HL 20: Organic Semiconductors: Transistors and OLEDs

Time: Tuesday 9:30–12:45 Location: H15

HL 20.1 Tue 9:30 H15

Ionic liquid gated polymer transistor — •Johannes Schöck, Daniel Secker, and Heiko B. Weber — Lehrstuhl für Angewandte Physik, Universität Erlangen-Nürnberg, Staudtstr. 7/A3, D-91058 Erlangen, Germany

We fabricate field-effect transistors with a polymer semiconductor using an ionic liquid top-gate, replacing the gate insulator. The geometry is bottom contact, liquid top gate. Electrical characterization yields a low conductance threshold of the device ($\sim -2.5\,\mathrm{V}$), and a steep increase of the source-drain current. An analysis points towards unusually high charge carrier mobility of the semi-conducting channel, with very favorable leakage currents through the gate. Strong hysteretic effects are observed.

HL 20.2 Tue 9:45 H15

Electrolyte-gated organic thin film transistors — •Felix Buth[1], Marin Steenackers[2], Deepu Kumar[1], Martin Stutzmann[1], and Jose Antonio Garrido[1] — [1]Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, 85748 Garching, Germany — [2]Institute for Advanced Study, Technische Universität München, Arcisstr. 21, 80333 München, Germany

Organic semiconductors are today widely used as the active material in several applications based on thin film transistors. For most of these devices large operational voltages are required. One approach to reduce the gate voltage is increasing the capacitance of the gate dielectric. Several materials, including high-k dielectrics, ultra-thin cross-linked polymers or polyelectrolytes have been tested for this purpose. Among those, polyelectrolytes offer extraordinarily high capacitances with a relatively low technology cost. The high capacitance results from the electrical double layer formed at the polyelectrolyte/semiconductor interface, opening the possibility of using organic thin film transistors for biological and chemical sensors, in which in-electrolyte operation is required. Since, however, water stable organic semiconductors are generally deposited by evaporation in UHV, the surface of the polyelectrolyte needs to be smooth to enable the growth of high quality films. In this contribution the properties of different polyelectrolyte dielectrics are investigated. We show how polyelectrolytes can be directly prepared on conductive substrates, resulting in homogeneous films with high interfacial capacitances. Furthermore, we show the preparation of high quality pentacene thin films onto the polyelectrolyte films.

HL 20.3 Tue 10:00 H15

Molecular weight dependent short channel effect in MDMO-PPV — •Ali Veysel Tunc, Elizabeth von Hauff, and Jürgen Parisi — University of Oldenburg, Department of Physics, Energy and Semiconductor Research Laboratory, Carl-von-Ossietzky Str. 9-11, 26129 Oldenburg, Germany

In this study, organic field effect transistors (OFETs) based on poly [2-methoxy,5-(3',7'-dimethyl-octyloxy)]-p-phenylene vinylene (MDMO-PPV) with two different weight-average molecular weights (Mw) were fabricated and the effect of the molecular weight on the device properties was investigated. It was observed that the operation performance of the OFET depends on the molecular weight and channel length. The short channel effect was observed, i.e. a lack of saturation in the output characteristic with a fixed gate voltage. We found that the saturation behavior and hole mobility of a given material strongly depend on molecular weight. Short channel effects were observed in higher molecular weight for MDMO-PPV. The hole mobility around 10 times better for higher molecular weight that has been shown in literature.

HL 20.4 Tue 10:15 H15

Electron Mobility in Methanofullerens — •Maria S Hammer[1], Carsten Deibel[1], and Vladimir Dyakonov[1,2] — [1]Experimental Physics VI, Julius-Maximilians-University of Würzburg, Am Hubland, D-97074 W\"urzburg — [2]ZAE Bayern, Div. Functional Materials for Energy Technology, Am Hubland, D-97074 Würzburg

Methanofullerenes are the state of the art acceptor-type semiconductors applied in flexible and printed electronic devices, e.g. they are used together with a donor-type polymer in (i) solar cells or (ii) complementary circuits. While the hole transport in polymers has been intensely investigated within the last years, less attention has been drawn to the fundamentals of the transport within methanofullerenes. In the present study, the electron mobility, which strongly depends on the electron density, is investigated.

