Measuring and modelling the generation of acetic acid in aged Ethylene-Vinyl Acetate-based encapsulants used in solar modules

Luca Gnocchi[1*], Heng-Yu Li[2], Alessandro Virtuani[1], Armelle Vallat-Michel[3], Andrew Fairbrother[1], Christophe Ballif [1, 2]

[1]École Polytechnique Fédérale de Lausanne (EPFL), Institute of Microengineering (IMT), Photovoltaics and Thin Film Electronics Laboratory, Rue de la Maladière 71b, 2000 Neuchâtel, Switzerland
[2]CSEM, PV-center, Jaquet-Droz 1, 2000 Neuchâtel, Switzerland
[3]University of Neuchâtel, Platform of Analytical Chemistry, 2000 Neuchâtel, Switzerland
*e-mail: luca.gnocchi@epfl.ch

Motivation & Goal

- The **Acetic Acid (HAc)** generated in solar modules with **Ethylene Vinyl Acetate (EVA)** as encapsulant has a negative impact. The development of long-term degradation models is of a crucial importance.
- The **experimental validation** of quantitative acid generation is an important but **difficult step**, that **requires invasive/destructive methods.**
- **We are developing a facile method** to extract HAc from modules, to validate such models.

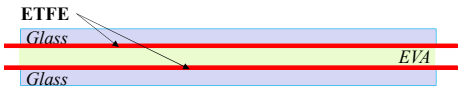
Experimental - samples

- **2 EVA formulations** are used with different Vynil Acetete (VA) content (28 and 33%).
- An **ETFE** foil (0.5mm thick) **is placed in between the glasses and the polymer (G-ETFE-G)**. Modules can be then **easily opened**.
- 1 cell (Al-BSF) **mini-modules** are tested with both EVAs using the standard **Glass-Glass (G-G)** design and the G-ETFE-G one, in order **to understand the influence of the ETFE foil**.

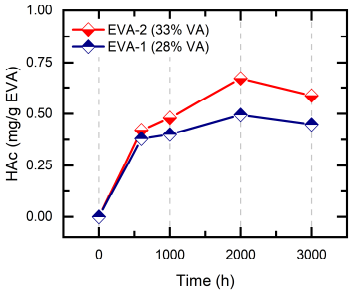
Characterization Methods

- HAc is extracted by **rinsing** the EVA surface **with de-ionized water**.
- HAc concentration is measured by means of a **Liquid Chromatographer coupled with a UV detector** (@ 210 nm).
- Modules are characterized by means of **I-V curves** , **electroluminescent images (EL)** and **visual images (VI)**.
- Aging conditions: **Damp Heat (DH)** (85ºC, 85%RH) test extended up to **3000h**.

ACETIC ACID GENENRATION

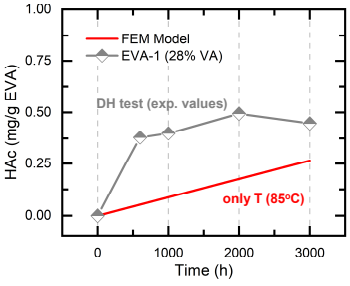


Liquid Chromatography coupled with UV



+ **HAc concentrations are comparable** with those found in literature [1,2,3].
+ Trend is consistent with that observed whit non-permeable back-sheets [1].
+ Differences in VA content can be detected.

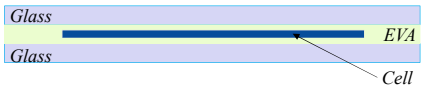
FEM Model – 1st attempt



+ Same order of magnitude w.r.t. experimental results.
− **Only thermal stresses** are taken into account (i.e. no RH).

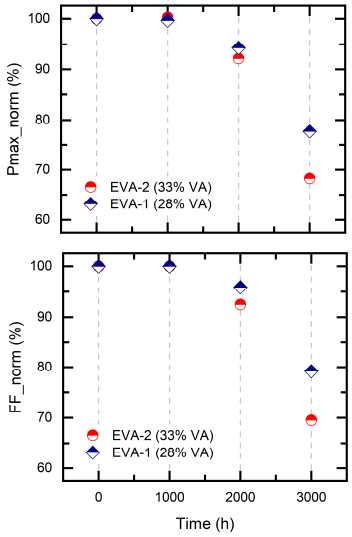
Model under development

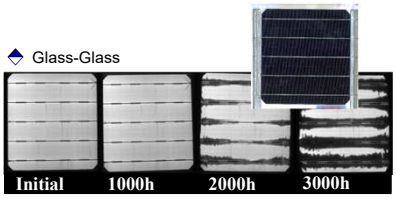
VA CONTENT INFLUENCE



Standard (28%) VS Higher (33%) VA EVA

DH 85ºC,85%RH

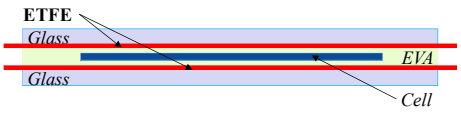




EL and VI images of a 28% VA EVA G-G

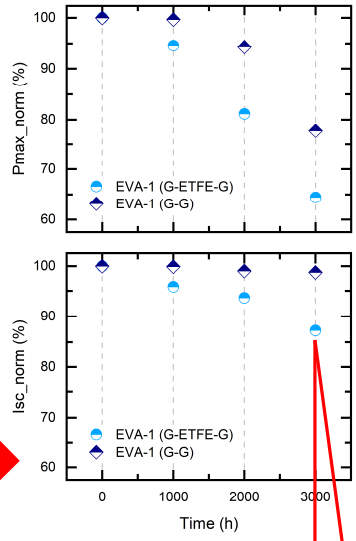
+ More VA content leads to higher degradation.
+ **LC-UV measurements are in agreement with module degradation.**

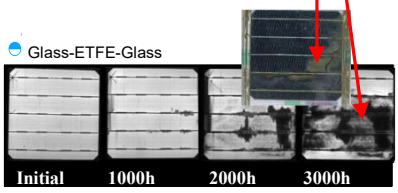
ETFE FOIL INFLUENCE



Glass – Glass VS Glass – ETFE – Glass

DH 85ºC,85%RH





EL and VI images of a 28% VA EVA G-ETFE-G

− The **ETFE foil accelerates the degradation** because of faster vapor penetration.
− Trapped water enhances the corrosion and decreases the transmittance.

Conclusions

- We are able (at this stage) to easily open-up samples and get access to the polymer foil.
- Acetic acid generation can be monitored during aging experiments by means of LC-UV.
- Mini-modules containing ETFE exhibit a faster degradation during DH test.
- The different degradation could be a limit in the use of this solution.
- Hydrolytic (and UV) stresses need to be added in the model in order to improve its accuracy.

References

[1] A. Masuda et al., 29th EU PVSEC, 2014
[2] S. Suzuki et al., Jpn. J. Appl. Phys., 2017
[3] T.J. Trout et al., 44th IEEE, 2017

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