Short-term and long-term field experiences in Japan in terms of PV encapsulant

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Mitsui Chemicals, Inc.
Mitsui Chemicals’ contribution to healthy PV market

- Analyze aged PV modules
  - Develop accelerated test

- Know PV modules installed in PV plants

- Understand what happens in PV plants under operation

- Feedback to accelerated test conditions accordingly

2009~2013
- Shared at workshops on 2011 and 2013

2014~
- launch services business
  - warning as needed
  - Shared at last workshop on 2015

2016~
- through services
Outline

1. Mitsui Chemicals’ adviser services for PV project
2. Actual examples of Findings of PV modules in Japan
3. Short-term and long-term field experiences in terms of PV encapsulant
4. Summary
-installed PV power plant capacity in Japan

- Installed PV power plant capacity in Japan

- 60-70 GWac
1. Mitsui Chemicals’ adviser services for PV project
   Since 2014

**Project Phases**

- Planning
- Construction
- Commissioning
- Operation
- Secondary - Transaction -

**Service Menu**

**One-Stop Solution**

- Quality Assurance
- Factory Visit
- Acceptance Inspection for Module Installation

**Best Practice**

- IR/EL Analysis (on-site)
- Plant Inspection
- Periodical Yield Performance Assessment
- Evaluation of O&M Performance

**Technical Due Diligence**

- Yield Assessment for the remaining period of FIT based on:
  - Yield Performance
  - Plant Inspection
  - Evaluation of O&M Performance/costs

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Mitsui Chemicals Expertise in PV Industry

Manufacturer of PV encapsulant
- <Subsidiary> Manufacturer and global supplier of competitive encapsulant sheets for over 25 years,
- 20 years of degradation study of PV modules and encapsulants.

Investor/Owner of PV plants
- Possess and manage several PV plants in Japan,
- Continuous improvement of technical skills and knowledge by studying various data and records from several plants including possessed plants.

Experiences worldwide through PI
- Part of our solid field inspection and laboratory testing is derived from expertise of an accredited lab, PI Berlin.

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Outline

1. Mitsui Chemicals’ adviser services for PV project

2. Actual Findings of PV modules in Japan

3. Short-term and long-term field experiences in terms of PV encapsulant

4. Summary
2. Actual findings of PV modules in Japan

Let’s see some photos of PV plants taken in Japan.

PV plant

Mt. Asama (volcano)

landslip

Vegetation

Railway track
◆ Failures related to solder bonding

**cell string**

**busbar**

~2y operation

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Failures related to encapsulant delamination

delamination

glass

during storage (~1y) in our temperature controlled warehouse

interconnector

~2y operation

edge of module

Failures related to encapsulant delamination

delamination

glass

during storage (~1y) in our temperature controlled warehouse

interconnector

~2y operation

edge of module
◆ Others

Broken glass and corrosion

Snail trail and delamination

PID?

~2y operation

~2y operation

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Summary of findings observed in Japan

- **Snail trail**
- **Delamination on cell**
- **Delamination at side**
- **Solder joint failure**
- **BPD working**
- **Linear performance warranty**
- **Melted connector**
- **Glass broken**

**ISSUEs**:
- Safety
- Performance

- **Retention of output power**
- **Duration of operation**
- **After 10 years operation**

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Outline

1. Mitsui Chemicals’ adviser services for PV project

2. Actual Findings of PV modules in Japan

3. Short-term and long-term field experiences in terms of PV encapsulant

4. Summary
◆ Summary of findings observed in Japan

- Snail trail
- Delamination on cell
- Delamination at side
  - Safety ISSUE

- Solder joint failure
- Melted connector
- Glass broken
- Browning

After 10 years operation

Retention of output power

Duration of operation

Linear performance warranty

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<table>
<thead>
<tr>
<th>RISK</th>
<th>Failure</th>
<th>Probable cause</th>
<th>Severity</th>
<th>Frequency in Japan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower energy yield</td>
<td>Delamination on solar cell</td>
<td>Manufacturing</td>
<td>low</td>
<td>Medium</td>
</tr>
<tr>
<td></td>
<td>browning</td>
<td>Design of EVA</td>
<td>low</td>
<td>High (Aged)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Encapsulant</td>
<td></td>
<td>Low (recently)</td>
</tr>
<tr>
<td></td>
<td>Snail trail</td>
<td>Manufacturing</td>
<td>low</td>
<td>Medium</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Shipping</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Installing</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Failed solder joint</td>
<td>Manufacturing</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(Specific type / manufacturer)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Broken glass</td>
<td>in operation</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>Failed bypass diode</td>
<td>Manufacturing</td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td></td>
<td>Melted connector</td>
<td>Installing</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Safety</td>
<td>Delamination at side and</td>
<td>Manufacturing</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>corrosion</td>
<td>(Specific type / manufacturer)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Scratch of backsheet</td>
<td>Installing</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>Failed solder joint</td>
<td>Manufacturing</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(Specific type / manufacturer)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Broken glass</td>
<td>in operation</td>
<td>High</td>
<td>High (Some case: long time deployed)</td>
</tr>
<tr>
<td></td>
<td>Melted connector</td>
<td>Installing</td>
<td>High</td>
<td>Low</td>
</tr>
</tbody>
</table>
◆ Browning – cross sectional view

