NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Status Update PVQAT Task Group 5

Presenter & US TG5: David.Miller@nrel.gov;
China TG5 : fjt79@163.com (Leo Feng, CEI);
Europe TG5 : michael.koehl@ise.fraunhofer.de;
Japan TG5: Tsuyoshi.Shioda@mitsui-chem.co.jp

NREL PV Module Reliability Workshop
Golden Ballroom Salons A-D, Denver Marriott West, Golden, CO
Weds, 2015/2/24

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Goal and Activities for QA TG5 (UV, T, RH)

- IEC qualification tests (61215, 61646, 61730-2) presently prescribe up to 137 days field equivalent (IEC 60904-3 AM 1.5) UV-B dose. This is << 25 years!
- **Goal**: develop UV- and temperature-facilitated test protocol(s) that may be used to compare PV materials, components, and modules relative to a field deployment.

Core Activities:

1: Consider weathering literature and climate meteorology (*location-dependent information*).
   e.g., known benchmark locations…Miami, FL; Phoenix, AZ

2: Leverage existing standards, including other industries.
   - summary exists from Kurt Scott *et. al.*

3: Improve understanding of existing PV UV tests.

4: Improve understanding of module durability.
   4-1 Collect information about field failure modes.
   e.g., the literature, site inspections
   4-2 Confirm appropriate models for UV aging.

5: Consider suitable UV sources.
   - summary of *module* capable equipment from David Burns *et. al.*

6: **Generate test procedure for accelerated UV aging.**
   Presently performing experiments to provide technical basis & confident decisions.

7: Perform laboratory verification of proposed test standard/failure mode.
   - mini-module study (Japan), SoPhia round-robin (Europe), E_a interlaboratory study (US)

China TG5: Plan for Activities

- Formed in 2014.
- Presently formulating plan based on input from 2014.
- Will compare indoor & field aging.
- Analyze meteorological conditions in China vs. other world locations.
- Outdoor sites:

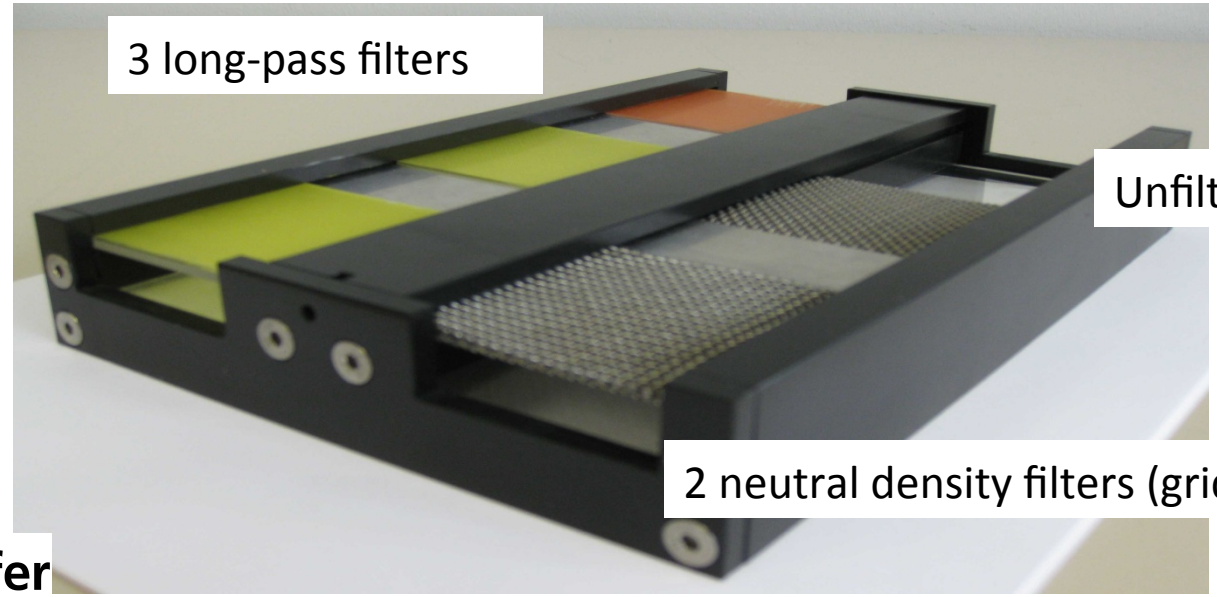
  QiongHai (HaiNan province, hot & humid)

  Turpan (XinJiang province, hot & dry)
- Expect to conduct experiments examining materials and components (likely encapsulation and backsheet). May use coupons and mini-modules.

