

## DS 15: Organic Electronics and Photovoltaics II (jointly with CPP, HL, O)

Time: Tuesday 9:30–12:45

Location: H32

DS 15.1 Tue 9:30 H32

**Influence of triplet excitons on the lifetime of polymer based organic light emitting diodes** — ●OILI PEKKOLA, ANDREA GASSMANN, CHRISTIAN MELZER, and HEINZ VON SEGGERN — Electronic Materials Division, Institute of Materials Science, Technische Universität Darmstadt, Petersenstr. 23, 64287 Darmstadt, Germany

Despite the promising development of polymer based organic light emitting diodes (PLEDs), device lifetime and stability are still among the most critical issues. One of the lifetime-related factors investigated to a lesser extent is the influence of the high density of non-emissive triplet excitons which could be responsible for local heating or act as traps for charge carriers, leading to a degradation of the device.

This study utilizes PLEDs based on poly(p-phenylene vinylene) (PPV) derivatives to understand the influence of triplet excitons on the fatigue by increasing their amount in the PPV film. This increase is achieved by blending different concentrations of the triplet sensitizer platinum (II) octaethylporphyrine ketone (PtOEPK) into the PPV matrix in order to convert PPV singlet excitons to triplets. One observes that in PLEDs both the  $t_{50}$  and  $t_{90}$  lifetimes are drastically shortened in the presence of PtOEPK. To rule out a possible influence of the sole presence of PtOEPK on charge carrier transport, single carrier devices with different sensitizer contents were prepared. In these devices, no fatigue is observed regardless of the sensitizer concentration, suggesting that the decrease in the lifetimes of the bipolar diodes is indeed caused by the increased triplet population in the diodes with sensitized polymer films and not by the sensitizer additive as such.

DS 15.2 Tue 9:45 H32

**Homogeneity of thin ZnTPP-films on silicon measured with reflectance anisotropy spectroscopy and Raman spectroscopy** — ●STEPHAN PETER KATE<sup>1</sup>, SIMONA POP<sup>1</sup>, JÖRG RAPPICH<sup>2</sup>, and KARSTEN HINRICHS<sup>1</sup> — <sup>1</sup>Leibniz-Institut für Analytische Wissenschaften - ISAS - e.V., Albert-Einstein Str. 9, Berlin, 12489 Germany — <sup>2</sup>Helmholtz-Zentrum für Materials and Energy GmbH, Kekulestraße 5, Berlin, 12489, Germany

Organic devices for electronic applications are an important field of research. To improve the efficiency of those components, the analysis of structure and homogeneity of thin films is of crucial importance. In this study we demonstrate that Reflectance Anisotropy Spectroscopy (RAS) and Raman spectroscopy are useful to investigate the homogeneity of thin films of zinc-tetra-phenyl-porphyrin (ZnTPP) on silicon substrates. The RAS spectra of the thin films show an optical anisotropy in the visible spectral range. Analyzing the anisotropy, conclusions about the homogeneity of the thin films can be drawn. The vibrational modes of the molecules seen with resonant Raman spectroscopy are sensitive to the film structure. A pyrrole-bending mode in the region of 1075  $\text{cm}^{-1}$  serves us as a marker for the film homogeneity. The RAS and Raman results are correlated with AFM measurements.

DS 15.3 Tue 10:00 H32

**Morphology evolution of diblock copolymer based ZnO nanostructures upon solvent vapor treatment** — ●KUHU SARKAR, CHRISTOPH SCHAFFER, ANNA NAUMANN, DANIEL MOSEGI GONZALEZ, and PETER MÜLLER-BUSCHBAUM — TU München, Physik Department, LS Funktionelle Materialien, James-Franck-Str. 1, 85748 Garching, Germany

