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EFFECT OF PANEL MATERIALS ON THE PERFORMANCE OF SOLAR CELLS

S. Thangalakshmi[1], V. Ganeshram[2], K. Sivasami[3], K. Sathiyasekar[4]*

[1*]Faculty, School of Marine Engineering and Technology, Indian Maritime University, Chennai Campus.

[2]Faculty, School of Marine Engineering and Technology, Indian Maritime University, Chennai Campus.

[3]Associate Professor, School of Marine Engineering and Technology, Indian Maritime University, Chennai Campus.

[4]Professor, Department of Electrical and Electronics Engineering, Prathyusha Engineering College, Tiruvallur.

[1*]stlakshmi@imu.ac.in,[2]vganeshram@imu.ac.in,[3]ksivasami@imu.ac.in,[4]ksathiyasekar@gmail.com

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ABSTRACT

Electrical energy has become part and parcel of our life as all the domestic modern appliances use electricity because of its cleanliness, availability and ease of control. Also, conservation of such energy is paramount not only on economic aspect but also to extend the life of resources for further use. Presently, most of the electricity is generated using power generating plants that use coal as fuel. In addition to produce energy, they do contaminate the environs by discharging flue gases chiefly carbon dioxide. The extent of carbon dioxide discharged into the air as an end result of actions of a specific individual, group or public is referred as carbon footprint and globally there is a call for reducing this carbon foot print to curtail its unfavorableimpacts on the society. Hence, though there are other resources like oil and gases are available for producing electrical energy, they do have the same effect. They are unsustainable. More than conserving the energy, it is highly needed to use renewable and sustainable energies to produce electricity. The cheap, clean and available renewable energy is solar energy. Photovoltaics (PV) is a guileless and smart method of hitching the solar energy. PV cells/solar cells are exclusive in that they reliably deliver electricity through the solar radiation hitting them. All the solar radiation falling on a PV cell or panel is not

completely converted as electrical energy but it is decided by the materials used for PV cells. There are various other factors that judge the outcome of a solar panel namely, the temperature, solar irradiance, fill factor etc. The aim of this study is to explore and relate the various materials used for PV panels based on their properties and other significant factors. This will serve as a guide for researchers for choosing a proper material for a particular application.

INTRODUCTION

The Indian power sector has to experience tremendous alterations in the market structure, supply-consumption chain etc., because of the global changes in energy market. Hence, government should pay attention on renewables keeping in mind the concerns related to changes in climate, reduced cost on renewables, and augmented use of electric conveyance owing to superior storage methodologies of electricity. The rural electrification is anticipated to raise by 33% in 2025. Besides, nation's economy and electricity consumption are very closely associated.

While increasing the electric power installed capacity, the mode of production is considered vital. The complete installed capacity to meet the electricity demand in our nation is expected to be 586 GW by 2025 and it is planned to generate 22% of total capacity through solarPV [1]. PV cells are nowadays extensively used for their economic feasibility as well as lower carbon footprint.This eco-friendly impact of generation of electric power make it significant to examine the different kind of photovoltaics [2].The carbon footprint is approximately 20 and 25 g of CO_2 equivalent for every unit (kWh) of electricity with regard tosilicon cells ofboth mono and polycrystalline cells . The pay-back period is also reduced drastically with solar PV. It is around 1 year and around 2 years for pc-Si and mc-Si respectively [3]. The material preferred for PV cell decides its suitability for a specific use and the efficiency. The yield of solar cell as well is influenced by numerous factors and supplementary fixtures used in combination with panel. The following sections of this paper highlights on those elements.

SOLAR ENERGY

Solar irradiance is made as useful electricity with the help of several techniques. Solar collectors are being used to heat the water for residential and industrial purposes. Passive collectors are employed for heating space and buildings. This can even be utilized for specific lighting needs. All these help to improve or satisfy the prime need of human fraternity without wasting the energy or without greenhouse gas effect. Exceptional mirrors are employed to get higher temperature to generator electrical energy. Other prominent applications of solar thermal include driers, desalination, heat pump, pumps for irrigation, day lighting of commercial buildings and factories [4-6].

A solar alias photovoltaic cell is an instrument comprising of semiconductors that alters daylight into electricity promptly. The impinging light on the cell develops voltage as well as current to produce electrical power. This is accomplished when the following two prime requirements are met: (i) a viable material which could raise an electron to next energy state by reasonable absorption of light photons; (ii) moving the excited electrons of higher energy level to the external network from the PV cell.

