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Effect of Surface Sulfurization on MBE-Grown $Cu(In_{1-x},Ga_x)Se_2$ Thin Film

Research Institute for Science and Technology, Tokyo University of Science

°I. Khatri, I. Matsuyama, H. Yamaguchi and T. Nakada

E-mail: i_khatri@rs.tus.ac.jp

MBE-grown CIGS thin films were sulfurized using a 10% H_2S-N_2 mixture gas at 450-550°C for 30 minutes. The film composition and surface morphology of the CIGS absorber layers were measured by ICP and SEM. The film composition was maintained to be Cu/(In+Ga)~0.9, and Ga/(In+Ga)~0.4. The surface morphology of CIGS was remarkably changed after sulfurization and the micro-roughness in the CIGS surface layer increased with increasing sulfurization temperature. The CIGS absorber layers before and after sulfurization were characterized by photoluminescence (PL) spectroscopy. We observed enhancement in near-band-edge PL intensity after sulfurization as shown in Fig. 1(a), which is expected due to the reduction of defects in the CIGS surface layer. The increase in PL intensity is consistent with the enhancement of the PL decay time. It was noted that PL decay time of CIGS absorber layer enhanced after sulfurization. The CIGSe(S) solar cell with Al/Ni/AZO/ZnO/CdS/CIGSe(S)/Mo/SLG structure were fabricated, and the cell performances were compared before and after sulfurization. The device results were characterized using current-voltage (J-V) and external quantum efficiency (EQE). The open circuit voltage (V_{oc}), short circuit current density (J_{sc}), fill factor (FF) and power conversion efficiency (η) were obtained as 0.664V, 33.5mA/cm^2, 0.743, and 16.6% for solar cell fabricated from sulfurized CIGS film, whereas the V_{oc}, J_{sc}, FF and η were 0.632V, 33.8mA/cm^2, 0.738, and 15.8% for solar cell fabricated from as-deposited CIGS film. Especially, the improvement in V_{oc} from 632mV to 664mV after sulfurization, enhanced the overall conversion efficiency as shown in Fig 1(b). However, external quantum efficiency of the CIGSe(S) solar cells was not significantly changed after sulfurization. The details of CIGS thin films properties and cell performance before and after sulfurization, including SIMS and EBIC data will be presented.

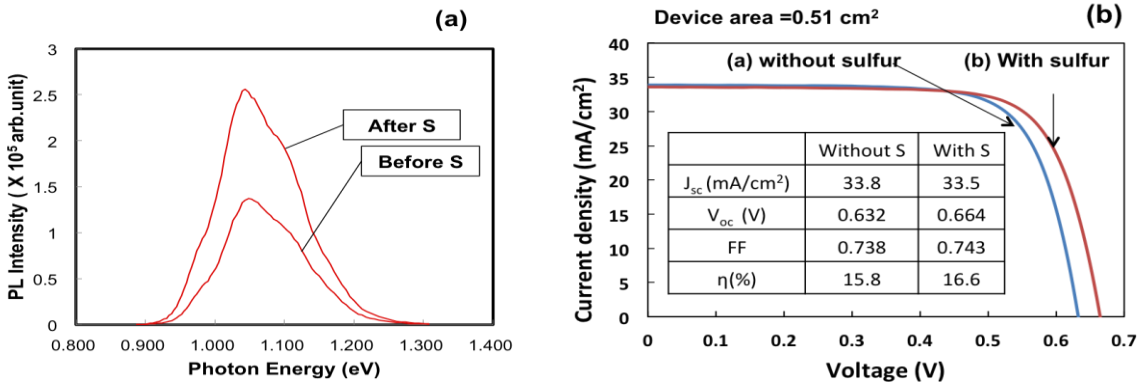

Figure 1 (a) PL spectra of CIGS films sulfurized at 500 °C for 30 minutes, and (b) J-V characteristics of CIGS solar cells with and without sulfurization.

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