

CPP 33: Organic Photovoltaics and Electronics I (joint session CPP/DS/HL, organized by HL)

Time: Wednesday 9:30–12:45

Location: POT 81

CPP 33.1 Wed 9:30 POT 81

Controlling Tamm-plasmons for organic narrowband NIR photodetectors based on intermolecular charge transfer —

•ANDREAS MISCHOK, BERNHARD SIEGMUND, DHIRTI GHOSH, JOHANNES BENDUHN, DONATO SPOLTORE, HARTMUT FRÖB, CHRISTIAN KÖRNER, KOEN VANDEWAL, and KARL LEO — Dresden Integrated Center for Applied Physics and Photonic Materials, Technische Universität Dresden, Dresden

Combining a periodic distributed Bragg reflector (DBR) with a thin metal film leads to the formation of Tamm-plasmon-polaritons (TP) as sharp resonances at the DBR-metal interface. Here, we utilize such TP states to realize cavity-enhanced near infrared photodetection using an organic donor-acceptor bulk heterojunction. In such blend films, intermolecular charge transfer states play an important role during the separation of excitons. Furthermore, they can also be directly optically excited, albeit exhibiting only weak absorption coefficients and a broad linewidth. The weak extinction typically makes these states uninteresting for direct photocurrent generation, however they provide an ideal base for cavity-enhanced devices. Controlling the formation of TP resonances in a DBR-solar cell stack, we create a high-Q microcavity in the near-infrared, targeting the CT state energy. These tunable Tamm-plasmon-charge-transfer (TPCT) resonances enable direct photodetection of light well below the bandgap of the organic absorbers at zero bias and facilitate detector external quantum efficiencies of 17% as well as a linewidth below 25 nm for spectroscopic applications.

CPP 33.2 Wed 9:45 POT 81

Field-induced exciton separation in organic solar cells: Quantifying binding energies via luminescence quenching studies —•MARINA GERHARD¹, ANDREAS P. ARNDT², ULI LEMMER^{2,3}, IAN A. HOWARD³, and MARTIN KOCH⁴ — ¹Department of Chemical Physics, Lund University, 22100 Lund, Sweden — ²Light Technology Institute, Karlsruhe Institute of Technology, 76131 Karlsruhe, Germany — ³Institute of Microstructure Technology, Karlsruhe Institute of Technology, 76344 Eggenstein-Leopoldshafen, Germany — ⁴Faculty of Physics and Materials Sciences Center, Philipps-Universität Marburg, 35032 Marburg, Germany

In this contribution we investigate the field- and temperature-dependence of luminescence quenching in organic solar cells (OSCs) employing a streak camera. We study the prototypical system PTB7:PC₇₁BM, where different emissive species i.e. singlet and CT states can be identified by choosing appropriate excitation conditions.^[1] The quenching behavior and PL dynamics are satisfactorily reproduced by a kinetic model based on exciton dissociation via a hopping mechanism,^[2] allowing us to take the important influence of disorder into account. Moreover, our experimental and simulative approach suggests that the binding energy of the emissive CT state (ca. 50 meV) is about one order of magnitude below that of singlet states. The absence of strongly bound CT states acting as 'deep' traps could essentially contribute to the high efficiency of the studied OSCs.

[1] M. Gerhard et al., *J. Phys. Chem. C* 119 (51), 2015, p. 28309[2] O. Rubel et al., *Phys. Rev. Lett.* 100 (19), 2008, p. 196602

CPP 33.3 Wed 10:00 POT 81

Dissipative Charge Transfer Dynamics at an Oligothiophene/ZnO Interface — •THOMAS PLEHN and VOLKHARD MAY — Institute of Physics, Humboldt University Berlin, Germany

A combined theoretical study of the entire "light to free charge carrier" kinetics on hybrid organic/inorganic interfaces describes a huge challenge, owing to the manifold of interdependent subprocesses. While studies of short time quantum dynamics demand for expensive methods including e.g. electron-phonon interaction, the long time scale kinetics, however, are very sensitive to a realistic size of the model systems. In order to meet both grades, we set up an open system dynamics study based on a stochastic Schrödinger equation method.