17 years field aged PV module

There are no delamination failures.

Yellowness Index
~20
~4
~2

Browning led by additive degradation has been happened at a thin layer of EVA.

T-peel strength to glass or backsheet was low. It would be around 1~5N/cm (initial ~15N/cm).
**Chemical change of EVA – cross sectional view**

Measurement points in cross section

<table>
<thead>
<tr>
<th>Glass</th>
<th>EVA</th>
<th>cell</th>
<th>EVA</th>
<th>Backsheet (BS)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>glass side</td>
<td>center</td>
<td>cell side</td>
<td></td>
</tr>
</tbody>
</table>

IR Spectra of field aged EVA – microscopic FT-IR/ATR

There were no differences in IR spectra of EVA in thickness direction.
Chemical change of EVA – cross sectional view

Measurement points in cross section

IR spectra of glass-face side EVA compared to that of cell side EVA

Chemical changes of EVA were observed in the vicinity of EVA layer contacted with glass.
Chemical change of EVA – cross sectional view

- Chemical change of EVA encapsulant including additives are happened at thin layer contacting glass.

- As for EVA at cell side, there have been no typical changes compared to initial one.

- When we study delamination failure concerning EVA, we have to consider interfaces and chemical change of EVA in thickness direction.
Delamination – cross sectional view

<table>
<thead>
<tr>
<th>Interface</th>
<th>Potential Causes</th>
<th>Frequency (in Japan)</th>
<th>Risk (safety)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Glass/EVA</td>
<td>inadequate lamination, formulation of EVA</td>
<td>Rare case?</td>
<td>high</td>
</tr>
<tr>
<td>B EVA/interconnector</td>
<td>Inadequate lamination, flux, formulation of EVA</td>
<td>Often</td>
<td>low</td>
</tr>
<tr>
<td>C EVA/cell</td>
<td>inadequate lamination, AR coating, formulation of EVA</td>
<td>Aged specific PV modules</td>
<td>low</td>
</tr>
<tr>
<td>D EVA/cell, finger electrode</td>
<td>Ag paste for finger electrode, formulation of EVA</td>
<td>Often (specific types)</td>
<td>low</td>
</tr>
<tr>
<td>E EVA/Backsheet</td>
<td>inadequate lamination, adhesiveness of Inner layer of backsheet, formulation of EVA</td>
<td>Rare case?</td>
<td>high</td>
</tr>
</tbody>
</table>
Delamination – cross sectional view

✓ Inadequate lamination, which means that inadequate lamination condition and/or quality control issue lead to insufficient thermal history for EVA including additives, causes delamination as an infant mortality.

✓ Originally durable adhesion of EVA has been designed for interface between glass and EVA with a silane coupling agent. Further its durability, which means that no delamination on glass was happened, has been proven by many long-term field aged PV modules with EVA having certain silane coupling agent.

✓ Adhesion of EVA/backsheet has sometimes become issues for long-term reliability. These days, UV absorber has been removed from glass side EVA. Thus inner layer of backsheet would be suffered by UV light compared to older type of PV module.

✓ PV module manufacturer shall conduct long-term UV exposure test using a PV module with EVA encapsulant with its lower limit or less of gel content, certain backsheet and interconnector to be used.
4. Summary

✓ Field failures related to encapsulant is mainly delamination in Japan. It would be led by inadequate lamination condition and/or quality control issue of PV module manufacturers.

✓ Delamination at edge of PV module would become safety issues such as ground fault. Of course, it would be mainly lamination problem which leads to infant mortality. However issues related to design of reliability, such as additive of EVA, inner adhesion of backsheet remain in terms of long-term reliability.

✓ PV module manufacturer shall conduct long-term UV exposure test using a PV module with EVA encapsulant with its lower limit or less of gel content, certain backsheet and interconnector to be used.