

## HL 30: Photovoltaics: Nanostructured materials

Time: Tuesday 10:15–11:45

Location: ER 164

HL 30.1 Tue 10:15 ER 164

**Theoretical Study of Frenkel to Wannier-Mott Exciton Transition in a Molecular Dye Aggregate-CdSe Nanocrystal Arrangement** — •THOMAS PLEHN<sup>1</sup>, DIRK ZIEMANN<sup>1</sup>, JÖRG MEGOW<sup>2</sup>, and VOLKHARD MAY<sup>1</sup> — <sup>1</sup>Institut für Physik, Humboldt-Universität zu Berlin, Newtonstraße 15, D-12489 Berlin, Germany — <sup>2</sup>Institut für Chemie, Universität Potsdam, Karl-Liebknecht-Straße 24-25, D-14476 Potsdam, Germany

Transfer processes at hybrid organic-inorganic interfaces have become one of the key research topics. Theoretical studies are presented which give insight into the nature of energy transfer in a realistic molecular-semiconductor hybrid system. Transitions are described from Frenkel excitons in a gigantic tubular cyanin dye aggregate (about 60 nm length and 15 nm diameter) to Wannier-Mott excitons in a nearby placed CdTe nanocrystal (4.5 nm diameter). Despite the size of the system the whole investigation is based on a full atomistic picture. The structure of the tube and the nanocrystal are obtained by molecular dynamics simulations and a tight-binding model, respectively. The Frenkel excitons are described by coupled single molecular excited states and the Wannier-Mott excitons in terms of Coulomb correlated electron-hole pairs. FRET-type rates have been calculated for diverse spatial set-ups. Even brought into contact, the transfer stays incoherent (rates of about  $1/k=1$  ns). The suggested creation of hybrid excitons does not occur due to only weak coupling across the interface.

HL 30.2 Tue 10:30 ER 164

**Investigation of the Spatial-Dependent Charge Carrier Collection Probability in CuInS<sub>2</sub>/ZnO Colloidal Quantum Dot Solar Cells** — •DOROTHEA SCHEUNEMANN, SEBASTIAN WILKEN, JÜRGEN PARISI, and HOLGER BORCHERT — University of Oldenburg, Department of Physics, Energy and Semiconductor Research Laboratory, 26111 Oldenburg

Colloidal quantum dot (CQD) solar cells with solution-producible absorber layers have made rapid progress in the last few years. In particular, the so-called depleted-heterojunction concept, consisting of a wide band gap n-type semiconductor and a p-type CQD film as absorber, appears promising. As an alternative to the commonly used but highly toxic Pb chalcogenide materials, we recently reported on the successful utilization of CuInS<sub>2</sub> nanocrystals as absorber layer in CuInS<sub>2</sub>/ZnO heterojunction solar cells [1]. However, to date, the efficiency of these devices remained limited compared to state-of-the-art Pb-based CQD solar cells. To investigate possible limitations of the CuInS<sub>2</sub>/ZnO system, we modeled the spatially and spectrally resolved absorption in the individual layers of the device stack using the transfer-matrix method. Here, we present a simple method to extract a spatial-dependent charge carrier collection efficiency based on the reconstruction of external quantum efficiency measurements using the modeled absorption profiles. With the help of this analysis, we identified a substantial “dead zone” in our devices, where the collection probability of excess carriers is dramatically reduced.

[1] D. Scheunemann *et al.*, Appl. Phys. Lett. **103**, 133902 (2013).

HL 30.3 Tue 10:45 ER 164

**Patterned growth of ZnO nanorods as light scatterers for photovoltaic application** — •NIVEDITA YUMNAM and VEIT WAGNER — Jacobs University, Campus Ring 1, 28759 Bremen, Germany

One of the major loss mechanisms in solar cells is due to inefficient absorption in active semiconductor layer. The absorption can be enhanced by incorporating ZnO nanorods. They can act as scattering centers of light and hence, they increase the optical path length of light. To grow ZnO, electrochemical deposition is employed since it can be done at relatively low temperature and hence, it is compatible for flexible substrates like PET (Polyethylene terephthalate). ZnO nanorods are grown on Au coated PET. Direct electrochemical deposition on Au/PET yields a very dense ZnO nanorod distribution, which is cumbersome for infiltration of semiconductor polymer. In order to tune the density of ZnO nanorods, self-assembled monolayer (SAM) of 1-octadecanethiol is applied on top of the Au surface. By doing so, the ZnO nanorods grow through the pinholes of the SAM layer, whilst creating gaps between them. The size of the ZnO nanorods is systematically varied by changing the parameters of electrochemical deposition such as temperature, growth time, concentration and volt-

age. An ultrathin layer of Au is sputter coated on top of the nanorods to improve the reflection characteristics. Angle resolved light scattering measurements are carried out to document the beneficial impact of these nanorods on the light scattering properties.