After an introducing overview of the organic/inorganic hybrid system under consideration we present the aspired excitation energy and charge transfer processes. The presentation gives insight into the combined coherent and dissipative kinetics in a huge organic oligothiophene cluster. An initial study has the focus on solely the organic part. Then we attend to the actual hybrid interface system by placing the molecular cluster on a ZnO surface. By means of an installed electronic excess

charge distribution in the inorganic counterpart, the hole motion inside the cluster becomes subject to a realistic Coulomb attraction across the interface. In order to clarify the principles of the aspired electron-hole pair separation across such interfaces, it is fundamental to understand how the hole overcomes this existing barrier.

CPP 33.4 Wed 10:15 POT 81

Charge carrier dynamics in polar organic metal-insulator-semiconductor diodes — •ALEXANDER HOFMANN¹, SIMON ZÜFLE², THERESA LINDERL¹, THOMAS ZEHEL¹, LARS JÄGER¹, STEPHANE ALTAZIN², BEAT RUHSTALLER², and WOLFGANG BRÜTTING¹ — ¹Institute of Physics, University of Augsburg, 86135 Augsburg, Germany — ²ZHAW School of Engineering, Technikumstrasse 9, 8401 Winterthur, Switzerland

Polar organic materials such as tris-(8-hydroxyquinolate) aluminum (Alq₃), whose strong permanent dipole moment leads to a pronounced accumulation of charge carriers at the interface, can take the role of an insulator in a metal insulator semiconductor (MIS) diode. Thus, classic wide-bandgap insulators are replaced with polar organic materials. MIS diodes in conjunction with impedance spectroscopy (IS) and charge extraction experiments (e.g. CELIV), however, represent an established device geometry to investigate charge carrier dynamics and dielectric material properties. From temperature dependent MIS-CELIV and IS on organic MIS diodes with different hole transport materials, we are able to independently determine the activation energy of hopping transport as well as the barrier for charge injection.

CPP 33.5 Wed 10:30 POT 81

Fast Organic Near-Infrared Photo-Detectors Based on Charge-Transfer Absorption —

•SASCHA ULLBRICH, BERNHARD SIEGMUND, ANDREAS MISCHOK, ANDREAS HOFACKER, DONATO SPOLTORE, CHRISTIAN KÖRNER, KARL LEO, and KOEN VANDEWAL — Dresden Integrated Center for Applied Physics and Photonic Materials (IAPP), Technische Universität Dresden, Dresden, Germany

In this work, we present organic near-infrared photo-detectors based on the absorption of charge-transfer states between ZnPc as donor and C₆₀ as acceptor material. By using a resonant optical cavity device architecture, we reach external quantum efficiencies above 1% at 1064nm for ZnPc:C₆₀ blends, well below (>200nm) the optical gap of the neat materials. We measure transient photo-current (TPC) responses at wavelengths of 355nm, 532nm, and 1064nm, exciting dominantly C₆₀, ZnPc, or the ZnPc-C₆₀ CT state, respectively, and obtain rise and fall times of a few nanoseconds at short circuit. We find that the response upon CT excitation is at least as fast as upon ZnPc or C₆₀ excitation, emphasizing the possibility to generate fast free carriers by intermolecular absorption. By reducing the active area of the devices, we are able to overcome the generally high RC time limitations caused by thin organic layers. The current transients are modeled with time dependent drift-diffusion simulations of electrons and holes which reconstruct the photo-current signal, including capacitance and series resistance effects. The hole mobility of the donor material is identified as the limiting factor for the high frequency response.

CPP 33.6 Wed 10:45 POT 81

Photovoltaic Performance of Organic Photodiodes Based on Homo-chiral Squaraine Compounds —•MANUELA SCHIEK¹, MATTHIAS SCHULZ², MAJGOR MACK¹, OLIVER KOLLOGE¹, DOMINIK HÖWELING¹, and ARNE LÜTZEN² — ¹University of Oldenburg — ²University of Bonn

