HL 12: Photovoltaic

Time: Monday 14:00–16:15 Location: EW 202

HL 12.1 Mon 14:00 EW 202

Measurement of interstitial iron content in multicrystalline silicon by microwave detected photoconductance decay — •Kevin Lauer[1,2], Abdelazize Laades[1], Alexander Lawerenz[1], Hartmut Übensee[1], and Heinrich Metzner[1] — [1]CiS Institut für Mikrosensorik GmbH, SolarZentrum Erfurt, Konrad-Zuse-Str. 14, 99099 Erfurt, Germany — [2]Institut für Physik, TU-Ilmenau, Weimarer Str. 32, 98693 Ilmenau

A new approach to evaluate the photoconductance decay measured by microwave reflection in thin multicrystalline silicon wafers is presented. The minority carrier lifetime as a function of the excess carrier density is extracted from the photoconductance decay signal. We use this new approach to detect the interstitial iron content with a high spatial resolution. This is done by measurements in the two different states of the meta-stable iron-boron pairs. The limits of this method are discussed and it is shown to be applicable to thin and surface passivated multicrystalline silicon wafers with low minority carrier lifetime. A quantitative comparison to results obtained by means of quasi steady-state photoconductance measurements (QSSPC) is presented.

HL 12.2 Mon 14:15 EW 202

Monolithic III-V- tandem solar cell lattice matched to InP(100) with a GaInAs/GaAsSb tunnel junction — •Nadine Szabó, Ulf Seidel, Erol Sagol, Klaus Schwarzburg, and Thomas Hannappel — Hahn-Meitner-Institut, Glienicker Str. 100, Berlin

At present, III-V triple junction (3J) solar cells are achieving the highest conversion efficiencies (η=40.7%) worldwide. These cells are grown slightly lattice mismatched to Ge(100) and are containing three absorber layers: Ge, GaInAs and GaInP. Even higher efficiencies are possible if more than 3 subcells were used. To obtain this, one can replace the Ge bottom cell by a GaInAsP/GaInAs tandem cell grown lattice matched to InP. The combination of these low band gap subcells with an established GaAs/GaInP tandem solar cell can be realised by mechanical stacking. The GaAs/GaInP// GaInAsP/GaInAs 4J tandem solar cell has a theoretical conversion efficiency limit of 61% (500 suns), which is clearly higher than the limit of the current world record 3J solar cell (49%). The serial connection of the two subcells of our tandem cell was realised by a tunnel junction. This tunnel junction was composed of a n-GaInAs and a p-GaAsSb layer. Depending on the preparation of the n-GaInAs layer, the p-GaAsSb layer was grown either on III-rich or on V-rich surfaces. Whereas the growth of the GaAsSb layer on a III-rich surface led to a sharper interface. Sun simulator measurements have been performed in order to investigate the influence of the different preparation methods on the cell efficiencies.

HL 12.3 Mon 14:30 EW 202

Photonic intermediate layer for silicon tandem solar cells — •Andreas Bielawny[1], Paul-Tiberiu Miclea[1], Ralf Wehrspohn[1], Seuong-Mo Lee[2], Mato Knez[2], Reinhard Carius[3], Marian Lisca[4], Carsten Rockstuhl[4], and Falk Lederer[4] — [1]Martin-Luther Universität Halle-Wittenberg, Inst. für Physik, Mikro-MD, D-06120 Halle — [2]Max-Planck-Inst. für Mikrostrukturphysik, D-06120 Halle, — [3]Forschungszentrum Jülich, Inst. für Photovoltaik (IEF-5), D-52428 Jülich — [4]Universität Jena, Dept. Physik, D-07743 Jena

The concept of incorporation of a 3D photonic crystal as diffractive spectral filter within a-Si/mc-Si tandem solar cells has been investigated as a promising application. Our intermediate reflective filter enhances the pathway of spectrally selected light within an amorphous silicon top cell in its spectral region of low absorption. From our previous work, we expect a significant improvement of the tandem's efficiency of about 1.2%(absolute). This increases efficiency for a typical silicon tandem cell from 11.2% to 12.4%, as a result of the optical current-matching of the two junctions. Our wavelength-selective optical element is a 3D-structured optical thin-film - prepared by self-organized artificial opal templates and finalized with atomic layer deposition techniques. The resulting samples are highly periodical thin-film inverted opals made of zinc-oxide. We compare recent experimental data on the optical properties with our simulations and photonic bandstructure calculations.

