Lab 6: Solar Cells

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EE 145L
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1 Abstract

The purpose of this lab is to characterize a solar cell by measuring its IV curve. The fill factor and efficiency of the solar cell will be sound as a measurement of it's quality. The fill factor was found to be 0.627, and the efficiency was initially found to be 6.48%, but was adjusted to 32.4% after the relative intensity of the light source was accounted for.

2 Introduction

Semiconductors have many practical uses. One relevant example is that they can transform light energy into electric energy. This is done using a PN junction, where an N-type and P-type semiconductor are placed next to each other. According to Figure 1, Excess electrons and holes diffuse across the PN junction and due to ionized acceptor and donor atoms, a carrier-free 'depletion region' is formed in the middle of junction. The depletion region has an electric field which acts as a barrier for charge carriers wanting to conduct accross the junction. When an Electric field is applied in forward bias, this counters the junction's electric field and allows current through the PN junction according to Equation 1, where I_o is the absolute value of the drift current and V is the applied voltage.

$$I = I_o(e^{\frac{qV}{kT}} - 1) \tag{1}$$

To generate electric energy from a solar energy, a solar cell is used. This is a PN junction that generates a photo-current when exposed to direct light. When a solar cell is exposed to light, an Electron-Hole Pair (EHP) is created according to Figure 2. The EHP then is sucked across the depletion region by the electric field resulting in an increase in the drift current and resulting in a current similar to that from Equation 1.

An IV curve can be generated for the solar cell similar to the one in Figure 3. The fill factor of the device is a measure of the quality of the cell, and can be found by first finding the maximum power point of the IV curve, and then applying Equation 2. The efficiency of the solar cell is the ratio of the output power over the input power, and can be found by Equation 3, where A is the area of the solar cell, and E is the solar constant which has an average value of approximately $1\frac{kW}{m^2}$

During this lab, we will characterize an solar cell by generating an IV curve. Then, we will determine a measure of quality of the solar cell by finding the fill factor and efficiency of the cell from the IV data.

$$ff = \frac{I_M V_M}{I_{SC} V_{OC}} \tag{2}$$

$$\eta = \frac{ff * I_{SC} * V_{OC}}{E * A} \tag{3}$$

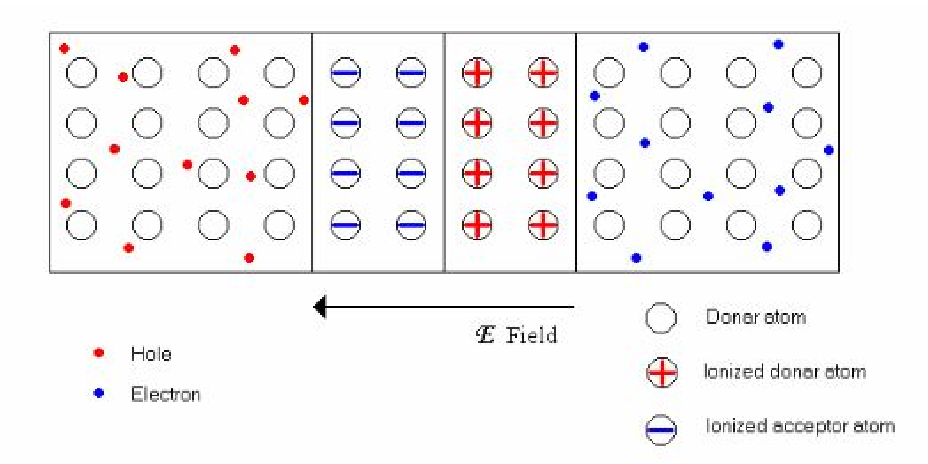

Figure 1: A PN junction showing the depletion region and corresponding electric field (Credit to Lab 6 brief)

