Improved Accelerated Test Methods for Solar Panel Service Life Prediction

Chiou-Fu Wang, Ph.D.
DuPont Photovoltaic Fluoromaterials (PVFM)

SECI Workshop
June 25, 2015
Environmental Stresses in the Field

- Photovoltaic modules are exposed to a wide range of stress conditions
- Stresses operate on the module simultaneously and sequentially; synergistic effects are observed
DuPont Collaborated with Downstream Stakeholders to Assess Solar Systems, Modules, and Materials in the Service Environment

Subcomponent degradation mode pareto based on visual inspection

- 41% inspected modules exhibited some visual defect
- Findings consistent with BP and SunPower data

- Inspected >60 global installations (>200 MW & 1.5 million modules) in NA, EU, & AP ranging from 0-30 years installed
- Data includes c-Si modules from > 45 module manufacturers

Accepted for presentation at IEEE PVSC (New Orleans, 2015, A. Bradley et al)
Backsheet is Critical to Protect a Solar Panel

- Durable and reliable backsheets can enable longer lifetime, maximize power output and reduce risk
Risks Associated with Using Unproven Backsheet Materials

- Backsheet degradation increases potential **safety risks** such as loss of electrical protection
- Yellowing is a one sign of polymer degradation and an early indicator of **performance issues**
- Cracking typically is associated with yellowing
Outer Layer Backsheet Cracking and Yellowing

Polyester-based backsheets
- Years in service: 4 years
- Location: Spain
- 5,000 modules affected
Yellowing of PET and Tedlar® PVF-Based Backsheets (Field Data)

Field test: Measurement of backsheet color change after modules have been exposed for years in the field

Results:
- Small color change for Tedlar®-based backsheets
- Significantly larger changes in b* for PET backsheets

Tedlar® shows exceptional color stability; PET color change indicates polymer damage & degradation.

Source: 227 modules with Tedlar® and 4 modules with PET-based backsheet from various locations and manufacturers
Aged Modules with PET-Based Backsheet Have Visible Degradation and Significantly Lower Power Output

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Crack</td>
<td></td>
<td>b* (Yellowing)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>9.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>14.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2.7</td>
</tr>
<tr>
<td>Wet leakage</td>
<td>Pass</td>
<td>Fail</td>
<td>Pass</td>
</tr>
<tr>
<td>b* (Yellowing)</td>
<td>9.0</td>
<td>14.2</td>
<td>2.7</td>
</tr>
<tr>
<td>Name plate rating</td>
<td>143 W</td>
<td>125 W</td>
<td>100 W</td>
</tr>
<tr>
<td>IV measurement</td>
<td>77 W</td>
<td>105 W</td>
<td>91 W</td>
</tr>
<tr>
<td>% power loss</td>
<td>46%</td>
<td>16%</td>
<td>9%</td>
</tr>
<tr>
<td>Annualized power loss</td>
<td>4.6%</td>
<td>1.3%</td>
<td>0.8%</td>
</tr>
</tbody>
</table>
Shortcomings of Current IEC Qualification Tests

- Current IEC qualification standards were designed to identify **early failures** due to module design; does not predict long-term durability.

- IEC qualification standards do **not adequately address durability of materials** to UV exposure and weathering and synergistic effects of multiple stress.

- UV and weathering tests are not applied to modules due to the **equipment challenges**.
UV Ageing in Standard is Far Below than the Environment

UV dosage under different climate conditions

<table>
<thead>
<tr>
<th>UV Dosage (kWh/m²)</th>
<th>Desert</th>
<th>Tropic</th>
<th>Temperate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual UV (kWh/m²)</td>
<td>91.7</td>
<td>78.5</td>
<td>56.9</td>
</tr>
</tbody>
</table>

25 year UV exposure to the back of module

<table>
<thead>
<tr>
<th></th>
<th>Desert</th>
<th>Tropic</th>
<th>Temperate</th>
</tr>
</thead>
<tbody>
<tr>
<td>275</td>
<td>235</td>
<td>171</td>
<td></td>
</tr>
</tbody>
</table>

Current Standard 15 - 100

Passing IEC certification test does not imply 25 year durability for backsheet materials.

Assumption: 12% UV reflectivity of the ground

"UVA: 70 °C, BPT 340nm, 1.2W/m²-nm @340nm, (65 W/m², 250-400nm), continuous, no condensation

"IEC 15 kWh = 70 days, so implied annual value is 78.2 kWh,

(3) "Weathering of Plastics: Testing to Mirror Real Life Performance", George Wypych, p17 (1999),
PET-Based Backsheets Yellow, Lose % Elongation in UVA Exposures

Yellowing and loss of mechanical properties are signs of polymer degradation.

UVA 65W/m² (250-400nm), 70°C BPT, 3000 hours is equivalent to 18 year desert exposure.
Recommended Sequential Tests

**Test:** Backsheet or Modules

- **Observe:** Backsheet Yellowing, Cracking

**Test:** Full-Size Laminates or Module

- **Observe:** Backsheet Cracking

**Test:** Backsheets: weathering (Xe), 102m light, 18m light + water spray

**Test:** Module: resistive loading, weathering exposure (above)

- **Observe:** Backsheet Yellowing, Mechanical Loss

- **Module:** Power Loss
Tedlar® film-based backsheets endures various climates for decades

- **Gansu**
  - 27 years
  - Power degradation: ~10%

- **Hainan**
  - 23 years
  - Power degradation: 6.1%

- **Zhejiang**
  - 23 years
  - Power degradation: 13.1%

Only solar panels with reliable materials maximize power output and 25 or more year system lifetimes
Conclusions

• Field inspections and fielded module analysis are key to fundamentally understand PV component performance and durability

• There are risks associated with using unproven backsheets.

• Passing IEC certification test does not imply 25 year durability for backsheet materials. New testing method shall be created to better simulate the environmental challenges, and new standard shall be established to ensure the durability of module materials.

• DuPont proposes better single stress conditions including UV durability and sequential testing using damp heat (DH), thermal cycling (TC) and UV exposure (UVA) to better predict long term outdoor performance.