COMPARATIVE ANALYSIS OF MONOCRYSTALLINE, POLYCRYSTALLINE AND THIN FILM PV CELLS

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ABSTRACT

There are basically three most commonly used types of solar panel options currently available. They are monocrystalline, polycrystalline (also known as multi-crystalline), and thin-film. These solar panels differ in how they're constructed, their appearance, their performance, their costs, and the installations. Each of these are best suited for one or the other applications and the solar panel type best suited for our installation will depend on the factors specific to our own property and desired system characteristics. We are here comparing all these types of solar panels analytically as well as economically, thus finding out the most efficient and cost effective panel for our further research.

Keywords :- monocrystalline, polycrystalline, thin-film, solar panels.

1. INTRODUCTION

The energy demand is skyrocketing and any steps towards meeting the demand are important. Considering the dual threat of extinction of fossil fuel on one hand and the health problem due to toxic gases liberated by the use of fossil fuels on the other hand, the use of photovoltaic cells is a smart option. It is an option worth exploring and an option definitely worth optimizing. An option which carries the promise of a cleaner, greener and a healthier tomorrow, the prospects are endless and so are the benefits. The process of converting light (photons) to electricity (voltage) is generally called the solar photovoltaic (PV) effect. Photovoltaic solar cells transform sunlight directly into solar power (electricity). They use a thin layer of semi-conductor that is charged differently between the top and bottom layers. The semi-conducting material can be encased between a sheet of glass or a polymer resin. When exposed to daylight, electrons in the semi-conducting material absorb the photons, increasing their energy. These vibrate between the top and bottom surfaces of the semi-conducting material. This movement of excited electrons generates a current known as a direct current (DC). This is then fed through an inverter, which converts the power to alternating current (AC) for use in our home.

2. ORIGIN OF PHOTOVOLTAIC

One important way to convert solar energy into electricity occurs by the photovoltaic effect which was first observed by Becquerel. It is generally defined as the emergence of electric voltage between two electrodes attached to a solid or liquid system with shining light onto this system. The word Photo-voltaic is a combination of the Greek word for Light and volt in the name of the physicist Allesandro Volta. It states the direct conversion of sunlight into energy by means of solar cells.[1]

3. CLASSIFICATION OF PHOTOVOLTAIC SOLAR CELL

There are varieties of solar cell present for the different energy requirements. Following are the solar cells available for the generation of the power given below;

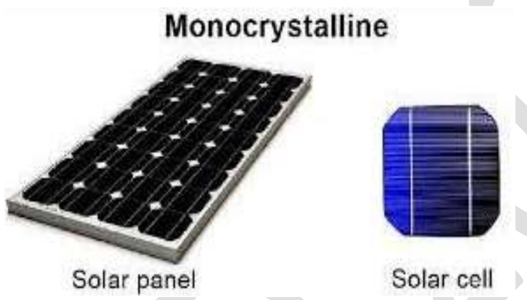
3.1 Monocrystalline silicon or single-crystal si (mono-si)

Monocrystalline silicon solar cell is a type in which the crystal structure is homogenous throughout the material also the orientation, lattice pattern, and electronic properties are constant throughout the material. Atoms like phosphorus and boron are often incorporated into the film to make the silicon n-type or p-type respectively. Monocrystalline silicon solar cell is fabricated in the form of silicon layers, usually by the Czochralski Growth method, and is quite expensive depending on the radial size of the designed single crystal wafer. This monocrystalline material is one of the chief expenses associated with producing photovoltaic cells where about 40% of the final cost of the product is attributable to the cost of the starting silicon wafer used in cell manufacturing.[1]

Monocrystalline silicon solar cell is generally used in the manufacturing of high performance solar cells. Single crystal is also often replaced by polycrystalline or multi crystalline silicon to reduce the cost. Monocrystalline solar cells can achieve 21% efficiency whereas other types of less expensive cells including thin film and polycrystalline are only able to achieve around 10% efficiency.

Advantages: i) Efficiency higher than poly-crystalline type.
ii) Better in shady condition.

Disadvantages: i) Affected by temperature.
ii) Cost is more.



