

# An Overview of OLED Display Technology

**Homer Antoniadis**

**OSRAM** Opto Semiconductors Inc.

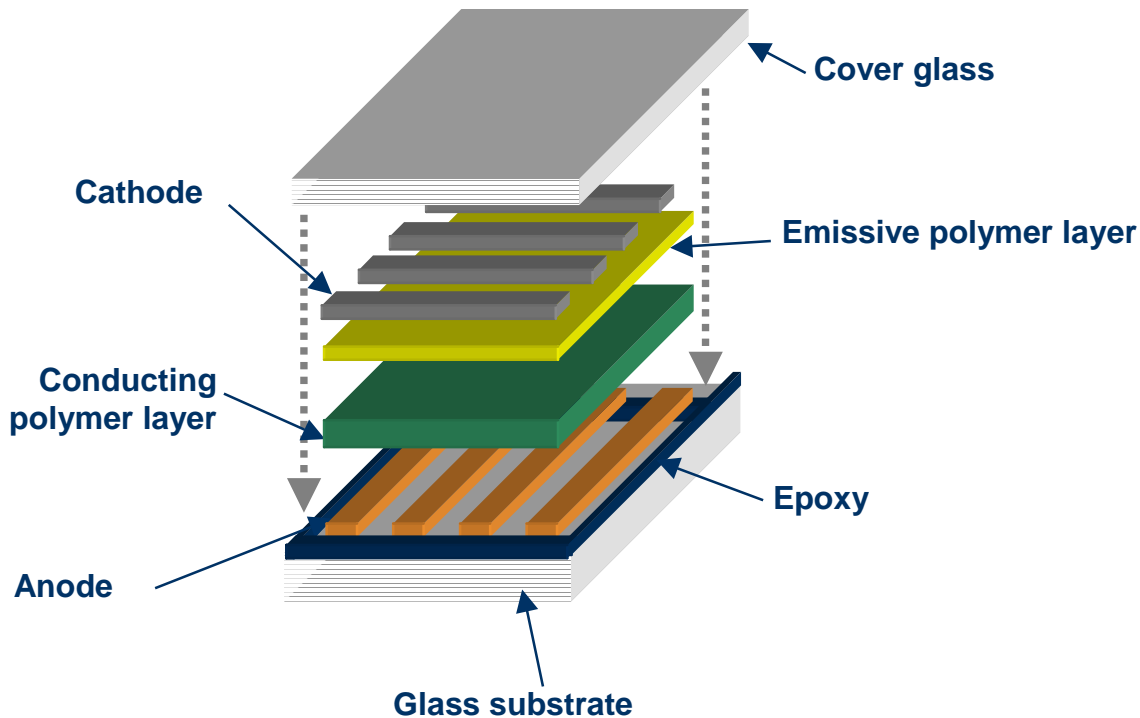
**San Jose, CA**

# Outline

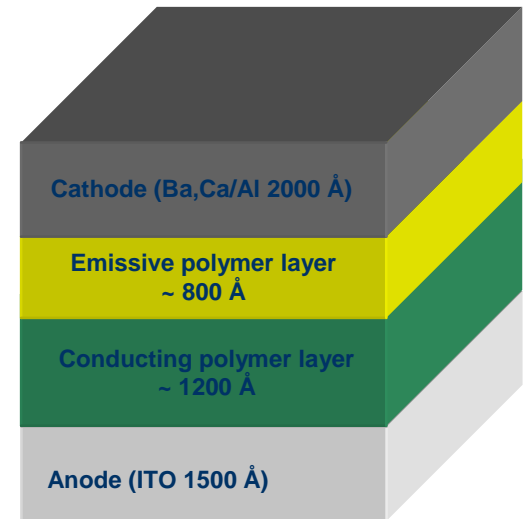
- OLED device structure and operation
- OLED materials (polymers and small molecules)
- Evolution of OLED performance
- OLED process and fabrication technologies
- White emitting OLEDs
- Color capabilities
- Products and demonstrators

