Moisture ingress rate and route into c-Si PV modules

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1. Introduction

Background
- The reliability of photovoltaic (PV) module is related to the moisture ingress in some cases.
- However, the moisture ingress rate and the route into PV modules have not been clarified.
- It is necessary to understand an accurate ingress rate and route to obtain guiding principle of appropriate material.

Objective
To develop measuring method of moisture ingress into PV modules

2. Methods

- In order to detect the moisture ingress route and rate into the module, we used Ca as a sensor.
  \[ \text{Ca} + 2\text{H}_2\text{O} \rightarrow \text{Ca(OH)}_2 + \text{H}_2 \] (metal color: transparent)
- Ca was evaporated on the material surface of the single cell module using multi-crystalline Si cells.
- To examine influence of permeability of back material, we prepared test modules using the back material of different water vapor transmission rates (WVTRs).

3. Results and Discussion

3.1 Damp Heat Test (DHT)

- Ca is an effective material to detect moisture ingress.
- Major moisture ingress route is back material.

<table>
<thead>
<tr>
<th>Backsheet</th>
<th>0mm WVTRs (10mm)</th>
<th>Initial</th>
<th>DH48h</th>
<th>DH96h</th>
<th>DH121h</th>
<th>DH191h</th>
</tr>
</thead>
<tbody>
<tr>
<td>PAP</td>
<td>Evaporation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SiOx BS</td>
<td>0.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TPT</td>
<td>2.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E50ETFE</td>
<td>14</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig.2. Change of appearance under DHT.

<table>
<thead>
<tr>
<th>Backsheet</th>
<th>Initial</th>
<th>DH108h</th>
</tr>
</thead>
<tbody>
<tr>
<td>PAP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TPT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Butyl</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig.3. Change of appearance under DHT.

Field exposure test
- Moisture ingress rate is larger by 28-34 times under DHT than field exposure test. (Ingress from edge)
- Moisture ingress rate is larger by 18-24 times under DHT than field exposure test. (Ingress from back material)

Field exposure test has been done at Kyushu Center, National Institute of Advanced Industrial Science and Technology. Climate division of Kyushu is the Temperate Zone. Test started on Feb. 7th, 2013, in winter. One year has past since test started.

4. Conclusions

1. Major moisture ingress route is backsheet and moisture ingress rate depends on WVTR of backsheet.
2. Moisture ingress rate from edge under DHT is 28 – 34 times larger than that under field exposure test.
3. Moisture ingress rate from backsheet under DHT is 18 – 24 times larger than that under field exposure test.

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Table 1: Accelerating effect for each test module

<table>
<thead>
<tr>
<th>Backsheet</th>
<th>PAP</th>
<th>SiOx BS</th>
<th>TPT</th>
<th>E50ETFE</th>
<th>Accelerating effect</th>
<th>Time equivalent to DH1000h (year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low WVTRs</td>
<td>3.2</td>
<td>2.4</td>
<td>2.1</td>
<td>2.1</td>
<td>28.1 - 33.5</td>
<td>3.2 - 3.8</td>
</tr>
<tr>
<td>High WVTRs</td>
<td>2.4</td>
<td>2.7</td>
<td>2.4</td>
<td>2.3</td>
<td>21.1 - 23.4</td>
<td>2.4 - 2.7</td>
</tr>
</tbody>
</table>

Fig.4. Moisture ingress under DHT.

Fig.5. Moisture ingress under field exposure test.

Accelerating effect is defined as moisture ingress rate under DHT / moisture ingress rate under field exposure
Moisture ingress rate is defined as moisture ingress distance / test time

Considering effect of area without Ca, we used two kinds of moisture ingress: measured value and measured value minus 10mm (area without Ca).

Moisture may quickly pass in the area without Ca. Therefore, we calculate accelerating effect including error bar.

- Samples with four kinds of backsheets were exposed outside from Feb 7th.
- Ca membrane of test module with SiOx BS, TPT, ETFE completely reacts with water in the mid of the test.
- Second samples with the same composition were exposed from Jul 25th.

- Ca membrane is evaporated in the discrete pattern. Moisture may quickly pass in the area without Ca. Therefore, we calculate accelerating effect including error bar.

- Moisture ingress rate from edge under DHT is 28 – 34 times larger than that under field exposure test. Therefore, we calculate accelerating effect including error bar.