SEMICONDUCTOR HETEROJUNCTIONS

February 10, 2011
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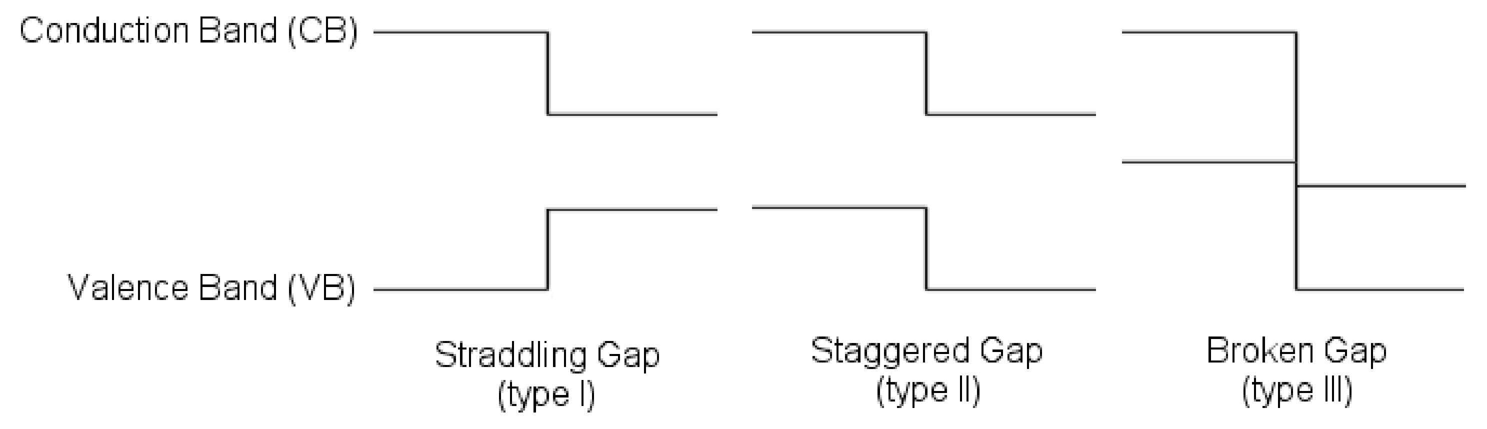
Principles and Varieties of Solar Energy (PHYS 4400)
and
Fundamentals of Solar Cells (PHYS 6980)

Heterojunction subtopics

- heterojunction bands
- band offsets
- type I and type II junctions

Types of semiconductor heterojunctions



Heterojunction: the interface between two layers or regions of dissimilar crystalline semiconductors.

Heterostructure: A stack of materials based on a central heterojunction can be considered a heterostructure.

