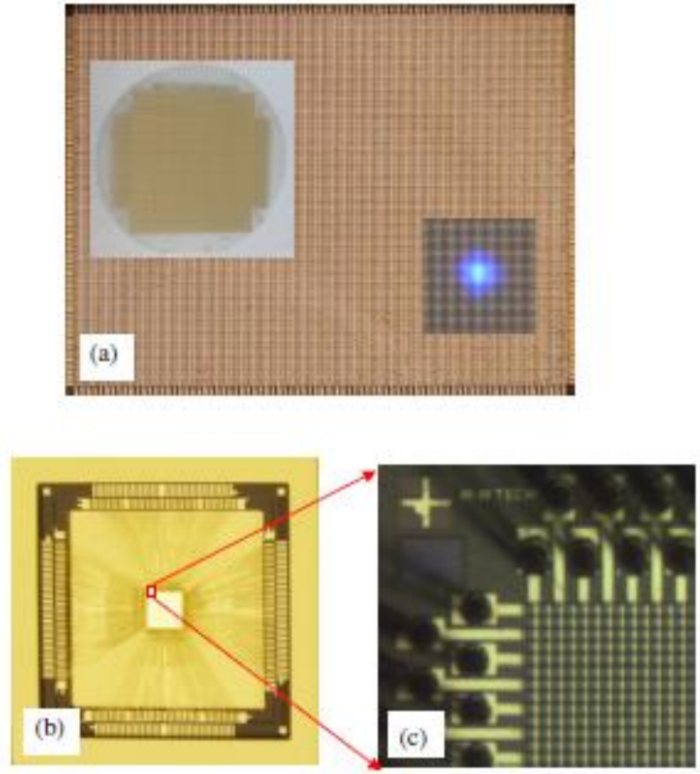


Figure 8. Microscope images of a (*a*) 160 × 120 microdisplay fabricated by the authors with inset showing the processed 2 in. wafer and one pixel turned on, (*b*) a 120 × 120 microdisplay device with a die size of 3.2 mm × 3.2 mm is encapsulated in the standard 281-pin PGA package and (*c*) the zoom-in image shows the device and wire bonding (courtesy: III-N Technology, Inc.).

Figure 7. (*a*) The top view and (*b*) the cross-section view of the schematic diagrams of the passive-driven microdisplay. (*c*) The cross-section view after surface planarization.

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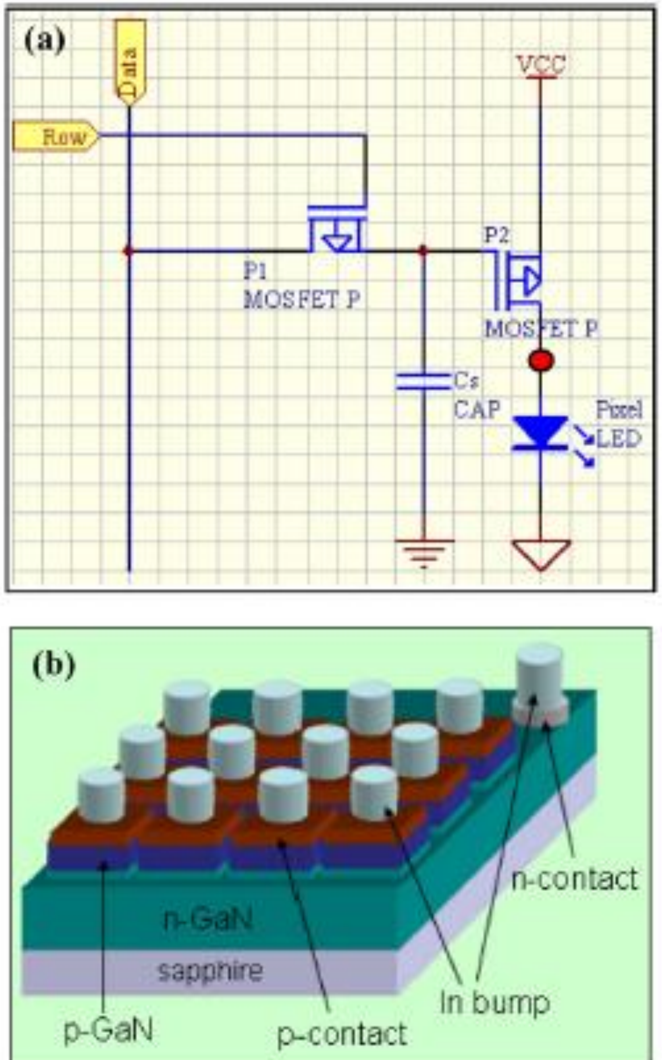
Active driven Micro LED array



