Nanomaker

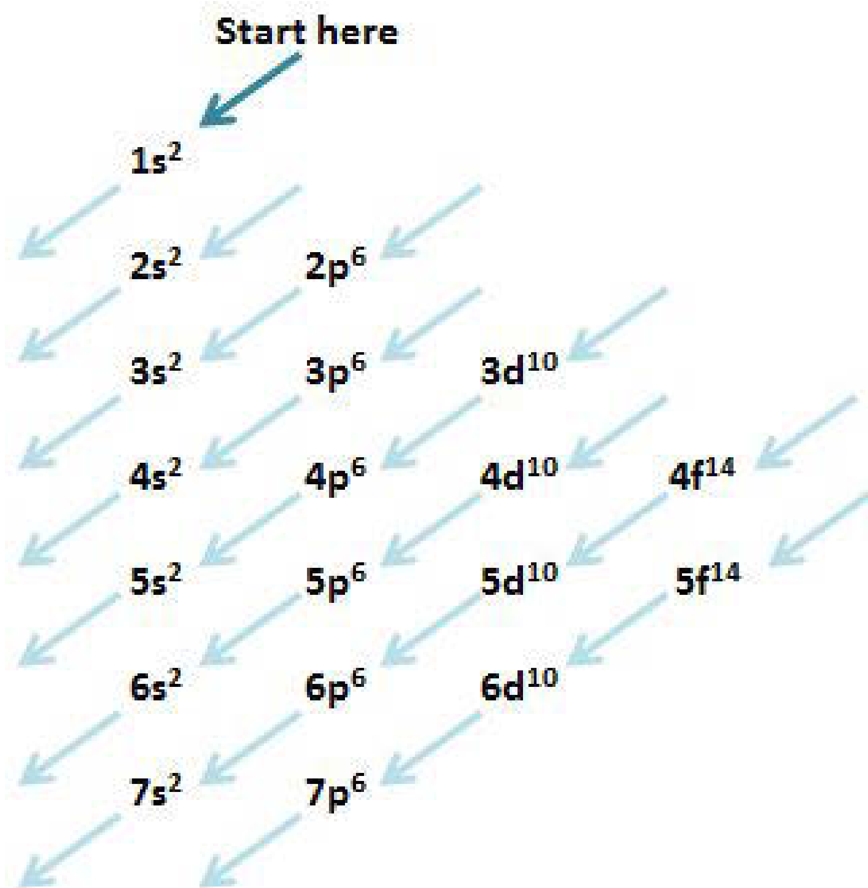
Lab #4: Organic Light Emitting Diode (OLED)

Why Does a Pickle Glow?

- Due to the sodium in the pickles, in the form of table salt (NaCl).
- The current heats up the water in the pickle and dries out regions near the electrodes.
- A spark leaps between the electrode and the wet region and excites the sodium to emit light.

Diagram of the sodium doublet from Hyperphysics removed due to copyright restrictions.

Just In Case You Forgot...



Organic LED Display

Charge Transport Layer Fabrication

Display Technology

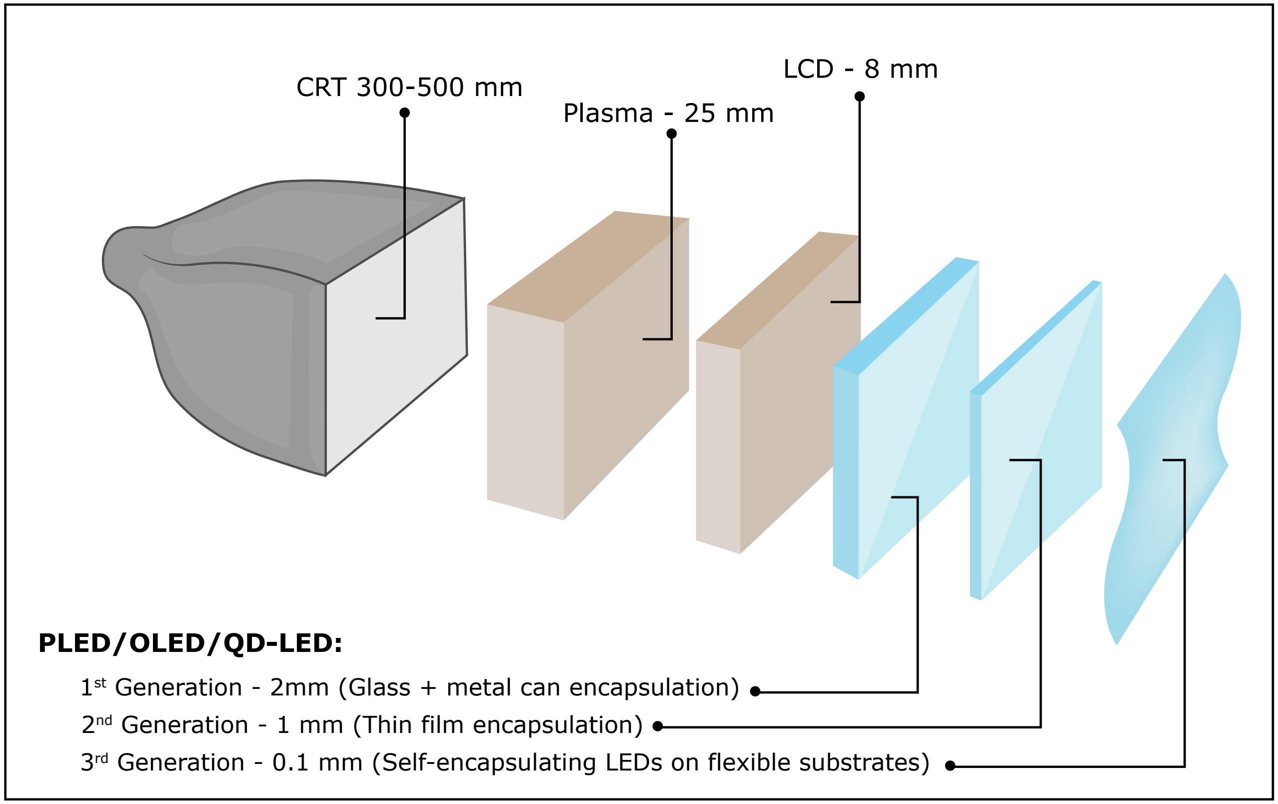
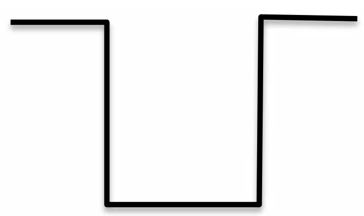
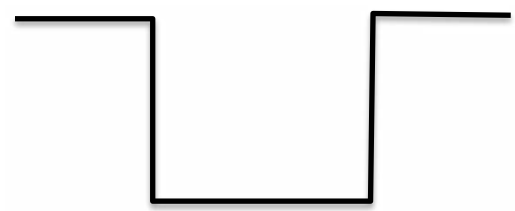


