Solar Cells: Recent Work in Materials

Michael Bertolli

Solid State II
Elbio Dagotto
Spring 2008
Department of Physics, University of Tennessee

Why Solar Cells?

- Alternative energy needed
- Solar power is endless
- Confronted with two issues:
  - Efficiency and Cost

Why Solar Cells?

- 1970: 10% efficiency first achieved
- 2006: 35% efficiency achieved

electricity: 10x commercial prices

Materials provide an answer.

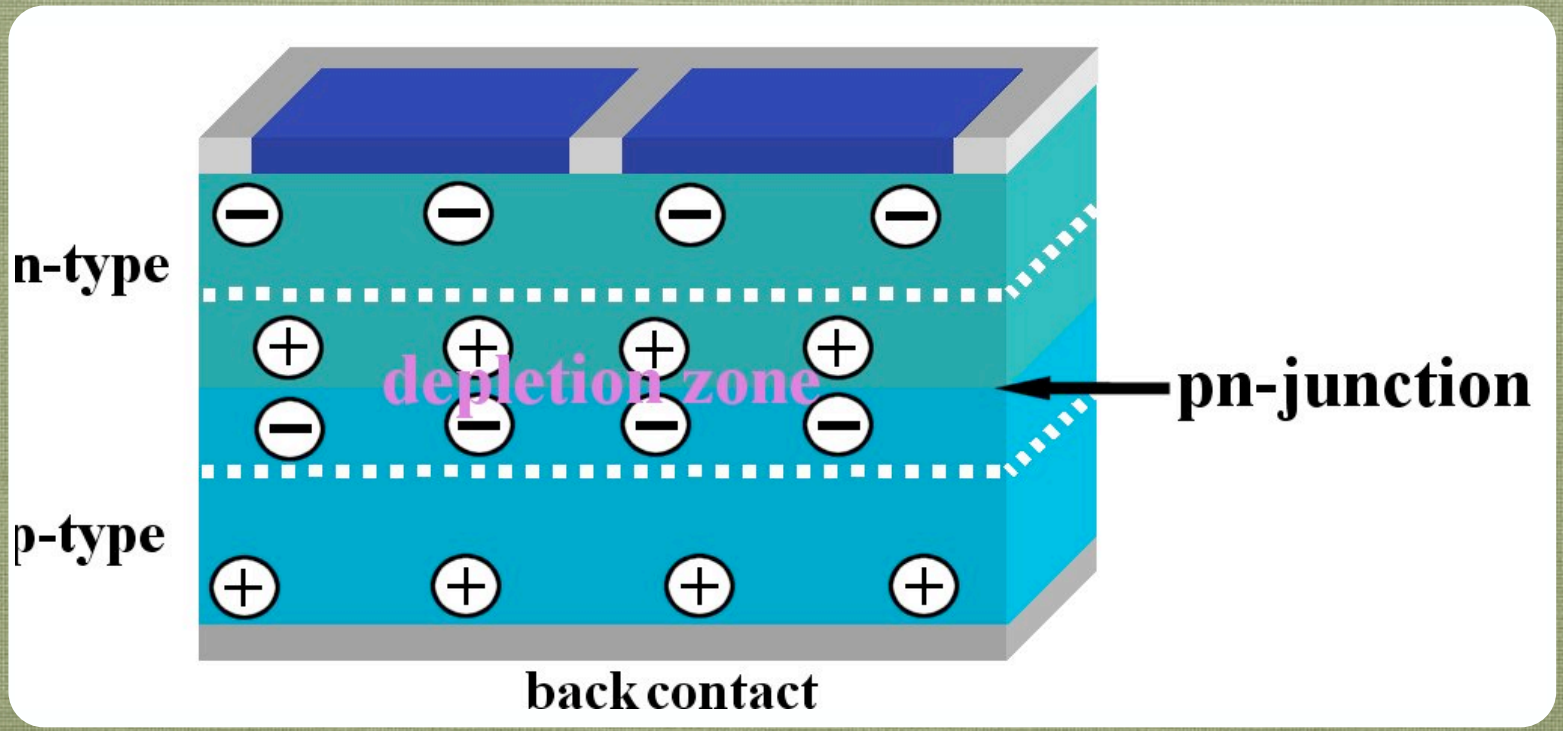
Solar Cell Basics

- Incident photon excites electron to the conduction band

$$h\nu > E_{gap}$$

- Photon flux determines current density
- Excess energy is lost to thermalization

