Course: Sustainable Energy Technology 1
12150310

Title: PV Technology-L1

Dr. Mahmoud Ismail

Photovoltaics Technologies

Photovoltaic effect: direct conversion of sunlight to electricity using photovoltaic devices without using heat engine or rotating equipment.

PV equipment has no moving parts and, as a result, requires minimal maintenance and has a long life.

It generates electricity without producing emissions of greenhouse or any other gases and its operation is virtually silent.

Photovoltaic systems can be built in virtually any size, ranging from milliwatt to megawatt, and the systems are modular

Photovoltaics Technologies

P-N Junction (Theory of operation):

Atoms consists of the nucleus and electrons that orbit the nucleus.

In elements that have electrons in multiple orbitals, the innermost electrons have the maximum negative energy and therefore require a large amount of energy to overcome the attraction of the nucleus and become free whereas the outermost electrons have less attractive force.

The electrons at the outermost shell are the only ones that interact with other atoms.

The outermost band called valence band where the electrons in it determine how an atom will react with others.

Photovoltaics Technologies

Semiconductors:

Some electrons are energetic that jump into the higher band and any force may make them free . This remote band is called conduction band.

The difference in the energy of an electron in the valence band and the innermost subshell of the conduction band is called the band gap or the forbidden gap.

Materials with full valence bands are called insulators. It needs very high band gaps (band gap >3 ev).

Materials with relatively empty valence band are called conductors (some electrons in the conduction band).

The valence and the conduction bands overlap.

Materials with partially filled valence band are called semiconductors. (band gap <3 ev)

Photovoltaics Technologies

Semiconductors:

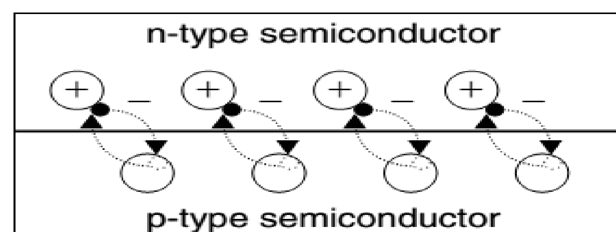
Pure Semiconductors are called intrinsic semiconductors.

Doped semiconductors with small amount of impurities are called extrinsic semiconductors.

N-type doped materials are doped with Phosphorous that has more electrons in the valence band. (e).

P-type doped materials are doped with Boron that has less electrons in the valence band. (Hole).

Diffusion of electrons from n-type to p-type (depletion region. An electric field is formed.



.

Photovoltaics Technologies

PV Technologies:

Raw material is sand (SiO3) that is melted at 1500 – 1700 C to extract pure silicon through number of chemical processes. (Purification).

The pure silicon is heated then cooled

The speed of cooling determines crystal size:

A- Slow cooling; larger one crystal; mono; dark blue; diameter 15 cm ; length 100 cm; Czochralski method.

A seed ingot crystal is used.

The crystal is then sliced (300 μm) and then doped and then add grid. It is round cell and then trimmed into other shapes.

Photovoltaics Technologies

B- The material is melted then poured in a square block.

During cooling, it crystallizes into imperfect manner.

Random crystal boundaries (Blue color).

C- Thin film panels (not crystalline) : Depositing silicon on a sheet of metal or glass. No need for slicing. Less amount of silicon.

Materials

Inorganic semiconductors (Si; Ge; compound semiconductors (gallium-arsenide and cadmium-telluride)

