

CPP 9: Organic semiconductors I (joint session HL/CPP)

Time: Monday 9:30–12:30

Location: POT 112

CPP 9.1 Mon 9:30 POT 112

Towards a plastic brain — ●MATTEO CUCCHI, HANS KLEEMANN, HSIN TSENG, ALEXANDER LEE, and KARL LEO — Dresden Integrated Center for Applied Physics and Photonic Materials (IAPP), Technische Universität Dresden, 01062 Dresden, Germany

Interconnectivity, fault tolerance and dynamic evolution of the circuitry have been long sought-after objectives of bio-inspired electronics and engineering. The massive parallelization of the neuronal circuitry grants the human brain superior efficiency and capabilities in cognitive learning and pattern recognition compared to digital, transistor-based machines. Here, we developed a technique to grow conductive networks and artificial synapses based on organic semiconductors. Their dendritic growth, stimulated by an AC signal, resembles the formation of new synapses in the nervous system (synaptogenesis). Moreover, their functions in saline solution emulate numerous brain features over multiple orders of magnitude in the time domain, such as learning, forgetting, time-dependent-spiking plasticity, and Pavlovian conditioning. We employ the artificial synapses to show a new device-concept capable of recognizing numerical patterns and explore possible pathways towards biocompatibility, neuroprosthetics and brain-inspired computing.

CPP 9.2 Mon 9:45 POT 112

Dibenzopentacene single crystals: growth, characterization and exciton dispersion — ●LUKAS GRAF, FUPIN LIU, BIPASHA DEBNATH, and MARTIN KNUPFER — IFW Dresden

Pentacene and its hydrocarbon relatives continue to attract researchers world-wide, as they promise applications due to their relatively high charge carrier mobilities and their intriguing photophysical behavior including singlet fission processes. We have studied a relatively unexplored member of this family, Dibenzopentacene (DBP).

Single crystals of DBP have been grown using the vapor phase transport method, which to the best of our knowledge are the first DBP single crystals reported so far. We have determined the DBP crystal structure using X-ray diffraction and complementary electron diffraction experiments. The electronic excitations of DBP have been investigated using electron energy-loss spectroscopy (EELS). We present results on the strongly anisotropic electronic excitations across the band gap, and in addition their momentum behavior, i.e. their dispersion. An analysis of this exciton dispersion using a simple model from the literature allowed to gain first information on the charge carrier hopping parameters in DBP.

This is supported by the DFG (KN393/25, KN293/26).

CPP 9.3 Mon 10:00 POT 112

Self-alignment OTFT structures — ●JÖRN VAHLAND, HANS KLEEMANN, and KARL LEO — TU Dresden, IAP

Organic thin film transistor (OTFT) parameters have significantly improved in regard to static transistor performance, e.g. contact resistance and mobility. The dynamic performance, though, is mainly governed by the device capacitance. A large device capacitance restricts the switching frequency and might ultimately lead to inefficient circuits. Historically, this limitation has been overcome in inorganic device architectures by employing a so-called self-aligned gate structure, which allows structuring of source- and drain-electrode with virtually no overlap to the gate, yielding low overlap capacitance.

The transfer to OTFTs is not trivial, since subtractive process steps such as etching need to be selective to various materials within a typical device stack i.e. the semiconductor and the gate dielectrics. First implementations of self-alignments for OTFTs employ process steps which are unfortunately not scalable (such as through-plane exposure or lift-off), effectively prohibiting such devices in actual circuits.

We propose a coplanar OTFT in top gate configuration where selective etching processes and additional passivation layers are used in order to form a truly self-aligned organic transistor. We discuss the scaling of the overlap capacitance and highlight the potential of such self-aligned devices for high-frequency operation. Furthermore, we discuss the influence of etching process on the channel properties, and describe how charge carrier mobility and on/off ratio of the transistor can be preserved.

CPP 9.4 Mon 10:15 POT 112

Exciton dispersion in rubrene single crystals — ●TOBIAS LETTMANN and MICHAEL ROHLFING — Institut für Festkörpertheorie, Westfälische Wilhelms-Universität Münster, 48149 Münster

Rubrene single crystals are proposed as components of various organic (opto-)electronic devices. Their electronic (quasiparticle) bandstructure shows an anisotropic behaviour with a relatively strong dispersion of several 100 meV along the Γ -Y direction, whereas the bands are almost flat along the Γ -X direction [1].

