Solar cells

Solar Cells Generations

Solar cells fabrication has passed through a large number of improvement steps from one generation to another.

Silicon based solar cells were the first-generation solar cells grown on Si wafers, mainly single crystals, Further development to thin films, dye sensitized solar cells and organic solar cells enhanced the cell efficiency.

The development is basically hindered by the cost and efficiency.

The modern photovoltaic technology is based on (the principle of electron hole creation in each cell composed of two different layers (p-type and n-type materials) of a semiconductor material).

In this arrangement of the structure, when a photon of sufficient energy impinges on the p-type and n-type junction, an electron is ejected by gaining energy from the striking photon and moves from one layer to another. This creates an electron and a hole in the process and by this process electrical power is generated.

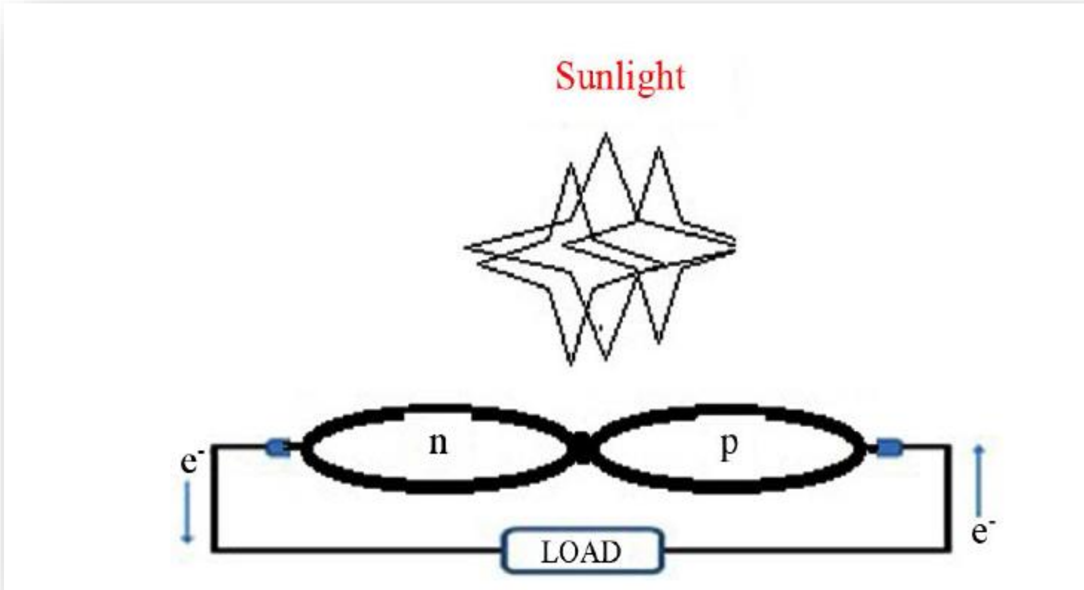

Fig. (19): The semiconductor p-n junction solar cell under load

The various types of materials applied for photovoltaic solar cells includes mainly in the form of silicon:

(single crystal, multi-crystalline, amorphous silicon)

cadmium-telluride, copper-indium-gallium-selenide, and copper-indium-gallium-sulfide.

On the basis of these materials, the photovoltaic solar cells are categorized into various classes as discussed in the following sections:

First Generation Solar Cell

Wafer Based As it is already mentioned,

The first-generation solar cells are produced on silicon wafers. It is the oldest and the most popular technology due to high power efficiencies.

The silicon wafer-based technology is further categorized into two subgroups named as:

1- Single/ Mono-crystalline silicon solar cell.

2- Poly/multi-crystalline silicon solar cell.

1- Single/ Mono-crystalline silicon solar cell

Mono crystalline solar cell, as the name indicates, is manufactured from single crystals of silicon by a process called Czochralski process.

During the manufacturing process, Si crystals are sliced from the big sized ingots. These large single crystal productions require precise processing as the process of “recrystallizing”.

The cell is more expensive and multi process, the efficiency of mono-crystalline single-crystalline silicon solar cells lies between17% - 18%.

2- Poly/multi-crystalline silicon solar cell

(Poly-Si or Mc-Si)

Polycrystalline PV modules are generally composed of a number of different crystals, coupled to one another in a single cell. The processing of polycrystalline Si solar cells is more economical, which are produced by cooling a graphite mold filled containing molten silicon. Polycrystalline Si solar cells are currently the most popular solar cells.

They are believed to occupy most up to 48% of the solar cell production worldwide during 2008.

During solidification of the molten silicon, various crystal structures are formed.

Though they are slightly cheaper to fabricate compared to monocrystalline silicon solar panels, yet are less efficient ~12% - 14%.

