Project title: ELECTRONIC AND OPTICAL PROPERTIES OF BULK HETEROJUNCTION ORGANIC SOLAR CELLS
Project number: 5CB/2008
Project duration: 1 year and 6 months
Project value: 83945 lei
Project Director: Prof. Dr. Stefan ANTOHE, University of Bucharest

Research activities performed in the frame of this project are a part of efforts of the scientific community towards an environmental friendly solution to the energy problem.

Tang [1] first presented a thin organic solar cell based on a donor-acceptor heterojunction two decades ago and from then tremendous effort has been done in improving the power conversion efficiency of organic photovoltaic devices. The first organic photovoltaic cells were on Schottky type M_1/Organic Layer/M_2 (M_1 and M_2 metals with different work functions, in such way that one contact should be ohmic and the other one a blocking contact). In these structures the organic dye was the monomeric phthalocyanines, merocyanines, porphiryns, and the photovoltaic response is due to the separation of the photogenerated charge carriers in the built electric field present at the rectifying metal/semiconductor interface. The power conversion efficiency was small of the order of 10^{-2} % [2]. Using two-layered structures in which the photoactive region is the heterojunction between two organic layers, with complementary absorption spectra, the power conversion efficiency was increased with about two orders of degree [3], than in the case of single layer structures. Trying to enlarge the photoactive region three-layered structures were reported with an increased efficiency due to the number of sites for exciton dissociation [4]. Following the photoactive mechanism, an excitonic one, which take place in this kinds of cells, the structures based on polymeric blends, seem to be more promising for photovoltaic cells with relatively high efficiency about 4-5 %, but more cheap than the organic monomeric thin films [5]. Among the large range of polymeric materials tested as active layers, polymer-fullerene bulk-heterojunction solar cells have shown promising perspectives because of the high quality of these materials in terms of mobility and thermal stability [6-10]. The two objectives of the projects were:

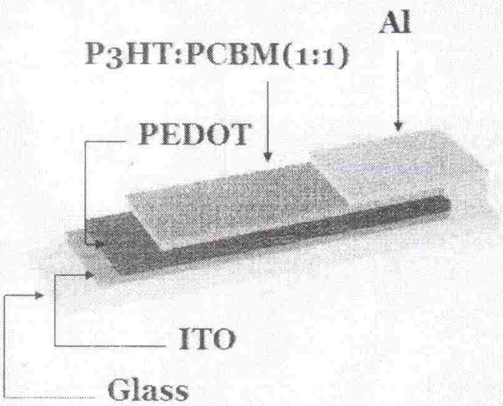

Fig. 1 Structure of the photovoltaic cells based on P3HT, PCBM or P3HT: PCBM blend, respectively

1. Preparation and structural, electrical and optical charac-terizations of thin films based on P3HT and PCBM, and analysis of the electrical and optical behavior of ITO/Polymer/Metal structures.
2. Realization and electrical and optical characterization of P3HT/PCBM photovoltaic cells.

Photovoltaic structures based on poly(3-hexylthiophene) (P3HT), 1-3-methoxycarbonyl)-propyl-1-phenyl-(6,6)C_{61} (PCBM) polymers and P3HT:PCBM (1:1) polymers blend, respectively, were prepared by spin coating technique, using optical glass substrates covered with 30 nm thick ITO, see Figure 1.

The current-voltage (I-V) characteristics, in the dark and illumination through ITO electrode of the ITO/PEDOT/P3HT/Al, ITO/PEDOT/PCBM/Al and ITO/PEDOT/P3HT: PCBM (1:1)/Al, structures were measured.

