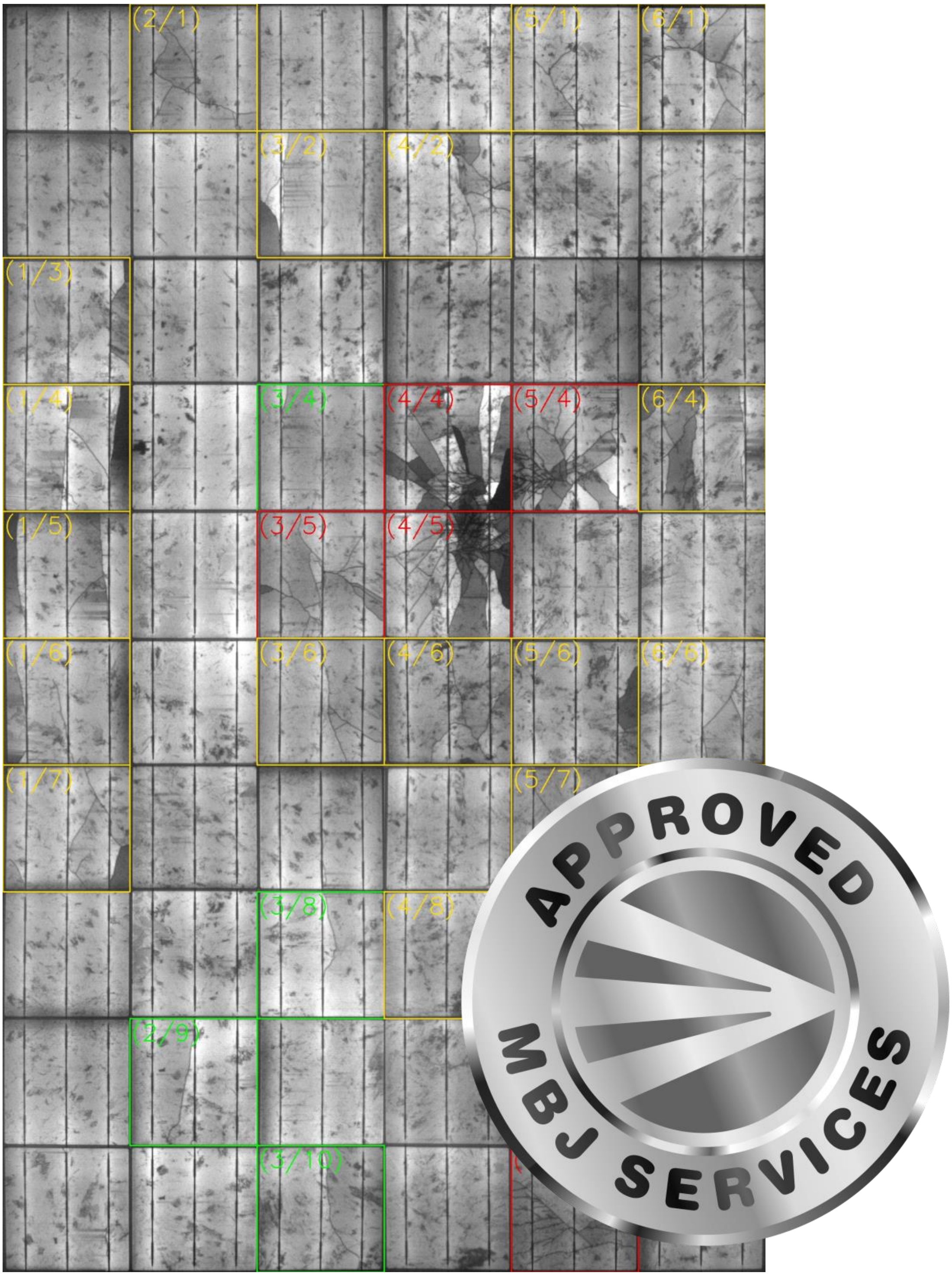
MBJ Solar Module Judgment Criteria

Analysis criteria for solar module testing in the Mobile Lab / Mobile PV-Testcenter

Date: 26.08.2019 – Revision 3.4

Compiled by the MBJ partner network in cooperation with TÜV SÜD and other solar module testing bodies



MBJ Services GmbH Neuer Höltigbaum 15 D-22143 Hamburg Tel +49 40 22 61 62 301
www.mbj-services.com

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Analysis criteria for PV module testing in the Mobile Lab / Mobile PV-Testcenter

The actual condition and possible preliminary damage to PV modules are tested in the Mobile Lab or Mobile PV-Testcenter from MBJ Services GmbH by different test methods.

An electroluminescence test is always performed to check for cell breaks in silicon, so-called 'micro-cracks', along with a power test under simulated or approximate STC conditions (ambient temperature or STC temperature). The modules can also be investigated by thermal imaging (if equipped) with a corresponding indication.

In order to guarantee a standard analysis of solar modules for all operators of our systems, this document explains the analysis criteria for the three test methods in more detail using examples.

1 Quality classes for PV modules

Modules are divided up into 4 classes on the basis of the test results:

Class A – No abnormalities that can lead to premature drop in power

Class B – A few abnormalities that do not lead to a premature drop in power

Class C – Increased abnormalities that may lead to a premature drop in power

Class D – Negative properties that can directly lead to a drop in power

In order to avoid a premature degradation, we recommend that you do not install modules from class C, or that these are at least grouped separately in strings that should be monitored and compared against "ok" strings.

Modules from class D would lead directly to a reduction of the generator's power, so that they should not be installed in any case.

2 Analysis criteria for the electroluminescence test

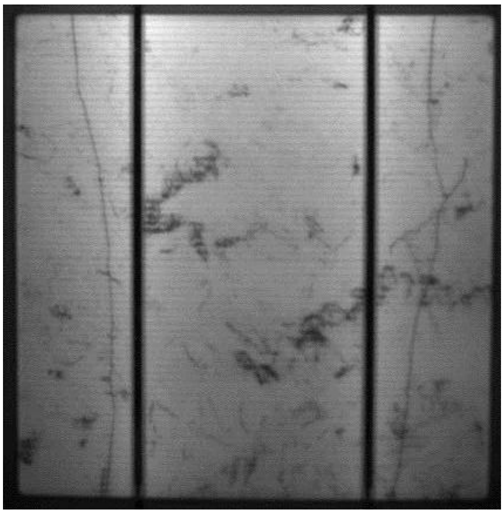
Since the test in the Mobile PV-Testcenter is carried out with regard to the module's output in future, we initially regard active and inactive cell breaks (micro-cracks) as being identical. However, active cell breaks often lead to a reduction in power at the time of the test; these are then quantified by the separate power test in the flasher.

