

## **Laboratory #5 Guide: I-V Performance Characterization of a Si Photodiode**

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### ***Introduction***

Following your extensive experience with development of LabView-controlled instrumentation and application to measurement of optical properties of transparent conductors and semiconductor absorbers, we now turn toward an understanding of how solar cells operate under different conditions. Parameters of interest include the cell area, light intensity (dark vs. light), current, and voltage. In this lab, you will ultimately measure the current-voltage characteristics of a Silicon photodiode, identifying such important parameters as the open circuit photovoltage, the short-circuit current density, the fill factor, and the series and shunt resistance values. In addition, you will measure the conversion efficiency of the photodiode, defined simply as the ratio of the maximum electrical power generated to the incident light power.

### ***Goals of Lab #5***

Broadly stated, your goals for Lab #5 involve developing a deep understanding and sound expertise in measurement of current density vs. voltage measurements of photovoltaic cells. Your understanding should extend from the detailed operation of the LabView software, through to the instrumentation, the I-V (or J-V – be sure you know the difference between I and J), and an understanding of how shunt resistance and series resistance impact the performance of a solar cell.

### **Sample List**

1. Resistor
2. Si photodiode
3. Si photodiode + resistor in series (10  $\Omega$ )
4. Si photodiode + resistor in parallel (variable, in the upper left corner of the optical breadboard – keep track of this parallel resistor and keep with your Team setup)
5. Si photodiode + both parallel and series resistors

### ***Concepts***

Below, you're instructed to make the necessary measurements in order to calculate the efficiency of the Si photodiode (Si PD). To do so, you'll need to know the power incident on the PD – that involves using your detector to separately measure the light intensity (or power) over a known area. Think carefully about how you can do this, and then to measure the response of the Si PD under the same illumination conditions. We already know that the illumination beam size varies with position, and that it's not possible to focus the beam tightly enough to fit all the light on the 2M

detector. But there are ways forward – please discuss them with us when you get to Step. 7 and before you proceed.

***Experimental Steps (Demonstrate understanding within your lab report)***

1. You will start with a .vi called Keithley 24XX Sweep and Acquire Measurements.vi, located on the laptop. Start by inspecting and investigating the .vi's elements (what's inside), and what roles and functions each sub-vi serves. It may very well be helpful to refer to the Keithley SourceMeter manual as you learn about the measurement .vi. Describe each element in your notebook and include this in your lab report. After you have completed your assessment and understanding of the .vi and its components, fine-tune the .vi so it communicates with the Keithley, and so it allows you to save the data to a user-friendly file format – as Amps vs. Volts.

Note: In order to protect against damage to the samples, all of your Current vs. Voltage measurements should be made from  $-1.0\text{ V}$  to  $1.0\text{ V}$  – Do Not Exceed these limits!

2. Measure the I-V characteristics of the “test resistor” (you’ll find this resistor in the upper right corner of the optical breadboard -- keep track of this resistor so it’s not confused with another, and keep it with your team during this lab). Provide a small but complete graph of the measured values, and indicate the results of your fit to Ohm’s Law in order to determine the resistance.
3. Measure the current vs. voltage of the Si photodiode, both in the dark and also when illuminated with the output from the light source. Recall that the light source will be at its most powerful when you switch to the “zero order” of the mirror (instead of using the diffraction grating). You *do not need to open* the CM 110 to change the grating selection to the mirror side. Also measure the Si PD in the room light, without any additional illumination.
4. Repeat step 3., with a  $10\ \Omega$  resistor in series with the Si photodiode.
5. Repeat step 3., now with a resistor in parallel (you’ll find this resistor in the upper left corner of the optical breadboard – please keep track of it and keep it with your team).
6. Now repeat step 3., using both resistors simultaneously ( $10\ \Omega$  in series, and the parallel resistor in parallel).
7. Measure the conversion efficiency of the Si photodiode (yes, the photodiode is a solar cell too). In order to do this, you’ll need to know the intensity ( $\text{W}/\text{cm}^2$ ) of the incident light beam. Think carefully about how you can measure the efficiency. You should arrive at values for the open circuit voltage ( $V_{\text{oc}}$ , in Volts) and the short circuit current density ( $J_{\text{sc}}$ , in  $\text{A}/\text{cm}^2$ ). Note that the

correct value of  $J_{sc}$  depends on the area of the illuminated portion of the detector.

***Analysis and considerations for your lab report***

For Steps 3, 4, 5, and 6 above, analyze your data to extract values (in the light) for the  $V_{oc}$ ,  $J_{sc}$ , and FF. Determine the inverse slope of  $I(V)$  at  $V = 0$  V and at  $I = 0$  A in order to determine approximate values for  $R_{shunt}$  and  $R_{series}$ . Also determine these value for the limiting portions of the  $I(V)$  curves – closer to -1 V, and to +1 V. Graph each pair of measurements (dark and light) on the same graph, and identify the critical points for the light curve on each graph. Extract and indicate the value of the dark current. Referring to your measurements in Step 3, based on your  $J_{sc}$  measurements, how much more intense is your light source than the room lights?

For Step 7, describe in detail what barriers existed to making the efficiency determination, and how you overcame these barriers to arrive at an answer. Include an estimated uncertainty, and your quantitative basis for that uncertainty.