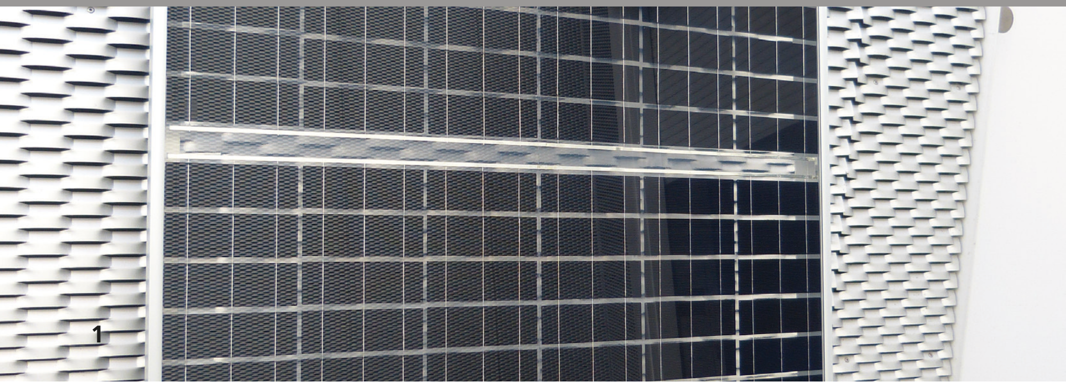
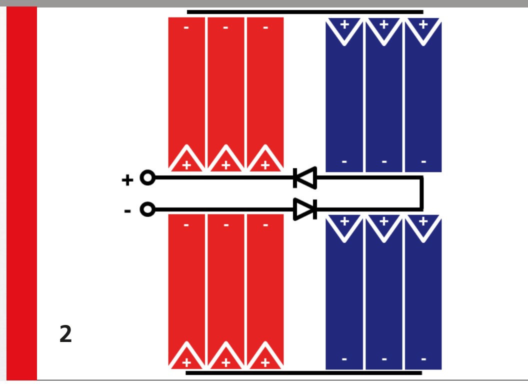
Fraunhofer CSP

FRAUNHOFER CENTER FOR SILICON PHOTOVOLTAICS CSP





1 *One-third module with in-laminated solar wafer as bypass diode.*
2 *The interconnection of the 144 one-third cells module. Every string consists of 12 one-third cells, three strings connected in parallel form a block and two blocks are secured with a bypass diode. The module has two blocks in series.*

ONE-THIRD CELL MODULE WITH IN-LAMINATED SOLAR WAFER AS BYPASS DIODE

The one-third cell module of Fraunhofer CSP is made in Module Technology Center (MTZ) in Schkopau. The module demonstrates five unique features compared to the conventional modules.

One-Third Cells

Cutting cells reduces the current through each cell and therefore, the losses due to the series resistances in ribbons are decreased. Since the series resistance losses are related to the square of the current, cutting the cells in half or three parts reduces the losses four and nine times respectively. Typically the series resistance losses in module level are 8W. With halved-cells 6W and with one-third cells 7W can be saved in a module. The module consists of 144 one-third cells and corresponds to a module with 48 full cells.

Extra Narrow Ribbons

Lower current and lower losses due to the series resistances allow us to reduce the ribbon widths. Here, there is always an optimization potential between the electrical and optical losses as well as the material costs. Optimization between the electrical and optical losses is important while the electrical losses scale with square of the current and irradiation but the associated optical losses changes linearly by variations of irradiation. In the areas with frequent high irradiation, reduction of the electrical losses is important while in the warm environments with low irradiation, the reduction of the optical losses is recommended. The ribbon width for the exhibited module is 0.8 mm.

Fraunhofer Center for Silicon Photovoltaics CSP

Otto-Eissfeldt-Strasse 12
06120 Halle (Saale) | Germany

Contact

Jens Schneider
Phone +49 345 5589 5500
jens.schneider@csp.fraunhofer.de

www.csp.fraunhofer.de

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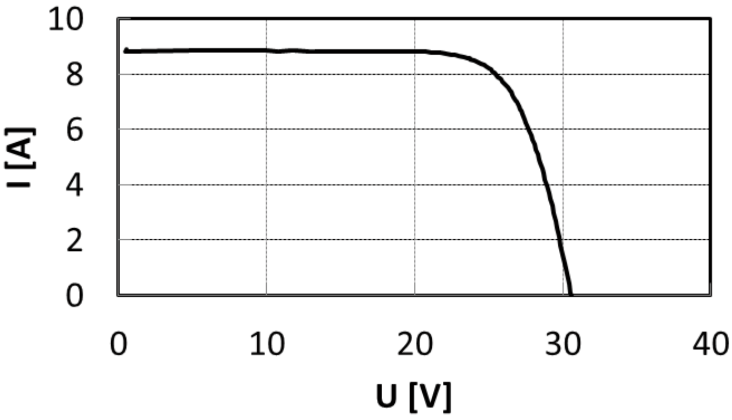

