APPLICATION NOTE

Localized I-V Characterization of Photovoltaic Solar Cells Using Monochromatic Light

Characterization is a critical part in the research of novel solar cells and photovoltaic (PV) materials. Because the PV properties can be affected at small scales, such as localized traps in the bandgap for semiconductor devices, or variances between grains in polycrystalline PV materials, it is important to be able to characterize these devices locally [1]. There are many parameters used in evaluating the characteristics of photovoltaic cells and comparing devices (e.g. conversion efficiency, fill factor, short circuit current, etc.) These parameters are commonly evaluated using voltage sweeps and current measurement through use of a semiconductor parameter analyzer. Localized measurements can be performed using laser illumination and scanning of the device.

This application note reports on using Imina Technologies miBot micromanipulators to carry out typical photovoltaic characterization of solar cells. A custom apparatus is described to bring laser light coupled in an optical fiber above the sample surface, while electrical probes contact the device, all three using miBots to control the movements.

Apparatus

Imina Technologies components apart, the apparatus consists of standard commercial optomechanical modules (Thorlabs, Inc.) and a 5 mW, 532 nm, HeNe laser (Newport Corp.) used as a light source coupled to a 250 µm diameter optical fiber [Figures 2 and 4].

The samples are monocrystalline silicon solar cells (SOL-EXPERT group, Germany) with top surface areas of 0.015 and 3.25 cm^2 and open circuit voltage (*VOC*) specified at 0.45 V. They are placed on a sample holder mounted on a manual X-Y stage with 25 mm of travel.

Two miBots equipped with 1 µm tungsten electrical probes are placed near the sample on top of the X-Y stage. The miBots are moved over individual stages (1-Bot), providing them the ability to translate the miBot over +/- 5 mm in each direction and to rotate them over +/- 180° while keeping the setup very compact.

In collaboration with:

L.E.S.S. SA, Lausanne, Switzerland
www.less-optics.com

Imina Technologies products in use:

- miBot™ BT-11 micromanipulator
- Compact stage CB-42
- MultiBot MB-11
- syDrive SD-10 piezoelectric controller

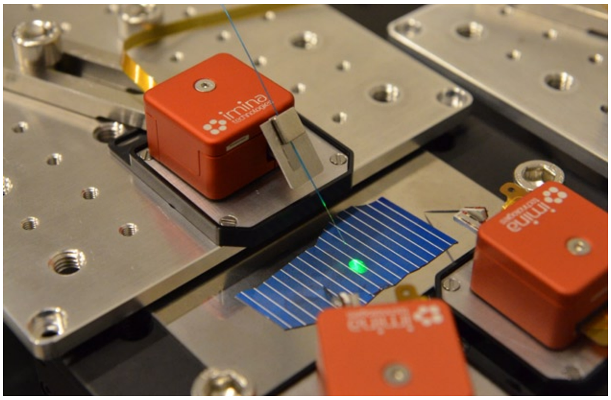

Figure 1: Photograph of a miBot micromanipulator holding an optical fiber over a sample of solar cell in order to illuminate it locally. The two other miBots are electrically contacting the cell.

Electrical contact is made between the negative electrode (the thin metalized strip on the PV surface) and the positive electrode (a conductive coating on the reverse of the sample) through the conductive metal sample holder.

The optical fiber is positioned with a third miBot whose 1-Bot stage is fixed above the X-Y stage. The fiber is held at 5 mm from the sample surface, making a laser spot of approximately 2 mm in diameter [Figure 1].

Measures

Photovoltaic characteristics

The first experiment is in determining the current-voltage characteristics of the samples using a forward bias under illuminated conditions. These characteristics were measured using an Agilent/HP 4156A semiconductor parameter analyzer. First, the samples were tested with no laser, in order to gather the photovoltaic characteristics of the environmental lights. Then a voltage sweep of 0 to 500 mV in 2.5 mV steps was performed using the laser at 5 mW. Figure 5 and 6 illustrate the I-V curve and the power curve produced for the 0.015 cm^2 sample.

