Metrohm Autolab

Application Area: Energy

Dye-Sensitized Solar Cells – i-V and Power Plots with the Autolab Optical Bench

Keywords

Photovoltaic devices, dye sensitized solar cells (DSC), Autolab optical bench

Introduction

A solar cell or photovoltaic cell is a device that converts light energy into electrical energy. Dye-sensitized solar cells (DSC) are currently a subject of intense research in the framework of renewable energies as a low-cost photovoltaic (PV) device. Electricity generated from a PV produces zero emissions, and it can produce energy anywhere the sun shines.

The standard characterization technique of a PV device consists of the determination of the DC Current-Voltage (i-V) curves under different incident light intensities.

Experimental setup

This application note illustrates the use of the Autolab PGSTAT302N in combination with the Autolab Optical Bench to perform DC characterization of a PV device.

The Autolab Optical Bench kit is comprised of an LED driver, an LED light and an optical rail, where the LED light and the solar cell can be placed at a defined relative distance.

All the measurements were performed on a dye-sensitized solar cell, using the N719 dye, supplied by Solaronix. Two LED light sources were used, a red-orange (617 nm) and a green light (530 nm). The light sources were a triple LED array driven by the output current of the Autolab LED Driver. The output of the LED Driver is controlled by the DAC164 of the Autolab, directly from the software. All the measurements were carried out with NOVA software.

Photocurrent-voltage measurements at 617 nm

The photocurrent-voltage measurements (i-V curves) can be obtained by applying a potential scan, from 0 V (V_{sc}, short-circuit conditions) to the open-circuit potential (V_{OC}), under constant illumination.

Figure 1 shows the measured i-V curves with increasing light intensity recorded with a red orange light (617 nm). As the light intensity increases, the short-circuit current i_{SC} increases and the open-circuit voltage V_{OC} decreases.

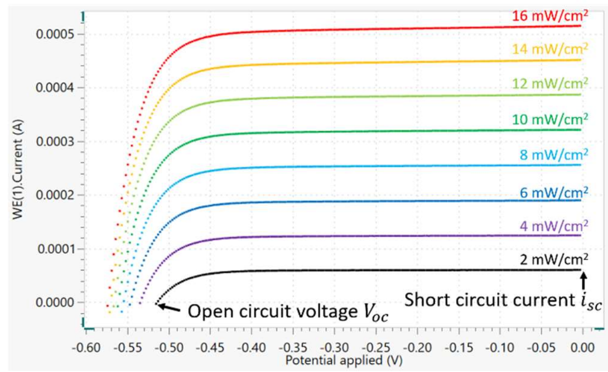

Figure 1 – i-V curves recorded with a red orange light (617 nm) at different light intensities

Figure 2 shows the power versus voltage curves with increasing light intensity recorded at 617 nm. As the light intensity increased, the power and the maximum power point (MPP) increased.

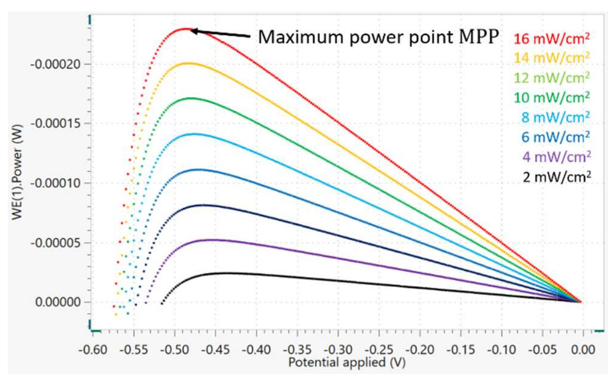

Figure 2 – Power vs. voltage curves recorded with red orange light (617 nm) at different light intensities

Photocurrent-voltage measurements at 530 nm

The same measurement can be repeated at a different wavelength, such as with a green light (530 nm). Figure 3 and Figure 4 show the i-V and the power versus voltage curves recorded under increasing constant illumination, with a green light source (530 nm). Same trend as the case of red orange light was observed when the green light was used for the experiment.

