University of Waterloo
Electrical & Computer Engineering Department

ECE 331
ELECTRONIC DEVICES

LAB 2: SOLAR CELL LAB STUDY

Contributors:
Paul Hayes, Albert Wasef, Manisha Shah, Marco Iskander

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1. Introduction

Solar cells are commonly made from pn junctions. When the pn junction is illuminated, electron-hole pairs are generated in the pn junction's depletion region. Since these charged particles find themselves in an electrical field, the electrons are immediately swept to the cathode or n side and the holes to the anode or p side. Our solar cells are **Amorphous Silicon Solar Cell (AM-5308) made by Sanyo.**

Ref: Section 8.1.1 and 8.1.2, Ben Streetman and Sanjay Banerajee, 6th Edition

Caution

Avoid contact of hot bulb with liquid or metal, as glass may shatter.
Avoid use at short distance on materials that are flammable or susceptible to heat damage.
Burning Position: Socket Base up only, i.e. light pointing down.

2. Prelab

i) Define the following terms:
   a) The Fill Factor,
   b) V_{oc} and I_{sc},
   c) The solar cell efficiency

ii) Briefly Explain the I-V characteristics curve of a typical solar cell.

The green color indicates in-lab data measurements
The yellow color indicates report work

3. Lab Measurements and Report Questions

3.1. Characteristics as function of light intensity

The characteristics of a solar cell are measured at different light intensities, by varying the "VARIAC - AC voltage" to the light source.

The objective of this part is to determine the light intensity with the (Light Meter, or, Power Meter) at various light source Variac voltage settings, while monitoring the Thermistor for temperature stability. Then we will measure the V_{oc} and I_{sc} at different light intensities.

Figure 1. Setup to measure light power at different light intensities using light power meter

a) Measure light power at various light intensity using different variac settings- maximum up to 120 V

   1) On the Amprobe solar power meter, press W/B button switch to select **W/m²** and press "**R**" to switch to the auto range on the solar power meter. *If "1999" or "OL" comes up on the screen, it means the device is overloaded. Press "R" once and that should fix it.*
   2) Measure the light intensity with the AMPROBE solar power meter at different light intensities We will vary the test setup Flood Light intensity by varing the voltage set on the VARIAC. Use Figure 1, and then fill in Table 1.

<u>IMPRTANT NOTE:</u> Turn on the Variac only while taking the readings and keep it off in between readings to prevent heating up of the power meter. The power meter will give wrong values if it heats up.

Table 1. Variac versus Light Intensity

Variac (V)	**Light Intensity W/m^2**
120	
110	
100	
90	
80	
70	
60	
50	
40	
30	
20	
10	

b) Measure the no-load voltage V_{oc} and short-circuit current I_{sc} at various light source intensities (by adjusting the Variac voltage), while monitoring the Thermistor for temperature stability, see Figure 2.

1) Measure no-load voltage (V_{oc}) of the solar cell using DMM and fill out the first two columns of Table 2.

- Select manual range on the DMM.
- Connect another DMM to the thermistor metalic ends on the solar cell. *V_{oc} and I_{sc} depend on temperature thus we will monitor the temperature using Thermistor. The solar cell can be kept at room temperature by turning the lamp off when not reading the DMM, and with the aid of a cold air blower. Make sure thermistor resistance* ***doesn't go lower than around 4kΩ*** *by recording its value at each step.*

2) Now measure short circuit current and fill out the last two columns of Table 2 again monitoring the thermistor resistance.

- Make sure that right connections are made on DMM for current measurement and select the manual range.

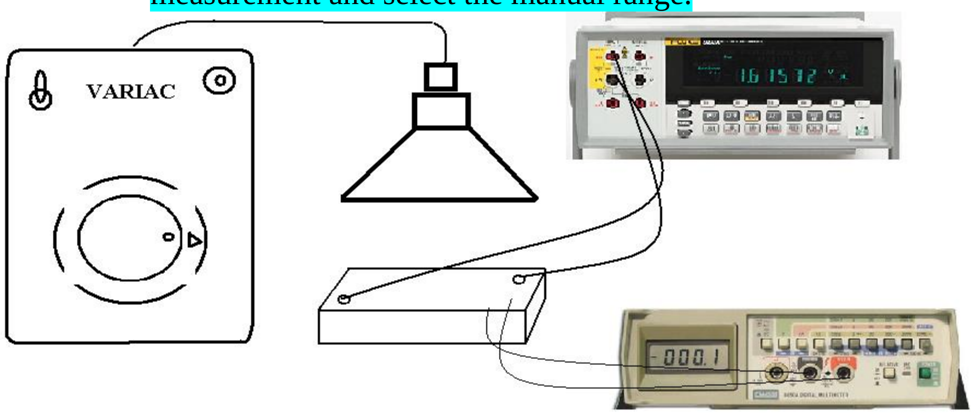


Figure 2. Measuring voltage, V_{oc} or Current I_{sc} and Thermistor resistance using Multimeters

