A Review on Comparison between Traditional Silicon Solar Cells and Thin- Film CdTe Solar Cells

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Abstract: Solar energy is one of the most significant types of the sustainable and renewable energy sources that have been used in the world. Photo voltaic (PV) is known as the direct conversion of the sunlight to electricity energy with the used of solar cells. Various materials and technologies are employed to produce solar cell fabrication based on low cost and high conversion efficiency.
Silicon is employed as first material to manufacture Solar cells but its disadvantages are high cost and lower efficiency. Thin-film solar cells are known as second generation of the solar cell fabrication technologies to produce power electrical energy.
In fact Thin-Film solar cells are manufactured based on higher efficiency as compare with traditional silicon solar cells this is because Thin-Film solar cells are comprised of several layers that help to reduce current losses. When the sunlight strives at the solar cells, photons with higher energy will be absorbed by higher layers, and vice versa, low energy photons will be absorbed with lower layers of Thin-Film solar cells that lead to prevention of wasting energy. In this paper the application of comparison between traditional and thin-film CdTe carried by other researchers (literature review) to compare the Thin-Film solar cell such as Cadmium Telluride and traditional silicon solar cells to indicate that Thin-Film solar cells like CdTe are more economical than traditional solar cells.

Keywords– Thin-Film Solar Cells; Photo Voltaic; Silicon Thin-Film; CdTe Thin-Film; Solar cell fabrication.

I. INTRODUCTION

The Solar cell is valuable by consideration of conversion efficiency and low manufacture cost. Thin-Film solar cell is proposed higher efficiency, this is because these cells have different layers in one cell which reduce the losses of current (Jsc) in solar cells. When the light’s spectrum strive the surface of the solar cells, some of photon’s energy will be absorbed and converted to electrical energy, and some of the photon’s energy will be converted to heat energy, and the rest will be lost [1]. When different absorber layers and buffer layers are employed, the efficiency of solar cells will be enhanced in solar modules [2].
Thin-film technologies reduce the amount of material required in creating the active material of solar cell. Most thin-film solar cells are sandwiched between two panes of glass to make a module. Since silicon solar panels only use one pane of glass, Thin-Film panels are approximately twice as heavy as crystalline silicon panels [2, 3].
Thin-film solar technologies have enjoyed large investment due to the success of First Solar and the largely unfulfilled promise of lower cost and flexibility compared to wafer silicon cells, but they have not become mainstream solar products due to their lower efficiency and corresponding larger area consumption per watt production. Cadmium telluride (CdTe), Copper Indium Gallium Selenide (CIGS) and amorphous silicon (A-Si) are three thin-film technologies often used as outdoor photovoltaic solar power production. CdTe technology is most cost competitive among them. CdTe technology costs about 30% less than CIGS technology and 40% less than A-Si technology in 2011 [3]. this research by gathering the information of both kinds of solar cells(traditional silicon cells and CdTe cells) shows that Thin-Film solar cells such as CdTe are more economical compared to traditional silicon solar cells (by saving the cost, energy, time) and why Thin-Film technology was started and is extending day by day[4].

II. THIN-FILM APPROACHES

Large numbers of materials exhibit the photovoltaic effect and can be used for the solar cells production; however, useful solar cell needs to satisfy some requirement as the following:

a) High cell conversion efficiency
b) The material should be inexpensive and available and non-toxic.
c) The cell production method should be low cost, fast and simple
d) The cells performance should be stable for long period of time around 20 years

Virtually, over 80 percent of today commercial PV modules are made of silicon. Other than silicon semiconductors materials like CdTe, CIGS, and etc, have been investigated for use in thin-Film cells [5]. CIGS shows considerable promise for higher efficiency and CdTe solar cell are promising for low cost production. Among the different PV technologies, thin-film is the most potential for low cost and high efficiency or commercially viable PV cells [6].
The main advantage of Thin-Film solar cell is their promise of lower cost, since less energy are required for processing and relatively lower cost for the materials are required and large scale production is feasible [7].
The research activities have shifted gradually towards thin- film solar cell compound semiconductors, which have great potential to attain high efficiency and high stability as compare to a-Si Solar cells [7].
Many easier methods of deposition have been used to produce poly crystalline CdTe layers. These methods are electrode position, close–spaced sublimation, sputtering, screen printing and spraying. The parameters that are used to characterize the solar cell output are open circuit voltage (Voc), short circuit current (Jsc), fill factor (FF), which ideally FF can be expressed with Voc. Energy gap also is a major factor of determining the electrical conductivity of a solid. In graphs of the electronic band structure of solids, the band gap generally refers to the energy difference (in electron volts) between the top of the valence band and the bottom of the conduction band in insulators and semiconductors.
This is equivalent to the energy required to free an outer shell electron from its orbit about the nucleus to become a mobile charge carrier, able to move freely within the solid material. the optimum Energy gap (Eg) for maximum output of solar cells is between 1.3-1.6 eV, CdTe solar cells have Eg=1.45eV which is suitable Eg for optimum cell's output. The criteria of choice for best materials of PV cells:

a) Value of Eg and the nature of the band to band transitions
b) The value of the photo carrier's life time as a fraction of doping and defects
c) The ability of material to be fabricated economically in large areas the ability to form efficient collecting structure
d) Ability of the cell to work eventually under concentrated radiation [8].

