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# Thin Film Solar Cells

**Amit Kumar Sharma**
Department of Physics
D.A.V. (PG) College,
Dehradun, Uttarakhand, India

**Roopesh Kumar**
Department of Physics
D.B.S. (PG) College,
Dehradun, Uttarakhand, India

## Introduction

Solar energy,the world's biggest energy source,as a renewable energy source,inexpensive and free emissions, has a special role in energy supply. The significance of solar energy is vindicated by the fact that the solar energy reflects by the Sun on the earth every hour is much greater than the total resources that the people of the world eat in a year [1-3]. On account of the need to produce solar energy,various kinds of solar power production systems have been developed with the correct capacity for solar radiation, so that the electricity is transmitted to the grids[4]. In current time, electricity supply generated using solar energy is around 178 GW, which is expected to grow up to 500 GW within next two years[5]. The Solar Energy can be utilized either using sunlight to produce energy directly or usage of solar thermal energy high-temperature power plants for the generation of electricity and in low-temperature power plants for the processing of hot water and the ventilation of houses, as well as for use of solar water desalination plants.

## SOLAR CELLS

The consumption of electric energy in the world is around 12-13 TW and the earth receives more solar energy in 1 hour than is the energy used in 1 year globally, considering the solar constant 1.7 x $10^5$ TW at the top of the earth's atmosphere[6]. However, the solar energy incidence, around 1 kW/$m^2$, is quite dilute and requires a vast area of energy converters to meet the world's energy consumption. Therefore, high efficiency solar energy conversion is crucial. The devices, like solar cells, convert the solar energy into electricity. This is known as the photovoltaic effect which was discovered by the French scientist Henri Becquerel. After the oil crises in the 1970s, solar cells have been acknowledged as an alternative power source, which are also a carbon free energy source. The Energy conversion efficiency of a solar cell is determined by the ratio of the electric power generated through the solar cell to the incident sunlight energy into the solar cell per time. Currently the solar cell efficiencies reported in laboratories are around 40% while the energy conversion efficiencies for thermal power generation are around 50%. This fact however never means the superiority of thermal generation since its resources such as fossil fuels are limited while solar energy is essentially unlimited. The incident energy flux spectrum of sunlight for reported solar cell efficiencies is standardized as some specifically defined spectra such as Air Mass 0 (AM0), Air Mass 1.5 Global and Direct (AM1.5G and AM1.5D)[7- 10].

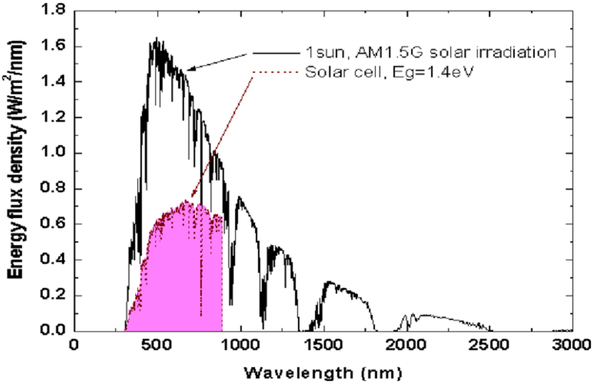

**Figure 1: Solar irradiation spectrum of AM1.5G and energy utilization spectrum by single-junction solar cell with energy band gap of 1.4 eV**

Figure 1 depicts the AM1.5G spectrum, most commonly referred for terrestrial- use solar cells under non-concentrated sunlight spectrum measurements. The range of the solar spectrum is considered from 300 nm to 2000 nm with its peak at 500-600 nm. The prominent dip observed around at1100 nm,1400nm etc .are due to the absorption by $CO_2$ and $H_2O$ in the atmosphere.The energy fraction of the solar spectrum utilized by an ideal single-junction solar cell with having energy bandgap of 1.4 eV determined by the detailed balance calculation based on thermodynamics considering recombination loss of carriers (electron-holepairs) proposed by Shockley and Queisser[10] is shown in Figure 1. The area ratio of this energy generation spectrum by the solar cell to the solar irradiation spectrum corresponds to the energy conversion efficiency and is 31% in this case. Concentration of sunlight into smaller incident area using lenses has two advantages for solar cell applications. The first is the material cost reduction with a smaller area of cells required to generate the same amount of energy. The second is the efficiency enhancement with the higher open-circuit voltage determined by the ratio of the ratio of the photocurrent the recombination current.However,too much concentration of sunlight would rather reduced the open-circuit voltage with increased temperature and also induce significant power loss by the series resistance.

Therefore, each solar cell hasan optimized concentration factor.

## WORKING OF SOLAR CELL

Sunlight contains various hair lengths of light continuum (ultraviolet, yellow,and red) from energy packets called photons. The solar cells on the surface of solar panels absorb the impinge Sunlight and convert the Sun’s energy into electricity as shown in Figure 2.