UV – Round Robin Samples (experiment on going)

SOPHIA
European Research Infrastructure

- Samples:
  - manufacturers provide different back-sheet types
  - ISE produces laminates (usual glass and EVA, 13x20 cm) and 300 sample holders



Fraunhofer ISE

- Backsheet R-R continues. Expect dissemination of results soon.

Japan TG5: Mini-Module Experiment, Applied Stress Sequence

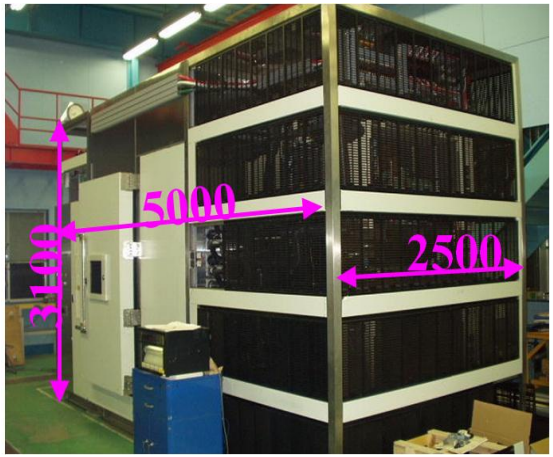
UV weathering test of 4-cells small size module

Irradiance ・・・ 90 W / m^2 （UV 300-400nm）
Nearly 2x UV （ASTM G173 Xenon Lamp)

Chamber temp. ・・・・・ 65 ℃
Chamber humidity. ・・・ No Control
（ typical 1 –10%RH）
Test Modules ・・・ 4-cells, polycrystalline Si
Termination ・・・ Open circuit

Backsheet ・・・ Multilayer laminated PET

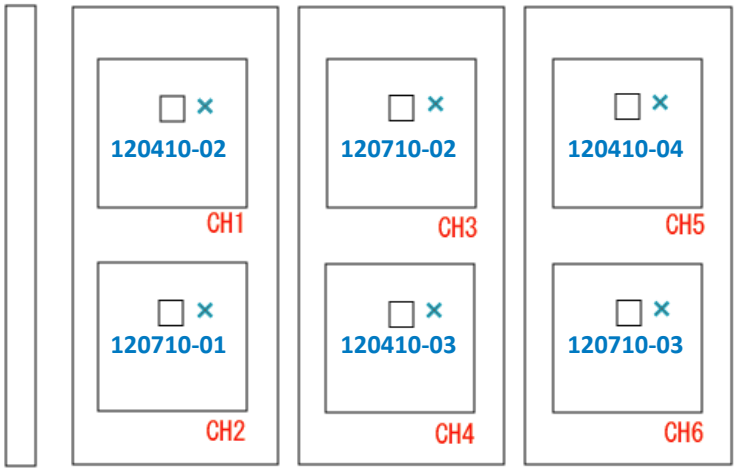
Encapusulant ・・・ EVA (fast cure)
EVA A ・・・ Within the shelf life
EVA B ・・・ Over the shelf life



Sample ID and Test sequence

ID	EVA	UV330h 1st RUN	UV660h 2nd RUN	UV990 h 3rd RUN	UV1320 h 4th RUN
120410-01	A	Control module			
120410-02 (CH1)	A	Front side	→	→	Back side
120410-03 (CH4)	A	Front side	→	→	Back side
120410-04 (CH5)	A	Back side	Front side	→	→
120710-01 (CH2)	B	Front side	→	→	Back side
120710-02 (CH3)	B	Front side	→	→	Back side
120710-03 (CH6)	B	Back side	Front side	→	→

