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SOLAR CELL

Solar cell, also called photovoltaic cell, any device that directly converts the energy of light into electrical energy through the photovoltaic effect which is a physical and chemical phenomenon. The overwhelming majority of solar cells are fabricated from silicon – with increasing efficiency and lowering cost as the materials range from amorphous (noncrystalline) to polycrystalline to crystalline (single crystal) silicon forms. Unlike batteries or fuel cells, solar cells do not utilize chemical reactions or require fuel to produce electric power, and, unlike electric generators, they do not have any moving parts.

Solar cells can be arranged into large groupings called arrays. These arrays, composed of many thousands of individual cells, can function as central electric power stations, converting sunlight into electrical energy for distribution to industrial, commercial, and residential users. Solar cells, whether used in a central power station, a satellite, or a calculator, have the same basic structure. The typical structure of Solar Cell is shown in Fiure-1.

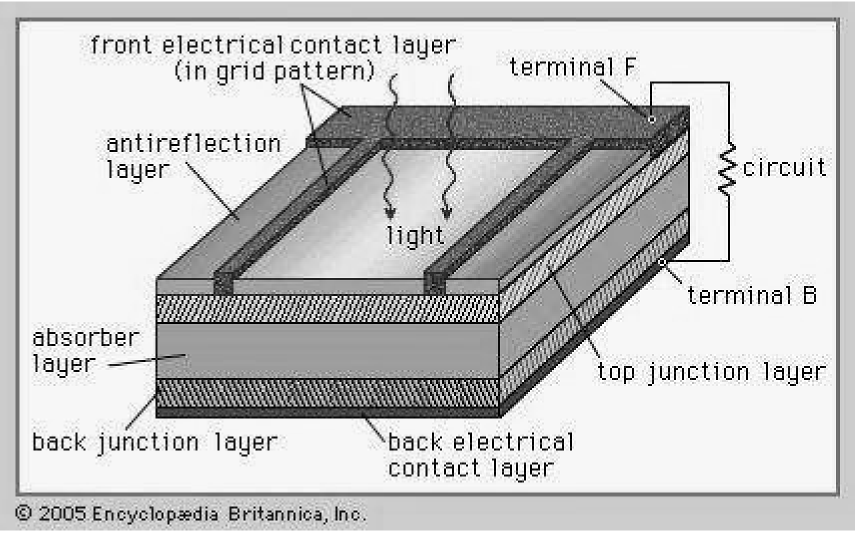


Figure-1

Light enters the device through an optical coating, or antireflection layer that minimizes the loss of light by reflection; it effectively traps the light falling on the solar cell by promoting its transmission to the energy-conversion layers below. The antireflection layer is typically an oxide of silicon, tantalum, or titanium that is formed on the cell surface by spin-coating or a vacuum deposition technique.

The three energy-conversion layers below the antireflection layer are the top junction layer, the absorber layer, which constitutes the core of the device, and the back junction layer. Two additional electrical contact layers are needed to carry the electric current out to an external load and back into the cell, thus completing an electric circuit. The electrical contact layer on the face of the cell where light enters is generally present in some grid pattern and is composed of a good conductor such as a metal. Since metal blocks light, the grid lines are as thin and widely spaced as is possible without impairing collection of the current produced by the cell. The back electrical contact layer has no such diametrically opposed restrictions. It need simply function as an electrical contact and thus covers the entire back surface of the cell structure. Because the back layer also must be a very good electrical conductor, it is always made of metal.

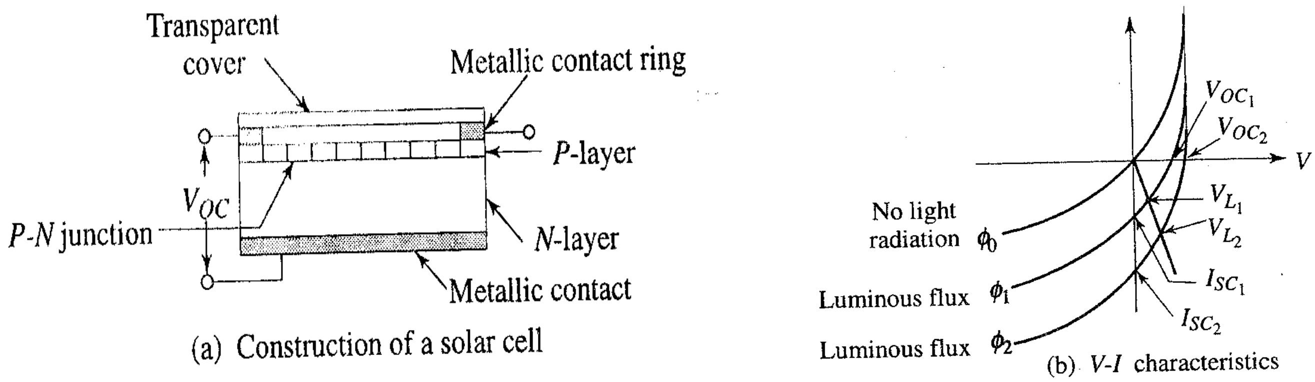
Since most of the energy in sunlight and artificial light is in the visible range of electromagnetic radiation, a solar cell absorber should be efficient in absorbing radiation at those wavelengths. Materials that strongly absorb visible radiation belong to a class of substances known as semiconductors. Semiconductors in thicknesses of about one-hundredth of a centimetre or less can absorb all incident visible light; since the junction-forming and contact layers are much thinner, the thickness of a solar cell is essentially that of the absorber. Examples of semiconductor materials employed in solar cells are silicon, gallium arsenide, indium phosphide, and copper indium selenide.

