I-V Characteristics of a Solar Cell

OBJECTIVES:

(I) Study of I-V Characteristic of a solar cell illuminated by an incandescent lamp, at different frequencies

(II) Study of I-V Characteristic of a solar cell illuminated by sun, at different frequencies

THEORY:

Solar cell is the basic unit of solar energy generation system where electrical energy is extracted directly from light energy without any intermediate process. The working of a solar cell solely depends upon its photovoltaic effect, hence a solar cell also known as photovoltaic cell. A solar cell is basically a semiconductor p-n junction device. It is formed by joining p-type (high concentration of hole or deficiency of electron) and n-type (high concentration of electron) semiconductor material. at the junction excess electrons from n-type try to diffuse to p-side and vice-versa. Movement of electrons to the p-side exposes positive ion cores in n-side, while movement of holes to the n-side exposes negative ion cores in the p-side. This results in an electric field at the junction and forming the depletion region. When sunlight falls on the solar cell, photons with energy greater than band gap of the semiconductor are absorbed by the cell and generate electron-hole (e-h) pair. These e-h pairs migrate respectively to n- and p- side of the pn junction due to electrostatic force of the field across the junction. In this way a potential difference is established between two sides of the cell. Typically a solar or photovoltaic cell has negative front contact and positive back contact. A semiconductor p-n junction is in the middle of these two contacts like a battery. If these two sides are connected by an external circuit, current will start flowing from positive to negative terminal of the solar cell. This is basic working principle of a solar cell. For silicon, the band gap at room temperature is E_g = 1.1 eV and the diffusion potential is U_D = 0.5 to 0.7 V. Construction of a Si solar cell is depicted in Fig.1.

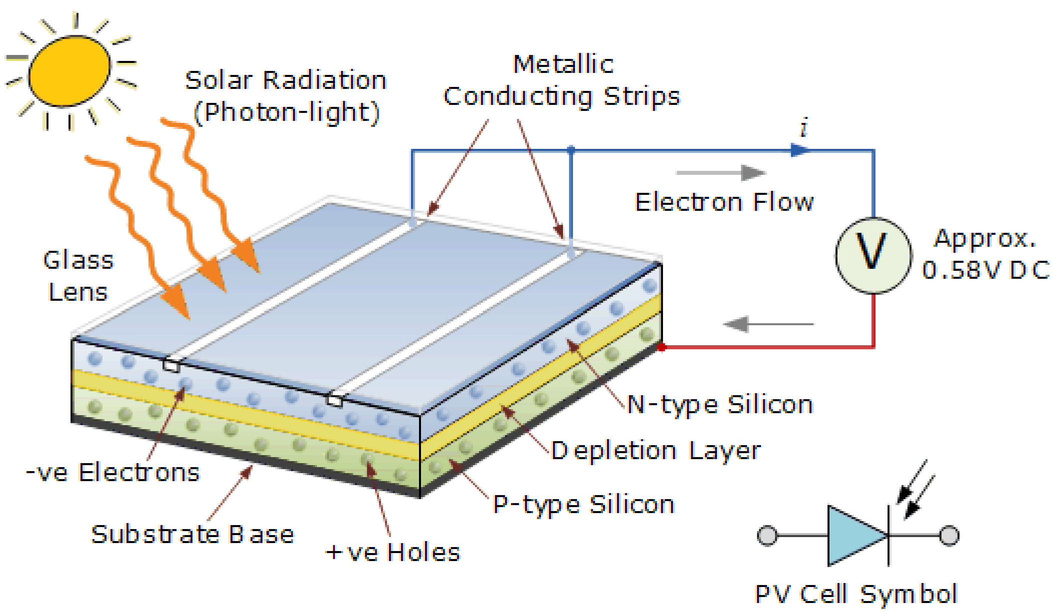

Fig. 1: Construction of a solar cell

Solar Cell I-V Characteristics Curve is the superposition of the I-V curves of the solar cell diode in absence (dark) and in presence of light. Illuminating a cell adds to the normal "dark" currents in the diode so that the diode law becomes:

$$I = I_0\left[\exp\left(\frac{qV}{nkT}\right) - 1\right] - I_L$$

where I_0 = "dark saturation current" or diode leakage current in absence of light

q = electronic charge

V = applied voltage across the terminals of the diode

n = ideality factor

k = Boltzmann's constant

T = temperature

I_L = light generated current.