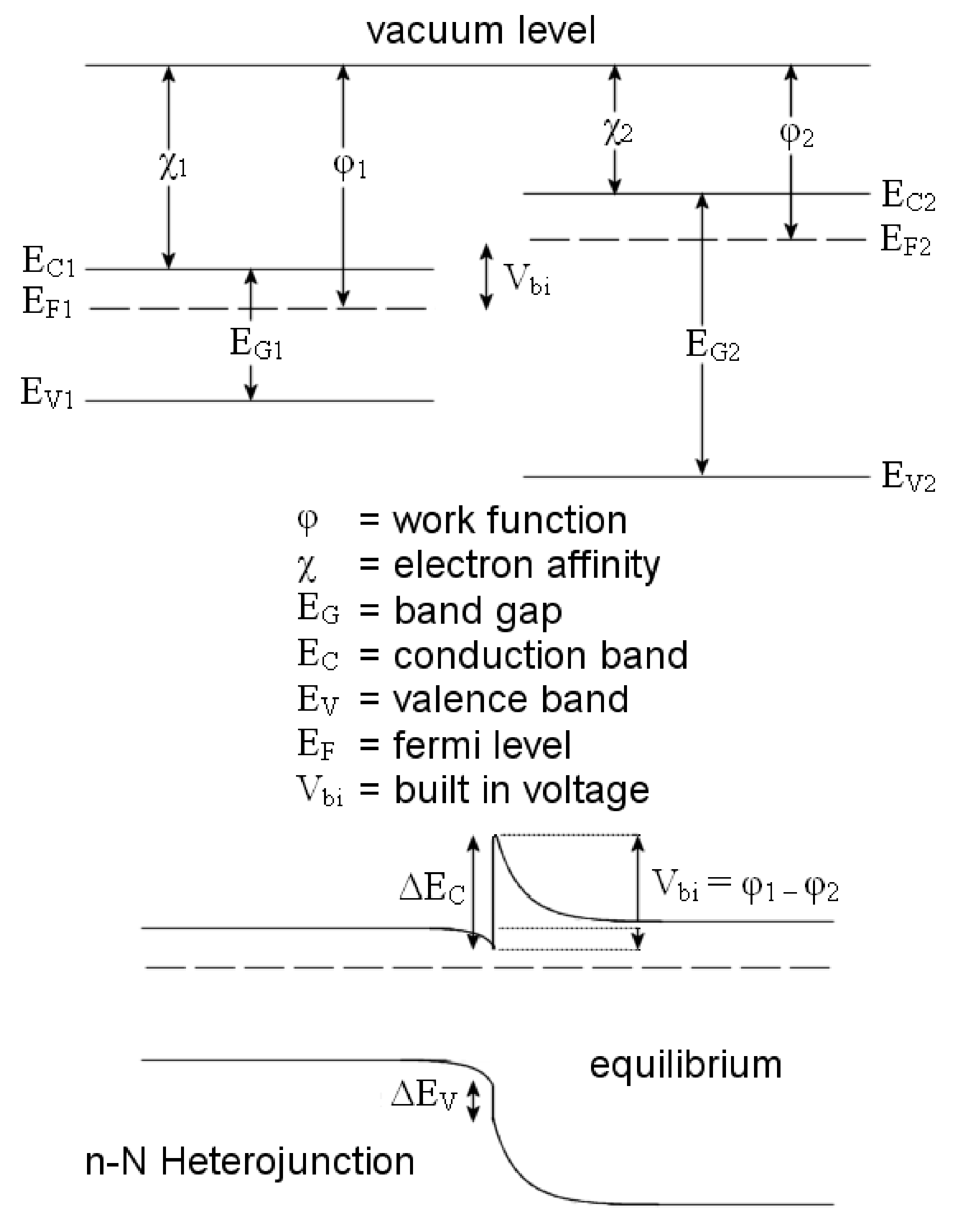
FYI:

"homo" means similar or the same (as in a *homo*junction of p-Si/n-Si)

"hetero" means different (as in a *hetero*junction of CdTe/CdS)