We utilize the organic field effect transistor (OFET) as it provides a way of probing the mobility within a wide range of electron densities via gate voltage. Nevertheless, the performance of an OFET sensitively depends on electron injection from the contacts and trapping at the dielectric interface. Therefore, in order to assess the transport parameters of methanofullerenes, it is indispensable to vary the work function of the electrodes as well as the insulator. We will investigate and discuss the ambipolar charge transport in dependence of the charge carrier density in [6,6]-phenyl-C61-butyric acid methyl ester and other derivatives, employing a variation of dielectric surfaces and injecting metals.

HL 20.5 Tue 10:30 H15

Correlation between the effective contact resistance and the charge carrier transport in organic semiconductors of different mobility — R. Winter[1], F. Wörner[1], M.S. Hammer[1], C. Deibel[1], and •J. Pflaum[1,2] — [1]Experimental Physics VI, Julius-Maximilians-University, 97074 Würzburg — [2]Bavarian Center For Applied Energy Research, 97074 Würzburg

In this presentation we address questions on the impact of the charge carrier mobility on the injection behavior in organic thin film transistors (OTFTs). Though many theoretical models treat the contact resistance, R, and the mobility, μ, independently, we demonstrate a significant correlation between these two quantities for P3HT and pentacene. Corresponding TFT measurements have been performed between 40 - 300K. To modify the effective contact resistance, monolayers of different oligoacenes were deposited between the Au bottom contacts and the active organic transport layer. Despite significant differences in the room temperature mobilities, $10^{-4}\mathrm{cm}^2/\mathrm{Vs}$ for P3HT and $10^{-2}\mathrm{cm}^2/\mathrm{Vs}$ for pentacene, the temperature dependent variations of the mobility as well as of the effective contact resistance prove to be similar. For both materials a change in the slope of the R(T) and μ(T)-slope can be detected. However, the cross-over temperature for pentacene amounts to 80K whereas that for P3HT is shifted to 185K. We will discuss this observation in the context of a balanced transport, i.e. that the injection at the metal contact interfaces is strongly related to the charge carrier transport in the semiconducting layer.
Financial support by BMBF (project GREKOS) is acknowledged.

HL 20.6 Tue 10:45 H15

Thickness dependence of contact and sheet resistance of thiophene and pentacene based organic field effect transistors — •Torsten Balster, Steve Pittner, Dagmawi Belaineh, Arne Hoppe, and Veit Wagner — School of Engineering and Science, Campus Ring 1, Jacobs University Bremen, 28759 Bremen, Germany

The electrical properties of evaporated organic semiconductors in dependence on the film thickness are affected by the growth mode of the thin film. While dihexyl-substituted oligothiophenes (DHnT) show a typical layer-by-layer growth mode on hexamethyldisilazane(HMDS)-treated silicon oxide, pentacene exhibits 3-dimensional growth. The growth mode as determined by AFM investigations is also reflected in the integral in-situ IV-measurements during growth. DHnT shows oscillatory behaviour in the mobility and the contact resistance within the first two monolayers, whereas the pentacene saturates without oscillations for 10nm. The total contact resistance with gold electrodes has been evaluated by the transfer line method. Furthermore the potential barriers at source and drain contact are determined separately by a four probe setup. For this purpose, additional sense fingers are prepared within the channel allowing the direct access to the channel potential. Major contact effects are identified for channel length smaller than 10 microns.

HL 20.7 Tue 11:00 H15

Semiconducting Thin Films of Fluorinated and Unsubstituted Phthalocyanines for Applications in Organic Field Effect Transistors — •Harry Brinkmann[1], Christopher Keil[1], Olga Tsaryova[2], Dieter Wöhrle[2], and Derck Schlettwein[1] — [1]Institute of Applied Physics, Justus-Liebig-University Giessen, Germany. email:schlettwein@uni-giessen.de — [2]Institute of Organic and

Macromolecular Chemistry, University of Bremen, Germany.

