HL 81: Poster: Energy materials incl. photovoltaics

Time: Wednesday 17:00–20:00 Location: P1

HL 81.1 Wed 17:00 P1

Plasmonic enhanced photocurrent on GaN and TiO_2 films decorated with Au-NPs — •Verena Hintermayr, Jacek Stolarczyk, and Jochen Feldmann — Photonics and Optoelectronics Group, Physics Department and Center for NanoScience (CeNS), LMU München, Germany

Utilization and storage of solar energy can be achieved by its direct conversion to chemical energy using photocatalysis. Thereby the energy of the photons is used to run chemical reactions like water splitting. These photocatalysts are usually wide band semiconductors and only utilize a small percentage of the solar irradiance. In order to sensitize them to visible light a combination of wide band gap semiconductors and metal nanoparticles is used. The plasmon decay in the nanoparticle leads to the generation of hot electrons which are then injected into the neighbouring semiconductor and drive the reduction reaction.

We investigate the dependency of the photocurrent measured on GaN and TiO_2 films on the Au nanoparticle decoration of the samples. To be able to measure the generated photocurrent for both systems suitable finger structures were defined using optical lithography. In both cases the Au nanoparticles were spin coated on the semiconductor in a further processing step. In the measurements of the GaN and TiO_2 films decorated with Au nanoparticles a plasmon-enhanced photocurrent by producing hot carriers even at energies below the semiconductor band gap can be observed.

HL 81.2 Wed 17:00 P1

3D nano-architectures for next generation solar water splitting devices — •Stefan Bösemann, Liaoyong Wen, Yang Xu, Min Zhou, and Zhibing Zhan — Ilmenau University of Technology, Institute of Physics & IMN MacroNano (ZIK), Prof. Schmidt-Str. 26, 98693 Ilmenau (Germany)

Solar energy is one of the major forms of renewable energy. Various solar water splitting concepts have been regarded as a feasible and cost-effective realization of an artificial analogy to photosynthesis. Unfortunately, the stringent requirements for the physical and chemical properties make it difficult to find suitable photoelectrodes able to perform solar energy conversion efficiently and inexpensively. Devices built from 3D ordered nano-architectures offer a number of advantages over those based on thin film technology, such as larger surface and reaction area to collect more sunlight and to improve the efficiency of solar water splitting. Innovations in 3D nano-architectured photoelectrodes offer potential breakthroughs in this field by taking the advantages correspondingly physical processes. Herein, with the assistance of various fabrication techniques and different templates, including anodic aluminum oxide (AAO) and polystyrene colloidal templates, photoelectrodes with different 3D structures have been achieved and applied in solar water splitting. For example, we have constructed 3D quaternary macro-mesoporous architectures, which showed improved solar energy conversion efficiency. Meanwhile, we also realized a tandem structure, which facilitate the hydrogen and the oxygen evolution at the same time in one single device.

HL 81.3 Wed 17:00 P1

Hierarchical NiMoO4@MnO2 core-shell heterostructured nanowire arrays on Ni foam as high-performance supercapacitor electrodes — Yaoguo Fang[1,2], Kin Mun Wong[1], Gerhard Wilde[2], and •Yong Lei[1] — [1]Ilmenau University of Technology, Institute of Physics & IMN MacroNano (ZIK) Prof. Schmidt-Str. 26, 98693 Ilmenau (Germany) — [2]Institute of Materials Physics and Center for Nanotechnology, University of Muenster, Wilhelm-Klemm-Str. 10, Muenster 48149, Germany

Supercapacitors, also known as electrochemical capacitors, have been considered as one of the most promising energy storage devices because of their many advantages, including high power density, faster charge and discharge processes, living cycle lifetime, compared the conventional capacitors. Recently, research has been particularly focused on MnMoO4, and NiMoO4 because of their superior electrochemical properties, abundant resources and environmental friendliness. In this work, we design and fabricate novel hierarchical NiMoO4@MnO2 core-shell heterostructured nanowire arrays on the nickel foam, which were used as the working electrodes to fabricate high performance supercapacitors. The NiMoO4 nanowires are "core" and ultrathin MnO2 film are "shell" structures. This structure shows attractive electrochemical behavior as electrode materials for supercapacitors. The findings exhibit the importance and great potential of metal molybdate based binary oxides in the development of high performance energy storage systems.

