JACOBS
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Solar Cell

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Contents

Abstract

The main objective of this experiment was to investigate the different properties of the solar cell by using two different light sources. The efficiency η and fill factor FF were determined for several temperatures and intensities. It was found that higher efficiency and fill factor is acheived in lower temperature and for higher intensity of light. In this experiment efficiency of 8.06% was achieved at $29.27°C$ and 8.04 when intensity of light was $590w/m^2$. Also, yellow light was found to be more efficient that green light and they have the efficiency of 10.5% and 5.6% respectively.

1 Introduction and theory

Solar cell is the electrical device that uses the energy in a photon of sunlight to separate a positive charge from a negative charge because of the "built-in" electric field at the junction of the p-type and n-type material. It operates as a current source by collecting those positive and negative charges on two different terminals so they can be used to do work in an electric circuit. As a photodiode, solar cell is formed using p- and n- type semiconductor layers. Having low charge carrier concentration, Pure silicon is doped with tri- and pentavalent impurity. In the n- type region, electrons in the conduction band are the charge carriers whereas in the p- type region positively charged holes in the valance band are charge carrier transport.

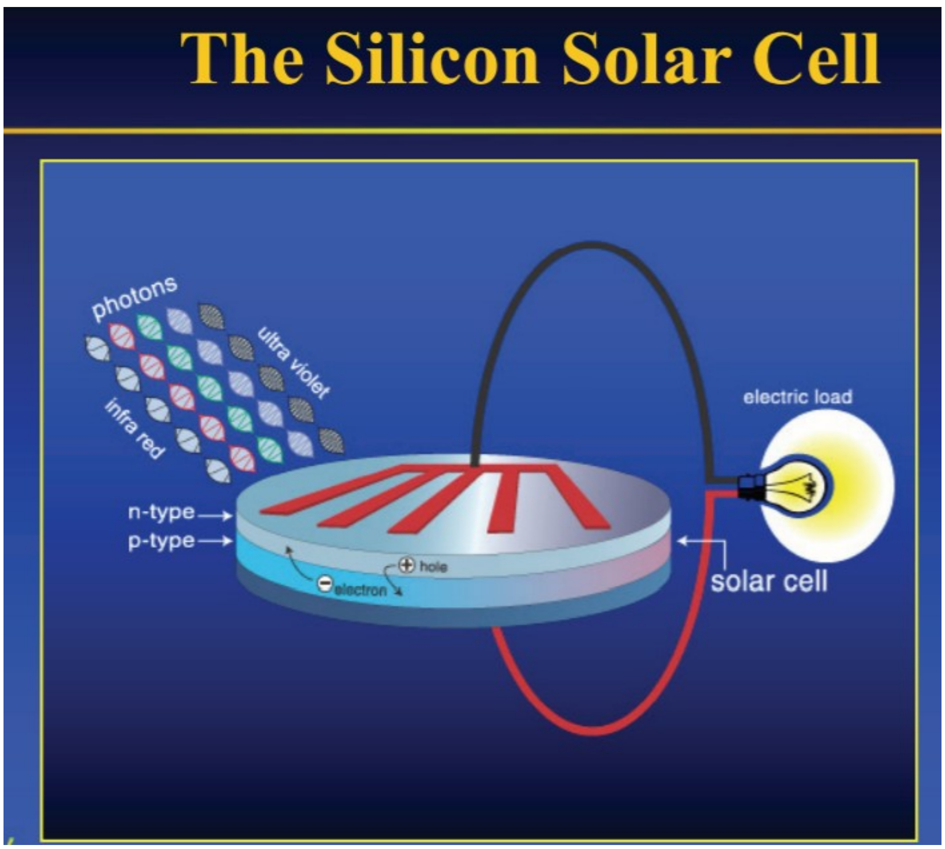

Figure 1: SILICON SOLAR CELL

In the absence of external voltage, the fermi energy will remains constant. Due to the doping of the silicon crystal, there are large numbers of mobile electrons on the n-type side, but very few mobile electrons on the p-type side. Because of the random thermal motion of the free electrons, electrons from the