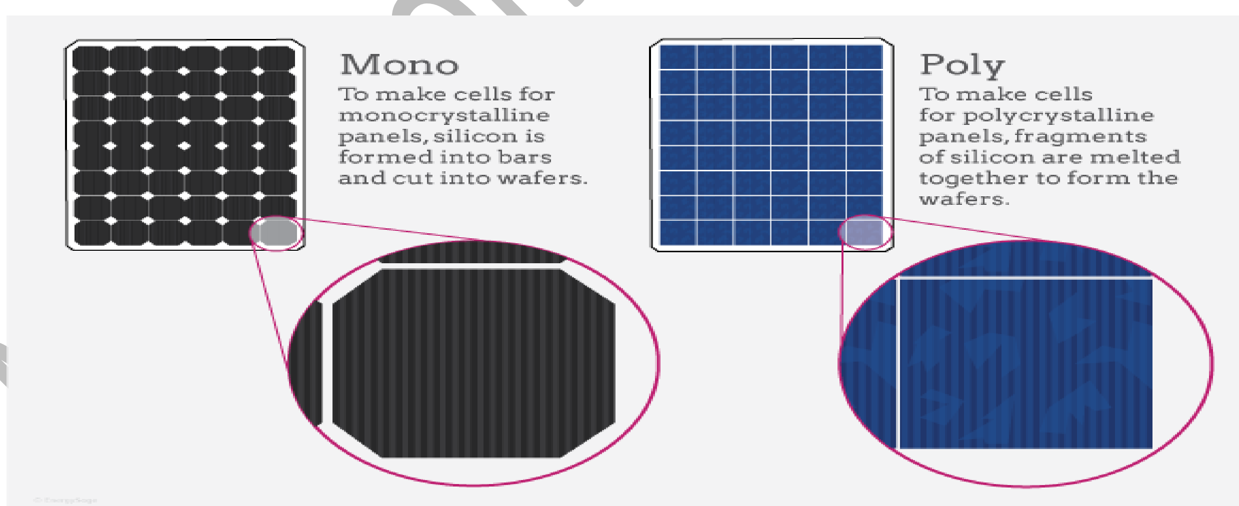

Fig. (20): A schematic explaining the Monocrystalline vs Polycrystalline Solar Cell

Second Generation Solar Cells—Thin Film Solar Cells

Most of the thin film solar cells and a-Si are second generation solar cells and are more economical as compared to the first-generation silicon wafer solar cells. Silicon-wafer cells have light absorbing layers up to 350μm thick, while thin-film solar cells have a very thin light absorbing layers, generally of the order of 1μm thickness.

Thin film solar cells are classified as:

1- Amorphous Silicon Thin Film (a-Si) Solar Cell.

2- Cadmium Telluride (CdTe) Thin Film Solar Cell.

3- Copper Indium Gallium Di-Selenide (CIGS) Solar Cells.

1- Amorphous Silicon Thin Film (a-Si) Solar Cell

Amorphous Silicon (a-Si) PV modules are : the primitive solar cells that are first to be manufactured industrially.

Amorphous (a-Si) solar cells can be manufactured at a low processing temperature, thereby permitting the use of various low cost, polymer, and other flexible substrates.

These substrates require a smaller amount of energy for processing. Therefore, a-Si amorphous solar cell is comparatively cheaper and widely available.

The "amorphous" word with respect to solar cell means that the comprising silicon material of the cell lacks a definite arrangement of atoms in the lattice, non-crystalline structure, or not highly structured.

These are manufacture by coating the doped silicon material to the backside of the substrate/glass plate. These solar cells generally are dark brown in color on the reflecting side while silverish on the conducting side.

Advantages of a-Si solar cells:

1-They can be easily operated at elevated temperatures.

2- Suitable for the changing climatic conditions where sun shines for few hours.

Disadvantages of a-Si solar cells:

almost unstable efficiency.

The cell efficiency automatically falls at PV module level. Currently, the efficiencies of commercial PV modules vary in the range of 4% - 8%.

