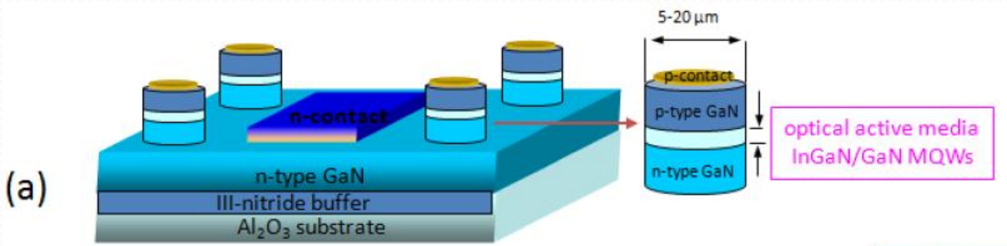
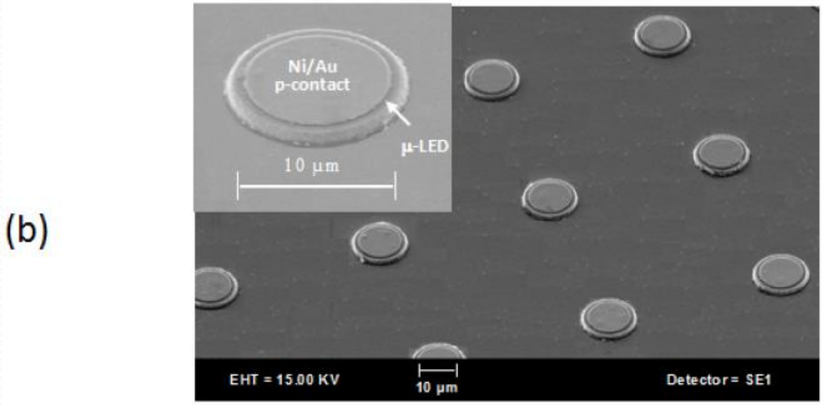
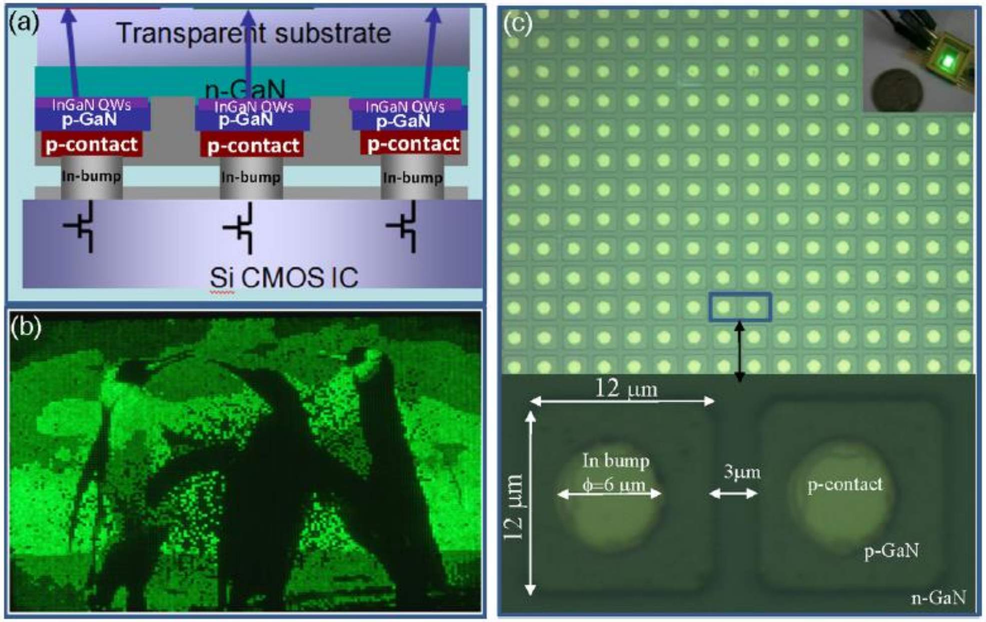
III-Nitride full-scale high-resolution microdisplays







Appl. Phys. Lett. 99, 031116 (2011)

Micro LED based full scale high-resolution microdisplays

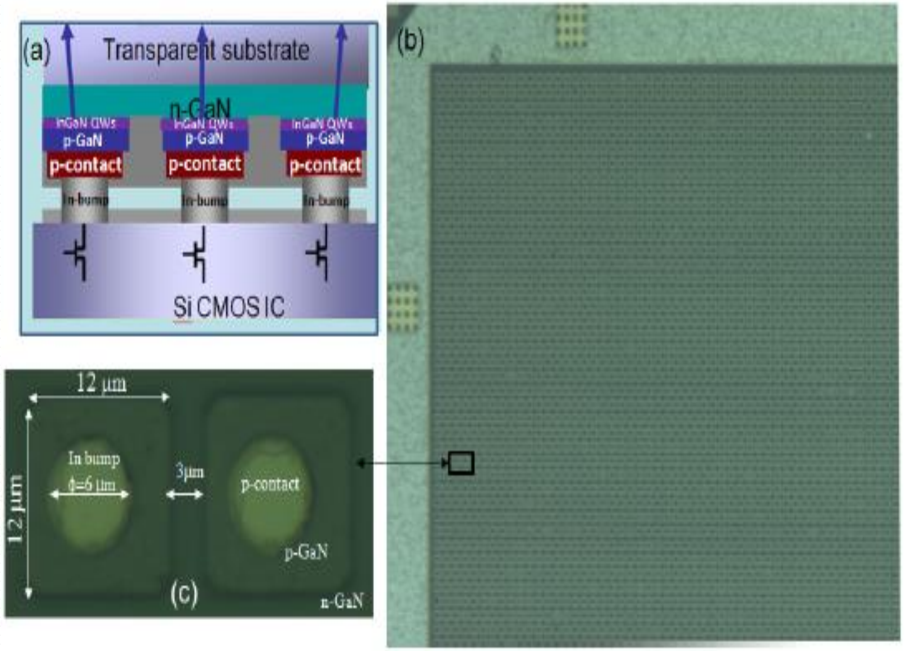


Fig. 5. (a) Illustration of flip-chip bonding between µLED matrix array and CMOS driver IC via indium bumps to form a highly integrated microdisplay in one package. (b) Optical microscopy image of a full scale (640 x 480 pixels) InGaN µLED array. (c) The zoom-in image of a flip-chip bonded package with µLED pixels and indium bumps viewed from the transparent sapphire side (after Ref. [14]).

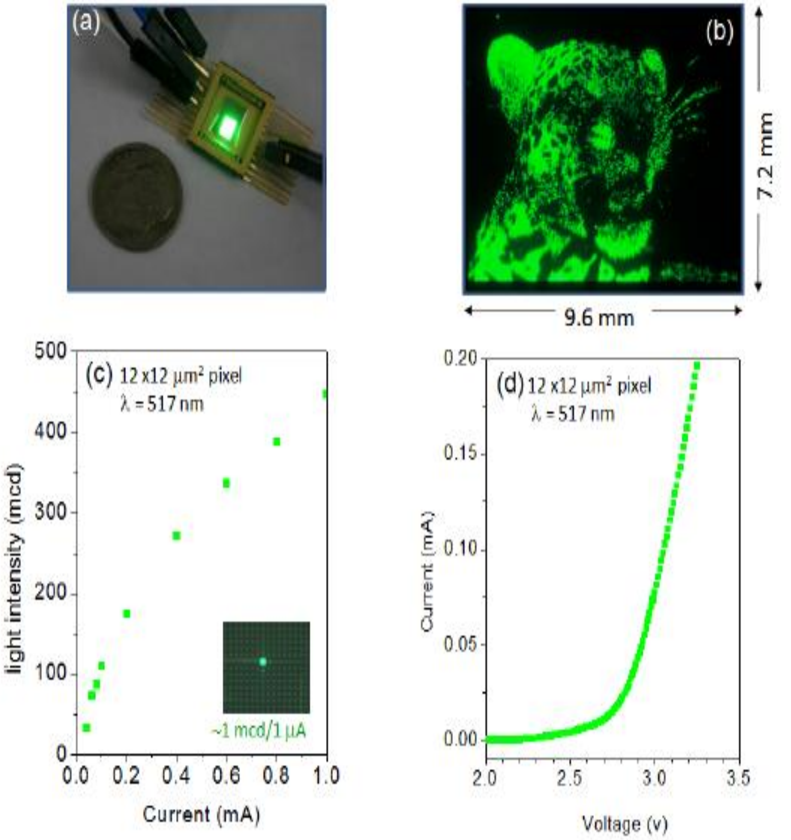


Fig. 6. Demonstration of an III-nitride self-emissive µdisplay. (a) A fully assembled InGaN µdisplay operating at a driving current of about 1 µA per pixel. (b) A grayscale projected image of a leopard from a green VGA InGaN microdisplay (having 640 x 480 pixel with a pixel size of 12 µm and a pitch distance of 15 µm) operating at a driving current of 1 µA per pixel. (c) L-I characteristic of a green µLED pixel. (d) I-V characteristic of a green µLED pixel (after Ref. 14).

OSA , Vol. 21, No. S3,2013

Micro-led arrays: a tool for two-dimensional neuron stimulation

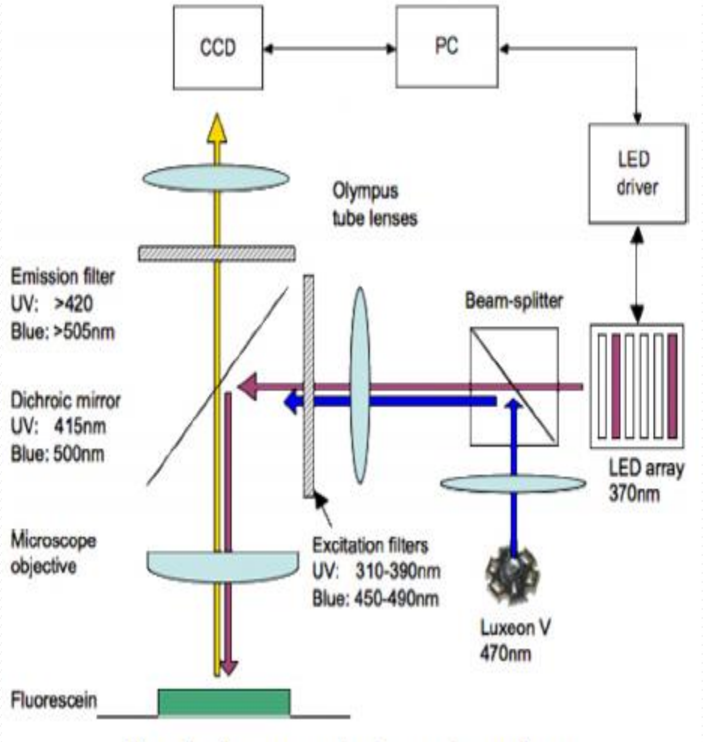
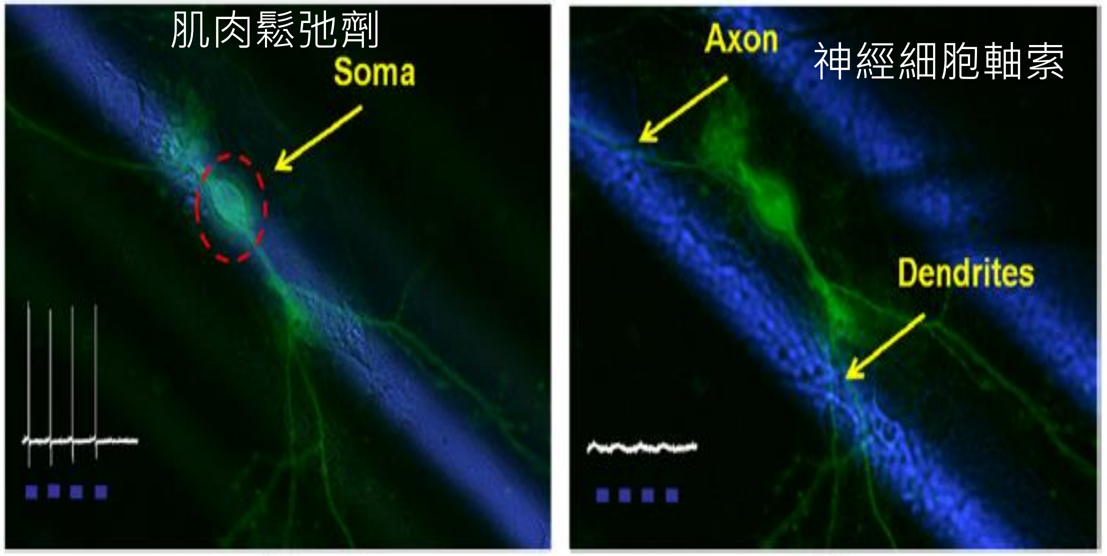


Figure 4. Microscope setup for photo-uncaging experiment.

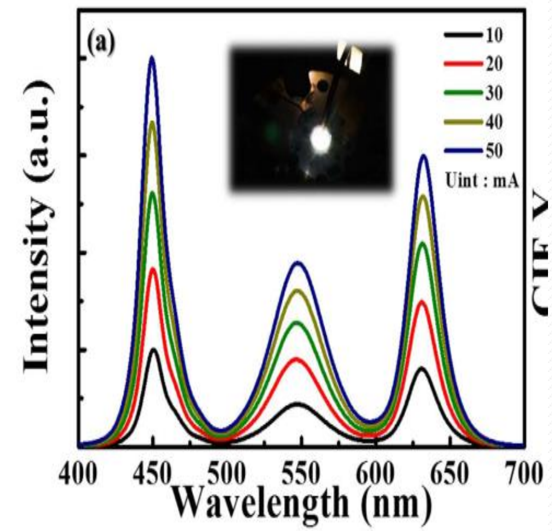


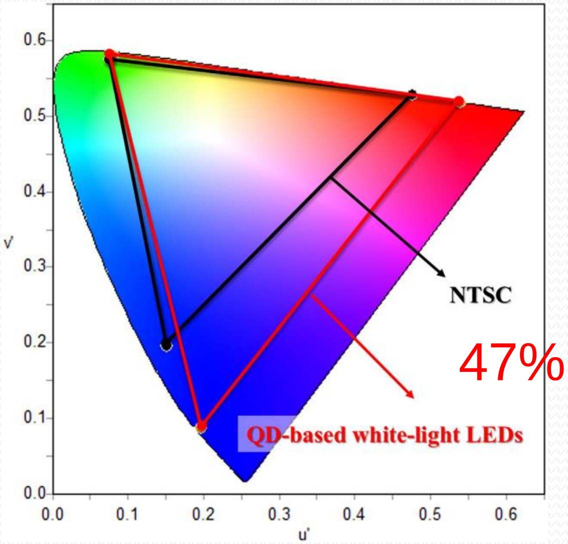
(a) (b)

Photostimulation of ChR2 transfected neuron using micro-LED array. (*a*) Somatic pulsed illumination result in corresponding spike train. (*b*) Illumination with neighbouring stripes has little effect on cell depolarization.

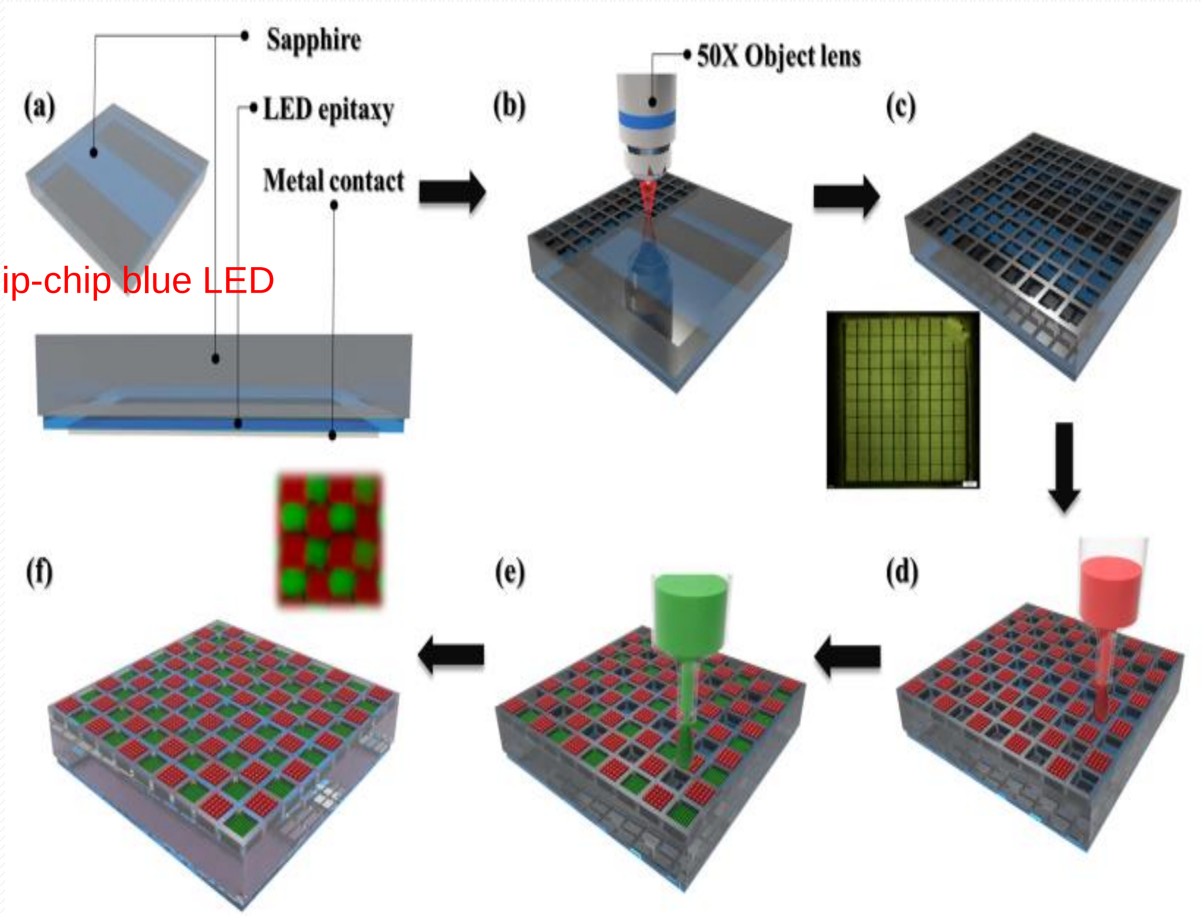
J. Phys. D: Appl. Phys. **41** (2008) 094014 (9pp)

Pulsed-laser micropatterned quantum-dot array for white light source





47%



Flip-chip blue LED

Scientific **Reports** | 6:23563 | DOI: 10.1038/srep23563

Flexible and Bio Applications

Fabrication, characterization and applications of flexible vertical InGaN micro-light emitting diode arrays

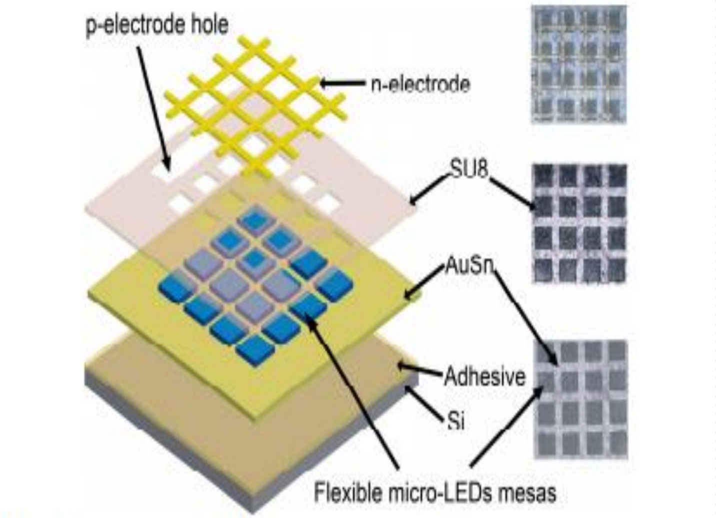


Fig. 1. In the left frame are illustrations of processing steps for fabricating flexible micro-LEDs. In the right frame are the microphotographs of flexible micro-LEDs during fabrication. Bottom: etched flexible micro-LED mesas. Middle: patterned SU8 as the isolation layer for *p*-pad and *n*-pad. Top: deposited Ti/Al/Ti/Au to form interconnected electrodes of flexible micro-LEDs array. The flexible micro-LED pixel size is 140 μm.

