# Transparent wide bandgap $Cu(In,Ga)S_2$ solar cells for tandem and bifacial applications

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**Abstract**

One possible way to bring photovoltaic conversion efficiency beyond Shockley-Queisser limit consists in developing tandem devices. A top cell with 1.7 eV absorption threshold has been identified as optimal to be combined with crystalline silicon bottom cell [1-2]. Among the numerous materials satisfying this criteria, $Cu(In_{1-x}Ga_x)S_2$ (CIGS) with x~0.25 appears as particularly well-adapted. Many approaches can be followed to combine CIGS and c-Si within a tandem structure. The one we focused on within the frame of the SITA* project relies on the fabrication of the CIGS cell onto transparent back contact (TBC), this structure being then connected to the c-Si bottom appropriately. Developing efficient glass/TBC/CIGS/window based devices additionally offers opportunities for bifacial applications. Nevertheless, processing such solar cells remains highly challenging due to the complex interface formed between the CIGS and the TBC.

In this contribution, we investigate the performance of devices based on 500 nm-thick co-evaporated $Cu(In_{1-x}Ga_x)S_2$ absorbers and completed with (CBD)CdS/i-ZnO/ZnO:Al/grid. The potential of these devices for both tandem and bifacial applications have been investigated, using different transparent back contacts (TBC), namely $In_2O_3$:Sn (ITO) of thickness of 100 nm and 350 nm, and $In_2O_3$:W (IOW) of thickness of 300nm and 500 nm. The various thicknesses of TBC have been addressed to identify the consequences of the transparency/conductivity tradeoff with thickness variation.

So far, the best efficiencies were reached with CIGS devices deposited onto 350 nm thick ITO TBC. In fact, efficiencies of 10.9 % and 10.0 % could be achieved in front and rear illumination conditions, respectively. This corresponds to about 92 % bifaciality. However, regarding the transparency in near infrared needed for tandem, the ITO is not optimal because of its high free carrier concentration. It will be shown that this criteria is strongly improved when using IOW as TBC; however, in that case the performance of the cells appears limited by the degradation of the TBC during the CIGS deposition.

All of these results will be presented and discussed during the talk, as well as perspectives of these very encouraging advances.

*Stable Inorganic TAndem solar cell, Acronym: SITA, Project ID: 101075626

[1] F. Meillaud et al., Solar Energy Materials and Solar Cells 90, issues 18-19, 2952-2959, 2006
[2] T. White et al., IEEE Journal of Photovoltaics, vol.4, no.1, January 2014
[3] M. Alonso et al., Physical Review B, Volume 63, 075203, January 2001