

HL 54: Joint Session: Organic Semiconductors IV: Excitations and Charges

Time: Wednesday 14:00–17:00

Location: ZEU 222

Topical Talk

HL 54.1 Wed 14:00 ZEU 222

Control of Charge Carrier Dynamics in Disordered Conjugated Polymers — ●DIRK HERTEL — Physical Chemistry, University of Cologne, Luxemburgerstr. 116, 50939 Cologne, Germany,

We developed a new method to probe charge carrier mobility on ultrafast time scale [1]. It is based on electric field induced second harmonic generation. The method is applied to prototypical amorphous conjugated polymers of the polyphenylene- and polyfluorene-type. Typically the carrier mobility in these organic polymers decreases with time in a power law fashion from about $1 \text{ cm}^2 \text{Vs}^{-1}$ at 1 ps to its stationary value of about $10^{-6} \text{ cm}^2 \text{Vs}^{-1}$ in hundreds of ns.

The dynamics of the mobility is discussed. It will be shown, that in nanoscale devices the macroscopic mobility is not adequate to describe charge transport. We study the influence of disorder, morphology and temperature on ultrafast transport. At early times the transport is dominated by tunneling [2] and disorder plays already an essential role. Comparison of transient photocurrents with Monte-Carlo simulation reveals that on-chain transport has to be invoked to rationalize our results [3]. The hopping rates for intrachain transport are much larger compared with interchain transport. The results give access to essential transport properties for the development of advanced theoretical models and may help to design improved solar cells.

[1] A. Devizis, et al. *Phys. Rev. Lett.* **103**, (2009) 027404.

[2] A. Devizis, et al. *Phys. Rev. B* **82**, (2010) 155204.

[3] A. Devizis, et al. *Chem. Phys. Lett.* **498**, (2010) 302.

HL 54.2 Wed 14:30 ZEU 222

Light-Emitting Organic Memory — ●PETER O. KÖRNER, R. CLAYTON SHALLCROSS, VINCENT AUBERT, EDUARD MAIBACH, PHILIPP ZACHARIAS, and KLAUS MEERHOLZ — Department of Chemistry, University of Cologne

We report on light-emitting organic memory (LE-OMEM) devices composed of multiple solution-processed layers. The active layer of our LE-OMEM devices is comprised of crosslinkable dithienylethene photochromes (XDTE) that can be optically switched between two energetically distinct and thermally stable isomers. Exploiting the difference in the HOMO and LUMO levels of these two isomers we use such a layer as an electrical switch within our OLED layer stack. We demonstrate that the ON/OFF ratio in current (OOR_j) as well as in electroluminescence (OOR_L) of such devices is exponentially dependent on the difference in the largest charge injection barrier between the ON and OFF state of the device. Optimized devices displayed impressive fatigue resistance and afforded values for OOR_j and OOR_L of greater than 10^3 . We focus on a variety of crosslinkable DTE molecules of varying structure and functionality with an emphasis on OOR , device stability over multiple read/write/erase cycles (fatigue resistance) and switching rates. Current induced switching allows for electrical writing and reading of grey level information in these XDTE devices. We studied this electrical switching behavior to gain further insight into the distinct switching mechanisms within the XDTE layer. These fundamental studies are a first step towards a completely electrically driven LE-OMEM.

HL 54.3 Wed 14:45 ZEU 222

Determination of the effective radiative quantum efficiency of light-emitting guest-host systems — ●TOBIAS SCHMIDT¹, DANIEL-STEFFEN SETZ², BENJAMIN LEBSANFT¹, THOMAS WEHLUS¹, JÖRG FRISCHEISEN¹, BENJAMIN KRUMMACHER², MICHAEL FLÄMMICH³, NORBERT DANZ³, and WOLFGANG BRÜTTING¹ — ¹Experimentalphysik IV, Universität Augsburg — ²OSRAM Opto Semiconductors, Regensburg — ³Fraunhofer-Institut für angewandte Optik und Feinmechanik (IOF), Jena

The efficiency of organic light-emitting diodes (OLEDs) is still limited as only a small part of the applied electrical power is converted into light and finally extracted from the device to air. Especially the radiative quantum efficiency (RQE) of the used guest-host system is often declared to be unity in phosphorescent emitter/matrix combinations. Due to interference effects, the radiative lifetime of the emitter and thus the effective RQE of the light-emitting guest-host system is influenced by coupling to different modes of the cavity formed by the metallic mirror and the partially reflecting ITO/glass interface. The effective RQE can be determined by measuring the external quantum

efficiency of the electrically driven OLED or the photoluminescence lifetime of the emitter inside the OLED at different emitter positions in the cavity. We have investigated the RQE of the commonly used emitter Ir(ppy)₃ in neat films with PMMA and CBP as matrices, yielding values of about 70 %, and compare it to OLEDs, where significantly lower values of only 40 % are obtained.

