Accelerate Product Development for PV in Alpine Installations

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Identification of alpine stressors and typical failures

First accelerated ageing tests

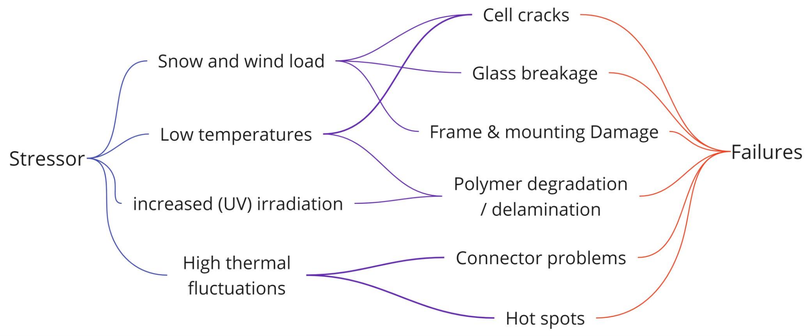
Material test at low temperature

Development of alpine module design

Test matrix for alpine climate

Motivation

Interest in alpine photovoltaic (PV) systems is growing in alpine countries, where large-scale alpine PV systems are planned. This requires the development of PV modules that can withstand the increased loads and extreme weather conditions characteristic of this harsh climate. To ensure the high reliability and sustainability of these systems, an innovative test strategy is being developed within the **PVDetect project**. The overall goal is to accelerate product development for Alpine PV. This strategy builds on the analyses of typical stressors and observed failure modes in existing alpine systems [1]. Highly accelerated aging tests have been developed to simulate/replicate the stressors of alpine conditions as closely as possible.



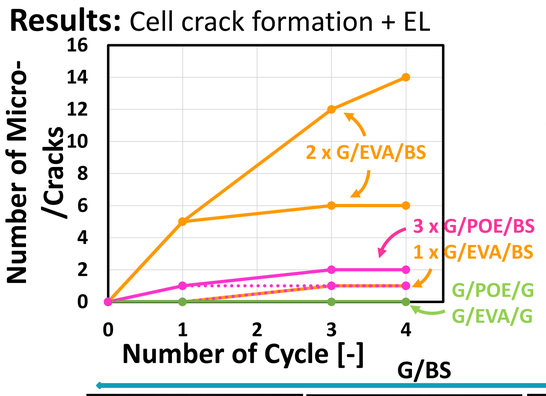
[2]

