An Overview of OLED Display Technology

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OSRAM Opto Semiconductors Inc.

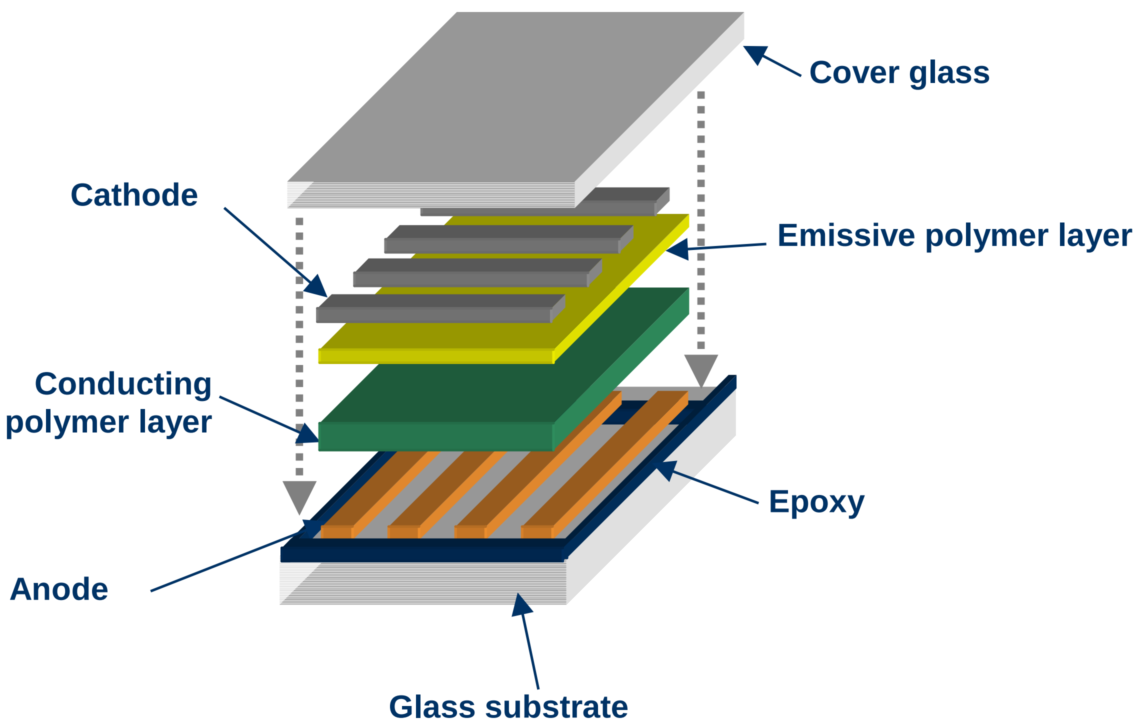
San Jose, CA

Outline

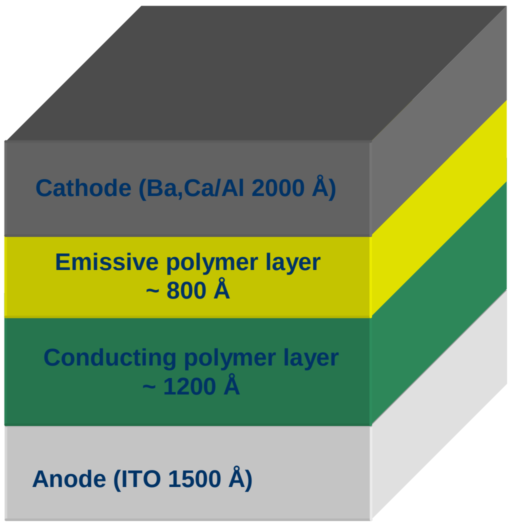
- OLED device structure and operation
- OLED materials (polymers and small molecules)
- Evolution of OLED performance
- OLED process and fabrication technologies
- White emitting OLEDs
- Color capabilities
- Products and demonstrators