Nanostructured inorganic metal oxides with tunable morphologies are desirable for optimizing many potential applications in the field of gas/chemical sensing, catalysis and energy storage. Zinc oxide (ZnO) is chosen in the present study owing to its outstanding optical and electrical properties. Different ZnO nanostructures are synthesized using a suitable diblock copolymer template via sol-gel chemistry. Zinc acetate dihydrate is used as the suitable commercial precursor for ZnO. There are several possibilities to tune the morphology as most of the diblock copolymers respond to the external fields such as temperature and solvent vapor. Hence, tetrahydrofuran solvent vapor treatment has been employed to the as-prepared thin films corresponding a grid-like morphology for different annealing times. Grazing incidence small angle X-ray scattering (GISAXS) has been performed to probe the structural order over the entire film volume. Evolution of the morphology has been followed by GISAXS studies as a function of different sol-

vent treatment times. The annealed films are subsequently calcined at a higher temperature in order to understand the preservation of higher orders in the ZnO structure even after removal of the diblock copolymer.

DS 15.4 Tue 10:15 H32

**Correlation of morphology and electronic properties of MoO<sub>3</sub> doped CBP layers I: TEM and electrical properties** — ●DANIELA DONHAUSER<sup>1,2</sup>, LEVIN DIETERLE<sup>1,2</sup>, PAUL HEIMEL<sup>3,2</sup>, TOBIAS GLASER<sup>3,2</sup>, MAYBRITT KÜHN<sup>4,2</sup>, MUSTAPHA AL-HELWI<sup>5,2</sup>, RASMUS R. SCHRÖDER<sup>6</sup>, ERIC MANKEL<sup>4,2</sup>, MICHAEL KRÖGER<sup>1,2</sup>, and WOLFGANG KOWALSKY<sup>1,2</sup> — <sup>1</sup>Institut für Hochfrequenztechnik, TU Braunschweig, Braunschweig — <sup>2</sup>InnovationLab GmbH, Heidelberg — <sup>3</sup>Kirchhoff-Institut für Physik, Universität Heidelberg, Heidelberg — <sup>4</sup>Institut für Materialwissenschaft, TU Darmstadt, Darmstadt — <sup>5</sup>BASF SE, Ludwigshafen — <sup>6</sup>CellNetworks, Universität Heidelberg

Since electrochemical doping can significantly improve the performance of organic devices, the understanding of the fundamental properties of doped thin films is crucial. For a variety of different material systems a very low doping efficiency was observed, although from energetic considerations a very efficient charge transfer is expected. Using bright-field TEM and electron tomography we show for MoO<sub>3</sub>-doped CBP ((4,4'-Bis(N-carbazolyl)-1,1'-biphenyl) thin films that this low doping efficiency is due to filament-like dopant agglomeration which can be controlled by changing the substrate temperature during the evaporation process [1]. The observed morphology is finally correlated with electrical properties like charge carrier density and mobility and depending on the dopant concentration an anisotropic charge transport is observed.

[1] Donhauser et al., Adv. Funct. Mater., 2012, 10.1002/adfm.201202089

DS 15.5 Tue 10:30 H32

**Correlation of morphology and electronic properties of MoO<sub>3</sub>-doped CBP layers II: IR spectroscopic study** — ●TOBIAS GLASER<sup>1,5</sup>, SEBASTIAN BECK<sup>1,5</sup>, DANIELA DONHAUSER<sup>2,5</sup>, MAYBRITT KÜHN<sup>3,5</sup>, BERND LUNKENHEIMER<sup>4,5</sup>, ANDREAS KÖHN<sup>4,5</sup>, ERIC MANKEL<sup>3,5</sup>, and ANNEMARIE PUCCI<sup>1,5</sup> — <sup>1</sup>Universität Heidelberg, Kirchhoff-Institut für Physik — <sup>2</sup>Technische Universität Braunschweig, Institut für Hochfrequenztechnik — <sup>3</sup>Technische Universität Darmstadt, Fachbereich Materialwissenschaft, Fachgebiet Oberflächenforschung — <sup>4</sup>Universität Mainz, Institut für Physikalische Chemie — <sup>5</sup>InnovationLab GmbH, Heidelberg