HL 54.4 Wed 15:00 ZEU 222

Exciton quenching in light emitting organic field-effect transistors studied by localized Spectroscopy — ●WOUTER KOOPMAN, STEFANO TOFFANIN, and MICHELE MUCCINI — ISMN-CNR, Via P. Gobetti 101, 40129 Bologna, Italy

The recent development of organic light-emitting transistors (OLETs) promises a new generation of light-emitting organic devices surpassing the efficiency of organic LEDs. The transistor structure prevents non-radiative processes connected to charge-carrier injection as for the ideal OLET the full recombination takes place inside the channel.

In this work we present an investigation of the influence of field-induced quenching on the luminescence intensity in OLETs based on *N,N'*-ditridecyl-*perylene-3,4,9,10-tetracarboxylic diimide* (PTCDI-C13H27) as a model compound. We have used localized photoluminescence and lifetime spectroscopy to study the quenching processes at the electrodes and in the channel region in working devices. Our measurements show a reduction of luminescence intensity up to 20% by applying a forward gate voltage, with a gate field in the order of $1 \times 10^8 \text{ Vm}^{-1}$. Upon application of a reverse bias a counter-intuitive enhancement of the PL spectrum was found. Excluding polaron-injection by a dielectric barrier, we can identify field induced effects to be responsible for the observed effects.

These results clarify the role of external electric field induced exciton-quenching on the luminescence efficiency of OLETs and establish a bases for the understanding of the limiting processes in more complex devices.

HL 54.5 Wed 15:15 ZEU 222

Triplet Excimer Emission in a Series of CBP-Derivatives — ●SEBASTIAN HOFFMANN¹, PAMELA SCHRÖGEL², RODRIGO ALBUQUERQUE¹, MICHAEL ROTHMANN², PETER STROHRIEGL², and ANNA KÖHLER¹ — ¹Department of Physics, University of Bayreuth, 95440 Bayreuth — ²Macromolecular Chemistry I, Department of Chemistry, University of Bayreuth, Bayreuth 95440, Germany

Carbazole-based materials such as 4,4*-bis(N-carbazolyl)-2,2*-biphenyl (CBP) and its derivatives are frequently used as matrix materials for phosphorescent emitters in organic light emitting diodes. An essential requirement for such matrix materials is a high energy of their first triplet excited state. Here we present a detailed spectroscopic investigation supported by DFT calculations on two series of CBP derivatives, where CH₃ and CF₃ substituents introduce strong torsion into the molecular structure. The resulting poor coupling between the two halves of the molecules leads to an electronic structure similar to that of N-phenyl-3,6-dimethyl-carbazole, with high triplet state energy of 2.95 eV. However, we also observe a triplet excimer emission centred at about 2.5-2.6 eV in all compounds. We associate this triplet excimer with a sandwich geometry of neighboring carbazole moieties. For compounds with more polar CF₃ substituents, the lifetime of the intermolecular triplet excited state extends into the millisecond range for neat films at room temperature. We attribute this to an increased charge-transfer character of the intermolecular excited state for the more polar substituents. [1] S.T. Hoffmann et al, J. Phys.Chem. B, in press.

15 min. break

HL 54.6 Wed 15:45 ZEU 222

The effect of energetic disorder on the spectral diffusion of singlet and triplet states in phenylene-type polymers — ●ANNA KÖHLER¹, SEBASTIAN T HOFFMANN¹, HEINZ BÄSSLER¹, JAN-MORITZ KOENEN², and ULLRICH SCHERF² — ¹Experimental physics II, Universität Bayreuth — ²Macromolecular Chemistry, Bergische Universität Wuppertal

We have employed quasicontinuous temperature dependent fluorescence and phosphorescence spectroscopy to monitor the spectral dif-

fusion of singlet and triplet excitons in a series of pi-conjugated polymers. (1) The experimental results are complemented by Monte-Carlo simulations. We investigated (i) how spectral diffusion is controlled by the degree of energetic disorder present in the amorphous film and (ii) how this process depends on the range of the electronic coupling by comparing singlet exciton diffusion via long-range Förster transfer against triplet exciton diffusion by short-range Dexter transfer. For singlets, we find that the fluorescence spectra bear out a bathochromic shift upon cooling the sample down to a critical temperature below which the shift saturates. This bathochromic shift is a signature of spectral relaxation. In contrast we observe a hypsochromic shift of the phosphorescence spectra below a characteristic temperature for triplets in systems with at least moderate energetic disorder. We show that Random-walk theory applied to excitation transport within a Gaussian density-of-states distribution is both necessary and sufficient to rationalize the experimental results in a quantitative fashion. (1) S.T. Hoffmann et al. PRB 81, 115103 (2010)

HL 54.7 Wed 16:00 ZEU 222

Surface Doping of Conjugated-polymer/Insulating-polymer Composite Film for Field-effect-transistor — •GUANGHAO LU^{1,2}, PATRICK PINGEL², INGO SALZMANN¹, NORBERT KOCH¹, and DIETER NEHER² — ¹Institut für Physik, Humboldt-Universität zu Berlin, Berlin, Germany — ²Institut für Physik und Astronomie, Universität Potsdam, Potsdam, Germany

