Studies of interfacial phenomena in organic thin film solar cells with frequency resolved opto-electronic techniques

Elizabeth von Hauff

Department of Physics and Astronomy, Vrije Universiteit Amsterdam

The power conversion efficiency of polymer solar cells has increased over the last years and record efficiencies for single junction cells are approaching 10%. The rapid increase in performance is largely due to the development of novel donor materials which incorporate a donor-acceptor structure leading to broader optical absorption. The polymer poly [[4,8-bis [(2-ethylhexyl)-oxy] benzo [1,2-b:4,5-b'] dithiophene-2,6-diyl] [3-fluoro-2- [(2-ethylhexyl) carbonyl] thieno [3,4-b] thiophenediyl]] (PTB7)[1] is a high performance material which has resulted in the highest power conversion efficiencies for single junction polymer solar cells to date. Efficiencies over 9 % were achieved when the polymer was blended with the electron acceptor C_{70}BM due to good optical absorption combined with high carrier mobility[2]. Stability remains the most critical issue for advances in polymer photovoltaics. Realizing high performance, stable organic photovoltaics requires an in depth understanding of not just the properties of the active layer, but also of transport layers and material interfaces. Solar cell stability is directly correlated with carrier extraction efficiency[3], as prolonged accumulation of charge can chemically alter material interfaces.

It is generally challenging to differentiate between loss mechanisms originating in the active layer or at contact materials in fully operational devices. Frequency resolved (opto)-electronic techniques such as impedance spectroscopy (IS) and intensity modulated photocurrent spectroscopy (IMPS) are powerful for gaining insight carrier transport, trapping and recombination phenomena in complex solar cell architectures[4]. The techniques are analogous and offer complementary information. In an IS measurement, a sinusoidal AC voltage perturbation is superimposed onto the applied DC voltage, while in an IMPS measurement a sinusoidal AC perturbation is superimposed on the background illumination. For both measurements, the frequency of the perturbation is varied and the current response is monitored, resulting in spectra.

In this study, we applied IS and IMPS to study PTB7:C_{70}BM solar cells. We chose high performance transport layers in an attempt to increase both the power conversion efficiency as well as the stability of the device. The ITO window electrode was modified with the high performance electron transporting layer Poly [(9,9-bis(3-(N,N-dimethylamino)propyl)-2,7-fluorene)-alt-2,7-(9,9–dioctylfluorene)] (PFN). For the top anode, we used thermally deposited vanadium pentoxide (V_2O_5), which has demonstrated interesting properties as a charge separation[5] and hole transport layer[6] in organic solar cells . With this architecture we achieve efficiencies of almost 8 %.

We observe that exposing the devices to ambient conditions for 4 weeks does not lead to a loss in power conversion efficiency. With IS and IMPS we demonstrate that there is no evidence of deterioration of the materials or interfaces in the solar cell, and we discuss this in terms of the device architecture. These results demonstrate the potential for realizing high efficiency, stable polymer:fullerene solar cells.

[1] Y. Liang, Z. Xu, J. Xia, S.-T. Tsai, Y. Wu, G. Li, C. Ray and Luping Yu, *Adv. Mater.*, 2010, 22, E135
[2] Z. He, C. Zhong, S. Su, M. Xu, H. Wu and Y. Cao, *Nature Photonics*, 2012, **6**, 593
[3] B. Ecker, J. Posdorfer and E. von Hauff, *Sol. Energy Mat. Sol. Cells*, 2013, **116,** 176.
[4] B. Ecker, J. Nolasco, J. Pallarés, L. Marsal, J. Posdorfer, J. Parisi and E. von Hauff, *Adv. Funct. Mat*. 2011, **21,** 2705.
[5] M. Terai, K. Fujita and T. Tsutsu, Jpn. J. Appl. Phys., 2005, **44,** L 1059.
[6] K. Zilberberg, S. Trost, H. Schmidt and T. Riedl, Adv. En. Mater., 2011, **1**, 377.