PV modules' reliability deployed in Japanese PV power plant from viewpoint of encapsulant

October 5th 2016

Tsuyoshi Shioda
Mitsui Chemicals, Inc.
Outline

1. Mitsui Chemicals’ services for PV plant
2. Actual examples of Failure of PV modules in Japanese PV plants
3. Influence of encapsulant on PV modules’ reliability, based on experiences through Mitsui’s services
4. Summary
Lack of third party’s checks for PV plant in Japan

- So far, third party’s inspection of PV plant had been insufficient for developing a PV plant.
- Consulting firms who had less expertise in PV field have performed as a third party.
- Most JP banks had tended to see credit of participants of PV plant PJ even project finance.
- These days, they have concerns about use of PV modules produced by non-Japanese companies, accuracy of energy yield estimation by a consulting firm and so on.
Mitsui Chemicals’ services for a PV project
- since March 2014 -

With Mitsui Chemicals’ services,
✓ you can have high quality of PV power plant.
✓ you can understand intrinsic risks in PV power plant.
✓ you can maximize value of PV power plant.
✓ you can know fair value of PV power plant to be purchased / sold.
Mitsui Chemicals’ strength – unrivalled expertise in Japan –

Reliability of PV module
Our subsidiary has supplied encapsulant sheets worldwide for >25 years.
We have analyzed long term aged PV modules and encapsulant using our test facilities for understanding what happened for 20 years.

Investor/Owner of PV plants
We have several plants in Japan and have known difficulties and value chain of developing PV plant.
With our PV plants, we can estimate accurate expected irradiance and loss factors appropriate O&M cost.

Experiences in Europe
We can utilize expertise in Europe through our partner, PI Berlin who is an accredited lab. for PV modules and has expertise for PV plant diagnosis worldwide.

Cutting edge technology
We have supported cutting edge researches of PV manufacturers and EPC.
We have made (invited) talks for international workshops and conferences.
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2. Actual examples of failure of PV modules in Japanese PV plants

Let’s see some photos of PV plants taken in Japan.
Lesson learn from actual cases in Japan -from PV plant inspection-

- vegetation on module

- hotspot due to shading

- Failure of bypass diode

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Lesson learn from actual cases in Japan
-from PV plant inspection-

- Scratch of backsheet (peeling of outer layer) -

- Snail trail -

- Corrosion of combiner box -

- Dew inside of pyranometer -
Lesson learn from actual cases in Japan -from evaluation of PV module-

delamination between Si and EVA during storage (~1y) in our warehouse

pulling cable off “easily” from connector

MC4 compatible connector
Lesson learn from actual cases in Japan
-same type but different material-

Same type of a PV module

Different backsheets

PID test chamber

Infra-red observation

Hotspot

Solder joint failure

Electroluminescence (EL) images after PID test

Same type of a PV module

Different encapsulant
Lesson learn from actual cases in Japan

✓ We have seen some troubles and failures of PV modules and PV plants in Japan.

✓ According to our services’ results, there were some cases that use of different PV materials for same type PV modules led to different durability and reliability of the PV modules.

Let’s see recent trend of encapsulant through our services.
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### Influence of encapsulant on reliability

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<th>root causes</th>
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<td>*Initial coupling strength *Break coupling bonds</td>
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<td>*Water penetration through delaminated portion *Chemical change of EVA -&gt; create acetic acid</td>
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We have performed analyses of over 20 y field aged PV modules and encapsulant and service life prediction based on their results.
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                 | *Break coupling bonds                                                               | Thermal history    |
|                |                                                                                      | Formulation        |
| Corrosion      | *Water penetration through delaminated portion  
                 | *Chemical change of EVA  
                 | -> create acetic acid                                                             | Formulation        |
UV exposure dependence of Browning of EVA

- 27 years outdoor exposure
  YI~27 (Miyakojima)
- 17 years outdoor exposure
  YI~15 (Miyakojima)

(Yellowness Index (YI))

Duration of UV exposure [h]
(Xe light: 60W/m² @ BPT=110°C)

EVA-a: old grade
EVA-c: new grade
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Contact resistance between finger electrodes and a solar cell would be increased during accelerated test, such as DH, UV, which creates free acetic acid from EVA.

- Dependence: type of silver paste and its sintering condition, **amount of acetic acid**

- **Prediction of desorption rate of acetic acid from EVA**
UV exposure dependence of desorption rate of acetic acid

![Graph showing UV exposure dependence of desorption rate of acetic acid]

- **Xe light**
- **glass**
- **EVA**
- **White backsheet with Al layer**
- **EVA-a**
- **EVA-c**
- **Duration of UV exposure**
  
  (Xe light: 60W/m² @ BPT=110°C)

- **Amount of free acetic acid [µg/g]**
  - 0
  - 1,000
  - 2,000
  - 3,000
  - 4,000

- **Duration of UV exposure**
  - 0
  - 1,000
  - 2,000
  - 3,000
  - 4,000

- **Amount of free acetic acid [µg/g]**
  - 0
  - 1,000
  - 2,000
  - 3,000
  - 4,000

- **UV exposure dependence of desorption rate of acetic acid**
  - **27 years browning**
  - **17 years browning**

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Amount of acetic acid in field aged PV modules

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Service life prediction
- UV exposure dependence of YI, acetic acid -

Xe light irradiation for \( \frac{1300}{2100} \) h roughly corresponds to outdoor exposure for \( 17 \) y.

(EVA-a) Yellowness Index (YI): 27y
(EVA-c) Yellowness Index (YI): 17y

Amount of free acetic acid \([\mu g/g]\):
(EVA-a) 2700 µg/g
(EVA-c) 1700 µg/g

Duration of UV exposure [h]
(Xe light: 60W/m² @ BPT=110°C)
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PV modules with EVA-5 has concern of delamination observed after less than 10 years operation.
# Recent trends

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(Q) Does PV modules to be installed recently in Japan have concerns of three failures?

(A) partially Yes! Browning issue is over but delamination and corrosion are still issues.
Mitsui Chemicals’ services for PV module

6 modules / lot

Appearance check
IV, EL

2 modules

PID test

IV, EL

2 modules

Cure state of EVA

Additive analysis of EVA

Peel strength between EVA and Backsheet

Layer structure of Backsheet

Final Report

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Recent trend of formulation from our additive analysis results

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<th>2014</th>
<th>2015</th>
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<tr>
<td>EVA-G</td>
<td>not detected</td>
<td>~40%</td>
</tr>
<tr>
<td>EVA-B</td>
<td>not detected</td>
<td>0%</td>
</tr>
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<td>EVA-G</td>
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<td></td>
<td>UV absorber</td>
<td>Additive “A” (light resistance)</td>
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<tr>
<td>~40%</td>
<td>Glass side</td>
<td>not detected</td>
</tr>
<tr>
<td></td>
<td>Backsheet side</td>
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- Some PV modules evaluated on 2014 have high risk of delamination according to our additive analysis.
- However the risk for those evaluated on 2015 would be low and not zero.
- We have to beware that function of UV absorber in EVA is mainly to protect backsheet against UV damage and completely differs from that of additive “A”.

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✓ Needs for third party’s assessment become high, because some PV plants have trouble and failures of PV modules.

✓ Mitsui Chemicals provide several professional services for PV plant as a third party.

✓ We found some risks for PV modules installed on 2014 from encapsulant point of view.

✓ PV module manufacturers should see reliability and durability of PV materials as well as those of PV module.