EFFECT OF ENCAPSULANT STORAGE CONDITIONS ON THE LONG-TERM PHOTO-INDUCED DEGRADATION OF EVA IN DOUBLE-GLASS SOLAR PV MODULES.

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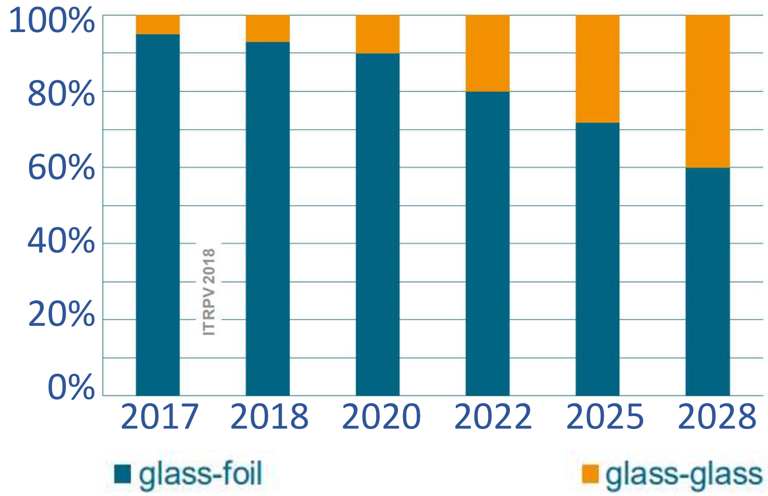
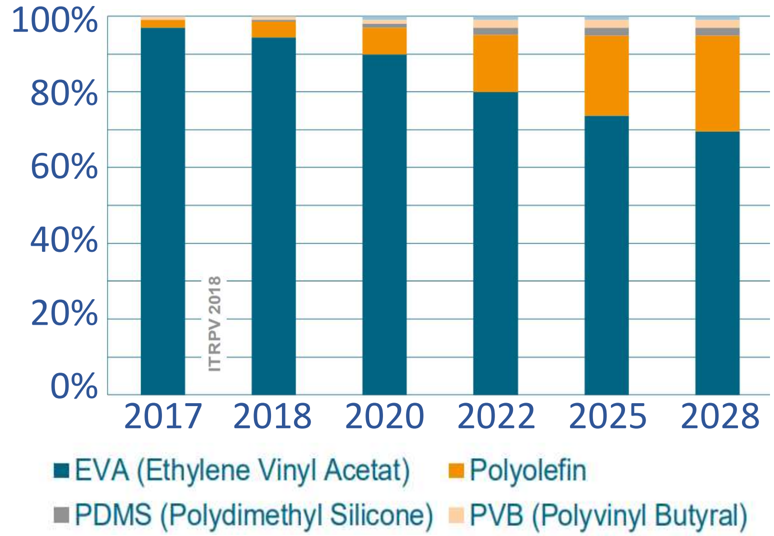
INTRODUCTION

Module layout: double glass configuration [1]



- Possibility to realize **bi-facial PV modules**;
- More **mechanical stability**;
- Improved physical and electrical **insulation**;
- **30 years** performance warranty **[2,3]**.

