

## Autolab Application Note PV02

# Photovoltaics

## Part 2 – 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 currently 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, is modular, and can produce energy anywhere the sun shines.

The standard characterization technique of a PV device consists in the determination of the DC Current-Voltage curves under different incident light intensities. The use of these measurement techniques has been explored the previous application note (PV01).

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 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 the Autolab PGSTAT302N/FRA32M in combination with the Autolab LED Driver kit to perform AC characterization of a PV device.

### Hardware setup

The measurements described in this application note require the Autolab LED Driver. This kit is used to set the DC light intensity of the light source.

### Experimental conditions

All the measurements were performed on a dye-sensitized solar cell, using the N719 dye, supplied by Solaronix. The light source was a triple LED array driven by the output current of the Autolab LED Driver. The DC output of the LED Driver is controlled by the DAC164 of the Autolab. The AC amplitude was set to 10 mV for all measurement. All the measurements were carried out with the NOVA software.

### DC measurements at 530 nm

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

Figure 1 shows the measured iV curves with increasing light intensity recorded at 617 nm (red-orange). As the light intensity increases, the maximum short-circuit current,  $i_{SC}$  and the open-circuit voltage,  $V_{OC}$  increase (in absolute value).

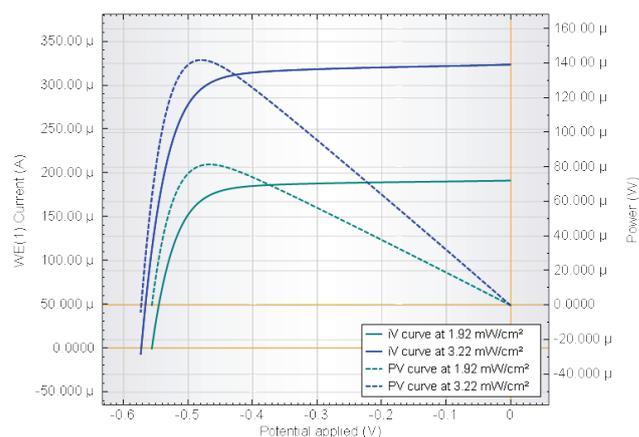


Figure 1 – iV and PV curves recorded at 1.92 and a 3.22 mW/cm<sup>2</sup> with a 530 nm light source

**Impedance measurements at short-circuit**

Figure 2 shows two Nyquist plots obtained at short circuit conditions under constant illumination at 1.92 and at 3.22 mW/cm<sup>2</sup>. The two curves are almost identical and overlap over the complete frequency range.

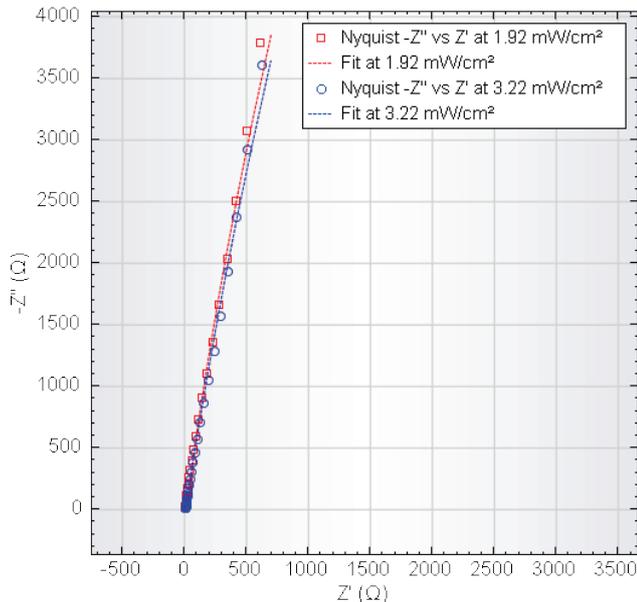


Figure 2 – Nyquist plot obtained at short-circuit conditions at 1.92 and at 3.22 mW/cm<sup>2</sup>

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

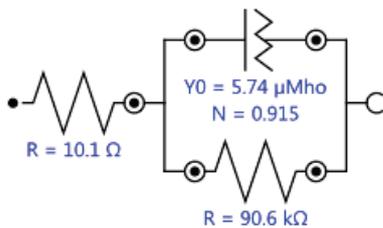


Figure 3 – The equivalent circuit used to fit the data obtained at the short circuit potential

**Impedance measurement at maximum power point**

Figure 4 shows two Nyquist plots obtained at maximum power point conditions under constant illumination at 1.92 and at 3.22 mW/cm<sup>2</sup>. Although the general trend is the same for both measurements, the impedance of the cell is lower at the maximum power point for higher illumination levels.

