HL 5: Photovoltaic

Time: Monday 11:00–13:15 Location: H14

HL 5.1 Mon 11:00 H14

Electrochemically prepared schottky-type nanoemitter solar cells — •Thomas Stempel Pereira, Katarzyna Skorupska, Michael Kanis, Michael Lublow, Mohammed Aggour, and Hans-Joachim Lewerenz — Hahn-Meitner-Institut, Glienicker Str. 100, 14109 Berlin

We produced a schottky-type nanoemitter solar cell with photoelectrochemical methods. It is known, that anodic current-oscillations in fluoride-containing solutions built up porous SiO_2 with an average thickness of 10 nm. The pores, some of which maintain contact to the Si-surface, have a diameter of several ten nm. Their distribution depends on the process-parameters and the chosen emersion current phase. These oxides can be used as a mask for selective alkaline Si-etching and subsequent electrodeposition of metals into the pores. Used in electrochemical solar-cells with Pt-nanoemitters and I^-/I_3^--redox-electrolyte we achieved efficiencies better than 5 %. AFM and HRSEM-images of the preparation steps and the complete device are presented, as well as a model for the bandstructure based on the determination of the flatband-potential by electrochemical impedance-spectroscopy.

HL 5.2 Mon 11:15 H14

Spectrally Selective Photonic Structures for Photovoltaic Applications — •Andreas Bielawny[1], Andreas von Rhein[2], Ralf Boris Wehrspohn[1], Rheinhard Carius[3], Carsten Rockstuhl[4], Marian Lisca[4], and Falk Lederer[4] — [1]Institute of Physics, AG Wehrspohn, MLU Halle-Wittenberg, Heinrich-Damerow-Str. 4, D-06120 Halle, Germany — [2]Dept. Physics, University of Paderborn, D-33095 Paderborn, Germany — [3]Institute for Photovoltaics, Research Center Juelich, D-52425 Juelich, Germany — [4]Dept. Physics, University of Jena, D-07743 Jena, Germany

One of the most appealing and lasting applications for photonics is photovoltaic (PV) energy conversion. While significant successes in material research and cell design were reported, photon management basically relies thus far on empirically obtained random rough surfaces.

We present a novel concept to incorporate a photonic crystal material with tailored properties into a photovoltaic tandem solar cell, causing two desirable effects. Firstly, our structure acts as a spectrally selective filter (according to the designed photonic stop-gaps) between PV-junctions of different electronic bandgaps: this increases multi-gap efficiency. Secondly, the periodicity of the photonic crystal provides diffraction of light into higher orders, which results in an enlargement of the optical path inside a PV-cell. This increases absorption and allows to improve current output or for the employment of even thinner cells. We present our work on photon management in a silicon-tandem cell with simulations based on experimental data, showing significant increase of the tandem cell's efficiency.

HL 5.3 Mon 11:30 H14

Growth and band gap characterizations of single crystals in the series ZrS_2Se_{2-x} — •Mohamed Moustafa, Thorsten Zandt, Christoph Janowitz, and Recardo Manzke — Institut für Physik, Humboldt-Universität zu Berlin, Newtonstraße 15, 12489 Berlin

Single crystals of layered transition metal dichalcogenides with composition ZrS_2Se_{2-x}, where x varies within the range 0-2, were grown by the chemical vapour transport technique using iodine as a transporting agent. Growth conditions are reported and the characterizations of the grown crystals were carried out with the help of LEED and EDX techniques. In addition, the absorption coefficient α was determined from transmission measurements at room temperature and approximate values of the band gaps were determined from the intercepts of the linear plots of the absorption coefficient on the energy axis [1]. The determined band gaps show good correspondence for the photovoltaic applications which is for a single junction cell about 1.45 eV and for two junctions about 1.1 eV and 1.8 eV. The observed exponential behaviour part in the absorption curve in the gap is also interpreted [2].

