

# How light exposure can influence the degradation of the CIGS absorber

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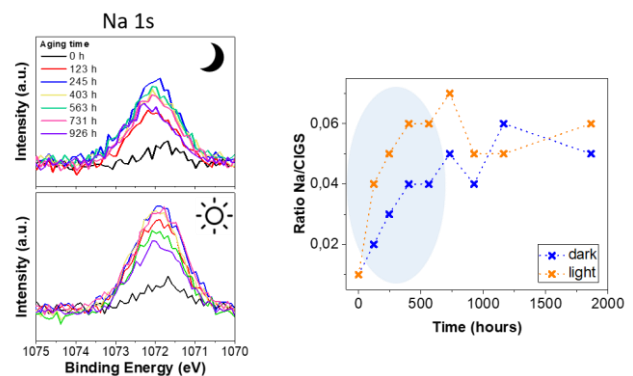
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One of the flagship solar absorbers is the quaternary alloy  $\text{Cu}(\text{In}_x\text{Ga}_{1-x})\text{Se}_2$  (CIGS), with solar cells reaching up to 23.6% efficiencies.<sup>1</sup> The majority of the cell efficiency improvements during the years concern the interface optimization, therefore, to avoid any efficiency deterioration over time, a good mastering of the interfaces and accordingly a good knowledge of the CIGS absorber's surface is needed.

In 2016 Theelen and Daume have reviewed all the different damage possibilities for CIGS solar cells, showing that relative humidity and light can trigger the cell degradation.<sup>2</sup> Nevertheless, only a few papers deal with the interaction of the CIGS absorber itself with the surrounding environment. Previous studies unveil the degradation of the CIGS layer when exposed to relative humidity when it comes to air aging.<sup>3</sup> Indeed, a remarkable chemical inertia of the absorber occurs when relative humidity is equal to 20% and a substantial evolution is observed when relative humidity reaches values higher than 40%. Here, we propose to investigate the chemical reactivity of the CIGS absorber when exposed to light (dark intensity: 400 lux, light intensity: 3500 lux and 4020 lux). The goal is understanding the aging mechanisms of the layer by using complementary techniques to investigate the surface chemical reactivity (X-ray Photoelectron Spectroscopy), the bulk chemical reactivity (Energy Dispersive Spectroscopy) and the topography evolution (Scanning Electron Microscopy).

Regarding the influence of light, the CIGS absorber degradation happens to be faster when the aging is performed under a light with an intensity higher than 3500 lux. Moreover, Na diffuses from the soda-lime substrate to the surface, and reacts with the surrounding air to form  $\text{Na}_2\text{O}$ . Precisely, in the first 700 h of aging, Na diffusion is faster when the aging is performed in light, to then stabilize to a similar trend under both conditions.

Lastly, topography degradation appears only on light exposed samples, with the growth of spots. In the literature, these spots are related to Na rich areas but are only linked to the relative humidity factor.<sup>4</sup>



On the left : evolution of Na1s photopeak when aging in dark and light  
On the right: evolution of Na/CIGS ratio over time when aging in dark and light

In conclusion, controlling the light exposure during the CIGS absorber aging can be fundamental, in order in order to keep the 23.6% of CIGS cell efficiency that has been reached this year.

<sup>1</sup> From NREL efficiency chart: [www.nrel.gov/pv/interactive-cell-efficiency.html](http://www.nrel.gov/pv/interactive-cell-efficiency.html)

<sup>2</sup> M. Theelen, F. Daume, *Solar Energy*, **2016**, 586-627, 133.

<sup>3</sup> S. Béchu, M. Bouttemy, J. Guillemoles, A. Etcheberry, *Appl. Surf. Sci.* **2022**, 576, 151898.

<sup>4</sup> Pern, F., Egaas, B., To, B., Jiang, C., J., Glynn, S., DeHart, C., *Proc. 34th IEEE PVSC*, **2009**, 287.