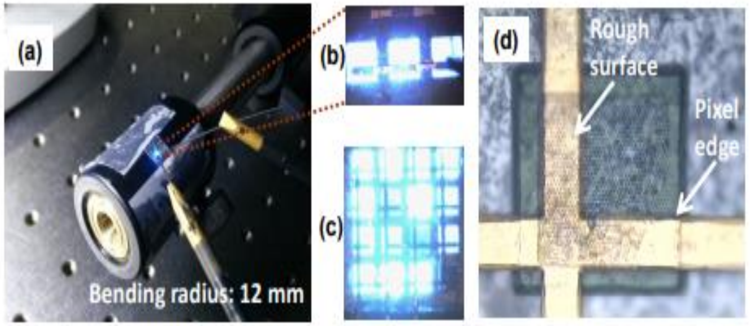


Fig. 5. (a) Typical optical image of probing interconnected flexible micro-LED pixels on a column with a bending radius 12 mm. Light emission of (b) a row and (c) a 4 × 4 array of flexible micro-LEDs. (d) Enlarged image of the interconnected metal track on a flexible micro-LED. The flexible micro-LED pixel size is 140 μm.

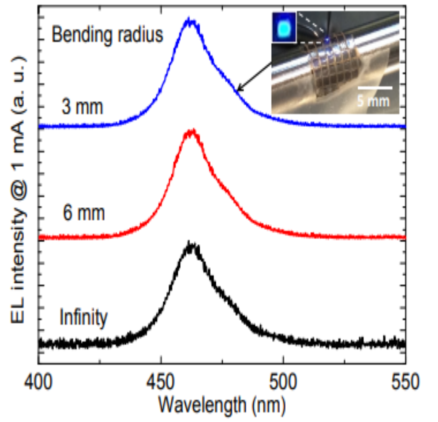


Fig. 3. Experimentally measured EL spectra of flexible micro-LEDs at 1 mA with substrate bending radii of infinity, 6 mm, and 3 mm, respectively. Inset: optical images of probing a flexible micro-LED pixel under a bending radius 3 mm. The pixel size is 140 μm.

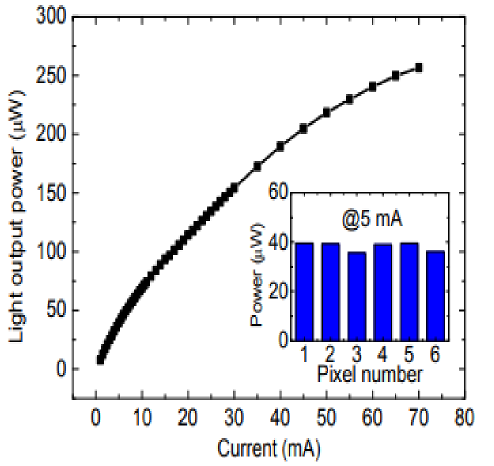
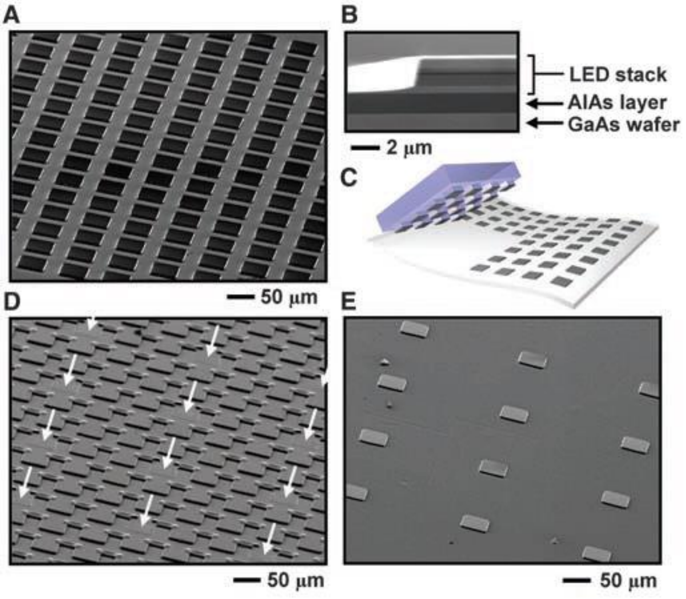


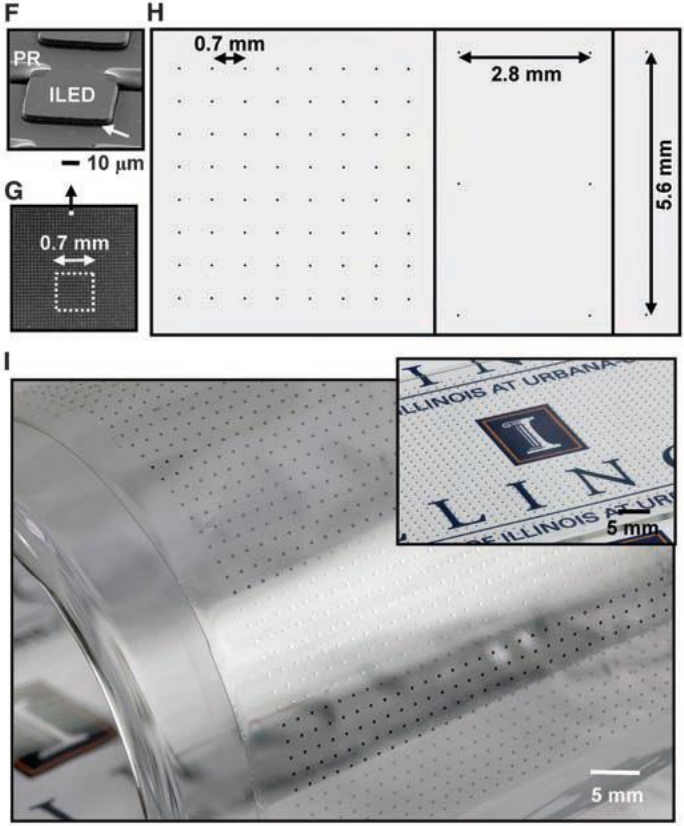
Fig. 4. *L-I* characteristics of a typical flexible micro-LED on a column with a bending radius 6 mm. Inset: light output power at 5 mA for 6 randomly picked pixels.

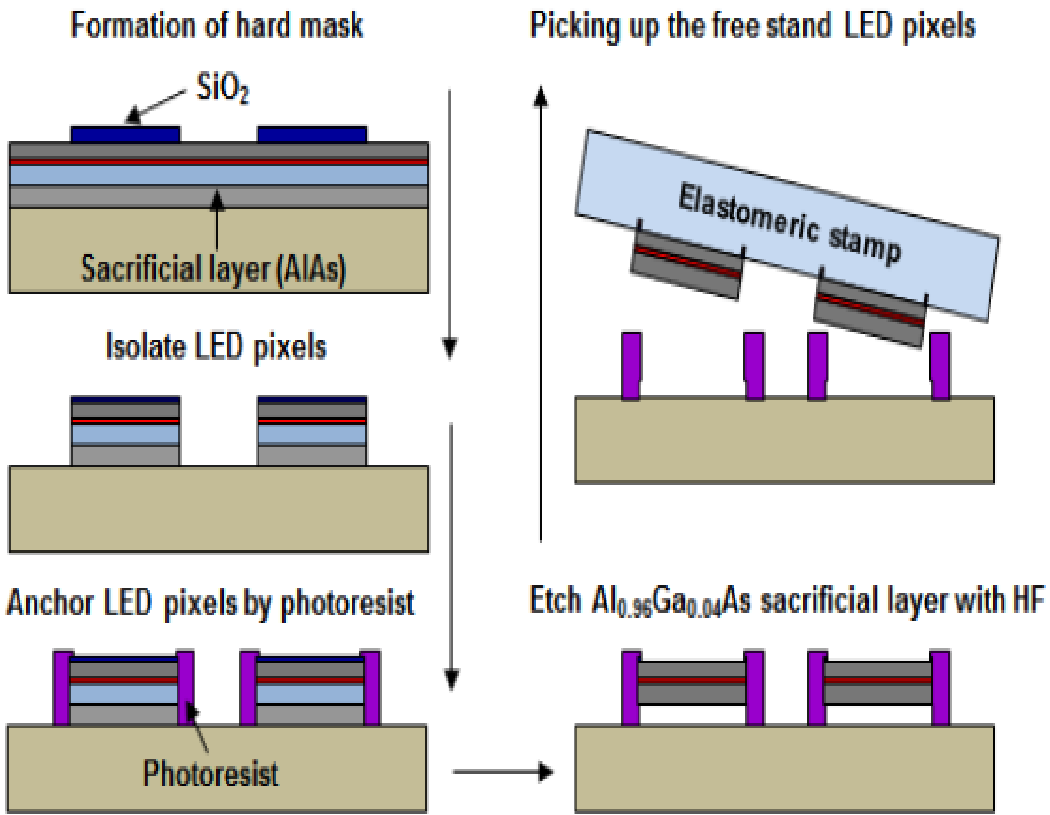
11 Jan 2016 | Vol. 24, No. 1 | DOI:10.1364/OE.24.000699 | OPTICS EXPRESS

Processing steps for retrieving Micro LEDs from a GaAs source wafer



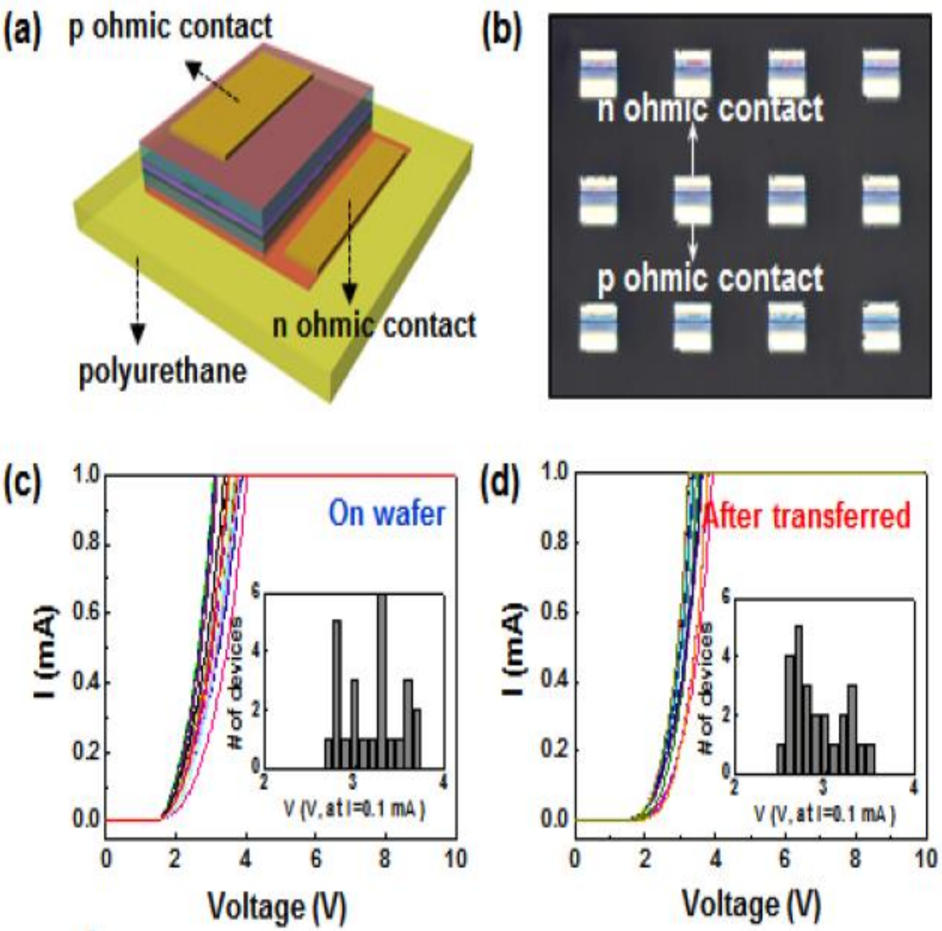
Chip size=50 µm





Science, **2009**, 325. 977-981.

Micro-ILED with ohmic metal contacts that is transfer printed on a foreign substrate



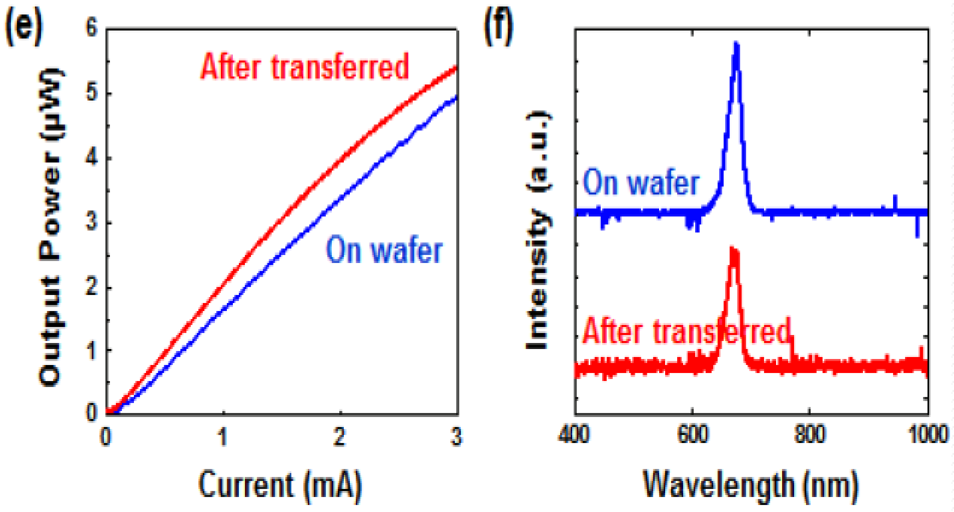
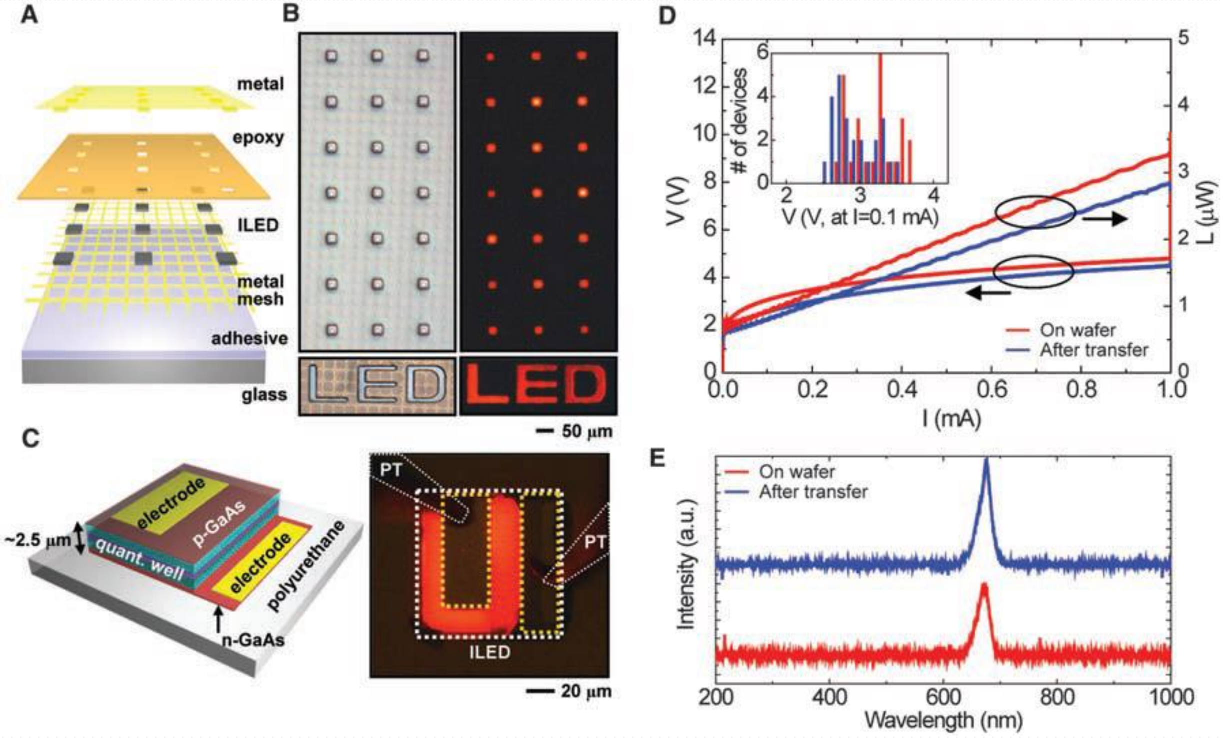
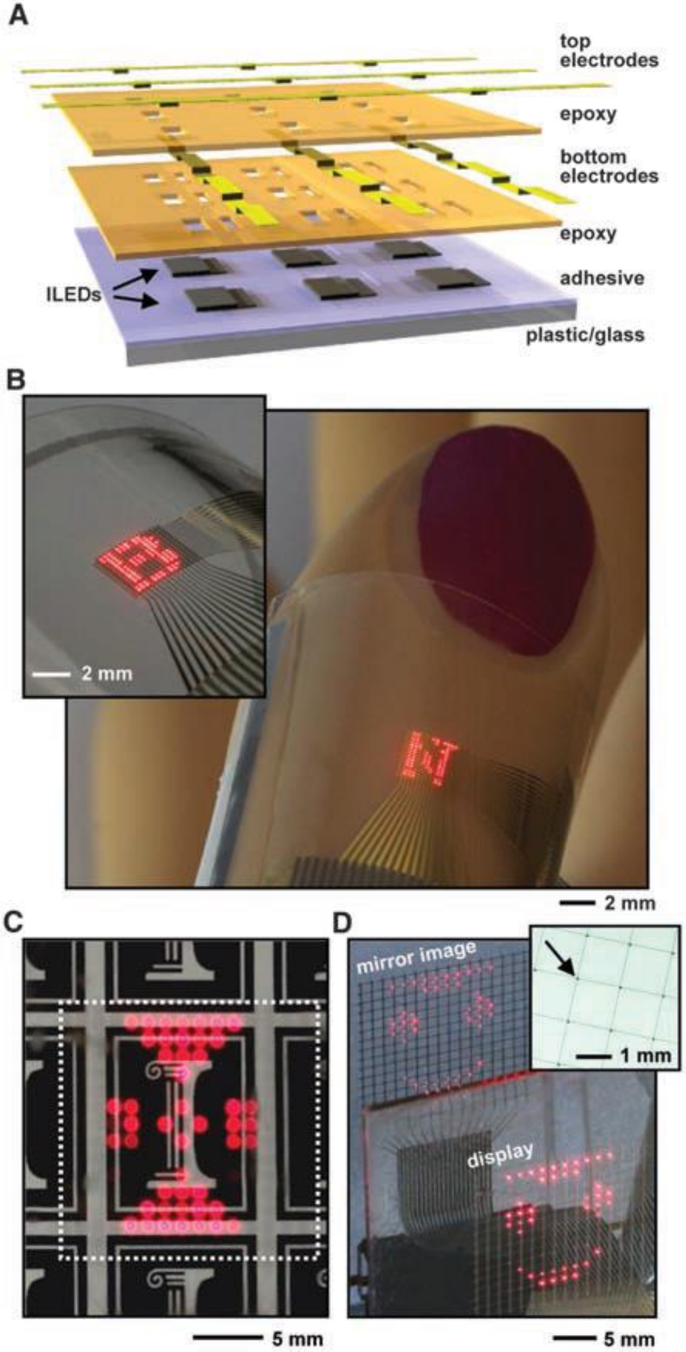


Figure2.7(a) Schematic illustration of the representative micro-ILED with ohmic metal contacts that is transfer printed on a foreign substrate. (b) Microscope image of a set of micro-ILED with ohmic metal contacts corresponding to Fig. 2.7(a).Current-voltage characteristics of 25 representative devices before undercut etching on the GaAs wafer (c), and after transfer printing onto an epoxy coated glass substrate(d). (e) Current-emissioncharacteristics of before undercut etching on the GaAs wafer, and after transfer printing onto aepoxy coated glass substrate. (f) Spectral characteristics of emission for a typical device on awafer and after transfer printingcases.

Science, **2009**, 325. 977-981.

