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A study of β-Cu(In,Ga)$_3$Se$_5$ effects on Cu(In,Ga)Se$_2$ thin film solar cells

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$\mathrm{Cu(In,Ga)_3Se_5}$ is known as a β-phase in the phase diagram of $\mathrm{Cu_2Se}$ and $\mathrm{(In,Ga)_2Se_3}$. The existence of this phase on the surface of $\mathrm{Cu(In,Ga)Se_2}$ absorber plays an important role for enhancing the performance of $\mathrm{Cu(In,Ga)Se_2}$ solar cells. The energy dispersive x-ray spectroscopy (EDX) is used to investigate and confirm the composition of single $\mathrm{Cu(In,Ga)_3Se_5}$ film and in order to obtain the deposition conditions. In this study, the β-$\mathrm{Cu(In,Ga)_3Se_5}$ with various thicknesses were deposited after a completion of the three-stage co-evaporation process of $\mathrm{Cu(In,Ga)Se_2}$ films. The solar cells with thinner $\mathrm{Cu(In,Ga)_3Se_5}$ showed an increase in open-circuit voltage (V_{oc}). The maximum V_{oc} of 0.707 V was obtained from $\mathrm{Cu(In,Ga)_3Se_5}$ film with 10 nm thick. It is noted here that the conversion efficiencies are slightly lower when compared with the standard three-stage growth solar cells without $\mathrm{Cu(In,Ga)_3Se_5}$. It is mainly due to a decrease in a short circuit current (J_{sc}) and a fill factor (FF). Based on previous studies, the higher V_{oc} was obtained by a larger energy band gap caused by valence band offset at the CdS/CIGS interface.

Primary author: Ms NAMNUAN, Boonyaluk (Department of Physics, Faculty of Science, Chulalongkorn University, Bangkok, THAILAND 10330)

Co-authors: Dr YOODEE, Kajornyod (Department of Physics, Faculty of Science, Chulalongkorn University, Bangkok, THAILAND 10330); Dr CHATRAPHORN, Sojiphong (Department of Physics, Faculty of Science, Chulalongkorn University, Bangkok, THAILAND 10330)

Presenter: Ms NAMNUAN, Boonyaluk (Department of Physics, Faculty of Science, Chulalongkorn University, Bangkok, THAILAND 10330)

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