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A Study of Thin Film Solar Cells and its Efficiency

Physics

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Kavita R. Kolte

Assistant Professor (Physics), Government Science College, Idar, Dist. Sabarkantha (Gujarat – India)

ABSTRACT

The Earth receives only one billionth of the sun's colossal power output, but, even this tiny fraction provides the Earth with more energy in one hour than all the energy consumed by humans in an entire year. This has led scientists for decades to develop solar cells. The second generation thin film solar cells are much thinner than the first generation crystalline silicon solar cells and have many advantages. They are easy to handle, offer great design flexibility for a variety of applications, has shorter energy payback time suitable for high energy production and is much cheaper than other cells. Thin film technology uses various photovoltaic substances like amorphous silicon, cadmium telluride, copper indium and gallium selenide. Each type of material is suitable for different types of solar applications and has different values of efficiency. The efficiency and fill factor of CIGS thin film solar cell is much higher than other thin film cells. The best CIGS and CdTe-based small-area thin film polycrystalline solar cells have reached laboratory efficiencies of 16-17%, which are approximately 80% of their theoretical maximum efficiencies. However, despite these achievements, commercial products based on these materials are not yet available because the fundamental research conducted so far has focused on improvements in efficiency. Now, however, the focus must shift to issues relevant to manufacturability.

INTRODUCTION:

The Earth which is located 150 billion Km from the Sun receives only one billionth of the sun's colossal power output. But even this tiny fraction provides the Earth with more energy in one hour than all the energy consumed by humans in an entire year. The sun's outpouring of free and non-carbon-emitting energy has led scientists for decades to develop solar cells. A solar cell is any device that directly converts the energy in light into electrical energy through the process of photovoltaics. The development of solar cell technology began in 1839 when French physicist Becquerel observed the photovoltaic effect while experimenting with a solid electrode in an electrolyte solution and he saw a voltage develop when light fell upon the electrode. This first conversion of sunlight to electricity was one percent efficient. That is, one percent of the incoming sunlight was converted into electricity. Willoughby Smith in 1873 discovered that Selenium was sensitive to light; in 1877 Adams and Day noted that selenium, when exposed to light, produced an electrical current. Charles Fritts, in the 1880s, also used gold-coated selenium to make the first solar cell, again only one percent efficient. Nevertheless, Fritts envisioned free solar energy to be a means of decentralization, predicting that solar cells would replace power plants with individually powered residences. Solar cells act as energy sources for a wide variety of uses including calculators and other small devices, telecommunications, rooftop panels on individual houses, and for lighting, pumping, and medical refrigeration for villages in developing countries. Solar cells in the form of large arrays are used to power satellites and in rare cases to provide electricity for power plants.

TYPES OF SOLAR CELLS:

Solar cell technologies are traditionally divided into three generations. First generation solar cells are mainly based on crystalline silicon wafers of about 200 μm thickness and typically demonstrate a performance about 15-20 %. They are made up of semiconducting p-n junctions and uses silicon in monocrystalline, polycrystalline and nanocrystalline forms. These types of solar cells dominate the market and are mainly those seen on rooftops.

A thin-film solar cell is a second generation solar cell. The film thickness varies from a few nanometers (nm) to tens of micrometers (μm) which is much thinner than thin-film's rival technology, the conventional first-generation crystalline silicon solar cell Thin-film solar cells are commercially used in several technologies and are made of different materials like cadmium telluride (CdTe), copper indium gallium diselenide (CIGS), and amorphous thin-film silicon (a-Si, TF-Si). The second generation thin film solar cell has a typical performance is 10 - 15%. It is used in building integrated photovoltaics, as semi-transparent photovoltaic glazing material that can be laminated onto windows and as rigid thin film solar panels in some of the world's largest photovoltaic power stations.

Third-generation solar cells are solar cells that are potentially able to overcome the Shockley–Queisser limit of 31–41% power efficiency for single bandgap solar cells. This Common third-generation systems include multi-layer ("tandem") cells made of amorphous silicon or gallium arsenide, while more theoretical developments include frequency conversion, hot-carrier effects and other multiple-carrier ejection techniques.[1].

Emerging solar cell technologies include copper-zinc-tin-sulphide (CZTS) solar cells, dye sensitized solar cells, organic solar cells, perovskite solar cells, polymer solar cells and quantum dot solar cells.