OLED display and pixel structure

Display



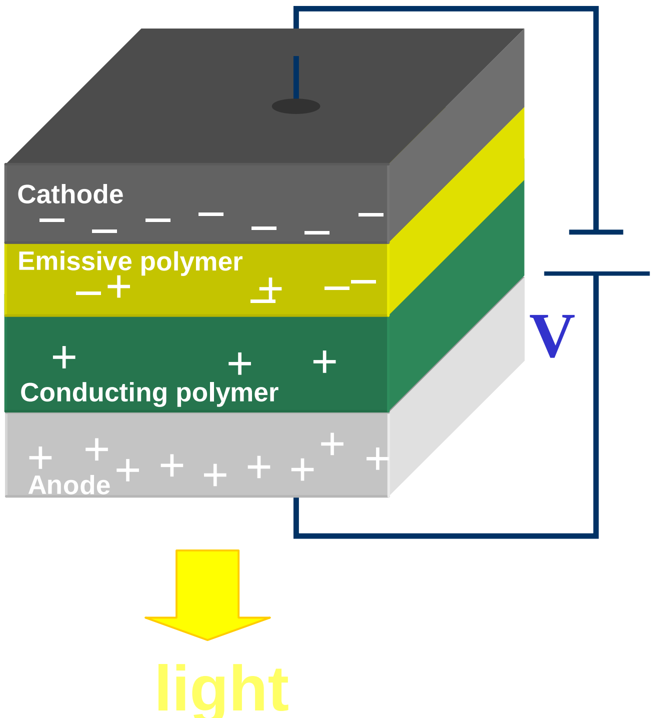
Pixel



Single pixel structure

Human hair is 200X the thickness of the OLED layers

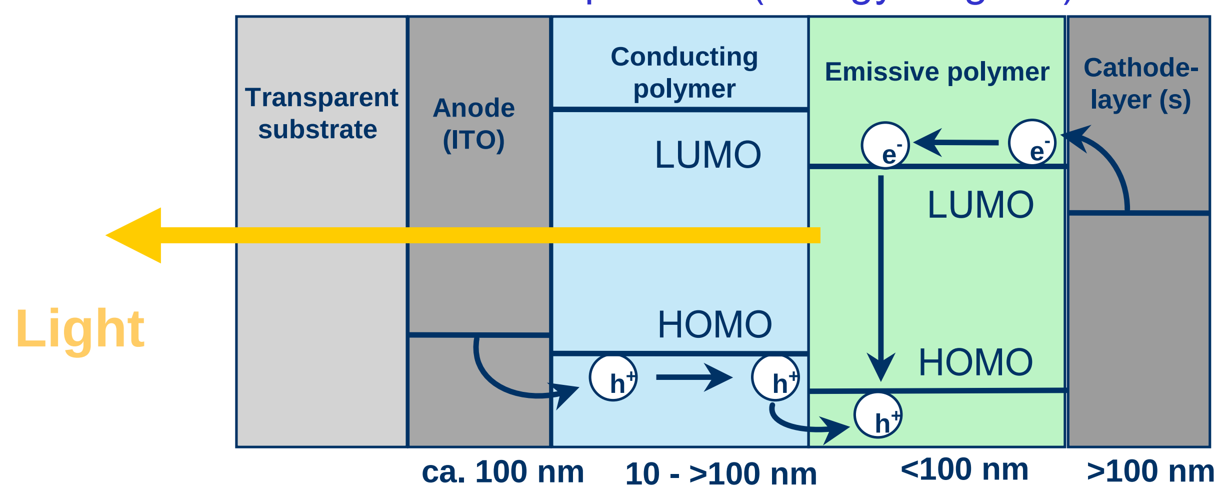
OLED Device Operation Principles



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

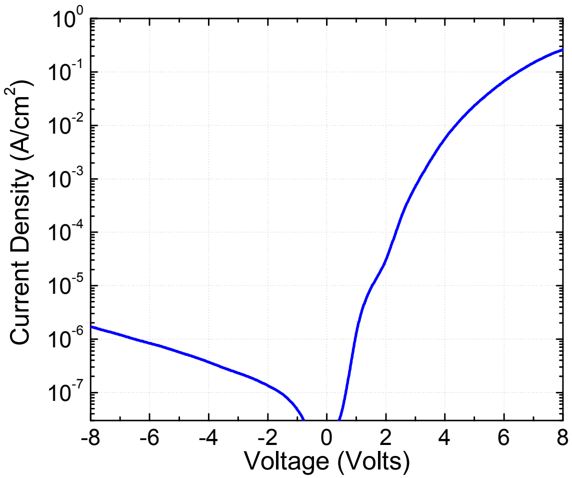
- Electrons injected from cathode
- Holes injected from anode
- Transport and radiative recombination of electron hole pairs at the emissive polymer

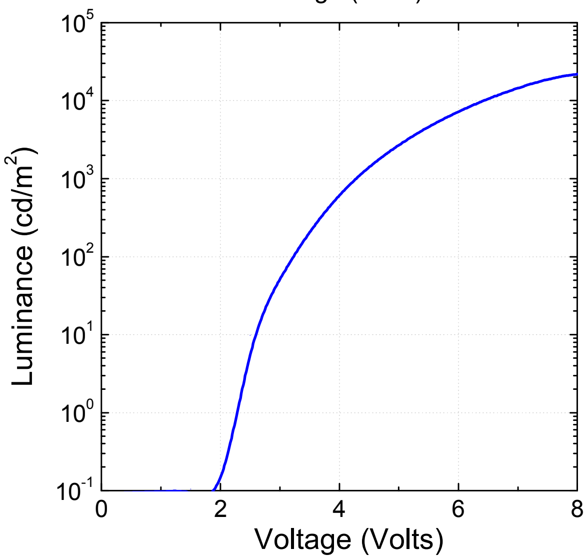
OLED device operation (energy diagram)



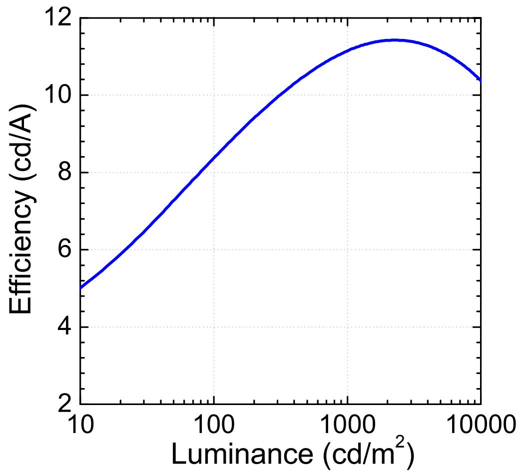
Optoelectronic Device Characteristics

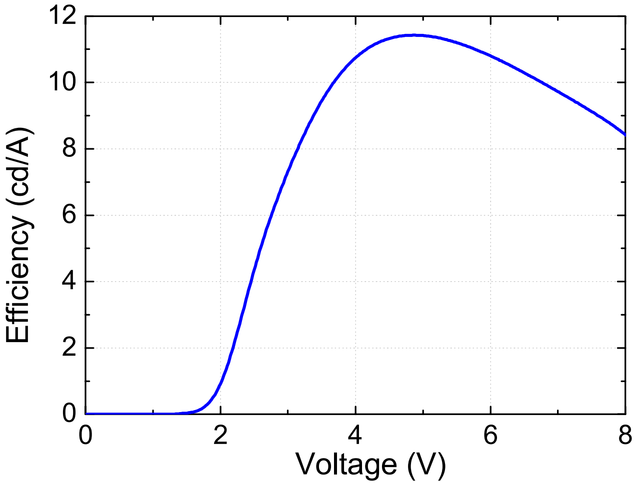
Luminance-Current-Voltage





Efficiency-Luminance-Voltage





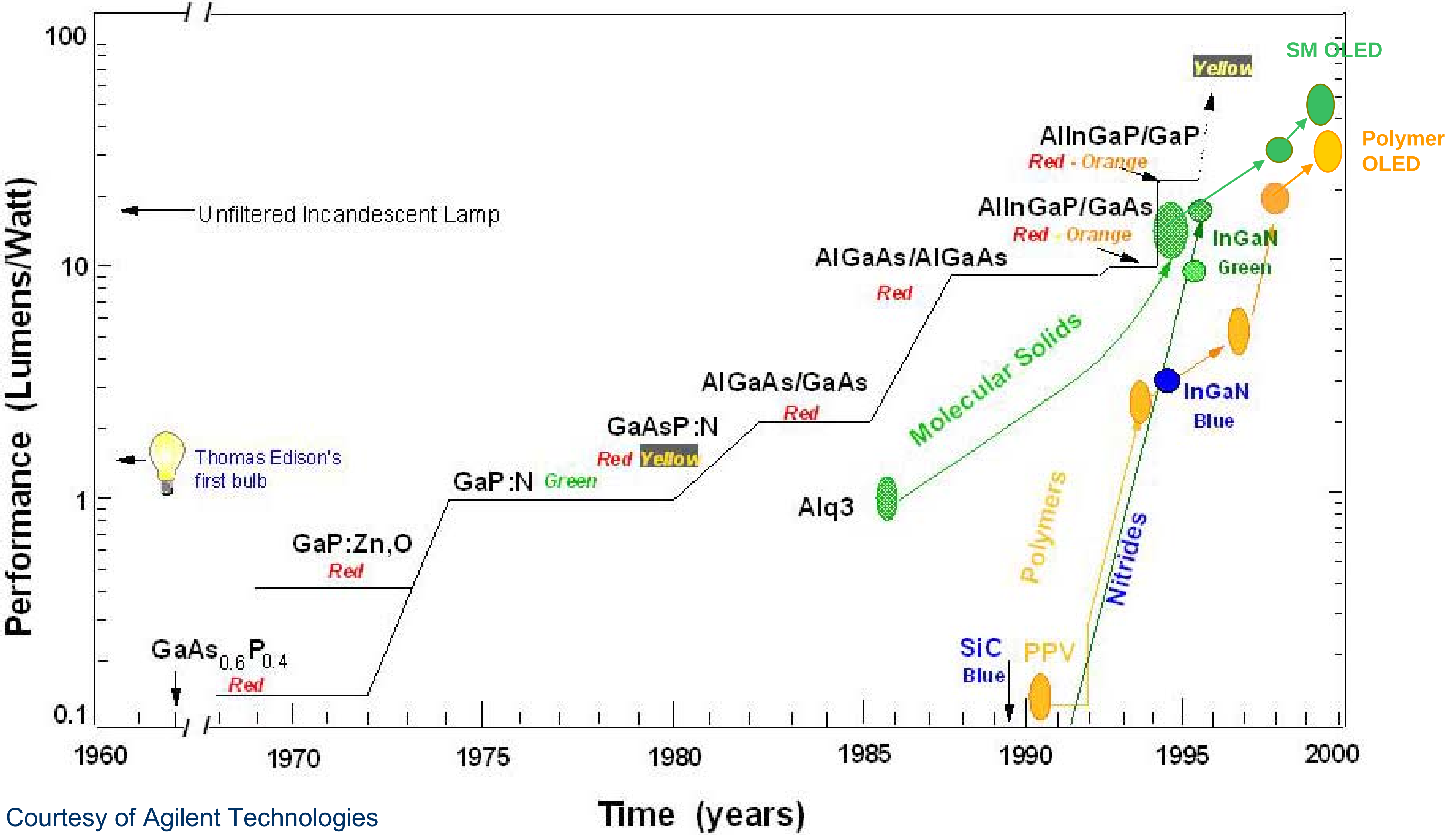
LUMINANCE is the luminous intensity per unit area projected in a given direction

