HL 38: Photovoltaics: CIGS and related Materials

Time: Tuesday 11:15–13:15 Location: ER 270

HL 38.1 Tue 11:15 ER 270

Characterization of grain boundaries in Cu(In,Ga)Se_2 by atom probe tomography — •Torsten Schwarz[1], Oana Cojocaru-Miredin[1], Pyuck-Pa Choi[1], Roland Würz[2], and Dierk Raabe[1] — [1]Max-Planck Institute for Iron Research GmbH, Düsseldorf, Germany — [2]Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg (ZSW), Stuttgart, Germany

Solar cells based on the compound semiconductor Cu(In,Ga)Se_2 (CIGS) as absorber material exhibit the highest efficiency among all thin-film solar cells. This is surprising high in view of the polycrystalline defect-rich structure of the CIGS absorber films. The high efficiency has been commonly ascribed to the diffusion of alkali metal atoms from the soda-lime glass substrate into the CIGS layer, which can render the grain boundaries (GB) electrally inactive.
However, the exact mechanisms of how these impurities enhance the cell efficiency are yet to be clarified.
As a step towards a better understanding of CIGS solar cells, we have analyzed the composition of solar-grade CIGS layers at the atomic-scale by using pulsed laser Atom Probe Tomography (APT). To perform APT analyses on selected GBs site-specific sample preparation was carried out using the Focused Ion Beam lift-out technique. In addition, Electron Back Scattered Diffraction was performed to characterize the structure and misorientation of selected GBs.
Using APT, segregation of impurities at the GBs was directly observed. APT data of various types of GBs will be presented and discussed with respect to the possible effects on the cell efficiency.

HL 38.2 Tue 11:30 ER 270

Correlation of surface contour, optoelectronic and spectroscopic properties of Cu(In,Ga)Se_2 by SNOM and AFM — •Oliver Neumann[1], Stephan J. Heise[1], Rudolf Brüggemann[1], Max Meessen[1], Wolfram Witte[2], Dimitrios Hariskos[2], and Gottfried H. Bauer[1] — [1]Institute of Physics, Carl von Ossietzky University Oldenburg, Germany — [2]Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg (ZSW), Stuttgart, Germany

Chalcopyrite absorbers exhibit local fluctuations of structural, optical and optoelectronic properties. We study the correlation of the surface contour and the local properties such as the integrated photoluminescence (PL) yield and the splitting of the quasi-Fermi levels in a Cu(In,Ga)Se_2-based thin-film system at room temperature by AFM and spatially resolved PL measurements at the identical position with a scanning near-field optical microscope (SNOM). The Cu(In,Ga)Se_2 layer is deposited on glass, etched with bromine-methanol to smooth the surface for a more homogeneous incoupling of laser light, and passivated with cadmium sulfide. Our measurements reveal a high structural correlation between surface contour, integrated PL yield and quasi-Fermi level splitting. Additionally, we observe trenches in the surface contour which correspond to a dip or to a peak in the splitting of the quasi-Fermi levels and integrated PL yield. Furhermore some trenches show spectral variation of the PL compared to their direct environment. We discuss these observations with respect to the optoelectronic property and the composition of the absorber.

HL 38.3 Tue 11:45 ER 270

Sub-band-gap absorption of Cu(In,Ga)Se_2 thin film semiconductors — •Max Meessen, Rudolf Brüggemann, and Gottfried H. Bauer — Carl von Ossietzky University Oldenburg, Germany

The sub-band-gap absorption of Cu(In,Ga)Se_2 thin films has been studied by photothermal deflection spectroscopy (PDS) in conjunction with optical transmittance spectroscopy. The resulting absorption coefficients are compared to those calculated from photoluminescence spectra using Planck's generalized law. Quantities related to the absorption like Urbach energy and defect densities are derived from the absorption curves.

This concept has been applied to a series of bromine-methanol etched Cu(In_{x-1},Ga_x)Se_2 (x=0.3) absorbers with varying thicknesses. A shift in the band gap is observed with both methods and can be related to the gallium gradient in the samples. In contrast, the Urbach energy and defect absorption values are not substantially affected by the etching process.

The influence of CdS buffer layers or highly thermally conductive metallic back contacts on PDS results is studied by measuring nominally identical samples with and without those layers.

HL 38.4 Tue 12:00 ER 270

Investigation of defects in Cu(In,Ga)S_2 and Cu(In,Ga)Se_2 solar cells by space charge spectroscopy — •Julia Riediger[1], Jörg Ohland[1], Martin Knipper[1], Jürgen Parisi[1], Ingo Riedel[1], and Alexander Meeder[2] — [1]Thin Film Photovoltaics, Energy- and Semiconductor Research Laboratory, University of Oldenburg, D-26111 Oldenburg — [2]Soltecture GmbH, 12487 Berlin

If deep defect states in the absorber of a solar cell act as recombination centers, they may limit the carrier lifetime and thus the open circuit voltage. This is related to the defect's activation energy and spatial position. In this study the defect landscape of chalcopyrite thin film solar cells with varied absorber composition was investigated by space charge spectroscopy. The absorber layer in Cu(In,Ga)S_2 samples arises from rapid thermal process (RTP) in sulfur vapor while Cu(In,Ga)Se_2 absorbers were processed via co-evaporation of the constituents. Several defect states were found by deep level spectroscopy (DLTS) and thermal admittance spectroscopy (TAS). With the knowledge of the defect activation energies we derived the spatial defect concentrations from (illuminated) capacitance-voltage (CV) measurements and discuss the results for both material systems. To identify the often discussed "N1" defect, the measurements were repeated after annealing and changes in the defect spectra were evaluated.