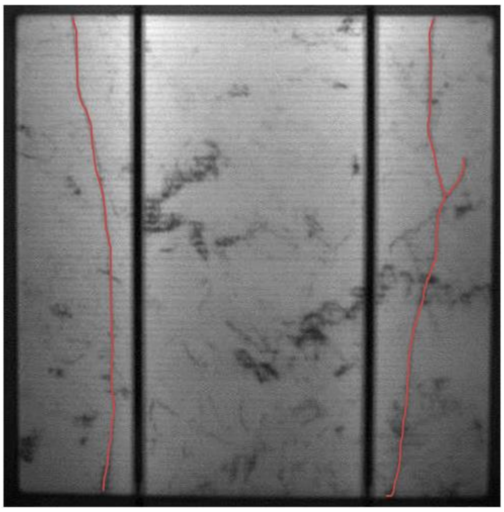
Cell breaks are classified into three categories:

- **Uncritical: <1% cell area affected**
- **Critical: >=1% and <=20% cell area affected**
- **Very critical: >20% cell area affected**

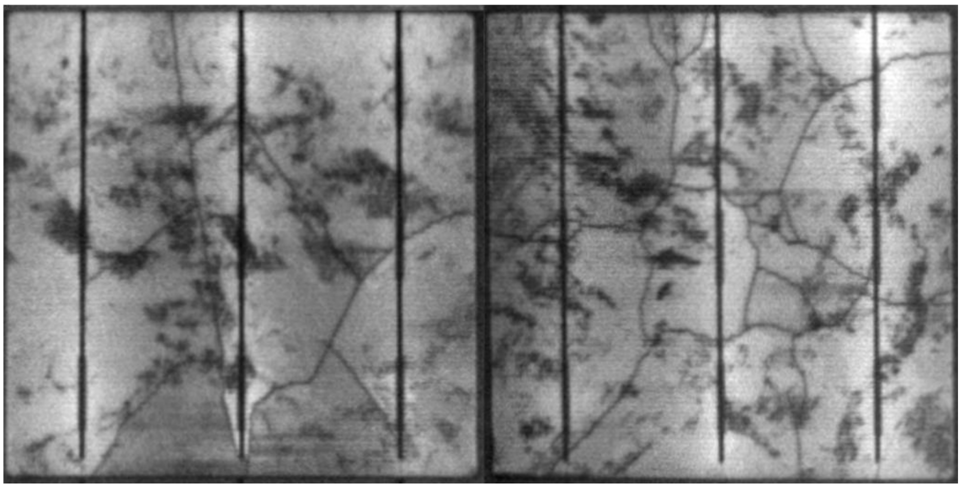
2.1 Cracks and breaks

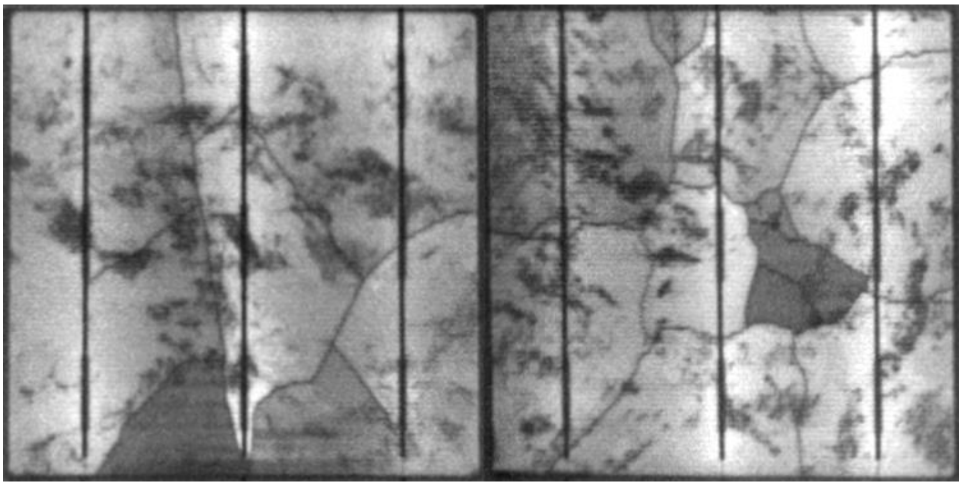
A micro-crack through a silicon solar cell separates parts from each other, which are further connected via the contact fingers to the bus bar, and thus remain electrically active. Micro-cracks produce therefore no dark areas in the electroluminescence image. The luminescence remains homogeneous despite the cracks. Micro-cracks alone lead to no or even at a high accumulation only to a slight power loss.

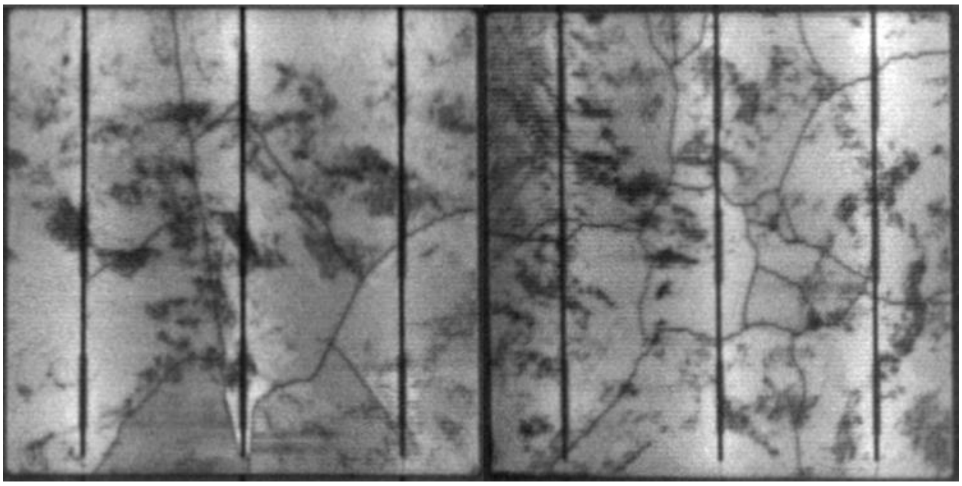




Micro-Cracks can turn into cell breaks by tearing the contact fingers (e.g. by thermal expansion) of two silicon parts, which are separated by a crack. The tearing of the fingers and thus the loss of connection to the bus bar leads to inactive cell parts. The breakage may not be immediately complete. It can begin with an increased contact resistance. The electrical connection may be interrupted temporarily, depending on the temperature or mechanical influences. The breaks are apparent through a lower luminescence on one side of the break, homogeneous or with a gradient depending on the location. Breaks lead in the worst case to completely dark (inactive) cell sections. The following images show captures that were made in the course of several hours at slightly different temperatures. This is to illustrate that the transition from crack to break may be smooth, but also reversible:


1st capture, about 16 ° C

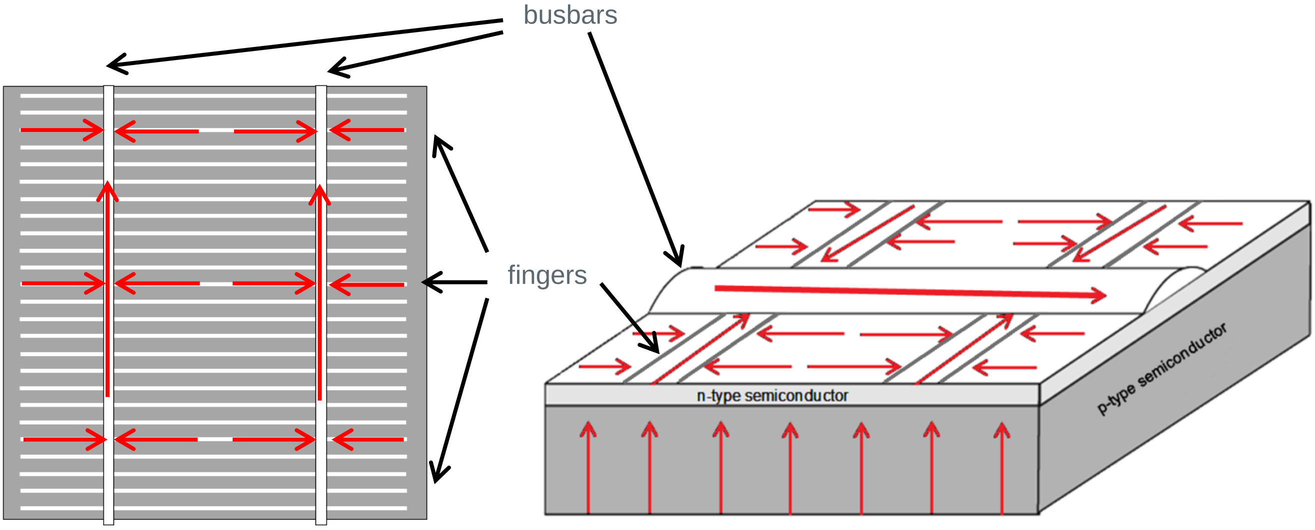

2nd capture, about 24 ° C


3rd capture, about 15 ° C

The relationship between the orientation of a crack/brake and the power loss associated with the loss of active cell area is considered in more detail in the following pages.

2.2 Cell without any break

The figure below shows the current flow in an intact solar cell.

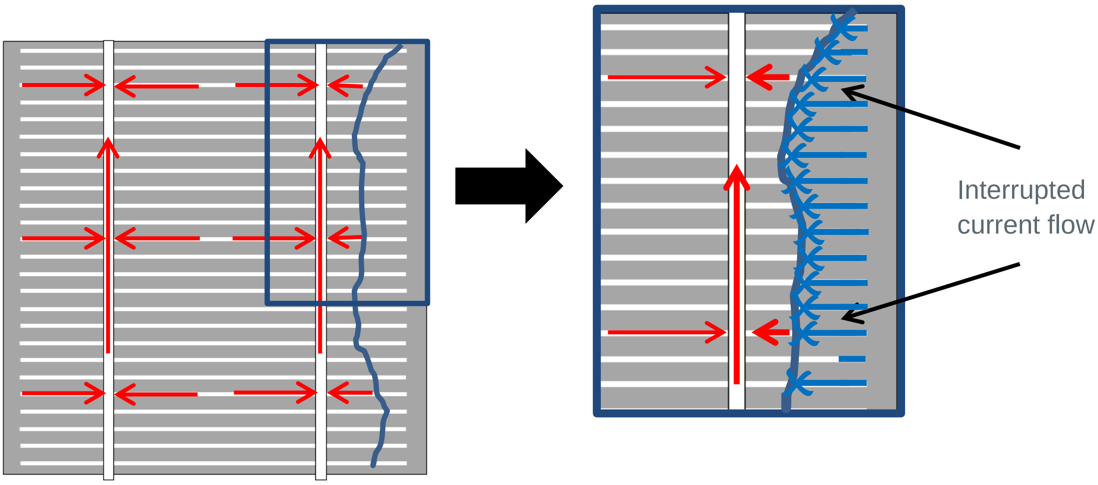


Solar Cell Top Contact

Current flow in a solar cell

2.3 Cell with active break

The following figure shows how the current flow is impaired through a break in the silicon and the resulting interruption of the contact fingers:



Solar Cell Top Contact

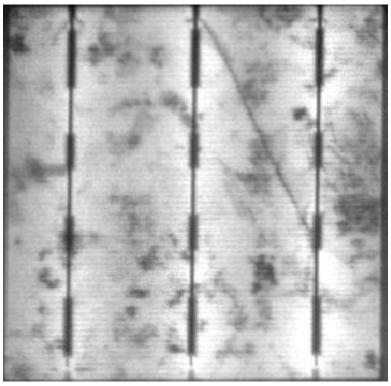
2.4 Uncritical cracks / cell breaks

If a cell break runs in a straight line between the 'bus bars' it cannot disconnect areas from the power supply via the 'finger'.

In principle, this is only possible between the bus bars or if the break runs absolutely horizontal. Such cell breaks are classified as 'uncritical' or green and do not lead directly to a degradation of the module.

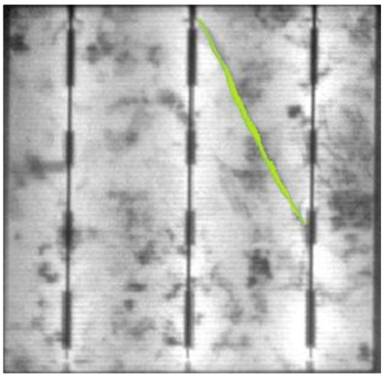
Other cracks and cell breaks are acceptable if they are not able to disconnect cell areas larger than 1 %.

Nevertheless, the development of the cell crack should be noted, especially if there is already a tendency to a fanning out of the crack or to y-crack, in which case the cell may have to be classified as 'conspicuous' or yellow. Since this may not be able to be detected with the existing pixel resolution, if more than 10% of cells in a module are marked green, this is also a degradation criterion (see section 2.8).