Organic semiconductors, and

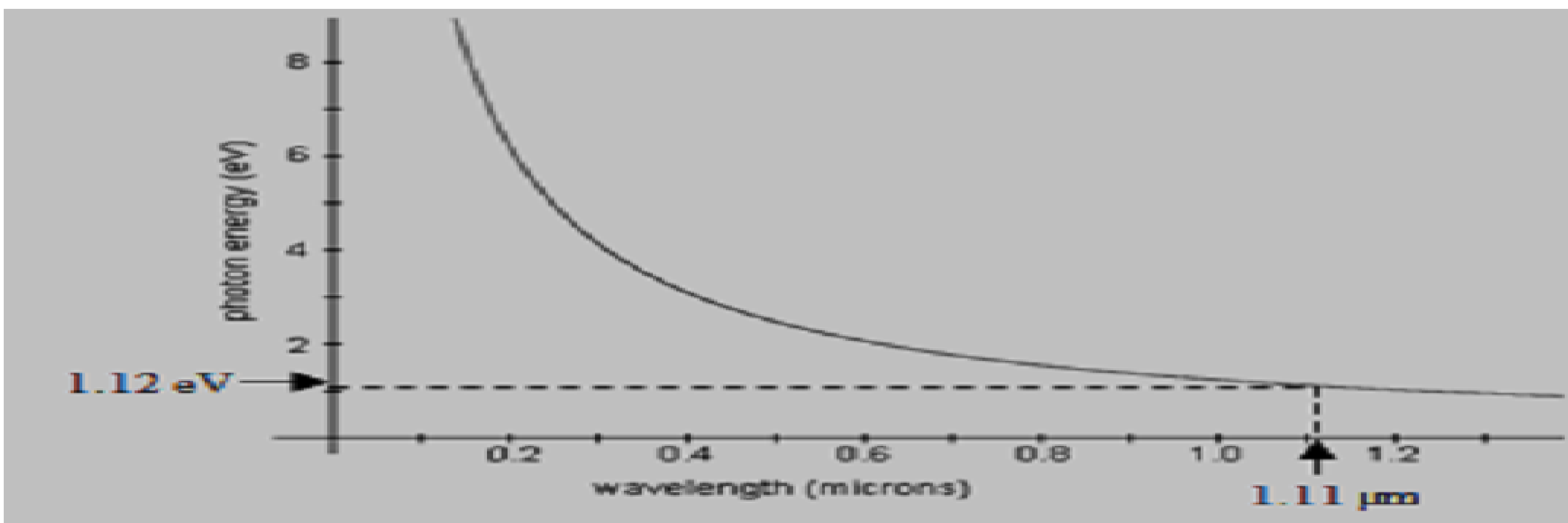
Electrochemical solutions

Photovoltaics Technologies

Photon energy:

Photons with wavelengths longer than 1.11 μm have less energy than the band-gap energy of silicon (1.12 eV), so all their energy is wasted as heat within the cell.

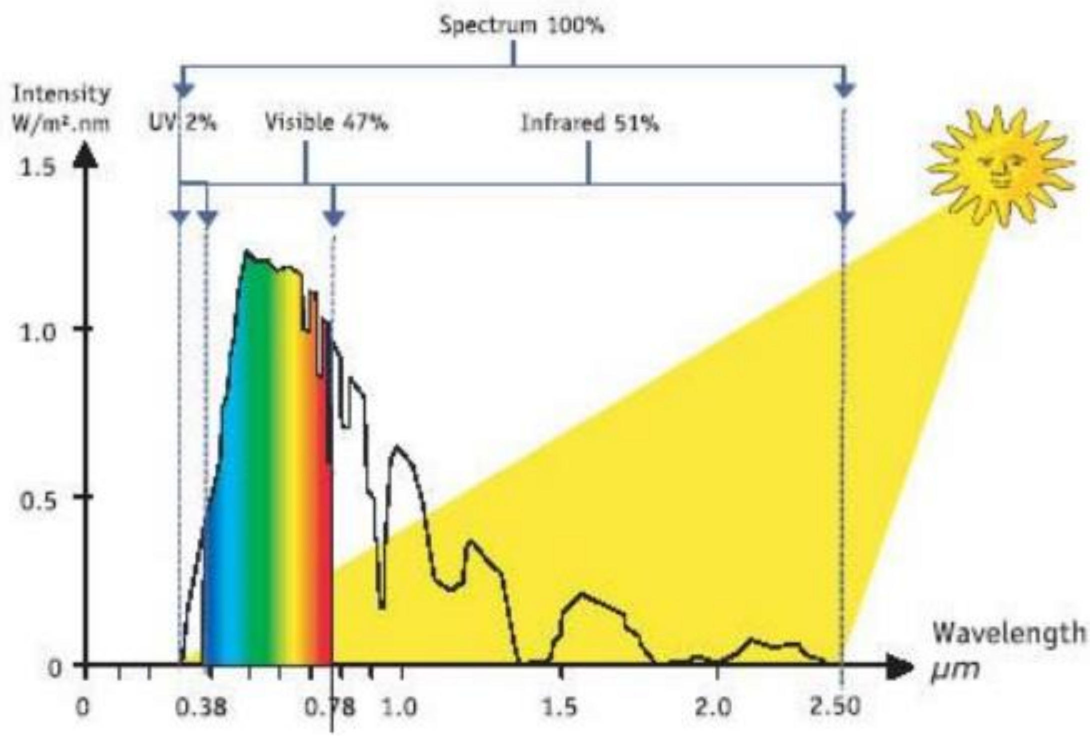
Photons with wavelengths shorter than 1.11 μm have more than enough energy to excite an electron.



Photovoltaics Technologies

Solar spectrum:

The solar spectrum at sea level contains nearly 2% of ultra-violet light ($\lambda \leq 0.38$ µm), 47% visible light (0.38 µm $\leq \lambda \leq 0.78$ µm), and 51% infrared light (0.78 µm $\leq \lambda \leq 2.5$ µm).



