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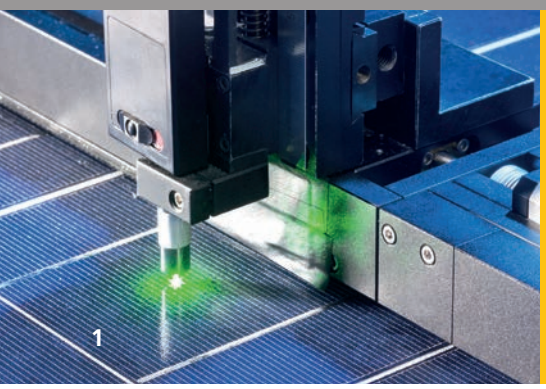
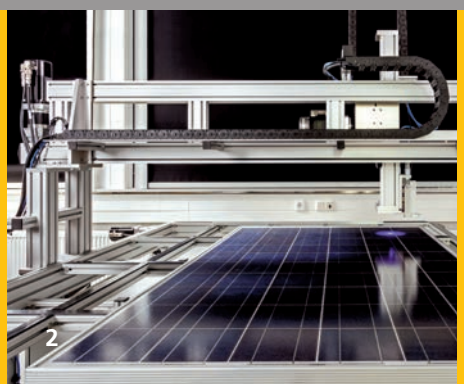
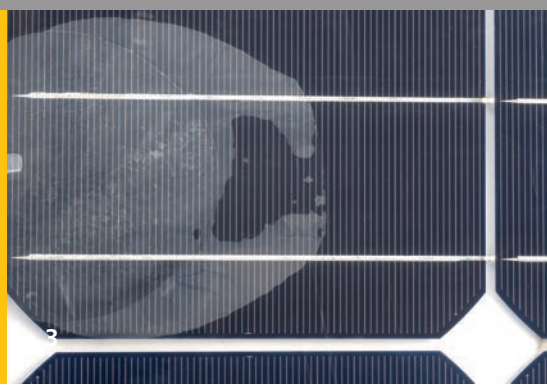
ISE

FRAUNHOFER INSTITUTE FOR SOLAR ENERGY SYSTEMS ISE







1 *Raman spectroscopic analysis of the encapsulating material in a c-Si PV module after extensive outdoor weathering.*
2 *Analytical examination platform for PV modules.*
3 *PV module showing a delamination after accelerated aging test.*

DEGRADATION MONITORING AND FAILURE ANALYSIS FOR PV MODULES

The principle factors affecting the reliability and performance of photovoltaic (PV) modules are the materials used and their interaction, module manufacturing and the local climate at the operating site. At Fraunhofer ISE we employ high resolution analytical methods to assess degradation indicators and mechanisms. These methods serve as powerful tools which complement the IV measurements; together they enable comprehensive service life analysis and predictions of PV modules.

By using various non-destructive procedures, we can repeatedly characterize the module components to monitor aging and degradation processes, at the same position at different times.

We are dedicated to meeting customer requests and offer, among others, the following services:

- investigations on the root cause of solar cell metallization corrosion, such as snail tracks
- development and implementation of Potential Induced Degradation (PID) tests at module and component level
- investigations on pathways of humidity into the PV module, especially for thin-film and organic PV
- determination of the reliability of PV modules in challenging climates displaying e.g. high UV exposure, elevated temperatures or corrosive salt air.

Precise Degradation Monitoring

Degradation is often caused by a whole chain of processes which can be detected as power loss, safety hazard or visible flaw only at a late stage.

We carry out high resolution analyses to detect the early stages of degradation, thereby reducing testing and exposure

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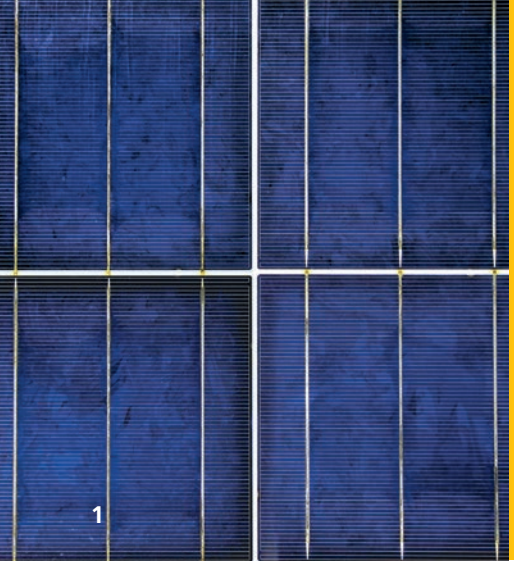

