

DS 6: [HL] Organic Semiconductors: Solar Cells (Joint Session DS/ CPP/HL/O)

Time: Monday 16:00–17:45

Location: H15

DS 6.1 Mon 16:00 H15

Pulsed Photocurrent Measurements in Bulk Heterojunction Solar Cells — ●MARKUS MINGEBACH¹, MORITZ LIMPINSEL¹, ALEXANDER WAGENPFAHL¹, ALEXANDER GOLDMANN¹, CARSTEN DEIBEL¹, and VLADIMIR DYAKONOV^{1,2} — ¹Experimental Physics VI, Physical Institute, Julius-Maximilians-University of Würzburg, Am Hubland, D-97074 Würzburg — ²Centre of Applied Energy Research (ZAE Bayern e. V.), Am Hubland, D-97074 Würzburg

The performance of organic bulk heterojunction solar cells greatly improved during the last years up to 6% power conversion efficiency. Nevertheless very important properties such as the voltage dependent photocurrent are not fully understood yet. We investigate the photocurrent in poly(3-hexyl thiophene) (P3HT) : [6,6]-phenyl-C₆₁ butyric acid methyl ester (PCBM) solar cells by applying a pulsed measurement technique (proposed by Ooi et al.) and also find a point of optimal symmetry (POS) at 0.52-0.64 V. In contrast to Ooi we identify this voltage not as the built-in voltage, but as the case of flat bands in the bulk of the cell (confirmed by macroscopic simulations). [1] To explain the voltage dependent photocurrent, we apply a combination of Onsager-Braun (polaron pair dissociation) and Sokel-Hughes (charge carrier extraction) theory in conjunction with the POS. In addition we observe and investigate a voltage-independent offset of the photocurrent, which is crucial for optimizing the device performance. [1] M. Limpinsel, A. Wagenpfahl, M. Mingeback, C. Deibel and V. Dyakonov, Investigation of the Photocurrent in Bulk Heterojunction Solar Cells, submitted (2009).

DS 6.2 Mon 16:15 H15

Analytical analysis of the CELIV theory — ●JENS LORRMANN¹, BEKELE HOMA BADADA², CARSTEN DEIBEL¹, OLLE INGANÄS², and VLADIMIR DYAKONOV^{1,3} — ¹Experimental Physics VI, Physical Institute, Julius-Maximilians University of Würzburg — ²Biomolecular and Organic Electronics, IFM, Linköping University, Sweden — ³ZAE Bayern, Div. Functional Materials for Energy Technology, Würzburg

Charge extraction by linearly increasing voltage (CELIV) has attracted much interest in organic semiconductor research, due to its feature of measuring charge carrier mobility and density directly and simultaneously. Up to now the theoretical description of this method has been solved for a low mobility approximation only, because the general solution was impeded by a Riccati type first order differential equation. In this contribution we present the analytical solution for this Riccati equation, thus completing the analytical framework of the CELIV method. We compare it with the approximated theory and show that especially for standard organic solar cell materials the low mobility approach is hardly valid. The evaluation of photo-CELIV measurements on poly(3-hexyl thiophene-2,5-diyl):[6,6]-phenyl-C₆₁ butyric acid methyl ester solar cells can then be done by fitting the current transients. Surprisingly the fit results are only in a good agreement with the experimental currents, if two extraction currents are taken into account – the origin of which we will discuss. Furthermore we present a new equation for mobility evaluation from numerical analysis within our framework, which can be applied over the entire experimental range.

DS 6.3 Mon 16:30 H15

Oxygen Induced Degradation of P3HT:PCBM Solar Cells — ●JULIA SCHAFERHANS, STEFAN NEUGEBAUER, ANDREAS BAUMANN, ALEXANDER WAGENPFAHL, CARSTEN DEIBEL, and VLADIMIR DYAKONOV — Experimental Physics VI, Faculty of Physics and Astronomy, Julius-Maximilians-University of Würzburg, Am Hubland, 97074 Würzburg, Germany

Power conversion efficiencies of 6% for organic solar cells have already been achieved, with growing tendency. A critical issue yet to be addressed are the factors influencing the device lifetime. To gain a detailed understanding of the device stability, the underlying degradation mechanisms and their impact on the solar cell performance is an important prerequisite for lifetime enhancement. We investigated the oxygen induced degradation of state of the art (PCE > 3%) P3HT:PCBM (poly(3-hexylthiophene):[6,6]-phenyl C₆₁ butyric acid methyl ester) solar cells in the dark as well as under simultaneous illumination. Current-Voltage measurements are supplemented by Thermally Stimulated Current (TSC) and Charge Extraction by Linearly Increasing

Voltage (CELIV) measurements. In the case of dark degradation the influence of oxygen results in a decrease of the short circuit current (I_{sc}), whereas degradation under bias light leads to a decrease of all solar cell parameters. With the aid of a macroscopic simulation we demonstrate that the origin of the loss in I_{sc} is oxygen doping, which we confirmed by CELIV measurements. In addition, TSC and CELIV measurements revealed an increase of deeper traps and a slight decrease of the mobility due to oxygen.