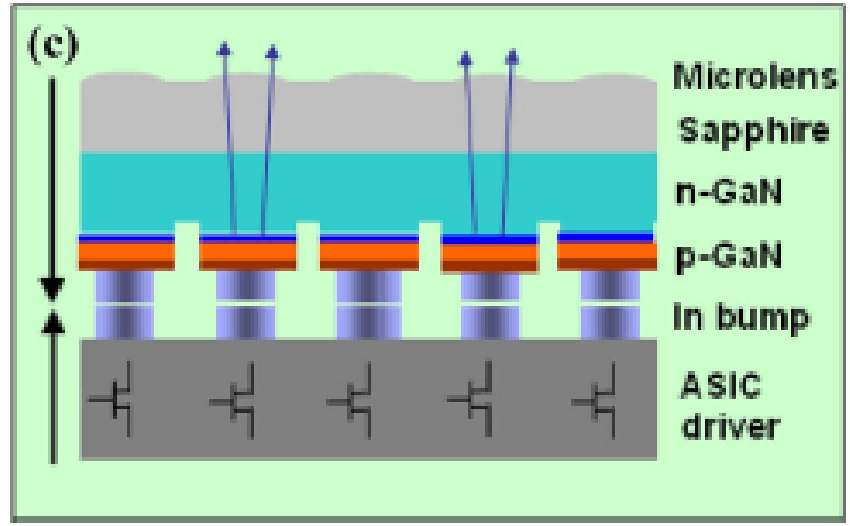


Figure 12. (*a*) Circuit schematic of an active driving unit cell. (*b*) The structure of a μLED array for active driving. (*c*) Integration of a μLED array with Si IC by flip–chip bonding for active driving.

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The fabrication steps of a vertically-stacked passive-matrix micro-LED array

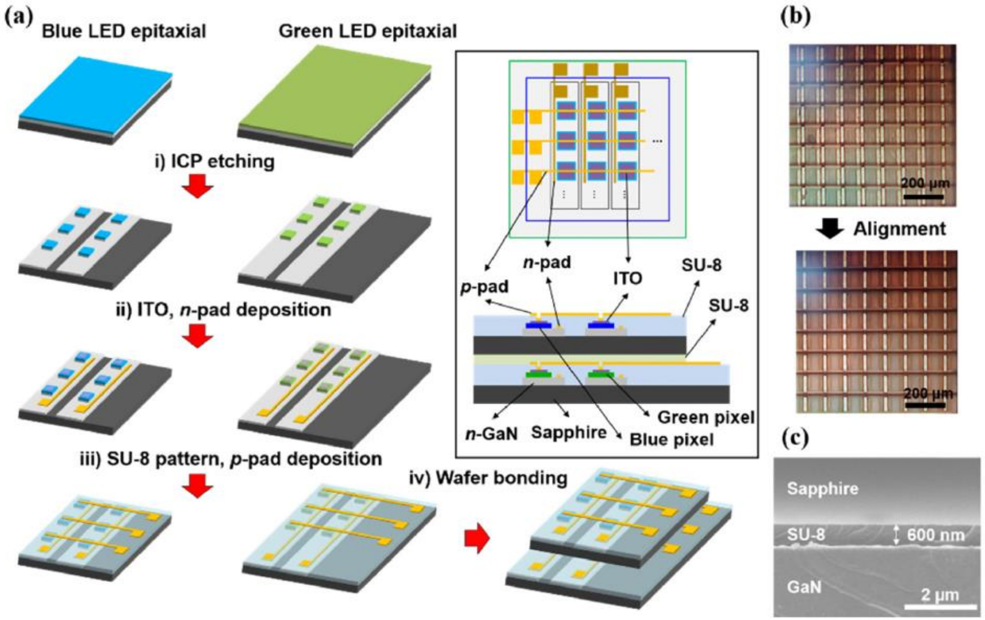
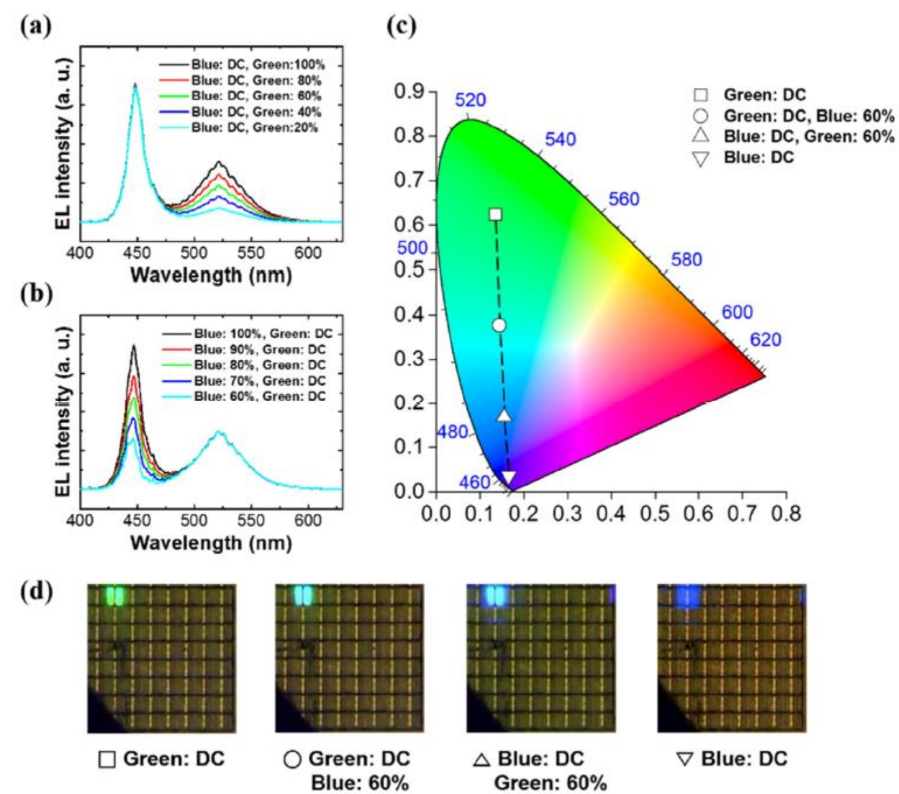