# OLED display and pixel structure

Display



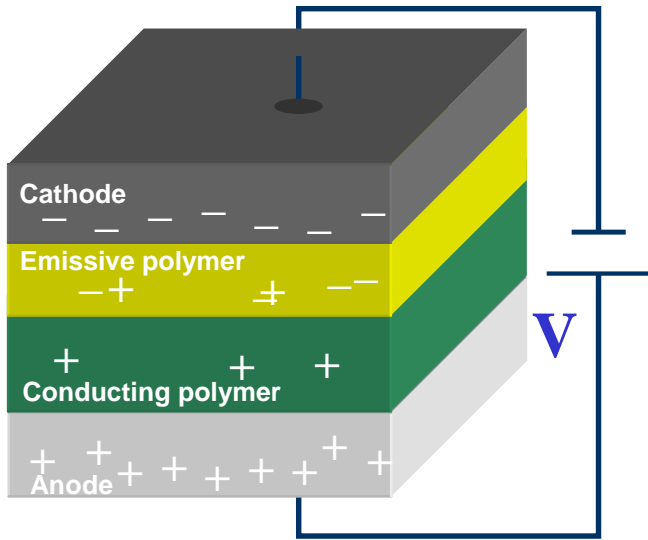
Pixel



Single pixel structure

Human hair is 200X the thickness of the OLED layers

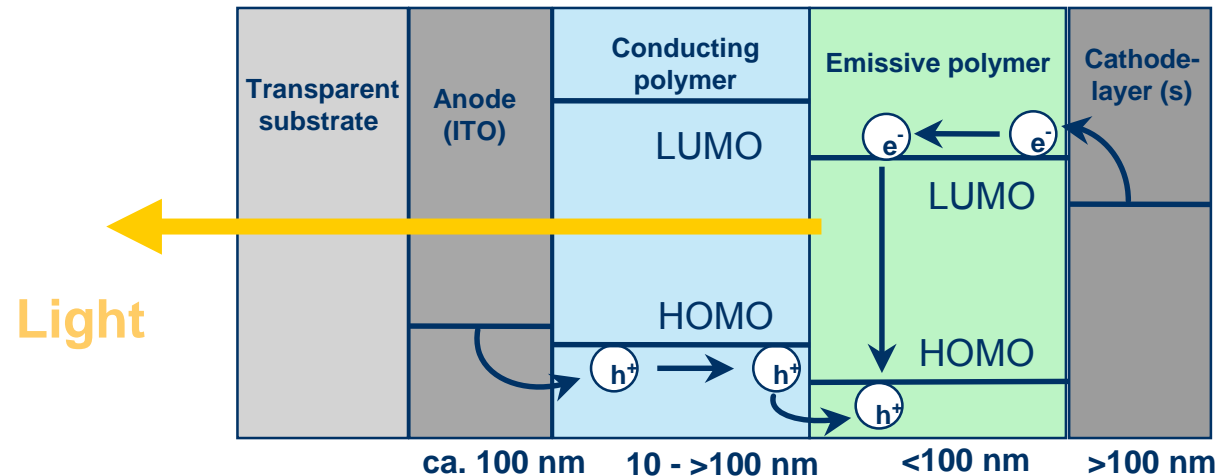
# OLED Device Operation Principles



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

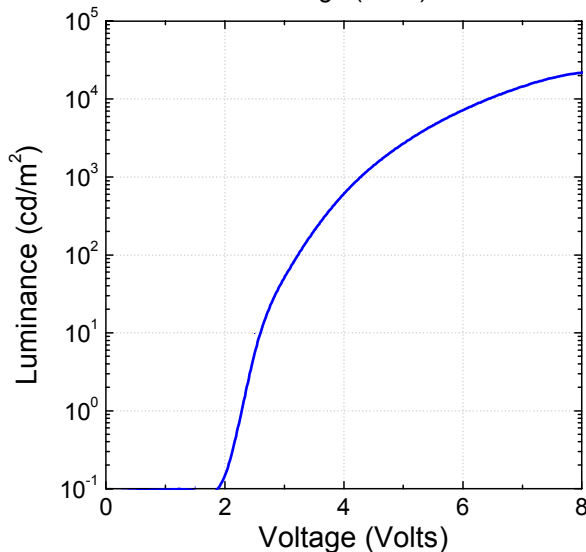
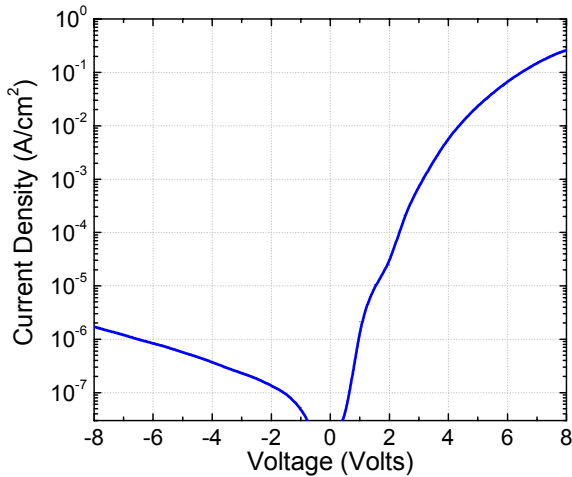
- Electrons injected from cathode
- Holes injected from anode
- Transport and radiative recombination of electron hole pairs at the emissive polymer

OLED device operation (energy diagram)

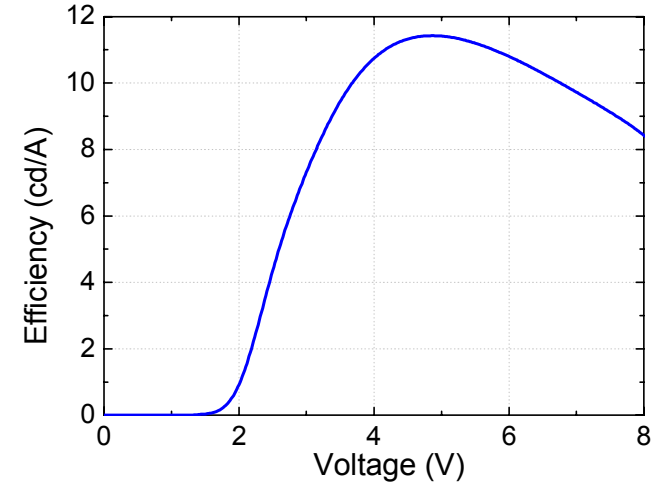
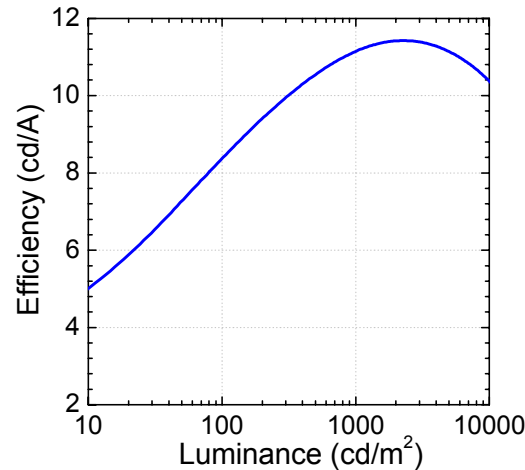


# Optoelectronic Device Characteristics

## 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<sup>2</sup>**), which is still sometimes called a **nit**

The **footlambert** (fL) is also in common use:  
1 fL = 3.426 cd/m<sup>2</sup>

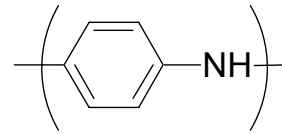
<http://www.resuba.com/wa3dsp/light/lumin.html>



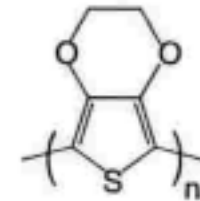
# Electroluminescent Conjugated Polymers

## Conducting polymers

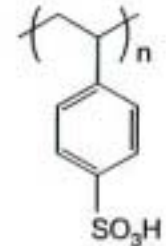
- Polyaniline (PANI:PSS)
- Polyethylenedioxythiophene (PDOT:PSS)



PANI



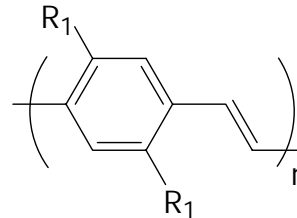
PDOT



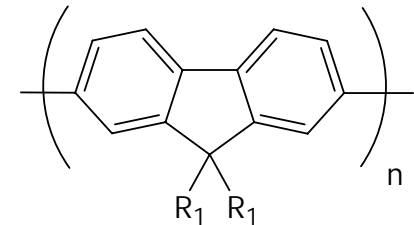
PSS

## Emissive polymers

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



R-PPV



PF

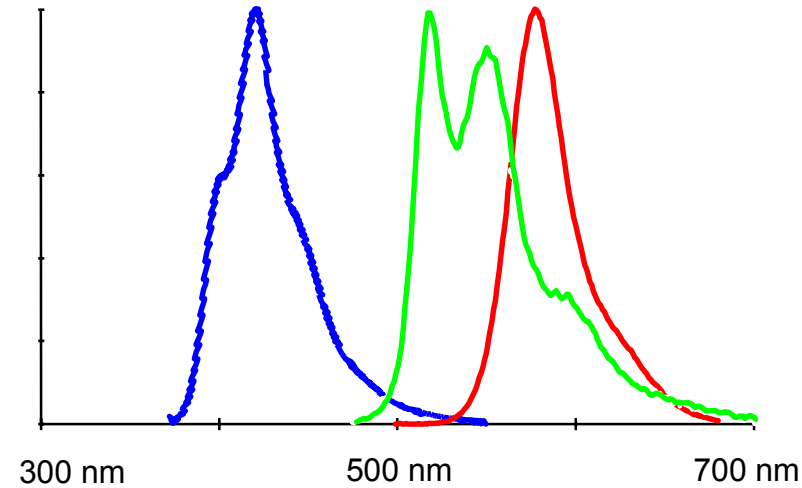
### Processed by :

