

CSP

# Material Passport **PV Module**



# **Individual PV Module Material Passport**

Comprehensive and quantitative material analytics to ensure **Quality, Safety** and **Recyclability** 





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# **PV Material Passport**

**Overview of Features** 





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# **Electrical Characteristic**

## PV Module Performance



- Power at STC (with 25°C, AM1.5 spectra, 1000 W/m<sup>2</sup>)
- Module efficiency: 17,6%

|                       | I <sub>sc</sub> | V <sub>oc</sub> | P <sub>MPP</sub> | U <sub>MPP</sub> | I <sub>MPP</sub> | FF   |
|-----------------------|-----------------|-----------------|------------------|------------------|------------------|------|
|                       | [A]             | [V]             | [W]              | [V]              | [A]              | [%]  |
| 1000 W/m <sup>2</sup> | 10.45           | 13.81           | 112.4            | 11.41            | 9.86             | 77.8 |

#### **Contraction:** Verification of Module Data Sheet



# **Electrical Characteristic**

## PV Module Performance



- Power at STC with 25°C, AM1.5 spectra (1000 W/m<sup>2</sup>) and power at low irradiation (200 W/m<sup>2</sup>)
- Module efficiency: 17,6%

|                       | I <sub>sc</sub><br>[A] | V <sub>oc</sub><br>[V] | P <sub>MPP</sub><br>[W] | U <sub>MPP</sub><br>[V] | I <sub>MPP</sub><br>[A] | FF<br>[%] |
|-----------------------|------------------------|------------------------|-------------------------|-------------------------|-------------------------|-----------|
| 1000 W/m <sup>2</sup> | 10.45                  | 13.81                  | 112.4                   | 11.41                   | 9.86                    | 77.8      |
| 200 W/m <sup>2</sup>  | 2.10                   | 12.89                  | 21.4                    | 10.94                   | 1.96                    | 79.2      |

#### **C** Application: Verification of Module Data Sheet



# **Electrical Characteristic**

#### Current Dependent Electroluminescence (EL) Imaging

#### EL, I = 12 A (overload current), 3 s



#### EL, I = 10.5 A (I<sub>SC</sub>), 1 s



#### EL, I = 1.05 A (low current), 10 s



- Influence of defects and quality of the cells with different operating currents of the PV module becomes visible.
- This module shows few defects, some cells show power gradients.
- The overall performance for this demonstrator is acceptable.



# **Glass Properties**

## Chemical Composition and Impurities





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# **Glass Properties** Optical Characteristics



- High visual transmittance is needed for optimal light absorption
- Present PV module has no ARC coating



# **Solar Cell Properties**

Identification of Cell Type: Mono-crystalline Bifacial PERC Solar Cells

PV module contains 40 mono-crystalline bifacial PERC half-cells (166 x 83 mm<sup>2</sup>, 9BB) with 150 µm thickness



Ribbon Cell Connector

Which material values (e.g. Ag) can be estimated from the solar cell metallization and from connectors? How much critical materials (e.g. Pb) must be expected?



# **Solar Cell Properties**

Estimation of Valuable and Critical Materials from Cell Metallization and Connectors by SEM/EDS

| Element | Ribbon<br>At % | Cell<br>Connector<br>At % | Cell FS<br>Pad<br>At % | Cell FS<br>Busbar<br>At % | Cell FS<br>Finger<br>At % | Cell BS<br>Pad<br>At % | Cell BS<br>Busbar<br>At % | Cell BS<br>Finger<br>At% |
|---------|----------------|---------------------------|------------------------|---------------------------|---------------------------|------------------------|---------------------------|--------------------------|
| 0       | 14.4           |                           | 10.8                   | 15                        | 16.4                      | 23.9                   | 12.7                      | 12.1                     |
| Cu      |                |                           | 1.4                    | 1.6                       | 1.2                       | 1.8                    |                           |                          |
| Mg      |                |                           | 1.3                    | 1.2                       | 1.1                       | 0.9                    |                           |                          |
| AI      |                |                           | 2.8                    | 2.4                       | 4.7                       | 3.3                    | 77.3                      | 74.2                     |
| Si      | 1.3            |                           | 10                     | 9.5                       | 9.2                       | 8.5                    | 7.8                       | 12.9                     |
| Ag      |                | 100                       | 73.7                   | 70.3                      | 67.4                      | 61.6                   | 1.7                       | 0.4                      |
| Fe      | 4.6            |                           |                        |                           |                           |                        |                           |                          |
| Pb      | 13.6           |                           |                        |                           |                           |                        |                           |                          |
| Sn      | 61.3           |                           |                        |                           |                           |                        |                           |                          |
| Са      | 4.7            |                           |                        |                           |                           |                        |                           |                          |

Tabular summary: Composition with data in atomic percent (FS = front side; BS = back side)

#### Estimation of 20-40 mg Pb and 1,6 g Ag (from connectors) and 3-5 g Ag (solar cells) for this module



SEM overview of EDS analyzed areas



## **Polymers**

## Identification and Evaluation of Condition of Used Polymer Materials for Quality Control

 Knowledge of the encapsulation material and its properties (e.g. degree of cross-linking, water content or the presence of additives) has a significant influence on the reliability of the modules and possible degradation mechanisms

#### Why is water content of interest?

- directly linked with inverter tripping and moisture-induced degradation
- Back sheet type defines the moisture content in the module and its lifetime



#### Identification of the module's polymers:

- Front side encapsulation: EVA
- Back side encapsulation: POE
- Backsheet: PET
  - Water ingress predestines future performance losses and can be used as an early degradation marker for lifetime assessments.
  - The concept enables module manufacturers and project developers to quickly check BOMs for water ingress.



## **Polymers**

## Non-destructive Lamination Control: Back and Front



- Module shows inhomogeneities in lamination
- Lamination flaws can be easily revealed (here due to material variability)
- Modules of any configuration (including double glass) can be measured



## **Polymers**

## Identification and investigation of the degradation of encapsulants

#### **Important Checks:**

- Present additives and their distribution in the roll
- Batch-to-batch variation
- Quantities



