MWT Silicon Heterojunction
A Simple Technology Integrating High Performance Cell and Module Technologies

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• From Cell to Module
• ECN developments foil based back-contact cells and module technologies
  – Thin cells
  – Cost reduction of module materials
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  – *MWT-HJ cells and implications for modules*
  – View towards applications
• Summary and Outlook
From standard to High $\eta$ Si cell concepts

- From p- to n-type front to back contacted (PERT, HJ)
- From front to back contact to back contact (MWT, IBC)
- From monofacial to bifacial (> kWh/kWp)

N mono IBC
N mono HJ
N mono PERC
P mono PERC
P monolike PERC
P multi PERC

ITRPV roadmap 2015

ITRPV 2015: Average stabilized efficiency values for Si solar cells (156x156mm²).
To be translated to High Power modules

• Products: 60 cells 156 mm
• Optimize CtM
• Low cost without sacrificing quality and reliability
• Long term reliability is crucial for stable growth

ITRPV roadmap 2015
Expected market shares

Trends according to ITRPV roadmap:

- PERC concepts will become mainstream
- Back Contact and HJ concepts expected to increase for niche markets
How to adapt the module technology so that it fits with a specific cell concept

Each cell concept has to be individually evaluated for the best module concept in terms of:

- Long term stability $\rightarrow >30$ years product lifetime
- Lowest cell to module losses $\rightarrow$ CtM value
- Optimized production costs $\rightarrow$ high yields, low investment costs
- Optimized Bill of Materials (BoM)
- Best energy yield $\rightarrow$ temperature, low light, incident angle, shadow...

There are special requirements for individual concepts, a.o.
- IBC: soldering not trivial
- SHJ: low Temperature interconnection, barrier for moisture ingress
- Etc...

Schneider, ISC, Tokyo, 2013
From cell to module.... different approaches

- **Standard**

- **Front to rear contact (Perc, HJ)**
  - Move to more busbars: 2,3,4,5
  - No Busbars: Multiwire/smartwire (Schmid, MB)
  - Shingling, cascading (Sunpower, Silevo)

- **Back Contact (MWT, IBC)**
  - Rear soldering (tabbing, woven fabrics, MW) (ISE, imc)
  - Smart tab edge interconnection (Sunpower)
  - **Foil interconnection technology (ECN, Eurotron,..)**
**Cell to module: Back Contact**

MWT, IBC: foil

- **Conductive back-sheet foil**
  - Copper as conductive layer
  - Patterning by chemical etching or milling
- **Contact cell to foil through conductive adhesive**
  - Printed on foil
- **Isolation cell from foil by encapsulant**
  - Holes at contacts
Cell to module: Back Contact

• Reliability proven
  – IEC certification achieved
• Production equipment developed by Eurotron: high level of automisation
  – >300 Wp nMWT certified
  – >280 Wp IBC (120 micron cells, special BoM design for recycling)
Back Contact Module R&D at ECN

- BoM testing in mini pilot module line: 4 cells modules as scale model for large area module
  - Integration of (thin) BC cells from ECN cell baselines or other sources
  - Comparison of module materials and new processes
  - CtM power optimization by optical and electrical engineering
  - Reliability, outdoor testing
  - Special prototypes

6 via MWT  All black IBC  Cu CBS  Cu Coldspray on Al CBS
Cell-to-module change

- A paper is published in PV-International this month on CtM changes specifically for back-contact module technology

Positive cell-to-module change: Getting more power out of back-contact modules

Bas B. van Aken & Lenneke H. Slooff-Hoek, ECN – Solar Energy, Petten, The Netherlands

ABSTRACT

Cell-to-module (CtM) loss is the loss in power when a number of cells are interconnected and laminated in the creation of a PV module. These losses can be differentiated into optical losses, leading to a lower photogenerated current, and resistive losses, leading to a decrease in fill factor. However, since the application of anti-reflection (AR) coatings and other optical ‘tricks’ can sometimes increase the $I_{oc}$ of the module with respect to the average cell $I_{oc}$, the CtM loss in such cases needs to be expressed as a negative value, which gives rise to confusion. It is proposed to use the CtM change, where a negative value corresponds to a loss in current or power, and a positive value to a gain. In this paper, the CtM changes for back-contact modules utilizing a conductive foil are described and compared with other mature module technologies. A detailed analysis of the CtM change for a full-size metal-wrap-through (MWT) module is presented.
Handling of thin cells

- IBC cells down to 80 micron cells with adapted processing
- 4 cells mini modules have been fabricated: no breakage/cracks and FF > 74%
- Cell handling down to 80 micron proven with industrial module equipment (Eurotron)

< € / m²

100 micron

80 micron

Automated handling with industrial equipment
Reduction cost conductive back-sheet foil

- Replacing copper by aluminium
- Local application of Copper powder by Cold-Spray on Al foil
- Conductive adhesive printed on the Copper pads: < 1 mOhm Rc
- Potential cost saving ~3 Euro per full size backsheet

Goris et al. EUPVSEC 2016
Reduction cost conductive back-sheet foil

Performance MWT and IBC modules

<table>
<thead>
<tr>
<th>Module</th>
<th>FF [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>MWT on Cu</td>
<td>75.9</td>
</tr>
<tr>
<td>MWT on Al + CuCS</td>
<td>75.9</td>
</tr>
<tr>
<td>IBC on Cu</td>
<td>74.9</td>
</tr>
<tr>
<td>IBC on Al + CuCS</td>
<td>74.9</td>
</tr>
</tbody>
</table>

