Overview of OLED Display Technology

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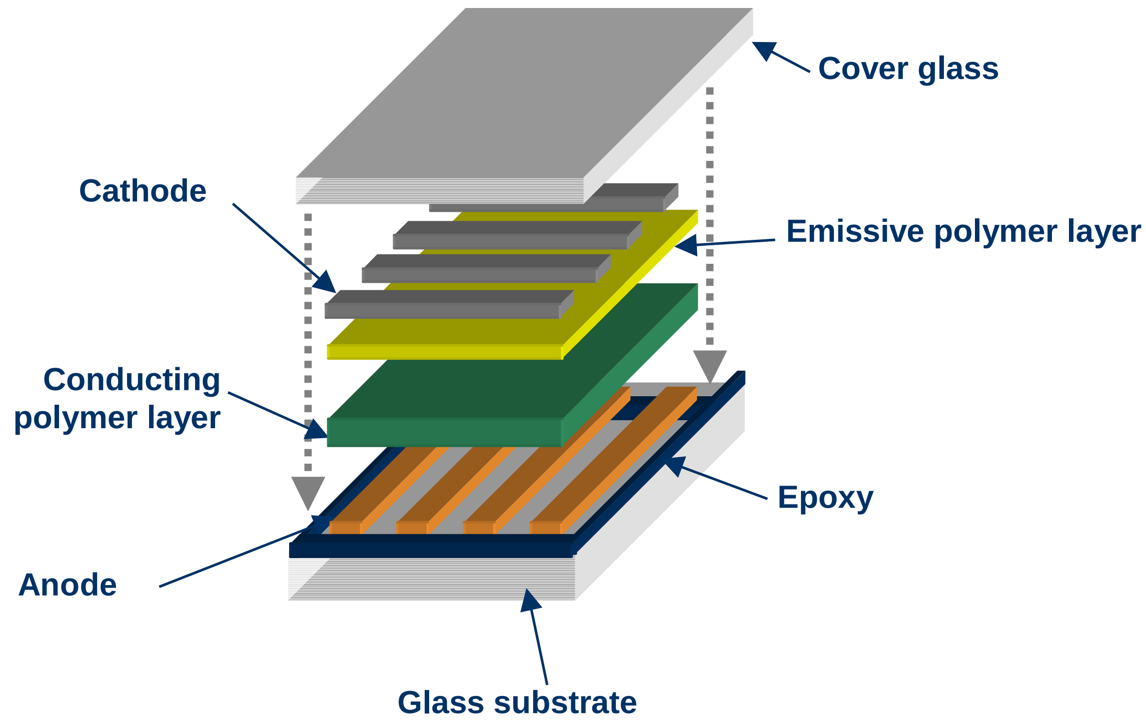
Opto Semiconductors OSRAM

Outline

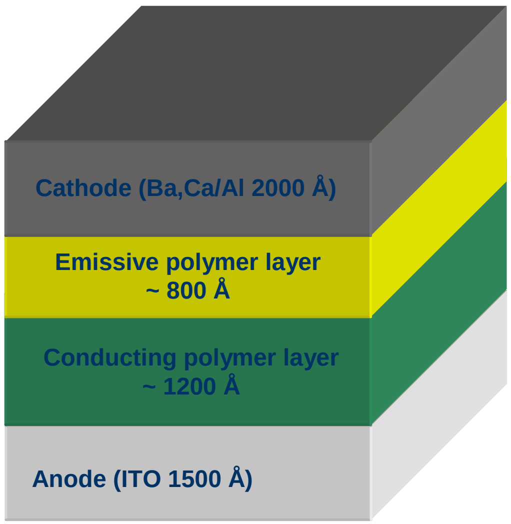
- OLED device structure and operation
- OLED materials (polymers and small molecules)
- Evolution of OLED performance
- OLED process and fabrication technologies
- Color capabilities
- White emitting OLEDs
- Passive and active matrix driving schemes
- OLED market potential
- Products and demonstrators

OLED Display and Pixel Structure

Display



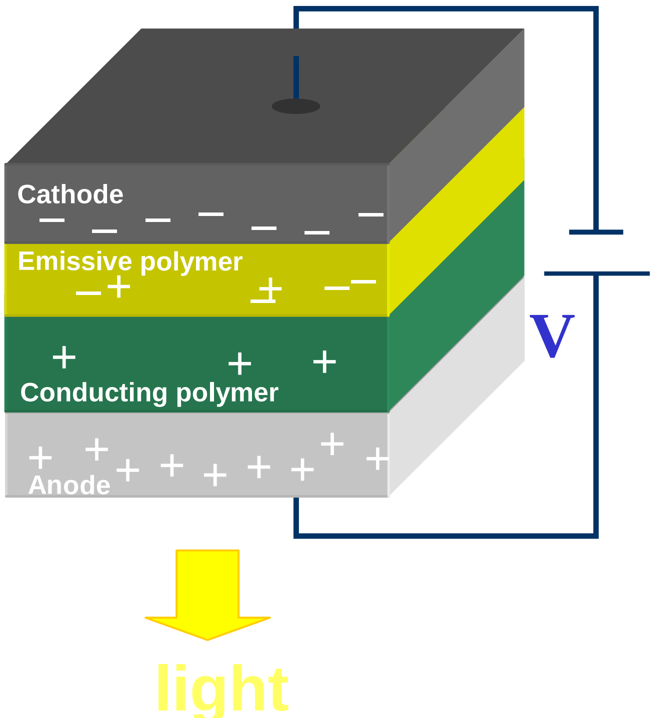
Pixel



Single pixel structure

Human hair is 200X the thickness of the OLED layers

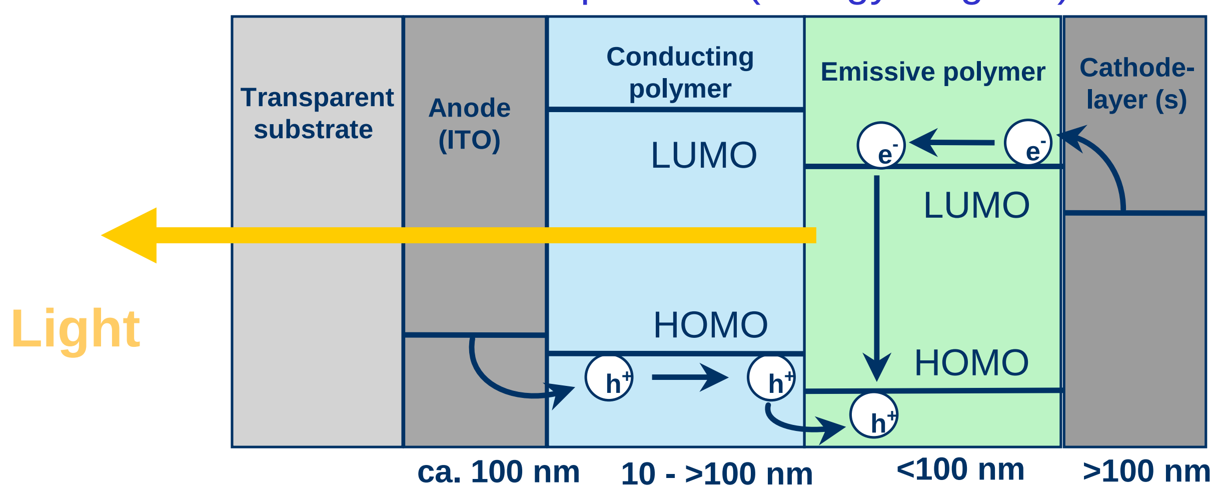
OLED Device Operation Principles



OLEDs rely on organic materials (polymers or small molecules) that give off light when tweaked with an electrical current

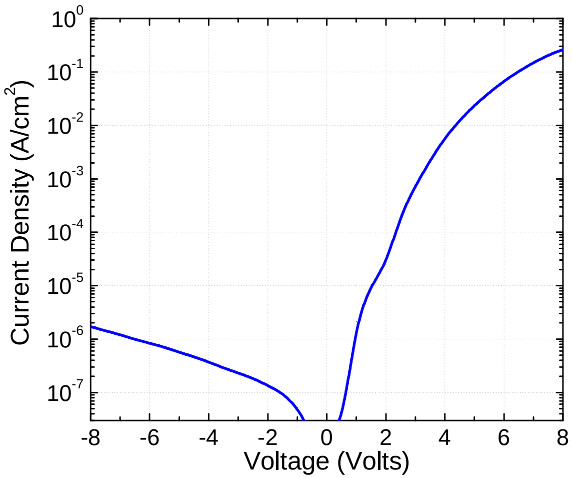
- Electrons injected from cathode
- Holes injected from anode
- Transport and radiative recombination of electron hole pairs at the emissive polymer

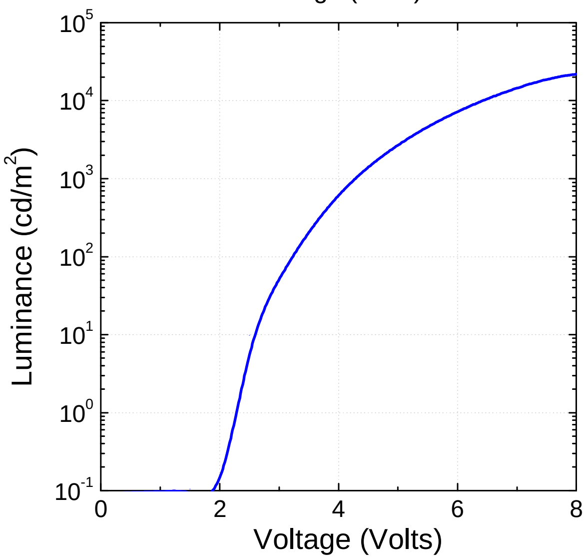
OLED device operation (energy diagram)