Solar Cell Basics



Solar cells act as arrays of pn-junctions

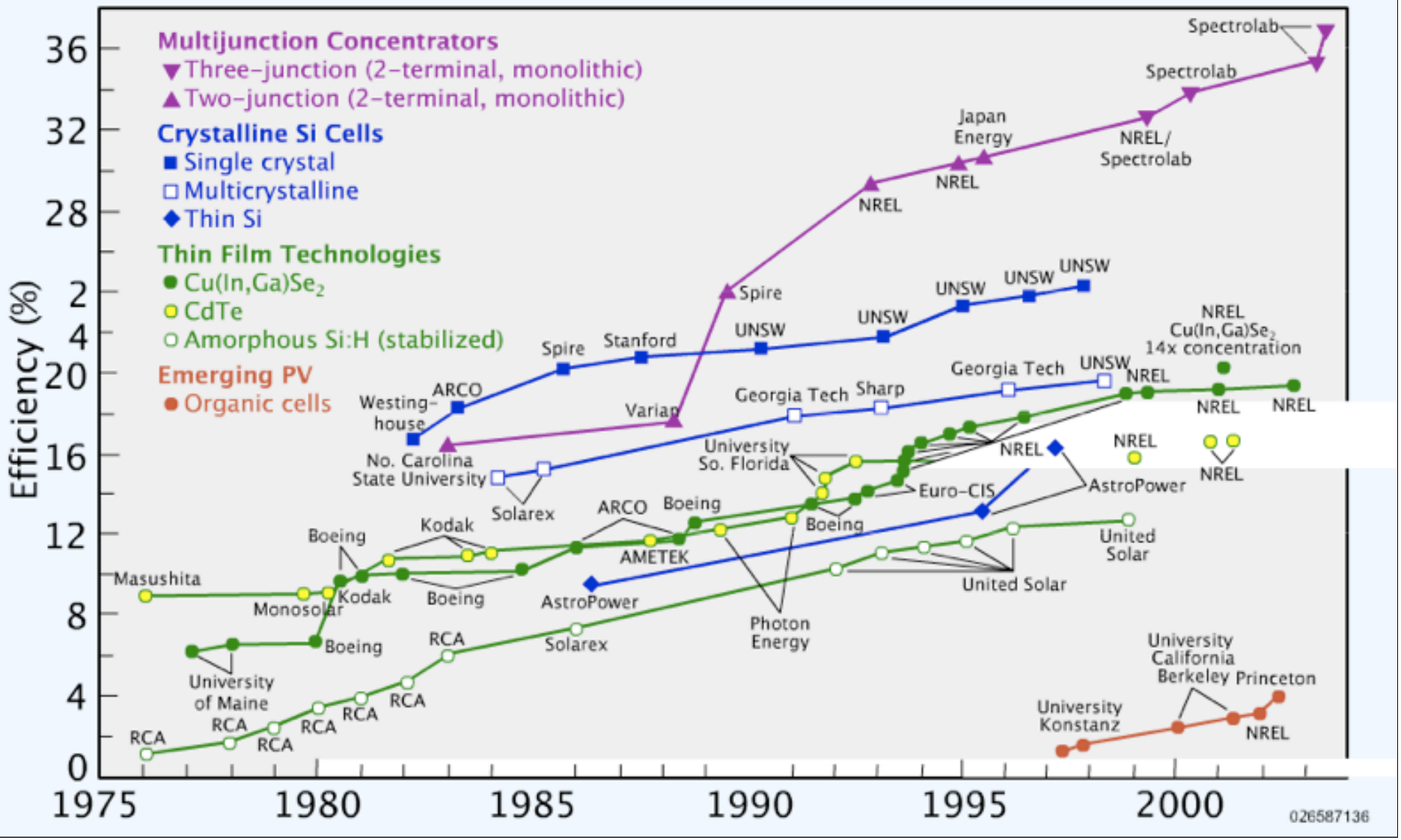
- Carrier mobility affects efficiency

Types of Materials

- Silicon: crystalline and amorphous
- Thin-Films: CIS, CIGS, CdTe
- Organic Polymers
- Nano-scale materials

NREL National Renewable Energy Laboratory National Center for Photovoltaics

Best Research-Cell Efficiencies



Crystalline Silicon

- 80% in production are (doped) crystalline silicon
  - Silicon wafers provide the base for assembly
- Efficiencies: 24% lab, 16% commercial

Advantages	Disadvantages
• Stable	• Silicon resources
• Relatively high efficiencies	• Size limitations, assembly

Thin-Films

- Depositions $< 10\mu m$
  - Allows for various substrates: glass, Aluminum
- Deposition via: PECVD, PVD, Sputtering
  - Low temperatures: ~220 C