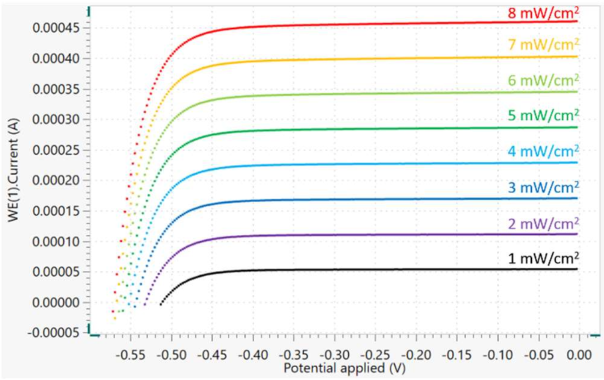

Figure 3 – i-V curves recorded with a green light (530) nm at different light intensities

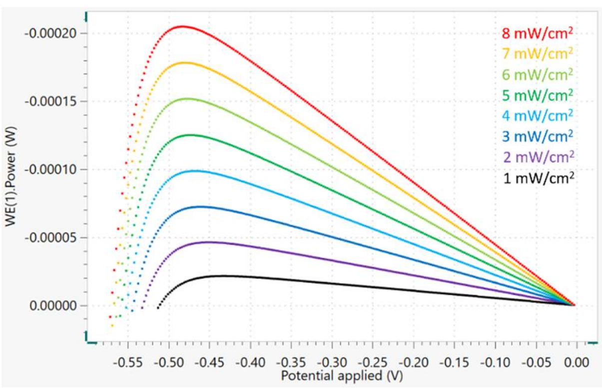

Figure 4 – Power vs. voltage curves recorded with a green light (530) nm at different light intensities

Comparison

Figure 5 shows the i-V behavior of the cell at same light intensity but different wavelengths. Figure 6 shows the PV plots for the cell at the same light intensity but different wavelengths. In both cases, the curves were obtained using an illumination intensity of 8 mW/cm^2.

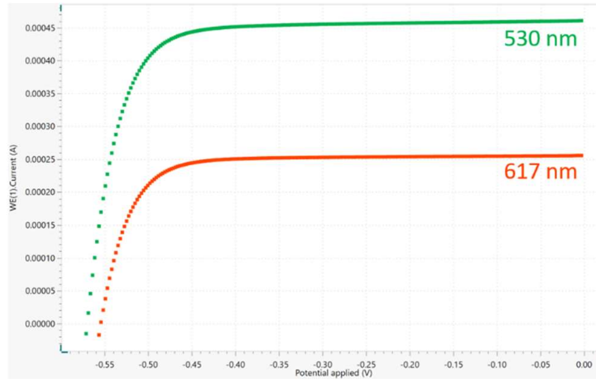

Figure 5 – Comparison of the i-V curves recorded at 8 mW/cm^2 for 617 nm and 530 nm

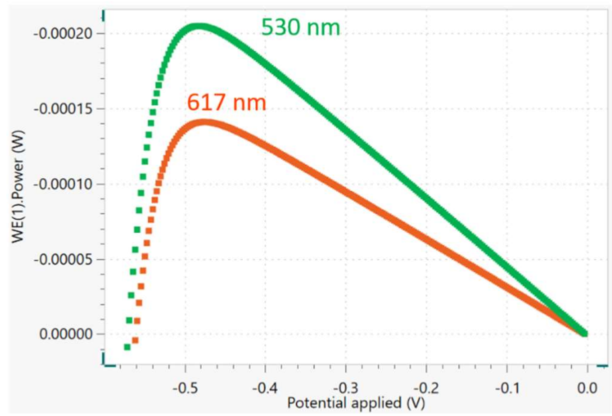

Figure 6 – Comparison of the PV curves recorded at 8 mW/cm^2 for 617 and 530 nm

The wavelength of the green light (530 nm) is close to the reported wavelength for maximum absorption of the N719 dye used in the cell under investigation, which explains the significant differences between the measurements at 530 nm and at 617 nm.