[1] P.A. Lee et al., J.Phys. Chem. Solids 30, 2719 (1969)
[2] F. Urbach, Phys. Rev. 92, 1324 (1953)

HL 5.4 Mon 11:45 H14

Interface Condition during Oscillatory Behavior of Silicon Photoelectrodes Investigated by Brewster Angle Reflectometry — •Michael Lublow and Hans Joachim Lewerenz — Hahn-Meitner-Institut Berlin, Abt. SE5, Glienicker Str. 100, 14109 Berlin

In-situ Brewster angle reflectometry was employed during anodic current oscillations of silicon electrodes in HF containing solutions. At selected points of the oscillation cycles, surface and interface topographies were investigated by Atomic Force Microscopy. The morphology of the anodic oxide was found to be built of regular cone shaped rods with uniform lateral diameter (80-120 nm) depending upon the oscillation state. In order to uncover the silicon oxide / silicon interface carefully, Brewster angle analysis was used during successive etch steps of the sample in 40% NH_4F. Thus, the change in film thickness of the anodic oxide as well as the variation of the roughened interfaces could be accurately quantified. It can be shown that the silicon interface is characterized by a transitory behavior from statistically rough to self-organized topographies.

HL 5.5 Mon 12:00 H14

Tuning the photovoltage of dye-sensitized solar cells based on electrodeposited ZnO — •Torsten Oekermann[1], Laurence Peter[2], and Tsukasa Yoshida[3] — [1]Institute of Physical Chemistry and Electrochemistry, Leibniz Universität Hannover, Callinstrasse 3-3A, 30167 Hannover, Germany — [2]Department of Chemistry, University of Bath, Bath BA2 7AY, United Kingdom — [3]Graduate School of Engineering, Gifu University, Yanagido 1-1, Gifu 501-1193, Japan

Nanoporous, fully crystalline ZnO films can be prepared by cathodic electrodeposition from aqueous solutions of Zn salts under the influence of structure-directing agents such as surfactants. Dye-sensitized solar cells (DSSC) based on such films have emerged as a possible alternative for nanocrystalline TiO2-based DSSC due to the very high porosity and good electron transport properties of the films.[1] In this study, we have investigated the influence of the sensitizer dye molecules on the photovoltage of the ZnO-based DSSC. Impedance measurements show that the adsorbed dye molecules lead to a shift of the flatband potential of the ZnO. Electron pushing or withdrawing effects of the dye molecules and protonation or deprotonation of the ZnO surface are discussed as possible explanations. The shifts in the flatband potential partly explain the differences in the photovoltages caused by different dyes, however, differences in the electron injection efficiency and the blocking of electron back reaction by the dye molecules have to be taken into account, too, for a complete description.

[1] Oekermann, T.; Yoshida, T.; Minoura, H.; Wijayantha, K. G. U.; Peter, L.M. J. Phys. Chem. B 2004, 108, 8364.

HL 5.6 Mon 12:15 H14

Deposition and characterization of (Zn,Mg)O buffer layers on CIGSSe thin film solar cells — •Felix Erfurth[1], Thomas Niesen[2], Jörg Palm[2], and Eberhard Umbach[1] — [1]University of Würzburg, Experimental Physics II, Am Hubland, 97070 Würzburg, Germany — [2]Avancis GmbH, München, Germany

The replacement of the CdS buffer layer in thin film solar cells based on $Cu(In,Ga)(S,Se)_2$ (CIGSSe), and the use of dry physical deposition methods, would be beneficial for high volume mass production. (Zn,Mg)O buffer layers deposited by radio frequency magnetron sputtering can result in efficiencies comparable to those of CdS containing solar cells. Using two separated ZnO and MgO sputter targets we are able to control the Zn/Mg – ratio of the buffer layer. A higher Mg content enhances the optical band–gap of (Zn,Mg)O, which is expected to have a great influence on the solar cell parameters by changing the electronic band alignment, too. In our experimental setup the sputter preparation chamber is connected with a UHV analysis system which allows in–situ characterization even during the layer deposition by interrupting the sputter process.

To understand the impact of sputter parameters, such as Mg content, on the cell efficiency, we investigated the buffer layer and the absorber–buffer interface by photoelectron spectroscopy (XPS, UPS) and inverse photoelectron spectroscopy (IPES). The combination of both techniques allows determining the buffer layer stoichiometry as well as the alignment of the conduction and valence band at the heterojunction interface.