Image by MIT OpenCourseWare.

Courtesy of Felice Frankel. Used with permission.

Heisenberg Uncertainty Principle





$$\Delta x \Delta p \geq \frac{\bar{h}}{2}$$

$$p = \sqrt{\langle (p - \langle p \rangle))\rangle^2}$$

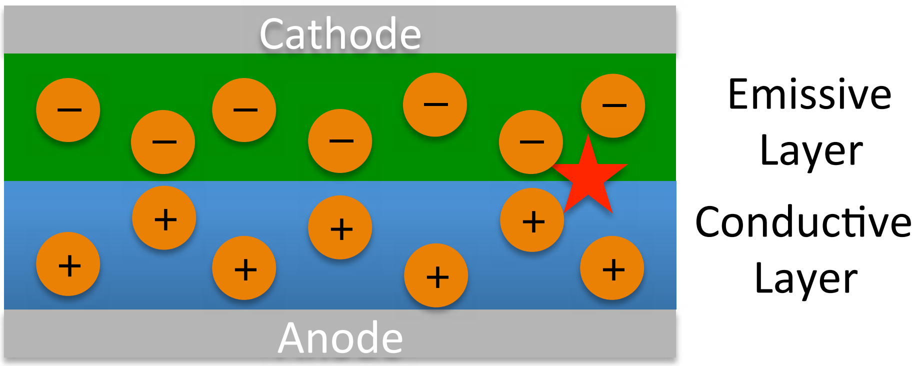
Courtesy of Felice Frankel. Used with permission.

Organic LED Display

Charge Transport Layer

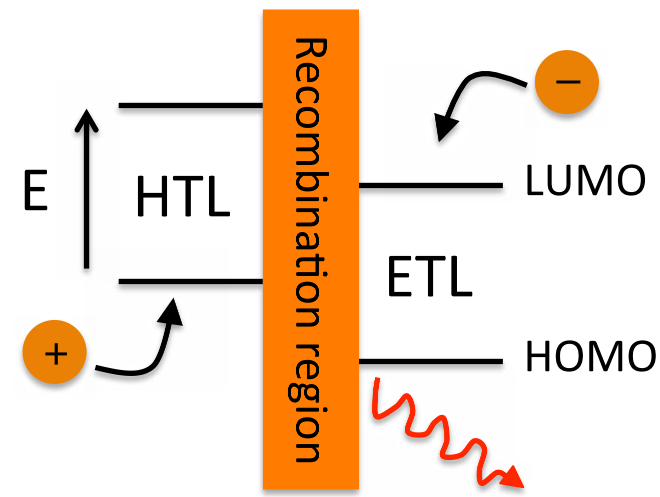
Fabrication

Principle of Organic LEDs

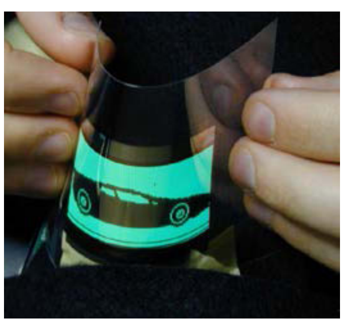


emissive electroluminescent layer is composed of a film of organic compounds

Electrons and holes form excitons (bound e- h+ pairs)



Some excitons radiate



Flexibility of OLED

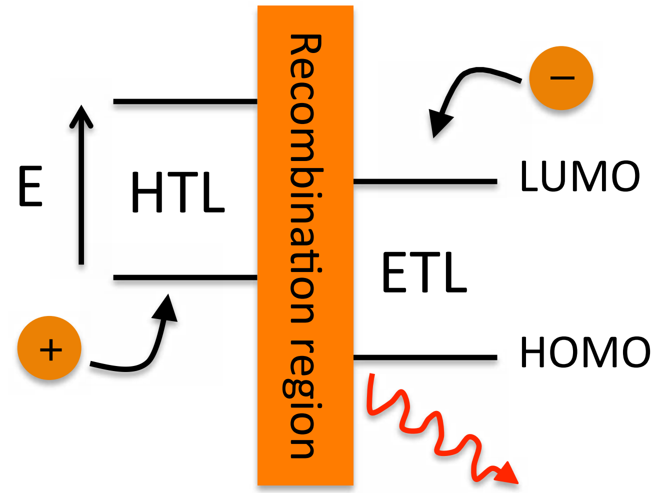
Courtesy of Universal Display Corporation. Used with permission.