Spin casting, Printing, Roll-to-roll web coating

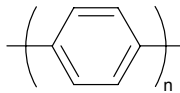
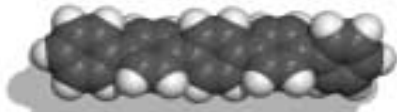
IP owned by Cambridge Display Technology

# Multiple emission colors achieved by Covion

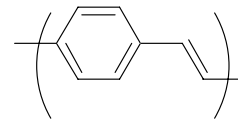
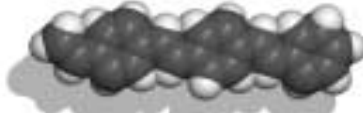
Different emission colors can be obtained with a variety of chemical structures



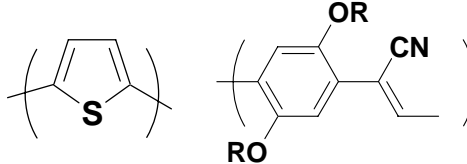
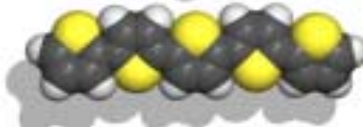
PPP



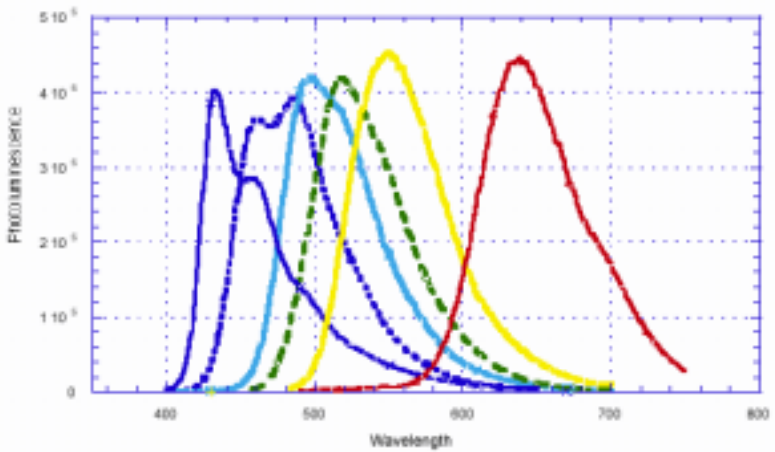
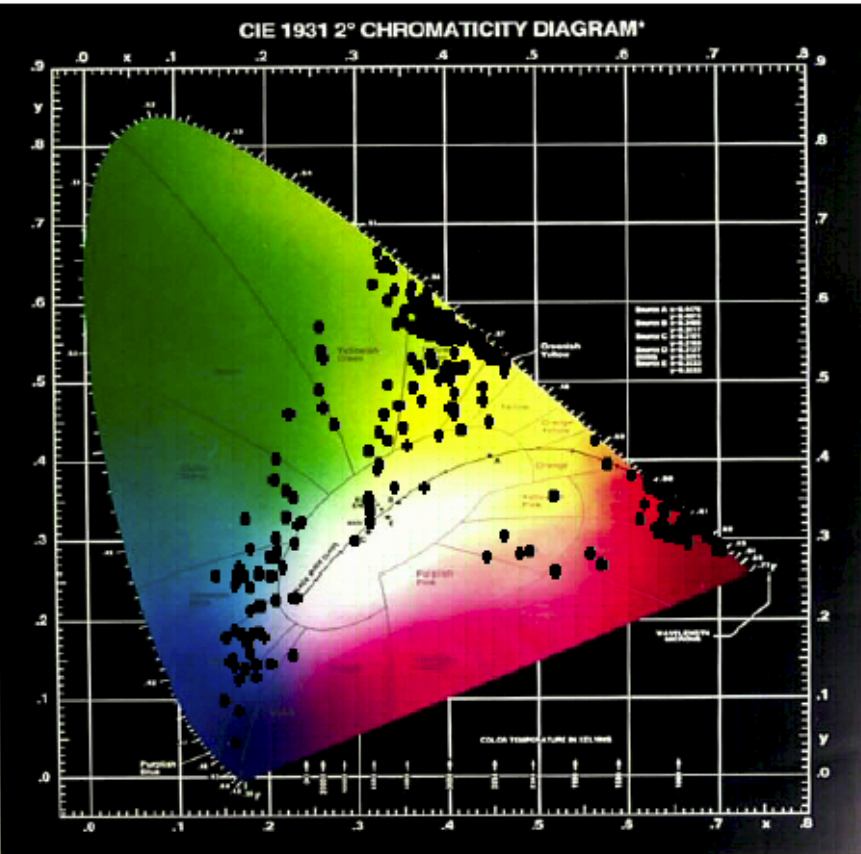
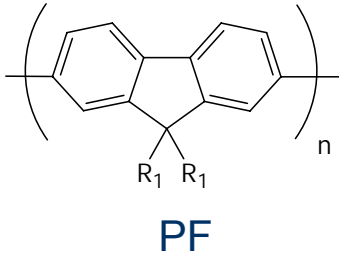
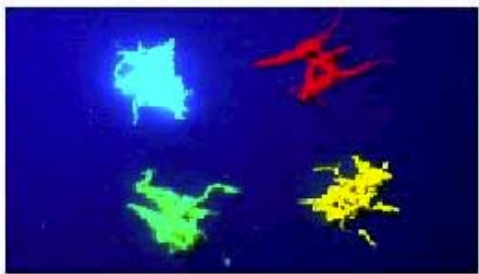
PPV