3.2 Polycrystalline silicon or polysilicon (poly-si)

Polycrystalline silicon solar cell consists of many smaller silicon grains of varied crystallographic orientation. This material can be obtained easily by cooling liquid silicon by using a seed crystal of the desired crystal structure. Additionally, another method for crystallizing amorphous silicon to form polysilicon is high temperature chemical vapour deposition (CVD). Poly-crystalline material is generally prepared from millions or billions of small silicon crystals. The poly-silicon solar cell is less efficient because electrons are captured or generated less efficiently where the crystals of silicon touch. However, poly solar cell panels are not as efficient, but they are cheaper to manufacture so that they can still be competitive on Rs./watt wise. This type of solar cell needs more area to produce the same amount of electricity as the mono-crystalline cells.

Advantages: i) Polycrystalline panels are less expensive to buy.
ii) Polycrystalline panels are less expensive to manufacture.
iii) As reliable as Mono-crystalline.

Disadvantages: i) Efficiency lowers than mono-crystalline type.
ii) Very sensitive to shade.
iii) A little more affected by high temperatures.

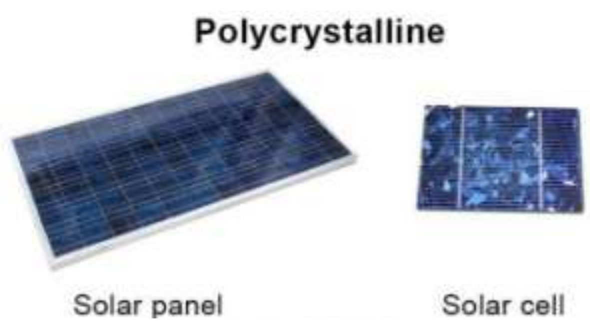


Figure 2: Polycrystalline silicon panel

3.3 Amorphous Silicon (A-Si)

Amorphous solar panels are well established form of thin film solar cell. Amorphous silicon solar cells are produced by vapor-depositing a thin layer of silicon material about 1 micrometer thick on a substratum material such as glass or metal. They have three layers to capture light from the full spectrum of the sun. Amorphous silicon can also be accumulated at very low temperatures, as low as 75℃, which as well as allows for deposition on plastic. In this type of simplest form, the cell structure has a same sequence of p-i-n layers. However, single layer solar cells suffer from significant deterioration in their power output when exposed to the direct sun. Amorphous silicon solar cell (a-Si) is the non-crystalline form of silicon. It is the well-developed of the thin film technologies having been on the market for more than 15 years. This type is generally used in pocket calculators, but it also provides powers to some private homes, buildings, and remote facilities.

Advantages:
i) Amorphous solar cells are less expensive.
ii) They are more flexible.
iii) Some are made with shade resistant technology or multiple circuits, which allow the panels to continue outputting electricity even if some of the cells are shaded.

Disadvantages:
i) They have a shorter lifetime and degrade faster than the other types of solar cells.
ii) Amorphous panels are less efficient.