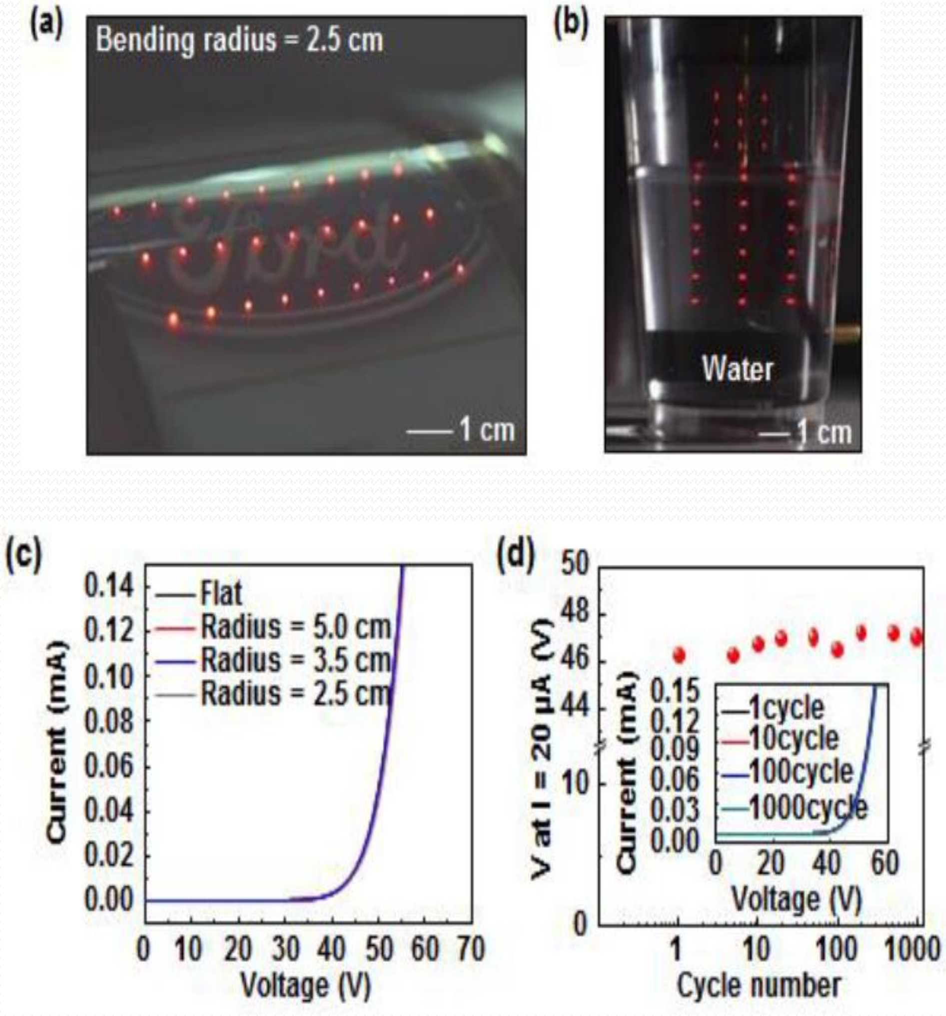
Printed Assemblies of Inorganic Light-Emitting Diodes for Deformable and Semitransparent Displays





Science, **2009**, 325. 977-981.

Micro-ILEDs on a sheet of plastic substratein



(a) Array of 3×9 micro-ILEDs on a sheet of plastic substratein its on-state. Focus are made on to logo, thereby revealing the semi-transparent property of the large area display system. (b) Same array wrapped around a plastic cup, indicatinghigh level of back side emissionfrom the array. (c) Current-voltage characteristics of this array (Fig. 2.11a) as a function of bending radius. (d) Fatigue test at bending radius of 2.5 cm.

Science, **2009**, 325. 977-981.

micro-ILEDs with graphene interconnects

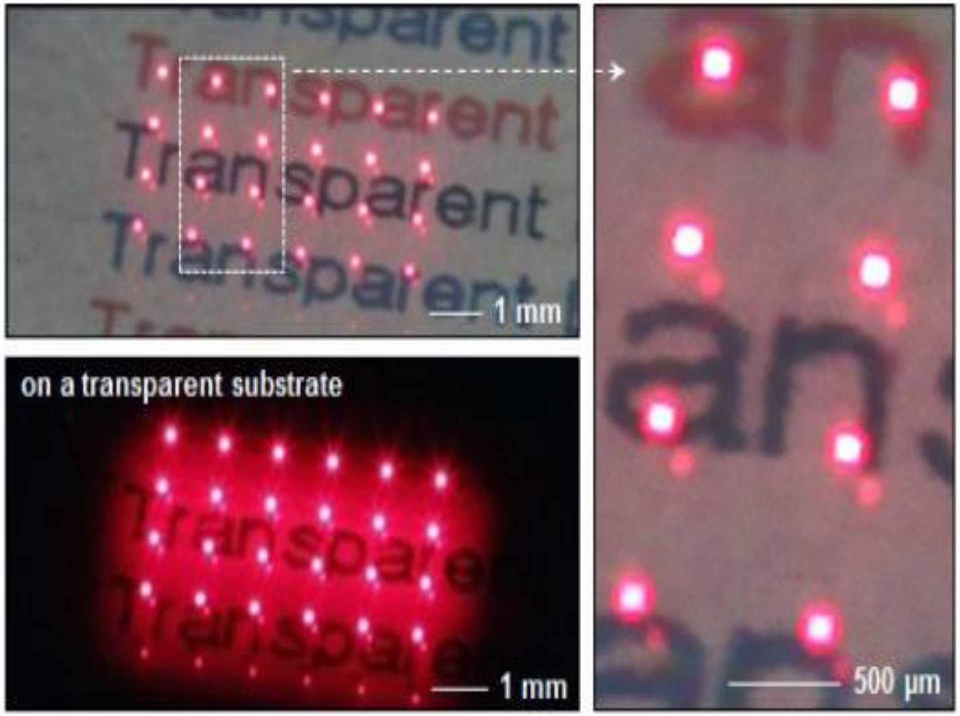
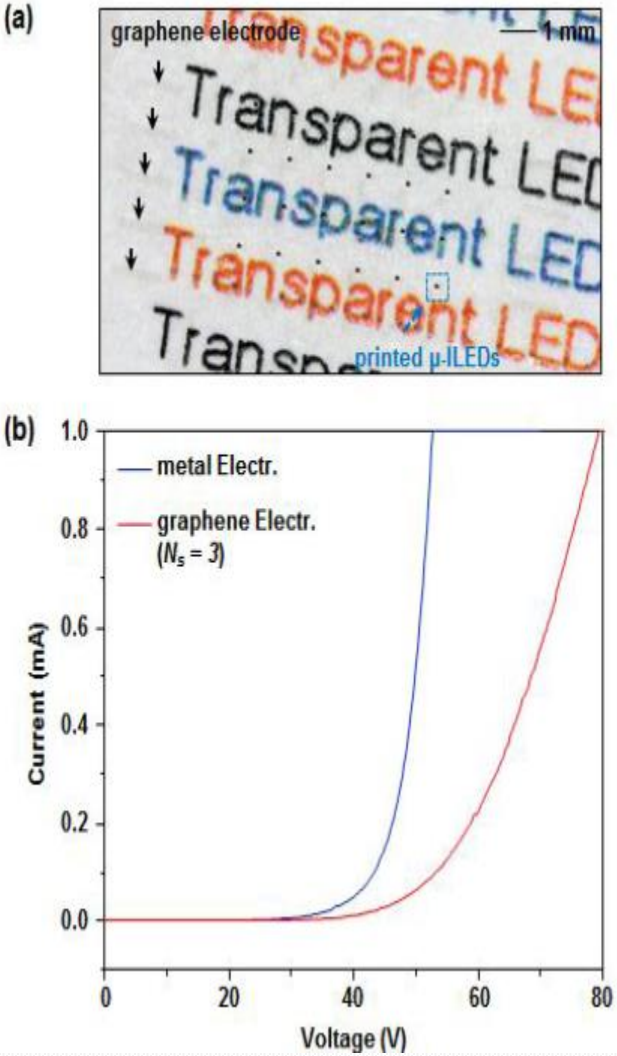
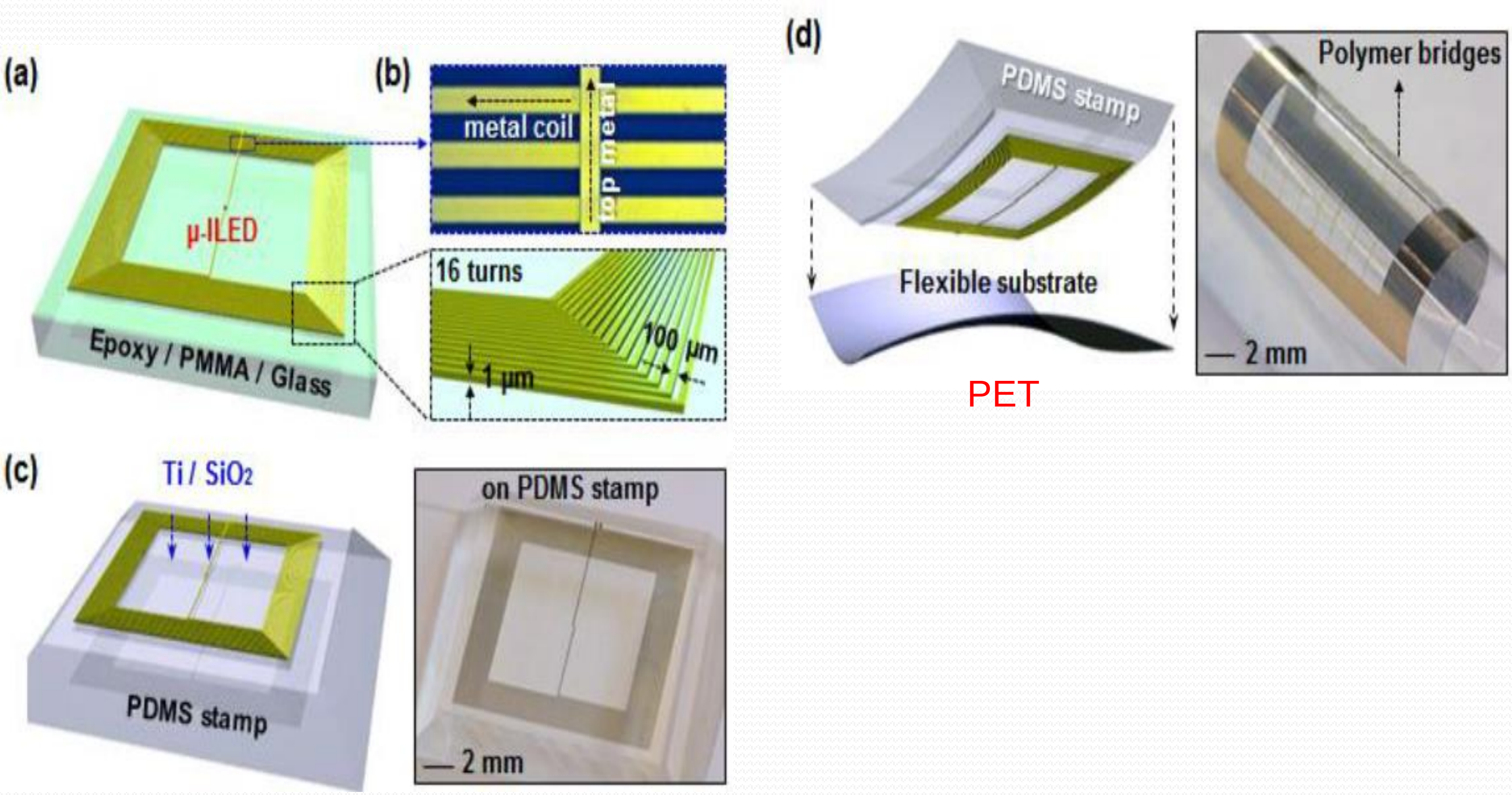


Figure 5.11 Photographs of an array of 4×6 μ-ILEDs with graphene interconnects, with (top) and without (bottom) external lighting. This device was formed on a glass substrate. The photograph in the right frame highlights the high level of transparency that is possible with graphene interconnects.



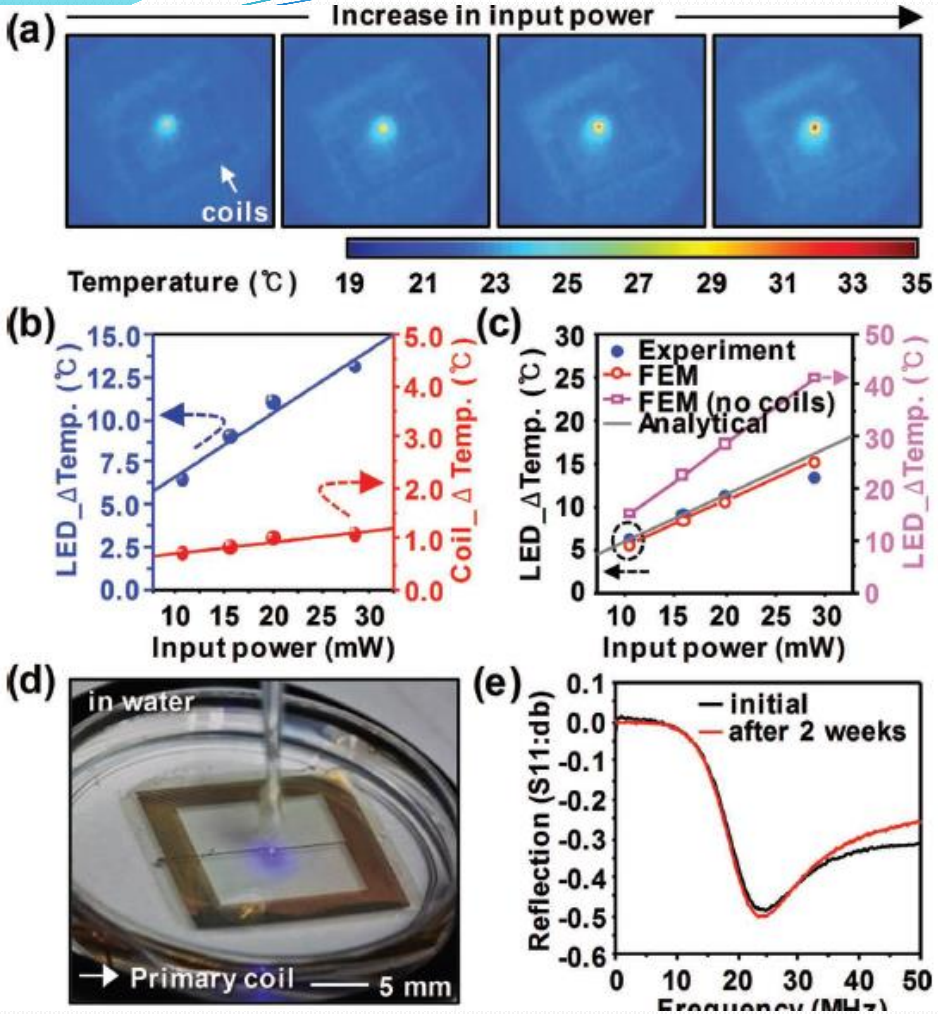
Nano Letters,**2011**, 11, 3881-3886.

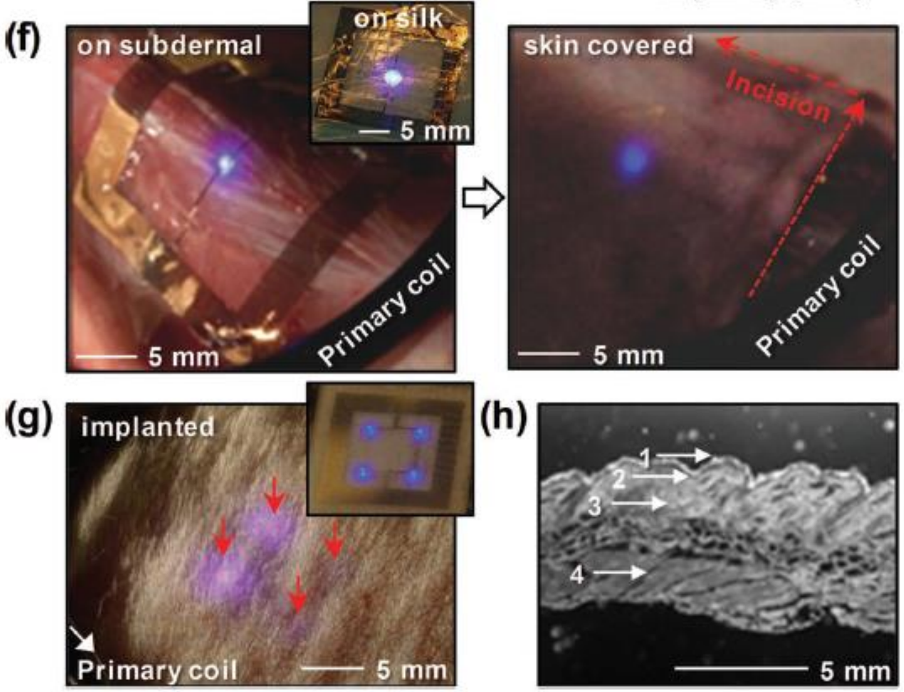
Wireless micro-ILED system on a temporary glass substrate coated with a bi-layer of epoxy / PMMA



PET

Small, 2012, 8, 2812-2818



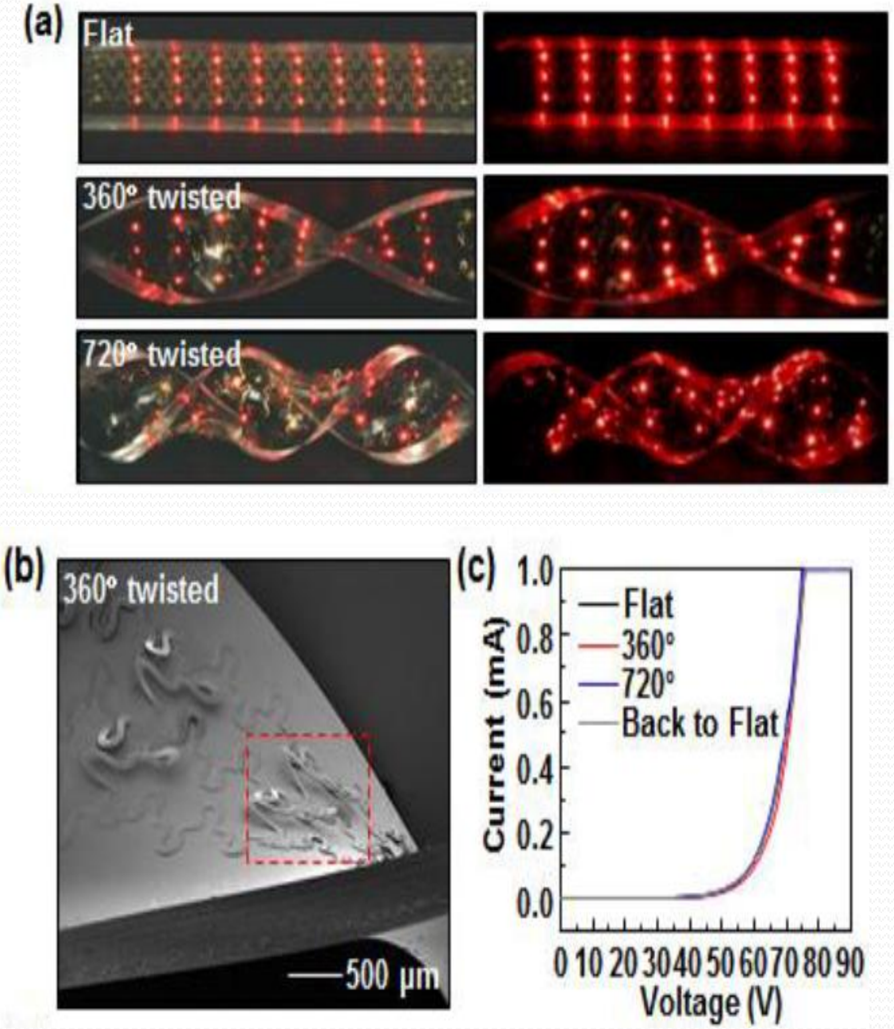


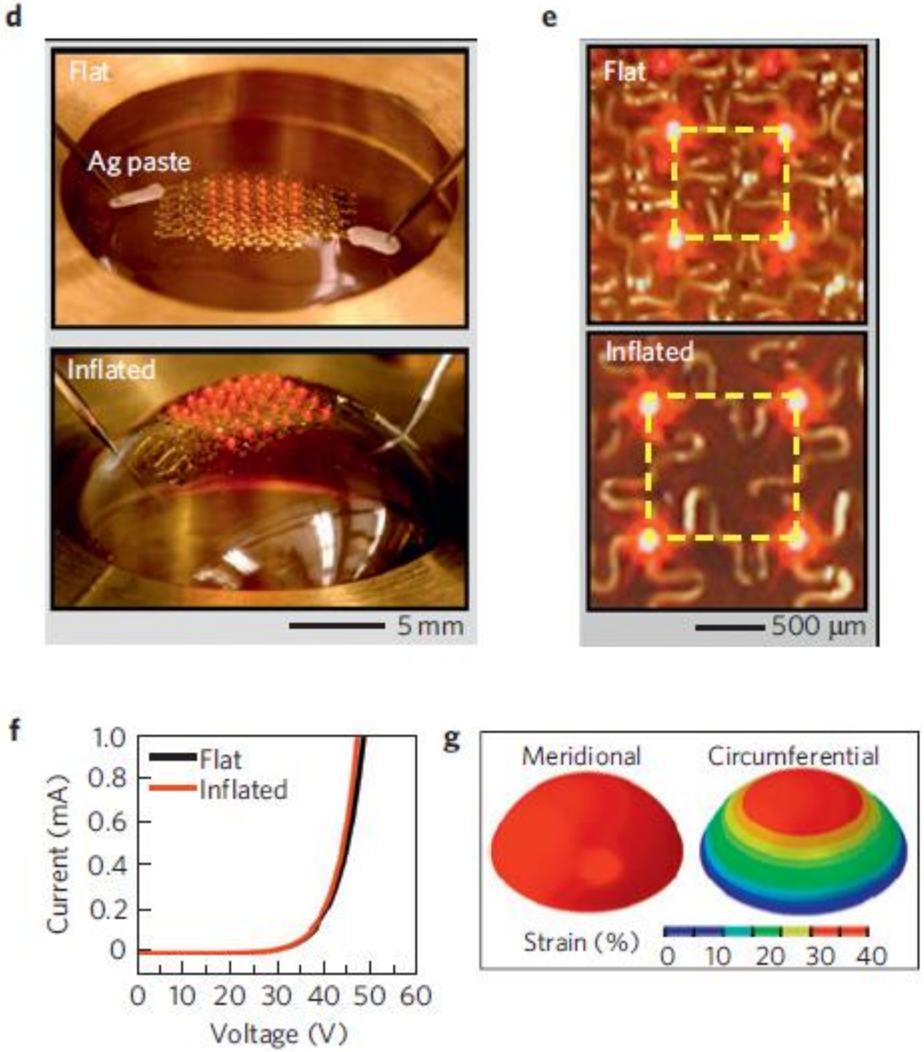
1. corneum, 2. epidermis, 3. dermis, 4. muscular layer.