DS 6.4 Mon 16:45 H15

Polaron Recombination Dynamics in Bulk Heterojunction Solar Cells — ●ANDREAS BAUMANN¹, ALEXANDER WAGENPFAHL¹, CARSTEN DEIBEL¹, and VLADIMIR DYAKONOV^{1,2} — ¹Experimental Physics VI, Physical Institute, Julius-Maximilians-University of Würzburg, Am Hubland, D-97074 Würzburg — ²Centre of Applied Energy Research (ZAE Bayern e. V.), Am Hubland, D-97074 Würzburg

Organic solar cells with more than 6% power conversion efficiency were recently shown, coming closer to commercialization. For further improvements, a better understanding of the loss mechanisms inside the solar cell are needed, such as the recombination of photo-generated charge carriers. We applied the experimental technique of charge extraction by linearly increasing voltage (Photo-CELIV) to investigate the recombination dynamics in poly(3-hexylthiophene) (P3HT) : [6,6]-phenyl-C₆₁ butyric acid methyl ester (PCBM) bulk heterojunction solar cells. It was found experimentally, that the dominating polaron loss mechanism in P3HT:PCBM solar cells is of Langevin type, but reduced by a factor in the range of 0.1 in pristine samples to 0.01 in annealed ones [1]. We propose a model taking the charge carriers profile inside the active layer into account, which describes the origin of the observed reduced Langevin recombination [2].

[1] C. Deibel, A. Baumann, V. Dyakonov, APL 93, 252104 (2008)

[2] C. Deibel, A. Wagenpfahl, V. Dyakonov, PRB 80, 075203 (2009)

DS 6.5 Mon 17:00 H15

Relation of open circuit voltage to charge carrier concentration in organic bulk heterojunction solar cells — ●DANIEL RAUH¹, ALEXANDER WAGENPFAHL², CARSTEN DEIBEL², and VLADIMIR DYAKONOV^{1,2} — ¹Bavarian Centre for Applied Energy Research e.V. (ZAE Bayern), D-97074 Würzburg — ²Julius-Maximilians-University of Würzburg, Institute of Physics, Experimental Physics VI, D-97074 Würzburg

A deeper understanding of the open circuit voltage V_{oc} in bulk heterojunction solar cells is crucial for further performance enhancements. In order to investigate V_{oc} , we measured temperature dependent current-voltage characteristics of poly(3-hexylthiophene):[6,6]-phenyl C₆₁ butyric acid methyl ester (P3HT:PCBM) solar cells (pristine and annealed) at various light intensities. With charge extraction measurements under the same conditions we could determine the corresponding charge carrier densities n in the operating device. Extrapolating V_{oc} to $T=0K$ gives a constant value for all intensities indicating the effective bandgap of the donor-acceptor system. Fitting the data with V_{oc} models [1,2] showed excellent agreement with only one free parameter, the effective density of states. From our analysis, we gain insights into the recombination mechanisms limiting V_{oc} .

[1] Koster et al., Appl. Phys. Lett. 86, 123509 (2005)

[2] Cheyns et al., Phys. Rev. B 77, 165332 (2008)

DS 6.6 Mon 17:15 H15

Charge Carrier Concentration and Temperature Dependent Recombination in Polymer-Fullerene Solar Cells — ●ALEXANDER FOERTIG¹, ANDREAS BAUMANN¹, DANIEL RAUH², THIEMO GERBICH¹, VLADIMIR DYAKONOV^{1,2}, and CARSTEN DEIBEL¹ — ¹Experimental Physics VI, Physical Institute, Julius-Maximilians-University of Würzburg, Am Hubland, D-97074 Würzburg — ²Centre for Applied Energy Research (ZAE Bayern e.V.), Am Hubland, D-97074 Würzburg, Germany

We performed temperature dependent transient photovoltage and photocurrent measurements on poly(3-hexyl thiophene):[6,6]-phenyl-C₆₁ butyric acid methyl ester bulk heterojunction solar cells. Thus we determined small perturbation carrier lifetime and charge carrier densities under operating conditions. We found a strongly charge car-

rier concentration and temperature dependent Langevin recombination prefactor. The observed recombination mechanism is discussed in terms of a bimolecular loss and compared with charge carrier extraction by linearly increasing voltage (photo-CELIV) measurements done on the same blend system. The observed charge carrier dynamics, following an apparent order larger than two, are explained by dynamic trapping of charges in the tail states of the Gaussian density of states.

DS 6.7 Mon 17:30 H15

Charge Carrier Generation Yield in Organic Solar Cells using a C80 Derivative as Acceptor — ●MORITZ LIEDTKE^{1,2}, ANDREAS SPERLICH², HANNES KRAUS², ANDREAS BAUMANN², CARSTEN DEIBEL², VLADIMIR DYAKONOV^{1,2}, and CLAUDIA CARDONA³ — ¹Centre for Applied Energy Research (ZAE Bayern e. V.), Am Hubland, D-97074 Würzburg, Germany — ²Experimental Physics VI, Physical Institute, Julius-Maximilians-University of Würzburg, Am

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Organic solar cells (OSC) with C₇₀ and C₈₀ fullerenes show a higher open circuit voltage (*V*_{oc}) than the standard [6,6]-phenyl-C[61]-butyric acid methyl ester (PCBM):poly-3-hexylthiophene (P3HT) bulkheterojunction cells. Devices containing the trimetallic nitride endohedral fullerene Lu₃:N@C₈₀ showed a *V*_{oc} of 910mV compared to 600mV with C₆₀-PCBM. Still the overall efficiency of these cells remain below the performance of our C₆₀-PCBM:P3HT reference cells. We address the origin of the lower efficiency by means of optical, magnetic and current measurement techniques. In samples containing Lu₃:N@C₈₀ we found photoluminescence quenching 3.2 times weaker, triplet yield higher and short-cut current about 2mA/cm² lower than in cells with C₆₀-PCBM as acceptor. We conclude that less efficient charge carrier generation in the Lu₃:N@C₈₀:P3HT bulkheterojunction system is the reason for the lower photocurrent.