

On the importance of chemical aspects for durability evaluation in photovoltaics.

P. Volovitch¹, A. Maltseva¹, S. Zhang², N. Schneider², G. Herting³, I. Odnewall Wallinder³

¹*IRCP, CNRS - Chimie ParisTech, PSL University, 11 rue P. et M. Curie, 75005 Paris France*

²*IPVF, CNRS - Ecole Polytechnique – Chimie ParisTech, 18, Bld. Thomas Gobert, 91120 Palaiseau, France*

³*KTH Royal Institute of Technology, Dr. Kristinas v. 51, 10044 Stockholm, Sweden*

Email: polina.volovitch@chimieparistech.psl.eu

The real photovoltaic (PV) electricity costs depend as much on the efficiency loss during service as on the initial efficiency. The warranty of the modules being guaranteed up to 25 years and the maximum service time being determined by the wear out failures often occurring at the end of the working lifetime, “in field” verifications are too long for a practical use. To overcome long-term reliability issues, representative accelerated failure tests and realistic numerical models are necessary. For their design, a detailed understanding of the degradation mechanisms and the right selection of the key factors influencing the degradation rates are fundamental. Numerous recent works reviewed the degradation rates and named the degradation modes of the existing PV materials in service conditions or in accelerated tests (see for instance [1-3]); however, the works dealing with detailed degradation mechanisms and factors affecting the kinetics of the rate determining steps in these mechanisms are less common. In the existing reliability approaches, the effects of the temperature, UV radiation, voltage and humidity start to be taken into account. The effects of the chemical composition of the atmosphere and more general the chemistry of the “in use” environment, which can result from the climate, atmospheric pollution, leaching from the cell materials themselves or degradation of the encapsulating material, etc. are however usually disregarded. At the same time, many of degradation mechanisms, such as corrosion of metallic contacts, solders, and silicon, discoloration of encapsulate (EVA), degradation of semiconductors (zinc oxide, aluminum doped zinc oxide...), delamination of the encapsulate etc. could be strongly affected by these chemistry.

In this work, we will discuss the chemical aspects of the degradation mechanisms in PV materials and their assemblies. First, different exploitation environments (industrial, marine, rural) and the chemistry of the atmospheric pollutants present in them will be reviewed. Second, the effect of selected pollutants present in rural and marine atmospheres on the stability of solar cell materials will be illustrated on the example of the encapsulated and non-encapsulated thin layer Al-doped ZnO (AZO) for thin layer cells, demonstrating that damp heat test can be insufficient for evaluation of the humidity resistance of these materials in real atmospheres. Finally, some mechanistic and methodological approaches, used in the area of atmospheric corrosion in order to precise degradation mechanisms and optimize protection strategy, will be discussed in order to extend them to materials and assemblies typical for photovoltaic systems.

[1] D. C. Jordan and S. R. Kurtz, Photovoltaic Degradation Rates—an Analytical Review, *Progress in Photovoltaics Research and Applications* 21(1) 12-29

[2] M. Theelen, F. Daume, Stability of Cu(In,Ga)Se₂ solar cells: A literature review, *Solar Energy* 133 (2016) 586–627

[3] A. Virtuani, M. Caccivio, E. Annigoni, G. Friesen, D. Chianese, C. Ballif, T. Sample, 35 years of photovoltaics: Analysis of the TISO-10-kW solar plant, lessons learnt in safety and performance—*Progress in Photovoltaics Research and Applications* 2019,1–12