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CIGS thin film solar cells with graded-band gap fabricated by CIS/CGS bilayer and CGS/CIS/CGS trilayer systems

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High efficiency $CuIn_{1-x}Ga_xSe_2$ (CIGS) thin film solar cells are usually deposited on Mo-coated soda-lime glass (SLG) substrates by the three-stage co-evaporation process which is intended to create double-graded band gap. It requires short total deposition time and changing of substrate temperature in order to obtain the double-graded band gap which is quite difficult for high source temperatures. When the total deposition time cannot be made short enough, uniform band gap is rather achieved. On the other hand, in this work, the depositions of CIS/CGS bilayer systems are employed in order to create front and back grading while CGS/CIS/CGS trilayers are for the double-grading, owing to non-uniformity and different diffusivity of In and Ga constituents in the films. In addition, the substrate temperature is held steadily at 560°C throughout the deposition of bilayers and trilayers in contrast to that of the three-stage process. The bilayers with back grading show the increasing short-circuit current density (J_{sc}) due to the assisting back surface field, but the open-circuit voltage (V_{oc}) is relatively low due to the reduction of Ga content at the front surface. For the CGS/CIS/CGS trilayers, double grading and the increassing of V_{oc} are observed when compared with the bilayers due to the increasing Ga content near the junction. The highest efficiencies of the devices fabricated from the CIS/CGS bilayer and CGS/CIS/CGS trilayer absorbers show the maximum value of 12.5% and 15.5%, respectively. The external quantum efficiency (EQE) of the bilayer and trilayer absorbers indicate the enhancement in the long wavelengths compared to that of the three-stage process absorbers.

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