Heterojunction cells combined with smart wire bifacial modules

Andreas Waltinger, Benedicte Bonnet-Eymard, Heiko Mehlich, Jun Zhao
Overview

- New PV generation
- Pilot line of Meyer Burger (Germany) AG
- Busbarless Heterojunction cells
- Bifacial properties of HJT cells
- Module designs of MB
- Summary
The new PV generation

A. Diamond Wire
- Thinner wafer → Lower costs
- Suitable for SmartWire Connection

B. Single Wafer Tracking
- Quality & performance control

C. Heterojunction (HJT)
- High efficiency
  - Lower system cost (BOS)
  - Independent of wafer thickness
- Only 6 process steps
  - Low COO
- Temperature coefficient
  - Higher energy yield
- Bifacial design
  - Higher energy yield

D. Adapted test metrology
- High cap cells
- Busbarless cells
- DragonBack
- PED (Chipping)

E. SmartWire Connection (SWCT)
- TCO layer and wafer thickness suitable for SmartWire
  - 80% less silver
  - Higher energy yield
  - Higher efficiency
  - Micro-crack resistant
Pilot Line  Cell Process Hohenstein-Ernstthal

- Pilot line with 15MW capacity was installed in Q1 2015
- Process Knowhow was transferred from the previous R&D line
- The key equipments HELiA PECVD and PVD as well as the Curing Furnace CALiPSO combined with Process Intelligence (Testing & MES) are from MB
- Other tools are from 3rd party vendors
HJT Pilot Production Cell Line Performance

- Weekly production: ~25,000 cells, averaged efficiency 22%
Certified busbarless cells

- GridTOUCH was established at ISE Callab in 2016 in strong collaboration with the Meyer Burger Group
- Shading-free Isc extrapolation by different wire configurations → 15, 25, 35 wire

- Calibration reports for busbarless cells available now
- Bifacial contacting by black contact foil or bottom wires

22,9% confirmed for industrial HJT cell
Cell properties

- Internal measurement shows 23.0% efficiency (22.9% confirmed independently)
- Excellent temperature coefficients

<table>
<thead>
<tr>
<th>Temperature Coefficient</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>TC Isc</td>
<td>+ 0.035 %/K</td>
</tr>
<tr>
<td>TC Voc</td>
<td>- 0.241 %/K</td>
</tr>
<tr>
<td>TC Pmax</td>
<td>- 0.239 %/K</td>
</tr>
</tbody>
</table>

- Pmax: 5.625 W
- Isc: 9.234 A
- Voc: 0.741 V
- Ipmax: 8.720 A
- Vpmax: 0.645 V
- Eff: 23.03%
Bifacial properties

- What happens in a backsheet module?

![I-V-curve MBG cell M2](image)

<table>
<thead>
<tr>
<th>1000 W @ front</th>
<th>1000W w/ Al-Backsheet</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pmax</strong> 5,625 W</td>
<td><strong>Pmax</strong> 5,666 W</td>
</tr>
<tr>
<td><strong>Isc</strong> 9,234 A</td>
<td><strong>Isc</strong> 9,383 A</td>
</tr>
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<td><strong>Voc</strong> 0,741 V</td>
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<tr>
<td><strong>Ipmax</strong> 8,720 A</td>
<td><strong>Ipmax</strong> 8,870 A</td>
</tr>
<tr>
<td><strong>Vpmax</strong> 0,645 V</td>
<td><strong>Vpmax</strong> 0,639 V</td>
</tr>
<tr>
<td><strong>Eff 23,03 %</strong></td>
<td><strong>Eff 23,20 %</strong></td>
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- \( I_{sc}\)-gain \(\approx 150\,mA \)
- \( \text{Eff}-\text{gain} \approx 0,2\% \)
Bifacial properties

- What’s about bifaciality factors?

<table>
<thead>
<tr>
<th>Parameter</th>
<th>1000 W @ front</th>
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</thead>
<tbody>
<tr>
<td>P&lt;sub&gt;max&lt;/sub&gt;</td>
<td>5,625 W</td>
<td>5,387 W</td>
</tr>
<tr>
<td>I&lt;sub&gt;sc&lt;/sub&gt;</td>
<td>9,234 A</td>
<td>8,605 A</td>
</tr>
<tr>
<td>V&lt;sub&gt;oc&lt;/sub&gt;</td>
<td>0,741 V</td>
<td>0,740 V</td>
</tr>
<tr>
<td>I&lt;sub&gt;pmax&lt;/sub&gt;</td>
<td>8,720 A</td>
<td>8,108 A</td>
</tr>
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<td>V&lt;sub&gt;pmax&lt;/sub&gt;</td>
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<td>22,06 %</td>
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I<sub>sc</sub>-Bifaciality = 93%

P<sub>max</sub>-Bifaciality = 96%
Bifacial properties

- $P_{\text{max}}$-bifaciality is a function of $I_{P_{\text{max}}}$-bifaciality and $R_{\text{ser}}$

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### I-V-curve MBG cell M2

- $P_{\text{max}}$-bifaciality is biased by FF-gain
- $P_{\text{losses}} = I_{P_{\text{max}}}^2 \cdot R_{\text{ser}}$
- $\Delta P_{\text{losses}} = \Delta I_{P_{\text{max}}}^2 \cdot R_{\text{ser}}$
- $\Delta P_{\text{losses}} \approx -3\%$

