UM-SJTU Joint Institute

Physics Laboratory
(Vp241)

Laboratory Report

Excercise 3

Solar Cells: I-V Characteristics

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[rev4.1]

1 Introduction

Solar energy is becoming more and more popular today because of its low pollution. A key component for solar energy is solar cell, which directly transforms the solar radiation into electrical energy.

The objective of this experiment is to get familiar with solar cell and learn something about its current-voltage Characteristics and also measure the cell's $fillfactor$ and energy conversion efficiency.

2 Experimental setup

2.1 Equipments used in the experiment

Devices used in the experiment include the following: a photovoltaic device (5W), a 300 W tungsten-halogen lamp functioning as the source of radiation, two digital multimeters, two adjustable resistors, a solar power meter, a wiring board and a measuring tape

2.2 Measurement procedure

In this experiment, we will look into the relationship between the four main configurations of the soalr cell: I, V, P, R. We will study the relationship of I-V,P-V and P-R. We also pay attention to the fill factor and energy conversion efficiency.

We do the following steps in the experiment:

- Turn on the light and the fan, and wait until it reaches its working intensity
- Design a measuring circuit with the photovoltaic device and connect the elements
- Adjust the distance between the light source and the photovoltaic device until proper distance is meter
- Do measurements, change the distance between these two devices and repeat measurements
- Plot out the desired graph

There is one important equation that we want to prove using teh results of experiment:

$$V = \frac{nkT}{q} \ln\left(\frac{I_{sc}}{I_0} + 1\right)$$

3 Measurements and Results

3.1 Light Source Power

We will need to know the area of the solar cell for further calculations. The data is recorded in the following tables:

length [cm]	width [cm]
5.3	5.8

Figure 1: Area of solar cell

	1	2	3	4	5	6
P__ [W]	single 100 cm 1.214	3 in 2 1.225	X	X	series 100cm 1.208	X
P__ [__]	X	X	X	X	X	II 100 cm 2.008

Figure 2: Power of solar cell

From the table we can see that the area of the cell should be $30.74cm^2$. And the corresponding power is shown in the data table.

3.2 I-V Characteristics without Load Resistance

We here use a digital multimeter to calculate and measure the I-V characteristics without load resistance. The results are shown in the following table:

3.3 I-V Characteristics with Load Resistance

Here we add a load resistance to the circuit for further calculation and study. For each of the four situations mentioned above, we change the value

	single device at 100 cm	single device at 80 cm	series	parallel
U_{oc}[V]	3.20	3.32	6.67	3.10
I_{sc}[mA]	19.84	26.81	19.54	41.08

Figure 3: I-V Characteristics Without Load Resistance

of resistance and take 20 groups of data for each situation. The data are given in the following charts:

All the data are presented in the tables above with the situations indicated at the heading of the charts. All there data will be plotted in one single figure together later in the next subsection.

3.4 I-V Curve

Using the data acquired from the foru situations given above, we plot all four of them into one single graph to show the relationship between I and V. The graph is given as following:

From this curve we see that the current and the voltage of solar cells show an inversely proportional trend. To be more precise, this matches the equation we wanted to prove at the beginning of this report:

$$V = \frac{nkT}{q} \ln\left(\frac{I_{sc}}{I_0} + 1\right)$$

From the figure of series connection, we can clearly notice that the voltage is twice of the single cell connection while the current remains unchanged. And for the parellel connection, the current was doubled while the volatge remains the same. Both connection methods meet the equation we would like to do handwaving proof.

4 Conclusions and discussion

4.1 Conclusions

In this experiment, we focused on the relationship, or say the I-V characteristics of solar cells. We first measured the power of the light source which acted as the sun, and thet take down the data of different light source situations for later analysis. Based on the results acquired from the experiment, we can say that we partly prove the equation:

$$V = \frac{nkT}{q} \ln\left(\frac{I_{sc}}{I_0} + 1\right)$$

	series		parallel	
	U [V]	I [mA]	U [V]	I [mA]
1	0.01	20.31	0.01	39.45
2	1.02	20.22	0.23	39.39
3	2.14	20.19	0.45	39.31
4	2.67	20.15	0.85	39.14
5	3.31	19.91	1.08	39.10
6	4.81	19.79	1.54	39.03
7	5.45	19.40	1.87	39.00
8	5.50	19.12	2.40	38.84
9	5.61	18.60	2.57	38.19
10	5.73	17.87	2.65	38.03
11	5.80	17.35	2.71	37.25
12	5.84	16.74	2.77	36.12
13	5.87	16.43	2.85	32.76
14	5.94	15.92	2.93	30.21
15	6.08	13.71	3.03	24.91
16	6.20	11.44	3.06	21.54
17	6.24	9.87	3.12	18.77
18	6.35	7.62	3.14	14.40
19	6.46	4.10	3.17	11.67
20	6.48	2.65	3.29	0.75
21				
22				
23				
24				
25				

Figure 4: I-V Characteristics with Load Resistance

	100 cm		80 cm	
	U [V]	I [mA]	U [V]	I [mA]
1	3.15	7.24	0.02	26.38
2	3.15	7.41	0.63	25.74
3	3.15	7.63	1.32	25.54
4	3.14	7.83	1.81	25.50
5	3.14	8.03	2.30	25.41
6	3.13	8.80	2.51	25.35
7	3.13	8.85	2.72	24.67
8	3.12	9.35	2.82	24.31
9	3.12	9.49	2.84	23.85
10	3.11	10.08	2.86	23.32
11	3.09	10.97	2.92	22.82
12	3.07	11.95	2.94	22.17
13	3.03	13.43	2.98	21.41
14	2.94	16.04	3.00	20.97
15	2.25	19.23	3.05	19.01
16	1.87	19.66	3.14	14.16
17	1.39	20.18	3.16	11.70
18	0.75	20.82	3.22	9.03
19	0.41	21.20	3.23	6.49
20	0.16	21.42	3.25	5.07
21				
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23				
24				
25				

