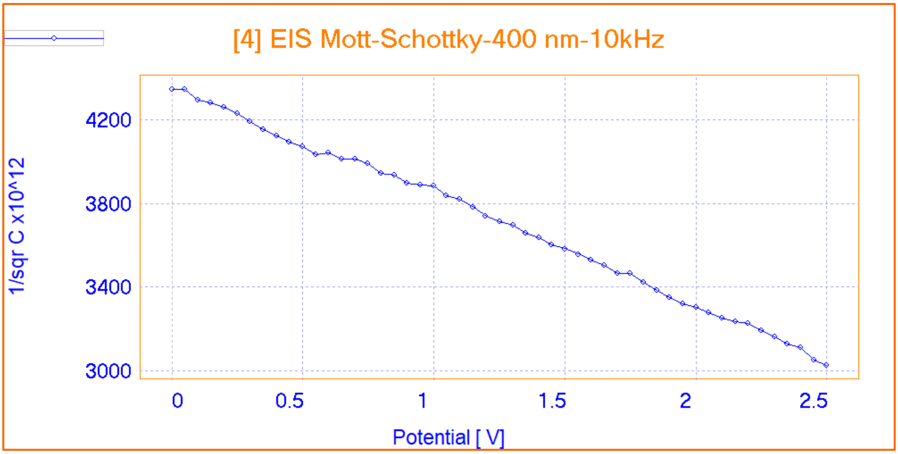
Application Note

Battery
AP-B08

Mott-Schottky characterization of solar cell



In this application note, Mott-Schottky test was run on a solar cell under different LED light sources by imposing two distinct frequencies.

Extracting data from Mott-Schottky analysis of solar cell has been investigated.

INTRODUCTION

A photovoltaic or solar cell, is an electrical device based on semiconductors, that converts the energy of light into electricity.
As in this process no fuel is using, this is a clean energy that could be replaced with other electricity generators in future for environment protection and reduce greenhouse effect.
There are two types of semiconductors: Negative (N) and Positive (P). Mott-Schottky impedance method is one of useful electrochemical method enabling users to qualify materials and to understand which type of semiconductor is used, or is a better one to use, in their solar cells or detectors, etc.

In this method, a fixed frequency signal is superimposed on DC potential while the DC potential is swept from OCP to zero. The potential step can be set on the method parameters. Useful data can then be extracted about the quality of semiconductor from the curve of $1/C^2$ vs Potential.

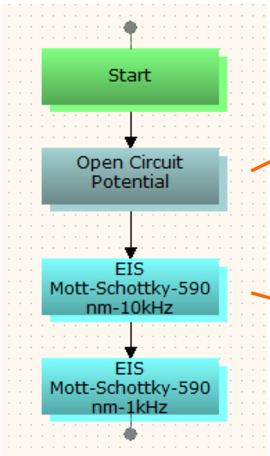
About the Light Source

The LED revolver used in this Application Note is a light source that contains 9 high power LEDs placed on a rotating stand. Only one of the LEDs can be turned on at the time.
LED selection, light intensity, light emission time and other parameters are controlled from the corresponding PC program (Figure 1).

Figure 1: LED revolver

PARAMETERS

This experiment was performed by OrigaMaster software. There are two main methods which could be seen on figure 2; OCP and EIS Mott-Schottky.



Open Circuit Potential	
Duration	4, min.
Meas. period (sec.)	0.2
Drift threshold (mV/min.)	0
Analog Filter	Auto
Polarise at end	No
Save points	Yes
Auxiliary input	No

Pot. Fixed Frequency EIS Mott-Schottky	
DC signal: Potential ramp and equilibration	
Potential 1 (mV)	0, FREE
Potential 2 (mV)	0, REF
Potential step (mV)	50
Step duration (sec.)	1
Stability criterium (µA/min.)	0
Analog Filter	Auto
View equilibration phase	No
AC signal: Impédance acquisition	
Fixed frequency	10, kHz
AC sine wave amplitude z...	10
Delay before integration (...	0.1
Average	5
Global parameters	
AC current range	Auto
Real time plot	Schottky
Open circuit at end	Yes

Figure 2: Mott-Schottky test parameters

Potential were swept from 0 mV vs OCP to 0 mV vs Reference potential. The potential step was defined as 50 mV. A fixed-frequency stimuli was superimposed on each step. The test is repeated twice at a 10 kHz then 1 kHz fixed-frequency.