http://en.wikipedia.org/wiki/Heterojunction

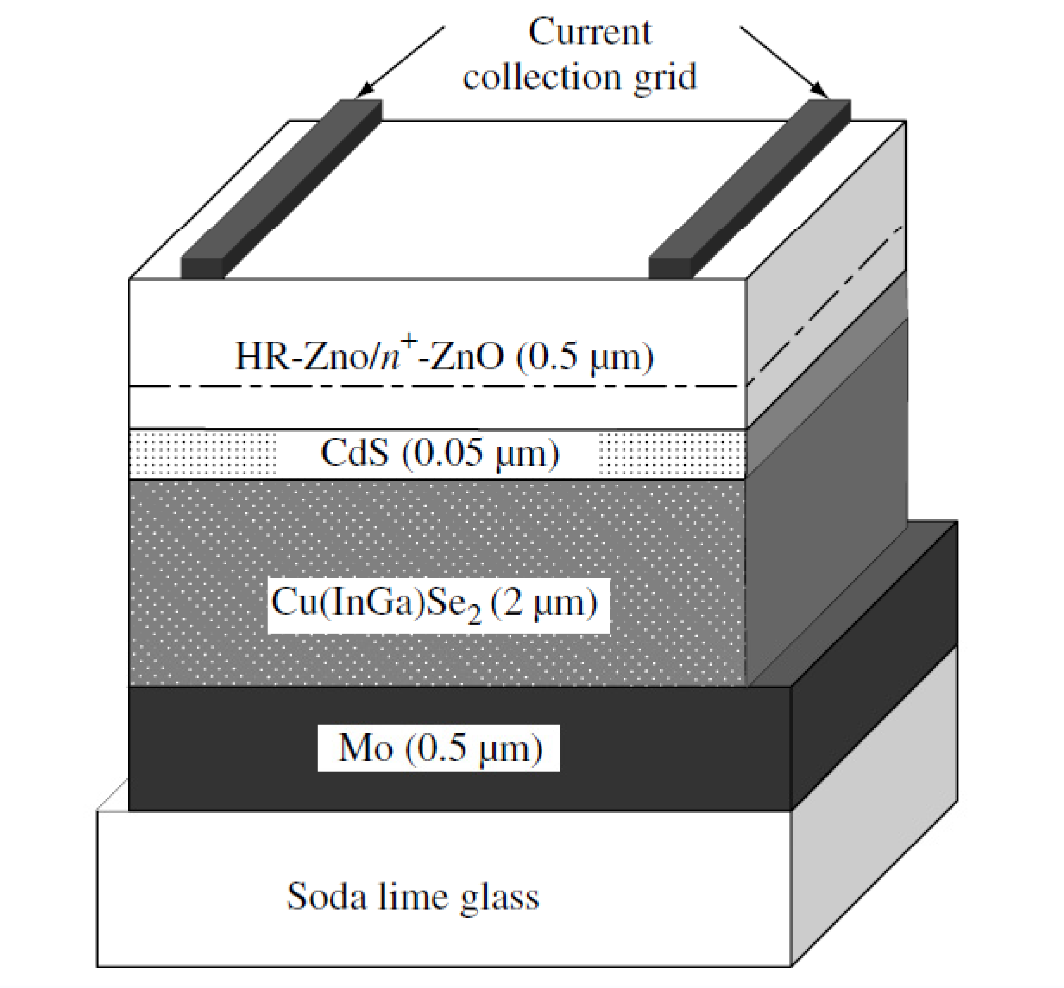
Ideal heterojunction



Anderson's rule is used for the construction of energy band diagrams of the heterojunction between two semiconductor materials. It is also referred to as the electron affinity rule. Anderson's rule was first described by R. L. Anderson in 1960. When constructing an energy band diagram, the vacuum levels of the two semiconductors on either side of the heterojunction should be aligned (at the same energy).

Anderson's model fails to predict actual band offsets for real semiconductor heterojunctions. – due to parameters such as strain, dislocation energies, and how the lattices align at the interface.

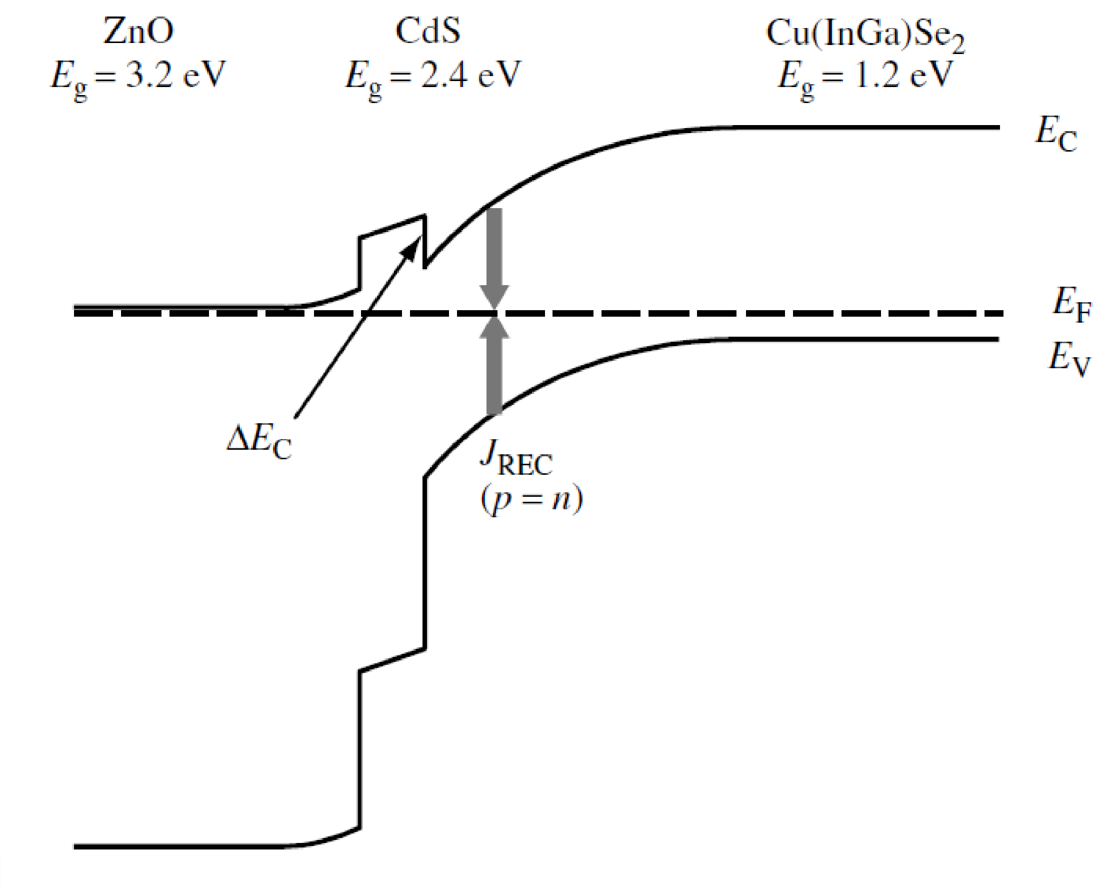
Heterojunction example: CIGS



Schematic cross section of a typical Cu(InGa)Se_2 solar cell

“Cu(InGa)Se2 Solar Cells”, William N. Shafarman and Lars Stolt, in *Handbook of Photovoltaic Science and Engineering*