Data analysis

From the i-V and PV curves, the following parameters can be retrieved [1] :

- Short circuit current i_{SC} (A): the cell current measured at an applied potential of 0 V. i_{SC} is a function of the light intensity.
- Open circuit voltage V_{OC} (V): the cell potential measured when the current is 0 A. V_{OC} is also a function of the light intensity.
- Maximum power point MPP (W): the maximum power generated by the cell. MPP is also a function of the light intensity.

The current at short circuit increased linearly as the light intensity increased (Figure 7, red dots), since the photon-to-current conversion rate increased. On the other hand, the open-circuit voltage increased with light intensity in a logarithmic structure. This is due to the distribution of the energy states in the semiconductor (Figure 7, blue dots).

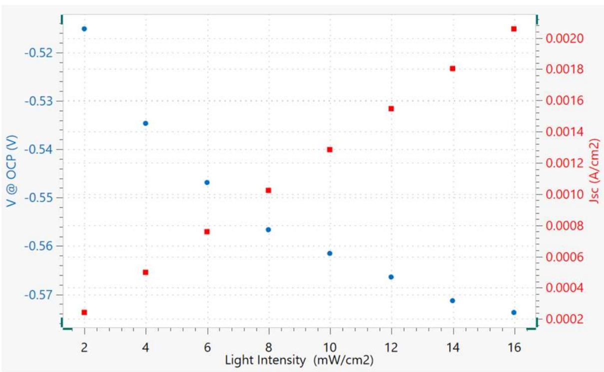

Figure 7 – Variation of V_{OC} (blue) and J_{SC} (red) versus light intensity at 617 nm

Figure 8 shows the maximum power point versus the light intensity at 617 nm. The maximum power point shows a linear increment with the light intensity.

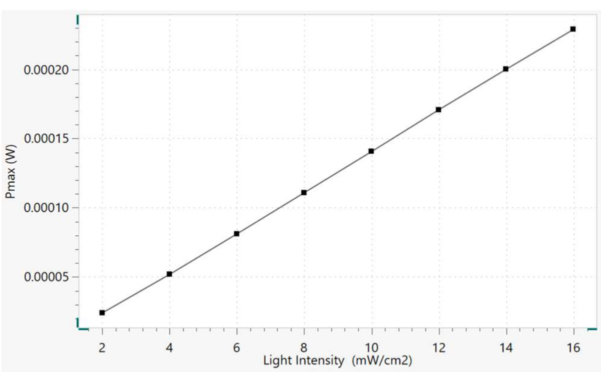

Figure 8 – Variation of the MPP versus light intensity at 617 nm

Additional parameters can be calculated from the measured values.

The fill factor (FF), is a parameter which show how much the solar cell power is close to the theoretical power. The FF is defined as the ratio of the maximum power from the solar cell to the product of V_{oc} and I_{sc}.

$$FF = \frac{MPP}{i_{sc} \cdot V_{oc}} \qquad 1$$

Figure 9 shows the evolution of the fill factor, versus the light intensity at 617 nm. The values fall within the normal range expected for this type of cells (average of 76.6 %).

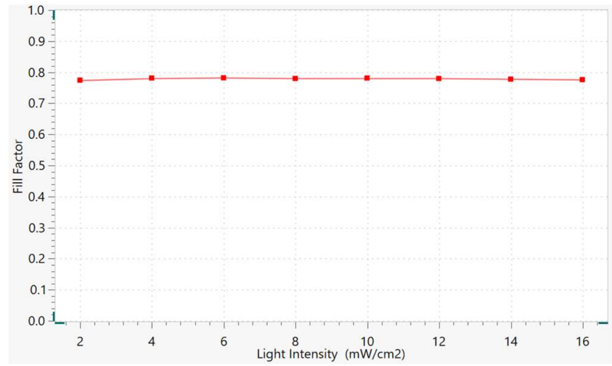

Figure 9 – Evolution of the fill factor (FF) versus the light intensity at 617 nm

Solar cell efficiency refers to the portion of energy in the form of sunlight that can be converted into electricity with the solar cell. The efficiency η (%), is defined as the ratio between the developed power (MPP) and input power, given by the light intensity LI (mW/cm^2).

$$\eta(\%) = \frac{MPP}{LI} = \frac{i_{sc} \cdot V_{oc} \cdot FF}{A \cdot LI} \qquad 2$$

Where A (cm^2) is the area of the solar cell and LI (W/cm^2) is the light intensity.