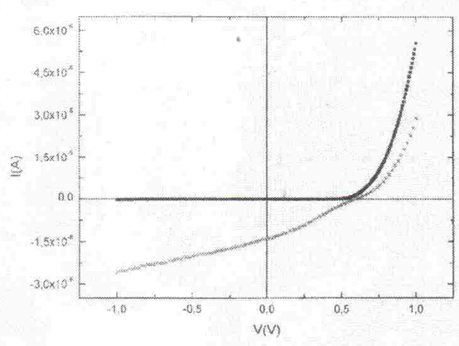

Fig.2. I-V characteristics of ITO/PEDOT/P3HT: PCBM (1:1)/Al at dark (black curve) and under 400 nm monochromatic light (green curve)

Their non-linearity and asymmetry of I-U characteristics in the dark, Fig. 2, were explained on the base of electrode/organic semiconductor interface behavior.
The measured action spectra of the cells revealed the features also observed in absorption spectra of the component polymers or the blend, Fig. 3

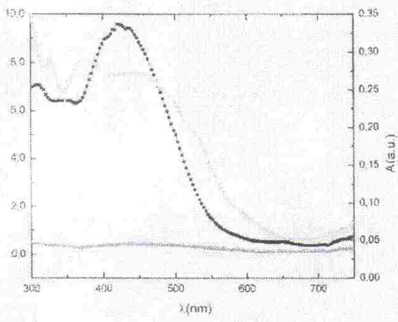

Fig.3. Photocurrent normalized to the power of the light source: 2h (black curve), and respectively 48h (blue curve) after the Al deposition for the ITO/PEDOT/P3HT: PCBM (1:1)/Al structure and the corresponding

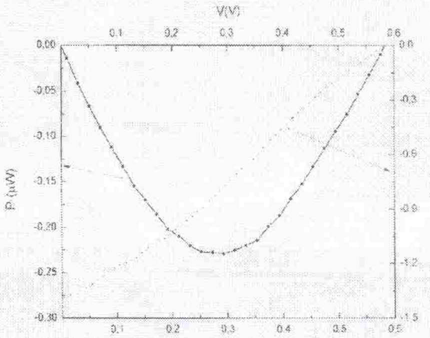

Fig.4. The fourth quadrant I-V characteristic of the ITO/P3HT: PCBM (1:1)/Al device under illumination with 400 nm monochromatic light and $P_{in} = 5.19\times10^{-5}$ W.

A fill factor (FF) of 28%, higher than in the case of single layer structures was measured experimentally for the blend structures. The power conversion efficiency on 0,44%, of the as prepared blend structures was higher, with about two order of magnitude, than those of the single layer structures based on the ordinary P3HT and PCBM layer, respectively, Fig.4 and table I.

Table I: The typical parameters in regime on photo element: Open-circuit photo voltage (V_{OC}), Short-circuit photocurrent (I_{ph}), Maximum output power (P_m), Incident light power (P_{in}), Fill factor (FF), Power conversion efficiency (η) of: ITO/PEDOT/P3HT/Al, ITO/PEDOT/PCBM/Al and ITO/PEDOT/P3HT: PCBM (1:1)/Al structures.

Parameter	ITO/PEDOT/P3HT/Al	ITO/PEDOT/PCBM/Al	ITO/PEDOT/P3HT:PCBM/Al
V_{OC} (V)	0.84	0.1	0.58
I_{ph} (A)	1.85×10^{-8}	4.1×10^{-8}	1.35×10^{-6}
P_m (W)	1.7×10^{-9}	5.88×10^{-10}	2.25×10^{-5}
P_{in} (W)	2.15×10^{-5}	3.3×10^{-5}	5.19×10^{-5}
FF (%)	10	14	28
η (%)	0.01	0.0017	0.44

The fourth quadrant parameters of the blend structures, determined in monochromatic light, change in time with respect of their values obtained on as prepared samples. The P3HT: PCBM (1:1) blend is a very promising material for polymeric photovoltaic cells but optimizations studies in both spatial and energy/time domains should be performed to increase their power conversion efficiency.
A part of the results obtained during the project were published in ref [11, 12] and other part were presented to different international and national conferences in the field, presented in references [13-18]

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