HL 30.4 Tue 11:00 ER 164

**Enhanced photoelectrochemical activity of vertically aligned ZnO-coated TiO<sub>2</sub> nanotubes** — •HUA CAI<sup>1,2</sup>, QIN YANG<sup>2</sup>, ZHI-GAO HU<sup>3</sup>, ZHIHUA DUAN<sup>3</sup>, QINGHU YOU<sup>2</sup>, JIAN SUN<sup>2</sup>, and JIADA WU<sup>2</sup> — <sup>1</sup>Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — <sup>2</sup>Fudan University, Shanghai, China — <sup>3</sup>East China Normal University, Shanghai, China

Vertically aligned ZnO-TiO<sub>2</sub> hetero-nanostructures constructed of anatase TiO<sub>2</sub> nanotubes (NTs) and wurtzite ZnO coatings are fabricated by atomic layer deposition of ZnO coatings on electrochemical anodization formed TiO<sub>2</sub> NTs, and their photoelectrochemical activities are studied through photoelectrochemical and electrochemical characterization. Compared with bare TiO<sub>2</sub> NTs, the transient photocurrent increases to over 1.5-fold for the annealed ZnO-coated TiO<sub>2</sub> NTs under visible illumination. The ZnO-coated TiO<sub>2</sub> NTs also show a longer electron lifetime, a lower charge-transfer resistance and a more negative flat-band potential than the bare TiO<sub>2</sub> NTs, confirming the improved photoelectrochemical activity due to the enhanced charge separation.

HL 30.5 Tue 11:15 ER 164

**Black Silicon Prepared by Maskless Plasma Etching at High Temperatures Above 0 °C for PV Applications** — •MARIA GAUDIG<sup>1,2</sup>, JENS HIRSCH<sup>1,3</sup>, JOHANNES ZIEGLER<sup>2</sup>, THOMAS SCHNEIDER<sup>2</sup>, MARTINA WERNER<sup>3</sup>, ALEXANDER SPRAFKE<sup>2</sup>, NORBERT BERNHARD<sup>1,3</sup>, and RALF WEHRSPHORN<sup>3,4</sup> — <sup>1</sup>Anhalt University of Applied Sciences, Technologies of Photovoltaics Group, Bernburger Str. 55, 06366 Köthen — <sup>2</sup>Martin Luther University Halle-Wittenberg, Institute of Physics, Group microMD, Heinrich-Damerow-Str. 4, 06120 Halle (Saale) — <sup>3</sup>Fraunhofer Center for Silicon Photovoltaics, Otto-Eißfeldt-Straße 12, 06120 Halle (Saale) — <sup>4</sup>Fraunhofer Institute for Mechanics of Materials, Walter-Hülse-Str. 1, 06120 Halle (Saale)

In this work, black silicon prepared by plasma etching at temperatures above 0 °C is demonstrated. The microtexturing is realised with a maskless dry plasma etch process with capacitive and additionally inductive plasma generation. Randomly distributed, parabolic shaped pits are created on the surface with dimensions in the micrometer range and an aspect ratio of the averaged vertical against the lateral dimension of about 2:1. After passivation of the textured samples with a thin aluminium oxide layer deposited by thermal atomic layer deposition, effective charge carrier lifetimes above 1 ms could be reached. Additionally, the absorption, weighted on the AM1.5g spectrum from 300-1150 nm, is slightly increased with the aluminium oxide layer to values about 95 %. In conclusion, a black silicon process at etch temperatures above 0 °C is introduced which could be an option for photovoltaic applications.

HL 30.6 Tue 11:30 ER 164

**Maskless Inductively Coupled Plasma (ICP) Generated Black-Silicon as Alternative Technique to Wet Chemical Textures for Crystalline Silicon Solar Cells** — •JENS HIRSCH<sup>1,2</sup>, MARIA GAUDIG<sup>1</sup>, MARCUS GLÄSER<sup>2</sup>, and DOMINIK LAUSCH<sup>1,2</sup> — <sup>1</sup>Anhalt University of Applied Sciences, Faculty EMW, Bernburger Str. 55 DE-06336 Köthen — <sup>2</sup>Fraunhofer Center for Silicon Photovoltaics CSP, Otto-Eißfeldt-Str. 12, DE-06120 Halle

The current standard for the frontside texturing of crystalline silicon wafers for photovoltaic applications is the wet chemical etching. An alternative technique to this standard process is the maskless inductively coupled plasma (ICP) nanotexturing of the front surface. Plasma technology allows the specifically texturing of mono and multicrystalline silicon, hence parabolic like surface nano structures can be generated on multicrystalline silicon of every orientation too. In this contribution, the results of industrial standard wet and dry SF<sub>6</sub>/O<sub>2</sub>-ICP textures will be compared. In contrast to wet chemical textures, the optical properties of ICP-Nanotextures are based on the so-called Moth-Eye-Effect. This effect is the reason for the excellent optical properties of ICP-Textures under a normal and oblique angle of in-

cidence. In particular, in this contribution the surface morphology, reflection and formation of dry ICP-Nanotextures will be investigated and compared to wet chemical standard textures. In this context, in-

tense attention is given to the surface recombination velocity (SVR). Finally, a first attempt for simulating the influence on the reflection through the geometric of the surface structure will be given.