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Controllable Growth of $MoSe_2$ in Kesterite Solar Cells

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Like CIGS solar cells, Mo film is served as back contact in CZTSSe solar cells. Generally, a $Mo(S,Se)_2$ interfacial layer can be formed be- tween CIGS or CZTSSe absorber and Mo back contact during the growth of CIGS or CZTSSe film. It is well known that a thin $Mo(S,Se)_2$ layer can act as a buffer layer to convert the Schottky contact to a quasi- ohmic contact, which is beneficial to the transportation of charge carriers. However, an over thick $Mo(S,Se)_2$ layer will block the transportation of charge carriers, which is detrimental to the performance of devices. Generally, to promote the growth of grains, suppress the surface decomposition, and avoid the formation of V_{Se} or V_S defects, CZTSSe films are often prepared at high temperature under high Se or S partial pressure. As a consequence, an over thick $Mo(S,Se)_2$ layer will be formed, which will increase the contact re- sistance between CZTSSe absorber layer and Mo back contact electrode. Thus, it is crucial to control the thickness of $Mo(S,Se)_2$ inter- facial layer for high efficient CZTSSe solar cells. Shin et al. indicated that the formation of $MoSe_2$ during selenization process under Se am- bient can be divided into three step processes: diffusion of Se through $Cu_2ZnSnSe_4$ (CZTSe), diffusion of Se through $MoSe_2$ which is growing with continued annealing, and reaction between Se and Mo. Thus, the formation of $Mo(S,Se)_2$ can be suppressed by such processes. For example, an intermediate layer, such as TiN, TiB_2, ZnO, and MoO_2, deposited between CZTSSe absorber and Mo back contact acts as a Se diffusion barrier to inhibit the formation of $Mo(S,Se)_2$. However, these intermediate layers may induce a rather high series resistance in the device and degrade the device performance.

To avoid the extra elements diffusing into absorber layer during selenization process, we developed a soft method to control the thickness of $MoSe_2$ interlayer without any barriers used. Our results indicate that the thickness of $MoSe_2$ can be tailored successfully by adding a low temperature annealing process before selenization process or adjusting the morphology of Mo film. The conversion efficiency is improved greatly as the growth of $MoSe_2$ is controlled. Temperature-dependent I-V measurements disclose that the contact barrier of Mo to CZTSSe is ca. 40 meV, which indicates that a quasi-Ohmic contact is realized.