CPP 86: Organic Electronics and Photovoltaics III

Time: Thursday 9:30–12:45 Location: ZEU 260

CPP 86.1 Thu 9:30 ZEU 260

Fast Processing of Charge Transport Layers in Organic Solar Cells — •Harald Hoppe[1,2], Shahidul Alam[1,2], Aman Anand[1,2], Aurelien Sokeng Djourmessi[1,2], Jose Prince Madalaimuthu[1,2], Peter Fischer[4], and Ulrich S. Schubert[1,2,3] — [1]Center for Energy and Environmental Chemistry Jena (CEEC Jena), Friedrich Schiller University, Jena, Germany — [2]Laboratory of Organic and Macromolecular Chemistry (IOMC), Friedrich Schiller University, Jena, Germany — [3]Jena Center for Soft Matter (JCSM), Friedrich Schiller University, Jena, Germany — [4]Faculty of Mechanical Engineering, Ilmenau University of Technology, Ilmenau, Germany

Charge transport layers (CTLs) are very important in organic solar cells to allow for an efficient and selective extraction of photogenerated charge carriers. Upon their optimization important photovoltaic parameters such as fill factors are being directly affected, for example since the series resistance and parallel resistance are often improved in combination with each other, when the contact becomes more selective. Unfortunately, CTLs often require an additional and rather intensive annealing process, which will add to the energy investment to such solar cells. In addition, such annealing processes may often either require too high temperatures to be compatible with flexible substrates or may be too time-consuming for fast web speeds. As one solution, we demonstrate the successful application of flash sintering for the annealing of CTLs.

CPP 86.2 Thu 9:45 ZEU 260

Single step production of a self-organized, low work function cathode interlayer from polymer blend solution — •Dominique Lungwitz[1], Keli Fabiana Seidel[2], Andreas Opitz[1], Thomas Krüger[3], Jan Behrends[3], Seth R. Marder[4], and Norbert Koch[1,5] — [1]Institut für Physik and IRIS Adlershof, Humboldt Universität zu Berlin, Germany — [2]Physics Department, Universidade Tecnológica Federal do Paraná, Brasil — [3]Berlin Joint EPR Lab and Institut für Experimentalphysik, Freie Universität Berlin, Germany — [4]School of Chemistry and Biochemistry and Center for Organic Photonics and Electronics (COPE), Georgia Institute of Technology Atlanta, USA — [5]Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Germany

Using cathode interlayers for reducing the work function of electrodes in organic electronic devices is a widely studied method. Here, we report a simple procedure to obtain a self-organized interlayer on ITO electrodes from a blend solution of P(NDI2OD-T2) and PEI. Reduced contact resistance and increased polymer conductivity are observed due to vertical phase separation. Fermi level pinning of P(NDI2OD-T2) at PEI covered ITO electrodes leads to the lowest possible electron injection barrier. Furthermore, an increased charge carrier density was measured. Finally, we relate the increase in polymer conductivity to a reduction of interfacial electron trapping and a morphology change. The results show clearly the importance of differentiation between work function reduction upon interfacial layers and conductivity increase upon changes of structural conformation.

CPP 86.3 Thu 10:00 ZEU 260

Studying the dynamics of PTB7:PCBM blend films — •Dominik Schwaiger[1], Wiebke Lohstroh[2], and Peter Müller-Buschbaum[1,2] — [1]Technische Universität München, Physik-Department, Lehrstuhl für Funktionelle Materialien, James-Franck-Straße 1, 85748 Garching, Germany — [2]Heinz Maier-Leibnitz Zentrum (MLZ), Technische Universität München, Lichtenbergstr. 1, 85748 Garching, Germany

In organic photovoltaics, donor - acceptor bulk heterojunctions are often used as active materials due to their superior performance compared to e.g. planar layered devices. In this optically active polymer layer, a photon is absorbed and an exciton created. After diffusion to a donor-acceptor interface, the exciton is dissipated and charge carriers can be extracted at the electrodes. A frequently applied and well-studied system is the combination of P3HT ((C10H14S)n) as electron donor and PCBM (C72H14O2) as electron acceptor. Previous studies have shown that internal dynamics and structural layout of the active layer influence its electronic properties and thus its performance in a device. A more modern, very promising low-band gap electron donor material is PTB7 ((C41H53FO4S4)n). We investigate films of PTB7, PCBM and a mixture of these two prepared out of chlorobenzene solutions. On these films we perform first quasielastic neutron scattering experiments. Hydrogen dynamics of pure compounds as well as blend films on a pico- to nanosecond timescale in a temperature range from 150 K to 400 K are investigated and compared with the established P3HT:PCBM system.

