CPP 26: Organic Photovoltaics I

Time: Wednesday 14:00–17:00 Location: ZEU 222

CPP 26.1 Wed 14:00 ZEU 222

Efficient Polaron Pair Dissociation in Polymer:Fullerene Blends — •Carsten Deibel[1], Thomas Strobel[1], and Vladimir Dyakonov[1,2] — [1]Experimental Physics VI, Institute of Physics, Julius-Maximilians-University of Würzburg, D-97074 Würzburg — [2]Bavarian Centre for Applied Energy Research e.V. (ZAE Bayern), D-97074 Würzburg

Organic bulk heterojunction solar cells already achieve energy conversion efficiencies of up to 6%. To a significant part, this is due to the very efficient separation of the bound electron–hole pairs, also called polaron pairs. This event is the intermediate but crucial step between exciton dissociation and charge transport to the electrodes. Using a simple model of Coulomb attraction of the bound charge carrier pair, the electric field needed to overcome the mutual attraction with a probability of 90% is larger than 10^8V/m. In contrast, in good organic solar cells, almost all polaron pairs are separated at fields smaller by a factor of around 50. We attempt an explanation of this significant discrepancy by performing Monte Carlo simulations of hopping transport in a bulk heterojunction blend system. We discuss the influence of phase separation and recombination rate on the efficiency of the polaron pair dissociation.

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Stability of organic electronics - P3HT as model to study general mechanistic effects. — •Holger Hintz[1], Hans-Joachim Egelhaaf[1,2,3], Christoph Brabec[3], Heiko Peisert[1], and Thomas Chassé[1] — [1]University of Tübingen, Institute for Theoretical and Physical Chemistry, Auf der Morgenstelle 8, D-72076 Tübingen — [2]Christian-Doppler Labor für oberflächenoptische Methoden, Johannes-Kepler University, Altenbergerstaße 69, A-4040 Linz — [3]Konarka Austria GmbH, Altenbergerstaße 69, A-4040 Linz

The stability of Polythiophene (P3HT) is still unsatisfactory and the degradation mechanism has not yet been fully understood. Photo-oxidation of thin P3HT layers was performed under ambient conditions and under varying partial pressures of oxygen, water and ozone using Xenon light. The kinetics were monitored by FTIR and UV/VIS spectroscopy and can be described by the laws of photo-oxidation of layer systems, considering the blue-shift of the absorption spectra of formed P3HT fragments. A sublinear dependence of the degradation rate on oxygen partial pressure is monitored, probably due to the formation of singlet oxygen via a long-lived triplet excited state of P3HT. This is supported by strongly reduced degradation rates upon addition of PCBM, due to the quenching of the polymer excited state. Further support comes from the comparison of the temperature dependences of photo degradation and oxygen diffusion. Photo-oxidation at different humidity levels showed enhanced degradation rates in the presence of water. As water in the absence of oxygen does not cause any degradation, this is due to either a solvent effect or a catalytic mechanism.

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Molecular semiconductor blends: microstructure, charge carrier transport and application in photovoltaic cells — •Andreas Opitz[1], Julia Wagner[1], Bernhard Ecker[1], Wolfgang Brütting[1], Alexander Hinderhofer[2], and Frank Schreiber[2] — [1]Institute of Physics, University of Augsburg, Germany — [2]Institute of Applied Physics, University of Tübingen, Germany

Blends of organic donor and acceptor materials have the potential of an increase of solar cell efficiency. However, the balance between charge carrier transport in phase-separated structures and exciton dissociation at the donor-acceptor interface has to be optimized. To analyze this relation in more detail the following molecular material combinations were investigated: (i) Copper phthalocyanine (CuPc) combined with fullerene C_{60} and (ii) CuPc in combination with perfluorinated CuPc (F_{16}CuPc).

Measurements by X-ray diffraction and scanning force microscopy indicate the formation of phase-separated nanocrystals for blends of CuPc/C_{60} and the formation of mixed crystals in the CuPc/F_{16}CuPc system. The formation of mixed crystals is an interesting feature for organic blends which has not yet been explored in organic solar cells. We will discuss the implications of the different molecular arrangements on the optical and electrical properties as well as for the solar cell performance.