n-type side start to diffuse into the p-type side. Similarly, due to the doping of the silicon, there are large numbers of mobile holes on the p-type side, but very few mobile holes on the n-type side. Holes in the p-type side, therefore, start to diffuse across into the n-type side. Due to lack of charges, it will leads to uniform distribution of charges and holes. The net current will be zero.
Although there is no net flow of current across the junction, there would be an electric field at the junction and it is this electric field that is the basis of the operation of solar cells. The photons are mainly absorbed in the p-lauer of the solar cell. When, photons are absorbed in space charge region, the built in electric filed will dissociate exicitions into free electron and holes and move to n- and p-layer respectively. The electrons prouduced in p-layer are minority charge carriers. Efficiency of solar cell is increased by increasing the collection of minority charge carriers which is done by limiting the thickness of the p-layer. When parallel and series resistance are taken into account, where parallel resistance R_P is defined by defects in materials and series resistance R_s sums up all other additional resistances like the material contacts and all connection to the solar cell.The current voltage relationship when applied voltages is near to zero can be characterized by:

$$I = -\frac{U}{R_p} + I_{SC} \tag{1}$$

Where I_SC is the short circuit current(No voltage is applied to solar cell). when the solar cell current is close to zero (I=0):

$$V = -I \cdot R_S + U_{OC} \tag{2}$$

where U_OC is the open ciruit voltage(when no current is coming out). In order to determine the efficiency η of the solar cell, the point of maximum generated power P_MPP is determined by maximum value of current voltage product.

$$P_MPP = max(UI) \tag{3}$$

Then, the efficiency of the solar cell is defined as the ratio of the maximum generated power and the power of the incoming light.

$$\eta = \frac{P_{MPP}}{P_{light}} \tag{4}$$

The fill factor is used to determine how much the solar cell behaves as the ideal power source and is calculated by:

$$FF = \frac{P_{MPP}}{U_{OC}I_{SC}} \tag{5}$$

2 Experimental Setup and procedure

2.1 Determination of intensity of a light source

Filament lamps were used as a source of light and a Mol thermophile with sensitivity of $22.69\mu V/W/m^2$ and are mounted in the optical bench as shown in figure 2. After necessary setting in cassy, the amplifer was used in the $'lowdrift'$ mode with amplification adjusted from factor 1 to 10^5. The minimum distance of 30 cm between lamp and thermopile was used. As intensity changes with changes with distance, light intensity was plotted for different distances.

