Photovoltaics: A Brief Overview

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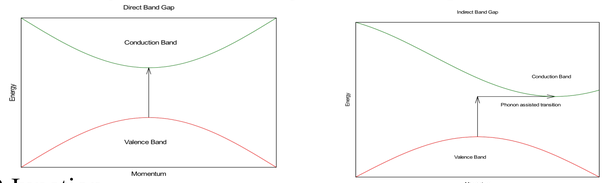
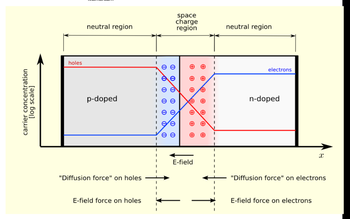
Background

- Semiconductors have a bandgap between valence band and conduction band in the solar spectrum energy range
- Direct and Indirect Band Gaps
  - Direct Bandgaps have equal crystal momentum at highest energy valence band config and lowest energy conduction band config
  - Indirect bandgaps have different crystal momentums, thus must emit a phonon to conserve crystal momentum
  - Direct bandgaps absorb/emit light much faster; phonon is not needed

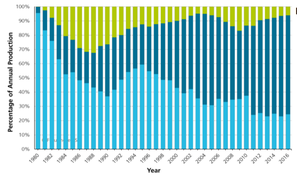


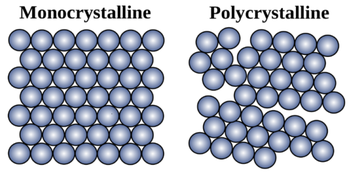
- N-P Junction
  - N-type has permanent C.B. electrons, P-type has permanent V.B. 'holes'
  - E-field created at junction, forces charge carriers to respective sides
  - Absorbed light creates free e^- and hole, separated by E-field to respective sides.
  - Electric potential can now be used to do work

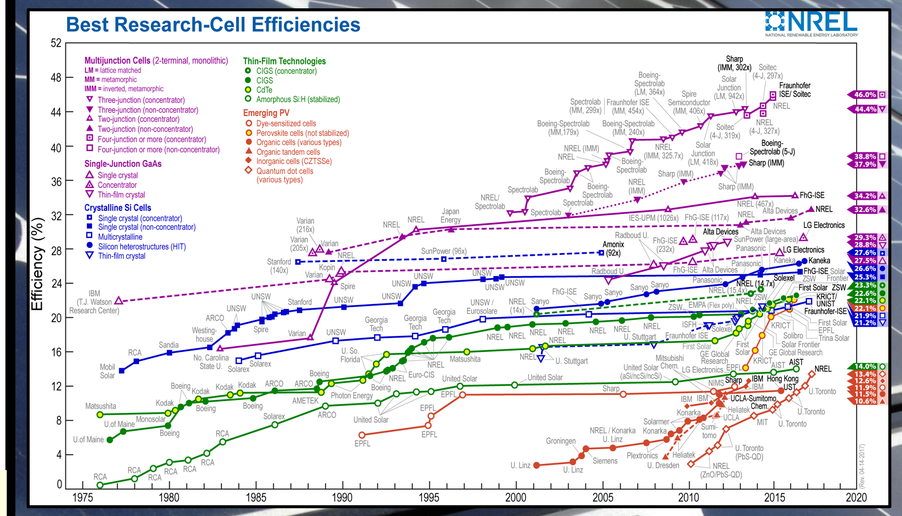


Crystalline Si

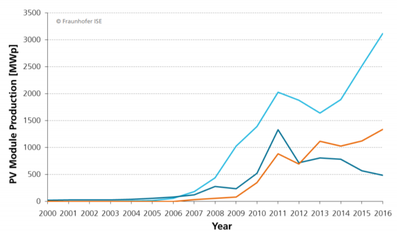
- Most frequently used type, currently cheapest to produce
- Typically in 16-26% efficiency range
- Indirect Bandgap, 100-500µm, requires more material to absorb
- N-P Junction Created by Doping
  - Doping is the process of intentionally introducing impurities
  - Create P-type by doping with electron deficient elements such as B,
  - Create N-type by doping with electron rich elements, such as P
- Mono vs. Polycrystalline
  - Monocrystalline consists of single crystal
    - High efficiencies, high manufacturing costs
  - Polycrystalline consists of many crystals
    - Lower efficiencies, much cheaper production