HL 81.4 Wed 17:00 P1

Black-silicon solar cells — •Philipp Assum, Svetoslav Koynov, and Martin Stutzmann — Walter Schottky Institut , Technische Universität München, Am Coulombwall 4, D-85748 Garching, Germany

Avoiding optical losses is a key issue for the improvement of photovoltaic solar cells. Therefore black nano-textured surfaces are a prospective possibility since they almost completely suppress reflection in the whole range of silicon absorption. Furthermore an enhancement of absorption occurs in thin solar cells due to light trapping effects.

The present work focuses on the application of black-silicon nanotextures to actual solar cells. Common approaches first perform the black nano-texture etch process followed by the formation of the emitter. This is due to the fact that the black etch process is problematic on heavily doped emitter layers which are commonly used for present solar cells. In contrast this work presents a new approach where the sequence of processes is changed. First a deep but weakly doped emitter is created. Subsequently a modified black etch process, which is feasible on the doping level of the emitter, is performed. Self-doping grid contacts are applied to form highly doped regions just in vicinity of the contact which is called the selective emitter concept.

Initial results will be reported in comparison with results concerning "black" solar cells produced by the common approach in which the black etch process precedes the emitter formation.

HL 81.5 Wed 17:00 P1

Nanoparticles with high pressure core structures and Si-ZnS nanocomposites: New Paradigms to Improve the Efficiency of MEG Solar Cells — •Stefan Wippermann[1], Marton Vörös[2], Balint Somogyi[3], Adam Gali[3], Dario Rocca[4], Francois Gygi[2], Gergely Zimanyi[2], and Giulia Galli[2] — [1]Max-Planck-Institute for Iron Research, Düsseldorf — [2]University of California, Davis — [3]Budapest University of Technology and Economics — [4]Universite de Lorraine, Nancy

The efficiency of nanoparticle (NP) solar cells may substantially exceed the Shockley-Queisser limit by exploiting multi-exciton generation. However, (i) quantum confinement tends to increase the electronic gap and thus the MEG threshold beyond the solar spectrum and (ii) charge extraction through NP networks may be hindered by facile recombination. Using ab initio calculations we found that (i) Si and Ge NPs with exotic core structures such as BC8 exhibit significantly lower gaps and MEG thresholds than particles with diamond cores, and an order of magnitude higher MEG rates. (ii) We also investigated Si NPs embedded in a ZnS host matrix and observed complementary charge transport networks, where electron transport occurs by hopping between NPs and hole transport through the ZnS-matrix. Such complementary pathways may substantially reduce recombination, as was indeed observed in recent experiments. We employed several levels of theory, including DFT with hybrid functionals and GW calculations.

HL 81.6 Wed 17:00 P1

Optimizing binary profiles for metallic solar cell back-plane reflectors — •Jan Marc Stockschläder and Erich Runge — Institut für Physik and Thüringer Landesgraduiertenschule für Photovoltaik PhotoGrad, Technische Universität Ilmenau, 98693 Ilmenau

Coupling light to the active medium of a solar cell is a crucial point for high efficiency. Structured substrates have been proposed to scatter light more efficiently into the absorber. Thin geometries are particularly attractive because they have the potential for low-cost fabrication. In acoustics, so-called Galois scatterer are often used because they scatter equally into every available scattering order[1]. However for solar cells, it matters whether scattering orders correspond to long or short path ways in the absorber. Taking this into account, we present a simple criterion as a basis for educated guesses for the absorption enhancement of a particular scattering profile. We compare the results of FDTD simulations and our heuristic estimate for Galois scatters and numerous structures of the same period length.