OLED TV - Sony

Photo courtesy of leumund on Flickr.

HTL (Hole transport layer)
ETL (Electron transport layer)

Organic LEDs

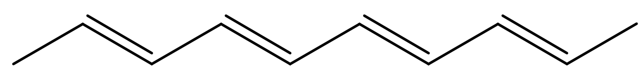


- First minimize the injection barriers for both hole injection and electron injection. This decreases the drive voltage required to create light from the device.
- Its desirable to match the charge mobilities in HTL and ETL layers.
- You want localize the emission of zone to the center of the device. It is better to have the charges collect at the interface and undergo a cross reaction to generate the emissive state.

Conventional and π-Conjugated Polymers

Conventional Polymers

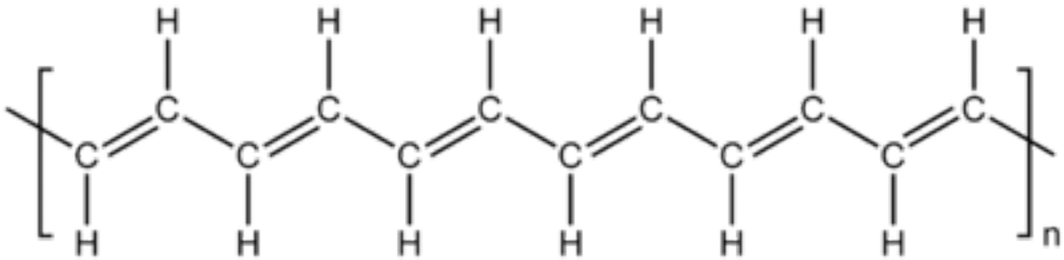
- Easy processing/fabricating over larger areas
- Low cost materials and fabrication
- Excellent mechanical properties
- Excellent insulators
- Lowest energy excited states in UV (4-6 eV)
- Low thermal stability (100-300 °C)



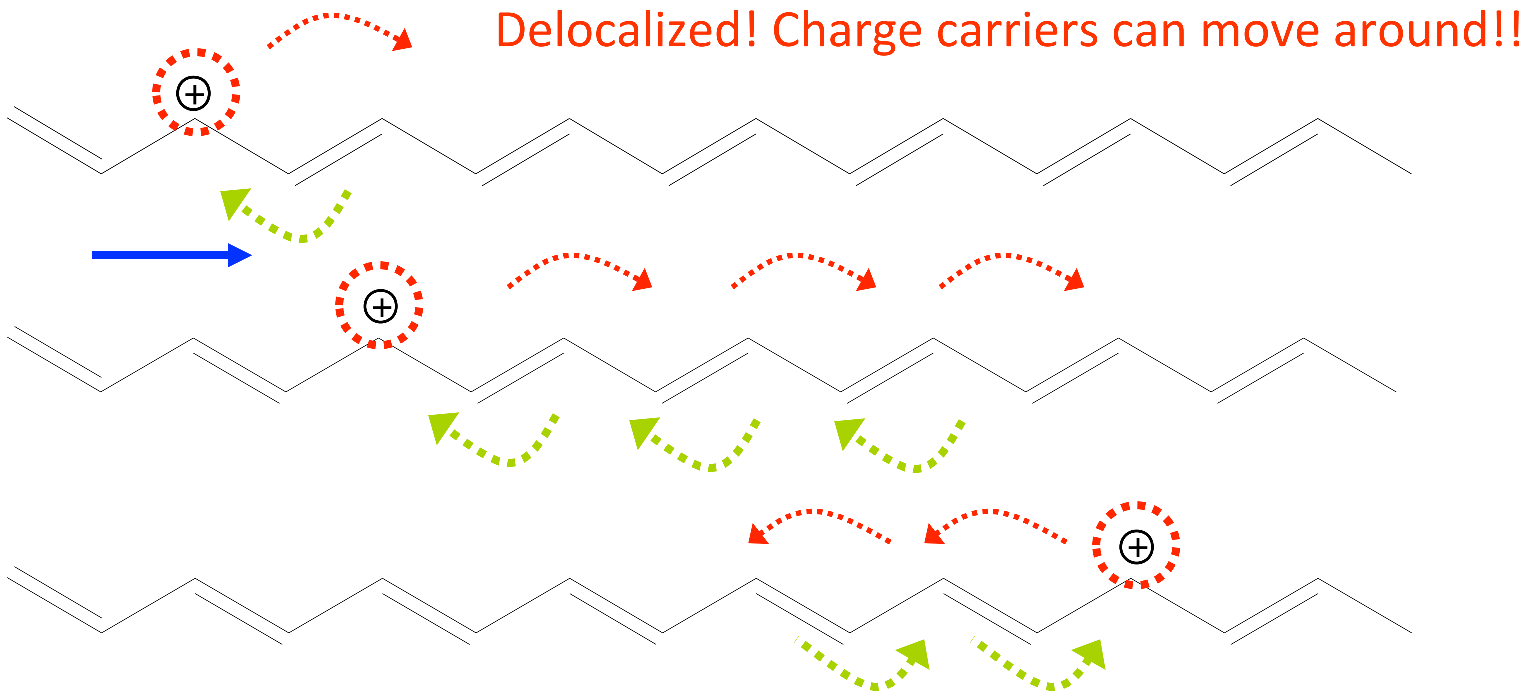
π - Conjugated Polymers

- Easy processing/fabricating over larger areas
- Low cost materials and fabrication
- Diverse electronic, optoelectronic and photonic properties
- Lowest energy excited states in Visible and Near-IR
- Better thermal stability (>300 °C)

