Enabling high-efficiency chalcogenide/Si tandem solar cells: a comparative study of different chalcogenide top cells on a thermally resilient Si bottom cell

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Abstract (max. 500 words)

Into 2021, the cost per Watt of photovoltaics is now dominated by module infrastructure and area-related costs, which are mostly common to all the core photovoltaic technologies. Therefore, in order to further improve the photovoltaic cost metrics, the module efficiency is becoming a key aspect. Chalcogenide on silicon tandem solar cells have the potential to combine the higher efficiency of tandem cells with the low costs of the core Si and thin film chalcogenide technologies.

Recently, our group demonstrated several protection strategies for achieving the direct growth of Cu_2ZnSnS_4 (CZTS) on Si, using a bottom Si cell based on Polycrystalline Silicon on Oxide (POLO) structures, including TiN-based diffusion barriers, SiN sacrificial protection layers and tuning of the polySi properties. In this contribution, we report on the generalization of our findings to other top cells from the chalcogenide family, by presenting a comparative study between CZTS, $CuGaSe_2$ (CGSe) and $AgInGaSe_2$ (AIGSe) tandems on Si fabricated in different institutes. We find that the compatibility of the different top cells with Si is largely determined by two aspects of the top cell: 1) the processing temperature, and 2) the Cu content of the absorber material. With its Cu content and high processing temperature (575 °C), CZTS was found to be the harshest of the three materials in terms of Si degradation, while the Cu-free AIGSe showed the least impact on Si. We reveal that the degradation occurs mostly through an increase in surface recombination at the polySi interfaces, associated with Cu contamination during the chalcogenide synthesis. As a result, the collection efficiency and open-circuit voltage (V_{oc}) of the Si bottom cell deteriorate.

By managing the impact on Si with the protection strategies mentioned, we were able to demonstrate a CZTS/Si tandem with 6.8% efficiency, the highest for a tandem of this kind. Additionally, we fabricated a CGSe/Si tandem with an open-circuit voltage of 1.3 V. Most importantly, in all cases the bottom Si cell achieves a V_{oc} above 575 mV, which is the highest reported for any chalcogenide/Si tandem cell, highlighting the potential of our Si architecture for achieving high-efficiency tandem cells with top cells fabricated in harsh conditions.

By overcoming the Si degradation hurdle, we suggest that the next challenge to advance this tandem concept lies in the realization of high-efficiency chalcogenide top cells on Si-based structures. With the current state of the art (i.e. single-junction results for high-bandgap chalcogenides), we identify a clear pathway for

tandem efficiencies above 15%, and further improvements are possible depending on future advances in the top cell efficiencies.

Keywords: CZTS, CGSe, AIGSe, Tandem, Silicon