

CPP 21 SYMPOSIUM Functional Organic Thin Films II

Time: Thursday 14:00–17:00

Room: ZEU Lich

Invited Talk

CPP 21.1 Thu 14:00 ZEU Lich

Recent Advances in Charge Transport in Organic Field Effect Transistors — ●ANANTH DODABALAPUR, LIANG WANG, LAWRENCE DUNN, and DEBARSHI BASU — Microelectronics Research Center, The University of Texas at Austin

This presentation will focus on two recent advances in studying charge transport in organic thin-film field-effect transistors with pentacene active semiconductor layers. With the help of electron-beam lithography we have fabricated transistors with short channel lengths. This, combined with careful surface treatments to improve hole injection, has enabled the fabrication of devices which are not seriously injection limited with channel lengths in the range between 250 nm and 5 microns. The electric-field dependence of carrier mobility has been measured in the range $10^4 - 6 \times 10^5$ V/cm and between 60–300 K by analyzing the transistor DC characteristics. The field dependence of the mobility more closely follows a Frenkel-type dependence than a polaronic dependence.

A new method to measure charge carrier mobility in organic field-effect has been developed in which the drift mobility of injected carriers (generated with a step voltage pulse) is measured. This permits the measurement of the velocity and mobility of the fastest carriers. The mobility evaluated in this manner is generally found to be higher than that obtained by the conventional technique based on an analysis of DC currents in a transistor. Extensions of our new method to measure the distribution of velocities or mobilities will also be described.

CPP 21.2 Thu 14:30 ZEU Lich

Ambipolar charge transport in the blend system $C_{60}/CuPc$ — ●ANDREAS OPITZ, MARKUS BRONNER, and WOLFGANG BRÜTTING — Experimental Physics IV, University of Augsburg, 86135 Augsburg, Germany

In recent years, large progress has been made in the realization of electronic circuits based on organic field-effect transistors (OFETs). However, these circuits as being built-up of unipolar (mostly p-type) OFETs only, have a number of drawbacks. To overcome them, recently, ambipolar OFETs have been suggested as a first step towards complementary organic circuits.

In this work we are analysing the ambipolar charge transport in blend systems of small organic molecules. These mixed layers are prepared by co-evaporation of n-conducting fullerene (C_{60}) and p-conducting copper-phthalocyanine (CuPc) on pre-structured TFT-substrates. It was found that the electrical characteristics (e.g. mobilities of holes and electrons) depend strongly on the composition of the blend and on the preparation conditions like substrate treatment and substrate temperature during the evaporation. The preparation parameters act on the film morphology analysed by scanning force microscopy and on the electrical properties of the films. We further demonstrate ambipolar and complementary inverters with these materials as a basic constituent of more complex organic electronic circuits. Comparison with simulations based on an analytical model [1] shows that asymmetric mobilities and threshold voltages have to be avoided to reduce shifts in the inverter transfer curves.

[1] R. Schmechel et al., *J. Appl. Phys.* **98** (2005) 084511.

CPP 21.3 Thu 14:45 ZEU Lich

Inversion layer formation in organic field-effect devices — ●THOMAS LINDNER¹, GERNOT PAASCH¹, and SUSANNE SCHEINERT² — ¹IFW Dresden — ²TU Ilmenau

One of the challenges for polymer electronics is the realization of complementary circuits (CMOS) requiring both n- and p- channel transistors on the chip. Depositing both an electron- conducting and a hole- conducting organic material is technologically cumbersome. Only recently both n- and p- channels have been achieved in the same material. The problems to create both accumulation and inversion layers in the same material have been attributed to the difficulty to engineer the metallic source/drain contacts for efficient injection of both electron and holes, and also to the fact that the electron and hole mobilities differ (often) by several orders of magnitude. Although the formation of inversion layers has been well understood in microelectronics, it has to be studied anew, since the mobility and the intrinsic density are many orders of magnitude lower. An analytical estimate of the relation between three relevant characteristic times reveals the peculiarities occurring in the organics. Detailed insight is obtained from a numerical simulation study for MOS

capacitors and transistors of different design. Both the design and the source/drain contact properties influence the formation of the inversion layer and the occurrence of hysteresis effects significantly.