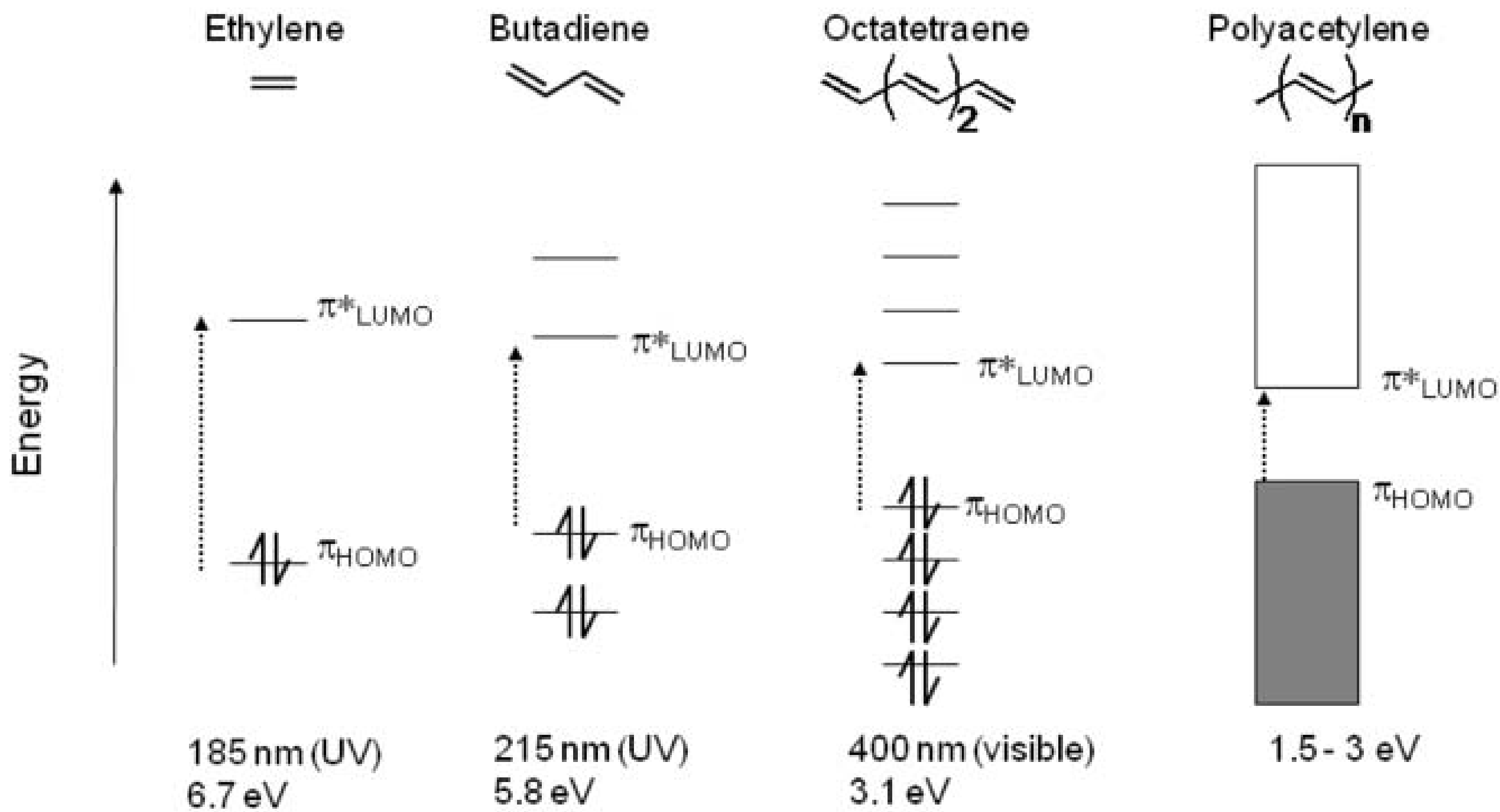
Delocalization of Charge Carriers



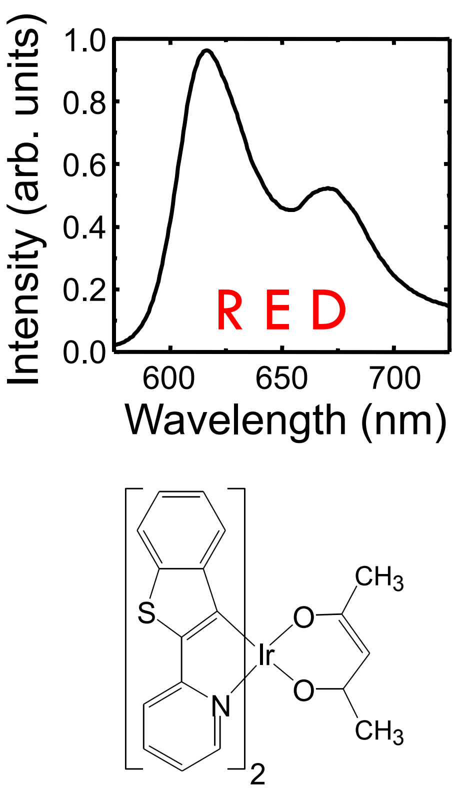
Polyacetylene $(C_2H_2)_n$



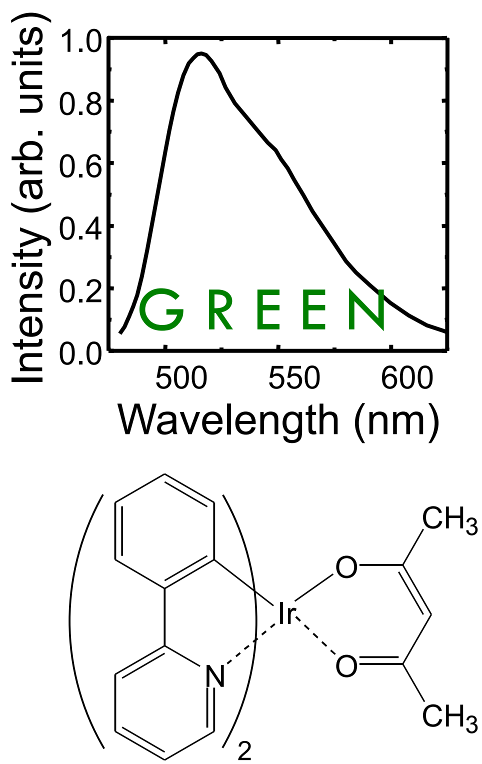
Light Absorption of Conjugated Materials



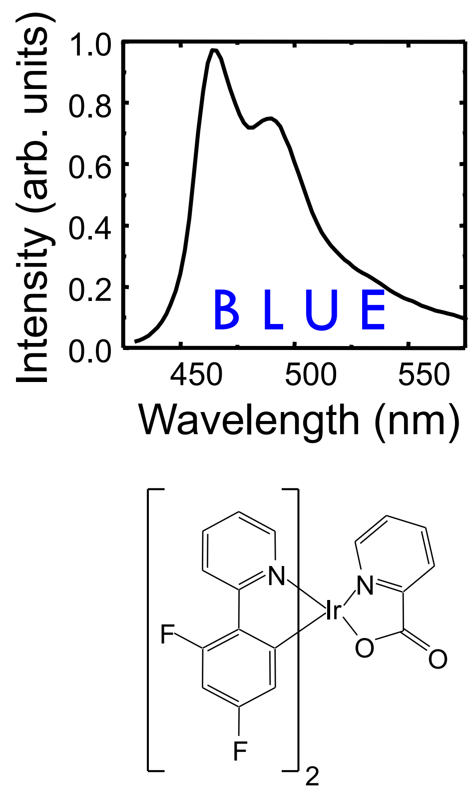
Examples of Organic Materials



