Flat Panel Displays

平板显示技术

OLED驱动技术

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一、OLED驱动技术

二、Beyond OLEDs

一、OLED驱动技术

LCD和OLED的重要差异

- LCD：通过电压差控制光阀
- OLED： 通过控制电流强度来控制发光

基板的主要功能

- 根据图像数据设置电流等级
- 为电流提供通路

OLED 面板电路

- 像素电路
- 总线电路
- 驱动ICs
- 内部互联电路
- 数据信号处理
- 电源

一、OLED驱动技术

寻址的三种方式

- 直接寻址（段显示）
- PM寻址:随着分辨率/占空比的增加，瞬间电流必须增加
- AM寻址:适合200行以上的分辨率。

Case	Diagonal (Inch)	Drive	Pixel Count Col x Row	Aspect Ratio	Pixels per inch	Line width (μm)	Panel area cm^2	Pixel current μA	Line current mA	Total current A
A	2″	PM	320 x 240	4 x 3	200	127	12.4	190	62	0.12
B	8″	AM	640 x 480	4 x 3	100	254	200	6.4	4.1	2
C	20″	AM	1600 x 1200	4 x 3	100	254	1240	6.4	10	12
D	30″	AM	1920 x 1080	16 x 9	73	346	2480	12	23	25

Content

1. Segmented Displays
2. Passive Matrix Drive
3. Active Matrix Drive
4. Gray Scale Control
5. Drive Electronics

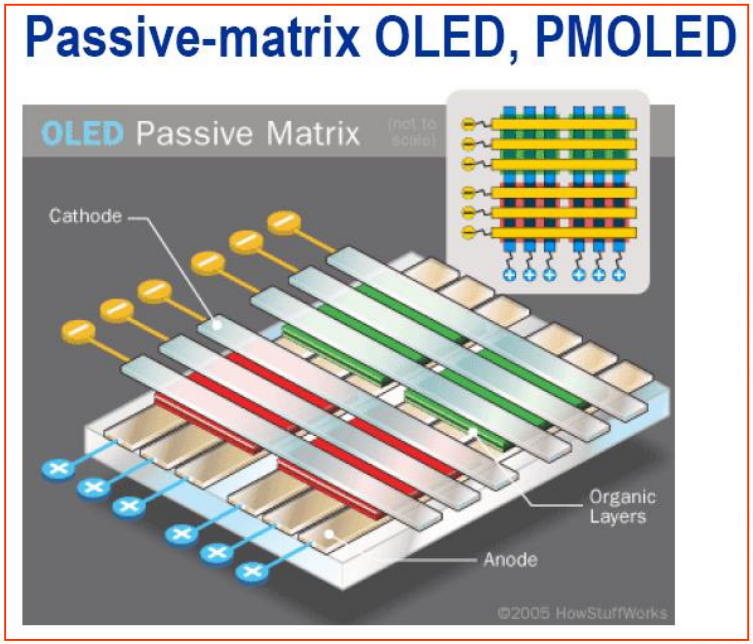
1. 段显示驱动

- 每个像素均被直接驱动
- 为在寿命期内得到稳定的性能，需采用电流驱动
- 由于段显示的尺寸不同，驱动IC的电流输出应可被编程

Examples of segmented OLEDs pioneering car radio displays and the smart card.

2. Passive Matrix Drive

- 透明 ITO 列电极在阳极一侧，金属行电极在阴极一侧
- 阴阳电极交叉点处，电流由阳极到阴极→发光
- 图像显示方式类似CRT，采用行扫描而非点扫描。瞬间亮度高，并通过帧间平均得到需要的灰度



PMOLED 和 PMLCD的比较

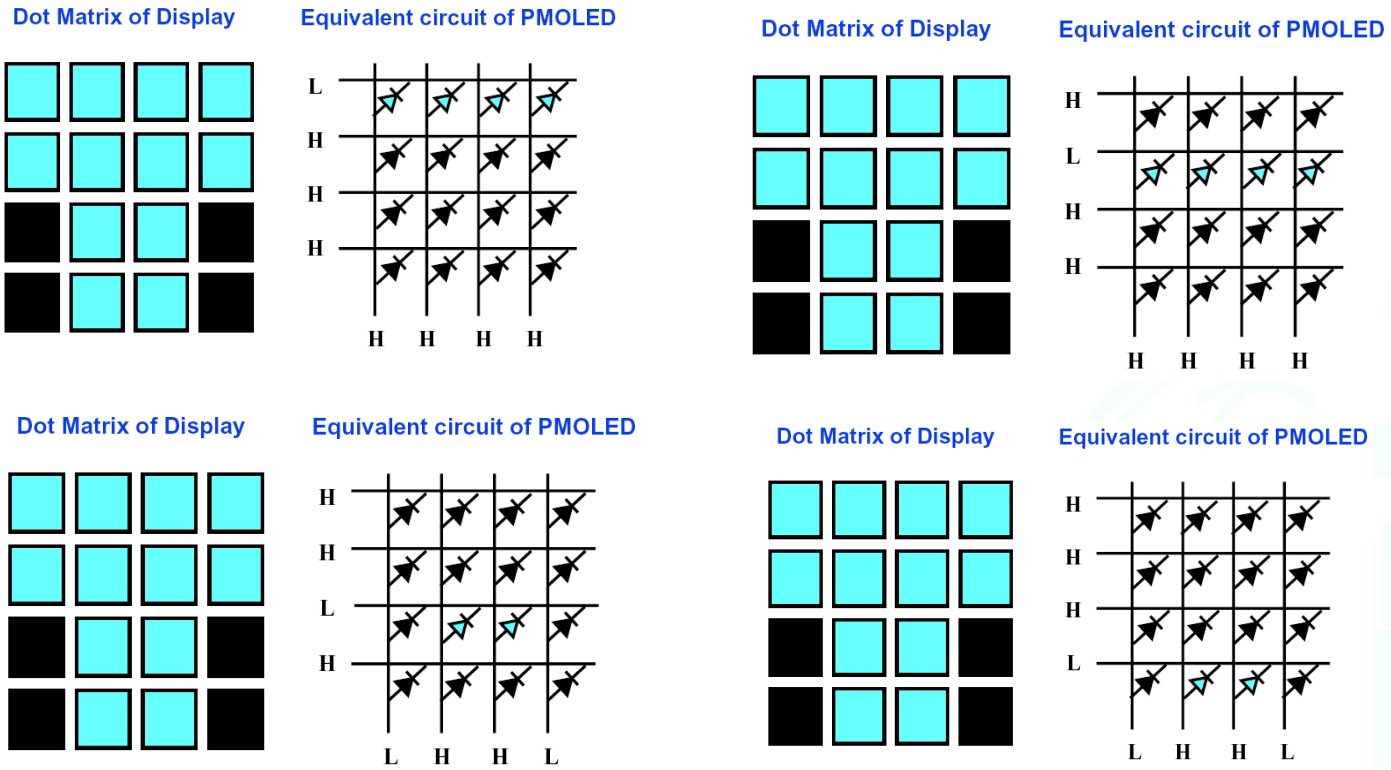
- 响应速度快
- 发光强度由通过的瞬间电流决定
- 和PMLCD一样，PMOLED图像质量不会恶化
- 增加驱动电压得到快速的响应
- 高的瞬间亮度在一场的时间内被平均，类似CRT电子枪扫描
- 超过100行时，需要电压超过15V，和5-7V时的电压相比，电阻和电容引起的损失随行数增加上升很快 。

一、OLED驱动技术

PMOLED 驱动原理

- 驱动ICs 通过在寻址期控制数据线的电流控制电流强度（亮度）
- 电流控制方式：PWM 或模拟控制。

Passive Matrix Driving

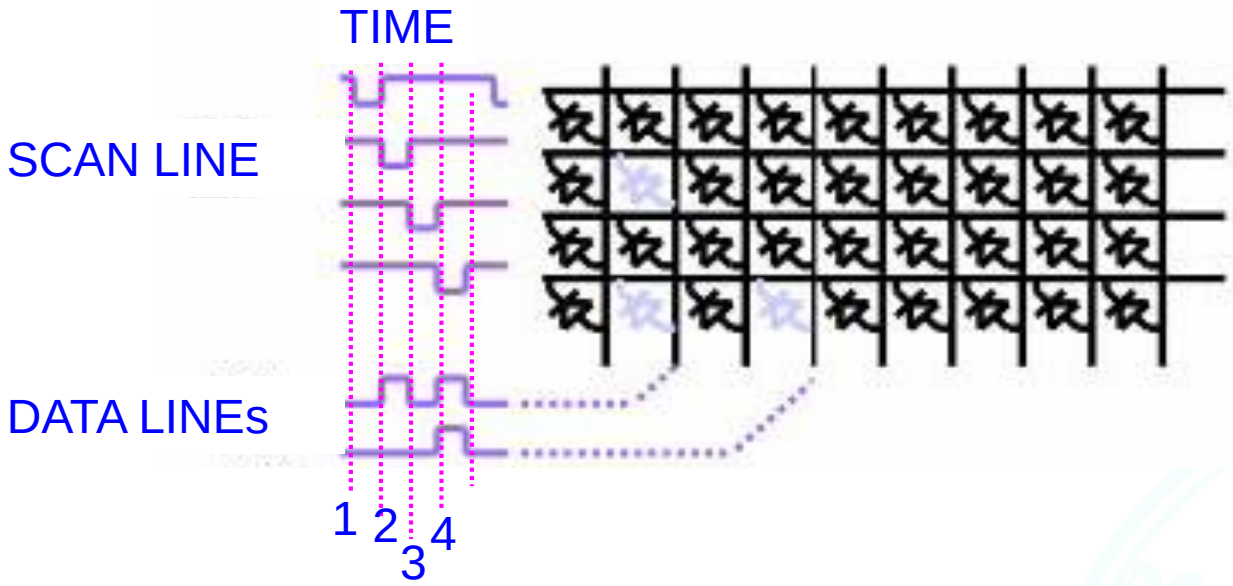


一、OLED驱动技术

存在问题

未选中的像素处于ON和OFF状态之间，被选中和未选中的像素之间存在串扰。

解决思路：校正PM OLED 的器件特性，抑制漏电流减少串扰



反偏压的OLED在行间扫描时需用电流源充电到驱动电压，但电极间的有机层间距很小(0.1-0.2μm)，电容相对大，需50 μs的充电时间。在可用的时间内充电会不足，占空比↓，亮度下降↓。