Fig. 1. (a) The fabrication steps of a vertically-stacked passive-matrix micro-LED array: i) ICP etching of GaN for the formation of the row and all pixels of the micro-LED array, ii) deposition of ITO on *p*-GaN, deposition of Ti/Au layers on *n*-GaN, iii) SU-8 pattern for isolation between metal electrodes, deposition of Cr/Au layers, iv) wafer bonding of the blue and the green LED chip. (b) Microscopy images before (top) and after (bottom) alignment of the blue LED chip stacked on green LED chip. (c) SEM image of the cross-sectional interface between the blue and the green LED chip.



$$Duty\,ratio = \frac{t_{on}}{t_{on} + t_{off}}$$

The duty ratio is defined as the percentage of one period in which a signal is active, where t_{on} and t_{off} are the duration in which a signal is active and non-active, respectively.

Micro LED arrays

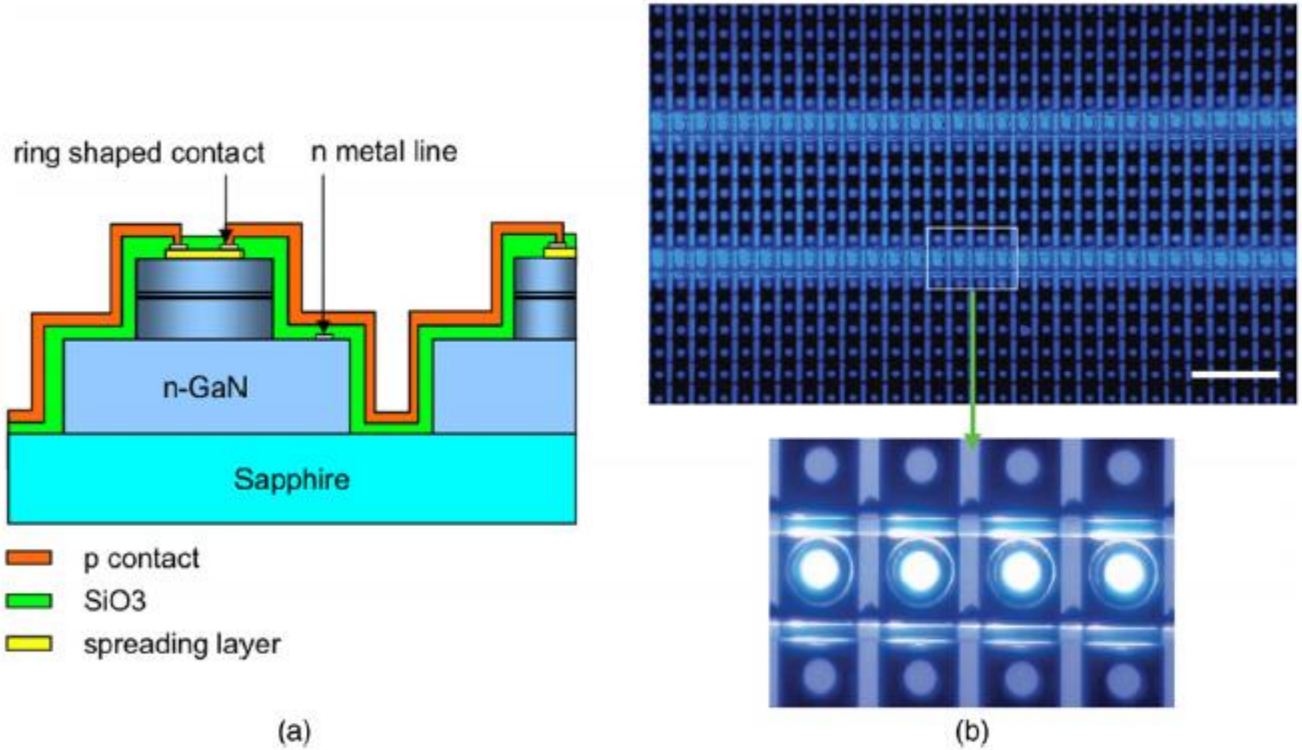


Figure 1. (*a*) Cross-section of a second generation matrix addressable LED array. (*b*) Microscope image of a blue 64 × 64 matrix LED where two rows of LEDs are turned on. The scale on the top image is 200 μm.

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Micro LED arrays

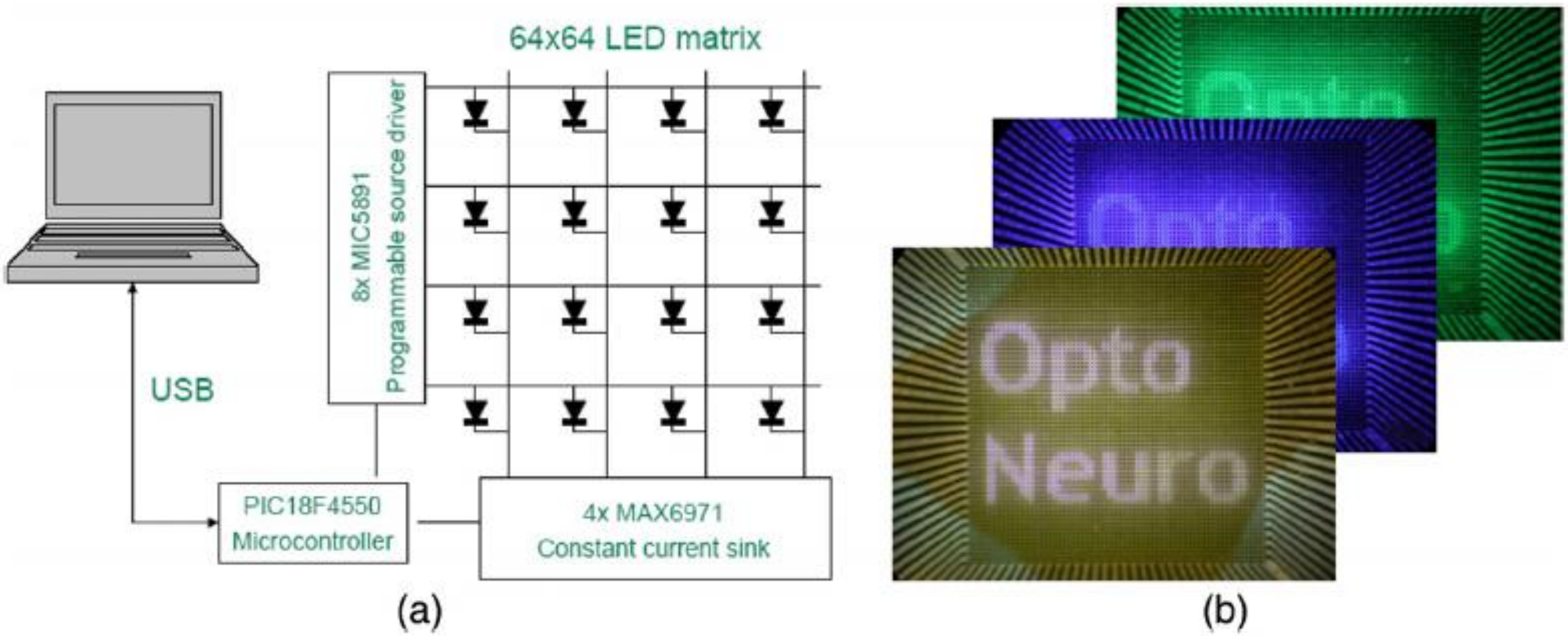

Figure 2. (*a*) Schematics of the matrix LED driver. (*b*) 'Opto Neuro' pattern being displayed on a UV, blue and green micro-LED array.