btp$_2$Ir(acac)

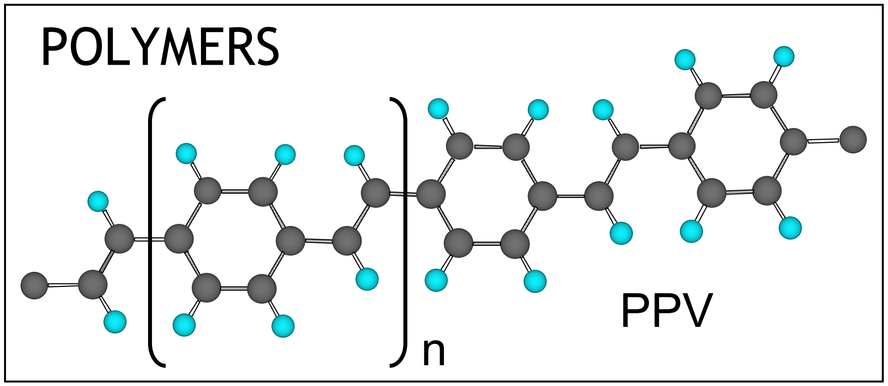


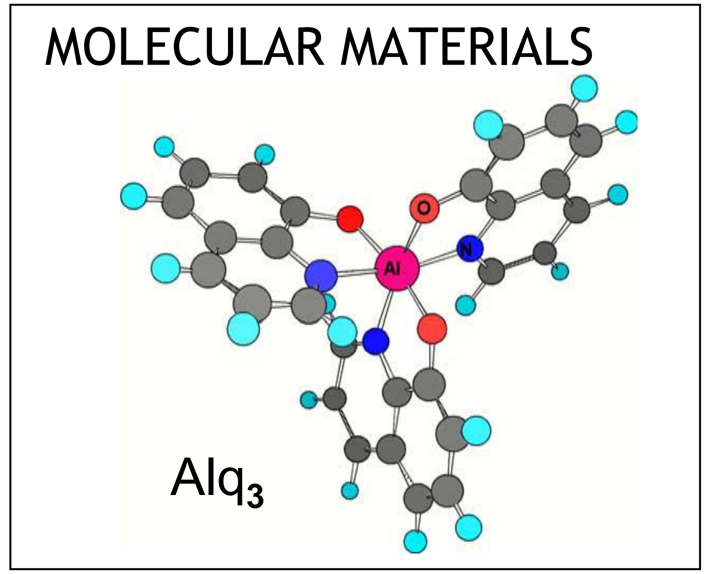
ppy$_2$Ir(acac)



FIrpic

Organic and Polymer LEDs





☺

- Integration with inorganic semiconductors
- Low cost and flexible
- Large area processing possible
- Tailor molecules for specific colors