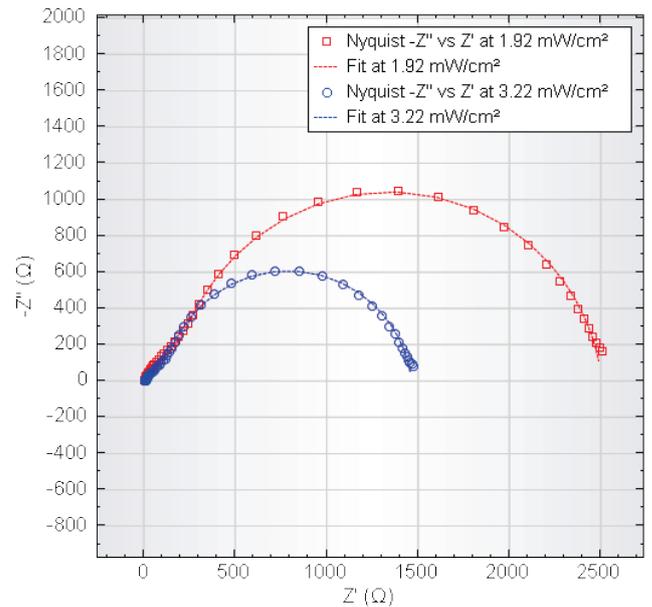


Figure 4 – Nyquist plots obtained at the maximum power point at 1.92 and 3.22 mW/cm<sup>2</sup>

Both spectra can be fitted with a [R(RQ)(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).

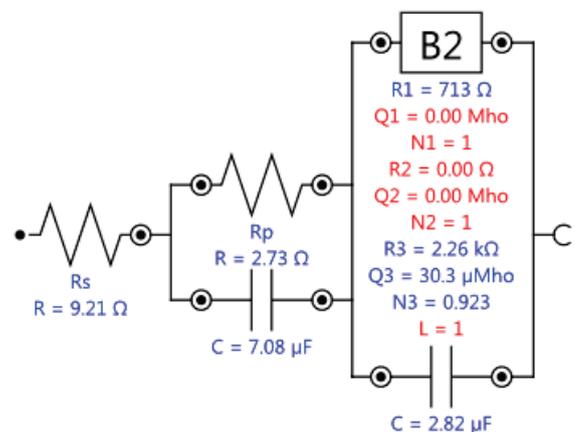


Figure 5 – The equivalent circuit used to fit the data obtained at the maximum power point

**Impedance measurements at open-circuit conditions**

Figure 6 shows two Nyquist plots obtained at open circuit conditions under constant illumination at 1.92 and at 3.22 mW/cm<sup>2</sup>. Again, 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.

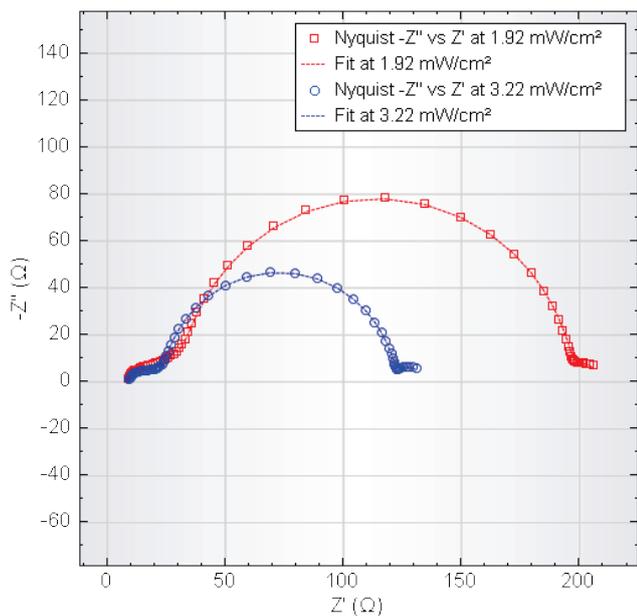


Figure 6 – Nyquist plot obtained at open-circuit conditions at 1.92 and at 3.22 mW/cm<sup>2</sup>

Both spectra can be fitted with a [R(RQ)B2O] equivalent circuit, wherein the B2 element is a transmission line element (see Figure 7).

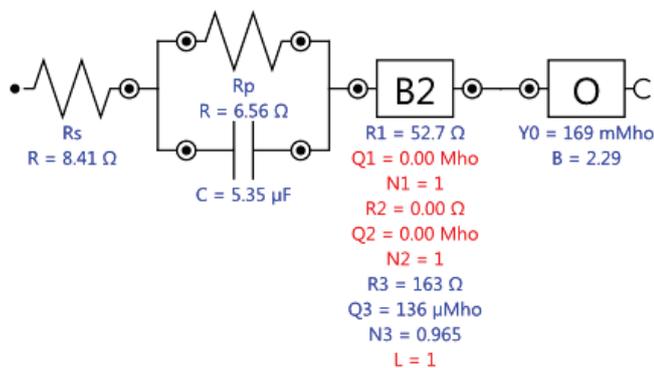


Figure 7 – The equivalent circuit used to fit the data obtained at the open-circuit potential

### 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

1 July 2012