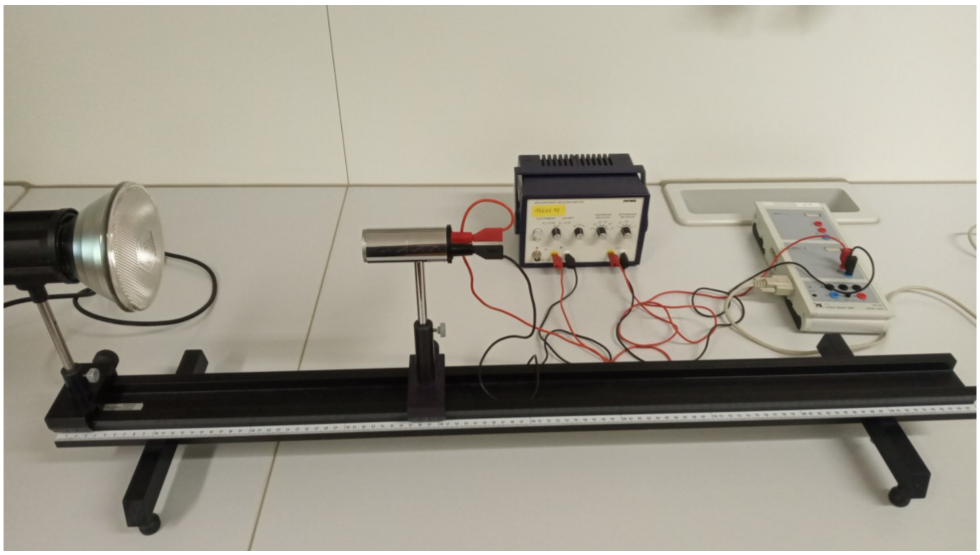

Figure 2: Experimental set-up for lamp calibration

2.2 Determination of ucurent- voltage characteristic of a solar cell

In this part of experiment, the solar cell was illuminatedd by using a light source and was connected to a electrical circuit as shown as in figure 3. Cassy inputs were used to measure the current and voltage generated by the solar cell. The cassy range for current and voltage was set to be $\pm 0.3A$ and $\pm 3V$ respectively with automatic mode measurement with 100 ms averaging time interval. Measurement were started form open circuit condition where all rheostat were set to 3 and were moved slowly from one end to other starting from 10 Ω, continuing with 33 Ω and last with 100 Ω. After the measurement, all rheostats were taken back to 0. The necessary setup is shown in figure 3.

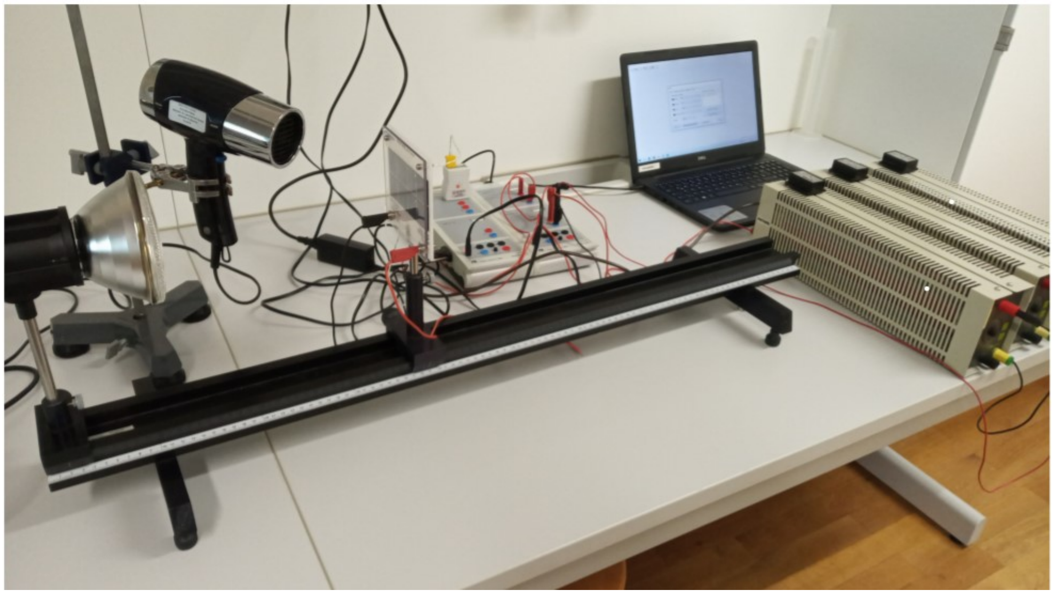

Figure 3: Experimental set-up for measurement of solar cell current-voltage characcteristic

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2.3 Current-voltage characteristic of solar cellin dependence of the light intensity

In order to determine the dependence, the distance between light souce and solar cell is varied in order to provide different intensities. The cell was cooled down using hair dryer. The measurement was performed for different distances.

2.4 Measurement of a solar cell using a different light source.

In this part of experiment, green light was used for illumination and the solar cell current-voltage characterisitic was measured at a distance where the intensity of the green lamp matches the intensity of thhe wihite lamp.