After dispelling the energy into the connected circuit in the periphery, the electron returns to the PV cell. Numerous materials are available that could possibly fulfil the needs of conversion of energy. Still, in real-world applications, the conversion process by photovoltaic effect exclusively makes use of semiconducting material forming PN junctions. It is a regular practise to fix the PV units on the front part and rooftops of the constructing structures [7].

SOLAR PHOTOVOLTAIC SYSTEMS

Solar photovoltaic systems utilizes PV effect and the working is more or less similar to that of a diode.

PhotoVoltaic Effect

It is a method of converting thermalenergy from sun into electrical energy. These contains zero emission ofCO_2 whichareecofriendly to the global. Photonsengrossed by these materials aretransmitted for the mobility of electrons. The Figure. 1. represents the general structure of a solar Photo-Voltaic cell.

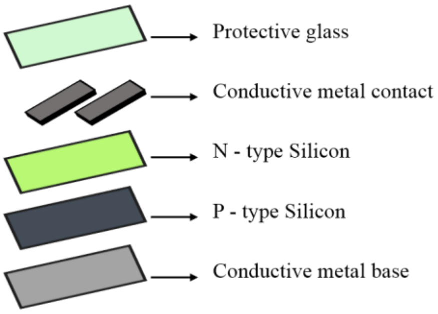

Figure 1. Structure of Solar PV Cell

Working Principle

The working principle of the cell is portrayedvia Fig. 2. As soon as two different layers of semiconductor are made to contact, an electric potential is created amongst the layers. The respective charge carriers cross the layers and while doing so, the leave opposite charge at the junction. The negative and positive carriers do combine and vanish. At one point of time a depletion region/zone is formed and it obstructs further possibilities of passage of charge carriers. The detached immobile charge carriers develop the electrical field through zone of depletion. The developed field gives the required voltage to the flow of current via the exterior network.

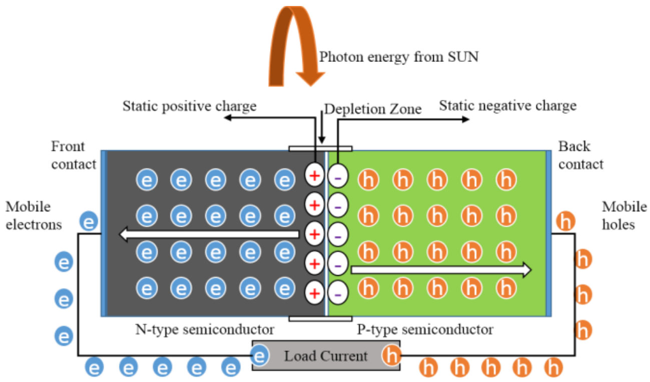

Figure 2. Working Principle of PV Cell

As per the principle of photovoltaic, the photon energy is involved by the form of layer and it istransported by the materials to the electrons because of which, the electrons aretransfer to the conduction band with adequate energy. It creates a vacant in the valence band. Finally the charge carriers migrate towards the opposite direction. With suitable energy or intensity of sun, the captivated energy exceed the energy in the bandgap, which depends on the type of the material. This makes atom collision possible and finally the electrons move freely to circulate the current through the external network [8-10]

CATEGORIES OF SOLAR PV CELL

The materials highly decide the movement of free electrons once daylight falls on the cell [11]. The Solar PV cells are largely categorized into four generations based on the period and type of materials that are employed during the fabrication. The commercially available cells belong to the primary generation cells and are popularly known as mono- and poly-crystalline silicon. The next generation cells were developed forlessening the price and to use minimum quantity of material. The material reduction was accomplished by decreasing the thickness of the films used and thereby they were referred to as thin- or micro- film silicon. Their thickness is hardly ranging from few nanometres to few micrometres. Further investigations paved way to light controlling methods by means of dye sensitized solar cells (DSSCS), organic solar cells, etc. The current generation solar PV cells utilizes composite materials in order to harvest the combined advantages of previous generation materials [12-14]. The various generations of solar PV cell is epitomized in Fig. 3.

