Atmospheric corrosion including humidity, temperature, and aerosol pollutants on the degradation of CIGS-based solar cells

Adèle Debono[a,b], Amelle Rebai[b], Andreas Erbe[c], Erlind Myslind[c], Nathanaelle Schneider[b], Jean-François Guillemoles[b], Polina Volovitch[a,b]

[a] *Chimie ParisTech-CNRS, PSL Research University, Institut de Recherche de Chimie Paris (IRCP), 11 rue Pierre et Marie Curie, 75005 Paris, France*

[b] *Institut Photovoltaïque d'Île-de-France (IPVF), UMR 9006, CNRS, Ecole Polytechnique, IP Paris, Chimie Paristech, PSL, Palaiseau, 91120, France*

[c] *Department of Materials Science and Engineering, NTNU, Norwegian University of Science and Technology, 7491, Trondheim, Norway*

adele.debono@chimieparistech.psl.eu ; polina.volovitch@chimieparistech.psl.eu

The current reliability approaches in photovoltaics (PV) mainly focus on studying the effects of temperature, illumination or even mechanical load, while among the chemical factors only humidity is generally considered [1]. In this work, we tried to take into account the presence of other species known in atmospheric corrosion and understand their impact on the stability of materials and assemblies relevant for thin layer Cu(In,Ga)Se_2 (CIGS)-based solar cells with ALD-Al_2O_3 encapsulation. The study focused on two layers of a thin film solar cell: a 500nm-thick Molybdenum back contact and 1.5 µm-thick CIGS absorber layer, deposited on Mo on glass or directly on glass. The stability of these systems was studied with and without encapsulation.

Three parameters are used to model this effect: relative humidity (RH) and temperature (T°C) cycled in a climatic chamber to mimic day and night or seasonal variations and accelerate the ageing as well as atmospheric aerosol pollutants deposited daily to form drops on the surface of the samples, as already demonstrated for AZO thin films [2]. Industrial, rural, and marine environments were modeled by typical components present as aerosols in theses atmosphere: sulphate Na_2SO_4, ammonium $(NH_4)_2SO_4$ and chloride NaCl salts respectively. The chemical evolution of the samples was surveyed using Scanning Electron Microscopy, Energy Dispersive X-Ray Spectroscopy, Raman spectroscopy and X-ray diffraction. The physical properties evolution was characterized using sheet resistance measurement.

Both, Mo and CIGS layers presented localized degradation mode with and without pollutants. The 25 nm-thick Al_2O_3 encapsulation was proven to efficiently protect the underneath materials efficient against temperature and humidity cycling but not against the pollutants. Because the encapsulating layer was destroyed in the locations where pollutants were deposited, the degradation mechanisms of unencapsulated samples were studied. The unencapsulated samples exhibited degradation spots on the surface of the CIGS/Mo/Glass which is coherent with the results of *Pern et al*. [3]. No spots appeared on the aged CIGS if it was deposited directly on glass. In situ and ex situ analysis of the degradation products by Raman spectroscopy and EDS were used to survey the evolution of the species in the degradation spots. In particular, growth and expansion of Na_2MoO_4 was observed on the top of the CIGS layer and $Cu_{2-x}Se$ was also detected (Fig. 1a-b). After rinsing of soluble Na_2MoO_4, the CIGS layer appeared more porous (Fig. 1c). These results evidenced Mo diffusion through the pores of CIGS layer. Speculative mechanisms of the CIGS/Mo/Glass system corrosion are proposed.

Commenté [NS1]: Il manque a b c sur ala figure et la legende, car ty les mentionnes dans ton texte

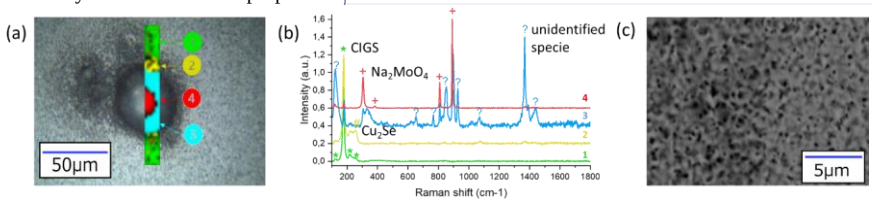

Figure 1 – (a) (b) Example of chemical species distribution before rinsing (Raman mapping) and (c) BSE surface appearance after rinsing of a CIGS/Mo/glass sample exposed to 45 °C and 82 % RH for 4 days.

REFERENCES

[1] J. H. Wohlgemuth et S. Kurtz, in *2011 International Reliability Physics Symposium* (2011), doi: 10.1109/IRPS.2011.5784534.

[2] S. Zhang *et al.*, *Progress in Photovoltaics*, 2021, doi: 10.1002/pip.3527.

[3] F. Pern *et al.*, in *34th IEEE Photovoltaic Specialists Conference (PVSC)* (2009), doi: 10.1109/PVSC.2009.5411676.