EFFECTS OF SUBSTRATE TEMPERATURE ON CONTROLLING INTERFACIAL QUALITY OF Cu(In,Ga)Se₂ SOLAR CELLS BY Se ANNEALING

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Introduction:
Cu(In,Ga)Se₂ (CIGS) is a promising absorber material for thin film solar cells because of its low cost and high performance potential. The CIGS deposition temperature affects the crystal structure and diffusion state of Ga, In and alkali metals, and consequently greatly influence the characteristics of the CIGS solar cell. To improve the efficiency, it is important to prevent interface recombination between the CIGS and CdS buffer layer. Up to now, we have revealed that the formation of a valence band off set ($\Delta E_v$) by the insertion of a wide gap surface layer between CdS (n-type buffer layer) and p-CIGS absorber can suppress interfacial recombination. One method to create a wide gap surface layer is the three-stage process with Se irradiation at a substrate temperature of 550 °C.[1] However, it is still unclear whether this method can be applied at lower temperatures. In this study, we demonstrate how the three-stage process with Se irradiation affects the CIGS interface on several deposition temperatures.

Experimental methods:
The CIGS solar cell structure was fabricated on a SLG substrate. An 800-nm-thick Mo bi-layer was deposited on the top of the substrate using DC sputtering. The CIGS absorber layers were grown using molecular beam epitaxy (MBE) by three-stage method at substrate temperature changed from 470 °C to 580 °C. Se irradiation time of 0, 5 and 20 min was introduced between the second and third stage. A CdS buffer layer was deposited on the CIGS layers by chemical bath deposition (CBD). The ZnO layer was deposited as a window layer by metal organic chemical vapor deposition (MOCVD). Finally, Al grids were deposited using thermal evaporation. $J$-$V$ characteristics of the fabricated solar cells were measured under AM1.5G sunlight.

Result and discussion:
Figure 1 shows the effect of deposition temperature and Se irradiation time on CIGS solar cells characteristics. The conversion efficiency increased by increasing the deposition temperature. It was confirmed that Se irradiation improves $V_{OC}$ and $FF$ at substrate temperature higher than 530 °C. However, efficiency improvement by Se irradiation could not be confirmed at substrate temperature of 470 °C.

Considering the Cu–Se binary phase diagram,[3] this result can be interpreted as an effect of Cu₂Se phase change. If Se is supplied to Cu₂Se phase heated at a temperature higher than 523 °C, the system moves to a coexistent condition of Cu-deficient Cu₃-xSe solid phase and Cu–Se liquid phase. From the experimental results, the Se irradiation is effective at substrate temperatures higher than 530 °C, indicating that the existence of the liquid phase is important.

References:

Figure 1: Characteristics of fabricated solar cells