[1] T. J. Cox , P. D'Antonio, and M. Schroeder, *Acoustic Absorbers and Diffusers: Theory, Design and Application*, JASA **117**, 3345 (2005)

HL 81.7 Wed 17:00 P1

Time-Resolved Single-Photon Counting Measurements of GaAs Nanowires for Photovoltaics — Rami Naklah[1], •Peter Kleinschmidt[1,2], Matthias Steidl[1], Sabine Nieland[2], Christian Koppka[1], Alexander Lawerenz[2], Werner Prost[3], and Thomas Hannappel[1,2] — [1]TU Ilmenau, Germany — [2]CiS Forschungsinstitut, Erfurt, Germany — [3]Universität Duisburg-Essen, Germany

Recent progress in the development of nanowire-based solar cells has led to devices which demonstrate efficiencies of 13,8 % using axial InP nanowires [1]. On the other hand, radial nanowires consisting of a GaAs core-shell structure [2] allow separation of the direction of charge carrier transport from that of the incident light, resulting in less stringent requirements on transport properties. However, surface recombination may have an impact on device performance. We have established a measurement setup which allows to measure time-resolved photoluminescence with high spatial resolution enabling the investigation of luminescence from nanowires with a typical length of a few microns and a typical diameter of 100 nm. While we are able to map the luminescence signal of homogeneously doped nanowires (deposited on sapphire substrates from solution), our measurements indicate charge carrier lifetimes on the order of 10 ps or less. We investigate the influence on lifetimes of TCO layers deposited wet-chemically or by ALD in order to evaluate their passivation properties.

[1] J. Wallentin et al, Science 339, 1057 (2013)
[2] C. Gutsche et al, Adv. Funct. Mater. 22, 929 (2012)

HL 81.8 Wed 17:00 P1

Surface passivation of Si by ZnO doped Al_2O_3 — •Thomas Schneider[1], Johannes Ziegler[1], Alexander N. Sprafke[1], and Ralf B. Wehrspohn[1,2] — [1]Institute of Physics Martin-Luther-Universität Halle-Wittenberg, Heinrich Damerow-Str. 4, 06120 Halle, Germany — [2]Fraunhofer Institute for Mechanics of Materials IWM, Walter-Hülse-Str. 1, 06120 Halle, Germany

The lifetime of the minority charge carriers in thin, high quality Si wafers is mainly limited by surface recombination processes[1]. Thin dielectric layers of Al_2O_3 deposited on the Si surface are known to provide a excellent surface passivation. In this work, ZnO is incorporated into thin Al_2O_3 films and the influence of the ZnO to Al_2O_3 ratio on the passivation quality is studied. The films are deposited by means of thermal atomic layer deposition on p-type Si. Different numbers of ZnO cycles are incorporated into an approximately 10 nm thick Al_2O_3 layer. The passivation quality is determined by lifetime measurements with the QSSPC method. For a certain ratio of ZnO in the Al_2O_3 an increase of the lifetime of the minority charge carriers occurred, indicating a enhanced passivation of the Si surface.

[1] A.G. Aberle, Prog. Photovolt: Res. Appl. 8(5), 473 (2000). doi:10.1002/1099-159X(200009/10)8:5⟨473::AID-PIP337⟩3.0.CO;2-D

HL 81.9 Wed 17:00 P1

Influence of a SiO_2 interlayer on AL_2O_3 passivated silicon wafers — •Johannes Ziegler[1], Thomas Schneider[1], Alexander N. Sprafke[1], and Ralf B. Wehrspohn[1,2] — [1]Institute of Physics Martin-Luther-Universität Halle-Wittenberg, Heinrich Damerow-Str. 4, 06120 Halle, Germany — [2]Fraunhofer Institute for Mechanics of Materials IWM, Walter-Hülse-Str. 1, 06120 Halle, Germany

