Industrialization of SHJ concepts

J. Krause, H. Mehlich, J. Zhao, M. König
HERCULES workshop – Konstanz 2015
Motivation - new PV generation

A. Diamond Wire
- Thinner wafer ➔ Lower costs
- 180 μm → 160 μm → 140 μm → 120 μm → 100 μm

B. Single Wafer Tracking
- Quality & performance control

C. Heterojunction (HJT)
- Texture
- a-Si front/ rear side
- TCO/metal rear contact
- Print front side
- Curing
- Test & Sort
- High efficiency
- Lower system cost (BOS)
- Independent of wafer thickness
- Only 6 process steps
- Low COO
- Temperature coefficient
- Higher energy yield
- Bifacial ➔ Higher energy yield

D. Adapted test metrology
- High cap cells
- Busbarless cells
- DragonBack

E. SmartWire Connection (SWCT)
- TCO layer and wafer thickness suitable for SmartWire
- 80% less silver
- Higher energy yield
- Higher efficiency
- Longevity and micro-crack resistant

Technology powered by Roth & Rau / 22/04/15

5th Silicon PV, Konstanz - March 2015
Outline

- Heterojunction Cell Concept – Bifacial Rear Emitter
- Module Performance
- Status Demo Line
- First Cell Results in Ramp Up Phase
Outline

- Heterojunction Cell Concept – Bifacial Rear Emitter
  - Module Performance
  - Status Demo Line
  - First Cell Results in Ramp Up Phase
Cell concepts/structures
Long term technology roadmap

Gen 3
Rear side contacts thin wafer (<120µm)

Gen 2
Rear side emitter device
Modified TCO, bifacial, wafer thickness 145µm

Gen 1
Classic HJT device w/intrinsic layer, front side emitter, monofacial, wafer thickness 180µm
POR Monitoring SWCT

-> increase in $I_{sc}$, excellent FF

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Si-HJT solar cell

Texture & Clean
Wet chemistry

a-Si Front (~10nm)
a-Si Rear (~10nm)
PECVD (< 200°C)

TCO front
TCO back
PVD (< 200°C)

Metal + Cure
screen printing (< 200°C)

n type c-Si

silver grid
ITO \((\text{In}_2\text{O}_3:\text{SnO}_2)\)
a-Si (in)

silver grid
ITO \((\text{In}_2\text{O}_3:\text{SnO}_2)\)
a-Si (ip)
Outline

- Heterojunction Cell Concept – Bifacial Rear Emitter
- Module Performance
- Status Demo Line
- First Cell Results in Ramp Up Phase
Concept
combine bifacial SHJ cell with SWCT module
Concept & Performance
Best HJT + SWCT module power

SUPSI

STS 531

P_{MPP} 327W
I_{SC} 9.5 A
V_{OC} 44.01 V
FF 78.2 %
Concept & Performance
HJT modules are quality tested

<table>
<thead>
<tr>
<th></th>
<th>Initial</th>
<th>DH3000</th>
<th>DH4000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eff (%)</td>
<td>21.1</td>
<td>20.8</td>
<td>20.9</td>
</tr>
<tr>
<td>$J_{SC}$ (mA/cm²)</td>
<td>37.6</td>
<td>37.0</td>
<td>37.2</td>
</tr>
<tr>
<td>$V_{OC}$ (mV/cell)</td>
<td>731</td>
<td>733</td>
<td>733</td>
</tr>
<tr>
<td>FF (%)</td>
<td>76.8</td>
<td>76.7</td>
<td>76.7</td>
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<tr>
<td>$P_{max}$ (W)</td>
<td>308</td>
<td>304</td>
<td>305</td>
</tr>
<tr>
<td>Degradation</td>
<td>0.0</td>
<td>-1.3%</td>
<td>-1.0%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Initial</th>
<th>TC200</th>
<th>TC600</th>
<th>TC800</th>
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</thead>
<tbody>
<tr>
<td>$P_{max}$ (W)</td>
<td>274</td>
<td>273</td>
<td>270</td>
<td>267</td>
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<tr>
<td>$I_{SC}$ (A)</td>
<td>8.21</td>
<td>8.18</td>
<td>8.21</td>
<td>8.27</td>
</tr>
<tr>
<td>$V_{OC}$ (V)</td>
<td>43.17</td>
<td>43.2</td>
<td>43.4</td>
<td>43.5</td>
</tr>
<tr>
<td>FF (%)</td>
<td>77.4</td>
<td>77.0</td>
<td>75.7</td>
<td>74.8</td>
</tr>
<tr>
<td>Degradation</td>
<td>0.0</td>
<td>-0.4%</td>
<td>-1.6%</td>
<td>-2.5%</td>
</tr>
</tbody>
</table>

Excellent Reliability
4 x IEC passed

[Faes, PVSEC 2014]
Concept & Performance
HJT SWCT module reliability proven

Certified by TÜV Saar according IEC 61215/61730, fire & PID testing included
Concept & Performance
Superior temperature coefficient – high energy yield

-0.20 %/K on Cell level!

-0.22 %/K on Module level!

