I-V Characteristics of Solar Cell

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In the modern era of the scarcity of energy resources, the demand for renewable energy sources is increasing with each passing day. The most reliable and sustainable energy source, Solar energy derived from the Sun can be used to meet our energy requirements and ensure sustainability. This process of deriving energy from the Sun is achieved by using a special kind of p-n junction diode, called the Solar cell whose I-V characteristics, we are studying in this report in both room light and daylight using different color filters. From this, we study the power generation in each case and compare them to get useful conclusions.

I. OBJECTIVES

- To study the I-V characteristics of a Solar cell illuminated by the room light using different color filters.
- To study the I-V characteristics of a Solar cell illuminated by the sunlight using different color filters.

II. THEORY

A. p-n Junction diode

A p-n junction diode is a basic semiconductor device that controls the flow of electric current in a circuit. It consists of a positive (p) side and a negative (n) side separated by a depletion region where the charge is stored. A p-n Junction Diode is one of the simplest semiconductor devices which has the electrical characteristic of passing current through itself in one direction only. However, unlike a resistor, a diode does not behave linearly with respect to the applied voltage. Instead, it has an exponential current-voltage (I-V) relationship and therefore we can not describe its operation by simply using an equation such as Ohm's law.

Forward bias:

If a suitable positive voltage (forward bias) is applied between the two ends of the PN junction, it can supply free electrons and holes with the extra energy they require to cross the junction as the width of the depletion layer around the PN junction is decreased.

Reverse bias:

Applying a negative voltage (reverse bias) results in the free charges being pulled away from the junction resulting in the depletion layer width being increased. This has the effect of increasing or decreasing the effective resistance of the junction itself allowing or blocking the flow of current through the diode.

B. Solar cell

A solar cell, or photovoltaic cell, is an electronic device that converts light energy directly into electrical energy by the photovoltaic effect. It is basically a p-n junction diode that produces electron-hole pairs as charge carriers when radiation is incident on it.

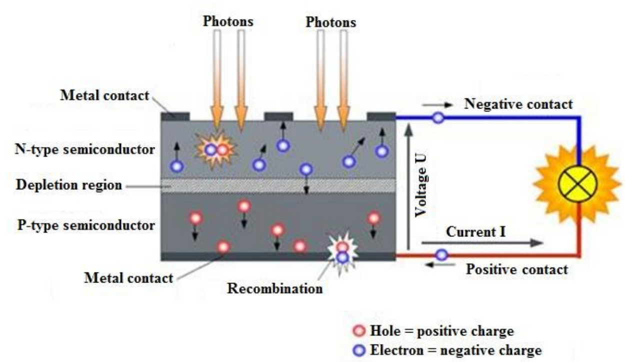

FIG. 1. Working of a typical solar cell

When the light falls on the surface of the solar cell, photons with energy greater than the band gap of the semiconductor (For Silicon, $E_g = 1.1eV$) create the e-h charge carrier pairs. These charge carriers when formed, migrate to different sides of the depletion region due to electrostatic force across the junction. As more radiation is absorbed, there is an accumulation of charges on the two sides of the cell producing a potential difference.

C. I-V characteristics of Solar cell

The solar cell I-V Characteristics Curve is the superposition of the I-V curves of the solar cell diode in the 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:

$$I(V) = I_o[e^{\frac{qV}{nkT}} - 1] - I_L \tag{1}$$

where
I_o = "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.
A typical I-V curve and power curve are shown in FIG.2.

