Chemical Bath Deposition of Zn-Compound Buffer Layers for Thin Film CIGS Solar Cells

Abstract: The deposition of ZnS-based buffer layers by chemical bath deposition (CBD) for Cu(InGa)Se_2 thin film solar cells was investigated. CBD is a deposition method that excels through low capital investment. Its fast, simple, reproducible and scalable realization allows for uniform surface coverage and the removal of surplus alkali metals, what is not possible for vacuum techniques. Due to larger band gaps and non-hazardous, readily available components, ZnS-based buffer layers represent a promising alternative to the common CdS buffer layers, which suffer from toxicity and current losses due to parasitic absorption. However, the use of Zn-based buffer layers comprises also drawbacks: similar solubility constants of ZnS, ZnO and $Zn(OH)_2$ complicate the control of stoichiometry during deposition. Furthermore, CIGS solar cells with zinc compound buffers suffer from metastable effects of the solar cell performance and reduced V_{OC} compared to devices with CdS buffer layers.

Zinc compound buffer layers were prepared by pH and temperature controlled CBD from $ZnSO_4$ and $SC(NH_2)_2$ reacted in alkaline aqueous solution. Resulting films were characterized by UV-Vis spectrometry, XRD, XRF, and SEM. For device completion, a window bilayer, consisting of a highly resistive layer (i-ZnO or ZnMgO) and a transparent conductive oxide (ZnO:Al) as front contact, was deposited by RF-magnetron sputtering.

By optimizing CBD and post-deposition treatment parameters and also the type, resistivity, and thickness of the high-resistive window layer, homogeneous solar cells with efficiencies up to 15.9 % with a CdS reference value of 17.0 % were obtained. Next to the thickness and resistivity of the window and buffer layers, the combination of K-treated absorbers with a Cd^{2+} partial electrolyte treatment was found to drastically reduce metastabilities in solar cells. The good homogeneity of the CBD process for Zn(S,O,OH) buffer layer was demonstrated by fabrication of a flexible mini-module of eight monolithically interconnected cells.