Degradation of CIGS solar cells due to alkali migration under damp heat and illumination

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Purpose of the work
The incorporation of sodium (Na) and potassium (K) into CIGS leads to enhanced cell performance, but the influence of these alkali elements on degradation is unclear. The purpose of this work is the investigation of the impact of damp heat and illumination on non-encapsulated CIGS solar cells with high and low concentrations of the alkali elements sodium and potassium.

Approach
Alkali rich and alkali poor CIGS solar cells were exposed to both damp heat and illumination. Their current voltage characteristics were continuously monitored in order to in-situ follow the degradation of the cells. Additionally, the samples were analysed before and after degradation by optical microscopy, EQE, IV(T), SIMS and SEM-EDX.

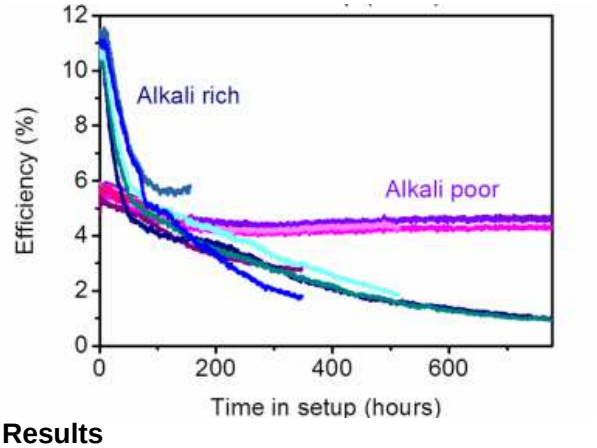

Figure 1: Evolution of the efficiency as a function of time in the setup taken at 107±1°C. The pink and purple lines represent the alkali poor samples, while the blue lines represent the alkali rich samples. The setup was set to 85°C, 85% relative humidity and 1000 W/m² illumination.

Results
The solar cells with a high alkali content exhibited higher initial conversion efficiencies, but degraded severely within 100 hours, while the alkali poor samples kept relatively stable performance under damp heat and illumination. The degradation of the samples with a high alkali content resulted in the formation of sodium rich spots on the top ZnO:Al surface of the samples. This is likely caused by light-induced Na^+ and possibly K^+ migration via the grain boundaries in the absorber to the depletion region, which resulted in the formation of shunt paths, leading to reduced shunt resistance and open circuit voltage. Therefore, these values as well as the fill factor and the efficiency showed a very rapid decrease.
Additionally, an increase in series resistance due to water ingression was observed for both types, while this increase was stronger for the alkali rich samples, probably due to additional sodium ingression.

Conclusions
In this study, we have shown that exposure to damp heat and illumination leads to very rapid degradation of alkali rich solar cells, while alkali poor cells are relatively stable. This can indicate that CIGS modules with high alkali contents are not stable when exposed to humidity and illumination, while alkali poor modules are stable.