Materials and Designs for Wirelessly Powered Implantable Light-Emitting Systems

Small, 2012, 8, 2812-2818

Micro-LEDs array with serpentine metal interconnects





Nat.Mater. **2010**, 9, 929-937.

Micro LEDs sensor/tube system

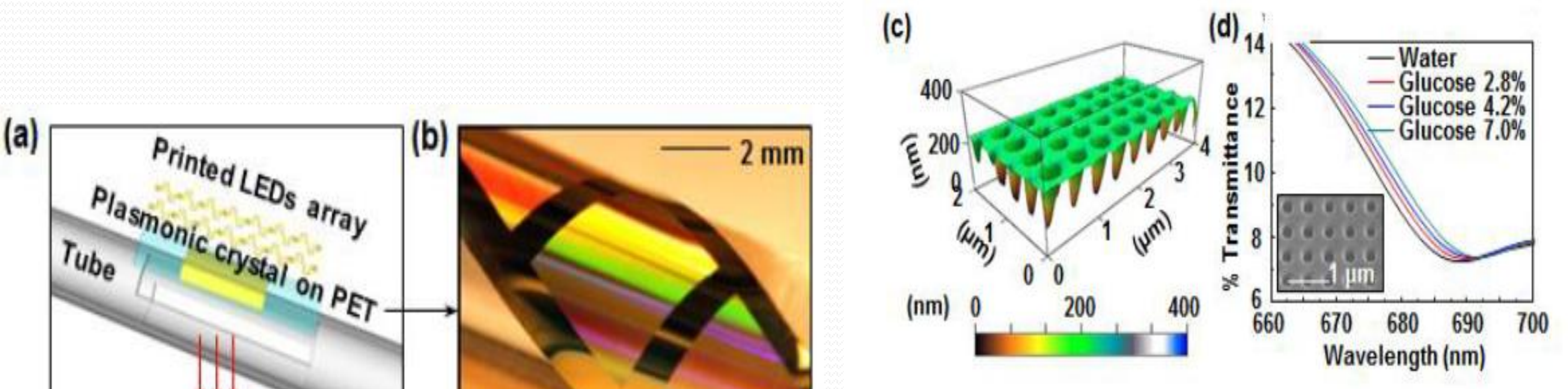
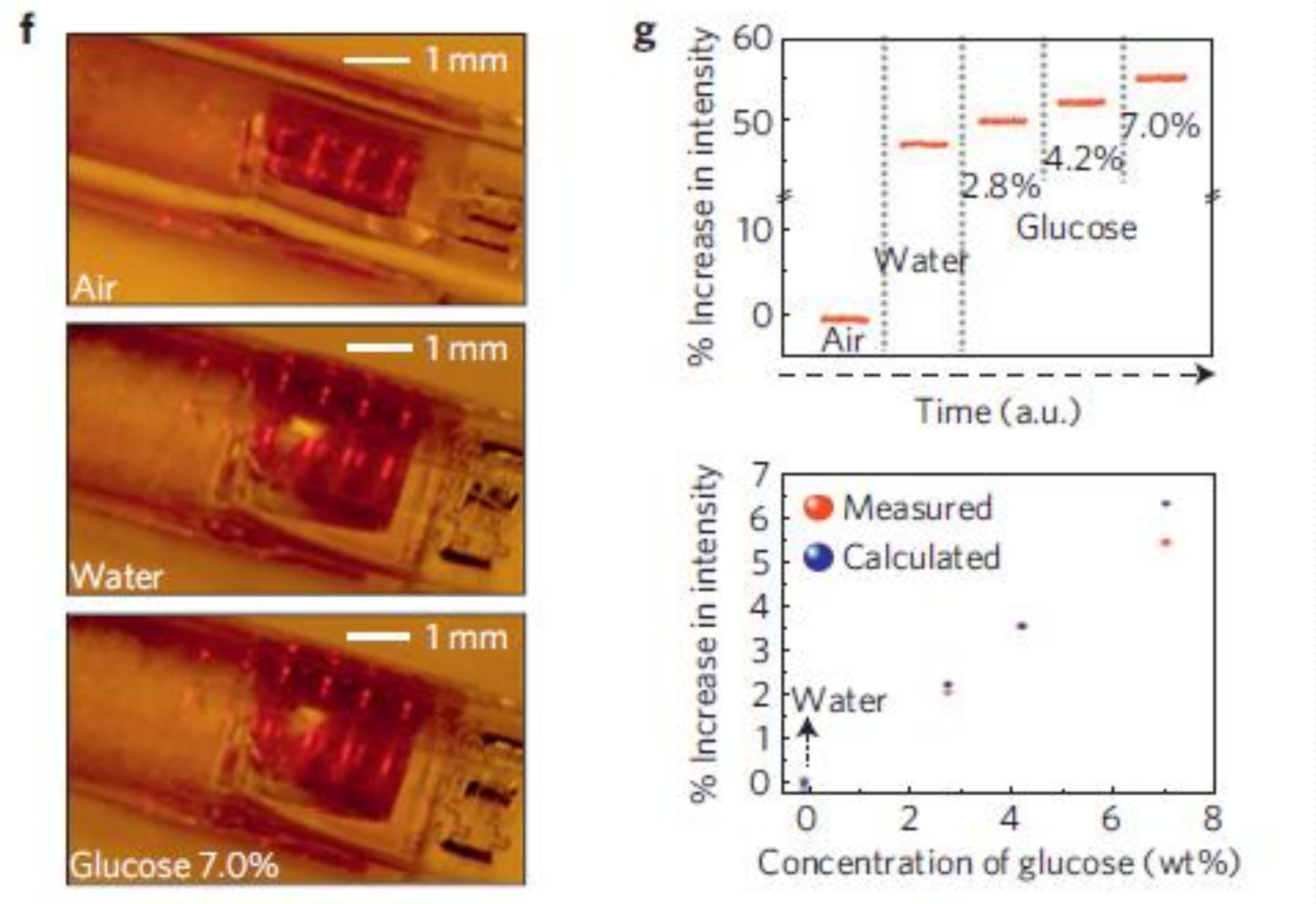


Figure 6.6 (a) Schematic exploded view of the sensor/tube system. (b) Thin, molded plasmonic crystal on a plastic substrate wrapped around a cylindrical support, showing colors due to diffraction. (c) Atomic force microscope image of the surface of such a crystal. (d) Normal incidence transmission spectra collected with a commercial spectrometer over a range of wavelengths relevant for illumination with red μ-LEDs.

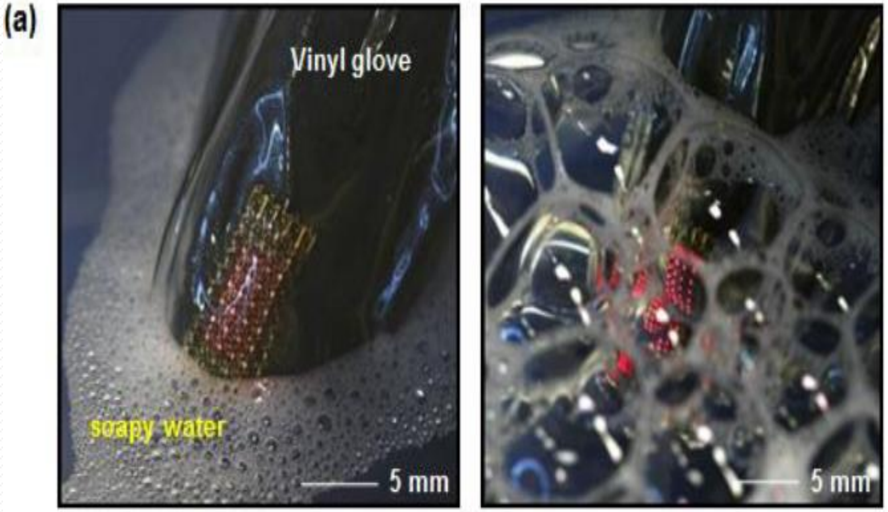
*Nat.Mater.***2010**, 9, 929-937

Optical image of a sensor integrated on an flexible plastic tube



*Nat. Mater.***2010**, 9, 929-937

Micro LED into soapy water



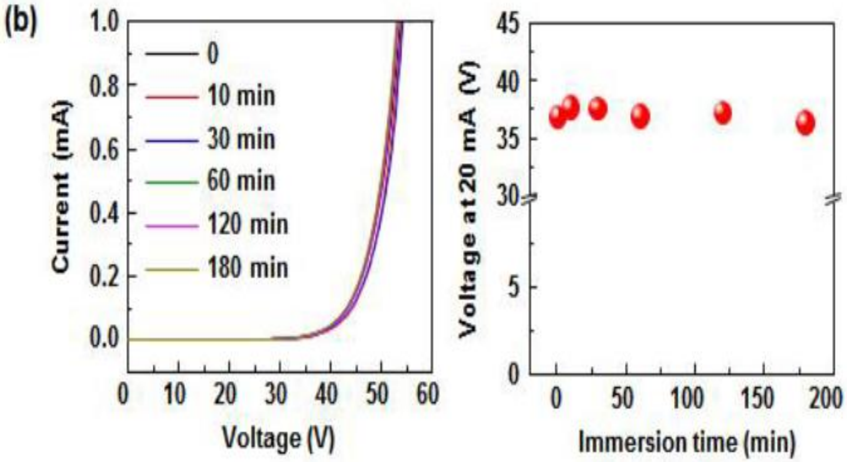
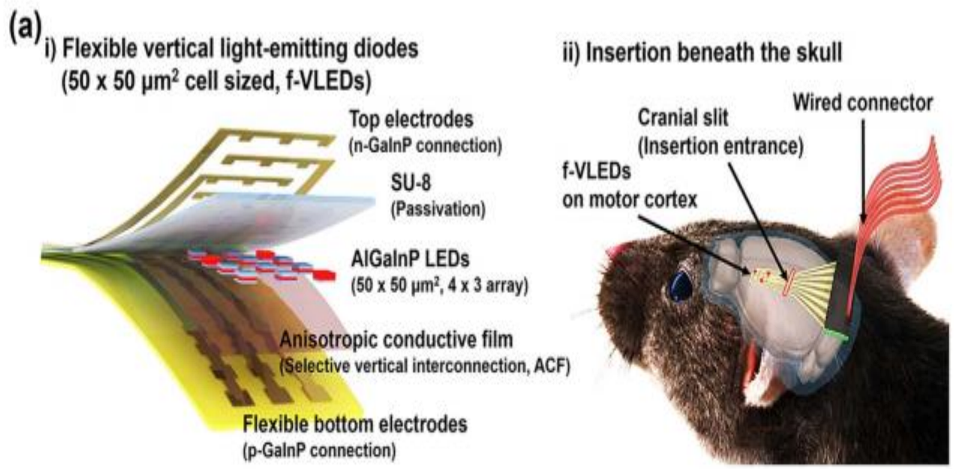
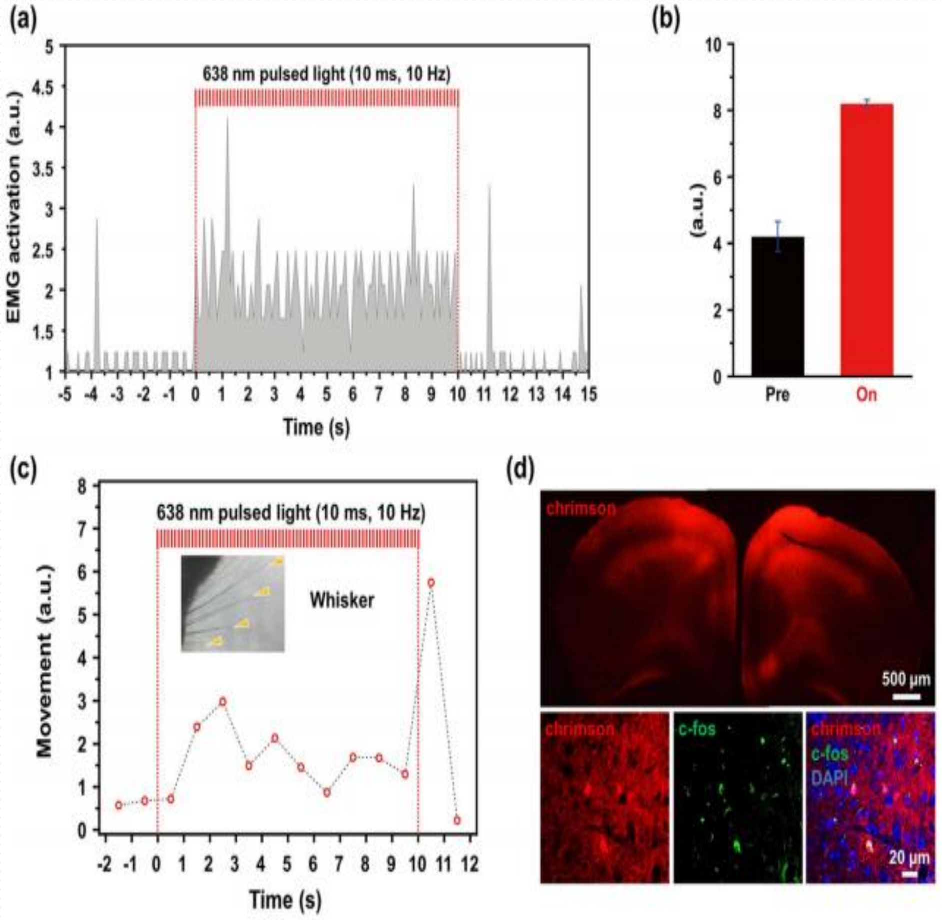


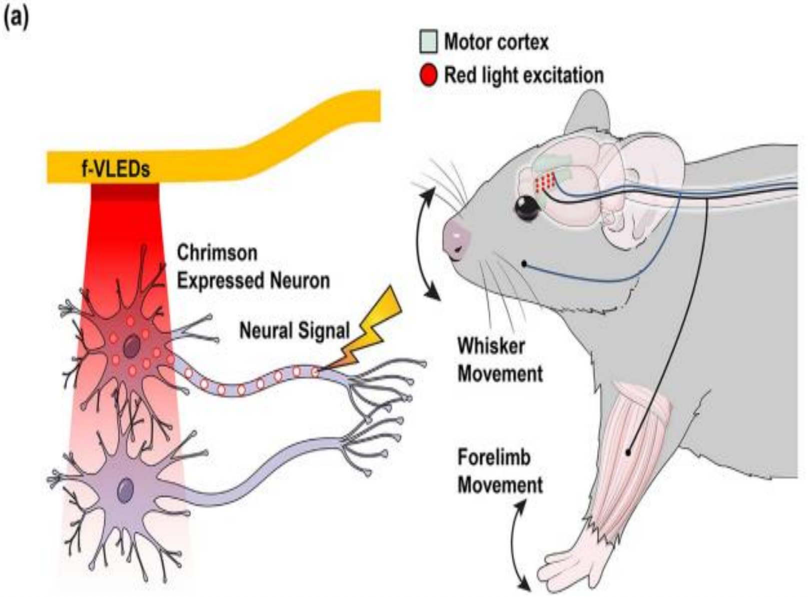
Figure 6.11 (a) Left and right frames correspond to images before and after immersion into soapy water, respectively. (b) IV characteristics of the same μ-ILEDs array as shown in (a) after operation in saline solution (~ 9%) for different immersion time.

*Nat.Mater.***2010**, 9, 929-937

Optogenetic control of body movements via flexible vertical light-emitting diodes on brain surface

