# HL 56 Photovoltaik I

Zeit: Dienstag 15:00–16:30 Raum: TU P-N202

HL 56.1 Di 15:00 TU P-N202

**Voltage dependent series resistance of thin film Cu(In, Ga)$Se_2$ solar cells** — •Osama Tobail and Juergen Werner — Pfaffenwaldring 47, D-70569 Stuttgart, Germany

Series resistance $R_s$ and ideality factor $n_{id}$ deteriorate the performance of solar cells. Usually, we measure the dark current($I$)/voltage($V$)-curves and determine $R_s$ and the $n_{id}$ from a plot of conductance($G$)/current($I$) versus conductance($G$) [1]. However, in the case of Cu(In, Ga)$Se_2$ (CIGS) this plot is curved, indicating that $R_s$ decreases with increasing $V$. In order to investigate this $V$-dependence in details, we use a series of samples with different thicknesses of the CdS-buffer and the CIGS-absorber. The ideality factor $n_{id}$ from the dark $I/V$-curve depends on the buffer thickness and correlates with the $V$-dependence of $R_s$. An analysis of the *illuminated* $I/V$-curves at different illumination levels is particularly suitable to investigate the voltage dependent $R_s$ in more details. The series resistance $R_s$ consists of two parts: One part is independent of $V$, the other part decays exponentially with $V$. This voltage dependence of $R_s$ is the result of a voltage dependent charge at the grain boundaries of the polycrystalline CIGS solar cells.

[1] J. H. Werner, Appl. Phys. A47, 291 (1988).

HL 56.2 Di 15:15 TU P-N202

**Effect of Zn and Mg doping on the electronic properties of CuInS2 thin films and solar cells** — •Tobias Enzenhofer, Thomas Unold, Roland Scheer, and Hans-Werner Schock — Hahn-Meitner-Institut Berlin, Glienicker Str. 100, D-14109 Berlin

Solar cells based on CuInS2 still suffer from Voc limitation compared to the theoretically achievable value as expected from the optical band gap of 1.5 eV. Open circuit voltage can be significantly enhanced from about 700 mV to more than 800 mV via controlled doping by Zinc or Magnesium, whereas the efficiency remains mostly constant. The increase of the open circuit voltage occurs in spite of an extended red response. In order to investigate this phenomenon we used on the one hand well-known standard tools to perform the basic characterisation of photovoltaic cells (I/U and quantum efficiency (QE) measurements). On the other hand we applied photoluminescence spectroscopy (PL) to analyse the defect structure of doped CuInS2. By combining electrical and photoluminescence analyses we evaluate the influence of doping on the device properties, i.e. the quality of the CuInS2-absorber layers and the ZnO-CdS-CuInS2 heterostructure.

HL 56.3 Di 15:30 TU P-N202

**Static solar concentrators under Stuttgart insolation conditions** — •C. Carlsson, M. B. Schubert, and J. H. Werner — Institut für Physikalische Elektronik, Uni-Stuttgart, Pfaffenwaldring 47, 705 69 Stuttgart

Static concentrators offer a possibility to concentrate sun light onto solar cells without a costly tracking device. The annual efficiency of such concentrators depends on their specific design, on the inclination angle towards the sun, as well as on the insolation conditions. This study evaluates the gain of two- and three-dimensional V-trough concentrators with a side-wall angle of 60°, located in Stuttgart with a tilt towards South with 48°. In order to simulate the optical acceptance of the V-troughs for all relevant incident angles of light, we developed an appropriate raytracing program. Calculations using the optical acceptance and radiation data representative for Stuttgart yield an annual irradiance gain of the order of 1.5 for both types of concentrating systems. In contrast to our first expectations, the three-dimensional trough exhibits a slightly lower annual irradiance gain than the two-dimensional system. This effect is explained by enhanced shadowing effects due to the restricted acceptance angle in the East-West direction.

HL 56.4 Di 15:45 TU P-N202

**Local inhomogeneities of the quality of the photo excited state and of material composition in $Cu(In,Ga)Se_2$-absorbers in the few micrometer scale by sub-micron resolved photoluminescence** — •Levent Gütay, Rudolf Brüggemann, and Gottfried Heinrich Bauer — Institute of Physics, Carl von Ossietzky University Oldenburg, Germany

We have recorded spectrally resolved photoluminescence from $Cu(In,Ga)Se_2$ absorbers (Ga content of 29% and 46%) deposited on Mo coated substrates and overcoated by a 50 nm thick CdS layer. The absorber quality corresponds to pilot line thin film solar cell production with module efficiencies of 12-14 %. We translate the lateral variation of the luminescence yield into the splitting of the quasi Fermi levels, say laterally varying open circuit voltages. Further we discuss the laterally varying low energy wing of PL-spectra, reflecting variations of optical threshold energies for absorption/emission (band gap) of about 15 meV, in terms of variations in material composition, such as Ga-content. The comparison of XPS-analyses with high lateral resolution fits qualitatively to this explanation.

HL 56.5 Di 16:00 TU P-N202

**Amorphous silicon solar cells under different illumination levels** — •A. Al Tarabsheh, M. B. Schubert, and J. H. Werner — Institut für Physikalische Elektronik, Uni-Stuttgart, Pfaffenwaldring 47, 705 69 Stuttgart

The use of hydrogenated amorphous silicon-based (a-Si:H) solar cells in consumer products, and their potential for clothing-integrated photovoltaics (*ipv*) motivate us to study their performance under different illumination levels. In this work, we analyse the current/voltage ($I/V$) characteristics of a-Si:H solar cells as a function of the illumination intensity $\Phi$. We start with the most simple equivalent circuit model of a real solar cell, with incorporating series and parallel resistances. Our measurements yield in an illumination-intensity dependent parallel resistance $R_p(\Phi)$ rather than a constant one. The decrease in $R_p$ with $\Phi$ follows a power law, which we explain by the photoconductivity of parallel resistances that are distributed over the whole solar cell area. The dependence of $R_p$ on $\Phi$ deteriorates the solar cell fill factor $FF$ and conversion efficiency at high illumination levels. Therefore the implicit relation between $FF$ and open-circuit voltage, which is generally valid for ideal solar cells, does not hold for our cells.

HL 56.6 Di 16:15 TU P-N202

**Photoluminescence, Open Circuit Voltage, and Photocurrents in $Cu(In,Ga)Se_2$ Solar Cells with Lateral Submicron Resolution** — •Tim Jürgens, Levent Gütay, Rudolf Brüggemann, and Gottfried Heinrich Bauer — Institute of Physics, Carl von Ossietzky University Oldenburg, Germany

Thin film $Cu(In,Ga)Se_2$ solar cells prepared under conditions similar to pilot line module production have been analyzed with respect to local photoluminescence and according splitting of quasi-Fermi levels with submicron lateral resolution under open circuit and short circuit conditions. The lateral patterns of luminescence yields, announcing variations of quasi-Fermi energies in the range of some tens of meV and extending to some microns, by far exceed the size of individual grains of 1 micron or less. The response of PL, say, of local $V_{oc}$, with that of short circuit currents turns out to be anti-correlated significantly. This behaviour will be discussed in terms of a two dimensional network coupling illuminated and dark regimes and containing non-linear elements.