

CPP 23 POSTER Functional Organic Thin Films

Time: Thursday 17:00–19:00

Room: P2

CPP 23.1 Thu 17:00 P2

Watching organic semiconductors grow: In-situ and real-time spectroscopic ellipsometry — ●S. KOWARIK^{1,2}, U. HEINEMEYER¹, G. HUMPHREYS², R. JACOBS², A. GERLACH^{1,2}, and F. SCHREIBER¹ — ¹Institut für Angewandte Physik, Universität Tübingen, Auf der Morgenstelle 10, 72076 Tübingen — ²Physical and Theoretical Chemistry Laboratories, Oxford University, South Parks Road Oxford OX1 3QZ

Thin films of organic semiconductors and dyes are receiving significant attention, and their potential for electronic and optoelectronic device applications is obvious. Optimisation of device performance requires the understanding of the underlying preparation procedures. For this purpose real-time measurements are particularly powerful since they detect possible changes in the functional properties already during growth. We demonstrate the use of spectroscopic ellipsometry as a non-invasive technique for following diindenoperylene and pentacene growth in situ and in real time. It is possible to take spectra in the entire spectral range between 1.25eV and 5 eV sufficiently fast to follow organic molecular beam deposition in detail. We show how this technique can be used to detect spectral changes occurring during growth of these complex materials.

CPP 23.2 Thu 17:00 P2

Growth of Pentacene on clean and modified Gold Surfaces — ●DANIEL KAEFER, LARS RUPPEL, GREGOR WITTE, and CHRISTOF WOELL — Physikalische Chemie I, Ruhr Universitaet Bochum, 44780 Bochum

Because of its high charge carrier mobility and the ability to form (poly-)crystalline films pentacene is still one of the most promising organic semiconductor for the fabrication of organic thin film transistors. Of particular interest is the interaction and growth at the gold interface which is commonly used as electrode material. In view of partly controversial results which have been reported so far for growth of pentacene on gold we have carried out a comprehensive study including temperature and rate dependency as well as the influence of substrate roughness. By combining various microscopy techniques (SEM, STM, AFM) with NEXAFS and UPS the growth scenario of pentacene on clean single crystals and polycrystalline gold surfaces has been compared.

On clean gold surfaces the first monolayer forms a chemisorbed seed-layer with planar adsorption geometry while subsequent growth is characterized by a pronounced dewetting and formation of needle-like islands where molecules adopt a bulk-like upright orientation. At very large deposition rates rather disordered films are formed where this molecular reorientation is quenched. A distinctly different growth scenario was observed for gold surfaces which had been modified before by a SAM. In that case no planar oriented seed-layer is formed and pentacene molecules grow immediately in an upright orientation without any dewetting.

CPP 23.3 Thu 17:00 P2

Quantitative investigation of the dielectric properties in the ab-plane of pentacene single crystals — ●MANDY GROBOSCH¹, THOMAS PICHLER¹, HELMUTH BERGER², MARTIN KNUPFER¹, and WIELAND ZAHN³ — ¹IFW Dresden, P.O. Box 270116, D-01171 Dresden, Germany — ²Institute of Physics of Complex Matter, EPFL, CH-1015 Lausanne, Switzerland — ³Westsaechsische Hochschule Zwickau (FH), Dr.-Friedrichs-Ring 2a, D-08056 Zwickau, Germany

Polarization dependence of the optical reflectivity spectra of pentacene single crystals grown by sublimation have been investigated over a wide range of frequencies from the middle infrared to the visible range (5meV to 3 eV) at room temperature. Furthermore measurements with electron energy-loss spectroscopy (EELS) in transmission have been performed on pentacene thin films. A series of optical phonon modes and electronic transitions have been observed. The determination of the electronic properties have been carried out in the energy rang from 1.7 eV to 2.3 eV within a Lorentz-model. In addition to previous studies we observed the onset of the optical absorption at 1.87 eV followed by a series of four excitations at 1.97 eV, 2.11 eV, 2.14 eV, and 2.28 eV. The results revealed that the dielectric function of pentacene single crystals shows a strongly anisotropic dependence in the ab-plane on the polarization of the incident light.

CPP 23.4 Thu 17:00 P2

Unit cell and defect densities of pentacene thin films — ●STEFAN SCHIEFER, MARTIN HUTH, BERT NICKEL, MATTHIAS FIEBIG, and UDO BEIERLEIN — Department für Physik & CeNS Ludwig Maximilians Universität München

Organic electronic devices generally employ thin films of a semi conducting material as the active region where charge is carried. So far there is no clear understanding of the charge transport mechanisms in the active region. By getting a better understanding of the structure-function relationship of the semi conducting organic thin film layer we hope to further improve the electron charge mobility.

We grew thin films of pentacene on SiO₂ in UHV and performed in situ x-ray diffraction experiments at the synchrotron source at HASY-Lab, Hamburg. By simulating and analysing the data, we were able to determine the unit-cell dimension and the defect densities of a pentacene thin film on SiO₂ surfaces.

CPP 23.5 Thu 17:00 P2

Optical spectroscopy of vapour deposited rubrene films — ●OLGA KRYLOVA, ANDREAS LANGNER, and MORITZ SOKOLOWSKI — Institut für Physikalische und Theoretische Chemie, Universität Bonn, Wegelerstr. 12, 53115 Bonn, Germany

Thin films of rubrene (150 nm) were fabricated by vapour deposition on glass and the absorption and fluorescence spectra were investigated as a function of temperature. We observe a reversible red-shift of the emission maximum of 500 cm⁻¹ at about 150-200 K. Interestingly, a similar change has been observed in the fluorescence spectra of thin tetracene films earlier and was attributed to a structural phase transition [1]. However, since rubrene films deposited at room temperatures were identified as amorphous [2], the origin of this shift may have a different origin for rubrene, which will be discussed. Supported by the DFG through the research unit 557.

[1] H. Nishimura et al., J. Phys. Soc. Japan 54 (1985) 4.

[2] D. Käfer, G. Witte, Phys. Chem. Chem. Phys. 7(15) (2005) 2850.

CPP 23.6 Thu 17:00 P2

Structure and Crystallinity Study of Conjugated Polymers — ●SIDDHARTH JOSHI¹, ULLRICH PIETSCH¹, SOUREN GRIGORIAN¹, ACHMAD ZEN², and DIETER NEHER² — ¹Festkörperphysik, Universität Siegen, Siegen, Germany — ²Institut für Physik, Universität Potsdam, Potsdam, Germany

The molecular aggregation structure of organic thin films based on semiconducting conjugated polymers has received much attention due to application to polymer electronic devices such as light-emitting diodes, field-effect transistors (FETs) and photovoltaic cells (PVs). One central problem in organic field-effect transistor concerns with the relatively low charge-carrier mobility compared to semiconductor devices. Our current studies are focussed on structure investigations of polymer thin films. Using Ruland*s method several fractions of regioregular (RR) polymers (P3HT, P3dHT) with different molecular weight fractions. To have access to thin films of about 10 nm thickness we used the grazing incidence X-ray diffraction (GIXD) and synchrotron radiation. We determined the degree of crystallinity, and average size of crystallites in polymer films. At the same time we have also employed atomic force microscopy AFM (tapping mode) and X-ray reflectivity methods to study the surface morphology and average thickness of organic thin film. As major result we found that polymers with low molecular weight show a higher degree of crystallinity compared to films with high molecular weight. The results of this structure investigations can be used to interpret the charge-carrier mobility for OFETs.

CPP 23.7 Thu 17:00 P2

Effect of the Spacer Chain length on the Molecular Orientation and Packing Density of Terphenylalkanethiols on Au(111): Combined STM and FTIR Characterization: — ●ASIF BASHIR¹, WALEED AZZAM¹, ANDREAS TERFORT², THOMAS STRUNSKUS¹, and CHRISTOF WÖLL¹ — ¹Lehrstuhl für Physikalische Chemie I, Ruhr Universität Bochum — ²Institut für Anorganische und Angewandte Chemie, Universität Hamburg

Recently, the charge transport properties of aromatic thiolate, have received extensive attention because of their relative stability to other

potential molecular electronic materials. Here, we report studies on Self-assembled monolayers (SAMs) of 4,4'-terphenyl-substituted alkanethiols $C_6H_5(C_6H_4)_2(CH_2)_n-SH$ (TPn, $n = 1-6$) adsorbed on Au (111) substrates using scanning tunneling microscopy (STM) and reflection absorption infrared spectroscopy (RAIRS). At 298 K, the structure and molecular orientation of TPn films (except TP2) exhibit a pronounced odd-even effect regarding both, the molecular orientation and packing density. Odd-numbered SAMs adopt a highly ordered $(2\sqrt{3} \times \sqrt{3})R30^\circ$ structure. SAMs made from even-numbered TPn thiols, on the other hand exhibit a very different structure with a reduced packing density. At 298 K, a $(5\sqrt{3} \times 3)$ rectangular unit cell was found for TP4 and TP6 SAMs. Whereas the structure of the odd numbered TPn SAMs is retained at a temperature of 333 K, the even-numbered SAMs undergo phase transitions to phases having a lower packing density. We will also report first results obtained for the geometric structures using ab-initio (DFT) electronic structure calculation.