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

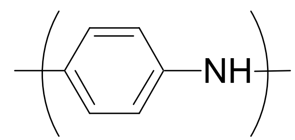


Courtesy of Agilent Technologies

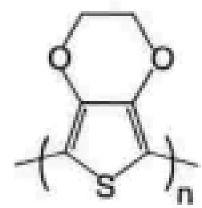
Electroluminescent Conjugated Polymers

Conducting polymers

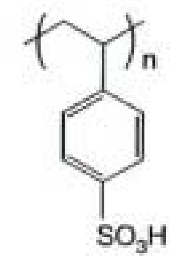
- Polyaniline (PANI:PSS)
- Polyethylenedioxythiophene (PDOT:PSS)



PANI



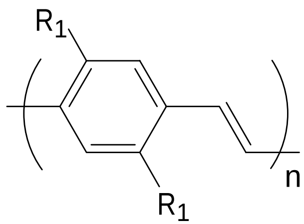
PDOT



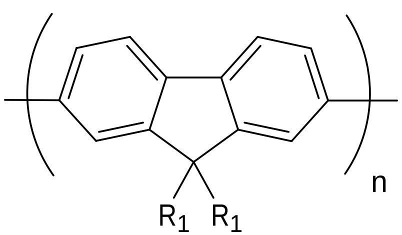
PSS

Emissive polymers

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



R-PPV



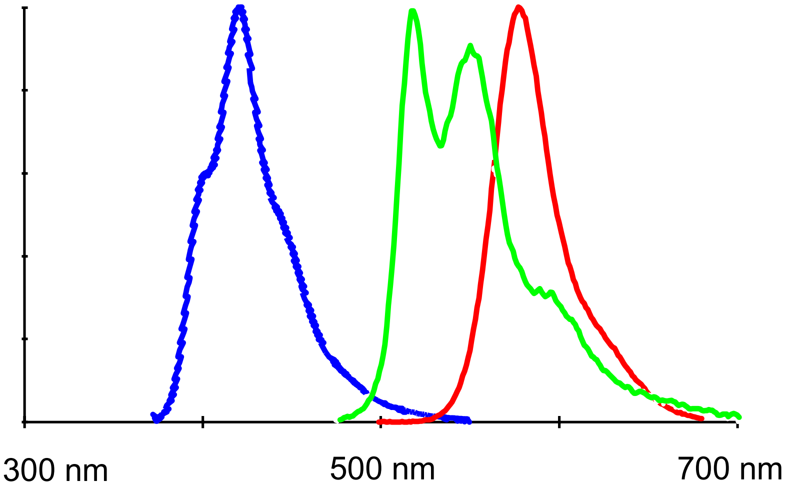
PF

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

IP owned by Cambridge Display Technology

Multiple emission colors achieved by Covion

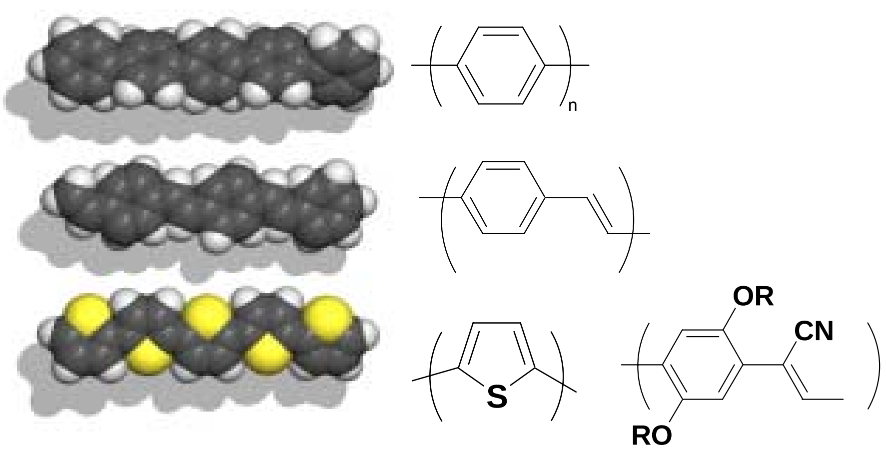
Different emission colors can be obtained with a variety of chemical structures



