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Defect Detection in Photovoltaic Modules using Electroluminescence Imaging

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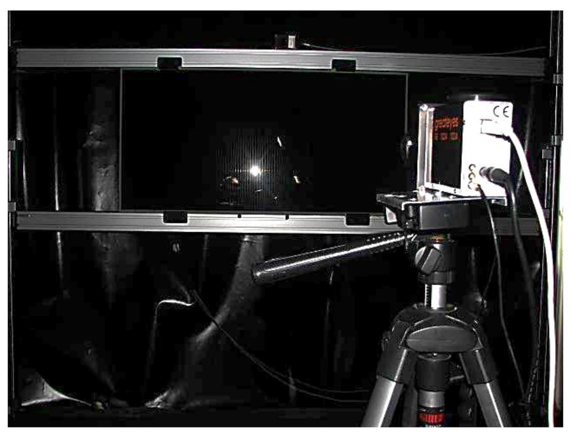
Electroluminescence (EL) imaging for photovoltaic applications has been widely discussed in the last years. In this contribution, the results of an all-around evaluation of this technique in regard to defect detection and quality assessment in photovoltaic modules are presented. The aptitude of the EL system for detecting failures and deficiencies in both crystalline and thin film PV modules (CdTe and CIGS) is thoroughly analyzed and an exhaustive defect catalogue is established.

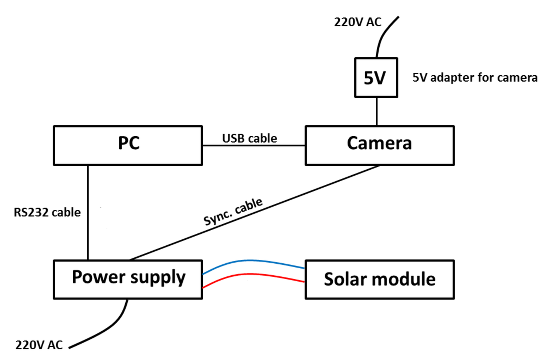
Measurement Setup

The setup consists of a back-illuminated Si-CCD camera with a high near infrared sensitivity mounted on a freely movable tripod inside an extra dimmed black tunnel. The system allows for overall shots of complete modules (size up to 2m x 2m) as well as for close-up measurements of different module sections with a minimum camera-object distance of 30 cm.



Camera setup inside the black tunnel

The power supply is ensured by a programmable DC unit with a maximum voltage output of 100V and a maximum current output of 15A. For measuring thin film modules with particularly high open circuit voltages, a conventional power supply providing up to 140V and 13A is used.

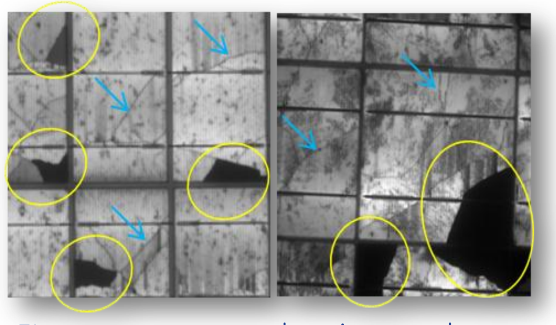


Components interconnection in the EL-measurement system

Defects of c-Si modules

Cracks and breakages:

Cracks and breakages in the semiconductor material are responsible for the majority of power loss cases in crystalline silicon cells. The EL and power measurements of 4 different c-Si modules showed a direct correlation between the power drop and the breakage size.

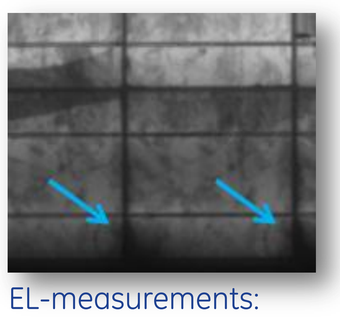


EL-measurements showing cracks and breakages in c-Si cells

Further experiments identified mechanical stress and temperature change as the major causes behind the proliferation of cracks and breakages.

Defective edge isolation:

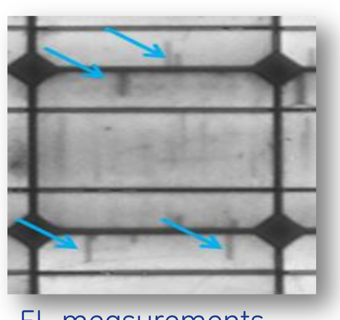
EL-measurements could also be used for identifying areas of defective edge isolation. These areas feature low luminescence values and appear dark on the EL-image.



EL-measurements: defective edge isolation

Contact grid interruptions:

Contact grid interruptions are a further common defect in c-Si modules. In the electroluminescence image, these defects are easily detectable in the form of dark areas surrounding the interrupted finger and reaching to the cell edges.