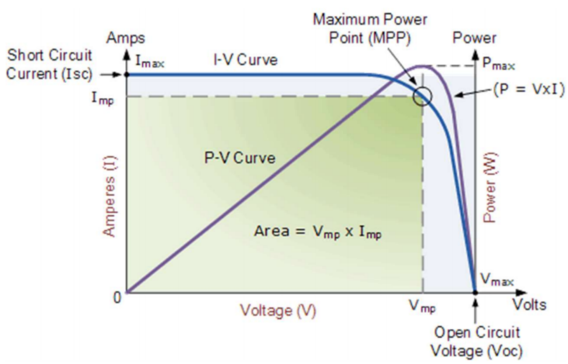

FIG. 2. A typical I-V curve and power curve of a solar cell

The various parameters mentioned in the plot above are:

- **Short circuit current (I_{SC}):** The maximum current that can be drawn from a solar cell when the voltage across the cell is zero or short-circuited.
- **Open circuit voltage (V_{OC}):** It is the maximum voltage available from a solar cell, which occurs at zero current.
- **Maximum power point (MPP):** It is the area of the largest rectangle that fits in the I-V curve.
- **Fill factor (FF):** It is defined as the ratio of the maximum power from the solar cell to the product of V_{OC} and I_{SC}.
- **Efficiency:** It is the ratio of energy output from the solar cell to input energy from the source light.

III. EXPERIMENTAL SETUP

A. APPARATUS

- **Solar cell:** A typical solar cell with a negative side on the upper surface and a positive side on the lower surface.
- **Power supply**

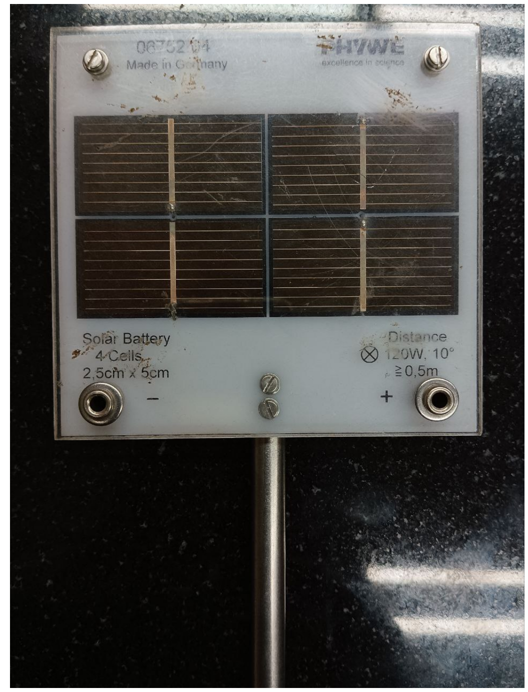

FIG. 3. Solar cell

- **Incandescent lamp:** light source (inside room).
- **Voltmeter and ammeter**: to measure the voltage across the solar cell and current.
- **Color filters**
- **Potentiometer:** to control the potential difference across the solar cell.

The circuit diagram for the experiment is shown in FIG.4.

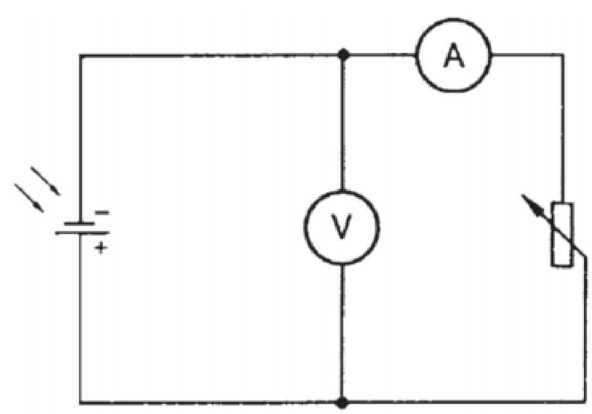

FIG. 4. Circuit diagram for I-V characteristics of a solar cell

IV. OBSERVATIONS AND DATA

Table 1: Data for I-V characteristics of the solar cell (inside room)

