

## DS 6: Organic photovoltaics and electronics - mostly cell design (jointly with CPP,DS)

Time: Monday 15:00–16:45

Location: EW 202

DS 6.1 Mon 15:00 EW 202

**Polymer/cathode interface barrier limiting the open circuit voltage in polymer:fullerene organic bulk heterojunction solar cells** — ●JAIRO CESAR NOLASCO — Energy and Semiconductor Research Laboratory, Department of Physics, Carl von Ossietzky University of Oldenburg, D-26111, Germany

Factors which limit the open circuit voltage  $V_{oc}$  in polymer bulk heterojunction solar cells is still a topic of controversy. Fundamentally, the  $V_{oc}$  is determined by the balance of photogeneration and recombination, with recombination occurring either at the internal donor/acceptor interface or at the contacts. In case of ohmic contacts the losses have been mainly attributed to the donor/acceptor interface, whereas for the case of non-ohmic contacts, the dominant losses have been discussed in terms of minority carrier surface recombination occurring at the acceptor/cathode interface. In this contribution it is demonstrated the existence of a majoritary free carrier recombination occurring at the polymer/cathode barrier interface [1].

[1] J. C. Nolasco, G. Ramos-Ortiz, J.L. Maldonado, O. Barbosa-Garcia, B. Ecker, E. Von Hauff, Appl. Phys. Lett., 104, 043308 (2014).

DS 6.2 Mon 15:15 EW 202

**Accurate Characterization of Serial Tandem Organic Solar Cells** — ●TONI MEYER, RONNY TIMMRECK, CHRISTIAN KÖRNER, KOEN VANDEWAL, and KARL LEO — Institut für Angewandte Photophysik, TU Dresden, Germany

A well known concept for further improvement of the efficiency of solar cells are tandem solar cells. The most common representative of this concept are the serial tandem solar cells (sTSC) where the subcells are connected electrically in series. Due to Kirchhoff's law this leads to a current limitation of the whole device by the subcell generating less current under a specific spectrum. For scientific comparison and practical application it is inevitable to determine the exact performance of such a device under different illumination conditions. However, the current limitation of a sTSC represents a major challenge for their characterization.

The spectrometric characterization, developed by Meusel et. al, represents a precise method of determining the performance of sTSC for any given illumination spectrum by using a multi-source sun simulator. We apply this method to a state of the art vacuum deposited sTSC with complementary absorbers and compare it to the minimal requirements of the standard ASTM E2236-05 for characterizing multijunction photovoltaic devices. We show that in case of differing fill factors of the subcells of the sTSC it is not sufficient to use only a single source sun simulator, which does usually not yield correct results for the solar cell efficiency in accordance with the standard reporting conditions.

DS 6.3 Mon 15:30 EW 202

**Investigation of semiconducting polymers with thermally cleavable side chains for application in multilayer devices II: Spectroscopy** — ●SABINA HILLEBRANDT<sup>1,5</sup>, JANUSZ SCHINKE<sup>2,5</sup>, TORBEN ADERMANN<sup>3</sup>, ERIC MANKEL<sup>4,5</sup>, ROBERT LOVRINCIC<sup>2,5</sup>, MANUEL HAMBURGER<sup>3,5</sup>, TOBIAS GLASER<sup>1,5</sup>, WOLFRAM JAEGERMANN<sup>4</sup>, WOLFGANG KOWALSKY<sup>2,5</sup>, and ANNEMARIE PUCCI<sup>1,5</sup> — <sup>1</sup>Kirchhoff-Institut für Physik, Universität heidelberg — <sup>2</sup>Institut für Hochfrequenztechnik, Technische Universität Braunschweig — <sup>3</sup>Organisch-Chemisches Institut, Universität Heidelberg — <sup>4</sup>Institut für Materialwissenschaften, Technische Universität Darmstadt — <sup>5</sup>Innovationlab GmbH, Heidelberg

Conjugated polymers are a promising material class for solution processed organic electronic devices. A major challenge in solution processing of multi-layer devices is the limited number of options regarding orthogonal solvents. Therefore solubility alteration of the functional layers is crucial for facilitating device fabrication. In this talk the removal of side-chains of novel naphthalene tetracarboxydiimide based semiconducting polymers by thermal treatment is analyzed by infrared transmission spectroscopy, photoelectron spectroscopy and charge transport characteristics in organic field effect transistors. Side chain residuals in the films are correlated to temperature and duration of the thermal treatment. Solvent stability is tested by washing the films after thermal treatment. Our findings show that although side chains can be removed completely after washing the thermally treated

films, the charge transport strongly depends on the parameters used for this treatment.

