The Advantage of Low Electron Affinity Materials as the Window Layer of Buffer-free $CIGS_2$ Solar Cells

○(D)Dwinanri Egyna, Kazuyoshi Nakada, Yamada Akira
Tokyo Institute of Technology
E-mail: egyna.d.aa@m.titech.ac.jp

$CuIn_{1-x}Ga_xS_2$ ($CIGS_2$) is the wide-bandgap alternative in the $CuIn_{1-x}Ga_x(Se_{1-y}S_y)_2$ ($CIG(SSe)_2$) chalcopyrite group, one of the leading absorber material in the thin-film heterojunction solar cell technology. The current efficiency record for wide-bandgap single-junction $CIGS_2$ solar cells is at 16.9%. Currently, most experimental studies of the $CIGS_2$ solar cell still adopts the CdS buffer layer and the ZnO window layer as the n-type layers from the narrow-bandgap $CIGSe_2$ design. However, other researches have indicated that other alternative n-type materials such as $Zn_{1-x}Sn_xO_y$ or $Zn_{1-x}Mg_xO_y$ are more fitting in the wide-bandgap $CIGS_2$ application, resulting in improved performance. In addition, the elimination of buffer layer will also reduce the production cost and the complexity of the manufacturing process.

In this study, we simulated several different models with different device designs using the one-dimensional solar cell capacitance simulator (SCAPS-1D). The electron affinity of the window layer (χ^{Window}) was varied between 4.40 eV to 4.95 eV to simulate the impact of different n-type layer materials on the V_{OC} of the device. The performance of the n-type materials under the effect of various defect concentration N_t was also investigated.

In Figure 1, we illustrated the window and $CIGS_2$ absorber layers energy band diagram of the simulated devices. Figure 1a represents a device with low electron affinity and Figure 1b shows a device with high electron affinity, in this case with χ^{Window}=4.45 eV and χ^{Window}=4.95 eV respectively. As shown in Figure 2, for the device with χ^{Window}=4.45 eV was able to maintain high V_{OC} up to the ideal-V_{OC} for all interface defect density conditions. The ability to withstand the effect of the defect on V_{OC} worsen in the higher χ^{Window} materials, especially on higher N_t. We believe that the larger diffusion potential V_d on the device with low electron affinity window layer material suppresses the interface recombination and increases the selectivity on the interface. Therefore, to achieve a buffer-free $CIGS_2$ solar cell design the selection of window layer material with low electron affinity is essential.

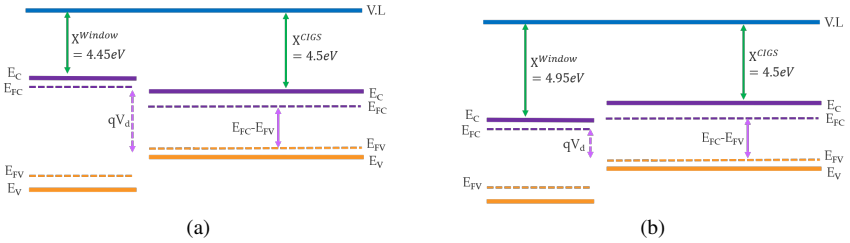

Figure 1: Illustration of the energy levels of the devices with (a)χ^{Window}=4.45 eV and (b)χ^{Window}=4.95 eV.

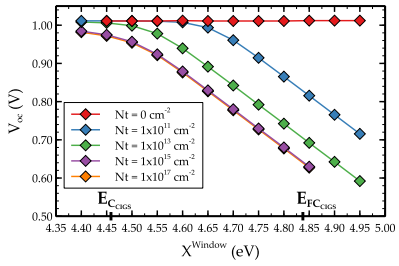

Figure 2: The effect of electron affinity variation of the window layer on the open-circuit voltage of a $CIGS_2$ solar cell

Acknowledgement: This work was supported by JSPS KAKENHI Grant Number JP20H02636.