The complete flow chart has been run for the solar cell at the following wavelengths: 372, 390, 400, 424, 449, 528, 590, 736 and 2740 nm.

PARAMETERS

Figure 3 shows the schematic of what is happening during Mott-Schottky test. In this application note the "Potential Step" was defined as 50 mV and the "Step Duration" as 1 second.

As explained before, the fixed frequency that imposed on each step of potential, was 10 kHz and 1 kHz.

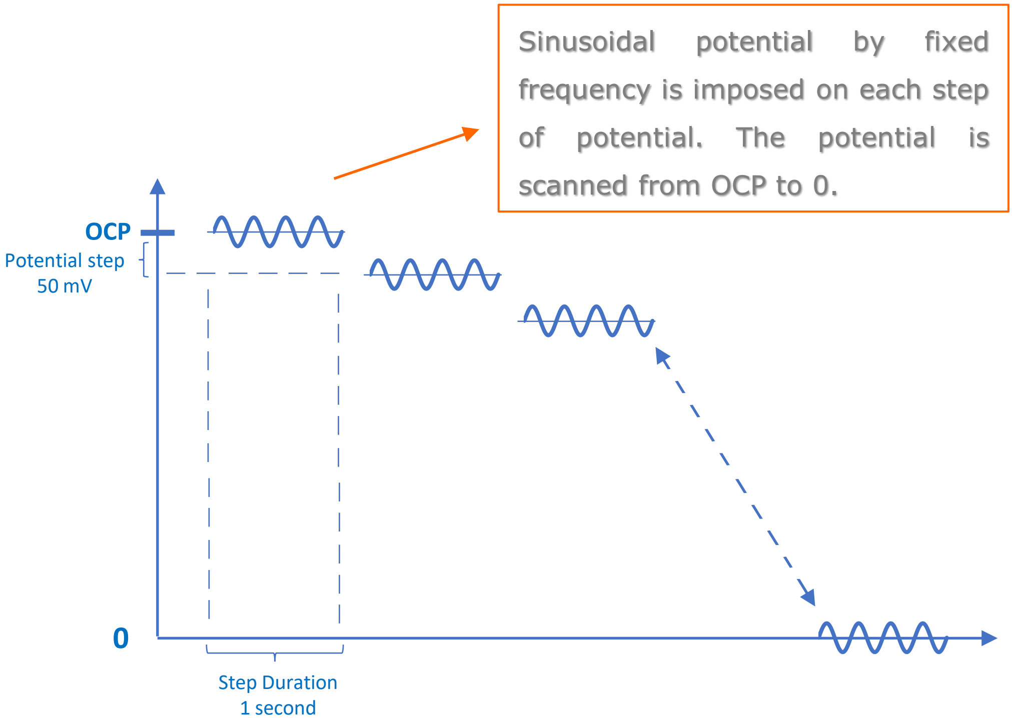


Figure 3: Schematic parameters of Mott-Schottky test

TIPS: the OCP is always measured before running the main test in order to have stable cell set up.

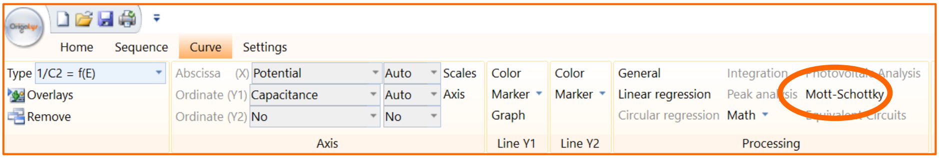
RESULTS AND DISCUSSIONS

According to Mott-Schottky equation, the $1/C^2$ versus DC Potential provides important data about semiconductor:

$$\frac{1}{C^2} = \frac{2}{e\varepsilon\varepsilon_0 N_D}\left(E - E_{FB} - \frac{kT}{e}\right)$$

Where C is space-charge capacitance, N_D is donor density, e is the electronic charge, ε is the relative permittivity, ε_0 is the vacuum permittivity, E is he applied potential, E_{FB} is the flat-band potential, K is the Boltzmann constant and T is the temperature.