Figure 10 shows the evolution of the efficiency at different light intensities, for the 627 nm light. The efficiency increases slightly as the light intensity increases.

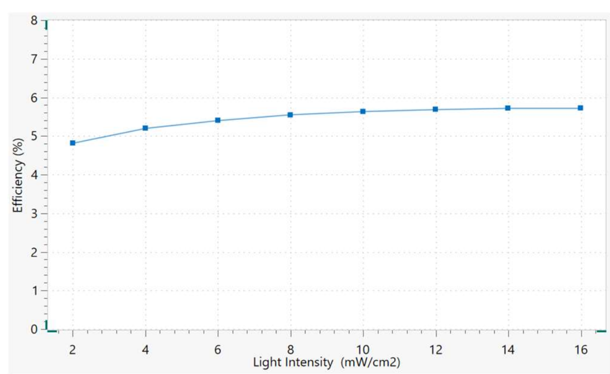

Figure 10 – Variation of the efficiency, η versus the light intensity at 617 nm.

The Incident photon-to-current conversion efficiency ($IPCE$, %, also known as internal quantum efficiency) is defined as the ratio between the number of electrons generated in the solar cell and the photon flux on the photoactive surface area of the cell, at a particular wavelength [2].

$$IPCE\ (\%) = \frac{1239}{\lambda} \cdot \frac{i_{sc,\lambda}}{A \cdot LI} \cdot 100 \qquad 3$$

Where $1239\ (W \cdot nm/A)$ is the conversion factor, $i_{sc,\lambda}$ is the photo current at a particular wavelength, $\lambda\ (nm)$ is the wavelength, $A\ (cm^2)$ is the solar cell area and $LI\ (W/cm^2)$ is the light intensity.

Figure 11 shows the IPCE measured at 617 nm at different light intensities. The IPCE remains more or less constant.

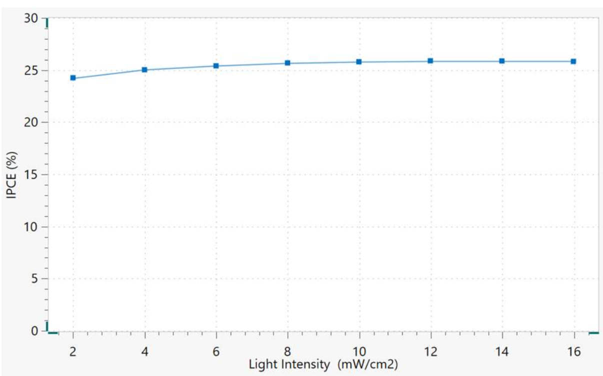

Figure 11 – Variation of the IPCE versus the light intensity at 617 nm.

Conclusions

This application note illustrates the use of the Autolab Optical Bench kit to study the DC behavior of a dye sensitized solar cell. The NOVA software provides the possibility of calculating the typical performance indicators and plotting these versus the light intensity.

The cell can be studied under different light intensities and different wavelengths. From the recorded data, typical performance indicators can be determined.

Acknowledgments

J. Halme and K. Miettunen from the Helsinki University of Technology are gratefully acknowledged for their assistance.

References

[1] Nelson, J., The Physics of Solar Cells, Imperial College Press, London, 2003

[2] Smestad, G.P., Optoelectronics of Solar Cells – SPIE Press Monograph, Washington, 2002

Date

March 2019 AN-PV-001

For more information

Additional information about this application note and the associated NOVA software procedure is available from your local **Metrohm distributor**. Additional instrument specification information can be found at **www.metrohm.com/electrochemistry**.