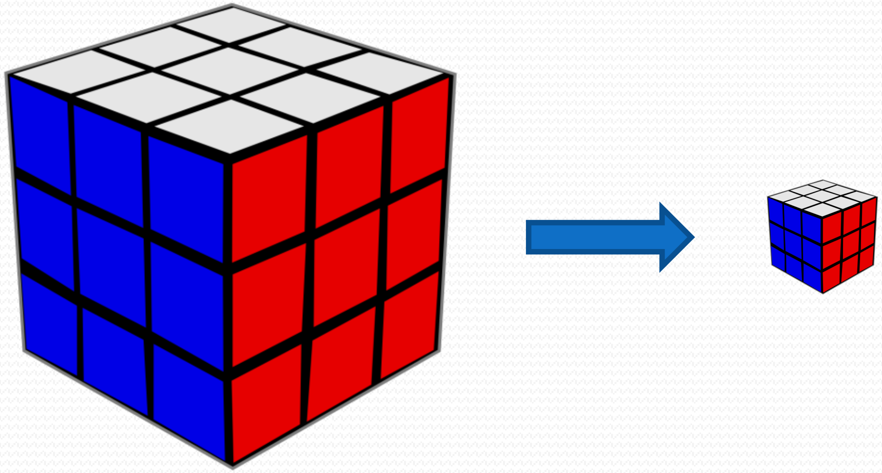




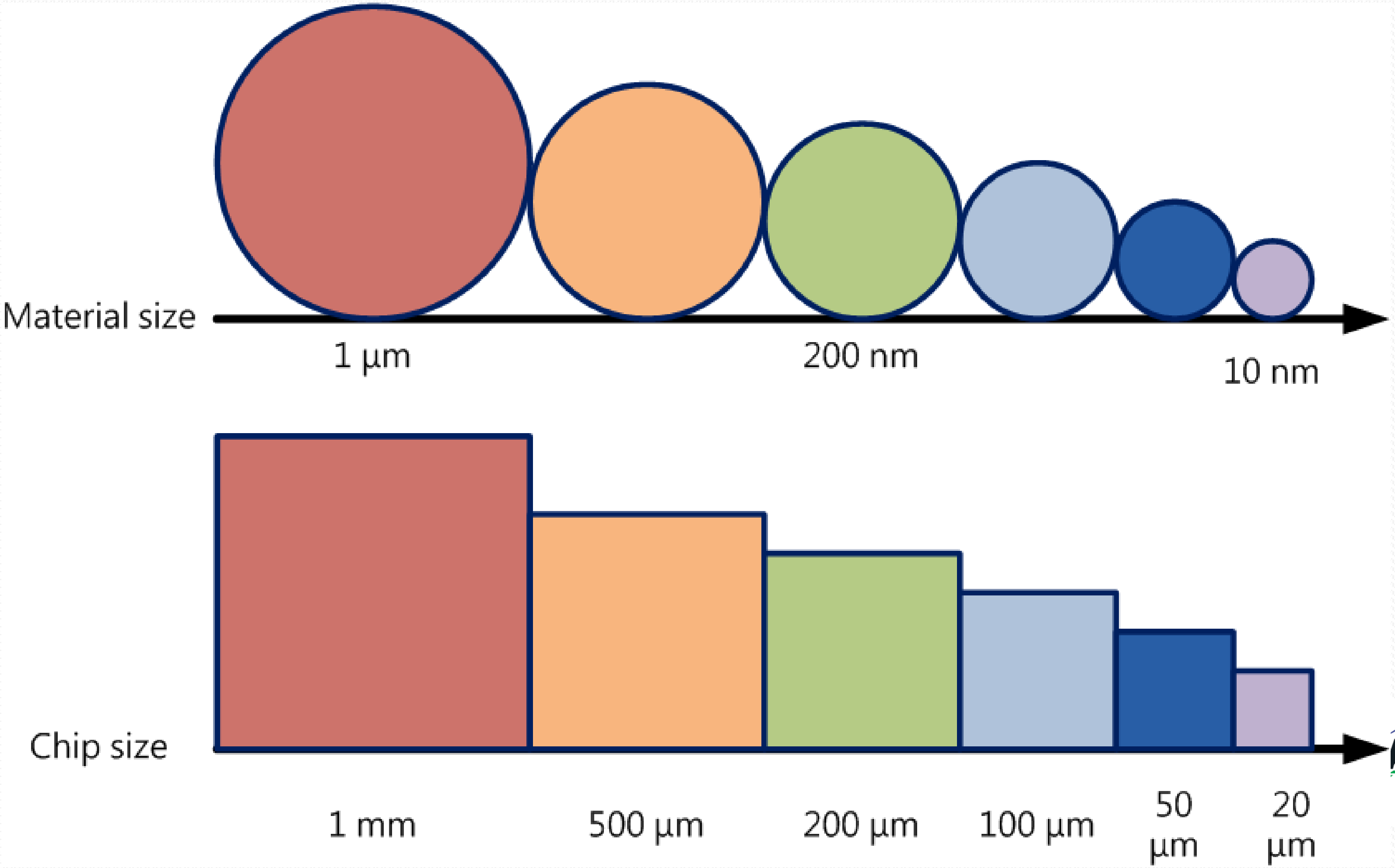


Nano Energy 44 (2018) 447–455

Mini/Micro LED 的尺寸效應

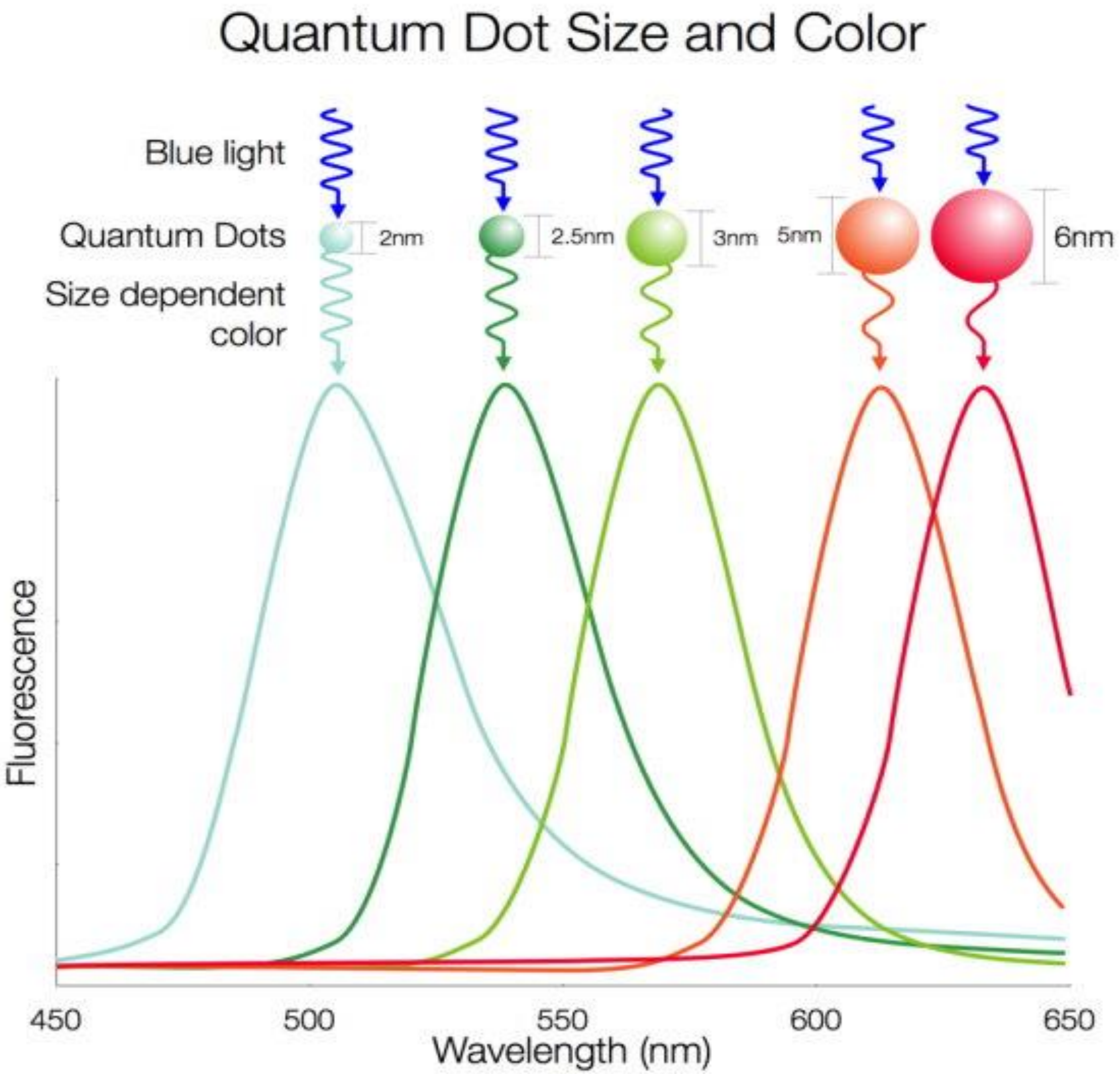


Size effects



AIPEI TECH

量子效應對量子點發光的影響



- 粒徑小⇨能隙大⇨波長短⇨顏色偏藍綠。
- 粒徑大⇨能隙小⇨波長長⇨顏色偏紅橙。

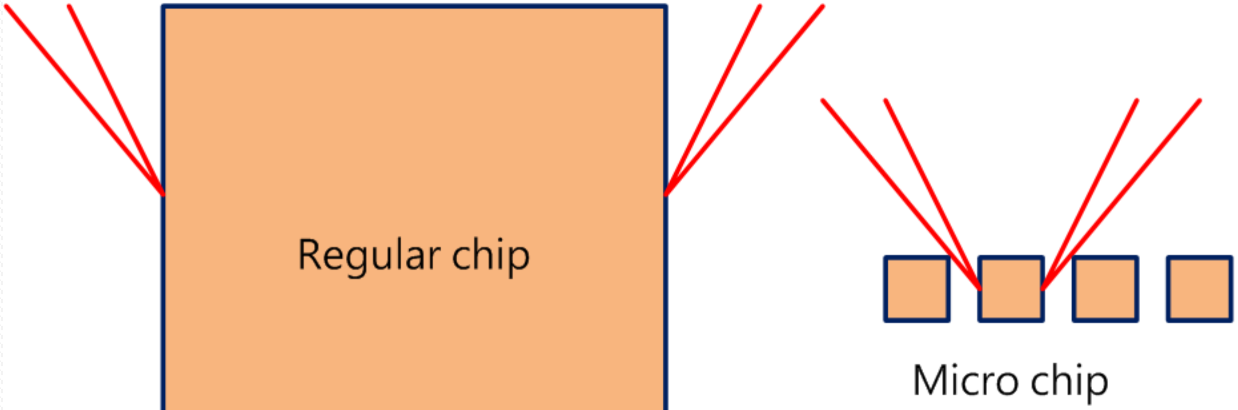
[圖片來源:Nanosys]

Properties of Micro LED

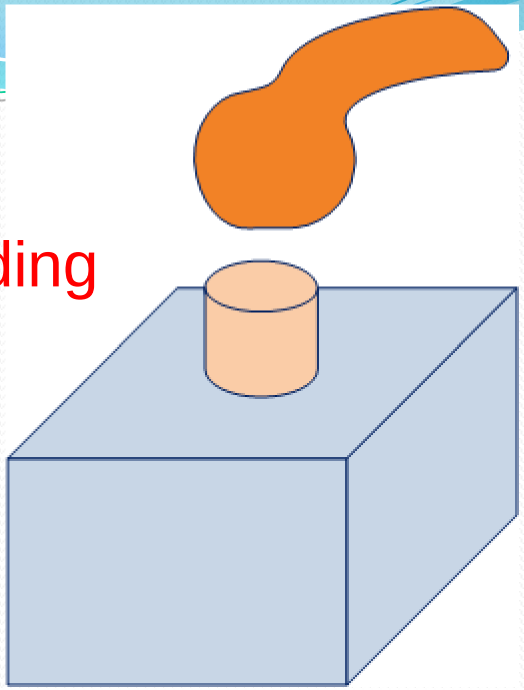
1. Enhanced light extraction
2. Lower junction temperature
3. Improved heat distribution
4. Better current density distribution
5. Reduced efficiency due to non-radiative recombination induced by sidewall defects.

Size issues

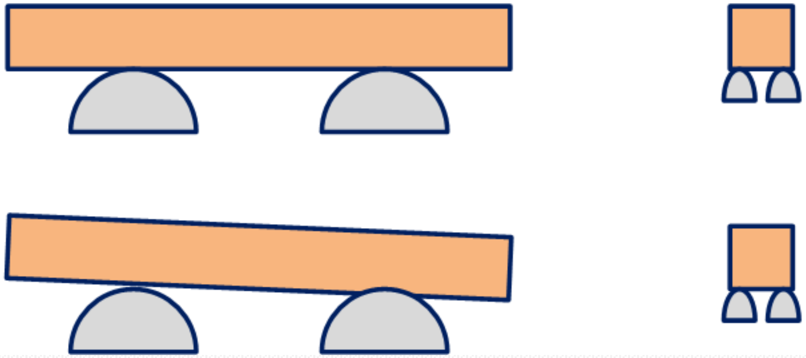
Pick and Place

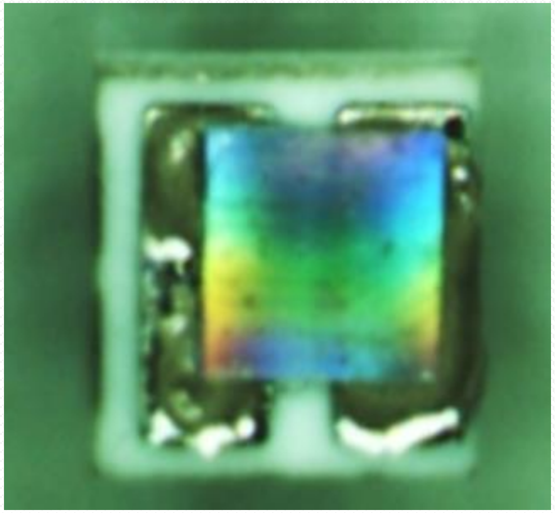


Pad and Bonding



Handling and Bonding





Crack

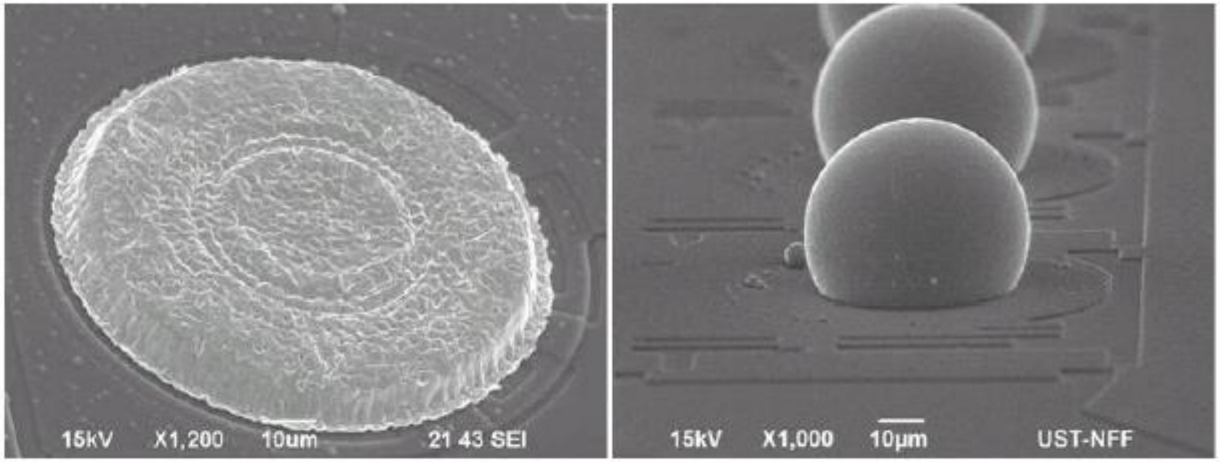
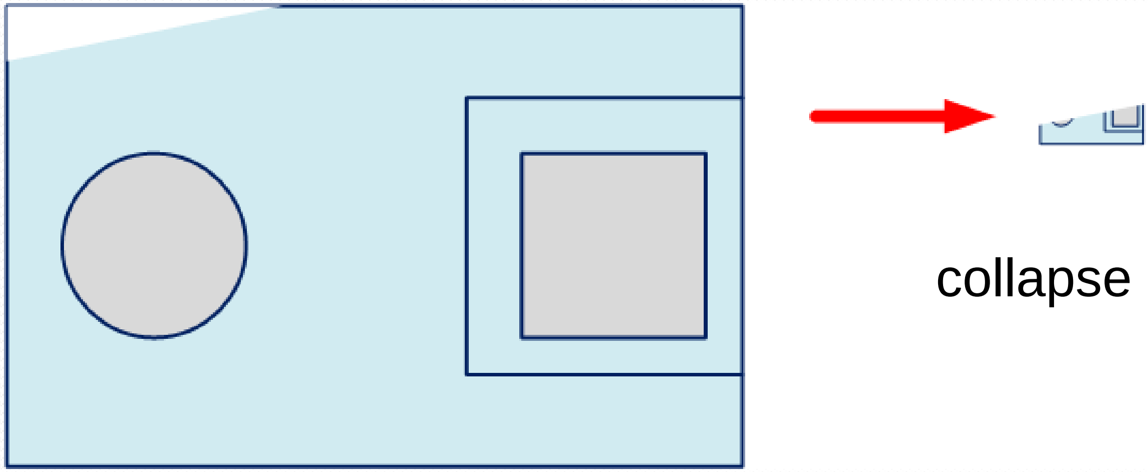


Figure 2. SEM images of circle-shaped indium plate on silicon CMOS driver after lift-off process (Left) and indium balls after reflow process (Right).

SID 13 Digest, 44(1)838-841.



collapse

Micro LED應用產品尺寸選擇

大尺寸 TV

- 50吋以上Full HD TV良率偏低
- 4K TV及未來8K TV X良率將更低，不易與LCD顯示技術競爭

高解析度中小尺寸

- 手機及平板電腦的顯示器製作難度仍高

低解析度中小尺寸

- 良率較高
- 具低耗電量
- 適用於穿戴式顯示器應用

Mini/Micro LED的技術挑戰

- Micro LED有機會成為顯示器的主流技術嗎？專家認為目前Micro LED Display的研發有三大挑戰，分別為：巨量轉移技術問題、電流控制問題及與現有LCD/LCD產業鏈的兼容性問題。
- Micro LED 最難克服的環節，另包括電路驅動、色彩轉換、檢測、晶圓波長均勻度等，也都是尚待突破的技術瓶頸。
- Micro LED的修補技術

Micro LED技術難點

- 製程精度高
- Epiwafer:均勻性待提高, particles, large wafer size
- 需採陣列式高速檢測技術
- IC須走向微型電路設計
- 產業鏈上到下的整合
- 成本高出一般顯示技術3-4倍
- Cross-talk

資料來源:聯合晚報

Cross-talk effect

Crosstalk在電子學上是指兩條信號線之間的耦合現象。這是因為空間距離近的信號線之間會出現不希望的電感性和電容性耦合從而互相干擾。

$$\text{Crosstalk}(\%) = \frac{\text{Leakage}}{\text{Intended channel}} \times 100\%,$$

PR mold

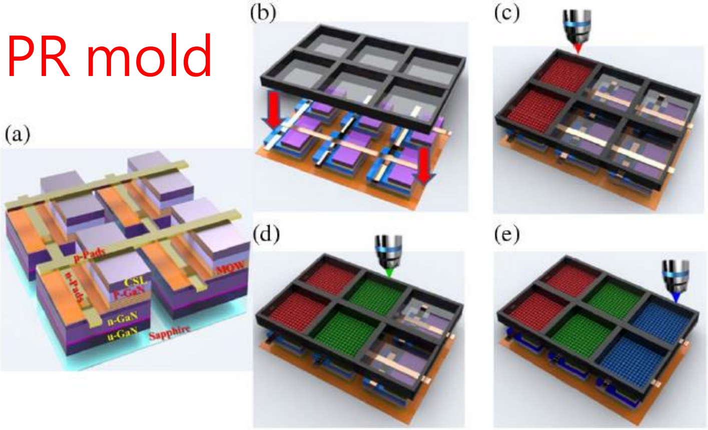


Fig. 4. Process flow of the full-color microdisplay. (a) The structure of the micro-LED arrays. (b) Aligning the mold to the UV micro-LED array. (c)–(e) Consequently jetting the RGB QDs inside the mold window to form the full-color pixels.

13.4 μm overlap

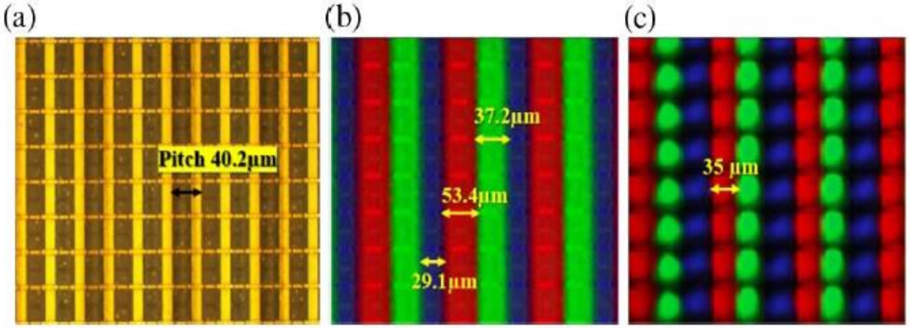


Fig. 7. (a) Top-view image of the micro-LED layout with the pitch of 40.2 μm defined as the intended channel. (b) Our previous work by the QD lines without the PR mold for the microdisplay, which caused cross talk. (c) The QD droplets jetted in the PR mold to confine the size and resolve the cross-talk effect.

螢光顯微鏡

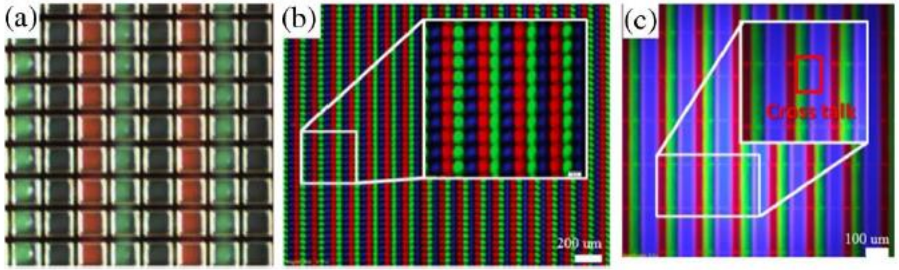


Fig. 6. (a) Microscope image of the full-color micro-LED after jetted QDs in the PR mold. (b) The RGB pixel array observed by fluorescence microscopy. (c) The fluorescence microscopy image of the jetted QD pixels without the PR mold.

The cross-talk value of the previous design is about 32.8%.