Corresponding to the electronic bands, excitons can also exhibit dispersion of their excitation energies as a function of their total momentum (related to their centre-of-mass motion). This dispersion and its anisotropy might be relevant for excitonic hopping transport. In this talk we use the GW/BSE approach of many-body perturbation theory (MBPT) to calculate the excitonic bandstructure of rubrene single crystals in order to investigate if the anisotropy is still present or mitigated by excitonic effects.

[1] S. Yanagisawa et al., Phys. Rev. B **88**, 115438 (2013)

CPP 9.5 Mon 10:30 POT 112

Conductivity studies at the crystal-film charge transfer interfaces — ●BIPASHA DEBNATH¹, MICHAEL BRETSCHNIEDER¹, SHUJEN WANG², MARTIN KNUPFER¹, YULIA KRUPSKAYA¹, and BERND BÜCHNER¹ — ¹Leibniz Institute for Solid State and Material Research Dresden, Dresden, Germany — ²Dresden Integrated Center for Applied Physics and Photonic Materials (IAP), Dresden, Germany

The charge transfer occurs at the interface of two organic semiconductor materials known as donor and acceptors. The alignment of the electron affinity of one material with the ionization potential of other material leads to enhance electrical conductivity at their interface by exchanging charge carriers between them. Herein, we try to explore the underlying mechanism of charge transfer with a systematic study by preparing interfaces between Rubrene and F6-TCNNQ, as donor and acceptor semiconductor materials, respectively. By thermally evaporating F6-TCNNQ film on the surface of highly-ordered Rubrene single-crystals, the charge transfer interfaces are fabricated. The electrical characterization of these interfaces reveals enhanced conductivity. Furthermore, temperature-dependent measurements demonstrate thermally activated conductivity. The fundamental properties such as charge carrier density and mobility are investigated through additional Hall-effect measurements. This work is financially supported by DFG (KR 4364/4-1)

30 min. break.

CPP 9.6 Mon 11:15 POT 112

Investigation of biodegradable devices — ●KEVIN KRECHAN¹, DANIEL FIRZLAFF², HANS KLEEMANN¹, KARL LEO¹, and KATHRIN HARRE² — ¹Technische Universität Dresden, Deutschland — ²HTW Dresden, Deutschland

In an aging society there is an increasing need for innovative health care and monitoring solutions. Sensor solutions for health monitoring are vital for improved treatment quality and the reduction of costs.

In particular, there is a strong need to continuous postoperative in-vivo surveillance systems. However, such sensor systems are required to be bio-compatible and ideally biodegradable in order to undesired postoperative complications.

In this contribution we discuss sensor concepts for e.g. in-vivo pressure or ion sensing based on bio-compatible organic semiconductor materials. Most importantly, we make use of biodegradable collagen-based substrate materials and discuss their decomposition behavior as well as the associated challenges during the fabrication of the sensor system. Overall, we believe that our approaches will enable the development of fully degradable sensor tags in future.

CPP 9.7 Mon 11:30 POT 112

High-gap donor-acceptor blends exhibiting both efficient emission and charge-generating properties — ●XIANGKUN JIA¹, SASCHA ULLBRICH¹, JOHANNES BENDUHN¹, VASILEIOS C. NIKOLIS¹, JINHAN WU¹, YUAN LIU¹, AXEL FISCHER¹, DONATO SPOLTORE¹, SEBASTIAN REINEKE¹, and KOEN VANDEWAL^{1,2} — ¹Technische Universität Dresden, Dresden, Germany — ²Hasselt University, Hasselt, Belgium

We demonstrate that the intermolecular charge-transfer (CT) states at the donor-acceptor interfaces are crucial for the operation of organic optoelectronics. Such D-A based OLEDs show electroluminescence external quantum yields (EQE_{EL}) of up to 16%, while in contrast, D-A systems for state-of-the-art OSCs typically only feature $EQE_{EL} \approx 0.01 - 0.0001\%$. The dominating non-radiative recombination in the latter is the main reason for their large voltage losses and low power-conversion efficiencies. Here, we adopt high-gap materials to increase the energy of CT states. This blend shows a fill factor of 70% and an internal quantum efficiency of 83% upon solar illumination, comparable to well performing OSCs. Meanwhile, its non-radiative voltage loss is reduced to 0.10V and EQE_{EL} reaches 1.5%. This work therefore shows that efficient photogeneration of free carriers and a high electroluminescence quantum yield do not necessarily need to be mutually exclusive in organic semiconductors.

