High-Performance Solar Cells and Modules for Future PV Market

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Outlines

1. Solar Technology Development outlook
2. Application Challenge (in Southeast Asia)
3. Solution: Innovative PV products
4. Technology Roadmap at Trina
Best research cell efficiency
**Best solar module efficiency**  
(Progress in Photovoltaic)

Confirmed terrestrial module efficiencies measured under the global AM1.5 spectrum (1000 W/m²) at a cell temperature of 25 °C (IEC 60904-3: 2008, ASTM G-173-03 global).

<table>
<thead>
<tr>
<th>Classification</th>
<th>Effic. (%)</th>
<th>Area (cm²)</th>
<th>V&lt;sub&gt;oc&lt;/sub&gt; (V)</th>
<th>I&lt;sub&gt;sc&lt;/sub&gt; (A)</th>
<th>FFd (%)</th>
<th>Test centre (and date)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Si (crystalline)</td>
<td>22.9 ± 0.6</td>
<td>778 (da)</td>
<td>5.60</td>
<td>3.97</td>
<td>80.3</td>
<td>Sandia (9/96)e</td>
<td>UNSW/Gochermmann [[37]]</td>
</tr>
<tr>
<td>Si (large crystalline)</td>
<td>22.4 ± 0.6</td>
<td>15775 (ap)</td>
<td>69.57</td>
<td>6.341f</td>
<td>80.1</td>
<td>NREL (8/12)</td>
<td>SunPower [[38]]</td>
</tr>
<tr>
<td>Si (multi-crystalline)</td>
<td>18.5 ± 0.4</td>
<td>14661 (ap)</td>
<td>38.97</td>
<td>9.149g</td>
<td>76.2</td>
<td>FhG-ISE (1/12)</td>
<td>Q-Cells (60 serial cells) [[39]]</td>
</tr>
<tr>
<td>Si (thin-film polycrystalline)</td>
<td>8.2 ± 0.2</td>
<td>661 (ap)</td>
<td>25.0</td>
<td>0.320</td>
<td>68.0</td>
<td>Sandia (7/02)e</td>
<td>Pacific Solar (&lt;2 µm on glass) [[40]]</td>
</tr>
<tr>
<td>GaAs (thin film)</td>
<td>24.1 ± 1.0</td>
<td>858.5 (ap)</td>
<td>10.89</td>
<td>2.255&lt;i&gt;h&lt;/i&gt;</td>
<td>84.2</td>
<td>NREL (11/12)</td>
<td>Alta Devices [[41]]</td>
</tr>
<tr>
<td>CdTe (thin film)</td>
<td>16.1 ± 0.5</td>
<td>7200 (t)</td>
<td>68.68</td>
<td>2.252f</td>
<td>74.8</td>
<td>NREL (2/13)</td>
<td>First Solar, monolithic [[42]]</td>
</tr>
<tr>
<td>CIGS (thin film)</td>
<td>15.7 ± 0.5</td>
<td>9703 (ap)</td>
<td>28.24</td>
<td>7.254&lt;i&gt;i&lt;/i&gt;</td>
<td>72.5</td>
<td>NREL (11/10)</td>
<td>Miasole [[43]]</td>
</tr>
<tr>
<td>CIGSS (Cd free)</td>
<td>13.5 ± 0.7</td>
<td>3459 (ap)</td>
<td>31.2</td>
<td>2.18</td>
<td>68.9</td>
<td>NREL (8/02)e</td>
<td>Showa Shell [[44]]</td>
</tr>
<tr>
<td>a-Si/a-SiGe/nc-Si (triple)</td>
<td>10.9 ± 0.4j</td>
<td>14305 (t)</td>
<td>224.3</td>
<td>1.015k, g</td>
<td>68.3</td>
<td>AIST (9/13)</td>
<td>LG Electronics [[13]]</td>
</tr>
</tbody>
</table>
Main stream PV modules efficiencies

[2] Data from websites of PV companies, enfsolar and solarshop.com
* Data from Trina Solar mass production
Main stream PV modules efficiencies

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Application Challenge (in Southeast Asia)

- Goble Climate Classification according temperature and precipitation:
  - Equatorial, Arid, Warm temperate, Snow, Polar.

- Thailand Climate is above
- The average amount of irradiation was 1800kwh/m²
Application Challenge (in Southeast Asia)

How to guarantee the field performance in tropical area?

- High temperature
- High humidity
- Irradiance and wind speed

Reliability and Energy Yield

- PID
- Snail Track
- Hot spot
- High temperature performance
- EVA & back sheet yellowing

Trina solar
Smart Energy Together
Energy yield in tropical area

– High temperature performance

- In typical area, while the temperature coefficient increases 0.01%, the energy yield of module will increase about 0.3%. While Open circuit voltage ($V_{oc}$) increases 6mV.

