ELECTROLUMINESCENCE TO TRACK CELL AND MODULE CHANGES – FROM SMALL-AREA CELLS TO LARGE-AREA MODULES

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Introduction

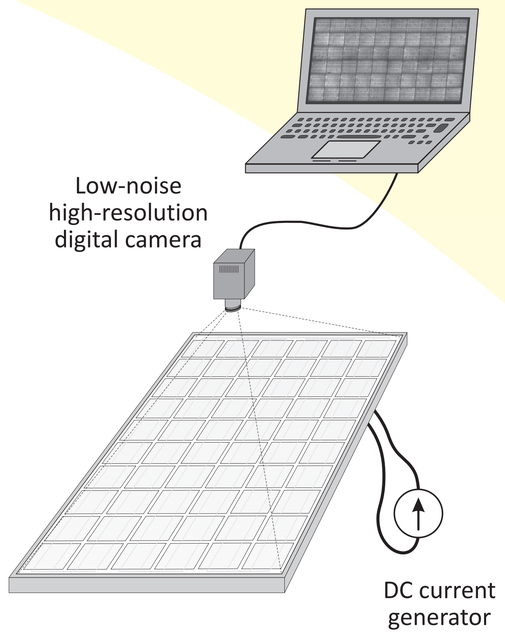
Small-area solar cell performance is always larger than the large-area PV module performance, primarily due to losses of series connection of cells into modules. In particular in thin film PV modules (a-Si, a-Si/mc-Si, CIGS, CdTe), front contact and monolithic contact losses often dominate. However, inhomogeneities distributed across the larger area can affect the cell or module performance.

Inhomogeneities do not origin from the production processes only, but they may evolve during the transport or installation and inevitably during their operation in the course of life.

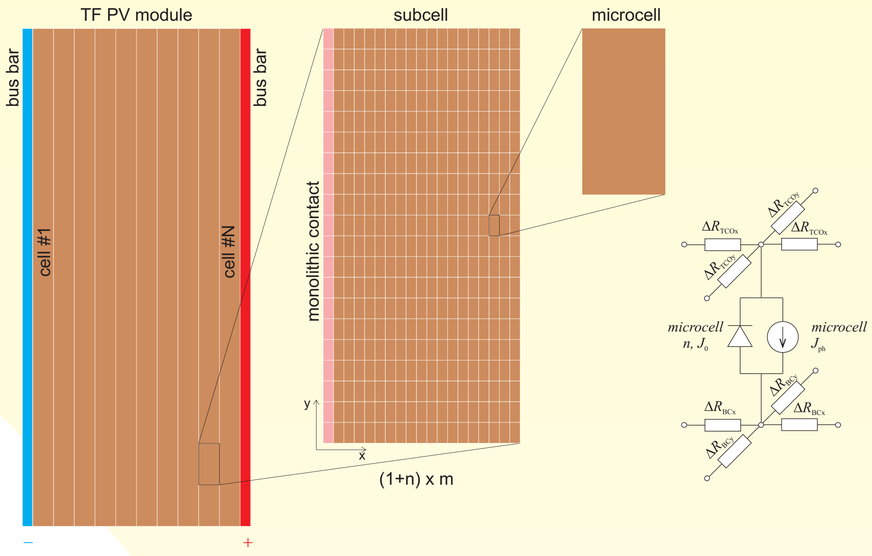
Electroluminescence (EL) systems have already proved to be fast and reliable inspection tool for detection and monitoring of inhomogeneities. Systems under development at both Ljubljana and Colorado State University aim at tracking small-area changes in thin-film cells and modules. EL is particularly attractive, because it can be directly related to cell performance, the field of view can be varied over two orders of magnitude with conventional optics, and the imaging time for large-area imaging is the order of seconds. Parallel to the system development, a joint program is in progress to expand the information acquired from the analysis of the recorded images.

SPICE simulations enable an evaluation of the impact of inhomogeneities from the microcell level to the subcell level with a focus on the type and strength of inhomogeneities and the consequent loss of sub-cell power. EL with SPICE simulations offers a powerfull platform for tracking changes and paths the way toward the degradation mechanisms throughout the life-time.

EL set-up



Thin Film PV module layout

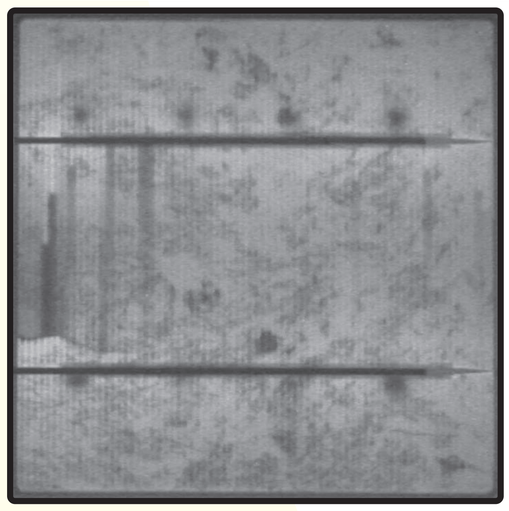


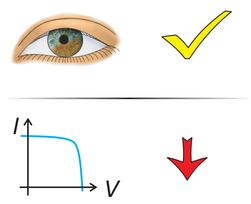
Shematic view of thin film PV module made of two bus bars and cells, which are divided into subcell. Each subcell consists of monolithic contact area and active area, which is divided/parcelled into microcells as the smallest unit. A model of microcell with adjacent discretized resistors (ΔR) of the front TCO and back contact.

