

## HL 53: Hybrid Perovskite and Photovoltaics II (joint session CPP/HL)

Time: Wednesday 15:00–16:15

Location: ZEU 260

HL 53.1 Wed 15:00 ZEU 260

**The Efficiency Potential of Neat Perovskite Films** — ●MARTIN STOLTERFOHT — Uni Potsdam

Perovskite photovoltaic (PV) cells have demonstrated power conversion efficiencies (PCE) that are close to those of monocrystalline silicon (m-Si) cells, however, in contrast to silicon PV, perovskites are not limited by Auger recombination. Nevertheless, compared to GaAs and m-Si devices, perovskite cells stand out by their significantly lower fill factors (FFs) which is due to a combination of resistive and non-radiative recombination losses. This necessitates a deeper understanding of the underlying loss mechanism and in particular the ideality factor of the cell. Here, by measuring the intensity (I) dependence of the external ( $V_{OC}$ ) and internal voltage (i.e. the quasi-Fermi level splitting, QFLS), we can quantify the transport resistance-free efficiency of the complete cell as well as the efficiency potential of any neat perovskite films with and without attached transport layers (TLs). Moreover, QFLS(I) measurements on different perovskite compositions allow to disentangle the impact of the interfaces and the perovskite surface on the non-radiative FF and  $V_{OC}$  loss. We find that potassium passivated quadruple cation perovskite films stand out by their exceptionally high implied PCEs of above 28% which could be readily achieved if charge collection losses and energy alignment issues are overcome. Finally, strategies are presented to reduce both the ideality factor and transport losses to push the FF to the thermodynamic limits.

HL 53.2 Wed 15:15 ZEU 260

**Shallow Nano-Textures for Light Management in Solution-Processed Perovskite Solar Cells** — ●PHILIPP TOCKHORN<sup>1</sup>, JOHANNES SUTTER<sup>1</sup>, KLAUS JÄGER<sup>1</sup>, AMRAN AL-ASHOURI<sup>1</sup>, CHRISTIANE BECKER<sup>1</sup>, and STEVE ALBRECHT<sup>1,2</sup> — <sup>1</sup>Helmholtz Zentrum Berlin - 12489 Berlin — <sup>2</sup>Technische Universität Berlin - 10623 Berlin

Metal halide perovskites have led to highly efficient thin-film solar cells in the past decade. Here, we report enhanced PCEs achieved by light management in spin-coated perovskite single junction solar cells on shallow nano-textures. For this, sinusoidal nano-textures with a period of 750 nm and a texture height of 380 nm are employed. In our p-i-n devices, the nano-textured substrate is coated with a bottom contact comprising ITO and a self-assembling monolayer as well as a spincoated perovskite, while the top contact is realised by evaporation. With this design, we obtain a PCE of 18.9%, which marks an increase of 3% with respect to its planar reference. This efficiency gain is mostly achieved by an increase in short circuit current density ( $J_{sc}$ ), achieved through enhanced light scattering by the sinusoidal nano-textures. External quantum efficiency and reflectance measurements on these devices confirm the observed increase in  $J_{sc}$  of about +1 mA/cm<sup>2</sup> promoted by the improved light in-coupling. Furthermore, we observe a systematic reduction of 10-20 mV in open-circuit voltage on the nano-textured devices. Therefore, we investigate the influence of the nano-textures on the electronic quality of the perovskite itself and its interfaces to charge selective contacts with absolute photoluminescence measurements as well as electrical simulations.

HL 53.3 Wed 15:30 ZEU 260

**Electronic structure nonionic surfactant-mixed PEDOT:PSS and its effects on perovskite solar cells** — ●DONGGUEN SHIN<sup>1,2,3</sup>, DONGHEE KANG<sup>3</sup>, NA EUN JUNG<sup>3</sup>, and YEONJIN YI<sup>3</sup> — <sup>1</sup>Institut für Physik & IRIS Adlershof, Humboldt-Universität zu Berlin, Brook-Taylor Straße 6, 12489 Berlin, Germany — <sup>2</sup>Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Albert-Einstein-Straße 15, 12489 Berlin, Germany — <sup>3</sup>Institute of Physics and Applied Physics, Yonsei University, 50 Yonsei-ro, Seodaemun-Gu, Seoul 03722, Republic of Korea