CPP 86.4 Thu 10:15 ZEU 260

Temperature dependence of the spectral linewidth of charge-transfer-state emission in organic solar cells; static vs. dynamic disorder contribution — •Kristofer Tvingstedt[1], Johannes Benduhn[2], and Koen Vandewal[3] — [1]Experimental Physics VI, Julius Maximillian University of Würzburg, 97074 Würzburg, Germany — [2]Dresden Integrated Center for Applied Physics and Photonic Materials (IAPP) and Institute for Applied Physics, TU Dresden, Nöthnitzer Straße 61, 01187 Dresden, Germany — [3]Instituut voor Materiaalonderzoek (IMO), Hasselt University, Wetenschapspark 1, BE-3590 Diepenbeek, Belgium

The origin and impact of energetic disorder remains a topic of intense controversy in the research field of organic photovoltaics (OPV). As the amount of energetic disorder of the photovoltaic material have a pronounced impact on both the open circuit voltage and the effective drift mobility of operational devices, a proper account of its foundation is strongly desired. Currently, both Gaussian and exponential, as well as static and dynamic disorder models are interchangeably being employed. We herein aim to increase the understanding of disorder contribution in organic solar cells by evaluating the spectral width of charge-transfer-state emission as a function of both carrier injection conditions and temperature, with the primary objective to disentangle dynamic and static disorder contribution. Both photoluminescence (PL) and electroluminescence (EL) of a large set of complete devices made of both small molecules and polymers are evaluated under weak injection conditions to shed more light on this topic.

CPP 86.5 Thu 10:30 ZEU 260

Organic narrowband near-infrared photodetectors for industrial applications — •Johannes Benduhn[1], Rico Meerheim[1,2], David Wynands[1,2], Marcel Dahms[2], Paul Vincze[2], and Robert Brückner[1,2] — [1]Institut für Angewandte Physik, Technische Universität Dresden, Dresden, Germany — [2]Senorics GmbH, Dresden, Germany

Near-infrared (NIR) spectroscopy is a powerful method to analyse the composition of various analytes. Nowadays, this method is mainly used in well-equipped laboratories since todays spectrometers are very large and expensive. To overcome these limitations, we present organic photodetectors which enable narrowband detection of NIR photons with full width at half maximum down to 15 nm and can be produced easily and cost efficiently. These detectors are based on organic donor-acceptor blends forming an NIR-absorbing charge-transfer state which is massively enhanced by utilizing an optical micro-cavity. Tuning the cavity resonance, different wavelengths can be detected. Placing different of such detectors in an array results in a miniaturized lateral spectrometer which can be employed to measure for example moisture content of carton, using a reflection geometry. In the near future, such miniaturized spectrometers can be used to optimize the production of paper and carton by controlling the moisture content. Furthermore, various related applications and products can be addressed.

CPP 86.6 Thu 10:45 ZEU 260

Integrated All-Organic Oxygen Sensor — •Toni Bärschneider[1], Jakob Lindenthal[1], Simone Lenk[1,2], and Sebastian Reineke[1] — [1]Dresden Integrated Center for Applied Physics and Photonic Materials (IAPP), Technische Universität Dresden — [2]CeTI Cluster of Excellence, Centre for Tactile Internet with Human-in-the-Loop, Technische Universität Dresden

Organic electronics devices, such as light-emitting diodes (OLEDs) and photodetectors (OPDs) are cheap, easy-to-fabricate and very versatile. For these reasons, it is advantageous to use them for sensor applications. For instance in case of oxygen (O_2), which is the most abundant element on earth, there is a big need for cheap sensors. Especially industry and biological research require cheap trace oxygen sensors. Optical O_2 sensors represent a promissing type, since they

offer fast response and no O_2 consumption. However, they suffer from photodegradation and a rather complex assembly. To overcome these drawbacks, organic electronics with their excellent adjustability can be used to realize a monolithic and therefore cheap implementation.

