HL 19: Organic photovoltaics and electronics - mostly properties of the absorber (with DS)

Time: Monday 17:00–19:00 Location: EW 202

HL 19.1 Mon 17:00 EW 202

Structural and electronic properties of planar organic heterojunction interfaces and their impact on diode characteristics — •A. Opitz[1], A. Wilke[1], N. Koch[1,2], U. Hörmann[3], W. Brütting[3], R. Hansson[4], and E. Moons[4] — [1]Humboldt-Universität zu Berlin, Germany — [2]Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Germany — [3]University of Augsburg, Germany — [4]Karlstad University, Sweden

The structural and electronic properties of organic heterojunction interfaces are of paramount importance. Here two prototypical interfaces are discussed: diindenoperylene (DIP) combined with fullerene (C60) and copper-phthalocyanine combined with its perfluorinated analog. Angle dependent near edge X-ray absorption fine structure measurements were performed to determine the molecular orientation and compared to measurements of the frontier level alignment by ultraviolet photoelectron spectroscopy.

The orientation of the rod-like DIP molecules is unaffected upon deposition of spherical C60 molecules on top and vacuum level alignment appears. In contrast, cofacial lying interface layers with π-orbital stacking of the two phthalocyanines is observed together with energy level bending. These results will be related to the solar cell performance [1,2]. The combined experimental approach results in a comprehensive model of the investigated interface. The presence of a π-orbital stacking is also of interest for ground-state charge transfer.

[1] J. Wagner et al., Adv. Funct. Mater. 20 (2010) 4295.
[2] A. Opitz et al., Org. Electron. 10 (2009) 1259.

HL 19.2 Mon 17:15 EW 202

Unified model approach for hybrid charge transfer states in organic-organic heterostructures — Tino Meisel, •Paul Beyer, Georg Heimel, Norbert Koch, and Andreas Opitz — Humboldt-Universität zu Berlin, Germany

There are different electronic coupling mechanisms for organic-organic heterostructures, which ultimately determine the charge separation in solar cells or the doping efficiency in blended systems. Here, these charge transfer mechanisms are investigated in blends of diindenoperylene (DIP) with different acceptor materials, namely core functionalized perylene alkyldiimide with cyano groups (PDIR-CN_2) and perfluoronaphthalene-diylidene dimalononitrile (F6TCNNQ), which show compatible optical gaps. To scrutinize the interplay between these molecules a combination of atomic force microscopy (AFM), UV/Vis/NIR absorption spectroscopy and electrical conductivity measurements is used.

From absorption spectroscopy the formation of new absorption features is clearly seen in blends with both acceptors. An increase in electrical conductivity is observed for DIP:F6TCNNQ blends, which is absent in the DIP:PDIR-CN_2 case. The formation of distinct islands in AFM shows a difference in morphology between pristine and blended films. From these investigations we conclude the appearance of new charge transfer states and a unified hybridization model is applied to explain the different regimes of charge transfer behavior.

HL 19.3 Mon 17:30 EW 202

New Insights on traps states in organic semiconductor devices using transient current measurements on metal-insulator-semiconductor capacitors — Hippolyte Hirwa and •Veit Wagner — Jacobs University, Bremen, Germany

A Transient current measurement technique utilizing metal-insulator-semiconductor (MIS) capacitors is developed, which does not need a light stimulus. The technique offers insights on carrier trapping states such as capture time of trapping states and the attempt-to-escape frequency of trapped carriers. For the analysis of the measurements Fourier transformation of imepdance-based circuit models to the time domain as well as direct numerical simulation of transient current of MIS capacitors were used. Numerical simulations allow to go beyond the usual assumptions of negligable extraction time for de-trapped carriers. It is shown, that re-trapping events are relevant in order to extract the proper band tail density of states and the corresponding characteristic parameters. For e.g. P3HT an exponential density of states with a total density of $4 \cdot 10^{17}$ cm^3 and a width of 50 meV was found to be representative for the band tail. Analyzing the multiple trap and release behavior in the numerical simulation, the average capture time and the attempt-to-escape frequency of band tail states were found to be 10^{-10} s and 10^8 s^{-1}, respectively.

HL 19.4 Mon 17:45 EW 202

Influence of trap distribution on the electrical characteristics of organic solar cells — •Alexander Wagenpfahl, Robert Hanfland, and Carsten Deibel — Chemnitz University of Technology, Institute of Physics, 09126 Chemnitz, Germany

Charge carrier traps have a strong impact on the performance of organic solar cell devices. It remains unclear, however, if either a Gaussion or an exponential distribution of the density of states (DOS) describes most organic photovoltaic devices better. In our work, we apply a macroscopic drift–diffusion simulation in combination with the multiple-trapping and release model to examine how the DOS distribution influences the current-voltage characteristics, diode ideality factor and effective charge carrier mobility of organic solar cells. We compare our findings to corresponding experimental data from different types of organic solar cells to determine the likely DOS shape. Its impact on the experimental device characteristics will be discussed.

