HL 35: Organic semiconductors: Photovoltaics (with CPP/DS/O)

Time: Tuesday 10:00–12:30 Location: POT 081

HL 35.1 Tue 10:00 POT 081

Analytical transmission electron microscopy on hybrid solar cells based on perovskites — •Diana Nanova[1,2,4], Anne Katrin Kast[1,3,4], Christian Müller[1,4], Rasmus R. Schröder[3,4], Robert Lovrincic[1,4], and Wolfgang Kowalsky[1,4] — [1]Institut für Hochfrequenztechnik, TU Braunschweig — [2]Kirchhoff Insitut für Physik, Universität Heidelberg — [3]Cryo-EM, CellNetworks, Bioquant, Universität Heidelberg — [4]InnovationLab GmbH, Heidelberg

Hybrid solar cells based on metal-organic perovskite absorbers are of major interest due to their remarkable power conversion efficiencies of up to 15%. Recently, it has been shown that the morphology of the perovskite itself as well as the interplay between the absorber and the mesostructured electron acceptor strongly affects the electrical properties of the device. We present a combined study of the structure-function relationship of solution processed solar cells based on mesostructured perovskites. The morphology of the solar cells was studied by analytical transmission electron microscopy (ATEM). In ATEM electron energy loss spectroscopy (EELS) and electron spectroscopic imaging (ESI) are applied in order to obtain material contrast. To be able to classify the TiO2 and the perovskite rich areas in the corss-section of the device a series of monochromatic images in the low-loss regime was acquired. We observed significant changes in pore size, pore filling and pore distribution of the mesostructured layer depending on the annealing conditions of the perovskite. Furthermore, we correlated our results to the I-V characteristics of the solar cells.

HL 35.2 Tue 10:15 POT 081

Alloyed zinc sulfide - copper indium disulfide nanocrystals for application in hybrid photovoltaics — •Björn Kempken, Nikolay Radychev, Christopher Krause, Jie Li, Holger Borchert, Joanna Kolny-Olesiak, and Jürgen Parisi — Carl von Ossietzky University of Oldenburg, 26111 Oldenburg

Semiconductor nanocrystals (NCs) continue to attract immense attention because of their size-dependent optical, physical, and chemical properties which causes them to be a favourable material for hybrid solar cell applications. A promising candidate for the inorganic/organic active layer is alloys of ZnS and CuInS2 (ZCIS NCs), which on the one hand strongly absorb in the visible range up to 800 nm, and, on the other hand, belongs to the "green" type of semiconductor NCs. In the present work, high quality ZCIS NCs were synthesized and subjected to hexanethiol ligand exchange procedures. Laboratory solar cells based on blends of treated ZCIS NCs and poly[2,6-(4,4-bis-(2-ethylhexyl)-4H-cyclopenta[2,1-b;3,4-b']dithiophene)-alt-4,7(2,1,3-benzothiadiazole)] (PCPDTBT) as active layer were prepared and investigated by current-voltage and electron spin resonance measurements. Hybrid ZCIS/PCPDTBT laboratory solar cells demonstrate well pronounced diode behavior with outstanding characteristics of the open-circuit voltage which reached up to 1.2 V.

HL 35.3 Tue 10:30 POT 081

Improving efficiency of solar power generation by combination of a sensitized mesoscopic solar cell with a thermoelectric generator — •Hans-Fridtjof Pernau, Jana Heuer, Karina Tarantik, Alexandre Jacquot, Jan D. König, Martin Jägle, and Kilian Bartholomé — Fraunhofer IPM, Freiburg, Germany

Standard photovoltaic(PV) solar cells use only about half of the light spectrum provided by the sun. The infrared part is not used for producuction of electrical energy. Even further, the infrared light heats up the pv cell and decreases thereby its efficiency. The basic idea for a combined pv and thermoelectric solar cell has been published in 2008 [1]. The improvements in thermoelectric materials and scientific work on thermoelectrics lead to new ideas for those systems [2] which will be investigated in the EU-FP7-Projekt Globasol. Within the project, a hybrid solar cell made of a sensitized mesoscopic solar cell and a thermoelectric generator (TEG) will being developed. The light of the sun is split at about 800nm. The visible and ultra violet part is transfered to the sensitized mesoscopic solar cell, the infrared part illuminates the TEG cell. With the hybrid solar cell, the full solar spectrum is exploited. We present the first modeling results of the project and the first evaluation version of the hybrid cell.

