

CPP 66: Organic Electronics and Photovoltaics V - Semiconducting Properties and Devices

Time: Friday 9:45–12:00

Location: H18

Invited Talk

CPP 66.1 Fri 9:45 H18

Coupled Organic-Inorganic Nanostructures for Optical Switches — ●MARCUS SCHEELE — Universität Tübingen, Tübingen, Deutschland

Optical switches are key components for data processing on the basis of silicon photonics, in which they perform the crucial conversion of a photonic information from an optical fiber into an electric information for a silicon-based processing unit. The status of the switch is controlled by an external light source, emitting at a wavelength suitable to be absorbed by the conductive channel to photo-induce additional charge carriers and modulate the current output of the switch in close analogy to a classic transistor. This presentation details how hybrid superlattices of semiconducting nanocrystals and organic pi-systems with long-range order are applied as active layers in functional optical switches. The particular novelty for optical switching is an activated absorption mechanism, in which stimulation with one optical signal sensitizes the material towards an amplified recognition of a second optical stimulus. Several examples with different material combinations are presented and the importance of exciton formation as well as charge transfer across the inorganic-organic interface is discussed.

CPP 66.2 Fri 10:15 H18

Comparative Study of Semiconductivity in Metal-Organic Frameworks — ●CHRISTOPH MUSCHIELOK and HARALD OBERHOFER — Technische Universität München, Germany

Metal-Organic Frameworks (MOFs) are artificial, self-assembled networks of metal centers connected by organic linker molecules. Often they exhibit large pores, into which small molecules may be absorbed. While many potential applications for semiconductive MOFs in e. g. sensors or electrocatalysis are imaginable, only very few examples of non-insulating MOFs have been found to date. Theoretical studies indeed suggest, that pure MOF bulk crystals have insufficient intrinsic charge carrier density to show finite conductivity. It is generally suggested that this drawback is overcome by defects in the crystal structure for the few known conductive MOFs. However, the intrinsic carrier density is only one factor governing electrical conductivity, with the other major contribution being the charge carrier's mobility. This, we study in bulk MOF crystals using a band transport model and thereby establish an upper limit estimate for the mobility. We outline the factors limiting the mobility exemplarily for $M(\text{ta})_2$ MOFs where M stands for different transition metal centers. These share the same crystal structures but vary strongly in their carrier mobilities, hinting at first design criteria for future semiconducting MOFs.

CPP 66.3 Fri 10:30 H18

Electrostatically designed metal-organic frameworks based p-i-n junctions — ●GIULIA NASCIMBENI¹, CHRISTOF WÖLL², and EGBERT ZOJER¹ — ¹Institute of Solid State Physics, Graz University of Technology, Austria — ²Institute of Functional Interfaces, Karlsruhe Institute of Technology, Germany

Metal-organic frameworks (MOFs) are highly crystalline porous materials consisting of metal ions or clusters coordinated mostly by oxygen or nitrogen atoms and connected by organic linkers. The nearly unrestricted choice of linkers and metal nodes leads to a variety of different materials, whose properties can be tuned simply by changing their chemistry. Recently new possible applications of MOFs in electronics and photonics [1, 2] have been suggested based on engineering their electronic band structures [3, 4]. In the spirit of this band structure engineering, in this contribution we present an innovative approach based on the layer-by-layer assembly of surface-anchored MOFs (SUR-MOFs) [5], which allows to integrate electric fields into molecular thin films, thus mimicking the electronic structure of p-i-n junction present in solar cells. We use band structure calculations to show how this can be achieved via the controlled manipulation of the potential energy landscape in MOFs through the regular assembly of dipolar molecules. [1] Sun et al., *Angew. Chem. Int. Ed.*, 2016, 55, 3566. [2] Neumann et al., *ACS Nano*, 2016, 10 (7), 7085. [3] Pham et al., *J. Phys. Chem. C*, 2014, 118, 4567. [4] Park et al., *J. Am. Chem. Soc.*, 2015, 137, 1774. [5] Liu et al., *Chem. Soc. Rev.*, 2017, 46, 5730.

CPP 66.4 Fri 10:45 H18

High-Speed and High-Current Vertical Organic Transistors

— ●FELIX DOLLINGER¹, HENNING ISEKE¹, KYUNG-GEUN LIM², AXEL FISCHER¹, PETR FORMÁNEK³, HANS KLEEMANN¹, and KARL LEO¹ — ¹Dresden Integrated Center for Applied Physics and Photonic Materials (IAPP), Dresden, Germany — ²Korea Research Institution for Standard Science (KRISS), Daejeon, Korea — ³Leibniz-Institut für Polymerforschung Dresden e. V. (IPF), Dresden, Germany

Organic thin-film transistors enable light-weight, inexpensive and flexible electronic applications. The Organic Permeable Base Transistor (OPBT) is a vertical transistor design that allows for very high current densities, and hence the fastest operating speed of all organic transistors with transit frequency reaching 40 MHz [Kheradmand-Boroujeni et al., 2018].