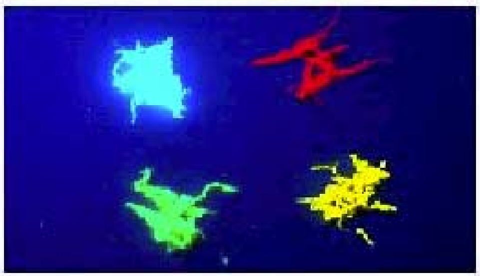
PPP

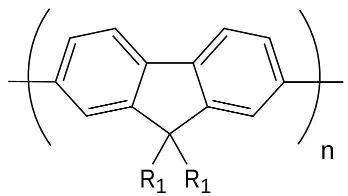
PPV

PT or CN-PPV

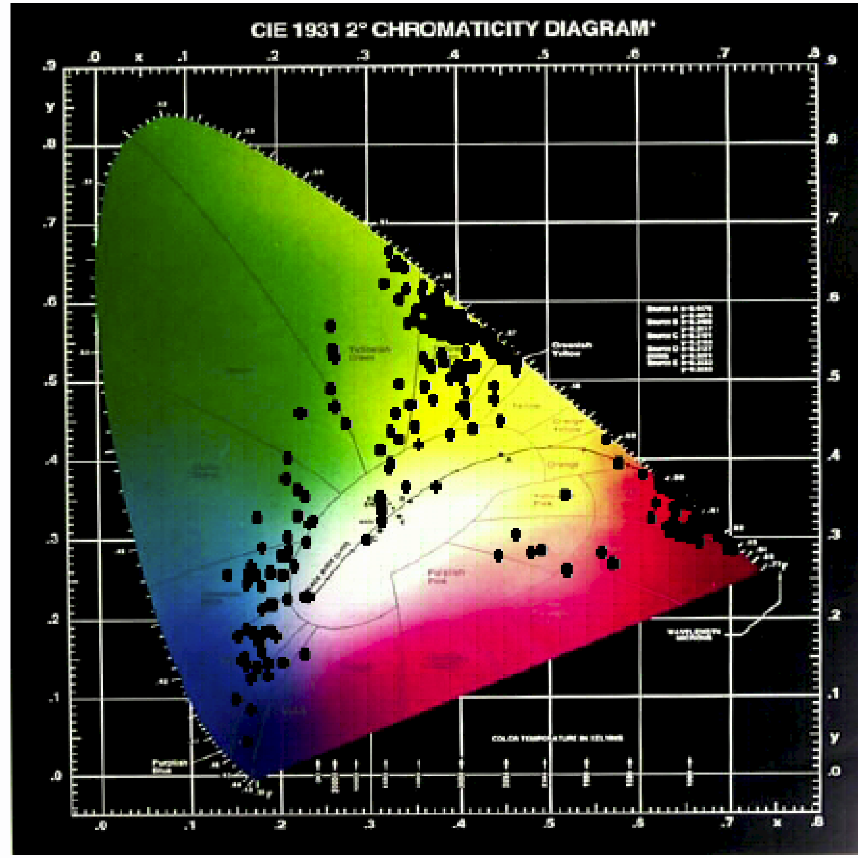


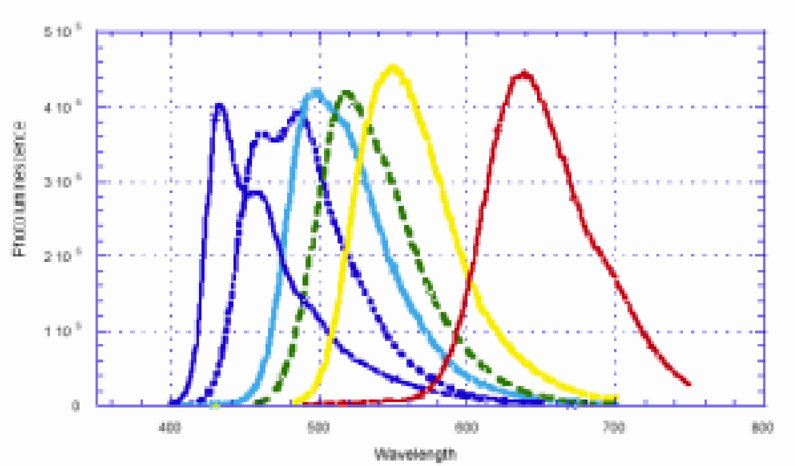
Multiple emission colors achieved by Dow Chemical





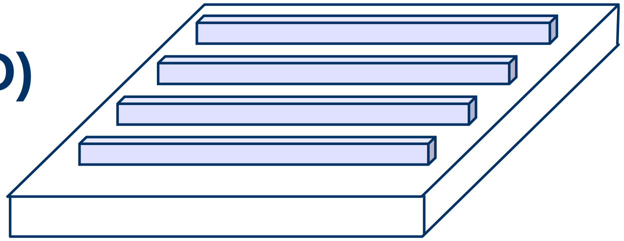
PF

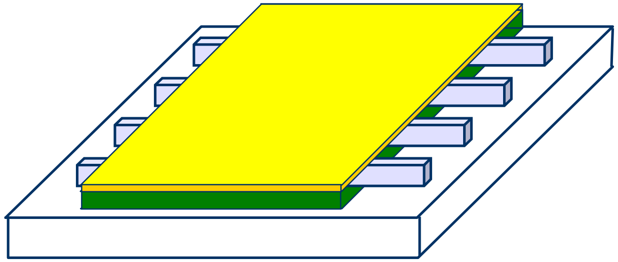




Polymer OLED display fabrication steps

Deposit and pattern anode (ITO)

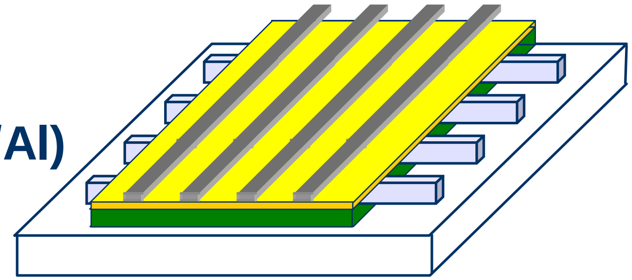




Pattern polymer layers
(first conducting then emissive)

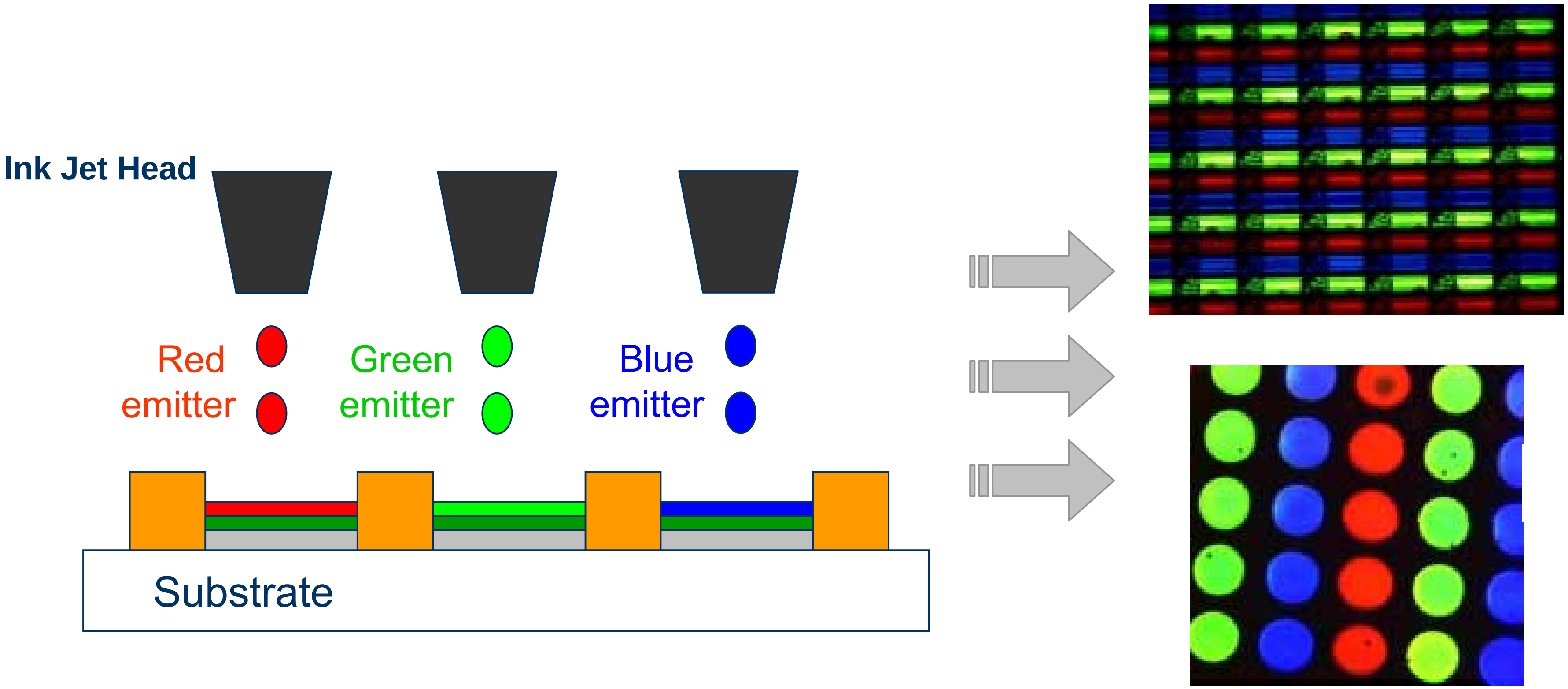
Spin coating
Ink Jet printing
Screen printing
Web coating