PT or  
CN-PPV

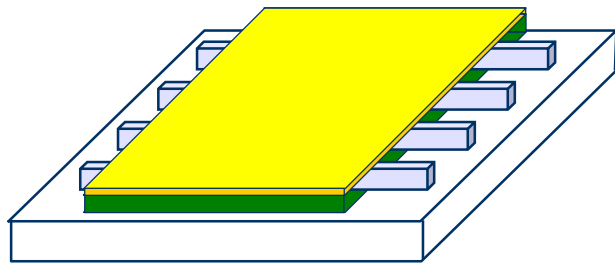
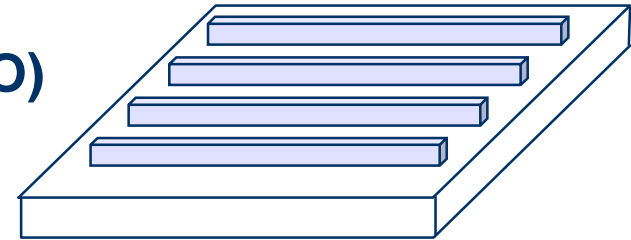


# Multiple emission colors achieved by Dow Chemical



# Polymer OLED display fabrication steps

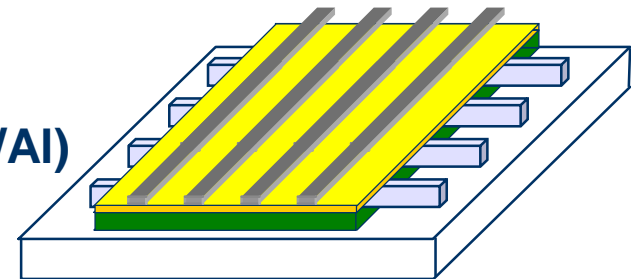
**Deposit and pattern anode (ITO)**



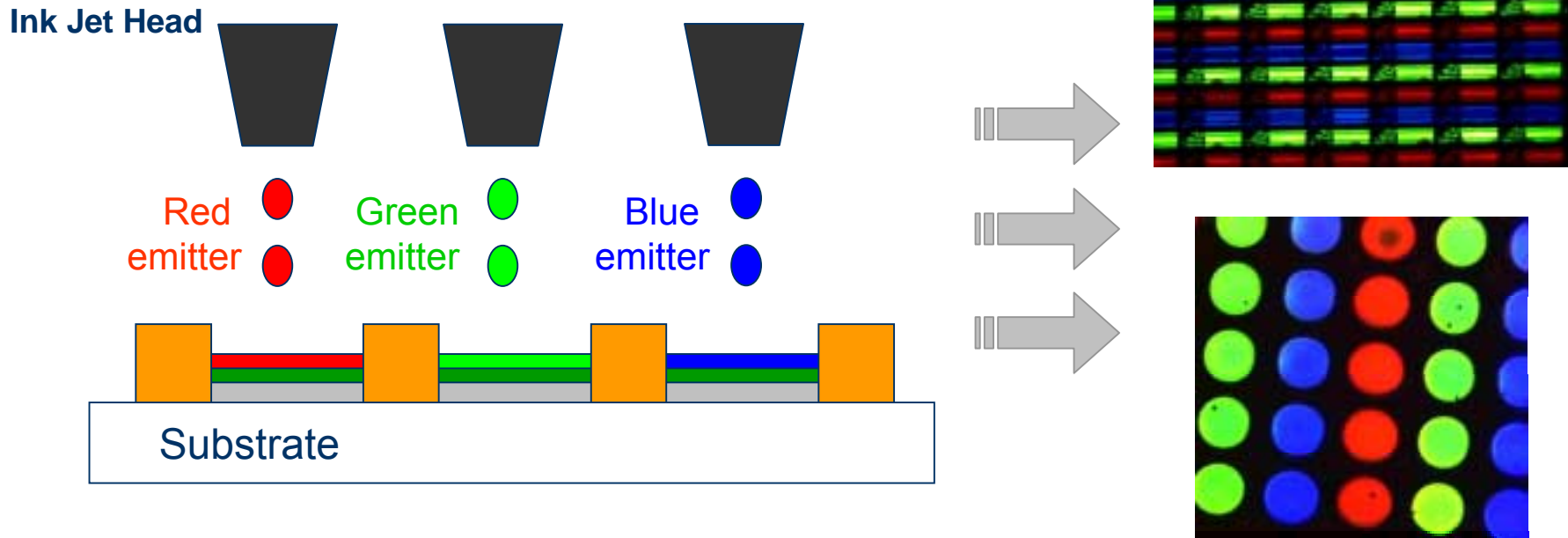
**Pattern polymer layers  
(first conducting then emissive)**

Spin coating  
Ink Jet printing  
Screen printing  
Web coating

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

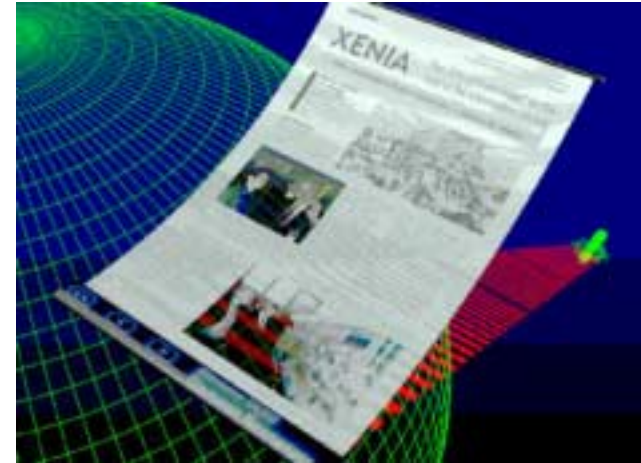
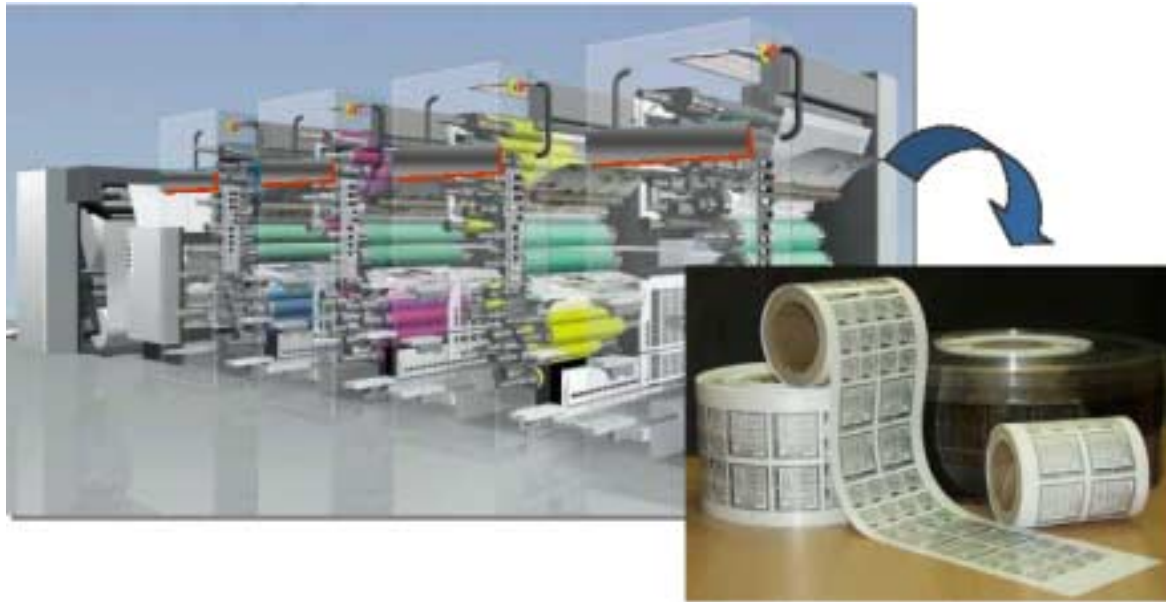