Figure 5: I-V Characteristics with Load Resistance

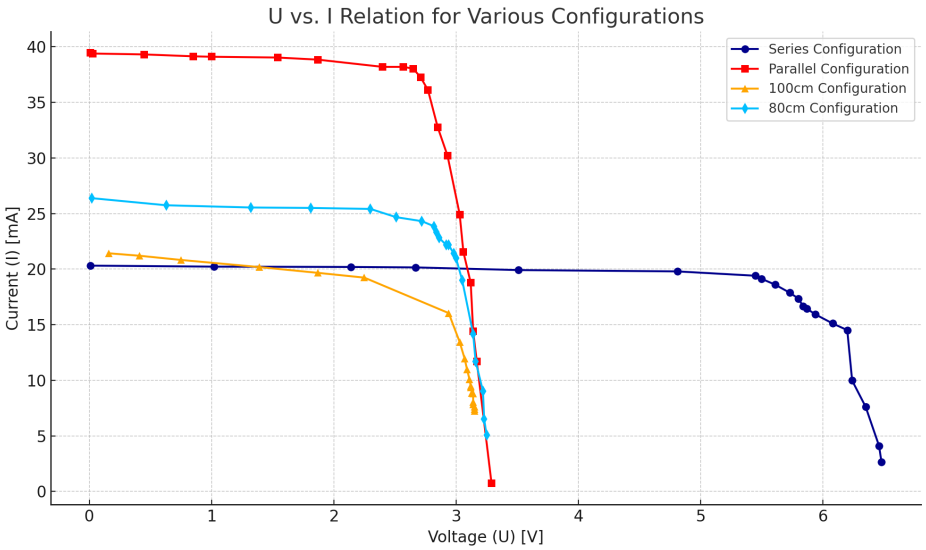

Figure 6: I-V Relationship

4.2 Discussion

There were also some potential errors in the experiment. For example, the time it took to measure all the data needed for the lab report and following analysis is too long. During this period, the solar curve of the cells might change dramatically due to the high temperature generated by the lighy source. This can cause errors in the curves. Also, the distance between the light and the cells are measured using a long ruler, which can be quite inaccurate. This might also have some negative effects on the value of data we get.

5 Works cited

Department of Physics, Shanghai Jiaotong University, Exercise 3 (Solar Cells: I-V Characteristics) - lab manual [rev. 2.4], 2024
Python Software Foundation. (2020). Python Language Reference, version 3.9. Available at http://www.python.org

All the figures displayed in the article (excluding the appendix) are given using Python 3.9.

A Datasheet

length [cm]	width [cm]
5.3	5.8

Figure 7: Datasheet 1

	1	2	3	4	5	6
P [W]	single 100 cm 1.214	3 80 1.225	X	X	series 100cm 1.208	X
P [ ]	X	X	X	X	X	II 100 cm 2.008

Figure 8: Datasheet 1

	single device at 100 cm	single device at 80 cm	series	parallel
U_{oc} [V]	3.20	3.32	6.67	3.10
I_{sc} [mA]	19.84	26.81	19.54	41.08

Figure 9: Datasheet 1

	series		parallel	
	U [V]	I [mA]	U [V]	I [mA]
1	0.01	20.31	0.01	39.45
2	1.02	20.22	0.23	39.39
3	2.14	20.19	0.45	39.31
4	2.67	20.15	0.85	39.14
5	3.31	19.91	1.08	39.10
6	4.81	19.79	1.54	39.03
7	5.45	19.40	1.87	39.00
8	5.50	19.12	2.40	38.84
9	5.61	18.60	2.57	38.19
10	5.73	17.87	2.65	38.03
11	5.80	17.35	2.71	37.25
12	5.84	16.74	2.77	36.12
13	5.87	16.43	2.85	32.76
14	5.94	15.92	2.93	30.21
15	6.08	13.71	3.03	24.91
16	6.20	11.44	3.06	21.54
17	6.24	8.87	3.12	18.77
18	6.35	7.62	3.14	14.40
19	6.46	4.10	3.17	11.67
20	6.48	2.65	3.29	0.75
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24				
25				

Figure 10: Datasheet 1

	100 cm		80 cm	
	U [V]	I [mA]	U [V]	I [mA]
1	3.15	7.24	0.02	26.38
2	3.15	7.41	0.63	25.74
3	3.15	7.63	1.32	25.54
4	3.14	7.83	1.81	25.50
5	3.14	8.03	2.30	25.41
6	3.13	8.80	2.51	25.35
7	3.13	8.85	2.72	24.67
8	3.12	9.35	2.82	24.31
9	3.12	9.49	2.84	23.85
10	3.11	10.08	2.86	23.32
11	3.09	10.97	2.92	22.82
12	3.07	11.95	2.94	22.17
13	3.03	13.43	2.98	21.41
14	2.94	16.04	3.00	20.97
15	2.25	19.23	3.05	19.01
16	1.87	19.66	3.14	14.16
17	1.39	20.18	3.16	11.70
18	0.75	20.82	3.22	9.03
19	0.41	21.20	3.23	6.49
20	0.16	21.42	3.25	5.07
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25				

Figure 11: Datasheet 1