Figure 3: Amorphous silicon panel

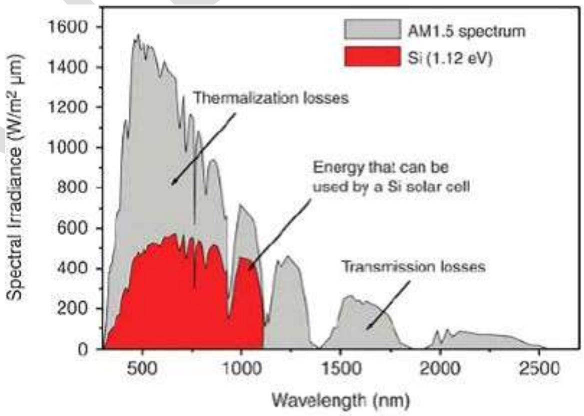


Figure 4: Absorption capacity of silicon solar cell

3.4 Multi-Junction Solar Cells or Tandem Cells

Multi-junction solar cells are solar cell with multiple p-n junctions made of different semiconductor materials. In this each material's p-n junction will produce electric current with respect to a different wavelength of light. Multi-junction solar cells are producing electric current at multiple wavelengths of light, increasing the conversion efficiency of the no-cost solar light power to usable electric power. Conventional single-junction solar cells have a maximum theoretical efficiency of 34%. Theoretically, with an infinite number of junctions, multi-junction cell efficiency would be 87% under highly concentrated sunlight. Currently, the best lab examples of conventional silicon solar cells have efficiencies around 25%, while lab examples of multi-junction cells have demonstrated performance over 43%. Commercial examples of tandem, two layer cells are widely present at 30% under one-sun illumination, and improve around 40% under concentrated sunlight. However, this efficiency is achieved at the cost of increased complexity and manufacturing price. To date, their higher price and higher price-to-performance ratio have restricted their use to special roles, particularly in aerospace where their high power-to-weight ratio is desirable. In terrestrial applications these types of solar cells have been suggested for use in concentrated photovoltaics (CPV). Commonly used triple-junction solar cells currently in production are made of GaInP (1.9 eV), GaAs (1.4 eV), and Ge (0.7 eV); advanced multi-junction solar cell concepts foresee use of AlGaInP (2.2 eV), GaInP (1.7 eV), AlGaAs (1.6 eV), GaInAs (1.2 eV), GaInNAs (1.0-1.1 eV).

Advantages: i) Maximum efficiency

Disadvantages: i) Difficult to produce.

ii) High cost.

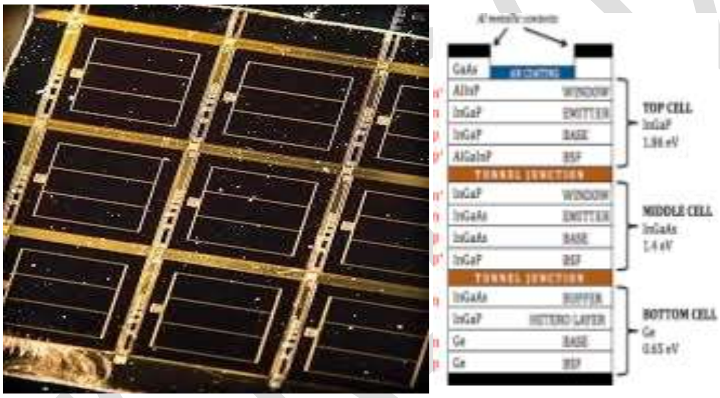


Figure 5: Multi junction solar cell

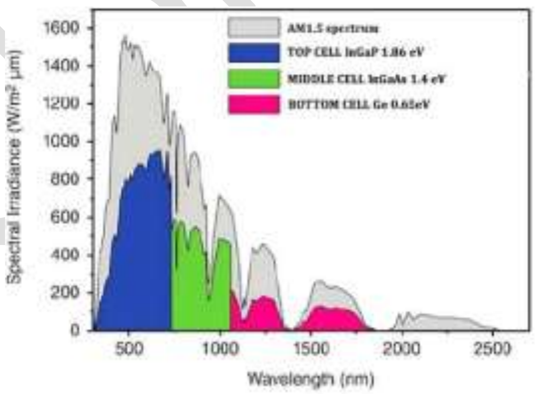


Figure 6: Absorption capacity of multi junction solar cell

3.5 Cadmium Telluride (CdTe)

Cadmium telluride (CdTe) photovoltaics describe a photovoltaic (PV) technology that is based on the use of cadmium telluride thin film, a semiconductor layer designed to absorb and convert sunlight into electricity. Cdte photovoltaics is the only thin film photovoltaic technology to surpass crystalline silicon PV in cheapness for a significant portion of the PV market, namely in multi-kilowatt systems. Cdte photovoltaic solar cell is considered the ecologically leading technology as it provides a solution to key ecological issues including climate change, energy security, and water scarcity. [2]

It is also considered the most eco-efficient current PV technology when comparing a range of application e.g. large scale ground mount applications or commercial rooftop applications. On a life cycle basis, Cdte photovoltaic solar cell has the smallest carbon footprint, lowest water use, and fastest energy payback time of all solar technologies. A fast energy payback time enables photovoltaic to scale with faster carbon reductions without causing short term energy deficits.

Advantages: i) Panels can be manufactured at lower costs than silicon based solar panels.
ii) Availability of cadmium.

