ESR 11 – Characterization of degradation behaviour and material interactions in PV modules

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Introduction and objectives

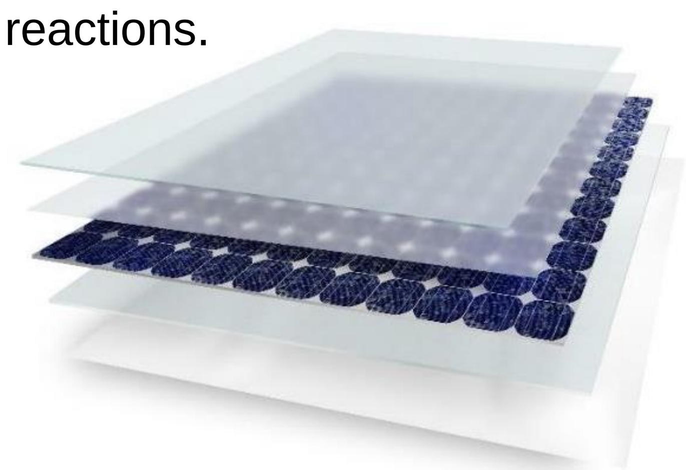
A photovoltaic (PV) module is characterized by the presence of different layers, which are typically: glazing or superstrate, encapsulant, crystalline Si wafer and backsheet.

The encapsulant, according to *Czanderna et al*. [1], must follow the following requirements:

- Provide structural support for PV cell fabrication, handling, installation and operation.
- Achieve and maintain durable optical properties (at lest 90% of the light transmission and <5% loss of transmission after 20 years).
- Provide physical insulation of solar cells and circuits from degrading environmental factors like rain, dirt pickup and salt spray.
- Achieve and maintain a reliable long-term electrical insulation of the circuit elements for safety reasons.

Nevertheless, during operation, PV modules are subject to degradation processes due to weathering conditions and UV radiations.

The degradation processes of EVA (the typical material used as encapsulant) can give rise to malfunctioning or failures. Photo-oxidative reactions produce acetic, which works as a catalyst for de-acetylation reactions and further degradations. Yellowing of EVA can also occur during aging and it is due to the interactions between encapsulants additives and products of the photo-oxidation reactions.