2.5 Temperature dependence of current-voltage characteristic of the solar cell

The white lamp was used as a light source and the distance was fixed as 30 cm. In order to control the temperature, hair dryer was used. In order to get homogeneous cooling, the dryer was mounted using triangular base, square base support as soon as in figure 3. Thermo-couple is used to measure the temperature using second Cassy unit. The current voltage characteristic was measured for three different temperature where highest temperature is measured when dryer is off and speed of fan was changed to obtain other two temperatures.

3 Result data and error analysis

3.1 calibration of lamps

Distance vs intensity was plotted for both yellow and green light. from the figure 4, it was found that at any distance,intensity of light of yellow light is always greater than that of green light. Also, equal intensity of about $112w/m^2$ was found at 50 cm and 80 cm for green and yellow light respectively. Intensity of light and power reaching the solar cell can be calculated using the formula below.

$$I = \frac{V_{TH}}{\rho} \tag{6}$$

$$P = I \cdot A \tag{7}$$

Where I, P, and V_{TH} are intensity of light, power reaching the solar cell and thermovoltage recorded at various distance respectively. The area of the solar plate is $5 \cdot 10^{-3} m^2$.

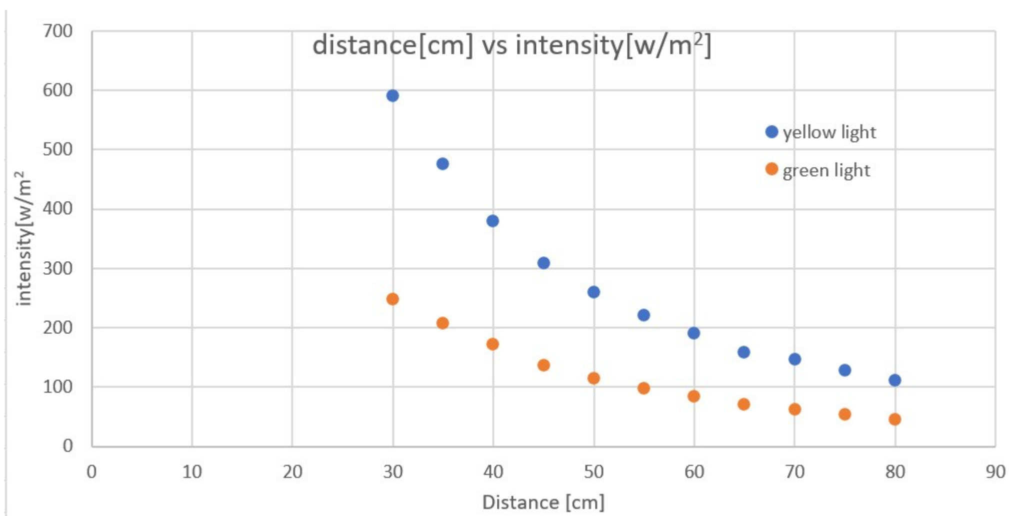

Figure 4: Experimental set-up for lamp calibration

3.2 Temperature dependence of current-voltage characteristic of solar cell

In this part, current voltage characteristics are determined for different temperatures of $29.27°C$, $39.8°C$ and $57°C$. The characteristic graphs are plotted below.