- Modules use high quality wafers, continuity improve advanced cell technologies (SE, RIE, BSF, etc.) to gain excellent energy yield performance at high temperature,
Potential Induced Degradation (PID) Issues

- Relative high voltage imposed between the frame (ground) and cells.
- Module power degradation can be more than 20%.
- It depends on ambient temperature and humidity.
Hot spot issues in tropical area

- Caused by cell mismatch/shading
- Big temperature difference between cells causes power degradation
- Worst case: Burnt backsheet, EVA; Broken Glass.
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Competitive PV module product

- High efficiency
  - Good high temperature performance
- High reliability
  - Low O&M cost
  - Low degradation
  - PID free
- Smart module
  - More power output
  - Smart O&M; Safety
  - Hot spot free

LCOE

TrinaSolar
Smart Energy Together
High efficiency Module Product

• New high efficiency solar cell of Trina Solar
  – i-PERC based technologies
  – Mono & Multi, Cell & Module world records
  – Mono: cell efficiency 20.40% (avg.), 21.40% (champion)
  – Multi: cell efficiency 18.80% (avg.), 21.25% (champion)

• Honey Plus Module
  – Mono: 285W – 295W
  – Multi: 270W – 280W

• Very good reliability
  – <3% PID after 600h, 85/85, 1000V extended PID test
  – ~2% LID after 360 kWh/m² extended LID test
High efficiency module with good temperature coefficient

- **Energy yield**
  - The correlation between temperature coefficient and Voc

  ![Module temperature distribution]

- SE, BSF, IBC cells and modules with High Voc
- Low NOCT. Good temperature coefficient.
PID (Potential Induced Degradation) Improvements

- Improved recent Anti-PID techniques
- Conventional modules (NOT double glass) with refined anti-PID process and material
- After about 600h, module power degradation <3% (IEC: 96h, deg. Should <5%)
- Independently confirmed by TUV Rheinland

**Test Conditions:**
- 1000V, 85°C, 1000V
- 85% RH, 85°C, 1000V

**<2% degradation (tested by TUV)**

**Test Conditions:**
- 1000V, 85°C, 85 RH, 600h
High reliability product---Dual Glass PV Module

Excellent Reliability

1. Glass replaces polymer back sheet, water can not penetrate to glass, no degradation outside, be satisfied for 1500V system voltage.
2. Excellent anti-salt fog, anti-Alkali & Acid, anti-sand & dust
3. Excellent Resistant to PID, black-line, hot-spot
4. Mass reliability tests, Warranty is extended to 30 years from 25 years
High reliability product---Dual Glass PV Module

**Novel design**: adopt 2.5+2.5mm-thick glass, firstly obtained the certificates listed below

- IEC61215
- IEC61730, including fire test-Class A
- UL1703
- UL2703 ;
- Top Class A in UL fire test

First obtain the accreditation in Asian–pacific region

More safer
- Top fire test – Class A
- Improved strong wind resistant

More reliable and durable
- Optimized anti-PID performance
- Excellent weatherability
- Dual glass design to protect cells and avoid cracks
- Warranty extended from 25 years to 30 years

Fast installation, lower system cost and LCOE
Advantages of Dual Glass Module

Value of 30 years linear Warranty

- TSM-PC05A traditional module, 25 years power warranty, 0.7% degradation per year
- TSM-PDG5 Dual Glass Module, 30 years power warranty, 0.5% degradation per year

Increase Rate of Yield (PDG5 VS PC05A)

25~30 years power degradation

Increase Rate of Yield (PDG5 VS PC05A)
New product--- smart module

- TrinaSmart DC
  - SubString
- TrinaSmart Safety
- TrinaSmart DC
- TrinaSmart AC

- MPPT (cell level)
- Monitoring & Switch off
- Monitoring & Switch off
- Monitoring & Switch off

- Higher Cost
- More features/functions

- DC-AC
- Monitoring & Switch off
- MPPT (module level)
- MPPT (module level)
Hot spot free module - Trinapeak

Hot spot test in Trina outdoor test site

- Optimization (instead of bypass) prevents reverse breakdown of PV cells
- Eliminates Hot Spots and related component failures
  Improve panel reliability

Module Temperature in Hot spot test
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Company overview – snapshot of global operations

Leadership for innovation

- State key Laboratory of PV Science and Technology - State-of-the-art R&D center for PV Science and Technology
- 11 times world records
- Patents: 652 innovation patents granted
- Participated 48 PV Standards

Leadership in Manufacture

- Founded in 1997, Changzhou, China
- Listed on NYSE: TSL
- World’s largest PV manufacturing campus – 14,000 employees
- Industrial bases in China: Changzhou, Yancheng, Hubei, Yabang, Xiantao, Xinjiang
- Abroad: Malaysia, Thailand, India and others
## Cell efficiencies for different types of crystalline silicon solar cells developed at Trina Solar Cell Technology

<table>
<thead>
<tr>
<th>Solar Cell Technology</th>
<th>Champion Cell Efficiency</th>
<th>Average Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Honey Plus Multi</td>
<td><strong>21.25%</strong>*</td>
<td>18.7%</td>
</tr>
<tr>
<td>Honey Plus Mono</td>
<td><strong>21.40%</strong>*</td>
<td>20.4%</td>
</tr>
<tr>
<td>n-PERT 125mm</td>
<td><strong>22.20%</strong></td>
<td>21.5%</td>
</tr>
<tr>
<td>HIT 125mm</td>
<td><strong>22.00%</strong></td>
<td>21.5%</td>
</tr>
<tr>
<td>IBC 156mm</td>
<td><strong>23.5%</strong></td>
<td>22.5%</td>
</tr>
</tbody>
</table>

* Independently confirmed
Continuous improvements in mass production technologies:

- Normal mc-Si cell efficiency >19%, Honey+ >20% and Honey+ mono >21% in 2020;
- Innovative technologies in laboratory R&D, that will be transferred and lead improvements in production:

  - mc-Si cell efficiency >21%, mono PERC >22%, n-type PERL and HIT >23%, while IBC >25% in 2020.
High efficiency cell and module for future

HJ 21.5% 310W

IBC 22.5% 320W

HJ+IBC 24.0% 345W (25.5% Lab)

Tandem Junction 27% 385W

SiN

N-type

n-aSi

Metal

i-aSi

p-aSi

High Eg S.C.

P

Silicon
THANK YOU

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