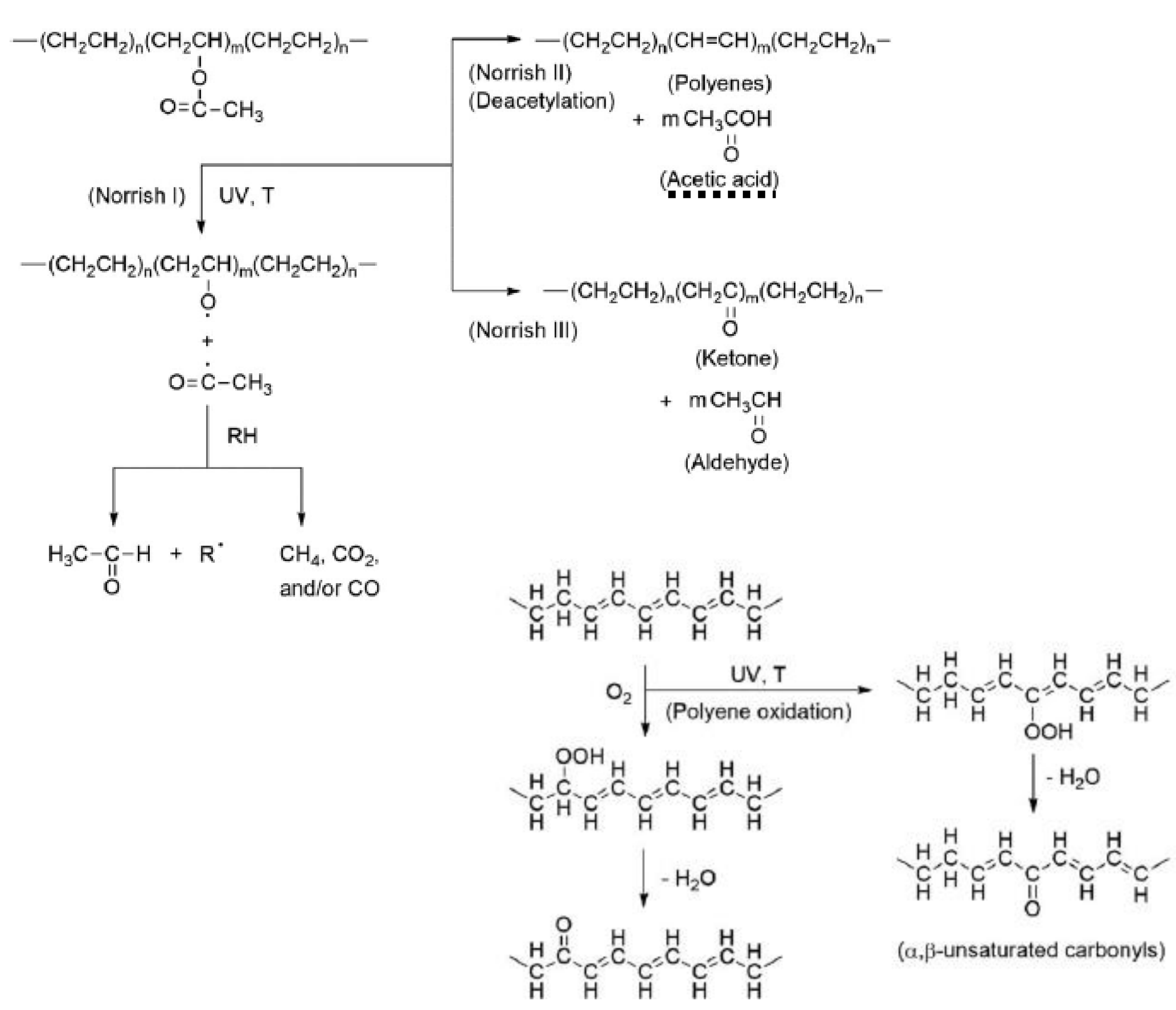


Aim of the study

➢ To obtain a full understanding of the **chemical reactions** occurring during aging, especially at interfaces, and to describe how different materials interact.

➢ To develop a correlation between **destructive** and **non-destructive methods** and to propose new characterization techniques able to provide early detection of degradation that might lead to failures.

Main degradation mechanism of EVA



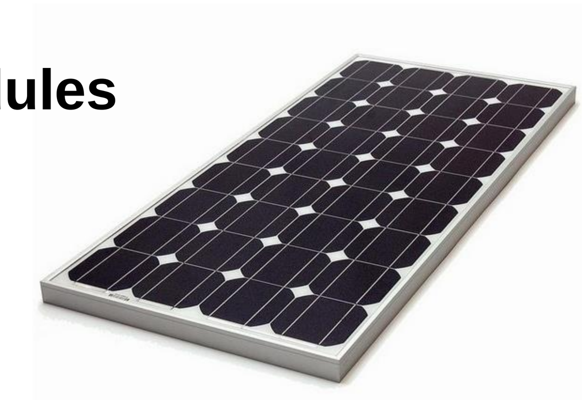
The degradation mechanism of EVA is characterized by the initial de-acetylation and the production of acetic acid and polyenes because of thermal energy and radiations, according to the Norrish II reaction.

The Norrish I reaction lead to the formation of acetaldehyde and other gases. [2]

