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Investigation and Performance Evaluation of of Solar Cell

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Abstract— **This search deals with the study of amorphous silicon cell which is relatively cheap and has a very high absorption capacity. Through previous studies found that the energy gap (1.7ev), which is not ideal where it's efficiency 5%. Also has been described by curves higher capacity we get with voltage and examine practical relationship between the filling coefficient and resistors R_{SH} , R_{S}. A typical fill factors range from 0.5 to 0.82.The ratio between input capacity and output capacity also has been calculated.**

Keywords-capacity, silicon cell, efficincy and ,fill factor.

I. I NTRODUCTION

A solar cell, also called a photovoltaic cell, is used to convert solar energy into electrical energy. Solar cells are the basic elements of a solar module (also known as a solar panel). Silicon is by far the commonest of a variety of semiconductors from which solar cells are made. A typical modern solar cell is squared-shaped measuri 10 cm × 10 cm. It is covered by a clear anti-reflection coating (ARC) that reduces the amount of light lost to reflection at the cell surface[5].

II. AMORPHOUS SILICON CELL

A amorphous silicon's unique properties, although the solar cells are designed needs to have an ultrathin (0.008 micrometer) p-type top layer, a thicker (0.5 to 1 micrometer) intrinsic middle layer, and a very thin (0.02 micrometer) n-type bottom layer. This design is called a "p-i-n" structure, being named for the types of the three layers. The top layer is made so thin and relatively transparent that most light passes right through it, to generate free electrons in the intrinsic layer.

The p- and n-layers produced by doping the amorphous silicon create an electric field across the entire intrinsic region, thus inducing electron movement layer[5].

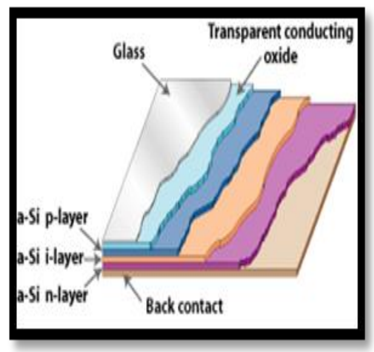

Figure.1 P-I-N amorphous silicon cell

A. Staebler -Wronski Effect

Instability is the greatest stumbling block for amorphous silicon. These cells experience the Staebler-Wronski effect, where their electrical output decreases over a period of time when first exposed to sunlight. Eventually, however, the electrical output stabilizes. This effect can result in up to a 20% loss in output before the material stabilizes. Exactly why this effect occurs is not fully understood, but part of the reason is likely related to the amorphous hydrogenated nature of the material. One way to mitigate—though not eliminate—this effect is to make amorphous silicon cells that have a multi junction design [5].

III. PHOTOVOLTAIC EFFECT

The photovoltaic effect is the basic physical process through which a PV cell converts sunlight into electricity. Sunlight is composed of photons (packets of solar energy). These photons contain different amounts of energy that correspond

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to the different wavelengths of the solar spectrum. When photons strike a PV cell, they may be reflected or absorbed, or they may pass right through. The absorbed photons generate electricity.

When the semiconductor is exposed to light, the energy

E(E=h*υ) where ***h*** is Plank's constant, ***v*** frequency of incident light Hz-of incident photons exceeding the threshold bandgap is absorbed by the semiconductor's electrons that access the conduction band starting to conduct electricity. Electrons in semiconductors, in fact, are weakly bonded to the atomic nucleus and occupy the valence energy band.

For each negatively charged electron, a corresponding mobile positive charge, a hole, is created. The electrons and holes near the p-n junction are swept across in opposite directions by the action of the electric field, where a contact drives such electrons to an external circuit where they lose energy doing work such as powering a light source and then return to the material's valence band through a second selective contact closing the circuit as shown in Figure 2 [3].

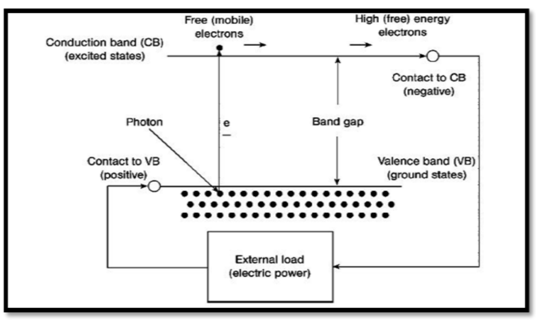

Figure 2 Relation between the energy and the spatial boundaries in a solar cell.