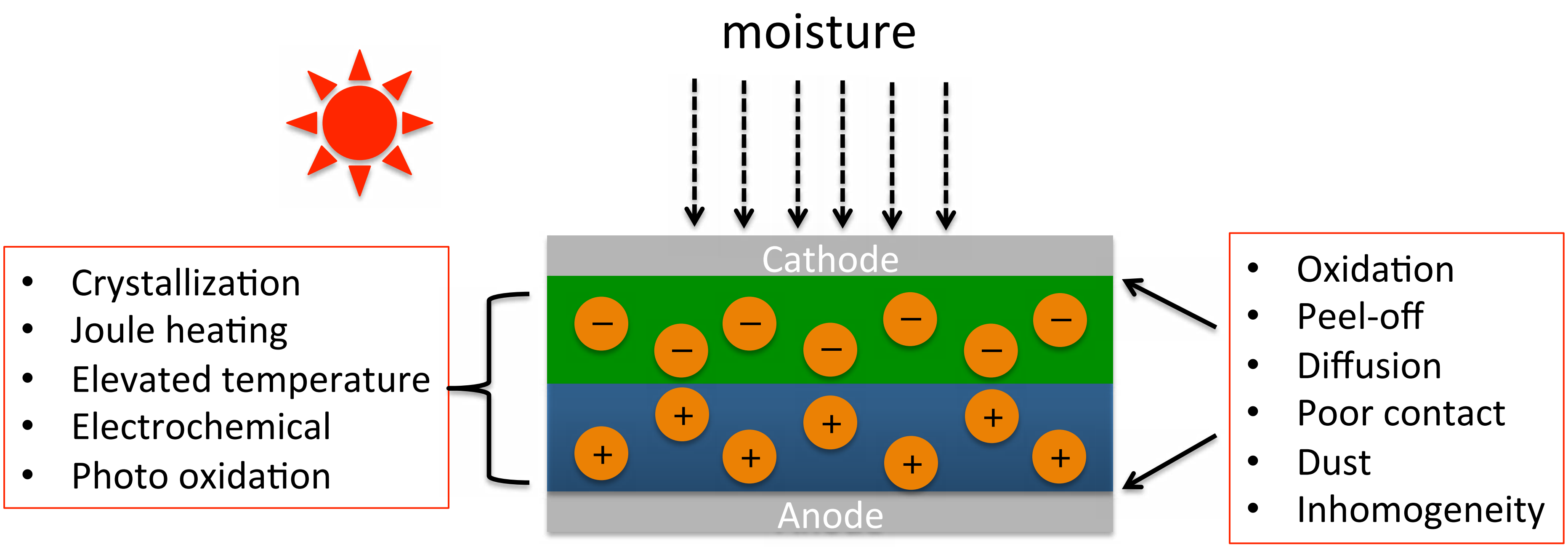
☹

- Stability
- Patterning
- Thickness control of polymer
- Low carrier mobility

Degradation Mechanism

Degradation modes:

- The growth of non-emissive area (Dark spots)
- Higher operation voltage
- Decay of luminance
- Short circuit electrical breakdown