- ➔ 扫描期间所有阴极接地
- ➔ 扫描电极分组，多电极同时扫描
- ➔ 行电极电流>>列电极➔金属阴极

一、OLED驱动技术

- 扫描线电阻功耗：**0.1V**压降即导致整个面板的亮度显著变化

- 电容功耗损失：***Pcap = C × Vswing × Vsupply × f***

  电容的损失影响严重，因为电流被逐行间传递。

  → 增加发光效率。采用低电压的磷光材料，而非荧光材料。

  → 列电极上下分离，降低电容值，但会提高**ICs**数量。

- 降低**PMOLED**功耗→手持设备

  → 面板分割为图标区（直接驱动）和图像区（矩阵驱动）。

  → 测试需要显示的图像，尽可能降低电压和亮度。

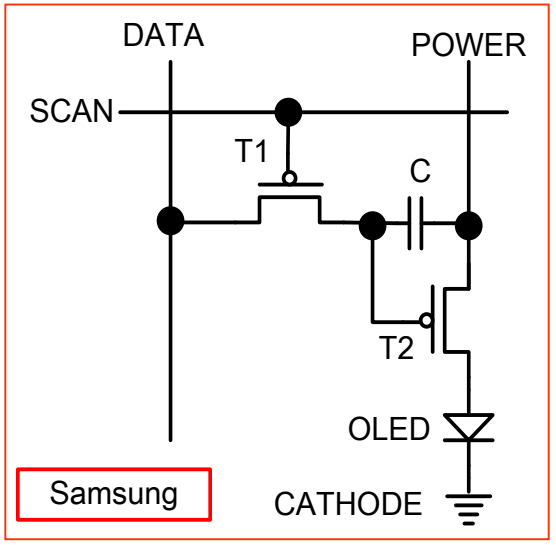
  → 待机模式中引入简单的驱动算法，满足最小信息显示要求。

  → 不扫描无信息的行，降低有用行的信息（**SmartScan**）。

- 像素间老化程度存在差异

  → 驱动**IC**可编程化，但仍难以处理这种单个像素间

3. Active Matrix Drive



阳极背板设计的关键问题

- 每个子像素需要多少TFTs？
- 那种半导体材料适合做TFTs？
- 像素应该是电压控制还是电流控制？

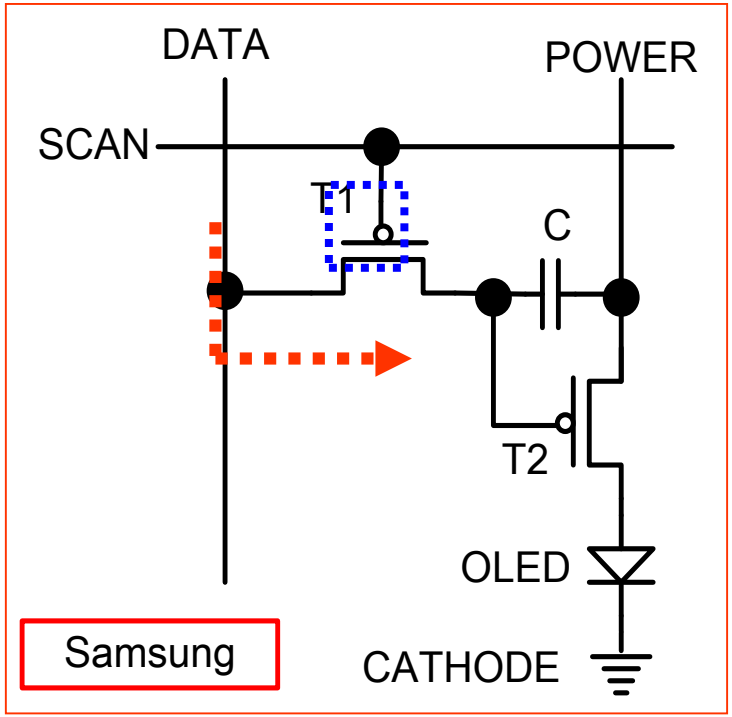
解决的出发点：

电致发光总量（光通量）和 制造工艺的难度。控制TFTs的两个关键特性：阈值电压和迁移率。

- 制造的不均匀性
- 因电流和发热引起的像素间的差异
- 对多晶硅AMOLED，迁移率的影响小于阈值电压，但仍影响显示。

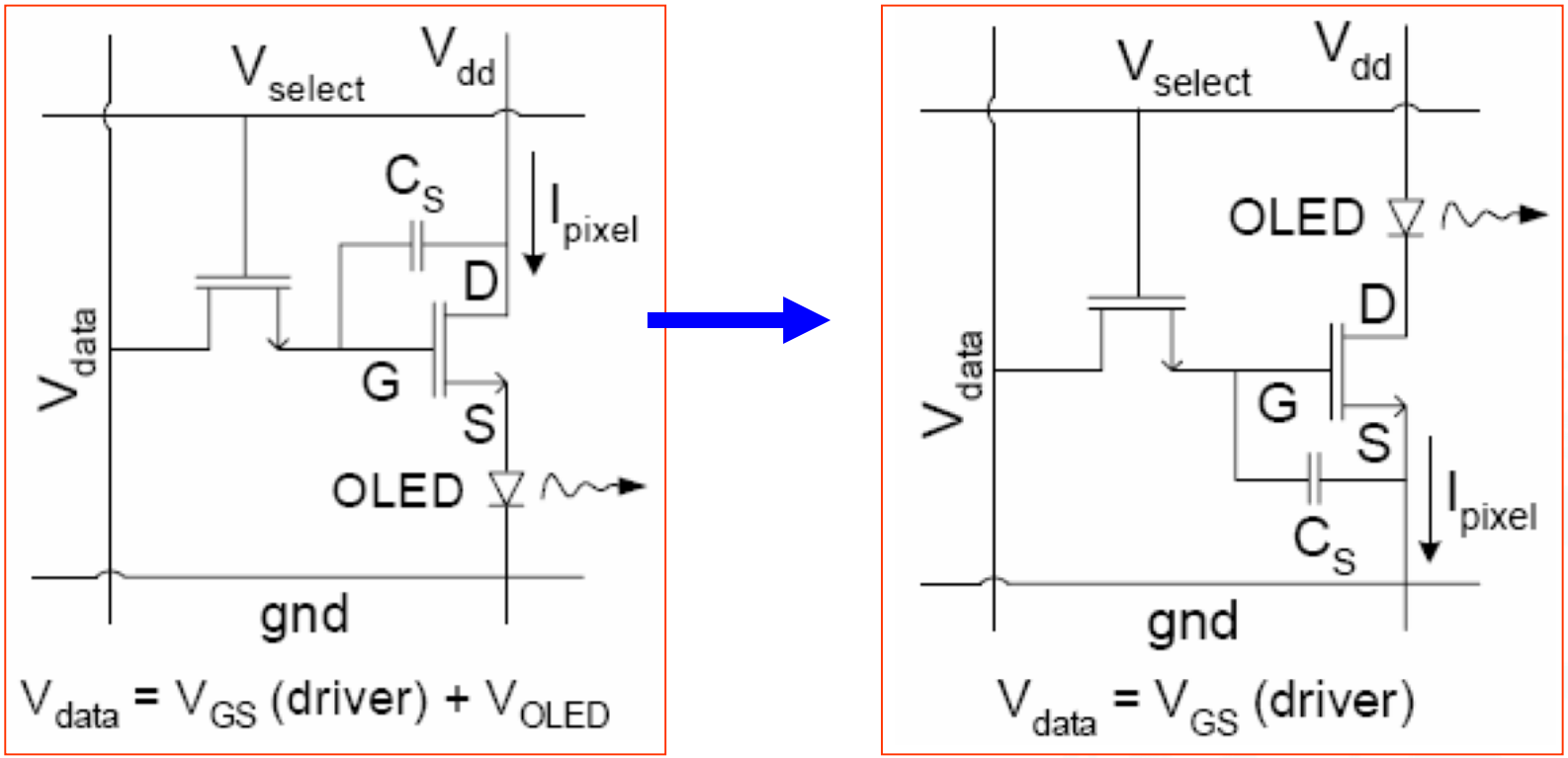
3.1 每个像素TFT的数目

- 设置T2栅极电压，控制电流源（TFT线性区）。
- 打开T1，使DATA电压到T2栅极（25μs）。
- T1关闭，T2端电压保持到下一帧→ 电流连续→其他行寻址。