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Interfacial adhesion in polymer blend P3HT:PCBM solar cells — •Ayse Turak[1], Jonas Hanisch[2], Esther Barrena[1,3], Erik Ahlswede[2], and Helmut Dosch[1,3] — [1]Max Planck Institute for Metals Research, Heisenbergstrasse 3, 70569, Stuttgart — [2]Zentrum für Sonnenenergie- und Wasserstoff-Forschung (ZSW) Baden-Württemberg, Industriestrasse 6, 70565, Stuttgart — [3]Institut für Theoretische und Angewandte Physik, Universität Stuttgart, Pfaffenwaldring 57/VI, 70550 Stuttgart, Germany

The nature of the contact at the electrode/organic interface has a major impact on device performance. Introduction of thin dielectric interlayers such as LiF have been successful in significantly improving device properties. However, examination of the buried interface is generally difficult as deposition of the top electrode may alter the nature of the contact. Using peel-off adhesion analysis with grazing incidence x-ray diffraction, atomic force microscopy and optical imaging, we have assessed the quality of the buried interfacial layer in P3HT:PCBM solar cells in the presence of interlayers. We see increased adhesion of the Al cathode without the interlayer, suggesting broader interfacial mixing of the Al with the polymer without LiF as a blocking interlayer. The confinement of the charge extraction to a well defined interface may be used to explain improved device performance with LiF interlayers.

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Block copolymer templating: a bicontinuous double gyroid hybrid solar cell — •Edward Crossland[1], Sabine Ludwigs[1], Marc Hillmyer[2], Ulrich Wiesner[3], Henry Snaith[4], and Ullrich Steiner[5] — [1]Freiburg Institute for Advanced Studies, Germany — [2]University of Minnesota — [3]Cornell University — [4]University of Oxford — [5]University of Cambridge

The conversion of light to electrical energy in hybrid solar cells based on organic-ceramic composites demands engineering of highly distributed, yet interconnected heterojunctions on the 10nm length scale. Microphase separation of block copolymers offers an extremely versatile bottom-up approach to high aspect ratio patterning of functional materials on these macromolecular scales in thin films. We fabricated highly ordered arrays of semiconductor nanostructures using selectively degradable block copolymers as porous electrochemical templates. Cylinder-forming poly(4-fluorostyrene)-b-(D,L-lactide) films were aligned using electric fields to template freestanding vertical nanowire arrays over 1μm long and 10nm in diameter while the network phase of a bicontinuous double gyroid morphology could be replicated without external alignment. Charge transport and recombination rates as well as photovoltaic power conversion efficiencies were probed in each morphology incorporated into dye sensitized solid-state and liquid-electrolyte solar cells. These results mark the first successful application of the gyroid morphology in a functioning electronic device. This templating technique is fully extendable to a enormous range of potentially high performance heterojunction systems.

CPP 26.6 Wed 15:15 ZEU 222

Preparation of hybrid solar cells from CdSe nanocrystals and poly(3-hexylthiophene) — •Folker Zutz, Marc-Daniel Heinemann, Irina Lokteva, Joanna Kolny-Olesiak, Ingo Riedel, Holger Borchert, and Jürgen Parisi — University of Oldenburg, Department of Physics, Energy and Semiconductor Research Laboratory, Carl-von-Ossietzky Str. 9-11, 26129 Oldenburg, Germany

Colloidally prepared semiconductor nanocrystals with particle sizes of a few nanometers possess particular physical and chemical properties. One example is the size-dependent band gap which enables tuning of optical properties by controlling the particle size. One potential application is the use of nanocrystals as a component in hybrid solar cells. Similar to organic composites of polymer and fullerenes, a nanocrystal-polymer composite is a donor/acceptor system where photo-generated charge carriers can be efficiently separated because of the affinity of the nanocrystals and polymers to accept electrons and holes, respectively. In contrast to fullerenes, semiconductor nanocrystals can additionally act as absorber themselves. This offers possibilities to optimize the exploitation of the solar spectrum. In the present work, we prepared high-quality CdSe nanocrystals. Composites of the nanocrystals and polymere (P3HT) were successfully used to prepare laboratory solar cells which were characterized by I-V curves and measurements of the

external quantum efficiency. Further experiments with different ratios of Cadmium to Selenium in the nanocrystals and different ratios of CdSe nanocrystals to polymere in the semiconductor blend were made. The results were compared with purely organic composites.

