Operando characterization for accelerated materials validation

DuraMAT
Durable Module Materials Consortium

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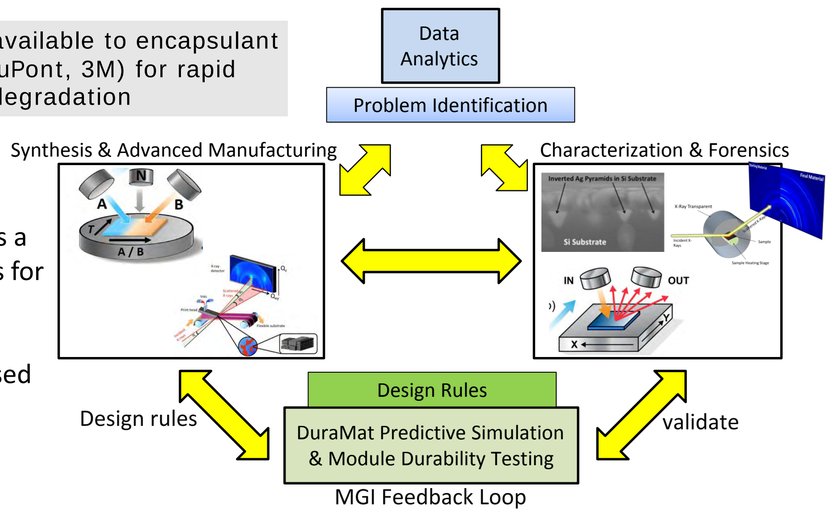
Abstract: Understanding the effects of aging and thermal cycling of solar module materials will be needed in order to reduce degradation rates, which is a key goal for DuraMat. Here we will develop collaboration between NREL's reliability and systems engineering group and SLAC to develop a greater understanding of the degradation mechanisms in module materials that can lead to loss in efficiency and module failure. These teams, with input from industry, will work together to identify, design, and ultimately down select the relevant experimental parameters to investigate. This collaboration will closely link NREL's experience and guidance with accelerated testing with SLAC's beamline capability development. SLAC will develop in-situ and operando forensic capabilities to study the structural and microstructural (3-dimensional) changes for both short term effects. A new forensic testing system will be designed allowing for environmental control (including atmosphere, humidity, temperature, light, electric field bias, mechanical loads) during module characterization. For example, such as the change that occurs with repeated thermal cycling through the glass-transition of encapsulant materials and the evolution of materials during a life time of aging.

Aiding the DuraMat Mission

This capability will be quickly available to encapsulant materials suppliers (such as DuPont, 3M) for rapid assessment of new materials degradation

- The *in-situ* and *operando* forensics system will serve as a model for similar capabilities for a host of other module components
- This capability will also be used for validation of models developed in the predictive simulation capability group.



MGI Approach

- Data Analytics
  - Problem Identification
- Predictive Simulation
  - Design Rules
  - Down selection of new materials
- Materials Discovery & Forensics
  - Combinatorial and high throughput synthesis
  - Testing and validation

Team Capabilities (Examples & DuraMat Upgrades)

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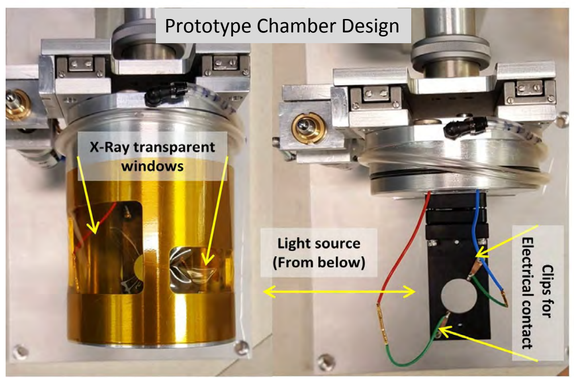
- Understand the effects of aging & thermal cycling
  - New and existing module materials (e.g. encapsulants)
- *Operando* Structural & Microstructural analysis

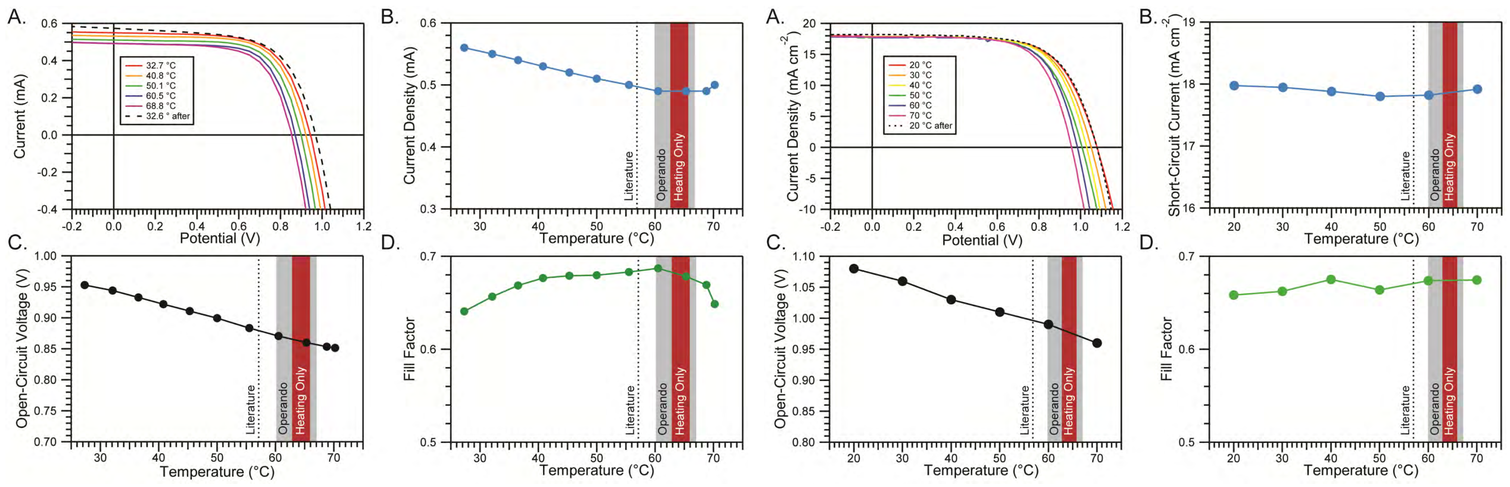


Applied Stressors

Current Chamber Capabilities:
- Atmosphere
- Humidity
- Temperature (heating)
- Light
- Electric field bias

DuraMat Upgrades:
- Mechanical loading
- Larger scale
- High-throughput sampling
- Temperature (cooling)

Pre-DuraMat research on Absorber (Proof of Concept) Chamber Prototype Design Validation Temperature & Voltage/Current Stressors



Operando Device Measurements

Ex-situ 1 sun Device Measurements

L. Schelhas, J. Christians et al ACS Energy Letters 2016

NREL NATIONAL RENEWABLE ENERGY LABORATORY

Reliability and Systems engineering group

Key experience in accelerated testing methods & synthesis of new module materials

Sandia National Laboratories

Predictive Simulation:

Validation of thermal-mechanical-electrical modeling efforts

Short and Long Term Outlook

(1 year) Complete design and build of the operando capability and demonstrate operando characterization of one new and one established PV material under at least two stresses.

(5 year) The long term value of the *operando* capability will provide validation of failure mechanisms modelled within DuraMat. Additionally, this capability will generate structural forensic characterization to develop design rules for new materials discovery.

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