When light falls on a solar cell, electrons in the absorber layer are excited from a lower-energy “ground state,” in which they are bound to specific atoms in the solid, to a higher “excited state,” in which they can move through the solid. In the absence of the junction-forming layers, these “free” electrons are in random motion, and so there can be no oriented direct current. The addition of junction-forming layers, however, induces a built-in electric field that produces the photovoltaic effect. In effect, the electric field gives a collective motion to the electrons that flow past the electrical contact layers into an external circuit where they can do useful work.

The materials used for the two junction-forming layers must be dissimilar to the absorber in order to produce the built-in electric field and to carry the electric current. Hence, these may be different semiconductors (or the same semiconductor with different types of conduction), or they may be a metal and a semiconductor. The materials used to construct the various layers of solar cells are essentially the same as those used to produce the diodes and transistors of solid-state electronics and microelectronics (see also electronics: Optoelectronics). Solar cells and microelectronic devices share the same basic technology. In solar cell fabrication, however, one seeks to construct a large-area device because the power produced is proportional to the illuminated area. In microelectronics the goal is, of course, to construct electronic components of ever smaller dimensions in order to increase their density and operating speed within semiconductor chips, or integrated circuits.

A solar cell is a bigger size photo-diode, operating in a photo-voltaic mode. It converts light energy into electrical energy. The solar cells are constructed from Selenium and Silicon oxides, providing the requisite P-N junction effect. The materials used in its construction are cadmium sulphide, gallium arsenide or indium arsenide. A thin P-layer is grown in the centre of the circular N-wafer by some manufacturing units.

Others have rectangular isolated junctions that can he interconnected in series-parallel groups to provide the required voltage-current rating panels. The basic construction of a rectangular single solar cell and its V-I characteristics as a function of the light radiation is shown in Figure-2(a) and (b).



(a) Construction of a solar cell

(b) V-I characteristics

Figure-2

When exposed to sunlight, electrons and holes in the form of minority charge carriers are generated. This is due to the extra energy provided by the 'photons' supplied by the light radiation, having a power density = 0.1W/cm The increased reverse currents, denoted as Isc1 and Isc2 in Figure-2(b), are said to be under short circuit conditions since the voltage along Y-axis is zero. The current along X-axis is zero, and the voltage available across the P-N junction is said to be an open-circuit voltage, denoted as VOC1 and VOC2. Under loaded conditions, VL1 < VOC1 and VL2 < VOC2. The load voltage available per unit varies from 0.35 V to 0.4 volts with a current rating of around 0.035 amps. An array of four such cells is capable of supplying more than 50 mW of electrical power. Thousands of such cells when grouped together to make panels capable of supplying power in kilo-watts, used by the satellite transmitters and other man made space equipments orbitting the earth. Streetlight solar cell- panels charge the accumulators which feed the inverters during night hours to provide streetlight through fluorescent lamps.

Generations of Solar Cells

First Generation Solar Cells

Traditional solar cells are made from silicon, are currently the most efficient solar cells available for residential use and account for around 80+ percent of all the solar panels sold around the world. Generally silicon based solar cells are more efficient and longer lasting than non silicon based cells. However, they are more at risk to lose some of their efficiency at higher temperatures (hot sunny days), than thin-film solar cells.

There are currently four types of silicon based cells used in the production of solar panels for residential use. The types are based on the type of silicon used, specifically:

1. Monocrystalline Silicon Cells

The oldest solar cell technology and still the most popular and efficient are solar cells made from thin wafers of silicon. These are called monocrystalline solar cells because the cells are sliced from large single crystals that have been painstakingly grown under carefully controlled conditions. Typically, the cells are a few inches across, and a number of cells are laid out in a grid to create a panel.

