SunShot
U.S. Department of Energy

Testing for PV Reliability

Test types and Test gaps

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Outline:

- Types of tests
  - Purpose
  - Stresses
  - Sample size
- Some important gaps (out of a much longer list)
  - In-field detection
  - PID in qualification test
  - Soiling
  - Corrosion and adhesion
  - Reduced cost through use of mini modules?
- What does success look like?

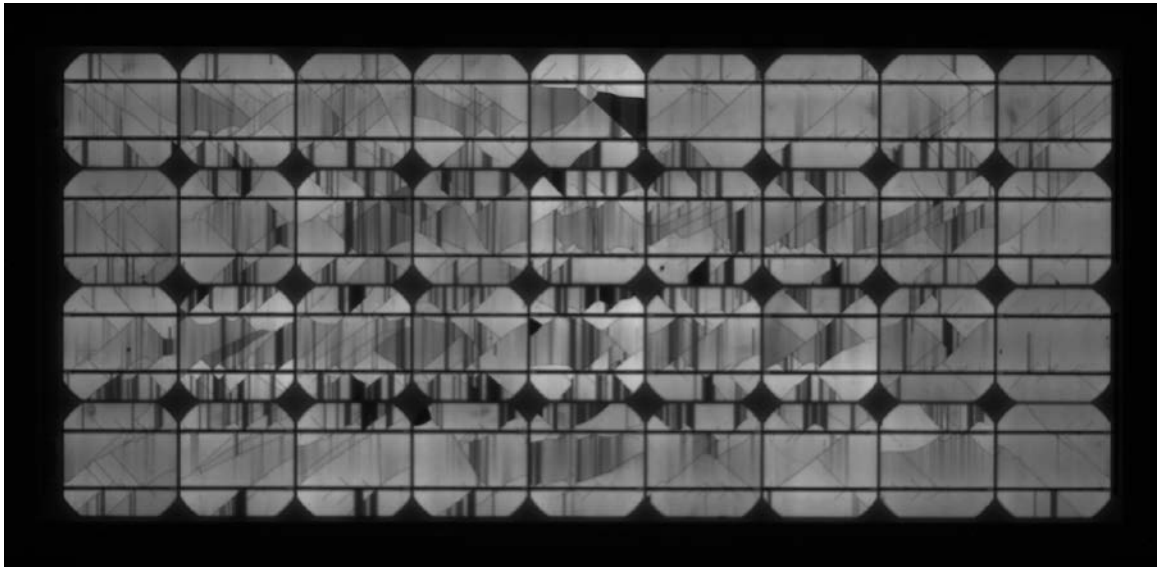
Overview: Types of tests – Lots of needs

- Purpose:
  - Lifetime
  - Qualification (during design or during manufacturing)
  - Process control
  - Failure detection/analysis
- Choice of stresses
  - Single stress
  - Combined stress (sequential or simultaneous)
  - Multiple stress levels (can define acceleration factors)
- Sample size or point in manufacturing process:
  - Material or component
  - Mini-module
  - Module

Following slides identify gaps for different types of tests

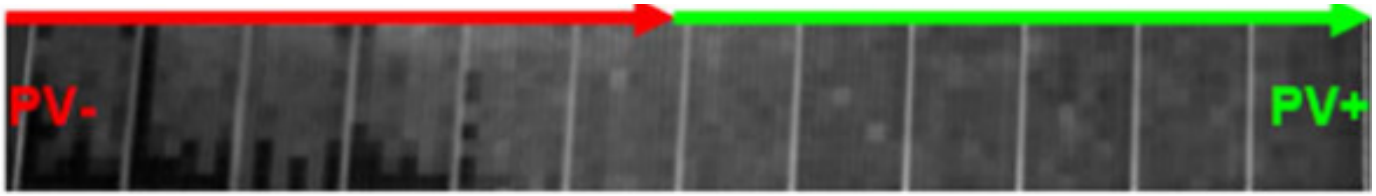
In-field failure detection – Gap: standard test

- Cracked cells can become disconnected from circuit and cause serious failures after thermal cycling in the field
- Gap: How do we identify modules that have been damaged (impending failures)? (Drones with EL or thermography?) What are *pass/fail criteria*?



Potential-induced degradation – Multiple gaps

- Voltage-driven current flow through the glass can cause large degradation
- Can easily be tested in a chamber with high humidity, temperature and bias.
- Gap: Important to have *material (encapsulant) and component (cell) level tests for quality control*
- Gap: Understanding of in-field degradation and recovery to be able to *model effects* related to chamber testing
- Gap: Complete qualification test by developing consensus around the (use-dependent?) *pass/fail criteria*!