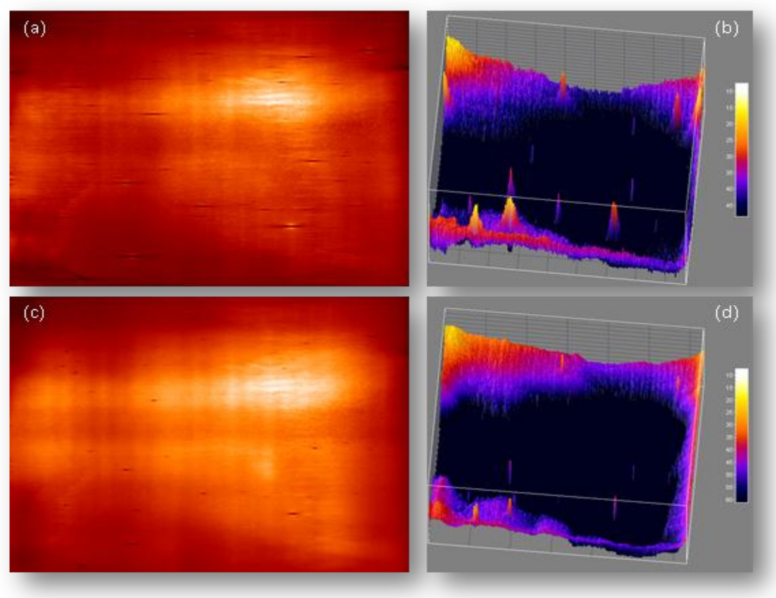
EL-measurements showing Contact grid interruptions

Defects of thin film modules

Shunts:

EL showed a good suitability for detecting shunts in thin film modules. These common defects, especially in CIGS-based modules have a very particular EL brightness pattern: a localized darkness within a single cell having a particularly dark (in some cases a particularly bright) center and a symmetric appearance along the cell.

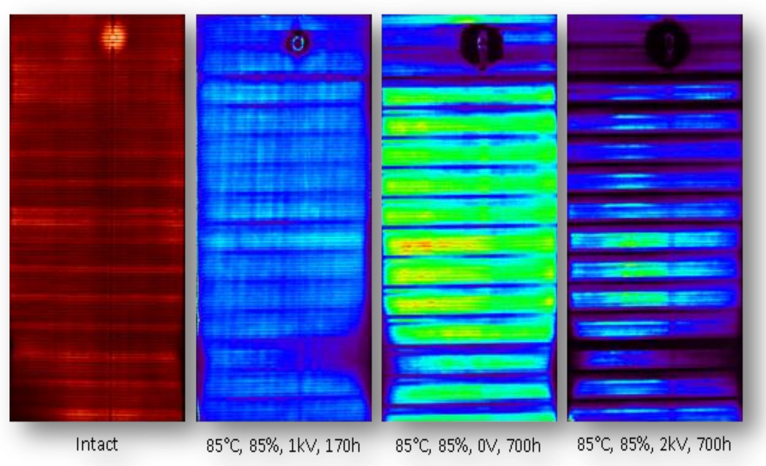
It could be shown through the comparison of EL-measurements that light soaking remarkably affects the size of the shunts and thus their impact on the module performance. A rise of up to 8% in the output power could be noticed after 24h of light soaking treatment.



EL-measurements showing shunts in CIGS-modules and demonstrating the effect of light soaking on their size ((c) and (d) compared to (a) and (b).

Laser scribing failures:

EL-measurements also allowed the detection of failures induced by the laser scribing process. Damages in the metallic rear contact or the TCO front contact are particularly easy to detect and appear as dark areas surrounding the laser scribe lines and covering variously large parts of the adjacent cells. Stress situations such as elevated temperatures, excess humidity or high voltages accelerate the failure process.

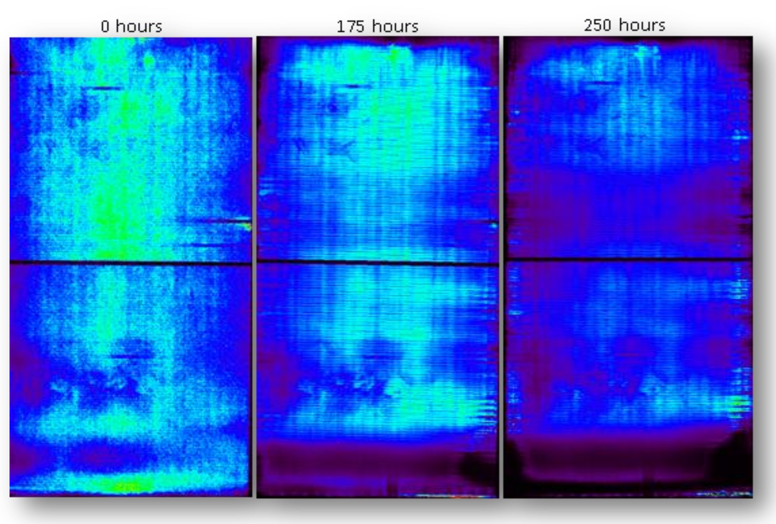


EL-measurements showing damaged cell interconnections along the laser scribe lines in CdTe modules

TCO-corrosion:

Additionally, the measurement setup allowed the detection of TCO-corrosion zones, induced by high negative voltages at high temperatures and humidity levels. Since the moisture penetration occurs at the module edges, the dark areas are concentrated in the outer zone of the module.

A linear dependence between the corroded area (darkness in the EL image) and the power drop could be shown.



EL-measurements showing zones of corroded TCO in a thin film CdTe module under the effect of stress conditions (1000V in reverse-bias at 85°C and 85% relative humidity)

Summary

In this work, EL imaging was shown to represent a powerful quality assessment tool for both crystalline and thin film solar modules. When properly adjusted and configured, the system is able of accurately detecting numerous failures and ageing effects in very short times.

imagination at work