HL 39: Photovoltaics II

Time: Wednesday 9:30–11:45 Location: H3

HL 39.1 Wed 9:30 H3

Sputter deposition of Cu_2O thin films, nitrogen-doping and formation of $Cu_2O - ZnO$ p/n junctions — •Swen Graubner, Achim Kronenberger, Julian Benz, Daniel Reppin, Martin Fischer, Angelika Polity, Detlef Hofmann, Torsten Henning, Peter Klar, and Bruno K. Meyer — I. Physikalisches Institut, JLU Giessen

Cu_2O is one of the rare intrinsically p-type conducting semiconductors, in addition the energy of its band gap is in the visible spectral range. Thus it is considered to be a promising material for thin-film-solar cell applications. Metallic and ceramic sputtering processes can be used for the thin-film deposition. Depending on the oxygen partial-pressure, the stoichiometric properties of Cu_xO are adjustable from $x = 2$ to $x = 1$. The electrical properties change considerably depending on the copper-to-oxygen-ratio. It is commonly assumed that copper-vacancies are the dominant intrinsic acceptors in Cu_2O, thus high carrier concentrations come along with a reduced crystalline quality. Using nitrogen-gas for doping allows carrier concentrations of $p = 10^{15} - 10^{17} cm^{-3}$ without significantly reducing the structural properties of the Cu_2O-thin-films. By using ZnO as n-type semiconductor, first p/n hetero-junctions were realized. The mesa etched structures show rectifying behaviour and its electrical properties will be discussed on the conference.

HL 39.2 Wed 9:45 H3

3D photonic crystal interlayers for mircomorph thin film silicon tandem cell — •Johannes Üpping[1], Andreas Bielawny[1], Martin Otto[1], Ralf B. Wehrspohn[1], Lorenz Steidl[2], Rudolf Zentel[2], Seung-Mo Lee[3], Mato Knez[3], Thomas Beckers[4], and Reinhard Carius[4] — [1]Institute of Physics, mikroMD, University of Halle Wittenberg — [2]Dept. of Chemistry, University of Mainz — [3]Max Planck Institute of Microstructure Physics Halle — [4]Institute of Energy Research, IEF-5 Photovoltaics, Forschungszentrum Jülich GmbH

A 3D photonic intermediate reflector for textured micromorph silicon tandem solar cells has been investigated. In thin-film silicon tandem solar cells consisting of amorphous and microcrystalline silicon with two junctions of a-Si/μc-Si, efficiency enhancements can be achieved by increasing the current density in the a-Si top cell. It is one goal to provide an optimized current matching at high current densities. For an ideal photon-management between top and bottom cell, a spectrally selective intermediate reflective layer (IRL) is necessary. We show results toward the first fully integrated 3D photonic thin-film IRL device incorporated in a state-of-the-art textured tandem solar cell. The design and the preparation of a 3D self organized inverted opal photonic crystal structure in a textured micromorph tandem solar cell is presented.

HL 39.3 Wed 10:00 H3

Defect reduction in silicon nanocrystals by low-temperature annealing — •Sabrina Niesar[1], Nadine Erhard[1], Andre R. Stegner[1], Rui N. Pereira[2], Hartmut Wiggers[3], Martin S. Brandt[1], and Martin Stutzmann[1] — [1]Walter Schottky Institut, Technische Universität München, 85748 Garching — [2]University of Aveiro, 3810-193 Aveiro, Portugal — [3]Institut für Verbrennung und Gasdynamik, Universität Duisburg-Essen, 47057 Duisburg