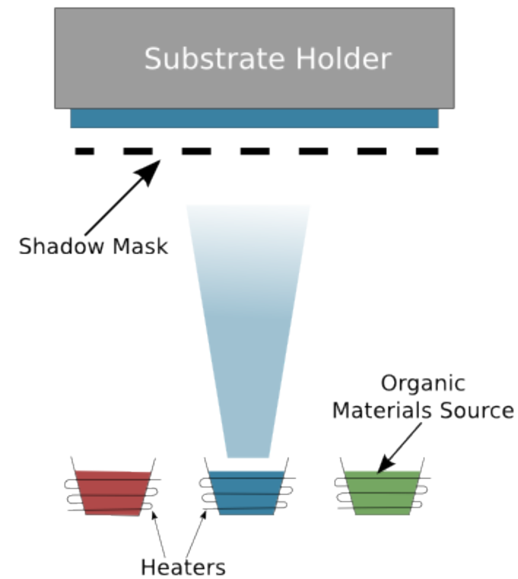


Organic LED Display
Charge Transport Layer
Fabrication

Thermal Evaporation

OLED

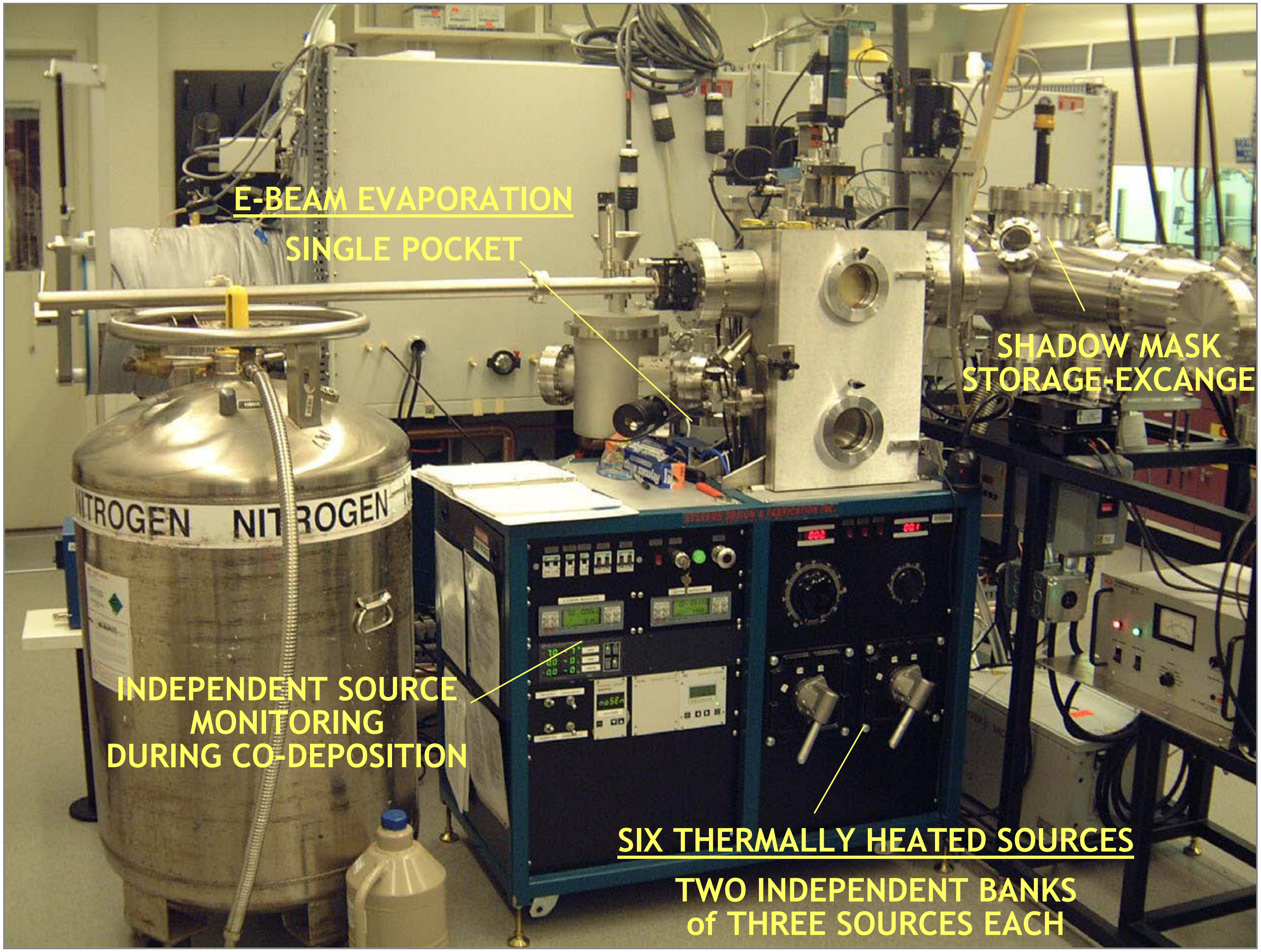
- Thermal vapor evaporation of small molecules occurs around 10 μTorr.
- It is usually carried out on glass substrate
- Multicolor displays are made using properly matched shadow masks for depositing RGB emitting materials



1. Thickness can be easily controlled
2. Easily fabricated in a single deposition procedure
3. Construction of very complex multi-layer structures

1. Expensive
2. Not flexible
3. No control to direct the materials to deposit on the desired areas
4. Inefficient use of materials

Thermal Evaporator

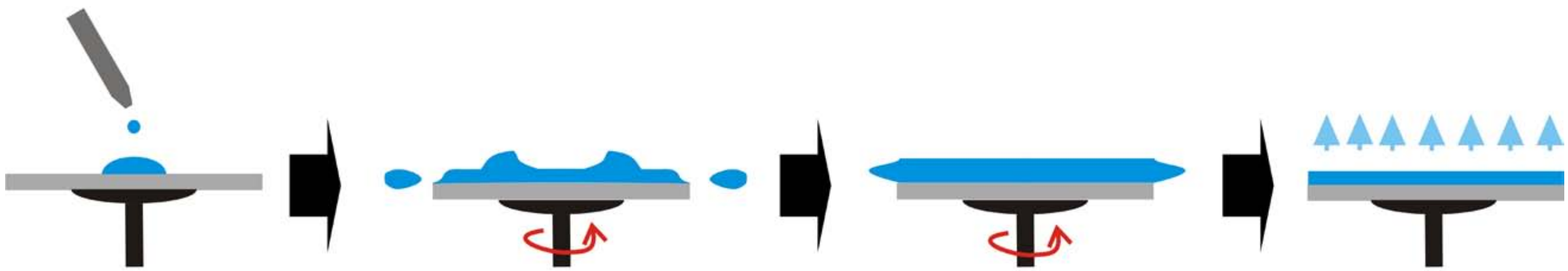


Spin Coating

PLED

Photograph of spinner removed due to copyright restrictions.

- Apply uniform thin films to flat substrates by spreading the fluid with centrifugal force
- The higher the angular speed, the thinner the film
- The more viscous a solution, the thicker the film
- Used intensively in photolithography



