Tiger Pro

UNSW seminar:

Latest TOPCon research progress in Jinko and industrial innovation discussion
About myself

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R&D Director, Jinko Solar Co., Ltd

◆ PhD, The Australian National University
  First-class honour, The University of New South Wales
◆ Member of International Electrotechnical Commission
◆ Jiangxi Province Thousand Talents Program
◆ Zhejiang Province Ten Thousand Talents Program
Outline

- n-TOPCon research at Jinko Solar
- Discussion about industrial innovation work
- Hot topics in PV industry (questions welcome)
TOPCon Concept

Key parameters

• $V_{oc} > 710 \text{mV}$
• Cell Efficiency $> 24.5\%$
Key technical aspects

- **Passivating contact technology**
  - Excellent passivation performance, $J_0$ as low as 2 fA/cm²;

- **Novel metallization system**
  - Semi-isolation between metal and bulk
  - Ohmic contact in the poly-region

- **Optical optimization**
  - Front side optical optimisation

- **Better bulk material**
  - High lifetime n-type wafers
  - No LID degradation

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*Diagram showing key components and processes.*
**World record mono-Si 24.79%**

<table>
<thead>
<tr>
<th>Group</th>
<th>Voc (mV)</th>
<th>Isc (A)</th>
<th>FF (%)</th>
<th>Eta (%)</th>
<th>Area (cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Champion Cell</td>
<td>714.6</td>
<td>11.134</td>
<td>83.43</td>
<td>24.79</td>
<td>267.7</td>
</tr>
<tr>
<td></td>
<td><strong>714.9</strong></td>
<td><strong>11.122</strong></td>
<td><strong>83.78</strong></td>
<td><strong>24.87%</strong></td>
<td><strong>267.8</strong></td>
</tr>
<tr>
<td>Best Average</td>
<td>712.7</td>
<td>11.125</td>
<td>83.10</td>
<td>24.61</td>
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**World record mono-Si 24.87%**

**mono-Si Cell**

- **Device ID:** GXb-5
- **Aug 7, 2020 12:03**
- **Spectrum:** ASTM G173 global

- **Device Temperature:** 24.8 ± 0.5 °C
- **Device Area:** 267.8 cm² ± 0.1 %
- **Irradiance:** 1000.0 W/m²

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<th>Best Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>V&lt;sub&gt;oc&lt;/sub&gt;</td>
<td>0.7149 ± 0.0019 V</td>
<td>0.7127 ± 0.0019 V</td>
</tr>
<tr>
<td>I&lt;sub&gt;sc&lt;/sub&gt;</td>
<td>11.122 ± 0.090 A</td>
<td>11.125 ± 0.090 A</td>
</tr>
<tr>
<td>J&lt;sub&gt;sc&lt;/sub&gt;</td>
<td>41.54 ± 0.34 mA/cm²</td>
<td>41.54 ± 0.34 mA/cm²</td>
</tr>
<tr>
<td>FF (%)</td>
<td>83.43%</td>
<td>83.78%</td>
</tr>
<tr>
<td>Eta (%)</td>
<td>24.79%</td>
<td>24.87%</td>
</tr>
<tr>
<td>Area (cm²)</td>
<td>267.7</td>
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**Chart:**

Graph showing current (A) versus voltage (V) for the mono-Si cell. The graph includes data points and lines indicating the performance characteristics.

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<th>Area (cm²)</th>
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</table>
World record multi-Si 24.40%

\[ A_{\text{cell}} = (267.5 \pm 1.1) \text{ cm}^2 \]

\[ I_{\text{sc}} = (11094 \pm 110) \text{ mA} \]

\[ V_{\text{oc}} = (713.2 \pm 3.6) \text{ mV} \]

\[ FF^1 = (82.49 \pm 0.91) \% \]

\[ P_{\text{mpp}} = (6527 \pm 85) \text{ mW} \]

\[ \eta = (24.40 \pm 0.34) \% \]

1 Front: Busbar-resistance-neglected contacting,
Rear: Grid-resistance-neglected contacting

Calmark: 001004
Loss analysis

<table>
<thead>
<tr>
<th>Jsc Losses</th>
<th>Proportion</th>
<th>Jsc Loss (mA/cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front Grid Shading</td>
<td>42.28%</td>
<td>1.04</td>
</tr>
<tr>
<td>Base Collection Loss + Parasitic Absorption</td>
<td>21.95%</td>
<td>0.54</td>
</tr>
<tr>
<td>ARC Reflection</td>
<td>12.20%</td>
<td>0.3</td>
</tr>
<tr>
<td>Front Surface Escape</td>
<td>17.48%</td>
<td>0.43</td>
</tr>
<tr>
<td>Blue Loss</td>
<td>6.10%</td>
<td>0.15</td>
</tr>
<tr>
<td>Total</td>
<td>100.00%</td>
<td>2.46</td>
</tr>
</tbody>
</table>
Loss analysis