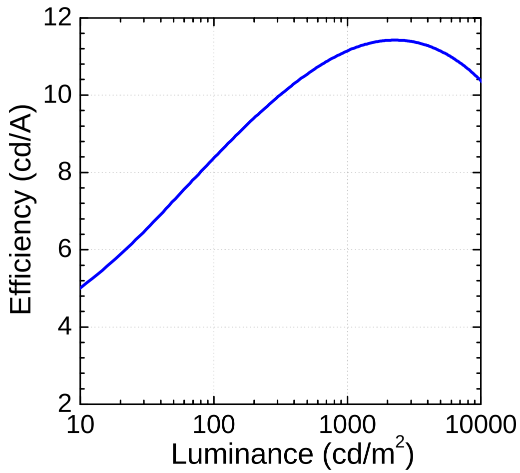
Optoelectronic Device Characteristics

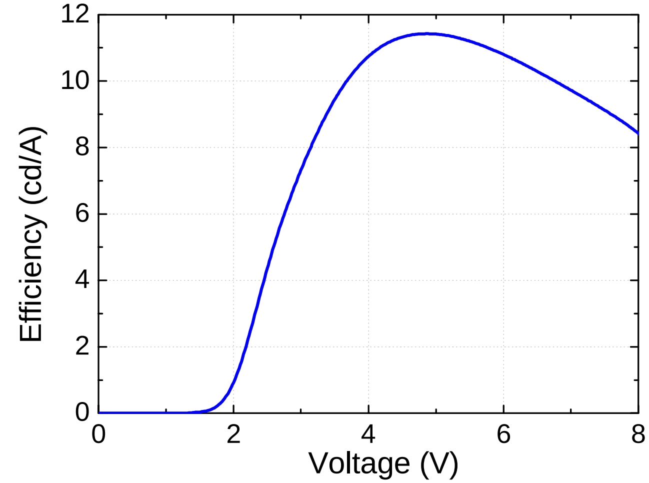
Luminance-Current-Voltage





Efficiency-Luminance-Voltage





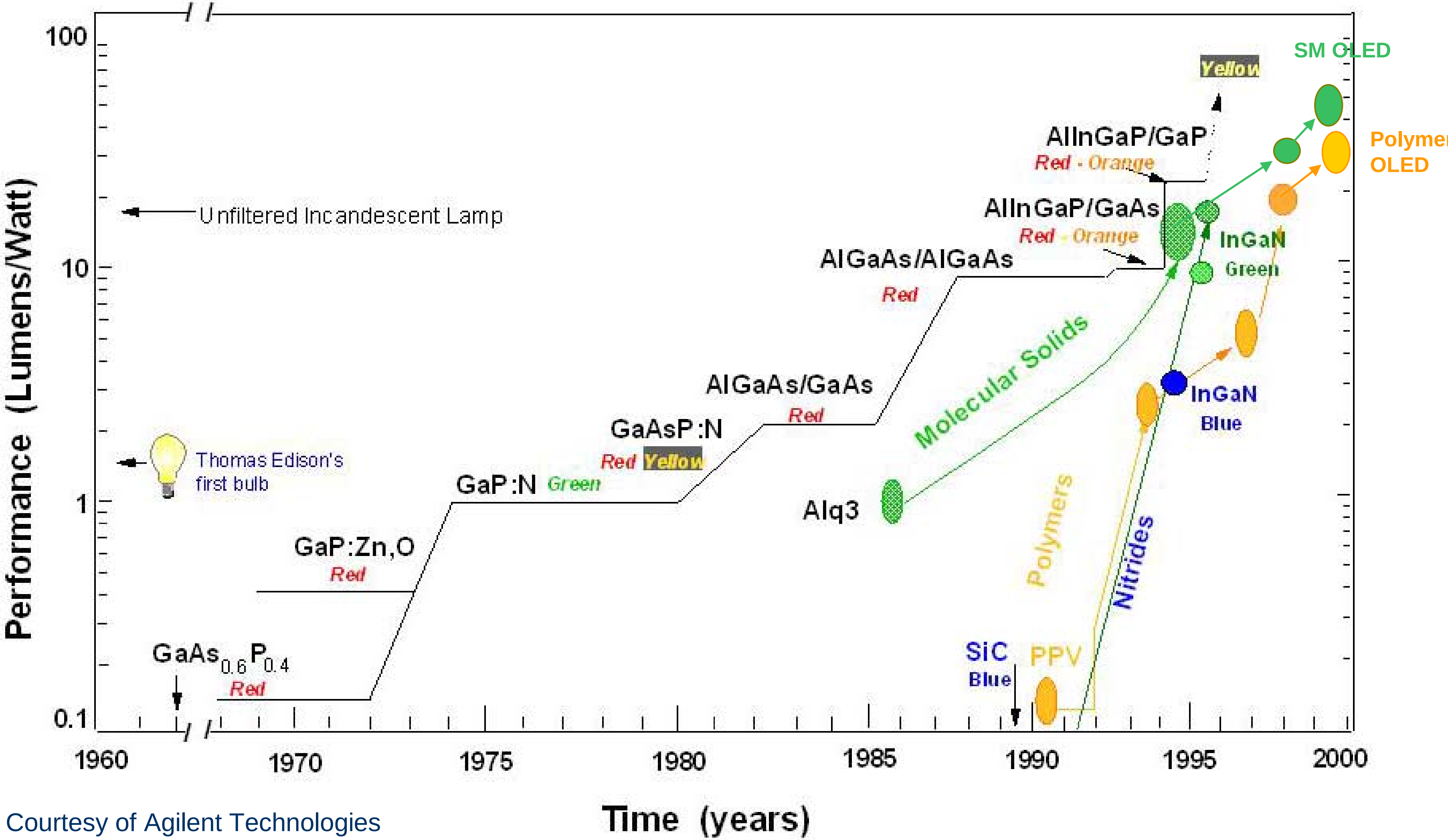
LUMINANCE is the luminous intensity per unit area projected in a given direction

The SI unit is the candela per square meter (cd/m^2), which is still sometimes called a nit

The footlambert (fL) is also in common use:
1 fL = 3.426 cd/m^2

http://www.resuba.com/wa3dsp/light/lumin.html

Evolution of LED Performance



Courtesy of Agilent Technologies

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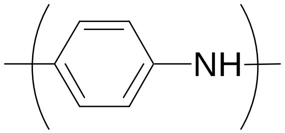
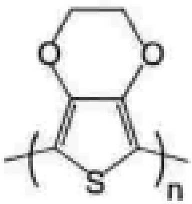
Electroluminescent Polymers

Conducting polymers

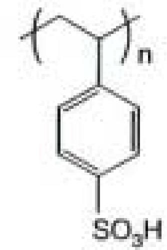
- Polyaniline (PANI:PSS)
- Polyethylenedioxythiophene (PDOT:PSS)



PANI



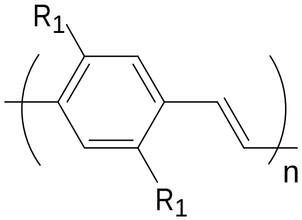
PDOT



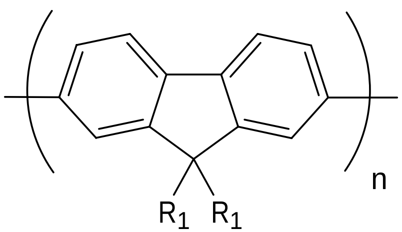
PSS

Emissive polymers

- Polyphenylenevinylene (R-PPV)
- Polyfluorene (PF)



R-PPV



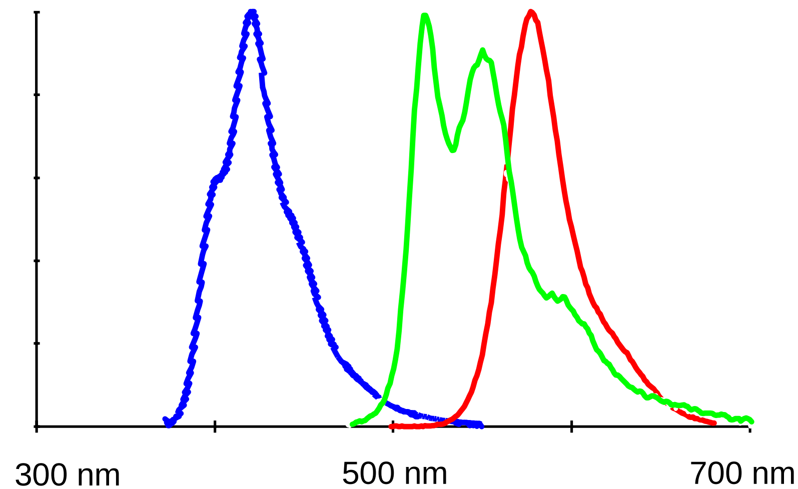
PF

Processed by :
Spin casting, Printing, Roll-to-roll web coating

IP owned by Cambridge Display Technology

Multiple emission colors achieved by Covion

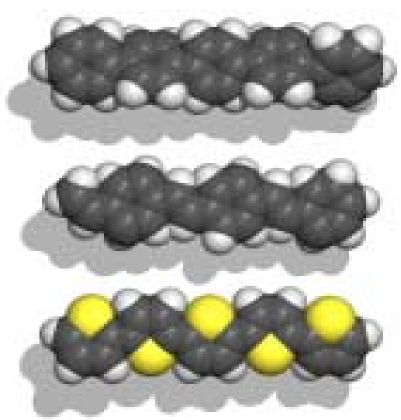
Different emission colors can be obtained with a variety of chemical structures