### Bifacialities

<table>
<thead>
<tr>
<th></th>
<th>$P_{\text{max}}$</th>
<th>$I_{sc}$</th>
<th>$V_{oc}$</th>
<th>$I_{P_{\text{max}}}$</th>
<th>$V_{P_{\text{max}}}$</th>
<th>Eff</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>96%</td>
<td>93%</td>
<td>100%</td>
<td>93%</td>
<td>103%</td>
<td>96%</td>
</tr>
</tbody>
</table>

### 1000 W @ rear

<table>
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<tr>
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<th>$P_{\text{max}}$</th>
<th>$I_{sc}$</th>
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Bifacial properties

- Equivalent irradiance method according Pasan for Albedo factors of 10% and 20%

1. Bifaciality determination at STC:
   \[ \varphi_{Isc} = \frac{Isc_{rear}}{Isc_{front}} \]

2. I-V characterization vs. backside illumination:
   Equivalent 1-side irradiance levels
   \[ G_{total} = 1000 \text{Wm}^{-2} + \varphi_{Isc} \cdot G_{rear} \]

3. Specific Pmax reporting:
   \[ P_{max\_Bifi10} = P_{max \ with \ G_{rear} = 100 \text{Wm}^{-2}} \]
   or at \[ G_{total}=1000 \text{Wm}^{-2} + \varphi_{Isc} \cdot 100 \text{Wm}^{-2} \]
Bifacial properties

- Equivalent irradiance method according Pasan for Albedo factors of 10% and 20%

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<tr>
<td>Pmax</td>
<td>6,136 W</td>
</tr>
<tr>
<td>Isc</td>
<td>10,072 A</td>
</tr>
<tr>
<td>Voc</td>
<td>0,742 V</td>
</tr>
<tr>
<td>Ipmax</td>
<td>9,508 A</td>
</tr>
<tr>
<td>Vpmax</td>
<td>0,645 V</td>
</tr>
<tr>
<td>Eff</td>
<td>25,12 %</td>
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Isc-gain ≈ 0,5A  
Eff-gain ≈ 2,1%
Bifacial properties

- $P_{\text{max}}^{\text{Bifi10}} = 6,136\,\text{W}$ and $P_{\text{max}}^{\text{Bifi20}} = 6,646\,\text{W}$ (illuminated with 1093\,W & 1186\,W)

I-V-curve MBG cell M2

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$I_{\text{sc}}$-gain $\approx 0.5\,\text{A}$
Eff-gain $\approx 2.1\%$
Module designs of MB

Glass-Glass modules with bifacial HJT cells and SWCT

Designs
- Abalone SmartWire (BOM: 10127096)
- Abalone SmartWire white (BOM: 10127097)
- Abalone SmartWire optimal (BOM: 10127098)

~400 modules
~50 modules
~50 modules

Specificity
- Centralized jbox (Tyco)
- Transparent back glass
- Centralized jbox (Tyco)
- White back glass
- Decentralized jbox (Renhe)
- Transparent back glass

Advantages
- Easy to produce on the wave line
- Bifacial module
- Easy to produce on the wave line
- No jbox shading
- Not dependant on rear side illumination
- Low jbox shadowing (6 cells covered by less than 1%)
- Jbox half the price than Tyco's
- 3 holes (instead of 4)
- Bifacial module

Disadvantages
- Jbox shadowing (2 cells over 20% covered)
- Mounting stage shadowing
- Rear illumination not collected
- Manual mounting of the jboxes
- Mounting stage shadowing
Bifacial glass-glass modules(7,9),(986,986)

**SmartWire**

- Polymeric foil with wires
- Encapsulant
- Cell
- Wire
- Foil

**Record modules**

- 320W black backsheets
- 330W white backsheets

**Outdoor data**

Example: Outdoor data from SUPSI (Switzerland) for March 2014 (max. module temp. 40°C)

- P_{module}/P_{TDC} [A.U.]
- HJT Mono-facial
- HJT Bifacial
- STD Multi

> 92% Isc-Bifaciality
Summary

- Meyer Burger enforces the **New PV generation** by optimizing modules across the entire value chain **on mass production level**. Machine and technology developments go hand in hand (Wafering – Cell – Module).

- Almost **500,000 HJT bifacial cells** were produced since 2015. Mean **efficiency** is **higher than 22%**.

- **Busbarless** cells are **measurable correctly** by calibrated reference cells (calibration measurements are available for 15, 25 and 35 wires).

- Heterojunction cells are very applicable for bifacial designs due to their symmetric architecture. A **$J_{sc}$-bifaciality of 93%** has been achieved.

- Equivalent irradiance method shows potential of **27% cell efficiency for 20% Albedo**.

- SWCT-glass-glass modules can be optimized for several application: → **white back glass or transparent back glass with decentralized J-box**

- **Outdoor tests show higher energy yield (+13%)** than other cell technologies
«Your task is not to foresee the future, but to enable it!»
Antoine de Saint-Exupéry

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Thank you!