The substitution pattern of non-toxic and environmentally stable dihydroxy-anilino squaraines [1] is modified with natural chiral functional groups such as a prolinol derivative. These natural compounds are available in their enantiomerically pure forms making costly separation of racemic product mixtures obsolete. Strong circular dichroism is measured in spin-casted thin films proving homo-chiral aggregation. Blended with a fullerene acceptor, these squaraines perform as light harvesting compound in a conventional bulk heterojunction photodiode. The performance depends on the blend ratio of squaraine and fullerene as well as on active layer thickness. In all cases, the devices suffer from low fill factors. Thinner layers lead to S-shaped current voltage characteristics around Voc. In addition, a thin active layer device with a high fullerene percentage is impacted by a photoshunt

under illuminated reverse current conditions [2]. This becomes visible in reverse voltage biased EQE measurements showing a spectrally dependent deformation of the photocurrent response with the EQE exceeding 100% in the spectral response regime of the fullerene. [1] Schiek et al. *Langmuir* 32 (2016) 8533. [2] Tress et al. *Phys. Stat. Solidi RRL* 7 (2013) 401.

Coffee Break

CPP 33.7 Wed 11:30 POT 81

Hybrid solar cells from antimony sulfide nanoparticles — ●WEI WANG, FRANK STRÖSSNER, EUGEN ZIMMERMANN, KEVIN WONG, and LUKAS SCHMIDT-MENDE — Department of Physics; University of Konstanz

Antimony sulfide (Sb₂S₃) is a promising candidate for hybrid thin film solar cells due to its various favorable properties, such as suitable optical band gap (1.75 eV), high dielectric constant and good band alignment in combination with many organic hole transport materials. In our study, amorphous Sb₂S₃ nanospheres were fabricated by a simple colloidal synthesis method. The Sb₂S₃ nanoparticles were capped by oleic acid (OA) or 1-dodecanethiol (DT) molecules. Thin film hybrid solar cells were made by using these prefabricated Sb₂S₃ nanoparticles as absorber material by depositing them on a TiO₂ covered FTO substrate. The film was then annealed to convert the particles in a crystalline film. P3HT was deposited on top as hole transporter. The device performance of the solar cells fabricated from DT capped nanoparticles was superior to the one capped with OA ligand. Fourier transform infrared spectra (FTIR) revealed that the OA molecules were still anchored to the Sb₂S₃ surface after high temperature annealing, while DT molecules were almost not detectable.

CPP 33.8 Wed 11:45 POT 81

Organic Light-Emitting Diodes for Optogenetic Stimulation of Neurons in *Drosophila* Larvae — ●CAROLINE MURAWSKI¹, ANDREW MORTON¹, IFOR D. W. SAMUEL¹, STEFAN R. PULVER², and MALTE C. GATHER¹ — ¹Organic Semiconductor Centre, SUPA, School of Physics and Astronomy, University of St Andrews, North Haugh, St Andrews KY16 9SS, UK — ²School of Psychology and Neuroscience, University of St Andrews, St Mary's Quad, South Street, St Andrews KY16 9JP, UK

Optogenetics is an emerging method in biology that enables controlling neurons non-invasively with light. Currently, however, only a small number of neurons can be controlled individually so that stimulation of neurons with light still lacks precision compared to the complexity of the brain. To overcome these limitations, we use organic light-emitting diodes (OLEDs), which enable unprecedented high-resolution optogenetic control of thousands of neurons at once. One of the challenges involves the need for very high light intensities (on the order of mW/mm²), a brightness at which OLED efficiency typically decreases dramatically. In this contribution, we show our recent development towards achieving higher brightness OLEDs employing doped charge transport layers. Using these light sources, we demonstrate optogenetic stimulation of neurons in *Drosophila* (fruit fly) larvae and investigate subsequent behavioral changes at different light intensities.¹

[1] A. Morton, C. Murawski, S. R. Pulver, M. C. Gather, *Sci. Rep.* 2016, 6, 31117.

CPP 33.9 Wed 12:00 POT 81

Low Voltage Losses in Cascade Organic Solar Cells by Reducing the Donor-Acceptor Interfacial Area — ●VASILEIOS CHRISTOS NIKOLIS, JOHANNES BENDUHN, FELIX HOLZMÜLLER, CHRISTIAN KÖRNER, DONATO SPOLTORE, and KOEN VANDEWAL — Dresden Integrated Center for Applied Physics and Photonic Materials (IAPP), Technische Universität Dresden, Germany

High photon energy losses (E_{loss}) significantly limit the open-circuit voltage (V_{OC}) and power conversion efficiency (PCE) of organic solar cells (OSC). Reduction of E_{loss} , while keeping a high charge generation yield, can lead OSC into a new, beyond 12%, PCE regime.