In organic field-effect-transistors, optimized devices are usually achieved at inert environment together with passivated dielectric surface, in order to prevent the possible doping by oxygen or polar groups at dielectric surface. However, in this work, we find that the field-effect properties of poly(3-hexylthiophene)/polystyrene (P3HT/PS) composite can be greatly improved upon surface doping. Upon exposure to air and using oxidably active dielectric surface, we doped the top surface and bottom surface of P3HT/PS film for top-contact and bottom-contact devices, respectively. The field-effect mobility of these films with only 2-5 wt% P3HT can be enhanced by more than 3 orders, reaching 0.05-0.2 cm²V⁻¹s⁻¹. This phenomenon is strongly contrary to the case of pure P3HT film. We proposed that, for pure P3HT, doping inevitably induces negatively charged sites or charge-transfer complexes, which act as new traps or undesired low energy sites. However, for conjugated-polymer incorporated within insulating-polymer matrix, the interaction between hole and surrounding negative sites is weaker because of the spatial occupation of a-PS among P3HT domains, which largely optimizes the positive aspect of doping and meanwhile restrained its negative role.

HL 54.8 Wed 16:15 ZEU 222

Investigation of single grains in nanoscale P3HT OFETs — •DILEEP DHAKAL, STEVE PITTNER, TORSTEN BALSTER, and VEIT WAGNER — School of Engineering and Science, Jacobs University Bremen, Campus Ring 1, 28759 Bremen

Regio-regular poly(3-hexylthiophene) (P3HT) has a chain length in the range of several nm up to more than 100 nm, depending on the molecular weight. In addition, the lateral correlation length of 50 nm thick spin-coated P3HT-layers was found to be 150 nm [1] corresponding to the range of structural order within the film. Therefore, the

reduction of the channel length L in organic field effect transistors towards the sub-100 nm range will open up the possibility for channels formed by single grains or individual P3HT chains. For this investigation transistor templates on oxidized silicon substrates are prepared by 2 approaches i) by electron beam lithography (EBL) and ii) by metal deposition under defined tilt angle at a preexisting contact edge. The resulting channel length between the source and drain electrode is in the range from 1 μm to 100 nm for EBL and reaches even lower channel sizes using the second approach. At L = 1 μm a mobility of 10⁻² cm²/Vs is typically extracted from transfer curve measurements. Without optimization of the gold/P3HT-interface we find a decrease of mobility by more than one order of magnitude for 100 nm devices, which is attributed to an increased influence of the contact resistance. The ratio can be clearly improved by optimizing the interface. [1] B. Gburek and V. Wagner, Org. Electronics 11 (2010) 814.

HL 54.9 Wed 16:30 ZEU 222

The impact of polar bonds on electron transport through self-assembled monolayers — •DAVID A. EGGER¹, FERDINAND RISSNER¹, EGBERT ZOJER¹, and GEORG HEIMEL² — ¹Institute of Solid State Physics, Graz University of Technology, Austria — ²Institut für Physik, Humboldt-Universität zu Berlin, Germany

Density functional theory based surface- and transport-calculations are performed to elucidate the role of intra-molecular polar bonds built into self-assembled monolayers (SAMs) sandwiched between two metal electrodes. Conjugated (oligo)phenylene-ethynylene thiols (also known as 'Tour wires') on gold are chosen due to their frequent appearance in past experimental and theoretical studies. Here, we substitute carbon by nitrogen atoms in a systematic way to realize two different molecules with zero dipole moment and virtually identical frontier molecular orbital energies. Despite this similarity in the electronic structure of the isolated species, the charge-transport characteristics of the corresponding SAMs are vastly different. We give a sound explanation for our observations based on an intuitive electrostatic rationale and conclude that the actual orientation of polar bonds in monolayers of preferentially oriented molecules crucially impacts characteristic parameters of molecular electronic devices, such as conductance gap or threshold voltage.

HL 54.10 Wed 16:45 ZEU 222

Photoinduced magnetoresistance in organic field-effect transistors — •THOMAS REICHERT and TOBAT P. I. SARAGI — Department of Mathematics and Science and Center for Interdisciplinary Nanostructure Science and Technology (CINSA-T), University of Kassel, Heinrich-Plett-Strasse 40, D 34132 Kassel, Germany

We report on negative magnetoresistance (MR) in low external magnetic fields in organic field-effect transistors. This effect can only be observed if the device is irradiated. MR strongly depends on gate voltage but is independent of drain voltage. Furthermore, the MR increases as the intensity of irradiation increases and the relationship of both parameters is not linear. The dependency of MR on magnetic field is not linear either, but it follows Non-Lorentian function. The triplet exciton-charge reaction model is a possible explanation for negative MR in irradiated organic field-effect transistors.