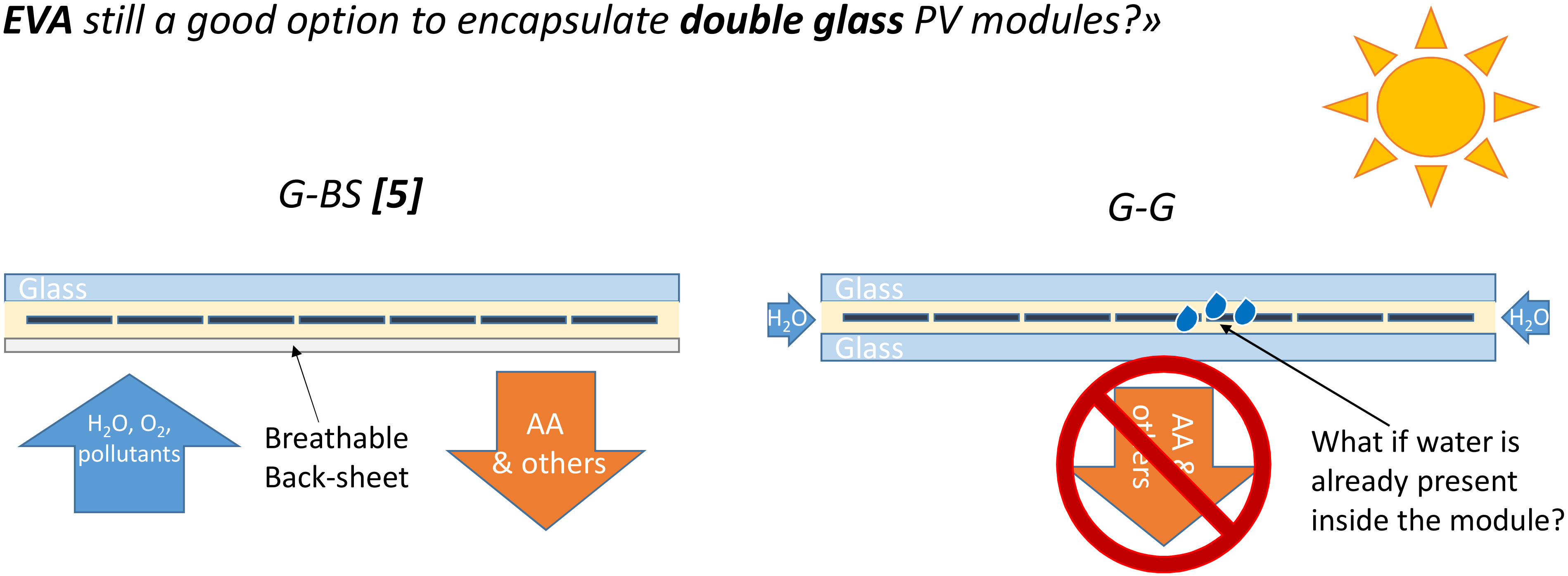
Encapsulant: polymer choice [1]



- Development of alternative **polyolefines [4]**;
- **EVA** will still remain the **dominant encapsulant** (for a while).

APPROACH AND OBJECTIVES

*«Is **EVA** still a good option to encapsulate **double glass** PV modules?»*



OVERALL OBJECTIVE:

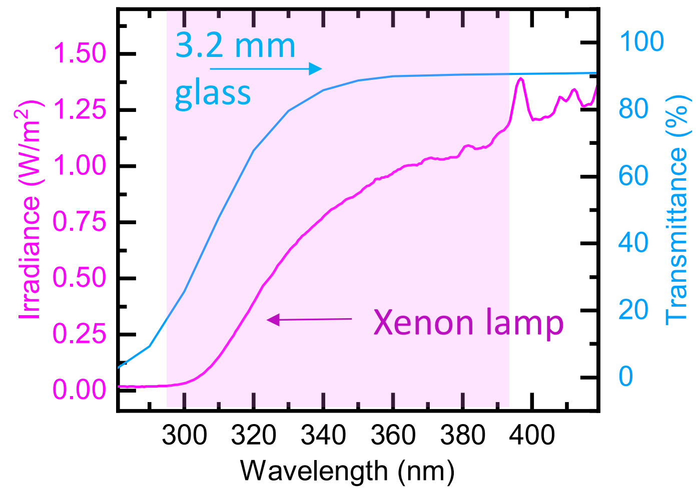
Investigation of the **effects of storage conditions** on the long-term degradation of G-G modules.

EXPERIMENTAL 1/2

- **EVA** with **high UV transmission** was used due to its **better stability under long-term UV exposure [6]**;

- EVA roll was subjected to 3 different **storage** conditions **before lamination**:

Relative Humidity [%]	Temperature [°C]	Time [days]	ID code
30	20	5	EVA-30
65	30	5	EVA-65
100	20	5	EVA-100



- Aging conditions: IEC 62788-7-2, **3000 h**:
  - Chamber air temperature: 65°C;
  - Relative humidity: 20%.

