# A combinatorial approach to clarify the role of Cu and Na in $Cu(In,Ga)S_2$ solar cells

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Despite recent advances, the efficiency gap between copper-indium-gallium sulfide (CIGS) and selenide (CIGSe) solar cells efficiency remains significant (16 vs 23%) due to the higher open-circuit voltages(VOC) losses. Two phenomena are involved in those losses: interface and bulk recombinations.

The severity of each loss depends on the composition, the structure, and the optoelectronic properties of the CIGS phase as well as on the presence of secondary phases.

The bandgap value is primarily determined by the In/Ga ratio and thus is easily set to an optimum ≈1.65 eV value.

Hence, the remaining key factors are related to the Cu content and the synthesis parameters. In particular, a key to achieving high-efficiency selenide cells is known to be a well-designed alkali (especially Na) supply, which is known to affect grains growth, the formation of secondary phases, and suppresses the formation of a VOC-killer electronical defect. To speed up the investigation of the role of Cu content and Na-supply while avoiding problems related to process reproducibility, we embarked on a combinatorial study of CIGS material and solar cells. CIGS layers were synthesized via co-evaporation with a tilted Cu-source resulting in a lateral Cu-gradient of about 20%(max to min). From a single deposition, we then obtain a series of 84 samples with varying Cu content.

Na-supply is controlled by substrate nature (Na-free or not) as well as NaF evaporation at different stages of the process.

After calibration with EDX and XRD, the composition and phases present in each sample are determined by Raman spectroscopy and intrinsic bulk properties (related to bulk recombination) by photoluminescence. Solar cells are finally prepared and characterized using IV and EQE, which provides us experimental VOC and allows us to analyze interface losses. Stability over time and illumination was investigated as well. The key parameters of all produced samples (>500) are finally compiled in a database which enables us to shine light on the role of Cu and Na on phases formation, optoelectronic properties, and ultimately devices performance and stability.