Table 2. Open Circuit Voltage and Short Circuit Current

Variac (Volts)	V_{oc}		I_{sc}	
	V_{oc} (V)	Thermistor(KΩ)	I_{sc}(A)	Thermistor(KΩ)
120				
110				
100				
90				
80				
70				
60				
50				
40				
30				
20				
10				

Report:

a) Plot your data of short-circuit current and no-load voltage vs light power (W/m^2) from Table 1 and 2.

b) Comment on your results.

3.2. Temperature Dependence of no-load voltage

We will estimate the dependence of no-load voltage on temperature and plot the current-voltage characteristics under different Temperature. You can use the blower for heating and\or cooling. We will monitor the solar cell with a thermistor.

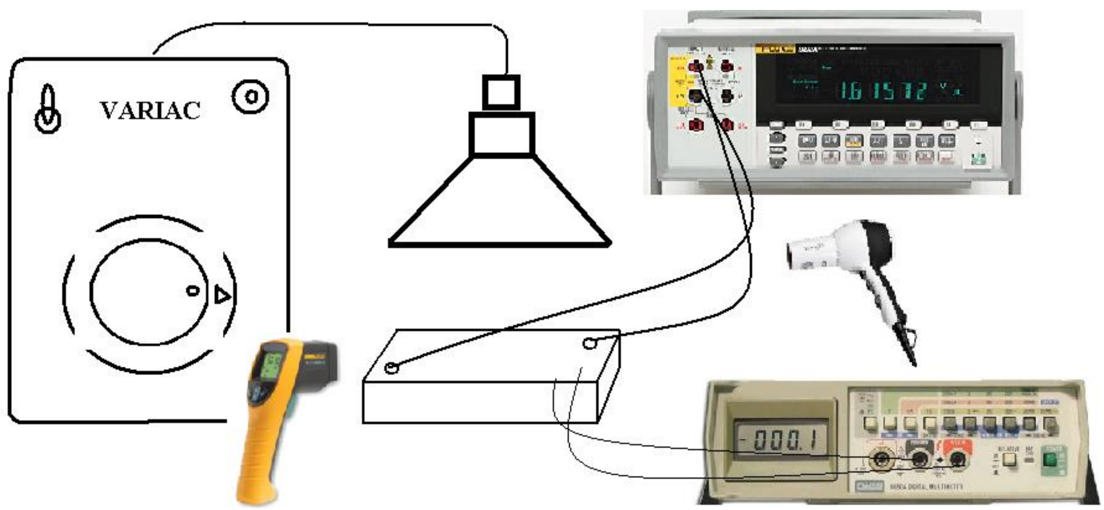


Figure 5. Solar cell characteristics as function of temperature

Caution: Do not point IR meter laser into anyone's eyes.

1) Connect the circuit as per Figure 5 to measure the open circuit voltage and observe the thermistor resistance using DMMs. The variac setting should be 60 V.
2) Start with a room temperature reading and then go in increments of around 10˚C. Do not exceed 80˚C. Blow the hot air with the blower on the solar cell and keep checking the temperature with the Fluke IR Thermometer. Read the following steps before making any measurement. Then fill in Table 3.
3) Record 4 digits after decimal for your voltmeter reading to get more precise values as values are close.
4) Wait for a little bit to get a stable value of resistance on the DMM and then record the value.
5) Turn off the variac while recording the temperature with the temperature gun to prevent the solar cell from heating up. If the lamp is not turned on and off, the lamp can heat the solar cell, and this may degrade the temperature measurement accuracy

using the hot air blower. The IR light will affect your readings so record V_{oc} before recording IR temperature.

Table 3. Temperature Effect on V_{oc}

Thermistor around 5k @~23˚C (room temperature)	Fluke IR ˚C	V_{oc} @ 60V variac
	room temp	
	80 ˚C (maximum)	

Report:

1) Plot the temperature vs. voltage from the data.
2) How does the voltage vary with the temperature and why?

