O 52: Focus Session: Nanophotonic Concepts and Materials for Energy Harvesting - Plasmonics, Transformation Optics, Upconversion, and beyond

Nanostructured and novel photonic materials can control the spectral composition of light, its propagation characteristics, and its interaction with matter. The use of these abilities is particularly rewarding in the context of energy harvesting in semi-conductor materials. This focused session appreciates and presents the most recent advancement in this field of research, where progress has been made from a conceptual but also from a materials perspective.

Organization: Carsten Rockstuhl (KIT, Karlsruhe), Jan Christoph Goldschmidt (FhG ISE, Freiburg), Ralf Wehrspohn (MLU Halle), Uli Lemmer (KIT, Karlsruhe)

Time: Wednesday 11:00–13:00 Location: EW 201

Invited Talk O 52.1 Wed 11:00 EW 201

Transformation Optics: From Fundamentals to Applications for Energy Harvesting — •Martin Wegener and Martin Schumann — Institute of Applied Physics and Institute of Nanotechnology, Karlsruhe Institute of Technology, 76128 Karlsruhe, Germany

Transformation optics can be seen as a versatile tool for designing devices in optics and other areas of physics. In this talk, we start by giving a broad introduction into this concept. A striking paradigm is invisibility cloaking. We briefly review experimental demonstrations in optics, thermodynamics, and mechanics. Next, we discuss a possible application: In order to extract the electrical power from solar cells, metal contacts at the sun-facing surface are required. Unfortunately, these contacts create optically dead areas, reducing the overall current per area by a few percent. We present a solution to this problem by using microstructures that are designed by transformation optics and that cloak the contacts. An experimental proof-of-principle demonstration based on three-dimensional direct-laser-writing optical laser lithography is given.

Invited Talk O 52.2 Wed 11:30 EW 201

Nanostructures and materials for intermediate band solar cells — •Antonio Martí — Instituto de Energía Solar, ETSI Telecomunicación, Universidad Politécnica de Madrid

Intermediate band solar cells (IBSCs) seek for materials that can harvest photons with energy lower than the semiconductor bandgap without degrading the output voltage of the cell. One of these material systems relies on the use of quantum dots (QDs). Under this approach, photons are harvested thanks to the energy states of the electrons confined in the quantum dots. In this contribution we review the theory that sustains the use of QDs for IBSC applications, the design constrains of these kind of solar cells, its limitations and challenges as well as the most recent experimental results. These experimental results refer to the empirical demonstration of the use of two below bandgap energy photons to generate an electron-hole pair and the preservation of the output voltage of the cell.

O 52.3 Wed 12:00 EW 201

Emission quenching of magnetic dipole transitions near an absorbing optical nanoantenna — •Dmitry Chigrin, Deepu Kumar, and Gero von Plessen — RWTH Aachen University, 52074 Aachen, Germany

The optical emission of an ionic emitter near an absorbing optical nanoantenna (such as a metal nanoparticle) can be enhanced or quenched due to near-field effects induced by the nanoantenna. A comparison of emission quenching of electric dipole (ED) and magnetic dipole (MD) transitions in the close vicinity of a metal nanoparticle has been carried out in this work. It is demonstrated that the emission quenching of the MD transitions becomes dominant at substantially shorter distances to the surface of the absorbing nanoantenna as compared to the ED transitions. This difference in quenching behaviour is due to different asymptotic dependencies of the quasi-static radiative and non-radiative decay rates of ED and MD transitions near a metal nanoparticle. It is shown that in the extreme near-field regime the non-locality of the dielectric response of the metal cannot be neglected, which leads to a reduction in the emission quenching for both ED and MD transitions near the absorbing optical nanoantenna.