CPP 26.7 Wed 15:30 ZEU 222

Hybrid Organic-Inorganic Bulk Heterojunctions with Silicon Nanocrystals for Solar Cells — •Sabrina Niesar[1], Roland Dietmüller[1], André Ebbers[2], Martin Trocha[2], Hartmut Wiggers[3], and Martin Stutzmann[1] — [1]Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, 85748 Garching, Germany — [2]Evonik Degussa GmbH, Paul-Baumann-Str.1, 45772 Marl, Germany — [3]Institut für Verbrennung und Gasdynamik, Universität Duisburg-Essen, Lotharstr. 1, 47048 Duisburg, Germany

Hybrid organic-inorganic solar cells, which incorporate both, organic and inorganic semiconductors, have received a lot of attention during the last years. Such solar cells typically consist of a bulk heterostructure made of organic semiconducting polymers and semiconducting nanocrystals. These hybrid organic-inorganic solar cells can benefit from the solution processing and from the broad spectral absorption range of semiconductor nanocrystals. We have studied hybrid bulk heterojunctions between Silicon nanocrystals (Si-nc), which have been synthesized by decomposition of silane in a microwave plasma reactor, and the organic hole conductor poly(3-hexylthiophene-2,5-diyl) (P3HT). Hybrid bulk heterojunction solar cells with P3HT and Si-nc have been produced and characterized by current-voltage measurements. For these devices, we have demonstrated by spectrally resolved photocurrent measurements that both components of the solar cell, the Si-nc and the P3HT, contribute to the photocurrent. Current-voltage measurements under white light illumination with 100 mW/cm^2 show a high open circuit voltage of up to 0.7 V.

CPP 26.8 Wed 15:45 ZEU 222

Inverted Bulk Heterojunction Solar Cells — •Sofie Khalil and Klaus Meerholz — University of Cologne, Institute for Physical Chemistry, Luxemburger Str. 116, 50969 Cologne, Germany

Solution processed polymer photovoltaics are nowadays a very promising low-cost fabrication technology for renewable energy sources. Nevertheless research made onto bulk heterojunction (BHJ) with structure: ITO/ PEDOT:PSS/ blends of regioregular poly-3-hexylthiophene (RR-P3HT) and the fullerene derivative [6,6]-phenyl C61 butyric acid methyl ester (PCBM) / Ca:Ag showed inherent lifetime limitations due the use of PEDOT:PSS and low work-function metal electrode. In this talk we will show an alternative device with a new stacking order of layers: the inverted solar cells. In these devices to avoid the air sensitive and lifetime limiting materials we use a stable transparent anode electrode with lower energy level than the stable high-work function metal top electrode. The direction of the carrier flow is therefore inverted due to the inversion of the direction of the internal field. Inverted bulk-heterojunction solar cell made RR P3HT and PCBM as the active layer in the structure: ITO / TiOx / RR-P3HT-PCBM / metal electrode were studied. The transparent TiOx acts as electron-collecting electrode and the metal electrode as hole-collecting electrode. Different parameters have been investigated: thickness and treatment of the TiOx layer, solvent, thickness of the active layer, molecular weight of the polymer, post-annealing process, work-function of the metal electrode. And then a comparison of lifetime between a regular solar cell and an inverted one will be presented.

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Transparent Metal Electrodes for Organic Solar Cells — •Jan Meiss, Moritz K. Riede, and Karl Leo — Institut fuer Angewandte Photophysik, Technische Universitaet Dresden, 01062 Dresden - http://www.iapp.de

Organic solar cells (OSC) are emerging as possible inexpensive alternative to inorganic photovoltaics. Current issues of OSC are the high price of indium tin oxide (ITO), the most commonly used transparent contacting material, and the fact that glass is used as substrate in almost all cases. We are exploring alternatives to the scarce and expensive ITO and investigate alternative OSC configurations, i.e. top-illuminated and inverted solar cells.

In this contribution, top-illuminated small-molecule organic solar cells with transparent metal cathodes consisting of different combinations of Al, Ag and Au are presented. The whole device stack has been prepared by thermal evaporation under vacuum. It is shown that multi-layer metal cathodes employing surface modifying interlayers achieve by far superior performance compared to single-layer cathodes. Scanning electron and atomic force microscopy show that this can be attributed to significantly improved morphology in multi-layer devices; these conclusions are supported by the electrical properties in the current-voltage curves. By additionally enhancing light incoupling with a capping layer and utilizing microcavity effects, promising efficiencies of over 2.2% are obtained for zinc phthalocyanine / C60 bulk heterojunction solar cells containing standard materials.