From the slope of $1/C^2$ vs Potential curve, Flat-band potential and donor density will be calculated automatically thanks to « Mott-Schottky » option in OrigaMaster software, « curve » tab of the ribbon.



It is just needed to enter the parameters as Temperature, Dielectric constant of cell and active geometric area of your solar cell or semiconductor.

Then, the calculation zone will be selected between « point 1 » and « point 2 » . Thus, by clicking on the « Draw » button, E_{FB} and N_D will be calculated (figure 4).

RESULTS AND DISCUSSIONS

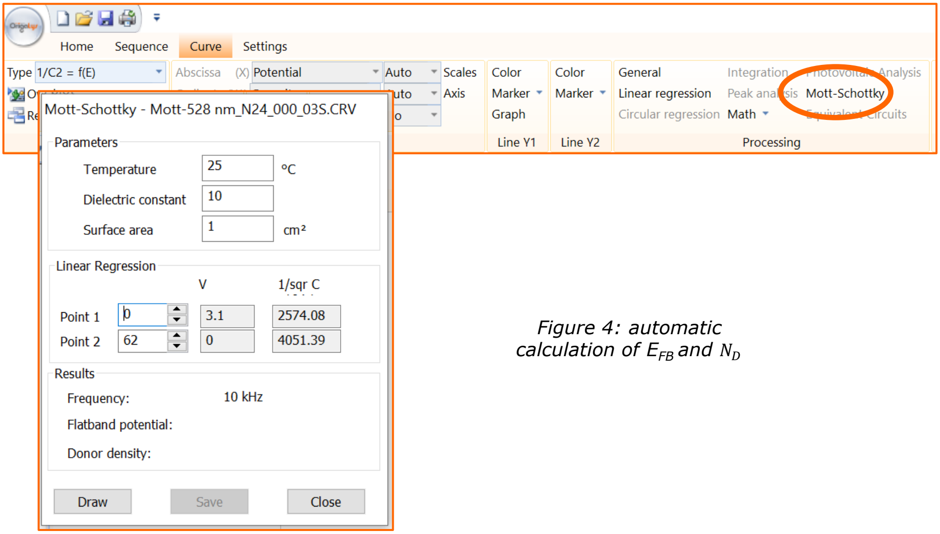


Figure 4: automatic calculation of E_{FB} and N_D

Figure 5 corresponds to the Mott-Schottky result of solar cell in front of a 528 nm light at two different frequencies.

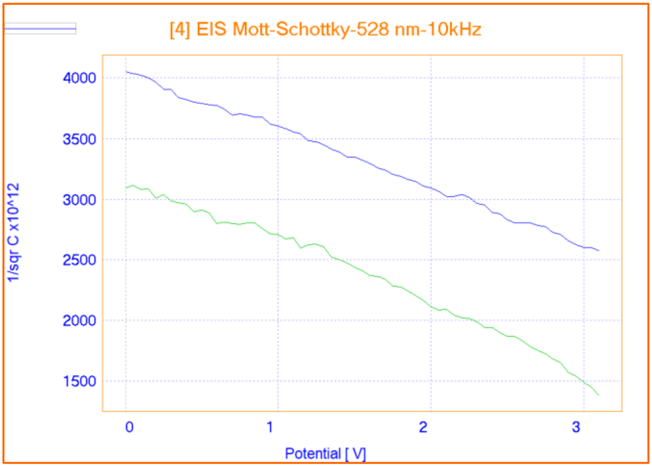


Figure 5: *Mott-Schottky under 528 nm light at 10 kHz fixed frequancy*
Mott-Schottky under 528 nm light at 1 kHz fixed frequancy

