Proposed new damp heat test standards for thin film PV modules

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Backgrounds

• Major international PV standards are now being created/revised under IEC TC82 WG2

  • a major “overhaul” of the whole set of test standards
    --- wider, stricter coverage of degradation modes

  • includes the IEC61215, Design qualification and type approval of PV modules
old IEC61215’s test procedure

wider/stricter coverage of degradation modes for improved reliability

revised IEC61215 (draft)
Question...

• Among the test procedures, "heating in dark" is often applied.
  • Damp heat
  • Thermal cycling
  • PID
    etc.

However, in REAL conditions,
how often does "heat + dark" happen?
Is it always the best test method?
When hot in field, there's always light (voltage)

In the real field, module temperature seldom exceeds 50°C without > 0.2 Sun irradiation.

⇒ "High temperature + dark" condition is rare.

At high temperatures, module is soaked in light and generating bias voltage.
Two examples of when conventional "damp heat" tests are NOT the optimum test procedure for PV modules.

Example 1: A flexible thin-film Si module (prototype)

Example 2: Some CIGS products in the market
Example 1

On damp-heat testing of a prototype flexible thin film Si module
Unique degradation mode observed in a prototype Thin film Silicon flexible module (1)

(A.Takano et al, EU PVSEC 2013, 3BO.5.4)
Reproducing the degradation by applying forward bias during damp heat test

![EL image](image)

Degradation reproduced by forward bias during damp heat testing

→ made it possible to fix the problem before mass production

(A.Takano et al, EU PVSEC 2013, 3BO.5.4)
Example 2

On damp-heat testing of the some CIGS products in the market
• The IEC61215-1-4 draft, which defines the new damp heat test standard for CIGS modules, requires a light soaking (LS) process before and after the damp heat test. Pass/Fail criteria are also changed from the current standard.

Then...
Light soaking effect of CIGS

Change of Pmax by light soaking
(sometimes takes years until maximum)

Pmax@STC

Initial (Nameplate)

Exposure time in field

long-term degradation
Damp heat test defined by the “old” IEC61215

- **Initial (NamePlate)**: Decreased output (loss of light soaking effect + real degradation)
- **Pmax@STC**
- **Time**
- **Damp heat test**: Pass/fail decision
- **Pass criterion**: Increased Pmax by light soaking in field
Use $P_{max}$ after light soaking for pass/fail decision (not the nameplate value)

Damp heat test

$P_{max}$ after light soaking

Decreased output (loss of light soaking effect + real degradation)

Pass/fail decision

Pass criterion
What actually happens

Loss of LS effect + “test-specific degradation” (not observed in field)

does not fully recover by LS (though no problems are observed in real field)
Exploring the "right" test options for CIGS

5 types of tests below were performed with 170W-class CIGS modules.

<table>
<thead>
<tr>
<th>Test type</th>
<th>Irradiation</th>
<th>Bias</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal DH</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>DH with irradiation</td>
<td>0.1~0.65 Sun*</td>
<td>—</td>
</tr>
<tr>
<td>DH with forward bias</td>
<td>—</td>
<td>(V_{pm@NMOT}^{**})</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(V_{pm@STC}^{*})</td>
</tr>
<tr>
<td>Normal dry heat test</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Dry heat test with forward bias</td>
<td>—</td>
<td>(V_{pm@NMOT}^{**})</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(V_{pm@STC}^{*})</td>
</tr>
</tbody>
</table>

* Performed at AIST. Others were performed at SF.
**NMOT: Nominal Module Operating Temperature.

Test sequence

<table>
<thead>
<tr>
<th>1st Pre-LS</th>
<th>2nd Pre-LS</th>
<th>Test 1000hrs</th>
<th>1st Post-LS</th>
<th>2nd Post-LS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open-circuit state</td>
<td>Each LS process:</td>
<td>1kW LS chamber for 21 hrs (SF) or Outdoor for one week (AIST)</td>
<td>Open-circuit state</td>
<td>Each LS process:</td>
</tr>
</tbody>
</table>
Experimental setup

Test with light irradiation

Module temperature: 85°C
Chamber humidity: 85 % r.h.

Test with forward bias

Module current: ~ 0.2 A (with NMOT-Vp, Tmod 85°C)

Module temperature: 85°C
Module humidity: 85 % r.h.
(raised the chamber humidity depending on chamber temperature)
Effect of light illumination

Test-specific degradation

Compared to illuminated DH,
DH in dark invokes a degradation not observed in field
Effect of light illumination + short-circuiting (preliminary)

Test-specific degradation

- DH+light 650W/m² load (n=1)
- DH+light 400W/m² load (n=1)
- DH+light 200W/m² load (n=1)
- DH+light 100W/m² load (n=1)
- DH+light 650W/m² short (n=1)
- DH dark, no bias (n=10)

Short circuiting of modules → test-specific degradation
→ not the light, but forward bias voltage?
Effect of forward bias + DampHeat(DH)/DryHeat(HT) tests

Bias voltage gives same results to light illumination
Test-specific degradation does not depend on humidity

Normalized Pmax

Damp heat test 85°C (module)
Damp: 95% r.h., Dry: <10% r.h. (chamber)
Light Soak 21kWh
Light Soak 21kWh

(各々、n=10)
Does the test-specific degradation recover by loooong light soaking?

No, it does not
Summary

➢ In the real field, high temperature is always accompanied with illumination & voltage.
   ("Hot+dark" does not happen -- it's the MOST unnatural test condition!)
➢ The examined CIGS modules after DH with light irradiation or forward bias showed similar
   behavior to real field. Meanwhile, conventional DH invoked “Test-specific degradation”,
   which is not observed in field.
➢ Test-specific degradation is irreversible by light soaking.

"DH+forward bias" option added to IEC 61215-1-4 (draft).

Mysteries

➢ The cause of test-specific degradation
➢ Some other products show same behaviors, while some others do not
   (private communications)

Homeworks

➢ Understanding of mechanism of test-specific degradation.
   • Wavelength dependency of light
   • Work on other samples
   • Destructive analysis
   • etc.
Important message

Over 50 IEC standards are being created or revised right now; Though people are working hard, mistakes can happen. Keep watch on the progress of IEC TC82 WG2! Next face-to-face meeting: October 2016, Colorado

Thank you for your attention
Contact : k-sakurai@aist.go.jp
Backup: How to determine the chamber RH value

The curve of chamber relative humidity as a function of chamber temperature can be plotted using Tetens’ formula:

$$RH_{CHM} = \frac{RH_{MOD} \times e(85)}{6.11 \times 10^6.11_{7.5 \times T_{CHM}/273.3+T_{CHM}}/100} \times \frac{1}{100}$$

RH$_{MOD}$: Relative humidity of the module surface (= 85 %)  
e(85): Saturated vapor pressure at 85 °C (= 581 hPa)  
RH$_{CHM}$: Relative humidity inside the chamber  
T$_{CHM}$: Temperature of the chamber

Chamber RH should be set to realize the module surface RH 85%.
In case of our study, chamber temperature was set 84 °C to realize the module temperature 85 °C. Then, according to this graph, we set chamber RH 88 %.