Description

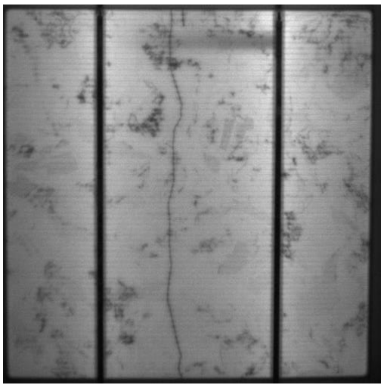
Cell break runs in a straight line between the 'bus bars'.



Judgment

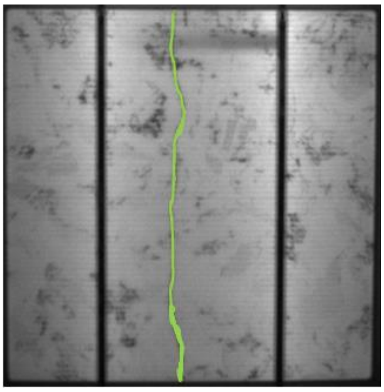
A further expansion of the cell break is not expected.

Possible cell area disconnection 0%.



Description

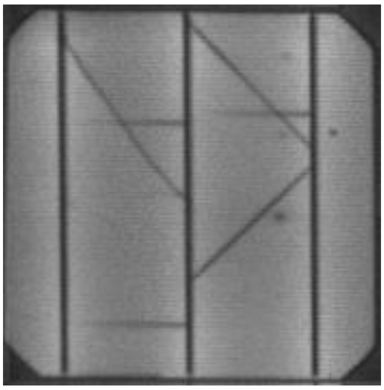
Cell break runs parallel between the 'bus bars'.



Judgment

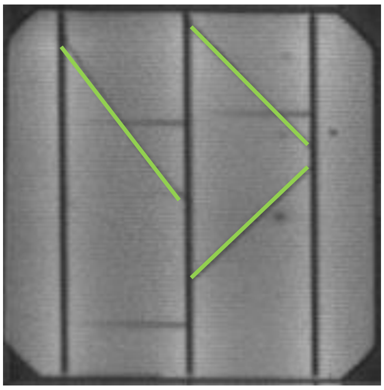
A further expansion of the cell break is not expected.

Possible cell area disconnection 0%.



Description

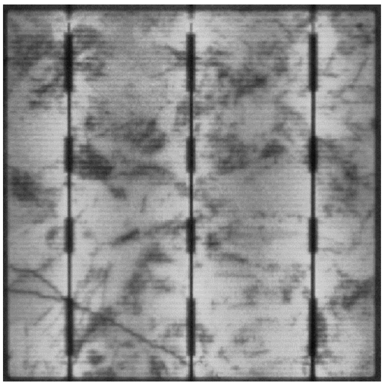
Various cell break run in a straight line between the 'bus bars'.



Judgment

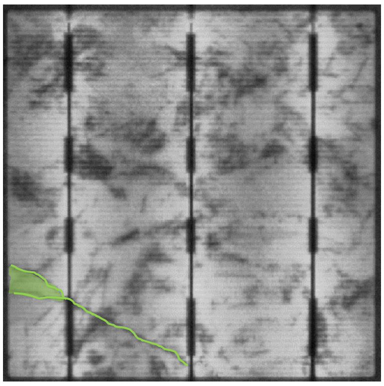
A further expansion of the cell breaks is not expected.

Possible cell area disconnection 0%.



Description

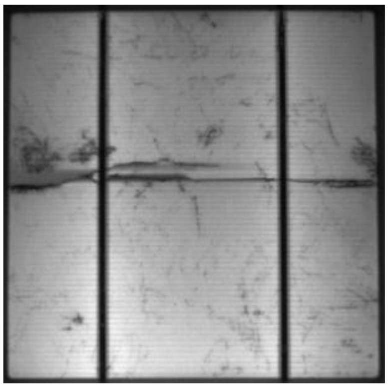
The endpoints of the cell breaks are the 'bus bars' and the cell edge.



Judgment

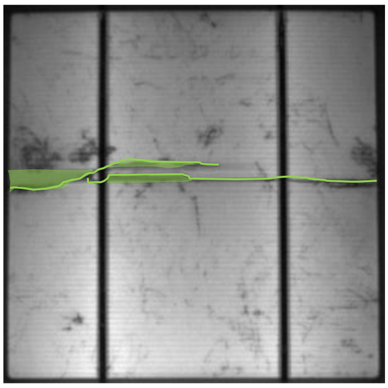
A further expansion of the cell breaks is not expected.

Possible affected cell area <1%.



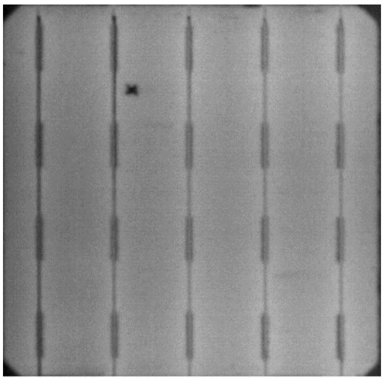
Description

Horizontal main crack with branching.



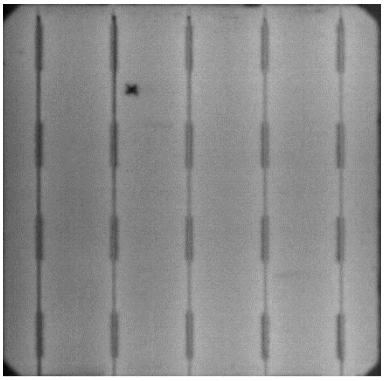
Judgment

A further expansion of the main crack is not expected. Disconnection of smaller cell areas <1% possible.



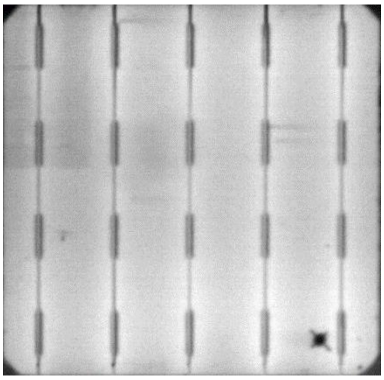
Description

Single tiny cross or x-crack (<=5 mm), that is slightly determin-able as an x. Caused by punctual stress on the cell, e.g. punctual stress on the back sheet foil of the module.



Judgment

A further expansion of the main crack is possible, but potentially disconnected cell area will be very small. One tiny x-crack per cell is uncritical.



Description

Large cross or x-crack (>5 mm), which is easy determinable as crack or break. Location close to the bus bar.