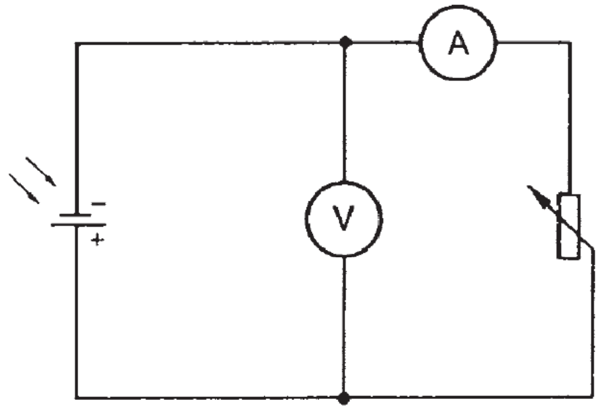

Fig. 2: Circuit for I-V characteristics of solar cell

A typical circuit for measuring I-V characteristics is shown in Fig.2. From this characteristics various parameters of the solar cell can be determined, such as: short-circuit current (I_{SC}), the open-circuit voltage (V_{OC}), the fill factor (FF) and the efficiency. The rating of a solar panel depends on these parameters.

The short-circuit current is the current through the solar cell when the voltage across the solar cell is zero (i.e., when the solar cell is short circuited). is due to the generation and collection of light-generated carriers. For an ideal solar cell at most moderate resistive loss mechanisms, the short-circuit current and the light-generated current are identical. Therefore, the short-circuit current is the largest current which may be drawn from the solar cell.

The open-circuit voltage, V_{OC}, is the maximum voltage available from a solar cell, and this occurs at zero current. The open-circuit voltage corresponds to the amount of forward bias on the solar cell due to the bias of the solar cell junction with the light-generated current.

The "fill factor", more commonly known by its abbreviation "FF", is a parameter which, in conjunction with V_{oc} and I_{sc}, determines the maximum power from a solar cell. The FF is defined as the ratio of the maximum power from the solar cell to the product of V_{oc} and I_{sc}. Graphically, the FF is a measure of the "squareness" of the solar cell and is also the area of the largest rectangle which will fit in the IV curve as shown in Fig. 3.

The efficiency is the most commonly used parameter to compare the performance of one solar cell to another. Efficiency is defined as the ratio of energy output from the solar cell to input energy from the sun. In addition to reflecting the performance of the solar cell itself, the efficiency depends on the spectrum and intensity of the incident sunlight and the temperature of the solar cell.