Perfluorinated phthalocyanines ($F_{16}Pc$) show n-type characteristics as active layers in organic field transistors while organic field transistors with unsubstituted phthalocyanines (Pc) exhibit p-type characteristics. The growth of $F_{16}Pc$ and Pc films has been studied in OFETs on organic (polyimide, $PMMA$) and inorganic insulating layers (SiO_2) with different surface modifications ($HMDS$ treatments). We report here about the dependence of the growth mode of the films and the field effect mobility on the used substrate for the copper complexes. The development of the electrical conduction was studied in-situ during film growth and the field effect mobility was determined for various film thicknesses in different regimes of the Stranski-Krastanov growth mechanism that led to the formation of ultrathin conductive layers in the monolayer range followed by reorganization towards island growth. Optical absorbance was measured in reflection or transmission in dependence of the used substrate to investigate details of the intermolecular coupling.

15 Min. Coffee Break

HL 20.8 Tue 11:30 H15

Carrier density in a Gaussian density of states: Approximation for the Gauss- Fermi integral — •Gernot Paasch[1] and Susanne Scheinert[2] — [1]IFW Dresden — [2]TU Ilmenau

The density of hopping transport states in organics can be approximated by a Gaussian DOS. As a consequence, the mobility becomes a function of carrier density, field and of course temperature. Such dependencies can now be implemented easily in advanced device simulation programs as Sentaurus Device. However, the carrier density as function of the Fermi energy is not taken into account until now. For inorganic semiconductors with a square root DOS the situation was similar with the carrier density expressed by the Fermi- Dirac integral F1/2. Further Fermi-Dirac integrals are needed for the electronic energy density and for Einstein's relation. For these cases analytical approximations have been developed early allowing for fast simulation. For the Gaussian DOS the carrier density is given by the integral over the product of Gaussian DOS and Fermi-Dirac distribution, the Gauss-Fermi integral. Related integrals describe the electronic energy density and occur in Einstein's relation. Here we present an extremely simple and accurate approximation for the Gauss-Fermi integral and discuss its potential applicability in simulation of organic devices.

HL 20.9 Tue 11:45 H15

Comparative transport studies in Bridgman and sublimation grown 9,10-Diphenylanthracene single crystals. — •Andreas Steindamm[1], Ashutosh K. Tripathi[2], Rainer Stöhr[3], Jörg Wrachtrup[3], and Jens Pflaum[1] — [1]Institute of Experimental Physics VI, Julius-Maximilians-University, 97074 Würzburg, Germany — [2]Holst Centre/TNO, 5656 AE Eindhoven, NL — [3]Physikalisches Institut, University of Stuttgart, 70550 Stuttgart, Germany

To improve organic electronic applications, knowledge about microscopic mechanisms determining the charge carrier mobilities is pivotal. 9,10-Diphenylanthracene (DPA) has been identified as model system to study those correlations due to its high electron and hole mobilities at room temperature [1] and its complex structural phase behaviour. We will demonstrate our temperature dependent Time-Of-Flight data on single crystals grown by vapor phase transport (VPT) and by Bridgman growth technique. Both preparation techniques revealed crystals of different morphologies resulting in significant variations of the related bipolar mobilities. As a key result, the charge carrier mobility of $\sim 1 cm^2/Vs$ at room temperature along the (111)-direction of Bridgman crystals exceeds that along the (001)-direction of VPT grown crystals by about one order of magnitude. The observed differences in the mobility data will be discussed in the context of the microscopic molecular arrangement within the respective crystal structure. Financial support by BMBF (project GREKOS) is acknowledged.