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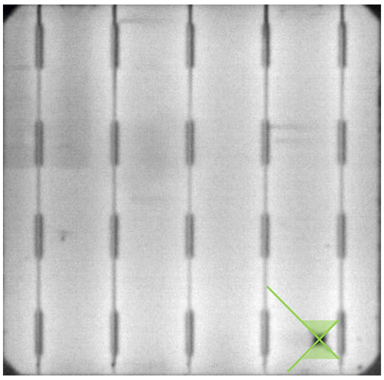
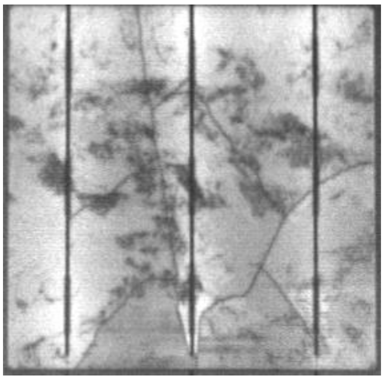


Judgment

A further expansion of the main crack is possible. Potentially disconnected area will stay below 1% of total cell area.

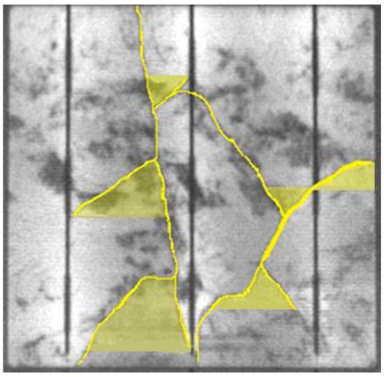
2.5 Critical cracks / cell breaks

All cell areas that can potentially disconnect cell areas larger 1 % and smaller 20 % from power supply or which already do so, should be classified 'conspicuous' or yellow.



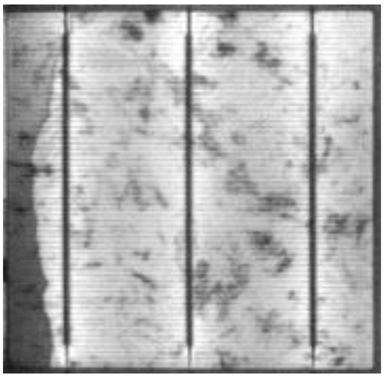
Description

Various Y-breaks between the 'bus bars'.



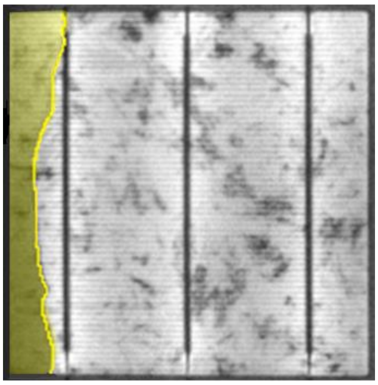
Judgment

Breaks can potentially reduce the active area of the cell approx. 10%.



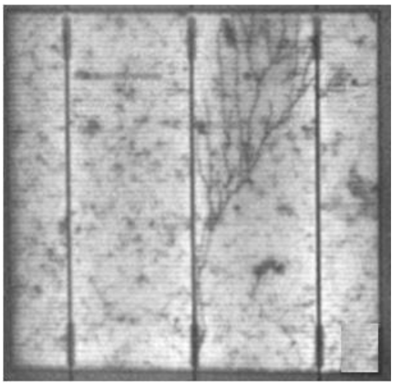
Description

Cell break between 'bus bars' and cell edge.



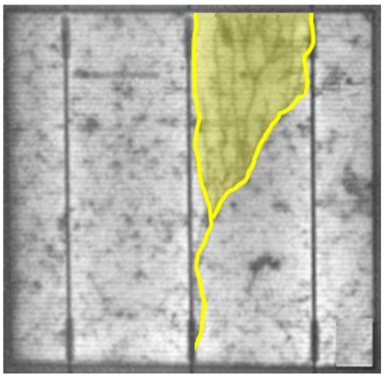
Judgment

Disconnected cell area approx. 10%.



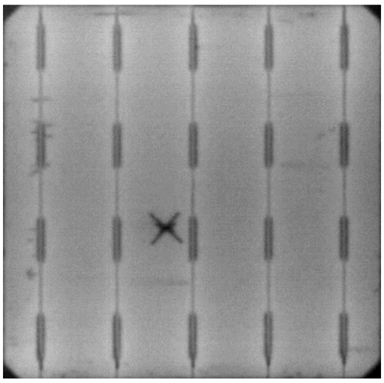
Description

Branched cracks between the 'bus bars'



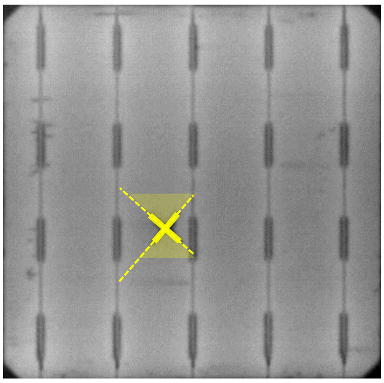
Judgment

Possible cell area disconnection approx. 10%.



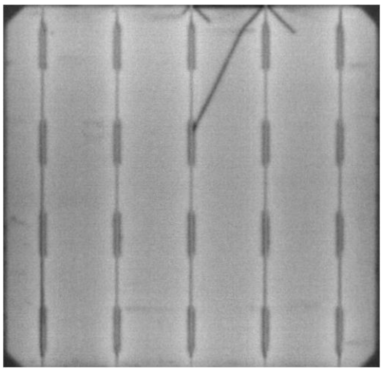
Description

Large cross or x-cracks which are easy determinable as crack or break. Location close to the center between the bus bars.



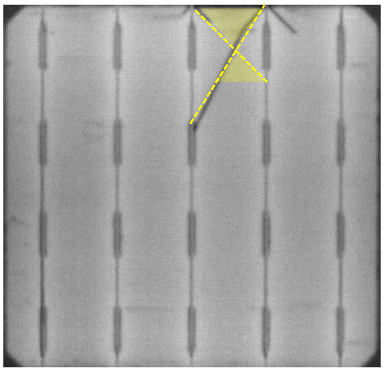
Judgment

Critical, if the potential disconnected cell area is more than 1% in total for all x-cracks in one cell.



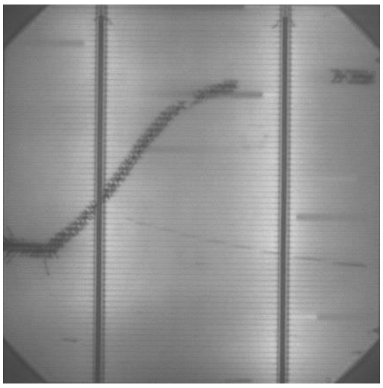
Description

Multiple x-cracks on the cell edge have a similar impact like an x-crack in the center of the cell.