Excellent Temperature Coefficient certified by ISE CalLab and TÜV Rheinland!
Energy yield – reliability in the field

+12.6% energy yield with HJT bifacial module compared to monofacial HJT.
Outline

- Heterojunction Cell Concept – Bifacial Rear Emitter
- Module Performance
- Status Demo Line
- First Cell Results in Ramp Up Phase
Demo cell line
## Processes

### Texturing and clean

**Wet Bench – Texturing & Clean**

- Advanced texturing & cleaning process for HJT solar cells
- Alkaline Texturing and Cleaning
- IPA free alkaline texturing
- Automatic Carrier Handling System

**Process steps:**
- Saw damage removal
- Texturing
- Clean and surface preparation

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### Process Steps

<table>
<thead>
<tr>
<th>Step 1</th>
<th>Step 2</th>
<th>Step 3</th>
<th>Step 4</th>
<th>Step 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test/Sort</td>
<td>PECVD a-Si:H</td>
<td>PVD TCO + metal</td>
<td>Contact Printing</td>
<td>Curing</td>
</tr>
</tbody>
</table>

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**5th Silicon PV, Konstanz - March 2015**
**HELiA<sub>PECVD</sub> – Intrinsic and doped Si layer**

- PECVD system for the deposition of semiconductor and dielectric layers
- Batch system with modular design and integrated automation
- Excellent intrinsic and doped a-Si layer properties
- Stable and uniform process without cross contamination
- Low temperature processing: lowest production costs, compatible with thin wafers
- Maintenance free chamber, dry clean
### HELiAPVD – TCO and metal layer

<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>PVD system</td>
<td>for the deposition of TCO and metal layers</td>
</tr>
<tr>
<td>Double-side deposition</td>
<td>in one pass through without wafer flipping</td>
</tr>
<tr>
<td>Integrated edge isolation</td>
<td></td>
</tr>
<tr>
<td>TCO and metal layers</td>
<td>with excellent optical, electrical and mechanical performance</td>
</tr>
<tr>
<td>Inline system</td>
<td>with integrated automation</td>
</tr>
<tr>
<td>Modular system</td>
<td>flexible coating-layer design, different custom stack-structures possible</td>
</tr>
<tr>
<td>Rotary magnetrons</td>
<td>for high target utilization, long MTBM and short MTTM for low production cost</td>
</tr>
</tbody>
</table>

**Processes**

PVD TCO + metal

**Texturing & clean**

PECVD a-Si:H

PVD TCO + metal

Contact Printing

Curing

Test/Sort

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**Metallization – Printing front contacts**

- High throughput metallization front side contacts
- High speed screen printer with multiple and flexible printing modules
- High accuracy and print repeatability
- Integrated front side inspection and paste-saving automatic dispensing
- Sensitive process adjustment
- Low footprint

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**Processes**

Fine line printing
CALiPSO – Flexible curing furnace

- Using the flexible inline furnace platform CALiPSO in A-C-D configuration
- Ceramic roller transport system for metal free and smooth cell transport
- Precise temperature control and excellent temperature uniformity
- Stable process conditions – excellent temperature uniformity (± 2°C across lanes)
- Lower consumption due to thermal equilibrium and low heat loss
## Tester & Sorter – SPOTLIGHT technology

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<tbody>
<tr>
<td>Cell testing &amp; sorting system</td>
</tr>
<tr>
<td>Special flasher design for characterization of high capacitive HJT solar cells</td>
</tr>
<tr>
<td>Two parallel flasher for high throughput</td>
</tr>
<tr>
<td>EL integration optionally</td>
</tr>
</tbody>
</table>

**Processes**

- Texturing & clean
- PECVD a-Si:H
- PVD TCO + metal
- Contact Printing
- Curing
- Test/Sort

Technology powered by ROTH & RAU CELL COATING SYSTEMS

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Outline

- Heterojunction Cell Concept – Bifacial Rear Emitter
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- First Cell Results in Ramp Up Phase
Best Cell in Pilot Production

**23.3 %**
on 6” CZ, screen print
av. 50 cells: 22.8%

### Performance Data

<table>
<thead>
<tr>
<th>Status</th>
<th>Cell</th>
<th>Area (cm²)</th>
<th>Eff. (%)</th>
<th>V&lt;sub&gt;oc&lt;/sub&gt; (mV)</th>
<th>FF (%)</th>
<th>J&lt;sub&gt;sc&lt;/sub&gt; (mA/cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>March 2015</td>
<td>CZ</td>
<td>238.5</td>
<td><strong>23.32</strong></td>
<td>739</td>
<td>80.7</td>
<td>39.06</td>
</tr>
<tr>
<td>Dec 2013</td>
<td>FZ</td>
<td>238.5</td>
<td>23.5%</td>
<td>738.8</td>
<td>83.1</td>
<td>38.3</td>
</tr>
</tbody>
</table>
Production run
March 2015
- Median 210 cells: 22.66% 
- Yield 98.1%
Next Steps

- further process window investigation
- Volume/Marathon testing, starting in May
- Manufacturing logistic optimization
Conclusion

- High Reliability for SHJ & SWCT certified
- Best Cell of Rear Emitter SHJ from production line >23% Eta
- av. 22.6% of 200 wafers in Ramp Up Phase
Thank you for your attention!

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