PEDOT:PSS, generally used hole transport layer, has the limitation of increasing the performance of perovskite solar cells (PSCs) due to

its semi-metallic properties. One of the manners of tailoring the electronic properties of PEDOT:PSS is mixing of the nonionic surfactant (e.g. Triton X-100 (TX)) into PEDOT:PSS, which supposedly get the affirmative impact on the charge extraction and exciton quenching at the interface. In this work, we explore the electronic structure of PEDOT:PSS with nonionic surfactant TX mixture by using the X-ray and ultraviolet photoelectron spectroscopy (XPS, UPS) measurement, and investigate the power conversion efficiency (PCE) enhancement of perovskite solar cells (PSCs) by using the mixture of PEDOT:PSS and TX surfactant in PSCs. We reveal that it led to the prevention of interfacial recombination as the insulating tunneling layer without energetic junction loss at the interface MAPbI<sub>3</sub> with PEDOT:PSS. Consequently, we establish an efficient charge extraction condition without the interfacial recombination on PSCs.

HL 53.4 Wed 15:45 ZEU 260

**In-situ study of slot-die printed titania films for up-scale fabrication of all-solid-state dye-sensitized solar cells** — ●NIAN LI<sup>1</sup>, WEI CHEN<sup>1</sup>, MANUEL SCHEEL<sup>1</sup>, VOLKER KÖRSTGENS<sup>1</sup>, MATTHIAS SCHWARTZKOPF<sup>2</sup>, STEPHAN V. ROTH<sup>2</sup>, and PETER MÜLLER-BUSCHBAUM<sup>1,3</sup> — <sup>1</sup>Technische Universität München, Physik-Department, Lehrstuhl für Funktionelle Materialien, James-Frank-Str. 1, 85748 Garching, Germany. — <sup>2</sup>Deutsches Elektronen-Synchrotron DESY Notkestrasse 85, D-22603 Hamburg, Germany. — <sup>3</sup>Heinz Maier-Leibnitz Zentrum (MLZ) Technische Universität München Lichtenbergstr. 1, D-85748 Garching, Germany.

Printing, a simple and low-cost technique, is employed to fabricate mesoporous titania films as electron-transporting layers for upscaling all-solid-state dye-sensitized solar cells (DSSCs). The deposition methods strongly affect the final titania morphology, and further solar cell efficiency. Therefore, a detailed understanding of structure formation is of crucial importance for optimizing the industrial coating films. In the present work, we provide insights into the structure evolution of slot-die printed films via in situ grazing-incidence small-angle X-ray scattering (GISAXS). The printing-solution synthesis is performed by sol-gel chemistry and a structure-directing template polystyrene-block-polyethylene oxide (PS-b-PEO) to achieve the structure tailoring. The evolution of nanostructure length scales of the titania/PS-b-PEO composite film is revealed in real-time and in situ during slot-die printing. The resulting mesoporous titania films with highly ordered structures serve as photoanodes of all-solid-state DSSCs.

HL 53.5 Wed 16:00 ZEU 260

**The role of anchors for the efficiency of p-type dye-sensitized solar cells** — ●MIFTAHUSSURUR HAMIDI PUTRA and AXEL GROSS — Institut für Theoretische Chemie, Universität Ulm, 89069 Ulm, Germany

In recent years, p-type dye-sensitized solar cells (pDSSC) have attracted a lot of attention as an alternative to conventional solar cells. However, the efficiency of this solar cell is still below 10% which hampers their utilization. One of the promising type of dyes for p-DSSC solar cells are ruthenium-based complexes [Ru(bpy)<sub>3</sub>]<sup>2+</sup> [1]. The efficiency of p-DSSCs is critically influenced by the anchors through which they are bound to a semiconductor substrate such as NiO. First-principles electronic calculations based on time-dependent density functional theory (TDDFT) have been performed in order to evaluate the performance of various candidates for anchoring [Ru(bpy)<sub>3</sub>]<sup>2+</sup> complexes. Results will be presented and discussed with respect to properties that are related to the efficiency of p-DSSC solar cells, such as injection free energy ( $\Delta G_{inj}$ ), light harvesting efficiency (LHE), hole injecting efficiency (HJE), regeneration free energy ( $\Delta G_{reg}$ ) and the excited state lifetime ( $\tau$ ) [1,2].

[1] Y. Pellegrin, L. Le Pleux, E. Blart, A. Renaud, B. Chavillon, N. Szuwarski, M. Boujtita, L. Cario, S. Jobic, D. Jacquemin, and F. Odobel, *J. Photochem. Photobiol. A: Chem.* **219**, 235 (2011).

[2] A. Sen and A. Groß, *Int. J. Quantum Chem.* **119**, e25963 (2019).