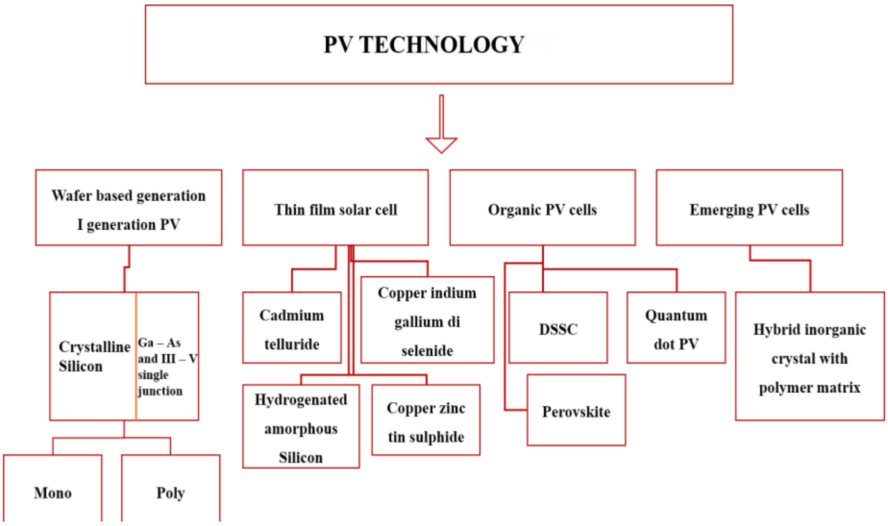

Figure 3. Various Generations of Solar PV Cell

SILICON CELLS (CRYSTALLINES)

Single crystalline cells are essentially made up of complete grown crystals they forms in one direction from tube- such as bars and then carved into tiny wafers. The standard mono crystalline PV cells used for trading would attain a greatest efficiency of 18 to 20 % based on the eminence of silicon employed in the cell. The fresh silicon is liquefied and drizzled into a mould of square shape, allowed to chill and seamlessly cut into square wafers for the case of poly crystalline cells. Though the process is relatively simpler the rate of purity is less and there exists considerable degree of non-uniformity, lower efficacy and space. In this case the empirical value of highest efficiency is about 16% [15-16]. Every wafer made of silicon is capable of carrying two to three watts of power. These crystalline cells have a voltage of 0.6 V at customary temperature and illumination levels. Thus, it becomes essential to connect as many number of solar cells as required in series to augment the power as well as voltage to make the panel well-matched with 12 V battery. There exists always a compromise amongst the usefulness and economy in case of crystalline technology [17-18]. The preliminary generation PV cells are again subdivided into 4 groups considering the technology used in fabrication such assilicone of monocrystalline, poly-crystalline, amorphous silicon and hybrid types.

mc-Si Solar PV cells

The cells of this category is generally made up of single crystal and the process used for manufacturing is Czochralski. This regular procedure is adopted to manufacture superior class of silicon wafers. The temperature needed for heating the chamber is 1773.15 K and the unprocessed silicon is thus melted down in a container. Subsequently the adequate doping is carried out to make p- or n- type. The controlling aspects such as rate of rise of temperature, pulling rate and rotational speed are carried out by plunging a seed crystal. Thus the slabs of silicon are cut into fine, thin, and uniform wafers. This types of production involves high cost but the efficacy of this type is superior to other types [19].

pc-Si Solar PV Cells

In this category, the PV cells are formed using silicon that is recrystallized. They are also cut into tiny wafers using saw. There is a huge saving in the cost of production by this type of fabrication but the commercial efficiency is relatively lower. To get better performance and outcomes, it is indispensable to fix these kind of panels in a larger surface area [20-21].

Amorphous Silicon

Instead of having a crystalline structure, the atoms of silicon is formed with several layers of minute thickness to form a particular structure of crystal. They have got the potential of captivating daylight even pasted as highly thin layers. For this reason, they may also called as thin film amorphous PV cells. They could withstand even high temperature but the drawback is that they require comparatively more space, approximately twice which is needed by crystalline silicon for yielding identical power.

THIN-FILM SOLAR CELLS

For producing this type of PV cells, two different layers are clutched amidst two contacting layers. The popular structures of this group are copper gallium di-selenide and CdTe. They are now manufactured with improved characteristics so as to enable them to yield an efficiency of around 23%. The absorbing materials applied in this category are said to have toxic contents. Modern technologies use non-toxic material for absorbing layer. The losses are comparatively less because of high energy absorption by thin material. The typical layer thickness of this group is 2.5 micro-metre, which is 100 times lesser than crystalline structure [22].