HL 38.5 Tue 12:15 ER 270

The influence of CdS buffer layer thickness on low-temperature deposited Cu(In,Ga)Se_2 solar cells — •Stefan Puttnins[1,2], Thomas Unold[3], Philipp Krüger[1], Felix Daume[1,2], Karsten Pelz[1], Andreas Rahm[1], and Marius Grundmann[2] — [1]Solarion AG, Ostende 5, 04288, Leipzig, Germany — [2]Institut für Experimentelle Physik II, Universität Leipzig, Linnéstraße 5, 04103 Leipzig, Germany — [3]Helmholtz Zentrum Berlin für Materialien und Energie, Hahn Meitner Platz 1, 14109 Berlin, Germany

An additional n-type layer between p-type Cu(In,Ga)Se_2 (CIGSe) absorber and n-type ZnO:Al transparent front contact is needed for highly efficient CIGSe solar cells. A CdS layer deposited in a wet chemical bath processes is commonly used for this so called buffer layer.

In this work we analyze the influence of the deposition time and therefore thickness of this CdS buffer in respect to solar cell performance via current-voltage, quantum efficiency (QE) and time resolved photoluminescence (TRPL) measurements.

Thicker buffer layers lead to higher open circuit voltages (V_{OC}), higher shunt resistances, current losses in the QE range of 400-600 nm wavelength and concurrently current gains in the range of 800-1100 nm. This current gain and the increase of V_{OC} can be correlated to an increase in carrier lifetime measured via TRPL.

HL 38.6 Tue 12:30 ER 270

Capacitance-spectroscopical investigations of the influence of buffer layers on defect generation in CIGS solar cells — •Robert Karsthof[1,2], Stefan Puttnins[1,2], Karsten Pelz[1], Matthias Schmidt[2], and Marius Grundmann[2] — [1]Solarion AG, Ostende 5, D-04288 Leipzig — [2]University of Leipzig, Institute for Experimental Physics II, Linnéstraße 5, D-04103 Leipzig

The beneficial effect of the presence of buffer layers in Cu(In, Ga)Se_2 (CIGS) thin film solar cells on the cell performance has already been confirmed in numerous investigations. Nevertheless, the influence of certain deposition parameters of these layers (implemented at the Solarion AG by a cadmium sufide and an intrinsic zinc oxide layer) on device properties like defect generation at the buffer/absorber or window/buffer interface as well as energetical and spatial distribution of buffer-induced defects is not fully understood yet. In this work ZnO:Al/i-ZnO/CdS/CIGS/Mo/polyimide(PI) solar cells were investigated and the influence of a variation of the sputtering power during the i-ZnO process was analysed. The used methods were thermal admittance spectroscopy (TAS), capacitance-voltage (CV) and photocapacitance (PCap) measurements as well as CV spectroscopy with additional optical excitation (OCV). From the latter doping profiles of single defect species can be obtained.

HL 38.7 Tue 12:45 ER 270

Investigations of lateral and vertical compositional gradients in Cu(In,Ga)Se_2 prepared through Rapid Thermal Processing by highly spatially and spectrally resolved cathodoluminescence spectroscopy — •Mathias Müller[1], Stefan Ribbe[1], Frank Bertram[1], Thomas Hempel[1], Humberto Rodriguez-Alvarez[2], Jakob Lauche[2], Hans-Werner Schock[2], and Jürgen Christen[1] — [1]Institute for Experimental Physics, Otto-vonGuericke-University Magdeburg, Germany — [2]Helmholtz Center Berlin for Materials and Energy, Germany

We analyze Cu(In,Ga)Se_2 thin films using highly spatially and spectrally resolved cathodoluminescence (CL) spectroscopy at low temperature (T = 5 K). The films were deposited by means of a rapid thermal selenization process with growth times varying from 70 to 150 seconds. We find that lateral integral spectra exhibit a broad dominant peak with energies from 0.95 eV to 0.99 eV and a shoulder on the low-energy side. By varying the excitation density, a shift to higher energies of the main peak by 12.8 meV/decade can be observed for the samples with growth times of 100 s and 120 s. Investigations of the cross-sections reveal two distinct regions in the layer sequence. A Ga-rich layer next to the back contact can be identified showing lower luminescence intensities. In contrast, the layer on top reveals an In-rich concentration.

HL 38.8 Tue 13:00 ER 270

Investigations of vertical chemical gradients in Cu(In,Ga)S_2-thin films prepared by sulfurization of sputtered precursor layers using highly spatially resolved cathodoluminescence microscopy — •Stefan Ribbe[1], Mathias Müller[1], Frank Bertram[1], Thomas Hempel[1], Humberto Rodriguez-Alvarez[2], Jakob Lauche[2], Hans Werner Schock[2], and Jürgen Christen[1] — [1]Institute for Experimental Physics, Otto-von-Guericke-University Magdeburg, Germany — [2]Helmholtz Center Berlin for Materials and Energy, Germany

The luminescence properties of Cu(In,Ga)S_2(CIGS)-absorber layers for thin film solar cells have been studied by highly spatially resolved cathodoluminescence (CL) at low temperature ($T = 5$ K). In/Cu-Ga-precursors were annealed with elementary sulfur pellets in a rapid thermal process at different annealing times to represent different growth steps of the CIGS absorber layer. Spatially integral CL spectra show a dominant peak at 825 nm accompanied by a low-energy shoulder at 890 nm. Only a slight blue shift of the main peak is observed by variation of the excitation density. Investigations of cross-sections show for all samples a similar luminescence distribution. Near the molybdenum back contact distinct areas show luminescence emitting at $680 - 750$ nm. In contrast, in upper regions of the layer a homogeneous low-energy luminescence at around 820 nm is observed which exhibits the most intensive spots on the cross-section. In local spectra we observe a change of the dominant recombination channel at the interface of these two regions.