Only photons whose energy is greater than the energy bandgap (E_G) are able to create an electron–hole pair and thus contribute to the energy conversion process. Therefore, the spectral nature of sunlight is a fundamental aspect affecting the design of efficient solar cells as shown in Figure 3 .

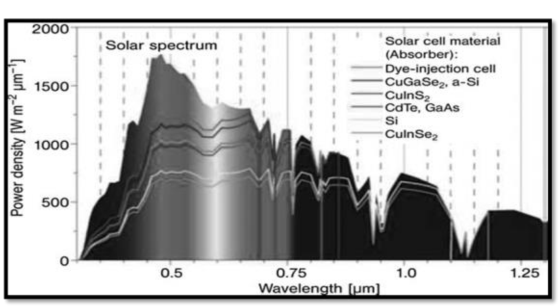

Figure 3 The solar spectrum of sunlight together with the quantum efficiency profile of semiconductor materials.

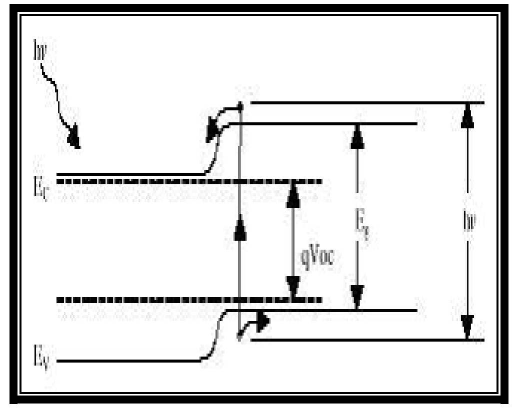

Figure 4 Energy Band Diagram of a Silicon *p-n* junction Solar Cell.

The actual structural design of a photovoltaic device depends on the limitations of the material used in the PV cell. We will look briefly at four basic device designs commonly used with the materials it discussed in the following points.

A. Homo junction Device :

An example of this type of device structure is a CIS cell, where the junction is formed by contacting two different semiconductors CdS and $CuInSe_2$. This structure is often chosen for producing cells made of thin-film materials that absorb light much better than silicon. The top and bottom layers in a heterojunction device have different roles. The top layer, or "window" layer, is a material with a high bandgap selected for its transparency to light. The window allows almost all incident light to reach the bottom layer, which is a material with low bandgap that readily absorbs light. This light then generates electrons and holes very near the junction, which helps to effectively separate the electrons and holes before they can recombine.

Heterojunction devices have an inherent advantage over homojunction devices, which require materials that can be doped both p- and n-type. Many PV materials can be doped either p-type or n-type, but not both. Again, because heterojunctions don't have this constraint, many promising PV materials can be investigated to produce optimal cells.

Also, a high-bandgap window layer reduces the cell's series resistance. The window material can be made highly conductive, and the thickness can be increased without reducing the transmittance of light. As a result, light-generated electrons can easily flow laterally in the window layer to reach an electrical contact[7].

B. p-i-n and n-i-p Devices :

Typically, amorphous silicon thin-film cells use a p-i-n structure, whereas CdTe cells use an n-i-p structure. The basic scenario is as follows: A three-layer sandwich is created, with a middle intrinsic (i-type or undoped) layer between an n-type layer and a p-type layer. This geometry sets up an electric field between the p- and n-type regions that stretches across the middle intrinsic resistive region. Light generates free electrons and holes in the intrinsic region, which are then separated by the electric field.
In the p-i-n amorphous silicon (a-Si) cell, the top layer is p-type a-Si, the middle layer is intrinsic silicon, and the bottom layer is n-type a-Si. Amorphous silicon has many atomic-level electrical defects when it is highly conductive. So very little current would flow if an a-Si cell had to depend on diffusion. However, in a p-i-n cell, current flows because the free electrons and holes are generated within the influence of an electric field, rather than having to move toward the field.
In a CdTe cell, the device structure is similar to the a-Si cell, except the order of layers is flipped upside down. Specifically, in a typical CdTe cell, the top layer is p-type cadmium sulfide (CdS), the middle layer is intrinsic CdTe, and the bottom layer is n-type zinc telluride (ZnTe)[9].