CPP 21.4 Thu 15:00 ZEU Lich

Field Effect Transistors and Space Charge Limited Currents on Perylene Single Crystals — ●G. ULBRICHT¹, J. SMET¹, A. TRIPATHI², J. PFLAUM², and K. VON KLITZING¹ — ¹Max Planck Institute for Solid State Research, 70569 Stuttgart — ²Universität Stuttgart, 3. Physikalisches Institut, 70550 Stuttgart

To understand the fundamental charge carrier transport in organic semiconductors, research on single crystals is necessary. Perylene is a well studied organic semiconductor and known to show high mobilities in time of flight experiments at low temperatures. We are studying Perylene single crystals by measuring space charge limited currents (SCLC) and field effect transistors (FETs). In the SCLC sandwich geometry, the crystals show exceptionally low trap densities down to $3 \cdot 10^{12} \text{ cm}^{-3}$ as well as a distinct hysteretic behaviour. The latter helps to interpret the SCLC data significantly, in particular while contacts are not ideal. FETs were fabricated on the surface of Perylene crystals and characterised down to 180 K. Only hole conduction was observed. With as-prepared contacts, we calculated from the FET characteristics a lower limit of the mobility of about $10^{-5} \text{ cm}^2/\text{Vs}$. Clear signs for the existence of significant contact barriers motivated us to explore different electrode materials and fabrication methods. We show that contact barriers can be significantly reduced by annealing source and drain electrodes after deposition. This does not change the threshold field of about $7 \cdot 10^7 \text{ V/m}$, but raises the lower limit of the hole mobility measured by 2-point FET characteristics up to $1.3 \cdot 10^{-3} \text{ cm}^2/\text{Vs}$. Supported by the DFG (Sm64/4, Pf385/2)

CPP 21.5 Thu 15:15 ZEU Lich

Light responsive ambipolar organic field-effect transistor based on amorphous thin films — ●TOBAT P. I SARAGI, IRINA SUSKE, KRISTIAN ONKEN, THOMAS FUHRMANN-LIEKER, and JOSEF SALBECK — Macromolecular Chemistry and Molecular Materials, Department of Science and Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), University of Kassel, Heinrich-Plett-Strasse 40, D 34109 Kassel, Germany.

In this contribution we demonstrate an ambipolar behavior of new spiro-linked compound. We used a field-effect transistor method to show the ambipolar behavior. Both p- and n-type transistor characters can be observed in our experiment. Surprisingly, both transistor characteristics are significantly enhanced as light used as additional control parameter. This effect makes the material is interesting for photosensor or other promising application. The change of drain current vs. drain voltage and drain current vs. gate voltage curves under illumination are presented and discussed as well. Moreover, the optical, thermal, surface morphology and electrochemical properties are presented and discussed as well.

— 15 min. break —

CPP 21.6 Thu 15:45 ZEU Lich

The realization of a defect-free pentacene based organic semiconductor diode: dominance of n-conduction — ●CARSTEN BUSSE¹, LARS RUPPEL¹, ALEXANDER BIRKNER¹, GREGOR WITTE¹, CHRISTOF WÖLL¹, and GERNOT PAASCH² — ¹Lehrstuhl für Physikalische Chemie I, Ruhr-Universität Bochum, 44780 Bochum, Germany — ²Leibnitz Institute for Solid State and Materials Research IFW Dresden, 01171 Dresden, Germany

We have fabricated an organic diode based on a defect-free organic semiconductor with two tunneling electrodes: Pentacene was deposited on an Au(111) surface, which was modified by an insulating self-assembled monolayer (SAM) of alkanethiols. High-resolution STM-data reveal the formation of virtually perfect pentacene islands. Using the tip of an STM and the Au-substrate as a pair of electrodes, we investigated the transport characteristics of this organic diode as a function of thickness of the pentacene layers and of temperature. In addition, the interface dipole at the pentacene / Au+SAM electrode was varied by changing the endgroups of the alkanethiols ($-\text{CH}_3$, $-\text{CF}_3$, $-\text{COOH}$). The results demonstrate that the transport properties are controlled by the

built-up of a region with space-charge limited current just below the tip. The temperature dependence indicates that at room temperature and below the current in this model device is due to band-like transport. In addition, n-type behavior is seen in contrast to the commonly observed p-type behavior for polycrystalline pentacene.

