Ag-alloyed wide gap Cu(In,Ga)S2 for tandem application : optimization of metallic precursor and sulfurization

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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, and 14.2% at 1.65 eV both by co-evaporation [2],[3]. In this study, we investigate a two-step fabrication process of Ag-alloyed CIGSu (ACIGSu), where metallic layers are first evaporated on Mo/glass substrates, followed by an annealing in the presence of sulfur. Ag alloying was chosen as it is known to improve the quality of CIGS, and is expected to help crystallization at low temperature. The cells are prepared without Cd, with a Zn(O,S) buffer layer. The influence of metals deposition parameters was investigated by studying three different stacking orders on Mo/glass, with stacks of Ag/Ga/In/Cu/Mo, Ag/In/Ga/Cu/Mo and Ag/Ga/Cu/In/Cu/Mo. The second gave the best results with a strong increase of Voc and fill factor, rising the best cell efficiency to 9.2% with a wide bandgap of 1.5 eV (Voc 773 mV, Jsc 20.1 mA/cm², FF 59.3%) thanks to a minimization of metals reorganization by alloying, and a resulting improved absorber morphology. The Jsc value is very close to values obtained with high efficiency cells at 1.5-1.6 eV [1]–[3], however the Voc still remains lower than voltages reported in these three publications, ranging from 868 mV [2] to 994 mV [1]. PL investigations show that highest efficiencies are associated with the highest signals. This investigation shows the potential of Ag alloying in wide gap sulfide CIGS, and the benefits of using a two-step deposition method where metal alloys formation and distribution can be managed, and where the composition can be finely controlled.

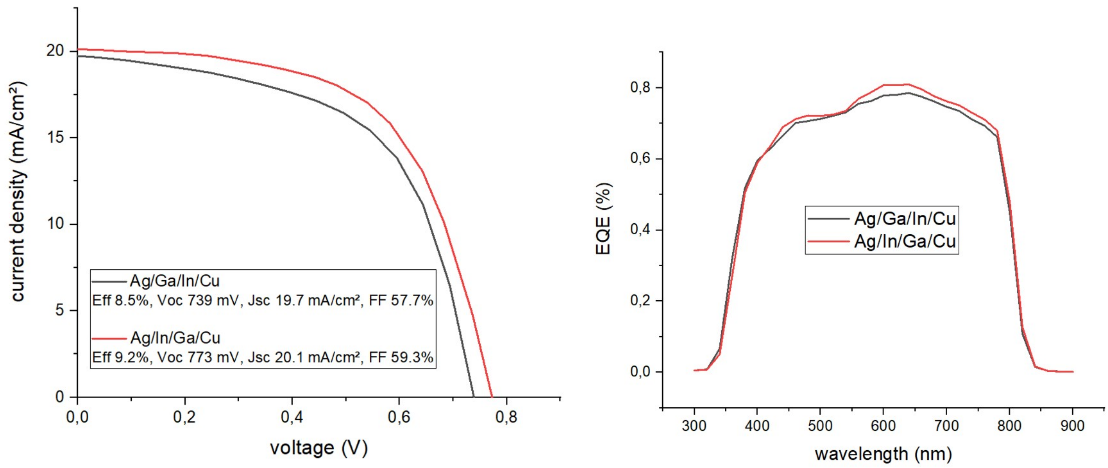

Figure 1: best solar cell results for two different precursor stack orderings.

References:
[1] H. Sugimoto *et al.*, 27th International Photovoltaic Science and Engineering Conference, 2017.
[2] S. Shukla *et al.*, Joule 5, 1–16, 2021.
[3] N. Barreau *et al.*, 47th IEEE Photovoltaic Specialists Conference, 2020.