Experimental procedure

Preparation of the specimens and conditioning

Materials ⇨ **Laminates** ⇨ **Modules**



Natural weathering

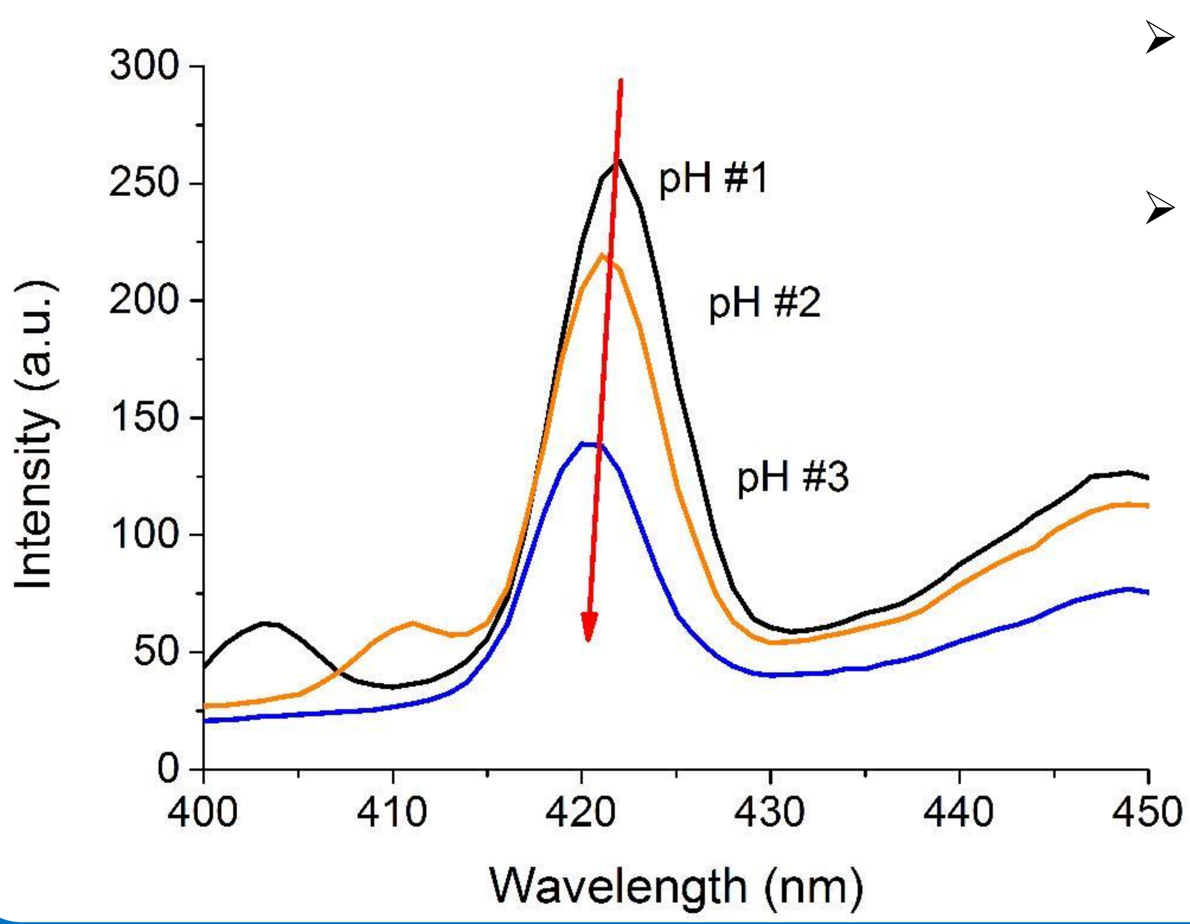
Artificial aging

In order to determine characteristics of material interactions and the exact reaction patways occurring during aging different levels will be investigated: materials, laminates and PV modules. The influence of different climatic conditions on reaction kinetics will be analysed and samples will be subjected to natural weathering and artificial aging.

Testing equipment proposed

Mechanical testing	Physical testing	Chemical methods	Microscopy and optical methods
Dynamic Mechanical Analyser	UV/Vis/NIR Spectrometer	Size Exclusion Chromatography	***Scanning Electron Microscope - EDX***
Nanoindenter	IR Spectrometer	Temperature Rising Elution Fractionation	***Raman Microscope***
Rotational Rheometer	***Fluorescence Spectrometer***	Liquid Chromatography-Mass Spectroscopy System	***Colorimeter***
	Photo-Differential Scanning Calorimeter	Gas Chromatography Mass Spectroscopy	
	Thermogravimetric Analysis		
	Electron Spin Resonance Spectrometer		

Acetic acid detection through pH variations



➢ Using a pH sensor within the PV module

➢ Using a fluorescent dye, whose emission peak intensity changes depending on pH values

Conclusions

This research will advance the state of the art in understanding PV module degradation and material interactions by developing and optimizing new characterization and assessment methods.

Different material will be tested, under different aging conditions ant type and rate of degradation will be determined carrying out tests on single materials, laminates and the whole PV modules.

References

[1] Czanderna, A.W., Pern, F.J, Encapsulation of PV modules using ethylene vinyl acetate copolymer as a pottant: A critical review, Solar Energy Materials and Solar Cells, Vol. 43, Issue 2, 1996, pp. 101-181

[2] Griffini, G., Turri, S., Polymeric materials for long-term durability of photovoltaic systems, Journal of Applied Polymer Science, vol. 133, Issue 11, 2016, Article number 43080

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