# Ink Jet Printing to Pattern Polymers (Full Color Applications)



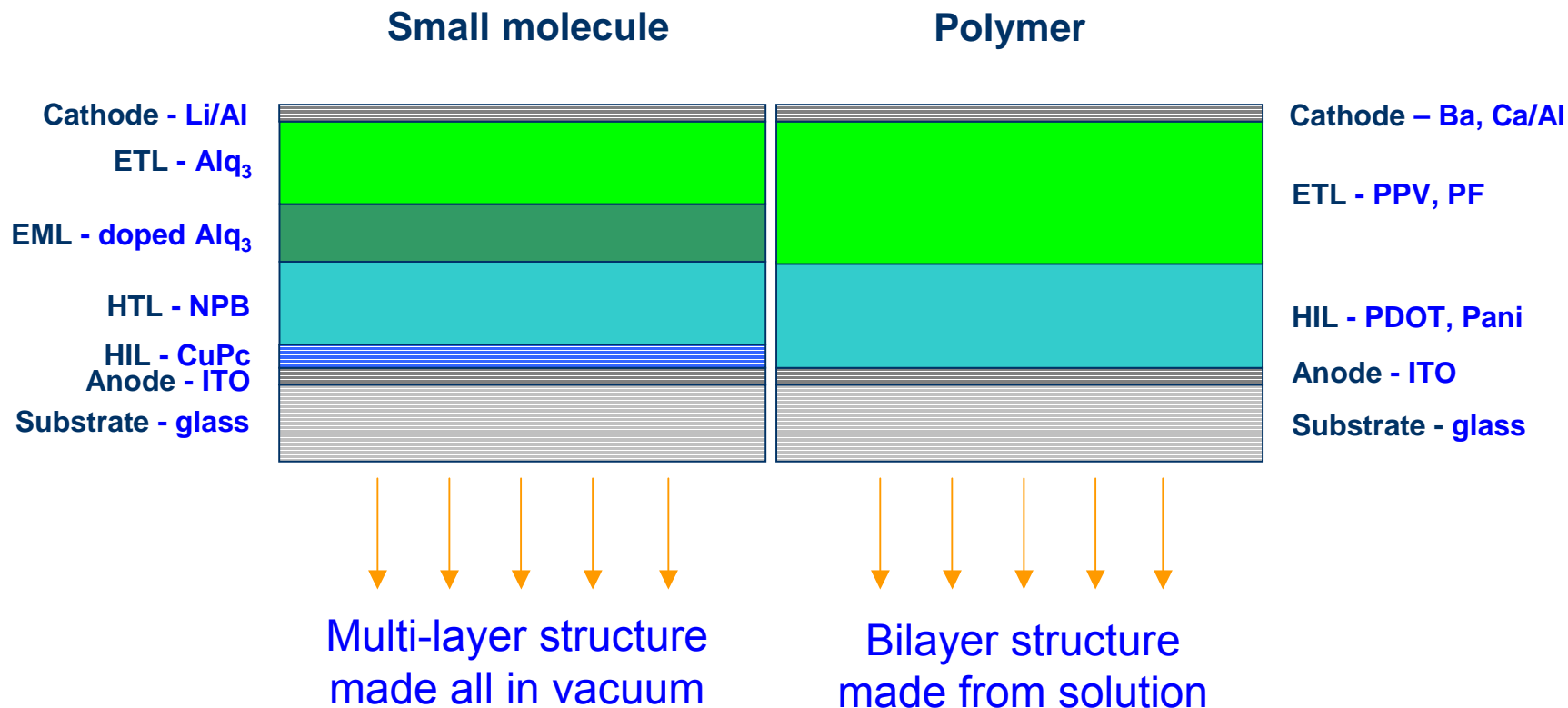
Ink Jet printing to define and pattern R, G, B emitting subpixels

# The Holy Grail: Flexible OLEDs



Sheila Kennedy, Harvard Univ., 1999

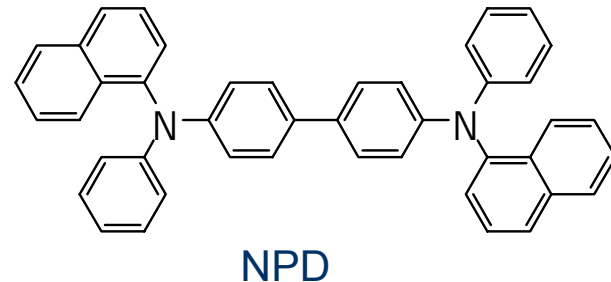
# Polymer and Small Molecule Device Structures