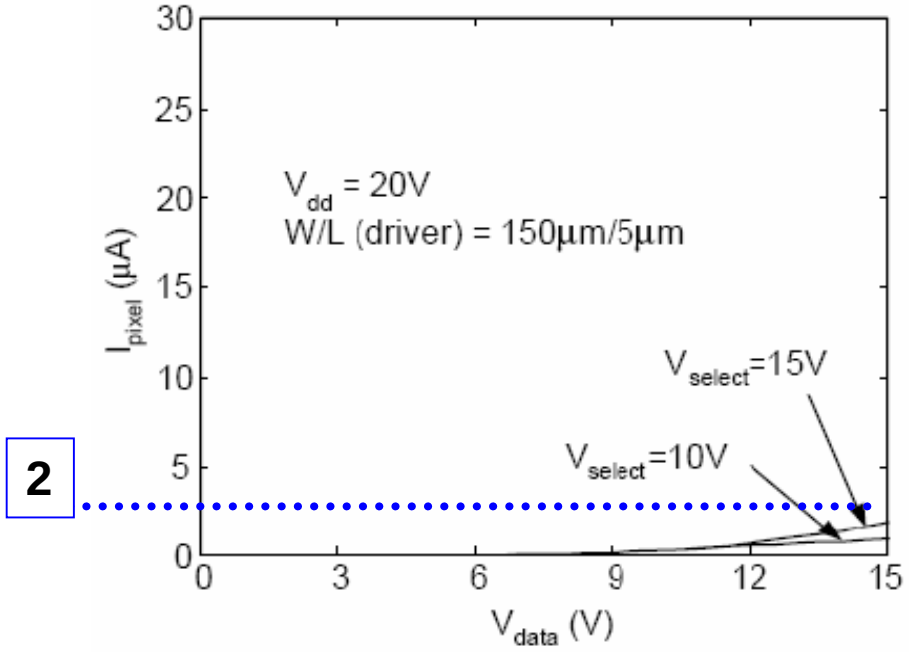
2T1C像素电路结构的改进（Inverted AMOLED TFTs）

OLED连接在漏极比连接在源极稳定，功率下降（Vds↓）

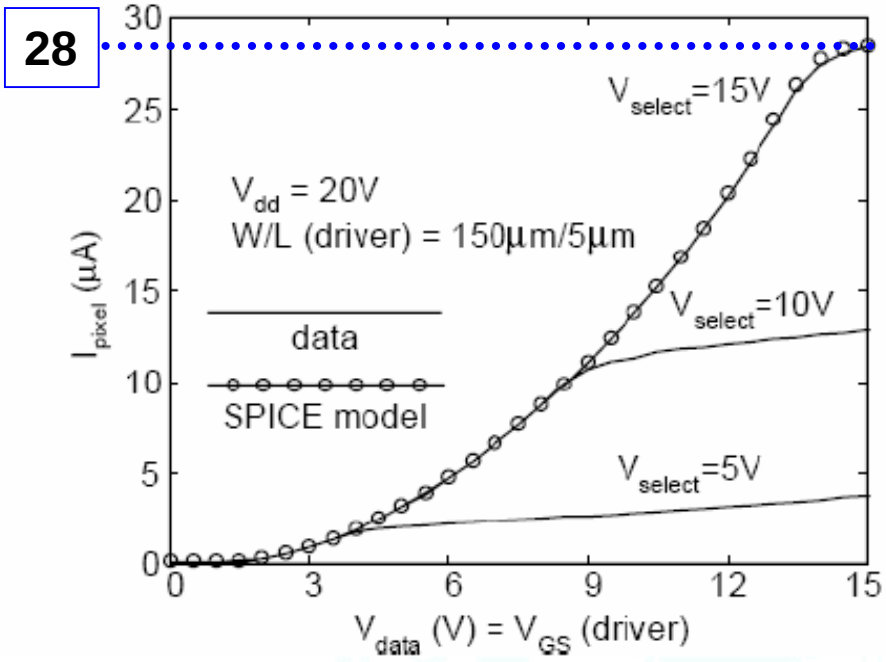


Driving current：

The results show a 10X increase in the driving current with the same bias, because the data voltage is applied directly across the gate-source voltage of the driving TFT rather than being split between the driving TFT and the OLED.



Conventional

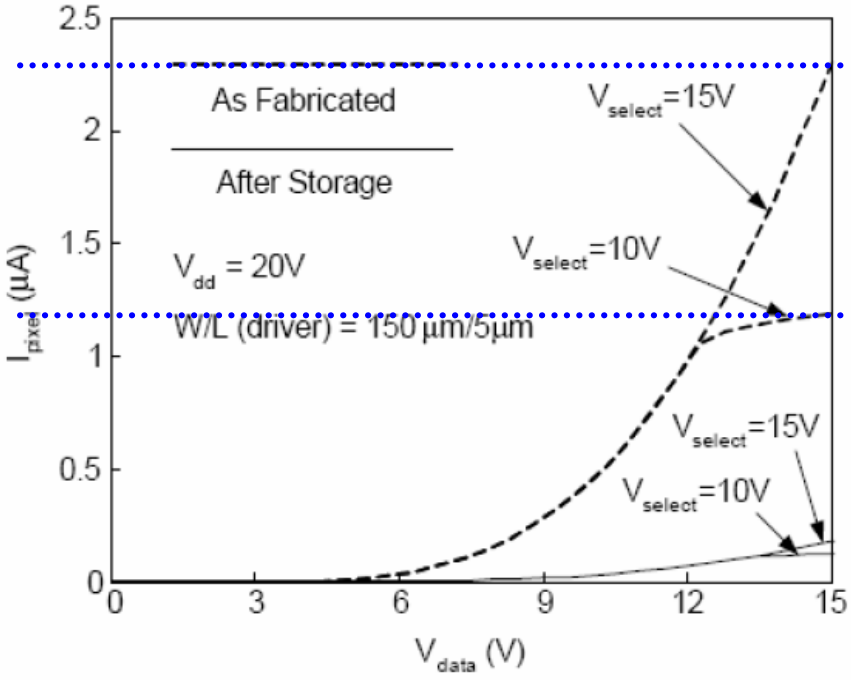


Inverted AMOLED

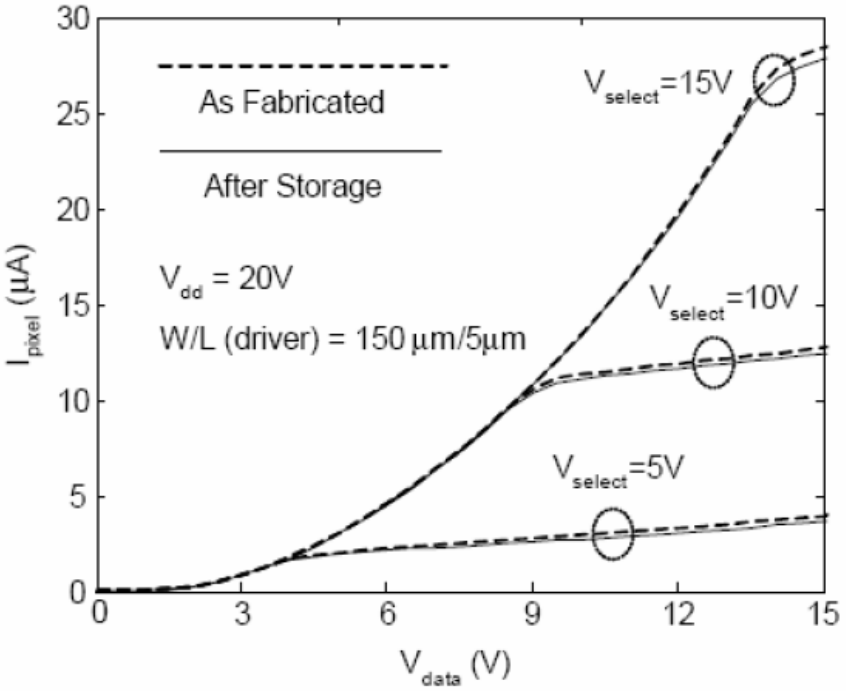
Life：

The pixel current in the inverted structure is not affected by the OLED degradation. a-Si and OLEDs to be used to fabricate large displays.

Conventional a-Si AMOLED pixel



Inverted a-Si AMOLED pixel



3.3 Choice of TFT Material

OLED的关键问题是控制每个像素电流的TFT的性能特性，随着新材料和设计步入市场，背板技术有了巨大的提升。

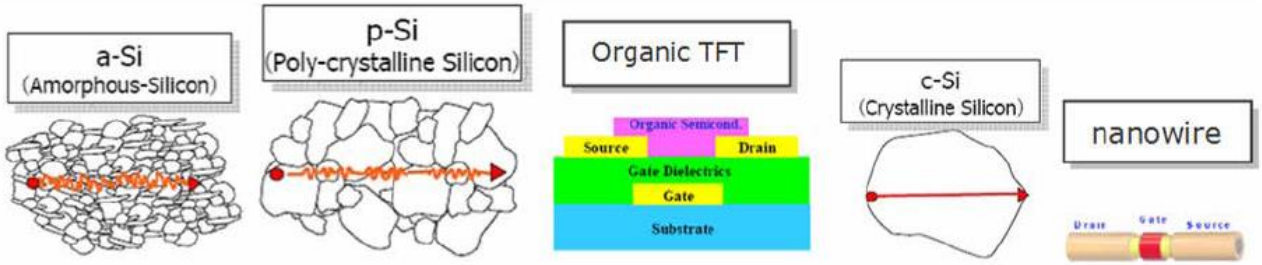
2T电路中，TFT必须满足的要求

- 驱动TFT（T2）必须能提供足够的电流用于发光。典型值：μA/T. 一些原型设计采用9-subpixel，可减少单个TFT的电流。
- 寻址期，T1可提供足够电流给电容充电（1pC，20μs）。
- 两个TFT的漏电流必须足够小（1pA），使Cst保持一帧。
- 像素电路面积小于像素的面积，底发射时，应远小于与像素面积。
- 阈值和迁移率的变化应足够小，至少可采用相关技术进行补偿， △Vth：p-Si为50mV，a-Si为200mV。

OLED与 LCD相比，在电学上的一个最大的区别是：

LCD为电压型器件，而OLED是电流型发光器件，因此，对于OLED需要至少两个TFT（一个提供OLED发光所需的驱动电流、一个提供信号开关的作用）才能实现有源驱动，而且驱动TFT性能（阈值电压、载流子迁移率）的任何变化都将显著影响到OLED显示屏亮度。这就对TFT器件的电流驱动能力，以及其性能在时间上的稳定性和空间上分布的均匀性提出了很高的要求。