O 52.4 Wed 12:15 EW 201

Light trapping with combined photonic elements — •Aimi Abass[1] and Bjorn Maes[2,3] — [1]Institute of Nanotechnology, Karlsruhe Institute of Technology, 76021 Karlsruhe, Germany — [2]Photonics Research Group (INTEC), Ghent University-imec, Sint-Pietersnieuwstraat 41, B-9000 Ghent, Belgium — [3]Micro- and Nanophotonic Materials Group, Faculty of Science, University of Mons, 20 place du Parc, B-7000 Mons, Belgium

Nanophotonics offers many avenues for enhancing solar cells. For example, one can tailor the incoming light flow to boost absorption via nanostructures. To ensure strong absorption over the whole spectral range of interest, one has to utilize many photonic phenomena. Oftentimes however, the nanoscale geometrical requirements for optimum excitation of one phenomenon can be at the expense of another. To address this challenge, we examine light trapping strategies with combined photonic elements and study conditions under which different elements complement each other. Here, we discuss the usage of dual interface gratings (DIGs) and diffuser-grating structures. The former enhances absorption by relying on guided mode excitation while the latter focuses on antireflection and scattering management. In such structures the responsibility of different optical components is split, enabling more flexibility in optimization. One main point of discussion is multiperiodic DIG systems, which provide a rich Fourier spectrum, while maintaining a straightforward geometry. In studying combined diffuser-grating structures, we developed a memory efficient calculation method, which evades dealing with rough diffuser geometries directly.

O 52.5 Wed 12:30 EW 201

Tailoring Disorder of Nanophotonic Light-Trapping Concepts for Thin-Film Silicon Solar Cells — •Ulrich W. Paetzold[1], Karsten Bittkau[1], Y. J. Donie[2], Guillaume Goumard[2], Radwanul H. Siddique[2], Michael Smeets[1], Hendrik Hölscher[2], Reinhard Carius[1], Uwe Rau[1], and Uli Lemmer[2] — [1]IEK5 * Photovoltaik, Forschungszentrum Jülich GmbH, 52425 Jülich, Germany — [2]Light Technology Institute and Institute for Microstructure Technology, Karlsruhe Institute of Technology, Engesserstr. 13, 76131 Karlsruhe, Germany

Light-trapping is essential for high performance thin-film solar cells applying optically thin photoactive absorber layer such as a-Si:H with thicknesses below 500 nm. Conventional devices apply randomly textured transparent conductive oxide substrates serving as light-scattering front contacts as well as reflective light-scattering metal back contacts. In recent years, a substantial progress in the development of nanophotonic light-trapping schemes has been reported. In order, to further advance the nanophotonic concepts, the role of tailored disorder in these nanophotonic light trapping concepts is investigated. We present a systematic experimental as well as simulation study on the impact of disorder in nanophotonic light-trapping employing periodic grating couplers in thin-film solar cells. Our results demonstrate a spectrally broad enhanced light trapping effect, i.e., a significant improvement of photocurrent generation, after introducing disorder in advanced nanophotonic light trapping concepts which already beat state-of-the-art light trapping concepts.

O 52.6 Wed 12:45 EW 201

Opaline Photonic Crystals as Back Side Reflector for Thin-Film Silicon Solar Cells — •Daniela Schneevoigt[1], Frederik Bub[1], Alexander N. Sprafke[1], Ralf B. Wehrspohn[1,2], André Hoffmann[3], Karsten Bittkau[3], Reinhard Carius[3], Samuel Wiesendanger[4], and Carsten Rockstuhl[5] — [1]Martin-Luther-Universität Halle-Wittenberg, Germany — [2]Fraunhofer IWM, Halle, Germany — [3]Forschungszentrum Jülich GmbH, Germany — [4]Friedrich-Schiller-Universität Jena, Germany — [5]Karlsruher Institut für Technologie, Germany

3D photonic crystals, such as opaline structures, have a tremendous potential to increase the efficiency of solar cells by enabling advanced light management concepts. Especially opaline structures applied to the back side of a solar cell provide various functions that can enhance the light path in the cell. Light in a specific spectral interval that is not absorbed during its first passage through the solar cell is strongly back reflected if the opal satisfies a Bragg condition. Light at other wavelengths might be diffracted back into the cell by the opal. By both means the probability of light absorption and thus the efficiency of the solar cell is increased. Here, we present the successful fabrication of large-area opaline structures at the back side of 1μm thick hydrogenated microcrystalline silicon (μc-Si:H) single junction solar cells via an automated spray coating process. The optical, structural, and electrical characteristics of these structures on different μc-Si:H textures were analyzed and the photovoltaic characteristics of the completely integrated system were evaluated and compared to simulations.