Improved CGSe photovoltaic devices for tandem applications

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To surpass 30% conversion efficiency, tandem solar cells based on crystalline silicon (c-Si) sub-cells seem to be one of the most promising architectures regarding the theoretical efficiency. Furthermore a monolithic two-terminal approach using wide bandgap thin films does not require a significant modification of the solar modules fabrication.

$CuIn_{1-x}Ga_xSe_2$ absorber layer is a promising candidate thanks to its good efficiency (22% for x = 0.3, single junction). Additionally CIGSe permits to tune the bandgap energy from 1.04 (x=0) to 1.68eV (x=1). Thus Indium-free $CuGaSe_2$ (CGSe) can be used as top cell absorber in a multi-junction device. Nevertheless, the current conversion efficiency of CGSe solar cell is still low (η = 11.9%). The CGSe growth procedure needs to be adapted in order to use this material in a tandem device with c-Si.

In this study we focus on optimizing CGSe growth using a 'CuPRO' co-evaporation process. Our preliminary results show that an addition of two relaxation steps during the process seems to improve the electrical properties of the absorber. External Quantum Efficiency (EQE) values of CGSe single junction solar cells elaborated with a CuPRO process with and without relaxation steps (fig. 1) show major differences. The relaxation steps allow a lower interface recombination and a better carrier diffusion length. This implies an increase of J_{SC} and V_{OC} and therefore in efficiency. Indeed for simple junction CGSe cell we notice that the conversion efficiency is increased by $2\%_{abs}$. Considering that the diffusion rate of gallium is low, the relaxation steps would allow a better crystallization and a lower inhomogeneity throughout the absorber layer.

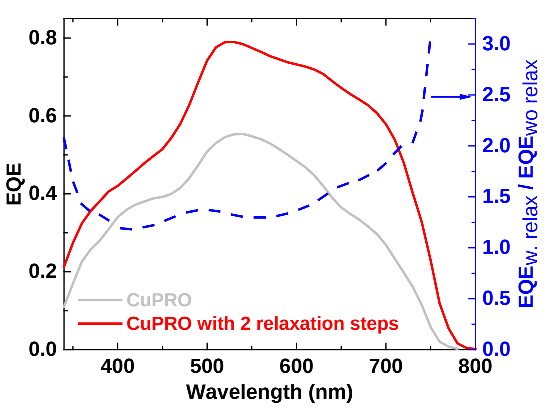

Figure 1: EQE of two CGSe solar cells realized with a CuPRO process with relaxation (red) or without (grey). The blue dash line represent the ratio between the two EQE

The second step of our work is to adapt the CGSe growth on c-Si and c-Si / ITO substrates in order to form a complete tandem cell. The first results showed a better recrystallization of CGSe on Silicon than on Molybdenum with larger grains for same growth conditions. Moreover, after these growth conditions (2 hours at 580°C under selenium flux), the c-Si bulk carrier lifetime measured by photoconductance was not affected, indicating that the silicon substrate does not suffer from major contamination issues.

First complete tandem solar cells (fig.2) should be prepared by the end of the year.

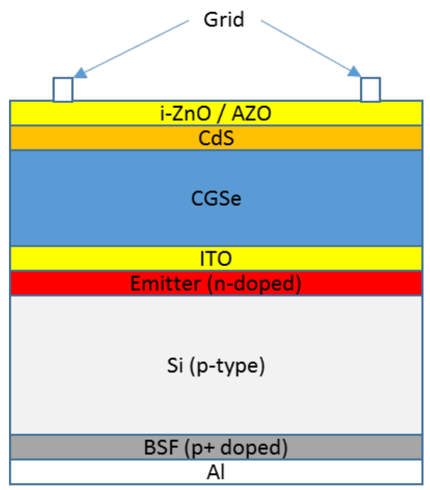

Figure 2: Diagram of the c-Si / ITO / CGSe tandem solar cell