Area 2: Thin-Film Compound Semiconductor PV.

ANALYSIS OF RECOMBINATION RATES IN CU(IN,GA)(S,SE)$_2$-BASED SOLAR CELLS WITH CDS, ZNS(O,OH), AND (CD,ZN)S BUFFER LAYERS

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Quantification of recombination losses in thin-film Cu(In,Ga)(S,Se)$_2$ (CIGSSe)-based solar cells at buffer/absorber interface, in space charge region (SCR), and quasi-neutral region (QNR) are of importance to understand the state-of-the-art and future development. The temperature-illumination-dependent open-circuit voltage (V_{OC}) method is utilized to extract the individual recombination rates at the buffer/absorber interface (R^i), in SCR (R^d), and in QNR (R^b) [1]. Moreover, from the method, the V-independent recombination coefficients at the buffer/absorber interface (R^i_0), in SCR (R^d_0), and in QNR (R^b_0) were obtained [1]. In this work, three structures of the CIGSSe solar cells with CdS, ZnS(O,OH), and $Cd_{0.75}Zn_{0.25}S$ buffer layers were fabricated. Namely, structure A is Glass/Mo/CIGSSe/CdS/ZnO/ZnO:Al/Ni-Al, structure B is Glass/Mo/CIGSSe/ZnS(O,OH)/ZnO/ZnO:Al/Ni-Al, and structure C is Glass/Mo/CIGSSe/ $Cd_{0.75}Zn_{0.25}S/Zn_{0.79}Mg_{0.21}O/Zn_{0.88}Mg_{0.12}O$:Al/Ni-Al. The CdS, ZnS(O,OH), and $Cd_{0.75}Zn_{0.25}S$ buffer layers were deposited by chemical bath deposition method. The ZnO, ZnO:Al, $Zn_{0.79}Mg_{0.21}O$, and $Zn_{0.88}Mg_{0.12}O$:Al were prepared by radio frequency co-sputtering. Ni-Al grids were grown by electron-beam evaporation. It is disclosed that the conversion efficiencies of CIGSSe solar cells with structures A, B, and C are 18.3, 17.4, and 20.6%, respectively. According to the measurements of the temperature-illumination-dependent V_{OC} of the CIGSSe solar cells with structures A, B, and C, the R^i_0, R^d_0, R^b_0, R^i, R^d, and R^b were estimated as demonstrated in Figure 1. In the structures A and C, the R^i is the lowest as compared with R^d and R^b, while in the structure B the R^i is the highest. It is noted that R^d_0, R^b_0, R^d, and R^b are not changed very much as compared with R^i_0 and R^i, when the structures of the solar cells were varied. As a result, the solar cell with structure C by replacing CdS/ZnO/ZnO:Al with $Cd_{0.75}Zn_{0.25}S/Zn_{0.79}Mg_{0.21}O/Zn_{0.88}Mg_{0.12}O$:Al leads to the primary decrease in R^i_0 and R^i, thereby resulting in the decrease in $V_{OC,def}$ and the increase in the conversion efficiency up to 20.6%, where the detail will be discussed.

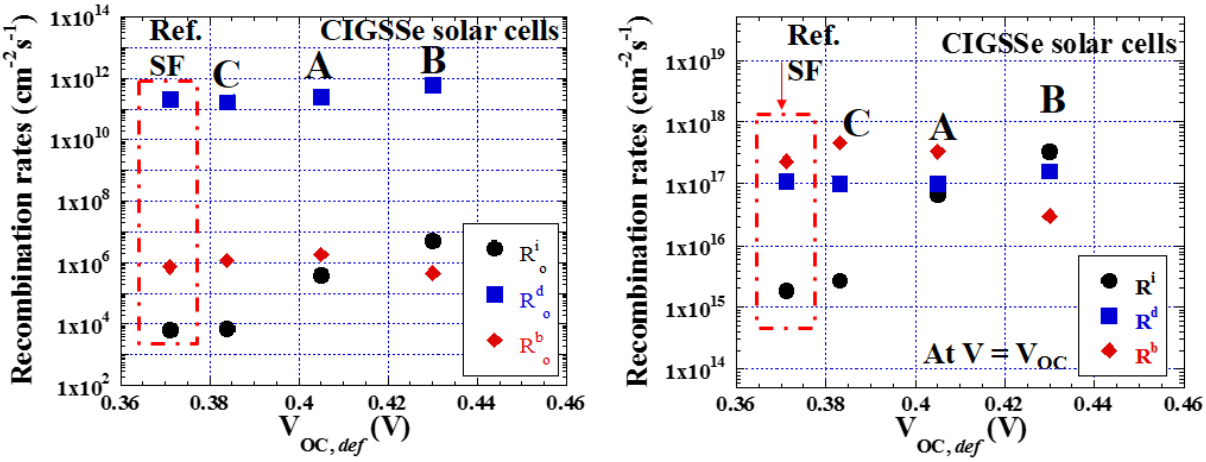

Figure 1: R^i_0, R^d_0, R^b_0, R^i, R^d, and R^b as a function of $V_{OC,def}$ for the solar cells with structures A, B, and C. The referent sample (Ref.) of CIGSSe solar cell was reported by Solar Frontier (SF) [2]. $Voc_{,def}$ is bandgap/q-V_{OC}.

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References
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