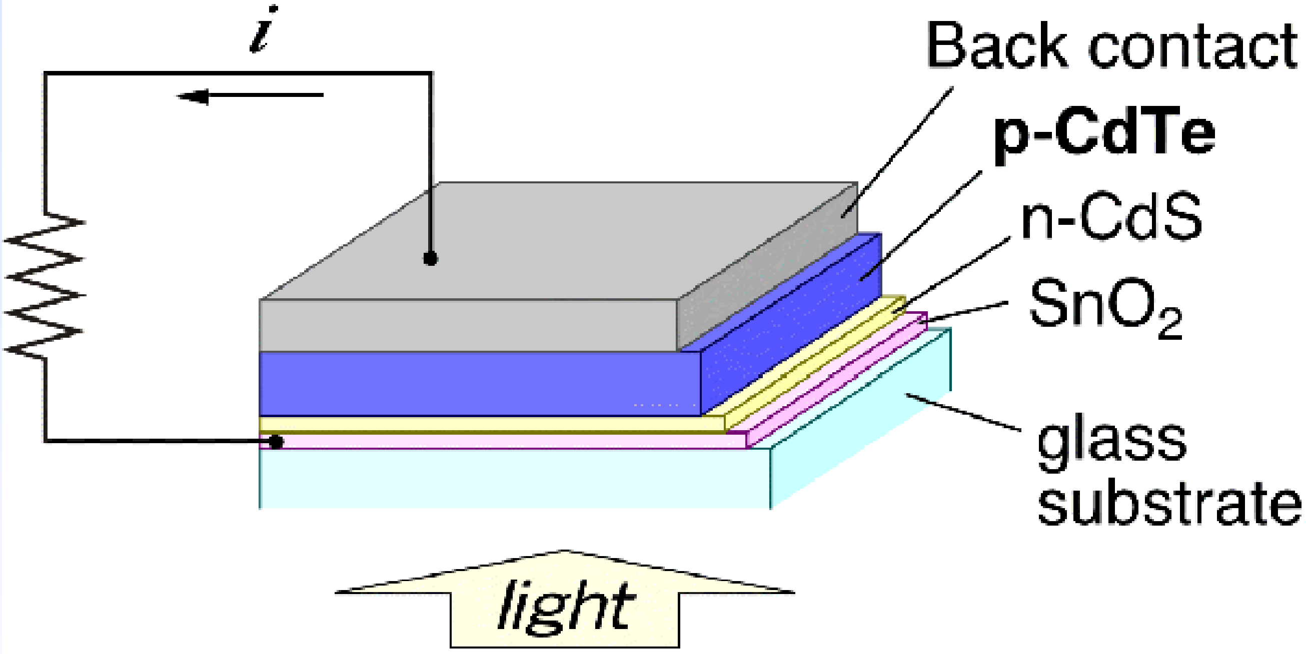
Heterojunction example: CIGS (cont.)



Band diagram of a ZnO/CdS/Cu(InGa)Se_2 device at 0 V in the dark. Note that the recombination current J_{REC} is greatest where $p = n$ in the space charge region of the Cu(InGa)Se_2 and not at the interface.

"Cu(InGa)Se2 Solar Cells", William N. Shafarman and Lars Stolt, in *Handbook of Photovoltaic Science and Engineering*

