Characterization of organic bulk heterojunction solar cells by impedance spectroscopy

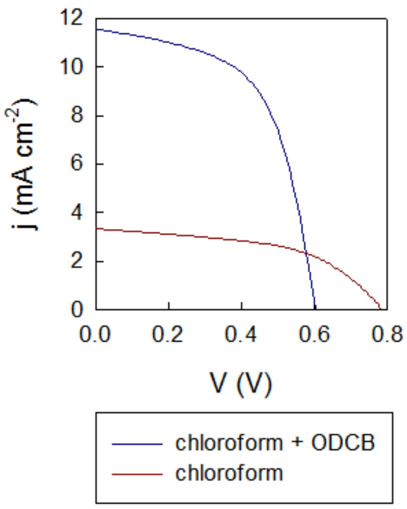
By Pablo P. Boix

The aim of this project is to go into the fabrication and characterization of polymer:fullerene solar cells devices. The characterization method, impedance spectroscopy, is a small perturbation technique by means of which the material response to small voltage variations is analyzed. The characterization by means of this technique can drive us to improve our knowledge of basic operation mechanisms, such as charge carrier recombination and storage. Through fitting the impedance spectra to a proper equivalent circuit, **recombination resistance** and **chemical capacitance** parameters can be extracted. Advances in the knowledge of the operating inner mechanisms of these cells would imply enhancement of the functioning parameters.

EXPERIMENTAL

Bulk-heterojunction solar cells based on a blend composed by a mixture of a narrow bandgap polymer, pBBTDPP2, and a PCBM derivative, C70, were made by coating the appropriate solution of pBBTDPP2:fullerene film on patterned indium-oxide-coated glass substrates covered with 60nm of poly(3,4-ethylenedioxythiophene):poly (styrenesulfonate) (PEDOT: PSS). Lithium fluoride (1nm) and aluminum (100 nm) were used as metal electrode. In order to modify the resulting morphology, two different solvents were used: chloroform and chloroform + ODCB. Those devices presented the characteristics plotted in FIG. 1.

a)



b)

	Voc (V)	Jsc (mA cm-2)	FF (%)	η (%)
Chloroform	0.76	3.35	0.51	1.35
Chloroform + ODCB	0.6	11.53	0.58	4.01

FIG.1: *a) I-V Curves at 1 sun for different devices. b) Characteristics of the devices.*

All the measurements were taken into an inert atmosphere glovebox, Those cells were analyzed by impedance spectroscopy with a Solartron.

RESULTS AND DISCUSION

Dark study of the capacitance at different applied bias showed a typical Mott-Schottky behavior: C-2 ∝ V. From the linear fitting of this plot, the slope and the intercept provided information about the acceptor concentration and the flat-band potential at the metal-polymer interface.

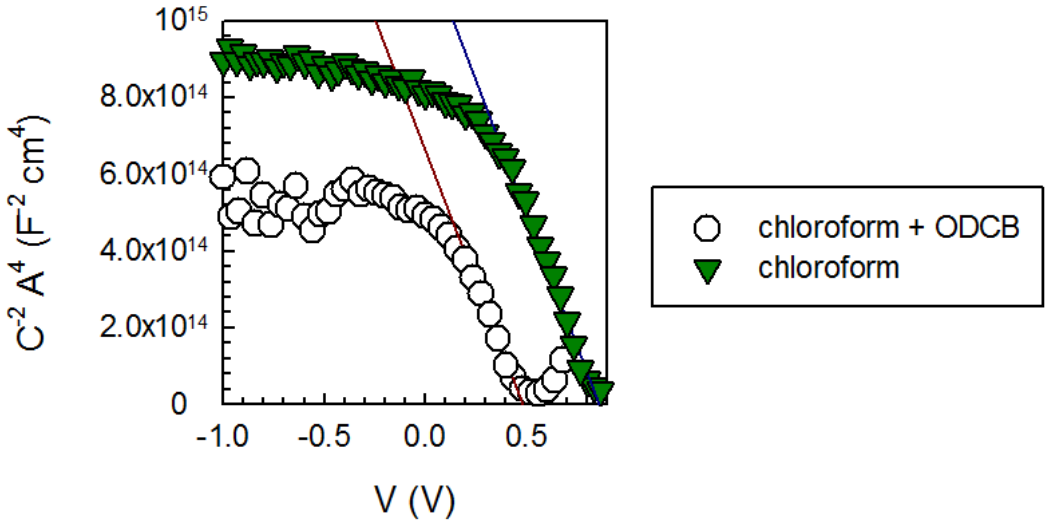


FIG.2: *Mott-Shottky plots obtained by varying the applied potential in dark conditions.*

While the acceptor concentration remains constant (with a value of $N=4.1\cdot10^{-16}$ cm^{-3}) on the devices regardless of which solvent was used, it is possible to appreciate a clear shift on the flat band potential, which varies from V_{fb}=0.48 V in the device made with chloroform to V_{fb} =0.86 V in the device made with chloroform and ODCB.

On the other hand, impedance spectroscopy measurements under different light intensities were carried out. In order to make sure that all the photogenerated current recombined into the cell, a bias voltage equals to the Voc at every illumination intensity was applied, forcing the cell to work with no current flow. The results were fitted to an equivalent circuit from where we extracted the chemical capacitance (C_{μ}) and the recombination resistance (R_{rec}).

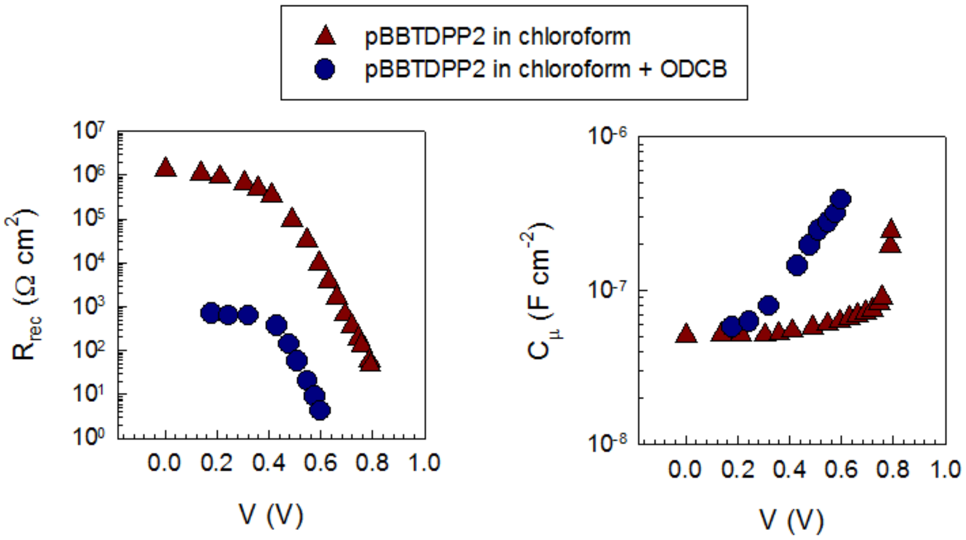


FIG.3: *Recombination resistance and chemical capacitance extracted from the impedance fits. Measurements were performed varying light intensity and applying a voltage equals to the Voc of the cell.*

These results indicate a shift of the capacitance very similar to the one shown in the Mott-Shottky plot (FIG 2), what could show a displacement of the HOMO level of the polymer by the effect of the morphology caused by the solvent.