Silicon surfaces are exellently passivated by Al_2O_3 due to the chemical passivation of recombination active dangling bonds by saturation, as well as field effect passivation generated by a high density of fixed negative charges in the Al_2O_3. Therefore, it is used to reduce parasitic charge carrier recombination in silicon solar cells [1]. However silicon tends to form a layer of SiO_2 on its surface. In most cases, Al_2O_3 is deposited on an Si/SiO_2 interface [2]. Thus the thickness and growing conditions of the SiO_2 interlayer influences the passivation quality of the $Si/SiO_2/Al_2O_3$ passivation stack. The influence of differently wet-chemically grown SiO_2 interlayers in such passivation stack is investigated by effective minority carrier lifetime measurements.

[1] F. Werner, B. Veith, D. Zielke, L. Kühnemund, C. Tegenkamp, M.Seibt, R. Brendel, J. Schmidt, J. Appl. Phys. 109, 113701 (2011).doi:10.1063/1.3587227
[2] V. Naumann, M. Otto, C. Hagendorf, R.B. Wehrspohn, J. Vac. Sci.Technol., A 30, 04D106 (2012). doi:10.1116/1.4704601

HL 81.10 Wed 17:00 P1

Opto-electronic properties of physical vapor deposited Bi_2S_3 on the mm- and μm-scale — •Hendrik Sträter[1], Sebastian ten Haaf[2], Rudolf Brüggemann[1], Gerhard Jakob[2], Niklas Nilius[1], and Gottfried Bauer[1] — [1]Carl von Ossietzky Universität Oldenburg, Institut für Physik, D-26111 Oldenburg — [2]Johannes Gutenberg Universität Mainz, Institut für Physik, D-55099 Mainz

Bismuth sulfide (Bi_2S_3) is a non-toxic n-type semiconductor with a band gap of $E_g = 1.3\,\text{eV}$ and thus a potential candidate for thin film solar cells. We present a temperature dependent photoluminescence (PL) study on the mm-scale and a laterally resolved PL study on the μm-scale and determine in both cases the opto-electronic properties of a physical vapor deposited Bi_2S_3 film. We find a splitting of quasi-Fermilevels (QFL) of $\mu = 650\,\text{meV}$ and an optical band gap of $E_{opt} = 1.3\,\text{eV}$ at room temperature. Although only stoichometric Bi_2S_3 can be found in the film, laterally resolved maps of the PL yield, QFL-splitting and optical band gap show modulations in the local properties most likely due to different crystal orientations of the Bi_2S_3 grains.

HL 81.11 Wed 17:00 P1

Drive Level Capacitance Profiling on CIGS-based Thin Film Solar Cells — •Lisa Paller[1,2], Felix Daume[1,2], Andreas Rahm[1], and Marius Grundmann[2] — [1]Solarion AG, Leipzig (Zwenkau) — [2]Institut für Experimentelle Physik II, Universität Leipzig

For the efficient conversion of solar energy into electrical energy, a high density of mobile charge carriers within the solar cell device is required. The density of defects and their energetic position within the band gap play a decisive role in the generation of such electron hole pairs. These defect properties have been studied on $CuIn_{1-x}Ga_xSe_2$-based thin film solar cells by means of drive level capacitance profiling (DLCP). The variation of the sample temperature and the frequency of the applied AC voltage during DLCP allowed an estimation of the ionization energy of the defects.

We compare DLCP and the strongly related capacitance voltage profiling (CV) in order to point out advantages and disadvantages of both techniques. In the literature an overestimation of the carrier densities acquired via CV-measurements is reported . In order to verify the meaning of these results for our samples, CV measurements have been performed and the resulting doping profiles have been compared to the ones obtained from DLCP. In addition to high efficiencies a large lifetime of the solar cell devices is desirable. Therefore the samples have been artificially aged by a damp heat treatment and the defect properties have been investigated again via the two aforementioned capacitance profiling techniques.

