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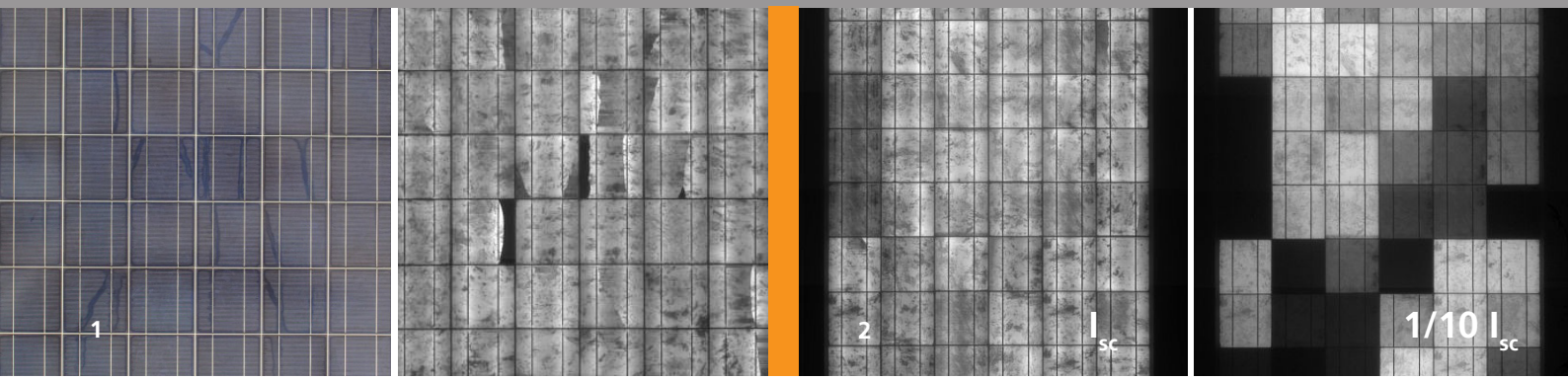
FRAUNHOFER CENTER FOR SILICON PHOTOVOLTAICS CSP



1 *Discoloration »snail trails« and corresponding crack in solar cells.*
2 *Detection of PID by means of electroluminescence with different levels of current.*

EXPERIENCES AND ANALYSIS OF DEFECTS IN PV MODULES UNDER OPERATION

An increasing number of defects in PV modules may appear due to the increased number of PV installations and product types. Those defects are due to product design, system design or handling. However, it has to be distinguished whether those defects have any influence on the performance and / or the physical integrity or safety of the product. Some defect can be identified easily be means of visual inspection. Other defects are not visible and in best case show an immediate influence on the power. Fraunhofer CSP offers services for characterizing of PV modules with non-destructive and destructive methods in order to identify and localize module defect. Furthermore, root cause analysis can be carried out in order to identify strategies for improvement of systems, modules and components.

Competencies

- Test and characterization of PV modules (IEC 61215, IEC 61646, IEC 61853, etc.)
- Assessment of the electrical and physical condition of PV modules
- Mechanical analysis by means of finite-element analysis (e.g. design and optimization of sub-structure, fracture analysis, fluid dynamic simulation)

Approach for the assessment of PV modules

- Continuous electrical monitoring and evaluation of gathered data
- Identification of defective areas in a PV installation by means of string monitoring, thermography and optical inspection
- Single module characterization in laboratory environment