[1] T.M. Tritt, H. Böttner and L. Chen, *Thermoelectric: Direct Solar Thermal Energy Conversion*, MRS Bulletin, vol.33 (2008) pp. 366-368; [2] D. Kraemer et al., *High-performance flat panel solar thermoelectric generator with high thermal concentration*, Nature materials vol.10 (2011) pp. 532-538.

HL 35.4 Tue 10:45 POT 081

Spin dynamics in organic solar cells measured by pulsed electrically detected magnetic resonance — •Alexander J. Kupijai, Konstantin M. Behringer, Martin Stutzmann, and Martin S. Brandt — Walter Schottky Institut, Technische Universität München, Am Coulombwall 4, 85748 Garching

Organic photovoltaics are of great interest in the development of sustainable energy sources. To investigate the recombination and transport processes in organic solar cells we use the technique of pulsed electrically detected magnetic resonance (EDMR) where we measure the change of the photocurrent caused by resonant X-band microwave pulses in the presence of an external magnetic field. As test devices, we use bulk heterojunction P3HT/PCBM (poly(3-hexylthiophene-2,5-diyl) / [6,6]-phenyl C_{61} butyric acid methyl ester) solar cells. At temperatures of 10K we are able to observe both positively and negatively charged polarons in the pulsed EDMR spectrum and can identify them as partners in a spin-dependent pair process by experiments using two microwave frequencies. Using the time resolution and sensitivity of pulsed EDMR we are able to quantify the spin dynamics of the system and measure the lifetime of parallel spin pairs, the lifetime of antiparallel spin pairs, the spin decoherence time and the coupling strength between the spin partners. All of these microscopic parameters provide valuable information for an optimization of overall solar cell efficiencies.

HL 35.5 Tue 11:00 POT 081

Imaging the origin of S-shaped current-voltage characteristics of organic solar cells by scanning Kelvin probe microscopy — •Christian Müller[1,2,3], Rebecca Saive[1,2,3], Janusz Schinke[1,3], Robert Lovrincic[1,3], and Wolfgang Kowalsky[1,2,3] — [1]InnovationLab GmbH, Heidelberg, Germany — [2]Kirchhoff-Institut für Physik, University Heidelberg, Germany — [3]Institut für Hochfrequenztechnik, Technische Universität Braunschweig, Germany

We investigated organic bilayer solar cells consisting of poly(3-hexylthiophene)/1-(3-methoxycarbonyl)propyl-1-phenyl[6,6]C61 (P3HT/PCBM). Scanning Kelvin probe microscopy (SKPM) was performed on the solar cell cross sections which were exposed with a focused ion beam. We prepared the P3HT/PCBM bilayer solar cells by solution processing. These bilayer solar cells showed normal and anomalous, S-shaped current-voltage characteristics. Using SKPM on the device cross sections, we found that in normal bilayer solar cells the potential dropped at the ITO/PEDOT:PSS contact and over the active area, whereas in S-shaped bilayer solar cells the potential dropped exclusively at the aluminium contact. This behavior confirms the assumption that S-shaped curves are caused by hindered charge transport at electrode interfaces.

Coffee break (15 min.)

HL 35.6 Tue 11:30 POT 081

Improving the Charge Transport Parameters of Near-Infrared Absorbers — •Sebastian Radke[1,2], Frank Ortmann[1,2], Reinhard Scholz[2,3], and Gianaurelio Cuniberti[1,2,4] — [1]Institute for Materials Science and Max Bergmann Center of Biomaterials, TU Dresden, Germany — [2]Dresden Center for Computational Materials Science, TU Dresden, Germany — [3]Institut für Angewandte Photophysik, TU Dresden, Germany — [4]Center for Advancing Electronics Dresden, TU Dresden, Germany

For an improved performance of organic tandem solar cells, efficient organic infrared absorber materials are necessary. A promising class already used successfully in organic solar cells are 4,4'-difluoro-4-bora-3a,4a-diaza-s-indacenes (BODIPYs). Based on a comparative study of the intramolecular electronic properties as well as the intermolecular coupling in the crystal phase of three potential candidates, we find that the benzannulation of the molecular core improves both electron and hole transfer. As the frontier molecular orbitals are delocalized over the entire molecule also by attaching additional functional groups

to the molecular core, the intermolecular coupling and especially the performance in amorphous phase can be optimized further. However, an immobilization of these substituents is necessary to regulate an increase in the reorganization energy for hole transfer. Based on these design rules, BODIPYs with optimized charge transfer properties can be synthesized increasing also the performance of the devices.