DS 6.4 Mon 15:45 EW 202

**Understanding thickness dependent onset voltage shifts in OLED IV-characteristics I: Internal electric field distributions** — ●MAYBRITT KÜHN<sup>1,2</sup>, ERIC MANKEL<sup>1,2</sup>, CHRISTOP PFLUMM<sup>3</sup>, THOMAS MAYER<sup>1,2</sup>, and WOLFRAM JAEGERMANN<sup>1,2</sup> — <sup>1</sup>Technische Universität Darmstadt, Institute of Materials Science — <sup>2</sup>InnovationLab GmbH, Heidelberg — <sup>3</sup>Merck KGaA, Darmstadt

Steady-state IV measurements are used as important characterization method for organic light-emitting diodes (OLEDs). Surprisingly, in some OLED devices the current onset voltage increases significantly depending on the emission layer (EML) thickness by approximately 2.7V/100nm. For experimental investigations of this phenomenon we focus on a three layer device architecture, using two different isomers synthesized by Merck as transport material in the EML - one showing changes in onset voltage (EML-A) the other (EML-B) not. To investigate the onset voltage shift the mean electric fields in the respective layers are determined in dependence of the current density. Therefore, systematic layer thickness variations of the injection layers and both EML materials were performed and the respective IV characteristics were evaluated. In contrast to EML-B a large field enhancement in EML-A can be identified induced by discontinuities of the electric field at the EML-A contacts. Using a simple drift model both EML field distributions and the discontinuities can be described quantitatively. Furthermore they can be allocated to a lack of bulk charge carriers, probably induced by an energetic interface barrier or trapped interface charges. A further consideration of the topic will be done in part 2.

DS 6.5 Mon 16:00 EW 202

**Understanding thickness dependant onset voltage shifts in OLED IV-characteristics II: Equilibrium band alignments and their impact on the steady-state situation** — ●ERIC MANKEL<sup>1,2</sup>, MAYBRITT KÜHN<sup>1,2</sup>, CHRISTOP PFLUMM<sup>3</sup>, THOMAS MAYER<sup>1,2</sup>, and WOLFRAM JAEGERMANN<sup>1,2</sup> — <sup>1</sup>TU Darmstadt, Darmstadt — <sup>2</sup>InnovationLab GmbH, Heidelberg — <sup>3</sup>Merck KGaA, Darmstadt

Steady-state IV measurements are used as important characterization method for organic light-emitting diodes (OLEDs). Surprisingly, in some OLED devices the current onset voltage increases significantly depending on the emission layer (EML) thickness by approximately 2,7V/100nm. In part 1 we used two isomers - one showing changes in onset voltage (EML-A) the other (EML-B) not - and concluded that enhanced internal electric fields explain this unexpected behavior. Here in part 2 we present how interface band offsets (a), interface dipoles (b) and space charge regions (c) influence the field distribution under steady-state conditions. First we show the impact of a, b and c on the electric and the electrochemical potential distribution as well as the IV-characteristic of a two layer model device. Then we allocate these results to the measured interface discontinuities of the electric field shown in part 1. Finally we present the interface band diagrams of the EML layers and the respective contact layers measured by XPS layer-by-layer experiments. The values for a, b and c were used to model the IV-characteristics of both, EML-A and EML-B containing devices. The described onset voltage shift can successfully be reproduced.

DS 6.6 Mon 16:15 EW 202

**SWNT:Fullerene solar cells** — ●ALEXEY GAVRIK<sup>1</sup>, STEFAN VÄTH<sup>1</sup>, ANDREAS SPERLICH<sup>1</sup>, IMGE NAMAL<sup>2</sup>, FLORIAN SPÄTH<sup>2</sup>, TOBIAS HERTEL<sup>2</sup>, and VLADIMIR DYAKONOV<sup>1,3</sup> — <sup>1</sup>Experimental Physics VI, Julius Maximilian University of Würzburg, 97074 Würzburg — <sup>2</sup>Physical and Theoretical Chemistry II, Julius Maximilian University of Würzburg, 97074 Würzburg — <sup>3</sup>ZAE Bayern, 97074 Würzburg

Single-wall carbon nanotubes (SWNTs) are a promising material for application in organic solar cells due to their attractive properties: solution processability, broadband absorption, high charge carrier mobility. Moreover, by selecting SWNTs of one chirality, it is possible to choose the energy gap, which determines the light absorption spectrum and therefore, solar cell performance.

In this study, solar cells were prepared using blends of (6,5)-SWNTs

and the soluble fullerene PC<sub>60</sub>BM. External quantum efficiency (EQE) spectra show spikes at ca. 570, 870 and 1000 nm, which correlates with absorption bands of SWNTs. This proves that charge carriers in SWNTs contribute to the photocurrent. Moreover, SWNTs are showing high performance of converting light into electricity: even at low SWNTs:fullerene ratios (1:100) the current from SWNTs in the EQE spectrum is comparable to the fullerenes' contribution.

This study shows the potential for the application of (6,5)-SWNTs as an active material in organic solar cells. While the device performance is still limited by film thickness and overall device characteristics, we were able to fabricate solar cells with reasonable efficiency.

DS 6.7 Mon 16:30 EW 202

**Effective injection barriers of organic Schottky diodes** —  
•THORSTEN ARNOLD and FRANK ORTMANN — Institute for Mate-

rials Science and Dresden Center for Computational Material Science, TU Dresden, Germany

We describe electron transport through organic semiconductors connected to two metallic electrodes. The microscopic approach is based on a dynamic master-equation and Poisson equation describing the space charge potential. Disorder is modeled by a Gaussian site energy distribution. The current-voltage characteristic depends on the effective height of the injection barrier at the metal-semiconductor interface, which can be influenced by several effects, and the bulk properties.

The model is applied to a Schottky diode with different work functions of the electrodes. The influence of bulk and surface disorder on the rectification of the diode are analyzed for various temperatures. Furthermore, the influence of the space charge on the effective injection barrier height is investigated.