Investigation of Potentials in Polymer Solar Cells

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Polymer photovoltaic cells are based on bulk heterojunctions (BHJ) being a molecular-level mixture of two materials: donor and acceptor that have different potentials and attract holes or electrons created by light. The BHJ is connected to cathode and anode electrodes which collect photo-excited charge carriers from donor and acceptor materials. A leading example is photovoltaic cell based on conducting polymer P3HT and fullerene derivative $PC_{61}BM$. Up to now most of research in polymer photovoltaics has been focused on optimization of the processing and structure of the active layer - BHJ, however our work was devoted to investigation of cathode materials with different work function, therefore supposed different influence on solar cell electrical parameters.

The organic photovoltaic cells were built of ITO anode contact, PEDOT:PSS hole blocking layer, P3HT:$PC_{61}BM$ blend as bulk heterojunction active layer and metal cathode contact. The influence of different metals (Li, Zn, Al, Ga, In, Cr, Ti, Au, Ag) and metal alloys as cathode materials is presented in this work.

In the initial research connected with organic photovoltaics, solar cells with a surface area only of the order of square millimeters have been generally studied to avoid problems with surface defects. In the presented work solar cell fabrication technique was scaled up to the cell surface area of the order of centimeters. Thanks to this, we achieved short circus current of the order of mA, which could power, for example, a light emitting diode. However, low voltage given by a single cell, forced us to make an integrated structure of serially connected cells. Donor material P3HT has potential difference between HOMO and LUMO levels amounting 1.8 eV, but P3HT:$PC_{61}BM$ solar cell generates open circus voltage of only about 0.5 V. The majority of potential drop is inside the active layer, nevertheless the work function of cathode material appears also very important[1, 2]. This motivated us to search for cathode materials which give hope for a higher potential. We used metals with very different electron affinities, among others Au and Li. The photovoltaic cells were examined by photocurrent spectroscopy and I-V characteristics under artificial sun illumination. The best so far electrical results for a single cell were: U_{OC} = 0.572 V, I_{SC} = 13.2 mA, J_{SC} = 4.4 mA/cm^2, FF = 35%, η = 0.9%, (obtained for Al cathode). It was observed that in case of several metals (e.g. Au, Ti) solar cells generated low voltage, U_{OC} = 0.1 - 0.2 V. However, relatively high voltage, U_{OC} = 0.5 V, was produced by a cell with In cathode. Important information regarding the behavior of cathode material in the cell was provided by electron microscopy studies. The cross-section of BHJ-metal electrode interface showed formation of oxygen-rich layer. It is possible that some reactions within the BHJ-metal interface change potential barrier and potential offset in the heterojunction. The model of potential distribution in the bulk heterojunction and electrodes will be discussed.

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