CPP 23.8 Thu 17:00 P2

Spectroscopic Investigation of Thioaromatic Self-Assembled Monolayers on Gold — •MIHAELA BADIN¹, ANDREAS TERFORT², THOMAS STRUNSKUS¹, and CHRISTOF WÖLL¹ — ¹Lehrstuhl für Physikalische Chemie I, Ruhr-Universität Bochum — ²Institut für Anorganische und Angewandte Chemie, Universität Hamburg

Self-assembled monolayers (SAMs) are the most important model system for investigating the physical and chemical properties of ultrathin molecular layers. Here, we report on several novel tips of SAMs based on synthesized organothiols. SAMs formed from triptycenythiol (C0T), mercaptomethyltriptycenythiol (C1T), and mercaptopropyltriptycenythiol (C3T) on gold are characterized by infrared reflection absorption spectroscopy, X-ray photoelectron spectroscopy and near-edge X-ray absorption fine structure spectroscopy. The aromatic rings and the rigidity of the aromatic system determine the molecular orientation and orientational order of the thioaromatic molecules. In C1T and C3T the insertion of the methylene group creates a conformational flexibility which is important to yield high quality films.[1] Measurement results confirm that these molecules form highly oriented monolayers on the gold surface. C1T and C3T molecules show a tilted orientation with respect to the surface normal. In addition several SAMs formed from different substituted triarylamines are studied under deprotection conditions.

[1] Cyganik, P.; Buck, M.; Azzam, W.; Wöll, C. J. Phys. Chem B 2004, 108, 4989-4996

CPP 23.9 Thu 17:00 P2

Electronic Properties of DNA Base Layers on H-passivated Si(111)(7x7) — •STEFAN SEIFERT¹, GIANINA GAVRILA¹, WALTER BRAUN², and DIETRICH R.T. ZAHN¹ — ¹Chemnitz University of Technology, Semiconductor Physics, D-09107 Chemnitz, Germany — ²BESSY GmbH, Albert-Einstein-Straße 15, Berlin, D-12489, Germany

Despite of the increasing interest in the charge transport properties of DNA base stacks and poly DNA strands, reliable data on the electronic properties of DNA bases in the condensed phase is rare if at all available. Therefore, an extensive photoelectron spectroscopy study of layers of adenine, cytosine, and guanine is presented in comparison with density functional theory (DFT) calculations for single molecules. The layers were prepared under ultra high vacuum conditions by organic molecular beam deposition onto H-passivated Si(111)(7x7). The valence band photoemission (VB-PE) spectra of these layers were obtained with 55eV and 150eV excitation energy at the synchrotron facility BESSY. The determined ionization energies for the bio-organic layers are considerably smaller than those of free molecules. The adenine and cytosine layers show formation of an interface dipole with the substrate while the interface between guanine layers and H-Si(111)(7x7) displays nearly vacuum level alignment. The comparison of the VB-PE spectra to DFT/B3LYP calculations for single molecules (with 6-311+G(p,d) basis sets) reveals clear signs of band formation in cytosine and guanine layers.

CPP 23.10 Thu 17:00 P2

Energy Level Alignment at Dihexylsexithiophene-Metal Interfaces — •STEFFEN DUHM¹, HENDRIK GLOWATZKI¹, ROBERT L. JOHNSON², JÜRGEN P. RABE¹, and NORBERT KOCH¹ — ¹Humboldt-Universität zu Berlin, Institut für Physik, Newtonstr. 15, D-12489 Berlin — ²Universität Hamburg, Institut für Experimentalphysik, Luruper Chaussee 149, D-22761 Hamburg

The energy level alignment at metal-organic interfaces is a key issue for improving the performance of novel organic (opto-) electronic devices. In

certain cases, solution-based processing of organic materials is preferred over vacuum sublimation. Frequently, alkyl side-chains are attached to the conjugated moieties for improved solubility. To investigate the influence of alkyl side-chain addition on interface energetics, we studied interfaces formed between the organic molecules sexithiophene (6T) and α,ω -dihexylsexithiophene (DH6T) and the metal surfaces Ag(111) and polycrystalline Au using ultraviolet photoelectron spectroscopy (UPS). Morphology was investigated with Atomic Force Microscopy (AFM) in ultra-high-vacuum. Interestingly, we observed significantly lower hole injection barriers (0.6 eV) for DH6T on the metal surfaces than for 6T. We explain this behavior in terms of the molecular orientation. In addition, we demonstrate that the hole injection barrier at interfaces between DH6T and metals can be further reduced by the insertion of (sub)monolayers of the strong electron acceptor tetrafluoro-tetracyanoquinodimethane (F4-TCNQ).

CPP 23.11 Thu 17:00 P2

Doping and Diffusion Properties of Alkali Metals in PTCDA Thin Films — •KATHRIN HEIMER, JENS WÜSTEN, STEFFEN BERGER, STEFAN LACH, and CHRISTIANE ZIEGLER — University of Kaiserslautern, Department of Physics, 67663 Kaiserslautern

n-doping of the molecular organic semiconductor perylene-3,4,9,10-tetracarboxylic-dianhydride (PTCDA) is often achieved by evaporation of alkali metals onto the surface of the PTCDA film. It is expected that there are differences in the doping behaviour between the alkali metals [1]. Furthermore it has been believed that the dopant shows a diffusion profile through the layer with most of the dopant accumulated in the first few layers [2].

In this contribution both experimental results concerning chemical composition ((angle resolved) X-ray photoemission spectroscopy ((AR-)XPS), Fouriertransform infrared spectroscopy (FT-IR), electronic structure (ultraviolet photoemission spectroscopy (UPS)), inverse photoemission spectroscopy (IPE)) [3] and theoretical results concerning FT-IR are shown before and after doping with three different alkali metals, sodium, potassium and cesium, respectively.

These results suggest that the three alkali metals diffuse into and react with the PTCDA film in different ways. Models for the dopant distributions are suggested.

[1] K. Heimer, Ch. Ziegler, in preparation

[2] J. Wüsten, Th. Ertl, Ch. Ziegler, Appl. Surf. Sci. 252 (1), 104-107 (2005)

[3] J. Wüsten, S. Berger, K. Heimer, S. Lach, Ch. Ziegler, J. Appl. Phys. 98, 013705 (2005)

CPP 23.12 Thu 17:00 P2

Hot Electron Dynamics in Sodium doped PTCDA thin Films — •JENS WÜSTEN, STEFFEN BERGER, MARC SALOMON, MICHAEL BAUER, STEFAN LACH, MARTIN AESCHLIMANN, and CHRISTIANE ZIEGLER — University of Kaiserslautern, Department of Physics, Erwin-Schrödinger-Straße 56, 67663 Kaiserslautern

Time resolved 2 photon photoemission (2PPE) measurements of the doping process of PTCDA thin films with sodium give insight into the dynamics of hot electrons in this system. Interaction with sodium results in a charge transfer from sodium to PTCDA ("n-doping") and is accompanied by an increase of the lifetime of electrons excited to unoccupied states 1.4 - 1.8 eV above the Fermi level. Supported by DFT-calculations of molecular orbital energies and excited state energies, this result can be explained from a joint physical viewpoint that combines the one electron picture, treated in "classical" photoemission spectroscopy theory, with many electron excitations as commonly considered in optical spectroscopy. As thin PTCDA layers on a Ag(111) surface show up similar features in UV photoelectron spectroscopy as sodium doped PTCDA, this system has also been investigated by 2PPE. An increase of lifetime can be observed for thin PTCDA coverages, which points at a charge transfer from Ag to PTCDA.

CPP 23.13 Thu 17:00 P2

Development of a high performance OFET on well ordered sapphire — •SÖNKE SACHS, MATTHIAS PAUL, ACHIM SCHÖLL, and EBERHARD UMBACH — Experimentelle Physik II, Am Hubland, 97074 Würzburg, Germany

The charge carrier mobility in organic field effect transistors strongly depends on the structural quality of the active medium. For thin film transistors the structural order is strongly influenced by the structure, morphology, and interaction potential of the substrate, which in case of

a bottom gate geometry is an insulator.

For such a geometry we try to optimize the film growth by using a highly-ordered, clean, and well-characterized single-crystalline (1120) sapphire ($\alpha\text{-Al}_2\text{O}_3$) substrate. With the organic semiconductor diindenoperylene (DIP) we demonstrate that the organic film grows polycrystalline with large single crystalline domains. An AFM analysis indicates that under optimized preparation conditions the size of these crystallites is only limited by the dimensions of the substrate terraces. Moreover, XPS and NEXAFS results show only weak interaction at the interface and a preferential upright orientation of the DIP molecules within the crystallites, thus exhibiting very favorable conditions for a high performance OFET. A design for an optimized model OFET is discussed.

CPP 23.14 Thu 17:00 P2

Charge carrier transport in P3HT diodes and transistors — ●SILVIU GRECU, ANDREAS OPITZ, and WOLFGANG BRÜTTING — Experimental Physics IV, University of Augsburg, 86135 Augsburg, Germany

It has been demonstrated recently that the hopping mobility in semiconducting polymers depends on the charge carrier concentration. Owing to differences in the densities of injected carriers of several orders of magnitude between organic field-effect transistors (FETs) and diodes, significant differences in the charge carrier mobilities of these devices have been observed.

