

## HL 29: Poster: Organic semiconductors and hybrid organic-inorganic heterostructures / Organic photovoltaics

Time: Monday 17:00–20:00

Location: P2

HL 29.1 Mon 17:00 P2

**Photoemission and photoluminescence spectroscopies of hybrid inorganic-organic heterostructures** — ●MARIEL GRACE DIMAMAY<sup>1,2</sup>, ABEBE TAREKEGNE<sup>3</sup>, AINA QUINTILLA<sup>3</sup>, DAVID TALAGA<sup>4</sup>, JULES ORIOU<sup>2</sup>, GEORGE HADZIOANNOU<sup>2</sup>, THOMAS MAYER<sup>1</sup>, and WOLFRAM JAEGERMANN<sup>1</sup> — <sup>1</sup>Materials Science Institute, Technische Universität Darmstadt, Darmstadt, Germany — <sup>2</sup>Laboratoire de Chimie des Polymères Organiques, CNRS, Université Bordeaux 1, Pessac, France — <sup>3</sup>Light Technology Institute, Karlsruher Institut für Technologie, Karlsruhe, Germany — <sup>4</sup>Institut des Sciences Moléculaires, CNRS, Université Bordeaux 1, Talence, France

Organic emitters are in general brighter than their inorganic counterparts, but their low carrier mobility still poses limitations to device efficiency. Several schemes are being developed to circumvent such problem by utilizing inorganic phases for carrier injection and transport. Through subsequent direct charge transfer or Förster energy transfer from the inorganic semiconductor to the organic emitter, followed by a radiative recombination, photons could be emitted efficiently. In this study, two hybrid inorganic-organic material systems, namely, ZnSe - Ir(4-tBupiq)<sub>2</sub>(acac) and nanocrystalline TiO<sub>2</sub> - squaraine-derived dye are investigated. Interface properties and energy level lineups are obtained by measurements involving XPS and UPS on evaporated Ir complex emitter molecules on ZnSe and on drop-casted squaraine-derived dye on TiO<sub>2</sub>. Photoluminescence of composite films are obtained to show a possible Förster transfer of exciton energy from matrix to emitter dopants.

HL 29.2 Mon 17:00 P2

**Electronic and structural properties of a novel Picene - F4TCNQ based charge transfer material** — ●TORSTEN HAHN<sup>1</sup> and BENJAMIN MAHNS<sup>2</sup> — <sup>1</sup>Institute for Theoretical Physics, TU Freiberg, D-09596 Freiberg — <sup>2</sup>IFW Dresden, P.O. Box 270116, D-01171 Dresden, Germany

Based on the resolved crystal structure the electronic structure, optical excitations and transport properties of novel Picene-F4TCNQ mixed crystals have been investigated using experimental as well as theoretical techniques. The results are compared to those of the pure compounds as well as to other charge transfer salts. The density functional theory (DFT) based theoretical calculations together with electron energy loss spectroscopy (EELS) and transport measurement results reveal the details of the charge transfer process and resolve the electronic structure close to the Fermi level.

HL 29.3 Mon 17:00 P2

**Charge transfer and electrical conductance at the F<sub>16</sub>CoPc-Rubrene interface** — ●YULIA KRUPSKAYA<sup>1</sup>, SUSI LINDNER<sup>2</sup>, BENJAMIN MAHNS<sup>2</sup>, MARTIN KNUFFER<sup>2</sup>, and ALBERTO MORPURGO<sup>1</sup> — <sup>1</sup>University of Geneva, CH-1211 Geneva, Switzerland — <sup>2</sup>IFW Dresden, D-01171 Dresden, Germany

Here we present an electronic transport study of the F<sub>16</sub>CoPc-Rubrene interface. Originally both materials Rubrene (5,6,11,12-tetraphenyltetracene) and F<sub>16</sub>CoPc (cobalt(II) 1,2,3,4,8,9,10,11,15,16,17,18,22,23,24,25-hexadecafluoro-29H,31H-phthalocyanine) are large-gap undoped semiconductors and eventually insulators. The interfaces were prepared by evaporating the F<sub>16</sub>CoPc film on top of the Rubrene single crystal. Four-probe electronic transport measurements were performed at applied voltages up to 40 V and temperatures between 30 K and 300 K. The measurements reveal the resistivity per square of the interface of approximately 300 kΩ at room temperature, which is in general rather low in comparison to previously studied organic interfaces [1] and lowest after outstanding TTF-TCNQ interface [2]. The obtained temperature dependence indicates slight metallic behavior of the resistivity which decreases by 20% while cooling from 300 K to 100 K. Below 100 K the resistivity increases reaching 370 kΩ at 30 K. The observed electrical conductance originates from a rather big charge transfer between the two materials that takes place at their interface.