In order to obtain a further understanding on the charge transfer process in p-type doping using transition metal oxides, we performed in-situ FTIR-spectroscopy on thin layers of 4,4'-Bis(N-carbazolyl)-1,1'-biphenyl (CBP) doped with MoO<sub>3</sub>. In the doped layers, charge transfer complexes (CTCs) are formed, that exhibit a broad electronic excitation in the near IR region. These CTCs are located at the interface of the MoO<sub>3</sub> agglomerates and the organic matrix, inducing an interface dipole. The intensity of this electronic excitation in the spectra of layers with various doping concentrations indicates a linear increase of the agglomerates' surface area with MoO<sub>3</sub> concentration. The vibrational changes in the spectra of the doped layers indicate a charge transfer of Z=1e within the CTCs. By cooling the substrate during the deposition process, the agglomeration of the dopants can be suppressed. Financial support by BMBF (project MESOMERIE) is gratefully acknowledged.

DS 15.6 Tue 10:45 H32

**Correlation of morphology and electronic properties of MoO<sub>3</sub>-doped CBP layers III: XPS and UPS study** — ●MAYBRITT KÜHN<sup>1,4</sup>, ERIC MANKEL<sup>1,4</sup>, DANIELA DONHAUSER<sup>2,4</sup>, TOBIAS GLASER<sup>3,4</sup>, THOMAS MAYER<sup>1,4</sup>, and WOLFRAM JAEGERMANN<sup>1,4</sup> — <sup>1</sup>Technische Universität Darmstadt, Fachgebiet Materialwissenschaft — <sup>2</sup>Technische Universität Braunschweig, Institut für Hochfrequenztechnik — <sup>3</sup>Universität Heidelberg, Kirchhoff-Institut für Physik — <sup>4</sup>InnovationLab GmbH, Heidelberg

Electro-chemical doping is a prerequisite to improve efficiency and conductivity of organic OLED materials. Here the p-type doping behavior of MoO<sub>3</sub> is analyzed using photoelectron spectroscopy (XPS/UPS). The doped CBP layers were evaporated and analyzed under UHV con-

ditions. Concerning the Fermi level shift three different regimes can be distinguished: At low doping concentrations ( $< 9 \text{ mol}\%$ ) a rapid shift towards the HOMO level of CBP can be observed, becoming less strong and finally saturating at a maximum shift of  $1 \text{ eV}$  at a doping concentration of  $45 \text{ mol}\%$ . The electron transfer from CBP to  $\text{MoO}_3$  leads to the formation of reduced  $\text{MoO}_3$ . Determining the amount of these species we get information of the surface to volume ratio of the  $\text{MoO}_3$  clusters in dependence of the doping concentration. Also here three different regimes can be distinguished. The morphology and Fermi level shift regimes will be correlated discussing the dopant morphology as shown in Talk I. Finally the amount of transferred charges is calculated regarding the reduced  $\text{MoO}_3$  species and is compared with the number of cations determined by IR-spectroscopy (Talk II).

### Coffee break (15 min)

DS 15.7 Tue 11:15 H32

#### Organic semiconductor devices on fibre shaped structures for smart textile applications. — •TOBIAS KÖNYVES-TOTH, ANDREA GASSMANN, and HEINZ VON SEGGERN —

Electronic Materials Department, Institute of Materials Science, Technische Universität Darmstadt, Petersenstraße 23, 64287 Darmstadt, Germany

In the development of smart textiles already realized prototypes utilize embedded LEDs, displays or interactive communication devices based on inorganic semiconductor technology. Yet, these wearable smart textiles are not always comfortable since inorganic devices are stiff and rigid. On the other hand, organic electronic devices can be realized on flexible substrates employing very thin active layers of only about  $100 \text{ nm}$  thickness. The aim of the present work is to process organic semiconductor based devices directly on fibre surfaces. This task is challenging as manufacturing related problems due to the cylindrical shape of the fibre substrates and their small diameter of about  $200 \text{ nm}$  have to be overcome. Here, we present our findings on functional OLEDs on fibre substrates. Also the choice of proper fibre materials, ways to acquire smooth fibre surfaces and the structuring and encapsulation of fibre-shaped devices will be discussed. Additionally, methods to characterize the functionality of the devices, like angle dependence emission, will be presented.