We have investigated the temperature dependence of the mobility for three different kinds of organic devices: hole-only diodes, metal-insulator-semiconductor (MIS) diodes and FETs fabricated from regioregular poly(3-hexylthiophene) (rr-P3HT). Surface treatment of the substrate and different solvents for the polymer are used to change the degree of ordering of the polymer and study its influence on charge carrier transport. The charge carrier mobilities as extracted from space-charge limited currents of diodes, from relaxation frequencies in MIS diodes and from the transfer characteristics of FETs show different magnitude and temperature dependence. Applying an analytical model [1] for the hopping mobility in amorphous films a distinction between the effects of charge carrier density on the one hand and of structural anisotropy on the other hand is possible.

[1] W.F. Pasveer et al., *Phys. Rev. Lett.* **94** (2005) 206601.

CPP 23.15 Thu 17:00 P2

Field-Effect Mobility in n -doped C_{60} Thin Films: Dependency on Gate Bias and Temperature — ●KENTARO HARADA¹, FENGHONG LI¹, MARTIN PFEIFFER¹, ANSGAR G. WERNER², and KARL LEO¹ — ¹Institut für Angewandte Photophysik, Technische Universität Dresden, 01062 Dresden, Germany — ²Novalad GmbH, Tatzberg 49, 01307 Dresden, Germany

We study the gate bias and temperature dependence of field-effect mobility in n -doped C_{60} thin films with different doping concentrations of Acridine Orange Base (AOB, $C_{17}H_{19}N_3$). The n -doping of AOB enhances the bulk conductivity of C_{60} , whereas the application of a gate bias leads to an increase of transverse conductance between source and drain. For a heavily doped C_{60} sample, the field-effect mobility has already reached its maximum without gate bias, and an increase of the gate bias does not give a contribution to the mobility at all. Yet, an elevation of temperature from 180 K to 340 K does give rise to the activation of the field-effect mobility until a clear transition to the saturation regime appears around 270 K; thereafter the mobility stays nearly constant at $0.13\text{ cm}^2/\text{Vs}$. On the other hand, for a lightly doped sample, the field-effect mobility is gate bias dependent within the measured bias and temperature range, indicating that both the field induced and the thermally activated carrier density play a role in mobility enhancement. We discuss these phenomena in accordance with the trap-filling models that have been proposed to explain the charge transport mechanism in organic materials.

CPP 23.16 Thu 17:00 P2

Organic Field-Effect Transistors Utilising Highly Soluble Oligothiophene Based Swivel Cruciform — ●ACHMAD ZEN¹, PATRICK PINGEL¹, DIETER NEHER¹, JOERG GRENZER², ASKIN BILGE³, TONY FARRELL³, ULLRICH SCHERF³, FERDINAND GROZEMA⁴, and LAURENS SIEBBELES⁴ — ¹Institute of Physics, University of Potsdam, Am Neuen Palais 10, 14469 Potsdam, Germany — ²Institute of Ion Beam Physics and Materials Research, Bautzner Landstrasse 128, 01328 Dresden, Germany — ³Macromolecular Chemistry, University of Wuppertal, Gauss Str.20, 42097 Wuppertal, Germany — ⁴Interfaculty Reactor Institute, Delft University of Technology, Mekelweg 15, 2629 JB Delft, The Netherlands

Two types of highly soluble oligothiophene based swivel cruciforms are presented as semiconducting materials in OFETs. Transistors made from these oligomers exhibited mobilities of more than $0.01\text{ cm}^2/\text{Vs}$ and current on/off ratio of $>10^5$. This is among the highest values reported to date for wet processed OFETs utilising oligothiophenes. In fact, the OFET-mobilities are comparable to values extracted from pulse-radiolysis time resolved microwave conductivity (PR-TRMC) experiments, indicating that carrier trapping is insignificant. In depth examination of the morphological, optical characteristics and thermal stability of the materials were carried to obtain information on the packing of the oligomers in the layer. Finally, the correlation between the transistor performance and the crystallinity of the layers is addressed.

CPP 23.17 Thu 17:00 P2

Growth and Characterisation of Substituted Phthalocyanines for Applications in Organic Field Effect Transistors — ●HARRY BRINKMANN, CHRISTIAN KELTING, and DERCK SCHLETTWEIN — Justus-Liebig-Universität Gießen, Institut für Angewandte Physik, Heinrich-Buff-Ring 16, D-35392 Gießen

Partially fluorinated phthalocyanines were examined aiming at their electric properties. According to the position of their electronic energy levels, located just intermediate between unsubstituted and perfluorinated phthalocyanines, interesting properties as molecular semiconductors can be expected. Thin films of these partially fluorinated phthalocyanines were deposited either on glass or polyimide, the latter serving as an insulator substrate to study possibilities in realization of an all organic field-effect-transistor. The organic layers were grown by PVD. Optical absorbance and electrical conduction were studied dependent on the film thickness, substrate and contact material. Applicability of such layers in technical devices will be discussed.

CPP 23.18 Thu 17:00 P2

60nm to 40µm channel lengths poly(3-hexyl-thiophene) field effect transistors - Identifying the inner transistor — ●J. SEEKAMP, A. HOPPE, T. BALSTER, T. MUCK, and V. WAGNER — School of Engineering and Science, International University Bremen, 28759 Bremen, Germany

Polymer based nanoscale field effect transistors with poly(3-hexylthiophene)(P3HT) as the organic semiconductor were characterised and compared to longer channel devices. Meaningful mobility values are essential for this comparison. Recent publications agree on applied models either not fitting sufficiently or demanding for physical insight hardly obtainable [1,2]. A slightly different approach to analyse bottom contact field effect transistors with interdigitated Ti/Au (3nm/20nm) gold electrodes, 50nm silicon oxide as the gate insulator, P3HT and channel lengths between 60nm and 40µm is proposed here. Firstly, results were analysed using the "classical" gradual channel approximation [2]. Apparent mobilities [1] achieved this way varied between $0.2\text{ cm}^2/(\text{Vs})$ for 40µm channel length and $10^{-3}\text{ cm}^2/(\text{Vs})$ for 60nm channel length in linear regime for high V_{gs} . These mobilities vary with V_{ds} and V_{gs} . To achieve more consistent values the measured data were corrected for a gate source and a bulk current modelled as voltage controlled current sources. Analysis of such corrected data resulted in mobilities of around $10^{-3}\text{ cm}^2/(\text{Vs})$ for channel lengths between 20µm and 125nm. Apparent short channel effects were only observed for shorter channel lengths which are comparable to the oxide thickness. [1]G.Wang, et al., J. Appl. Phys. 93(10)(2003)6137; [2]M.L.Chabiny, et al., J. Appl. Phys. 96(4)(2004)2063

CPP 23.19 Thu 17:00 P2

Electrical investigations on nanoscale oligothiophene transistors — ●ARNE HOPPE, JÖRG SEEKAMP, TOBIAS MUCK, TORSTEN BALSTER, and VEIT WAGNER — International University Bremen, Bremen, Germany

High transfer frequencies demand for nanoscale channel lengths combined with relatively high mobilities. Since contact properties seem to play an important role when downscaling the channel lengths of the device, materials have to be found, which show acceptable mobilities and good contact properties in short channels. Potential candidates are alkyl-substituted oligothiophenes. We showed already for micrometer-sized organic field-effect transistors (OFETs) that with growing number of thiophene rings the mobility increases. Channel lengths of interdigitated electrodes in the range from $40\mu\text{m}$ to below 50 nm , produced by e-beam lithography, were investigated. We used Dihexyl-n-thiophenes (DHnT) with n , the number of thiophene rings, ranging from four to seven as organic semiconductor. Organic molecular beam deposition (OMBD) in ultra-high vacuum was used to deposit the semiconductor onto the substrate at temperatures between $100\text{ }^\circ\text{C}$ and $190\text{ }^\circ\text{C}$. The $40\mu\text{m}$ devices serve as a long channel reference point. Mobility values evaluated within the gradual channel approximation are as high as $0.11\text{ cm}^2/(\text{Vs})$ for the $40\mu\text{m}$ reference transistor. Lower mobilities were observed for smaller channel lengths. We found an increase in mobility with a higher number of thiophene rings for nanoscale channels. A model is presented to explain the correlation between mobility values, the length of the π -system and the channel length.

CPP 23.20 Thu 17:00 P2

Patterning of Thin Films for Organic Electronics by Microcontact Printing of Self Assembled Monolayers — ●AMARE BENOR, KAH-YOONG CHAN, and DIETMAR KNIPP — International University Bremen, School of Engineering and Science, 28759 Bremen, Germany

Micro Contact Printing (μCP) has become widely used technique in patterning thin film structures on the micron and nanoscale. Printing self-assembled monolayers (SAMs) in combination with selective surface wetting was used to realize radio frequency micro coils and electrodes of pentacene thin film transistors for radio frequency information tags (RFID tags). In this study we used the self-assembled monolayers (Octadecyltrichlorosilane, OTS), $\text{CH}_3(\text{CH}_2)_{17}\text{SiCl}_3$, which was printed on cleaned silicon or glass substrate by a poly(dimethylsiloxane), PDMS. The printed monolayer leads to the formation of hydrophobic regions, and the unprinted region remained hydrophilic which facilitates the selective deposition of polymers or resists like Poly(methyl methacrylate), PMMA on the hydrophilic region. In the next step, a standard lift-off process was used to pattern gold, titanium metal thin films. This technique was applied to realize radio frequency (RF) coils and electrodes for pentacene thin film transistors. The influence of processing parameters like: the geometry of the structures, the chemistry of the heterogeneous substrate and the polymer will be discussed. Moreover, fundamental printing limits of the method will be seen based on simple model to describe the limiting factors. Finally, the pentacene transistors will be compared with transistors prepared by optical lithography.