[1] I. Gutiérrez Lezama et al. *Nature Mat.* **11**, 588-794 (2012)[2] H. Alves et al. *Nature Mat.* **7**, 574-580 (2008)

HL 29.4 Mon 17:00 P2

**Correlation between structural and electrical properties**

**of co-evaporated doped organic thin films** — ●DANIELA DONHAUSER<sup>1,2</sup>, ANNE K. KAST<sup>1,2,3</sup>, MARTIN PFANNMÖLLER<sup>3</sup>, RASMUS R. SCHRÖDER<sup>3</sup>, MARKUS GÖLZ<sup>2,4</sup>, ALEXANDER MÜLLER-BRAND<sup>2,4</sup>, MICHAEL KRÖGER<sup>1,2</sup>, ROBERT LOVRINCIC<sup>1,2</sup>, and WOLFGANG KOWALSKY<sup>1,2</sup> — <sup>1</sup>Institut für Hochfrequenztechnik, Technische Universität Braunschweig — <sup>2</sup>InnovationLab GmbH, Heidelberg — <sup>3</sup>CellNetworks, Universität Heidelberg — <sup>4</sup>Kirchhoff-Institut für Physik, Universität Heidelberg

Nowadays, organic devices like OLEDs or OPV are often realized by employing electrochemically doped transport layers to enhance device performance and stability. However, a comprehensive and detailed understanding of the doping process in organic semiconductors is still missing. In this work the organic semiconductor CBP (4'-Bis(N-carbazolyl)-1,1'-biphenyl) doped with the transition metal oxide MoO<sub>3</sub> was used as a model system and structural as well as electrical measurements were conducted to gain a better understanding of the fundamentals of electrochemical doping. Electron tomography revealed that the dopant forms a filamentous structure with nanofilaments preferentially orientated perpendicular to the substrate. To investigate whether the structural anisotropy influences the electrical properties, IV- and cryo-IV characteristics of device structures with current flowing along and perpendicular to the substrate were measured. Based on these results a model for charge transport in CBP:MoO<sub>3</sub> composites will be presented.

HL 29.5 Mon 17:00 P2

**External Quantum Efficiency of novel PTCDA derivatives** — ●ROBIN DÖRING, NILS ROSEMAN, EDUARD BAAL, JÖRG SUNDERMEYER, and SANGAM CHATTERJEE — Philipps-Universität Marburg, Marburg, Germany

3,4,9,10 perylene tetracarboxylic dianhydride (PTCDA) is a well-studied and widely commercially available dye and n-channel organic semiconductor. A major disadvantage of PTCDA is its low solubility in organic solvents. We studied the optical properties of novel PTCDA derivatives featuring high solubility in organic solvents such as CH<sub>2</sub>Cl<sub>2</sub> and C<sub>7</sub>H<sub>8</sub>. A “fluorophore-spacer-receptor” configuration based photoinduced electron transfer (PET) is assumed. If the PET between the receptor (amine group) and fluorophore (perylene core) within the molecule is suppressed, the PL intensity is expected to increase significantly. Hence, protonation of the amine functional group should disallow PET. This, in turn, makes applications like non-contact sensing of pH possible. The experimental setup features an integrating sphere which allows measurements of the absolute photoluminescence. These measurements then yield the external quantum efficiency  $\eta$  of the samples. In combination with time resolved photoluminescence measurements this enables us to determine the true radiative ( $\tau_r$ ) and non-radiative ( $\tau_{nr}$ ) decay times of the excited states. Our results confirm a strong dependency of the quantum efficiency on the fact whether or not PET is enabled.