1. Simple and Fast
2. Thickness can be easily controlled as low as 100nm
3. Flexible substrate

1. Inefficient use of materials
2. Requires masks
3. Sensitive to substrate defects

Inkjet Printing

PLED

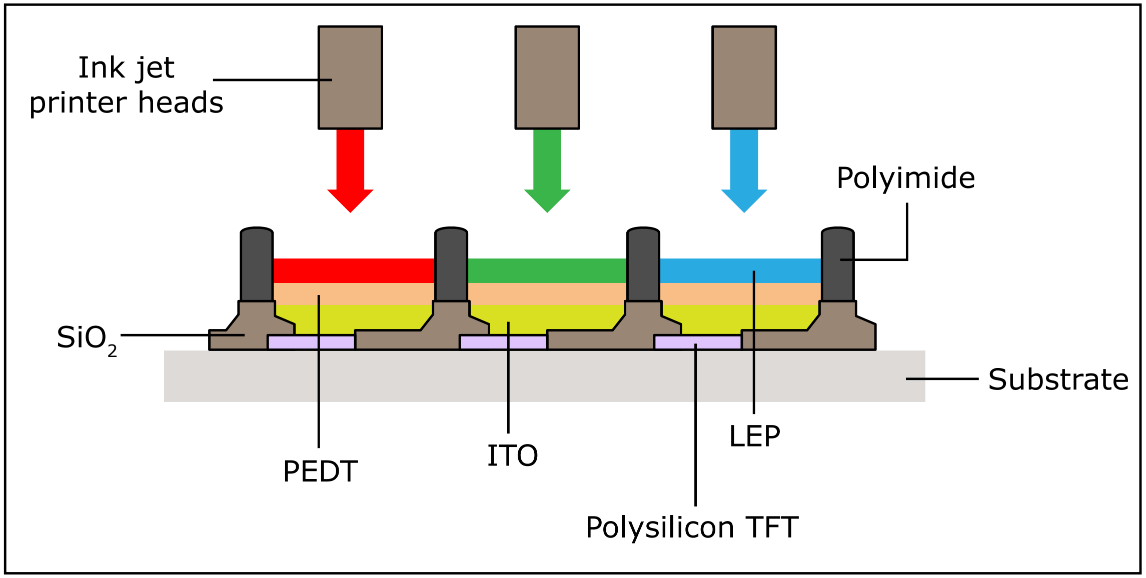
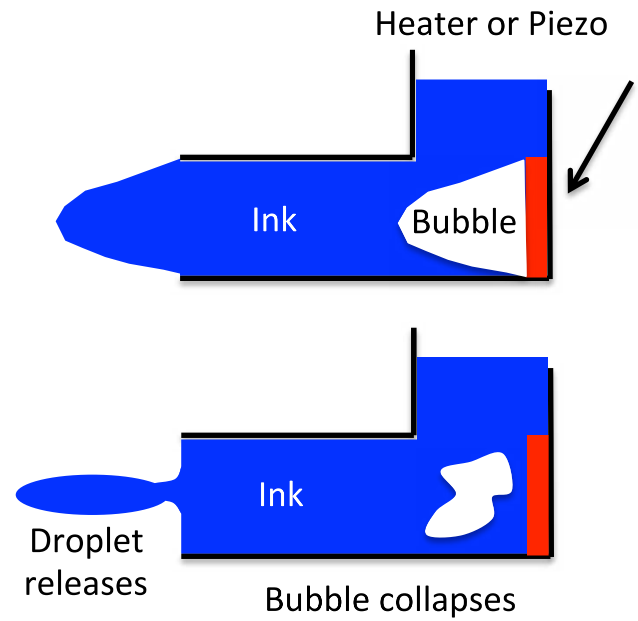


Image by MIT OpenCourseWare.



- A microscopic nozzle creates a continuous stream of ink droplets via creating a bubble by a heater or an acoustic wave by a piezoelectric crystal

1. Low fabrication cost for full color
2. Scalable to very large areas
3. Compatible with roll process for flex manufacturing

1. Speed
2. Non-uniform film thickness

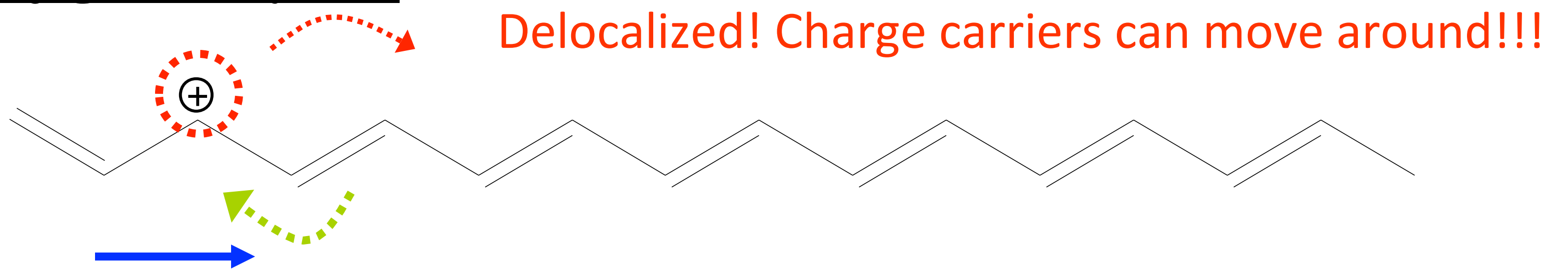
Homemade Spin Coater

$$h = \frac{h_0}{\left(1 + \frac{4\rho\omega^2 h_0^2 t}{3\eta}\right)^{\frac{1}{2}}}$$

How to determine the thickness of layers?

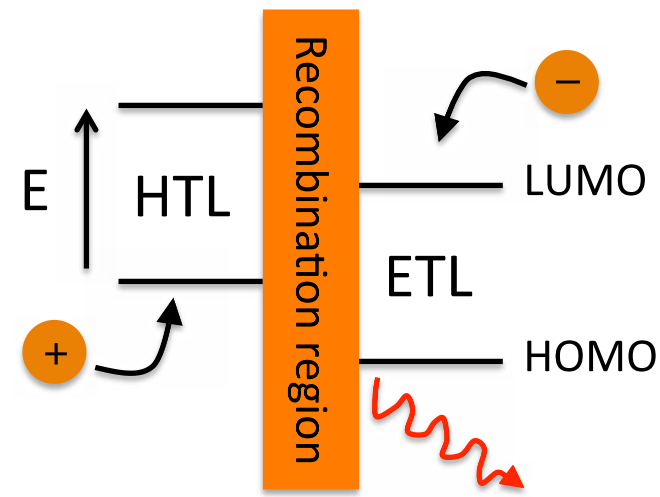
Conclusions

π-Conjugated Polymers



OLED

Electrons and holes form excitons
(bound e- h+ pairs)



Some excitons radiate

Fabrication Techniques

Thermal Evaporation
Inkjet printing
Spin coating

$$h = \frac{h_0}{\left(1 + \frac{4\rho\omega^2 h_0^2 t}{3\eta}\right)^{\frac{1}{2}}}$$

6.S079 Nanomaker
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