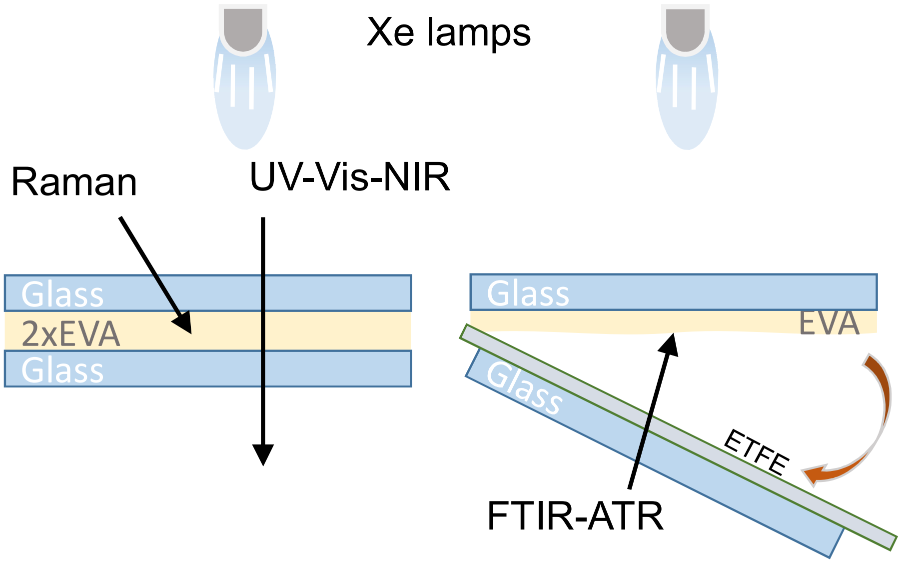
≅ 2.5 years outdoor exposure in central Europe/ temperate climate

UV dose at the back of the front glass = 55W/m^2 → **165 kWh/m2 (@ 3000h)**

EXPERIMENTAL 2/2

- Samples design:

- G-G 1 cell (PERC) mini-modules;
- G - 2xEVA - G;
- G - 1xEVA – ETFE – G;



- Characterization techniques:

1 cell mini-modules	G-2xEVA-G	G-1xEVA-ETFE-G
IV, visual inspection, EL, flourescence	UV-Vis-NIR, and Raman spectr.	FTIR-ATR spectr.

Results: MODULE INSPECTION 1/3

AFTER LAMINATION
NOT AGED

An **increase in the RH** during storage brings to **bubbles formation** along the edges of the module already **after lamination**.

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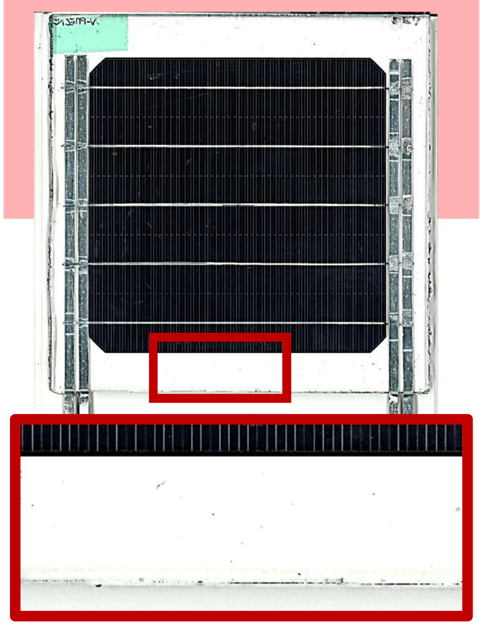
Results: MODULE INSPECTION 2/3

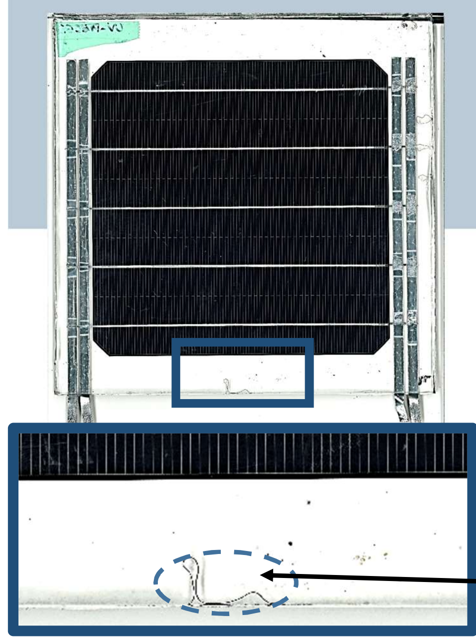
UV dose: 13.8 → 165 kWh/m²

EVA-30



No visible defects on EVA-30.

