Nanomaker

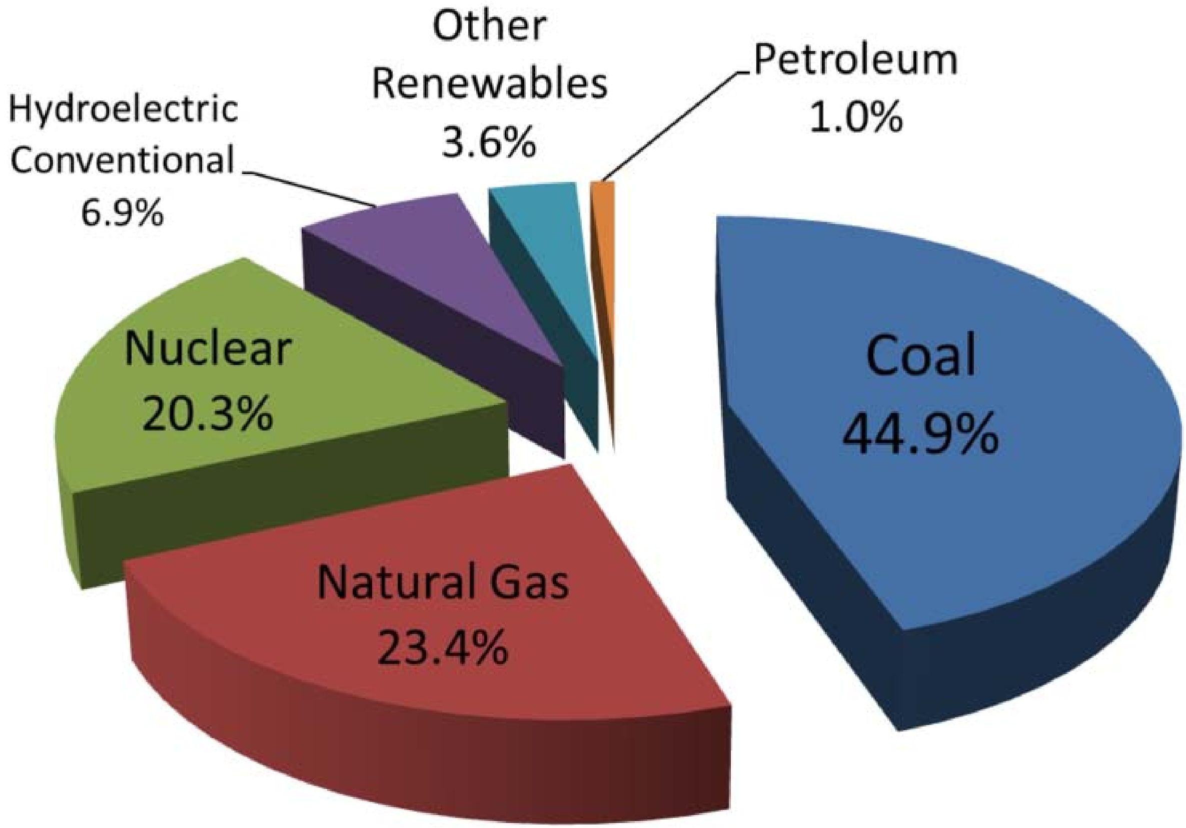
Lab #10: Organic Photovoltaics (PV)