Module layout in the UV chamber



X: Thermocouple gage
☐ : Junction BOX

Japan TG5: Activities

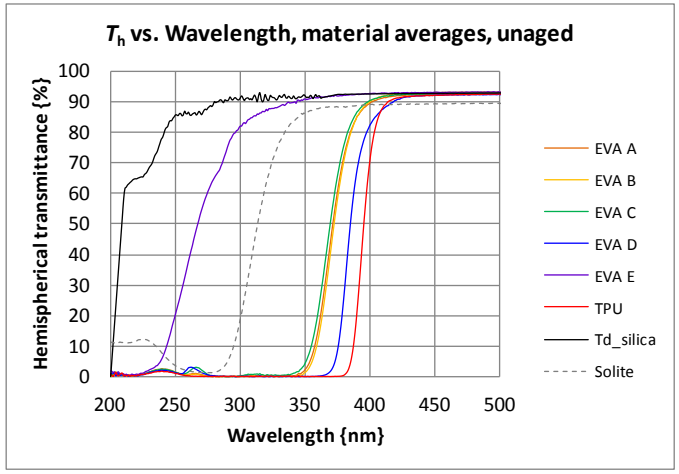
- Early effort examined the sequence of applied stress (*e.g.*, UV → aging sequence → DML; or UV → aging → DH).
- Different results (I/V, discoloration) were obtained, depending on the sequence of stress applied.

- Recently: examination of fielded modules.
- Interest in delamination.

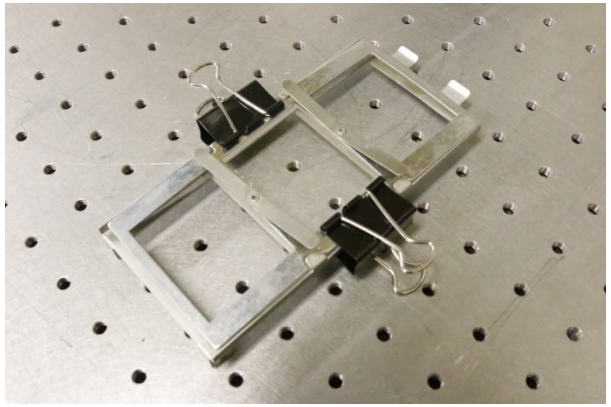
- Have started second mini-module experiment.
- This also examines the sequence of applied stress tests.
- Wet leakage test has become of interest as pass/fail.

US TG5: Details of the E_a Methods and Experiment: Encapsulation Transmittance Test

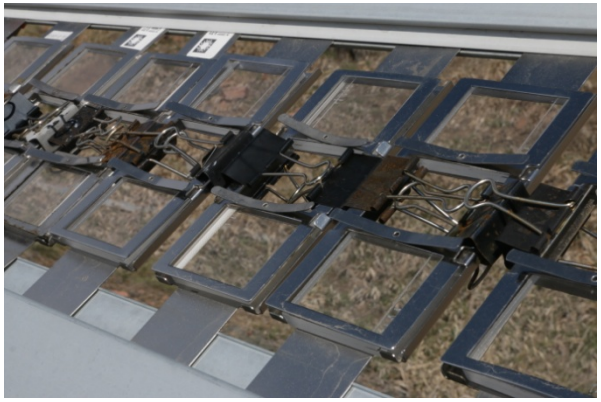
- Glass/polymer/glass coupon specimens measured using a spectrophotometer (with integrating sphere)
- Measure at specimen center (anaerobic, no O_2) and edge (aerobic)
- Analyze: solar-weighted transmittance, yellowness index, and UV cut-off wavelength.



Transmittance will be examined using silica/polymer/silica samples.



Specimen in sample holder for indoor aging at NREL.



