Influence of Na on the performance of $Cu(In,Ga)Se_2$ photovoltaic solar cells fabricated on Molybdenum substrates

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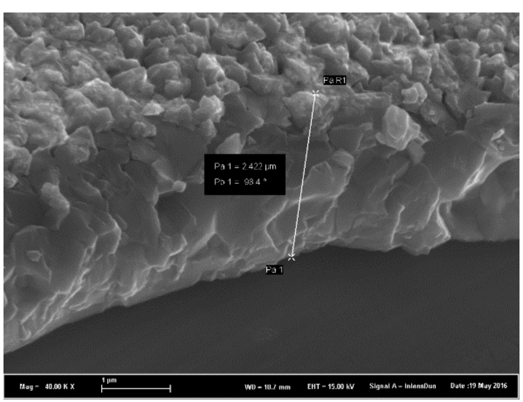
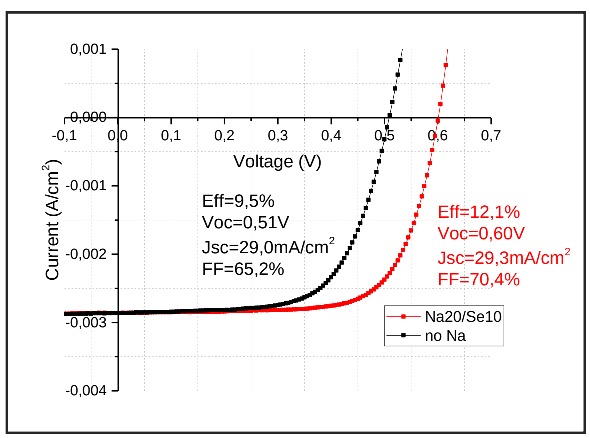
The photovoltaic industry today is making considerable progress in improving the performance of photovoltaic cells and reducing production costs. A pathway to cost reduction is through the cost of the materials utilized or the fabrication process used. A good illustration of this is the development of thin film $Cu(In,Ga)Se_2$ (CIGS) based solar cells on flexible metallic substrates. A huge benefit of this type of substrate is that it provides a strong support for the cells and at the same time has the advantage of being light and flexible compared to its glass counterpart.

Metals considered for use as a suitable substrate include but not limited to Stainless Steel and Molybdenum. While these materials are much more stable than glass at elevated temperatures, it should be noted that they could contain impurities e.g Fe, which degrades the electronic properties of the CIGS absorber. Another challenge encountered is the incorporation of Sodium (Na) in the absorber as Sodium is known to improve the absorber properties especially the Voc and fill factor (FF). On glass substrates, Na present in the glass diffuses naturally during deposition through the Molybdenum back contact into the bulk, however, for metals which seldom contains Na, alternative routes have to be explored for the incorporation of beneficial Na in the CIGS absorber. In this work, Mo was used as a substrate, hence, the CIGS layers was deposited directly on Mo strips of thickness around 150µm. The CIGS absorbers were realized by the coevaporation of the constituent elements (Cu, In, Ga and Se) in the 3-stage deposition process at temperatures around 480°C. To effectively improve the electronic properties, Na is introduced in a post-deposition treatment step at a temperature lower than the deposition temperature of the CIGS absorber (350°C). The focus was mainly on controlling the Na flux at $2nmmin^{-1}$ with different exposure times and deposition temperature in order to achieve a higher Voc in the cells with efficiencies reaching up to 12.1% as compared to only 9.5% in cells with no Na. To understand the physical and structural properties, an in-depth analysis of the samples was conducted using various methods that includes Scanning Electron microscopy (SEM), Energy Dispersive x-ray Spectroscopy (EDS), X-ray Diffraction (XRD), Glow-Discharge Optical Emission Spectroscopy (GD-OES) and X-ray fluorescence (XRF) for determining the composition of the cells. The optical and electronic properties were investigated by IV and External Quantum Efficiency (EQE). Drawing a parallel between cells deposited with and without Na highlights the importance and potential benefits of optimizing the Na content of the CIGS cells. Below is a cross-section of a typical CIGS cell on Mo substrate deposited at 480°C with Na introduced via NaF PDT at 350°C. The IV scheme shows the superior quality of the Na cells which is seen in a higher Voc, efficiency and FF.



(a)



(b)

Figure 1. (a) SEM cross-section of a CIGS cell. (b) IV curve two cells deposited with and without Na incorporation