Multi junction Devices

This structure, also called a cascade or tandem cell, can achieve a higher total conversion efficiency by capturing a larger portion of the solar spectrum. In the typical multi-junction cell, individual cells with different bandgaps are stacked on top of one another. The individual cells are stacked in such a way that sunlight falls first on the material having the largest bandgap. Photons not absorbed in the first cell are transmitted to the second cell, which then absorbs the higher-energy portion of the remaining solar radiation while remaining transparent to the lower-energy photons. These selective absorption processes continue through to the final cell, which has the smallest bandgap[3].

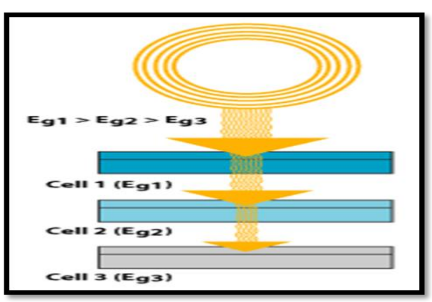

Figure 5 Three layer multi junction device.

A multi junction cell can be made in two different ways. In the mechanical stack approach, two individual solar cells are made independently, one with a high bandgap and one with a lower bandgap. Then the two cells are mechanically stacked, one on top of the other. In the monolithic approach, one complete solar cell is made first, and then the layers for the second cell are grown or deposited directly on the first.

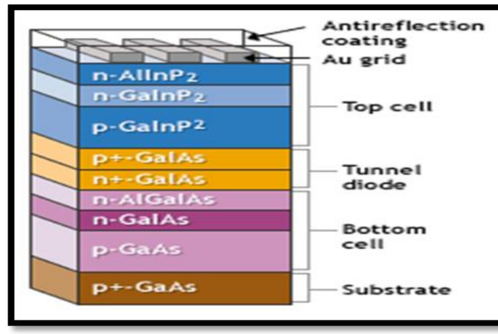

Figure 6 GaInP-GaAs multi junction device.

Much of today's research in multi junction cells focuses on gallium arsenide as one (or all) of the component cells. These cells have efficiencies of more than 35% under concentrated sunlight which is high for PV devices.

C. I-V characteristics:

PV cells can be modeled as a current source in parallel with a diode. When there is no light present to generate any current, the PV cell behaves like a diode. As the intensity of incident light increases, current is generated by the PV cell, as illustrated in Figure (7).

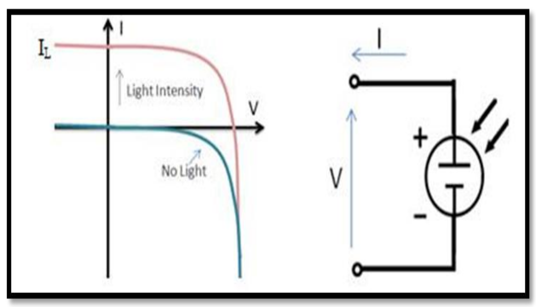

Figure 7 I -V curve for ideal photovoltaic cell

In an ideal cell, the total current I is equal to the current I_ℓ generated by the photoelectric effect minus the diode current I_D, according to the equation:

$$I = I_l - I_D = I_l - I_0(e^{q*v/KT} - 1)$$

Where

$\boldsymbol{I_0}$ is the saturation current of the diode
q is the elementary charge Coulombs
k is a constant of value
T is the cell temperature in Kelvin

where **n** is the diode ideality factor (typically between 1 and 2.Where **V** is the measured cell voltage that is either produced (power quadrant) or applied (voltage bias). Expanding the equation gives the simplified circuit model shown below and the following associated equation.