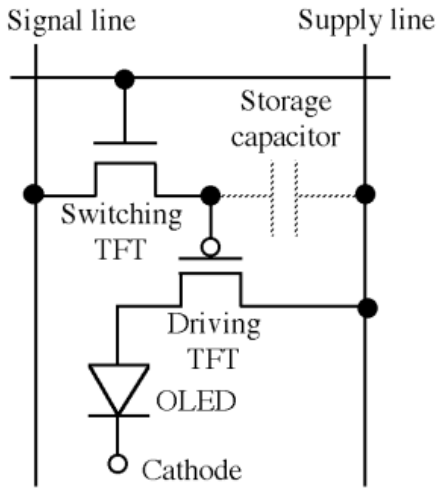
Comparison of Alternative Backplane Technologies



		a-Si	p-Si	OTFT	c-Si	nanowire
Mobility		0.5 ~ 1	50 ~ 300	0.05 ~ 0.1	~1000	20 ~ 30
TFT Type		NMOS	PMOS, CMOS	NMOS	CMOS	CMOS
TFT Uniformity		Good	Poor		Very Good	Very Good
Process Step		4 ~ 5	PMOS 5 ~ 6, CMOS 9	Process Dependant		4 ~ 5
Cost	TFT	Low	High	Very Low	High	Low
	Module	High	Low	High	Low	Low
	Total	Better for Large	Better for Small	Better for Flex	Better for Small	Better for All Types
Device Stability		Less Stable	More Stable		Highly Stable	Highly Stable
Display Type		LCD	LCD, OLED	EPD	none	LCD, OLED
Temperature		300°C	4-500°C	~100°C	>500°C	100 ~ 300°C

4 Gray Scale Control: Digital or Analog Drive

（1）数字驱动：**Time-Ratio Gray-Scale**：和**PDP**类似，分子场，不同权重表示不同灰度级：**1-2-4-8-16…**。会和**PDP**一样，产生伪像（**DFC**）。



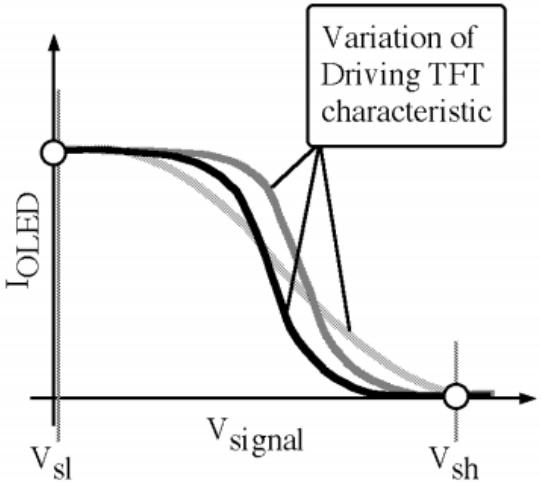
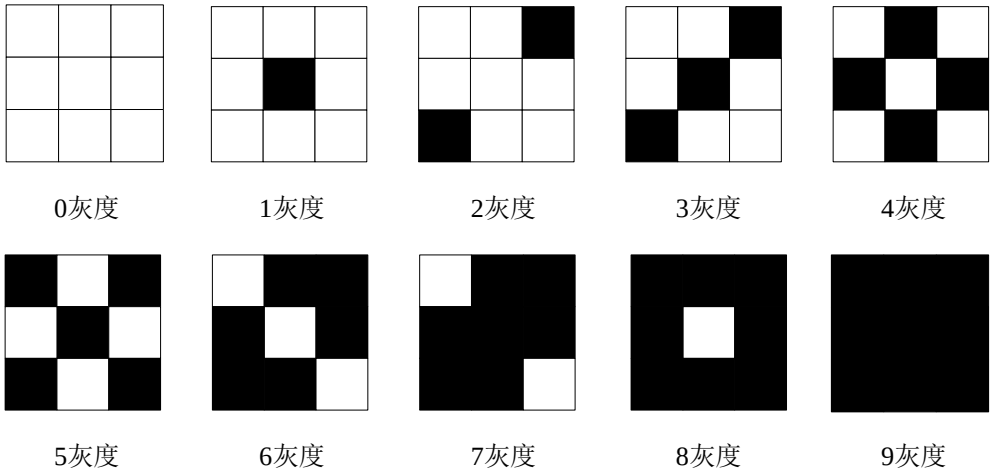