EVA-65



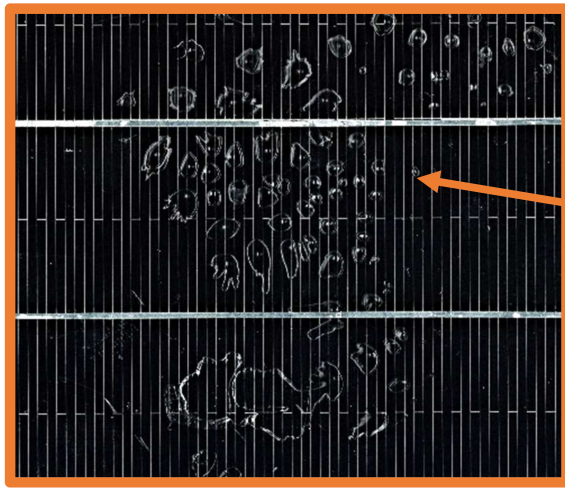
Bubbles were gattered and degassed from EVA-65.

EVA-100

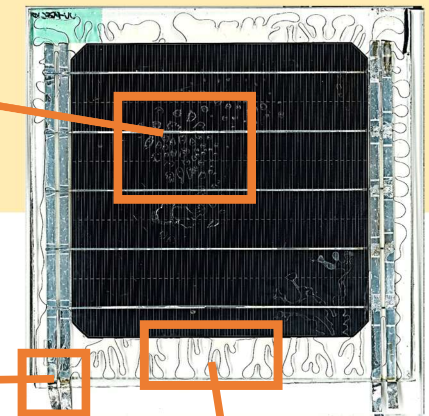
Results: MODULE INSPECTION 3/3

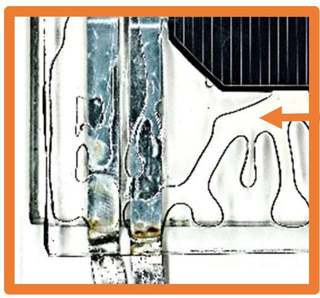
UV dose: 13.8 → 165 kWh/m²

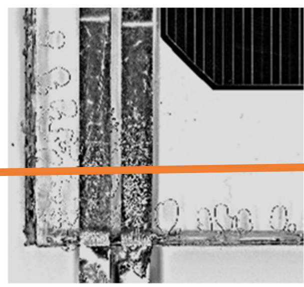
Bubbles formed also in the center of the module.



EVA-100



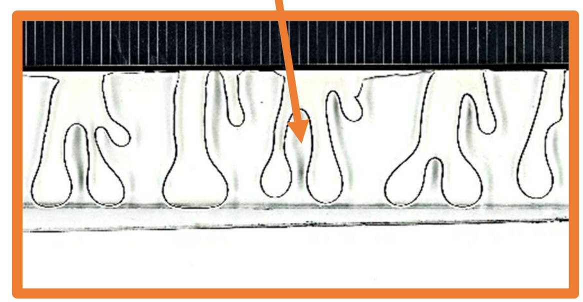




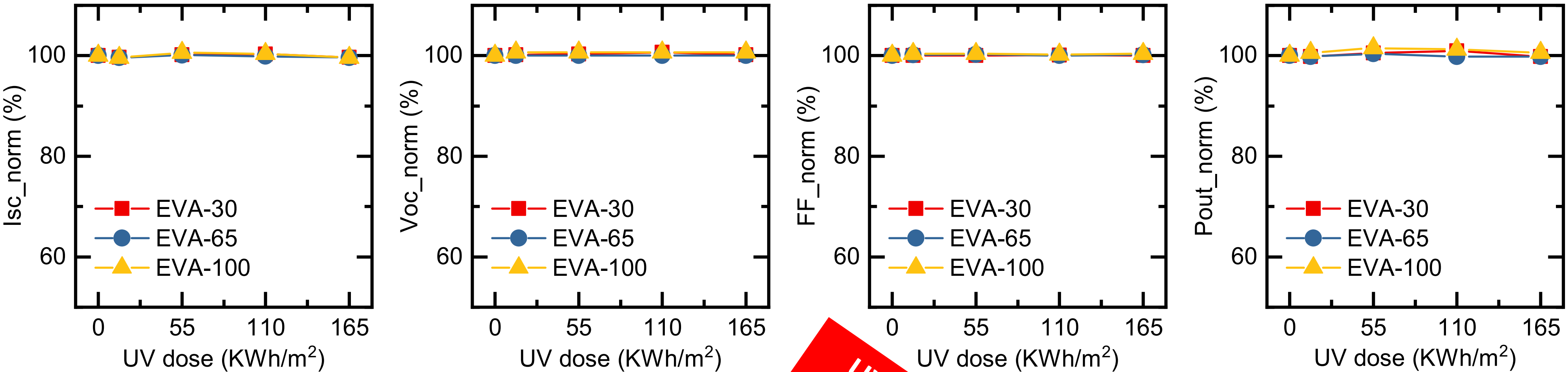
For comparison.
EVA-100 after lamination

Glass displacement → low adhesion.
Corrosion on exposed ribbons.