CPP 23.21 Thu 17:00 P2

Improvement of the ambience stability of field effect transistors based on poly(3-hexylthiophene) by molecular design modification — ●DESSLAVA SAINOVA¹, SILVIA JANIETZ¹, UDOM ASAWAPIROM¹, LORENZ ROMANER², NORBERT KOCH², and AN-TJE VOLLMER³ — ¹Fraunhofer Institute for Applied Polymer Research, Geiselbergstr. 69, 14476 Golm — ²Humboldt-Universität zu Berlin, Institut f. Physik, 12489 Berlin — ³BESSY GmbH, 12489 Berlin

Regioregular poly(3-hexylthiophene) (P3HT) belongs to the most attractive soluble polymers for applications in organic field effect transistors (OFETs). The key feature of P3HT is the self-alignment ability that facilitates the formation of crystalline thin films with well-ordered lamellae of co-facially stacked main chains. This assembly ensures fast charge transport in the layer of the ordered backbones and consequently high field effect mobilities. Nevertheless the successful performance of P3HT in OFETs is hindered by the limited operation under air. Both high field effect mobility and ambience stability are essential for practical application purposes. To achieve this attractive combination of properties we have modified the molecular structure of P3HT by introducing tetrafluorobenzene (TFB) units linked in the main chain. The TFB amount is varied to find an optimum between the processability, the ionization potential (IP) and the transistor performance of the synthesized polymers. As a result have been achieved field effect mobilities of $10\text{-}2\text{ cm}^2/\text{Vs}$ and ON/OFF ratios of 104. In addition, the OFET performance is retained after several days of air exposure due to the IP-shift up to 0.3 eV as determined by photoemission investigations.

CPP 23.22 Thu 17:00 P2

Encapsulated organic thin film transistors at elevated temperatures — ●S. MEYER¹, J. PFLAUM¹, S. SELLNER², G. ULBRICHT², F. SCHREIBER³, H. DOSCH², M. FISCHER⁴, and B. GOMPFF⁴ — ¹III. Physikalisches Institut, Universität Stuttgart — ²Max-Planck-Institut für Metallforschung, Stuttgart — ³Institut für Angewandte Physik, Universität Tübingen — ⁴I. Physikalisches Institut, Universität Stuttgart

To address the problem of thermal stability of organic semiconductor layers under realistic device conditions we have performed studies on pentacene thin film transistors with and without encapsulation. The capping is realized by a $2\mu\text{m}$ polymer layer of poly-*para*-xylylene (PPX) or, alternatively, by a 100 nm thick sputtering layer of aluminum oxide (AlOx.). On capped pentacene TFTs a field-effect can be demonstrated for both encapsulations up to temperatures of $140\text{ }^\circ\text{C}$ which is about $40\text{ }^\circ\text{C}$ above the desorption point of uncapped pentacene films on SiO_2 . From the TFT characteristics a complex behavior of the temperature dependent hole mobility can be deduced, indicating that the device operation at these elevated temperatures is predominantly limited by the transistor structure and not by the organic material itself.

This is confirmed by thermal desorption spectroscopy and X-ray diffraction studies on pentacene thin films, showing that the organic layer remains crystalline for both capping materials far above the breakdown temperature of the TFTs. As was previously demonstrated for AlOx.-capped diindenoperylene thin films [1], the structural breakdown is a function of heating rate and thickness of the capping layer.

[1] Sellner et al., Adv. Mat. **16**, 1750 (2004)

CPP 23.23 Thu 17:00 P2

Influence of source/drain contact metal on organic field-effect transistors and MIS- capacitors — ●ANDREI HERASIMOVICH, INGO HOERSELMANN, and SUSANNE SCHEINERT — TU Ilmenau, PF, 98684 Ilmenau, Germany

We have investigated the influence of the contact material on the current characteristics of organic field-effect transistors (OFETs) and on the frequency response of MIS-capacitors, based on spin coated poly(3-hexylthiophene) (P3HT). Aluminium contacts were evaporated on one half of the substrate and gold contacts on the other one. The measured frequency response of the capacitance shows clearly a smaller cut-off frequency in the case of the Al contact. The measured output characteristics of the transistor with gold source/drain contacts show a linear dependence at small drain voltages whereas the increase of the current for Al contacts is non-linear. Such non-linearity was attributed in [1] to the field dependence of the mobility due to the Poole-Frenkel effect, whereas in [2] series resistances are described as the reason. Using different materials for the contacts, we can investigate these effects separately. We discuss the temperature influence on the non-linearities in the characteristics of the OFETs and on the impedance of the MOS- capacitors and compare the obtained results with these ones obtained from 2D simulations to clarify the reasons for the measured peculiarities.

[1] P. Stallinga et al., Appl. Phys. Lett. **96**, 5277 (2004)[2] G. Horowitz et al., J. Appl. Phys. **87**, 4456 (2000)

CPP 23.24 Thu 17:00 P2

Analysis of pentacene-OFET characteristics by a modified a-Si-model — ●SUSANNE SCHEINERT¹ and GERNOT PAASCH² — ¹TU Ilmenau — ²IFW Dresden

Measured current characteristics of pentacene OFETs depend strongly on the silanisation process [1]. Traps can be the reason for such peculiarities in organic field-effect transistors (OFET) and often the so-called a-Si-model is the appropriate one. We have investigated whether it is possible to describe the measurements with this model. Numerical two-dimensional simulations have been carried out with a systematic variation of interface and bulk trap parameters. Comparison with the measured curves shows, that both donor-like and acceptor-like traps near the valence band have to be supposed to describe the measurements. However, with a high trap concentration in a narrow distribution one obtains the same current characteristics, including the temperature dependence, as with a lower concentration and a broader distribution. Moreover, in addition also distributed interface traps have to be taken into account to obtain a satisfactory description of the experimental current characteristics. Even though the characteristics can be described well, a unique extraction of trap parameters solely from transistor current characteristics is not possible.

[1] I.K.P. Pernstich, S. Haas, D. Oberhoff, C. Goldmann, D.J. Gundlach, B. Batlogg, A.N. Rashid, G. Schitter, J. Appl. Phys. **96** (2004) 6431.

CPP 23.25 Thu 17:00 P2

Analysis of OTFT Device Parameters based on Measurement and Simulation of IV and CV Characteristics — ●CHRISTOPH ERLÉN and PAOLO LUGLI — Munich University of Technology

Advances in fabrication techniques have led to organic TFTs (OTFTs), which are increasingly interesting for electronic applications. We have used different methods including finite element device simulations in a commercial environment (ISETCAD)[1] in order to extract relevant material and transistor parameters from experimental data. Dynamic CV measurements have been analyzed to crosscheck results for e.g. interface charges and trap densities obtained by simulation. These measurements are additionally employed to address dynamic OTFT characteristics. It is shown that next to material properties, device layout plays an important role in determining the transient transistor behavior. The research is conducted in close cooperation with M. Fiebig, S. Schiefer, M. Huth, U. Beierlein and B. Nickel, Department fuer Physik, Ludwig-Maximilians-Universitaet, Munich, who provided the experimental data for bottom contact Pentacene TFTs.

[1] Bolognesi et al. IEEE Trans. Elect. Dev., 51(12):1997, 2004.

CPP 23.26 Thu 17:00 P2

Charge mobility in Pentacene TFTs: a comparison of I-V and capacitance measurements — ●MATTHIAS FIEBIG, STEFAN SCHIEFER, MARTIN HUTH, UDO BEIERLEIN, and BERT NICKEL — Department für Physik and CeNS, Ludwig-Maximilians-Universität, München

Pentacene is one of the most promising materials for organic thin film transistors (OTFTs). We have prepared bottom contact Pentacene TFTs on SiO₂ by deposition in UHV. The high structural quality of the devices has been characterized by AFM and synchrotron x-ray diffraction. Transistor behavior has been tested by IV-measurements and mobilities of the order of 1 cm²/Vs have been achieved. Complementary capacitance measurements have been performed to address dynamic properties of the charge transport. The experimental results are simulated and analysed in collaboration with C. Erlen and P. Lugli, Institute for Nanoelectronics, TU München.