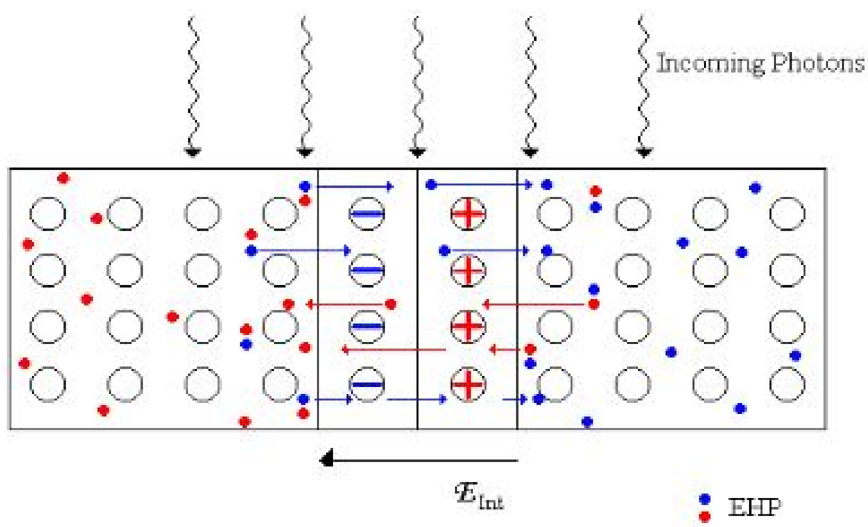

Figure 2: Creation of an EHP and increase in Drift Current (Credit to Lab 6 brief)

3 Materials and Methods

Materials:
- breadboard
- solar cell

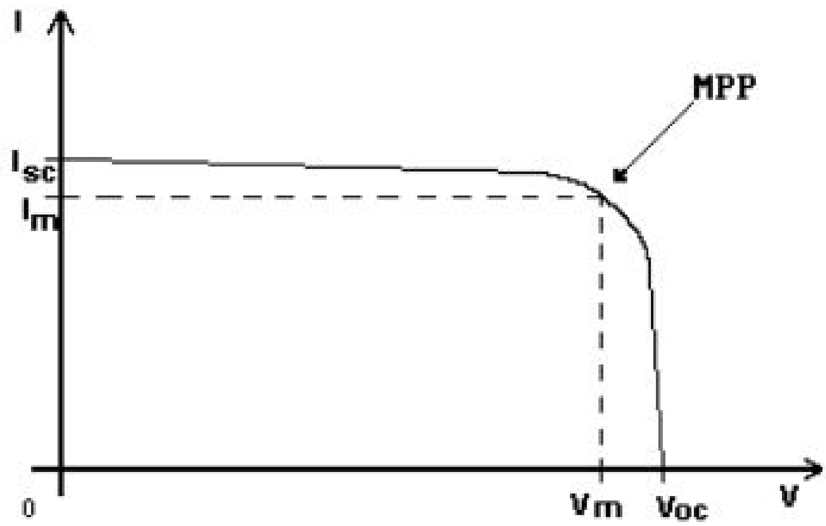

Figure 3: IV curve and MPP for solar cell (Credit to Lab 6 brief)

- 2k potentiometer
- 2 digital multimeters
- desk lamp
- light intensity meter

Methods:
First, the circuit from Figure 4 was constructed. The desk lamp was placed over the solar cell and was held stationary for the duration of data recording. The variable resistor was varied from 0.01Ω to 2kΩ and corresponding current and voltage values were recorded and plotted in real time, to aid with filling out the curve. The short circuit current was found by shorting the resistor with a wire and measuring the current through the circuit. The open circuit voltage was found by disconnecting the resistor from the solar cell and measuring the voltage across the solar cell.

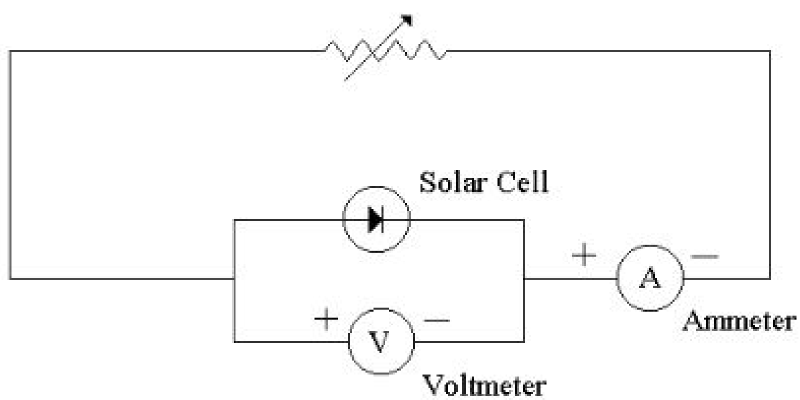

Figure 4: Lab 6 circuit (Credit to Lab 6 brief)

