Understanding the Mechanisms of Surface Cracking of Multilayer Photovoltaic Backsheets after Accelerated Aging

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Introduction

In the field, surface cracking of polymeric multilayer backsheet can be detrimental to photovoltaic (PV) modules, causing catastrophic failure and safety concerns. This is a costly problem for industry due to the lack of comprehensive knowledge of multilayer system during weathering.

In this study, surface channel crack that was occurred under externally applied tensile stress/strain was characterized using a channel cracking fragmentation testing approach. The mechanisms of surface cracking of multilayered PV backsheet after accelerated aging is investigated and presented.

Results and Discussion

Tensile Testing Results

- UV humid – an example

Channel Cracking Fragmentation Testing

- Laser scanning confocal microscope (LSCM) + Displacement controlled tensile fixture

Crack Depth Measurement

- Min. displacement scale ~ 10.4 µm
- High magnification optical imaging
- Crack depth measured by LSCM
- Capability of automatic testing

Surface Cracking Behaviors

- UV humid 255 h – an example

Analysis results based on experimental data and analytical model

<table>
<thead>
<tr>
<th>Aging conditions</th>
<th>Aging time (h)</th>
<th>ε (%)</th>
<th>σ (MPa)</th>
<th>KIc (MPa m1/2)</th>
<th>σc (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>UV dry</td>
<td>255</td>
<td>0.122</td>
<td>1.042</td>
<td>1.46 ± 0.23</td>
<td>70 ± 10</td>
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The reported KIc for a typical fresh PET is 4.5 MPa m1/2 to 5.5 MPa m1/2 [1].

The strain caused by thermal and mechanical stress in the backsheet of a typical silicon PV module is estimated to be in the order of 0.1% [2,3]. The analysis results provide good explanation to the observed PET-type backsheet surface cracking after 5-6-year field exposure [4].

Chemical and Morphological Change

- ATR-FTIR Results
  - UV dry difference spectra
  - UV humid difference spectra

AFM Results

- UV dry (700 h)
- UV humid (700 h)
- Dark dry (700 h)

Summary

- The embrittled surface layer resulting from the UV photo-degradation is responsible for surface cracking. Moisture plays a synergistic affect in the degradation mechanisms.
- The mode I fracture toughness (KIc) of the embrittled surface layer aged under UV humid conditions is lower than that under the UV dry conditions, which is consistent with their chemical and morphological degradation.
- The channel cracking fragmentation testing approach is possibly used to assess the tendency of cracking formation for PV backsheet after weathering.

References

1. Semiconductor Institute of Industry, Engineering Department, Materials Group, National Institute of Standards and Technology, Gaithersburg, MD 20899, USA.