CPP 21.7 Thu 16:00 ZEU Lich

How single conjugated polymer molecules respond to electric fields — ●F. SCHINDLER¹, J. M. LUPTON¹, M. J. WALTER¹, U. SCHERF², and J. FELDMANN¹ — ¹Photonics and Optoelectronics Group, Physics Department, LMU München — ²FB Chemie, Universität Wuppertal

For a microscopic understanding of the operation principle of optoelectronic devices based on organic thin films, such as polymeric light-emitting diodes, it is imperative to investigate the role of external electric fields (EFs) on the single molecule level. Single molecule fluorescence spectroscopy is a versatile tool for studying the intrinsic properties of individual chromophores which constitute the photophysical entity of a conjugated polymer (CP) molecule [1]. Here, we present the first report on how EFs influence the emission of single chromophores at low temperatures. Surprisingly, we observe a linear Stark effect which originates from a permanent polarisation of the π -electron system [2]. This can be thought of in terms of an effective dipole, which is averaged out in the ensemble but nevertheless sensitively controls bulk effects. The effective dipole orientation with respect to the backbone is identified for different CPs and provides direct insight into the intrinsic internal EFs acting on the single chromophore. These fields lead to charge conjugation symmetry breaking of the π -electron system and naturally bear substantial implications for the use of conjugated polymers in functional organic thin films.

[1] F. Schindler et al., PNAS 101, 14695 (2004)

[2] F. Schindler et al., Nature Mat. (in press)

CPP 21.8 Thu 16:15 ZEU Lich

Energy transfer between zinc-phthalocyanine and CdSe/ZnS nanocrystals for sensitizing organic photovoltaics — ●ROBERT KOEPPE, ANITA FUCHSBAUER, SHENGLI LU, and NIYAZI SERDAR SARICIFTCI — Linz Institute for Organic Solar Cells (LIOS), Altenbergerstr. 69, A-4040 Linz, Austria

Zinc-phthalocyanine (ZnPc) and C60 is a material combination for the manufacturing of high efficiency thin film organic solar cells [1]. The low absorption coefficient of both materials around 500nm light wavelength where the solar photon flux has its maximum is a loss mechanism leading to a low quantum efficiency in this range. A Förster energy transfer from a donor absorbing in this wavelength range onto the ZnPc molecule is proposed. As a model system we investigate CdSe/ZnS core-shell nanocrystals as energy transfer donor together with ZnPc as acceptor. In a bilayer configuration we see strong quenching of the nanoparticle luminescence in dependence on the size of the organic ligand shell around the nanocrystals. This distance dependence indicates an effective energy transfer between the nanocrystals and the ZnPc film. [1] D. Wohrle, D. Meissner, Adv. Mater., 3, 129 (1991)

CPP 21.9 Thu 16:30 ZEU Lich

Impedance spectroscopy on organic semiconductors for solar cell application — ●MARTIN KNIPPER¹, JÜRGEN PARISI¹, and VLADIMIR DYAKONOV² — ¹Energy and Semiconductor Research Laboratory, Department of Physics, University of Oldenburg, 26111 Oldenburg, Germany — ²Faculty of Physics and Astronomy, University of Würzburg, Am Hubland, 97074 Würzburg, Germany

Impedance spectroscopy is a powerful tool for studying the electrical transport properties of bulk heterojunction solar cells. The photovoltaic absorber consist of a mixture of poly(3-hexylthiophene) (P3HT) and [6,6]-phenyl-C₆₁-butyric acid methyl ester (PCBM), sandwiched between a transparent indium tin oxide (ITO) front electrode and a metal (Au or Al) back electrode as well as a polymer buffer layer (PEDOT:PSS). We look at the individual material components as well as the composites with and without the PEDOT:PSS interfacial layer. It allows us to investigate the internal device structure, the behaviour of the interfacial layer and the metal/P3HT junction. For the various devices we find different equivalent circuit diagrams. Upon varying the thickness of the semiconductor layer, it is aimed to discriminate bulk and surface effects, in order to improve the preparation process of the composite absorber. From this measurements we found an ϵ_r of 3 for the P3HT and one of 3.4 for the PCBM:P3HT bulk heterojunction.

CPP 21.10 Thu 16:45 ZEU Lich

Optimising Polythiophene based bulk heterojunction solar cells reaching 5% power conversion efficiency — ●HARALD HOPPE, TOBIAS ERB, and GERHARD GOBSCH — Institute of Physics, Ilmenau Technical University, Weimarer Str. 32, 98693 Ilmenau, Germany

State of the art plastic solar cells reaching power conversion efficiencies of 5% are reported. These solar cells are based on the poly(3-alkyl)thiophene-fullerene bulk heterojunction system, exhibiting a relatively low fullerene content. To obtain the optimum balance between charge generation and transport, the film thickness of the photoactive layer was varied. Morphological factors for reaching efficient and stable devices are discussed.