We will explain the operating mechanism for OPBTs and give insights into optimizations of the base oxide layers and investigations on the stability of the device.

The modulation of current in an OPBT is achieved by a metallic base electrode that is located in the center of the vertical stack. In the on-state, this thin aluminum electrode is permeable for electrons. It is passivated by a native oxide layer to prevent leakage current. We have been able to significantly improve the oxide layer and reduce parasitic leakage currents. Electrical stress measurements on OPBTs help to understand the suitability of these transistors for long-time real-life applications. Illustrative TEM images will be shown to clarify the device's structure and function.

15 min. break

CPP 66.5 Fri 11:15 H18

Determination of the Equilibrium Charge Distribution by Impedance Spectroscopy of P-Doped Organic Semiconductors — ●VICTORIA WISSDORF^{1,2}, MARKUS FRERICKS^{2,3}, CHRISTOP PFLUMM¹, WOLFRAM JAEGERMANN^{2,3}, and ERIC MANKEL^{2,3} — ¹Merck KGaA, Darmstadt — ²Technische Universität Darmstadt, Darmstadt — ³InnovationLab, Heidelberg

Impedance spectroscopy is a powerful tool to investigate the intrinsic properties of organic semiconductors. One possibility is, to link capacitance voltage measurements at zero bias voltage to the interface energy level alignment of doped hetero-junctions [1]. This description is based on the assumption that the capacitance is solely determined by the metal-semiconductor contact [1],[2]. With this Mott-Schottky approach any additional contributions from interfaces, injection barriers or space charge regions inside the device are neglected. Furthermore, the measured p-doping dependence cannot be explained within the framework of this picture. Within this work we present a theoretical description that couples a continuous equivalent circuit model with the solution of the drift-diffusion equation for equilibrium. This approach yields a direct link between the material parameters and interfaces to the results of impedance spectroscopy measurements. We furthermore compare the theoretical model to measurements of p-doped single layer devices and can explain how the material and device parameters change with varied p-doping concentration.

[1] Lee et al., *Adv. Funct. Mater.* 22, 855-860 (2012)[2] R.L. Anderson, *Solid-State Electronics* 5, 341 (1962)

CPP 66.6 Fri 11:30 H18

Remote doping at organic heterointerface — ●ILIA LASHKOV, KEVIN KRECHAN, KATRIN ORTSTEIN, HANS KLEEMANN, and KARL LEO — Dresden Integrated Center for Applied Physics and Photonic Materials, Nöthnitzer Str. 61, 01187 Dresden, Germany

Organic and molecular electronics is a novel field of microelectronics that provides the possibility of producing electronic devices onto flexible substrates and at a low process temperature. However, organic thin-film transistors suffer from a low charge carrier mobility which lowers their potential for applications. Both problems have been successfully solved in inorganic electronics by the concept of remote doping. In our work, we investigate remote doping at a junction between two organic semiconductors with a different energy gap. The offset of valence states leads to charge carrier transfer from the wide gap semiconductor. Charge transfer at the interface between the organic semiconductors is investigated by in-situ conductivity measurements during film deposition. We directly monitor the charge transfer by means of the film conductivity which experiences a sudden increase

upon the deposition of the first molecular monolayer of the narrow gap material onto the wide gap semiconductor. Additionally, we investigate the transfer by ultra-violet photo-electron spectroscopy (UPS) and present first steps towards the realization of a remotely doped organic thin-film transistor.

CPP 66.7 Fri 11:45 H18

Electronic interactions in precursor solution of F4TCNQ doped P3HT polymers — •VANDANA TIWARI¹, HONG-GUANG DUAN^{1,2,3}, AJAY JHA¹, and R. J. DWAYNE MILLER^{1,3,4} — ¹MPSD, Hamburg, Germany — ²I. Institut für Theoretische Physik, UH, Germany — ³CUI, Hamburg, Germany — ⁴University of Toronto, Canada

Unraveling the favorable electronic interaction between dopant and polymer is the key to the success of molecular doping in organic semiconductors. Here we use two-dimensional electronic spectroscopy to explore the electronic dynamics of F4TCNQ-doped conducting polymer, P3HT in precursor solution mixtures. The electronic interactions among the ion-pairs formed in precursor solutions are captured in the form of off-diagonal peaks connecting the electronic states of polymer and dopant radicals. We have theoretically modeled our system to simulate the experimental data and achieve a quantitative picture of the Coulombic interaction between cation and anion radicals in solution. Our study reveals the heterogeneous electronic interactions that possibly serve as a seed for the structures in the spin-casted films.