

- 1** UV chamber with sample.
- 2A** Module with delamination and browning after combined UV-damp-heat-test.
- 2B** Same PV module type after UV test without humidity showing snail tracks.

UV TESTING AND QUALIFICATION OF PV MODULES AND MATERIALS

PV power plants have become a competitive option for electricity generation in many regions with high solar irradiation levels like the sun belt region. For reliable operation in challenging climates with elevated UV doses, PV modules have to be engineered and qualified carefully. UV irradiation is well known to be a crucial degradation factor, strongly depending on the radiation spectrum.

Fraunhofer ISE has investigated natural UV spectra at different locations, lamp spectra and associated aging effects in detail. To simulate various climatic conditions, we have developed UV chambers that are able to simultaneously expose samples to different temperatures, levels of humidity and UV spectra. Especially the combination of UV with other degradation factors delivers valuable results (Fig. 2A and 2B).

Our test services support module and material manufacturers in developing and qualifying their products, also helping investors to assess risks associated with degradation and service life.

Environmental Analysis

Based on our experience in outdoor exposure, we design accelerated tests to simulate real climatic conditions. We operate outdoor test sites at four different climates:

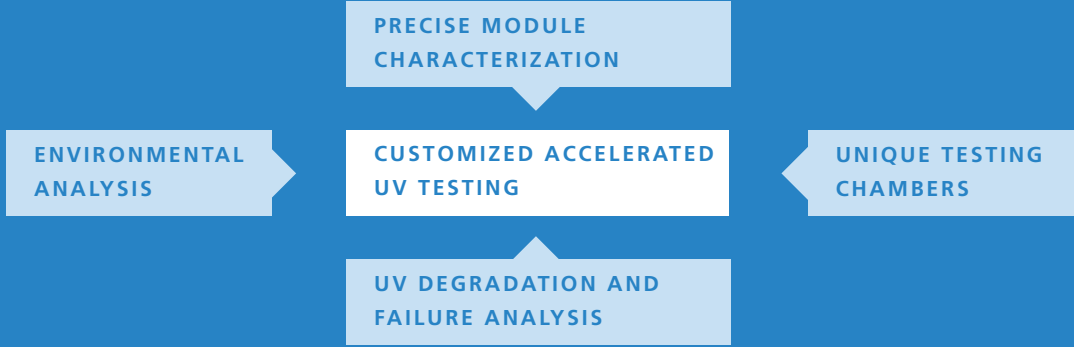
- moderate climate
Central European reference location with moderate temperature, humidity, UV irradiation, moderate snow and wind loads
- alpine climate
Location with a cold alpine climate, wide temperature fluctuations and high UV radiation as well as high snow and wind loads

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■ hot arid climate

Desert climate with elevated operating temperatures, extreme temperature fluctuations and high levels of global and UV irradiation

■ maritime climate

Maritime climate with elevated temperatures, high global irradiation levels and a saline atmosphere to study the corrosion resistance of modules and components

Through comprehensive environmental analysis we are able to quantify the climatic factors that play a crucial role in aging processes and to examine their effects.

The UV irradiation in the UV-A and UV-B range is, amongst others, measured at these test sites. Furthermore the spectral distribution of the global irradiance is monitored. We use this data to design appropriate UV tests for different regions.

Customized Accelerated UV Testing and Environmental Simulation

Within the scope of module certification according to IEC, UV tests are only performed as preconditioning using 15 kWh/m². As this UV dose only corresponds to a few months of exposure in Germany, it is not an appropriate stress level to simulate UV impact during the lifetime of modules in areas with high UV irradiation. For this reason we offer enhanced UV tests that cover specific irradiation doses. Our tests can combine

UV with other degradation factors (e. g. high temperature, humidity), reproducing the most important parameters of a specific climate simultaneously.

Precise Module Characterization

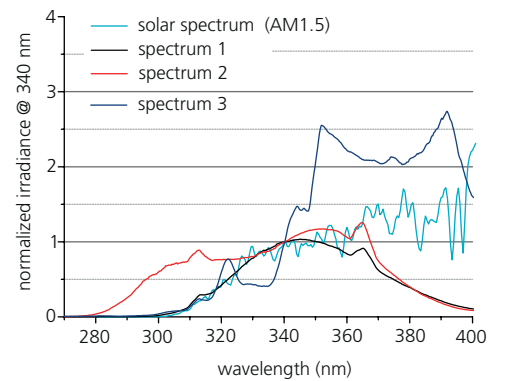
We characterize the test modules in our CalLab PV Modules, one of the world's leading flasher labs. With a measurement uncertainty down to 1.8 % and highest reproducibility, performance losses due to UV induced degradation in the lab and in the field can be assessed precisely. The characterization includes energy rating at elevated temperatures and weak light conditions.

In-Depth UV Degradation and Failure Analysis

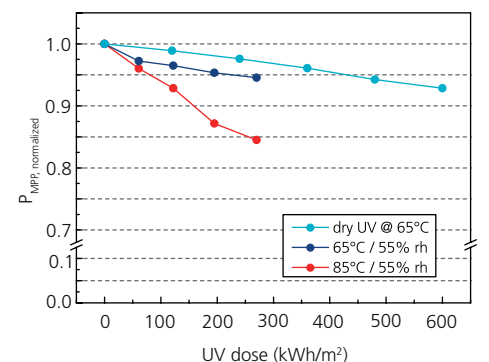
Some UV-induced degradation processes are observable by means of a professional visual inspection and electric module characterization, others require comprehensive analytics for early detection and quantitative progress monitoring. We developed non-destructive characterization methods that reveal detailed information. Customers benefit from our unique analytic equipment, partially developed in-house:

- high-resolution electroluminescence camera
- microscopes (visible light, AFM, Raman)
- spectrometers (AES, FT-IR)
- high sensitivity permeation testing
- surface energy analysis
- dynamic mechanical analysis

3 UV qualification scheme.



4 Three simulated UV spectra used at Fraunhofer ISE for accelerated aging, in comparison to the solar spectrum.



5 Power degradation of one module type during a UV test at three different climate conditions.