PV Magazine Webinar
Secure your investment: Discover urgently required game changing solutions in managing LeTID
Andrea Viaro | Head of Technical Service Europe, JinkoSolar | 14.03.2019
Mechanism postulate 1: Metal-Induced Degradation

- **MID – Metal Induced Degradation:**
  Metal Ions in silicon gather at the grain borders to form stable defects acting as recombination centers

**Jinko Solution:** Reduce the ratio of Metal Ion impurity in mono-crystal ingots by optimizing production process and parameters

*Source: Mallory A. Jensen, MIT, IEEE JOURNAL OF PHOTOVOLTAICS, 2018*

*Source: Klaus Ramspeck, 27th European Photovoltaic Solar Energy Conference and Exhibition, 861-865*
Mechanism postulate 2: Hydrogen-Induced Degradation

HID – Hydrogen Induced Degradation:
Hydrogen Atoms diffuse into the silicon and combine with positive ions into more stable state, which reduces the PV cell activity.

Jinko Solution: Optimal Hydrogen content and fine-tuning of equipment employed in mass production (also in cooperation with external R&D centers e.g. UNSW).

Source: Alison Ciesla née Wenham, Hydrogen-Induced Degradation, UNSW, 7th world conference on photovoltaic energy conversion, P1-8, 2018.
Mechanism Study: Mono VS Poly

<table>
<thead>
<tr>
<th></th>
<th>Poly PERC</th>
<th>Mono PERC</th>
</tr>
</thead>
<tbody>
<tr>
<td>MID</td>
<td>Higher content of metal impurities $\rightarrow$ higher MID</td>
<td>Lower content of metal impurities $\rightarrow$ lower MID</td>
</tr>
<tr>
<td>HID</td>
<td>Same effect on poly and mono, relative to cell process</td>
<td></td>
</tr>
</tbody>
</table>

Source: Daniel Macdonald, AIST, JOURNAL OF APPLIED PHYSICS 97, 033523 2005

Source: E. Garcia Goma, Eternal Sun Group and UNSW, 35th European Photovoltaic Solar Energy Conference and Exhibition, Brussels, Belgium 2018
LeTID mitigation: Possible Strategies

**Incorporation of H(?)**
- Less H incorporation reduces LeTID 
  ➔ lower firing $T$
  ➔ adapted $T$ ramps
  ➔ H-lean passivation layer

**Wafer Thickness**
- Thin wafers show less LeTID 
  ➔ $<120 \, \mu$m wafer thickness

**Annealing Steps**
- Annealing steps change defect kinetics
  ➔ regenerated state can be reached faster

**Regeneration**
- Going through degradation/regeneration cycle
  ➔ stable state reached
Solution Technology: Advanced Recipe

Crystal Growing

Slicing wafer

Mono PERC Cell

Module

Process fields Controlling Technology

Impurities Controlling Technology

LIR Technology

Decrease the content of Metal Impurities and Oxygen

Decrease the content of impurities and defect in stable level

Control the Hydrogen content to reduce LID (insufficient H) and LeTID (excessive H)
The technology developed by Jinko R&D can reduce Metal and Oxygen atoms by optimizing the different process phases parameters
Solution Technology: Impurities Controlling & LIR tech.

Design specific process parameters (e.g. Temp.) to:

1. Remove effectively impurities from the surface
2. Reduce metal impurities diffusion into the silicon
3. Decrease probability of forming stable defects
4. Reduce energy consumption and CO2 emission

1. Optimize Hydrogen content to Control both
   - LID caused by insufficient hydrogen
   - LeTID caused by excessive hydrogen

2. LIR single-cell, in-line stabilization is more effectively in mass production, compared to CIR stacked-batch processing
Light Induced Regeneration (LIR)

- Illumination of mono cz. P-type solar cells → Eff. reduction up to 5% abs
- Main cause: recombination of active **Boron–Oxygen** complexes (B-O), especially in highly Boron-doped & Oxygen-rich silicon

**Light-induced Hydrogen Passivation** (LiHP) can dramatically reduce LID, i.e. improve regeneration process

- Key parameters to deactivate Boron–Oxygen complex (Passivation): Temperature, carrier injection, Hydrogen diffusion
Mass Production Control: long-term test of samples

- 300 kWh LeTID test result on Mono PERC Modules
- After 60Kwh regeneration starts

Testing temperature: 75±5°C (surface)
Light source: 1Kw (steady)

Power Degradation

- Mono PERC Sample No.1
- Mono PERC Sample No.2
Mass Production Control: third-party test result

- LeTID test at 75±5°C with CID procedure
- Result from mass production (average -0.6% Pmpp)
- Jinko Mono Perc Modules (2018)

**Graph:**

<table>
<thead>
<tr>
<th>Sample</th>
<th>Power Degradation Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample.1</td>
<td>0.60%</td>
</tr>
<tr>
<td>Sample.2</td>
<td>0.80%</td>
</tr>
<tr>
<td>Sample.3</td>
<td>0.40%</td>
</tr>
<tr>
<td>Sample.4</td>
<td>0.70%</td>
</tr>
<tr>
<td>Sample.5</td>
<td>0.60%</td>
</tr>
<tr>
<td>Sample.6</td>
<td>0.70%</td>
</tr>
</tbody>
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Mass Production Control: sampling data

- 60Kwh LeTID test result of Mono Perc Modules (throughout 2018)
- LID test 1kW (steady) with Temperature raised to 75 ± 5°C
- Simulating extreme environment → Similar to LeTID
Conclusions: management control integration

- Manufacturer efforts in L(eT)ID reduction enable to effectively reduce risk in PV investments.
- IEC Standard, under development, will give an accurate approach to evaluate the phenomenon.
- Ingot purity, wafer processing and cell stabilization are key to control L(eT)ID effect in mass-production.
- PV cell and module regeneration strictly depend on temperature and light/current intensity.
- High silicon quality and optimized manufacturing lead to reliable PV modules.

Advantage of complete value-chain vertical integration.
Thank You!