Progress and outlook at an industrial level R&D for Photovoltaic products

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1. Jinko Introduction: Company, Products, R&D
2. Representative work updates 2017
3. What do industrial level R&D team do: projects and interests
4. Collaboration with research institutes and universities
JINKO SOLAR: PV manufacturing company

- Multi-business PV manufacturer: wafer → cell → module → system
- Share code (New York): JKS
- **9.7 GW shipment, No.1 in 2017**
- 7 manufacturing factories globally, 23 branches world-wide, 3 R&D departments
- Top 100 World Energy Company, Top 500 Chinese Company
The Jinko Map

Transition from a “company with global business” to a “globalised company”.
Main Product Family

- **EAGLE**
  - 1000V module
  - 1500V module
  - Smart module

- **EAGLE PERC**
  - Conventional PERC module
  - All-black PERC module

- **EAGLE BLACK**
  - MCT black-silicon Module
  - All-black module

- **EAGLE PLUS**
  - Eagle P Plus
  - Eagle Q Plus
  - Eagle I Plus

- **EAGLE DUAL**
  - Conventional dual-glass module
  - Edging sealed dual-glass module
Data from PHOTON LAB: Jinko product leads in power generation in 2014 and 2015 among the P type silicon modules, demonstrating the highest quality and reliability standards for industry.
High Quality Assurance (Jinko product to be “top runner”)

1. The first company authorized with the 1st class efficiency certification for poly module by CQC

   **CQC TOP RUNNER**

   The first company authorized with the 1st class efficiency certifications in poly and mono product at the same time

3. 1500V/PERC/RIE/Dual glass technologies are certified by CGC advanced technology top runner

   **CGC TOP RUNNER**

4. Won the reward of “highest efficiency competition PV module” by TÜV Rheinland

   **ALL QUALITY MATTERS**

5. Jinko’s production poly modules offer main power rating (265-280W), 1-2 level higher than industrial main stream.

   **INDUSTRIAL LEADING PRODUCT**
State key lab (3 locations)
(State accredited enterprise technical center)

– Solar Cell department

City of Haining, Zhejiang Province, China

Total area 15400m²
SCD: >7000m²

70+ researchers
(PhD. 10; Master 55)

>210 research equipment
Ambition and targets

Jinko technology to lead the industry

- High efficiency
- High power generation
- High reliability
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2.1 High Efficiency Solar Cell/Module Techniques

P-type multi-Si solar cell: 22.04% (Fraunhofer ISE)
Control parameters are measured during the cell fabrication process.
Front and rear J0 are measured on control wafers.
Contact resistivity for the front and rear are measured by TLM.
Bulk lifetime of the wafers are measured after high temperature process
Control parameter used for simulation purpose

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front J0</td>
<td>30fA/cm²</td>
</tr>
<tr>
<td>Rear J0</td>
<td>15fA/cm²</td>
</tr>
<tr>
<td>Bulk lifetime $\tau$</td>
<td>500μs</td>
</tr>
<tr>
<td>Front contact J0</td>
<td>1500fA/cm²</td>
</tr>
<tr>
<td>Rear contact J0</td>
<td>600fA/cm²</td>
</tr>
<tr>
<td>Front contact resistivity</td>
<td>5mΩ.cm²</td>
</tr>
<tr>
<td>Rear contact resistivity</td>
<td>20mΩ.cm²</td>
</tr>
</tbody>
</table>
2.1 High Efficiency Solar Cell/Module Techniques

01 P-mono

• Best cell: 23.45%
• Advanced structure average: >23%
• Mass production average: >21.7%

02 N-PERT

• Best cell: 22.5%
• Mass production average: >21.9%

03 N-High Efficiency

• Best cell: 24%
2.1 High Efficiency Solar Cell/Module Techniques

60P: 347.6W

Tested by TÜV Rheinland

60P: 356.7W
Jinko solar was the first Chinese manufacturer to achieve 3*IEC certification, first Chinese company to achieve Q+ certification, with the optimized by cell design, module material, fine processing control, and etc.