Legend: naked eye visibilty; effect on performance

Defects in c-Si cells and modules

CRACKS

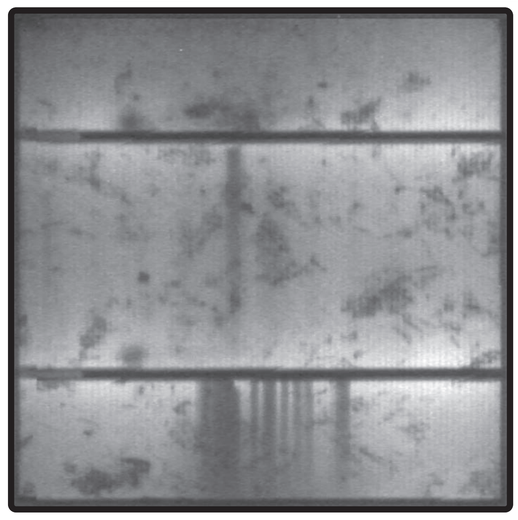


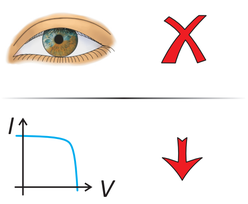


presence [%]

inactive	1.6
active	0.5

BROKEN FINGERS



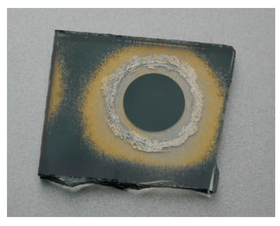


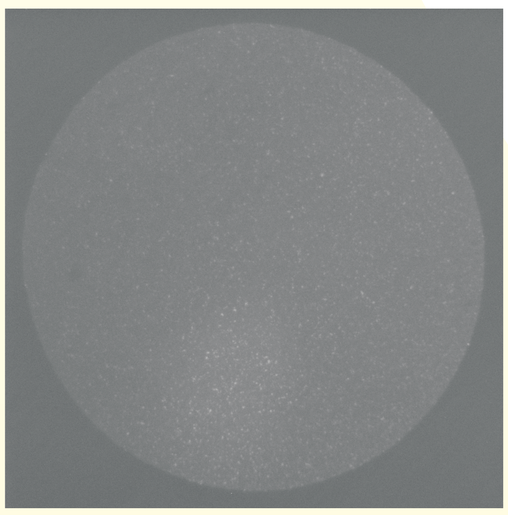
presence [%]

weak	15.5
strong	2.0
complete	0.2

Cracks and broken fingers on individual c-Si cells in strings occur during module production process, and they both affect performance of a PV module. These defects are important to inspect in production, because they decrease production line power yield.

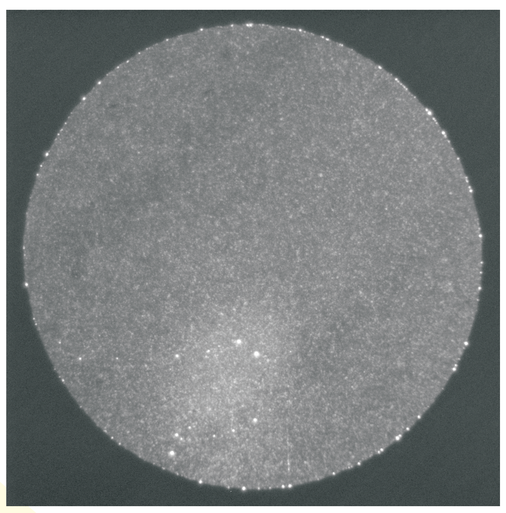
Defects in thin-film CdTe solar cells





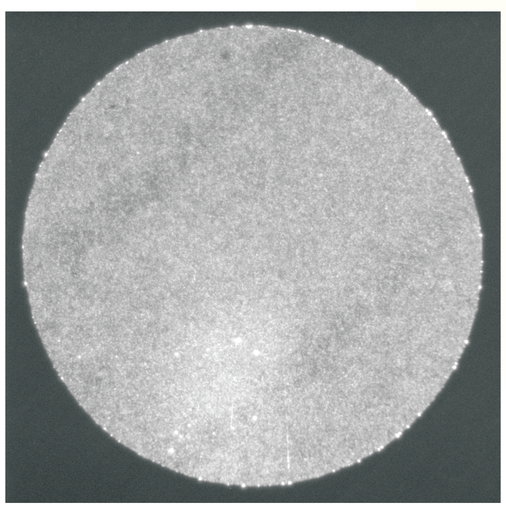
J_F = 2.4 mA/cm^2

Low injection level with little EL response.



J_F = 4.9 mA/cm^2

Mid injection level generates bright spots. At the cell edge shunts can be identified, while in the inner part of the cell it is not clear whether they are shunts or regions of better performance .



J_F = 7.9 mA/cm^2

High injection level generates overall higher intensity with even brighter spots.

Conclusions

- EL is a fast and powerful method for inline cell and module inspection regardless the PV technology.
- Cracks and broken fingers arise in individual mc-Si solar cells during the module fabrication steps.
- In c-Si PV modules cracks and broken fingers are the most common drivers of the module power loss.
- EL increases roughly linearly with current; individual features, however, become more at higher currents.
- Field of view can range from 3 mm to 500 mm by changing lenses.

Acknowledgements

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