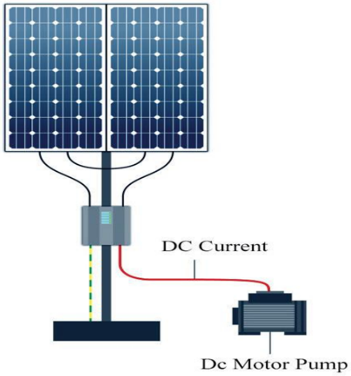

**Figure 2: A Simple Circuit Of Photovoltaic**

A solar cell is a semiconductor device that transforms sunlight energy directly to electricity through photovoltaic influence. When light shines on a p-n diode it generated electron-hole pairs across the whole device.If the device is open circuited, the electron hole pairs generated near the depletion region tend to recombine with the charge in the depletion region, thus reducing the depletion region charge and eventually reducing the depletion region.The reduction in depletion region is equivalent of applying a forward bias to the device i.e. this reduction in depletion region tends to develop a potential across the open terminals of the device. The maximum voltage that can be developed is the maximum forward drop across the device which theoretically is possible with the complete elimination of the depletion region. This maximum voltage that can be developed across the open circuited device is called the open circuit voltage represented by the point C in Figure 3.

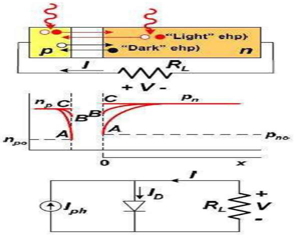

**Figure 3: Working Of A-pn diode solar cell**

If the device is short circuited, the generated holes and electrons produce a current corresponding to the incoming photons. This current is called the short circuit current represented by the point A in Figure 3.

When the p-n device is used to drive an external load, say 'R' the region of operation is somewhere in between these two points. The reason being a current I flow through the device which creates a drop across the resistor and the direction of the current is such that the device comes into forward bias condition. As there is some drop across the load and the device the maximum output voltage is not equal to open circuit voltage. The forward bias conducts the device in the direction opposite to the current generated by the photons called the dark current. The presence of the dark current does not allow the device to operate at short circuit current. Thus the device operates in the fourth quadrant where the voltage is positive but the current is negative making the power negative i.e. the device generates power using light as source.

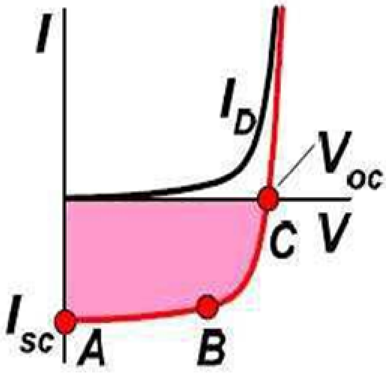

**Figure 4:Current Voltage Characteristics Of Solar Cell**

## Silicon Solar Cells

The First-generation solar cell technology is based on silicon wafers with a thickness of between 300 and 400 microns with a single crystal or multi-crystal structure.The silicone materials used are mixed with different elements in order to generate sufficient amounts of electrons-holes. Such solar cells are made up of a combination of electron-contaminated and perforated silicone layers that emit electron-cavitylight[11]. These solar cells have been popularized because of their high performance, but the major drawbacks of these are the high processing cost of silicon raw materials and the high energy usage[12]. Large area, high quality and single junction devices form the ‘first generation solar cells. Reduction in production costs of this technology is nullified owing to high energy and labor costs, material costs mostly for the silicon wafer, strengthened low-iron glass cover sheet and costs of other encapsulants. This trend is continuing as the photovoltaic industry is expanding. Although it has a broad spectral absorption range, the high energy photons at the blue and violent end of the spectrum are wasted as heat. Producing solar cells using high-efficiency processing sequences with high energy conversion efficiency are thus favored provided they do not increase the complexity of the solar cell. Theoretical limit on efficiency for single junction silicon solar cells i.e. 33% and this is also being reached very rapidly. To address these problems of energy requirements and production costs of solar cells a switch from ‘first generation’ to ‘second generation’ of thin-film cell technology has been imminent.

## Thin Film Solar Cells

A thin-film solar cell is a second generation solar cell that is made by combining other thinlayers, or thin film (TF) of photovoltaic material on a substrate, like glass, plastic ormetal. The thicknesses of thin film varies from a few manometers (nm) to micrometers (µm), which is many times thinner than the conventional, first-generation crystalline silicon solar cell (c-Si), that uses wafers of up to 200 µm thick. This permits thin film cells to be conciliatory, and less in weight. According to the type of photovoltaic material used, the thin film solar cells are classified into four types. They are a) Amorphous silicon (a-Si) and other thin-film silicon (TF-Si) b) Cadmium Telluride (CdTe) c) Copper indium gallium deselenide (CIS or CIGS) d) Dye-sensitized solar cell (DSC) and other organic solar cells