Figure 2 Current of OLED

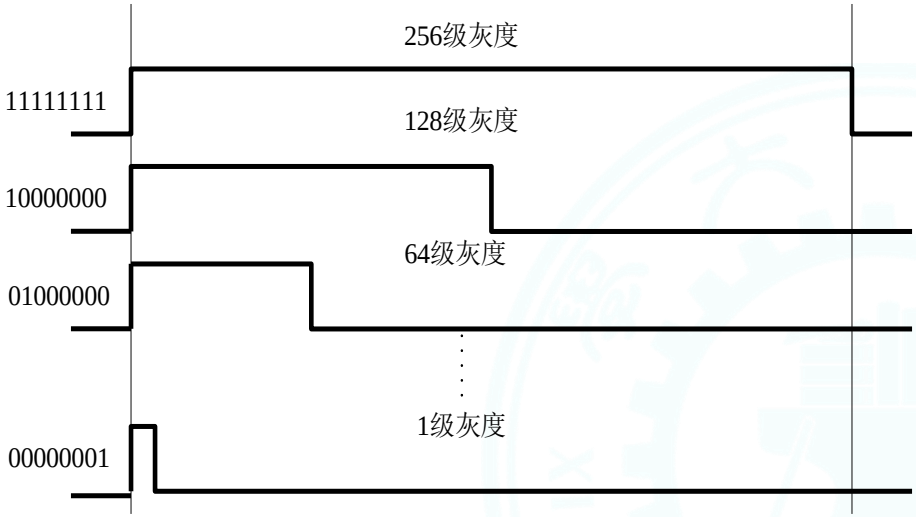
幅度调制实现灰度：模拟驱动的缺点

一、OLED驱动技术

空间调制实现灰度



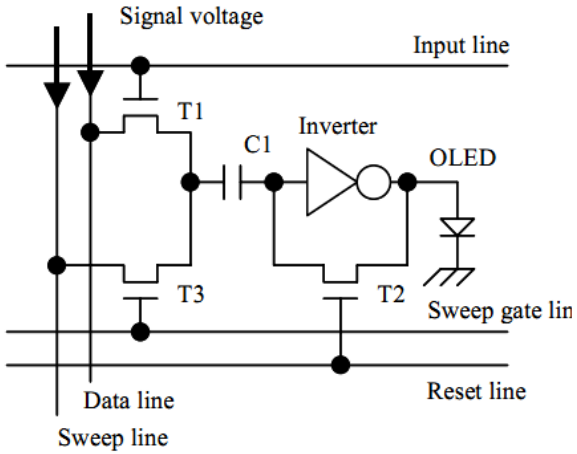
时间调制实现灰度

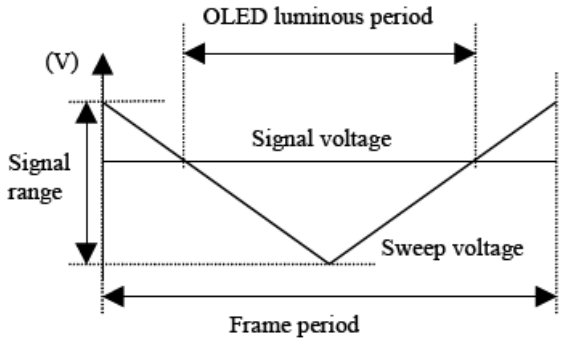


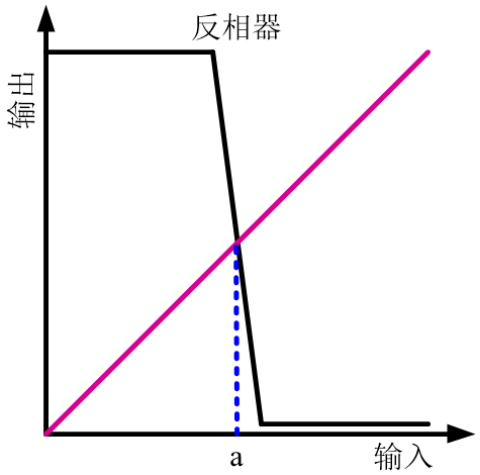
一、OLED驱动技术

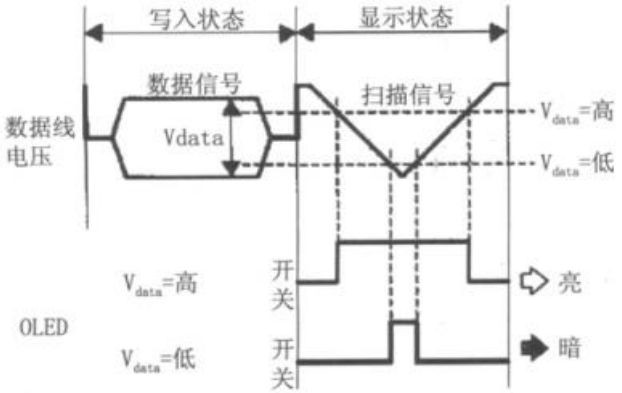
Pulse width modulation：

在一帧的周期内，每个像素只打开和关闭一次，打开时间受**data**电压控制。



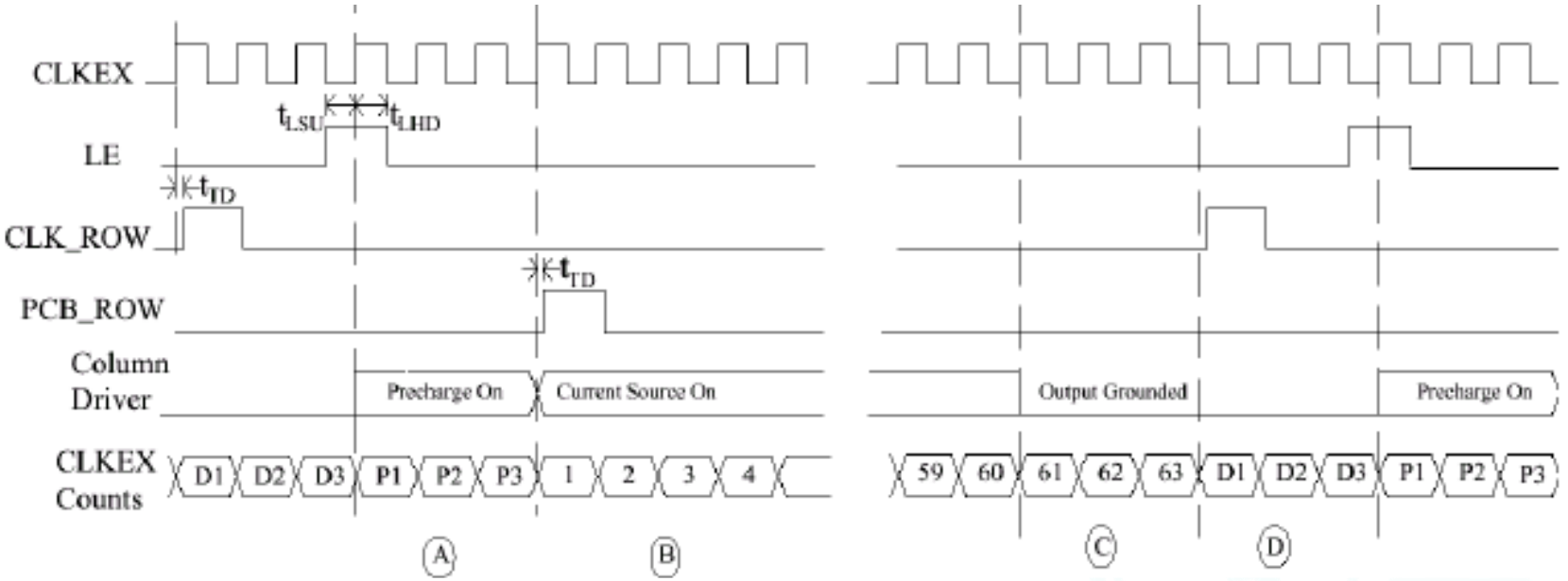






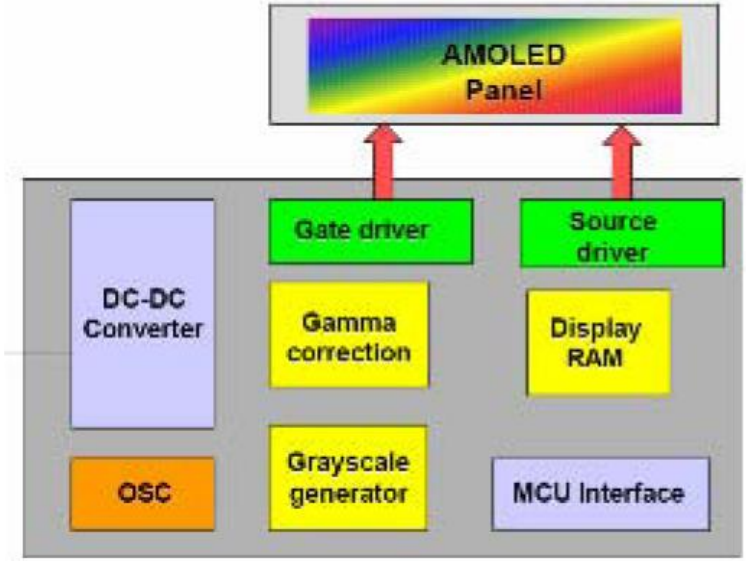
5. Drive Electronics（PM OLED）

- **PM OLED驱动IC的驱动时序**
  - 充电期: 预充电脉冲（7 CLK）同时加到所有像素，电压幅度刚好小于阈值。
  - 发光期: 0-63 CLK，6-bit gray scale。
  - 消隐期：使输出接地，剩余扫描期内不发光。
  - 放电期： 每列放电，准备进行下一行的扫描。



AM OLED 驱动电路系统架构：

- Graphics accelerator
- Segment and common drivers
- Multi-function MCU interface
- Display memory
- Analog functions
- Low power driving scheme
- DC-DC converter



一、OLED驱动技术

二、Beyond OLEDs

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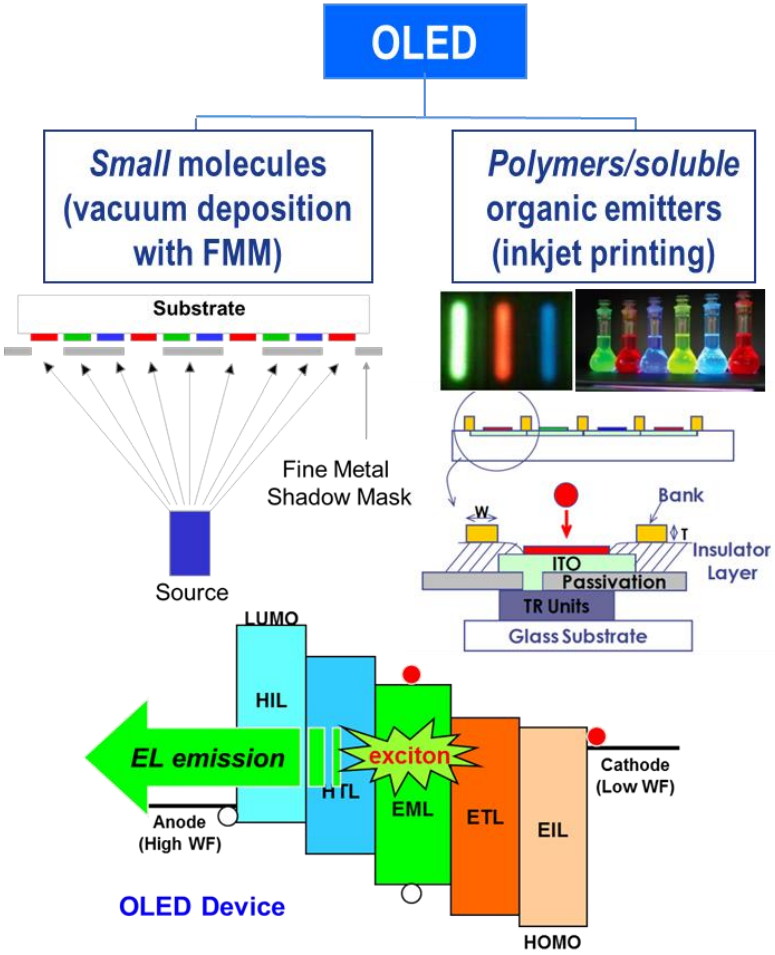
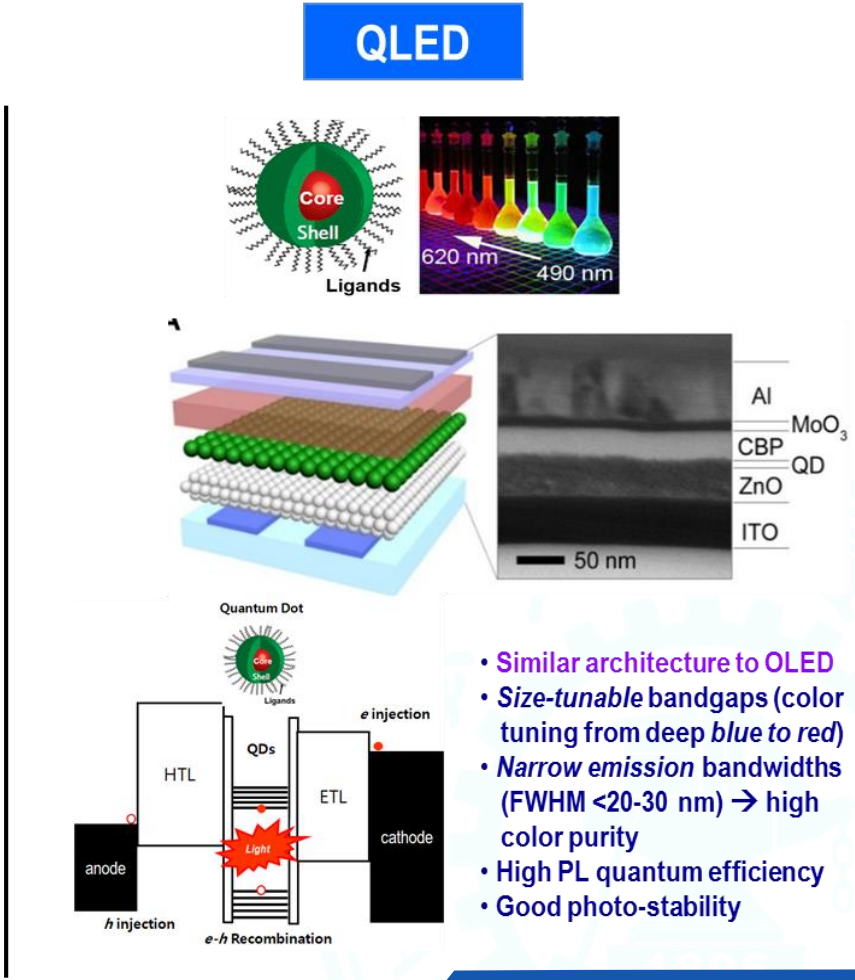
二、Beyond OLEDs

