Improving polymer solar cells by small molecule electron transport layers

A. Colsmann, J. Junge, C. Kayser, T. Wellinger, U. Lemmer

Light Technology Institute (LTI) and Center for Functional Nanostructures (CFN),
Universität Karlsruhe (TH), Kaiserstrasse 12, 76131 Germany
Author e-mail address: uli.lemmer@lti.uni-karlsruhe.de

In this work we discuss organic solar cells based on conjugated polymer/fullerene blends with different cathode materials and electron transport layers. We combine the good charge carrier separation and transport properties of the P3HT:PCBM blends with the flexibility of evaporated small molecule layers. The systematic optimization results in higher fill factors and open circuit voltages compared to simple aluminum cathodes. In particular we study the influence of additional electron transport layers consisting of C_{60}, PBD and BCP.

EXPERIMENTAL

For the preparation of the solar cells, commercially available ITO coated glass substrates (Merck, 20 Ohms/sq) are structured with hydrochloric acid and subsequently cleaned. PEDOT:PSS is spin-cast and dried for 30 minutes at 120°C in vacuum. Afterwards, a 200 nm film of P3HT:PCBM with a weight ratio of 1:0.9 is spin-coated from dichlorobenzene solution. Organic electron transport layers are evaporated in high vacuum using effusion cells. BPhen:Li layers are prepared by co-evaporation of BPhen and lithium from two effusion cells with a doping ratio of about 1:1 (molecule per atom). To study the effect of a varying transport layer thickness on the cell properties an additional shutter is moved in front of the samples inside the evaporation chamber. This combinatorial approach ensures that all samples undergo exactly the same process but have different transport layer thicknesses. The actual cathode is evaporated in the same vacuum chamber. All I-V-characteristics are measured with a home made solar simulator at 1 sun. The total irradiance was calibrated with a silicon photodetector. Our measured data matches the values obtained with a commercial 1000 Watt solar simulator (Oriel) within a relative error of 10 %.

RESULTS

An intermediate C_{60} layer between the P3HT:PCBM blend and the cathode does not show any positive effect on the cell properties regardless the layer thickness. On the contrary, cell parameters become worse. A similar result is obtained for thin BCP layers. The application of a thin BCP layer leads to decreased short circuit currents and hence reduced power conversion efficiencies. This behavior can be attributed to the fact that exciton dissociation in P3HT:PCBM is much more effective than in CuPc:C_{60} heterojunction, where an exciton blocking layer is required for high efficiencies [1].

In contrast, a thin layer of the electron transport material PBD can have a significant positive impact on the device properties. We have examined the influence of a vacuum deposited PBD layer for thicknesses varying from 0 nm to 7 nm. We find that even thin layers of 1 nm PBD between the absorbing bulk heterojunction and the aluminum cathode change the open circuit voltage of the device. Accordingly, the

overall power conversion efficiency increases. The effect is most pronounced for polymer cells with moderate efficiencies.

As shown in Fig. 1 an n-doped electron transport layer consisting of BPhen:Li shows a similar behavior. The power conversion efficiency rises from 2.3 % to more than 3 % upon the insertion of the additional layer between the absorbing material and the cathode. Due to the high conductivity, the power conversion efficiency does not depend on the thickness of the BPhen:Li layer. Using an aluminum cathode we measure open circuit voltages as high as 638 mV compared to 520 mV without BPhen:Li. While the short circuit current density remains unchanged, the fill factor also increases upon the application of a BPhen:Li layer.

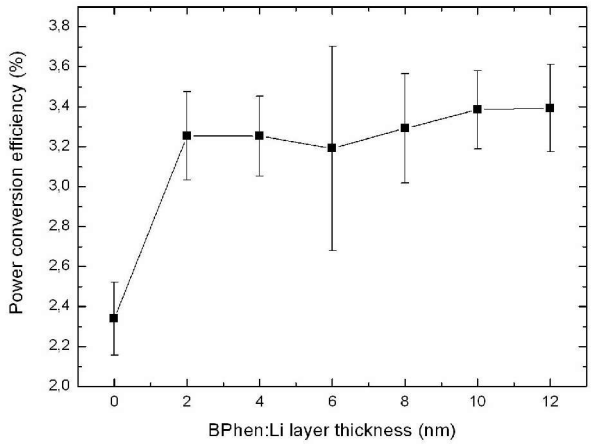

Fig. 1: Lithium doped BPhen layers between the absorption layer and the cathode increase the open circuit voltage, the fill factor and thus the power conversion efficiency of the solar cell. Due to the good electron transport properties, the layer thickness of BPhen:Li is of secondary importance.

In conclusion we have shown, that the combination of polymer blends processed from solution and small molecule electron transport layers evaporated in high vacuum can be advantageous for the overall power conversion efficiency of an organic solar cell.

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REFERENCES

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