HL 81.12 Wed 17:00 P1

Accuracy comparison for different methods of extraction of parameters of CIGS solar cells — •Jose Fabio Lopez Salas, Jan Keller, and Ingo Riedel — Laboratory for Chalcogenide Photovoltaics, Energy and Semiconductor Research Laboratory, University of Oldenburg

The Shockley equation describes the current density in a solar cell resulting from a voltage bias. Especially the temperature dependent ideality facotr n and saturation current density J_0 are usually evaluated to understand the fundamental physical loss mechanisms of solar cells, such as the localization of dominant recombination paths. If these parameters are not properly derived, the Shockley equation may not reflect the real current-voltage (IV) characteristics which leads to misinterpretations of internal electrical losses. In this work a number of methods for extraction of the mentioned parameters are applied to different CIGS solar cells and are compared. The accuracy of the parameters is compared for the cases of light, dark, temperature-dependent and intensity-dependent measurements, while the mean square error of the corresponding fits serves as the quality indicator. The objective is to find a reliable method for extraction of parameters of CIGS solar cells which yields the best possible reproduction of their real IV behaviour and to quantify the inaccuracy of each approach.

HL 81.13 Wed 17:00 P1

Impact of light soaking and dark annealing on the electronic properties and transient photoluminescence of Cu(In,Ga)Se2 thin-film photovoltaic solar cells and absorbers. — •Viktor Gerliz, Stephan Heise, Jörg Ohland, Jürgen Parisi, and Ingo Riedel — Carl von Ossietzky University of Oldenburg, Germany

Continuous light soaking (LS) at elevated temperature and dark

annealing (DANN) can significantly affect the performance of Cu(In,Ga)Se2 (CIGSe) thin film solar cells. LS at T=90°C under white-light illumination results in improved cell performance due to evident increase of the open circuit voltage and doping concentration. The long-term dark annealing of devices reduces this effect while swapping between meta-stable and relaxed states appears to be more or less reversible. It can be anticipated that both conditioning procedures affect the recombination dynamics of the minority carriers. To investigate such dependence we performed time-resolved photoluminescence measurements (TRPL) using the time-correlated single-photon counting (TCSPC) technique. In this contribution we discuss the progressive change of the photoluminescence decay characteristics as obtained for light-soaked and annealed CIGSe solar cells and CIGSe/CdS heterostructures.

HL 81.14 Wed 17:00 P1

Development of an automated process for chemical bath deposition (CBD) of thin CdS films under inert-gas atmosphere — •Marcus Dressler, Christine Chory, Jan Keller, Ulf Mikolajczak, Jürgen Parisi, and Ingo Riedel — Energy and Semiconductor Research Lab, Dept. of Physics, Univ. of Oldenburg, 26111 Oldenburg

$Cu(In_{1-x}Ga_x)Se_2$ (CIGSe) thin film solar cells are commonly exposed to air prior to the deposition of the n-type buffer layer (e.g. CdS). To avoid atmospheric degradation of the CIGSe surface during the device fabrication process chain we develop an automated technique for chemical bath deposition (CBD) of CdS thin films which is to be performed in a nitrogen glove box. To establish CdS thin films as an in house reference for the future development of alternate buffer materials the scope of this master thesis is to develop a well-defined and reproducible CdS-CBD process which has to be integrated into the automated baseline device fabrication process. In this contribution we present first results of chemical bath deposited CdS films on glass and CIGSe thin films. This poster will particularly focus on the optical and morphological characterization of CdS films manually processed under ambient conditions with the aim to identify promising synthesis-parameters like bath temperature, concentration of reagents and deposition time. While the optical transmission is of crucial importance to minimize parasitic absorption of the buffer layer in completed solar cells we also investigated the film roughness and coverage of the substrate as obtained for different process recipes. These investigations have been carried out by laser-scanning, atomic-force and scanning-electron-microscopy.