Vol. 5, No. 5 / October 2017 / Photonics Research

巨量轉移(Mass Transfer) 技術

如何搬運數千萬顆微米級LED晶粒的挑戰
要把數百萬甚至數千萬顆微米級的LED晶粒正確且有效率的移動到電路基板上。以一個4K電視為例，需要轉移的晶粒就高達2400萬顆（以4000 x 2000 x RGB三色計算），即使一次轉移1萬顆，也需要重複2400次。

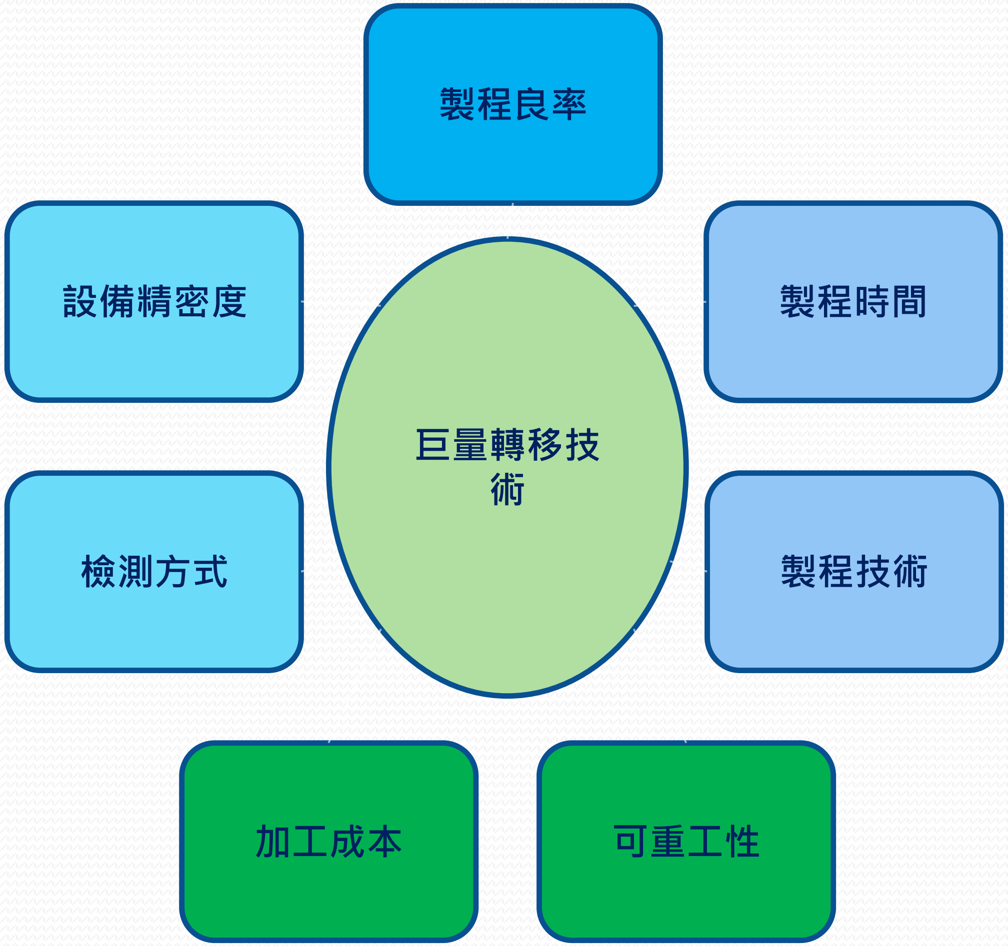
Pick and Place: 黏or 吸: 真空, 靜電, grip pressure(電子作用)

Micro LED巨量轉移技術

磊晶部分結束後，需要將已點亮的LED晶體薄膜無需封裝直接搬運到驅動背板上，這種技術叫做巨量轉移。其中技術難點有兩個部分：

1）轉移的僅僅是已經點亮的LED晶體磊晶層，並不轉移原生基板，搬運厚度僅有3%，同時MicroLED尺寸極小，需要更加精細化的操作技術。

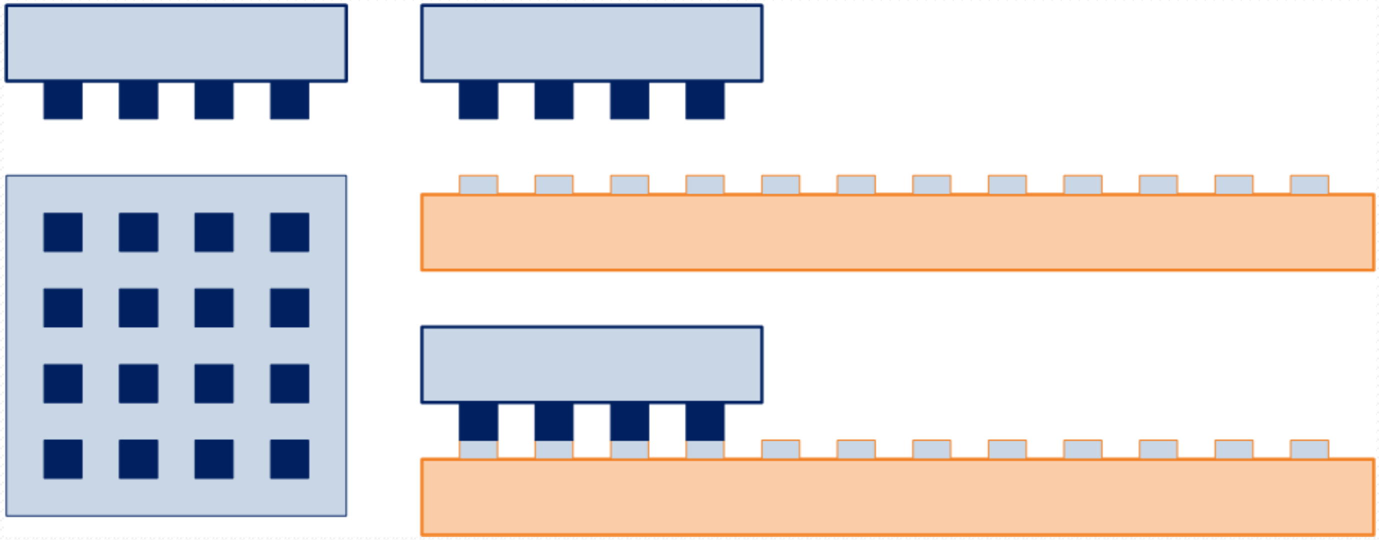
2）一次轉移需要移動幾萬乃至幾十萬顆LED，數量巨大，需要新技術滿足這一要求。



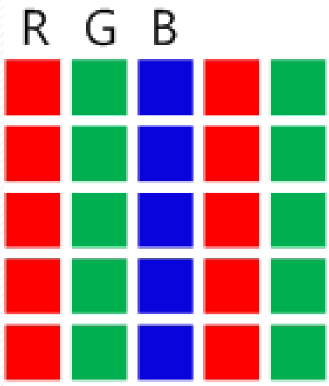
資料來源:LEDinside

Mass transfer

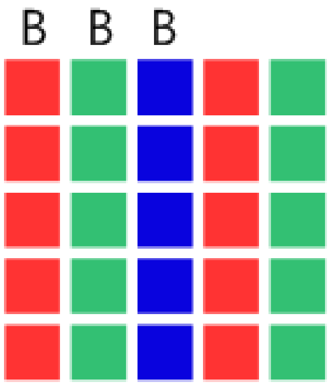
- Pick-up with very precise arrange
- Alignment of pick-up head and substrate
- Bonding and repeat



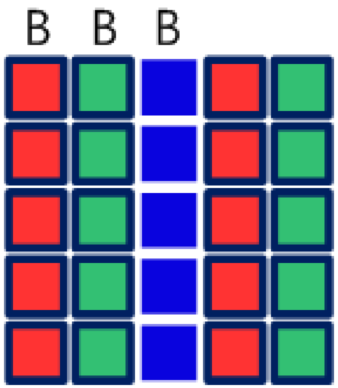
技術挑戰-RGB



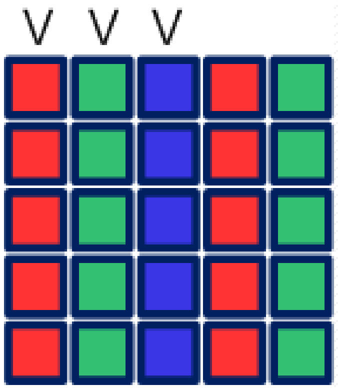
LED chips



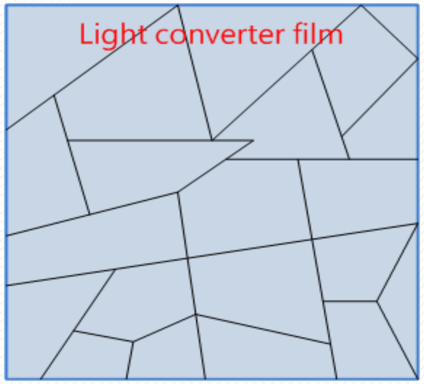
B LED chips +
R/G phosphors

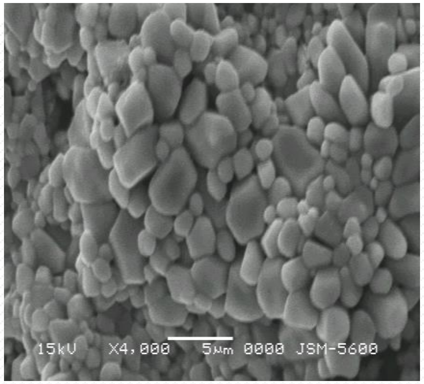


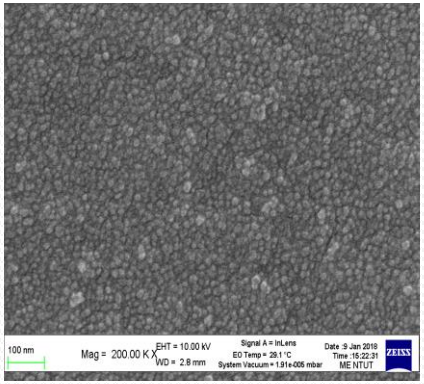
B LED chips +
R/G QDs



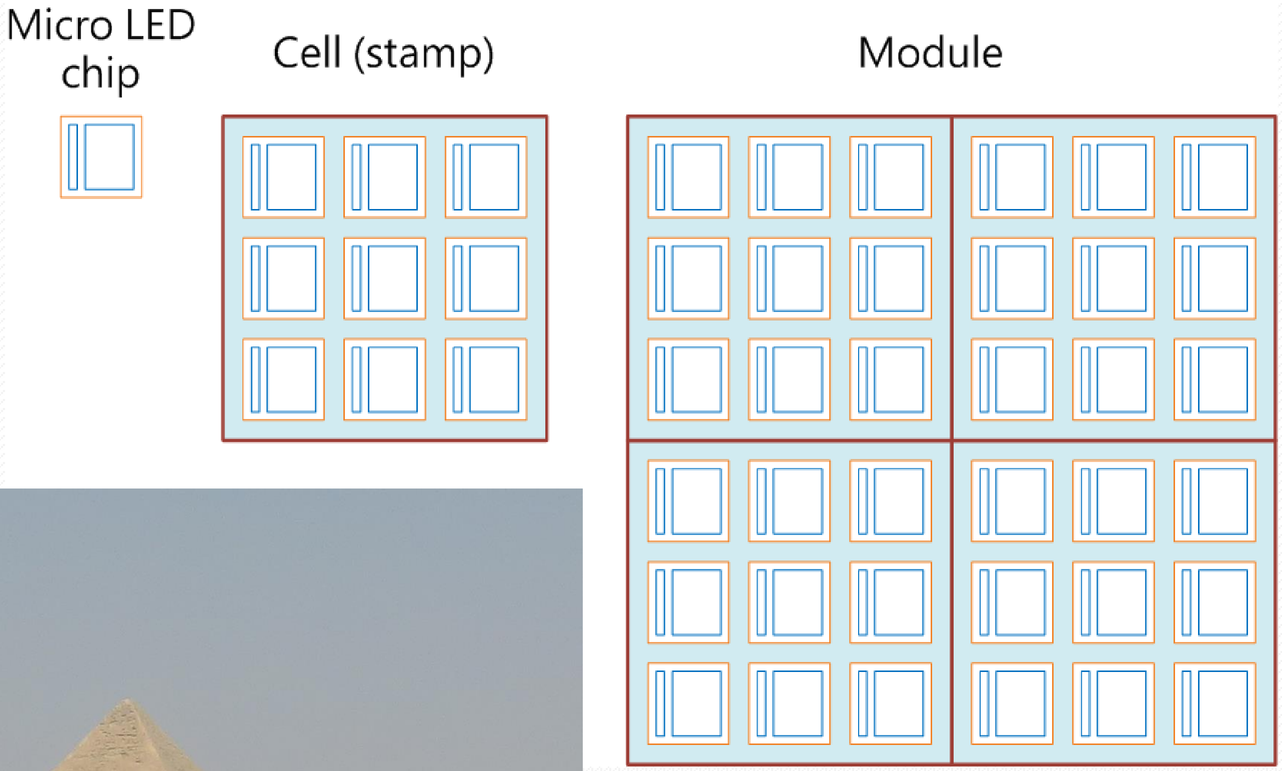
UV LED chips +
R/G/B
phosphors/QDs





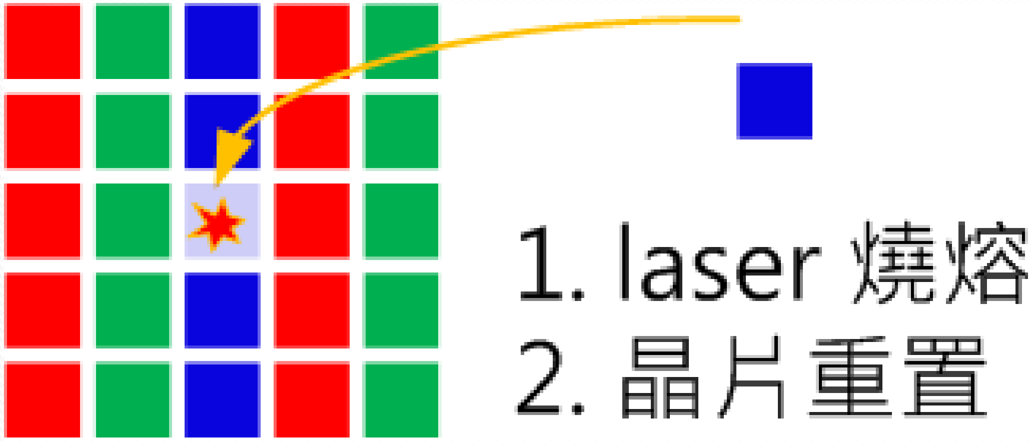


技術挑戰-array



Display

技術挑戰-修補技術



1. laser 燒熔
2. 晶片重置

Or 銲錫高溫熔融+真空吸取

Micro LED 專利技術

發光元件的轉移方法以及發光元件陣列

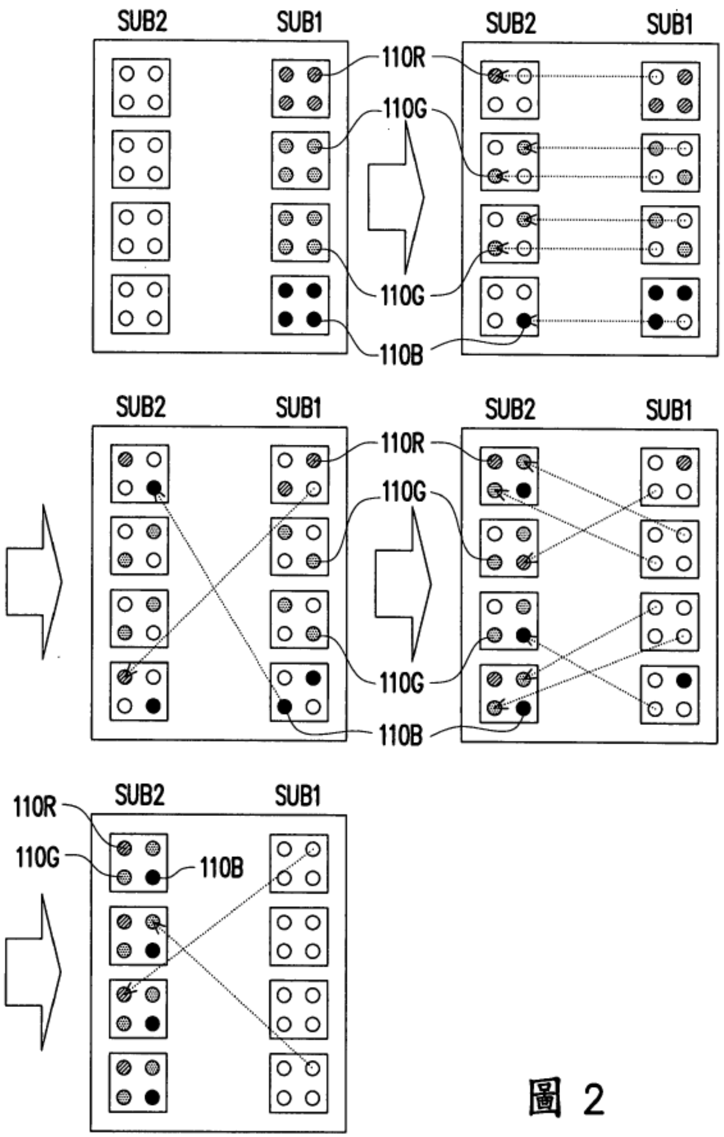


圖 2

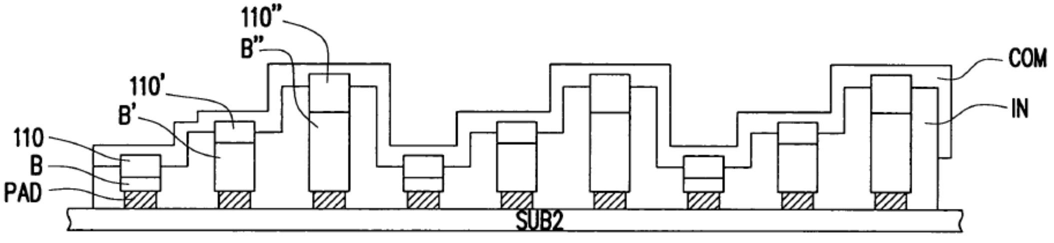


圖 1J

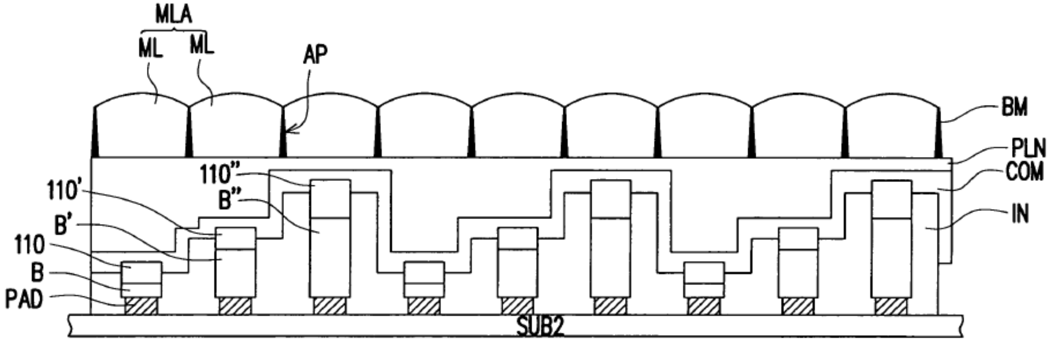
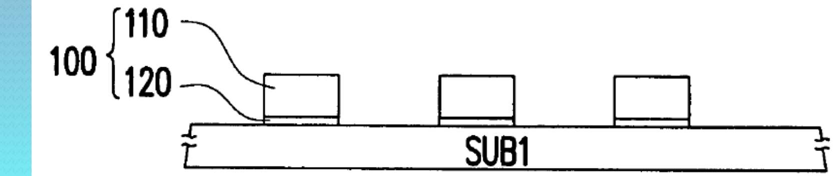
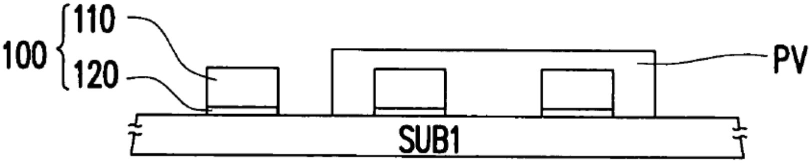


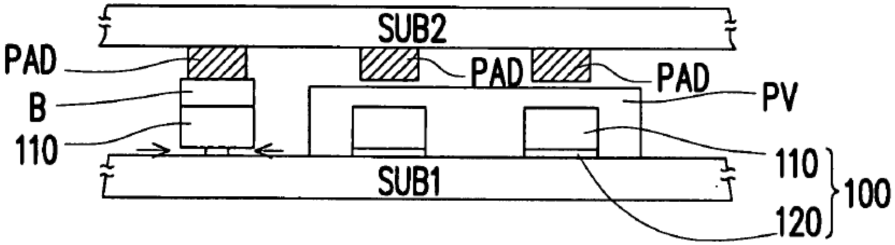
圖 1K

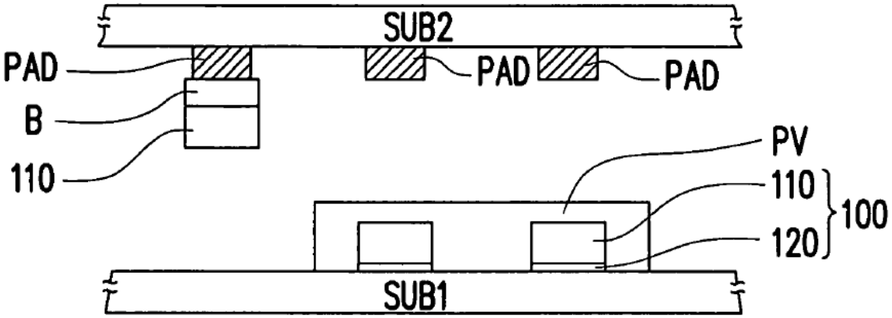
工業技術研究院在此篇專利係有關發光元件的轉移方法，步驟為先於基板1上形成多個LED陣列之排列，一個陣列為一種顏色的LED，例如圖1中紅光、綠光、藍光各自為一陣列。轉移過程需要透過多次焊接步驟，依序將基板1上的LED移轉到基板2的預定位置，所以如圖2所示，每次焊接前先用保護層蓋住沒有要移轉的LED，再將要移轉的LED之導電凸塊與基板2的接墊接合，最後基板1的LED將全數轉移到基板2上。