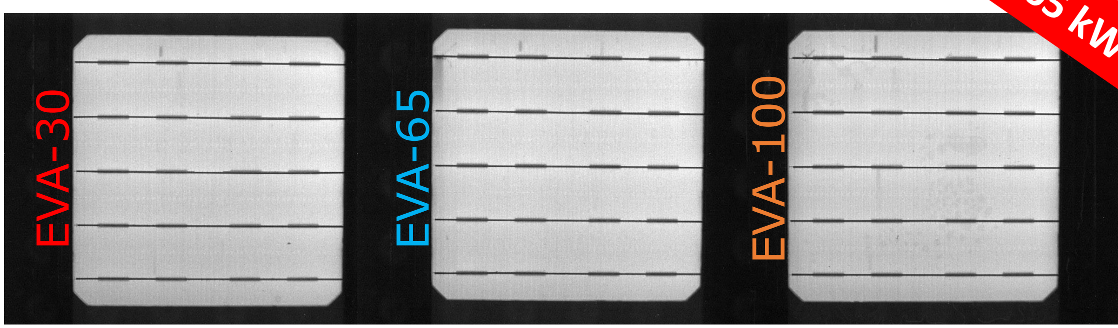
Complete delamination at the edges.



Results: MODULE PERFORMANCE



UV dose: 165 kWh/m²



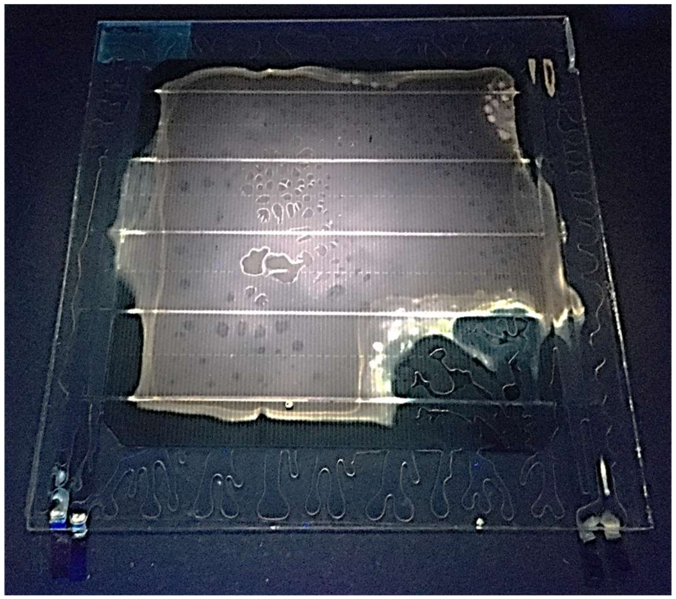
EL images of laminated cells from 3 different storage condition after UV aging.

Up to a UV dose of 165kWh/m2, mini modules' perfomance is stable.

FROM MODULE TO MATERIAL DEGRADATION

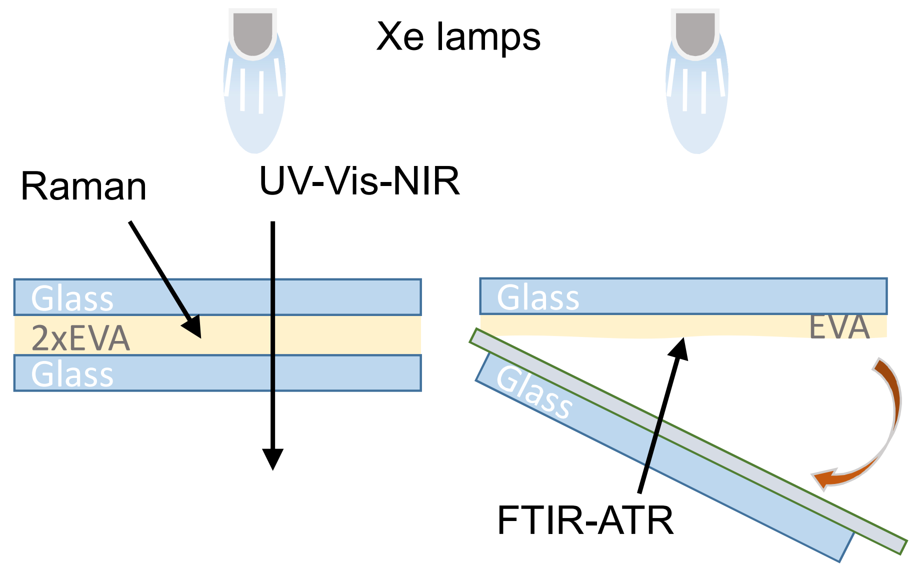
However….