R_S and **R_{SH}** represents the series and shunt resistances that are described in further detail later in this document[1].

$$I = I_l - I_0 exp(^{q(V+Rs*I)/n*KT}) - V + IRs/R_{SH})$$

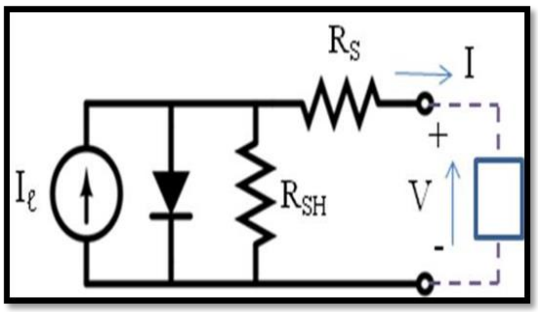

Figure.8 Simplified Equivalent Circuit Model for a Photovoltaic Cell

The **I-V curve** of an illuminated PV cell has the shape shown in Figure (9) as the voltage across the measuring load is swept from zero to V_{OC}, and many performance parameters for the cell can be determined from this data, as described in the sections below.

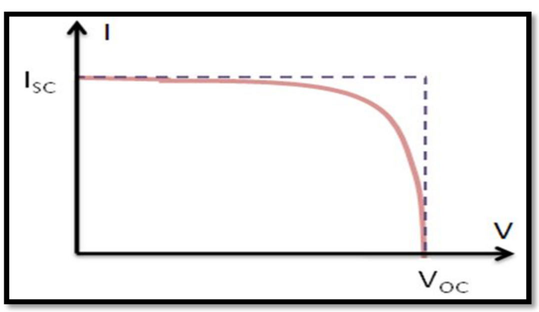

Figure9 Illuminated I-V Sweep Curve

VI. SHORT CIRCUIT CURRENT

The short circuit current I_{SC} corresponds to the short circuit condition when the impedance is low and is calculated when the voltage equals 0.

$$I \text{ at } (V=0) = I_{SC}$$

I_{SC} occurs at the beginning of the forward-bias sweep and is the maximum current value in the power quadrant. For an ideal cell, this maximum current value is the total current produced in the solar cell by photon excitation.

$$I_{SC} = I_{max} = I_L \qquad \textit{(for forward-bias power quadrant)}$$

V. OPEN CIRCUIT VOLTAGE

The open circuit voltage **(V_{OC})** occurs when there is no current passing through the cell.

$$V \text{ at } (I=0) = V_{OC}$$

V_{OC} is also the maximum voltage difference across the cell for a forward-bias sweep in the power quadrant.

$$V_{OC} = V_{max} \qquad \textit{(for forward-bias)}$$

VII. MAXIMUM POWER POINT

The power produced by the cell in Watts can be calculated along the I-V sweep by the equation P=I*V . At the I_{SC} and V_{OC} points, the power will be zero and the maximum value for power will occur between the two. The voltage and current at this maximum power point are denoted as V_{MP} and I_{MP} respectively[4].

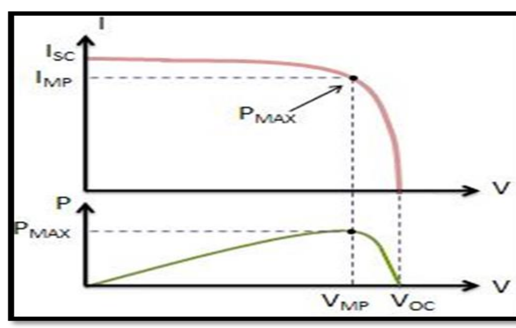

Figure.10 Maximum Power for an I-V Sweep

VIII FILL FACTOR

The Fill Factor (**FF**) is essentially a measure of quality of the solar cell. It is calculated by comparing the maximum power to the theoretical power (**P_T**) that would be output at both the open circuit voltage and short circuit current together. FF can also be interpreted graphically as the ratio of the rectangular areas depicted in Figure (11)[8].

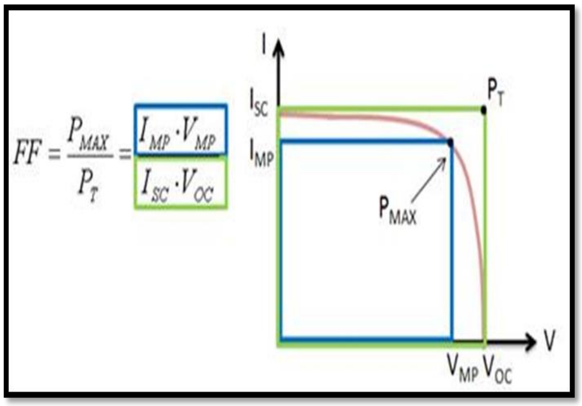

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Figure 11 Fill Factor

A larger fill factor is desirable, and corresponds to an **I-V** sweep that is more square-like. Typical fill factors range from 0.5 to 0.82. Fill factor is also often represented as a percentage.