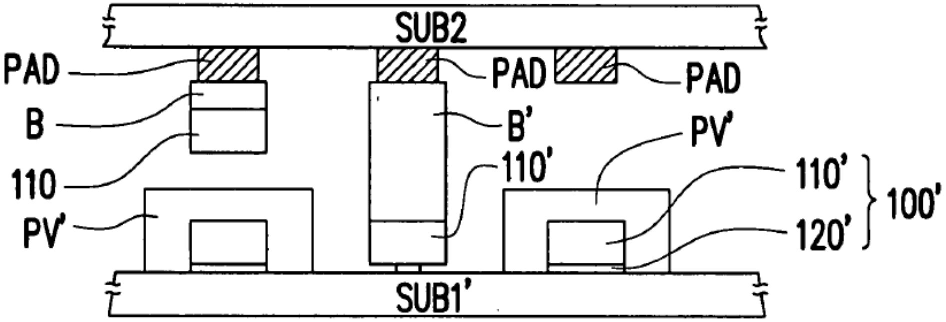
資料來源: 專利 TW I521690

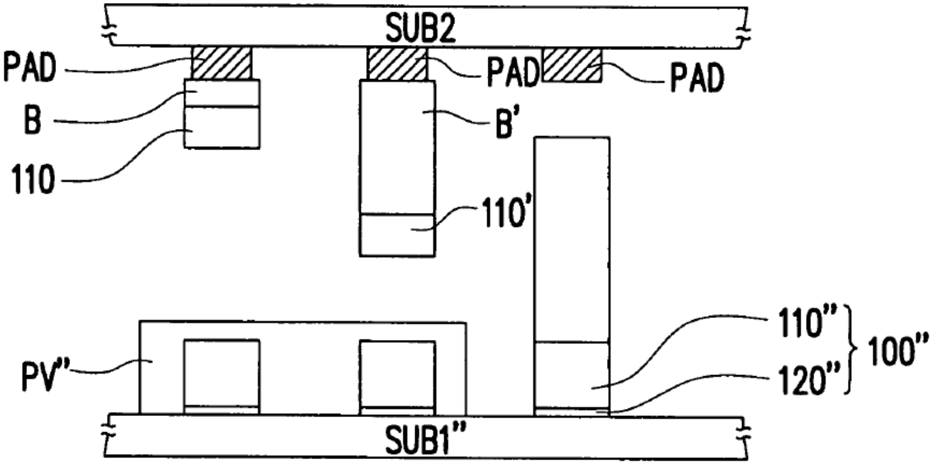








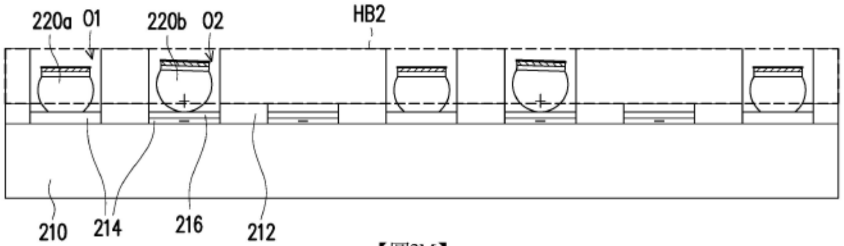




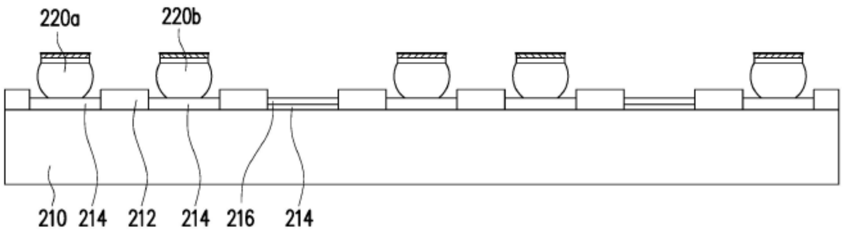
一種發光元件的轉移方法，包括：(a)於一第一基板上形成多個陣列排列之發光元件，各發光元件包括一元件層以及一犧牲圖案，且該犧牲圖案位於該元件層與該第一基板之間；(b)於該第一基板上形成一保護層以選擇性地覆蓋部分的發光元件，其中部分的發光元件未被該保護層所覆蓋；(c)令未被該保護層所覆蓋之元件層與一第二基板接合；以及(d)將未被該保護層所覆蓋的犧牲圖案從該第一基板與該元件層上移除，以使部分的元件層與該第一基板分離而轉移至該第二基板上。

資料來源: 專利 TW I521690

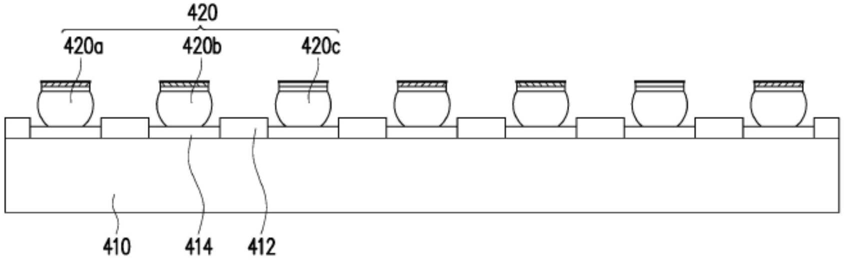
發光元件以及顯示器的製作方法



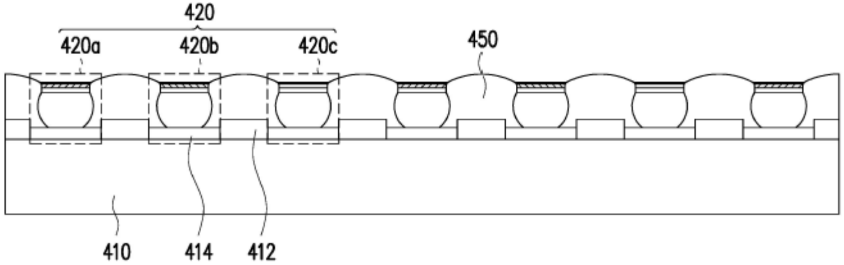
【圖2M】



【圖2N】



【圖4A】



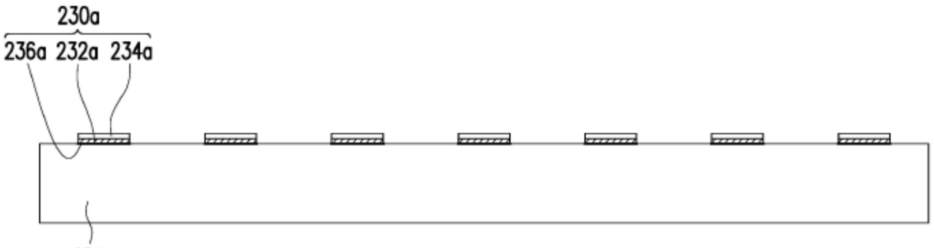
【圖4B】

在基板上形成LED陣列，其中半導體磊晶結構、第一電極以及第二電極構成發光二極體晶片，而發光元件包含發光二極體晶片及球狀延伸電極，完成後將發光元件從基板移除

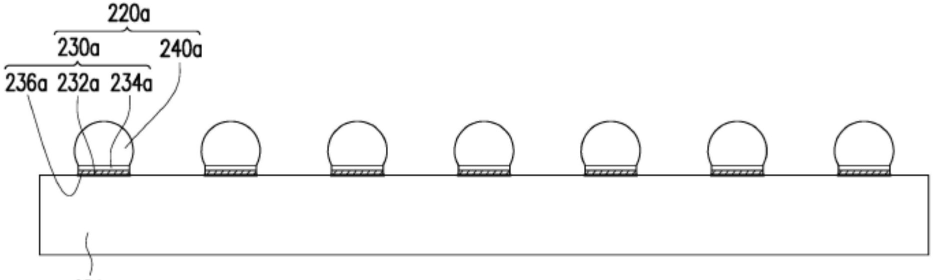
接著透過噴嘴將發光元件噴出，藉由發光元件與噴嘴的磨擦，使球狀延伸電極帶有靜電電荷，而接收基板的接點則透過電路結構傳送電訊號使其亦帶有靜電電荷，在說明書的實施例中球狀延伸電極帶有正電荷而接點則帶有負電荷。

如圖所示，工研院透過例如搖篩的方式，使發光元件落入接收基板的開孔中，由於球狀延伸電極的體積大於發光二極體晶片的體積，因此在落下的過程中，發光元件的球狀延伸電極轉向下落入孔中與皆點接觸。

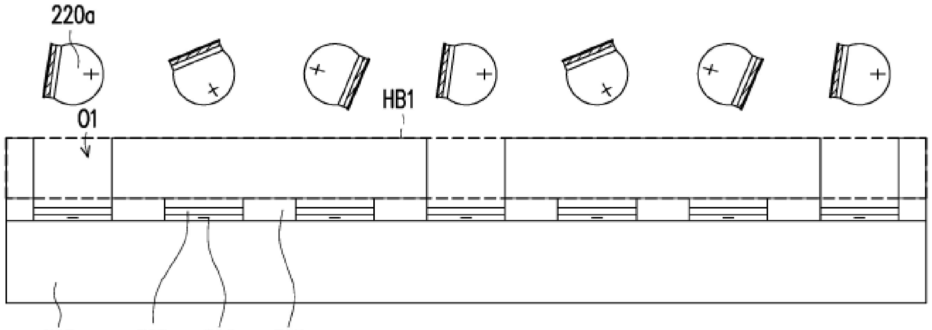
資料來源: 專利 TW I590433



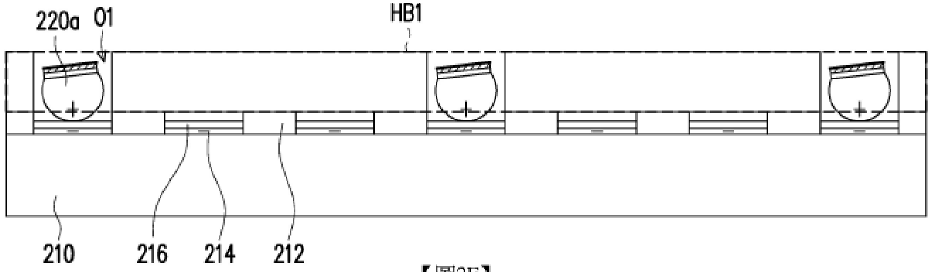
【圖2A】



【圖2B】



【圖2E】



【圖2F】

一種發光元件，包括：一發光二極體晶片，包括一半導體磊晶結構、一第一電極以及一第二電極，其中該第一電極與該第二電極分別配置於該半導體磊晶結構的兩對側；以及一球狀延伸電極，該第一電極配置於該半導體磊晶結構與該球狀延伸電極之間，且該球狀延伸電極透過該第一電極與該半導體磊晶結構電性連接，其中該球狀延伸電極的體積大於該發光二極體晶片的體積。

資料來源: 專利 TW I590433

Micro device transfer head array

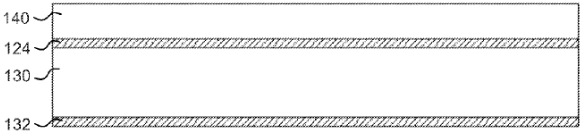


FIG. 6A

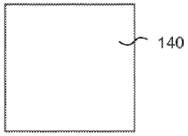


FIG. 6B

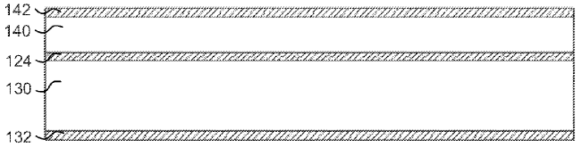


FIG. 7A

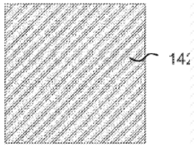


FIG. 7B

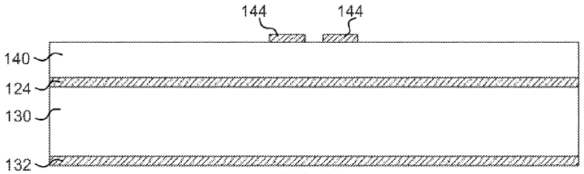


FIG. 8A

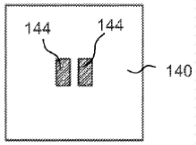


FIG. 8B

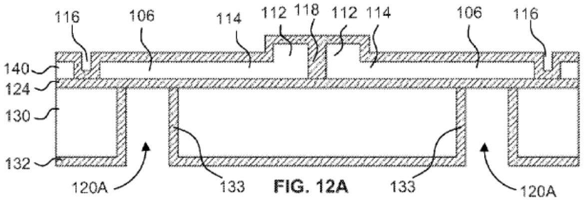


FIG. 12A

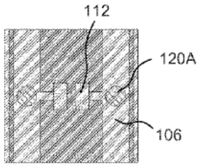


FIG. 12B

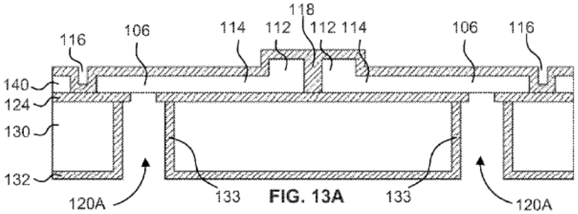


FIG. 13A

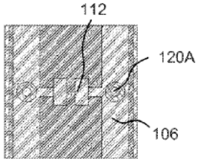


FIG. 13B

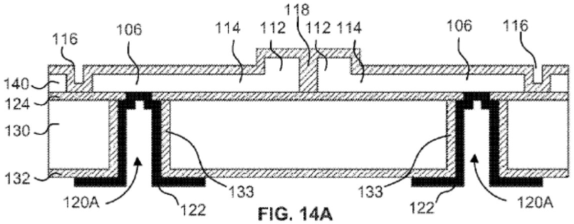


FIG. 14A

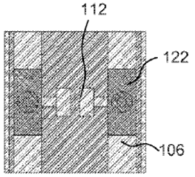
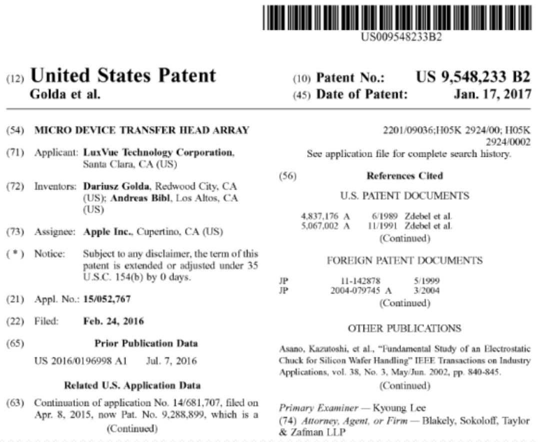


FIG. 14B

為了達到更好的轉移效率，使用巨量轉移技術的廠商不斷開發出各式各樣的轉移頭，而Apple這篇專利的特殊之處在於其轉移頭具有雙極的結構，可以分別施予正負電壓。

轉移頭的平台結構被介電層對半分離形成一對矽電極，當要抓取基板上的LED時，對一矽電極通正電，對另一矽電極通負電即可將目標LED拾取。



US009548233B2

(12) **United States Patent**
Golda et al.

(10) **Patent No.: US 9,548,233 B2**
(45) **Date of Patent: Jan. 17, 2017**

(54) **MICRO DEVICE TRANSFER HEAD ARRAY**

(71) Applicant: **LuxVue Technology Corporation**, Santa Clara, CA (US)

(72) Inventors: **Dariusz Golda**, Redwood City, CA (US); **Andreas Bibl**, Los Altos, CA (US)

(73) Assignee: **Apple Inc.**, Cupertino, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **15/052,767**

(22) Filed: **Feb. 24, 2016**

(65) **Prior Publication Data**

US 2016/0196998 A1 Jul. 7, 2016

Related U.S. Application Data

(63) Continuation of application No. 14/681,707, filed on Apr. 8, 2015, now Pat. No. 9,288,899, which is a

(Continued)

2201/09036;H05K 2924/00; H05K 2924/0002

See application file for complete search history.

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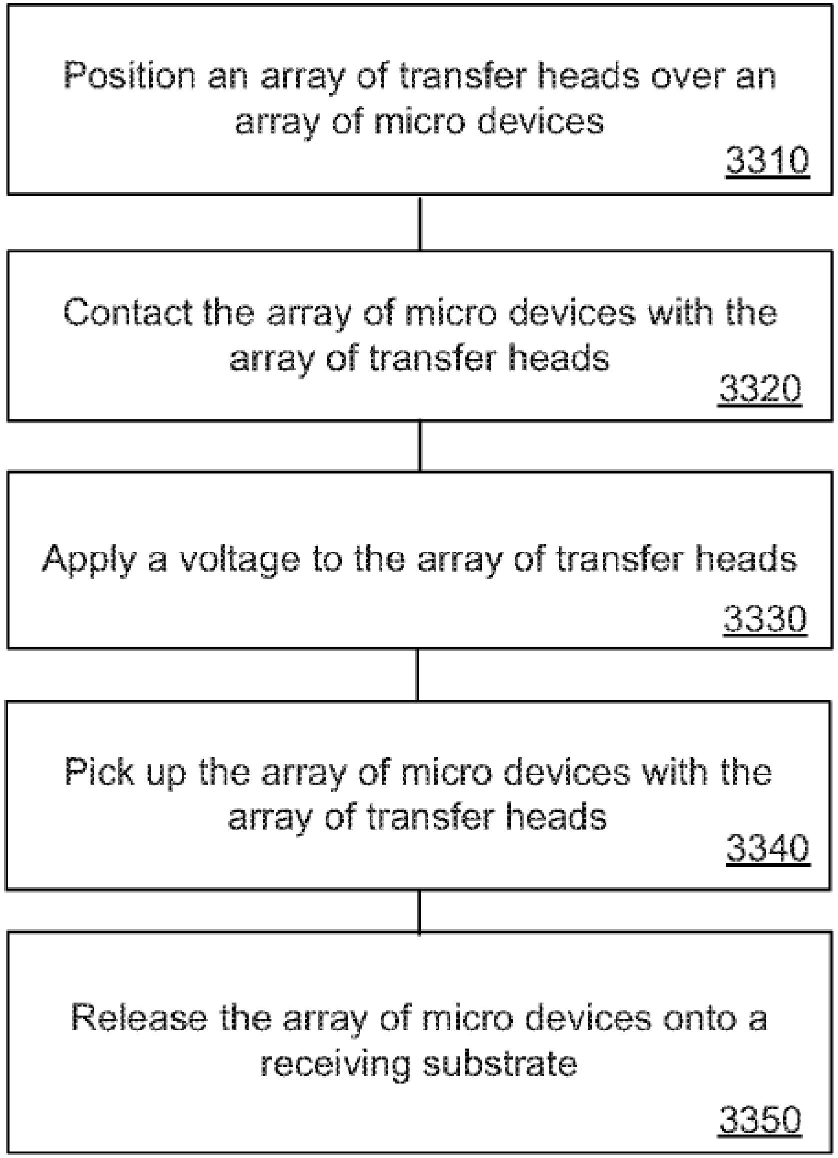
(Continued)

