HL 45: Organic photovoltaics and electronics

Time: Thursday 15:00–17:45 Location: EW 203

HL 45.1 Thu 15:00 EW 203

Excitons under the Microscope: Optical Observations in Organic Bulk Heterojunctions — •Martin Streiter, Alexander Wagenpfahl, and Carsten Deibel — Institut für Physik, Technische Universität Chemnitz, 09126 Chemnitz, Germany

Most properties of organic bulk heterojunction photovoltaic devices are influenced by energetic disorder in the film. In order to investigate the effects of local morphology and different molecular conformations causing energetic disorder, we investigated organic donor–acceptor films by confocal microscopy with variable excitation photon energies. At higher photon energies we measured photoluminescence lifetimes of neat donor materials accessing the exciton diffusion lengths by varying the acceptor concentration. At lower photon energies, we observed local radiative recombination at the interface of such bulk heterojunctions in order to determine the charge transfer ground state energy by combining photoluminescence and excitation spectroscopy measurements. The combination of optical measurements with different ranges of excitation energies provides insights into bulk heterojunction films at the micron scale.

HL 45.2 Thu 15:15 EW 203

On the impact of capacity and transport on transient photovoltage measurements of organic solar cells — •Uli Würfel, Mathias List, and Moritz Unmüssig — Fraunhofer ISE, Heidenhofstr. 2, 79110 Freiburg, Germany

Transient photovoltage measurements (TPV) are applied to organic solar cells (OSC) to reveal recombination dynamics in these devices. From the recorded transients, charge carrier lifetimes are often derived by fitting an exponential function to the experimental data. In this contribution, numerical simulations of TPV experiments are presented which show that capacitive effects (due to very thin absorber layers) can have large impacts on the voltage transients which can lead - if not accounted for correctly - to questionable interpretations of TPV data. An analytical model describing generation, recombination and displacement current agrees very well with full numerical drift-diffusion simulations - but only for high charge carrier mobilities. In fact, the change in Voc can be dominated by the charge carrier mobilities, as the displacement current involves carrier transport in the absorber. Therefore we developed an expanded analytical model which takes explicitly into account the transport of charge carriers within the device. The results are in excellent agreement with full numerical drift-diffusion simulations for different absorber thicknesses and charge carrier mobilities and with experimental data. This shows that advancements in understanding recombination dynamics from photovoltage transients can only be achieved when properly considering carrier transport required for the displacement current.

HL 45.3 Thu 15:30 EW 203

Surface-tension driven assembly of a novel perylene diimide derivative leads to highly crystalline monolayers — Ilja Vladimirov[1,2], Matthias Kellermeier[1], Thomas Gessner[1], Zahra Molla[3], Souren Grigorian[3], Ullrich Pietsch[3], Lilian Schaffroth[4], Michael Kühn[1], Falk May[1], and •R. Thomas Weitz[1,2,4] — [1]BASF SE Ludwigshafen — [2]InnovationLab GmbH Heidelberg — [3]Fakultät für Physik, Universität Siegen — [4]Physics of Nanosystems, NIM and CeNS, LMU Munich

The charge carrier mobility in thin films composed of organic semiconductors benefits from high crystalline order. An everlasting challenge with organic semiconductors when processed from solution is, that currently there is no general understanding of how to select solvents to yield a certain crystal morphology of the organic semiconductor. One approach is the crystallization of organic semiconductors at the liquid-air boundary of a drying droplet [1,2]. The systematics of why the used small molecules assemble preferably at the liquid-air interface have not been the focus of these studies. Here we show using a novel perylene diimide derivative that it is mainly the surface tension of a liquid, that drives the crystallization at the liquid-air interface of a drying droplet [3]. This confinement allows the growth of mm sized, few-nm thin crystals. We show that such crystals have excellent electrical performance. For example, electron field-effect mobilities of larger than 4 cm*/Vs were realized in only 3 nm thin films. [1] G. Giri et al. Nature Commun. 2014, 5, 3573 [2] H. Minemawari et al. Nature 2011, 475, 364 [3] I. Vladimirov et al. Nano Lett. 10.1021/acs.nanolett.7b03789

HL 45.4 Thu 15:45 EW 203

Circular Polarized Light Sensor based on Organic Photodiodes — •Manuela Schiek[1], Matthias Schulz[2], Dorothea Scheunemann[1], Oliver Kolloge[1], Arne Lützen[2], Oriol Arteaga[3], and Stefan C. J. Meskers[4] — [1]University of Oldenburg, D — [2]University of Bonn, D — [3]University of Barcelona, ES — [4]University of Eindhoven, NL