Disadvantages: i) Non availability of telluride.
ii) Lower efficiency.
iii) Toxicity of cadmium.

Figure 7: CdTe thin film solar cell

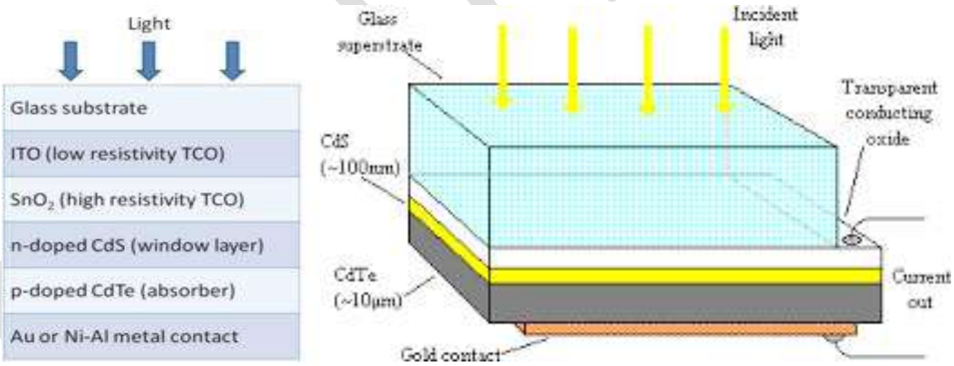


Figure 8: Cross-section of a CdTe thin film solar cell

3.6 Copper Indium Gallium Selenide (Cigs)

Copper indium gallium selenide (CuInxGa1-xSe2 or CIGS) is a direct band-gap semiconductor useful for the manufacture of solar cells. The copper indium gallium selenide absorber is deposited on a glass or plastic backing, along with electrodes on the front and back to collect current. Because the material of CIGS has a high absorption coefficient and strongly absorbs sunlight, a much thinner film is required than of other semiconductor materials.

Devices made with CIGS materials belong to the thin-film category of photovoltaics. CIGS is one of three mainstream thin-film photovoltaic technologies, the other two being cadmium telluride and amorphous silicon. Like these materials, copper indium gallium selenide layers are thin enough to be flexible, allowing them to be deposited on flexible substrates. However, all of these technologies are normally used in high-temperature deposition techniques; the best performance normally comes from cells deposited on glass. Even then the performance is marginal as compared to modern polysilicon based solar panels. Advancement in low temperature deposition of CIGS cells has erased much of this performance difference, even with flexible designs.

Advantages: i) CIGS has highest energy yield (KWh/kWp).

ii) Exceptionally high absorption coefficient.

iii) Better resistance to heat.

Disadvantages: i) Difficult to make.

ii) Cost is higher than mono-crystalline silicon cells.

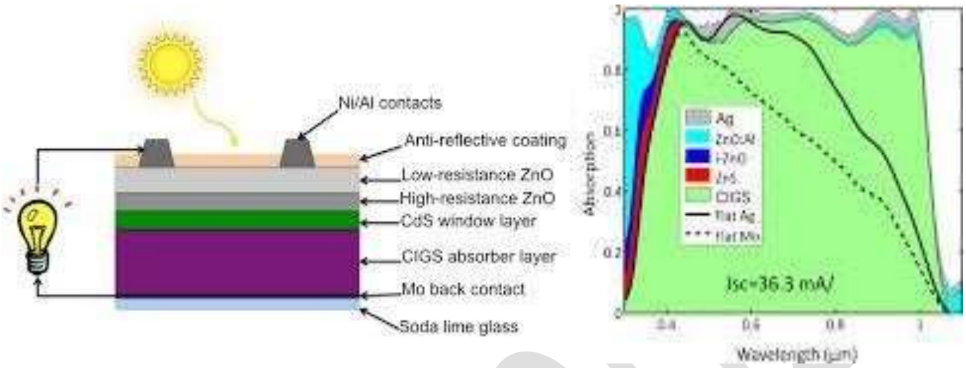


Figure 9: CIGS device structure

3.7 Dye Synthesized Solar Cell

A dye- synthesized solar cell (DSSC, DSC) is a low-cost solar cell belonging to the group of thin film solar cells. DSSC solar cell is based on a semiconductor formed between a photo-sensitized anode and an electrolyte, a photo electrochemical system. The modern version of a DSC, also known as the Grätzel cell, was originally co-invented in 1988 by Brian O'Regan and Michael Grätzel at UC Berkeley and this work was later developed’8 by the aforementioned scientists at the École Polytechnique Fédérale de Lausanne until the publication of the first high efficiency DSSC in 1991.[2]

