

QUALITY ASSURANCE OF CRYSTALLINE PHOTOVOLTAIC MODULES BY USING DIFFERENT CHARACTERISATION TECHNIQUES

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1. Abstract:

In recent years electroluminescence (EL), photoluminescence (PL) and infrared measurements (IR) demonstrated to be powerful, non-destructive tools for qualitative analysis of PV module performances. In spite of the number of available analyzing techniques, many failure and degradation mechanism are still unknown.

Therefore, the aim of this work was to improve the quality and reliability of PV modules by a more precise defect detection, the “defect tracking method”. The “defect tracking method” is started with the analysis of crystalline cells and ended with the characterization of crystalline PV-modules which were produced from these cells.

2. Experiments:

Approx. 200 single crystalline Si-solar cells (sc-Si solar cells) were characterized by EL and current-voltage measurements (I-V-measurements). After these measurements it was possible to sort out defect and broken cells and to classify the cells concerning their determined power output and their short circuit current results. The selected cells were numbered and placed in a few modules by module producers. Some modules were equipped with cells with minor defects and a high cell mismatch rate and some were equipped with cells with hardly defects and a low cell mismatch rate.

The produced PV-modules were also analyzed by EL- and IV-characteristic measurements as well as IR-thermography imaging was executed and compared on modules operated under different conditions (I_{SC} , U_{OC} , MPP).

Additionally, solar cells where a low short circuit current was determined, were compared with hot cells, which were identified by means of IR-thermography measurements of the modules.

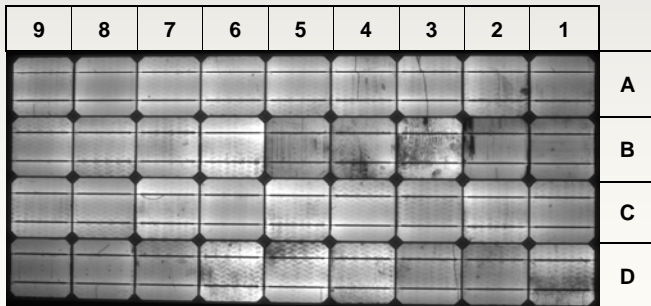


Fig.1: EL-image, sc-Si-module III (injected current: 8A)

For the sc-Si-module III 36 cells with minor defects and high cell mismatch rate (classified: 4.080W – 4.200W) were used. In the EL-image of the sc-Si-module III (see Fig.1) some cracks, process failures and darker cells are visible.

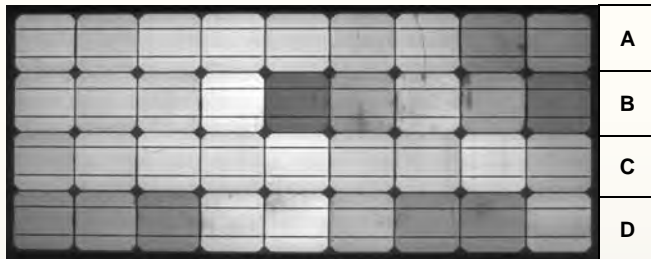


Fig.3: EL-image, sc-Si-module III (injected current: 0.8A)

When low currents are injected (1/10 of I_{SC}) the EL-intensity of cells with high series or contact resistances is considerably reduced. In Fig.3 some darker cells with lower electrical activity are visible.

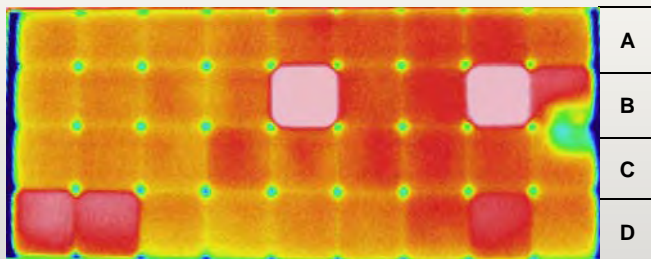


Fig.4: IR-image, I_{SC} -operated, sc-Si-module III

The illuminated IR-image of the sc-Si-module (see Fig.4), under I_{SC} conditions, shows some hot cells. Cells with lower I_{SC} distinctly caused higher cell temperatures and are in accordance with the darker cells in Fig.3.