Amorphous Silicon

- ~20% in production are amorphous silicon
  - a-Si:H thin-films
  - First thin-film in large scale production
- Efficiencies: 13% lab, 8% commercial

Advantages	Disadvantages
• Higher optical absorption • Cheap substrates • Ease of assembly	• Deposition times • Lifetime, Staebler-Wronski effect

CIS/CIGS

- Copper-Indium:Diselenide and Copper-Indium:Gallium-Diselenide
  - Direct-gap polycrystalline p-type
  - E_{gap} between 1.1 and 1.2 eV
- Efficiencies: 18.8% lab

Advantages	Disadvantages
• High optical absorption • Higher efficiencies • Stability	• Sensitive to heat/ humidity • Use of Indium

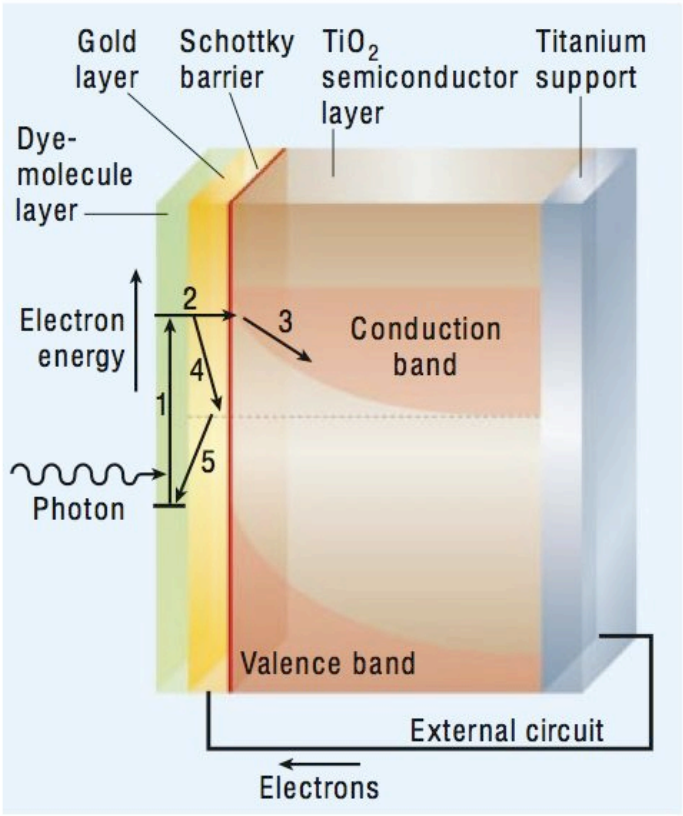
CdTe

- Cadmium-Telluride
  - E_{gap} of 1.45 eV
  - Higher current density and enhanced carrier multiplication
- Efficiencies: 16% lab, 9% commercially

Advantages	Disadvantages
• High optical absorption	• Uniformity of deposition
• Carrier multiplication	• Use of Cadmium
• Easier to produce	

Dye Sensitized

- Uses only injected electrons
  - multilayer structure reduces recombination
- Efficiencies: 10% lab