No filter		Yellow filter		Red filter		Pink filter		Green filter	
I(mA)	V(mV)	I(mA)	V(mV)	I(mA)	V(mV)	I(mA)	V(mV)	I(mA)	V(mV)
0.99	6.2	0.61	3.9	0.31	2.2	0.64	3.9	0.26	1.5
0.98	14.5	0.6	45.1	0.31	24.3	0.64	34.9	0.26	26.6
0.97	75	0.59	91.2	0.3	61.8	0.63	71.7	0.25	48
0.95	122.8	0.57	134.1	0.28	99.7	0.62	97.1	0.24	82.9
0.93	170.6	0.56	174.3	0.26	153.4	0.61	126.5	0.23	110.3
0.91	229.3	0.54	219.3	0.24	205.8	0.6	159.1	0.23	130.8
0.88	267.3	0.54	254	0.21	255.6	0.57	213.7	0.22	152
0.84	335.6	0.49	308.3	0.19	310.4	0.54	263.3	0.21	176.3
0.82	377.8	0.47	338.4	0.15	365.8	0.52	307.3	0.19	215.8
0.78	423	0.45	380.7	0.14	382.7	0.5	342.2	0.16	265.3
0.74	470	0.4	437	0.12	407	0.46	395.1	0.15	297.2
0.68	530	0.37	469	0.1	433	0.43	438	0.12	330.5
0.61	591	0.33	513	0.07	466	0.39	480	0.11	349.1
0.53	645	0.25	580	0.06	475	0.34	528	0.08	389.8
0.45	691	0.21	610	0.05	491	0.3	567	0.07	403
0.43	707	0.15	647	0.04	501	0.23	619	0.06	424
0.33	753	0.11	674	0.03	508	0.18	650	0.04	443
0.27	776	0.09	684	0.02	517	0.09	702	0.03	457
0.25	783	0.06	698	0.01	523	0.07	711	0.02	467
0.16	812	0.05	708	0	537	0.05	721	0.01	474
0.1	830	0.03	714			0.03	729	0	486
0.03	849	0.01	723			0.02	736		
0.01	855	0.01	726			0	742		

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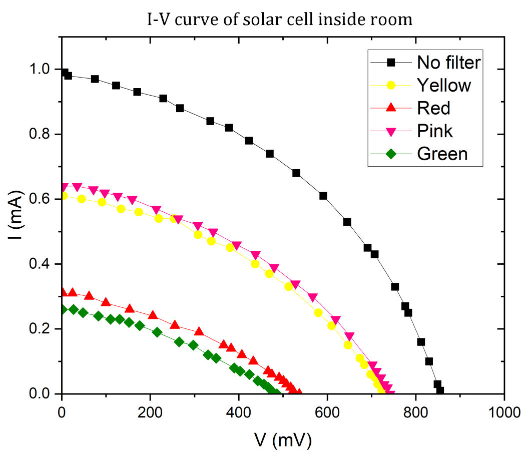

FIG. 5. I-V curve of solar cell inside room

Table 2: Various parameters of the solar cell obtained (inside room)

Parameters	No filter	Yellow filter	Red filter	Pink filter	Green filter
I_{SC} (mA)	0.99	0.61	0.31	0.64	0.26
V_{OC} (mV)	855	726	537	742	486
P_{max}(μW)	360.51	174.8	58.976	188.34	44.58
FF	0.4259082049	0.3947071309	0.3542740434	0.3966054582	0.3528015195

Table 3: Data for I-V characteristics of the solar cell (in sunlight)

