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Total number of authors:
14

Publication date:
2019

Document Version
Publisher's PDF, also known as Version of record

10th European Kesterite+ Workshop & PhD Day
Uppsala University 20-22 November 2019
Sponsored by STandUP for ENERGY

Monolithic Cu_2ZnSnS_4-on-Silicon Tandem Solar Cells Enabled by a Diffusion Barrier

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Abstract: Recently, Si-based tandem solar cells have been the most compelling strategy to improve the efficiency of the existing photovoltaic technology beyond its practical and theoretical limits. Thin-film chalcogenides have shown performance, reliability, stability and costs comparable to the Si technology, and could be suitable top-cell partners for Si. However, limited work has been done to evaluate the compatibility of these two technologies. The synthesis process of chalcogenides generally includes high temperature annealing (> 500 oC) of the precursors in a reactive atmosphere, which could lead to in-diffusion of the detrimental metallic species into the Si cell. In this work, we investigated monolithic integration of Cu2ZnSnS4 (CZTS), a promising representative from the chalcogenides family, on top of a thermally resilient silicon structure featuring polysilicon-based electron and hole selective passivating contacts. We used different Ti-based barrier layers, namely TiN, Ti(OxNy), and TiN-Al-TiN, between the two cells to serve both as diffusion barrier and recombination layer. By carrier lifetime measurements, we show that an ultra-thin (< 10 nm) TiN layer can successfully protect the Si during the full fabrication of the CZTS cell. Moreover, Deep Level Transient Spectroscopy (DLTS) showed no evidence of electrically active deep defects in silicon when protected by 10 nm TiN. We have demonstrated proof-of-concept tandem devices with efficiencies spanning from 1 – 5% so far, with Voc up to 1.06 V and Jsc up to 11 mA/cm2 using different barrier layer configurations. We discuss the optical and electrical

impact of each barrier layer on the performance of our tandem devices. Since the CZTS top-cell is deprived of any alkali-doping source, experiments where Na is added in the form NaF, are ongoing to improve the efficiency of the cells further. Preliminary results show that the Si bottom cell is more sensitive to the sequence in which NaF is introduced.