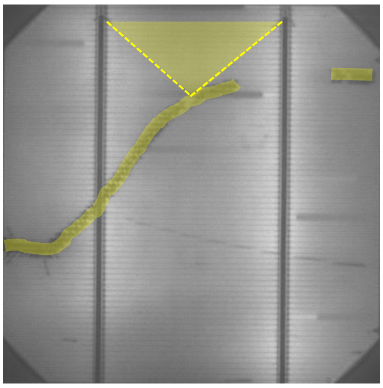
Judgment

Critical, because the potential disconnected cell area is typically more than 1% in total for two or more x-cracks in one cell.



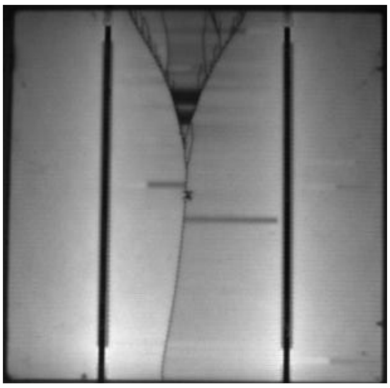
Description

Cross crack lines. Scratch on the back sheet of the module.



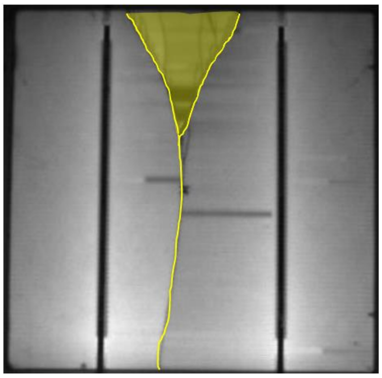
Judgment

Critical, as it is unclear how the cracks will propagate. Cell areas can be disconnected (as indicated in the example)



Description

Y-break between the bus bars.



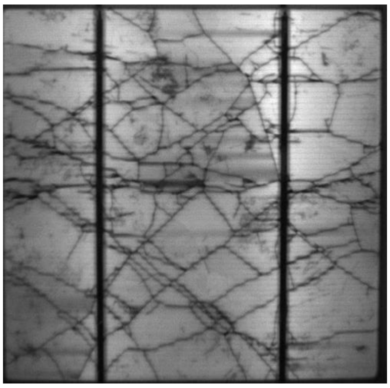
Judgment

Possible cell area disconnection approx. 10%.

2.6 Very critical cracks / cell breaks

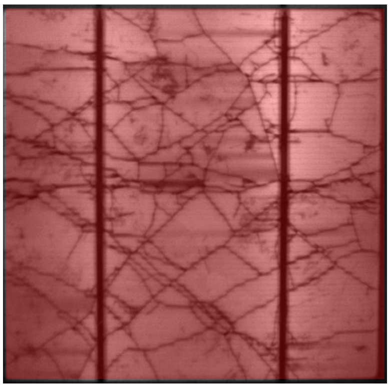
Cell breaks that can potentially disconnect more than 20% of the cell area from the power supply are classified in the 'very critical' category and marked red.

This category includes above all comminuted or fan-like breaks. Red cells lead directly to the classification of a PV module in the class C (see section 2.8).



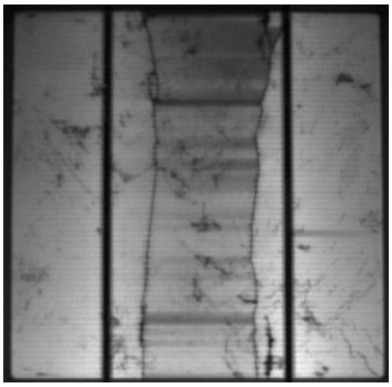
Description

Numerous branched cracks in different size and location.



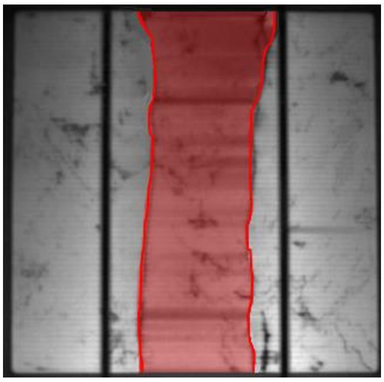
Judgment

These cracks can potentially reduce the active area of the cell far more than 20%.



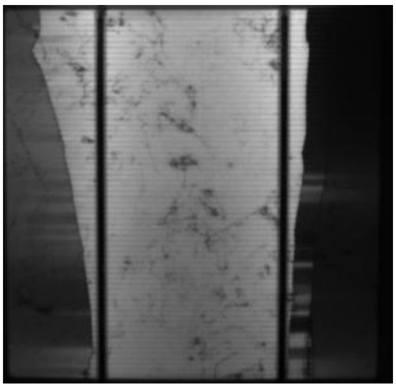
Description

Two cracks run parallel to the 'bus bars'.



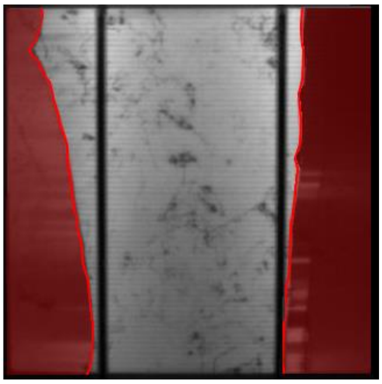
Judgment

Possible cell area more than 20%.



Description

Cell brakeage. Inactive area between 'bus bars' and cell edges.

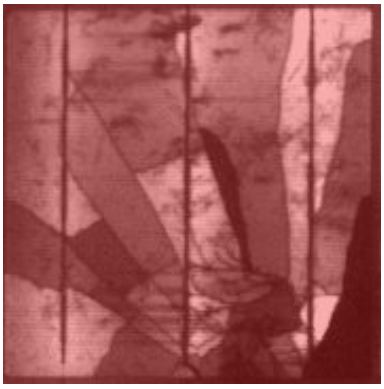


Judgment

Disconnected cell area far more than 20%.

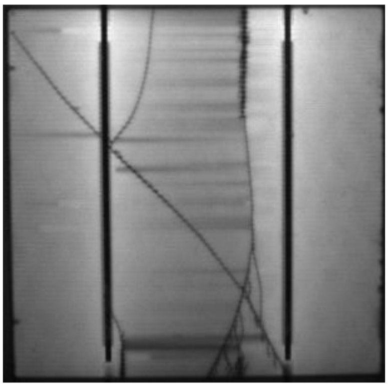
Description

Various cell brakes caused by mechanical impact e.g. hail.