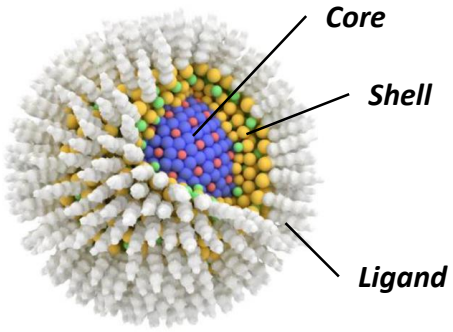
Quantum Dot (QD) QLED: Prof. C-H. Lee, 16.1 Invited Talk, Apr. 11





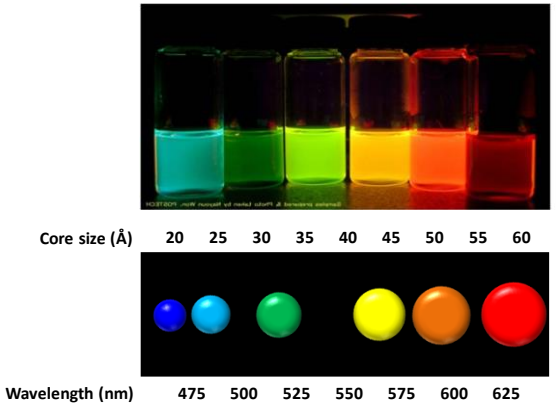
- Similar architecture to OLED
- *Size-tunable* bandgaps (color tuning from deep *blue to red*)
- *Narrow emission* bandwidths (FWHM <20-30 nm) → high color purity
- High PL quantum efficiency
- Good photo-stability

QD Structure & Advantage



[Ref] http://en.rusnano.com/

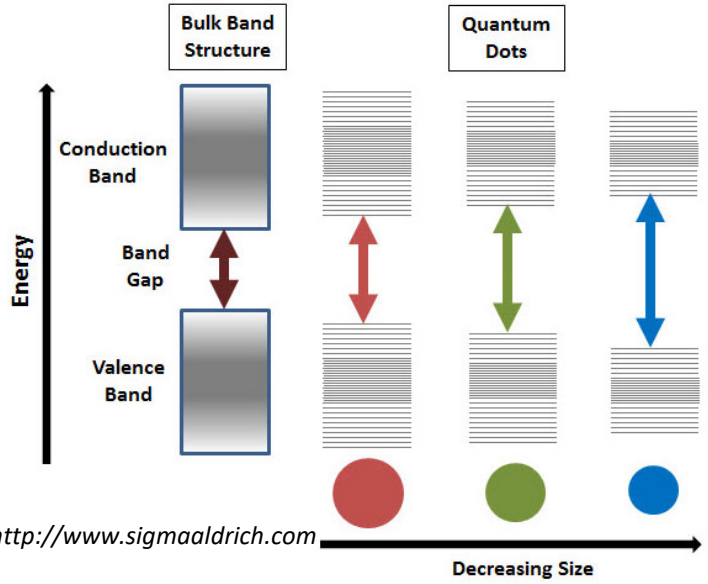
1) **Material : Inorganic semiconductor**
2) **Core : Determination of emission wavelength**
   ex) CdSe, CdTe, ZnTe, CdS, InP etc…
3) **Shell : Surface passivation / Protection layer**
   ex) ZnSe, ZnS, CdS etc…
4) **Ligand : Surface stabilizer / QD solubility**
   ex) COOH, NH_2, TOP, TOPO, OA etc…
5) **Solvent : Organic or Alkane solvent** (toluene, hexane etc…) , **Water**



[Ref] http://www.nanotrio.com/

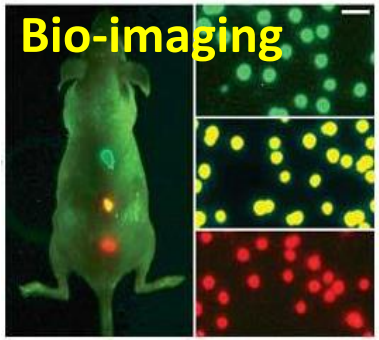
Quantum-dots properties

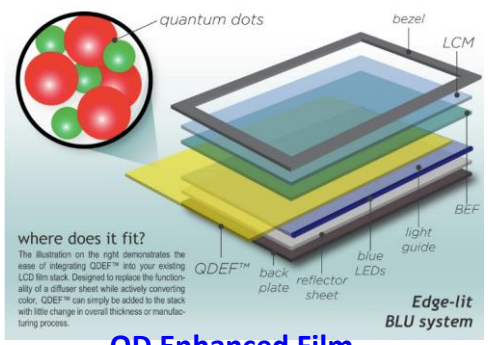
- Inorganic material
- High color purity (FWHM < 35 nm)
- High electron mobility
- Band-gap tunability (QD diameter control)
- Solution process capability



[Ref] http://www.sigmaaldrich.com

Application & QLED vs OLED



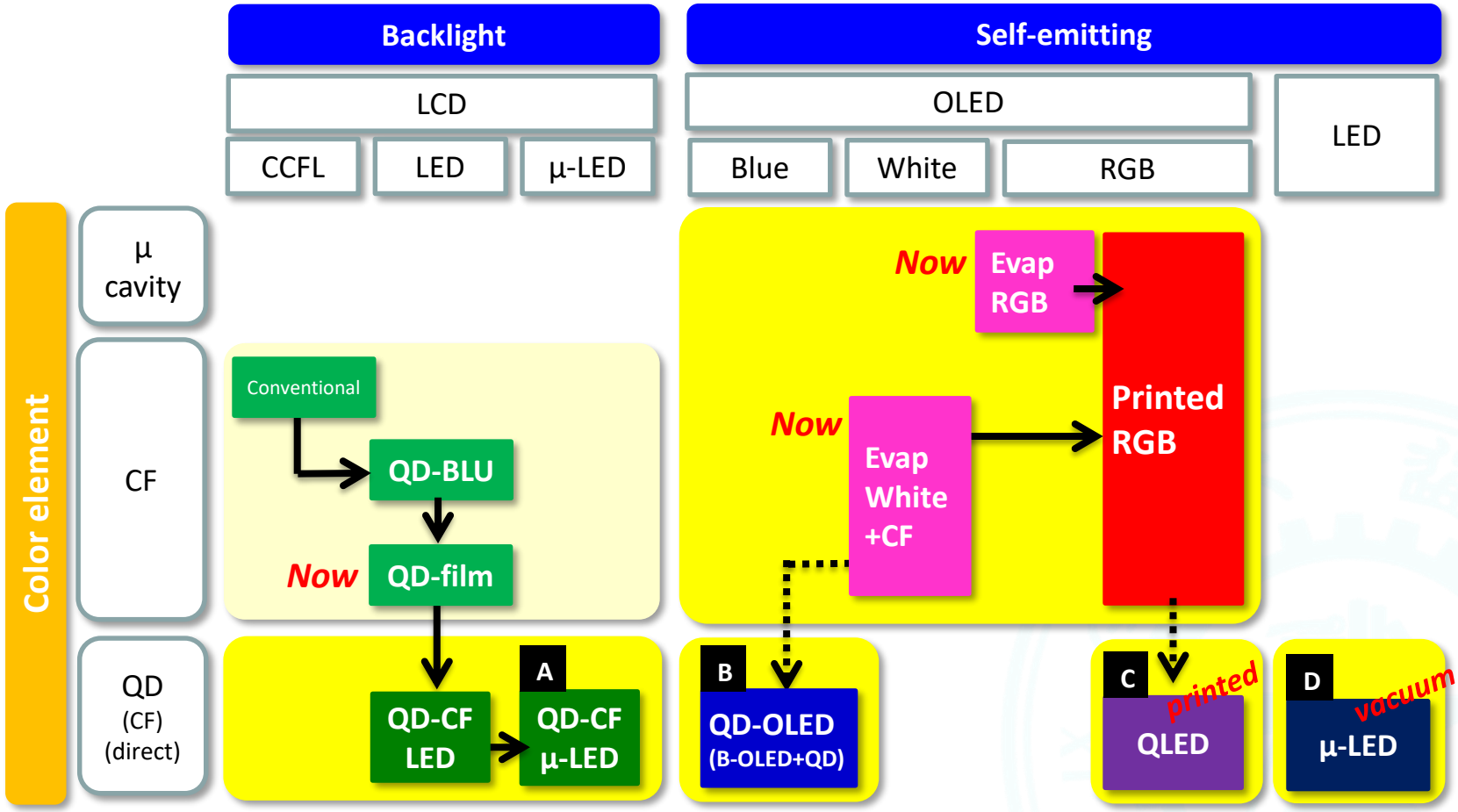


QD Enhanced Film

Features	OLED	QLED
Efficiency	> 80 cd/A (Single unit, bottom emitting, green OLED)	***~ 80 cd/A (Best) (Single unit, bottom emitting, green QLED)***
Emission bandwidth (color saturation)	Broad (FWHM 50~100 nm)	***Narrow (FWHM < 35 nm)***
Color Tunability	Low : Different emitter	***Excellent : Change QD core size***
Cost of Emitter	High	***Low***
Manufacturing process	Vacuum / Solution	Solution
Large display area	Yes	Yes
Flexibility	Yes	Yes
Near-IR emission (Telecommunication, Sensor)	No	***Yes***

Roadmap of display technology

- Printed-RGB is a next technology of Evap-RGB and WOLED+CF.
- Emerging and competing technologies over OLEDs will be A, B, C and D below.