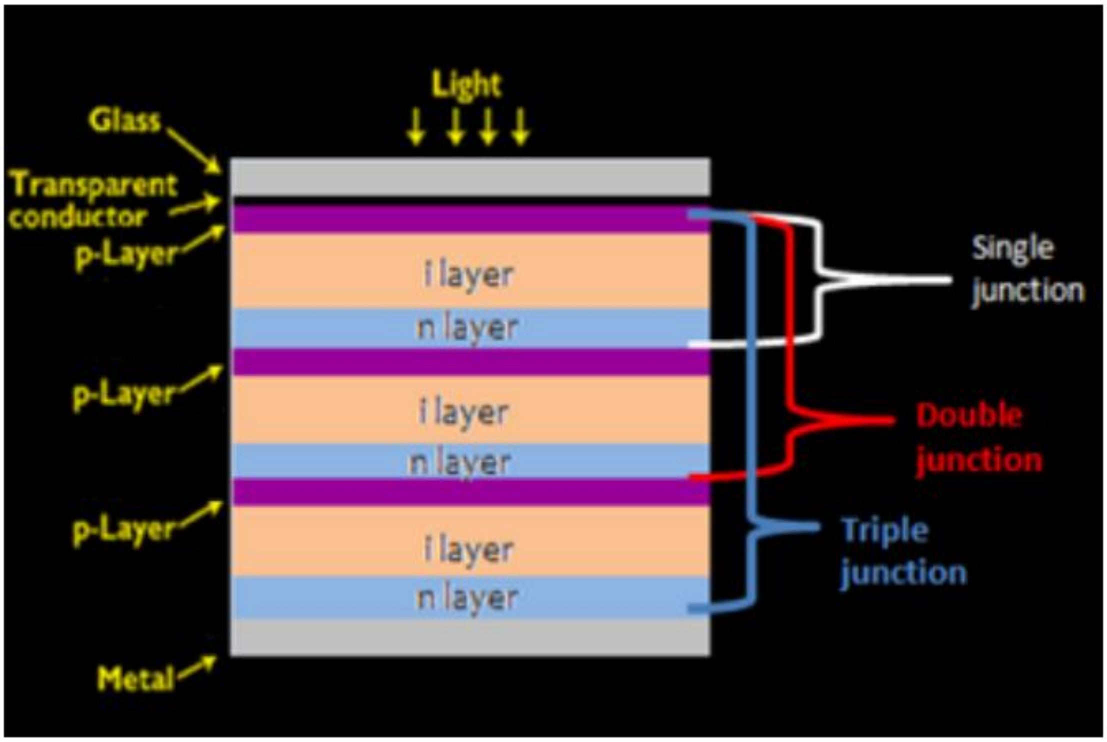

Fig. (21): Structure of amorphous silicon solar cells

2- Cadmium Telluride (CdTe) Thin Film Solar Cell:

Among thin-film solar cells, cadmium telluride (CdTe) is one of the leading candidates for the development of cheaper, economically viable photovoltaic (PV) devices, and it is also the first PV technology at a low cost.

CdTe has a band gap of ~1.5 eV as well as

(high optical absorption coefficient and chemical stability).

These properties make CdTe most attractive material for designing of thin-film solar cells.

CdTe is an excellent direct band gap crystalline compound semiconductor which makes the absorption of light easier and improves the efficiency.

It is generally manufacture by sandwiching between cadmium sulfide layers to form a p-n junction diode.

The manufacturing process involves two steps:

First process

The CdTe based solar cells are synthesized from polycrystalline materials and glass is chosen a substrate.

Second process

involves deposition, *i.e.*, the multiple layers of (CdTe solar cells) are coated on to substrate using different economical methods.

CdTe solar cells can be made **on polymer substrates and flexible.**

It is already mentioned that CdTe has a direct optimum band gap (~1.45 eV) with high absorption coefficient over 5×10^{15}/cm, therefore, its efficiency usually operates in the range 9% - 11%.

Disadvantages of CdTe solar cells:

There are various environmental issues with cadmium component of solar cell:

1- Cadmium is regarded as a heavy metal and potential toxic agent that can accumulate in human bodies, animals, and plants.

2- The disposal of the toxic Cd based materials as well as their recycling can be highly expensive and damaging too to our environment and society .

Therefore, a limited supply of cadmium and environmental hazard associated with its use are the main issues with this CdTe technology.