…Encapsulant degradation takes time to *translate* into module degradation.



1 cell mini-modules encapsulated with EVA-100, after UV aging, under a UV fluorescent lamp.

Sample geometries used to study EVA degradation:



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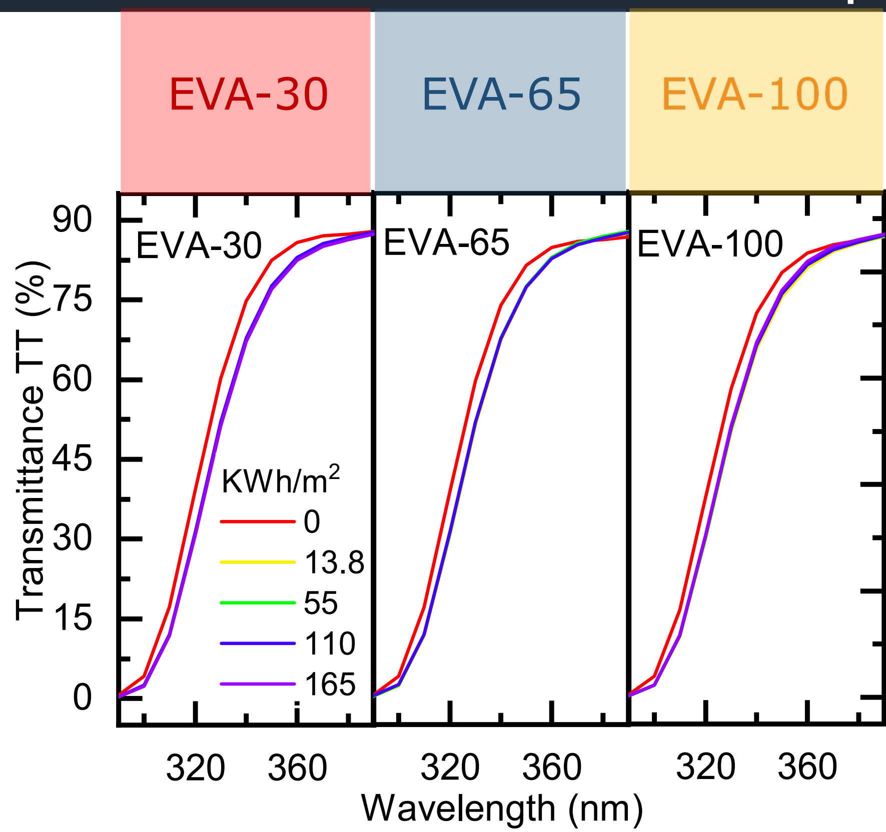
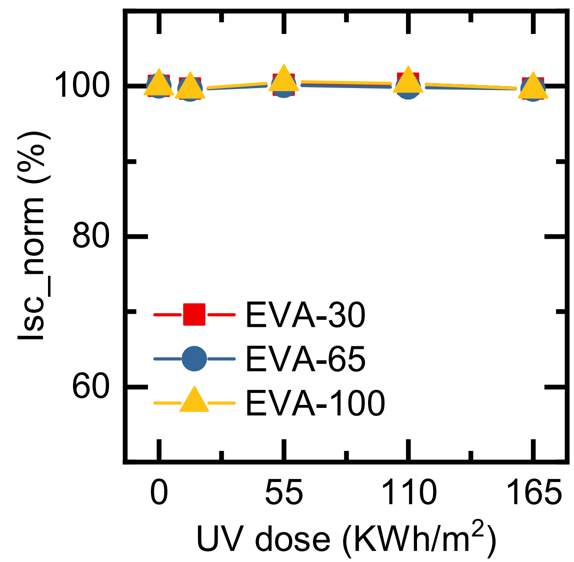
EVA STUDY – UV-Vis-NIR spectrospcopy





Transmittance of glass/EVA/glass samples **is not affected (yet)** by the storage condition.