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



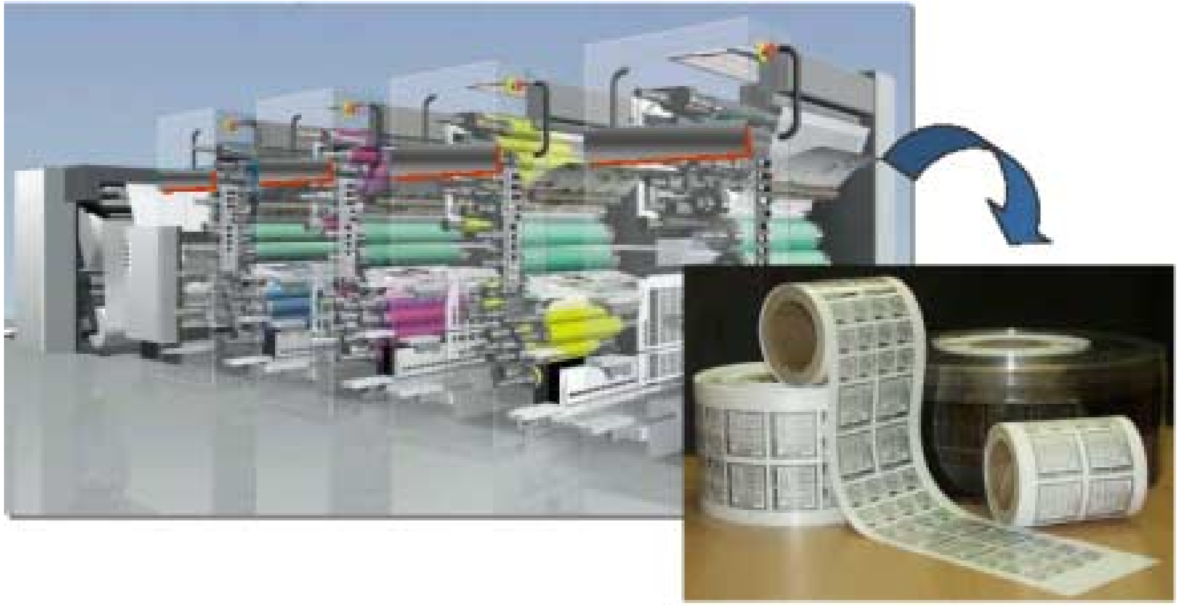
Opto Semiconductors OSRAM

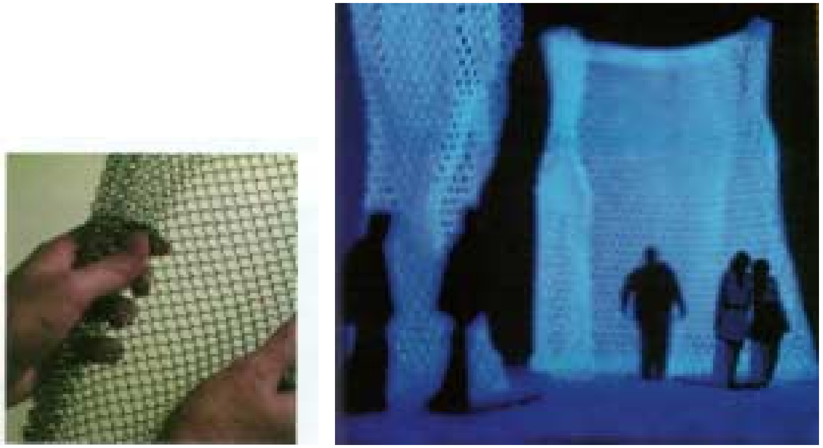
Ink Jet Printing to Pattern Polymers (Full Color Applications)



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

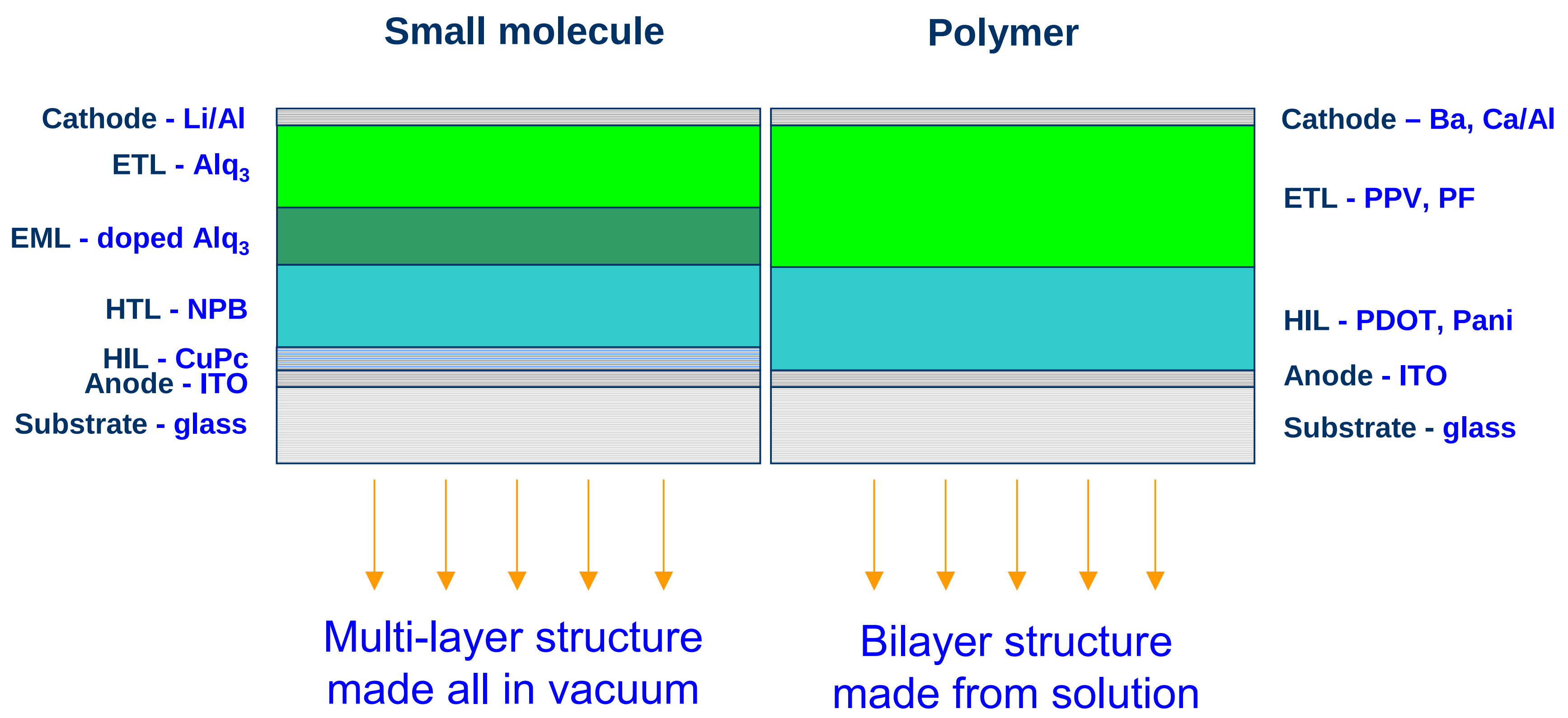
The Holy Grail: Flexible OLEDs





Sheila Kennedy, Harvard Univ., 1999

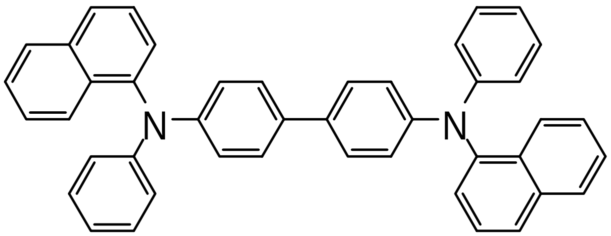
Polymer and Small Molecule Device Structures