CONSTRUCTION AND WORKING OF THIN FILM SOLAR CELLS:

The basic substance of a photovoltaic cell is semiconductors. The semiconductor doped with phosphorus develops an excess of free electrons (usually called N type material) and a semiconductor doped with boron, gallium or indium develop a vacancy (called holes) and this doped materials known as P type materials. These n type and p type materials combine (join) to form a Photo voltaic cell. During the absence of light, a very small amount of atoms are excited and 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. The old solar panel technology use silicon semiconductor for the production of p-type and n-type layers and has several disadvantages, but, thin film solar cells are characterized by the manner in which various type of semi-conducting materials are layered on top of one another to create a series of thin films. A thin-film solar cell is made by depositing one or more thin layers, or thin film (TF) of photovoltaic material on a substrate, such as glass, plastic or metal. The photovoltaic material may be cadmium telluride (CdTe), copper indium gallium diselenide (CIGS), amorphous thin-film silicon (a-Si, TF-Si), silicon, gallium arsenide (GaAs) or it may even be a dye or organic material or perovskite. Each type of material is suitable for different types of solar applications. Figure-1 shows the block diagram of thin film solar cell and Figure-2 show

The amount of electricity depends on a number of factors like cell material, cell size, and the intensity and quality of the light source. The most effective and desirable light source is the sun which is the most available and costs nothing. Larger cell size means more individual cells translating into either more voltage or current.

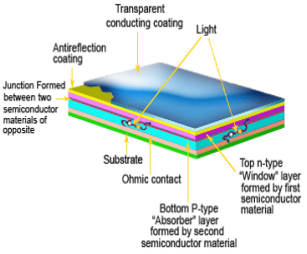


Figure-1

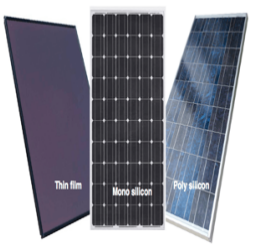


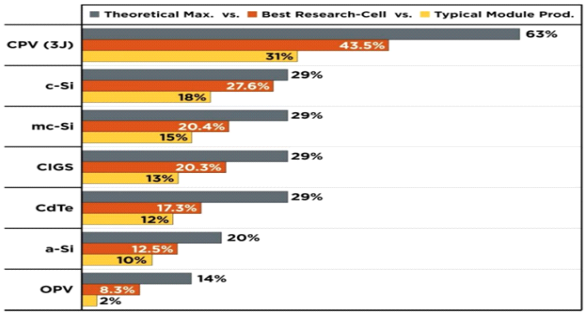
Figure-2

ADVANTAGES OF THIN FILM SOLAR CELLS:

Thin-film solar cells offer the most promising options for substantially reducing the cost of photovoltaic systems.[2] Mass production is much easier than crystalline-based modules, so the cost of mass producing thin film solar cells is relatively cheap. TFSC are easy to handle and offer a great design flexibility for a variety of applications. The color integrates easily into most exterior designs and they are ideal for low angle installations. Another perk is that high heat and shading have less of a negative impact on thin film technologies.TFSC have a shorter pay back time which aids in creating high energy production and resource savings. They are also less susceptible to damage than their silicon rivals. For these reasons, the thin film market continues to grow.

EFFICIENCY OF THIN FILM SOLAR CELLS:

Solar cell efficiency refers to the portion of energy in the form of sunlight that can be converted via photovoltaics into electricity. Another key parameter in evaluating the performance of thin film solar cells is its fill factor. It is the ratio of solar cell's actual power output versus its dummy power output. Higher the fill factor of a solar panel, lesser are the parasitic losses due to series and parallel resistances within the cell itself. A multiplicity of options, in terms of materials and devices are currently being developed worldwide. Enormous progress in device performance has been made in most of these technologies and considerable effort is devoted to commercialization of these technologies. Exciting new developments are happening in some relatively new materials and devices.[3]. Figure-3 shows the comparison of efficiencies of various thin film solar cells.



Source: NREL

As seen in figure, though the efficiency of thin film solar cells seems to be a little less than conventional solar cells, it should be noted that their efficiency has significantly improved over the years. The efficiency and fill factor of CIGS thin film solar cell is much higher than other thin film cells. The best CIGS and CdTe-based small-area thin film polycrystalline solar cells have reached laboratory efficiencies of 16-17%, which are approximately 80% of their theoretical maximum efficiencies. The lab cell efficiency for CdTe and CIGS is now beyond 21 percent, outperforming multicrystalline silicon, the dominant material currently used in most solar PV systems. Furthermore, efficiencies above 13-14% have been obtained by more than one process for each class of solar cells.[4]. This shows that real progress continues to be made in thin film solar cells and we should be a bit more optimistic.

CONCLUSION:

c-Si technology has been around for a while and has proven its worth and mettle, while thin film solar cell is still pretty much in its infancy but it has the potential to be significantly less expensive and at least comparable in efficiency and reliability with its conventional counterpart. There is no doubt that solar cells provide more energy per ounce of weight than all other conventional energy sources and they are cost-effective. A type of thin film solar cell to fully meet domestic energy needs has not as yet been developed because commercial products based on these materials are not yet available. This is due to the fact that research conducted so far has mainly focused on improvement in efficiency which is very important. Now, however, the focus must shift to issues relevant to manufacturability of a viable product.

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