HL 19.5 Mon 18:00 EW 202

Investigation of DCV5T-Me Solar Cells on Presence of Traps — •Natalia Sergeeva[1], Janine Fischer[1], Paul Pahner[1], Lorenzo Burtone[1,2], Christian Körner[1], Koen Vandewal[1], and Karl Leo[1] — [1]Institut für Angewandte Photophysik Technische Universität Dresden, Germany — [2]Globalfoundries, Dresden, Germany

Traps play an important role in the performance of organic solar cells (OSC). They influence the mobility, the amount of extracted charge carriers at the electrodes and lead to trap assisted recombination. Better understanding of traps is necessary to further improve the efficiency of OSC. We investigate bulk heterojunction OSC based on the donor material DCV5T-Me with regards to the presence of traps by performing Impedance spectroscopy (IS) and temperature stimulated currents (TSC) measurements. We discuss the observed impedance and TSC spectra, evaluate the density and distribution of trap states and the attempt to escape frequency.

HL 19.6 Mon 18:15 EW 202

Charge transport: Mobility in organic donor-acceptor blends for photovoltaics — •Johannes Widmer, Julia Oelker, Janine Fischer, Christian Koerner, and Karl Leo — IAPP (Institut für Angewandte Photophysik), TU Dresden, Germany

The charge carrier mobility μ is the key parameter describing charge transport in semiconductors. In amorphous material with predominating hopping transport, the effective mobility is affected by disorder. The resulting μ varies with electric field strength F and charge carrier density n, and is influenced by the layer morphology.

In this contribution, we analyze the mobility of various small molecule organic semiconductors in neat as well as blend layers. The mobility is measured by means of electric potential mapping (POEM), varying the thickness of single carrier devices and evaluating them at constant current density.[1] This measurement technique allows for resolving the field dependence and the density dependence of $\mu(F, n)$ independently of each other, separately for electrons and holes.

Substrate heating during the deposition of donor-acceptor blend layers is known to substantially improve the device performance of solar cells, and we show which role the charge carrier mobility plays in this context. Furthermore, the influence of the blend ratio on μ is investigated, which allows for a refined interpretation of the role of the acceptor phase in hole transport. These findings improve the understanding of charge transport in organic solar cells and inspire paths for efficient further improvement of device performance.

[1] Widmer et al., OrgEl 14, p. 3460 (2013)

HL 19.7 Mon 18:30 EW 202

Mobility Relaxation in PTB7:PC_{70}BM on nanosecond timescale — •Andreas Fritze[1], Andreas Sperlich[1], Carsten Deibel[2], and Vladimir Dyakonov[1,3] — [1]Experimental Physics VI, Julius Maximilian University of Würzburg, 97074 Würzburg — [2]Institute of Physics, Chemnitz University of Technology, 09107 Chemnitz — [3]ZAE Bayern, 97074 Würzburg

For photovoltaics, charge carrier lifetime is an essential parameter

due to its influence on short circuit current, and thus on power conversion efficiency. In organic photovoltaics, for several material systems, charge carrier lifetime exceeds predictions from recombination models by orders of magnitude. In literature, this phenomenon is discussed in the context of reduced langevin recombination, for instance the high-efficiency bulk heterojunction polymer fullerene solar cell PTB7:$PC_{70}BM$, it is shown that recombination is also reduced. However, the physical processes responsible for these low recombination rates, such as mobility relaxation, energetic traps, and morphological traps, are hard to observe separately. Here, we present simultaneous transient absorption (TA) and transient microwave conductivity (TRMC) measurements on PTB7:$PC_{70}BM$ films. From the experimental data we calculate time dependent mobility, since TA is sensitive to charge carrier density and TRMC is sensitive to conductivity. A relaxation of mobility on these time scales is measured the first time separately. Thus, we can distinguish mobility relaxation from other recombination influencing processes in PTB7:$PC_{70}BM$.

HL 19.8 Mon 18:45 EW 202

OTRACE: The technique to study charge carrier mobility and lifetime in organic thin film solar cells under real operating conditions — •Andreas Baumann[1], Andreas Zusan[2], and Vladimir Dyakonov[1,2] — [1]Bayerisches Zentrum für Angewandte Energieforschung, Am Galgenberg 87, D-97074 Würzburg — [2]Experimentelle Physik 6, Julius-Maximilians-Universität Würzburg, Am Hubland, D-97074 Würzburg

For the development and design of new promising semiconducting materials for organic electronics material parameters like the mobility and the lifetime of photogenerated charge carriers need to be investigated and optimized. Usually, techniques such as TOF, SCLC, or photo-CELIV are used to study the charge carrier transport. Especially, the latter technique principally enables one to study both charge carrier mobility and lifetime. However, all of these techniques are not really suited to study real solar cell devices under ambient conditions. With our newly developed experimental method of open circuit corrected transient charge extraction (OTRACE)[1] it is feasible to easily determine the charge carrier mobility and lifetime under operating conditions of the solar cell device. In addition, the mobility determined by OTRACE is the most relevant one for organic solar cells at open circuit conditions without suffering from injected charge carriers, which would result in major RC limitations. In combination with IV measurement this technique can be easily used for material screening producing fast output of relevant solar cell parameters. [1] Baumann et. al., AM, 2012. 24(32): p. 4381-4386.