Champion cell

Power (mV/cm²)

- Modelled Efficiency
- p+ contact recombination
- p+lateral hole transport
- p+ non-contact recombination
- Bulk Auger/radiative recombination
- Front finger contact resistance
- Front finger contact resistance
- n+ non-contact recombination
- Bulk carrier transport
- n+ contact recombination
- Bulk defects/impurities
- Resistive loss (fingers, busbars)
- Rear finger contact resistance
### Latest breakthrough – doping activation

#### Dopant activation rate improvement

<table>
<thead>
<tr>
<th>Dopant</th>
<th>Sheet resistance</th>
<th>Surface doping concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>BSL</td>
<td>~105 ohm/sq</td>
<td>1.50x10^{19} cm^{-3}</td>
</tr>
<tr>
<td>80% BSL</td>
<td>~110 ohm/sq</td>
<td>1.48x10^{19} cm^{-3}</td>
</tr>
</tbody>
</table>

- PL counts increase >50%

[Graph showing Internal Quantum Efficiency]

- BSL
Latest breakthrough – contact system upgrade

Accurate extraction of $J_{0,\text{metal}}$

Recollection reduction at contact region

Metal finger width control

Metal finger width reduction
Recombination loss improvement

<table>
<thead>
<tr>
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<th>Now</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voc (mV)</td>
<td>716.5</td>
<td>719.1</td>
</tr>
<tr>
<td>Jsc (%)</td>
<td>41.54</td>
<td>41.60</td>
</tr>
<tr>
<td>FF (%)</td>
<td>83.70</td>
<td>83.98</td>
</tr>
<tr>
<td>Eta (%)</td>
<td>24.90</td>
<td>25.13</td>
</tr>
</tbody>
</table>

Target for near future
Performance in mass production

- **N型HOT钝化接触电池量产成熟度提升迅速：平均效率，档位分布，良率，成本等**
  N-type HOT technology is developing rapidly at production level: average efficiency, distribution of efficiency, product yield, cost...

- **大面积N型钝化接触电池可量产最高效率预计可以达到25.5%以上；**
  N-type HOT passivated contact cells are expected to achieve efficiency >25.5% for mass production
Major n-type process challenges overcome

Boron diffusion

Tunnel oxide growth

Wrap-around removal

Poly-Si layer light absorption

Firing + paste
N 型钝化接触电池大面积效率预期可超过26%，量产效率预期可超过25.5%。
Module technologies

MBB

Gap reflective coating

Tilling Ribbon

Soldering wire
No cell gap
Tiger Pro Module

610+W
Module power

>22%
Module efficiency
Reliability

**Module front side reliability**

- DH1000
- TC200
- TC100+HF10
- LID90kwh
- PID192
- PID384

**Module rear side reliability**

- DH1000
- TC200
- TC100+HF10
- LID90kwh
- PID192
- PID384
Outline

- n-TOPCon research at Jinko Solar
- Discussion about industrial innovation work
- Hot topics in PV industry (questions welcome)
Industrial R&D Innovation

Key characters of R&D

- Target Results-orientation
- Timing
- Repeatable and reliable
- Step-by-step
Big changes come from very detailed analysis and continuous observation

Main electrical losses:
- Bulk lifetime
- Front surface passivation
- Emitter sheet resistance
- Combined metal grid resistance
- Front contact recombination
Examples

- Do not be afraid to be the first one
- Do not insist secondary deductions
- Theories vs practical finding
Large size wafer trend – benefits for n-type wafers

Due to the separation coefficient ($k$) change for dopants: $B > P > Ga$

N-type wafer’s relative cost is reducing comparing to p-type wafers.

$$k = \frac{C_s}{C_l}$$

Dopant concentration in ingot

Dopant concentration in liquid Si

(a) $\frac{C_s}{C_l} < 1$; (b) $\frac{C_s}{C_l} > 1$

Growth surface

Cutting direction

Resistivity reduce

N-type wafers become “large-size” friendly

RRV performance of different wafers
Hot topics in PV industry

- Wafer Size
- Technical roadmap
- Industry-academic relations
TOPCon vs HJT

Conversion efficiency vs Year

- HIT/HJT solar cell
- TOPCon solar cells
Thanks !