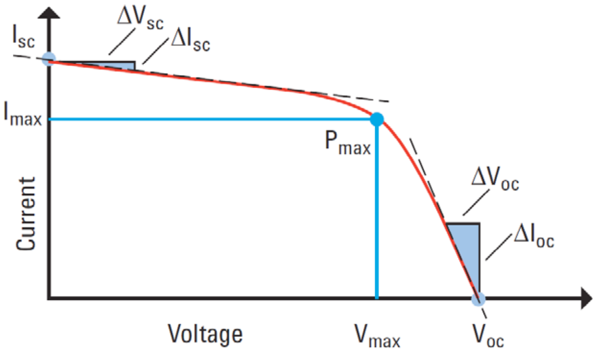

Figure 3: Forward bias I-V curve in illuminated conditions showing PV cell parameters (Source [2]).

From the I-V curve, the short circuit current (*ISC*), *VOC*, series resistance (R_s), and shunt resistance (R_{sh}) can be determined [Figure 3]. The maximum power (P_{max}) and corresponding current (I_{max}) and voltage (V_{max}) can be determined from the power curve. Additionally, the solar efficiency (η) and the field factor (*FF*) which give valuable information on how a PV cell behave can be determined with the following equations:

$$\eta = \frac{P_{max}}{E \cdot A_{cell}}$$

$$FF = \frac{P_{max}}{V_{OC} \cdot I_{SC}}$$

Device uniformity

The second experiment seeks to examine the uniformity of the PV devices by measuring the current while the laser

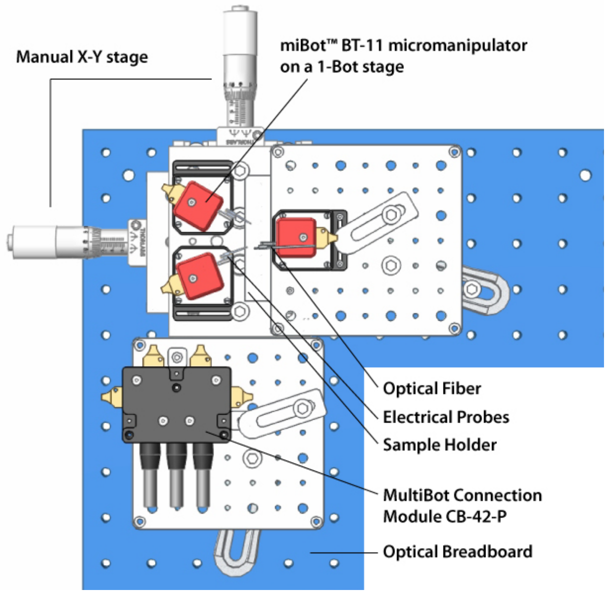

Figure 2: Schematic of the setup mounted on a standard optical breadboard (Thorlabs).

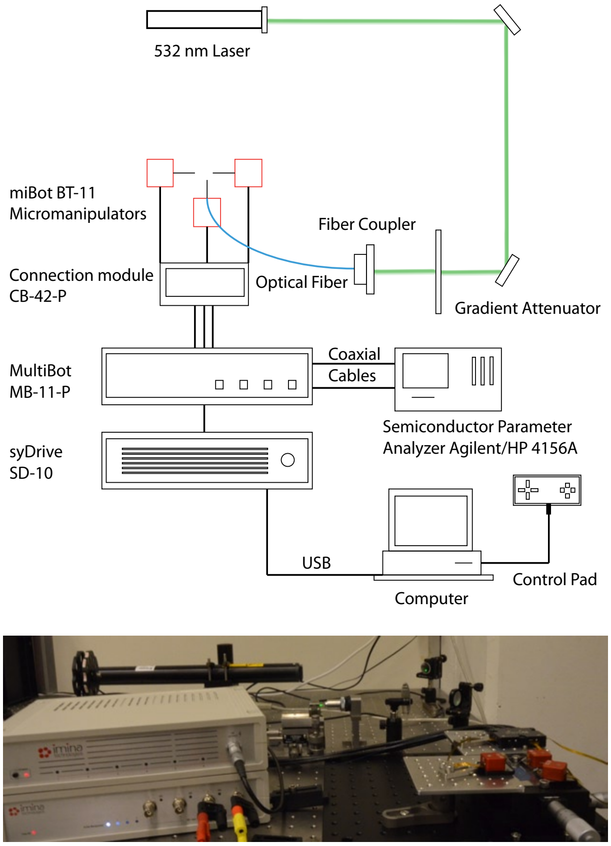

Figure 4: Block diagram and photograph of the apparatus assembly, with the sample and micromanipulators (front-right), the syDrive piezoelectric controller and MultiBot (front-left) and the laser followed by optical components to couple it with the fiber (back).

spot is moved along the sample in a line. While locating defective sites could be made possible with more advanced techniques like LBIC, a line scan gives an idea of the uniformity across the scan direction and one can observe changes in the current. Figure 7 shows a line scan over the 3.25 cm^2 sample linearly moved by the X-Y stage over 7 mm in 10 seconds. In order to ensure reproducibility of the scan, it was repeated with three passes and shifted to an average value to account for drift in the current values between passes. A region of visibly decreased current response observed at the start of the scan is attributed to the fact that the laser spot was near the edge of the sample.

