Solar cell

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1 Introduction

A solar cell is an eletrical device that generates electricity by the photovoltaic effect. Upon exposure to illumination, the device creates voltage, which in turn gives rise to an electric current. Solar cells are becoming increasingly common as an alternative source of electricity.

A solar cell can be described as a $p-n$ junction, which is an interface between p-type material (acceptors) and n-type material (donors) inside a semiconductor. Electrons will diffuse from the n-side to the p-side, while holes will diffuse from the p-side to the n-side. At the same time, an electric field comes into existance between the diffused electrons at the p-side and the diffused holes at the n-side. Whereas the diffusion force pulls electrons to the n-side and holes to the p-side, the force from the built-in electric field will pull both electrons and holes in the opposite direction, counteracting the diffusion. Sooner or later the forces will be equal, and an equilibrium is established.

Free electron-hole pairs can be generated in a semiconductor when it is exposed to light with sufficient energy to excite electrons to the conduction band. If this happens close enough to the interface between the two sides, the electron and hole will feel the built-in electric field, and will consequently be swept in different directions. When the sides are shortcircuited, electrons will flow from the n-side to the p-side to recombine with the holes. This is how solar cells generate an electric current. Note that the direction is the opposite of a diode, because we have minority carriers instead of majority carriers.

2 Experimental procedure

The solar cell we used in this laboration is a polycrystalline silicon thin film. The area of the solar cell was 2.3×6.0 cm^2. A 60 W standard desk lamp provided the illumination.

3 Measurement results

Diagrams... Fit to the diode equation $I = I_{sat}\left(1 - \exp\left(-\frac{eV}{nk_BT}\right)\right)$, where n is the ideality factor.

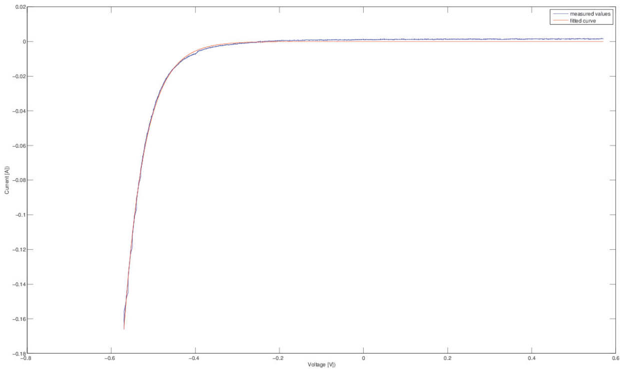

Figure 1: Current as function of voltage. Fitted according to the diode equation.

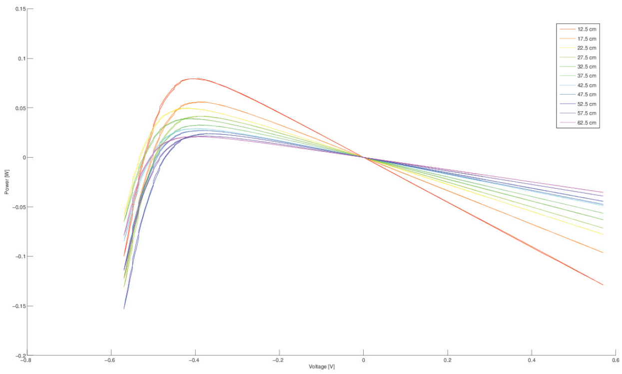

Figure 2: Power as function of voltage for different distances from lamp to solar cell.

4 Discussion of the results

The power delivered to the solar cell should of course satisfy $4\pi R^2\Phi = P$, where P is the effect. (We measured the maximal effect P_{max}). Hence, if we fit the curve according to the formula $P_{max} = kf(d)/f(0)$, where k is a proportional constant, $f(d) = \frac{1}{(d+x_0)^2}$ and d the distance from the lamp to the solar cell, we should obtain something that is linear, see figure 3. We introduced x_0 in order to compensate for systematic errors and found that $k = 1.76 \cdot 10^{-6}$ wm^2 and $x_0 = 4.98$ cm, however some differences still remain; some possibly arising from the fact that the lamp is not a perfect sphere.