Renewable Energy

PN Junction

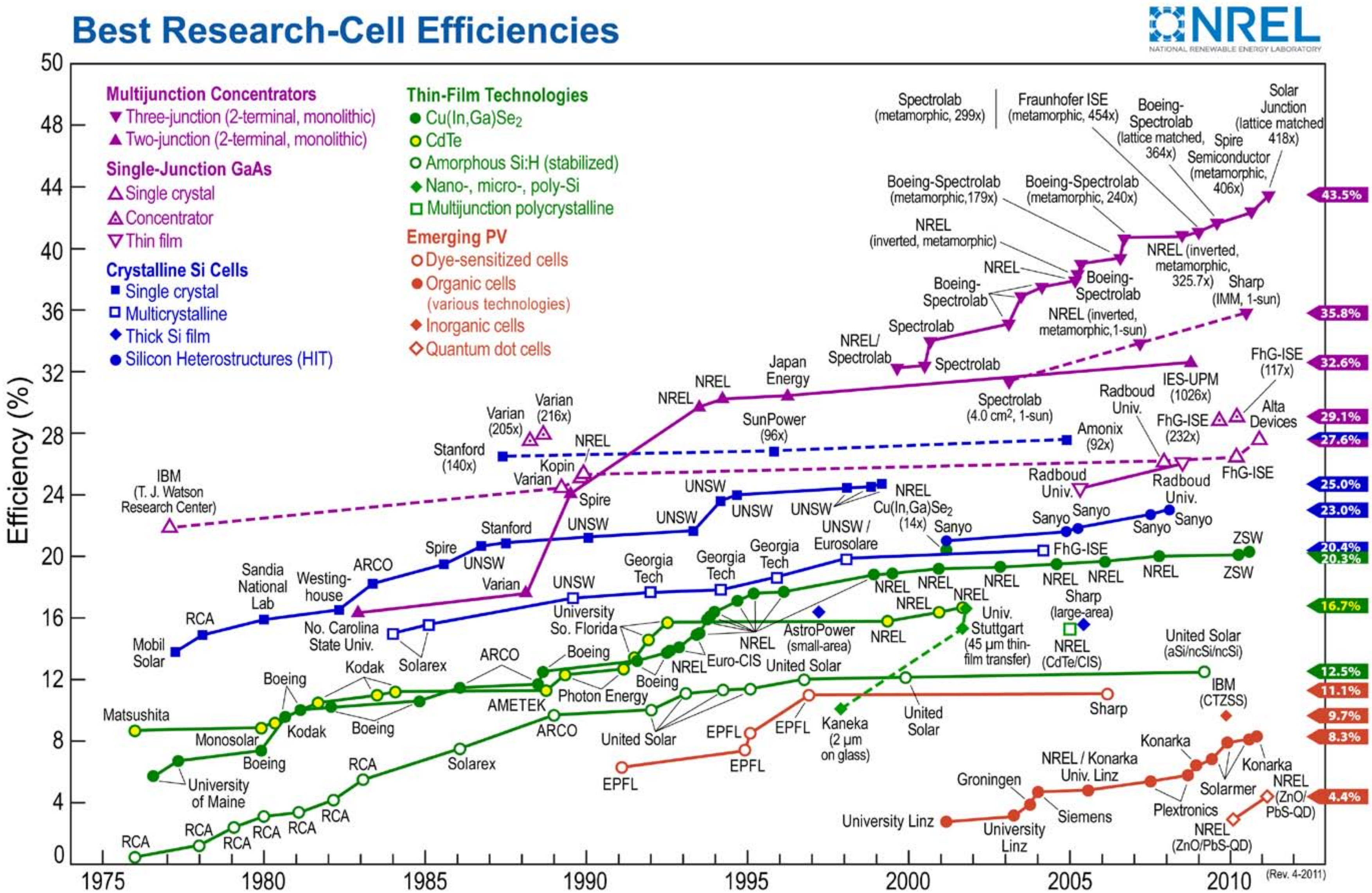
Organic Solar Cell

Electrical Energy Production Cost



Current energy sources are 2-8 ¢/kW-hr
Except renewables: 25-50 ¢/kW-hr

Renewable Energy Efficiency

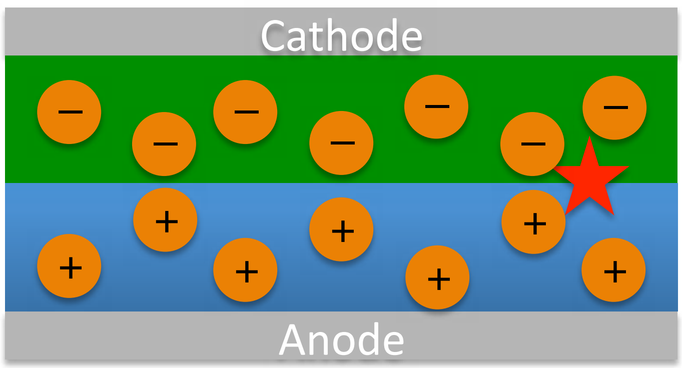


Renewable Energy

PN Junction

Organic Solar Cell

Principle of Organic LEDs

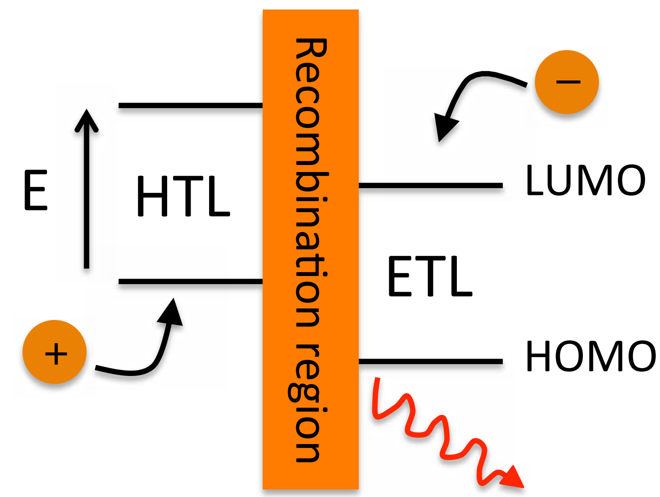


Emissive Layer

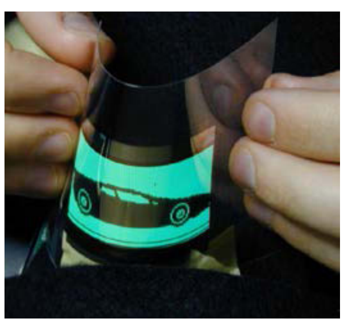
Conductive Layer

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.

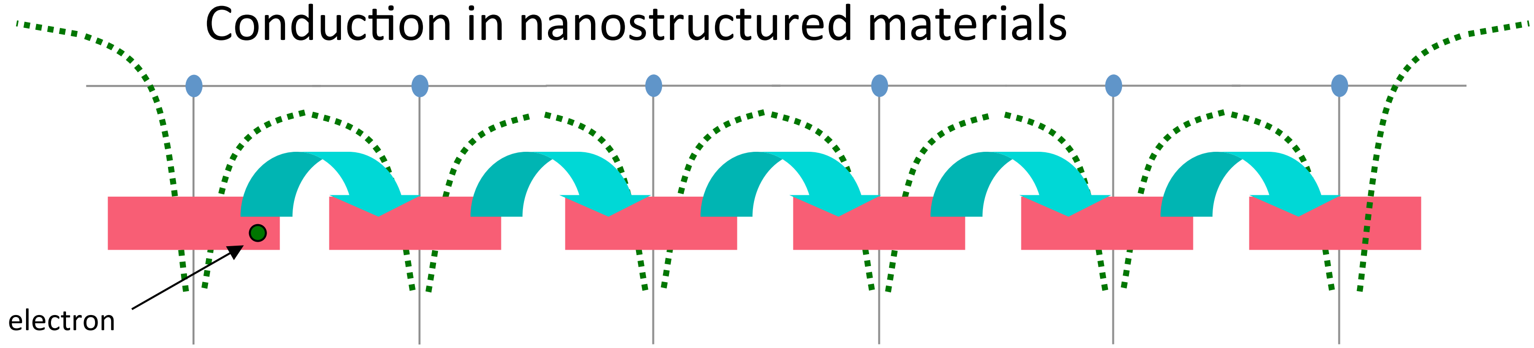
OLED TV - Sony

Photo courtesy of leumund on Flickr.

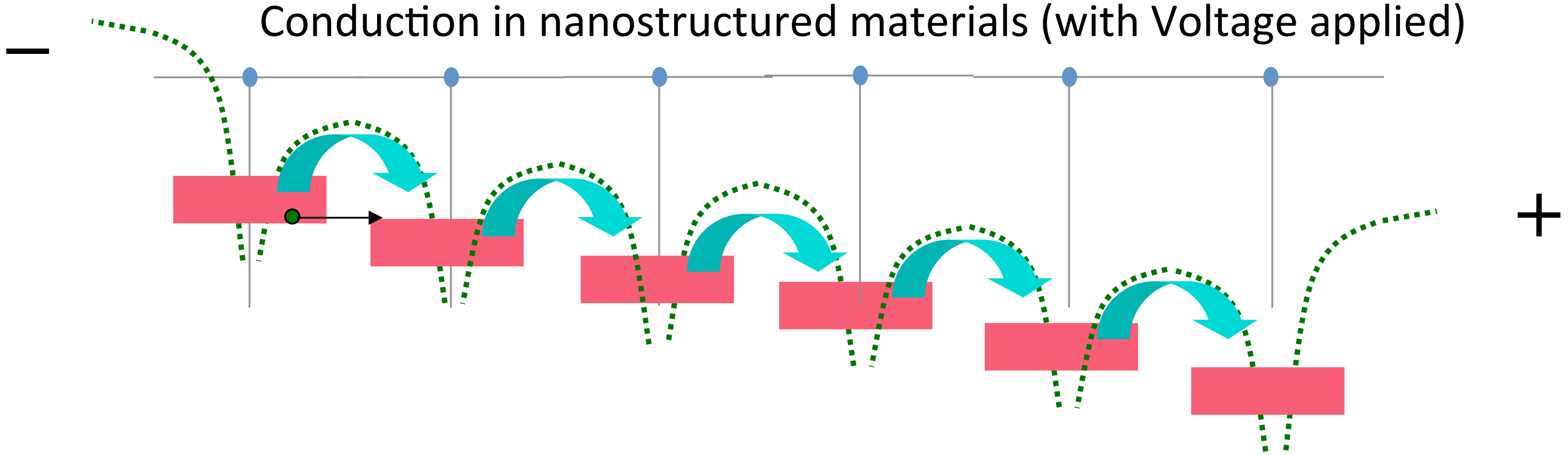
HTL (Hole transport layer)
ETL (Electron transport layer)