HL 29.6 Mon 17:00 P2

**Vapour-phase absorption of aromatic molecules** — ●NIKLAS KRAUS, SANGAM CHATTERJEE, and ANDRE RINN — Philipps Universität, Marburg, Deutschland

Organic semiconductors are promising materials for future electronic applications. To understand the complex optical properties of organic molecular crystals, one needs to obtain the single molecular response first. Hence, we investigated the optical properties of different molecules in solution and in the vapour phase. Therefore, we construct an evaporation cell where the optical transmission through a 5cm long gas volume is measured in the 1-6eV energy range. Using this apparatus, we analyzed the vapour-phase absorption and photoluminescence of the aromatic molecules perylene, pentacene, and perfluoropentacene at temperatures up to 590K.

HL 29.7 Mon 17:00 P2

**Time-resolved spectroscopy of interfacial states in P3HT-PCBM blends** — ●MARINA GERHARD<sup>1</sup>, ANDREAS ARNDT<sup>2</sup>, AINA QUINTILLA<sup>2</sup>, ULRICH LEMMER<sup>2</sup>, and MARTIN KOCH<sup>1</sup> — <sup>1</sup>Faculty of Physics and Material Sciences Center, Philipps-Universität Marburg, Renthof 5, D-35032 Marburg, Germany — <sup>2</sup>Light Technology Insti-

tute, Universität Karlsruhe, Kaiserstrasse 12, D-76131 Karlsruhe, Germany

We have studied the time-resolved photoluminescence (PL) of organic donor-acceptor bulk heterojunctions based on the polymer poly(3-hexylthiophene) (P3HT) blended with varying concentrations of the fullerene derivative [6,6]-phenyl-C<sub>61</sub> butyric acid methyl ester (PCBM). Those blends represent a well-known material for potential solar cell applications. By comparing the emission of the blends to that obtained for neat polymer and fullerene films, most of the contributions could be allocated to radiative recombination inside the polymer domains. In addition, we identified a weak but slower decaying signature in the IR-regime that was only present in the blends. We thus attributed this feature to carriers recombining at the interfaces between donor and acceptor. Currently, the role of such interfacial "charge transfer" states in the process of free carrier generation is intensely being discussed. We discovered that the dynamics of the interfacial state was almost independent of temperature and excitation density. These findings indicate that the electrons and holes which cause the interfacial PL-emission are trapped inside isolated states where further diffusion is unlikely.

HL 29.8 Mon 17:00 P2

**Effect of the donor-acceptor morphology on the recombination behavior in polymer-fullerene bulk heterojunction solar cells** — ●SEBASTIAN WILKEN, MICHAEL KOOPMEINERS, JÜRGEN PARISI, and HOLGER BORCHERT — University of Oldenburg, Department of Physics, Energy and Semiconductor Research Laboratory, Carl-von-Ossietzky-Str. 9-11, 26129 Oldenburg, Germany

In this study, we discuss the impact of the donor-acceptor morphology on the recombination behavior in polymer-fullerene bulk heterojunction solar cells based on poly(3-hexylthiophene) (P3HT) and [6,6]-phenyl-C<sub>61</sub>-butyric acid methyl ester (PCBM). Different amounts of nanoscale phase separation have been obtained by using 1,2-dichlorobenzene and chlorobenzene as spin-casting solvents, respectively, as is visualized by atomic force microscopy (AFM) and transmission electron microscopy (TEM). Both the current-voltage characteristics and the white-light bias external quantum efficiency with respect to varying illumination intensities suggest that the dominant recombination mechanism, i.e., monomolecular and bimolecular recombination, is strongly correlated with the respective nanomorphology of the P3HT:PCBM blend. To further evaluate the influence of charge carrier trapping, transient photocurrent measurements have been performed and analyzed in terms of emission time constants  $\tau_{e,i}$ , assuming that each  $\tau_{e,i}$  is characteristic for one distinct trap level  $i$ . In addition, the temperature dependence of  $\tau_{e,i}$  was investigated to gain information about the thermal activation energy  $\Delta E_i$  of the corresponding emission process.