Due to the potential of low-cost solution processing, freestanding silicon nanocrystals (Si-ncs) are a promising base material for application e.g. in photovoltaics, thermoelectric and printable electronics. They can be synthesized in macroscopic amounts with diameters tunable between 4 and 50 nm by microwave-induced decomposition of silane in a low-pressure plasma reactor. In this work, we investigate different cost-efficient post-growth methods to reduce the number of silicon dangling bond defects (Si-dbs) which are a limiting factor for many electronic applications. Using electron paramagnetic resonance measurements, it is found that an etching step with hydrofluoric (HF) acid combined with a low-temperature vacuum annealing at 200°C leads to a reduction of the Si-dbs density by a factor of 10. Furthermore, conductivity measurements performed on thin Si-ncs films show that HF etching and annealing also improves the electronic properties. For highly doped Si-ncs, we observe a significant and persistent increase of the room-temperature conductivity. Moreover, current-voltage measurements on Si-ncs/organic semiconductor heterojunction solar cells will be presented.

HL 39.4 Wed 10:15 H3

Thin film solar cells prepared on polycrystalline seed layers using low temperatures — •C. Jaeger[1], T. Matsui[2], M. Takeuchi[2], M. Karasawa[2], D. Wozniak[1], M. Kondo[2], and M. Stutzmann[1] — [1]Walter Schottky Institut, Technische Universität München, Garching, Germany — [2]Research Center for Photovoltaics, National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba, Japan

High costs and large material consumption are the main drawbacks of single crystalline Si wafer-based solar cells. Therefore, alternative methods using thin films are heavily investigated today. In this work, we present data from solar cells with PECVD-Si as the absorber material prepared on polycrystalline seed layers. For the seed layer preparation, the reverse aluminum-induced layer exchange (R-ALILE) process is used. In a R-ALILE process, a substrate/amorphous silicon/oxide/Al layer stack is annealed at temperatures below 570°C, leading to a layer exchange and the crystallization of the silicon. After the layer exchange is completed, a substrate/Al (+Si)/oxide/polycrystalline silicon film structure is formed.

We found that the proper treatment of the seed layers prior to the absorber layer deposition is crucial for a good solar cell performance. We studied different wet chemical methods (HF-solution, Al-etch) and the influence of an hydrogen plasma treatment. Furthermore, we investigated the influence of an additional Ag/ITO-back contact on the solar cell performance. We found that solar cell efficiencies over 5% can be obtained using the presented seed layer concept.

15 Min. Coffee Break

HL 39.5 Wed 10:45 H3

Interface recombination in heterojunction solar cells: influence of buffer layer thickness and interface charge — •Helena Wilhelm, Roland Scheer, and Hans-Werner Schock — Helmholtz Zentrum Berlin für Materialien und Energie, 14109 Berlin

In window/buffer/absorber type heterojunction solar cells the buffer/absorber interface is a very sensitive part. Due to the lattice mismatch there may be a high density of defects that can lead to a dominant recombination at the buffer/absorber interface. The recombination current depends on the carrier densities and thus on doping ratios, buffer layer thickness and interface charge.

The recombination current is characterized by two parameters - the diode quality factor and activation energy of saturation current density. These two parameters help to determine the recombination process and its location and can be extracted from the data of the temperature dependent current/voltage measurements.

The goal of this work was to investigate the influence of the buffer layer thickness and the interface charge on the diode quality factor and activation energy in cells with inverted buffer/absorber interface and to develop appropriate analytical expressions that include this influence. The analytical equations are verified by numerical device simulation. They describe that the diode quality factor largely depends on the buffer layer thickness and only to a minor extent on the interface charge.

HL 39.6 Wed 11:00 H3

Shunts in Thin-Film Photovoltaics — •Stephanie Malek[1], Uli F. Wischnath[1], Juan Rechid[2], Ingo Riedel[1], and Jürgen Parisi[1] — [1]Energy and Semiconductor Research Laboratory, Department of Physics, University of Oldenburg, 26111 Oldenburg, Germany — [2]CIS Solartechnik GmbH & Co. KG, 20539 Hamburg, Germany

Shunts can lead to severe performance reductions in thin film solar cells. This work aims to look in more detail at the shunts in order to find their microscopic causes.