Dye Sensitized

Advantages

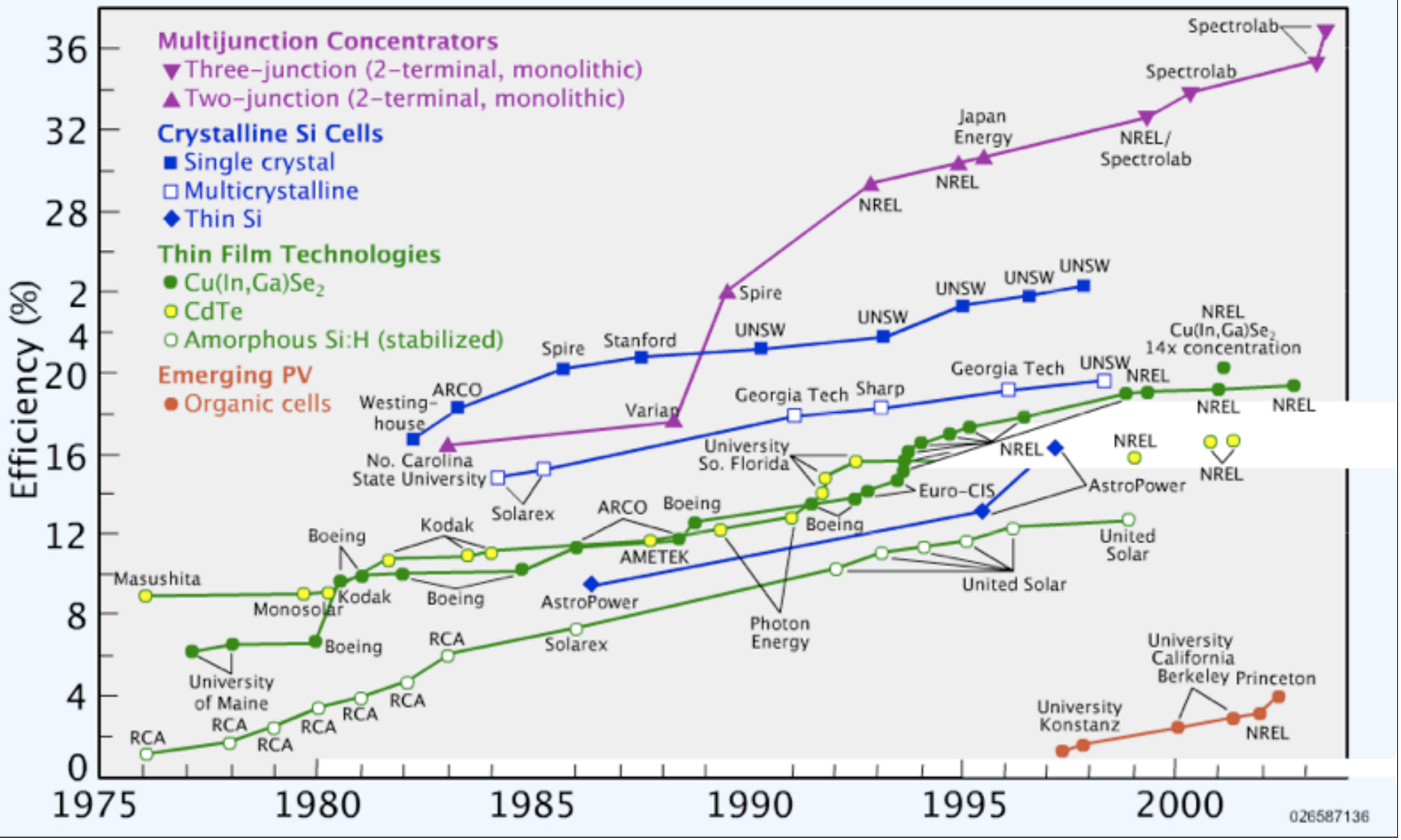
- Low cost
- Possibility of greater carrier mobility

Disadvantages

- Temperature sensitive
- Assembly costs

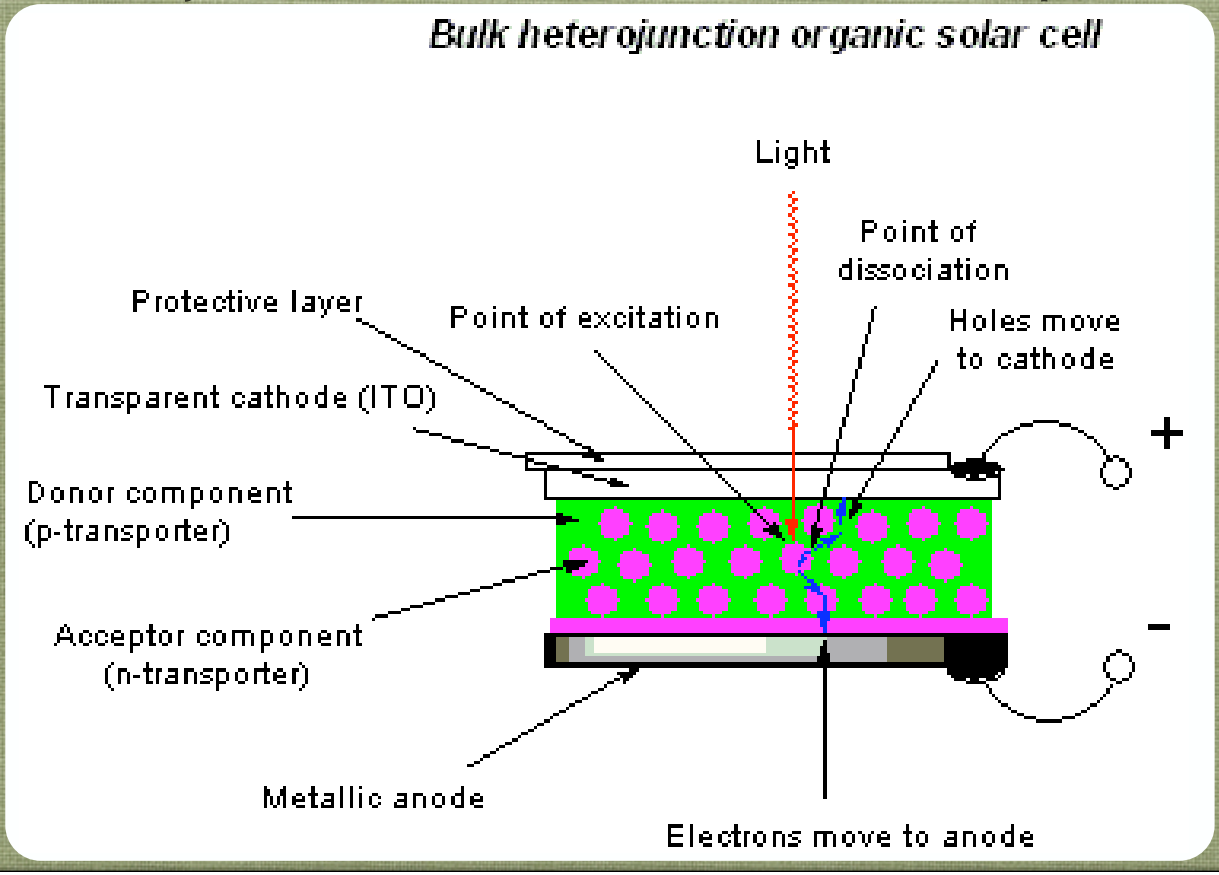
NREL National Renewable Energy Laboratory National Center for Photovoltaics