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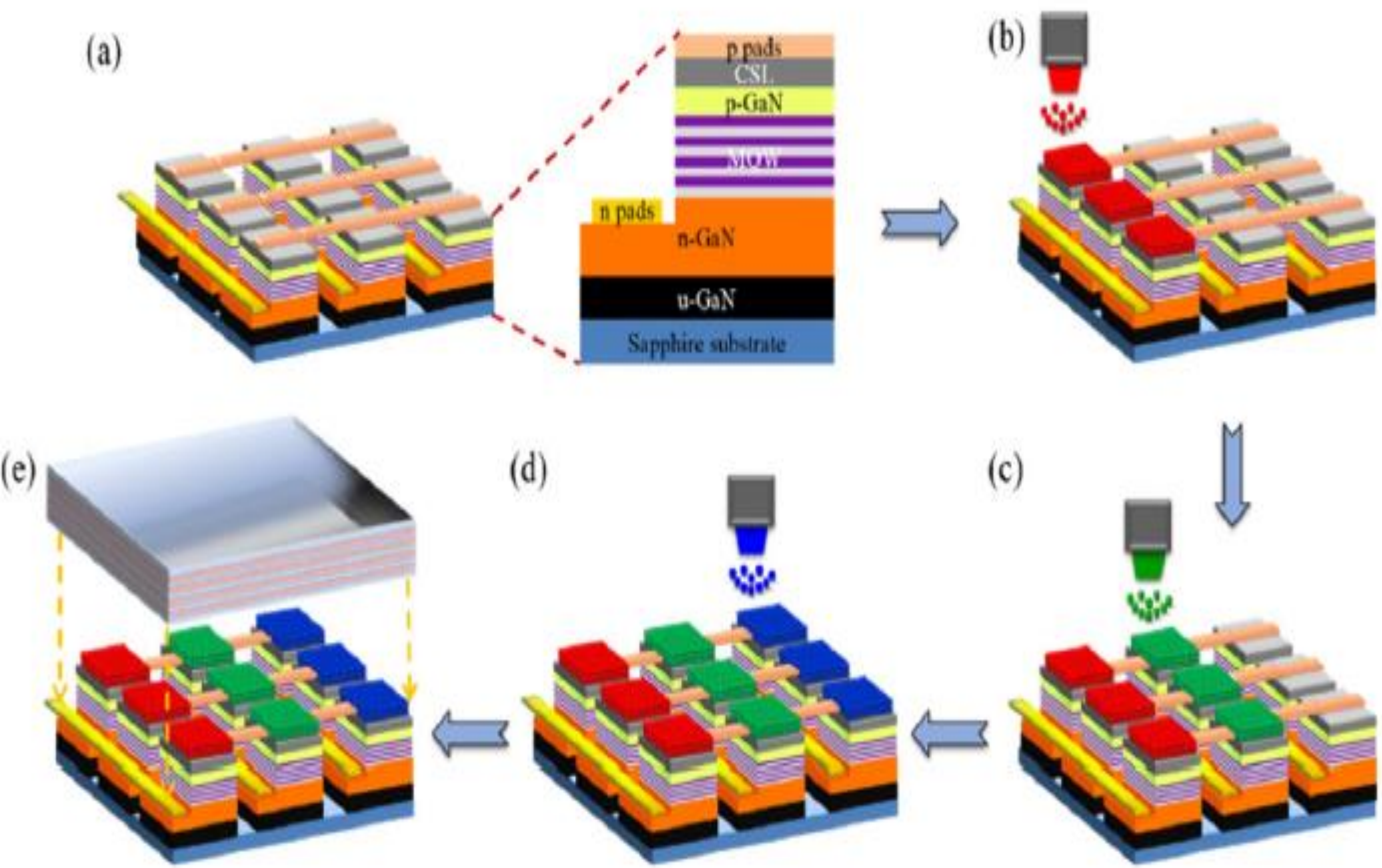
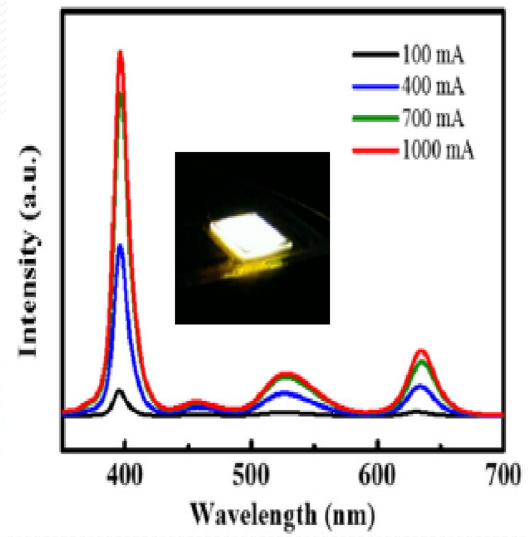
