

Autolab Application Note PV03

Photovoltaics Part 3 – Dye sensitized solar cells, IMVS and IMPS measurements

Keywords

Photovoltaic devices, dye sensitized solar cells (DSC), impedance spectroscopy, intensity-modulated photovoltage spectroscopy (IMVS), intensity-modulated photocurrent spectroscopy (IMPS)

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).

Alongside DC characterization methods, it is also possible to analyze the behavior of these devices using electrochemical impedance spectroscopy (EIS). This was illustrated in application note PV02.

To characterize photovoltaic devices, two additional frequency domain methods can be used. These methods are based on the modulation of the light intensity. The response from the cell is measured as a voltage or a current depending on the experimental conditions:

- *Intensity modulated photovoltage spectroscopy* (IMVS): measurement of the transfer function between modulated light intensity and generated AC voltage
- *Intensity modulated photocurrent spectroscopy* (IMPS): measurement of the transfer function between modulated light intensity and generated AC current.

This application note illustrates the use of the Autolab PGSTAT302N/FRA32M in combination with the Autolab LED Driver kit to perform IMVS and IMPS characterization of photovoltaic devices.

Hardware setup

The measurements described in this application note require the Autolab LED Driver. This kit is used to set the DC and AC 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 and the AC output of the LED Driver is controlled by the FRA32M module. The AC amplitude was set to 10 % of the DC output. All the measurements were carried out with the NOVA software.

IMVS measurements

The intensity-modulated photovoltage spectroscopy measurements provide additional information on the internal dynamics of the cell. The IMVS data corresponds to the values of the transfer function, H_{IMVS} , between the modulated light intensity and the measured AC potential of the cell, at open-circuit:

$$H_{IMVS} = \frac{\Delta V}{\Delta \Phi} e^{(i\varphi)}$$

Where H_{IMVS} is the transfer function, ΔV is the variation of the cell voltage, $\Delta \Phi$ is the variation of the photon flux and φ is the phase angle. IMVS measurements provide information about the electron lifetime and electron-hole recombination dynamics under open-circuit conditions. Figure 1 shows a schematic overview of the IMVS measurements.

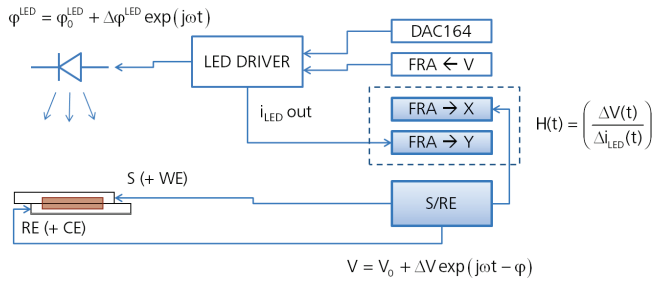


Figure 1 – Overview of the experimental setup of the IMVS measurements

Figure 2 shows complex plane IMVS data recorded under different DC light intensities under a constant illumination at 627 nm. The light intensities are 3.3, 5.9 and 13.7 mW/cm².

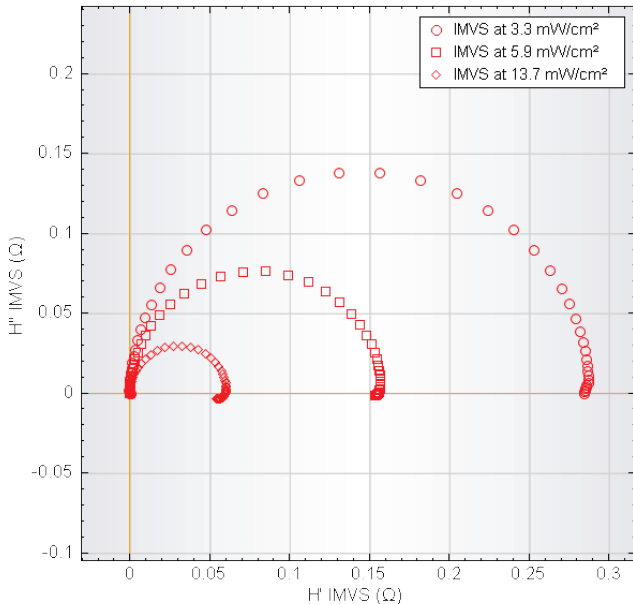


Figure 2 – IMVS measurement obtained at 627 nm, at three different light intensities

As light intensity increases, the semi-circle radius decreases. The frequency corresponding to the minimum in the complex plane increases as the light intensity increases, which indicates that the electron lifetime decreases. Therefore, the electron recombination is more pronounced at high illumination intensities. The same conclusion can be inferred from the plot of the imaginary component versus the frequency (see Figure 3).

