Investigation on N-PERT Bifacial Solar Cell and Module

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Outline

1. PANDA - N-PERT Cell
2. N-PERT SBSF Cell Investigation
3. PANDA Cell Module
4. Summary
B and P diffused regions made by different technologies (two diffusions, co-diffusion using doped glasses, ion implantation with anneal)

Most of existing P-type Si cell process technology can be used
PANDA — N-PERT Cell

**Yingli Panda Cell Efficiency**

- Simple cell structure and easy manufacture
- Cost-effective production steps and compatible with existing production lines
- Sun-light can be accepted by double sides, produce more electricity
- Excellent anti-LID performance

**Key Features:**

- Front contact
- Rear contact (Ag)
- Textured front surface with antireflection coating
- Boron diffused emitter (P⁺)
- Phosphorus diffused BSF
- SiNx passivation coating
- CZ N-Si Substrate
- Incident light

**Additional Diagram Details:**

- Double Printing
- Rear Polishing
- Ion implantation
- Four Busbars Metallization

**Efficiency Timeline (2009-2017):**

- 2009: 18.0%
- 2010: 18.5%
- 2011: 19.0%
- 2012: 19.5%
- 2013: 20.0%
- 2014: 20.5%
- 2015: 21.0%
- 2016: 21.5%
N-PERT SBSF Cell Investigation

Conventional back surface field

- Low contact resistance
- High back surface recombination velocity

Selective back surface field (SBSF)

- Low contact resistance
- Low back surface recombination velocity
N-PERT SBSF Cell Investigation

- (P+) emitter
- N-type Substrate
- N+ BSF
- n++
- Depth
- Mask Width
- BSF passivation
- Alignment
- Voc Jsc FF
- Efficiency
- Voc Jsc FF
- Efficiency
Thermal treatment has great impact not only on the $R_{\text{sheet}}$ but also on the doping profile.

Increasing rate of $R_{\text{sheet}}$ is related to the doping profile.
Suitable etching depth has to be selected for balancing the Voc, Jsc and FF that have great effect on the final cell efficiency.
## Mask width optimization

<table>
<thead>
<tr>
<th>Group</th>
<th>Mask width(um)</th>
<th>Voc(mV)</th>
<th>Jsc(mA/cm²)</th>
<th>FF(%)</th>
<th>Eff(%)</th>
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</thead>
<tbody>
<tr>
<td>G1</td>
<td>6a</td>
<td>657</td>
<td>39.17</td>
<td>80.73</td>
<td>20.78</td>
</tr>
<tr>
<td>G2</td>
<td>5a</td>
<td>659</td>
<td>39.21</td>
<td>80.66</td>
<td>20.84</td>
</tr>
<tr>
<td>G3</td>
<td>4a</td>
<td>661</td>
<td>39.26</td>
<td>80.65</td>
<td>20.93</td>
</tr>
<tr>
<td>G4</td>
<td>3a</td>
<td>660</td>
<td>39.30</td>
<td>80.62</td>
<td>20.91</td>
</tr>
</tbody>
</table>

**Etch back**

**Metalization**
# N-PERT SBSF Cell Investigation

## Mask width optimization

<table>
<thead>
<tr>
<th>Group</th>
<th>Finger number</th>
<th>Mask width(um)</th>
<th>Voc (mV)</th>
<th>Jsc (mA/cm²)</th>
<th>FF (%)</th>
<th>Eff (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>G1</td>
<td>Normal N-PERT</td>
<td>653</td>
<td>38.85</td>
<td>80.43</td>
<td>20.40</td>
<td></td>
</tr>
<tr>
<td>G2</td>
<td>n1</td>
<td>A1</td>
<td>662</td>
<td>39.35</td>
<td>79.54</td>
<td>20.72</td>
</tr>
<tr>
<td>G3</td>
<td>n2</td>
<td>A2</td>
<td>661</td>
<td>39.31</td>
<td>80.12</td>
<td>20.83</td>
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</tbody>
</table>