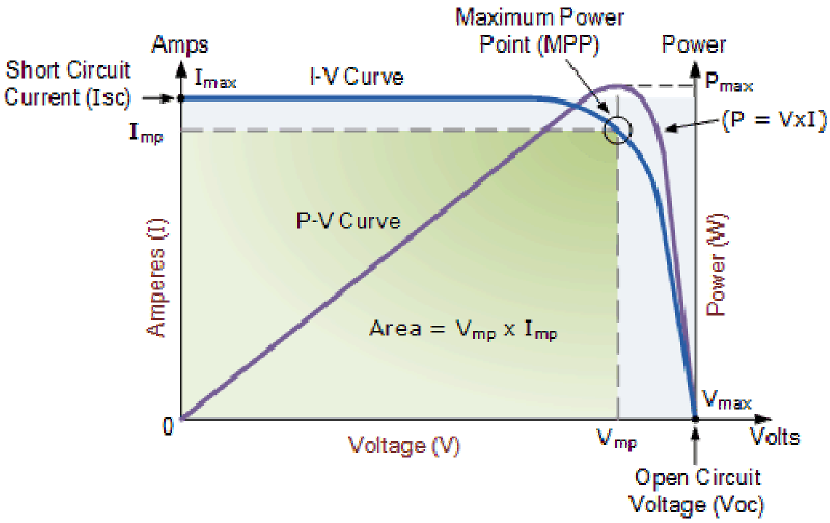

Fig. 3: A typical I-V curve and power curve of a solar cell

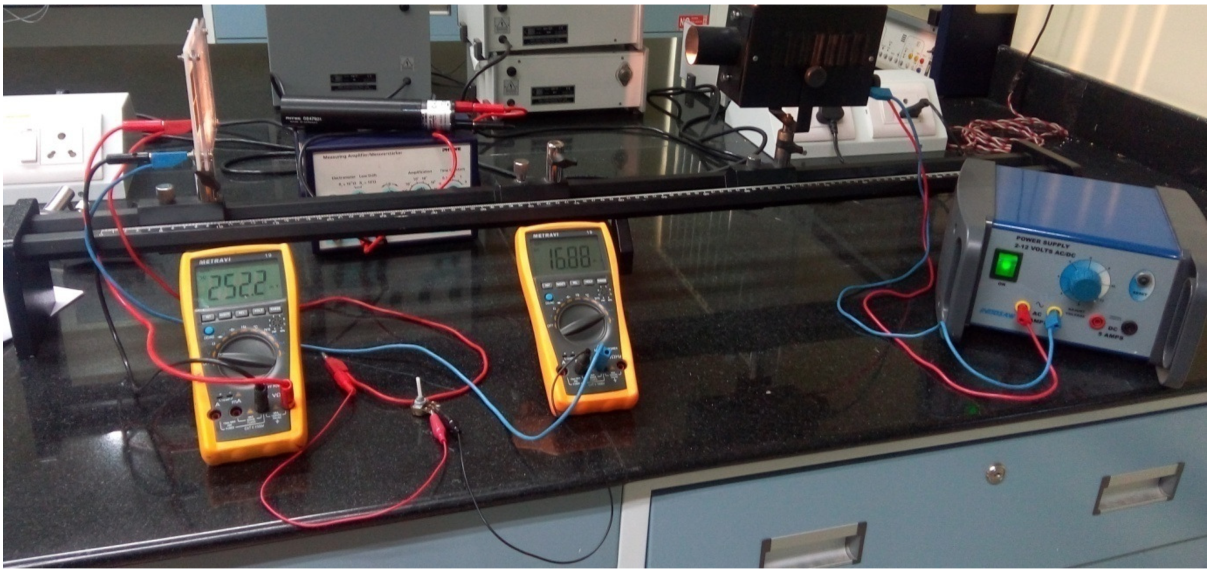

Fig 4: Experimental arrangement for solar cell characteristics

APPARATUS:

1. Solar cell
2. Incandescent amp with power supply
3. Potentiometer
4. Optical filters
5. Multimeters
6. Optical bench and clamp
7. Connecting wires

PROCEDURE:

1. Connect the solar cell to the potentiometer and multimeters as shown in Fig.2. Set the potentiometer at the minimum.
2. Connect the incandescent lamp with its power supply. Switch on the lamp and adjust further so that maximum area of the solar cell can be illuminated. Record the distance between the lamp and the solar cell.
3. Vary the potentiometer and record the values of current and voltage across the solar cell, keeping the supply voltage to the lamp fixed. Now attach a filter to the lamp and record I and V values for each filter from the filter set.
4. Plot I-V curve for each frequency and estimate short circuit current, no load voltage. Determine the maximum power output at the turning points on the curves (marked by a circle in Fig. 3).
5. Plot the maximum power as a function of different filter wavelength.
6. Repeat the same above procedure by replacing the lamp with sunlight.
7. Compare the spectral response of Si solar cell with the spectrum of lamp and sun.

OBSERVATIONS:

Table 1: I-V characteristics of solar cell illuminated incandescent lamp

supply voltage = ... **Distance between lamp and solar cell = ...**

Sl. No.	No filter		λ_1		λ_2		λ_3		λ_4		λ_5	
	I	V	I	V	I	V	I	V	I	V	I	V

Table 2: I-V characteristics of solar cell illuminated by sun

Sl. No.	No filter		λ_1		λ_2		λ_3		λ_4		λ_5	
	I	V	I	V	I	V	I	V	I	V	I	V

GRAPH:

Plot I-V characteristics for each filter. Determine the no-load voltage and short circuit current. Estimate the maximum power output in each case. Compare the maximum power output for incandescent lamp and sun at various wavelengths.

References:

1. http://www.pveducation.org
2. http://nptel.ac.in/courses/113106062/Lec19.pdf