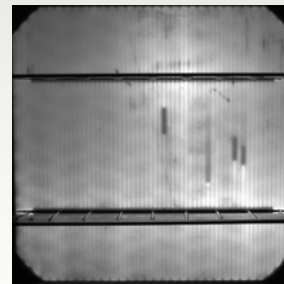


Fig.2a: sc-Si-cell

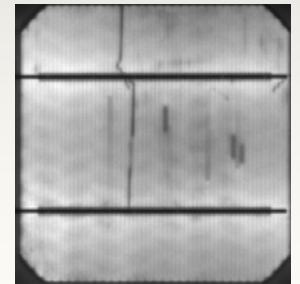


Fig.2b: sc-Si-cell (A4)

Fig.2a shows one sc-Si-cells before and Fig.2b shows the same cell after integration in the sc-Si-module III.

Table 1: measured I_{SC} [A] values of the sc-Si-cells:

9	8	7	6	5	4	3	2	1	
8.308	8.265	8.245	8.254	8.252	8.270	8.230	8.273	8.187	A
8.252	8.264	8.267	8.310	8.111	8.212	8.220	8.137	8.109	B
8.160	8.231	8.228	8.168	8.266	8.246	8.259	8.239	8.233	C
7.951	8.006	8.203	8.312	8.301	8.274	8.224	8.189	8.264	D

Before the sc-Si cells were integrated in a module, current-voltage-characteristic measurements of each cell were performed. The determined I_{SC} values of each cell are given in Table 1. In the majority of cases cells with low I_{SC} values also had high series resistances (R_s).

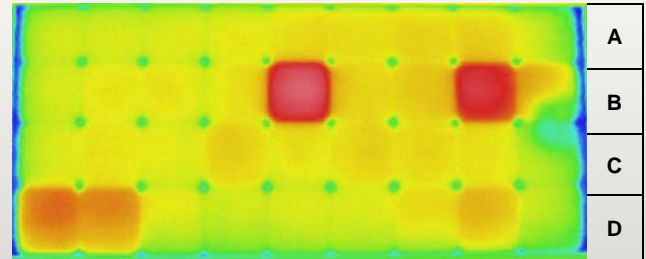


Fig.5: IR-image, MPP-operated, sc-Si-module III

When the sc-Si-module is operated at MPP (see Fig.5) some cells have lower temperature than under I_{SC} condition. This is caused by different grade of I_{SC} of the cells.

3. Results:

This work made it possible to determine the origin of a number of failures in a module and to interpret the EL- and IR-measurements results in more detail. It was demonstrated that a combination of both techniques (EL and IR) is necessary to identify as many defects as possible.

Additionally it was observed that the number of defects in solar cells increases (e.g. crack length) because of the stress the cells have to stand during module manufacturing. (e.g. soldering and lamination process).

Small cracks in solar cells, which are mainly caused by the screen printing process, are not noticed during power measurements since they have no influence on the power output of the cells. Therefore sorting of cells by means of EL- or PL-imaging before module production could help to reduce the number of later occurring defects.

Normally solar cells are classified according to their rated power output in Watts independent of the I_{SC} of the cells. Thus, even if module producers take care that the rate of cell mismatch is very low, cells with low I_{SC} and suitable power output can cause hot cells in a module (identified by IR-measurements) and reduce the power output of the module. Therefore a classification according to the measured I_{SC} of the cells would be advisable. In the majority of the cases cells with low I_{SC} values also had high series resistance values.

By means of current-dependent EL-measurements cells with low electrical activity (reduced EL-intensity) could also be determined in modules with high cell mismatch rate. In the case of modules with low cell mismatch rates only IR-measurements allow to determine hot cells with low I_{SC} values.