DS 24: Fundamentals of Perovskite Photovoltaics IV (jointly with CPP/HL)

Time: Tuesday 14:00–16:00 Location: ZEU 222

Invited Talk DS 24.1 Tue 14:00 ZEU 222

Ultrafast transient absorption spectroscopy of organic-inorganic hybrid perovskites on mesoporous titanium dioxide in contact with hole transport materials — •Thomas Lenzer — Universität Siegen, Physikalische Chemie, Adolf-Reichwein-Str. 2, 57076 Siegen

Organic-inorganic hybrid perovskites, such as methylammonium lead iodide, are particularly promising for applications in solar light harvesting and optoelectronics. We present our recent results on the carrier dynamics of such materials using ultrafast pump - supercontinuum probe spectroscopy in the 260-1600 nm range. The perovskite systems are investigated over a wide range of carrier densities. Slow carrier recombination processes, "phonon bottlenecks" during carrier cooling and confinement effects in low-dimensional perovskite structures are identified. We investigate electron injection processes from the perovskite into the mesoporous titania scaffold and estimate the relative contributions of electron transport pathways in the perovskite and titanium dioxide. We also discuss the hole transfer from the perovskite into triarylamine-based hole transport materials (HTMs).

DS 24.2 Tue 14:30 ZEU 222

Identification of charge transport limiting factors in perovskite-based solar cells by Time-of-Flight measurements — •Irene Grill[1,2], Meltem Aygüler[1,2], Nadja Giesbrecht[1,2], Pablo Docampo[1,2], Thomas Bein[1,2], Matthias Handloser[3], and Achim Hartschuh[1,2] — [1]Department of Chemistry & CeNS, LMU Munich — [2]Nanosystems Initiative Munich (NIM) — [3]Toptica Photonics AG

Hybrid perovskites represent one of the most promising absorber materials for future photovoltaic applications due to the recently achieved high PCE values [1]. In this work, we determine the transport time of photoinduced charges in between the top- and bottom-electrode in perovskite thin film solar cells upon pulsed laser excitation, using Time-of-Flight (ToF) photocurrent measurements. To extract the influence of the individual layers on the transport characteristics and to identify limiting factors we carried out additional ToF studies on the respective absorber layer of the photovoltaic device in a lateral architecture. The results of the single film measurements are discussed in terms of crystal size and orientation. The direct comparison of the data obtained for the individual layers and the photocurrent transients of the final device under working conditions permits the identification of limiting factors for inter-facial and intra-film charge transport simultaneously to allow for the optimization of both the fabrication techniques [2,3] and device architecture. [1] M. Saliba et al., Energy Environ. Sci. 2016, 9, 1989. [2] I. Grill et al., Sol. Energ. Mat. Sol. Cells 2016, accepted. [3] A. Binek, I. Grill et al., Chem. Asian J. 2016, 11, 1199.

DS 24.3 Tue 14:45 ZEU 222

Fill factor optimization strategies in efficient, stable triple cation perovskite solar cells — •Martin Stolterfoht, Christian Wolff, Yochai Amir, Andreas Paulke, and Dieter Neher — Institute of Physics and Astronomy, University of Potsdam, Potsdam-Golm, Germany

Perovskite solar cells (PSCs) now compete with their inorganic counterparts in terms of power conversion efficiency. To advance this technology even further, more insights into the physical mechanisms that define the bias dependence of the photocurrent are required. In this work, we varied the organic electron/hole transport layers (ETL/HTL) thickness in efficient triple cation PSCs and studied the charge carrier recombination and transit through the device. Using resistance dependent photovoltage (RPV), we identify the transit time through the transport layers as key figure of merit for maximizing the fill factor (FF) and the overall photovoltaic performance. The results are complemented by intensity dependent photocurrent measurements which elucidate the role of the HTL thickness on the bias dependence of the recombination losses and recombination order. By optimizing the transit time through the HTL (undoped PTAA) we demonstrate efficiencies under solar AM1.5G conditions of up to 20.4% with high FFs of 80%. The reported cells also exhibit excellent stability under light illumination and stability in air, even without encapsulation. However, further improving the FF via a continuous reduction of the HTL leads to significant open-circuit voltage losses which highlights the challenge to simultaneously optimize the FF and open-circuit voltage.

DS 24.4 Tue 15:00 ZEU 222

Optical phonons in methylammonium lead halide perovskites and implications for charge transport — •Michael Sendner[1,2], Pabitra K. Nayak[3], David A. Egger[4], Sebastian Beck[1,2], Christian Müller[1,2,5], Bernd Epding[2,5], Wolfgang Kowalsky[1,2,5], Leeor Kronik[4], Henry J. Snaith[3], Annemarie Pucci[1,2], and Robert Lovrincic[2,5] — [1]Kirchhoff-Institut für Physik, Universität Heidelberg — [2]InnovationLab, Heidelberg — [3]Clarendon Laboratory, University of Oxford — [4]Department of Materials and Interfaces, Weizmann Institute of Science — [5]Institut für Hochfrequenztechnik, TU Braunschweig