HL 12.4 Mon 14:45 EW 202

Deposition and characterization of (Zn,Mg)O buffer layers on CIGSSe thin film solar cells — •Benjamin Hussmann[1], Felix Erfurth[1], Thomas Niesen[2], Jörg Palm[2], Alexander Grimm[3], Achim Schöll[1], and Eberhard Umbach[1,4] — [1]Universität Würzburg, Experimentelle Physik II — [2]Avancis GmbH, München — [3]Hahn-Meitner-Institut, Berlin — [4]Forschungszentrum Karlsruhe

(Zn, Mg)O buffer layers on Cu(In,Ga)(S,Se)$_2$ (CIGSSe) thin film solar cells are promising alternatives to CdS buffer layers by featuring comparable efficiencies, better environmental compatibility and the possibility to implement the deposition process into a vacuum processing line. The (Zn, Mg)O buffer layers are deposited by radio frequency magnetron co-sputtering from two separate ZnO and MgO ceramic sputter targets to control the Mg-content and therefore the band gap of the buffer layer. In our experimental setup the sputter preparation chamber is connected with a UHV analysis system which allows in-situ characterization with X-ray photoelectron spectroscopy (XPS). The interface between the absorber and the buffer layer is believed to have a major influence on the cell efficiency and is thus of particular interest in this work. This interface has been investigated during layer deposition by sequentially interrupting the sputter process and performing XPS scans. We observed island growth of (Zn,Mg)O on CIGSSe and a strong oxidation of the absorber surface induced by the deposit. In order to complement the chemical and electronic information with structural data, energy dispersive X-ray analysis, X-ray diffraction, and scanning electron microscopy have been applied.

HL 12.5 Mon 15:00 EW 202

Influence of gap state defect passivation on transport properties in SiO$_2$/Si/SiO$_2$ quantum layers — •Daniel Sixtensson, Bert Stegemann, and Manfred Schmidt — Hahn-Meitner-Institut Berlin, Abt. Silizium-Photovoltaik, Kekuléstraße 5, 12489 Berlin

The maximum efficiency of standard silicon single bandgap photovoltaic devices is given by the Shockley-Queisser limit of 32.7 %. A major loss source is thermalization of hot photogenerated charge carriers. Novel methods utilizing quantum confinement effects have recently been proposed to circumvent this limit. Si/SiO$_2$ quantum well structures, utilizing stacked absorbers with different bandgaps, can better be adjusted to the solar spectrum and thus, avoid thermalization losses. However, the interface-to-volume ratio increases tremendously in such structures. Therefore, due to strong interface recombination and Coulomb scattering from charged interface states, the Si/SiO$_2$ interfaces are a major factor limiting carrier transport. In the present work, the impact of defect passivation by hydrogen treatment on interface gap state defect densities at structurally and chemically well-defined Si/SiO$_2$ interfaces has been analyzed using surface photovoltage (SPV) measurements and constant final state photoelectron spectroscopy. Moreover, transport properties in single SiO$_2$/Si/SiO$_2$ quantum well structures are analyzed and related to interface quality by means of highly sensitive photoconductivity measurements.

HL 12.6 Mon 15:15 EW 202

Angle dependent optics in nano-textured thin-film silicon solar cells — •Rahul Dewan[1], Christian Haase[2], Helmut Stiebig[2], and Dietmar Knipp[1] — [1]School of Engineering and Science, Jacobs University Bremen, D-28759 Bremen, Germany — [2]Institute of Photovoltaics, Research Center Jülich, D-52425 Jülich, Germany

Highly effective light trapping and optical light incoupling concepts are essential in realizing highly efficient thin-film solar cells with absorbers in the range of micrometers. To investigate and optimize both effects, wave propagation in thin-film silicon solar cells with integrated grating couplers was modeled in two and three dimensions solving the Maxwell equations by a Finite Difference Time Domain approach. Simulations were carried out for different wavelengths and angles of incidence of light, keeping the period of the grating structure fixed. Simulation results reveal that for small angles of incidence (close to normal incidence) the absorption of the solar cells with integrated couplers is enhanced in comparison to structures without grating couplers. Such behavior is observed for shorter and longer wavelengths (500 nm and 800 nm). For intermediate angles of incidence (30° - 60°) the absorption of the structures without grating couplers exceeds the absorption attained for structures with integrated couplers. As the wavelength of the incident light increases from 500 nm to 800 nm for structures without couplers, the maxima of the absorption shifts from 60° to 40°

angle of incidence. Structures with and without grating couplers exhibit similar absorption behavior for angles of incidence larger than 75°.