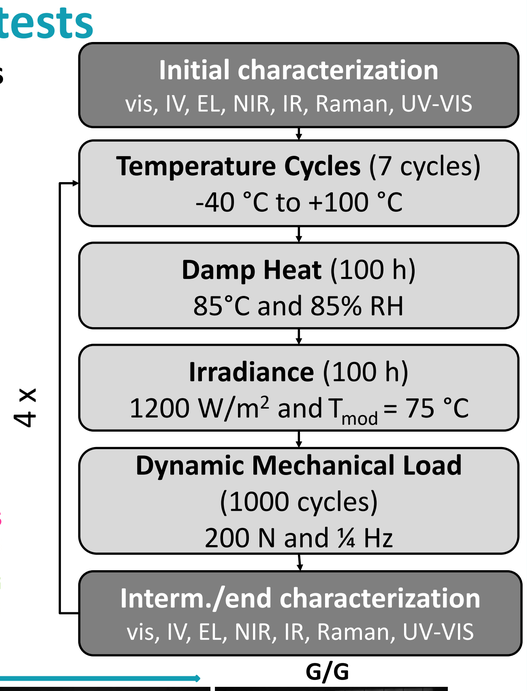
First accelerated ageing tests

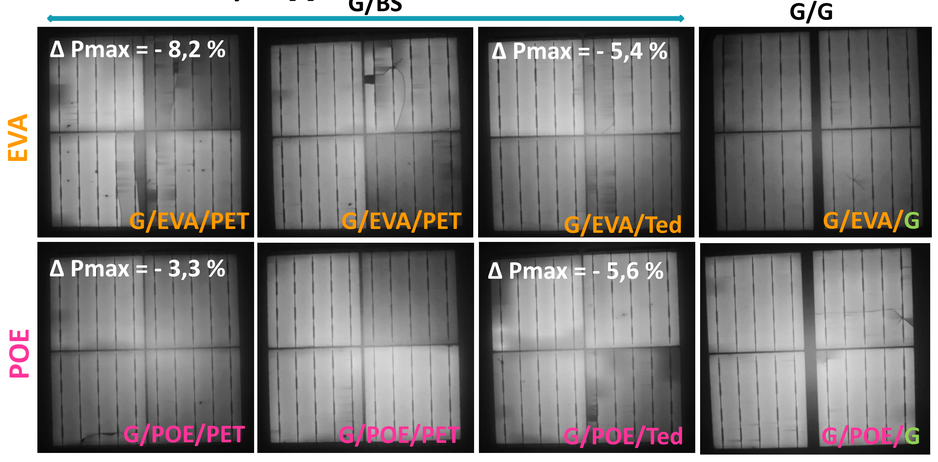
Aim: Screening of ageing-parameters and characterization methods

- Reproducing typical alpine failures
- **Test modules**: 4-cell (PERC)
  - Encapsulants: EVA, POE
  - Backsides: PET, Tedlar, Glass

Results: Cell crack formation + EL





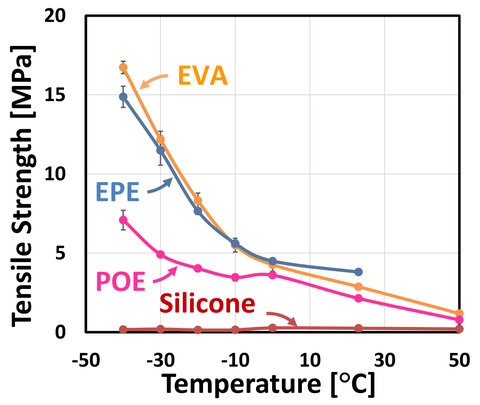


Outcome: Probability of cell damage on G/EVA/BS modules is larger than on other modules; using POE decreases the probability of cell crack and finger damages

Material tests at low temperature

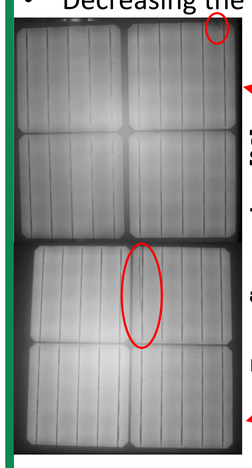
Aim: Material selection for alpine modules considering low temperature behavior of polymers

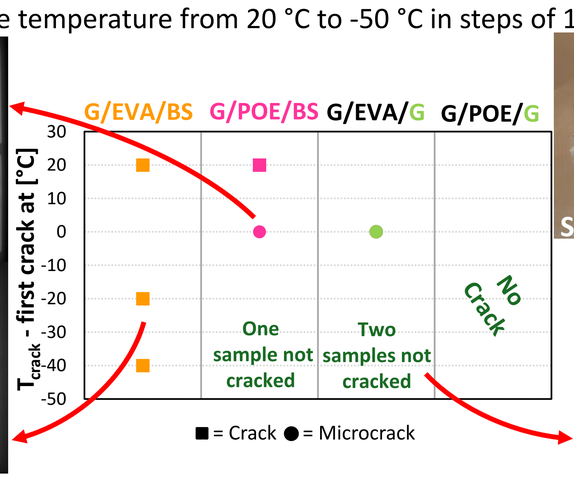
- Encapsulants can play a critical role in the mechanical behavior of a module
- Glass transition measured with DSC:
  - EVA: -30 °C
  - POE: -50 °C
  - Silicone: -122 °C
  - EPE: -30 and -51 °C
- Tensile strength measurements:
  → Encapsulants show different behavior at temperatures below zero
  → Elasticity is reduced, which can impact mechanical behavior



➡Static Mechanical load at different temperatures (20 °C → -50 °C)

- 3-point test with 5400 Pa for 1 hour at each step
- Decreasing the temperature from 20 °C to -50 °C in steps of 10 °C





Outcome: Highest probability of cracking with G/EVA/BS → POE is preferred encapsulant; G/G modules have less deflection than G/B and therefore a lower probability of cracking.