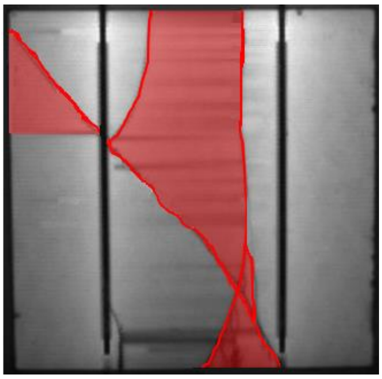
Judgment

These cracks can potentially reduce the active area of the cell far more than 20%.



Description

Various cracks in different size and location.

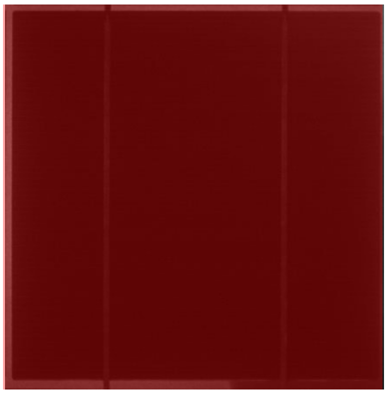


Judgment

These cracks can potentially reduce the active area of the cell more than 20%.

Description

Dark cell.



Judgment

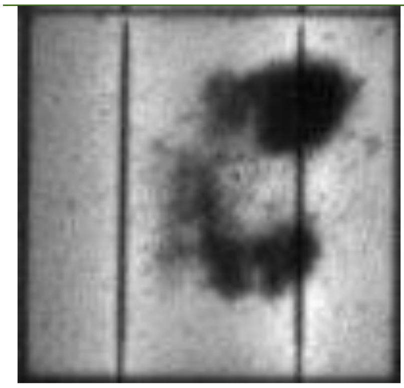
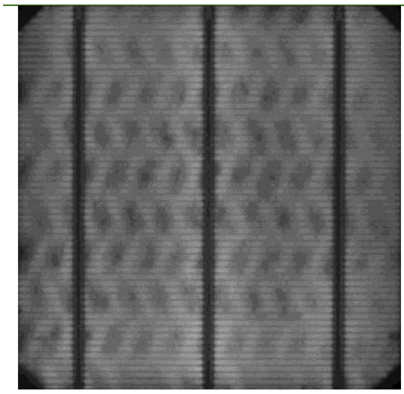
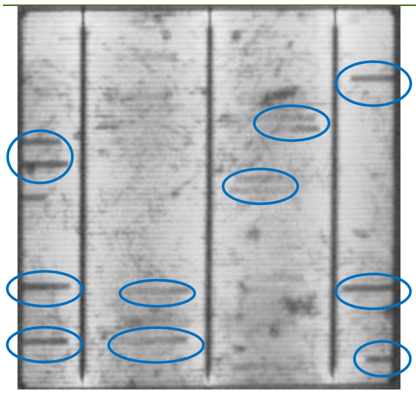
Inactive cell. Should not happen for new modules.

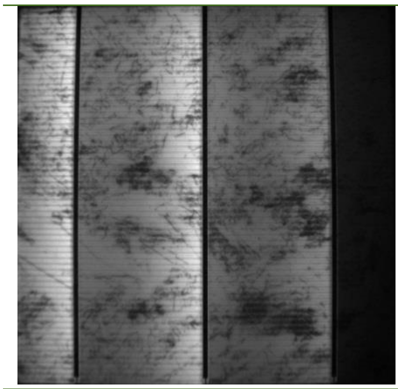
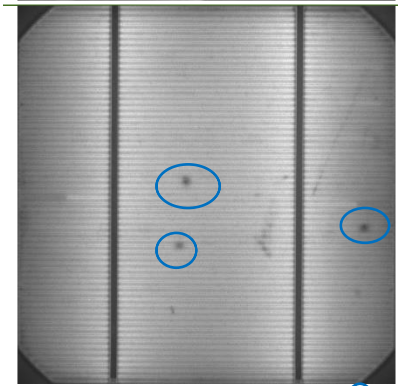
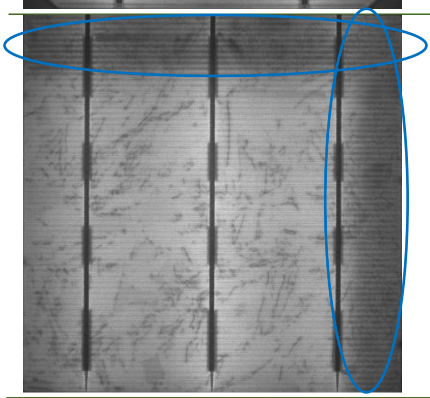
2.7 Other EL abnormalities

This category includes all defects which have occurred in the module manufacturing process and which have no negative impact on performance within the lifetime of the photovoltaic module.

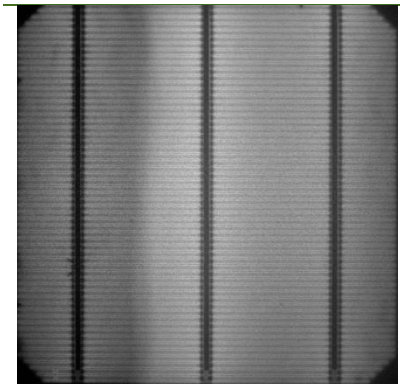
Such defects are normally uncritical and marked blue, since the power loss of the cell is already entered in the performance specified by the manufacturer. Consequential damages are not expected.

Cell process

Defect image	Defect type	Defect description
	Dark areas	Cloudy area with a lower luminescence Firing process Temperature gradient from the cell center to the cell edge
	Chain pattern	Local areas with a lower luminescence Firing process Inhomogeneous temperature distribution caused by the conveyor belt
	Printing failure (Grid finger)	Area of a grid finger with a lower luminescence Interrupted or non-existent grid finger Failure is generated during the screen printing process

	Printing failure (Back contact)	Gradation of the luminescence from one cell edge to the another cell edge The printing of the cell back is shifted Failure is generated during the screen printing process
	Shunts	Points with almost no luminescence E.g. direct contact of the grid finger to the cell base, defect in the pn-junction etc. Verifiable only with the Lock-In thermography or EL under reverse bias
	Ingot edge piece	Lower luminescence on one or two cell edges Contamination of the cell material in the edge area of the ingot Typical for polycrystalline solar cells

Soldering process

Defect image	Defect type	Defect description
	Dark cell	Area with a lower luminescence around the bus bar Not or only partially connected ribbon
		Completely dark cell Inactive cell ➔ E.g. short circuit through a wrong ribbon placement, inverted polarity or a defective cell. Possibly PID (potential-induced degradation, then often with "checkerboard pattern") In any case, such cells should be tested thermographically, hot spots at the soldering points can be expected.

