Wide bandgap pure sulfide CIGS layers for Si/CIGS tandem cells from metal coevaporation and sulfur annealing

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Abstract

$Cu(In,Ga)S_2$ (CIGSu) is seen as a very good candidate for top solar cell absorber in a tandem configuration, thanks to its tunable bandgap from 1.5 to 2.4 eV. Recent developments showed a strong increase in CIGSu-based solar cells efficiencies, with values of 16.9% at 1.55 eV by a two-step sequential process were reported [1], together with 15.2% at 1.6 eV by co-evaporation [2], and 14.2% at 1.65 eV by co-evaporation [3]. In this study, we investigate a two-step deposition method where metallic precursors are deposited by evaporation, followed by a reactive sulfur annealing. The deposition method was validated on Mo/glass substrates with the fabrication of a 7.5 % efficient wide gap pure sulfide CIGSu solar cell (with CdS buffer layer), and a 6.3% efficient CIGSu solar cell with a Zn(O,S) buffer layer. JV characteristics are shown on figure 1a). This deposition method was then transferred to the synthesis of CIGSu on p-type silicon substrates, as a first step towards CIGSu/Si tandem solar cells. Optimization of the evaporation sequence led to the formation of dense and adherent films on silicon, with a spontaneous in-depth gallium gradient resulting in the formation of a two-layer structure (figure 1b), compatible with high efficiency solar cells [3]. XRD and EDS mapping measurements confirm that the two layers are composed of an indium-rich chalcopyrite CIGSu phase at the top of the film, and a gallium-rich phase at the bottom. Photoluminescence analyses show a strong emission above 1.5 eV. Owing to the superior photovoltaic performances of two step processes, using coevaporation may provide a route for further improvement as compared to sputtering.

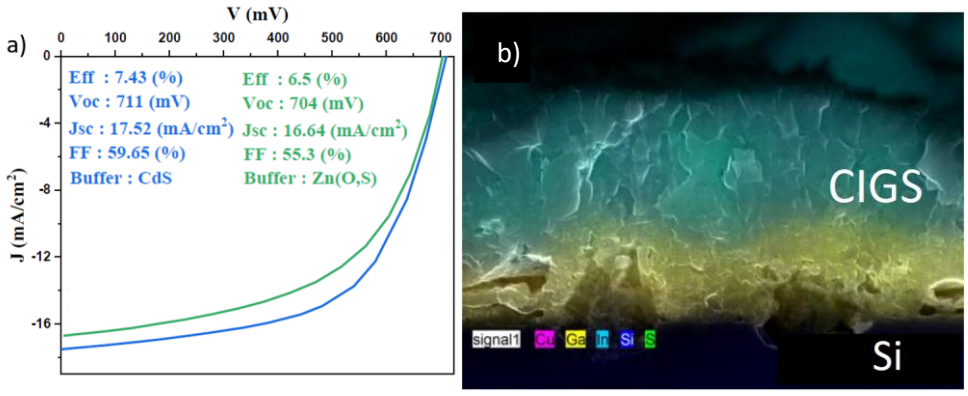

Figure 1 : a) IV measurement of pure sulfide CIGS solar cells with a CdS buffer layer (in blue) and a Cd-free Zn(O,S) buffer layer (in green). b) SEM cross section image of pure-sulfide CIGS on silicon, with EDX mapping of In (blue) and Ga (yellow).

References:

[1] H. Sugimoto, H. Hiroi, Y. Iwata, and A. Yamada, 27th International Photovoltaic Science and Engineering Conference, Japan 2017.

[2] S. Shukla et al., Joule 5, 1–16, 2021.

[3] N. Barreau and A. Thomere, 47th IEEE Photovoltaic Specialists Conference, 2020.