Enantiopure prolinol-functionalized squaraines with opposite handedness have been obtained via an ex-chiral pool strategy. Strong intrinsic circular dichroism within the green spectral range is probed in spin-casted thin films by Mueller matrix spectroscopy. Blended with a fullerene acceptor these small molecular squaraines function as active layer in a photodiode with reasonable frequency response in transient photocurrent recordings. Within the green spectral range circular polarized light is highly selectively converted into photocurrent outperforming the polymer-based devices by far [1]. Connecting such photodiodes of opposite handedness, we provide a fully integrated organic circular polarization light sensor that does not require any active manipulation of the polarization of the incoming light. [1] J. Gilot, R. Abbel, G. Lakhwani, E.W. Meijer, A.P.H.J. Schenning, S.C.J. Meskers, Adv. Mater. 22 (2010) E131-E134.

HL 45.5 Thu 16:00 EW 203

Flexible Vertical Organic Transistors for MHz Circuits — •Felix Dollinger, Markus P. Klinger, Axel Fischer, Hans Kleemann, and Karl Leo — Dresden Integrated Center for Applied Physics and Photonic Materials (IAPP), Dresden, Germany

Organic large area electronics have the potential to enable fully flexible applications. This requires efficient transistors on flexible substrates as well as capacitors, inductors, and resistors to design an electrical circuit.

We operate Organic Permeable Base Transistors (OPBT) on polymer substrates to combine impressive transistor characteristics, facile manufacturing techniques and mechanical flexibility. Large current densities and on/off-ratios are achieved with simple shadow mask structuring. Currently our flexible devices reach on/off-ratios exceeding 10^6 and current densities above 1 A/cm^2.

Flexible transistors are presented and analyzed for their DC behavior and for frequencies up to the MHz regime. Information on the challenges and solutions connected to the transfer of our thin-film technology from rigid glass-substrates to flexible and bendable polymer substrates will be given. Thin-film capacitors and inductors are produced to fit the needs of a transmitter circuit that we aim to use for indoor wireless localization applications.

15 min. break.

HL 45.6 Thu 16:30 EW 203

Microscopic simulations of doped organic semiconductors and their layers — •Artem Fediai[1], Franz Symalla[2], and Wolfgang Wenzel[1] — [1]Karlsruhe Institute of Technology — [2]Nanomatch GmbH, Hermann-von-Helmholtz-Platz 1 76344 Eggenstein-Leopoldshafen

Thermally activated hopping transport in doped organic semiconductors has been studied using the efficient implementation of the kinetic Monte Carlo (KMC) method [1]. We present results for two types of simulation set-ups: (1) a bulk doped material and (2) a single doped layer sandwiched between two metallic electrodes.

For bulk systems, we have particularly investigated how the doping efficiency and the intrinsic energy disorder depend on dopant molar ratio for various energy disorders and offsets between IP of the host material and EA of the acceptor. Besides, the hole mobility in the same parameter space has been investigated.

For a single doped layer sandwiched between two electrodes, we have investigated the dopant molar ratio dependence of the chemical potential of the donated particles in the bulk of a material, and how the injection barrier at a metal/semiconductor interface evolves as the dopant molar ratio increases. Finally, the conductivity of a doped layer has been studied as a function of various parameters.

Our study allows a better understanding of microscopic mechanisms,

which changes conductivity and other properties of doped organic semiconductor materials/layers in response to doping.

[1] F. Symalla et.al., Phys. Rev. Lett. 117, 276803.

HL 45.7 Thu 16:45 EW 203

Ideality and Charge Transfer State Characteristics of "Real" Organic Solar Cells — •Clemens Göhler and Carsten Deibel — Institut für Physik, Technische Universität Chemnitz, 09126 Chemnitz, Germany

Organic solar cells show promising progress by using the concept of a charge transfer (CT) state, but still trail their inorganic and hybrid counterparts in efficiency. One of the reasons might lie in the comparably high recombination of charge carriers, as numerous studies found links between recombination, CT state properties, and losses in the open circuit voltage of the solar cell.

In-depth analysis of the CT state is frequently performed with external quantum efficiency (EQE) measurements in the sub-gap region, focusing on small currents resulting from direct CT excitations; and by inducing electroluminescence (EL) emission from the solar cell using an applied driving current. Recombination effects can be quantified with the ideality factor n_{id} from the Shockely equation, usually acquired from the current–voltage (JV) characteristics of the solar cell.