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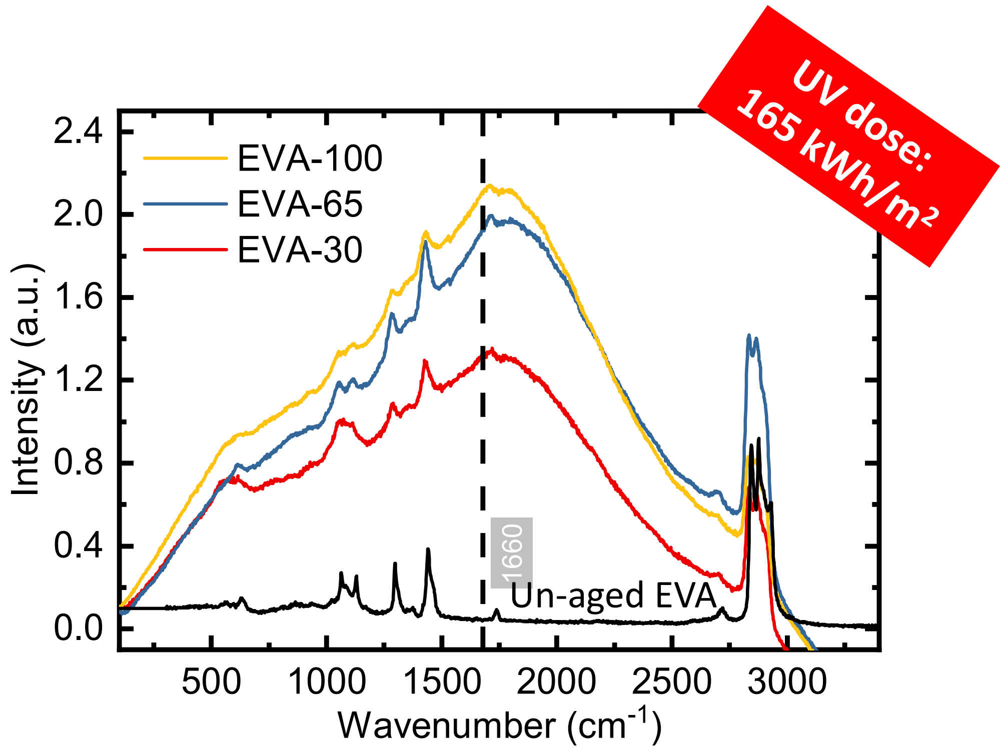
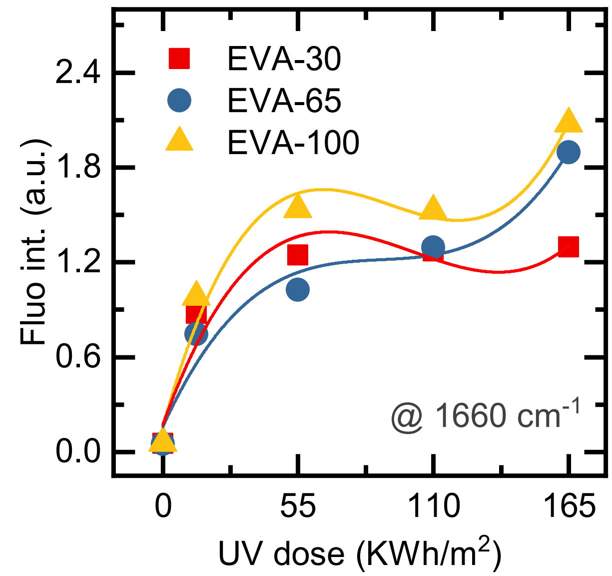
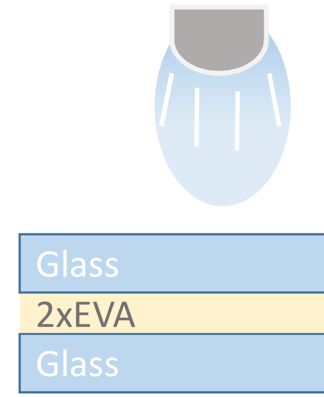
EVA STUDY – Raman spectroscopy