2.8 Module judgment criteria for the electroluminescence test

2.8.1 Class A

Only modules with fewer than 10% uncritical (green) cells. The sum total of the marked cells may not exceed 10% of the cells. Critical cells (yellow, red) are not allowed.

green

<10% of the total amount of cells in the module

Example: 60 cell PV-Module:
<6 cells allowed

NO **yellow**

0% of the total amount of cells in the module

Example: 60 cell PV-Module:
0 cells allowed

NO **red**

0% of the total amount of cells in the module

Example: 60 cell PV-Module:
0 cells allowed

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total

<10% of the total amount of cells in the module

Example: 60 cell PV-Module:
<6 cells allowed

2.8.2 Class B

Modules without very critical (red) cells and with no more than 10% critical (yellow) cells and no more than 20% uncritical (green) cells. The sum total of the marked cells may not exceed 20% of the cells.

	green	**<20%** of the total amount of cells in the module Example: 60 cell PV-Module: **<12 cells** allowed
	yellow	**<10%** of the total amount of cells in the module Example: 60 cell PV-Module: **<6 cells** allowed
NO	**red**	**0%** of the total amount of cells in the module Example: 60 cell PV-Module: **0 cells** allowed
	total	**<20%** of the total amount of cells in the module Example: 60 cell PV-Module: **<12 cells** allowed

2.8.3 Class C

Modules with fewer than 10% very critical (red) cells, more than 10% critical (yellow) cells or more than 20% uncritical (green) cells and in total less than 30% of marked cells.

green

≥20% of the total amount of cells in the module

Example: 60 cell PV-Module:

≥12 cells

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yellow

≥10% of the total amount of cells in the module

Example: 60 cell PV-Module:

≥6 cells

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red

<10% of the total amount of cells in the module

Example: 60 cell PV-Module:

<6 cells

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total

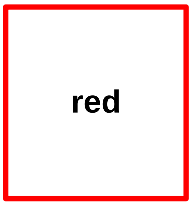
<30% of the total amount of cells in the module

Example: 60 cell PV-Module:

<18 cells

2.8.4 Class D

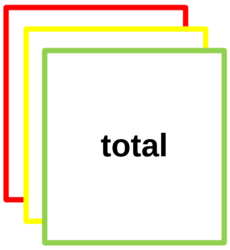
Modules with more than 10% very critical (red) cells or more than 30% marked cells in total.



≥10% of the total amount of cells in the module

Example: 60 cell PV-Module:

≥6 cells



≥30% of the total amount of cells in the module

Example: 60 cell PV-Module:

≥18 cells

3 Module judgment criteria for the power measurement

Class A

Only modules whose measured output is above the panel manufacturer's warranted power taking into account the measurement uncertainty of the Mobile Lab or Mobile PV-Testcenter.

Class B

Only modules whose measured output is above the warranted power but within the positive measurement uncertainty.

Class C

Only modules whose measured output is below the warranted power but still within the negative measurement uncertainty.

Class D

Modules whose output is below the warranted power taking into account the measurement uncertainty of the Mobile Lab or Mobile PV-Testcenter.

Example:

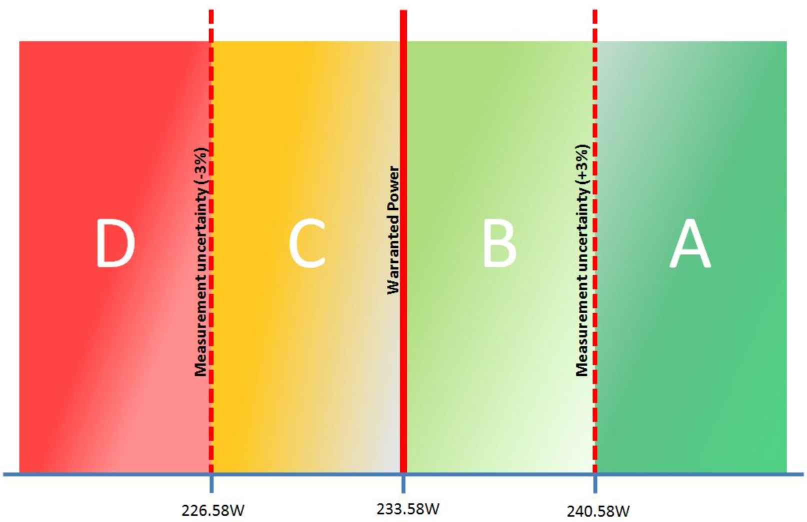
Nominal power = 250W; Manufacturer Tolerances = ± 3%: means ± 7.5W
Warranted power = 250W - 7.5 W = 242.5W
Initial degradation (first year) = 3%; means 7,275W for 242.5W
Linear degradation = 0.7%/year; means 1.698W/year for 242,5W
Module age = 2 years
Warranted power after aging = 242.5 - 7,275W - 1.698W = **233,58W**
Measurement uncertainty of MBJ Flasher (example): ± 3% means ± 7W for 233,58W (226,58W, 240,58W)

CLASS A: Power MBJ@STC ≥ 240.58 Watts

CLASS B: Power MBJ@STC ≥ 233.58 Watts < 240.58 Watts

CLASS C: Power MBJ@STC ≥ 226.58 Watts < 233.58 Watts

CLASS D: Power MBJ@STC < 226.58 Watts



4 Module judgment criteria for the thermal imaging

The focus of the thermal imaging lies especially in the so-called "hot spots". These small regions have a significantly higher temperature than the rest of the module.

Class A

Only modules that have no thermographically conspicuous areas.

Class B

Only modules whose difference between the temperature of conspicuous areas on the module and average temperature of the module is below 5 °C.

Class C

Only modules whose difference between the temperature of conspicuous areas on the module and average temperature of the module is between 5°C and 30°C.

Class D

Only modules whose difference between the temperature of conspicuous areas on the module and the average temperature of the module is more than 30 °C.

5 Overall module judgment

The resulting overall module judgment will be the worst judgment of the three test methods. Means the worst class the module was judged to at electroluminescence, power measurement or thermal imaging.

Example:

Electroluminescence result:	Class B	worst class wins
Power measurement result:	Class A	
Thermal imaging result:	Class A	
Overall module result:	**Class B**	