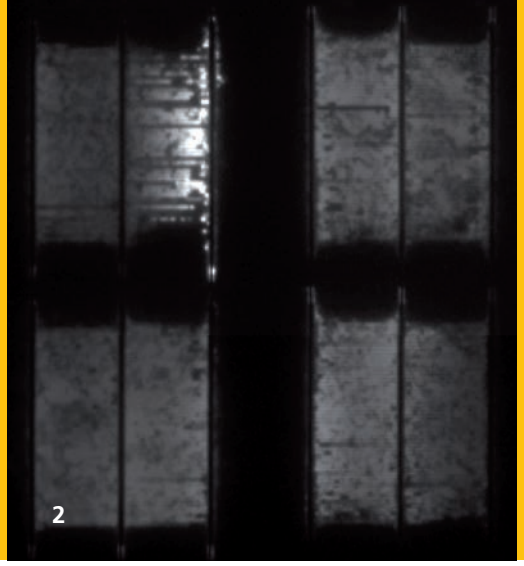

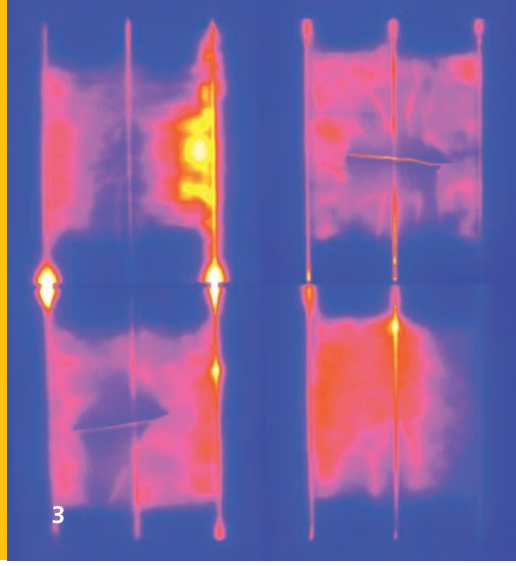

time. Non-destructive analytical methods enable us to monitor the progress of degradation taking place within the PV modules quantitatively. Degradation monitoring can be utilized for indoor accelerated aging, for certification as well as for outdoor weathering tests.

We offer customized test sequences for accelerated aging tests and outdoor exposure in different climates. With the monitoring data, we are able to validate degradation models and their kinetics, such as the humidity ingress in PV modules over time at different locations.

Failure Analysis

Modules that failed in R&D laboratory tests, in certification tests or in field operation can be investigated using both non-destructive and destructive analytical methods.

While visual inspection and flasher characterization provide a first idea on the failure mechanism, our analyses help to reveal the root causes of degradation and failure. We assist our customers in identifying the critical materials which are responsible for the module failure.

Many years of module testing, certification and outdoor monitoring with different PV technologies serve as the basis for our investigations of different module failures such as:

- snail tracks
- cell cracks
- PID
- metallization corrosion
- yellowing
- delamination

Unique Equipment

In our laboratory we use a variety of imaging and spectroscopic methods to gain a full picture of the PV module's condition. Our unique equipment has been partly developed in-house.

We can attain spatially resolved data over the entire module area and combine the results of different investigations which are performed at the same position on the module.

At Fraunhofer ISE we use the following equipment for our investigations:

- confocal Raman microscope with high spatial resolution
- luminescence spectroscope
- FT-IR/UV/VIS spectroscope with integrating sphere
- portable gloss meter for surface measurements
- high-resolution electroluminescence and lock-in thermography systems
- high-precision dark-IV system

Several of these measuring systems can also be implemented on site during outdoor module operation.
Our accredited calibration laboratory, CalLab PV Modules, determines furthermore the electrical characteristics with a worldwide unique measurement uncertainty of 1.6 %.

Equipment	Characterization of			Components to be analyzed				
	Chemical Structure	Optical Characteristics	Electrical Characteristics	Glazing	Encapsulation	Cell	Metallization	Back-sheet
Raman Microscope	✓				✓	✓	✓	✓
Luminescence Spectroscope	✓				✓			✓
FT-IR/UV/VIS Spectroscope	✓	✓		✓	✓			✓
Portable Gloss Meter		✓		✓				✓
Electroluminescence System			✓			✓	✓	
Lock-In Thermograph			✓			✓	✓	
Dark-IV System			✓			✓		

1 *Partial image of a c--Si PV module after the „Fraunhofer ISE Combined Test", testing realistic stresses simultaneosly and sequentially.*
2 *Electroluminescence image of cells in Fig. 1.*
3 *Lock-in thermographic image of cells in Fig. 1.*
4 *Matrix of PV module analysis: overview and classification of the methods shown, sorted by the components in a PV module.*