Development of alpine module design

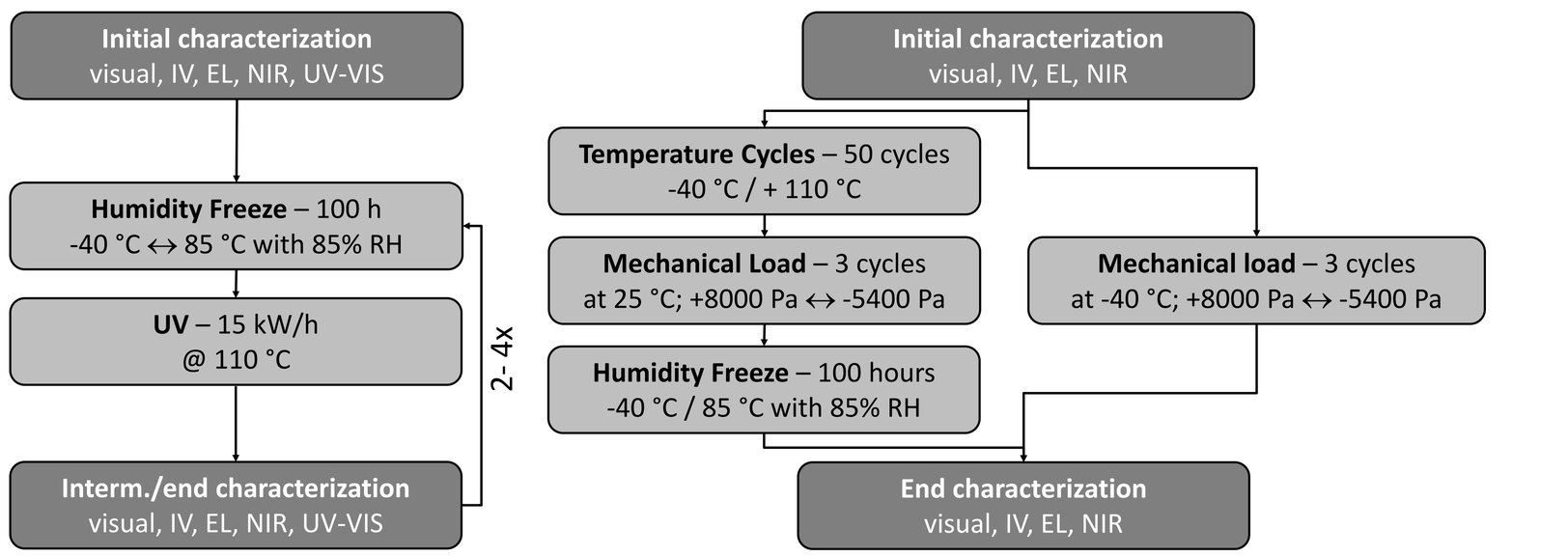
Alpine modules require high mechanical stability. The tests showed the **best module structure** to be a **G/POE/G** laminate. Next, different module sizes & module designs are tested: **glass thicknesses: 2x4 mm, 2x3 mm, 2x2 mm, (4 mm G + backsheet as reference) ↔ Frame and Frameless**

Alpine test matrix

UV test sequence
Higher UV load

Mechanical load test sequence
Mechanical stresses like snow, wind etc. @ low temperature

High thermomechanical stress
Higher diurnal T- change and fast T- excursion



Summary and Outlook

- Accelerated ageing and material tests were conducted to reproduce **typical failures** of PV in the **alpine environments**
- EL images of the test samples showed formation of **cell cracks**, especially in the **G/EVA/BS** design
- Material tests indicated **higher elasticity** of silicone and POE encapsulants at **low temperatures**
- Mini-modules with **POE** had a **lower probability of cracking** after static load application at low temperatures
- **G/G** is the preferred **structure,** and **POE** is the preferred **encapsulant for alpine conditions**
- Design of **Alpine-specific test matrices** to evaluate PV modules focus on the effects of **glass thickness**, **backside** and **frame**

Reference: [1]: Increased reliability for PV in alpine environment; Anika Gassner, Gabriele C. Eder, Ebrar Özkalay, Gabi Friesen, Markus Feichtner, Markus Babin, Friedrich Bleicher; Poster at EU PVSEC 2023; [2] Mind-map modified from PVPS Task 13 report

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