Electroluminescent Small Molecules

Hole transport small molecules

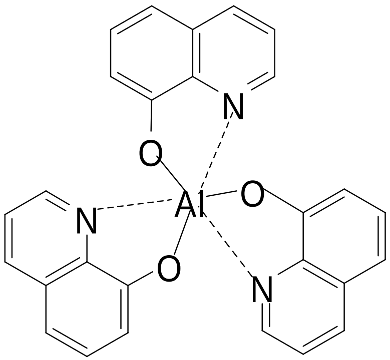
- Metal-phthalocyanines
- Arylamines, starburst amines



NPD

Emissive small molecules

- Metal chelates, distyrylbenzenes
- Fluorescent dyes

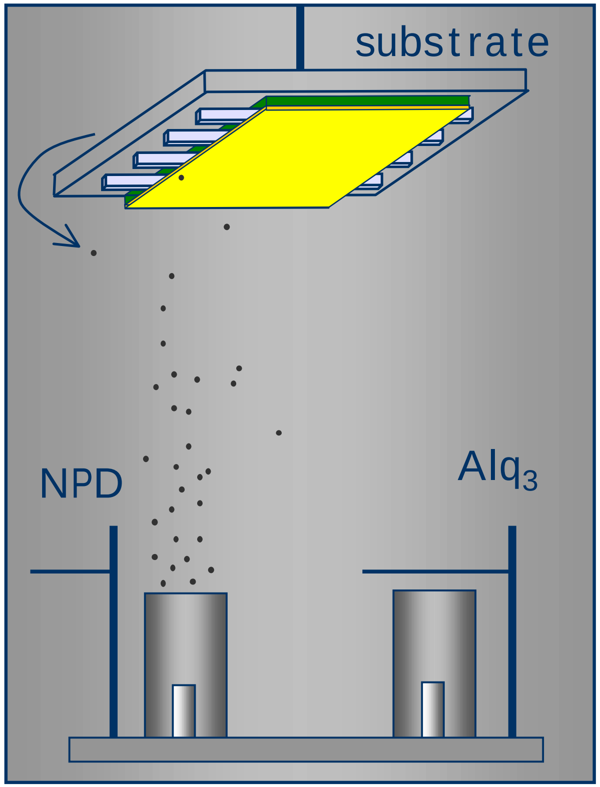


Alq_3

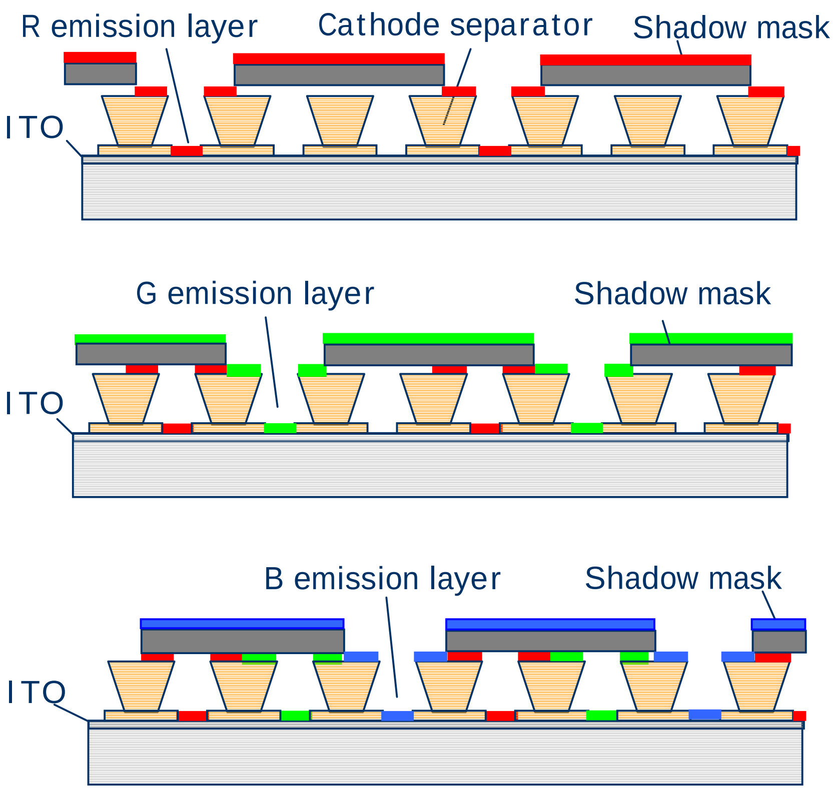
Processed and deposited by :
thermal evaporation in vacuum

IP owned by Eastman Kodak

Full color patterning with small molecules

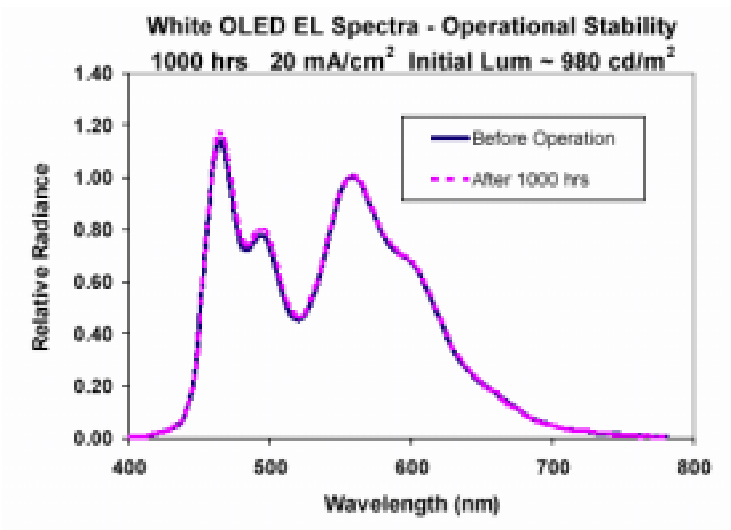


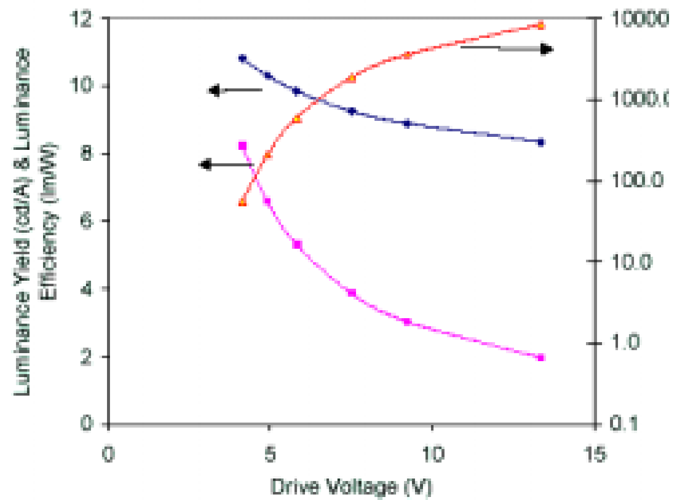
Small molecules are thermally evaporated in vacuum