HL 5.7 Mon 12:30 H14

InP(100)-based low band gap tandem solar cell with an In-

GaAs/GaAsSb tunnel junction — •Ulf Seidel, Erol Sagol, Ulrike Bloeck, Klaus Schwarzburg, and Thomas Hannappel — Hahn-Meitner-Institute, Glienicker Str. 100, 14109 Berlin, Germany

Triple junction III-V solar cells lattice-matched to GaAs(100) and grown on a Germanium bottom cell have recently shown world record conversion efficiencies of 39% under concentrated sunlight. Even higher efficiencies can be expected when employing more than 3 junctions with optimized band gaps. However, to realize high-efficiency multi-junction solar cells with more than 3 junctions an appropriate absorber material with a band gap around 1eV is needed. Therefore, a monolithic low band gap tandem solar cell on the lattice constant of InP(100) was designed with optimized band gaps. It is thought to be combined with a GaAs-based high band gap tandem or triple cell via different techniques.

Here, we report on our results obtained when realizing an InP(100)-based low band gap tandem structure. The cell was grown monolithically on p-doped InP(100) via MOVPE in an AIX-200 reactor. The bottom cell (InGaAs E_g = 0.73eV) and the top cell (InGaAsP E_g = 1.03eV) of the low band gap tandem solar cell are connected via an Esaki-diode-like tunnel junction that includes n-InGaAs and p-GaAsSb. The influence of different preparation procedures on the critical InGaAs-GaAsSb hetero-interface and on the cell performance was investigated in detail.

HL 5.8 Mon 12:45 H14

Electrical Detection of Spin Coherence in Microcrystalline pin Solar Cells — •Jan Behrends[1], Christoph Boehme[1,2], Stefan Haas[3], Bernd Rech[1,3], and Klaus Lips[1] — [1]Hahn-Meitner-Institut Berlin, Abt. Silizium-Photovoltaik, Berlin, Germany — [2]Department of Physics, University of Utah, Salt Lake City, UT, USA — [3]Institute of Photovoltaics, Forschungszentrum Jülich, Jülich, Germany

Defects in the band gap of hydrogenated microcrystalline silicon (μc-Si:H) pin solar cells, even at low concentrations, can act as recombination centres and thus, they can influence the electronic properties of the device significantly. A powerful technique to investigate these recombination processes is pulsed electrically detected magnetic resonance (pEDMR). This method is based on transient photocurrent measurements after varying specific recombination or transport rates and reveals information about the microscopic mechanisms of recombination and transport that involve paramagnetic states. In this study we report on the application of pEDMR on state-of-the-art μc-Si:H pin solar cells prepared on ZnO coated glass. An adapted contact structure allows the observation of Rabi oscillations in the photocurrent at low temperatures (T=10K) reflecting coherent spin motion. The coherence time is found to be on the order of several hundred nanoseconds and is determined by recombination. A Fourier analysis of the observed Rabi oscillations allows a distinction between the involved recombination processes. A discussion on the different recombination mechanisms in μc-Si:H cells will be given.

HL 5.9 Mon 13:00 H14

A Systematic Study on the Deposition of μm Thick $CuInS_2$ Spray ILGAR Layers — •Christian Camus, Daniel Abou-Ras, Nicholas Allsop, Wolfgang Bohne, Sophie Gledhill, Iver Lauermann, Martha Christina Lux-Steiner, Jörg Röhrich, and Christian-Herbert Fischer — Hahn-Meitner-Institut Berlin, Glienicker Str. 100, D-14109 Berlin

The Spray Ion Layer Gas Reaction (ILGAR) is a new non-vacuum process, well suited for roll-to-roll production. In the first step of the process a metal salt solution is sprayed onto a heated substrate. The resulting solid layer is converted to the metal sulfide by H_2S. Both steps are repeated until the desired thickness is achieved. Recently In_2S_3 buffer layers for highly efficient $Cu(In,Ga)(S,Se)_2$ solar cells have been deposited by this method. Now we have significantly extended the process and enabled the deposition of copper containing compounds, such as $CuInS_2$. By aerosol preheating, temperature optimization and the use of appropriate precursor-salts, the deposition rate has been increased from 3nm/cycle up to 35nm/cycle in order to achieve μm thick films needed for solar cells. However, in addition to $CuInS_2$, In_2O_3 was also detected, which was strongly reduced by H_2S-postanealing. Nevertheless, XPS-, ERDA-, SEM- and EDX-measurements still revealed some structural and chemical inhomogeneities. Thus several approaches like a reducing atmosphere were tested to further improve the layer quality. Working solar cells have been produced with these $CuInS_2$ absorber layers. Their optimization with respect to photovoltaic performance is in progress.