※Same mask area for G2 and G3
### N-PERT SBSF Cell Investigation

#### Cell performance comparison

<table>
<thead>
<tr>
<th>Group</th>
<th>Voc (mV)</th>
<th>Jsc (mA/cm²)</th>
<th>FF (%)</th>
<th>Eff (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N-PERT Cell</td>
<td>656</td>
<td>38.98</td>
<td>80.95</td>
<td>20.70</td>
</tr>
<tr>
<td>SBSF Cell</td>
<td>662</td>
<td>39.62</td>
<td>80.91</td>
<td>21.22</td>
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</tbody>
</table>

**Graphs:**
- **Top right graph:** Shows IQE vs Wavelength for Panda Cell and SBSF Cell.
- **Bottom right graph:** Displays cell efficiency distribution for N-PERT Cell and N-PERT SBSF Cell.
### N-PERT SBSF Cell Investigation

#### Typical cell parameters

<table>
<thead>
<tr>
<th>Cell Parameters</th>
<th>Area (cm²)</th>
<th>$V_{oc}$ (mV)</th>
<th>$J_{sc}$ (mA/cm²)</th>
<th>FF (%)</th>
<th>Eff (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front Side</td>
<td>244.3</td>
<td>664.3</td>
<td>40.01</td>
<td>80.95</td>
<td>21.52</td>
</tr>
<tr>
<td>Rear Side</td>
<td>244.3</td>
<td>661.6</td>
<td>36.53</td>
<td>80.87</td>
<td>19.54</td>
</tr>
</tbody>
</table>

Bifaciality factor > 90%
PANDA Module

LID characteristics

20 Kwh outdoor test

AVE. LID = 0.00 %

Excellent anit-LID performance
Gain of power output from Panda module compared to traditional mono c-Si solar cell module

### One Month Data

<table>
<thead>
<tr>
<th>Average Gain of Power Output</th>
<th>Maximum Gain of Power Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>20.20%</td>
<td>33%</td>
</tr>
</tbody>
</table>

### Generating Test

- **Power Gain (%)**
- **Radiation of titled surface (kWh/m^2)**

![Graph showing power gain and radiation of titled surface over a month from 2015/8/15 to 2015/9/14]
- Power output collection for 1 year with installed modules on a bright rooftop
- The distance from module to the ground of 30 cm
- The test result shows the Panda module average power output is 21% higher than normal module.

<table>
<thead>
<tr>
<th>STC power output</th>
<th>increased 5%</th>
<th>10%</th>
<th>15%</th>
<th>20%</th>
<th>25%</th>
<th>30%</th>
</tr>
</thead>
<tbody>
<tr>
<td>290 W</td>
<td>304 W</td>
<td>319 W</td>
<td>333 W</td>
<td>348 W</td>
<td>362 W</td>
<td>377 W</td>
</tr>
</tbody>
</table>
PANDA Module

Power gain under different reflective conditions

- 10% power output gain at the ground and grassland with reflectivity of 25%
- 15% power output gain at the Sand/gray cement floor with reflectivity of 50%
- 25% power output gain at the bright rooftop with reflectivity of 78%
- 30% power output gain at the snowfield with reflectivity of 90%
PANDA Module

Self-cleaning function

Panda Module vs Normal Module

Panda Module vs Normal Module
Summary

- YINGLI N-PERT bifacial cell with SBSF structure have already reached efficiency of 21.52%, and 19.54% on rear side.

- There are still many rooms to improve the N-PERT solar cell performance such as doping, passivation and metallization. Manufacturing technique aiming to 22% efficiency of N-PERT cell with bifaciality > 95% is under investigation and will be realized at YINGLI soon.

- YINGLI PANDA module with excellent anti-LID performance provides 10% - 30% output gain compared to monofacial module depending on ground reflective conditions.
Thanks for your attention