III. TRADITIONAL SILICON SOLAR CELLS

Traditional solar cells are made from silicon, and are currently the most efficient solar cells available for residential use and account for around more than 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 [7].
There are currently four types of silicon based cells that are used for the production of solar panels for residential usage. The types are based on the type of silicon used, specifically:

A. 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 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 been the highest of all the solar panel types [3].
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 [3].

B. 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 grows 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%).

C. Amorphous Silicon Cells

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 [3].

D. 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 [3].

IV. CdTe THIN-FILM

Various materials and technologies are used to produce solar cell fabrication based on low cost and high efficiency. One of these solar cells is CdTe solar cell. Thin-Film CdTe based PV cells are one of the most promising candidates for low cost PV energy conversion because of the possibility of higher efficiency with reduced materials, reliable and stable cell operation. CdTe solar cells have some advantages. First of all the CdTe based solar cells are produced from polycrystalline materials and glass. Secondly the layer of CdTe solar cells can be deposited using different low cost techniques. Thirdly CdTe has direct optimum band gap (1.45ev) with high absorption coefficient over 5x10power15 per centimeter. This means all the potential photons with energy greater than the band gap can be absorbed within a few micrometer of CdTe absorber layer. Hence, this makes the cost of material for based CdTe solar cells relatively very low which the objective of PV cell researcher which is using less material by making the cells thinner. By choosing the baseline CdTe solar cells with supersaturate structure, we can modify the baseline case to increase the efficiency and reduce the cost. The baseline case efficiency has been recorded around 15% which is low and has higher cost compared to thinner CdTe solar cells. The way which we can modify the baseline cases are:

a) Reducing the thickness of the front contact by inserting suitable buffer layer which reduces the cost. The buffer layer increases the morphology of the window layer and reduce the leakage current due to pinholes, Buffer layer such as ZNO [9].

b) Choice of suitable window layer with high energy gap and reducing its thickness which increase the blue region response of the cells and reduces the surface recombination current in the window layer.

c) Inserting suitable back surface field layer which reduces the back surface recombination and reduce the barrier height of holes. This subsequently increases the Voc and Jsc and efficiency.BSF such as ZnTe, Sb2Te3, As2Te3.

d) Increasing the doping and minority carrier life time of absorber layer which increase the Voc and FF.

The maximum theoretical efficiency of CdS/CdTe cell at standard solar spectrum is about 29% but with above improvements practical devices with higher efficiency around 19% is feasible [10]. The some result which has been obtained by using 1D AMPS software is [11]:

ITO/ZNO/CDS/CdTe/ZnTe/ni

Voc=.97 Jsc=25.66 FF=.81 EFF=20.00%

ITO/ZnO/CdS/CdTe/Sb2Te3/Mo

Voc=.97 Jsc=25.04 FF=.76 EFF=18.59

ITO/ZnO/CdS/CdTe/As2Te3/Al

Voc=.93 Jsc=25.87 FF=.82 EFF=19.90

V. COMPARISON

Silicon cells are non toxic and is abundant compared to CdTe cells. As we know the optimum band gap for a layer to have optimum Jsc and Voc is between 1.4-1.6 eV but energy gap of silicon solar cells are 1.1ev which is lower than CdTe Thin-Film (1.45). First generation solar cells accounted for 80% of commercial production compared to Thin-Film solar cells (second generation solar cells), though the market share of these solar cells are declining [3].
The advantages of Thin-Film solar cells are the following:

a) Lower manufacturing costs
b) Lower cost per watt can be achieved
c) Reduced mass
d) Less support is needed when placing panels on rooftops
e) Allows fitting panels on light or flexible materials, even textiles.

The current Disadvantages of Thin-Film solar cells are the following:

a) Typically, the efficiencies of thin-film solar cells are lower compared with silicon (wafer-based) solar cells
b) Increased toxicity Advantages of traditional silicon cells are the following:
c) Broad spectral absorption range High carrier motilities

Disadvantages of traditional silicon are the following:

a) Requires expensive manufacturing technologies
b) Growing and sawing of ingots is a highly energy intensive process
c) Fairly easy for an electron generated in another molecule to hit a hole left behind in a previous photo excitation.
d) Much of the energy of higher energy photons, at the blue and violet end of the spectrum, is wasted as heat

VI. CONCLUSION

One of the more significant findings to emerge from this study is that new generation of solar cells can be guaranteed as future energy in the world and based on the energy and cost efficiency. So second generation of solar cells provided many advantages rather than traditional solar cells (silicon solar cells) .the second major finding was that the evaluation of solar cells are based on low cost and high conversion efficiency of the cells. Traditional Silicon cells have a quite high efficiency compared to CdTe Thin-Film cells, but very pure silicon is needed, and due to the energy-requiring process, the price is high compared to the power output. By making ultra thin CdTe solar cell, we decrease the required material, required energy, required time and cost of the CdTe solar cells and subsequently increasing the efficiency. Hence the second generation solar cells (Thin-Film solar cells) such as CdTe solar cells are preferred to be used which the cost of the cells are not very high compared to output power. The objective of this research is to show that Thin-Film solar cells like CdTe are more economical to be used in solar cells compared to traditional silicon solar cells.

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