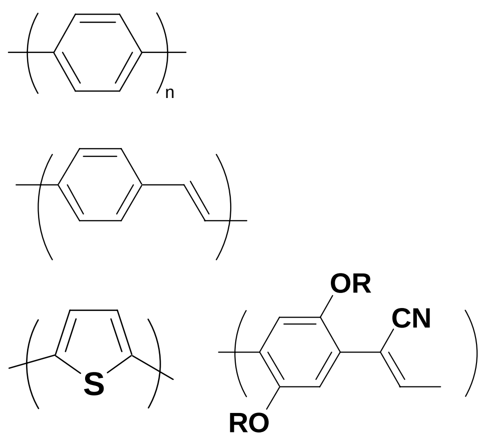


PPP

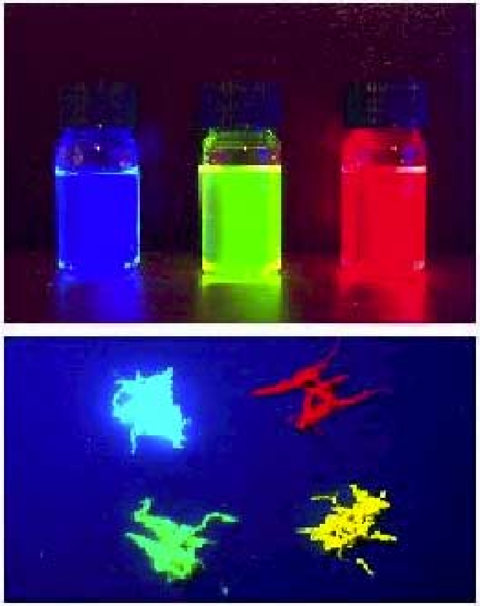
PPV

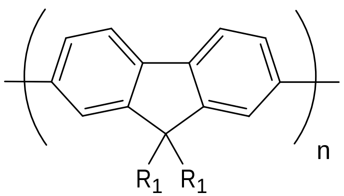
PT or CN-PPV



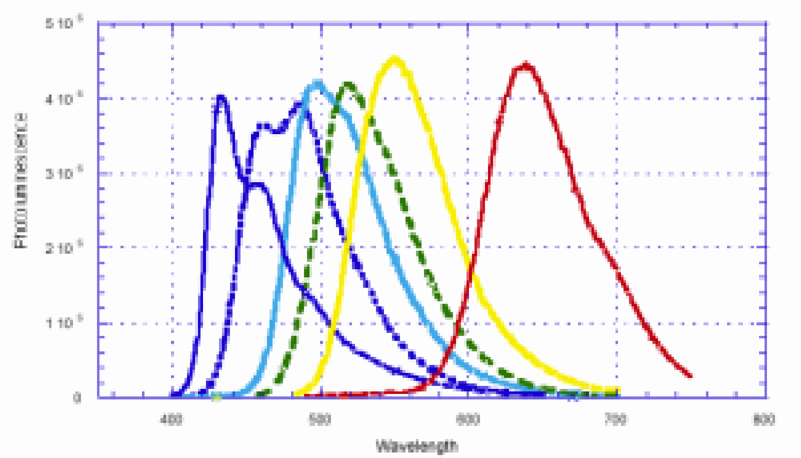


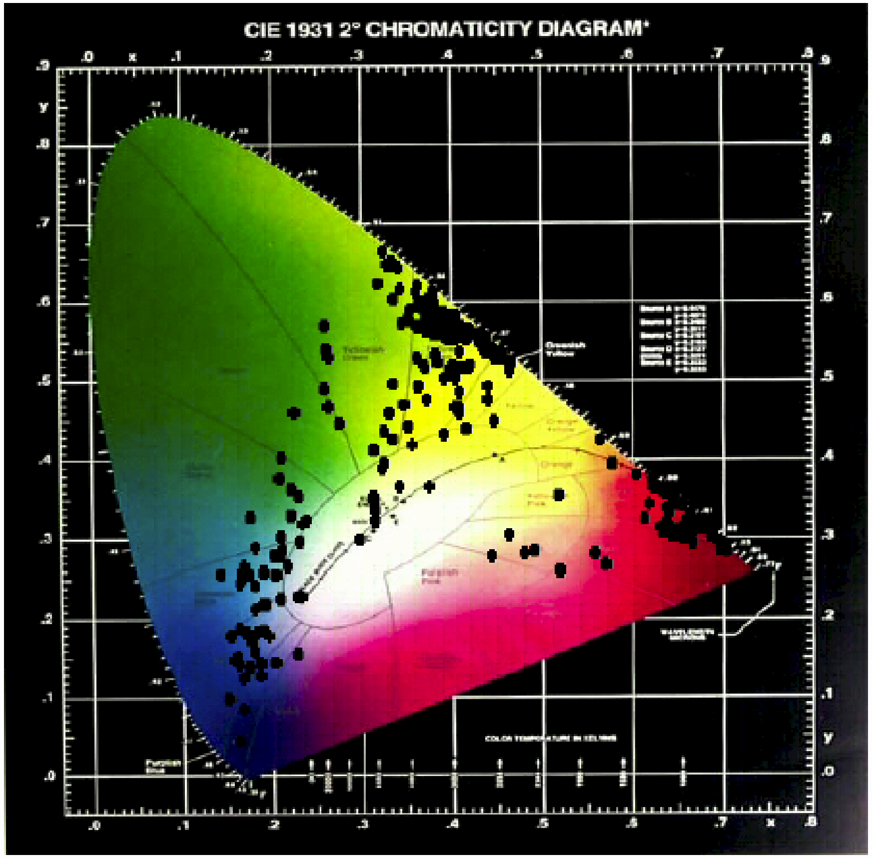
Multiple emission colors achieved by Dow Chemical





PF





lumation

DOW

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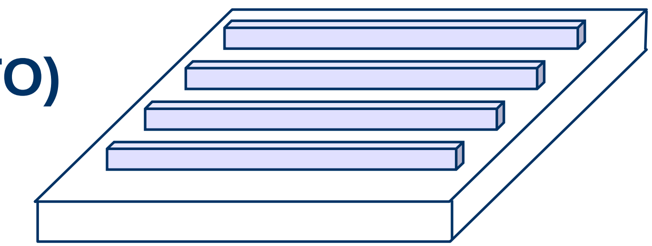
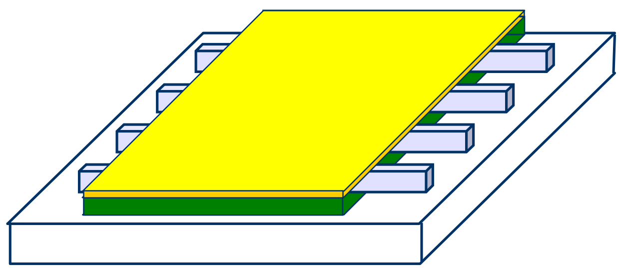
Polymer OLED display fabrication steps

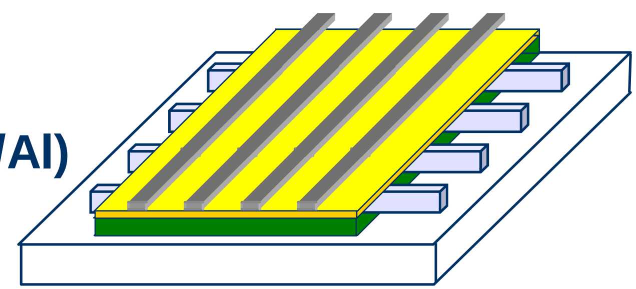
Deposit and pattern anode (ITO)





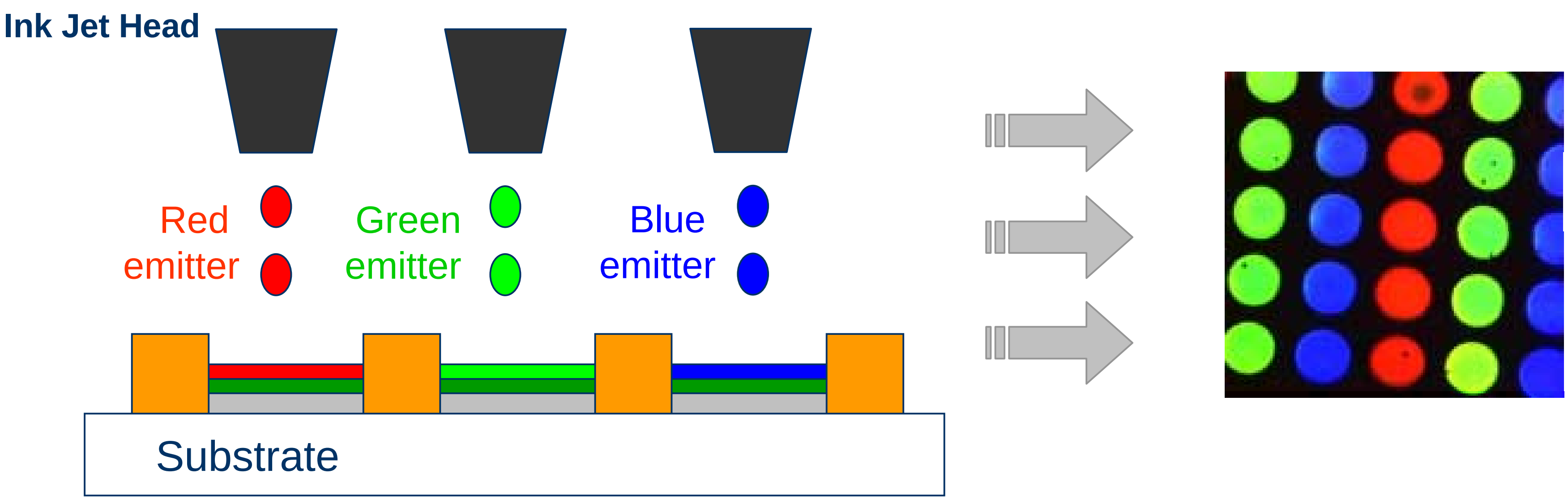
Pattern polymer layers
(first conducting then emissive)