VIIII EFFICIENCY (η)

Efficiency is the ratio of the electrical power output P_{out}, compared to the solar power input, P_{in}, into the PV cell. P_{out} can be taken to be P_{MAX} since the solar cell can be operated up to its maximum power output to get the maximum efficiency.

$$\eta = \frac{P_{OUT}}{P_{in}}$$

$$\eta_{max} = \frac{p_{max}}{p_{in}}$$

P_{in} is taken as the product of the irradiance of the incident light, measured in W/m^2 or in suns ($1000\ W/m^2$), with the surface area of the solar cell [m^2]. The maximum efficiency (η_{MAX}) found from a light test is not only an indication of the performance of the device under test, but, like all of the I-V parameters, can also be affected by ambient conditions such as temperature and the intensity and spectrum of the incident light. For this reason, it is recommended to test and compare PV cells using similar lighting and temperature conditions. [8]

VV. TEMPRETURE MEASUREMENT CONSIDERATIONS

The crystals used to make PV cells, like all semiconductors, are sensitive to temperature. Figure (12) depicts the effect of temperature on an I-V curve. When a PV cell is exposed to higher temperatures, I_{SC} increases slightly,
while V_{OC} decreases more significantly.

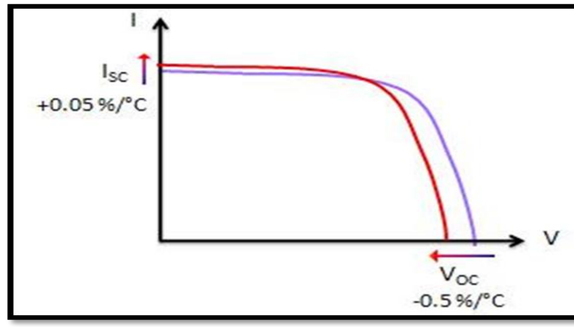

Figure 12 Temperature Effect on I-V Curve

For a specified set of ambient conditions, higher temperatures result in a decrease in the maximum power output P_{MAX}. Since the I-V curve will vary according to temperature, it is beneficial to record the conditions under which the I-V sweep was conducted[14].

VVI. I-V CURVES FOR MODULES

For a module or array of PV cells, the shape of the I-V curve does not change. However, it is scaled based on the number of cells connected in series and in parallel. When n is the number of cells connected in series and m is the number of cells connected in parallel and I_{SC} and V_{OC} are values for individual cells, the I-V curve for a module or an array is shown in Figure (13) [8].

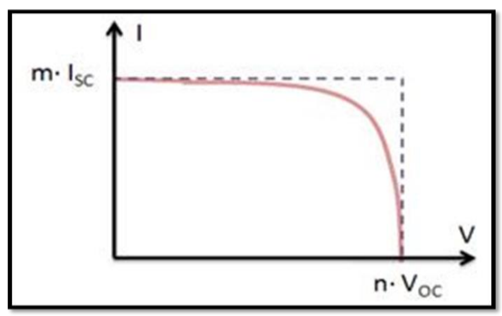

Figure. 13 **I-V** Curve for Modules and Arrays.

VVII CONCLUSION

From this work it conclude that:

- Very little maintenance is required to keep solar cells running. There are no moving parts in a solar cell.
- Photovoltaic cells are made from silicon which is the most abundant solid element on earth.
- Thin-Film are relatively cheap and has a much higher absorptivity than its silicon counterparts. Its main

drawbacks are that it has a low efficiency rate (approx. 5%), and its band-gap energy (1.7e.v) is not ideal.

- Mono-crystalline panels have a very high efficiency (up to 23 %) under unconcentrated sunlight, and a workable band-gap of 1.1. However, mono-crystal silicon cells are expensive and have low absorptivity.
- Polycrystalline silicon has the same band-gap as mono-crystalline, cheaper, but has a lower efficiency. Polycrystalline panels are significantly cheaper to produce than monocrystalline panels, they convert at a peak efficiency of around 12 percent. This is lower than monocrystalline panels, but significantly higher than thin film panels.

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