# T11

## Solar Cells

The objective to this lab is to gain expertise at using standard electronics laboratory equipment to extract electronic device parameters. In this instance you will be carrying out experiments to determine the I/V characteristics of solar cells under different lighting condition. With no illumination on the solar cell you can extract the two parameters that describe the I/V characteristics of a diode ($I_S$ and n). With illumination you can work out the solar cell characteristics ($V_{OC}$, $I_{SC}$, FF and efficiency). Finally we would like you to compare and contrast the efficiencies of two types of solar cell under high and low intensity lighting.

### Schedule

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| Preparation time | : | 3 hours |
| Lab time | : | 3 hours |

### Items provided

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|---|---|---|
| Samples | : | Two types of solar cell |
| Components | : | resistors |
| Equipment | : | Light-source, resistor box, multimeter, current/voltage source |
| Software | : | Curve fitting software (your choice e.g. Excel, Matlab) |

### Items to bring

Essentials - a full list is available on the Laboratory website at https://secure.ecs.soton.ac.uk/notes/ellabs/databook/essentials/

***Before*** you come to the lab, it is essential that you read through this document and complete ***all*** of the preparation work in section 2. If possible, prepare for the lab with your usual lab partner. Only preparation which is recorded in your laboratory logbook will contribute towards your mark for this exercise. There is no objection to several students working together on preparation, as long as all understand the results of that work. Before starting your preparation, read through all sections of these notes so that you are fully aware of what you will have to do in the lab.

> **Academic Integrity** – *If you undertake the preparation jointly with other students, it is important that you acknowledge this fact in your logbook. Similarly, you may want to use sources from the internet or books to help answer some of the questions. Again, record any sources in your logbook.*

### Revision History

September 17, 2012 Darren Bagnall (dmb) First version of this lab

## 1 Aims, Learning Outcomes and Outline

This laboratory exercise aims to:

- Provide a practical introduction to device characterisation
- Explore the characteristics of solar cells
- Practise curve fitting to extract empirical fitting parameters

Having successfully completed the lab, you will be able to:

- Apply appropriate laboratory techniques to measure semiconductor device characteristics
- Develop analytical approaches to understanding complex physical systems

In circuit or system design is important to know the precise electrical characteristics of the electronics devices being used. In many cases, (transistors and solar cells are good examples) the actual characteristics of nominally identical devices can vary considerably because semiconductor properties such as mobility ate hard to control. In such cases it is important to be able to use a range of simple tests to determine the actual device properties. We then use well-established semi-empirical equations to establish a minimum number of fitting parameters that define the device behaviour. Once these values are established they can then be used in SPICE or other circuit models.

In this exercise you will determine the I/V characteristics of solar cells in dark and light conditions and use semi-empirical device models for diodes and solar cells to extract device parameters. Your final task will be to consider the relative merits of two different types of solar cell for use indoors and outdoors.

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## 2 Preparation

Read through the course handbook statement on safety and safe working practices, and your copy of the standard operating procedure. Make sure that you understand how to work safely. Read through this document so you are aware of what you will be expected to do in the lab.

### 2.1 The Diode

*What is the diode equation? You should obtain (or derive) and consider your answer in both its derived and empirical forms (the empirical form usually contains the fitting parameter n)?*

Use your preferred software (e.g. Matlab or Excel) to plot an I/V curve for a 1cm$^2$ diode with n=2 and $I_S$= 10x10$^{-8}$A in the range (-2 to +2 V). Set up an algorithm that will allow you to fit this curve to empirical data during the lab.

Devise a method for taking I/V measurements in the lab.

### 2.2 The solar cell

*What does the characteristic I/V curve look like for a solar cell? Draw it in your logbook.*

Determine an experimental procedure that will allow you to plot such an I/V curve in the lab, and thereby calculate values for VOC, ISC, FF and efficiency.

**Tips:**

a) During the lab you will be provided with a measure of the optical power density of the light source as a function of distance (in Wm$^{-2}$).

b) You will also be provided with decade resistor boxes, though for better accuracy you may wish to use an array of resistors and a breadboard (note that at the extremes of the solar cell I/V curve you tend towards open circuit and short circuit conditions so some values of $R_L$ greater than a MΩ and some smaller than 1Ω are helpful – correspondingly you need to change resistance values on a logarithmic rather than linear scale. The more points you have on your curve the more accurate the parameters you can obtain – especially if those points are evenly spaced across the voltage and current ranges involved.

c) You should not usually measure a current using an ampmeter in series, you are better off determining a small current by measuring a voltage across a known resistance.

### 2.3 Equivalent Circuit

- *What does the simple (1 diode) solar cell equivalent circuit look like? Draw it in your logbook, and list the 5 fitting parameters for the circuit.*
- *What expression will provide the I/V characteristics for a solar cell based on these fitting parameters and equivalent circuit?*
- *How can you estimate values for the 5 fitting parameters using dark and light I/V curves?*

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## 3 Laboratory Work

At the start of the lab familiarise yourself with the available equipment and the solar cells.

### 3.1 Solar cell dark characteristics.

Using the methodology determined in 2.1 obtain the dark characteristics for the solar cells provided. You will need to use the current/voltage supply and should cover the solar cell during the measurements.

Using the methodology determined in 2.1 find values for $I_S$ and n that provide the best fit to your data.

### 3.2 Semiconductor light characteristics

Using the methodology determined in 2.2 take current and voltage characteristics for each of the solar cells provided. Take these characteristics both under direct illumination from the light-source provided and with the cells in just ambient light

Plot the I/V curve and list the values of $V_{OC}$, $I_{SC}$, FF and efficiency.

- *What observations can you make regarding the different device parameters?*

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## 4 Optional Additional Work

*Marks will only be awarded for this section if you have already completed all of Section 3 to an excellent standard and with excellent understanding.*

Consider the equivalent circuit of a solar cell and the methodologies you considered in section 2.3. Extract the 5 fitting parameters for the equivalent circuit ($I_S$, n, $I_P$, $R_{SE}$ and $R_{SH}$) for each of the devices under direct illumination.

## References

[1] C. Honsberg and S. Bowden. *PVCDROM* [online]. Available: http://www.pveducation.org/pvcdrom (last accessed September 2012).