Sunlight		Yellow filter		Red filter		Pink filter		Green filter	
I(mA)	V(V)	I(mA)	V(V)	I(mA)	V(V)	I(mA)	V(mV)	I(mA)	V(mV)
153.4	0.54	69.7	0.303	39.6	0.202	41	0.314	25.23	0.187
151.8	0.572	68.3	0.35	39.4	0.237	40.8	0.37	25.17	0.251
146.2	0.624	69.2	0.4	38.64	0.296	40.2	0.39	25.02	0.395
152.1	0.662	64.7	0.556	38.52	0.45	39.2	0.49	24.99	0.418
150.6	0.695	63.3	0.64	38.5	0.683	37.4	0.887	24.68	0.727
149.7	0.738	62.2	0.7	36.12	0.758	35.8	1.015	24.44	0.801
148.1	0.775	61.6	0.572	31.45	0.867	11.89	1.375	19.24	1.16
141.2	0.87	61.1	1.323	16.74	1.362	9.09	1.387	10.38	1.308
133	0.989	9.39	1.469	7.45	1.401	5.5	1.399	9.87	1.315
126.9	1.095	2.669	1.483	4.3	1.413	4.18	1.404	8.05	1.33
36.4	1.397	2	1.492	3.67	1.418	2.26	1.411	6.36	1.345
13.6	1.491	0	1.499	0.2	1.427	1.29	1.414	5.37	1.355
13.41	1.5			0	1.428	0.01	1.416	3.91	1.364
10.54	1.52							2.02	1.377
0.01	1.54							1.68	1.384
								0.13	1.396
								0	1.4

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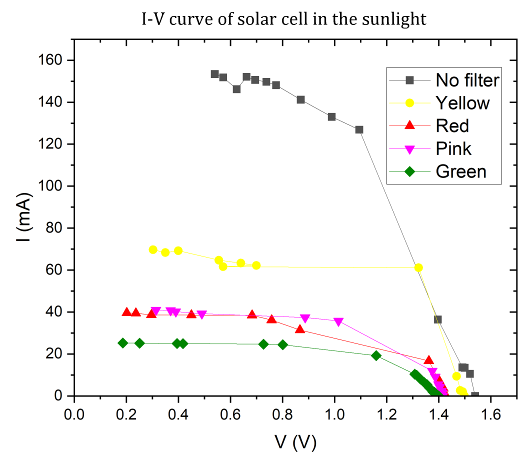

FIG. 6. I-V curve of solar cell in sunlight

Table 4: Various parameters of the solar cell obtained (in sunlight)

Parameters	No filter	Yellow filter	Red filter	Pink filter	Green filter
I_{SC} (mA)	153.4	69.7	39.6	41	25.23
V_{OC} (V)	1.54	1.499	1.428	1.416	1.4
P_{max}(mW)	138.9555	80.8353	27.37896	36.337	22.3184
FF	0.5882062852	0.7736893941	0.4841651812	0.6258956869	0.6318555008

V. CONCLUSIONS AND DISCUSSIONS

- From figures 5 and 6, we can observe that the I-V curve we got for both the cases in room light and sunlight suffices the theoretical prediction, i.e. the current remains almost constant at lower values of voltage across the solar cell and drops to a very small value after some voltage.

- The short circuit current and open source voltages are different in the case of different filters, and hence the maximum power generated in the case of different filters are different.

- Different power generated can be explained as: Since different filters allow different values of energy to incident on the solar cell, the charge carriers excite differently with different kinetic energies, hence generating different power.

- The maximum power generated is maximum when no filter is used, in both cases, as there are no filters to any wavelength (or energy) of the incident radiation.

- The striking curve came out was in the case of the green filter. Despite having higher energy, it produces minimum power in both cases. It could be because of scattering of lower wavelength photons or scratches on the filter or high density of the filter so that the required energy couldn't have transmitted to the solar cell.

- The maximum power generated in the case of solar cell in sunlight is approximately 400 times that of the solar cell inside the room.

VI. SOURCES OF ERRORS AND PRECAUTIONS

- Since it is an observation-based experiment, the only error found in maximum power output depends on the least count of the voltmeter and ammeter.

- High sensitivity of the potentiometer created a very difficult task to note down the data as the measurement was not stable at all (especially in the sunlight case).

- The data for the I-V curve in sunlight was erroneous because of the frequently changing environmental conditions. For better data, the surrounding temperature should be constant.

- The observational errors in the data could be due to differences in temperature, angle of incidence of the light radiation, etc. over the time course of the experiment.

VII. REFERENCES

- NISER Lab Manual

- `https://www.britannica.com/technology/solar-cell`

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