As a way to check the results, consider the following: Approximate the solar cell together with the Power Cassy as a simple circuit, where the solar cell and the Power Cassy has resistance R_0 and R, respectively. By Ohm's law, we know that $U = RI$ and $P = IR^2$. Then, since $U_0 = (R + R_0)I$, it follows that

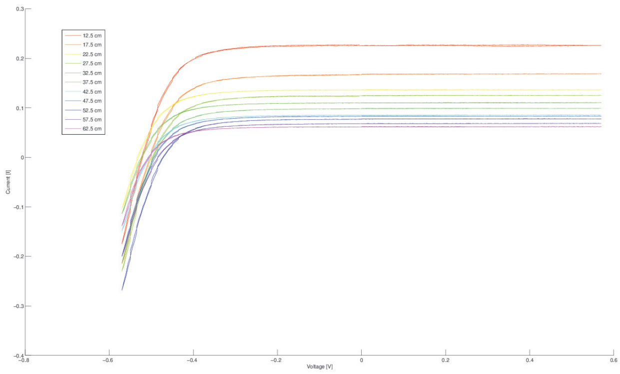

Figure 3: Current as function of voltage for different distances from lamp to solar cell.

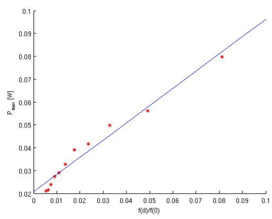

Figure 4: Current as function of voltage for different distances from lamp to solar cell.

$P = RI^2 = R\left(\frac{U_0}{R+R_0}\right)^2$. The voltage at maximum power it therefore given by

$$0 = \frac{dP}{dR} = -\frac{U_0^2(R-R_0)}{(R+R_0)^3} \iff R = R_0.$$

In this case, the voltage is also maximal and given by $U_{max} = R_0 I = R_0 \frac{U_0}{R_0+R_0} = \frac{U_0}{2}$. From figure 3, we see that $U_{max} \approx -0.4$ V and from figure 3, we see that $U_0 \approx 0.5$ V, which does not at all agree with theory.

The most ideal solar cell are of course those whose energy gap coincide with the sun. Now, from theory, we know that the maximum efficiency is given by $E_g/(k_B T) \approx 2.3$ and since the temperature of the photosphere is approximately 5800 K, the best solar cells are those with an energy gap of around 1.15 eV. Our solar cell with an energy gap of around 1.11 eV at 300 K is therefore an excellent choice.

In this report, we considered a 60 W light bulb with an effective temperature around 3000 K. This implies that $E_g/(k_B T) \approx 4.3$ so that theory gives us a efficiency of 25%. Also, we know that the theoretical upper limit for the efficiency $\eta = \frac{\text{output power}}{\text{input power}}$ is given by $\frac{E_g}{k_B T} \approx 2.3$. Obviously, we do not reach 25%, in fact, it is considerably lower as the following shows. The area of the solar cell was 13.8 cm^2 and as a rough approximation, assume that the wavelength of the 60 W light bulb to is 1100 nm. Then elementary physics implies that it emits approximately $3.3 \cdot 10^{20}$ photons per second. Assuming that they are distributed spherically and perfectly aligns with the solar cell, at a distance of 37.5 cm, $13.8/(4\pi 37.5^2) \approx 0.078\%$ of the photons hit the solar cell. Thus, the efficiency is

$$\frac{0.078 \cdot 10^{-2} \cdot 3.3 \cdot 10^{20} \cdot 6.6 \cdot 10^{-34} \cdot 3 \cdot 10^{8}}{1100 \cdot 10^{-9} \cdot 0.033} \approx$$

5 Conclusions

It works.