Localization of hot spots is commonly addressed by infrared thermography via visualization of the Joule heating. The resolution of this method is restricted to the μm-range. We use Lock-In-Thermography (LIT) for the fast localization of imperfections in order to identify positions of interest. For more detailed analysis of hot spots we use high

resolution microscopy like Scanning Electron Microscopy (SEM) and AFM-based Scanning Thermal Microscopy (SThM). These small-scale investigations can for example reveal if areas of high heat dissipation are rather related to the inner structure of the involved thin films or to accidentally incorporated imperfections.

HL 39.7 Wed 11:15 H3

Synthesis and Characterization of Cu_2ZnSnS_4 (CZTS) Nanoparticles for Application in Printed Solar Cells — •Folker Zutz, Christine Chory, Jörg Ohland, Ingo Riedel, and Jürgen Parisi — University of Oldenburg, Department of Physics, Energy and Semiconductor Research Laboratory, 26111 Oldenburg, Germany

Cu_2ZnSnS_4 (CZTS) is a novel compound semiconductor based on abundant and non-toxic precursor elements. The material has a high potential for photovoltaic application and exhibits a direct optical band gap of 1.5 eV and an absorption coefficient $> 10^4 cm^{-1}$. CZTS nanoparticles (NP) are derived from colloidal synthesis presenting high yields of the CZTS nanopowder. The material is intended for development of solar cells with printed light absorber which stochiometry is already established in the nanoparticles prior to thin film formation.

We report on the structural and photoelectrical characterization of printed CZTS thin films and CZTS nanopowders. The crystal structure of CZTS NPs was investigated by XRD analysis of dried powders while the internal structure of the thin films was studied by AFM, SEM in combination with EDX spectroscopy. Absorption and photoluminescence (PL) spectroscopy were applied for analysis of the general optical properties while time-resolved PL was used for estimation of the minority carrier lifetime in thin films. Photoconductance of the thin films was studied for derivation of the threshold absorption and activation energy of charge transport.

HL 39.8 Wed 11:30 H3

Entwicklung von Lift-off Techniken zur Herstellung von hocheffizienten invertierten III-V-Mehrfachsolarzellen — •Karen Dreyer, Tobias Roesener, Vera Klinger, Eduard Oliva, Frank Dimroth und Andreas W. Bett — Fraunhofer-Institut für Solare Energiesysteme ISE, Freiburg

Die Kombination von Solarzellen verschiedener Bandlücken, sogenannte Mehrfachsolarzellen, führt zu einer besseren Ausnutzung des Sonnenspektrums und somit zu einem höheren Wirkungsgrad. So wurden am Fraunhofer ISE bereits Effizienzen von bis zu 41% bei $454 kW/m^2$ mit einer Struktur aus GaInP, GaInAs und Ge erreicht. Die drei pn-Übergänge werden in einem Epitaxieverfahren (MOVPE) auf Ge aufgewachsen und anschließend mit Kontakten und Antireflexschicht versehen. Neue Konzepte arbeiten teilweise mit invertiert gewachsenen Strukturen, in denen die Teilzellen in umgekehrter Reihenfolge auf einem GaAs Substrat abgeschieden werden.

Grundlegend für diese invertierten Solarzellenkonzepte ist die Entwicklung eines Ablöseprozesses (Lift-off) zur Trennung der nur wenigen μm dicken Epitaxiestruktur vom GaAs Substrat, um dieses in späteren Prozesse wiederzuverwenden. Hierfür wurden insbesondere nasschemische Lift-off Prozesse untersucht. Dazu wird zwischen der Zellstruktur und dem Substrat eine selektiv ätzbare AlGaAs Schicht epitaktisch aufgewachsen. Verschiedene Konzepte zur Erhöhung der Ätzgeschwindigkeit wurden untersucht und auf ihre Anwendbarkeit in einem Standardprozess geprüft. Prozessdauern von weniger als 10 Stunden für das Ablösen eines 4-Zoll Substrats wurden erreicht.