CPP 23.27 Thu 17:00 P2

The influence of SiO₂ dielectric interface modification on ambipolar transport in Pentacene TFTs — ●NIELS BENSON¹, MARCUS AHLES¹, THOMAS MAYER¹, ERIC MANKEL¹, ANDREA GASSMANN¹, ROLAND SCHMECHEL², and HEINZ V. SEGGERN¹ — ¹TU Darmstadt, Institute of Materials Science, Petersenstraße 23, D-64287 Darmstadt, Germany — ²Forschungszentrum Karlsruhe (FZK) Institut für Nanotechnologie, PF 3640, 76021 Karlsruhe, Germany

Recently an n-type Pentacene OFET, using traces of Calcium between SiO₂ and Pentacene has been demonstrated. This OFET exhibits electron transport properties similar to those of holes observed in a corresponding p-type OFET. Results on XPS measurements unveiling the influence of Ca on the SiO₂ surface are presented. According to these measurements, the first deposited Ca performs a chemical reaction with the SiO₂ interface. Metallic Ca is found only at higher nominal thickness. Moreover, characteristics of OFETs are presented, where thin intermediate polymer dielectrics selected with respect to functional end groups and their polarity have been employed between SiO₂ and Pentacene. A clear correlation between the occurrence of ambipolar transport and the molecular polarity has been revealed. From the present results, interface modifications with different polymer dielectrics as well as traces of Ca result in different interfacial electron trap densities, allowing a modification of the OFET threshold. This is a step toward to a better control of the device properties for organic integrated circuits and ambipolar OFETs.

CPP 23.28 Thu 17:00 P2

P(VDF/TrFE) as ferroelectric insulation layer for organic field effect transistors — ●KLAUS MÜLLER, KARSTEN HENKEL, IOANNA PALOUMPA, and DIETER SCHMEISSER — Brandenburgische Technische Universität Cottbus, Angewandte Physik-Sensorik, Konrad-Wachsmann-Allee 1, 03046 Cottbus

The ferroelectric polymer poly(vinylidene fluoride trifluoroethylene) (P(VDF-TrFE)) is used as insulating material for organic field effect transistors (OFET) and metal-insulator-semiconductor (MIS)-structures. For the MIS-structures, we find the typical hysteresis in the CV characteristic upon increasing the voltage scan window. Based on these results, we fabricate OFET with regioregular poly(3-hexylthiophene) (P3HT) as

organic semiconductor. The transistors are constructed in bottom gate architecture with thin layers of spincoated P(VDF-TrFE) as gate insulation (100nm). The drain-source current of the OFET is reversible affected by the polarized gate, which gives opportunities for organic nonvolatile memory elements. We present characteristic features like the hysteretic drain current response or the data retention. Furthermore, we present measurements with Kelvin probe force microscopy, a method which gives informations on the lateral distributions of the surface potential.

CPP 23.29 Thu 17:00 P2

Toward the fabrication of a monomolecular insulator film — ●MICHAEL ZHARNIKOV, YIAN TAI, HIROYUKI NODA, ANDREY SHAPORENKO, and MICHAEL GRUNZE — Angewandte Physikalische Chemie, Universität Heidelberg, Im Neuenheimer Feld 253, Heidelberg

Progress in fabricating smaller and more efficient structures in electronic and spintronic devices depends on better dielectric materials for nanofabrication. A perspective nanoinulator is a molecular thin organic film - self-assembled monolayer (SAM), which provide an alternative to commonly used oxide dielectrics. A so far unresolved technological problem for insulator applications of SAMs is the difficulty of fabricating stable metal layers on their surfaces, i.e. at the SAM-ambient interface. Such a film is generally leaky for metal adsorbates, which makes it impossible to integrate it into a multilayer assembly (e.g. in a tunnel junction magnetic memory cell) or to fabricate metal electrodes on its surface (e.g. in an organic thin film transistor). Using nickel as a test metal adsorbate and several different substituted and non-substituted SAMs as test substrates, we show that this difficulty can be overcome by the combination of a special design of the SAM constituents and their extensive cross-linking by low-energy electron irradiation. The properties of the SAM insulator and the metal overlayer were monitored by several complementary experimental techniques, including X-ray absorption spectroscopy and electrochemical measurements. The approach represents an important step toward the technological applications of monomolecular dielectric layers.

CPP 23.30 Thu 17:00 P2

Top emitting organic light emitting diodes with improved out-coupling efficiency by organic capping layer — ●QIANG HUANG¹, KARSTEN WALZER¹, MARTIN PFEIFFER¹, GUFENG HE¹, KARL LEO¹, MICHAEL HOFMANN², and THOMAS STÜBINGER² — ¹Institut für Angewandte Photophysik, TU Dresden, D-01062 Dresden, Germany — ²Novald GmbH, Tatzberg 49, D-01307 Dresden, Germany

The improvement of light outcoupling from organic LEDs is a significant way for increasing the device efficiency. One way to reach this is the use of organic outcoupling layers. We study the emission properties of top emitting OLEDs with different organic capping layer thickness to understand the effect of the capping layer. The distribution pattern of the emitted light from a top emitting OLED depends strongly on the capping layer thickness, with a maximum enhancement of current efficiency by 38%, and quantum efficiency by 35%. This enhancement is not due to the redistribution of emitted light but mainly due to the improvement of outcoupling efficiency by changing the overall optical device structure. At 90 nm capping layer thickness, the device has optimum performance, showing 78 cd/A at 1000 cd/m² in forward direction as well as a quantum efficiency of 17.8 % and power efficiency of 69 lm/W.

[1]V. Bulovic, G. Gu, P. E. Burrows, V. Khalfin, V. G. Kozlov, and S. R. Forrest, Nature (London) 380, 29 (1996). [2]H. Riel, S. Karg, T. Beierlein, B. Ruhstaller, and W. Rieß, Appl. Phys. Lett. 82, 466 (2002). [3]G. F. He, M. Pfeiffer, K. Leo, M. Hofmann, J. Birnstock, R. Pudzich, and J. Salbeck, Appl. Phys. Lett. 85, 3911 (2004).

CPP 23.31 Thu 17:00 P2

Efficient polymer electrophosphorescent devices with interfacial layers — ●XIAOHUI YANG¹, FRANK JAISER¹, BURKHARD STILLER¹, DIETER NEHER¹, FRANK GALBRECHT², and ULLI SCHERF² — ¹Universität Potsdam, Am Neuen Palais 10, 14469 Potsdam — ²Bergische Universität Wuppertal, Fachbereich Chemie, Makromolekulare Chemie, Gaußstr. 20, 42097 Wuppertal

We show that several large band-gap hole-transporting polymers can form insoluble interfacial layers on PEDOT:PSS. The thickness of the interlayer is dependent of the characteristics of underlying PEDOT:PSS and the molecular weight of the polymers. It is further shown that the electronic structures of the interlayer polymers have a significant effect on the properties of red-emitting polymer-based electrophosphorescent devices. Upon increasing the HOMO and LUMO level positions, a sig-

nificant increase in current density and in device efficiency was observed. This is attributed to the efficient blocking of electrons in combination with the direct injection of holes from the interlayer to the triplet dye. Upon proper choice of the interlayer polymer, efficient polymer deep-red electrophosphorescent devices with a peak luminance efficiency of 5.5 cd/A (external quantum efficiency = 6 %) and a maximum power conversion efficiency of 5 lm/W could be realized.

CPP 23.32 Thu 17:00 P2

High efficiency white organic light emitting devices combining fluorescent and phosphorescent emitter systems — ●GREGOR SCHWARTZ, KARSTEN WALZER, MARTIN PFEIFFER, and KARL LEO — Institut für Angewandte Photophysik, Technische Universität Dresden, D-01062 Dresden

Light sources suitable for lighting applications need to combine high power efficiency at high brightness, good color rendering as well as color coordinates matching those of the standard reference illuminants. We demonstrate white organic light emitting devices (WOLED) combining a blue fluorescent dye with red and green Iridium based phosphorescent dopants in separate host materials. The devices are competitive with the best reported ones based on three phosphorescent emitters. In our WOLEDs, we could simultaneously achieve a power efficiency of 13.7lm/W at a brightness of 1000cd/m², a color rendering index of 85 and color coordinates of (0.47/0.42), which is a color very close to the standard warm white illuminant A. Crucial features of the devices are the use of electrically doped transport layers (p-i-n concept) which leads to low driving voltages, and a thin additional layer separating the fluorescent dye from the two phosphorescent emitter systems to prevent Dexter type quenching of the phosphorescent emission. We studied the influence of thickness and doping ratio of the different layers on the electroluminescence spectrum and on the current-voltage characteristics to understand the charge carrier balance and mechanisms of exciton generation inside the devices.

CPP 23.33 Thu 17:00 P2

Highly efficient and long-living red p-i-n bottom emission OLEDs based on triplet emitter systems — ●RICO MEERHEIM, KARSTEN WALZER, MARTIN PFEIFFER, and KARL LEO — Institut für Angewandte Photophysik (IAPP), Technische Universität Dresden, George-Bähr-Str. 1, D-01062 Dresden, Germany

A way to reach highly efficient red bottom emission OLEDs is the use of doped transport layers and phosphorescent emitter materials for high quantum yield. We will show how the efficiency of such devices can be further increased. The p-i-n devices consist of doped transport layers, charge and exciton blockers, and a dilute emitter substance within an appropriate emitter matrix. Most advantageous for high efficiency is a nearly ambipolar emission system to create a broad light generation zone. Therefore, the favoured charge carrier type of different emission layers was studied. By combining preferably electron and hole conducting hosts, doped with the same triplet emitter dye, we reach a well-balanced emission layer (leading to a double emission layer structure) where the charge recombination occurs mainly close to the interface of both emission layer. This approach enables us to increase the 100 cd/m² efficiency from 9.3 cd/A to 11.2 cd/A with a high device stability of more than 50.000 hours lifetime. Both can be explained by reduced number of charge carriers leaking to the opposite blocking layers and less exciton-exciton quenching due to a reduced charge and exciton accumulation.