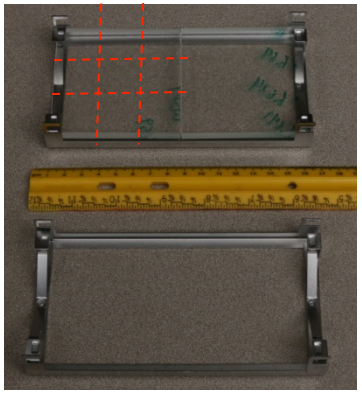
Specimens on outdoor rack, aging in Golden, CO at NREL.

User summary:

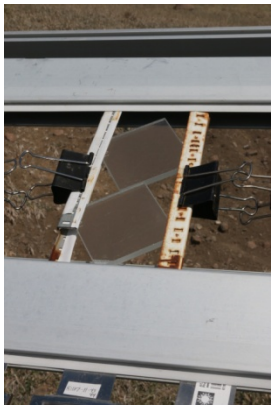
- Geometry: glass/polymer/glass (3.2 mm/0.5 mm/3.2 mm)
- Size: 2” x 2”
- Quantity: 3 replicates of 6 materials (pre-conditioned), and 1 reference (not pre-conditioned)
- Aging: 0, 15, 30, 45, 60, 75, 90, 120, 150, 180 cumulative days (indoors) or 0, 1, 2, 3, 4, 5 years (outdoors)
- Measurements (non-destructive): repeatedly age and measure at each laboratory/test site

US TG5: Details of the E_a Methods and Experiment: Encapsulation CST Adhesion Test

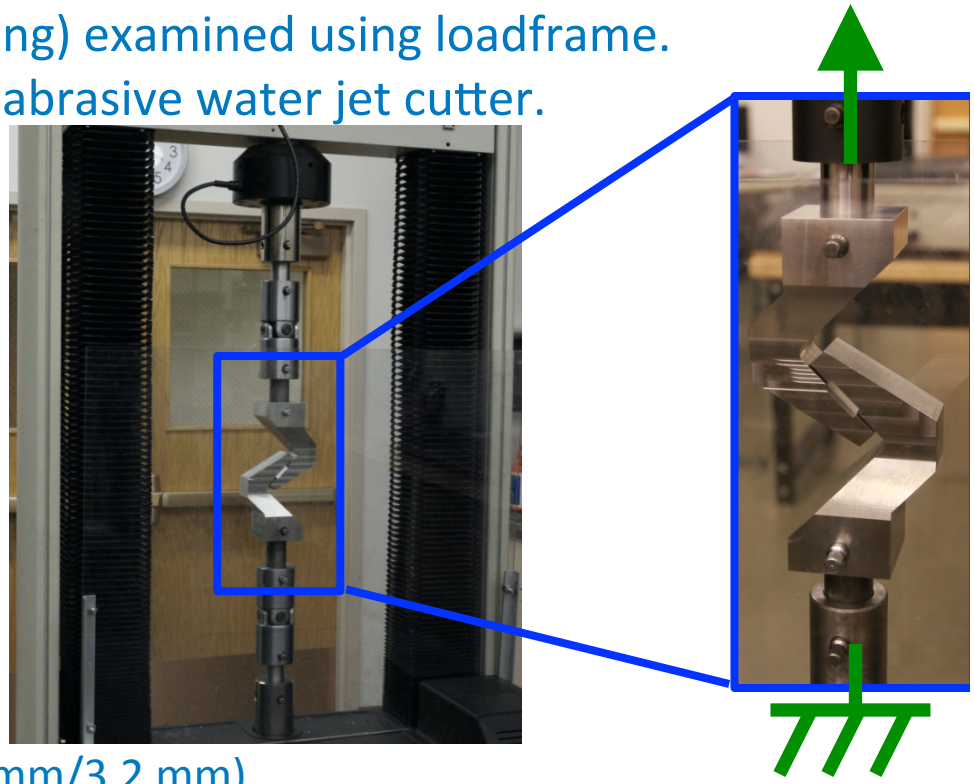
- Better physics-based methods being developed as IEC standard.
- 25 mm square specimens (diced, after aging) examined using loadframe.
- Pristine edge quality is critical. Dice using abrasive water jet cutter.



