Enhancement of $Cu(In,Ga)Se_2$ solar cells by optimizing the KF post-deposition treatment

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Photovoltaic technology based on polycrystalline $Cu(In,Ga)Se_2$ (CIGS) has become very attractive because of the very high efficiencies achieved (up to 22.6% on soda-lime glass [1] and 20.4% on polyimide [2] substrates) compared to other thin film materials. Thin-film photovoltaic devices can be manufactured on flexible substrates, enabling the employment of roll-to-roll deposition techniques, and offering new opportunities in areas such as building integration, portable electronics, and space applications. Achieving high efficiencies on polyimide is particularly challenging as the growth temperature must be kept below 450°C, which strongly affects the element diffusion and the absorber quality. Sodium must be provided by a NaF treatment of the absorber, as it is not present in the substrate. Over the last 5 years, a strong efficiency improvement has been obtained by applying a potassium fluoride post-deposition treatment (KF-PDT) to the absorber prior to CdS deposition. It has been suggested that potassium reacts with the absorber and forms a thin layer of $KInSe_2$ or $K:In_2Se_3$, [3], [4] and that it has an effect on grain boundaries, but more investigations are needed. Ordered vacancy compound (OVC) phases forming at the surface of the absorber might be necessary to the effectiveness of the PDT. [3], [5]
In this work, the role of In and Ga during the last stage of the evaporation process and during the PDT is investigated. In particular, different In fluxes are added during the KF-PDT to favor the formation of K-In-Se compounds and the Ga gradient is re-optimized for the new KF-PDTs. The electrical performances will be analyzed and discussed in light of characterization data such as glow-discharge optical emission spectroscopy (GD-OES), Raman and x-ray diffraction (XRD). Our preliminary results on polyimide substrates show a record efficiency of 18.1 % (without anti-reflective coating) and a Voc improved by 43 mV with respect to NaF-PDT only.

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