In this work, we present an optimization route, which increases V_{OC} by reducing the interfacial area between electron donor (D) and acceptor (A) in planar heterojunction solar cells. Through an introduction of thin and discontinuous interlayers between D and A, we increase the V_{OC} of a cascade organic solar cell from 0.98 V to 1.16 V. Although the V_{OC} maximizes at the expense of short-circuit current and fill factor for thick interlayers, an optimum interlayer thickness for increased PCE exists. By appropriately measuring the optical gap (E_{opt}) of the device at 1.73 eV, the obtained $E_{\text{opt}}-qV_{\text{OC}}$ losses of 0.57 eV are among the lowest observed for organic photovoltaics. Most importantly, for these devices, the external quantum efficiency (EQE) peak at the edge of the spectrum (705 nm) remains high and reaches 79%.

Our work shows that low energy losses for strongly absorbed photons can be combined with a high EQE in organic photovoltaic devices.

CPP 33.10 Wed 12:15 POT 81

Flexible organic solar cell with the effects of light trapping — ●YOONSEOK PARK¹, KOEN VANDEWAL¹, KARL LEO¹, JANA BER^{2,3}, and ANDRÉS FABIÁN LASAGNI^{2,3} — ¹Dresden Integrated Center for Applied Physics and Photonic Materials (IAPP), Technische Universität Dresden, Germany — ²Fraunhofer-Institut für Werkstoffund Strahltechnik IWS, Dresden, Germany — ³Institute for Manufacturing Technology, Technische Universität Dresden, Germany

Organic solar cells are one of the most promising candidates for future solar power generation. They are thin and lightweight with several advantages, e. g. scalability, environmental sustainability and low cost for processing and installation. In order to set up a roll-to-roll process, flexible substrates and electrodes are required. Conventional materials, e. g. glass as substrate and ITO as electrode, are however rigid and brittle. Therefore, flexible polymer materials are investigated. Besides being flexible, polymers are much easier to process and manipulate due to their relative softness as compared to glass and metal oxides. This gives the opportunity to easily introduce light trapping structures into these materials. In this study, we apply several light trapping approaches to organic solar cells. First, PET films structured with a direct laser patterning system as well as optical display films commercially developed to be used for LCD are examined as substrates. Moreover, since PEDOT:PSS electrode is prepared by a solution-based process, nanoparticles are added as light scattering elements. Finally, 2-D nanostructures are printed by a nano-imprinting technique onto the surface of PEDOT:PSS electrodes with PDMS stamps.

CPP 33.11 Wed 12:30 POT 81

Metal-free OLEDs with organic transparent electrodes — ●IRMA SLOWIK, AXEL FISCHER, PAUL-ANTON WILL, SIMONE LENK, SEBASTIAN REINEKE, and KARL LEO — Technische Universität, Dresden, Deutschland

Organic light emitting devices (OLEDs) have versatile applications for flexible transparent devices as transparent displays or lightning panels. Transparent electrodes can be realized by thin metal electrodes, transparent, conducting oxides, conducting polymers, 2D materials, and metal nanowires. Organic molecular layers are mostly not suitable as electrodes due to their low conductivity, resulting in a lateral voltage drop within the organic layer and inhomogeneous emission and low efficiency of the device. However, their processing by thermal evaporation is the same as for the OLED allowing a simple fabrication process. Here, we introduce a fully organic OLED using highly doped C₆₀ as transparent electrode having a sufficiently high conductivity as well as transparency. Utilizing a tunnel junction between two highly and contrary doped semiconductors, n-doped C₆₀ is suitable as top and bottom electrode, resulting in a complete organic device architecture. Although the emission decreases laterally due to the residual sheet resistance of the doped C₆₀ layer, nearly uniform emission is reached within a range of several hundred microns, larger than the standard display pixel. The OLEDs provide small angular spectral shift due to the low refractive index change between electrodes and organic layers. By that approach, transparent OLEDs with bidirectional emission can be easily realized.