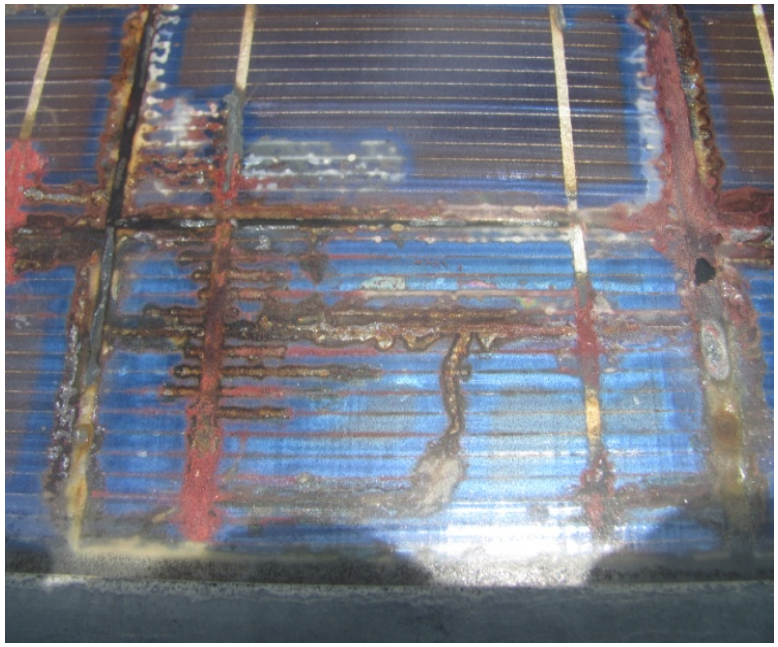


Soiling – Gaps: predictions and multiple tests

- Soiling can lead to large uncertainty in system output
- Tests are needed for:
  - Susceptibility of surface to soiling under different conditions
  - Durability of anti-reflection coatings to the abrasion associated with cleaning and/or sand blasting from windy desert conditions.
  - Understanding local conditions

Corrosion – Gaps: adhesion and combined stress

- Corrosion may be a multi-step process:
  - UV exposure weakens the EVA-glass bonds
  - EVA absorbs moisture
  - Freezing expands moisture and causes delamination
  - Drops of water enter module and causes corrosion



Gap: *Understand subtleties of combined stresses*

Gap: *Quantify adhesion between encapsulant and cell*

Which size to use?

- Sample size:
  - Material – lowest cost, but is it relevant?
  - Mini-module
  - Module – highest cost, but most relevant
- Example: Backsheet
  - UV irradiation of full module is expensive
  - But, some backsheet failures depend on the size of the sample: thermal expansion differences may cause backsheet to pull away in a full size module.
  - Is a mini-module a useful compromise??
- Gap: How to fully test a backsheet's function in a module without prolonged UV exposure of a full module

Ideal tests – what does success look like?

- Give quantitative indication of lifetime
  - Uncover all relevant failure modes
  - Avoid stimulating unwanted failure modes
- Be completed quickly
  - For new product launch: < 6 months
  - For process control: < 1 day
- Low cost
  - As low as possible: < 1% of total cost?

If our goal is a set of ideal tests, then we have gaps everywhere!

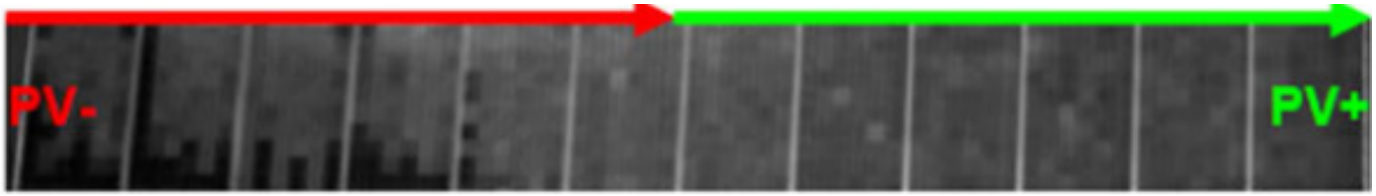
Biggest opportunities today will:

- *Reduce failures in the field (improved design qualification and improved quality control)*
- *Reduce time (and cost) to bring a new product to market*

Breakout Session 2

- Breakout session 2 on Gaps in Testing Protocols
  - Worksheets with pre-populated degradation modes will be provided
  - Please identify the gaps or inadequacies in testing protocols
    - Tests can be accelerated test protocols, need for field testing, characterization needs, metrology needs, etc. (maybe multiple gaps per failure mode – see next slide)
    - If there is a need for test standard, please identify
  - In the 3rd column, please identify if there is a need for DOE funding.
    - If "yes" how can DOE funding be most impactful?
    - How can industry best leverage DOE funding?
    - Are there ways DOE can help facilitate data sharing, collaborations, etc.?

Degradation or Failure Mode	Inadequacy in Testing Protocols	Needs for DOE funding

PID – Shows example of multiple testing gaps

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