In this work, we developed a monolithic all-organic oxygen sensor which is composed of a biluminescent sensing layer, an ultraviolet OLED with a peak wavelength of 375 nm as an excitation source and a novel narrow bandwidth OPD. The biluminescent sensing layer shows fluorescence and phosphorescence at the same time which enables self referencing to avoid photodegradation caused distortion. Furthermore, the long lifetime phosphorescene allows sensing within the ultra-trace oxygen range.

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High-Speed and High-Current Vertical Organic Transistors — •Felix Dollinger[1], Kyung-Geun Lim[2], Axel Fischer[1], Petr Formánek[3], Hans Kleemann[1], and Karl Leo[1] — [1]Dresden Integrated Center for Applied Physics and Photonic Materials (IAPP), Dresden, Germany — [2]Korea Research Institution for Standard Science (KRISS), Daejeon, Korea — [3]Leibniz-Institut für Polymerforschung Dresden e. V. (IPF), Dresden, Germany

The Organic Permeable Base Transistor (OPBT) is a vertical organic transistor design allowing for very high current densities, and hence the fastest operating speed of all organic transistors with transit frequency reaching 40 MHz. The modulation of current in such a device is achieved by a thin aluminum base electrode, corresponding to the gate in a conventional field effect transistor. This base layer is located in the center of the vertical stack and is permeable for electrons.

Using an improved fabrication technique of the base layer, we show OPBTs with excellent properties. Specifically, the devices show very large current gain and reduced parasitic leakage currents. This has been achieved by applying electrochemical anodization to the base layer, which most interestingly, can be carried out atop of the organic semiconductor layer without compromising the transistor performance [Dollinger et al., **Advanced Materials, 2019**].

In addition, we investigate the behavior of OPBTs under electrical stress, which helps to understand the suitability of these transistors for long-time real-life applications [Dollinger et al., **Advanced Electronic Materials, 2019**].

15 min. break

CPP 86.8 Thu 11:30 ZEU 260

***In Situ* and *In Operando* KPFM Studies on Hexadecafluoro-Copper-Phthalocyanine ($F_{16}PcCu$) in OFET to Access Electrical Contact Resistance and Energy Level Alignment** — •Pascal Schweitzer, Clemens Geis, and Derck Schlettwein — Justus Liebig University Gießen, Institute of Applied Physics

Contact resistances are considered the major limiter of performance of organic field effect transistors (OFET). Perfluorinated copper-phthalocyanine ($F_{16}PcCu$) is a promising material as n-conductor to build complementary logical circuits. It is characterized by chemical stability under ambient conditions and a reasonably high charge carrier mobility. In this work, we used *in operando* Kelvin probe force microscopy under high vacuum to study the influence of contact resistances at the source and drain contacts on the OFET performance. Potentiometry at different applied external voltages revealed voltage drops at the interfaces to the source and drain metal contacts which allow for calculation of contact resistances. Thereby, the field-effect charge carrier mobility of $F_{16}PcCu$ was corrected for contact effects. Significantly higher values were obtained. *In situ* KPFM during film growth on polycrystalline gold visualizes film formation and corresponding shifts of energy levels confirming the existence of an injection barrier. We conclude, that tuning the energy level alignment and the interface effects to reduce contact resistances will lead to considerably improved performance of $F_{16}PcCu$ in OFET.

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Impact of electron-phonon-interaction on transport in organic molecular crystals: Naphthalene as a case study — •Konrad Merkel, Michel Panhans, Sebastian Hutsch, and Frank Ortmann — Center for Advancing Electronics Dresden, TU Dresden, 01062 Dresden

Understanding charge carrier transport in organic semiconductors is a key requirement for developing advanced electronic and opto-electronic devices such as OLEDs, OFETs and organic solar cells. However the general transport mechanism remains unclear. It is widely believed that electron-phonon-interaction plays an important role, due to the large fluctuations in the electronic coupling associated to the van-der-Waals-bonds between adjacent molecules. The interaction leads to a subtle interplay of scattering and phonon-assisted transport. Within the Kubo formalism, we derive a simulation technique, where we model the low-frequency phonon modes as local and non-local disorder in a tight-binding scheme and where all material parameters are calculated from density functional theory. We study the impact of such modes in naphthalene and compare our results to studies from literature.