4 Results and Analysis

Figure 5 shows the IV curve for the solar cell and shows the maximum power point of the IV curve. By inspection, the fill factor seems low, and the curve itself is very flat, indicating a low efficiency. By multiplying the I and V values, power can be calculated. The maximum power point can be found by plotting power against either current or voltage and finding the value of current or voltage for which the power is maximized. The maximum power point in this case was found to be approximately $I_m = 33.3mA$ and $V_m = 0.308V$.

From the data, V_{oc} was found to be 0.436V and I_{sc} was found as 37.5mA. Using Equation 2, the fill factor was found as .627. Then, using the measured area $A = 15.84cm^2$ and assuming $E = 1\frac{kW}{m^2}$, the efficiency was found to be $\eta = 6.48\%$, which is abysmally low. One main source of error is the assumed value for E. This value is an average energy flux for a solar cell that is in direct sunlight on the earth's surface. Our light source was a desk lamp that was held at about a foot away from the solar cell, which should have much less intensity than direct sunlight. According to Wikipedia, the intensity of full, unobstructed sunlight is about 10000 foot candles. The measured intensity of the lamp was about 2000 foot candles, about one fifth the intensity. Assuming the relationship between intensity and solar constant is proportional, that means the efficiency of the solar cell is more like 32.3% which is only a little higher than the 'best theoretical value' range of 20-28%.

Another result of note is that the measured voltage across the short-circuited solar cell was 0.224V rather than 0V. The main reason for this error is because there is some non-zero resistance in the breadboard, wires, potentiometer and even the solar cell itself, so a truly zero resistance can never be achieved.

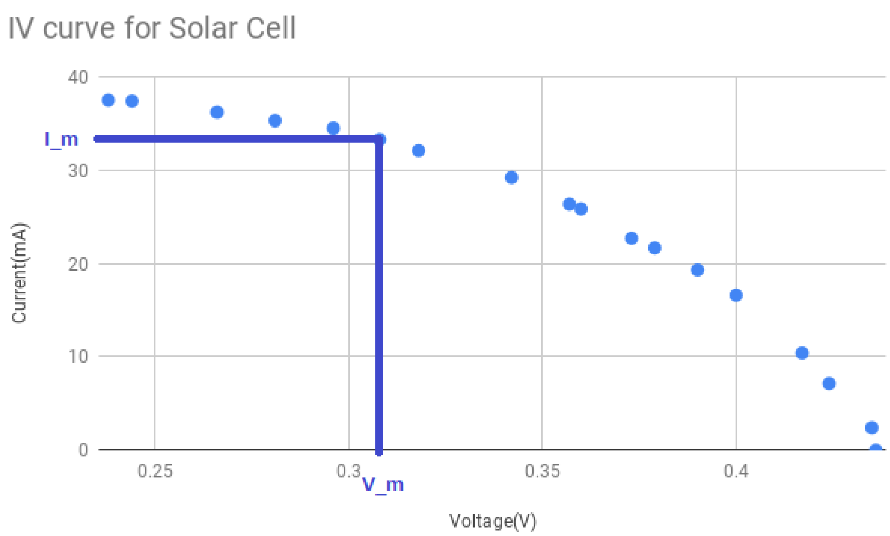

Figure 5: IV curve for solar cell showing maximum power point

5 Conclusions

The results in this lab were fair. Since the desk lamp provided a low light intensity compared to full sunlight, the assumed solar constant of $E = 1\frac{kW}{m^2}$ was inaccurate and the calculated efficiency value was inaccurate as a result. However, once this error was accounted for, the efficiency value of 32.3% was much closer to the mark. During this lab, I gained a better understanding of how a solar cell functions. I learned that a solar cell functions similarly to a diode in that it is a PN junction that uses light as a mechanism for generating diffusion current.