Conduction

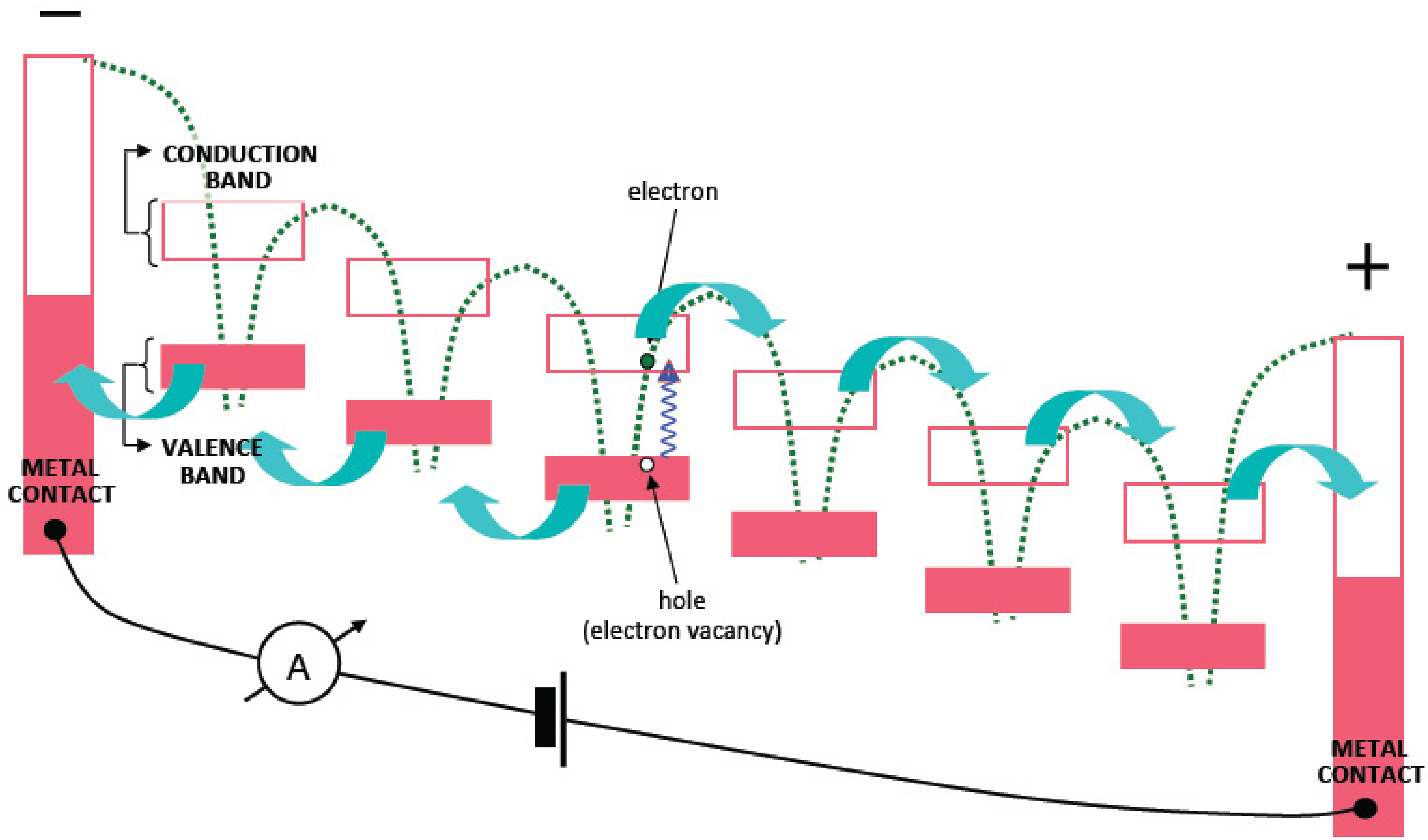
Conduction in nanostructured materials



Conduction in nanostructured materials (with Voltage applied)