Recent reports indicated that the mechanical and electronic properties of lead-halide perovskites are strongly affected by the lattice vibrations. Herein we report far-infrared spectroscopy measurements of $CH_3NH_3Pb(I/Br/Cl)_3$ thin films and single crystals at room temperature (RT) and a detailed quantitative analysis of the spectra. We find strong broadening and anharmonicity of the lattice vibrations for all three halide perovskites, which indicates dynamic disorder of the lead-halide cage at RT. We determine the frequencies of the transversal and longitudinal optical phonons, and use them to calculate, via appropriate models, the static dielectric constants, polaron masses, electron-phonon coupling constants, and upper limits for the phonon-scattering limited charge carrier mobilities. Within the limitations of the model used, we can place an upper limit of 200 $cm^2V^{-1}s^{-1}$ for the RT charge carrier mobility in $MAPbI_3$ single crystals.
See also: Sendner et al., Materials Horizons, 3, pp 613-620, 2016.

DS 24.5 Tue 15:15 ZEU 222

Advances in Vapour Deposition of Metal-Halide Perovskite Thin-Films for Solar Cells — •Juliane Borchert, Jay B. Patel, Henry J. Snaith, and Michael B. Johnston — Department of Physics, University of Oxford, Clarendon Laboratory, Parks Road, Oxford, OX13PU, UK

Hybrid metal-halide perovskite materials are promising absorber materials both for use in single junction and tandem solar cells. A particular focus in recent research has been on the fabrication of perovskite absorber layers from solution. Alternatively, perovskite thin-films can also be deposited using co-evaporation in vacuum. This method offers several benefits. The obtained films show high uniformity over large surface areas. Thus the technique is well suited to the fabrication of large-area planar heterojunction solar cells. Additionally, the uniform film thickness makes the evaporated films ideal for precision characterisation of the optical properties of metal halide perovskite materials. Furthermore, the vapour deposition is solvent-free, which makes it compatible with a wide range of substrates and interlayers. This is for example advantageous in the fabrication of tandem solar cells. Here we present current advances in the understanding of the influence that different process variables have on the quality of the obtained films, as well as the application of co-evaporated perovskite absorber layers in devices.

DS 24.6 Tue 15:30 ZEU 222

Carrier Recombination Analysis in Perovskites Using Time-Resolved Photoluminescence — •Liudmila Kudriashova[1], Philipp Rieder[1], Kristofer Tvingstedt[1], Andreas Sperlich[1], Georgy Astakhov[1], Andreas Baumann[2], and Vladimir Dyakonov[1,2] — [1]Experimental Physics VI, Julius Maximilian University of Würzburg, 97074 Würzburg — [2]Bavarian Center for Applied Energy Research (ZAE Bayern), 97074 Würzburg

Despite the incredible progress of perovskite-based photovoltaics, many aspects of charge carrier recombination in organometal halide perovskites still remain unclear, inhibiting the targeted production of high-performance solar cells. Under solar cell operating conditions photoluminescence (PL) in perovskites is mainly caused by recombination of free photogenerated charge carriers. Hence the time-resolved photoluminescence (TRPL) is a powerful tool to reveal the complex charge carrier behaviour in perovskite films. Here, we implement the combination of several kinetic models for TRPL in $CH_3NH_3PbI_3$ and $CH_3NH_3PbI_{3-x}Cl_x$ films to extract the characteristic recombination rates and estimate the trap concentration. We obtain trap densities

in the range of $10^{15} - 10^{16}$ cm^{-3} and show that PL decay drastically depends on interfaces between the perovskite and conducting layers. Currently controversial aspects, such as different recombination pathways, origin of trap states, and the effect of photon recycling, are discussed. In summary, TRPL analysis enables the calculation of trap density and clarifies the origin of defects, which is crucial for the further development of perovskite-based photovoltaics.

DS 24.7 Tue 15:45 ZEU 222

Monolithic serial interconnection of perovskite solar cells using laser ablation — •Felix Schneider[1], Christof Schultz[1], Rutger Schlatmann[1,2], Steve Albrecht[3], and Bert Stegemann[1] — [1]HTW Berlin - University of Applied Sciences, Wilhelminenhofstr. 75a, 12459 Berlin, Germany — [2]Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, PVcomB, Schwarzschildstr. 3, 12489 Berlin, Germany — [3]Helmholtz-Zentrum Berlin, Institut für Silizium-Photovoltaik, Kekuléstraße 5, 12489 Berlin, Germany

Based on recent work on serial interconnection of thin film solar cells by laser ablation, the proper laser parameters for scribing planar, inverted perovskite solar cell samples were determined. A device design with the layer sequence ITO/PTAA/perovskite/PCBM/Ag was used in which the P1 scribes the ITO, the P2 separates the perovskite and the selective contact layers and the P3 the metal electrode. As a result, successful P1 to P3 laser scribes with sufficiently small area losses, i.e. small dead areas, were obtained. Degradation due to humidity of the perovskite layer during laser scribing was avoided by complete laser processing in nitrogen atmosphere. Detailed characterization of the sample composition by energy dispersive x-ray spectroscopy, the morphology by atomic force microscopy as well as of the electrical functionality of the P2 scribes will be provided. The influence of laser-induced material modifications in the vicinity of the laser scribes on the module performance will be discussed.