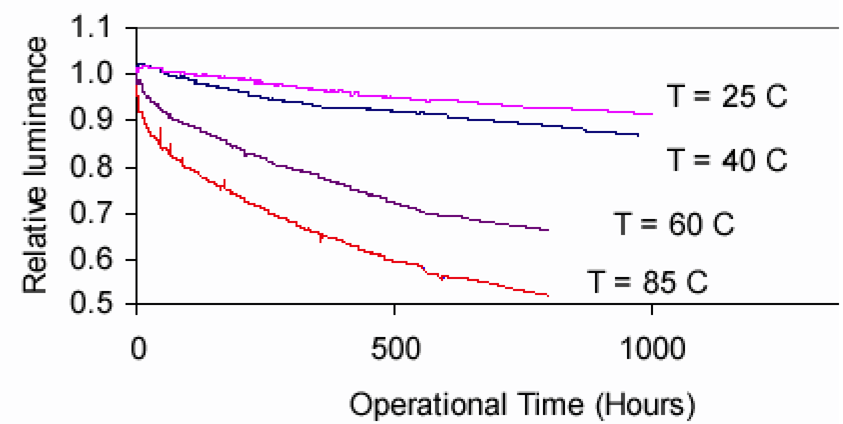
R, G, B pattering is defined by shadow masking in vacuum

White emitting small molecule OLEDs



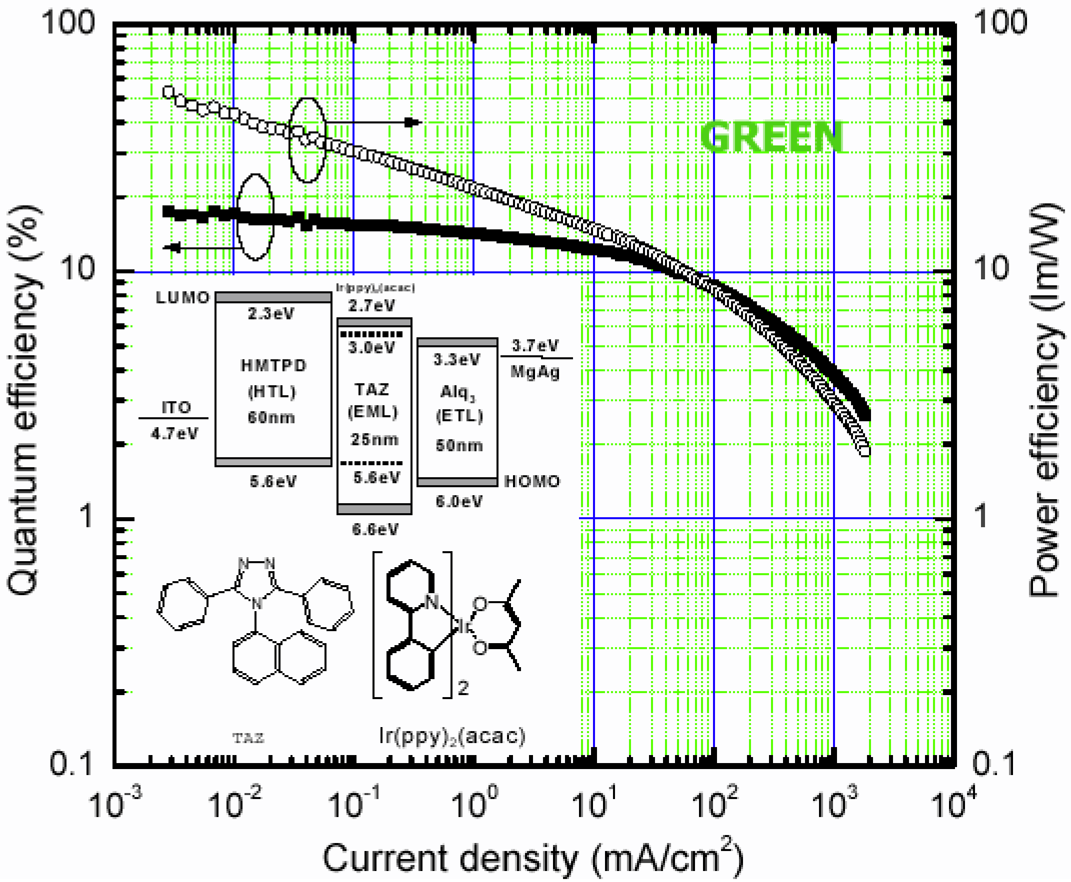


Initial Luminance 1000nits



Phosphorescent small molecule OLED
(both singlets and triplets are harvested)

Phosphorescence enhanced by mixing the singlet and triplet excited states by spin orbit coupling via heavy metal atom (Pt or Ir)



η_{ext}=19% and η_{int} =87%

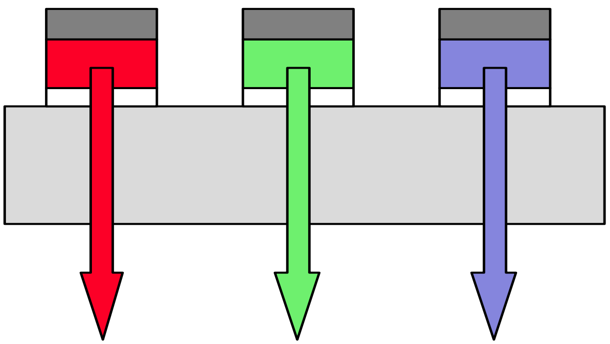
UNIVERSAL DISPLAY CORPORATION™

Princeton University

Opto Semiconductors OSRAM

Full-color/Multi-color Approaches

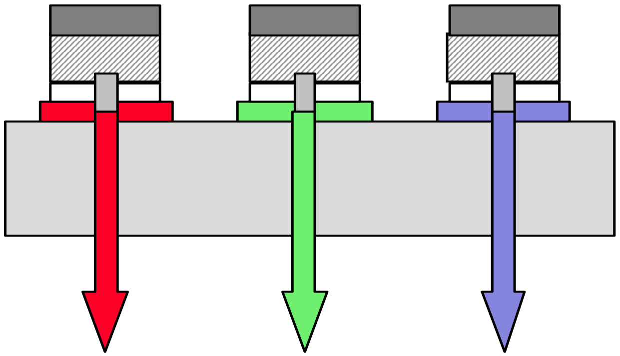
RGB- polymer emitters



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

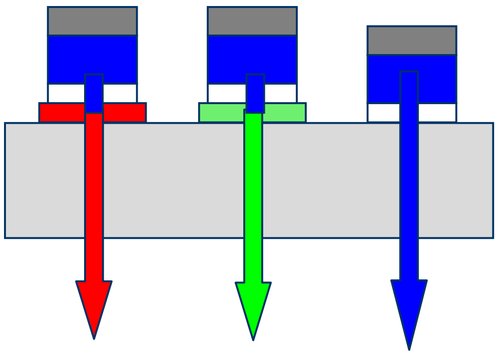
Color filters
White emitter



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)