CPP 23.34 Thu 17:00 P2

Investigation of triplet exciton quenching in red phosphorescent OLEDs — ●SEBASTIAN REINEKE, MARTIN PFEIFFER, KARSTEN WALZER, and KARL LEO — Institut für Angewandte Photophysik, Technische Universität Dresden, George-Bähr-Str. 1, D-01062 Dresden, Germany

We studied the quenching processes which contribute to the roll-off in quantum efficiency of phosphorescent OLEDs at high brightness. Possible processes are triplet-triplet annihilation (TTA), energy transfer to charged molecules (polarons) and the dissociation of excitons into free charges. The investigated OLED comprises a host-guest system as emission layer (EML) within a five layer structure including blocking and p- and n-doped transport layers. Here, N,N'-di(naphthalen-2-yl)-N,N'-diphenyl-benzidine is used as matrix and tris(1-phenylisoquinoline) iridium as phosphorescent emitter material. We found that the decrease of efficiency can be appointed to both TTA and energy transfer to

charged molecules. Field-induced dissociation of excitons was not observed. Time-resolved measurements for the investigation of TTA as well as cw measurements for triplet-polaron quenching were performed. They are analyzed and combined to understand the efficiency drop in OLEDs. This work shows that both processes occur in the range of current density which is typical for OLED operation. An analytical discussion of both processes will be used to point out the magnitude of the different mechanisms.

CPP 23.35 Thu 17:00 P2

Enhancement of light out-coupling for OLEDs — ●DIRK BUCHHAUSER^{1,2}, CHRISTOPH GAERDITZ^{1,3}, RALPH PAETZOLD¹, OIIVER WEISS^{1,4}, JOACHIM WECKER¹, and JUERGEN RUEDIGER NIKLAS² — ¹Siemens AG, Corporate Technology, Günther Scharowsky Str. 1, 91058 Erlangen, Germany — ²Department of Experimental Physics, University of Freiberg, Silbermannstrasse 1, 09599 Freiberg, Germany — ³Department of Material Science VI, University Erlangen-Nuremberg, Germany — ⁴Department of Materials Science, Technical University of Darmstadt, Petersenstraße 23, 64287 Darmstadt, Germany

OLED technology is attracting more and more attention for lighting applications, because they provide striking advantages over competing technologies and can cover completely new application fields by offering a new freedom in design and shape for next generation lighting. Large area OLEDs might hence be used as 2-dimensional light sources which are thin and lightweight while providing diffuse illumination. OLEDs for illumination require brightness levels of 1000 cd/m² or more and an active area in the order of tens of cm². The efficiency of the lighting tiles can be significantly enhanced by using scattering structures on top of the substrate in order to improve the out-coupling behavior. Furthermore, such scattering layers can provide improved color stability over the entire viewing angle. Scattering layers are realized by films containing a certain concentration of particles or by physically structured surfaces. We present results on OLEDs based on white light-emitting polymers. The impact of scattering foils for light extraction and angular color stability are analyzed compared with simulations.

CPP 23.36 Thu 17:00 P2

Distributed Feedback Structures in active OLED-Layers by Photolithography — ●MATTHIAS DE LA ROSA, KLAUS MEERHOLZ, and JONAS KREMER — Physical Chemistry Department II, Luxemburgstr. 116, 50939 Köln

Waveguide losses often result in poor external efficiencies with thin-film organic light emitting diodes (OLEDs). Among other approaches distributed feedback (DFB) structures have been used to overcome this problem by applying additional structured layers underneath the emissive layers in the device. Correct choice of the DFB structure properties like amplitude and period of the grating can lead to enhanced directed emission. Furthermore, such periodic modulations are of great importance in amplified spontaneous emission (ASE) applications like organic polymer lasers. We introduced a lithographic pathway of direct structuring to the OLED fabrication process using cross-linkable emitter and hole-transport materials, respectively. The impact of the DFB gratings onto the performance and spectral emission of the OLEDs was examined and an increase in the efficiency [Cd/A] by a factor of 1.5 could be observed whilst the emission spectra of the corrugated devices hardly changed. Other experiments with DFB structures in ASE materials are in progress to achieve better understanding for further organic polymer laser applications.

CPP 23.37 Thu 17:00 P2

Optical Studies on the Leaky Mode Emission of Organic Light Emitting Devices — ●NILS A. REINKE, MICHAEL HUTZEL, JOHANNES HÖCHTL, CLAUDIA ACKERMANN, and WOLFGANG BRÜTTING — Experimental Physics IV, Institute of Physics, University of Augsburg, Germany

In bottom emitting OLEDs, usually a large fraction of light generated in the organic multilayer stack is wave-guided inside the substrate and is either reabsorbed by the organic layers or edge emitted. Thus light propagating at angles larger than the critical angle for total internal reflection ($\approx 42^\circ$) is not accessible. These losses can be decreased by coupling the substrate to an optical element. This allows observation of light emission over all angles and increases the emission intensity of ITO-based OLEDs in forward direction by 50% with respect to the freestanding device.

In order to enhance the coupling of the guided leaky modes to the adjacent optical element and therefore to external modes, we utilized

a microcavity structure by replacing the ITO anode by a thin metal film. In this configuration, the metal film enhances the gain of guided leaky modes whereas the contribution of non-guided modes is suppressed. These devices show highly polarised emission (TE mode) and tuneable emission wavelength over a wide angular range. The observed behaviour can be predicted quantitatively by simulations which are based on the transfer matrix formalism.

CPP 23.38 Thu 17:00 P2

Lasng from Optically Structured Organic Microcavities — ●PHILIPP SCHNEEWEISS, MARKO SWOBODA, ROBERT GEHLHAAR, VADIM G. LYSSENKO, MICHAEL HOFFMANN, and KARL LEO — Institut für Angewandte Photophysik, Technische Universität Dresden, 01062 Dresden, Germany, www.iapp.de

The emissive properties of an organic microcavity laser filled with the guest:host system of tris-(8-hydroxy quinoline)aluminium (AlQ₃) and 4-(dicyanomethylene)-2-methyl-6-(p-dimethylaminostyryl)-4H-pyran (DCM) are studied. Simultaneous excitation with two pump-pulses leads to the formation of an interference grating-structure in the active layer. Besides to the expected vertical cavity-surface emitting laser behaviour, this results in two additional outer modes appearing under an angle defined by the distance of the interference fringes. The outer modes show a blueshift varying around 0.2 nm that can be tuned with the interference pattern. Optical anisotropy in the dielectric layers of the microcavity mirrors leads to polarization splitting and emission at two perpendicularly polarized lines.

CPP 23.39 Thu 17:00 P2

Pump-probe spectroscopy of organic semiconductor-hetero-systems — ●R. NÜSKE, E. ENGEL, K. LEO, and M. HOFFMANN — Institut für Angewandte Photophysik, TU Dresden, 01062 Dresden, Germany, www.iapp.de

The transport properties of photo-generated excitons in organic semiconductors are important parameters for the development of optoelectronic devices. We investigate double-layer systems with thin films of PTCDA (perylene-3,4,9,10-tetracarboxylic-dianhydride) and TiOPc (titanyl-phthalocyanine). Excitons generated in PTCDA are transferred by diffusion or Förster transfer to TiOPc. A femtosecond white-light continuum is used to record transient absorption spectra in the range between 1.2 eV and 2.6 eV. From the dynamics of the transient spectra, we infer the transfer rates of excitons from PTCDA to TiOPc. These rates are in accordance with luminescence quenching experiments reported recently [1].

[1] R.Schüppel et al., *J.Lumin.* **110**, 309 (2004).

CPP 23.40 Thu 17:00 P2

The different effect of anode/organic-interlayers on electrical fatigue and photodegradation of organic light emitting diodes — ●ARNE FLEISSNER, CHRISTIAN MELZER, ROLAND SCHMECHEL, and HEINZ VON SEGGERN — Electronic Materials Department, Institute of Materials Science, Darmstadt University of Technology, Petersenstr. 23, 64287 Darmstadt, Germany

Recently, the photodegradation of organic light emitting diodes (OLEDs) due to the exposure to visible and near-ultraviolet light through the Indium Tin Oxide (ITO) anode has been investigated [*J. Appl. Phys.* **97**, 124501 (2005)]. The ITO/organic-interface and the occurrence of excited organic molecules has been identified as crucial. Introducing appropriate interlayers between ITO and organic, e.g. a thin film of pentacene, suppressed the photodegradation. However, a PEDOT:PSS interlayer did not. In this work, the influence of such anode/organic-interlayers on electrical fatigue is studied. For that purpose, OLEDs with different interlayers between ITO and organic are operated in constant current mode while the time dependent driving voltage, electroluminescence intensity, and photoluminescence intensity are measured. The PEDOT:PSS interlayer shows a remarkable difference in the two degradation modes: It decreases electrical fatigue, however, it does not suppress photodegradation. The different role of PEDOT:PSS in photodegradation and electrical fatigue and the underlying mechanisms are discussed.