Sample holder configuration for indoor aging at NREL. Samples are diced after aging.



Specimens on outdoor rack, aging in Golden, CO at NREL.



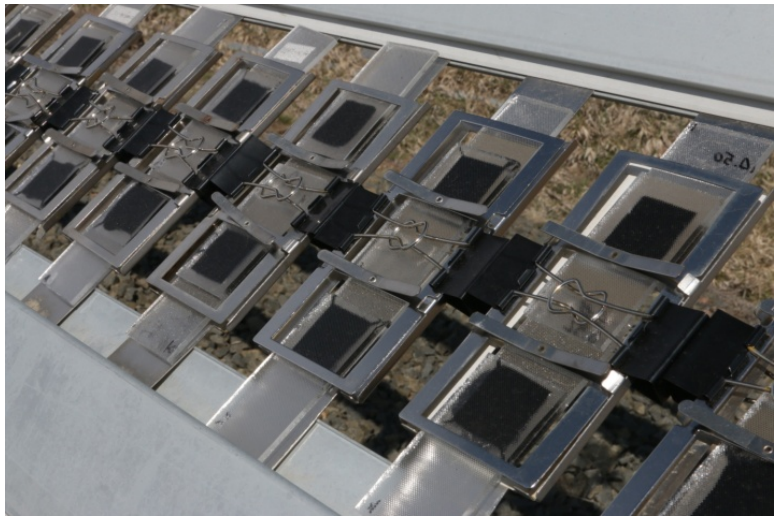
The CST will be used to examine the attachment of EVA. Method from: Chapuis et al., PIP, 22 (4), 2014, pp.405–41. (EPFL)

User summary:

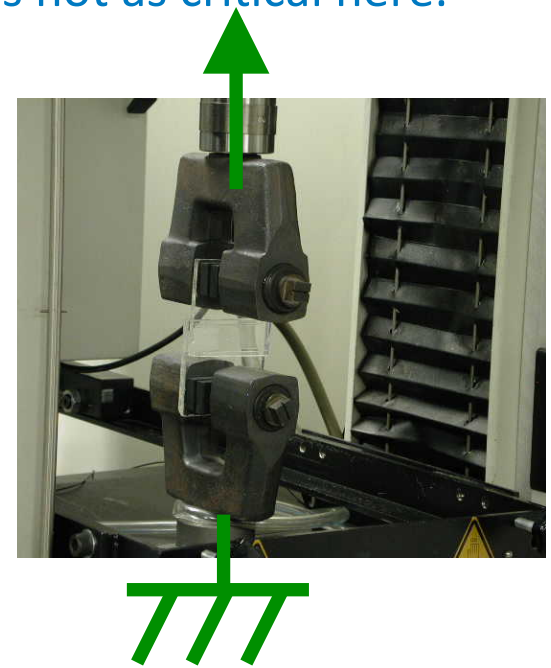
- Geometry: glass/polymer/glass (3.2 mm/0.5 mm/3.2 mm)
- Size: 3” x 3”
- Quantity: 10 replicates of 1 material (pre-conditioned), plus 5 extras (not pre-conditioned)
- Aging: 15, 30, 45, 90, and 180 cumulative days (indoors), or 1, 2, 3, 4, 5 years (outdoors)
- Remove 2 coupons at each increment
- Measurements(destructive): age at each laboratory/test site, then sent to NREL for measurement

US TG5: Details of the E_a Methods and Experiment: Edge Seal Lap Shear Adhesion Test

- Lap shear is the standard test method for RTI and other certification protocols.
- Edge quality (handling of the glass specimens) is not as critical here.



Specimens on outdoor rack, aging in Golden, CO at NREL.