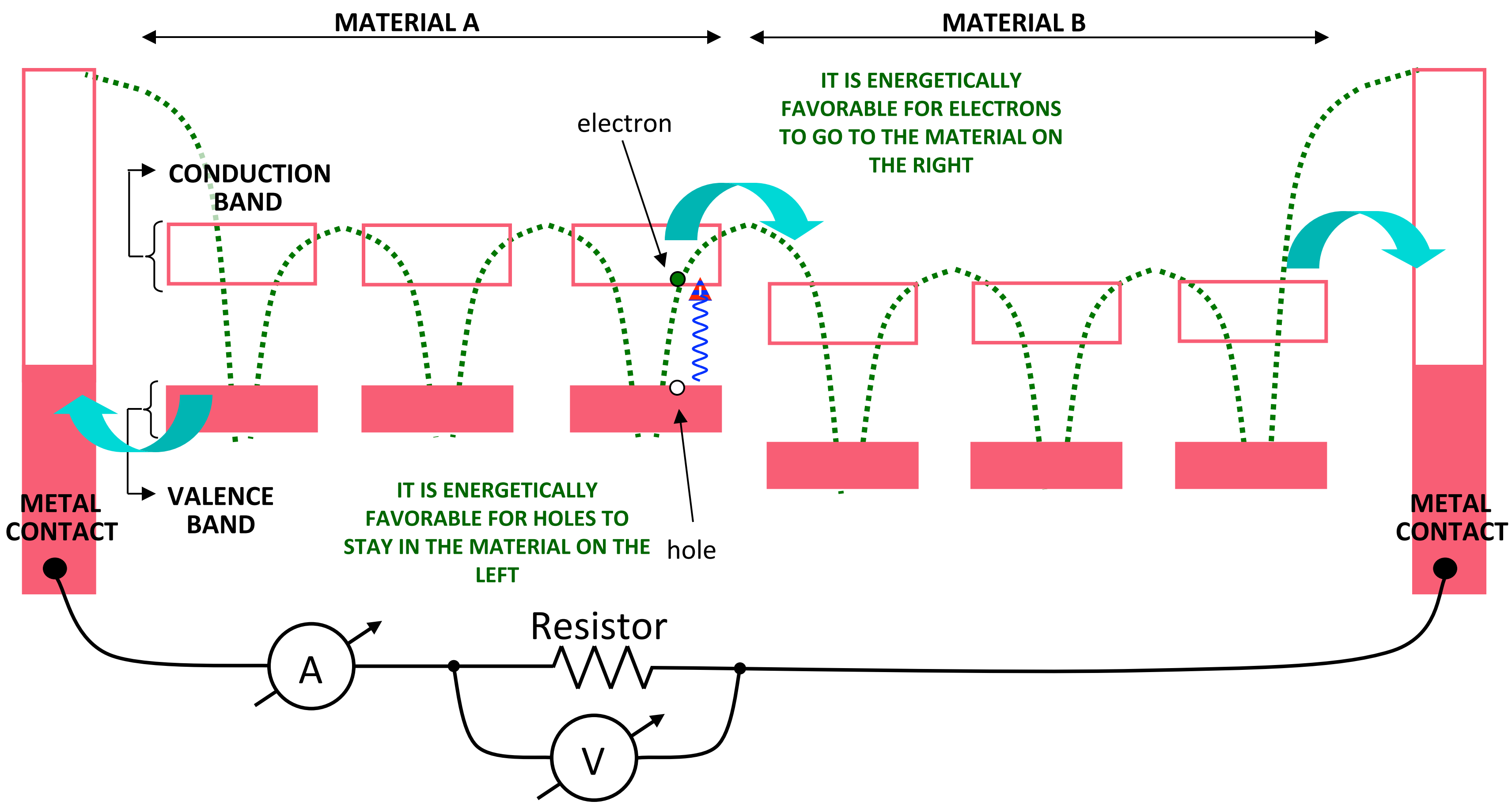


Biased Semiconductor: Photodetector



1. Photon can excite an electron from
   Valence Band (ground state) to Conduction Band (excited state)
2. The externally applied bias (that generates the electric field in the semiconductor) will separate
   the photo-generated electron and hole
3. The electron and a hole will reach the metal contacts, be collected by the bias battery, and be
   measures as a photocurrent.
4. If more photons are absorbed by the semiconductor, more current we will measured

Semiconductor Junction: Solar Cell



1. Photon can excite an electron from
   Valence Band (ground state) to Conduction Band (excited state)
2. At the heterojunction the electron and hole can separate, resulting in buld-up of electrons on the right
   and build-up of holes on the left → WE GENERATED PHOTOVOLTAGE
3. If solar cell is connected to a resistor, the photo-voltage will drive current through the resistor

PHOTODETECTORS

Apply bias (spend energy) to measure photocurrent
generated by light shining on the photodetector

SOLAR CELLS

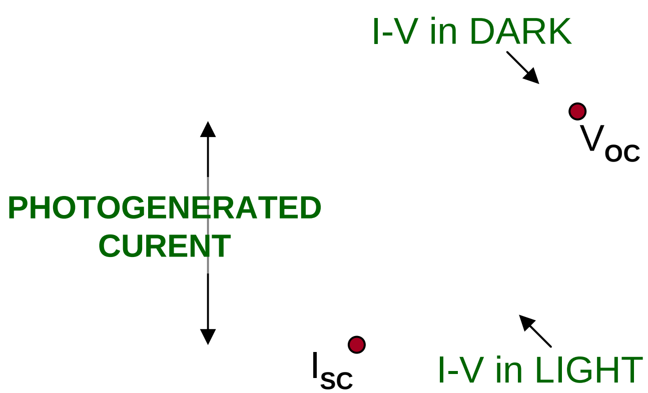
Shine light on the solar cell and
generate voltage and current (power, energy)

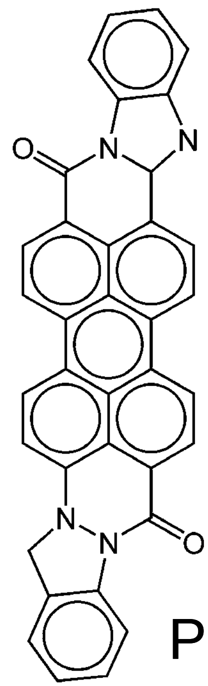
Renewable Energy
PN Junction
Organic Solar Cell

First Organic Solar Cell

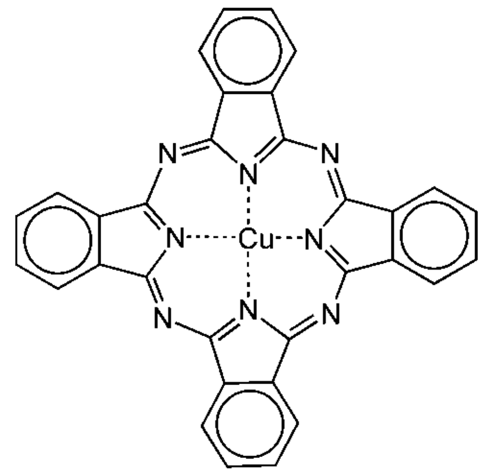
Power conversion efficiency ~ 1%

Image removed due to copyright restrictions. Please see Tang, C. W. “Two-layer organic photovoltaic cell.” *Applied Physics Letters* 48 (January 26, 1986): 183-185.