HL 35.7 Tue 11:45 POT 081

Qualitative und quantitative Auswertung von komplementären bildgebenden Methoden zur Degradationsuntersuchung und Qualitätskontrolle von Polymersolarzellen — •Roland Rösch, Marco Seeland, Daniel Fluhr, Burhan Muhsin, Peter Fischer, Rolf Öttking und Harald Hoppe — Institut für Physik, TU Ilmenau, Deutschland

Wir berichten über beschleunigte Alterungstests an modernen organischen und polymeren Solarzellen, ergänzt durch bildgebenden Methoden, wie z.B. bildgebende Lumineszenz, Lock-in Thermographie und lichtinduziertes Kurzschlussstrommapping. Neben einer qualitativen Interpretation der Daten, ist es durch die Kombination der verschiedenen Methoden möglich, auch eine quatitative Auswertung der Dynamiken der verschiedenen Degradationsmechanismen zu erhalten. Desweiteren vergleichen wir die experimentellen Ergebnisse mit theoretischen Modellen des Ladungsträgerflusses und -Rekombination. Daraus lassen sich intrinsische Paramter der Bauelemente, wie Elektrodenwiderstand und Diodenidealitätsfaktor bestimmen. Die wichtigste Erkenntnis aus diesen Untersuchungen ist, dass die Stabilität von modernen organischen Solarzellen vor allem durch die Elektrodendegradation und die Qualität der Versiegelung begrenzt ist. Diese Arbeit liefert einen Leitfaden für weitere Verbesserungen hin zu stabilen organischen Solarzellen.

HL 35.8 Tue 12:00 POT 081

Visualization of Lateral Phase Separation in Polymer: Fullerene Solar Cells by Quantitative Evaluation of Luminescence Imaging Measurements — •Marco Seeland, Christian Kästner, and Harald Hoppe — Institut für Physik, TU Ilmenau, Ilmenau, Germany

Luminescence imaging has evolved to a versatile characterization method for studying the laterally resolved behavior of polymer solar cells. Especially in degradation studies the use of luminescence imaging is beneficial as it is non-invasive and offers short measurement times. By either electrical or optical excitation separate characterization of the electrical contacts and the active layer is feasible. However, the data analysis so far is mainly qualitative, i.e. interpretation of the measured luminescence image by comparison with other techniques. In this work we present a quantitative analysis of electroluminescence images of laterally inhomogeneous polymer solar cells. By decoupling the local parameters within an iteration procedure this analysis allows calculation of the local current flow through and the local voltage applied to the active layer. Furthermore quantitative images of the local series resistance and the saturation current-density are achieved. The local saturation current-density contrast was found to correlate perfectly with the strong lateral phase separation occurring in PPE-PPV:PCBM based devices. Further analysis of the lateral difference in the saturation current-densities delivers information on the thermal activation of charge carriers at the donor/acceptor-interface and in the phase separated bulk.

HL 35.9 Tue 12:15 POT 081

The influence of fullerene loading on the photogeneration in intercalated polymer: fullerene bulk heterojunction solar cells — •Andreas Zusan[1], Koen Vandewal[2], Benedikt Allendorf[1], Nis Hauke Hansen[1], Jens Pflaum[1], Martin Heeney[3], Alberto Salleo[2], Vladimir Dyakonov[1,4], and Carsten Deibel[1] — [1]Experimental Physics VI, Julius-Maximilians-University of Würzburg, D-97074 Würzburg — [2]Department of Materials Science and Engineering, Stanford University, Stanford, California 94305, USA — [3]Department of Chemistry, Imperial College, London, SW7 2AZ, UK — [4]Bavarian Centre for Applied Energy Research e.V. (ZAE Bayern), D-97074 Würzburg

The conjugated polymer, pBTTT, allows a systematic tuning of the blend morphology by varying the acceptor material and blend ratio, making it a well-suited structural model for studying the fundamental processes in organic BHJ solar cells. To analyze the correlation between photogeneration and intercalation, we have performed time delayed collection field (TDCF) measurements and Fourier-transform photocurrent spectroscopy (FTPS) on pBTTT:PCBM devices in various stoichiometries. An increased PCBM loading resulted in a less field dependent dissociation, which we attribute to enhanced electron delocalization along extended PCBM nanophases and energetically driven spatial separation of polarons due to the presence of pure acceptor domains. The highly efficient transfer of charge carriers from the intercalated phase into the pure phase has been studied further by extending TDCF measurements to include segregated pBTTT:bisPCBM blends.