HL 81.15 Wed 17:00 P1

Electronic structure of Cu/In/Ga/Se-containing semiconductors — Juliana Srour[1], Fouad El Haj Hassan[1], •Andrei Postnikov[2], Michael Yakushev[3], and Tatyana Kuznetsova[4] — [1]Lebanese University, Beirut, Lebanon — [2]University of Lorraine, Metz, France — [3]Strathclyde University, Glasgow, UK — [4]Institute of Metal Physics, Yekaterinburg, Russia

Semiconductors based on the chalcopyrite-type $CuInSe_2$ (1-1-2) are promising for applications in photovoltaics, not least because their properties are not much deteriorated by the presence of typical point defects and deviations from stoichiometry. For tuning of electronic characteristics, indium is sometimes used in isoelectronic substitution by gallium. Such 1-1-2 compounds belong to a larger family of ternary phases, including notably 1-3-5 and 1-5-8 as particularly stable ones, which do often appear in practical synthesis. The structure of these phases can be generally derived from the zincblende one, with different substitutions on the cationic sublattice and a possible inclusion of ordered defects; however, some details of structures are still subject to debate. The 3-component region of the phase diagram, on its side of binary In-Se, borders to InSe (or, correspondingly, GaSe) semiconductors of not zincblende type (double-layer structure with cation-cation bonds). Different packing of layers gives rise to several polytypes. We study electronic structure of some representative binary and ternary compounds from first principles, using several flavours of exchange-correlation potentials, in order to test the impact of the latter on the band structure and on comparison with available experimental spectra.

HL 81.16 Wed 17:00 P1

Optical, Structural and Surface Properties Te added CIGSeTe Thin Films — •songül fiat[1], Emin Bacaksiz[2], Michael Kompitsas[3], and Güven Çankaya[4] — [1]Dumlupinar University — [2]Karadeniz Technical University — [3]National Hellenic Research Foundation — [4]Yildirim Beyazit University

The aim of this work was to study the dependence of the optical, structural and morphological properties of CuIn0.7Ga0.3(Se(1-x)Tex)2 (briefly CIGSeTe) thin films for three different stoichiometries (for x=0.0 x=0.4 and 1.0). The films have been deposited onto soda lime glass (SLG) substrates by the e-beam evaporation technique. The films showed high absorption and revealed optical band gaps ranging from 1,21-1,11 eV for x=0 and 1,15-1,09 eV for x=0.4 from as deposited to highest annealing temperature 525 °C and as last 1.05-1.00 eV from as deposited to highest annealed temperature 600 °C for x=1.0 amounts. The linear dependence of the lattice parameters as a function of Se and Te contents was examined. X-ray diffraction analyses showed that the films had the single phase chalcopyrite structure. The lattice parameters (a and c) varied linearly with the increase in Te content x from x=0.0 to x= 1.0. AFM maps have been analysed. and the relative elemental composition present in the deposited CIGSeTe films have been measured by using energy dispersive X-ray analysis (EDX).

HL 81.17 Wed 17:00 P1

Photo electric converters (Photovoltaic) and the solar energy power systems — •Ia Trapaidze, Gela Goderdzishvili, Rafiel Chikovani, and Tamaz Minashvili — Dep. of Physics, Georgian Technical University, 77 Kostava Ave. IV block, 0175, Tbilisi, Georgia

Renewable energy sources, such as wind, solar, hydro and geothermal energies, attract increasing attention in the world. Photo electric converters (PV) play an important role in Renewable Power generation. Numerous studies have been recently conducted regarding problems of Photovoltaics.

In this article we discuss physical concepts of Photovoltaics, new materials and structures used in fabrication of PV, constructers types, parameters and all technology of manufacturing. For developing of photovoltaics is very important to use cascaded and concentrating system. In cascaded systems vast amount of solar radiation is converted into electric energy through several cascades, which is the reason of increasing efficiency of photovoltaics. In the article we pay particular importance to the improvement of Photovoltaics parameters. We also discuss principles of design of solar energy power systems based on PV.