HL 29.9 Mon 17:00 P2

**Measurement of the harvesting factor under realistic conditions for organic solar cells** — ●TRINATH REDDY PINNAPA, BENJAMIN OESSEN, JOHANNES WIDMER, RICO MEERHEIM, CHRISTIAN KOERNER, and KARL LEO — Institut für Angewandte Photophysik, Technische Universität Dresden, 01062 Dresden, Germany

The efficiency of organic solar cells is usually measured under standard reporting conditions (SRC). The efficiency measurements carried out under SRC disregard the influence of varying parameters such as temperature, illumination intensity of sun, angle of incidence, and spectrum of the sunlight, although these varying parameters are very important for the overall energy harvesting. Thus, measurement con-

ditions which are on par with real time data should be used to obtain precise efficiency values. To measure the harvesting factor, the realistic efficiency of cells for a period of one year, the accumulated solar irradiation energy and the efficiency at SRC are to be compared. This study is aimed at measuring the harvesting factor by investigating the performance of a pin structured organic solar cell under realistic conditions, then, the harvesting factor of organics are compared with an equivalent silicon cell. To understand the performance of organic solar cells, efficiency measurements of DCV5T-Me and F4-ZnPc donor cells with respect to changing illumination intensity and temperature are performed and then their respective harvesting factors are estimated.

HL 29.10 Mon 17:00 P2

**Charge Carrier Mobility of a Quinquethiophene Derivative Deposited on Heated Substrates** — ●JULIA OELKER, JOHANNES WIDMER, CHRISTIAN KOERNER, and KARL LEO — Institut für Angewandte Photophysik, Technische Universität Dresden, 01062 Dresden

The absorber material DCV5T-Me has been successfully used in small molecule organic solar cells. Fundamental properties of this material are of special interest to learn more about the mechanisms that lead to highly efficient solar cells. For organic solar cells with DCV5T-Me and C<sub>60</sub> as donor-acceptor blend layer, the power conversion efficiency is strongly dependent on the substrate temperature during the deposition of the absorber layer. This parameter is known to change the morphology and the degree of disorder in the blend layer which affects the transport properties.

In this contribution, the carrier mobility as one of the key parameters to achieve highly efficient solar cells is investigated. Electric potential mapping by thickness variation (POEM) is applied to pip-hole-only-devices with DCV5T-Me:C<sub>60</sub> as intrinsic layer to measure the hole mobility in the blend. The substrate temperature during the deposition of the intrinsic layer is varied to get particular insight into the influence of substrate heating.

HL 29.11 Mon 17:00 P2

**White top-emitting OLEDs with nanoparticle scattering layers** — ●TIM SCHAEFER<sup>1</sup>, TOBIAS SCHWAB<sup>1</sup>, SIMONE HOFMANN<sup>1</sup>, KARL LEO<sup>1</sup>, and MALTE C. GATHER<sup>1,2</sup> — <sup>1</sup>Institut für Angewandte Photophysik, Technische Universität Dresden, George-Bähr-Straße 1, 01069 Dresden, Germany — <sup>2</sup>School of Physics & Astronomy, University of St Andrews, North Haugh, St Andrews, KY16 9SS, Scotland, UK

We present white top-emitting organic light-emitting diodes (OLEDs) with a random nanoparticle scattering layer as outcoupling structure on top of the OLED stack. The nanocomposite scattering layer consists of titanium dioxide particles embedded into a transparent photoresist matrix. The scattering layer can be deposited directly on top of the small molecule OLED stack by solution-based dip- or spin-coating, without affecting the electrical performance of the device. The optical properties of the scattering layer are widely tunable by adjusting particle size and concentration. In first proof-of-principle experiments, the spectral radiant intensity for the blue spectral range of a white top-emitting OLED is nearly doubled and the overall external quantum efficiency at 1000 cd/m<sup>2</sup> is increased by 18% in comparison to a reference device with standard organic capping layer for outcoupling. Furthermore, light scattering by the randomly distributed nanoparticles strongly improves the color stability with viewing angle. The proposed process is cost-efficient, scalable and compatible with different types of substrates and OLED architecture. It is expected that it can be readily adopted for large area OLEDs and is thus promising for lighting applications.