HL 12.7 Mon 15:30 EW 202

Locally resolved characterization of CuInS2 thin film solar cells — •Markus Wendt, Jo Klaer, Thomas Unold, and Hans Werner Schock — Hahn-Meitner-Institut Berlin Glienicker Str. 100 14109 Berlin

CuInS2 thin film solar cells were produced by sulfurization of metallic precursor layers using a rapid thermal anneal process. Depending on the processing conditions variations of the total photocurrent were found. At the same time, scanning electron microscopy revealed an inhomogeneous morphology for many of the solar cells processed. To investigate the influence of processing conditions on the photocurrent collection in more detail, laser beam induced current (LBIC) measurements were applied to selected solar cells. The excitation wavelength was 525nm and the local resolution was 1-3 um. The typical scanning range of the experiments was 1sq.mm. LBIC-maps collected at low light-intensities of approximately 1 sun showed variations of 5% in the local photocurrent collection. However, LBIC maps at high intensities of approximately 1000 suns showed very large variations in the local photocurrent collection of nearly a factor of 2-3. We conclude that the local variation of current collection under high illumination is due to current crowding effects caused by inhomogeneities in the morphology of the solar cells.

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Light-Beam Induced Current-investigations of Copper/Nickel - co-doped, wafer-bonded silicon bicristals — •Philipp Saring, Carsten Rudolf, Oliver Voss, Linda Stolze, and Michael Seibt — IV.Physikalisches Institut, Georg-August-Universität Göttingen, D-37077 Göttingen, Germany

Light Beam Induced Current (LBIC)-measurements were performed on samples of Czochralski-silicon, containing a small-angle grain boundary. This dislocation-network is visible on cross-section samples as a line with strong LBIC-contrast. Copper-doped samples exhibit precipitates with polyhedral structure and a strong contrast, whereas the Nickel-doped samples (same indiffusion conditions) do not reveal regions of such strong recombination activity. The samples, co-doped with Copper and Nickel, exhibit precipitates with LBIC-characteristics comparable to that in the Copper-samples. All samples containing precipitates show a higher concentration of them in one Wafer, probably due to the presence of oxygen related defects acting as nucleation sites. We greatfully acknowledge M. Reiche, Th. Wilhelm for providing bonded silicon wafers. This work was financially supported by Volkswagen foundation (SOBSI-Project).

HL 12.9 Mon 16:00 EW 202

Invenstigation of the Silicon-Oxide-Platinum interface for photoelectrochemical solar cells — •Thomas Stempel Pereira[1], Aggour Mohammed[2], Katarzyna Skorupska[1], Michael Lublow[1], Andres Munoz[1], and Hans-Joachim Lewerenz[1] — [1]Hahn-Meiter-Institut, Devision of Solar Energy, Glienicker Str. 100, 14109 Berlin, Germany — [2]Ibn Tofail University, Rabat, Marocco

Photoelectrochemical solarcells on the basis of Si can be fabricated with standart electrochemical methods. However, corrosion of the semiconductor surface leads to a degeneration of such cells. Attemps have been made to passivate the Si surface with an oxide while allowing charge transfer through metal deposits on the surface. Thus efficiencies of more than 10% can be achived. We present experimental results of various preparation methods of anodic oxides on Si. The deposion of Pt nanoemitters on the electrode through pores in the oxide layer is investigated. The interface density of states was examined by capacitance measurements. Low interface density states can be achived by anodic oxidation in phtalate solutions. Model experiments of electrochemically deposited Pt with synchrotron radiation photoelectron spectroscopy show that Si is oxidized during Pt-deposition, thus reducing the influence of metal induced gap states at the interface.