Relative to the other types of cells, they have a higher efficiency (up to 24.2%), meaning you will obtain more electricity from a given area of panel. This is useful if you only have a limited area for mounting your panels, or want to keep the installation small for aesthetic reasons. However, growing large crystals of pure silicon is a difficult and very energy-intensive process, so the production costs for this type of panel have historically are the highest of all the solar panel types.

Production methods have improved though, and prices for raw silicon as well as to build panels from monocrystalline solar cells have fallen a great deal over the years, partly driven by competition as other types of panel have been produced.

Another issue to keep in mind about panels made from monocrystalline silicon cells is that they lose their efficiency as the temperature increases about 25˚C, so they need to be installed in such a way as to permit the air to circulate over and under the panels to improve their efficiency.

2. Polycrstalline Silicon Cells

It is cheaper to produce silicon wafers in molds from multiple silicon crystals rather than from a single crystal as the conditions for growth do not need to be as tightly controlled. In this form, a number of interlocking silicon crystals grow together. Panels based on these cells are cheaper per unit area than monocrystalline panels - but they are also slightly less efficient (up to 19.3%).

3. Amorphous Silicon Cells

You probably never thought about it before, but most solar cells used in calculators and many small electronic devices are made from amorphous silicon cells.

Instead of growing silicon crystals as is done in making the two previous types of solar cells, silicon is deposited in a very thin layer on to a backing substrate – such as metal, glass or even plastic. Sometimes several layers of silicon, doped in slightly different ways to respond to different wavelengths of light, are laid on top of one another to improve the efficiency. The production methods are complex, but less energy intensive than crystalline panels, and prices have been coming down as panels are mass-produced using this process.

One advantage of using very thin layers of silicon is that the panels can be made flexible. The disadvantage of amorphous panels is that they are much less efficient per unit area (up to 10%) and are generally not suitable for roof installations you would typically need nearly double the panel area for the same power output. Having said that, for a given power rating, they do perform better at low light levels than crystalline panels - which is worth having on a dismal winter's day, and are less likely to lose their efficiency as the temperature climbs.

However, there flexibility makes them an excellent choice for use in making building integrated PV (e.g., roofing shingles), for use on curved surfaces, or even attached to a flexible backing sheet so that they can even be rolled up and used when going camping / backpacking, or put away when they are not needed!

4. Hybrid Silicon Cells

One recent trend in the industry is the emergence of hybrid silicon cells and several companies are now exploring ways of combining different materials to make solar cells with better efficiency, longer life, and at reduced costs.

Recently, Sanyo introduced a hybrid HIT cell whereby a layer of amorphous silicon is deposited on top of single crystal wafers. The result is an efficient solar cell that performs well in terms of indirect light and is much less likely to lose efficiency as the temperature climbs.

Second Generation Solar Cells

Second-generation solar cells are usually called thin-film solar cells because when compared to crystalline silicon based cells they are made from layers of semiconductor materials only a few micrometers thick. The combination of using less material and lower cost manufacturing processes allow the manufacturers of solar panels made from this type of technology to produce and sell panels at a much lower cost.

There are basically three types of solar cells that are considered in this category, amorphous silicon (mentioned above), and two that are made from non-silicon materials namely cadmium telluride (CdTe), and copper indium gallium diselenide (CIGS). Together they accounted for around 16.8% of the panels sold in 2009.

First Solar, the number one producer and seller of solar panels in the world currently makes their solar cells using cadmium telluride. The big appeal of these type of solar cells is that they are inexpensive (currently below $1.00 / watt to produce and heading towards $0.70 / watt). However, as we discuss in the accompanying articles about cadmium telluride (CdTe) and First Solar – there are some concerns about this technology.

Venture capitalists love CIGS solar cells (or at least used to – as they have invested over $2.3 billion into companies developing these cells but have yet to see them be a commercial success) – as they have been able to reach efficiency levels of 20% in the laboratory. Unfortunately it has turned out to be much more difficult to produce CIGS solar cells in mass quantities at competitive prices with anywhere near than efficiency level, so the jury is still out on this technology.

Third Generation Solar Cells

Currently there is a lot of solar research going on in what is being referred to in the in the industry as Third-generation solar cells. In fact according to the number of patents filed last year in the United States – solar research ranks second only to research in the area of fuel cells.

This new generation of solar cells are being made from variety of new materials besides silicon, including nanotubes, silicon wires, solar inks using conventional printing press technologies, organic dyes, and conductive plastics. The goal of course is to improve on the solar cells already commercially available – by making solar energy more efficient over a wider band of solar energy (e.g., including infrared), less expensive so it can be used by more and more people, and to develop more and different uses.

Currently, most of the work on third generation solar cells is being done in the laboratory, and being developed by new companies and for the most part is not commercially available.