# Electroluminescent Small Molecules

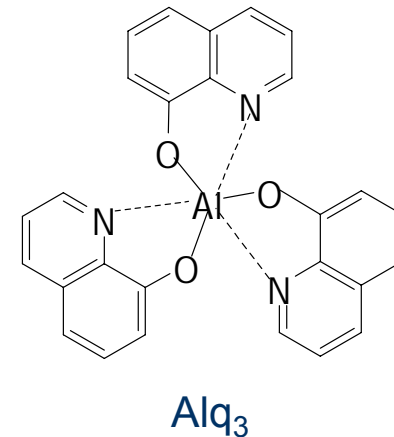
## Hole transport small molecules

- Metal-phthalocyanines
- Arylamines, starburst amines



## Emissive small molecules

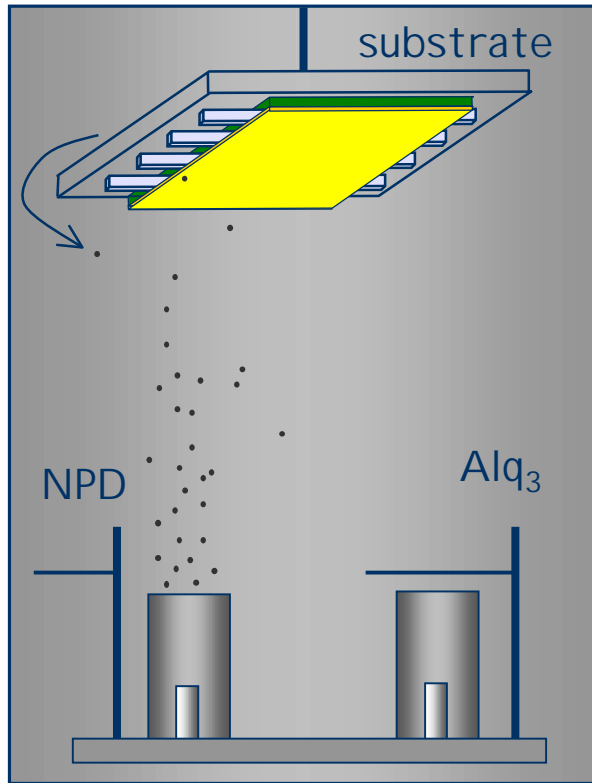
- Metal chelates, distyrylbenzenes
- Fluorescent dyes



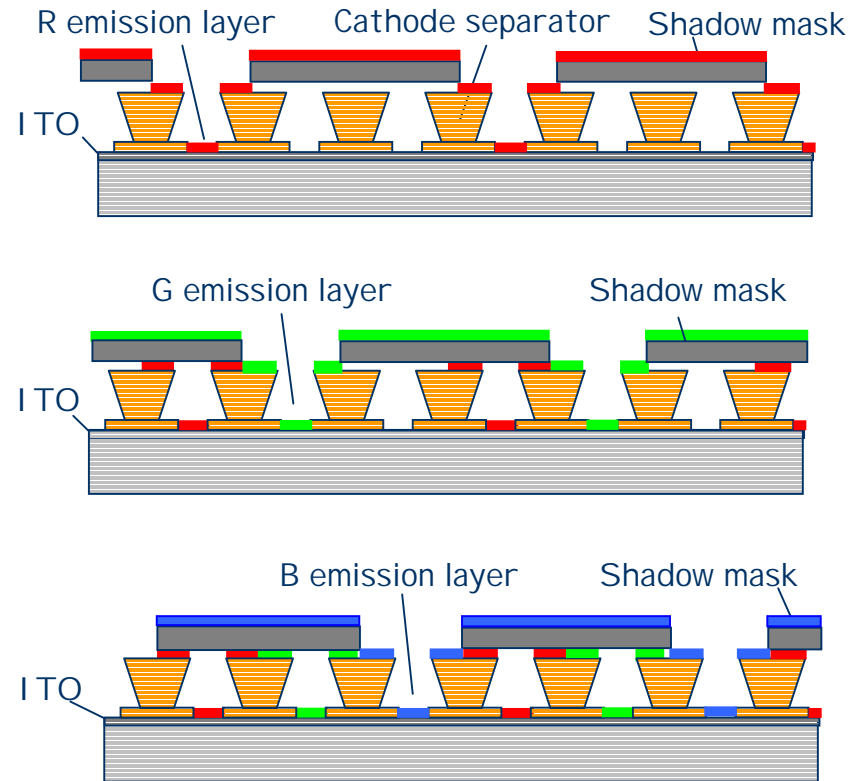
**Processed and deposited by :**  
thermal evaporation in vacuum

**IP owned by Eastman Kodak**

# Full color patterning with small molecules

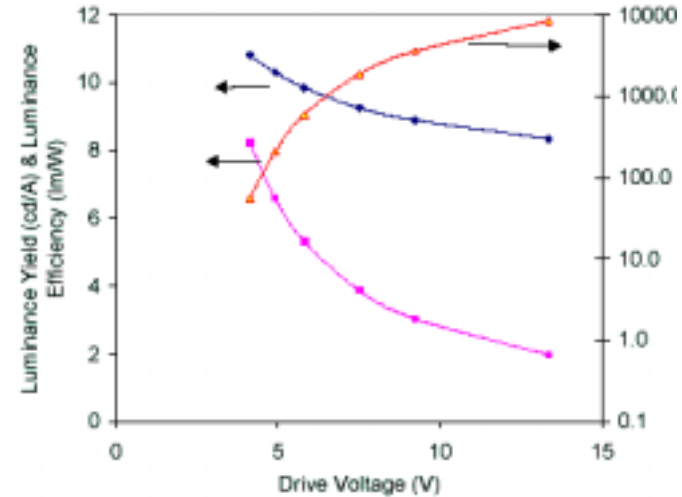
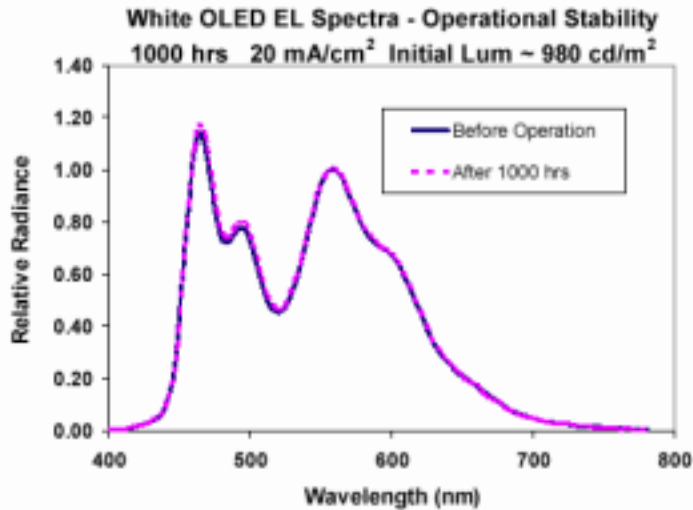


