Comprehensive analysis of $CuIn_{1-x}Ga_xSe_2$ based solar cells with $Zn_{1-y}MgO_y$ buffer layer.

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Recently, Cu(In,Ga)Se_2 thin film solar cells with conversion efficiency of 20.8 % have been reported in literature for laboratory cells [1], and commercial modules are now fabricated large quantities. In these solar cells, CdS deposited by chemical bath deposition (CBD) is widely used as buffer layer to form a p-n heterojonction between n-CdS and p-CIGS. One of the key factor for obtaining a record efficiency of polycrystalline CIGS based solar cells is related to the presence of high quality p-n heterojonction between CdS buffer layer and CIGS absorber. However, the use of CdS is undesirable in large-scale production of CIGS solar cells because of its toxicity. Moreover, the decrease of the short circuit voltage due to the optical absorption of the short wavelengths by the CdS layer is a concern for the scientific community of CIGS solar cells. Therefore, Cd-free materials have been intensively investigated as alternative to the CdS [2]. Thus, most attention is focused on the zinc oxide due to its potential applications as transparent conducting films for different optoelectronic devices such as liquid crystal displays and solar cells. ZnO thin films have been already used as an alternative to the highly toxic CdS layers in $CuInGaSe_2$ based solar cells. However, there some limitations in the application of ZnO in thin film solar devices since its band gap is not wide enough. As a result, a tuneable band-gap material such as $Zn_{1-x}Mg_xO$ (ZMO) has recently received a lot of attention [3]. The advantage of this buffer layer is that, its conduction band can be adjusted to optimize the band alignment at the buffer layer/absorber interface. In this study, the performance of ZMO/CIGS heterojunction solar cell have been modeled and numerically simulated using one-dimensional simulation program (SCAPS-1D) and a detailed analysis of the Mg and Ga content in the buffer and absorber layer is presented using current-voltage, capacitance-frequency, quantum efficiency characteristic. The resulting performance parameters of open-circuit voltage (V_{oc}), short-circuit density (J_{sc}), fill factor (FF) and efficiency (η) are determined using current density-voltage (J-V) characteristics. The obtained results show that the best solar cells with the Zn(Mg,O) buffer layer can be achieved when Mg content in the buffer layer is approximately 0.15-0.2. In comparison to the conventional CdS buffer layer, the best solar cells with the Zn(Mg,O) buffer layer has lower V_{oc}, FF but higher J_{sc} which result in slightly lower conversion efficiency. The simulation results suggest that the high defect density in the Zn(Mg,O) buffer layer may be the cause of poor performances of Zn(Mg,O)/CIGS solar cells. A comparison of the simulation results with published data for the CIGS cells with the Zn(Mg,O) buffer layer shows an excellent agreement.

References

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