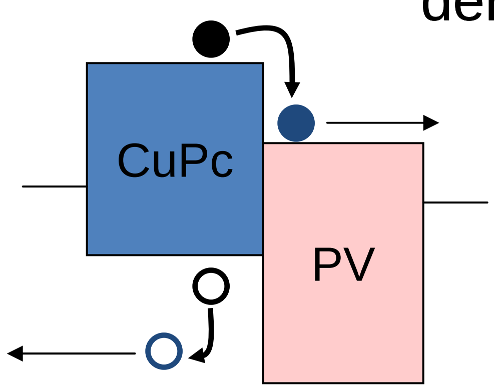


Perylene tetracarboxylic derivative (PV)



CuPc

Need interface to maximize exciton dissociation



V_{OC} = open-circuit voltage
I_{SC} = short-circuit current

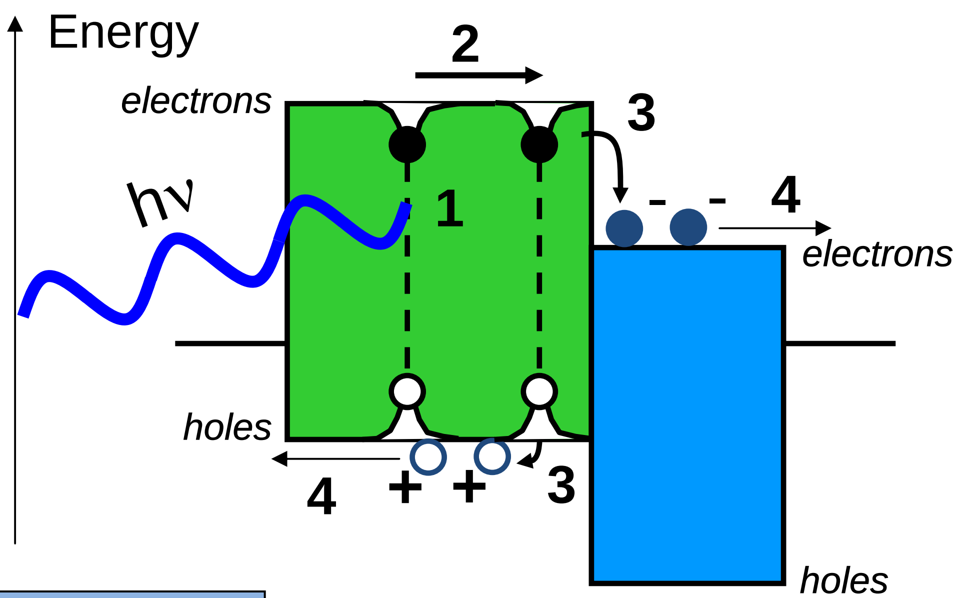
Courtesy of V. Bulovic

*from Tang, Applied Physics Letters, **48** 183 (1985)*

Organic Solar Cell

Room temperature deposition – **organics are compatible with plastic substrates**

- Disorder causes strong localization.
- Carrier pairs strongly bound – not easily broken by field.
- Must use interface between two materials to dissociate carrier pairs



1. Photon absorbed
2. Excited state diffuses
3. Charge formed at interface
4. Charge diffuses out

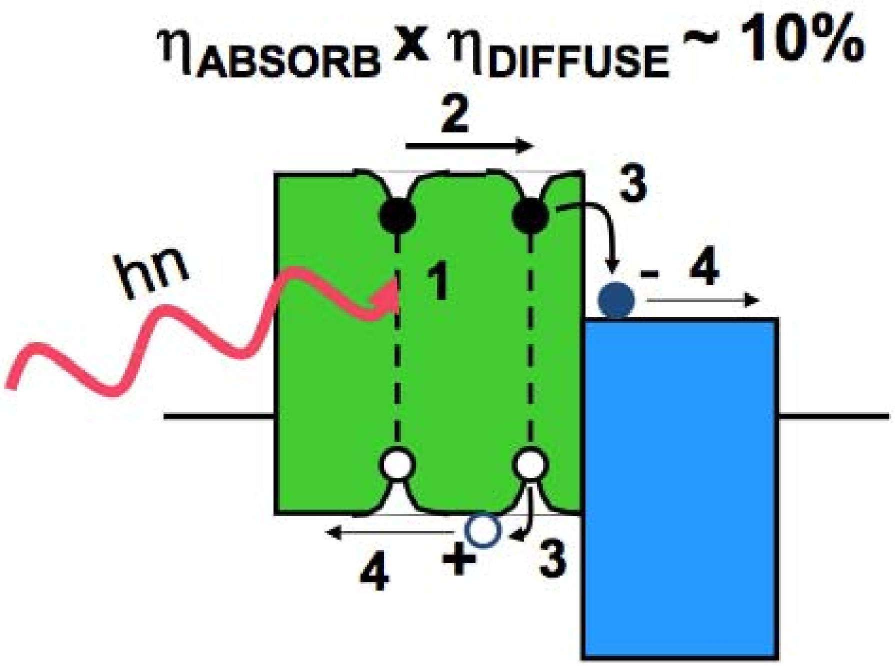
Courtesy of V. Bulovic

Courtesy of Vladimir Bulovic. Used with permission.

Performance peaks at 5% power conversion efficiency (cf. Si ~ 25%)

Efficiency of Organic Solar Cell

Organic PV cells must simultaneously maximize absorption and exciton dissociation



	efficiency
1. Photon absorbed	10% (1 and 2)
2. Excited state diffuses	
3. Charge formed at interface	100%
4. Charge diffuses out	100%

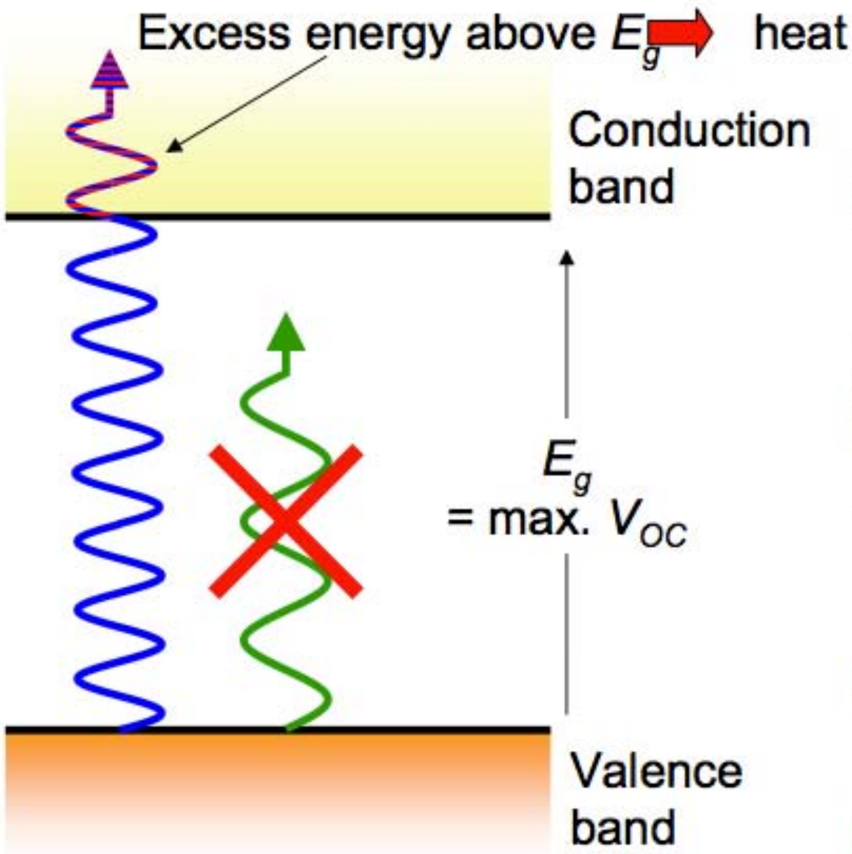
Courtesy of Vladimir Bulovic. Used with permission.