3.3. I-V characteristics of the solar cell

You will get the plot for the solar cell I-V characteristics with no light/dark condition by placing the solar cell in a dark enclosure and then with few light settings (variac=30V, 60V and 90V). Follow the instructions given below to plot the I-V characteristics of your solar cell using SMU B2900 series:

1. Ensure that "Force" in Agilent B2912A/2902A unit is connected to the red terminal, this is the P region of the solar cell P-N junction, and that "**Low**" in Agilent B2912A/2902A unit is connected to **black terminal**, this is the N-region of the solar cell P-N junction.
2. Go to Start →Programs→ Keysight B2900A Quick IV Measurement Software → Quick IV Measurement Software
3. From the top right corner Pane, select "CHANNEL Communication" , then,
   a. Select "**Search CHANNEL**" icon.
   b. In the opened window do the following:
      i. Set "**Select interface type**" to "**USB**"
      ii. Press "**Search**" icon.

    iii. The software should be able to locate the address of the connected Agilent B2912A/2902A unit.
    iv. Select "**Close**"
  c. Set "**Address**" to address found in the previous step.
  d. Set "**Channel**" to "**Channel 1**".
  e. Edit "**Name**" to be "**Solar cell**"
4. From the top right corner Pane, select "Channel Setting" and adjust the following.
   a. Select "**Source Function**" to be **VAR1**.
   b. Set "**Mode**" to "**V**" and "**shape**" to "**DC**".
   c. Set "**Sweep**" to "**Linear Single**".
   d. Set "**Start**" to **-2 V** and "**Stop**" to **2.5 V**.
   e. Set "**Compliance**" to **0.01 A**.
   f. Set "**Source Range**" to **Auto**.
   g. Check "**Voltage Measure**" and "**Current Measure**"
   h. Set "**Range**" to "**Auto**"
   i. Set "**Measure speed**" to "**medium**" or "**long**" <u>if it is noisy</u>
5. In "**Common Sweep Setting**" at the bottom adjust the following
   a. Set "**VAR1 (Primary Sweep) Count**" to **100**.
   b. Set "**Repeat**" to **1**.
   c. Set "**Trigger**" to **Auto**.
   d. Uncheck "**Specify Minimum Auto Trigger Period**".
6. Press the "**Graph**" icon.
7. In the "**Quick Setting**" tab, set "**X Data Type**" to **Voltage** and "**Y1 Data Type**" to **Current**
8. Now place the solar cell in the enclosure and close the lid for <u>dark condition</u>
9. Press the "**Measure**" icon to start measurements.
10. Right click on the resulting figure and select "Dump" to save the graph.
11. Include the plot in your inlab report.
12. Press the "Table" icon. Right click on the resulting Table and select "Export as csv". Save the Excel file under your N: drive in a secure folder. You will use this file in post lab.

13. Open the lid and set variac to 30V and then repeat step 9 to 11

14. Set variac to 60V and then repeat step 9 to 11.

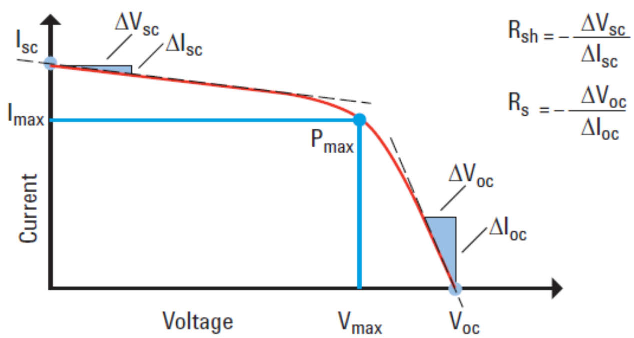
15. Set variac to 90V and then repeat step 9 to 11.

Report

1- Plot the I-V all the cases (dark, variac =30V, variac =60V and variac =90V) in one figure using Excel and include it in your report. Note that the current in the table is the negative value of the solar cell current, so you should inverse the sign. Format the axis, labels and legends, and comment on your plot.
No need to include the spreadsheet.

2- Use the spreadsheet to calculate or find (present your answer in a table format):
   a. V_{oc} and I_{sc} values for all the cases
   b. R_{sh} and R_s for all the cases
   c. Maximum Power and voltage and current values at maximum power.
   d. Fill factor for all the cases
   e. Maximum efficiency for 30V, 60V and 90V cases (Hint: you will need data from Table 1 and the solar cell area from datasheet of AM-5308)

3- Plot the power vs voltage for all the cases and comment on your plot.



3.4. Carrier life time, response time

1) Wire up the circuit according to Figure 3.
2) Note: No " DC" supply voltage, RL=5 Kohm,
3) Adjust the settings on the stroboscope to be 1489 RPM with 300 usec pulse.
4) You will need to place the stroboscope on the metal holder that sits above the solar cell.
5) Adjust the oscilloscope to have the same settings as those in Figure 4.
6) Keep the trigger level at the center of the pulse. You can move the ground reference towards the bottom of the screen to zoom in your pulse.
7) In order to obtain the required curve, you may need to increase the time scale of the oscilloscope to capture many pulses then decrease the time scale to have only one of the pulses displayed on the screen. Sample plot is shown in Figure 4.
8) Take a screenshot (using intulink) and insert it in your data. Measure the decay time using cursors from maximum voltage of 100% to decay to 37 % on the falling edge of the scope display.