MWT Modules passed 3.5 x IEC test!
Similar trends observed for IBC after 1 x IEC
Reduction cost conductive adhesive

- Reduction silver content from >80% to <20%
- Reduction volume by using thinner encapsulants ➔ Powder coating
- More contact points possible without cost penalty
Reduction cost conductive adhesive

**Powder coating process**
- Electrostatic deposition technique
- Large freedom to tune layer thickness
- Applied on solar cells and glass
- Cleaning contact pads (punching is eliminated)

Spray booth and controller

Contact point cleaner

Coated cell and clean contact points
Reduction cost conductive adhesive

• MWT modules with Thermoplastic powder coated encapsulant on solar cell and glass: process proven for 150-200micron

<table>
<thead>
<tr>
<th>Encapsulant</th>
<th>Isc (A)</th>
<th>Voc (V)</th>
<th>FF (%)</th>
<th>Pm(W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Powder coat</td>
<td>8.81</td>
<td>2.52</td>
<td>75.9</td>
<td>16.82</td>
</tr>
<tr>
<td>EVA ref</td>
<td>8.75</td>
<td>2.52</td>
<td>75.9</td>
<td>16.66</td>
</tr>
</tbody>
</table>

• Challenge:
  – Find right materials that with stand IEC testing
  – Proof mechanical stability
Outdoor performance
p-MWT module (2007-2016)

**Fill factor:** -0.30%/year
1000 W/m²

**Current:** -0.36%/year
1000 W/m²

**Power:** -0.68%/year

**Electrical losses**
- FF loss
- Isc loss:
  - No module cleaning
Performance improvements? Back to cells......

- MWT-SHJ combines advantages of silicon heterojunction (SHJ) and metal wrap through (MWT) technologies in one device:
  - SHJ shows record Voc and has a low temperature coefficient for higher module energy yield
  - MWT shows Ag cost reduction and less shading in a module
  - Module technology meet low T requirements by soldering-free

\[ > \text{Wp/m}^2 \]
Results MWT-HJ cells

- Front side metallization improvements

From low T Ag to Cu-plated, 6 x 6 vias (developed at CIC)

<table>
<thead>
<tr>
<th>Structure</th>
<th>Front metal</th>
<th>$J_{sc}$ [mA/cm²] (shading)</th>
<th>$V_{oc}$ [mV]</th>
<th>FF [%]</th>
<th>$\eta$ [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>H-pattern</td>
<td>Ag 3BB*</td>
<td>38.9 (5.6%)</td>
<td>722</td>
<td>77.3</td>
<td>21.7</td>
</tr>
<tr>
<td>MWT 4x4</td>
<td>Ag</td>
<td>39.1 (3.7%)</td>
<td>726</td>
<td>76.6</td>
<td>21.7</td>
</tr>
<tr>
<td>MWT 6x6</td>
<td>Ag</td>
<td>39.2 (3.4%)</td>
<td>723</td>
<td>77.6</td>
<td>22.0</td>
</tr>
<tr>
<td>MWT 6x6</td>
<td>Ag</td>
<td>39.3</td>
<td>719</td>
<td>80.0</td>
<td>22.6</td>
</tr>
</tbody>
</table>

area = 243 cm²
$J_{sc}$ = 39.7 mA/cm²
$V_{oc}$ = 731 mV
FF = 79.8%
$\eta$ = 23.1%

Coletti, EUPVSEC proc. 2016
Ishimura, EUPVSEC proc. 2016
Results MWT-HJ cells

Reverse characteristics

\[ I_{\text{rev}} < 0.5 \, \text{A} \text{ at } -10 \, \text{V} \text{ for } 4 \times 4 \text{ and } 6 \times 6 \]

Sensitivity towards illumination

Shunt and recombination behavior comparable to H pattern SHJ

\[ > \frac{W_p}{m^2} \]
From MWT HJ cell to module.....

Concept is ideally suited for conductive back sheet module technology as is IBC HJ

- Low Temperature interconnection
- Solder free

Challenges for glass / polymer back sheet modules

- Optimize CtM:
  - First trials with single cell laminates (next slides)

- Reliability: change and optimize BoM to cope with increased sensitivity towards moisture
  - Work in progress
From MWT HJ cell to module.....

CtM change of the fill factor for various interconnection schemes

- Only resistive losses in interconnection material: tabs, wires, foil
- the calculated power loss is inversely proportional to resistance and thus to the total cross-section of the interconnection material

Van Aken, PV international October, 2016
From MWT HJ cell to module....

CtM change for soldered and back contact single cell laminates
- Electrical layout not optimized: explains larger CtM change
- Relative improvement CtM change BC vs. Soldered

> Wp / m²
View towards applications

- Broaden applicability: Focus on systems and applications in BIPV
  - aesthetics, uniform appearance
  - size flexibility, shade tolerance
  - freedom of design

**TESSERA**

Low-current diode

ECN patent pending

Eurotron, Heliox, Stafier
Summary & Outlook

• All different HE solar cell concepts can be translated to a specific module concept and fulfill all the demands: highest yield, lifetime, low costs,.. there is not one module concept that fits all cell concepts

• Market adoption of new cell and module concepts is not straightforward
  – Incremental improvements preferred
  – Bankability: lack of long term field experience data

• How to accelerate market uptake?
  – Show competitiveness by significant performance improvements, cost reduction approaches and field data collection!!
  – Broaden applicability BIPV: Aesthetics, transparency, colours, flexibility of shape & size, etc, I2PV: Bifaciality
Acknowledgements

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