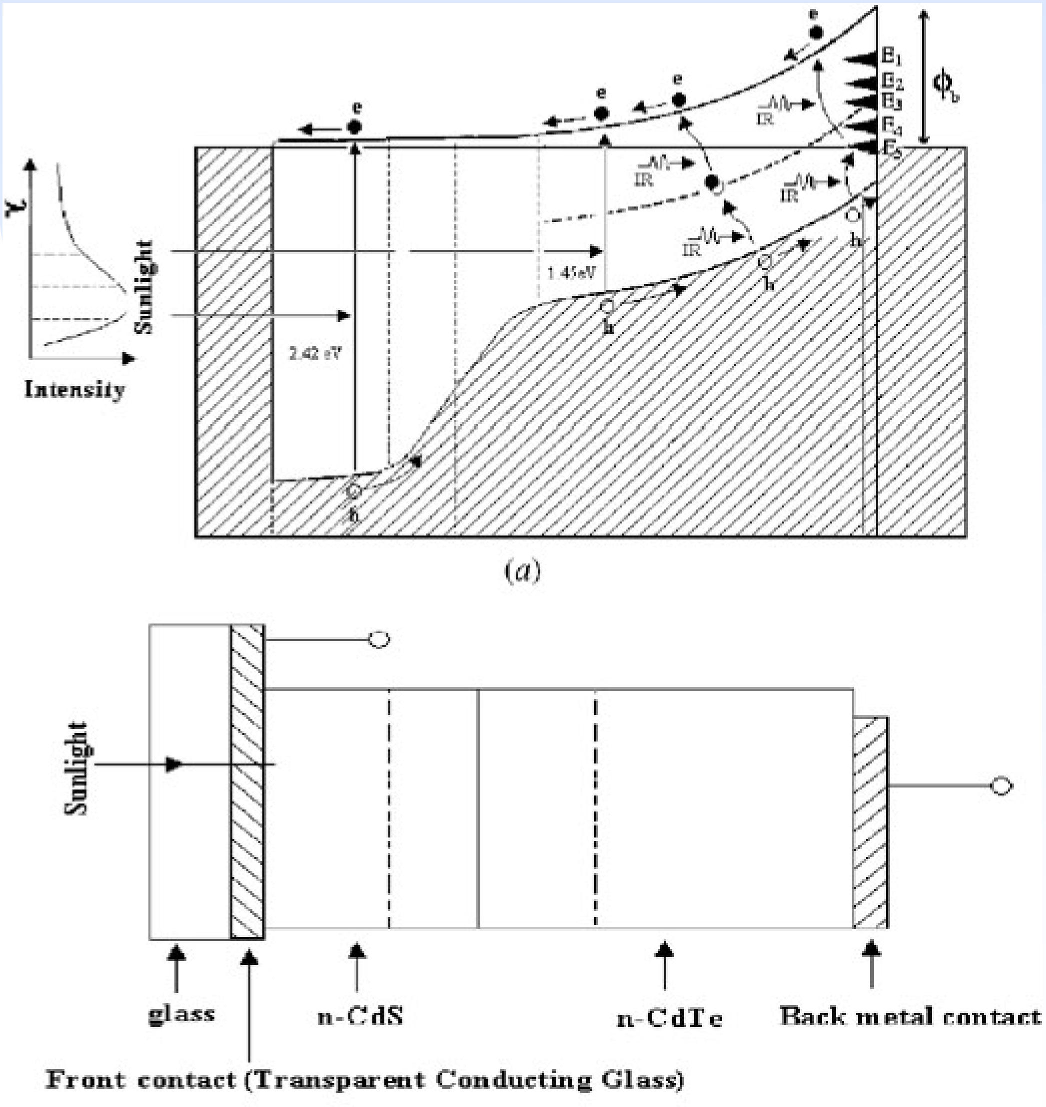
Heterojunction examples: CdTe/CdS



Schematic cross section of a typical CdTe/CdS solar cell

http://www.mtl.kyoto-u.ac.jp/groups/awakura-g/index-e.html

Heterojunction examples: CdTe/CdS (cont.)



(a)

(b)

http://iopscience.iop.org/0268-1242/17/12/306/fulltext

Illumination band diagram for CdTe/CdS heterojunction solar cell. Diagram shows effect of alloying at CdS/CdTe interface (crystal growth and alloying results from $CdCl_2$ treatment).

Types of solar energy conversion

Photovoltaic: Absorbing photons from the Sun with $h\nu > E_g$ generates free electron-hole pairs; in this case the electronic potential energy is increased through a reconfiguration of the charge density. Photogenerated carriers are collected through electrodes, and electrical power can be extracted. Requires an energy gap such that $E_g >> k_B T$. Semiconductors work well for this approach.

Solar thermal: Absorption of photons from the Sun increases the average thermal (kinetic) energy of the electrons and atoms, raising the temperature of the converter. The solar thermal converter can be used to drive an engine (e.g., steam turbine) to do work, in turn producing electrical power if desired.

Photochemical: Similarly to the case of photovoltaic conversion, in the case of photochemical conversion the absorbed photons raise the electronic potential energy ; the photoexcited electrons then drive a chemical reaction. One prime example of this process is photochemical hydrogen production, which has proven to be an elusive task to accomplish through economical technologies.