Spin coating
Ink Jet printing
Screen printing
Web coating



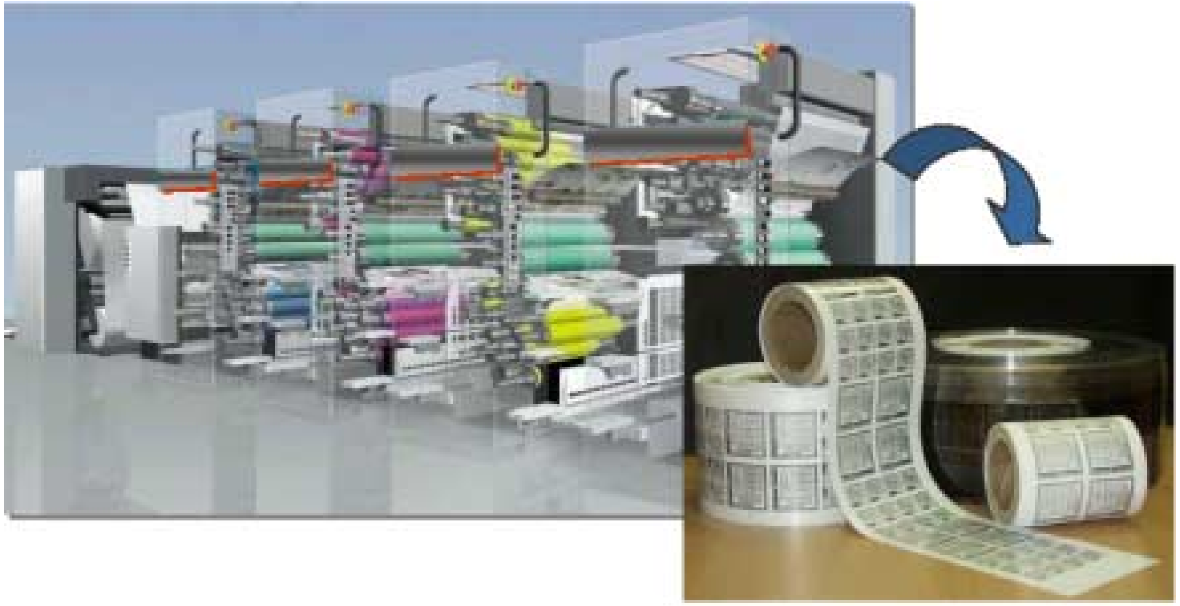
Vacuum deposit and pattern cathode (Ba,Ca/Al)

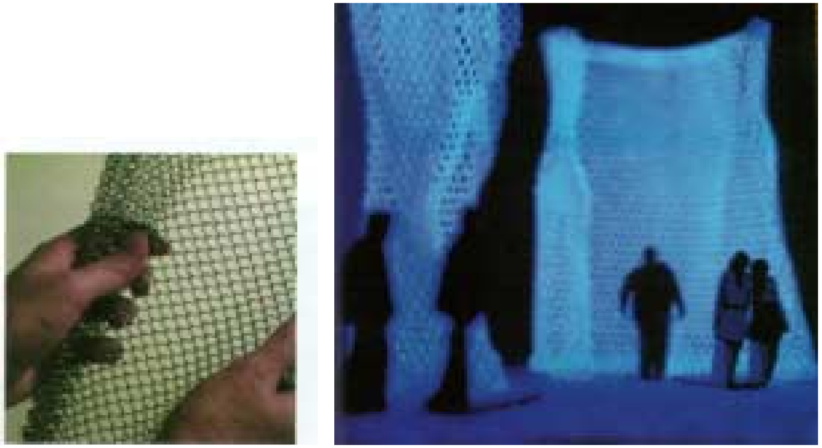
Ink Jet Printing to Pattern Polymers (Full Color Applications)



Ink Jet printing to define and pattern R, G, B emitting subpixels

The Holy Grail: Flexible OLEDs



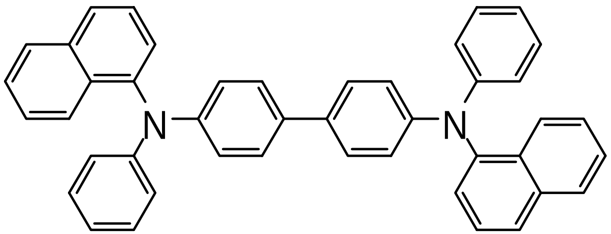


Sheila Kennedy, Harvard Univ., 1999

Electroluminescent Small Molecules

Hole transport small molecules

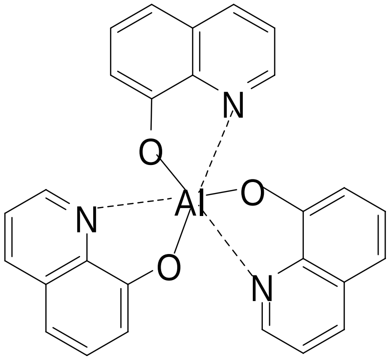
- Metal-phthalocyanines
- Arylamines, starburst amines



NPD

Emissive small molecules

- Metal chelates, distyrylbenzenes
- Fluorescent dyes

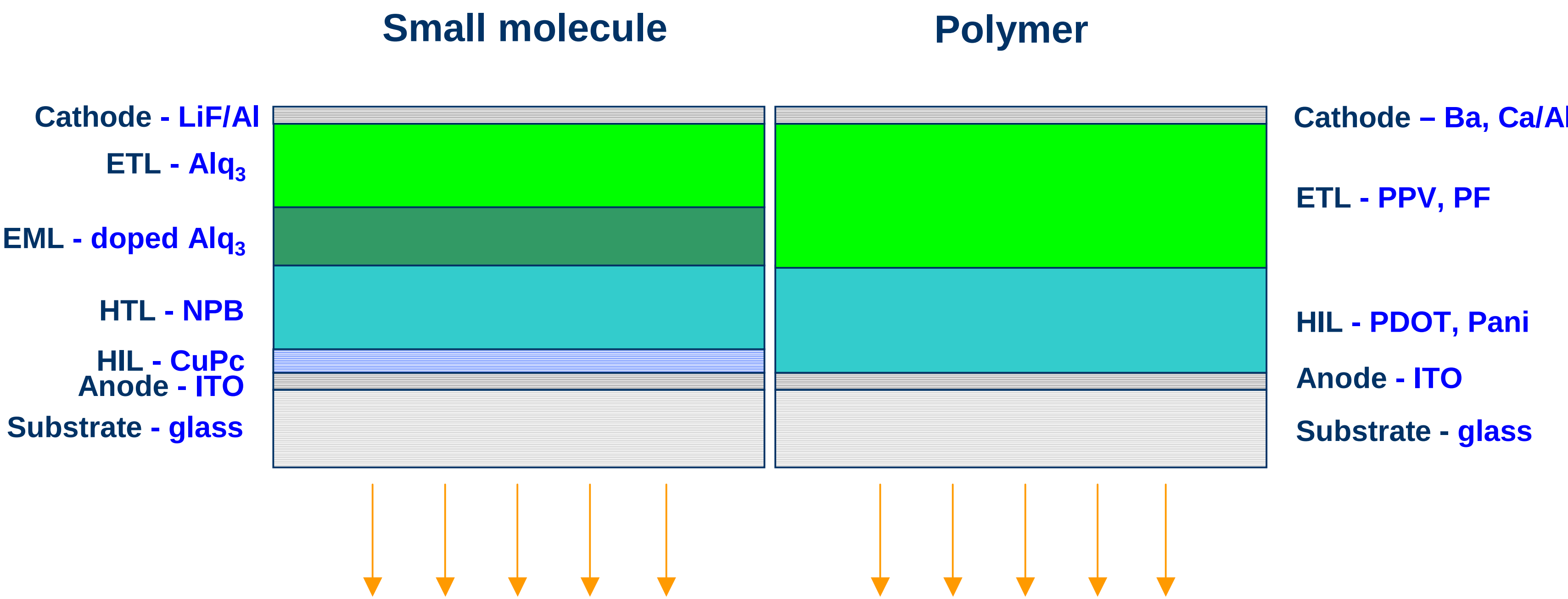


Alq_3

Processed and deposited by :
thermal evaporation in vacuum

IP owned by Eastman Kodak

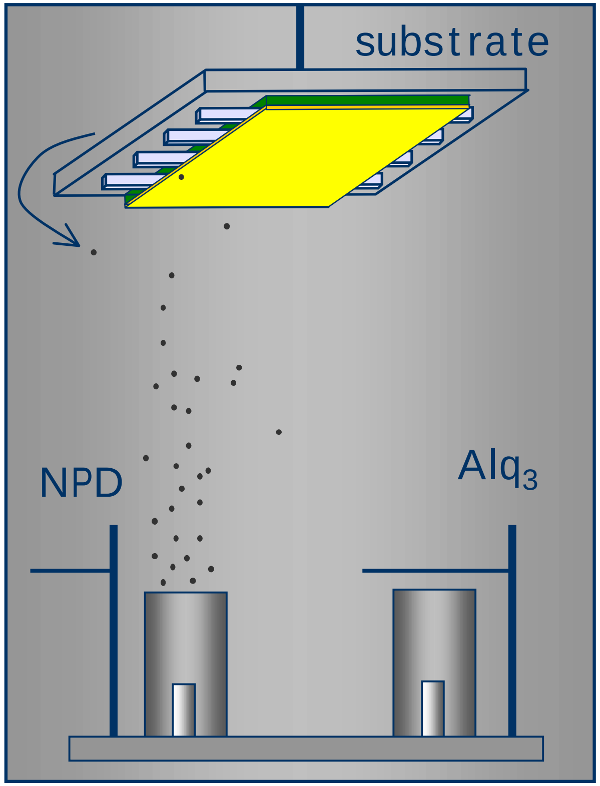
Polymer and Small Molecule Device Structures



