Examination of Cu(In,Ga)Se_2 Films Deposited by Multi-Layer Precursor Method Using Optical Deep Level Transient Spectroscopy

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Cu(In,Ga)Se_2 (CIGS) solar cell is considered as one of the highest conversion efficiency thin-film solar cells. In this work, CIGS films on both soda-lime glass (SLG) and stainless steel (SUS) substrates were deposited by the so-called "multi-layer precursor method", explained in Ref. [1]. The CIGS films with different band-gap energies (E_g), which were controlled by [Ga]/([Ga]+[In]) denoted by GGI, were prepared to investigate effect of GGI (i.e., E_g) on cell performances. Moreover, deep defect levels of CIGS films with different E_g were examined by optical deep level transient spectroscopy (ODLTS). In Fig. 1, open-circuit voltage (V_{OC}) of CIGS solar cells is increased with increasing GGIs to ~ 0.37 and 0.45 in cases of SUS and SLG substrates, respectively. This is attributed to the increase in E_g. However, with further enhancing GGIs, the V_{OC} is decreased. This is because the E_1 defect level observed in CIGS films on both SLG and SUS substrates by ODLTS as seen in Fig. 2 is located at ~ 0.8 eV from valence band maximum (E_V) regardless of the change of E_g, thus becoming carrier recombination center with increasing GGI (i.e., E_g). In Fig. 2, T and e_n denote temperature and electron emission rate from trap. In addition, V_{OC} in case of SLG substrate in Fig. 1 is higher than that in case of SUS substrates. This is because E_2 defect level, situated at ~ 0.61 eV from conduction band minimum (E_C), is only observed in CIGS film on SUS substrate, whereas this level is not detected in CIGS film on SLG substrate. The E_2 defect level is feasibly originated from Fe in CIGS film on SUS substrate. Ultimately, 17%-efficient CIGS solar cell on flexible SUS substrate was obtained with optimized GGI of ~ 0.34 under the so-called "multi-layer precursor method".

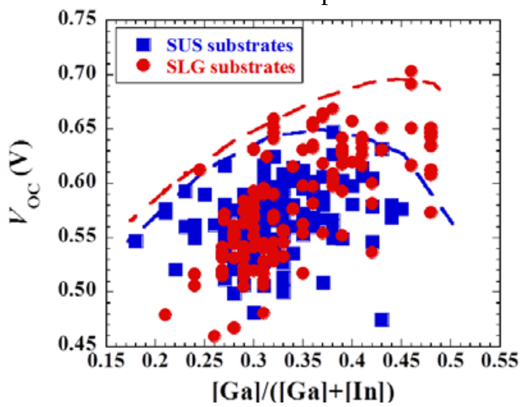

Figure 1 V_{OC} of CIGS solar cells on SLG and SUS substrates as a function of [Ga]/([Ga]+[In]) in CIGS absorbers.

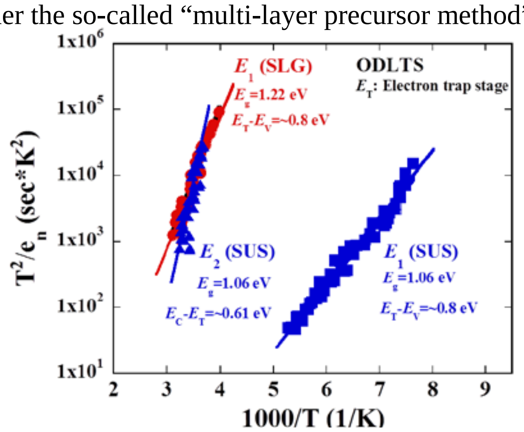

Figure 2 T^2/e_n potted against 1000/T for the deep defect levels (E_1 and E_2) in CIGS films on SUS and SLG substrates with E_gs of 1.06 and 1.22 eV.

Reference: [1] Jakapan Chantana et. al., Solar Energy Materials & Solar Cells **133** (2015) 223.