Thin-film solar cells based on chalcogenide (CIGS) and kesterite (CZTS) quaternary semiconducting compounds

Keywords : Thin-film solar cells; Surface passivation; Opto-electrical characterization; Device modelling and simulations.

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Abstract* – CIGS and CZTS are promising materials in photovoltaic (PV) technologies thanks to their direct band gap and high absorption properties. The main efforts of our research group are focused on the understanding of interface-electronic recombination and its impact on the PV cell performance. To do this, advanced opto-electrical characterization techniques were successfully employed to extract the electronic properties of materials and devices. Additionally, SCAPS simulation models provide deeper understanding of the device physics and also serve as a predictive tool for further optimization.

Among all thin-film (TF) technologies, photovoltaic (PV) cells based on copper indium gallium diselenide (CIGS) absorbers yield the highest efficiency (>22%). Current approaches and future priorities within the CIGS TF PV community are focused on CIGS thickness reduction to further lower material costs and surface passivation concepts to reduce the electronic recombination at interfaces and further enhance the solar cell performance. These approaches involve novel methods to passivate the front and rear surfaces of the CIGS absorber by implementing (i) alkali post-deposition treatments at the front surface and (ii) rear surface field-effect passivation using gallium grading schemes within the CIGS absorber layer.

However, above-mentioned surface passivation approaches have been shown less effective when considering ultra-thin (<400nm) absorber layers. Hence, as an attempt to address these challenges, our research is focused on the "Rear surface passivated ultra-thin CIGS solar cell architectures" (i.e. PercIGS), notably by introducing an aluminum oxide passivation layer at the CIGS/Mo-back contact interface. More specifically our research, in collaboration with Uppsala University and IMEC, is aimed at the interface of material and electronic properties with a focus on novel cell technologies and architectures for next generation TF solar cells. A first major achievement resulted in significantly enhanced cell performance (by 4.5% in absolute values) on ultra-thin (<400nm) CIGS absorber layers, i.e. a reduced CIGS absorber usage (by 5-6 times) compared to the conventional CIGS thickness (> 2μm) [1]. Additionally, in-depth analyses on the materials and devices were carried out using advanced opto-electrical and material characterization techniques to understand, correlate and optimize these properties towards stable, efficient solar cells [2,3]. Lastly, to generalize these electronic and interface passivation effects on the CIGS solar cell performance, a simulation model has been developed using Solar Cell Capacitance Simulator (SCAPS) TF PV software [4]. Future research priorities include: (a) to develop 2-D simulation model addressing the rear surface passivation effects, (b) rear-point-contact pitch optimization and (c) to develop Cd-free CIGS PV cells.

Another promising semiconductor material which responds to the requests of using only low-cost, non-toxic and earth-abundant elements is Cu_2ZnSnS_4 (CZTS). It is very close by its nature to CIGS, but not fully understood yet. This explains the motivation for CZTS absorber layer as well as full device studies. Moreover, in frame of collaboration with AC&SC research center, the application of steel is proposed as flexible substrate, which introduces some new specific problems, but open doors on a huge market. The aim of our research is to understand the physical phenomena occurring in a CZTS cell built on a steel substrate. The main present focus is on the Mo-back contact/absorber interface problem. To study this, modeling and simulation are performed as well as full opto-electrical characterization, not only of the completed cells, but also on specific test structures like TLM and MIS as well.

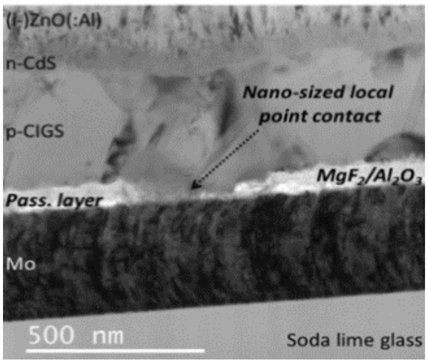

Figure 1: TEM cross-section of a rear surface passivated Cu(In,Ga)Se_2 solar cell [1].

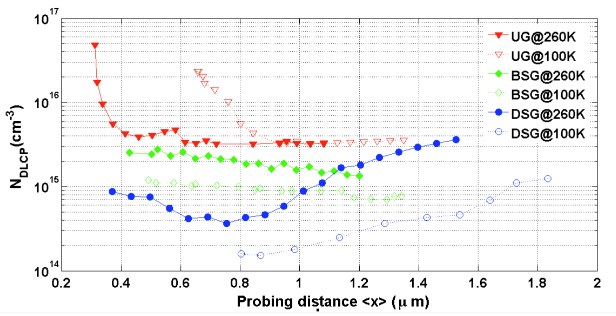

Figure 2: Deep-level-capacitance-profiling (DLCP) of Cu(In,Ga)Se_2 solar cells [2].

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