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Multifrequency Spin-Resonance Experiments on Organic LEDs based on Inter- and Intra-molecular Triplet-Singlet Conversion — •Sebastian Weissenseel, Rebecca Bönnighausen, Jeannine Grüne, Nikolai Bunzmann, Vladimir Dyakonov, and Andreas Sperlich — Experimental Physics VI, Julius Maximilian University of Würzburg

The world of organic light emitting diodes (OLEDs) regained a lot of attention with the publication of Goushi et al. in 2012 [1], where the thermal activation of non-radiative triplets via reverse intersystem crossing (RISC) was applied to enhance the fluorescence in OLEDs. This process can be investigated by spin sensitive techniques such as electroluminescence detected magnetic resonance (ELDMR). The idea behind these experiments is that the static magnetic field applied to devices under test modifies only the energy levels of triplet states due to the magnetic moment, resulting in Zeeman splitting, thus changing the emission rates. We observed that resonant microwave radiation, applied to OLEDs by a stripline, led to a change in electroluminescence [2]. Here, we show the difference between inter- and intra-molecular TADF systems by applying a broad range of resonance frequencies. With this method, we gain knowledge about the magnetic field dependence of the linewidth of the ELDMR signal.

[1] Goushi, et al., Nat. Photon. 6, 253 (2012)
[2] Bunzmann et al., arXiv:1906.06073. (2019)

CPP 86.11 Thu 12:15 ZEU 260

What is the effective electrical bandgap of an OLED? — •Axel Fischer, Jinhan Wu, and Sebastian Reineke — Dresden Integrated Center for Applied Physics and Photonic Materials (IAPP) and Institute of Applied Physics, TU Dresden

Organic light-emitting diodes (OLEDs) are used since several years in commercial products, such as displays. However, there are still open questions. For example, there is a lack of studies about the (effective) electrical bandgap of state-of-the-art OLEDs although it is quite important to know the energy that free charge carriers have to overcome before they can recombine. Here, we illuminate OLEDs with UV light which results in generation of free charge carriers that create an open-circuit voltage similar to what one typically observes for solar cells. A comprehensive analysis of temperature dependent measurements then allows to determine an effective electrical bandgap that will be compared to the energy levels of the molecules used in the investigated OLED [Wu et al., Adv. Opt. Mater. **2019**, 7, 1801426]. The future importance of the results relies in determining voltage losses, both, from internal non-radiative relaxation as well as from charge transport.

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Increasing the triplet-to-singlet ratio in photoluminescence of TADF emitters using phosphorescent sensitizers: a pathway to study non-linear effects — •Paulius Imbrasas, Simone Lenk, and Sebastian Reineke — Dresden Integrated Center for Applied Physics and Photonic Materials (IAPP) and Institute for Applied Physics, Technische Universität Dresden, 01187 Dresden, Germany

Organic emitters based on thermally activated delayed fluorescence (TADF) have been extensively investigated in the past decade. The main appeal of TADF is that it allows excited triplet state up-conversion to the singlet manifold, leading to increased light generation efficiencies. However, due to comparably long lifetimes of triplet states in TADF emitters, non-linear quenching mechanisms as triplet-triplet annihilation (TTA) or triplet-polaron quenching (TPQ) start playing a role. Adding to that, due to the nature of exciton generation in organic light-emitting diodes (OLEDs), 75% of created excitons are triplet states, which is different in the case of photophysical emitter studies. This typically leads to a high mismatch between triplet densities in photoluminescence (PL) and electroluminescence (EL). In this work, we introduce phosphorescent sensitizer molecules to TADF

based emission layers to increase the triplet-to-singlet exciton density ratio under optical excitation to close the gap to EL exciton distributions. This allows us to investigate triplet-related detrimental effects under practical lab conditions. This simple and versatile approach represents a powerful toolbox to thoroughly probe unfavorable high brightness effects.