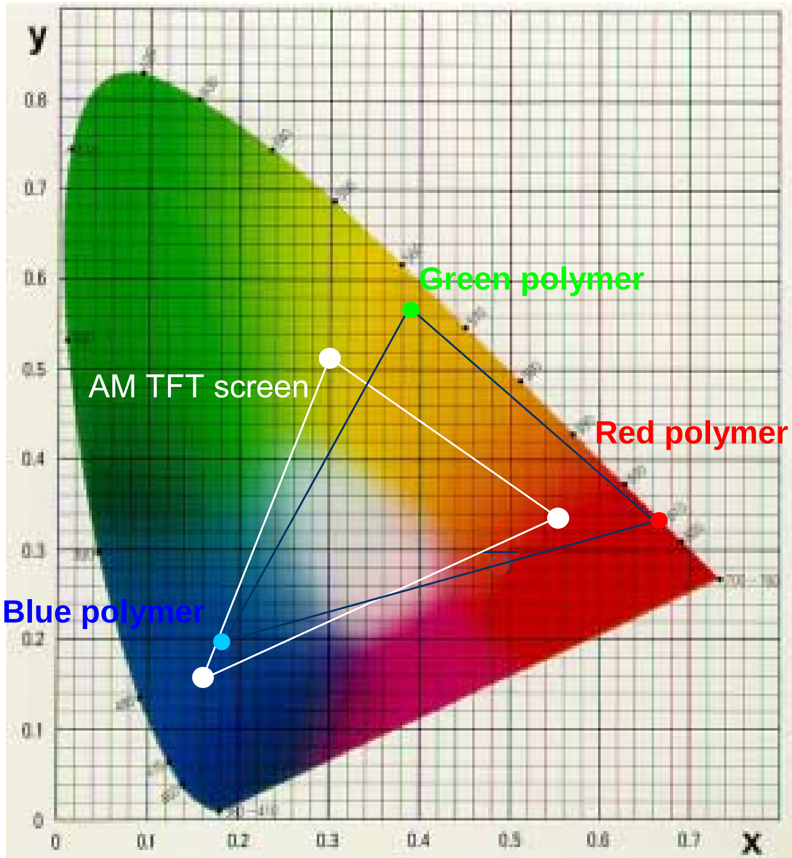
Advantages:

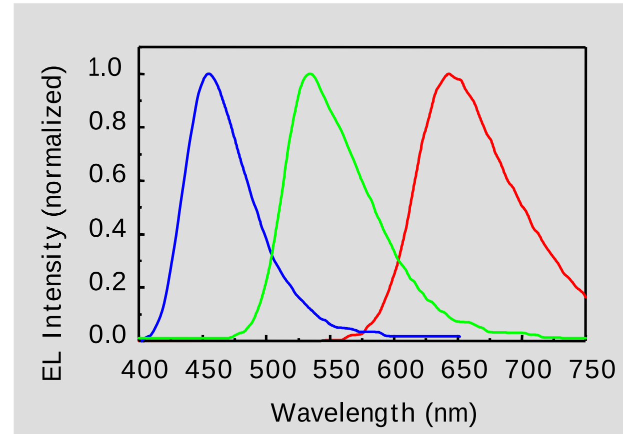
homogeneous aging of emitter (?)
more efficient than filters
no patterning of emitter necessary

Disadvantages:

ITO Sputtering on CCMs
stable blue emitter necessary
aging of CCMs

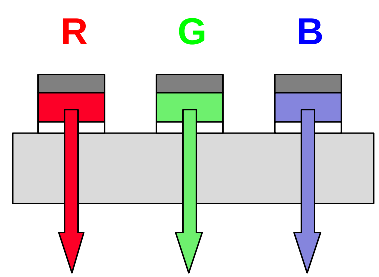
Obtaining a Full Color OLED Display

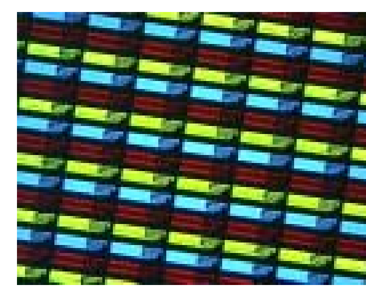




Ink Jet printing **of R,G,B emissive polymers defines the R,G,B subpixels**

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





Device Color, Efficiency and Lifetime

	Polymers		Small Molecules	
Color	Efficiency (cd/A)	Half-Life* (hrs) @150 nits, RT	Efficiency (cd/A)	Half-Life* (hrs) @150 nits, RT
Red	1-2	>20,000	4-5	>40,000
Green	8-10	15,000	8-9	>40,000
Blue	4	3,000	3	10,000
Yellow	8-10	>30,000	8	>30,000
White	2-4	5,000	6-8	20,000

**Extrapolated Lifetime under constant current conditions*

Small Molecule Passive Matrix Display Products

Motorola (by Appeal)

Lucky Goldstar (LG)

96x64 Full Color PM Display

Samsung Electronics

Kodak Licensed SNMD to Manufacture PM OLED Displays

Small Molecule Active Matrix Display Products

Eastman Kodak: Digital camera

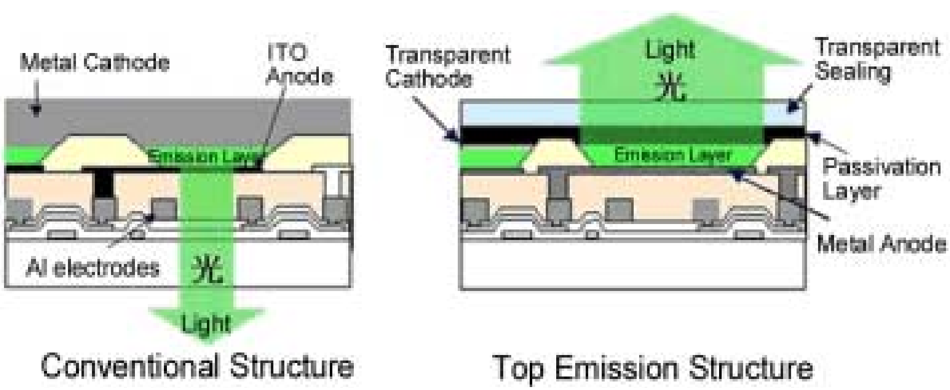
Sanyo: Cell Phone with Digital camera

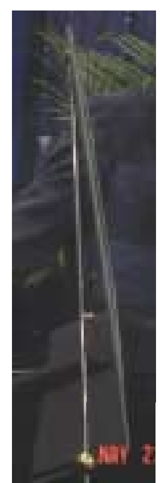
Top Emitting Active Matrix OLED Display

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.

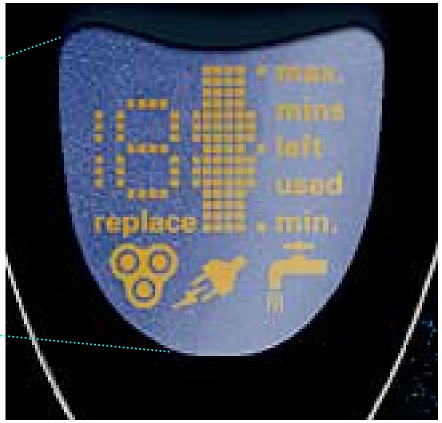
Display format: 800 x 600 (SVGA); pixel pitch 0.33x0.33mm^2





SONY

Polymer Passive Matrix Display Products



Philips: Electrical Shaver

Delta Electronics: Display for MP3 player

OSRAM Opto Semiconductors evaluation kit

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.