Small molecules are thermally evaporated in vacuum

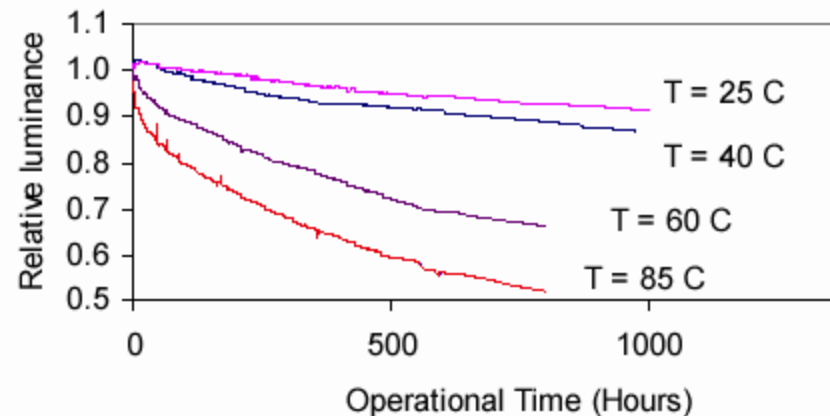


R, G, B patterning is defined by shadow masking in vacuum

# White emitting small molecule OLEDs

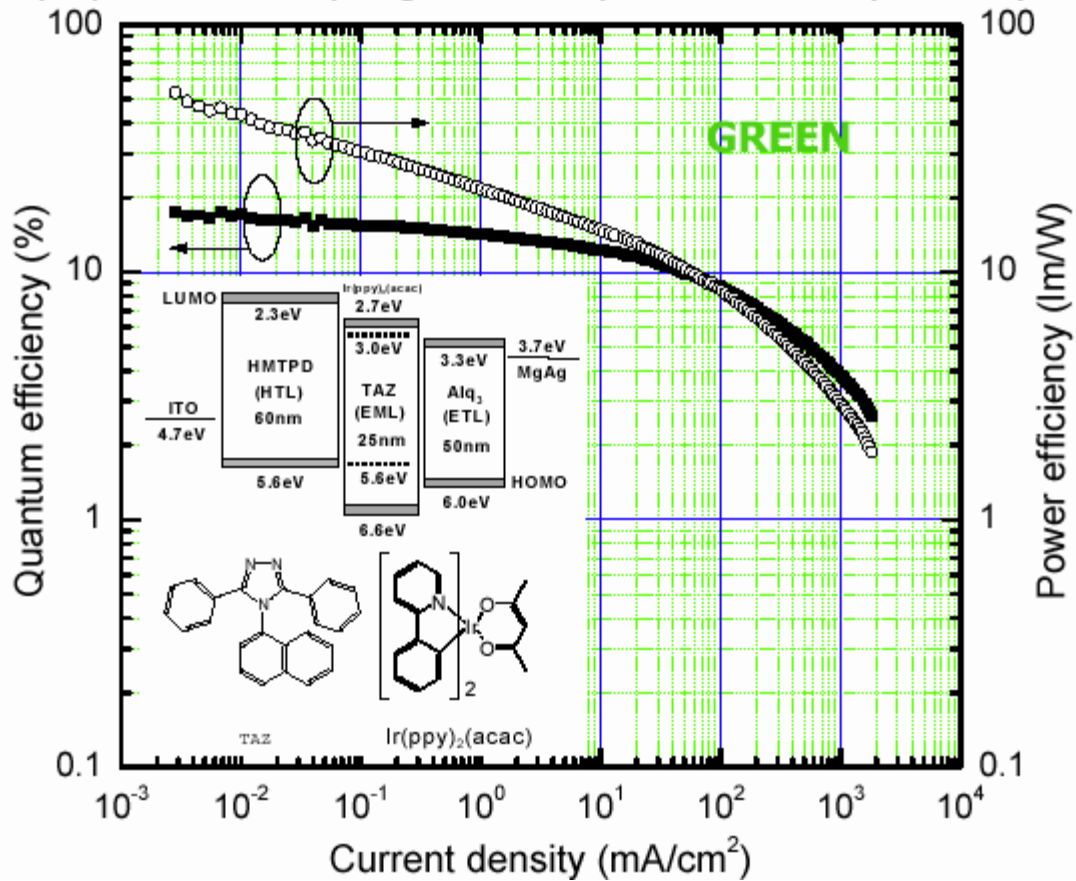


Initial Luminance 1000nits



# 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)

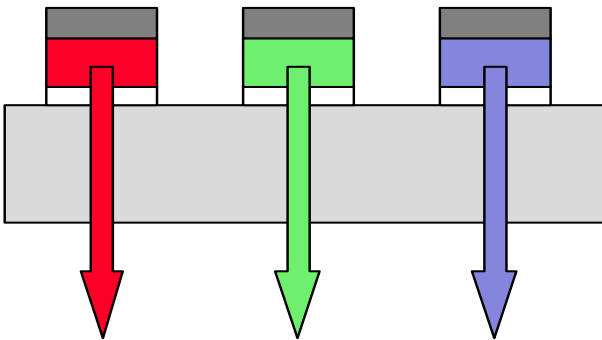


Princeton University

$$\eta_{\text{ext}} = 19\% \text{ and } \eta_{\text{int}} = 87\%$$

# Full-color/Multi-color Approaches

## RGB- polymer emitters



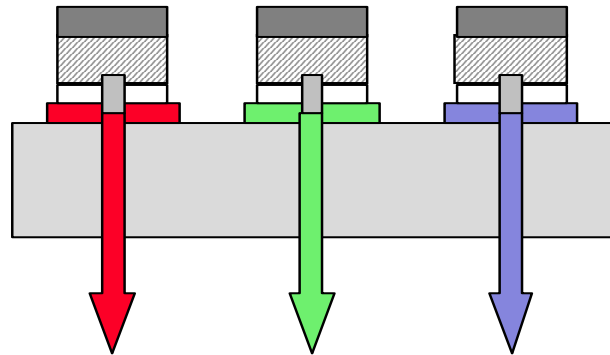
### Advantages:

- 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



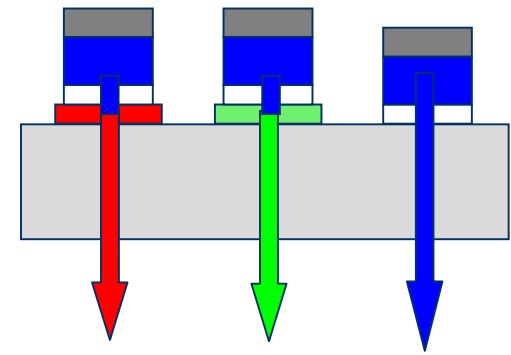
### Advantages:

- 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)



