Metrohm Autolab

Application Area: Energy

Dye sensitized solar cells, impedance measurements

Keywords

Photovoltaic devices, dye sensitized solar cells (DSC), impedance spectroscopy

Summary

A solar cell or photovoltaic cell is a device that converts light energy into electrical energy. Dye-sensitized solar cells (DSC) are 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 can produce energy anywhere the sun shines.

The standard characterization technique of a PV device consists of the determination of the DC Current-Voltage curves under different incident light intensities. However, DC techniques do not provide any information about the internal dynamics of the PV device. Therefore, additional information can be obtained using time dependent and frequency dependent measurements. Electrochemical impedance spectroscopy (EIS) in particular offers the possibility to investigate the behavior of the device in the frequency domain under operating conditions, at various light intensities.

This application note illustrates the use of EIS to characterize a PV device.

Experimental conditions

The measurements were performed with a Metrohm Autolab PGSTAT302N, equipped with a FRA32M module. A Metrohm Autolab Optical Bench is also used to apply lights with different intensities to the solar cell.

A dye-sensitized solar cell, with the N719 dye by Solaronix was investigated. The light source was a 530 nm green LED light.

After a calibration of the LED light (please refer to the application note AN-PV-005), a preliminary photocurrent versus voltage (i-V) measurement was performed. This measurement can help in detecting the open circuit potential (V_{oc}) and the potential at which the maximum power point occurs (V_{MPP}). The i-V plot and the relative power versus voltage (P-V) plot were taken at light intensities of 4 mW/cm^2 and 8 mW/cm^2.

The EIS measurements were performed at light intensities of 4 mW/cm^2 and 8 mW/cm^2. Three different EIS measurements were performed, at V_{oc}, V_{MPP}, and $0\ V$, per each light intensity value.

Each EIS measurement were performed from 100 kHz to 10 mHz, with an AC amplitude of 10 mV, ten points per decade. Only the Nyquist plot is shown.

The experiments were performed with 15 cm of distance between the light source and the solar cell. The distance can be adjusted to other values if needed.

DC measurements

The i-V curves can be obtained by applying a potential scan, from $0\ V$ (short-circuit conditions) to V_{oc}, under constant illumination.

Figure 1 shows the measured i-V curves recorded under light intensities of 4 mW/cm^2 (blue line) and 8 mW/cm^2 (red line). The relative P-V curves are also shown in blue dots and red dots for both light intensities, respectively.

As the light intensity increases, the maximum short-circuit current, i_{SC} and the open-circuit voltage, V_{OC} increase (in absolute value).

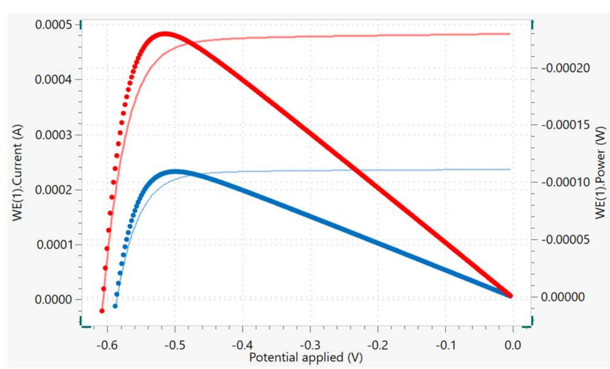

Figure 1 – i-V (lines) and P-V (dots) curves recorded at 4 mW/cm^2 (blue) and at 8 mW/cm².

Impedance measurements at 0 V (short-circuit)

Figure 2 shows two Nyquist plots obtained at short circuit conditions under constant illumination of the green light at 4 mW/cm² (blue circles) and 8 mW/cm² (red circles).

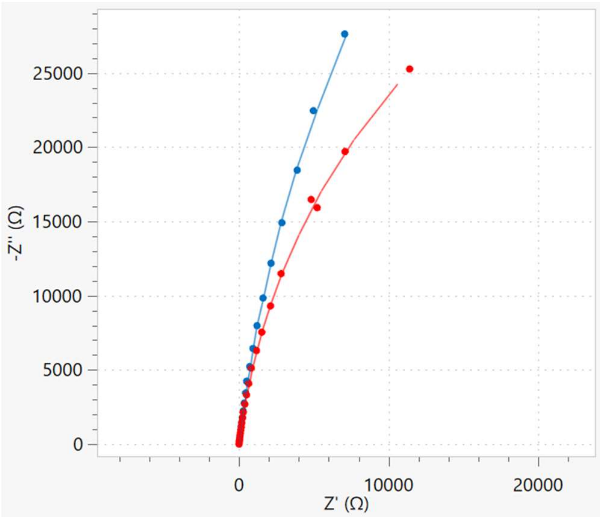

Figure 2 – Nyquist plot obtained at short-circuit conditions under light intensities of 4 mW/cm² (blue dots) and at 8 mW/cm² (red dots). The lines represent the results of the data fitting: blue line for the fit of the data at 4 mW/cm² and red line for the fit of the data at 8 mW/cm².

Both spectra can be fitted with a Rs(RpCPEdl) equivalent circuit, giving comparable values for both elements (see Figure 3).

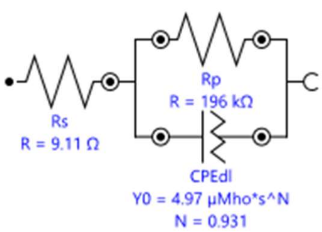

Figure 3 – The equivalent circuit that was used to fit the data obtained at the short circuit potential shown in figure 2.