[1] Tripathi A. K. et al., Adv. Mater. 19 (2007) 2097

HL 20.10 Tue 12:00 H15

Probing charge carrier dynamics in conducting polymers using single molecules as sensors — •Maximilian Nothaft[1], Steffen Höhla[2], Aurélien Nicolet[3], Jens Pflaum[4], Fedor Jelezko[1], and Jörg Wrachtrup[1] — [1]3. Phys. Ins., Univ. Stuttgart — [2]Chair of Display Technology, Univ. Stuttgart — [3]MoNOS, Huygens Laboratory Leiden — [4]Exp. Phys. VI, Univ. Wuerzburg and ZAE Bayern

Doping of conducting polymers by guest molecules is widely applied in organic light emitting devices to improve their efficiency. By reducing the concentration of suited guest molecules it becomes possible to study the dynamics of single molecule emitters using confocal microscopy.

In our contribution we discuss the optical properties of single Dibenzoterrylene dye molecules dispersed in an OLED consisting of PPV as host material. It will be shown how to prepare devices of photostable single molecules in PPV emitting a constant flux of single photons at room temperature by excitation from a Ti:sapphire laser.

By simultaneous laser excitation and electrical operation it is possible to detect the effect of injected charge carriers on the dynamics of single quantum emitters. Since the ratio of singlet to triplet exciton formation in the device is 1:3, this leads to an effective pumping to the triplet state of the single molecule thereby reducing its fluorescence intensity. Modeling this process it becomes possible to associate the reduced fluorescence intensity with the local current density at the position of the molecule. This correlation enables us to optically probe the current density in an OLED with nm spatial resolution.

HL 20.11 Tue 12:15 H15

Energy band alignment at the oxide-organic interface ITO/ZnPC determined by photoelectron spectroscopy — •Jürgen Gassmann and Andreas Klein — Surface Science Department, Istitute of Materials Science, TU Darmstadt, Germany

The possibility to generate light on the front- and backside of an organic light-emitting diode (OLED) is given for inverted top-emitting OLEDs. For them the transparency of the back contact is crucial. Here transparent conductive oxides (TCO) like indium tin oxide (ITO) or zinc oxide are of special interest, because these films can be deposited with magnetron sputtering at room temperature. In this work the energy band alignment between the organic material zinc phthanalocyanine (ZnPC) and the transparent oxide ITO is evaluated. For this the X-ray photoelectron spectroscopy technique (XPS) is used and combined with an in-situ preparation of the films. The energy band alignments of the deposition sequences ITO on ZnPC and vice versa are compared. Here valence band offsets up to 1.3eV can be detected. The energy band alignment shows a strong dependence on the deposition sequence. Additionally the electrical and optical properties of ITO films sputtered at room temperature are investigated.

HL 20.12 Tue 12:30 H15

Highly efficient white top-emitting organic light-emitting diodes with forward directed light emission — •Patricia Freitag, Sebastian Reineke, Mauro Furno, Björn Lüssem, and Karl Leo — Institut für Angewandte Photophysik, TU Dresden, George-Bähr-Straße 1, 01069 Dresden, Germany

The demand for highly efficient and energy saving illumination has increased considerably during the last decades. Organic light emitting diodes (OLEDs) are promising candidates for future lighting technologies. They offer high efficiency along with excellent color quality, allowing substantially lower power consumption than traditional illuminants. Recently, especially top-emitting devices have attracted high interest due to their compatibility with opaque substrates like metal sheets. In this contribution, we demonstrate top-emitting OLEDs with white emission spectra employing a multilayer hybrid cavity structure with two highly efficient phosphorescent emitter materials for orange-red (Ir(MDQ)2(acac)) and green (Ir(ppy)3) emission as well as the stable fluorescent blue emitter TBPe. To improve the OLED performance and modify the color quality, two different electron blocking layers and anode material combinations are tested. Compared to Lambertian emission, our devices show considerably enhanced forward emission, which is preferred for most lighting applications. Besides broadband emission and angle independent emission maxima, power efficiencies of 13.3 lm/W at 3 V and external quantum efficiencies of 5.3% are achieved. The emission shows excellent CIE coordinates of (0.420, 0.407) at approx. 1000 cd/m2 and color rendering indices up to 77.