DS 15.8 Tue 11:30 H32

#### Doping of organic semiconductors in case of dopant precipitation: the internal interface charge transfer doping model —

•THOMAS MAYER<sup>1,2</sup>, ERIC MANKEL<sup>1,2</sup>, CORINNA HEIN<sup>1</sup>, and WOLFRAM JAEGERMANN<sup>1,2</sup> — <sup>1</sup>Technische Universität Darmstadt, Institute of Materials Science, Surface Science Division — <sup>2</sup>Innovation Lab Heidelberg

Doping of organic semiconductors is of paramount interest for device optimization as in addition to improved conductivity, engineering of space charge regions at interfaces e.g. of donor acceptor heterojunction solar cells is achieved. Photoemission data taken at the synchrotron BESSY on co-sublimed and bilayer films of prototypical organic semiconductors as CuPc and spiro-MeOTAD and prototypical p-type organic and inorganic dopants as TCNQ and  $\text{WO}_3$  show similar electronic trends, which can be explained assuming phase separation of the dopants within the matrix material. For metal oxides the precipitation is directly observed using TEM. For the doping induced variations of the matrix Fermi level in such semiconductor-dopant composites we propose the internal interface charge transfer doping model. According to this model the doping limit can be predicted from pristine matrix and pristine dopant electronic band diagrams. The model also admits of deriving measures that can be taken to improve doping efficiency.

DS 15.9 Tue 11:45 H32

#### Molecular orientation at heterojunctions for organic photovoltaics studied by NEXAFS — •ANDREAS OPITZ<sup>1</sup>, NORBERT KOCH<sup>1</sup>, ULRICH HÖRMANN<sup>2</sup>, WOLFGANG BRÜTTING<sup>2</sup>, CHRISTOPHER LORCH<sup>3</sup>, ALEXANDER HINDERHOFER<sup>3</sup>, FRANK SCHREIBER<sup>3</sup>, and ELLEN MOONS<sup>4</sup> —

<sup>1</sup>Inst. f. Physik, Humboldt-Universität zu Berlin, Germany — <sup>2</sup>Inst. of Physics, University of Augsburg, Germany — <sup>3</sup>Inst. of Applied Physics, University of Tübingen, Germany — <sup>4</sup>Dept. of Physics and Electrical Engineering, Karlstad University, Sweden

Organic/organic heterojunctions are widely used in organic photovoltaic cells. The morphology at the interface, where the charge carrier separation takes place, plays an important role. In this contribution the interfaces between sexithiophene (6T) as donor and the acceptor materials fullerene ( $\text{C}_{60}$ ) and diindenoperylene (DIP) [1] were anal-

ysed by angle resolved near-edge X-ray absorption fine structure spectroscopy and the results were compared to X-ray scattering data.

Different orientations are observed for molecules in the bulk, at free surfaces and at buried interfaces. Here, the orientation at the free surfaces depends on the substrate temperature during deposition for 6T but not for DIP. Furthermore, the acceptor molecules influence the orientation of the underlying 6T molecules. An improved crystallization and pronounced upright standing of the molecules in the underlying 6T film was observed upon deposition of  $\text{C}_{60}$ . In contrast the deposition of DIP on top of 6T leads to an orientational relaxation of the 6T molecules to the bulk inclination angle.

[1] U. Hörmann et al., *phys. stat. sol. RRL* 5 (2011) 241.

DS 15.10 Tue 12:00 H32

#### Electronic interface properties of PCBM using photoelectron spectroscopy — •JULIA MAIBACH<sup>1,2</sup>, ERIC MANKEL<sup>1,2</sup>, THOMAS MAYER<sup>1,2</sup>, and WOLFRAM JAEGERMANN<sup>1,2</sup> — <sup>1</sup>Technische Universität Darmstadt, Fachbereich Materialwissenschaft — <sup>2</sup>InnovationLab GmbH, Heidelberg