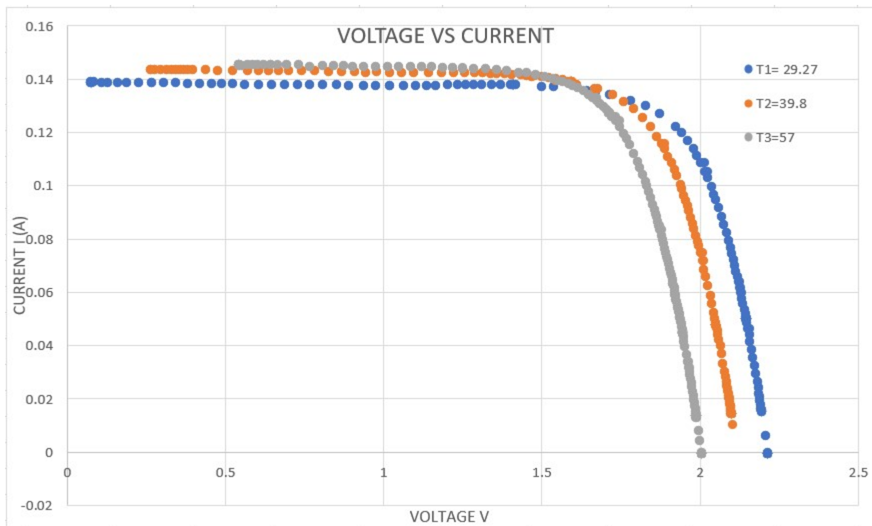

Figure 5: Current-voltage characteristic of solar cell in dependence of temperature

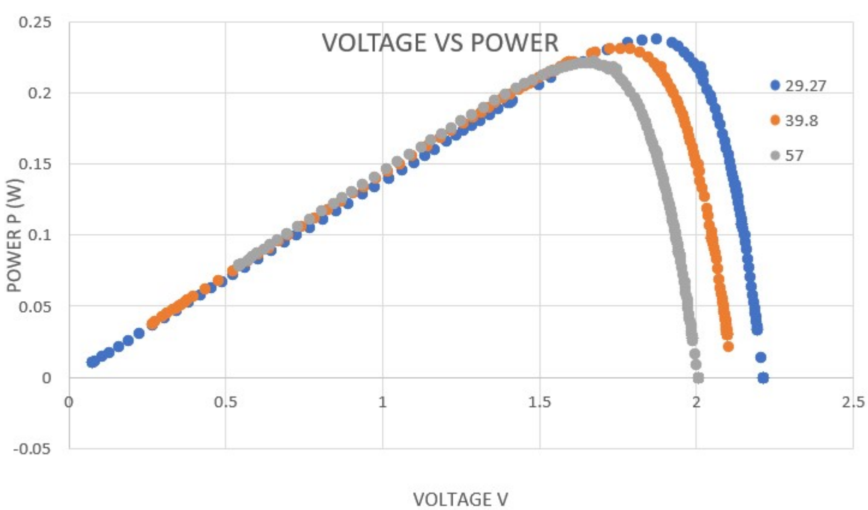

Figure 6: Power-voltage characteristics of solar cell in dependence of temperature

After performing mathematical observation to the graphs,different electrical characteristics of the solar cell were determined.From the table, it can be concluded that with the rise in temperature, the efficiency and fill factor will decreases. Maximum power can be generated at lower temperature.

Temperature	Uoc	Isc	Pmpp	FF	η[%]
29.27	2.21	0.139	0.235	0.76	8.06
39.8	2.1	0.144	0.231	0.76	7.8
57	2.004	0.15	0.22	0.73	7.45

Figure 7: Parameters for different temperature of solar cell

3.3 Determination of electrical characteristics of a solar cell for different light intensities

Current voltage characteristics of solar cell was plotted for different intensities of light and respective electrical charateristics were determined for different light intensities. From the table, it is found that the rise in intensity would leads to decrease in fill factor and effiency of the solar cell.