Primary Examiner — Kyoung Lee

(74) *Attorney, Agent, or Firm* — Blakely, Sokoloff, Taylor & Zafman LLP

資料來源: 專利 US 9548233



Position an array of transfer heads over an array of micro devices 3310

Contact the array of micro devices with the array of transfer heads 3320

Apply a voltage to the array of transfer heads 3330

Pick up the array of micro devices with the array of transfer heads 3340

Release the array of micro devices onto a receiving substrate 3350

FIG. 33

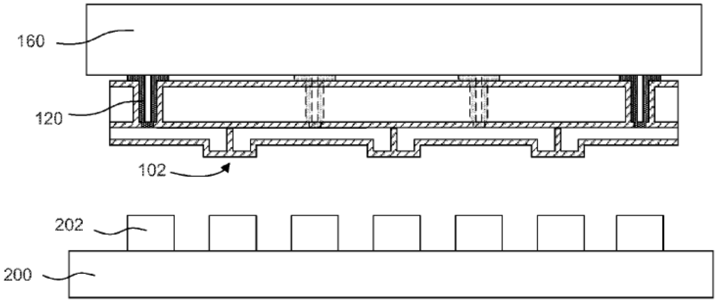


FIG. 34

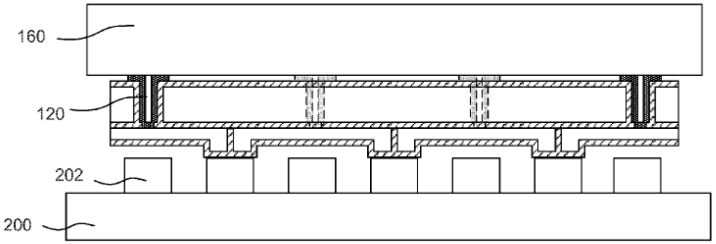


FIG. 35

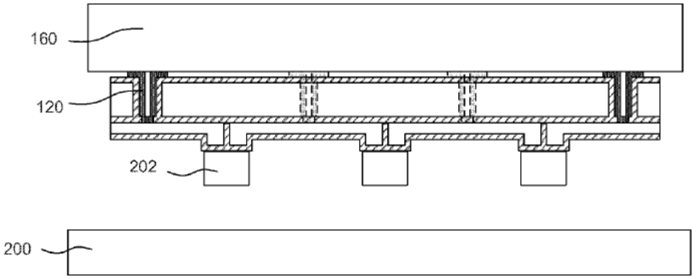


FIG. 36

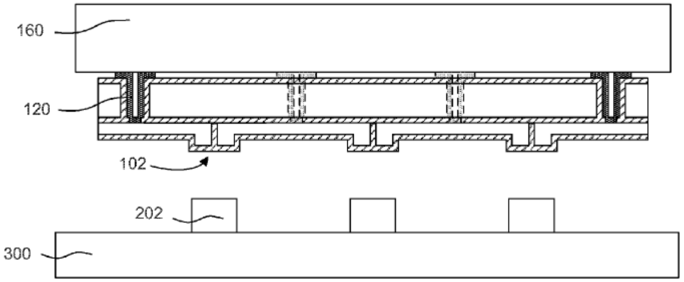
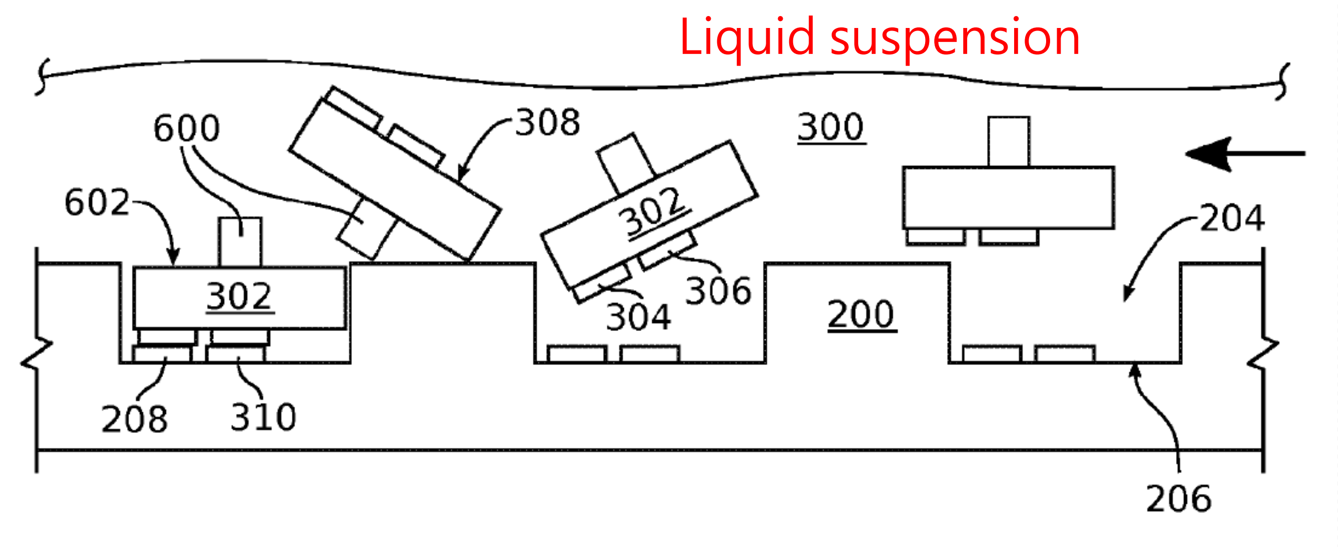


FIG. 37

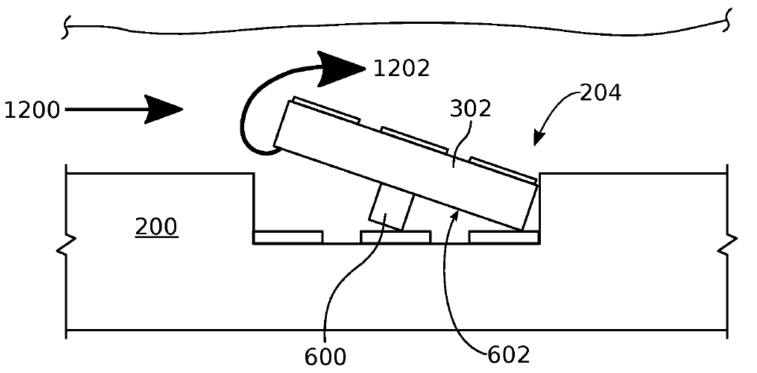
資料來源: 專利 US 9548233

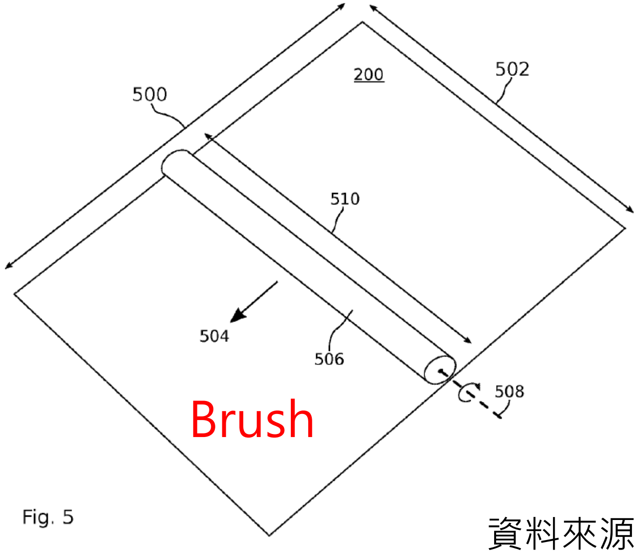
System and Method for the Fluidic Assembly of Emissive Displays



Liquid suspension

鴻海將收購Micro LED新創公司eLux，該公司在專利上有二點值得注意。首先是其轉移技術與市場主流不同，其次是其在美國申請的專利，利用CIP方式大量串接Sharp與自己的專利





Brush

Fig. 5

資料來源: 專利 US 2017-0133558

Micro device transfer head array

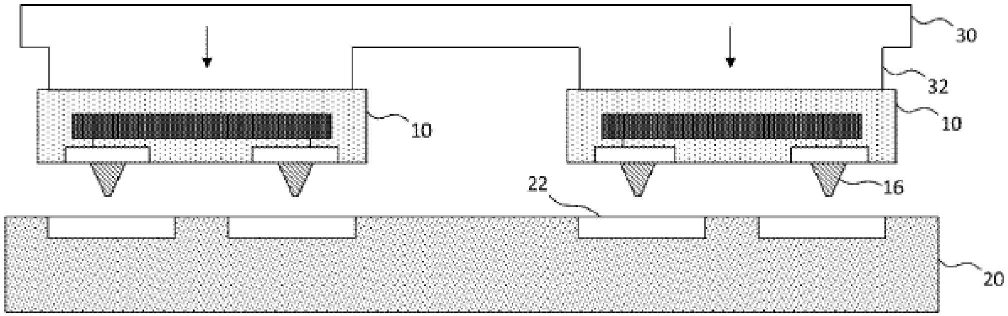


FIG. 5

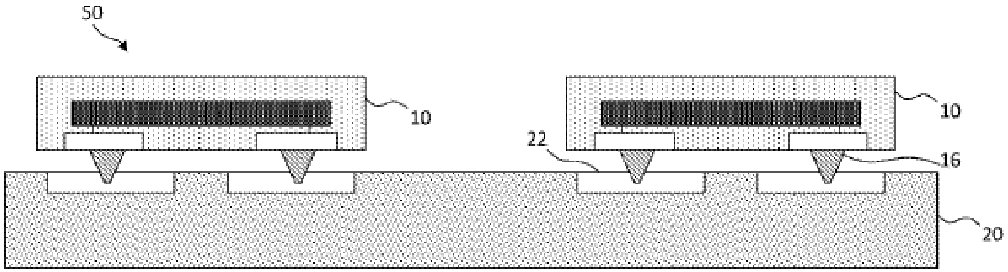
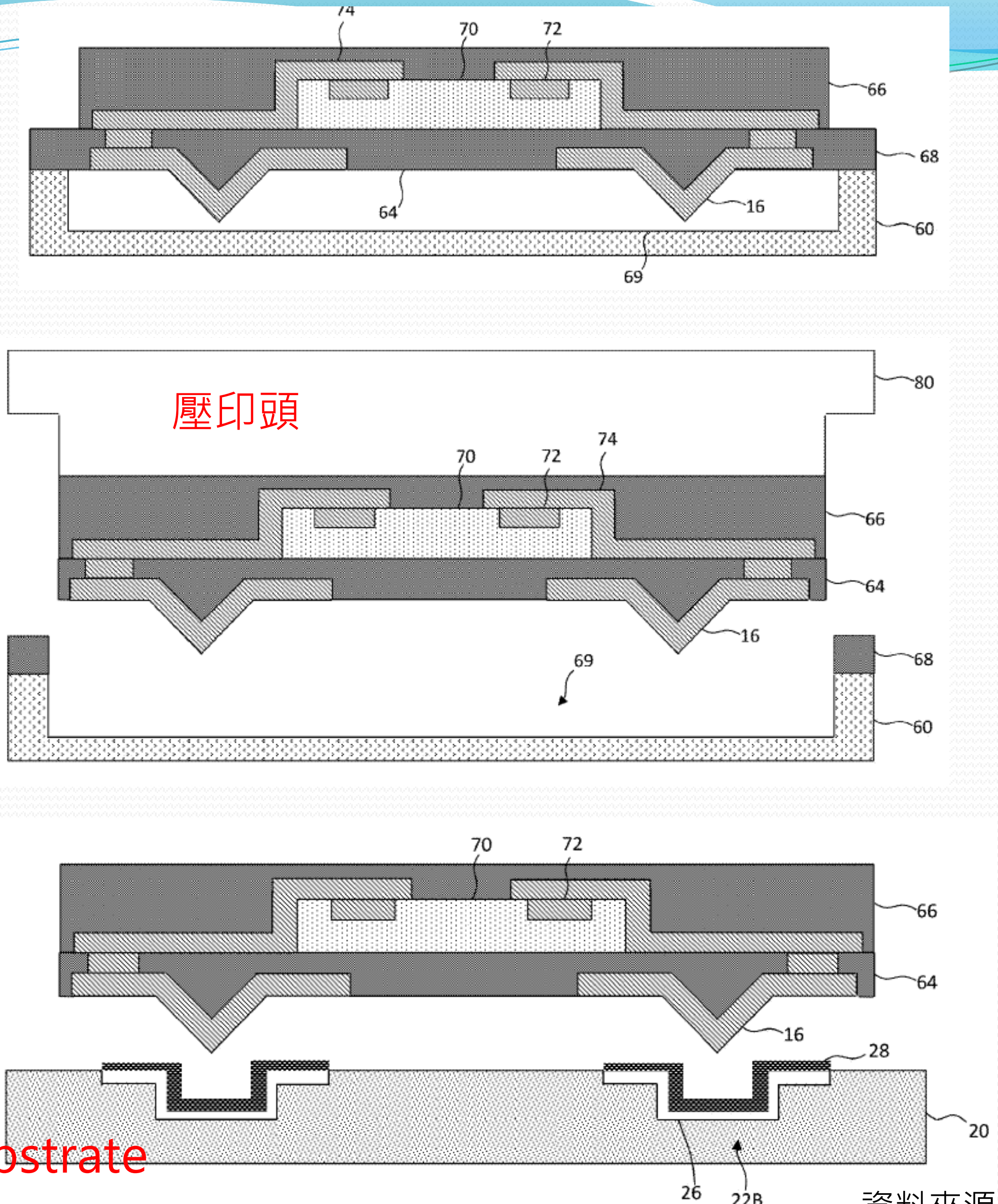


FIG. 6

X-Celeprint的巨量轉移技術Micro-Transfer-Printing (μTP)是用壓印頭在LED上施壓，利用凡得瓦力讓LED附著在壓印頭上後，再從來源基板上將其拾取，移至目標基板上的預定位置上後，壓印頭連同LED壓向目標基板，使LED上的連接柱插入背板接觸墊後完成LED轉移。

資料來源: 專利 US 2017-0048976



壓印頭

Destination substrate

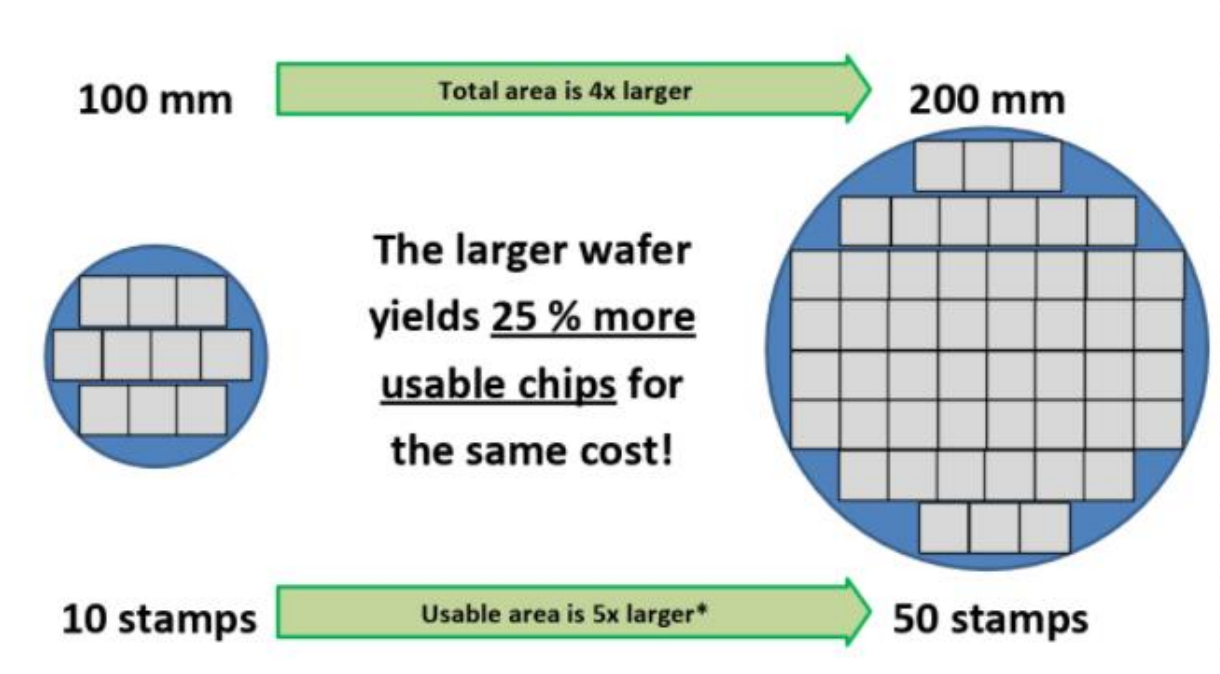
FIG. 24

資料來源: 專利 US 2017-0048976

產業趨勢

ALLOS Semiconductors（德國）

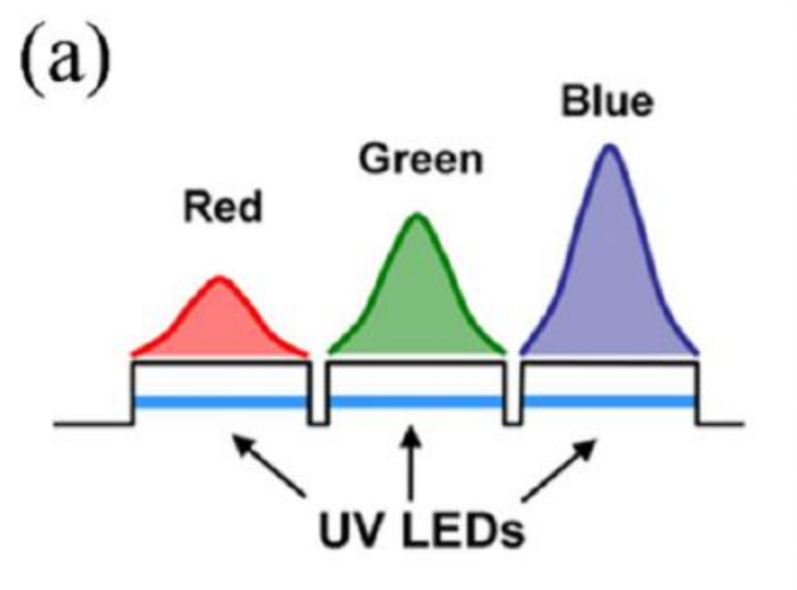
200→ 300 mm GaN-on-Si Micro LED 晶圓技術。



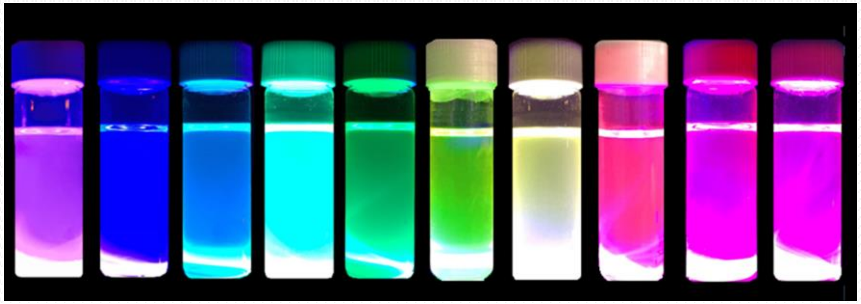
（Source：ALLOS Semiconductors）

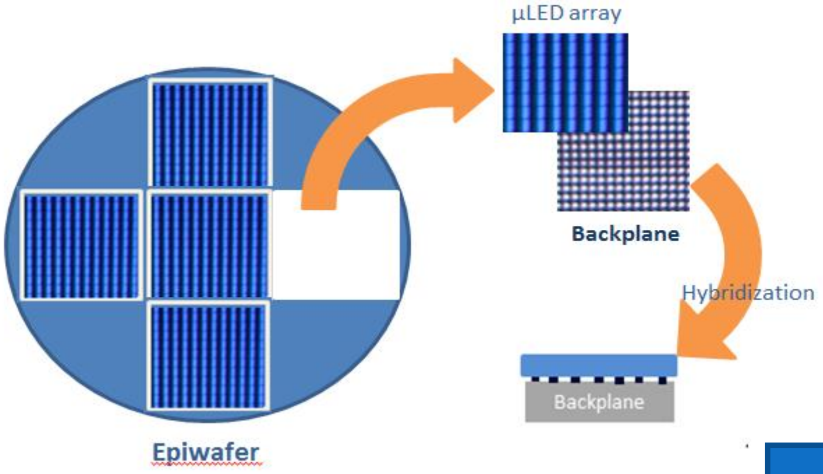
結論

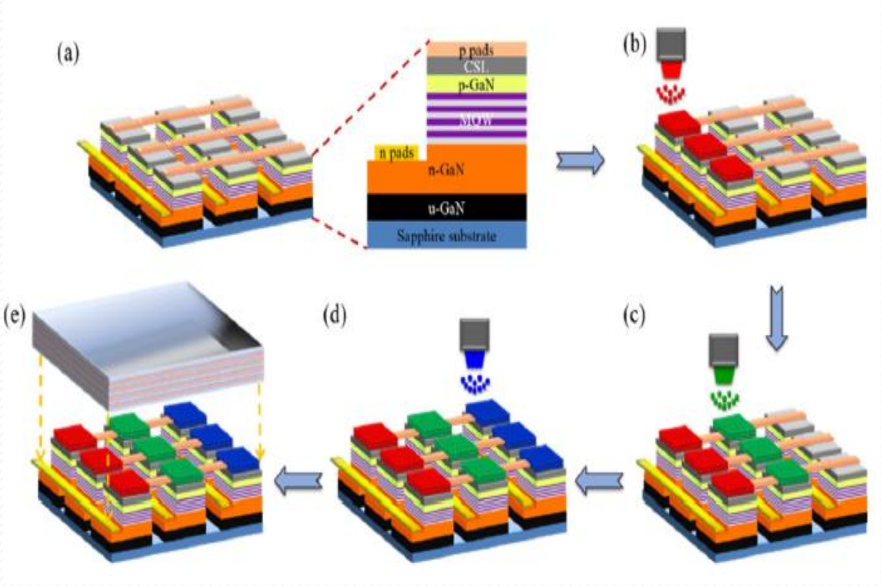
- GaN-based Micro LEDs
  - Same structure and dimension for RGB
  - Blue LED + GB color convertors
  - UV LED + RGB color convertors



結論




μLED array
Backplane
Hybridization
Backplane
Epiwafer


(a)
p pads
CSL
p-GaN
MQW
n pads
n-GaN
u-GaN
Sapphire substrate
(b)
(c)
(d)
(e)

結論

1. LCD, OLED的亮度不夠, 但是Micro LED可以提供非常高亮度的微型顯示器
2. 採用commercial Epiwafer
3. Power consumption can be 90% lower then LCD and up to 50% lower than OLED.
4. Better daylight viewing. (0-1050 nits)
5. 由於晶粒尺寸的差異，其各自的應用也就有所不同。

(1) 一般的LED晶片以照明與顯示器背光模組為主；

(2) Mini LED則也將會運用在背光應用上，但會是在高階的消費產品，或者是車用市場；

(3) Micro LED，其應用概念跟前兩者則完全不同，將會是一種全新的顯示技術，而它的競爭對象則會是OLED。

結論

- 從技術規格與應用概念來看，MicroLED在亮度、反應速度、電耗與耐用度上皆完勝目前市面上的顯示技術，幾乎可以說是具備完全取代LCD和OLED顯示的潛力，但唯一的問題就是其生產成本與量產的能力。
- 總之----MicroLED完勝所有顯示技術 成本與量產是唯一挑戰

感謝聆聽
敬請指教