High-Throughput Optical Mapping for Accelerated Stress Testing of PV Module Materials

Imran Khan1, Caleb Phillips1, Steve Robbins1, Robert White1, David C. Miller1

*National Renewable Energy Laboratory

DuraMAT Capabilities
1. Data Management & Analytics, DuraMAT Data Hub
2. Predictive Simulation
3. Advanced Characterization & Forensics
5. Field Deployment
6. Techno-Economic Analysis

Capability Goals
• Demonstrate rapid batch specimen measurement capability, e.g., allowing measurement time to be reduced from 6 minutes/specimen to 5 seconds/specimen.
• Demonstrate specimen mapping measurement capability, allowing the spatial dependence of material degradation to be assessed within the same specimen.

Approach
• Transmittance (hemispherical and direct) and reflectance (hemispherical channels) will be added to the NREL CED array spectrometer for thick specimens.
• Measurement capability will be benchmarked against existing specimens, examined in a round-robin study using conventional spectrophotometer instruments.
• Data acquisition and storage will be integrated into the DuraMAT DataHub network along with data visualization tool, facilitating sharing of information.

Outcomes and Impact
• The measurement tool may be applied for other materials (encapsulants, backsheets, optical coatings) and accelerated test methods in the DuraMAT network.
• The study here will provide guidance towards the design and application of larger and/or outdoor-use intended instruments.

Motivation
• Traditional spectrophotometers require a long measurement time (~ 6 minutes) because macroscopic components must be physically actuated for measurement.
• Traditional spectrophotometers are limited to measurement of single spots (~1 cm²).
• Traditional spectrophotometers require physical reconfiguration (with associated setup delay) for measurements of separate characteristics.

Key Components
- DH-2000-BAL (deuterium and halogen light source)
- Optical Fibers (solarization resistant and UV durable)
- FOIS-1 Integrating Sphere (hemispherical and -direct) and reflectance (-hemispherical and -direct)
- ISP-50-B-R-GT integrating sphere (reflectance measurements)
- EPP2000-UVN-SR spectrometer (all optical measurements)

Project Timeline
<table>
<thead>
<tr>
<th>Project Phase</th>
<th>Key Milestones</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1-2020</td>
<td>Benchmark PVGFT Tec samples</td>
</tr>
<tr>
<td>Q4-2021</td>
<td>Develop data pipeline &amp; visualization capability</td>
</tr>
<tr>
<td>Q1-2021</td>
<td>Compare weathered specimens including encapsulant coupons (PVGFT Tec) and MiMo (e.g., C-AST)</td>
</tr>
<tr>
<td>Q3-2021</td>
<td>Present results for weathered MiMo specimens</td>
</tr>
<tr>
<td>Q4-2021</td>
<td>Photograph of the OM instrument on the Combi tester</td>
</tr>
</tbody>
</table>

Optical Mapping Instrument (In Development)
• The Optical Mapping instrument has been added to the Combi tester at NREL to leverage the existing network along with data visualization and optical mapping.

General Operation (Traditional Spectrophotometer)
• The procedure used for conventional spectrophotometer measurements (e.g., as in IEC 62788-1-4) can be applied here to minimize measurement noise and verify proper instrument operation.
• NREL’s usual procedure requires (i.e., for p): working reference sample, calibrated reference, and a light trap.

Custom masks
• Greatly improve measurement quality. (see below)

Initial Measurements & Shortcomings
• Minimizing the effect of background noise

Early Benchmark of Unaged Encapsulant Coupons

Compare spectrophotometer & Optical Mapping Instrument
• Developed early prototype Igor Pro loader and procedure for data analysis
• Preliminary benchmark results of unaged encapsulant coupons showed comparable results for spectrophotometer and combi optical mapper instruments.

Future Work
• (Year 1) Measure and compare hemispherical transmittance of IEC 62788-1-4 round-robin samples.
• (Year 2) Example the reflectance of weathered backsheet materials on MiMo samples.