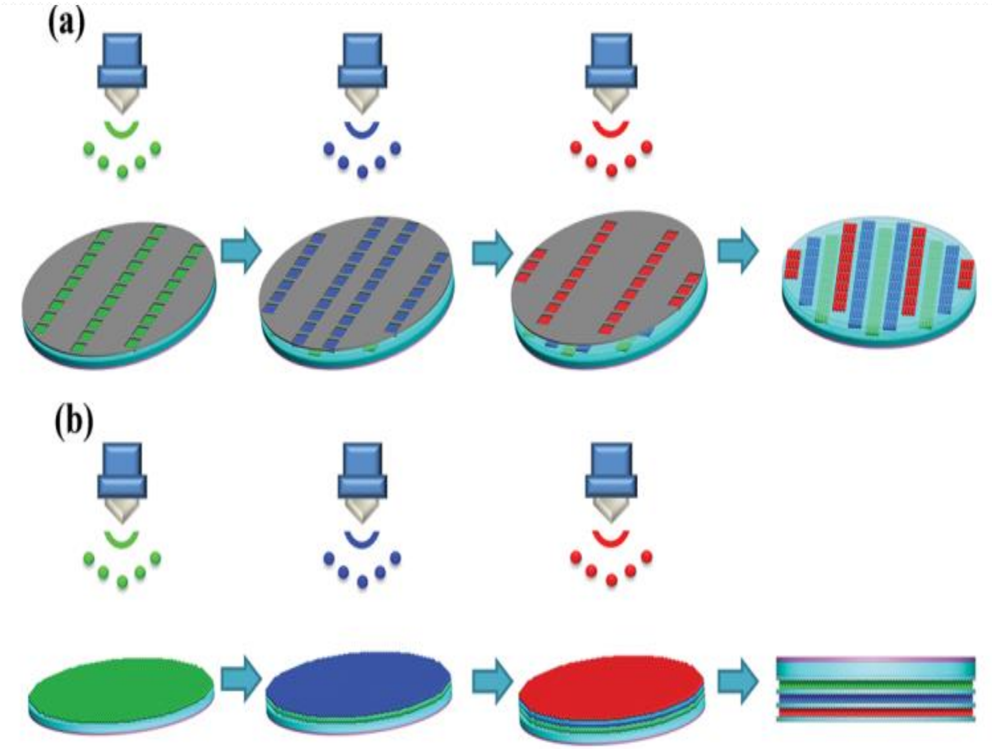
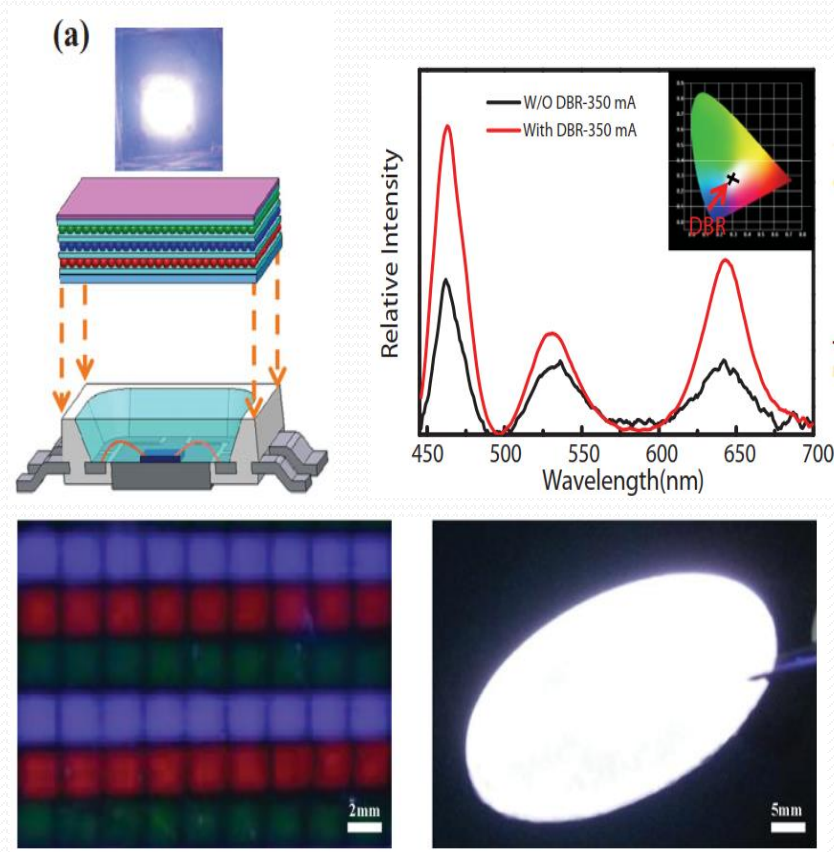
Resonant-enhanced full-color emission of quantum-dot-based micro led display technology