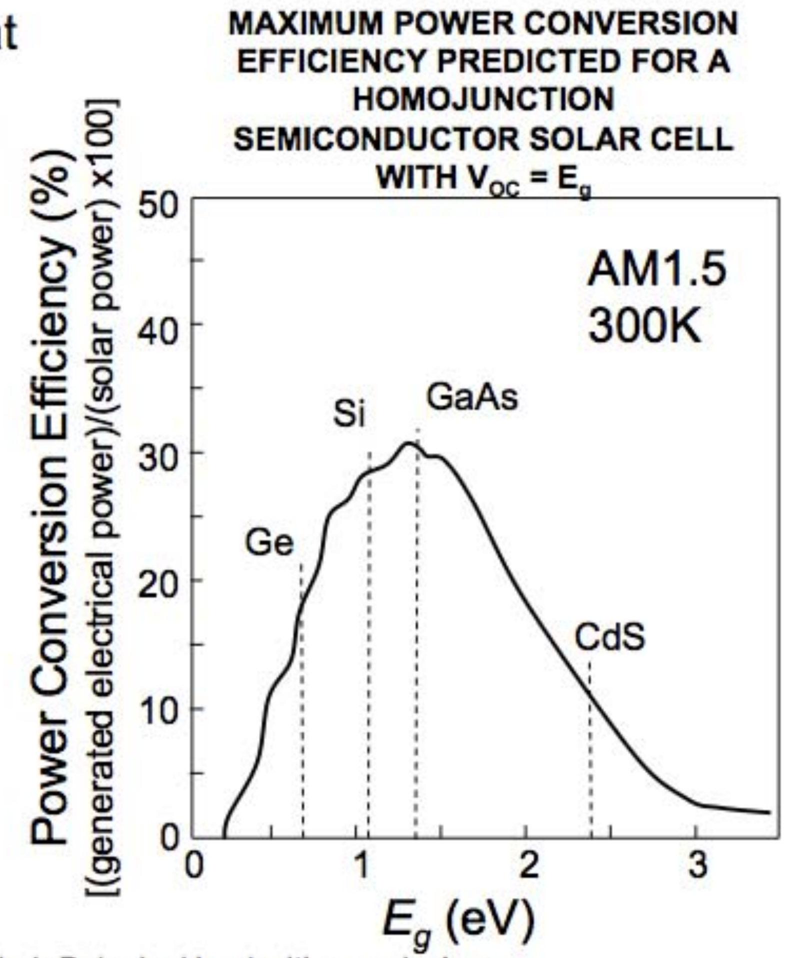
Tradeoff:

THICK device = high absorption, lots of exciton losses
THIN device = low absorption, few exciton losses

Courtesy of V. Bulovic

Efficiency Limit





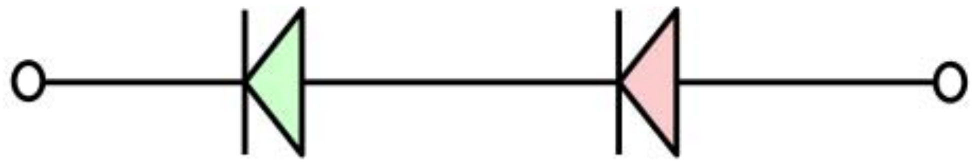
Courtesy of Vladimir Bulovic. Used with permission.

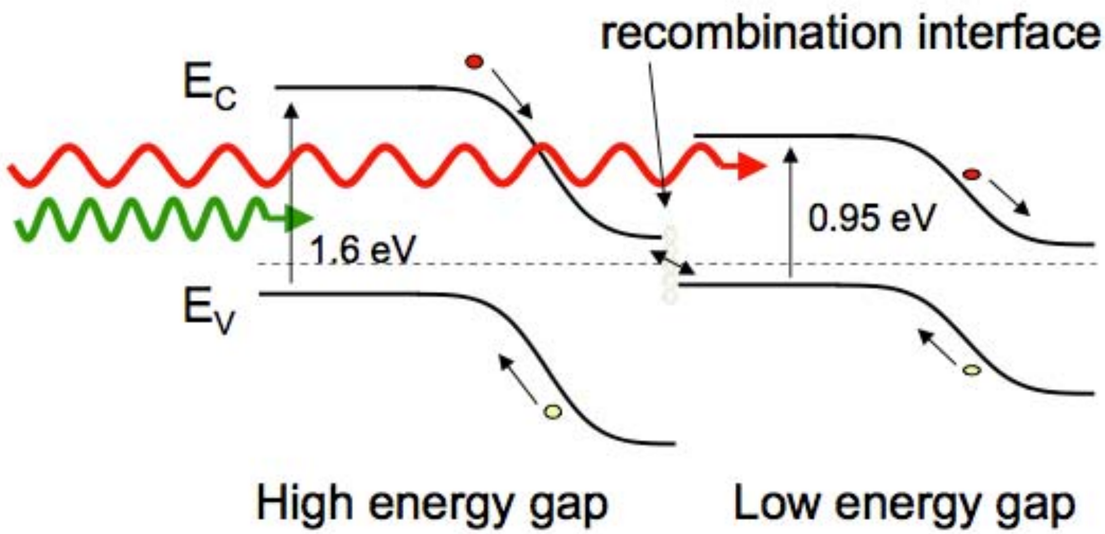
As band gap increases, the maximum open circuit voltage increases, but the fraction of the solar spectrum absorbed decreases.

Courtesy of V. Bulovic

Multiple Junction Cell

Connect solar cells in series.
Usually wide gap cells in series with narrow gap cells.