Micro-LED

Micro-LED Technologies and Applications

Light-emitting diodes (LEDs) offer extraordinary *luminance, efficiency, and color quality*, but to date are largely used in displays as backlights or packaged pixel elements in large-area LED billboard displays. Building high-performance emissive displays in a smaller form factor requires a new micro-LED technology separate from what is used for large LED billboards. Several approaches have been proposed to *isolate micro-LED elements and integrate these micro-LEDs into active-matrix arrays*. Technologies that use micro-LEDs offer the potential for significantly increased luminance and efficiency, unlocking new possibilities in high dynamic range, augmented/mixed reality, projection, and non-display light-engine applications.by V. W. Lee, N.Twu, and I. Kymissis (*Information Display*, 2016)

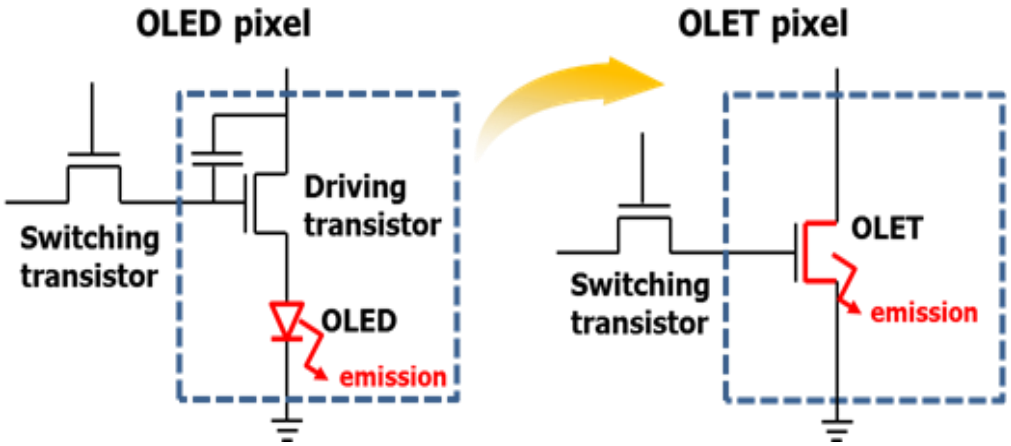
Challenging Issues

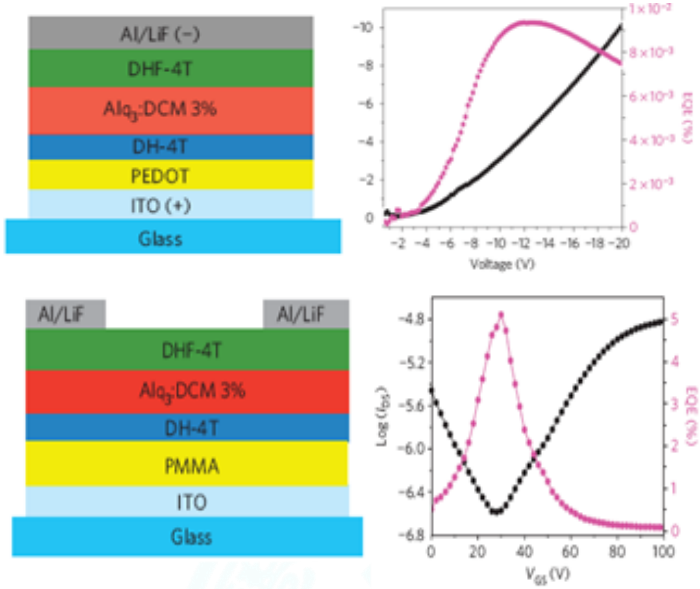
- Integration of color-generating materials
- Integration of phosphor materials
- Stacking of R-, G-, and B-LED epitaxial layers
- Scalability of integrated semiconductor processes: flip-chip, LED epitaxial transfer to CMOS, and TFT methods → *high resolution, cost down, large size*

Organic Light-Emitting Transistor (OLET)

OLED vs OLET

- Driving TR + OLED pixel in a single device
  - High aspect ratio, low power consumption





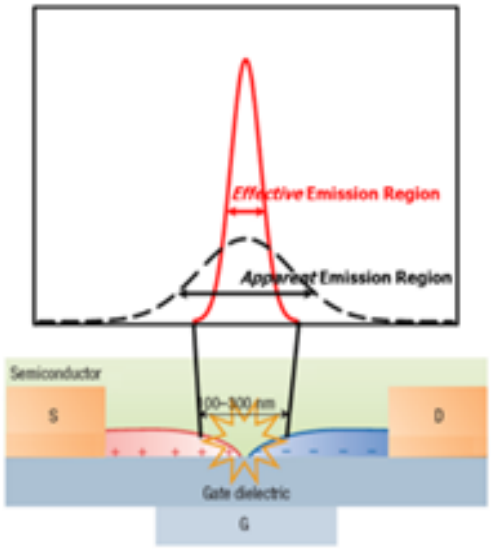
- Architecture: 2-Terminals → 3-Terminals
  - Control of charge transport by electrical scheme
  - High quantum efficiency (reduced quenching)

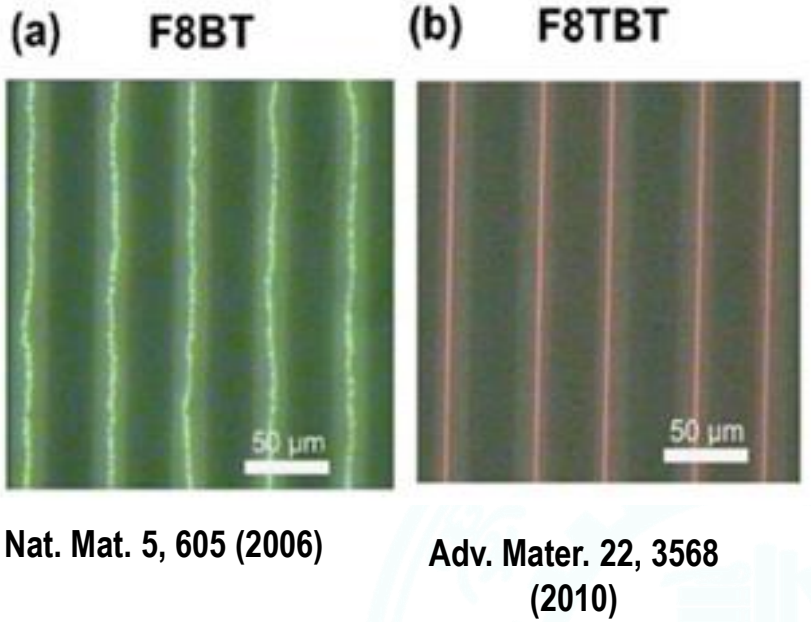
Nat. Mat. 9, 496 (2010)

Performance Issues on OLETs

1) Narrow width of emission zone

- *Recombination* of h+ and e- in limited region of 100~300 nm in single layer OSC → Narrow effective emission region





Nat. Mat. 5, 605 (2006)

Adv. Mater. 22, 3568 (2010)

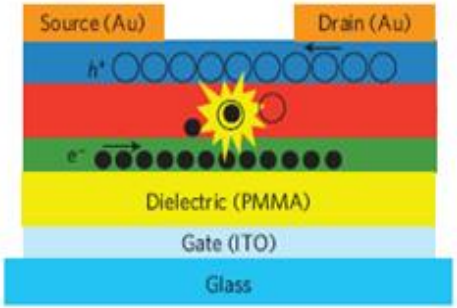
2) Low current on/off ratio

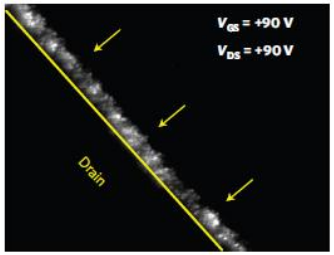
- On/off current ratio < 10^2
- High off-current → not suitable for active displays

二、Beyond OLEDs

Previous Works for Performance Improvement

Multiple organic layers

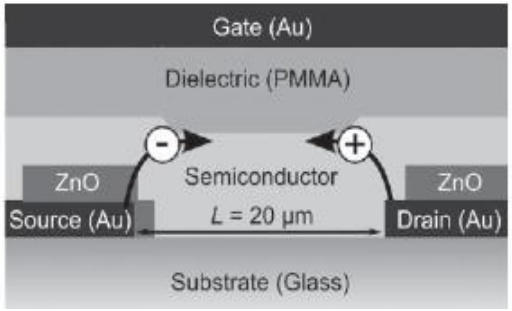


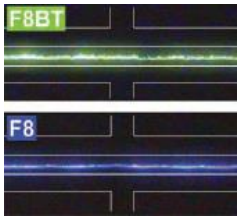


- Control of carrier transport & recombination by multiple organic layers
- Increased on/off ratio (~10^3)
- Still limited to line emission

Nat. Mater. 9, 496 (2010)
Adv. Funct. Mater. 21, 3667 (2011)
Adv. Mater. 24, 1171 (2012)

Modified/bilayer electrodes





- Control of carrier injection by modified electrodes and work function
- High external quantum efficiency (~8%)
- Still limited to line emission

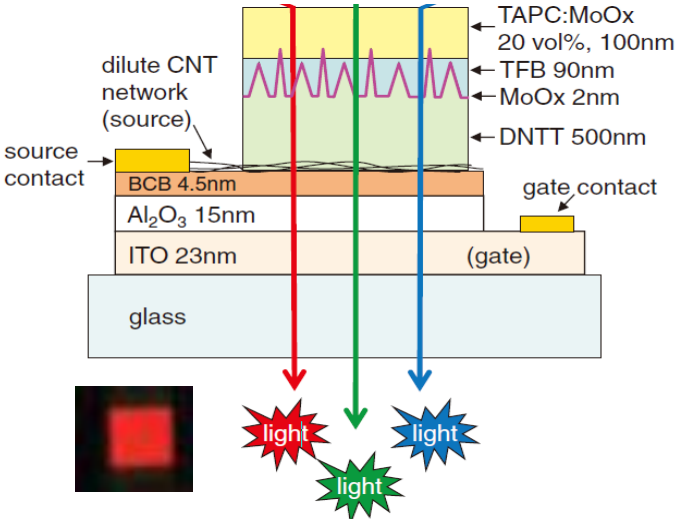
Adv. Funct. Mater. 20, 3457 (2010)
Adv. Mater. 22, 3568 (2010)
Adv. Mater. 24, 2728 (2012)