Photovoltaics Technologies

– With a **smaller band gap**,

• more solar photons have the energy needed to excite electrons, which is good since it creates the charges that will enable current to flow. However, a small band gap gives those charges a lower voltage.

– With **a higher band gap**,

• fewer photons have enough energy to create the current carrying electrons and holes, which limits the current that can be generated. On the other hand, a high band gap gives those charges a higher voltage.

– In summary, low band gap gives more current with less voltage while high band gap results in less current and higher voltage.

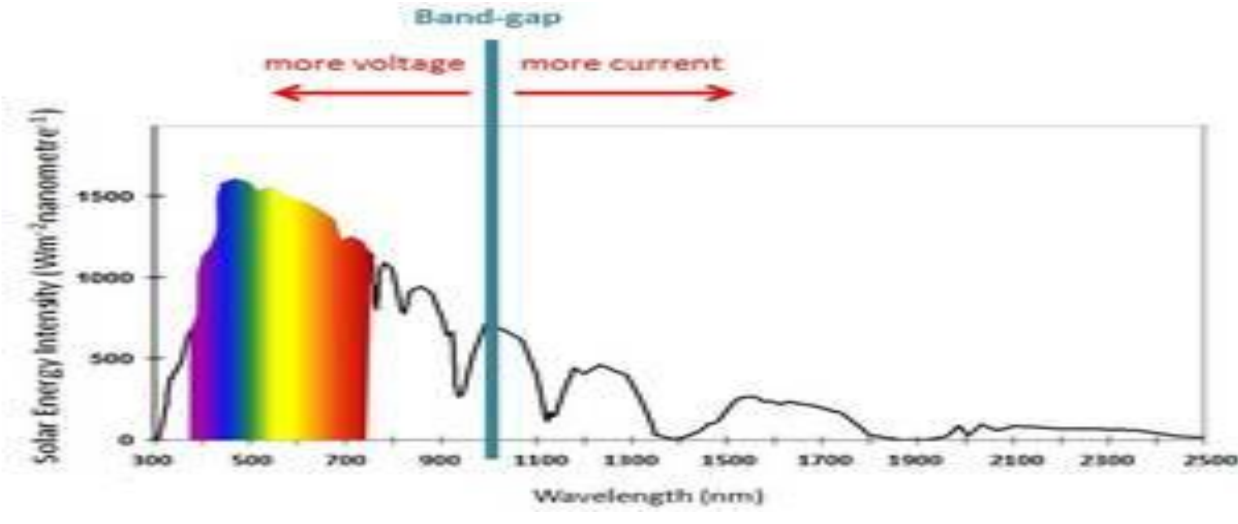
• Since power is the product current and voltage, there must be some middle-ground band gap, usually estimated to be between 1.2 eV and 1.8 eV , which will result in the highest power and efficiency.

Photovoltaics Technologies

The band-gap is the amount of energy a charge needs to absorb before it can become properly excited.

For light of energy higher than the band-gap (light to the left of our line), our charges will get excited and our solar cell will put out current.

The voltage of the cell is directly related to the band-gap of the cell, increasing as the band-gap goes higher in energy - to the left in the above diagram.



Photovoltaics Technologies

For sunlight on Earth, the 'best-position' line is at <u>about 1200nm</u>, corresponding to a <u>maximum efficiency of about 31%.</u>

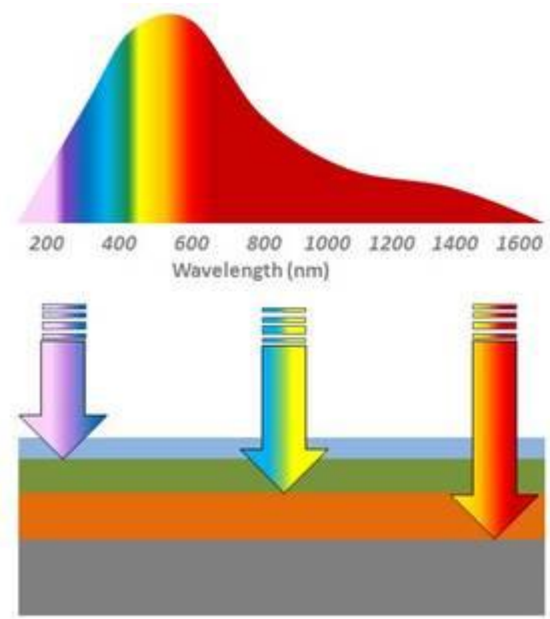
<u>Third Generation Photovoltaics</u>

1- concentrating light: better efficiency up to 40%

2- Multi junction cells: 50%. Having more than one band-gap line on the solar spectrum

The maximum theoretical limit is

86% (Carnot limit).



3- Nanostructured Photovoltaics

Plasmonics (charge and light resonate together)