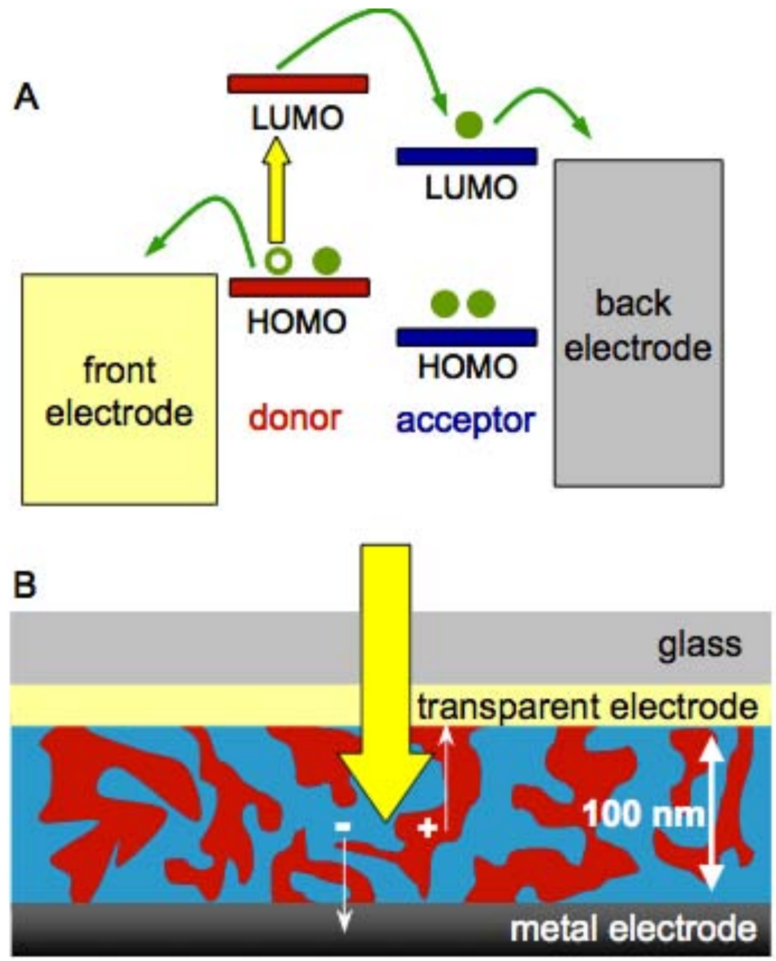
Courtesy of Vladimir Bulovic. Used with permission.

Voltage of cells adds.
But need same current through each cell. Must carefully tune absorption.

Advantage: highest performance cells made this way.

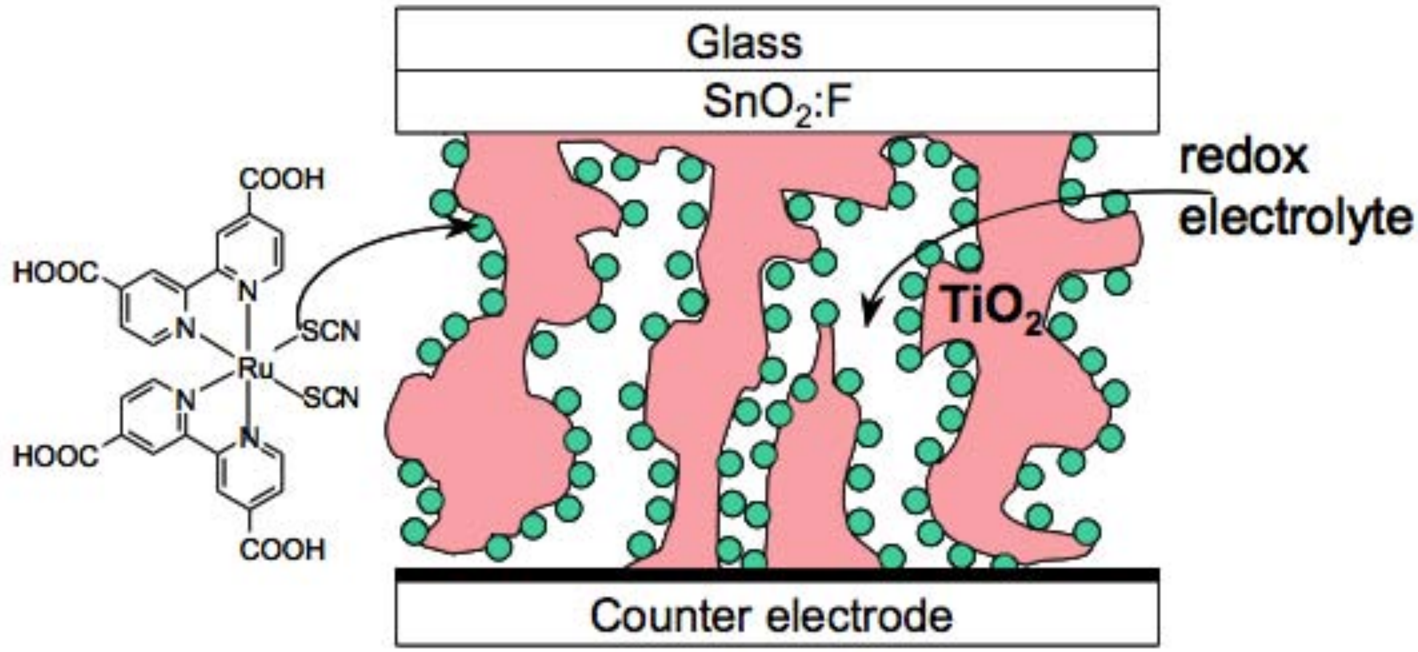
Courtesy of V. Bulovic

Heterojunction Solar Cells



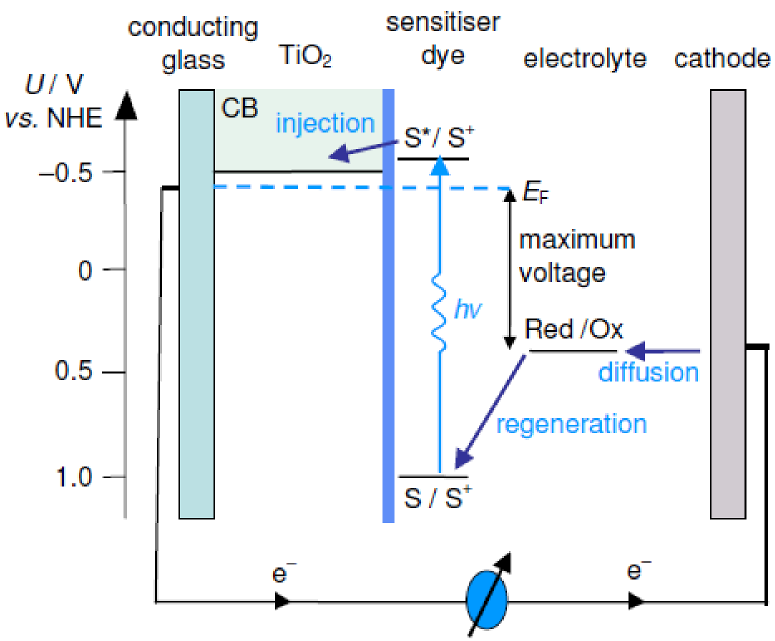
After absorption of light by the photoactive material, charge transfer can easily occur due to the nanoscopic mixing of the donor and acceptor. Subsequently, the photogenerated charges are transported and collected at the electrodes.