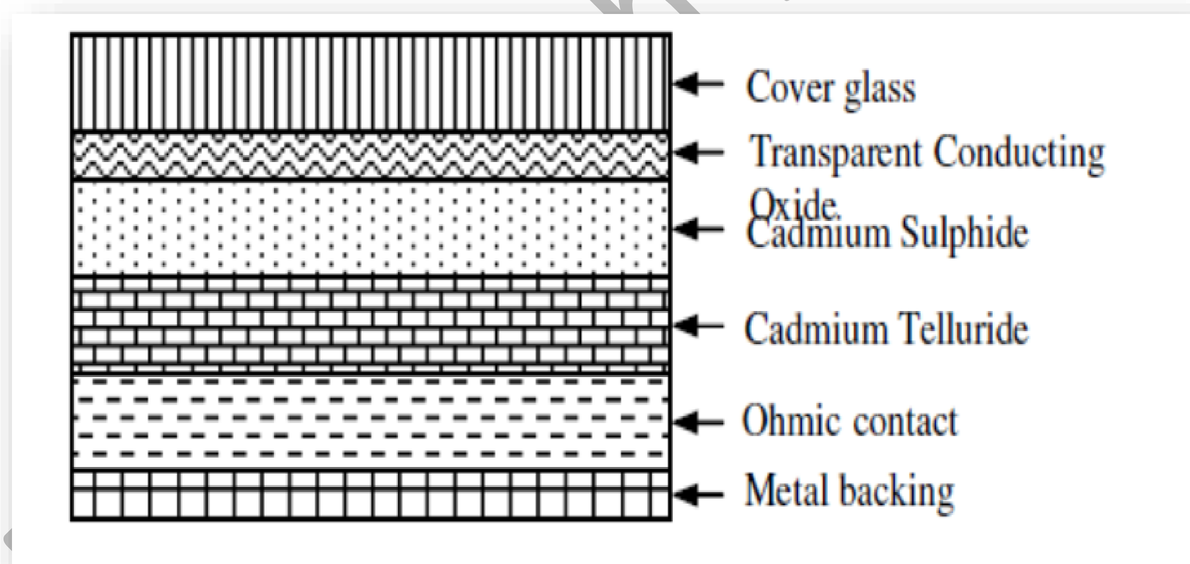

Fig. (22): Structure of CdTe solar cell

3- Copper Indium Gallium Di-Selenide (CIGS) Solar Cells

CIGS is a quaternary compound semiconductor comprising of the four elements, namely:

Copper, Indium, Gallium and Selenium.

CIGS are also direct band gap type semiconductors. Compared to the CdTe thin film solar cell, CIGS hold a higher efficiency ~10% - 12%.

***CIGS based solar cell technology forms one of the most likely thin film technologies?**

Due to their significantly high efficiency and economical.

The processing of CIGS is done by the following techniques:

1-sputtering

2- evaporation

3-electrochemical coating technique

4-printing

4- electron beam deposition.

***The substrates for CIGS material can be chosen from**:

glass plate, polymers substrates, steel, aluminum etc.

The advantages of CIGS:

Thin film solar cells include its prolonged life without a considerable degradation.

These properties of CIGS indicate an easy solution to enhance the efficiency.

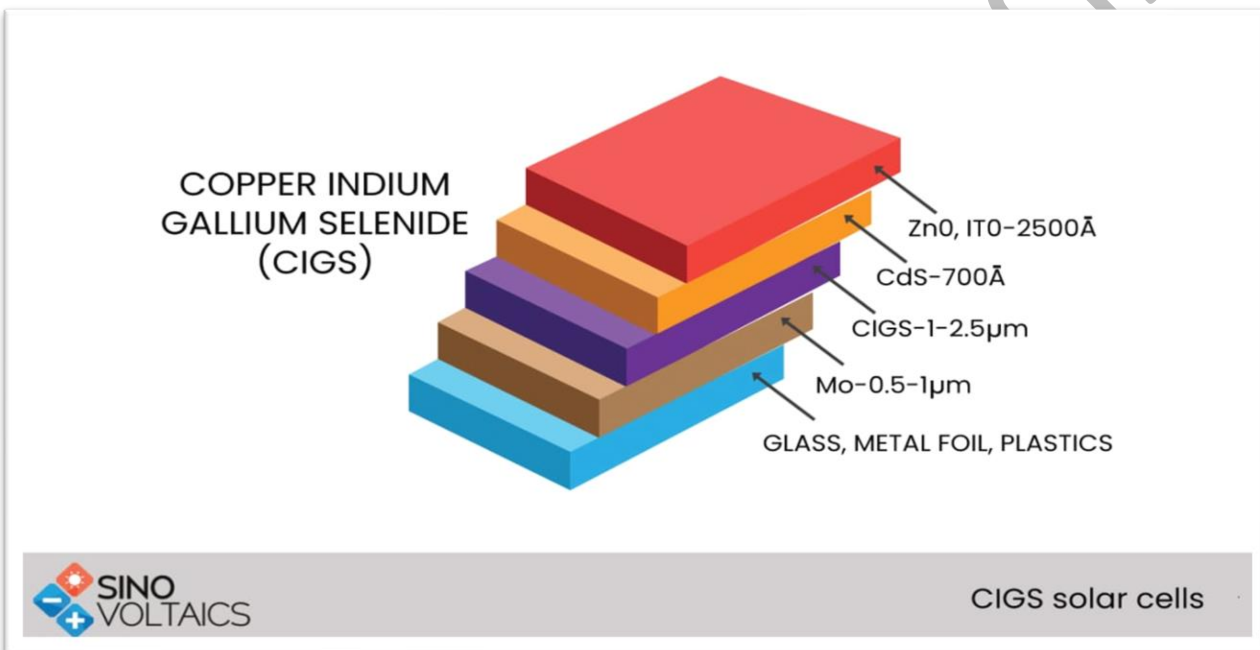

Fig. (23): Shows CIGS solar cell consisting of 5-layers