The electronic interface properties of wet processed organic materials are of current interest as many fabrication techniques for organic electronic devices are based on inks. Photoelectron spectroscopy (PES) has proven to be a powerful method to investigate the electronic structure at semiconductor contacts. Due to high surface sensitivity of PES, the interface is generally prepared step by step in UHV. For films deposited from solution we integrated a newly developed ultrasonic nebulizer unit to the UHV cluster-tool of the analytic competence center at the InnovationLab, Heidelberg. Dilute solutions of Phenyl-C61-butyric acid methyl ester (PCBM) in Chlorobenzene were used to deposit the material on ozone and polymer treated ITO as well as on gold to investigate the contact behavior of PCBM. With the nebulizer method layer thicknesses in the range of  $10\text{-}20 \text{ \AA}$  can be achieved while repeated exposure to the nebulae increased step by step the emission intensities of the PCBM. Furthermore drop-casting of thicker layers has been performed allowing in combination the thickness dependent determination of the electronic properties. In case of PCBM on ozone treated ITO the HOMO spectra shift  $0.4 \text{ eV}$  to higher binding energy with increasing thickness, indicating the formation of a space charge region in PCBM due to electron transfer from ozone treated ITO.

DS 15.11 Tue 12:15 H32

#### Carbon Nanotubes and Organic Solar Cells — •GERHARD LACKNER<sup>1</sup>, RICHARD BOUCHER<sup>2</sup>, VLADIMIR SHVARTSMANN<sup>1</sup>, VIKTOR BEZUGLY<sup>2</sup>, INGOLF ENDLER<sup>3</sup>, MARIO KRUG<sup>3</sup>, FRANK MEISSNER<sup>3</sup>, MARTIN MKANDAWIRE<sup>4</sup>, and DORU C. LUPASCU<sup>1</sup> —

<sup>1</sup>Universität Duisburg-Essen, Essen, Germany — <sup>2</sup>Technische Universität Dresden, Dresden, Germany — <sup>3</sup>Fraunhofer-Institut für Keramische Technologien und Systeme IKTS, Dresden, Germany — <sup>4</sup>Verschuren Centre for Sustainability in Energy and the Environment, Cape Breton University, Canada

Materials like carbon nanotubes (CNT) attracted much attention by researchers all around the world due to their exceptional electrical, mechanical and chemical properties. Especially single-walled carbon nanotubes (SW-CNT) offer great opportunities in the field of new electrical devices, for instance field effect transistors based on their semiconductor properties. CNT are also used in organic photovoltaics (OPV) as acceptor material, to enhance charge carrier transport within organic layers or as transparent electrodes. The application of CNT as acceptor material and for charge carrier enhancement is the main topic of this work. Therefore, we studied the photovoltaic device performance of different material combinations of CNT, regio regular Poly(3-Hexylthiophen-2,5-diyl) (rr-P3HT), Phenyl-C61-butyric acid methyl ester (PCBM) and copper phthalocyanine (CuPc). Furthermore, different device architectures were investigated and compared with each other.

DS 15.12 Tue 12:30 H32

#### n-channel percolation in a pentacene-C60 ambipolar organic thin film transistor — SIMON NOEVER, STEFAN FISCHER, and •BERT NICKEL — Ludwig-Maximilians-Universität, Fakultät für Physik & CENS, München, D

We present [1] a well balanced ambipolar organic field effect transistor with high hole and electron saturation mobilities of  $0.28 \text{ cm}^2/\text{Vs}$  and  $0.18 \text{ cm}^2/\text{Vs}$ , respectively. The structure and morphology of the respective films are analyzed using AFM and GIXS methods. Furthermore, we track the formation of a pentacene-C60 heterojunction by in-situ measurements during deposition of  $\text{C}_{60}$ . Upon percolation

---

of the n-channel, the heterojunction charges, acting as an additional top gate for the hole conducting channel. The fact that the p-channel threshold does not shift before the n-channel develops highlights two interesting findings for bilayer ambipolar TFTs. Apparently, before the C60 film percolates, the fullerene islands are electronically floating and the charging of the interface is confined to the pentacene-C60 con-

tact area. Secondly, the threshold voltage shift of the p-channel upon fullerene percolation implicates the generation of a second hole conducting channel at the pentacene top surface. The introduced method demonstrates a way to evaluate the electrostatic situation in operating organic heterojunction devices. [1] S. Noever, S. Fischer, B. Nickel, *Advanced Materials* (in press)