Conclusions

I-V characteristics of photovoltaic samples under illuminated conditions are successfully reported in this application note. The positioning of the electrical probes and optical fibers anywhere on the sample was quick thanks to the mobility of the miBot micromanipulators over 4 degrees of freedom. The adjustable step resolution of the piezoelectric actuators allowed for localized illumination and measurements on even the smallest samples. Finally, the individual miBot stages enabled easy integration of the manipulators to the optical setup, allowing one to take full advantage of the compactness of the miBot and limit the footprint of the positioning devices on the overall setup size.

[1] S. Dueñas, E. Pérez, H. Castán, H. García, and L. Bailón, The role of defects in solar cells: control and detection, 2013 Spanish Conference on Electron Devices (CDE), 12-14 Feb. 2013, pages 301-304. http://dx.doi.org/10.1109/CDE.2013.6481402

[2] Agilent Technologies, Inc., IV and CV Characterization of Solar/Photovoltaic Cells Using the B1500A, Application Note B1500A-14.

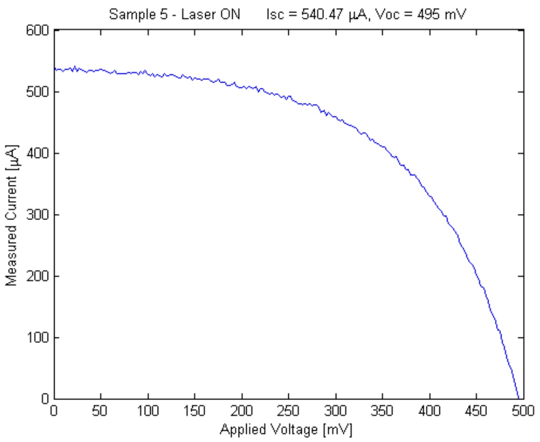

Figure 5: Forward bias I-V curve for the 0.015 cm^2 sample under a 5 mW laser with corresponding the I_{SC} and V_{OC}.

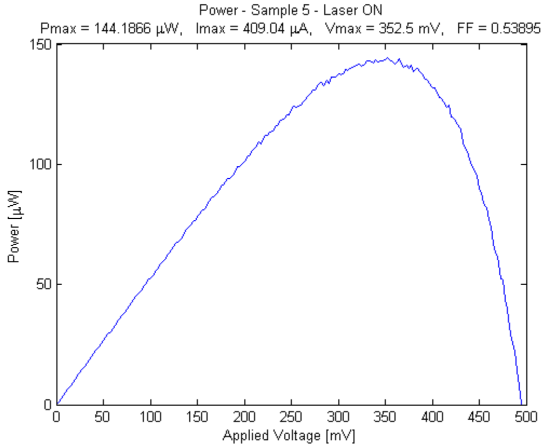

Figure 6: Power curve for the 0.015 cm^2 sample under a 5 mW laser with corresponding the P_{max}, I_{max}, V_{max} and FF.

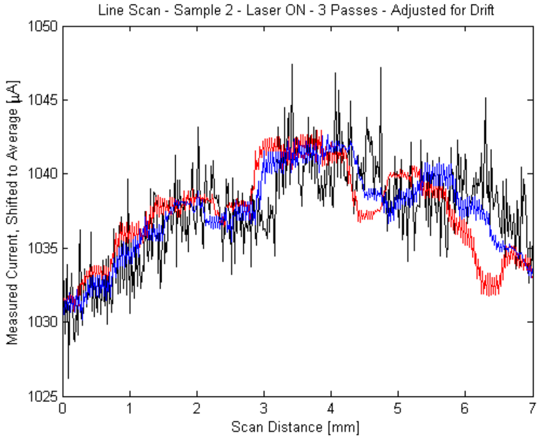

Figure 7: Line scan over the 3.25 cm^2 with three passes.

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