Advantages: i) DSSCs are currently the most efficient third-generation solar cell.

ii) It is simple to make using conventional roll-printing techniques and semi-transparent which offers a variety of uses not applicable to glass based systems

iii) Most of the materials used are low-cost.

Disadvantages: i) Temperature stability problem.

ii) Costly ruthenium (dye), platinum (catalyst) and conducting glass or plastic (contact) are needed to produce a DSSC.

iii) Electrolyte solution contains volatile organic compounds (or VOC's), solvents which are hazardous to human health and the environment.

Figure 10: Dye-sensitized solar cell

3.8 Nano Crystal Solar Cells

Nanocrystal solar cells are based on a substrate with a coating of nano crystals. These nanocrystals are generally based on silicon, CdTe or CIGS and the substrates are generally silicon or various organic conductors. Quantum dot solar cells are examples of this approach, but take advantage of quantum mechanical effects to achieve further performance. Dye-sensitized solar cell is another related example, but with the nano structuring as a part of the substrate.

Solar cells made from cheap nanocrystal-based inks possess the potential to be equally efficient as the traditional inorganic cells recently used in solar panels, but can be printed less expensively. Corps like Solexant has recently started manufacturing solar cells to test the technology. Solexant is investing on simpler, cheaper printing processes and materials, with lower initial capital costs to build its plants. This company expects to sell modules for $1 per watt, with efficiencies above 10 percent. Nanocrystal solar cells are the solar cells made on a roll-to-roll printer from an ink consisting of the rod-shaped inorganic semiconducting nano crystals shown below in fig. The nano crystal cells were printed on a flexible metal foil and will be topped with a glass plate.

Advantages: i) Flexibility
ii) Lower costs
iii) Clean power generation

Disadvantage: i) Nanocrystal solar cells are not suitable for large scale manufacturing.

Figure 11: [illegible] ocrystal cell

4. COMPARISON OF THREE MAIN TYPES OF SOLAR PANELS

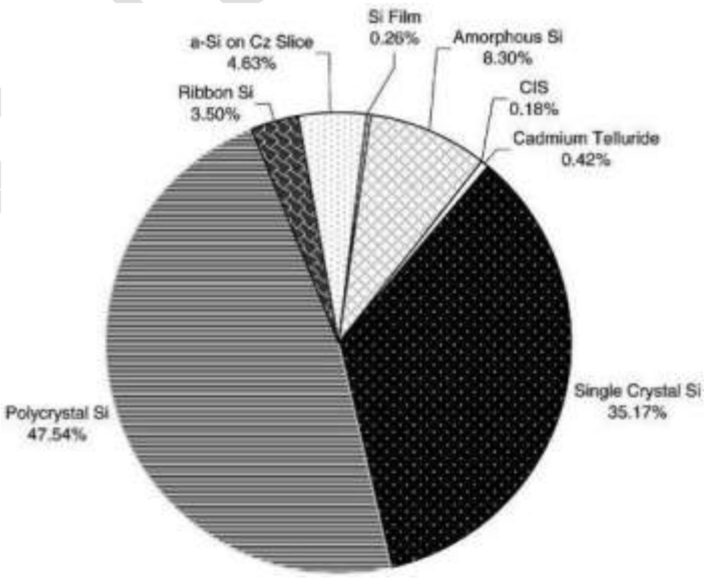


Figure 12: Market shares of different photovoltaic materials

To generate electricity, solar cells are manufactured from a semiconducting material that converts light energy into electricity. Silicon is the most commonly used semiconductor material for manufacturing a Solar

Cell. On comparing the performance of three types of solar cells in general lighting conditions on a sunny day following results were found which are graphically represented as.[1]