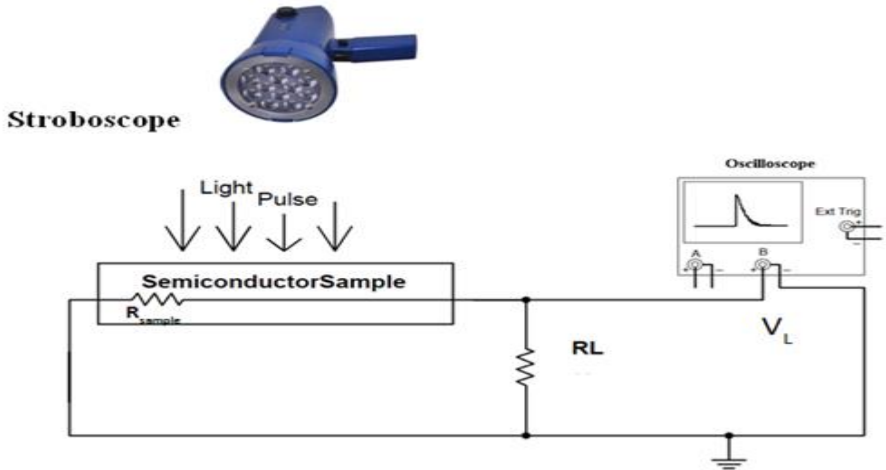


Figure 3. Carrier life time, response time of Solar cell

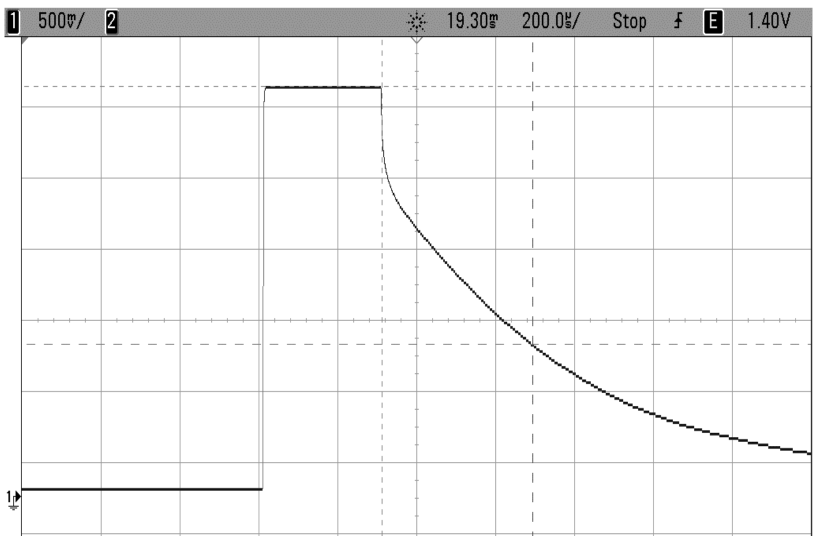


Figure 4. No dc voltage, RL=5 K ohm ~ V_{oc},300usec pulse ~ V_{oc}

Report:

(a) We know that in ECE209 the minority carrier life time for both the N silicon wafer sample and the P silicon wafer sample was measured to be between 10 mirco seconds and 20 mircro seconds, comment on why we are measuring a longer life time for the solar cell.

Hints:

A variety of time domain measurement methods are also being developed to evaluate the recombination parameters of solar cells, such as minority carrier lifetime (t_{au}) , surface recombination velocity (S) and minority carrier diffusion length (L_d) .

One of the most popular techniques is open circuit voltage decay (OCVD) where the excitation is supplied either electrically or optically (see Figure 3). In the electrical case a constant current equal to I_{sc} is forced into the solar cell and the voltage decay across the solar cell is observed after abruptly terminating the current. In the optical case a light pulse is used to stimulate the solar cell instead of a current. For the short circuit condition the current flow across the solar cell is measured after removing the light stimulus, and this is called the short circuit current decay (SCCD).

Make sure you got all measurements and screenshots. Please tidy up your station.
Submit you "data2.pdf" file to learn **before leaving.**

Report Submission "Report2.PDF" should include prelab**, data and postlab in PDF**
Format.
A penalty will be applied for otherwise.