CPP 23.41 Thu 17:00 P2

Comparison of the SIMS and XPS depth profile of new and aged OLED structures — ●SEBASTIAN SCHOLZ¹, KARSTEN WALZER¹, STEFFEN OSWALD², and KARL LEO¹ — ¹Institut für Angewandte Photophysik, TU Dresden, George-Bähr-Straße 1, 01069 Dresden — ²Leibniz-Institut für Festkörper- und Werkstofforschung Dresden, Helmholtzstraße 20, 01069 Dresden

An important issue of current organic light emitting diodes (OLED) research is the understanding of degradation mechanisms and the improvement of device lifetime. In this work we study the migration and/or diffusion of several metals (in neutral or ionic state) through the OLED during lifetime measurements. We take a closer look to the contact materials Ag, Al, Au, Sn and In, and the behaviour of Cs, the doping material in the electron transport layer. Since these metals are expected to quench the radiative recombination in the emitting layers of OLEDs, they should not enter the emission zone at any time. For the analysis of the metal diffusion we performed depth profiling on new and aged OLEDs and test devices by secondary ion mass spectroscopy (SIMS) and X-ray photoemission spectroscopy (XPS) for the characterization of the organic and metallic layers.

CPP 23.42 Thu 17:00 P2

Temperature Stability of Organic Light Emitting Diodes — ●PHILIPP WELLMANN, MICHAEL HOFMANN, ANSGAR WERNER, ANDRÉ GRÜSSING, MICHAEL LIMMERT, ANDREA LUX, and JAN BIRNSTOCK — Novald GmbH, Tatzberg 49, 01307 Dresden, Germany

Organic Light Emitting Diodes (OLED) have received much attention during the last years and are now approaching mass production. Using the so-called PIN-Technology (p- and n-doped transport layers) we have demonstrated a combination of very low driving voltage, high efficiency and long lifetime. However, for applications (especially for automotive) a high temperature stability is an important issue. A well know material combination for n-doping is BPhen (4,7-diphenyl-1,10-phenanthroline) doped with pure Cs in a co-evaporation process. However, this system is known to have a low temperature stability. BPhen has a Tg of approx. 65°C and the conductivity of n-doped BPhen quickly decreases at temperatures about 70°C. Using improved host materials and newly developed organic dopands, we have been able to increase Tg and the thermal stability of our n-doped transport layers significantly. A storage test at 110°C leads to a significant increase in driving voltage and strongly decreased efficiency for BPhen:Cs, whereas the OLEDs using a molecular dopand stay essentially unchanged. The operational lifetime of PIN-OLEDs has strongly increased in the last year reaching values of more then 20.000h for red /green and 5.000h for a deep blue at 500 cd/m² and room temperature. Using our molecular doping we have now been able to demonstrate a lifetime of more then 6.000h at 500 cd/m² at 80°C.

CPP 23.43 Thu 17:00 P2

Numerical Simulation of Multilayer Organic Light Emitting Diodes — ●OLIVER WEISS^{1,2}, CARSTEN TSCHAMBER^{3,2}, CHRISTOPH GÄRDITZ^{3,2}, DIRK BUCHHAUSER^{4,2}, ARVID HUNZE², JOACHIM WECKER², and HEINZ VON SEGGERN¹ — ¹Dept. Materials Science, Technical University of Darmstadt, Germany — ²Siemens AG, CT MM 1, Günther-Scharowsky-Str. 1, 91058 Erlangen, Germany — ³Dept. Materials Science VI, University of Erlangen-Nuremberg, Germany — ⁴Dept. Experimental Physics, University of Freiberg, Germany

Modelling of OLED devices helps understanding the corresponding physics and accelerates the development of stable and efficient organic stacks. A one-dimensional numerical model for the quantitative simulation of multilayer OLEDs was introduced by Staudigel. It includes amongst others charge carrier drift and diffusion, trapping, recombination, singlet exciton diffusion and quenching. The simulation program being developed at Siemens CT MM 1 is based on Staudigels work. The model is extended to handle an arbitrary number of organic layers and was further improved in numerous points. For low injection barriers, ohmic contacts are assumed and charge carriers drift from the electrodes to the organic monolayers driven by the electric field. For barriers higher than 0.3 eV a thermionic injection mechanism was implemented. Analytical solutions of a simple monolayer device including one discrete trap level are reproduced over several orders of magnitude by numerical simulation using the same set of input parameters. The presented results of modelling an efficient organic stack demonstrate the simulation tool's ability of characterising up-to-date multilayer OLEDs.

CPP 23.44 Thu 17:00 P2

Kinetic Monte Carlo Model of Space Charge Limited Currents in Organic Semiconductors — ●MICHAEL MÜLLER, KARSTEN ALBE, YURI GENENKO, FREDERIK NEUMANN, ROLAND SCHMECHEL, and HEINZ VON SEGGERN — Institut für Materialwissenschaft, Technische Universität Darmstadt, D-64287 Darmstadt

Kinetic Monte Carlo (KMC) simulations have proven to be a valuable tool for investigating the characteristics of hopping charge transport in disordered organic semiconductors [1]. However, owing to their long range nature, electrostatic interactions between the individual charge carriers commonly had to be neglected. In consequence, the applicability of the KMC method has been restricted to hopping transport at low charge carrier densities where interactions are regarded negligible, as it is the case for the injection limited regime.

Here, we present a KMC model that fully includes the electrostatic interactions between the charge carriers. Using this model, we investigate the current-voltage characteristic and the field dependence of the charge carrier mobility in the space charge limited regime for hopping systems with various degrees of disorder. In doing so, different models for the microscopic hopping rates (Miller-Abrahams hopping in the exact and the commonly used approximated formulation as well as the small polaron model) are applied. A significant dependence of the obtained characteristics on the choice of model is found and discussed.

[1] H. Bässler, *phys. stat. sol. (b)* **175**, 15 (1993)

CPP 23.45 Thu 17:00 P2

Electronic Transport in Thin Layers of Nano-Composites — ●VOLKER KUNTERMANN^{1,2}, CAROLA KRYSCHI¹, and DIETRICH HAARER² — ¹Department of Physical Chemistry I, Friedrich-Alexander-Universität Erlangen — ²Experimentalphysik/BIMF, Universität Bayreuth

We are reporting dynamic TOF (time-of-flight) experiments on single and double layers of organic and inorganic photoconductors. These experiments yield mobilities of the involved organic materials and of the inorganic/organic composite materials. As inorganic particles we focus on nano silicon particles, these we characterize in conjunction with typical organic hole transport materials, such as various TPDs (triphenyl-diamines). Parallel experiments are performed with the standard xerographic technique. The comparison of both experimental techniques allows us to cover an extremely wide range of materials mobilities.

CPP 23.46 Thu 17:00 P2

High Temperature Stable Solar Cells — ●RUDOLF LESSMANN, MARTIN PFEIFFER, and KARL LEO — Institut für Angewandte Photophysik - Technische Universität Dresden

We present an efficient MIP solar cell with p-doped layer using organic dopants that shows only low degradation upon 100 hours irradiation with a full sun at 80 °C and even withstands heating to 105 °C for some hours. The active layer is formed by a blend of buckminsterfullerene (C₆₀) and zinc-phthalocyanine (ZnPc); for the hole transport layer, a large triarylamine-based amorphous wide gap material with high glass transition temperature (NPD2) is used. The device structure is ITO / C₆₀ (5 nm) / C₆₀ : ZnPc [2:1] (30 nm) / NPD2 (5 nm) / p : NPD2 (40 nm) / p : ZnPc (10 nm) / Au (30 nm). The organic p-dopant was provided by NOVALED GmbH. It is used instead of the widely used F₄TCNQ because of its better thermal stability. Devices with good performance and high fillfactors up to 53% are obtained when grown with substrate temperature of 110 °C for the active layer and 40 °C for the p-doped layer. The power efficiency of these cells, working at ambient temperature, is around 1.5%.

CPP 23.47 Thu 17:00 P2

Investigation of excited states in P3HT and P3HT/PCBM composites — ●MORITZ LIEDTKE, JOHANNES SIEGER, CARSTEN DEIBEL, and VLADIMIR DYAKONOV — Experimental Physics VI, Physical Institute, University of Würzburg, 97074 Würzburg, Germany

Polymere-Fullerene composites exhibit efficient charge carrier generation due to ultrafast electron transfer which can be exploited for photovoltaic applications. Power efficiencies up to 5% have been achieved with bulk heterojunction solar cells fabricated from Poly(3-hexylthiophene) (P3HT) / [6,6] phenyl-C61-butyric acid methyl ester (PCBM) (1). In our work we studied excited states in regio-regular and regio-random P3HT by optical spectroscopy techniques like photoluminescence and photoinduced absorption (PIA) measurements. We discuss our results with re-

spect to the morphology of the P3HT and P3HT / PCBM blend films. (1) *Appl Phys Lett* **87**, 083506, 2005, Marisol Reyes-Reyes, Kyungkon Kim, and David L. Carroll

CPP 23.48 Thu 17:00 P2

Photoinduced Charge Transfer versus Triplet Exciton Formation in Polymer-Fullerene Composites: Consequences for Photovoltaic Performance — ●JOHANNES SIEGER¹, CARSTEN DEIBEL¹, VLADIMIR DYAKONOV¹, INGO RIEDEL², and MICHAEL PIENKKA³ — ¹Experimental Physics VI, Physical Institute, University of Würzburg, 97074 Würzburg, Germany — ²Bavarian Centre for Applied Energy Research (ZAE Bayern), Am Hubland, 97074 Würzburg, Germany — ³Energy and Semiconductor Research, Department of Physics, University of Oldenburg, 26129 Oldenburg, Germany

The conjugated polymer OC1C10-PPV blended with the electron accepting fullerene derivative PCBM is a material system which had a strong impact on the development of organic photovoltaics. Searching for alternative acceptor materials, the attention has recently been drawn to a class of dimethanofullerenes, which are fullerene derivatives with a higher solubility and a well established chemistry enabling structural modification of the side groups in a desired way. By replacing the PCBM with 1,1-bis(4,4-dodecyloxyphenyl)-(5,6)C61 (DPM-12), a high open-circuit voltage (close to 1 V) combined with a rather low photocurrent was obtained in DPM-12 based devices. In order to explain the phenomena observed, i.e., the formation of triplet excitons in the solar cell absorber containing DPM-12, systematic studies using light induced electron spin resonance and photoluminescence detected magnetic resonance were applied. For proving the triplet nature of the new photoinduced absorption band, a spin sensitive technique called photoinduced absorption detected magnetic resonance was used.