Empirically, however, organic solar cells oftentimes do not represent an ideal Shockley diode, but should better be treated with regard to shunt and series resistances. Consequently, we find that even small driving currents applied during EL measurements cause significant heating of the solar cell that requires careful analysis; and that a resistance free method to obtain n_{id} is preferable to JV measurements.

HL 45.8 Thu 17:00 EW 203

Defect Patterns of Thin Film PV Devices: Imaging Experiments vs. Electric Circuit Simulations — •Daniel Fluhr[1], Marco Seeland[2], Burhan Muhsin[3], Stefan Krischok[1], and Harald Hoppe[3] — [1]Institute of Physics, Technische Universität Ilmenau, 98693 Ilmenau, Germany (D) — [2]Institute for Computer and Systems Engineering, Technische Universität Ilmenau, 98693 Ilmenau, D — [3]Center for Energy and Environmental Chemistry Jena (CEEC Jena), Friedrich Schiller University Jena, 07743 Jena, D

Defects and degradation are important issues for low cost photovoltaics. Laterally resolving imaging techniques have already proven their ability for resolving the location of performance decreasing problems. A one to one correlation between physical defect types and imaging measurement features cannot be established on a single imaging method alone. However, a combination of several measurement methods is suitable to distinguish different defect types. We classify defects by their electrical properties and correlate them with three different imaging techniques by simulation and experiment. The imaging techniques investigated are Electroluminescence Imaging, Light-Beam Induced Current mapping and Dark Lock-In Thermography. Our software is based on electrical simulations of a resistive network of diodes. The locally resolved current and voltage distributions are used for computing. We simulate a variety of defect types and correlate their electrical properties to fingerprints of the imaging methods. We confirm our findings by comparing with experiments with artificially induced defects and observe good agreement of the defect patterns.

HL 45.9 Thu 17:15 EW 203

Understanding the Capacitance Voltage Characteristics of Organic Light Emitting Diodes by Combining Photoelectron Spectroscopy, Impedance Spectroscopy and Current Voltage Measurements — •Victoria Wissdorf[1,2], Paula Connor[2], Maybritt Kühn[2,3], Christof Pflumm[1], Wolfram Jaegermann[2,3], and Eric Mankel[2,3] — [1]Merck KGaA, Darmstadt — [2]Technische Universität Darmstadt, Darmstadt — [3]InnovationLab GmbH, Heidelberg

The determination of reliable material parameters, such as the mobility or injection barrier of charge carriers in organic semiconducting materials, is a crucial step towards an advanced understanding of the physical processes that determine the performance of Organic Light Emitting Diodes (OLEDs). This determination is by far means not trivial: It highly depends on the theoretical model assumed, the measurement technique used and the device that is evaluated. Within this study we present a drift-diffusion approach based on [1] that can be correlated with the photoelectron spectroscopy measurements of hole transport materials and their corresponding Hole-Only-Device (HOD) characteristics for current voltage and impedance spectroscopy (capacitance voltage) measurements. Based on the doping model presented in [2] we can explain how the Capacitance Voltage curves of HODs are influenced by the p-doping of the organic semiconductor.

[1] Kühn et al., Organic Electronics 37, 336-345, (2016)
[2] Mayer et al., Organic Electronics 13, 1356-1364, (2012)

HL 45.10 Thu 17:30 EW 203

Field-Assisted Charge Generation in PffBT4T-2OD:PC71BM Organic Solar Cells — •Andreas Weu[1], Tom Hopper[2], Artem Bakulin[2], and Yana Vaynzof[1] — [1]Centre for Advanced Materials, Universität Heidelberg — [2]Department of Chemistry, Imperial College London

Although remarkable progress has been made in both synthesis of new organic materials and optimisation of processing procedures for organic solar cells, the principle process of photo-induced charge generation in donor:acceptor systems with low driving energy remains unclear. Here, we present a photophysical study of the high performance material system PffBT4T-2OD:PC71BM, which shows efficiencies ˜11% despite having only minimal energy offset. We demonstrate by steady-state and ultra-fast optical techniques that the built-in field within a device structure is required for long-range charge separation, while in neat blend films an energetic barrier prevents exciton dissociation and charge transfer to the fullerene acceptor.[1] Our observations are likely to be applicable to other material systems with low driving energy and highlight the importance of using complete devices for photophysical studies.

[1] Andreas Weu, Thomas R. Hopper, Vincent Lami, Joshua A. Kress, Artem A. Bakulin and Yana Vaynzof, "Field-Assisted Charge Generation in Highly Efficient PffBT4T-2OD:Fullerene Organic Solar Cells", submitted to J. Phys. Chem. Lett.