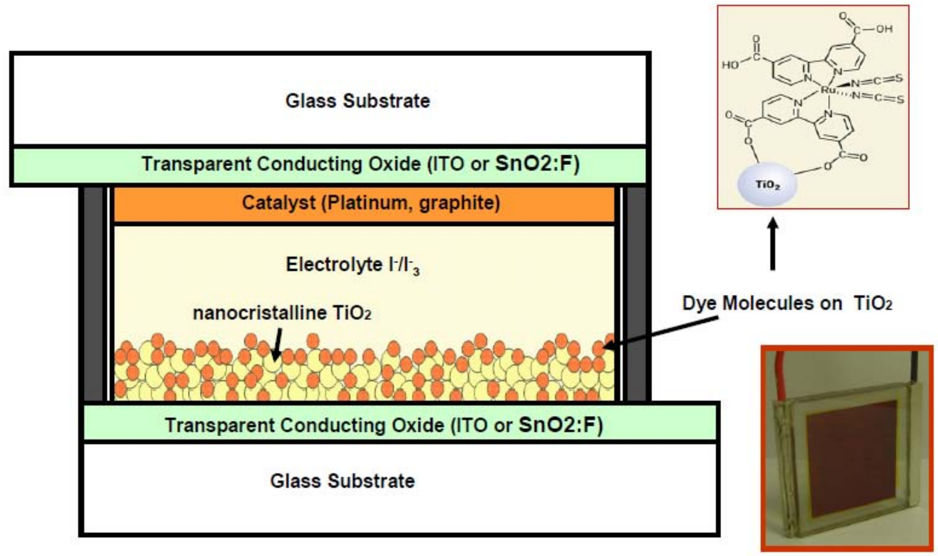
Dye-Sensitized Solar Cells



The dye-sensitized solar cell. After absorption of light by the ruthenium dye, an electron is transferred to TiO2. The dye is then reduced by a redox electrolyte, I-/I3-, which in turn, is reduced at the metal counter electrode. As a result, a positive charge is transported from the dye to the metal electrode via the electrolyte. The electron in TiO2 is transported to the SnO2:F electrode.

We are Making Grätzel Cell on Wed





Dye + Light → Dye*

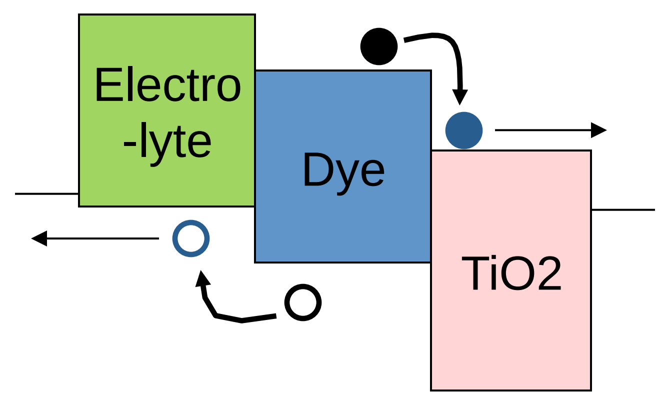
Dye* + TiO_2 → e^- (TiO_2) + oxidized Dye

Oxidized Dye + 3/2I^- → Dye + 1/2I_3^-

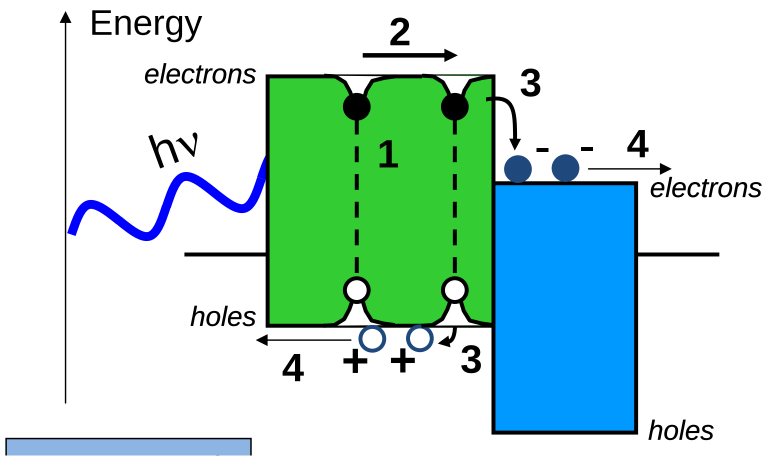
1/2I_3^- + e^- (counterelectrode) → 3/2I

1/2I_3^- + e^- (TiO_2) → 3/2I^-

Need interface to maximize exciton dissociation



Conclusions



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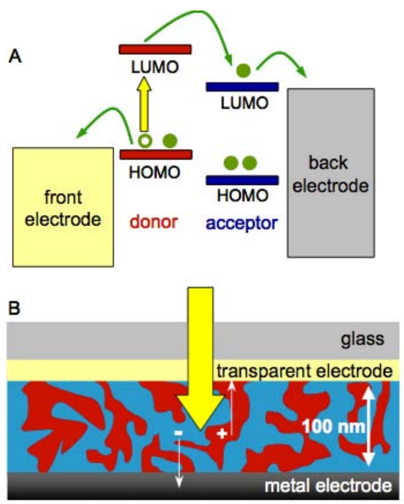
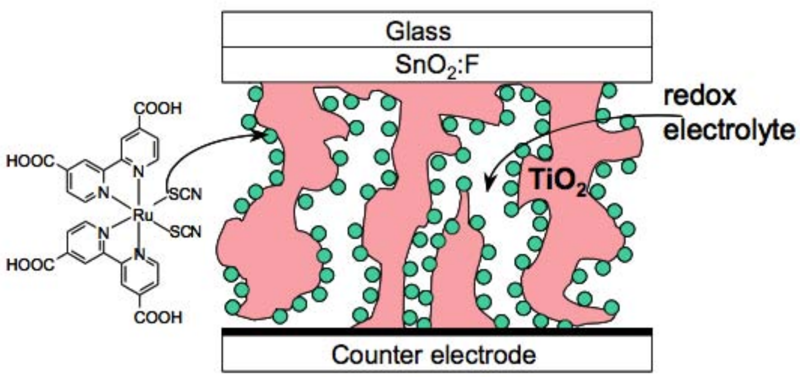
Heterojunction Solar Cells



Dye-Sensitized Solar Cells



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