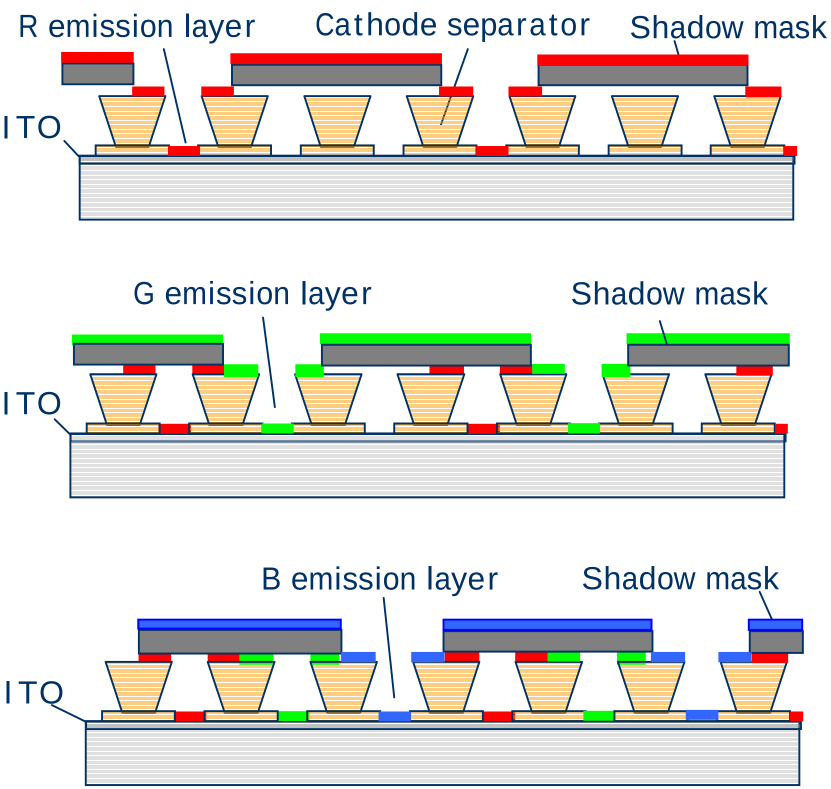
Multi-layer structure made all in vacuum

Bilayer structure made from solution

Full color patterning with small molecules



Small molecules are thermally evaporated in vacuum



R, G, B pattering is defined by shadow masking in vacuum

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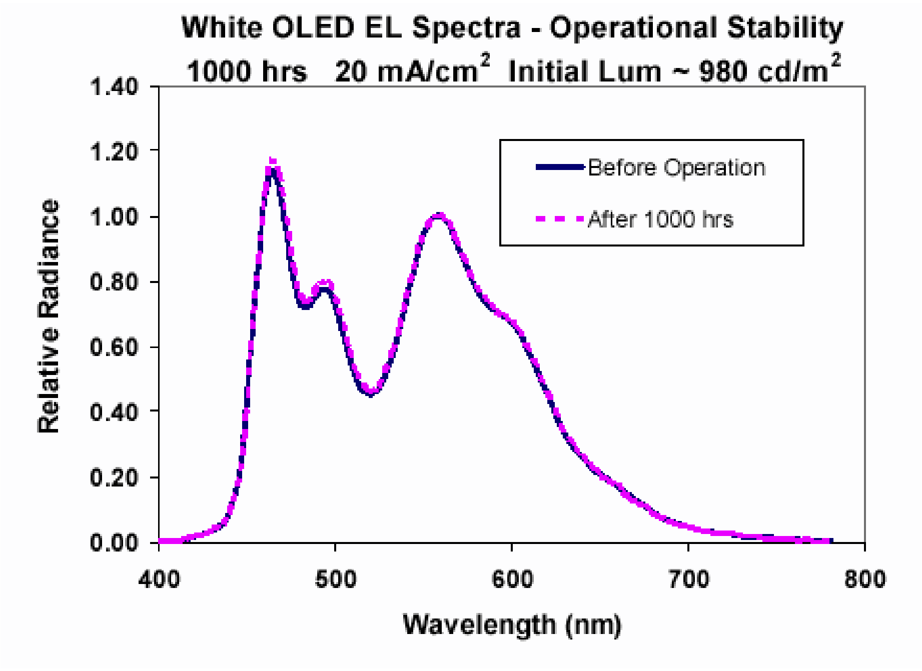
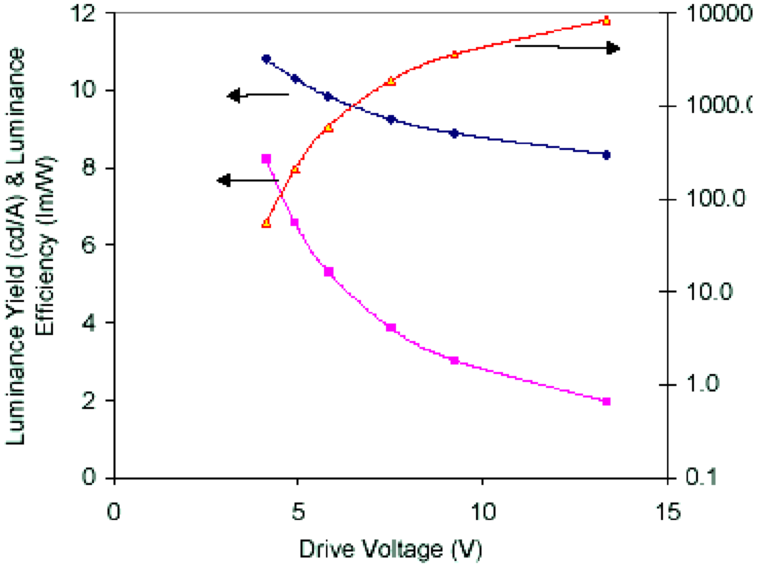
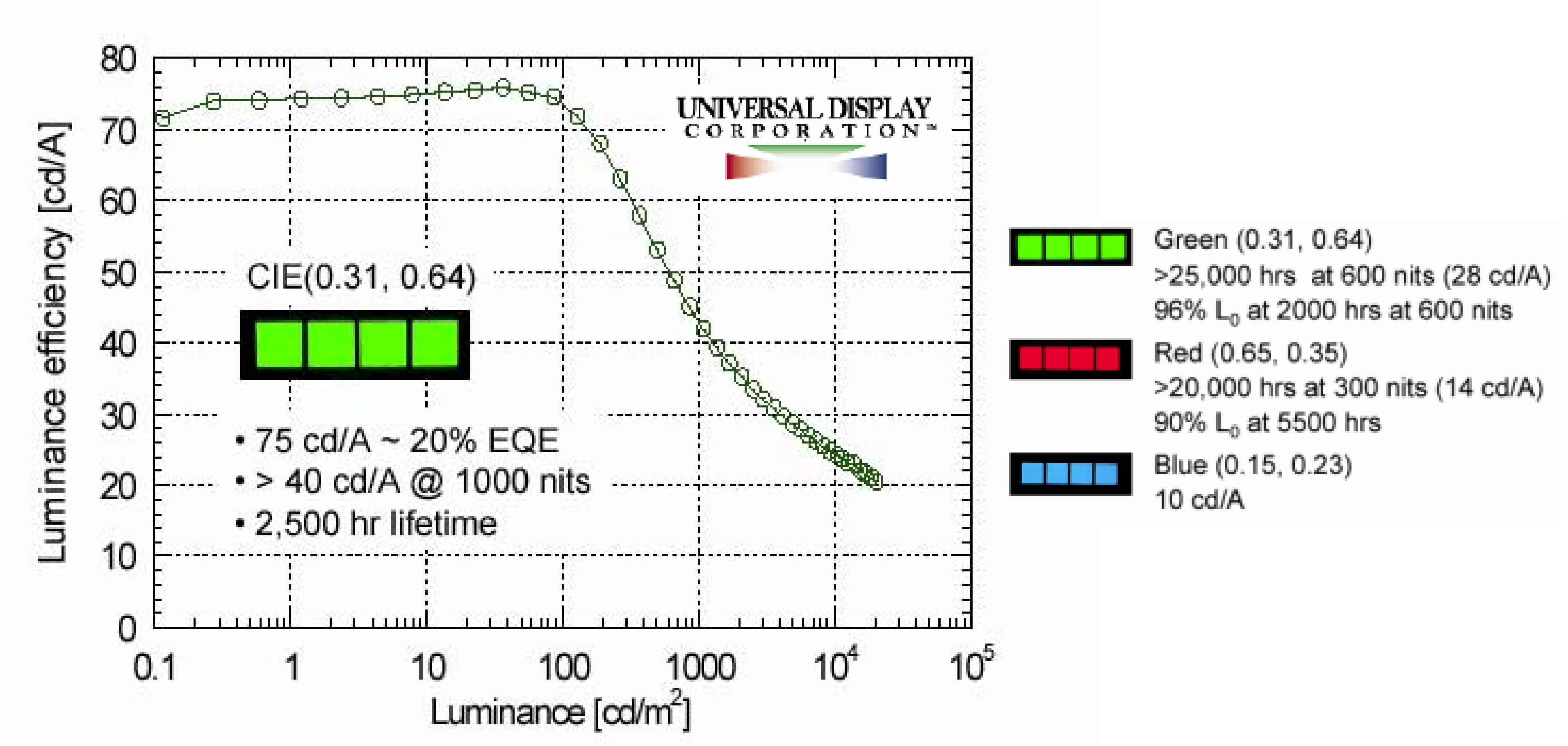
White emitting small molecule OLEDs





