LONG-TERM STABILITY OF AMORPHOUS-SILICON MODULES

JET PROPULSION LABORATORY

R. G. Ross, Jr.

Amorphous Silicon Module Test Program Objectives

Objective

• Assess reliability characteristics of amorphous silicon modules
• Assess attributes of various test methods
• Establish research priorities

Approach

• Establish strawman mechanism-specific reliability goals
• Test a number of first-generation amorphous silicon modules using a wide variety of tests
  • Block qualification tests
  • Field aging (various electrical loading points)
  • Field aging (at elevated temperatures)
  • Dark oven aging (various electrical biases)
  • Photothermal oven aging
MODULE AND RELIABILITY TECHNOLOGY

Life-Cycle Cost Impacts and Allowable Degradation Levels for Thin-Film Modules

<table>
<thead>
<tr>
<th>Type of Degradation</th>
<th>Failure Mechanism</th>
<th>Units of Degrad.</th>
<th>Level for 10% Energy Cost Increase*</th>
<th>Allocation for 30-Year-Life Module</th>
<th>Economic Penalty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Component failures</td>
<td>Open-circuit between cells</td>
<td>%/yr</td>
<td>0.08 0.13</td>
<td>0.02</td>
<td>Energy</td>
</tr>
<tr>
<td></td>
<td>Short-circuit cells</td>
<td>%/yr</td>
<td>0.24 0.40</td>
<td>0.05</td>
<td>Energy</td>
</tr>
<tr>
<td>Power degradation</td>
<td>Light induced effects</td>
<td>%</td>
<td>10 10</td>
<td>5</td>
<td>Energy</td>
</tr>
<tr>
<td></td>
<td>Cell gradual power loss</td>
<td>%/yr</td>
<td>0.67 1.15</td>
<td>0.20</td>
<td>Energy</td>
</tr>
<tr>
<td></td>
<td>Module optical degradation</td>
<td>%/yr</td>
<td>0.67 1.15</td>
<td>0.02</td>
<td>Energy</td>
</tr>
<tr>
<td></td>
<td>Front surface soiling</td>
<td>%</td>
<td>10 10</td>
<td>3</td>
<td>Energy</td>
</tr>
<tr>
<td>Module failures</td>
<td>Module glass breakage</td>
<td>%/yr</td>
<td>0.33 1.18</td>
<td>0.1</td>
<td>O&amp;M</td>
</tr>
<tr>
<td></td>
<td>Module open circuits</td>
<td>%/yr</td>
<td>0.33 1.18</td>
<td>0.1</td>
<td>O&amp;M</td>
</tr>
<tr>
<td></td>
<td>Module hot-spot failures</td>
<td>%/yr</td>
<td>0.33 1.18</td>
<td>0.1</td>
<td>O&amp;M</td>
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<tr>
<td></td>
<td>Bypass diode failures</td>
<td>%/yr</td>
<td>0.70 2.40</td>
<td>0.05</td>
<td>O&amp;M</td>
</tr>
<tr>
<td></td>
<td>Module shorts to ground</td>
<td>%/yr²</td>
<td>0.022 0.122</td>
<td>0.01</td>
<td>O&amp;M</td>
</tr>
<tr>
<td></td>
<td>Module delamination</td>
<td>%/yr²</td>
<td>0.022 0.122</td>
<td>0.01</td>
<td>O&amp;M</td>
</tr>
<tr>
<td>Life-limiting wearout</td>
<td>Encapsulant failure due to loss of stabilizers</td>
<td>Years of life</td>
<td>27 20 35</td>
<td>End of life</td>
<td></td>
</tr>
</tbody>
</table>

* k = Discount rate

Block-V Qual Testing of Amorphous Silicon Modules

- Good performance in mechanical loading tests
  - Mechanical cycling at 50 psf
  - Hail impact with 1 in. ice balls
- Slight degradation (10%) in thermal cycle and humidity tests
  - Corrosion of monolithic interconnects
  - Some open-circuiting of monolithic interconnects
- Good performance in hot-spot test
- Mixed performance with encapsulant system
  - Frame softening
  - Some delamination of non-EVA systems
Amorphous-Silicon Module Field Performance
(Ambient-Temperature Aging)

![Graph showing changes in current and voltage over time at different temperatures and aging periods.](image)

**85°C during daylight hours**
- **UNAGED**
- 20, 80 days

**100°C during daylight hours**
- **UNAGED**
- Increasing series resistance
- 10, 5, 2 days

**Graphs**
- Current vs. Voltage
- Data points indicate changes over time and temperature.
Module and Reliability Technology

Amorphous-Silicon Field Performance
(Elevated-Temperature Aging)
Amorphous Silicon Module I-V Performance (Dark Oven Aging)

- **UNAGED**
- **10 DAYS**
- **20 DAYS**

**85°C 5% RH NO BIAS**

**85°C 85% RH NO BIAS**

**85°C 5% RH FORWARD BIASED**

**85°C 85% RH FORWARD BIASED**
Amorphous Silicon Cell Photothermal Aging Performance
(85°C, 5% RH, 1 Sun UV)
MODULE AND RELIABILITY TECHNOLOGY

Summary

• Block V crystalline-silicon qualification test insufficient for amorphous silicon modules
  • Good indicator of mechanical and hot-spot endurance
  • Poor indicator of electrical stability of amorphous silicon
• Electrical stability of amorphous silicon modules is very complex
  • Light induced effects
    • Sensitive to electrical loading point (Voc, Isc, Pmp)
    • Complex temperature dependency
  • Corrosion induced effects
    • Strong (Arrhenius) temperature dependency
    • Strong humidity dependency
• Accelerated laboratory and field testing must address the complex parameter dependencies
• Tests appropriate for amorphous silicon procurement specifications do not exist at this time

Present Research Thrusts

• Developing useful accelerated test for amorphous silicon electrical stability
• Developing solutions to corrosion-induced effects
• Continuing broad-spectrum testing to identify research priorities