Vertical (V)-OLET

Vertical Configuration of Gate-Source-Drain

- High current density at low operation voltage
- Quasi-surface emission

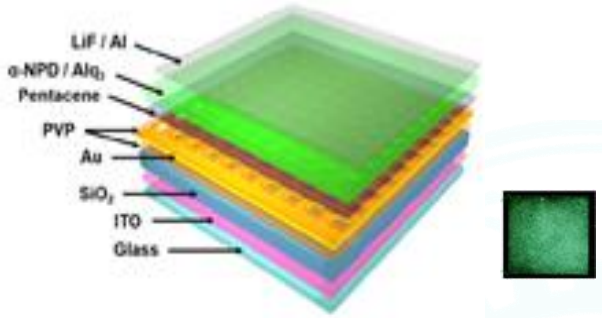
SW-CNT



Science 332, 570 (2011)

✓ Instability / poor morphology of SW-CNT

Network Electrode

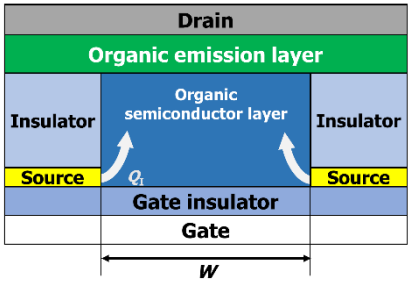


Opt. Express 22, 14750 (2014)

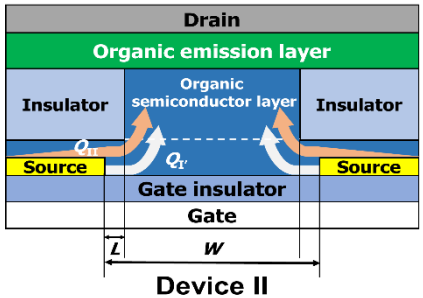
✓ Lateral expansion of current flow and emission zone within network

二、Beyond OLEDs

Charge Flow Pathways in 3 Types of V-OLETs (J. Appl. Phys. 121, 024502 ,2017)



Opt.. Express. 22, 14750 (2014)



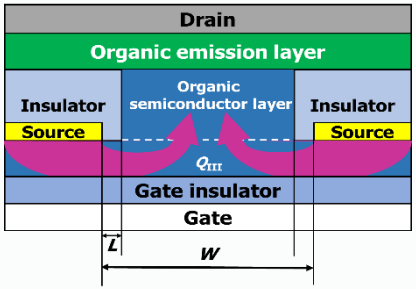
Device II
Jpn. J. Appl. Phys. 47, 1889 (2008)

Device I: GI-S-SI (source electrode covered directly with insulator)

- Q_I: injection from the side of S
  - → transported along the vertical source-drain pathway by high E-field from drain
  - → less charge accumulation at interface of GI
- high off-current (source-drain) → low on/off ratio

Device II: GI-S-OSC-SI (over-covered source insulator)

- Q_{II} : over-covering insulator blocks high E-field from D
  - → better control over $Q_{I'}$ by the gate voltage
- $Q_{I'}$: injection from the top side of S
  - → not controlled by the gate voltage → leakage current
- substantially high off-current → insufficient on/off ratio

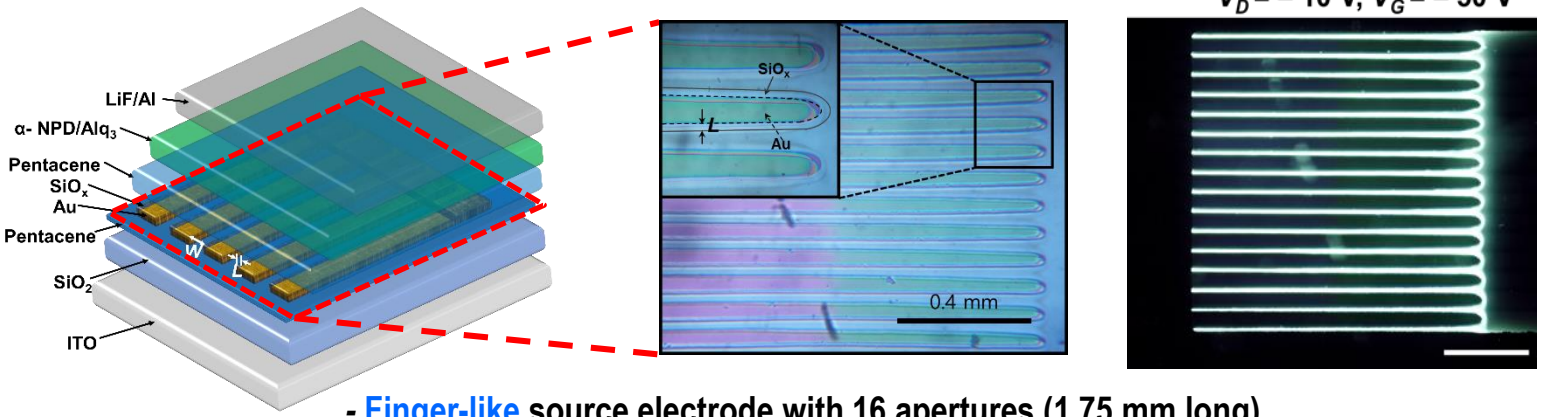


Device III
J. Appl. Phys. 121, 024502 (2017)

Device III: GI-OSC-S-SI (encapsulating source insulator)

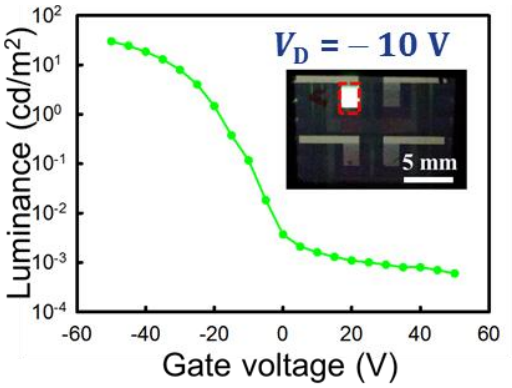
- Q_{III}: injection from the bottom side of S
  - → charge accumulation at the interface by the gate voltage
  - → laterally transported and recombined in the emission layer
- reduced off-current → high on/off ratio

V-OLET with encapsulated source electrode



- Finger-like source electrode with 16 apertures (1.75 mm long)
- Width of aperture W = 45 μm, dielectric encapsulation length L = ~ 10 μm
  (Effective aperture width $W_e = W - 2L$ = 25 μm)

- **Luminance characteristics**



- Contrast ratio ~ 10^4 at V_D = - 10 V
- Complete turn-off at V_G = 50 V
- Luminance controlled well by the gate voltage
- Emission in the effective aperture
  → quasi-surface emission in whole device area
  (2.0 mm × 2.5 mm in the inset)

Next Big Thing in Display: *Flexible, AR/VR, ……*

- Self Emission: wide viewing angle
- Ultra Thin (< 200um): slim design
- Free Form: curved, edge-free

Foldable, Rollable, Stretchable ?

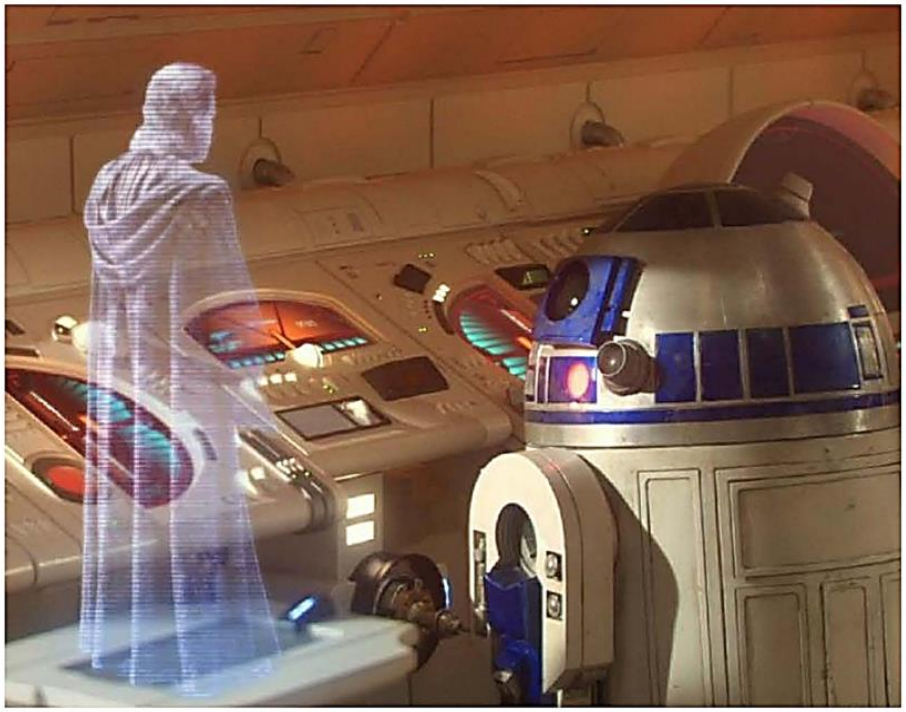
二、Beyond OLEDs

Wearable: *Is The Market Big Enough for Major Companies?*

Glass/Lens, Bracelet

The Detroit News, Automakers

Ultimate AR/VR Displays



- Transparent display hardware
- Display of 3D virtual image
- Occlusion of real object

本课程到此结束

祝同学们：

学有所获，生活快乐