Phosphorescent small molecule OLEDs



PHOLED technology offers significant room for further performance advances

The Head-Start of Small Molecule OLEDs

- **Manufacturing started**
  - Pioneer 1997
  - TDK (Alpine, 2001)
  - Samsung-NEC Mobile Display (SNMD) (2002)
  - RiTdisplay (2003)
  - Sanyo-Kodak (2003)

- **R, G, B colors available**
  - limited lifetimes for blue

- **Shadow masking allows easy patterning for area color**
  - presents challenges with scalability and high volume manufacturing

- **Shadow masking challenging for full color**
  - high throughput and scalability is a challenge

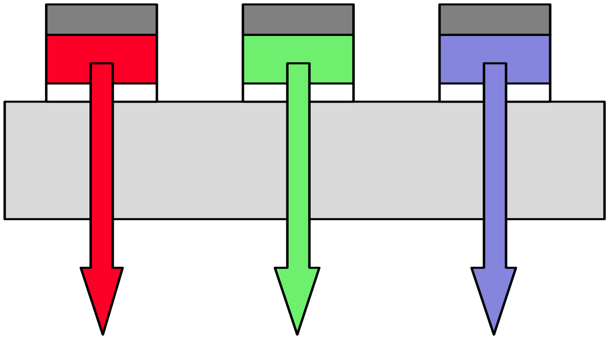
Advantages of Solution Processing (Polymer) OLEDs

- **Lower fabrication cost**
  - fewer vacuum deposition steps - lower capital cost
  - advantageous materials usage and scalability (I/J printing)

- **Solution processing techniques**
  - compatible with printing techniques
    - lower cost for full color
  - scalable to very large substrates (high volume manufacturing)
  - better mechanical integrity
  - compatible with roll process for flex manufacturing

Full-color/Multi-color Approaches

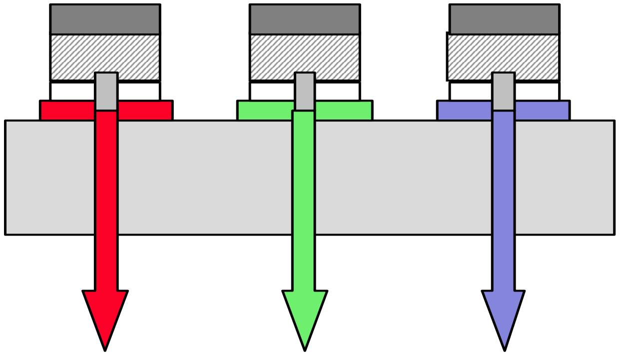
RGB- polymer emitters



Advantages:
- power efficient
- lower production cost
- mature ITO technology

Disadvantages:
- emitters have to be optimized separately (common cathode?)
- differential aging of emitters
- patterning of emitters necessary

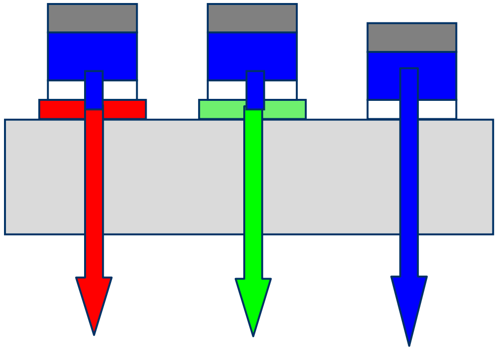
Color filters White emitter



Advantages:
- well-established technology (LCD)
- no patterning of emitter necessary
- homogeneous aging of emitter (?)

Disadvantages:
- power inefficient
- ITO sputtering on filters
- efficient white emitter necessary

Color Changing Media (CCMs)



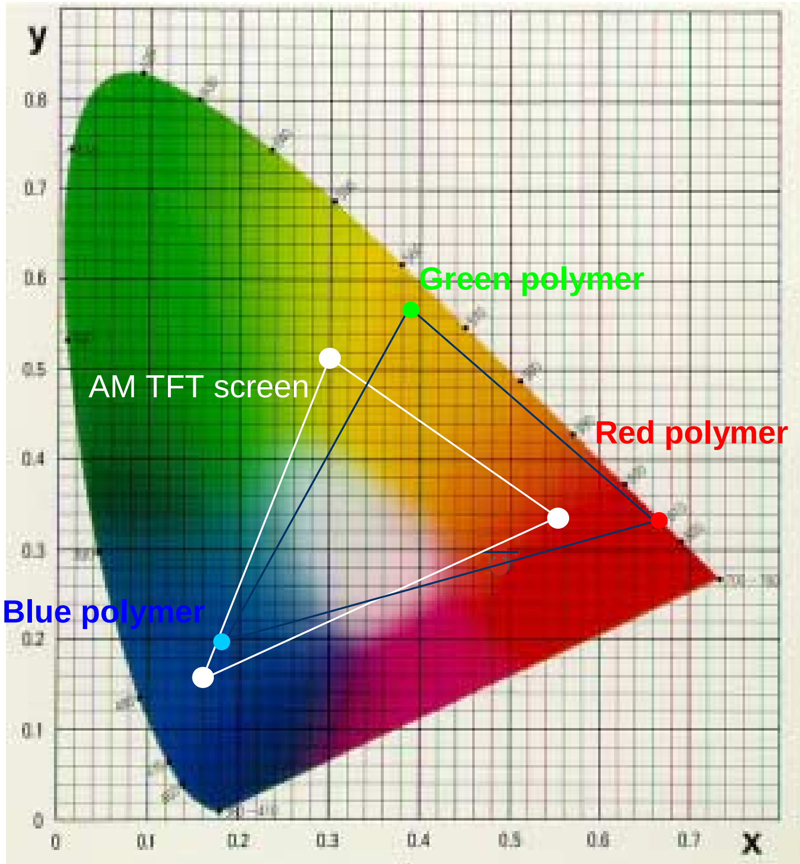
Advantages:

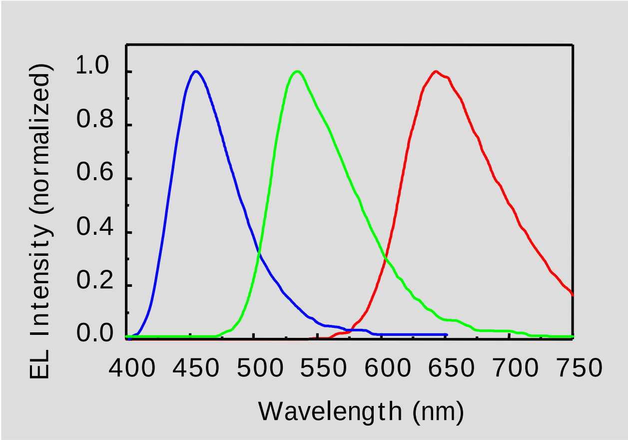
homogeneous aging of emitter (?)
more efficient than filters
no patterning of emitter necessary

Disadvantages:

