Quantification of recombination losses in thin-film Cu(In,Ga)(S,Se)₂ (CIGS) 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_{i0}), in SCR (R_{d0}), and in QNR (R_{b0}) were obtained [1]. In this work, three structures of the CIGS 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/CIGS/ZnO/ZnO:Al/Ni-Al, structure B is Glass/Mo/CIGS/ZnS(O,OH)/ZnO/ZnO:Al/Ni-Al, and structure C is Glass/Mo/CIGS/CdS/ZnO/ZnO: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 CIGS 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 CIGS solar cells with structures A, B, and C, the R_{i0}, R_{d0}, R_{b0}, 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_{d0}, R_{b0}, R_i, and R_d are not changed very much as compared with R_i and R_d, 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 and R_d, 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.

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References