Impedance measurement at maximum power point

Figure 4 shows two Nyquist plots obtained at maximum power point conditions under constant illumination at intensities of 4 mW/cm² (blue dots) and 8 mW/cm² (red dots).

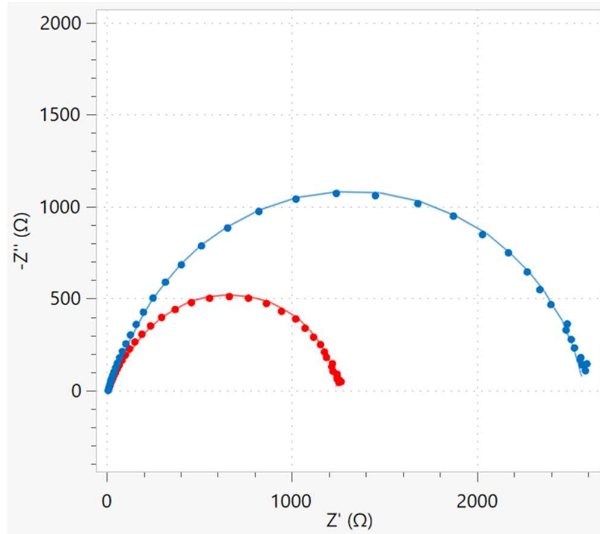

Figure 4 – Nyquist plots obtained at the maximum power point at 4 mW/cm² (blue dots) and at 8 mW/cm² (red dots). The lines represent the results of the data fitting: blue line for the fit of the data at 4 mW/cm² and red line for the fit of the data at 8 mW/cm².

Although the general trend is the same for both measurements, the impedance of the cell is lower at the maximum power point for higher light intensities.

Both spectra can be fitted with a [Rs(RpCdl)(B2C)] equivalent circuit, wherein the B2 element is a transmission line element described in the references provided at the end of this document (see Figure 5).

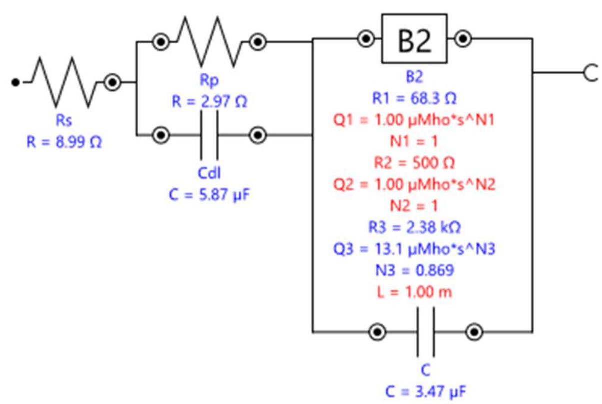

Figure 5 – The equivalent circuit that was used to fit the data obtained at the maximum power point.

Impedance measurements at open-circuit conditions

Figure 6 shows two Nyquist plots obtained at open circuit conditions under constant illumination of light at intensities of 4 mW/cm² (blue dots) and 8 mW/cm² (red dots).

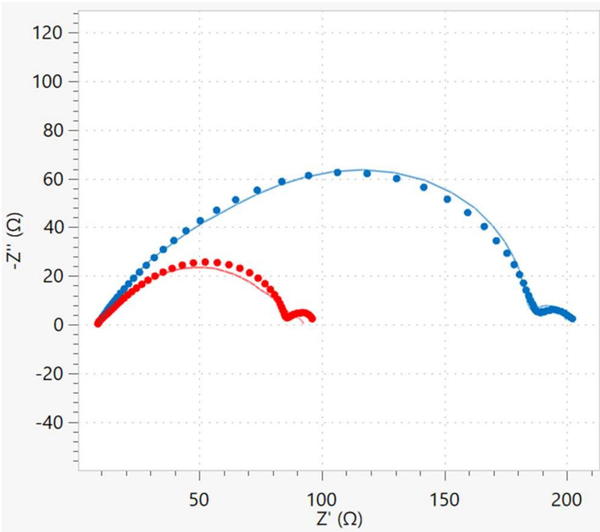

Figure 6 – Nyquist plot obtained at open-circuit conditions at 4 mW/cm² (blue dots) and at 8 mW/cm² (red dots). The lines represent the results of the data fitting: blue line for the fit of the data at 4 mW/cm² and red line for the fit of the data at 8 mW/cm².

Although the general trend is the same for both measurements, the impedance of the cell is lower at open circuit conditions for higher illumination levels.

Both spectra can be fitted with a [Rs(RpCPEdl)B2O] equivalent circuit, wherein the B2 and O elements are transmission line elements (see Figure 7).

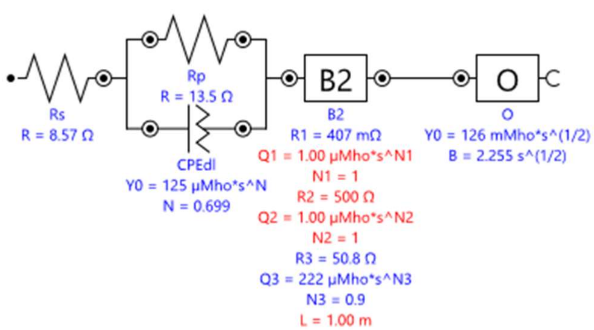

Figure 7 – The equivalent circuit used to fit the data obtained at the open-circuit potential

Conclusions

This application note has illustrated the use of the Autolab LED Driver kit to study the AC behavior of a dye sensitized solar cell. The cell can be studied under different light intensities and for a wide range of frequencies. The data can be fitted using common electrical equivalent circuits, including circuit involving a transmission line model.

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References

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Date

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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**.