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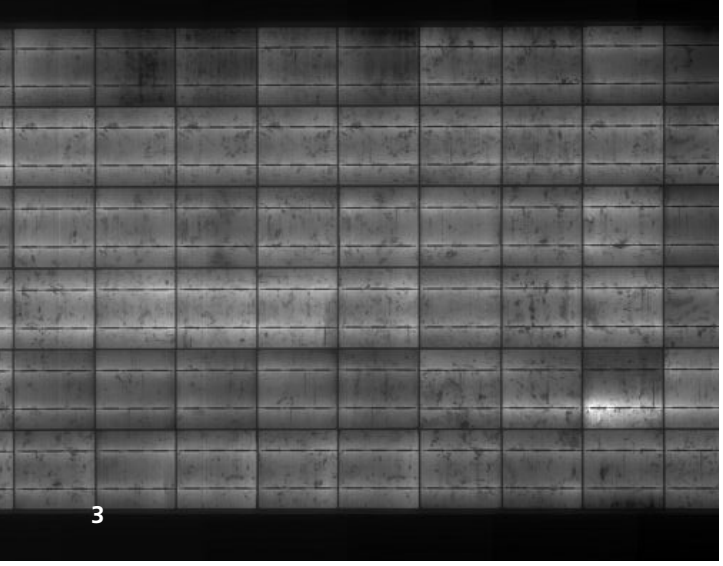
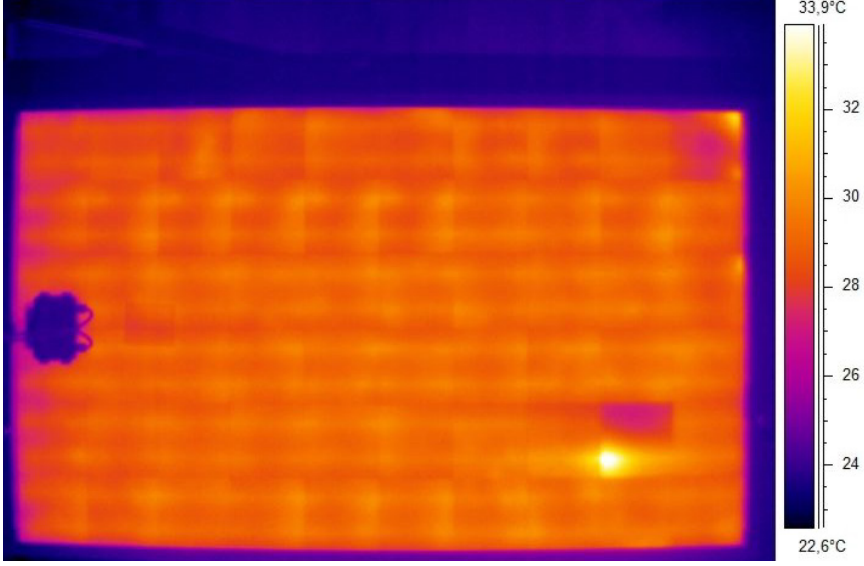
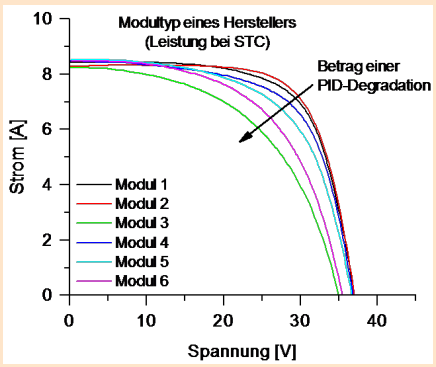




Extraction of methods for module characterization

Method	Goal
Power measurements at standard test conditions	Comparison of data sheet and performance guarantee
Performance at low irradiance	Identification of Rsh problems (e.g. PID and shunts due to to cracks)
Electroluminescence at I_{sc}	Localization of electrical and mechanical defects
Electroluminescence at 1/10 I_{sc}	Localization of R_{sh} problems
Thermography	Localization of serial resistance problems
Visual inspection	Localization of visual and physical defects
Polymer analysis	Assessments of the condition of polymeric materials

3 *Detection of failure of cell interconnectors by means of EL and thermography.*



4 *IV curves for modules with different grades of PID.*

Defect	Detection	Possible Causes	Possible Effect
cracks in solar cells	electroluminescence	manufacturing, transport, installation, wind- and snow loads	power drop, hot spots, shunting
snail trail	visual	polymer + silver particles + oxygen ⇨ discoloration	optical blemish
crack of cell interconnectors	electroluminescence, thermography	mechanical loads in the field, temperature changes	power drop, arcing
delamination	visual, lock-in thermography	material selection, degradation of interface due to environmental influences, manufacturing, etc.	intrusion of water into the laminate, compromising electrical integrity
discoloration	visual	material selection, degradation of interface due to environmental influences, manufacturing, etc.	reduction of light transmission in certain wave length regions which may lead to power drop
failure of diodes	electroluminescence	improper material selection and combination cause chemical processes which may lead to discoloration of polymer foils	power drop, thermal runaway