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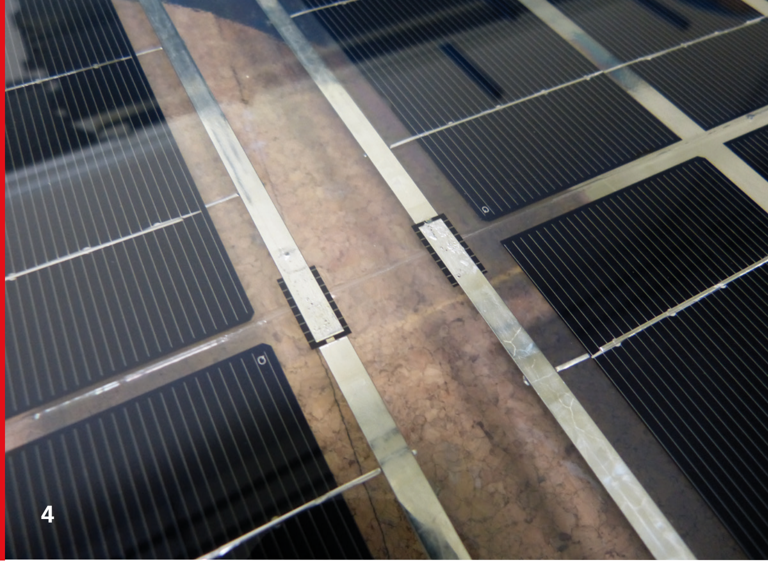

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Shade Resistance Module

In order to keep the module with one-third cells compatible with the other conventional modules, the electrical current at the module's terminals should be similar to the standard modules. Therefore, in module with divided cells, strings should be connected in parallel. In this case, three strings of one-third cells are connected in parallel and the current remains the same as the standard modules. In principle, a cell is divided to three parts and connected to each other in parallel. This can be interpreted as a 9-ribbons cell made from 3-ribbons cells. Moreover, the parallel strings have the advantage that when a string is shadowed, the other two continue to carry the power. This interconnection enables a power balance between the strings and extra power is gained under shading conditions.

Solar-wafer Based In-Laminated Bypass Diode

Smaller cells means more cells in module. To prevent hot-spots, not more than 20-24 cells should be connected in series. Therefore, the modules with a higher number of cut cells are always a challenge concerning the interconnection layout. In particular, gathering the strings busbars in a central junction box is very complex and unattractive.

Using decentralized junction boxes or in-laminated bypass diodes allow for elegant solutions. In-laminated bypass diodes could not find a way to PV market since the standard designs of available flat Schottky diodes are not reliable to be laminated inside modules. Fraunhofer Center for Silicon Photovoltaics CSP follows the approach of producing bypass diodes on solar wafers with typical photovoltaic material and production processes. The bypass diode used in the exhibited module is indeed a solar cell. The diode works sufficiently well in reverse direction (With power dissipation of 111 mW under STC and 0.5rel.% of power loss). However, the cell becomes too hot in forward direction. Currently at Fraunhofer CSP, a Schottky diode is being developed on a solar wafer which is suitable to be used as the in-laminated bypass diode.

Electrical Characteristics of the Module:

Power	P_{mpp} = 205W
Efficiency (for cell area)	η = 17,6%
CTM power ratio	CTM = 91,6%
Open-circuit voltage	V_{oc} = 636mV/
Short-circuit current	I_{sc} = 8,87A
Fill factor	FF = 75,7%

Transparent ETFE Back Sheet

The module has transparent back sheet. This allows a closer inspection of the module in the exhibition as both sides of the module remains visible. ETFE foils have excellent lifetime and very high transparency. By surface activation or coating, very good adhesion properties are achieved. Therefore, ETFE foils are used as front and back sheets for all types of solar modules. Due to the relatively high costs, ETFE foils play a minor role in photovoltaics. ETFE foils can be used as view in modern buildings. One of the known examples is the Allianz Arena in Munich, the football stadium of Bayern Munich and TSV 1860 Munich.

3 *Current-voltage curve for the one-third module.*

4 *Solar cells as bypass diodes. These cells will be replaced by the Schottky diodes made from solar wafers.*