# Additive analysis in encapsulant materials and correlation to encapsulant degradation modes

C. Barretta[1], G. Oreski[1], K. Resch-Fauster[2]

[1] Polymer Competence Center Leoben GmbH (PCCL), Roseggerstraße 12, 8700 Leoben, Austria – chiara.barretta@pccl.at
[2] University of Leoben, Department of Material Science and Testing of Polymers, 8700 Leoben, Austria

## INTRODUCTION AND OBJECTIVES

- The "**recipe**" of additives used strongly depend on polymer **application** and it becomes crucial when the polymer is meant to be used **outdoor** due to the effect of **UV radiation**, **temperature** and **humidity**.
- **Stabilizers** used in encapsulant materials for PV applications **improve polymer lifetime**.
- **Unfavourable combinations** as well as unfavourable reactions with the polymer itself or its degradation products might lead to **further degradation processes**.

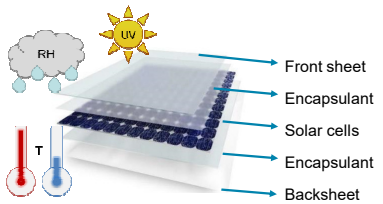


*Fig. 1 – Schematic of a PV module*

- The **aim** of this work is:
  - to analyse the **additive composition** of encapsulant materials,
  - to correlate changes in additive composition to **changes** in **material properties**,
  - to identify suitable **characterization methods** able to describe the processes.

## EXPERIMENTAL

| Materials | Accelerated ageing tests | Properties of interest → Characterization methods |
|---|---|---|
| 1) EVA<br>2) TPO<br>***Laminated, not encapsulated*** | 1) Damp Heat (85 °C, 85% R.H.) – 3300 hours<br>2) UV (@ 340 nm, ISO 4892-3 Cycle 1) – 1000 hours | **Additives composition** → Thermal Desorption GC-MS<br>**Thermal properties** → Differential Scanning Calorimetry, Thermogravimetric Analysis<br>**Optical properties** → UV-Visible-Near Infrared spectroscopy<br>**Chemical properties at the surface** → FT-IR spectroscopy in ATR mode |

## RESULTS

### Thermal Desorption GC-MS – Additive analysis

| | Additive | 0 hours | DH 3300 hours | UV 1000 hours |
|---|---|---|---|---|
| TPO | UV absorber (Benzotriazol) | | ✓ | |
| | Antioxidant (Irganox) | ✓ | (✓) | |

- One antioxidant is detected for unaged **TPO**.
- After DH ageing, a **fragment** of the above mention antioxidant is detectable and an **additional UV absorber**.
- **Stabilizers** are **no longer detectable** after UV test.

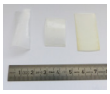

*Fig. 2 – TPO samples: unaged (left), DH (middle), UV (right)*

**Molar Mass reduction** ← **Chemical Ageing** → **Formation of Functional Groups**

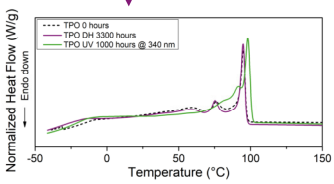


*Fig. 3 a – Cooling step of DSC measurements - TPO*

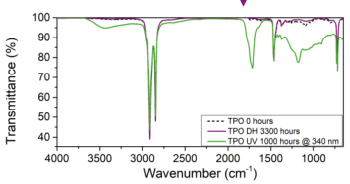


*Fig. 3 b – FT-IR ATR spectroscopy measurements - TPO*

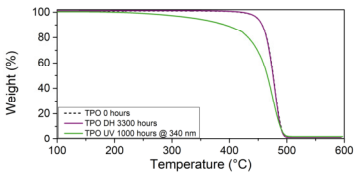


*Fig. 3 c – TGA - TPO*

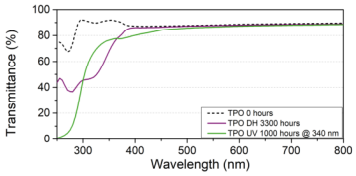


*Fig 3 d – UV-Vis-NIR spectroscopy measurements - TPO*

| | Additive | 0 hours | DH 3300 hours | UV 1000 hours |
|---|---|---|---|---|
| EVA | Antioxidant (BHT) | ✓ | ✓ | ✓ |
| | UV absorber (Octabenzone) | ✓ | ✓ | ✓ |
| | UV absorber (Benzotriazol) | | ✓ | |

- **Stabilizers** present in **EVA** before ageing are **still detectable after ageing**.
- An additional UV absorber is detectable after DH test. The additional UV absorber (also for TPO) is maybe detectable because of more free volume after ageing and easier desorption.

**No relevant signs of degradation detectable**

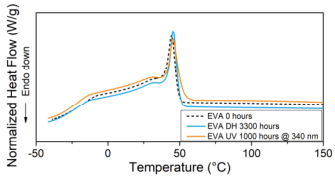


*Fig. 4 a – Cooling step of DSC measurements - EVA*

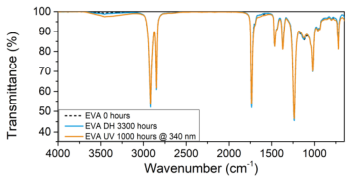


*Fig. 4 b – FT-IR ATR spectroscopy measurements - EVA*

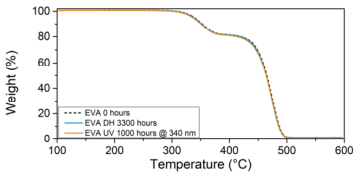


*Fig. 4 c – TGA - EVA*

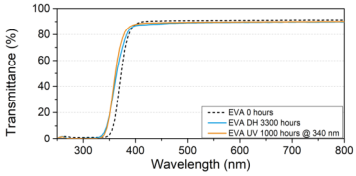


*Fig. 4 d – UV-Vis-NIR Spectroscopy measurements - EVA*

### Discussion

- Cooling step of **DSC** measurements shows a shift of crystallization temperature indicating **changes** in **molar mass** [1]. Same differences can be seen in the second heating (now shown) meaning **irreversible changes** in **TPO** after **UV test**.
- Thermograms from **TGA** show a significant reduction of the onset of decomposition process after UV test, indicating **reduction** in **thermal stability** of **TPO**.
- Relevant **chemical changes** can be seen for **TPO** from **FT-IR ATR spectroscopy**. measurements. Peaks at 1715 and 1175 $cm^{-1}$ are detectable (C=O stretch due to ketones formation).
- **Strong yellowing** can be seen for **TPO** from **UV-Vis-NIR spectroscopy** measurements. A reduction in transmittance occurs in the blue region (450-485 nm).
- **No relevant changes** are detectable for **EVA**.

## CONCLUSIONS

- **TD GC-MS** measurements are used to determine **qualitatively additive composition** of encapsulant materials before and after ageing. Higher number of stabilizers have been detected in EVA with respect to TPO. When **additives** are **no longer detectable**, **strong** signs of **degradation** can be observed.
- **No relevant differences** are detectable after the two different ageing tests for **EVA** encapsulant.
- More **relevant damages** are detectable for **TPO** after **UV test**. Stabilizers are no longer detectable and it correlates well to significant worsening of thermal and optical properties as well as chemical changes at the surface.
- **Characterization methods** described above give a good overview of the processes taking place at molecular level due to different accelerated ageing conditions.

[1] M. Knausz *et al.*, "Degradation of photovoltaic backsheets: Comparison of the aging induced changes on module and component level," (en), *J. Appl. Polym. Sci.*, vol. 132, no. 42093, pp. 1–8, 2015.

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