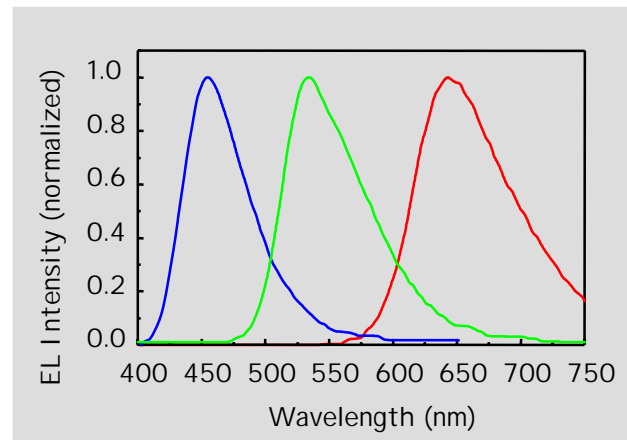
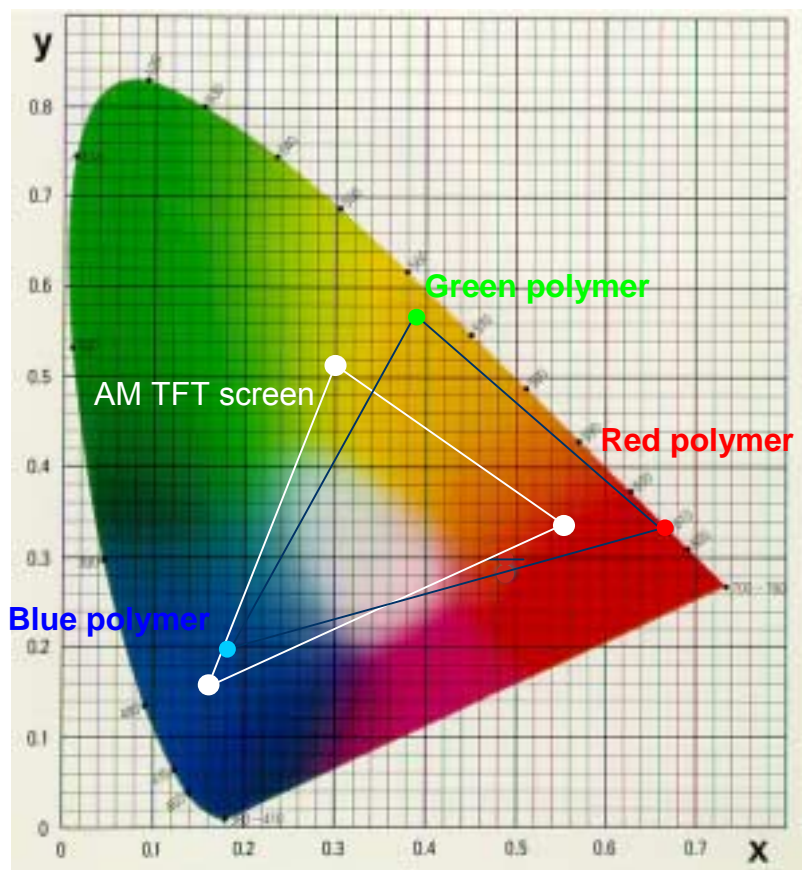
### Advantages:

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

### Disadvantages:

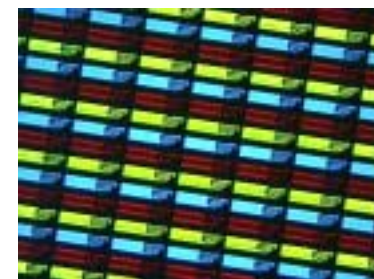
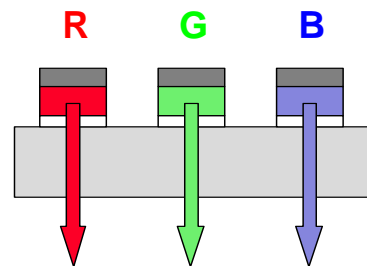
- ITO Sputtering on CCMs
- stable blue emitter necessary
- aging of CCMs

# 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
<b>Red</b>	1-2	>20,000	4-5	>40,000
<b>Green</b>	8-10	15,000	8-9	>40,000
<b>Blue</b>	4	3,000	3	10,000
<b>Yellow</b>	8-10	>30,000	8	>30,000
<b>White</b>	2-4	5,000	6-8	20,000

*\*Extrapolated Lifetime under constant current conditions*

# Small Molecule Passive Matrix Display Products



Motorola (by Appeal)



96x64 Full Color PM Display



Samsung Electronics

Kodak Licensed SNMD to Manufacture PM OLED Displays



Lucky Goldstar (LG)



# Small Molecule Active Matrix Display Products



**Eastman Kodak:** Digital camera



**Sanyo:** Cell Phone with Digital camera

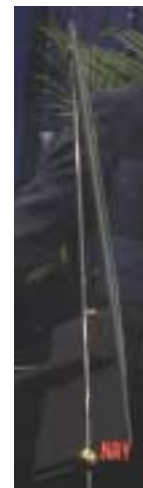
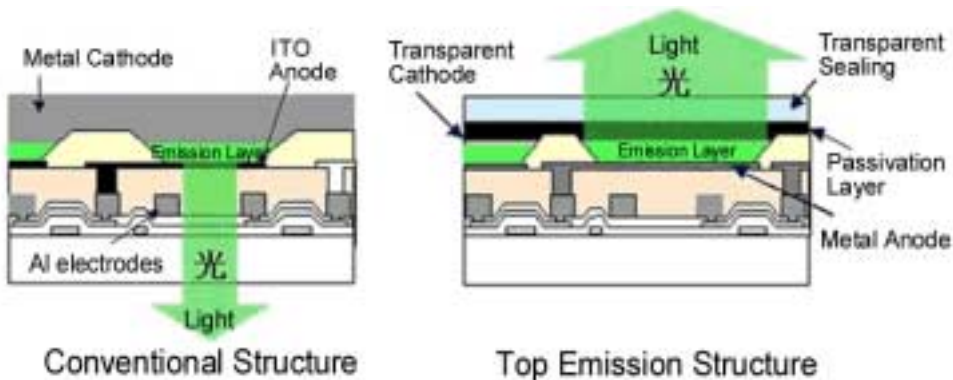
# Top Emitting Active Matrix OLED Display

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.

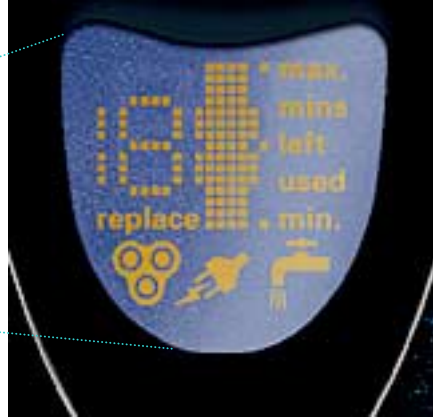
The schematic vertical structure of the device is substrate/TFT/metal anode/organic layers/transparent cathode/passivation layer/transparent sealing.

Display format: 800 x 600 (SVGA); pixel pitch 0.33x0.33mm<sup>2</sup>



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.