CPP 23.49 Thu 17:00 P2

Enhanced intersystem crossing in oligothiophene:fullerene blends — ●R. SCHÜPPEL¹, T. MÜLLER¹, C. UHRICH¹, A. PETRICH¹, M. PFEIFFER¹, K. LEO¹, P. KILICKIRAN², E. BRIER², and P. BÄUERLE² — ¹Institut für Angewandte Photophysik, Technische Universität Dresden, Germany, www.iapp.de — ²Abteilung Organische Chemie II, Universität Ulm, Germany, www.uni-ulm.de/oc2

Photoinduced and transient absorption spectroscopy is used to study the excited state properties in thin films of Dicyanovinyl-terthiophene (DCV3T) and blends of DCV3T with fullerene C₆₀. We find an enhanced triplet exciton generation in the blend layer, which is explained as an excitonic “ping-pong”-effect: Singlet energy transfer from DCV3T to C₆₀, evidenced by sensitized emission of C₆₀, followed by immediate intersystem crossing on C₆₀ and triplet exciton back transfer. The rate constants involved into the certain energy transfer mechanisms are discussed in detail. Furthermore, we discuss the triplet exciton densities achieved by the pump laser irradiation including annihilation processes in the precursor singlet state to obtain the triplet diffusion length. Based on long-ranged triplet exciton diffusion in combination with efficient intersystem crossing, a promising new concept of solar cells with an enlarged active layer thickness is introduced.

CPP 23.50 Thu 17:00 P2

Self assembled nanostructured photovoltaic devices made of functionalized block copolymers — ●SVEN HÜTTNER¹, STEFAN LINDNER², ARNAUD CHICHE¹, GEORG KRAUSCH¹, and MUKUNDAN THELAKKAT² — ¹Physikalische Chemie II, Universität Bayreuth, D-95440 Bayreuth, Germany — ²Makromolekulare Chemie I, Universität Bayreuth, D-95440 Bayreuth, Germany

We investigate the concept of photovoltaic devices based on block copolymers. The use of a functionalized block copolymer made of electron donor (D) and acceptor (A) polymers lead to a self assembled microstructure that insures the photon to be absorbed within a very short distance (tens nm) to the D-A interface. A block copolymer made of a poly(vinyltriphenylamine) (D) and poly perylene bisimide acrylate (A) has been synthesized [1]. Photovoltaic devices made of such a copolymer film have shown significantly better efficiencies than similar devices made from a blend of the corresponding homopolymers. The reason for that clearly lies in the different morphologies. The blend-based device exhibits a phase separation resulting in micron sized domains and resulting in an important loss of post-absorption excited states that cannot reach the interface.

[1] S. Lindner, M. Thelakkat: *Macromolecules* **37**, (2004) 8832-8835

CPP 23.51 Thu 17:00 P2

Optimization of organic thin-film photovoltaic cells based on the low gap oligothiophene derivative DCV3T — ●CHRISTIAN UHRICH¹, RICO SCHÜPPEL¹, KERSTIN SCHULZE¹, KARL LEO¹, MARTIN PFEIFFER¹, and PETER BÄUERLE² — ¹Institut für Angewandte Photophysik, TU Dresden — ²Abteilung Organische Chemie II, Universität Ulm

We have recently reported about a new oligothiophene derivate featuring dicyanovinylene end groups that can be used as acceptor material in organic thin-film photovoltaic cells. The material DCV3T has a high absorption coefficient ($\alpha = 2.5 \times 10^5 \text{ 1/cm}^2 @ 540\text{nm}$) absorbing light in a wide range. We prepared cells based on a flat heterojunction between DCV3T and 4P-TPD, a weakly donor-type amorphous material, embedded between ITO and a p-doped hole-transport layer. These cells reach an open-circuit-voltage of up to 1.04 V. Supported by optical simulations, we optimized the individual film thicknesses and improved the efficiency to 2.3 % at 100 mW/cm² simulated sunlight. The simulations also allow us to estimate the exciton-diffusion length in DCV3T. Moreover, we investigated the heterointerfaces comprised in the solar-cell structure by UPS and XPS measurements. These measurements give information about the HOMO-levels and possible interface dipoles.

CPP 23.52 Thu 17:00 P2

Efficient heterojunction organic solar cells with high photovoltages based on a new low-band-gap oligothiophene — ●KERSTIN SCHULZE¹, CHRISTIAN UHRICH¹, KARL LEO¹, MARTIN PFEIFFER¹, EDUARD BRIER², and PETER BÄUERLE² — ¹Institut für Angewandte Photophysik, Technische Universität Dresden, George-Bähr-Str. 1, 01069 Dresden — ²Abteilung Organische Chemie II, Universität Ulm, Albert Einstein Allee 11, 89081 Ulm

We report on efficient vacuum deposited heterojunction organic solar cells containing a new oligothiophene derivative with absorption onset at around 700nm as a donor and fullerene C60 as an acceptor. At the heterointerface between the low-band-gap oligothiophene and C60, photogenerated excitons from both materials are efficiently separated into electrons on C60 and holes on the low lying HOMO of the oligothiophene. With these materials we can reach high open circuit photovoltages of up to 1.0V. The most efficient solar cells (3.1% power efficiency at 133mW/cm² simulated sunlight) are obtained when the photoactive heterojunction is embedded between a p-doped hole transport layer on the anode side and a thin exciton blocking layer and aluminium on the cathode side. However, due to the high ionization energy of the oligothiophene (around 5.6+/-0.1eV as determined from UPS), hole injection from any anode or hole transport layer is difficult and the IV-curves thus show a characteristic s-shape which reduces the fill factor FF. It is found that the actual FF sensitively depends on the workfunction of the p-doped hole transport layer and the thickness of the oligothiophene layer.

CPP 23.53 Thu 17:00 P2

Exciplex dynamics in a M3EH-PPV:CN-Ether-PPV blend film and a D-A block copolymer film — ●CHUNHONG YIN¹, TH. KIETZKE^{1,2}, H.H. HÖRHHOLD³, and D. NEHER¹ — ¹Am Neuen Palais 10, 14469 Potsdam — ²Institute of Materials Research and Engineering (IMRE), Research Link 3, Singapore — ³University of Jena, Institute of Organic Chemistry and Macromolecular, Chemistry, Humboldtstr.10, 07743 Jena

Solar cells based on semiconducting polymers have attracted a lot of interest. However, currently the efficiencies of polymer-based solar cells are still lower than the values obtained from their inorganic counterparts. Here, we demonstrate efficient charge carrier recombination via exciplex emission in blends of M3EH-PPV and CN-Ether-PPV. We also show that the intensity of exciplex emission is significantly reduced upon annealing. At the same time, the corresponding solar cell efficiency increases largely. We attribute the improvement of solar cell efficiency to partial de-mixing of the polymer components. Apparently, charge carrier recombination via exciplex formation constitutes one of the loss channels which limits the efficiency of solar cells based on these polymers. In addition, a statistical D-A block copolymer, which can be considered as a model system of an ultra fine blend, was studied. In this case, the intensity of exciplex emission and the solar cell efficiency was only weakly altered upon annealing, indication that the significant changes observed for the blends are due to morphological effects.

Reference: Th. Kietzke, H.-H. Hörhold, D. Neher, Chem. Matter, in press

CPP 23.54 Thu 17:00 P2

Nanoporous TiO₂ / polyelectrolyte films — ●ROLF KNIPRATH and STEFAN KIRSTEIN — Humboldt University of Berlin

Porous TiO₂ films are a prerequisite for the fabrication of efficient dye-sensitized solar cells (DSSCs). They are used as an electrode and for sufficient absorption of light a very rough and highly porous TiO₂ surface is desired. In this work we report on the preparation and characterization of thin porous films of TiO₂ by alternate adsorption of TiO₂ nanoparticles and various polyelectrolytes from aqueous solutions. It is found that the structure of the films depends on the polyelectrolyte used and the preparation method. Besides surface roughness the porosity is determined by adsorption / desorption of dye molecules. The current transport through the films is investigated by measuring the current voltage characteristics of ITO/TiO₂/Au structures. The samples behave like Schottky diodes and it will be shown that the energy barriers at the Au / TiO₂ interface depends on the film structure.