RESULTS AND DISCUSSIONS

Thanks to the "Mott-Schottky" option in "Curve" tab, by entering parameters as bellow:

- Temperature: 25°C
- Dielectric Constant: 10
- Surface Area: 15 cm^2

Flat-band Potential and Donor Density will be gained as 8.5 V and -131.26 cm^{-3}, respectively in 10 kHz. These values are 5.9 V and -115.61 cm^{-3} for 1 kHz frequency as it is shown in figure 6.

The negative slope of the curve is typical of the P-type (positive) semiconductor.

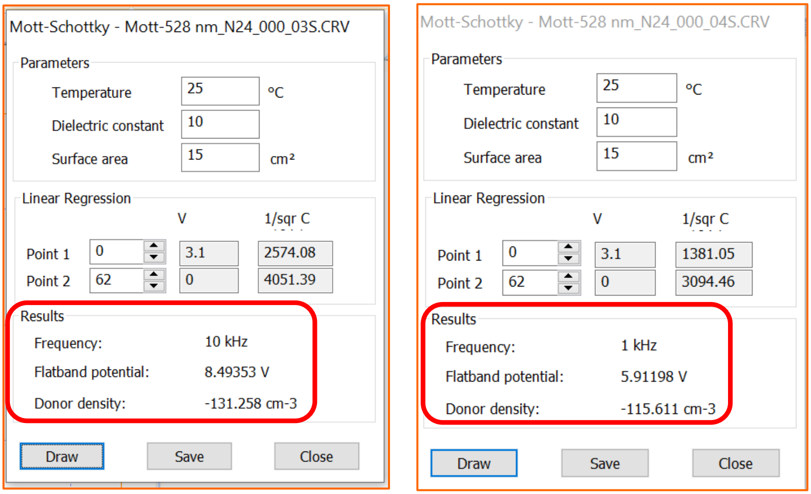


Figure 6: Data extracted from the Mott-Schottky test at two fixed-frequencies: 1 kHz and 10 kHz

RESULTS AND DISCUSSIONS

Wavelenght (nm)	Flatband Potential (V)		Donor Density (cm-3)	
	In 1 kHz	In 10 kHz	In 1 kHz	In 10 kHz
372	7.38	8,66	-104,49	-109,31
390	6,16	8,74	-134,12	-138,87
400	6,46	8,32	-125,89	-119,57
424	6,06	8,74	-134,71	-137,87
449	6,17	7,86	-140,45	-122,17
528	5,91	8,49	-115,611	-131,25
590	7,31	8,51	-99,39	-107,72
736	5,71	8,42	-136,20	-139,11
2740	6,08	8,02	-113,03	-124,71

Table 1: Comparison of data obtained by Mott-Schottky analysis on a solar cell in front of different light sources.

Table 1 shows the data extracted from the "Mott-Schottky" window for all the nine different wavelengths LEDs.

INSTRUMENT AND ELECTRODES

Figure 7: OrigaFlex OGF500 + OGFEIS Impedance module

Electrode setup	
Sample	Solar Cell, 0.5W power
Instrument	OrigaFlex OGF500 + OGFEIS Impedance module + LED Revolver
Software	OrigaMaster

Figure 8: solar cell

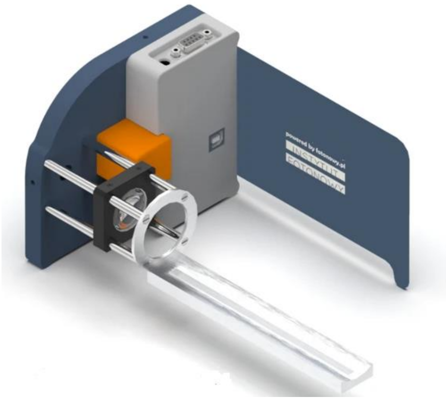


Figure 9: LED revolver

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