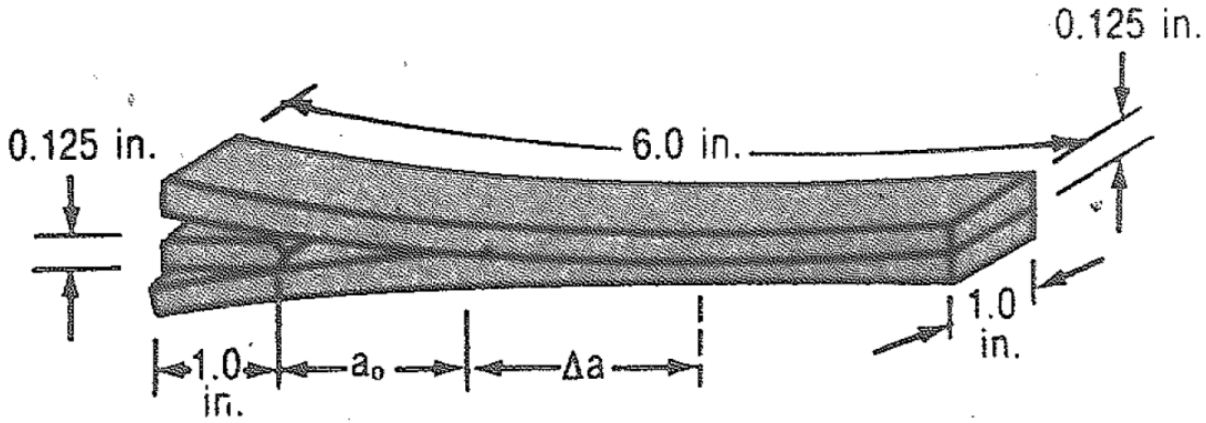


Testing Summary:

- Geometry: glass/polymer/glass (3.2 mm/0.5 mm/3.2 mm). 25 mm X 25mm test area.
- Quantity: 10 replicates of 2 test materials
- Aging: 15, 30, 45, 90, and 180 cumulative days (indoors), or 0.5, 1, 2, 3, 4, 5 years (outdoors)
- Remove 2 coupons of each material at each increment
- Measurements (destructive): aged at each laboratory/test site, then sent to NREL for measurement
- Use a displacement rate of 10 mm·min^{-1}. Record σ_{max}, ε_{max}, and failure mode.

US TG5: Details of the E_a Methods and Experiment: Edge Seal Wedge Adhesion Test

- Fracture mechanics test for interfacial adhesion ($J \cdot m^{-2}$), not an attachment strength test ($N \cdot m^{-2}$ or $N \cdot m^{-1}$) .
- Specimens will be examined visually and using a micrometer.



G = Fracture Energy

$$G = 3Et^3 h^2 / 16a^4$$

A DCB wedge test will be used to examine the attachment of edge seals.
Marceau *et al.*, Adhesives Age, 1977, 28-34.
Also: ISO 10354, ASTM D3762.

User summary:

- Geometry: glass/polymer/glass (3.2 mm/0.5 mm/3.2 mm)
- Size: 1” x 9”
- Quantity: 2 replicates of 2 test materials
- Aging: 0, 15, 30, 45, 60, 75, 90, 120, 150, 180 cumulative days (indoors) or 0, 0.5, 1, 2, 3, 4, 5 years (outdoors)
- Measurements (semi-destructive): aged and measured at each laboratory/test site

Timeline of Activities for TG5

- NREL specimens are presently at 150 days (Ci5000) and 180 days (UV suitcase).
- Results will be used to assign t, T, %RH for a climate- & configuration-specific UV test.

	Qualification	QMS	Climate- & Configuration-Specific Test	Service Life Prediction
Current status	Issued as standards	Revised NWIP submitted	Proposed as concepts	Concepts
2014 goal	Submit 61215 (Ed 3) 61730 (Ed 2)	Publish new TS	Initiate E_a test. Create strawman UV standard.	Develop criteria to evaluate QMS related to service life; NWIP
2015 goal	Publish new editions	Start use of the TS in factory inspection	Submit UV standard NWIP. Create strawman test sequence standard. Complete indoor E_a test.	
2016 goal		Revise QMS document to reflect feedback	Publish E_a results. Submit CD of UV standard.	
Chamber test times	Modules: ~ 6 weeks	TBD	~6 months	~18 months