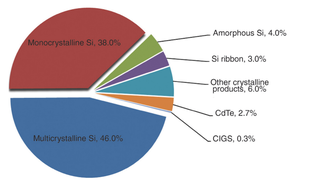




Established Thin Film

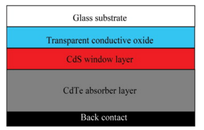


Thin-film PV production over time

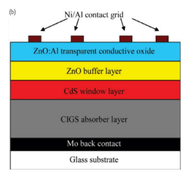


Market share of solar cell types sold during 2006

- Direct band gap allows for layers only a few microns thick
- Lower production costs, but lower efficiency
- Potential to be spread in many areas
- Silicon-based, ex. hydrogenated amorphous silicon
  - Alloying with germanium increases efficiency and decreases E_g
- Cadmium Telluride (CdTe)
  - Absorbs light at ideal wavelengths
  - Inexpensive, but lower efficiencies
  - Toxicity of cadmium is a concern, must be highly regulated
- Copper Indium Gallium Diselenide (CIGS)
  - E_g can be tuned by manipulating the proportions of In and Ga



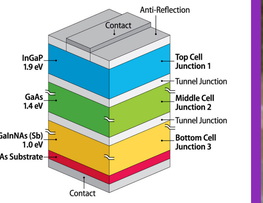
CdS/CdTe cell



CdS/ CIGS cell

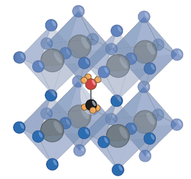
Multijunction

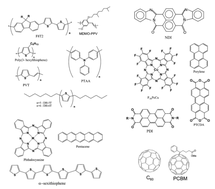
- Energy is lost if photons are not exactly equal to E_g
  - Photons below E_g are not absorbed
  - Photons above E_g are absorbed, but extra energy is lost to heat
- Multijunction Cells are composed of stacked layers with different bandgaps, each absorbing different energy photons, minimizing losses
- Made from III-V groups with direct band gaps, e.g. GaAs
- Efficiency record of 46%, but expensive

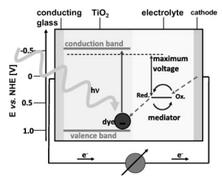


Emerging Tech

- Perovskite solar cells (PSC) - easy to synthesize inorganic-organic hybrid compounds, ABX_3 structure
  - Small E_g, high extinction coefficients & carrier mobility
- Organic solar cell: semiconductors between the two electrodes are organic polymers with highly electronically polarizable π e^-
- Dye-sensitized solar cells (DSCs) – spatially separate light absorption and charge separation
  - Light is absorbed by a sensitizer, charge separation occurs as electrons move from the dye to the semiconductor

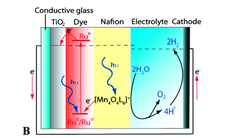






Energy Storage

- Currently: collected energy during the day is wasted due to lack of storage capability
- Possible solution: fuel cells
  - Utilize a standard chemical reaction to store energy in bond:: products can be stored indefinitely & without capacity degradation
- Hydrolysis – Producing H_2 and O_2
  - Direct photochemical: catalyst with the ability to absorb visible light & oxidize water directly
  - Photoelectrochemical: rely on an external source of electric potential, use catalyst to promote water oxidation. Current catalysts use precious metals, finding cheaper alternatives is a priority



Cross-sectional arrangement of proposed DSC for direct photochemical water oxidation