CPP 9.8 Mon 11:45 POT 112

Quantifying the Damage Induced by Monoatomic Ion Beam Etching during X-ray Photoemission Spectroscopy Depth Profiling of Conjugated Polymers — •YVONNE JASMIN HOFSTETTER^{1,2} and YANA VAYNZOF^{1,2} — ¹Integrated Center for Applied Physics and Photonics, Dresden, Germany — ²Center for Advancing Electronics Dresden, Dresden, Germany

X-ray photoemission spectroscopy (XPS) depth profiling using monoatomic Ar⁺ ion etching sources is commonly used to probe the vertical compositional profiles of polymer-based organic photovoltaic devices, focusing on compositional variations across interfaces and vertical phase separation within bulk-heterojunction active layers. The damage induced by the monoatomic etching is generally considered to be very shallow and is assumed to not significantly alter the XPS signal acquired at each step of the depth profile. Herein, we quantify the damage depth for a variety of conjugated polymers for monoatomic Ar⁺ ion beams of variable energy from 0.5 to 4 keV. Our results indicate that even when etching with the lowest available ion beam energy for as little as 3 s, the damage inside the polymer bulk material significantly exceeds the XPS probing depth (approx. 10 nm). We find that the damaged material exhibits a distorted composition which strongly changes the resulting XPS depth profile. In contrast, we find that Ar gas cluster ion beam etching is significantly less damaging and preserves compositional information demonstrating its superior suitability for XPS depth profiling of organic materials.

CPP 9.9 Mon 12:00 POT 112

Momentum dependent investigation of electronic excitations in β -metal-phthalocyanines — •LOUIS PHILIP DOCTOR and MARTIN KNUPFER — Leibniz Institut für Festkörper- und Werkstofforschung, Helmholtz Str. 20, 01069 Dresden

This work presents an investigation of the electronic excitations of β -metal-phthalocyanines. We prepared 120 nm thick thin films by physical vapour deposition, which afterwards underwent an annealing process. Infrared spectroscopy revealed that the annealed films were in the β -phase. The films were further characterised in the visible regime. The prominent feature in this regime is the Q-band, which consists of four peaks arising from the HOMO to LUMO transition split by solid-state effects. Furthermore, the dispersion of the Q-band was measured using electron energy loss spectroscopy. We found a complex momentum dependent behaviour. Most interesting is the negative dispersion of the lowest-lying excitation, which also has a tremendous effect on the performance of optoelectronic devices. This redshift partially correlates with the intermolecular distance and the charge carrier transfer integrals. The latter were determined by a theoretical model, which describes the interaction of Frenkel and charge transfer excitons in metal-phthalocyanines. Our results clearly indicate a prominent influence of charge transfer excitons to the lowest electronic excitations.

CPP 9.10 Mon 12:15 POT 112

Comparing Charge Generation and Extraction in Y6 and LM11 Devices — •SEYED MEHRDAD HOSSEINI¹, YINGPING ZOU², and SAFA SHOAEI¹ — ¹Institute of Physics and Astronomy, University of Potsdam, Karl-Liebknecht-Straße 24-25, Potsdam-Golm D-14476, Germany — ²College of Chemistry and Chemical Engineering, Central South University, Changsha 410083, P.R. China

In the last few years, non-fullerene acceptors (NFA) have dominated organic solar cells. Whilst in thin films, exceptional fill-factor (FF) can be obtained, in thicker junctions however, FF is usually affected. Reduced FF is the manifestation of voltage-dependent charge photogeneration and/or inefficient free charge extraction³. In this study, we compare two NFAs, named Y6 and LM11, when blended with PM6. Our results show that although PM6:LM11 device has a higher open-circuit voltage (Voc) than PM6:Y6, lower FF limits the efficiency. We employed time-delayed collection field (TDCCF) measurements to reveal the reason behind the poorer FF in PM6:LM11 device by studying charge generation and recombination in both systems.