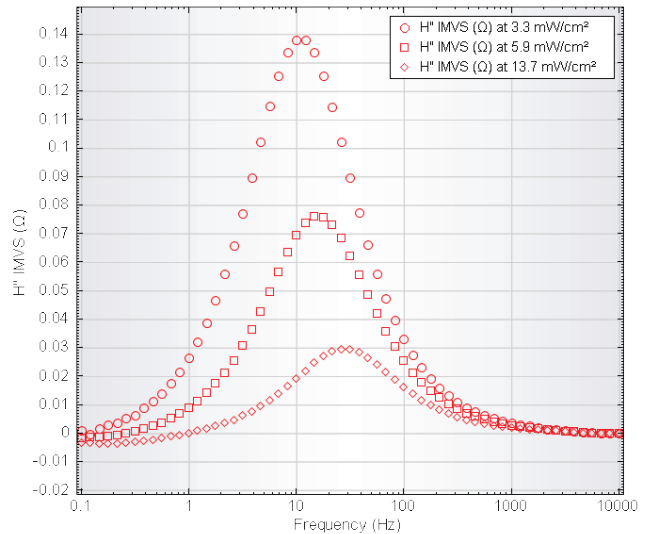


Figure 3 – Imaginary component (H'' IMVS) plotted versus the frequency at different light intensities

An increase of DC light intensity leads to an increase in the characteristic frequency of the electron recombination, which indicates a decrease of electron lifetime.

IMPS measurements

The intensity-modulated photocurrent spectroscopy measurements provide complementary information on the internal dynamics of the cell. The IMPS data corresponds to the values of the transfer function, H_{IMPS} , between the modulated light intensity and the measured AC current of the cell, at short-circuit.

$$H_{IMPS} = \frac{\Delta i}{\Delta \Phi} e^{(i\varphi)}$$

where H_{IMPS} is the transfer function, Δi is the variation of the cell current, $\Delta \Phi$ is the variation of the photon flux and φ is the phase angle. IMPS measurements provide information about the electron lifetime and electron-hole recombination dynamics as well as the equivalent mass transport of the charge carriers. Figure 4 shows a schematic overview of the IMPS measurements.

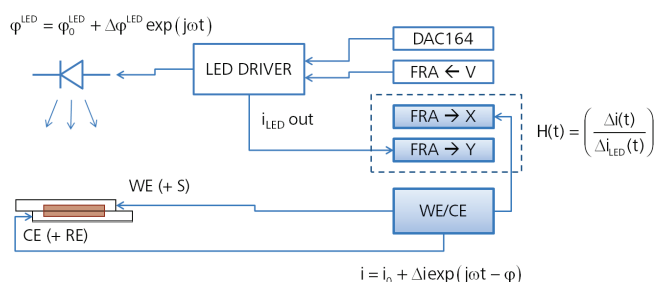


Figure 4 – Overview of the experimental setup of the IMPS measurements

Figure 5 shows complex plane IMPS data recorded under different DC light intensities under a constant illumination at 627 nm. The light intensities are 3.3, 5.9 and 13.7 mW/cm².