THIN- ORGANIC PV CELLS / DYE-SENSITIZED SOLAR CELLS

They come under the third generation. They are highly unique in comparison with the previous generation PV cells. That is, they do not require conventional PN junction for departing the charge carriers with photon energy.They do have many levels of energy, various electron-hole pair generation. They in fact catch the charge carriers well before the thermal ionization process. They offer many advantages like the bandgap can be tuned, they reap light from wide solar spectrum, flexible in fabrication, involves molecule to molecule relations [14].

EMERGING SOLAR CELLS

They are the current (fourth) generation PV cells that consists of composite materials. The polymers are combined with Nano-particles to form a single layer, which is capable of higher light absorption. They are piled into minute spectrum of compound layers and are economically viable. Also the efficiency is highly superior to any other generation PV cells. As there many layers of harvesting various spectrums of sunlight, they also sometimes called as Tandem PV cells [23].

SOLAR CELL PARAMETERS

As the material used for PV cell is basically semiconducting material and as the conduction of cell is enabled only if light impinges on it with appropriate intensity, the cell may be considered equivalent to a diode. The usual parameters or specification based on which, the yield of the cell is decided are the Fill Factor (FF), open-circuit voltage (Voc),short circuit current (Isc), and the efficiency (η).Like all other diodes, the volt-current characteristics or IV curve is essential for analysing the functions of PV cell. Current on solar Photo-Voltaic cell follows the equation for conventional diode current, which is mathematically expressed as,

$$I = I_0\left(e^{\frac{qV}{KT}} - 1\right)$$

Where, I = Flowing of net current in the diode, I_0 = Current leakage in diode during unavailability oflight, V = Voltage across the terminals of diode,q = absolute charge value, T& K are absolute temperature in kelvin and Boltzmann's constant.

Current in Short Circuit

The current obtained with diode terminals areshort-circuited. During short circuit the voltage is ideally zero. This is represented in the IV-curve of Fig. 4.

Open Circuit Voltage

Voltage maximum available across the Photo Voltaic cell while zero current flowing is referred so. This is linked to the quantity of forward bias when the junction is activated through the solar light current and is represented in Fig. 4.

Fill-Factor

The highest value of current and voltage that can happen in a PV cell is Isc and Voc respectively and at each value the power goes zero as one of the other quantity approaches zero. Fill-factor (FF) parameter is used for the measure of maximum current from a PV cell.

The ratio of highest current drawn through a Photo Voltaic cell to the material of open-circuit voltage and short-circuit current. Mathematically,

$FF = \frac{P_m}{I_{sc}V_{oc}}$Where, Pm is the maximum power.

S. No.	Author (s)	Point of concern	Observation and Remarks
1	Singh et al [26]	Temperature dependence on various parameters	Current increases in the reverse saturation with temperature and causes Voc to decrease which decreases the fill factor and hence the efficiency of the solar cell.
			Once the temperature increases the Band gapdecreases and this result in an increase in Jsc which acts to improve the efficiency of the cell
			Temperature dependent parameters and variation of efficiency during the temperature is small as the maximum temperature available is around 40℃, so we may not experience the increase in the efficiency of solar cell.
2	Fadliondi et al.[27]	Shading effects on the panel	A bypass diode can improve panel outcome during shading conditions.
			If shading over the PV panel, the positioning or locating of bypass diodes have a strong effect on the PV panel output power characteristics. By locating them properly, the output current increases and new peaks and maximum power point appears.
3	Chegaar et al. [28]	Upshot of light intensity	Various Authors have found that the changes in cell factors such as, Rsh, Is, Rs and n, with one diode model, in the brightness intensity over an approximate range of 160–1000