Best Research-Cell Efficiencies



Organic Polymers

- Excitons: bound electron-hole pairs
  - Higher rate of recombination
- Heterojunctions increase carrier separation area



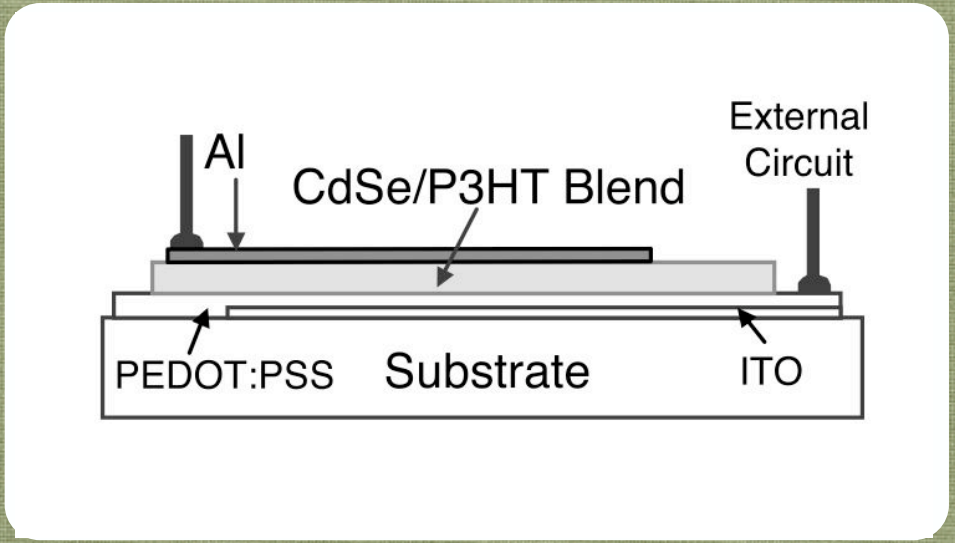
Organic Polymers

- Discovered ~20 years ago
  - Photons illuminate a donor and acceptor species
- Efficiencies: 5% lab

Advantages	Disadvantages
• Very cheap	• exciton separation
• Broad assembly options	• limited absorption

Nano-Scale Materials

- Confinement allows tuning of electronic states
  - Crystal structure leads to customization of absorption spectrum
- Hybridization



Nano-Scale Materials

- A new and promising future
  - Greater impact ionization: carrier multiplication
- Efficiencies: 2.5% lab, 44% theoretical

Advantages	Disadvantages
• Hybrids	• Electron transport
• Assembly at low temp.	• Low efficiencies

Conclusion

- Alternative energy needed
- Sun delivers more energy in one hour than is used in a year
- Solar cells unlikely to carrier bulk of the energy needs
  - Best: Silicon at 16% efficiency
  - Nanocrystals have bright future
  - Multiple carrier generation