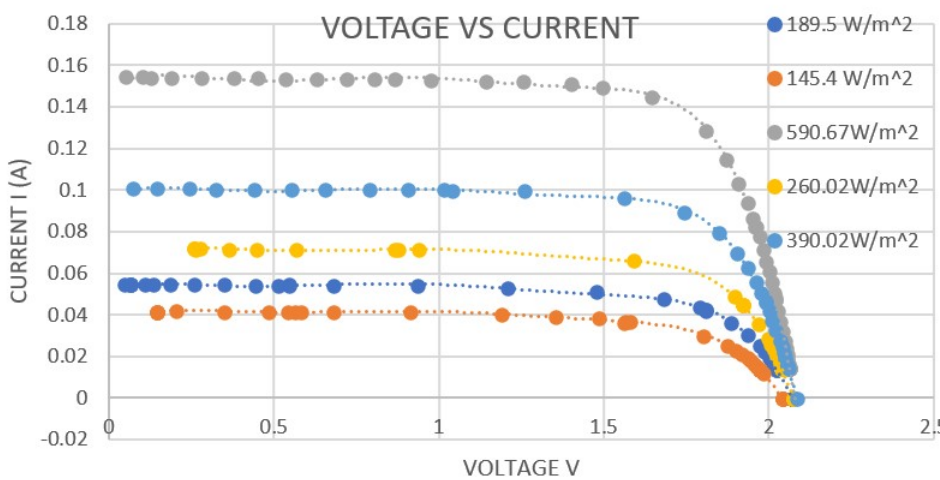

Figure 8: current voltage characteristics for different intensities of light

Intensity [w/m^2]	Uoc[v]	Isc[A]	FF	η[%]
590.67	2.085	0.1542	0.74	8.04
390.02	2.06	0.1	0.732	8.1
260.02	2.039	0.0716	0.71	8.02
189.5	2.0715	0.0543	0.676	8
145.4	2.04	0.0414	0.64	7.9

Figure 9: Parameters for different intensities of light

3.4 Characteristics for different light source

In this section of experiment, current-voltage characteristics were determined for intensity of $112 w/m^2$ for both yellow and green light at a fixed temperature.

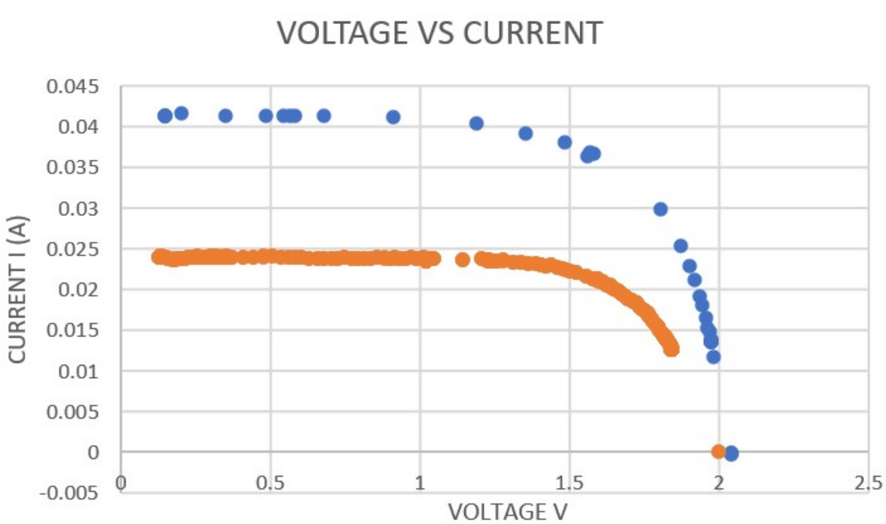

Figure 10: current voltage characteristics for different light source at same intensity

The following table in figure 10 shows different characteristics for green and yellow light at same intensity.

Lamp	Uoc[v]	Isc[A]	FF	η[%]
Yellow	0.0417	2.04	0.68	10.5
Green	0.0237	2	0.67	5.6

Figure 11: parameters for different source of light

4 Discussion and conclusion

From the above experiment several statements can be concluded. It was found that the increase in temperature would result in declination of the efficiency and fill factor of the solar cell by certain extend of linear nature. Also, when the experiment was carried out at optimum lower temperature, the data shows that the efficiency and fill factor would decrease with the decrease of the intensity of light. efficiency of 8.06% was obtained at the stable temperature of $29.27°C$.At this temperature, the effieciency was found to maximum at intenisty of $590.67w/,^2$. Comparing yellow light and green light, it was found that at same intensity, yellow light was more efficient than green light.

5 References

- Advance physics Lab Manual C0-486 fall 2020 (Prof.Dr.Arnulf Materny and Dr. Vladislav Jovanov).
- Error analysis booklet for physics teaching lab at Jacobs university
- University Physics by Young and Freedman