Resonant-enhanced full-color emission of quantum-dot-based display technology using a pulsed spray method





1) 11-pair HfO_2/SiO_2 DBR on glass
2) Mask
3) RGB QDs
4) R/G/B, PDMS

Adv. Funct. Mater. **2012**, DOI: 10.1002/adfm.201200765

Full-colour quantum dot displays fabricated by transfer printing

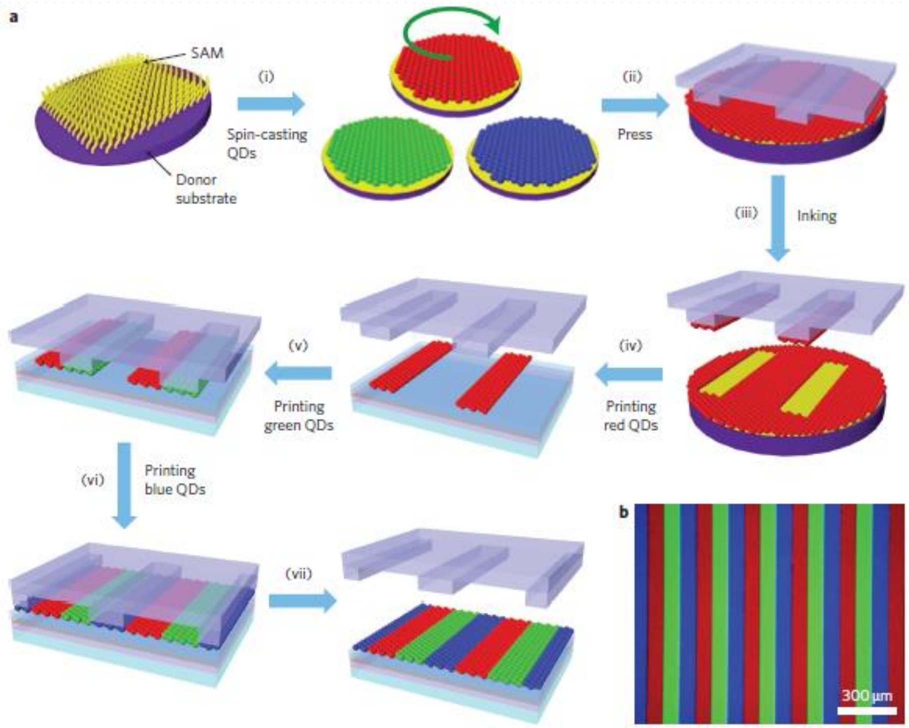
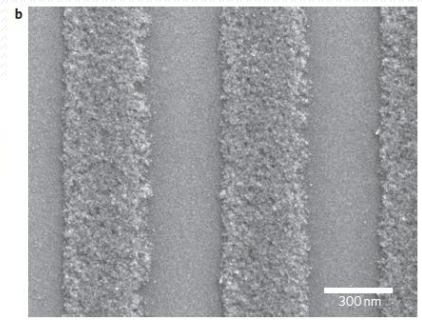
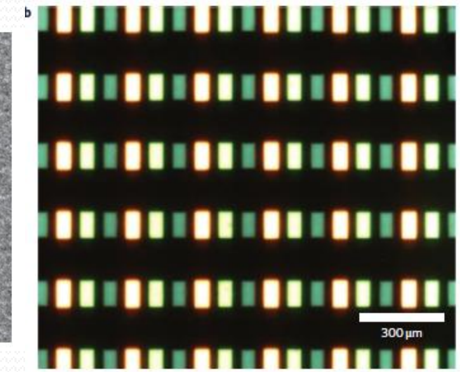


Figure 1 | Schematic illustration of solvent-free transfer printing. a, Schematic of transfer printing process for patterning of quantum dots. The first step of the process begins with surface modification of the donor substrate by the introduction of a chemically bound SAM. After printing the red-emissive QDs, green- and blue-emissive QDs are printed by the same process, with precision alignment. (i) Modification of the donor surface with SAM, and spin-coating of QDs. (ii) Application of an elastomer stamp to the QD film with appropriate pressure. (iii) Peeling of the stamp, quickly, from the donor substrate. (iv) Contacting the inked stamp to the device stack, and slowly peeling back the stamp. (v)–(vii) Sequential transfer printing of green and blue QDs. **b,** Fluorescence micrograph of the transfer-printed RGB QD stripes onto the glass substrate, excited by 365 nm UV radiation.