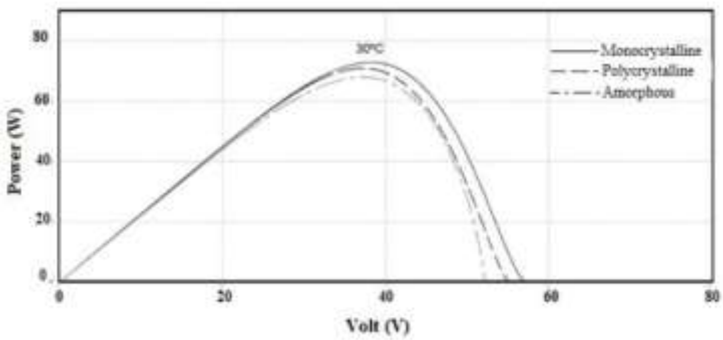


Figure 13: Performance results of different types of solar cells

It can be observed that each type of PV panel is not suitable in all locations also each location having its own weather characteristics like ambient temperature and solar irradiance that make a certain PV panel is better than the other. Only the temperature as environmental parameter is the main factor considered in this study. From the observed results Table 1 illustrates some recommendations upon each type of solar array and the best temperature range to use it. These recommendations are built on the effect of ambient temperature on the cell efficiency, which vary from one type of solar panel to another and the cost of each type of solar panel, which when the efficiency of the solar cell varies due to temperature change the cost also varies since the price per watt peak of each type is constant and given at certain temperature. [2]

Table - 1: Types of solar panel as per different location temperature

Location Temperature	Type Of Solar Panel
30 ℃ Or Less	Monocrystalline
40 ℃ Or Less	Polycrystalline
More Than 40 ℃	Amorphous Thin Film

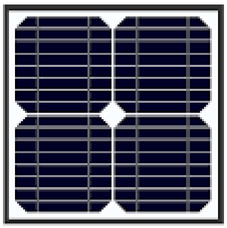
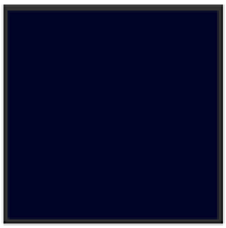
There are three major types of solar cells: monocrystalline, polycrystalline, and thin-film. Each cell type has its own unique advantages and disadvantages, and the solar panel type best suited for your installation will depend on factors specific to your own property and desired system characteristics.

Table - 2: Advantages and disadvantages of different types of solar panel

Type Of Solar Panel	Advantages	Disadvantages
Monocrystalline	• High efficiency/performance • Aesthetics	• Higher costs
Polycrystalline	• Low cost	• Lower efficiency/performance
Amorphous Thin Film	• Portable and flexible • Lightweight • Aesthetics	• Lowest efficiency/performance

The overall comparison analysis of the three types of solar cells, viz. Monocrystalline, Polycrystalline and Amorphous Thin Film on the basis of all the review done can be concluded in the following tabular format.

Table - 3: Overall comparison of three types of solar cells

Type	Monocrystalline 	Polycrystalline 	Amorphous Thin Film 
Efficiency	14% to 18% cell efficiency	12% to 14% cell efficiency	5% to 6% cell efficiency
Temperature tolerance	0% +5%	-5% +5%	-3% +3%
Life time	25 to 30 years life span	20 to 25 years life span	15 to 20 years life span

5. CONCLUSION

The three types of solar cells; amorphous thin film, monocrystalline and polycrystalline are affected by the temperature rise and also each type has its own efficiency having the monocrystalline in the first place then the polycrystalline and finally come the amorphous thin film. But not only the efficiency that matters the effect of temperature is also important; the amorphous thin film having the least temperature factor shows the least decrease in efficiency because of the rise in temperature then comes the polycrystalline and finally the monocrystalline. Each type of PV panel is not suitable in all locations; each location having its own weather characteristics like temperature, solar irradiance, dust density and other factors which makes certain PV panel better than the other. For locations having a maximum average ambient temperature equal to 30℃ or less, the monocrystalline type would be the most suitable to use, while if the average maximum ambient temperature of the location is 40℃ or less the polycrystalline would be better. The amorphous thin film type would be most suitable for locations having average maximum ambient temperature more than 40℃.

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