			W/m^2 for one pc-Si Solar PV with 156.25 square cm area, below room temperature.
			The short-circuit current, the photo-current, the ideal-factor and the increase of maximum power are found to be in a linear fashion with regard to rise in the intensity of radiation in the experimental range of watts per square metre, in room temperature. The voltage during open-circuited condition grows in a logarithmic fashion. At higher values of brightness intensity for about 500 watts per square metre, it reduces while a mild increase is observed in the fill-factor for a lower range of light intensity.
			The efficiency of conversion rises in a logarithmic manner for light intensities below 400 watts per square metre, but this value is exceeded, there is no significant increase in the efficiency or it is almost maintained at a same value. The current saturation increases exponentially. The resistance series is not changing with regard to light intensity. Shunt resistance is practically constant when the brightness intensity is lesser than 200 watts per square metre, but it starts dropping in a linear manner for the range of watts per square metre between 200 and 1000.
			For indoor and outdoor use the outcome shows the importance of considering the application oriented installations of solar-PV both with lower and higher range of brightness intensities.
4	Ebhota & Jen [29]	Low cost Nano materials	CO_2emissions suchas in Fossil fuels are the greatest economic drivers amongst the available fuels, but they have huge environmental threats and consequences. The increasing global energy demand coupled with the complex nature of the global energy dynamic make management challenging.
			CO_2emissions suchas in Fossilfuels are reduced by using an alternative tool such as Solar energy. It is the best option.
			Proper utilization of solar resource amongst renewable energy sources and the production of low-cost flexible PhotoVoltaic cells will facilitate energy trilemma success.
5	Praveen &Vijay aRamar aju[30]	Selection of Materials to optimize efficientsol arpanels	Material Selection such as CdTe, GaN, Si-Gallium Arsenide, Germanium, Metal oxide vapour deposition designs, thin films using amorphous silicon and c-Si will stretch the band gap so as to improve the competence of photo-voltaic cell. The levitation in demand can be administrated with these new generation supplies.
			The converting of solar energy into electrical energy is found to be more effective by incorporating materials having many layers and multiple junction as it permits to change the existing bounds in the bandgap.

Efficiency

It is computed as a part of incident input power that is transformed into useful electricity and is given by,

$$\eta = \frac{I_{sc}V_{oc}\,FF}{P_{in}}$$

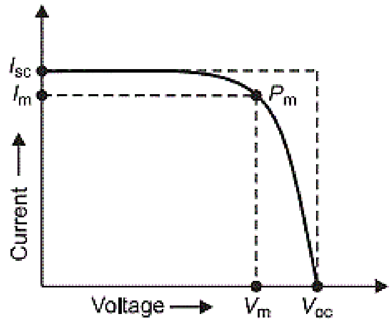

Figure 4.I - V Characteristics of Solar PV cell [25]

Tracking of Maximum Power point (MPPT)

Photo voltaic cell has desirable character to trace tracking of maximum power pointarray. Moreover, tracking of maximum power point (MPPT) is wanted in connecting -grid as well as captive photovoltaic modules as the solar irradiance and the temperature vary all through the day, as well as along seasons and topographical settings. This in turn modifies the I-V and P-V curve of the unit. The MPP is marked on theP – V curve and is depicted in Fig.5.

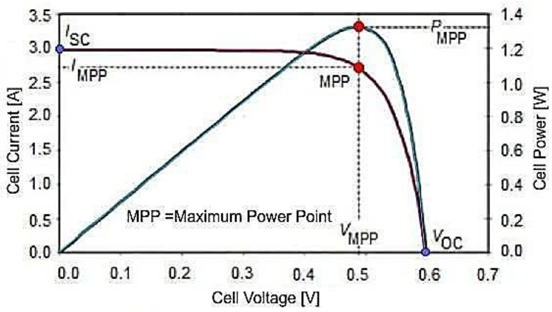

Figure 5.P - V Curve of Solar Cell [26]

OTHER MAJOR FACTORS DECIDING THE PERFORMANCE OF THE PV CELL

There are several aspects that decide the quality and performance of solar PV cell in addition to the materials. In other words, selection of material play a key role in addition to other factors for properly getting the electricity [31]. Most of the literatures have emphasized on these factors. Few of them are listed in Table I.The major factors reported in literature that are judged by selection of materials for panel are the solar irradiance and temperature.

CONCLUSION

There are variety of silicon and other semiconducting materials that are used for solar PV panels. The output or outcome of solar panel are decided majorly by short circuit current and open circuit voltage. They in turn provide proper maximum power. All the above parameters are influenced the band gap energy. In fact, it is this energy that decides the fill factor and efficiency of solar panel. Hence, selection of materials play a vital role in the performance of PV cells. Though, fourth generation PV cells are available and gaining popularity, the efficiency is still higher for crystalline structures. That too, for mono-crystalline structure out performs the poly-crystalline structure for its efficiency and least carbon footprint. However, the multi-layer structure and multi spectrum capabilities of emerging PV cells are economically viable but still more researches have to be performed to yield better efficiencies without much complications.

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