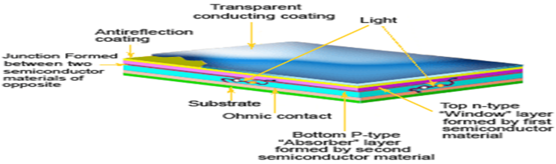

**Figure 5: structure of thin film solar cells**

Thin film solar cells are far superior in manners to produce electricity from sunlight than any other technology or device. Thin film solar panels can be implemented conveniently in forest areas, solar fields, traffic and street lights, and many more. Additionally, these panels are cost-effective when compared to the older generation silicon wafer cells.It is used in building-integrated photovoltaics and as semi-transparent, photovoltaic glazing material that can be laminated onto windows.Other commercial applications use rigid thin film solar panels in some of the world's largest photovoltaic power stations. The thin-film technology is cheaper in terms of price but is less efficient than conventional c-Si technology. The thin film solar cell structure is depicted in figure 5. The functioning of thin film solar cells is nearly the same as that of conventional silicon wafer cells but the main difference is of the basic solar substance used and in the thin flexible arrangement of the different layers which helps solar cells to be more efficient than the conventional silicon wafer cells.

Accelerated life testing of thin film modules under laboratory conditions measured a somewhat faster degradation compared to conventional PV, while a lifetime of 20 years or more is generally expected.By eliminating the silicon wafers major reduction in material costs have been possible in the thin-film technology.They also have an advantage of increasing the unit size from silicon (~100cm$^2$) to glass plate (~1m$^2$). Over time the second-generation solar cells are expected to bridge the gap between them and the first-generation cells with respect to energy conversion efficiency. With the increase in dominance of this technology the costs of the constituent materials also go up for top cover and other encapsulants to give it a longer life. The materials generally used in this thin film technology are cadmium telluride, copper indium gallium arsenide, amorphous silicon and micro amorphous silicon. These materials reduce mass and therefore cost by forming substrates for supporting glass and ceramics. Not only do they reduce costs but also promise very high energy conversion efficiency. Fortunately, with the development of new materials over the coming decades the future of thin-film technology seems to be promising. Research for improving solar cell performance by enhancing its efficiency and pushing it closer to the thermodynamic limits has led to the development of next generation solar cells[13].

**Working**

The basic substance of a photovoltaic cell is semiconductors. The semiconductor doped with phosphorus develops an excess of free electrons (called N type material) and a semiconductor doped with boron, gallium or indium creates holes and these doped materials known as P type materials. Combining these n type and p type materials form the basis of Photovoltaic cell. In the absence of light, excited atoms are very few in number which move across the junction. This causes a small voltage drop across the junction. In the presence of light, more atoms are excited and flow through the junction and cause a large current at the output. This current can be stored in a rechargeable battery and used for several applications based on our requirement.

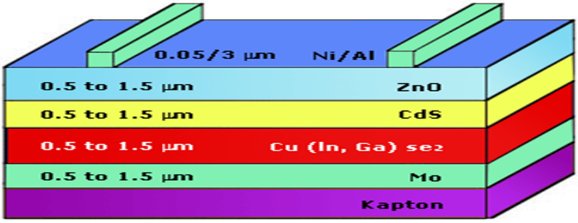

**Figure 6: Layer arrangement of thin film solar cell**

The silicon semiconductor used in old generation solar panel technology for the production of p-type and n-type layers has several disadvantages. But in the Thin Film Layer technology,the silicon semiconductor materials are replaced by either cadmium telluride (CdTe) or copper indium gallium diselenide (CIGS).

## Efficiency Of Thin Film Solar Cells

In the thin film solar cell, the achievable efficiency is extremely dependent on the semiconductor chosen. Incremental improvements in efficiency began with the invention of the first modern silicon solar cell in 1954. By 2010 these steady improvements had resulted in modules capable of converting 12 to 18 percent of solar radiation into electricity.

The improvements to efficiency have continued to accelerate in the years since 2010. The newer materials used to make solar cells tend to be less efficient than bulk silicon, but are inexpensive to produce. Their quantum efficiency is also lower due to reduced number of collected charge carriers per incident photon.The performance and potential of thin-film materials are high, reaching cell efficiencies of 12–20%; prototype module efficiencies of 7–13%; and production modules in the range of 9%. The thin film cell prototype with the best efficiency yields 20.4% (First Solar), comparable to the best conventional solar cell prototype efficiency of 25.6% from Panasonic.

## Conclusion and Discussion

These thin film solar cells are attracting due to their cost effectiveness, easy to handle and more flexible than conventional solar cells, while using ample available nontoxic element like silicon.Though these have disadvantages in terms of less efficiency and complex structure but there are large research efforts going on worldwide to reach sufficient conversion efficiency implementing various different technologies. These other thin-film technologies that are still in an early stage of ongoing research or with limited commercial availability are often classified as emerging or third generation photovoltaic cells and include organic, dye-sensitized, as well as quantum dot, copper zinc tin sulfide, nanocrystal, micromorph, and perovskite solar cells. The future of the thin film solar power industry seems bright as only about 2 percent of electrical generation globally comes from solar today which is expected to grow up to 30 percent in the next decade.

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