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Effects of geminate and bimolecular recombination on the performance of polymeric-small molecular solar cells — •Marcel Schubert[1], Chunhong Yin[1], Mauro Castellani[1], Alan Sellinger[2], and Dieter Neher[1] — [1]University of Potsdam, Institute of Physics and Astronomy, 14476 Potsdam-Golm, Germany — [2]IMRE and A*Star, 3 Research Link, 117602 Republic of Singapore

Many physical properties of organic photovoltaics are related to the nature of the geminate pair, an intermediate state that forms after dissociation of photogenerated excitons and prior to free charge carrier generation. Whereas it was found that photocurrent generation is dominated by the strong field dependent process of geminate pair dissociation, the recombination of uncorrelated free charge carriers and the formation of space charge seem to play a minor role in the prominent P3HT/PCBM combination. The situation may change, when using different D/A combinations or other soluble acceptor molecules.

We present organic solar cells comprising a novel small molecule based on 2-vinyl-4,5-dicyanoimidazole (Vinazene) as acceptor and M3EH-PPV as donor. While bilayer devices show promising results with a fill factor up to 57 %, the IU-characteristics of bulk heterojunction devices are dominated by bimolecular recombination and space charge effects even at moderate illumination intensities. Photo-CELIV measurements were performed to study the bimolecular recombination in detail. By combining photo-CELIV results with PL and IU measurements we are able to analyze the interrelation of recombination losses, free charge carrier generation and exciplex formation.

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Highly doped layers as efficient electron-hole conversion contact for tandem organic solar cells — •Ronny Timmreck, Selina Olthof, Moritz Riede, and Karl Leo — Institut für angewandte Photophysik, TU Dresden, Dresden, Germany

To achieve high power conversion efficiencies with stacked organic solar cells, several requirements concerning their layer structure have to be fulfilled. A key feature is an efficient conversion contact at the interface between the single solar cells of a stacked cell: Here, an electron current has to be converted into a hole current without loss of energy. We investigate such contacts for small-molecule organic solar cells and present an approach adopted from inorganic tandem solar cells by using highly doped organic layers. We also compare metal-cluster based conversion contacts reported in literature to our new approach. For this purpose, comparable structures are characterised by UPS, by I-V-characteristics of organic p/n-heterojunctions, and by I-V-characteristics of corresponding solar cells. The experiments show that our approach is superior to the metal cluster based approach, e.g. it allows a full addition of the open circuit voltage Voc of the subcells independent from the used organic materials. It is thus possible to avoid the metal clusters which allows for a wider choice of materials and has advantages for future mass production. Using these results, a possible working mechanism of these contacts is discussed: high recombination rates at the conversion contact result in low sheet resistances and a removal of quasi-Fermi level splitting such that no reverse voltage occurs which would reduce Voc of the stacked solar cell.

CPP 26.12 Wed 16:45 ZEU 222

Light- and touch-point localization using flexible large area organic photodiodes — •Petr Bartu[1], Robert Koeppe[1,2,3], Siegfried Bauer[1], and Niyazi Serdar Sariciftci[2] — [1]Department of Soft Matter Physics (SoMaP), JKU Linz, Altenbergerstr. 69, A-4040 Linz, Austria — [2]Linz Institute for Organic Solar Cells (LIOS), JKU Linz, Altenbergerstr. 69, A-4040 Linz, Austria — [3]isiQiri interface technologies GmbH i.G., c/o tech2b, Hafenstr. 47-51, A-4020 Linz, Austria

A large area photodiode using a heterojunction of zinc-phthalocyanine and fullerene C60 as active layer sandwiched between resistive electrodes of Poly(ethylenedioxythiophenes) Polystyrenesulfonate (PEDOT:PSS) and semitransparent aluminum can be used as a two dimensional position sensitive device for detecting light spots. The current generated in the photodiode drops over resistive electrodes to the

edges of the device and depends on the distance between the excitation and the point where the resistive electrode is connected with the outer circuit. For precise tuning of the device, a variation of the electrode sheet resistance as well as a change in modulation of the frequency can be used. Additionally, localized out-coupling of light from a waveguide of silicone rubber by pressure allows the construction of a pressure sensitive optical touchpad.