ITO Sputtering on CCMs
stable blue emitter necessary
aging of CCMs

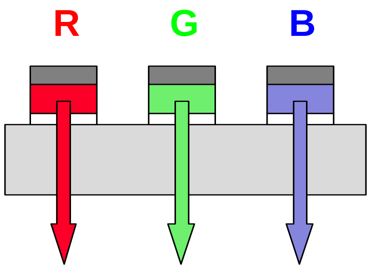
Obtaining a Full Color OLED Display

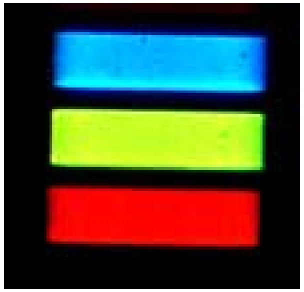




***Ink Jet printing* of R,G,B emissive polymers defines the R,G,B subpixels**

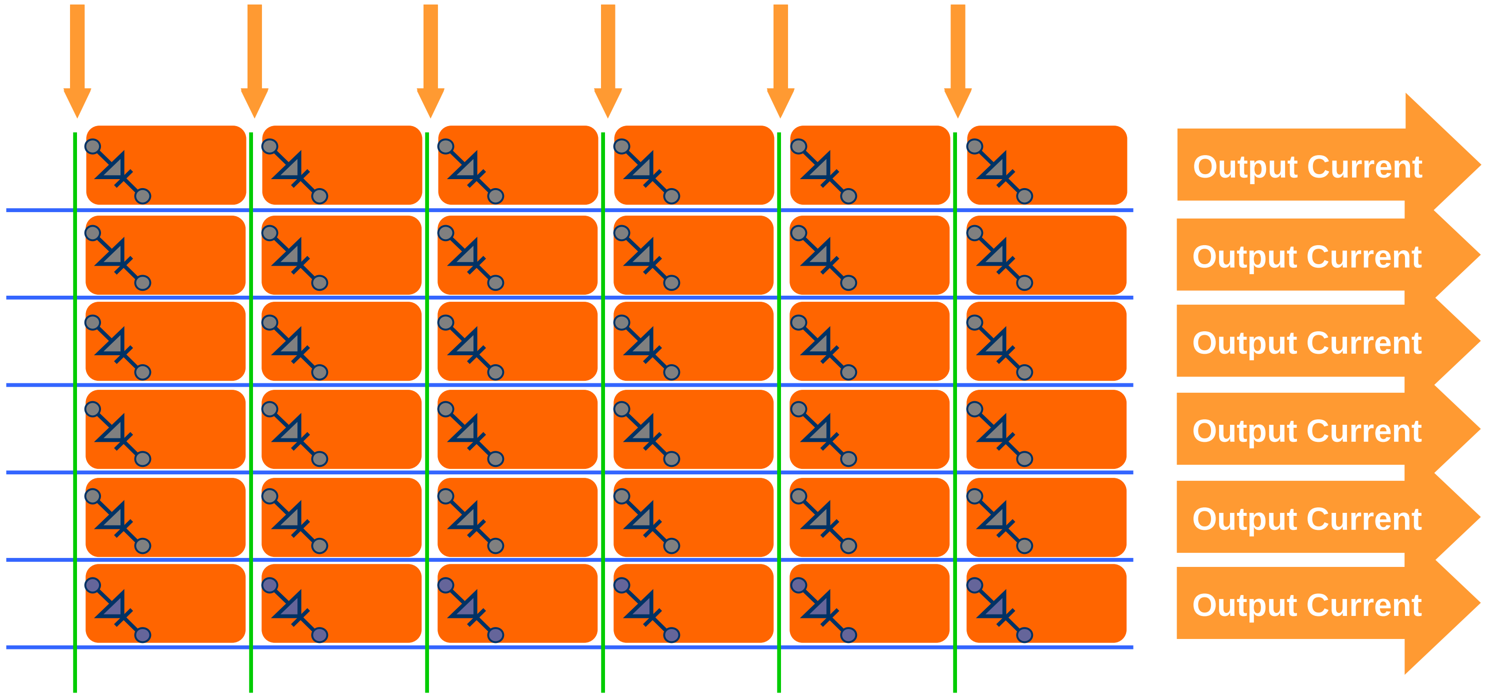
(x_R, y_R) (x_G, y_G) (x_B, y_B)





Single pixel

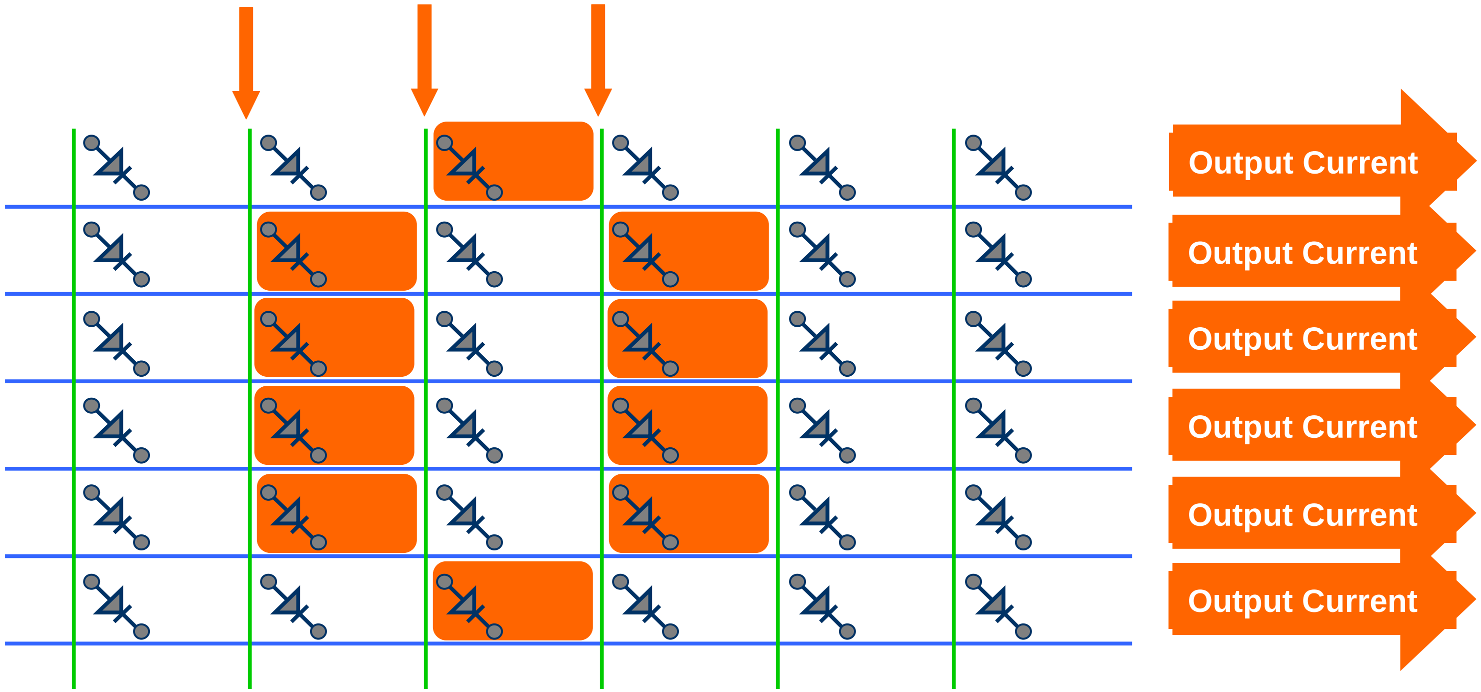
Passive Matrix Addressing



Courtesy of Philips Electronics

- Line by line multiplex scanning
- Duration of addressing is 1/mux rate
- Pixel pulsed luminance = mux rate times average luminance
  - if 64 rows then pixel L=6400 nits for an average of 100 nits
- Limited addressed lines

Passive Matrix Addressing



- Line by line multiplex scanning

Courtesy of Philips Electronics

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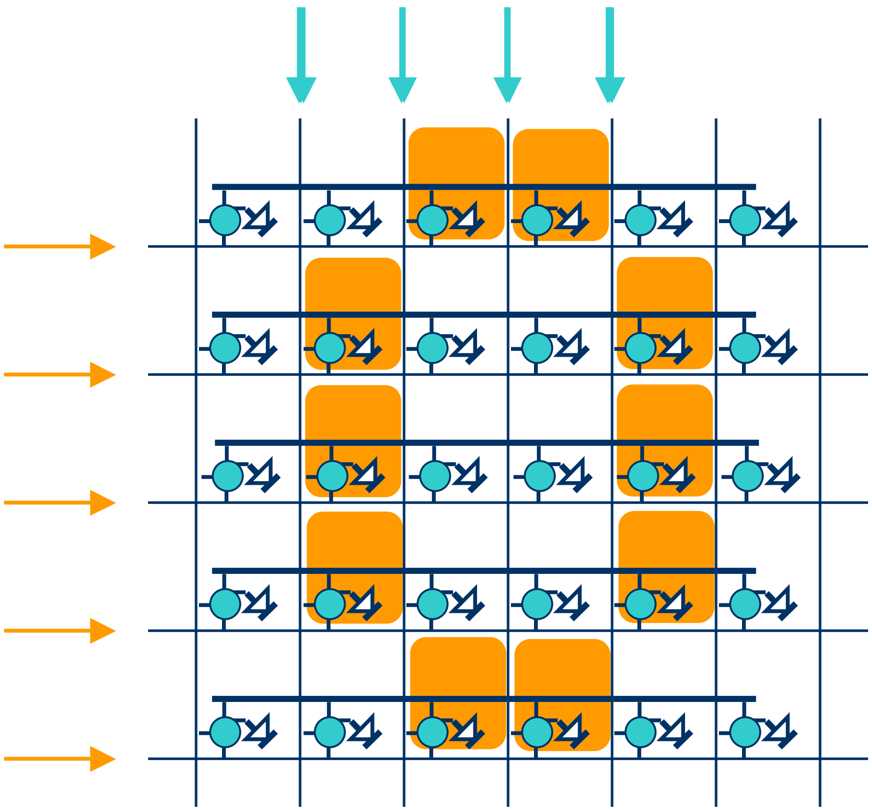
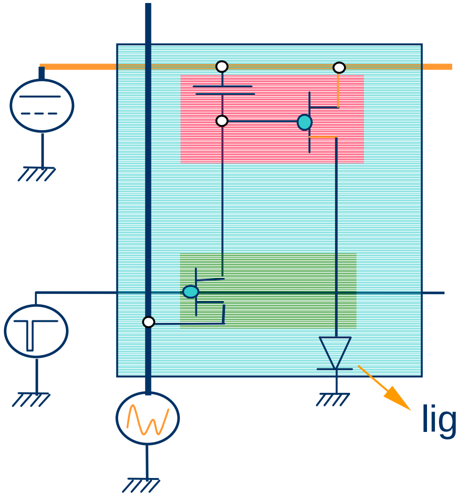
Active Matrix Addressing