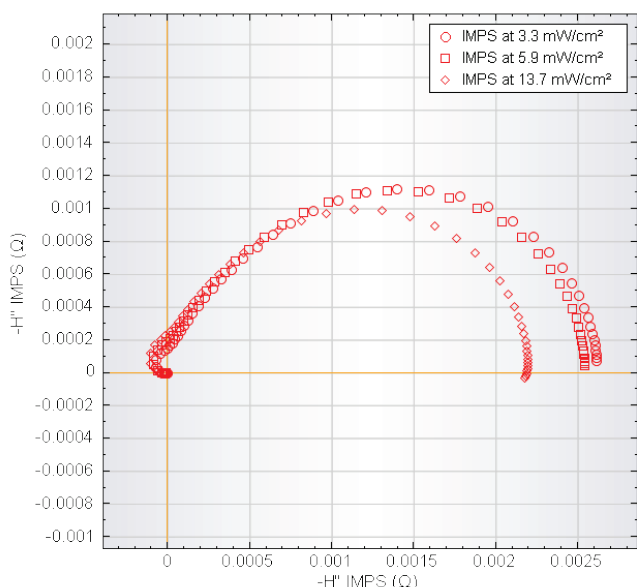


Figure 5 – IMPS measurement obtained at 627 nm, at three different light intensities

The IMPS data is similar to the data obtained in the IMVS measurements. At high frequencies the modulated photocurrent approaches zero, indicating that the modulation frequency is faster than the relaxation of the charge carrier density by transport to the contacts and back reaction.

The same conclusion can be inferred from the plot of the imaginary component versus the frequency (see Figure 6). As the light intensity increases, the electron lifetime decreases.

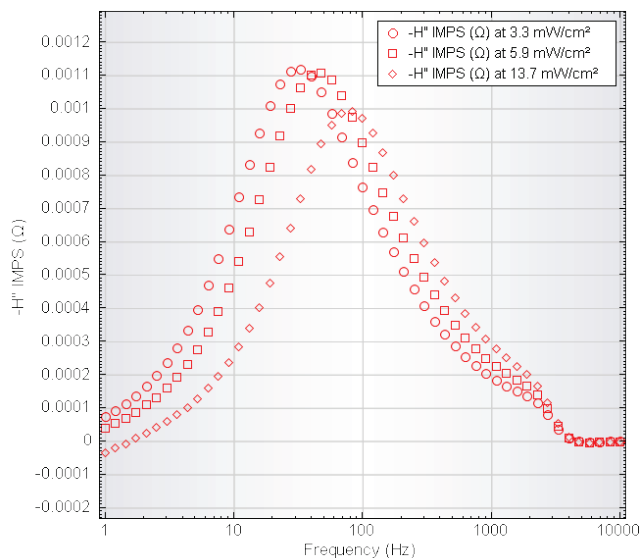


Figure 6 – Imaginary component (-H'' IMPS) plotted versus the frequency at different light intensities

Comparison of the characteristic frequencies obtained with IMPS and IMVS data indicates that the electron lifetime is larger at open-circuit conditions (as indicated by the IMVS data) compared to the short-circuit conditions (see Figure 7).

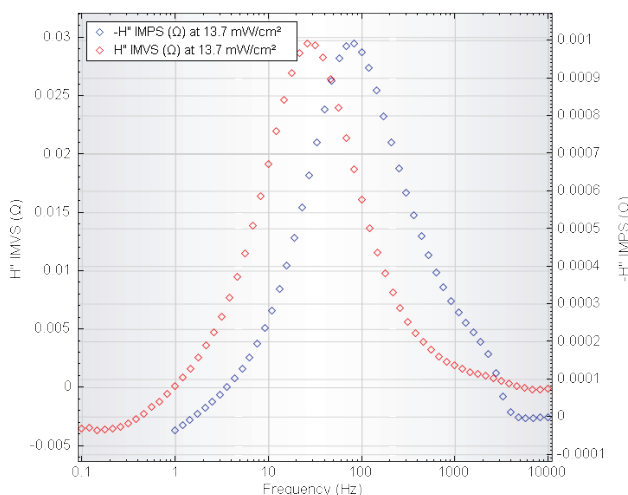


Figure 7 – Comparison of the H'' versus frequency plots for IMPS and IMVS data, obtained at 13.7 mW/cm²

Conclusions

This application note has illustrated the use of the Autolab LED Driver kit to perform IMPS and IMVS measurements in combination with the Autolab. The cell can be studied at different experimental conditions and under different light intensities. The IMPS and IMVS data provide additional information related to the electron lifetime.

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Date

1 July 2012