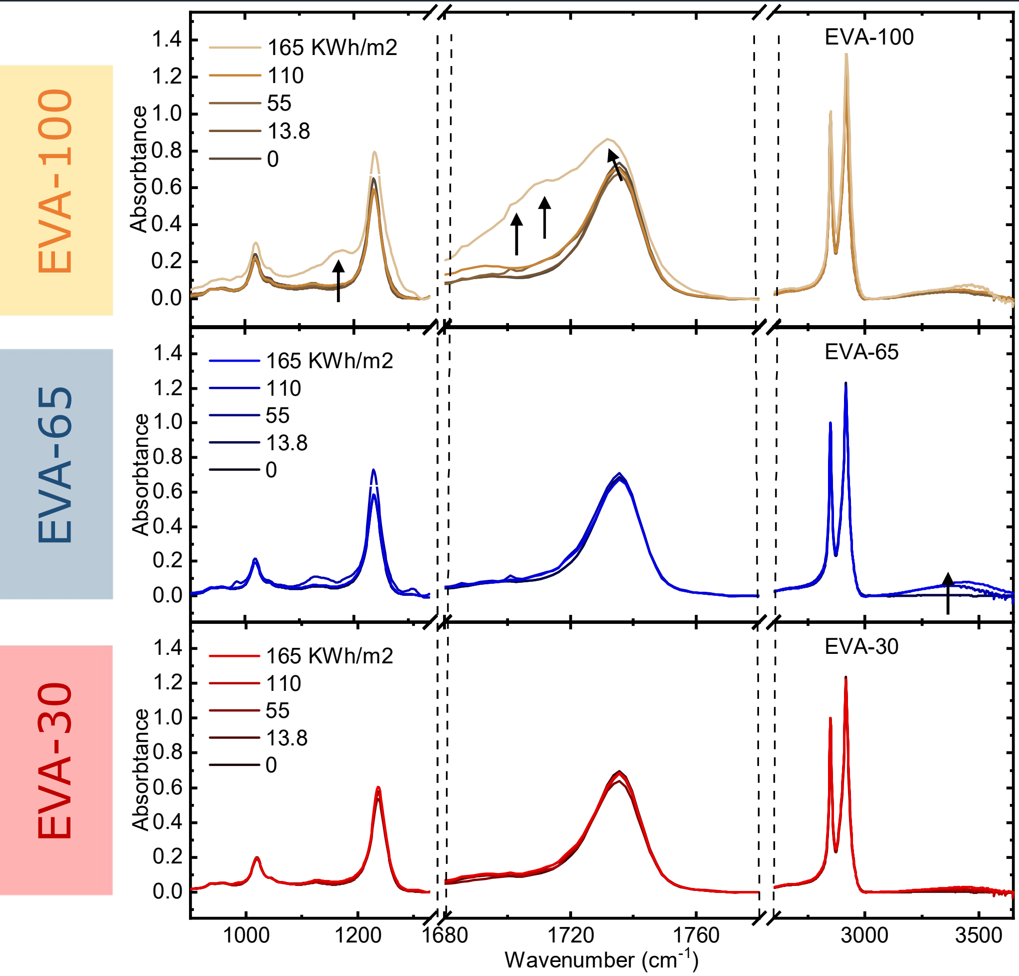






Fluorescence shows the **same trend** regardless the storage condition up to 110 kWh/m^2;
Changes in functional group peak intensity (qualitative observation).

EVA STUDY – FTIR_ATR mode



- Properly stored **EVA-30 shows no sign of degradation**;
- The **bad stored EVA show signs of chemical degradation** after 165 kWh/m²:
  - **EVA-65** has a slight increase in **hydroxyl group** (3100-3500 cm⁻¹);
  - **EVA-100**, had **hydroxyl gropus** (3100-3500 cm⁻¹) already **after lamination**. At UV dose of 165 kWh/m² formation of **saturated and unsaturated acid and ketone** groups (1715–1680 cm⁻¹) and **alyphatic esters C-O-C** (1160 cm⁻¹) **[7]**.

CONCLUSIONS

Effects of the storage conditions on the long-term degradation of G-G modules encapsulated with EVA.

- We investigate 3 different storage conditions;
- A **high UV tranmittance EVA** was used;

Some preliminary results **after 165 kWh/m2 of UV exposure** (~2-2.5 years of operation in a temperate climate):

1. No impact on the performance of aged-mini-modules, yet;
2. Preliminary signs of chemical aging for the bad-stored EVA (hydroxil groups, etc.)

*«Is **EVA** still a good option to encapsulate **double glass** PV modules?» - No answer yet.*
EVA storage conditions may have an impact on the long-term performance of modules.

The work is on-going: we will continue the exposure of samples to UV…

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