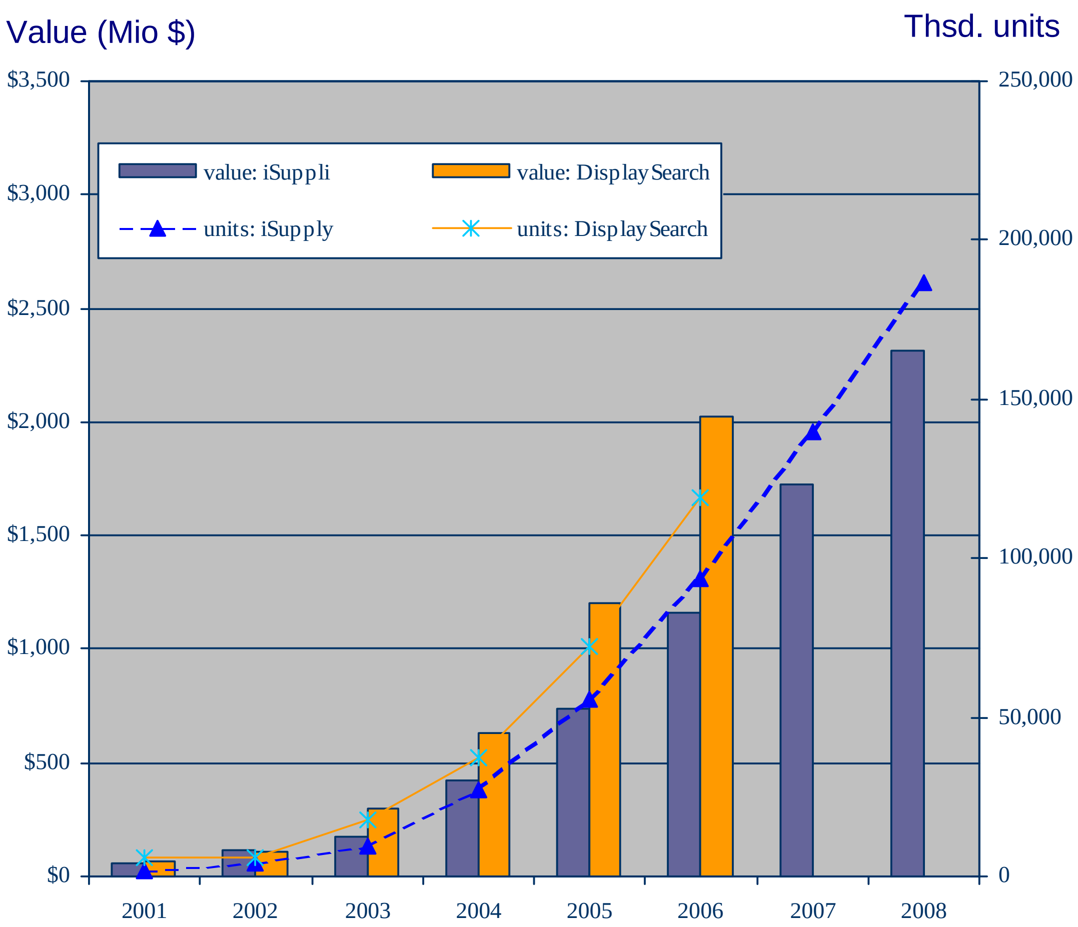




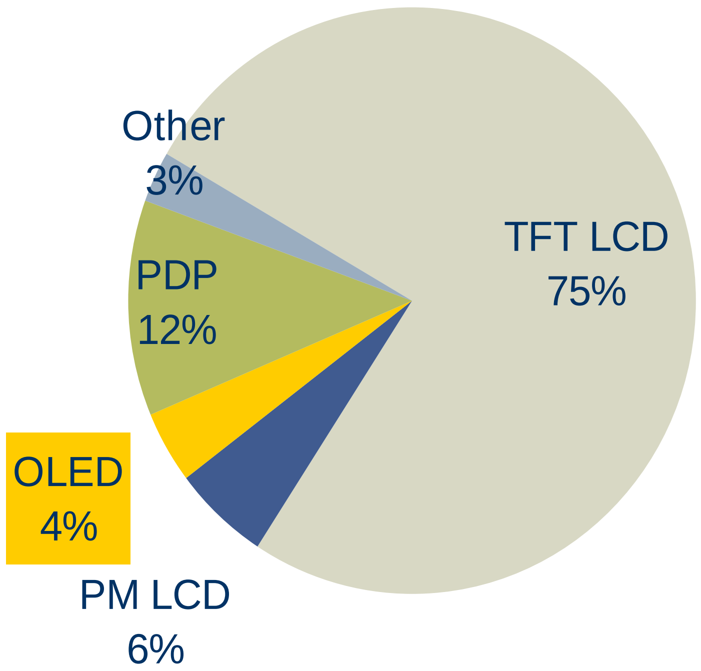
- Place a switching TFT at each pixel
- Selected pixel stays on until next refresh cycle (pixels are switched and shine continuously)
- Common cathode
- Unlimited addressed lines

OLED Market will show strong growth

Worldwide OLED Market, 2000-2006



Flat panel market 2006 $57B



Other:
VFD: vacuum fluorescent display
EL: electroluminescence
DLP: Digital Light Processing

source: iSupply/SRI 2002, Display Search 2002

Small Molecule Area Color Passive Matrix Displays

Motorola (by Appeal)

Samsung Electronics

Lucky Goldstar (LG)

Examples of Wireless Products
With Kodak Display Technology

Small Molecule Full Color Passive Matrix Displays

Caller ID Subdisplays

Samsung Electronics

96x64 Full Color PM Display

Kodak Licensed SNMD to Manufacture PM OLED Displays

Fujitsu F505i GPS

With Pioneer Full Color (4,096 colors) PHOLED 1.1-inch 96x72 pixels display. Phosphorescent material developed by Universal Display Corp.

Small Molecule Active Matrix Display Products

Eastman Kodak: Digital camera

Sanyo: Cell Phone with Digital camera

Kodak-Sanyo 15-in flat panel display (based on white)

15-inch HDTV format (1280x720) AM a-Si OLED display by Sanyo-Kodak

Full Color based on white OLED with Integrated Color Filters.

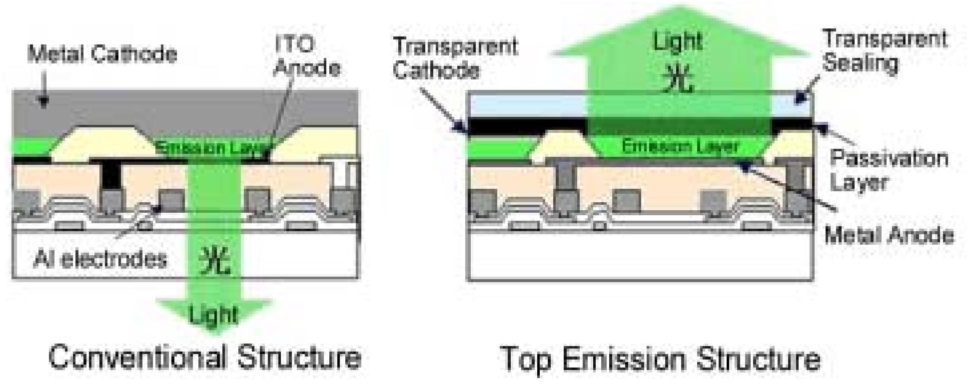
The two companies showed the prototype at the CEATEC JAPAN trade show (Sep 2002).

Top Emitting Active Matrix OLED Display

Top Emission Adaptive Current Drive technology, allows OLEDs to be larger and higher in brightness and resolution.
A 13-inch full-color AMOLED using poly-Si TFT was made where the light emits through the transparent cathode and thus, the filling factor does not depend on the TFT structure.

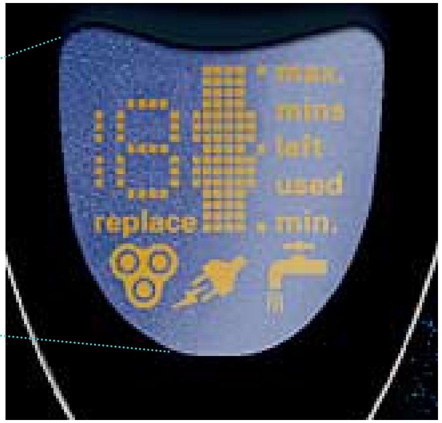
The schematic vertical structure of the device is substrate/TFT/metal anode/organic layers/transparent cathode/passivation layer/transparent sealing.

Display format: 800x600 (SVGA); pixel pitch 0.33x0.33mm^2



SONY

Polymer Passive Matrix Display Products



Philips: Electrical Shaver

Delta Electronics: Display for MP3 player

OSRAM Pictiva™ Evaluation Kit (www.pictiva.com)

San Jose, CA – May 15, 2003 -- Osram Opto Semiconductors, a global leader of solid-state lighting devices, today announced its Pictiva™ Evaluation Kit. Announced earlier this week, the Pictiva brand is Osram's suite of organic light emitting diode (OLED) technologies. Pictiva displays offer a high level of brightness and contrast, video capabilities, wide viewing angles and a thin-profile, enabling developers and engineers to have greater design flexibility when developing the next-generation state-of-the-art electronics products.