- TC500/ Bypass diode test
- HS/Bypass diode Thermal 96h test
- UV/DML/TC50/HF10
- 60℃ 85%RH 96h PID

- Q+ certification is based on IEC 61215, but much tougher than it.
- All the items in red are beyond IEC 61215, demonstrating better performance of PV modules.
2.2 Quality and Reliability Control

Jinko is the first company to:

- Pass the low temperature (-40 °C) dynamic mechanical load test
- Pass the 1000h, 85 °C, RH85%, PID test
- Pass the transportation and shipping of PV module stacks
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3.1 Advantages of Research at an industrial level

- High throughput guaranties rich experimental data
- Baseline results from production line enables reliable comparisons
- Accessible to latest technologies and equipment
- Support from wafering and module research
- Assistance for characterization and analysis by collaborative partners

These significantly benefits industry players to speed up their technical development

Many good results achieved by Jinko, Longi, Trina, LG...
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3.2 This is the real world

Distribution of R&D focus based on the number of projects

- Efficiency Gain Techniques Development: 31%
- New Product Launch: 22%
- Intergration Project Problem Solving: 16%
- Quality and Reliability Improvement Projects: 13%
- Mass Production Problem Solving: 9%
- Other work: 9%
3.2 What people “think” R&D should do

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**Early stage R&D work**
- Efficiency Gain Technique Development
- New Product Launch
- Quality and Reliability Improvement Projects
- Mass Production Problem Solving
- Integration Project Problem Solving
- Other work

**Scale-up R&D work**
3.3 Product Quality Topics Are Crucial

The PV market is and will be “quality” driven

- Efficiency Gain Technique Development, 31%
- New Product Launch, 22%
- Integration Project Problem Solving, 16%
- Mass Production Problem Solving, 9%
- Other work, 9%
- Quality and Reliability Improvement Projects, 13%
- More strict Standards
3.3 Market requirements lead R&D directions

Market Requirement 2017

- **US**: 1x IEC, DML+TC50+HF10, Q+, PID
- **Europe**: 1x IEC, PID
- **India**: 2x IEC, PID
- **China**: 2x IEC, PID
- **Japan**: 2x IEC, PID
- **Brazil**: 2x IEC, PID
- **South Africa**: 2x IEC, PID
- **Australia**: 2x IEC, PID
- **Middle East**: TC500, 2x IEC, PID
Industry and end users point out
Light elevated and temperature induced degradation problems, hot weather power plant users may suffer from this

UNSW:
- Mechanism, possibilities, comparisons ...
- Solutions, reliabilities...

JINKO R&D:
- Scale-up tests;
- Stability monitoring;
- Product updates
3.3 All sorts of problem solving .... and problem solving ... and ...

Integration problems:
- Wafer resistivity shift
- Wafer thinning
- Module EL failure issues
- Packaging problems...

Mass production problems:
- Efficiency variation
- A product rate
- Appearance issues
- BOM changes...

✓ A R&D engineer needs to be cautious, humble, and comprehensive-thinking.
✓ Cutting-edge explorations are exciting but risky, that’s why we need partners!
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4. Global research collaboration network

Domestic collaboration
- Tsinghua University; Zhejiang University;
- Zhongshan University; Nanchang University;
- Chinese Academy of Sciences (Beijing, Ningbo)

U.S.
- UC, Berkeley
- MIT
- ASU

EU
- Belgium: IMEC
- Netherlands: ECN
- Switzerland: EPFL
- Norway: UiO, IFE

Singapore
- NUS, NTU
- Fukushima PV Lab

Australia
- UNSW & ANU
4. Looking for research collaborations in various areas

**Application**

Techs have great application potentials for current products:
- Hydrogenation
- Ad. passivation
- Ad. metallisation

**Fundamental**

Fundamental studies on solar cells:
Loss analysis, structure optimisation, degradation mechanisms...

**Standards**

International standards related study and tests:
eg. bifacial cell or module measurement

**Revolutionary ideals**

Next generation technologies:
- Tandem
- Full spectrum absorbing cells
- New bulk...
Thank you for your time!

Q & A