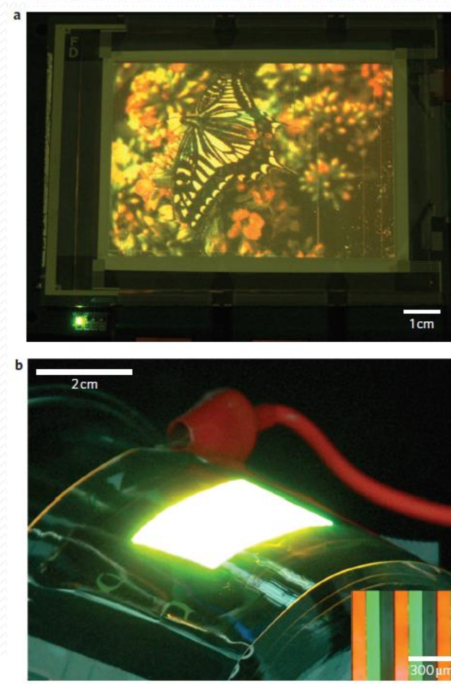


Figure 5 | Full-colour QD display and its flexible form.

Mini/Micro LED 應用與趨勢

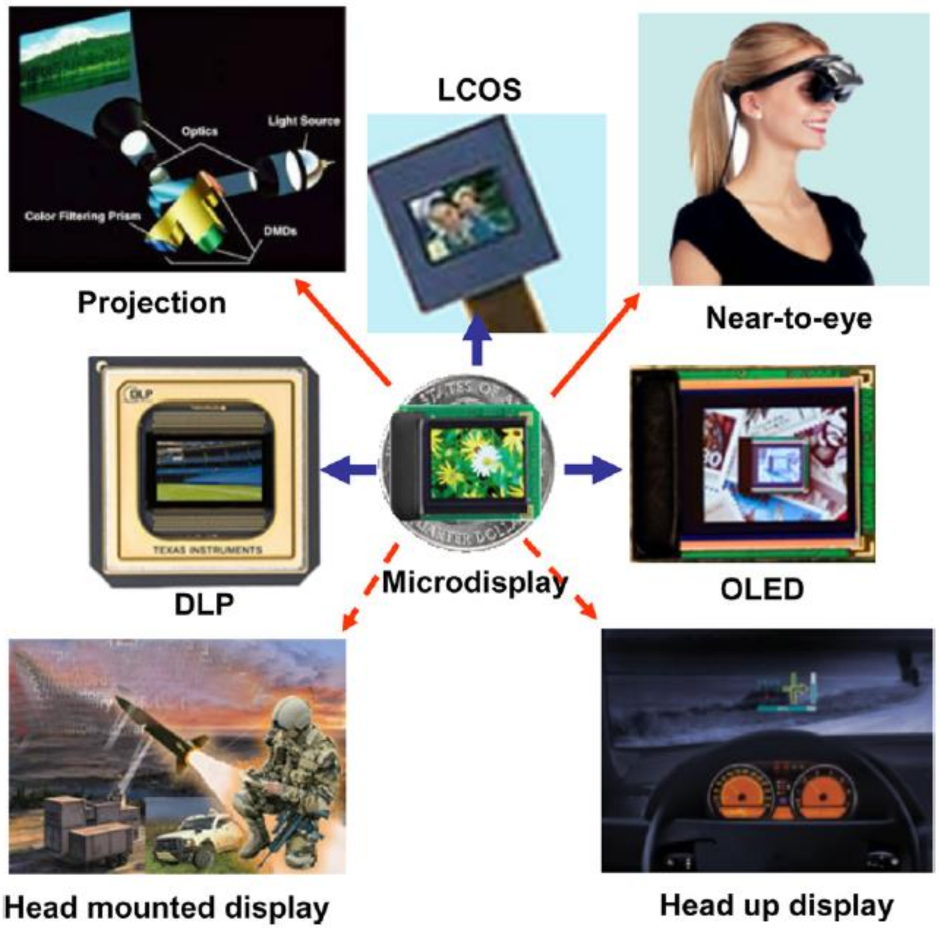


Figure 6. Coin-size microdisplays have two categories of applications: projection or near-to-eyes. The current technologies are based on LCOS, DLP and OLED, and all of them have limitations in brightness, efficiency and robustness, especially for applications such as head-up displays used in a car running under sunlight, or head-mounted displays used in the extreme condition of field applications (Image sources: http://www.ti.com, http://www.emagin.com, http://www.siemensvdo.com).

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