Progress since the first workshop: What's New & What's Needed

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NREL

Purpose

- **Review of Progress since first AA mtg.**
- **Review of NREL reliability capability**
- **Coring technique to evaluate interface toughness/outdoor weathering correlation.**

Activities since AA I

- **FMEA study initiated**
- **Coring technique to evaluate interface toughness/outdoor weathering correlation.** *PIP April 2008 pp.1-9*
- **TTF report completed.** *NREL report*
- **Failure mechanisms for the different PV technologies itemized**
- **Expand small systems capability**
- **Added chamber capability**
- **Convene AA II**

Standard qual/safety testing:

- Damp heat – 42 days
- 200 thermal cycles – 34 to 50 days
- UV/TC/HF – 35 to 40 days
- Outdoor exposure – 30 to 40 days
- Mechanical load – 2 to 4 days
- Ice ball impact – 1 to 2 days
- Hot-spot protection – 14 to 21 days
- Intermediate tests (I-V, hi-pot, etc.)

Other accelerated tests:

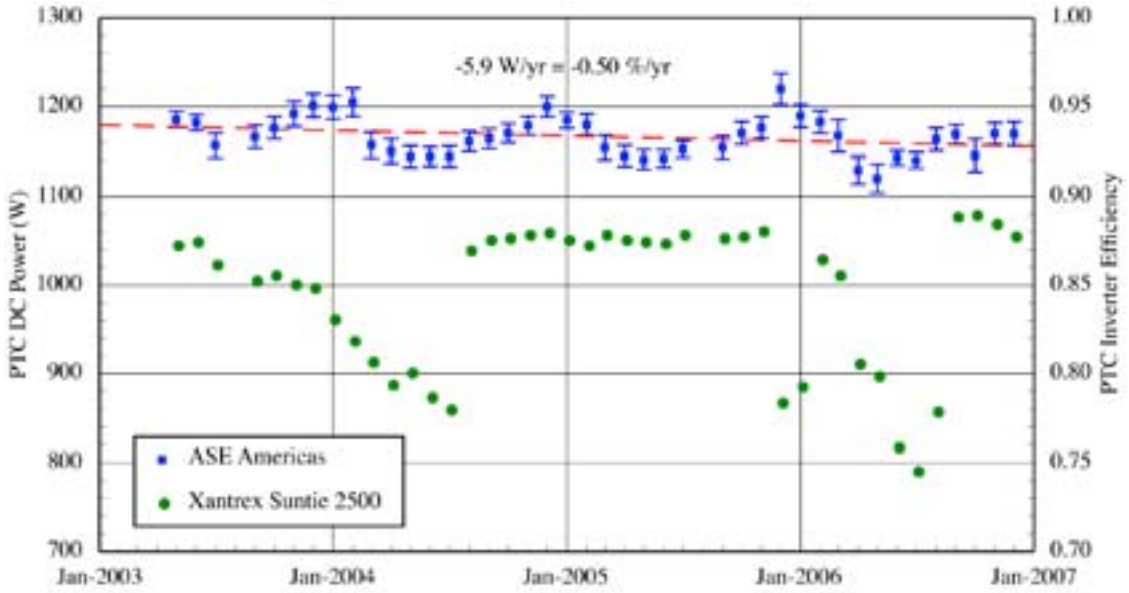
- Damp heat with high-voltage bias: thin-film corrosion
- Lengthen standard tests, such as 2000 hours of damp heat or 500 thermal cycles
- Combine damp heat and thermal cycling
- Larger ice balls
- Higher mechanical loads > 2400 Pa
- 24 hour/day light soaking under load

Real-time testing:

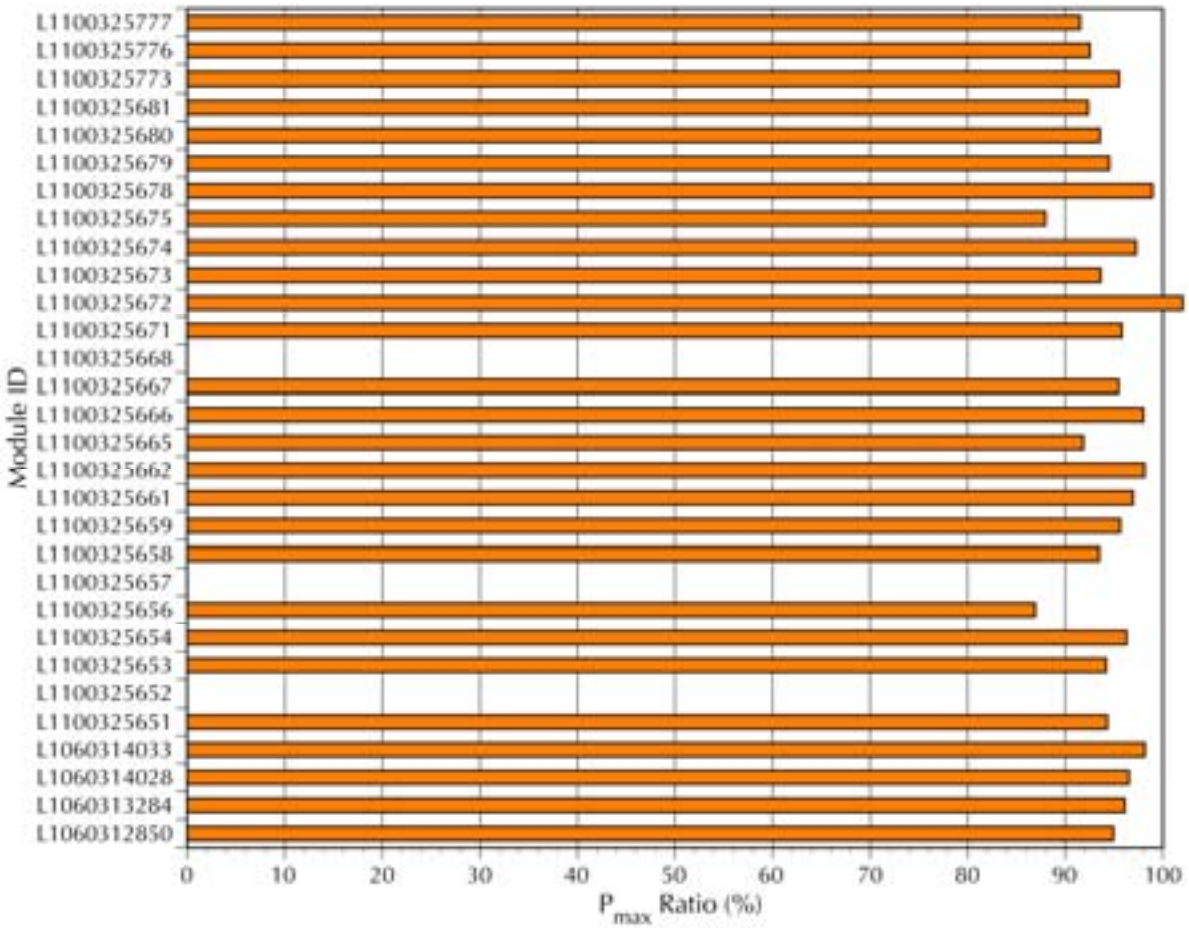
- Time-consuming, but absolutely vital
- Should be started as early as possible
- Many times will uncover problems that are not seen with standard tests
- Degradation rates – only way to measure

Array degradation rates:

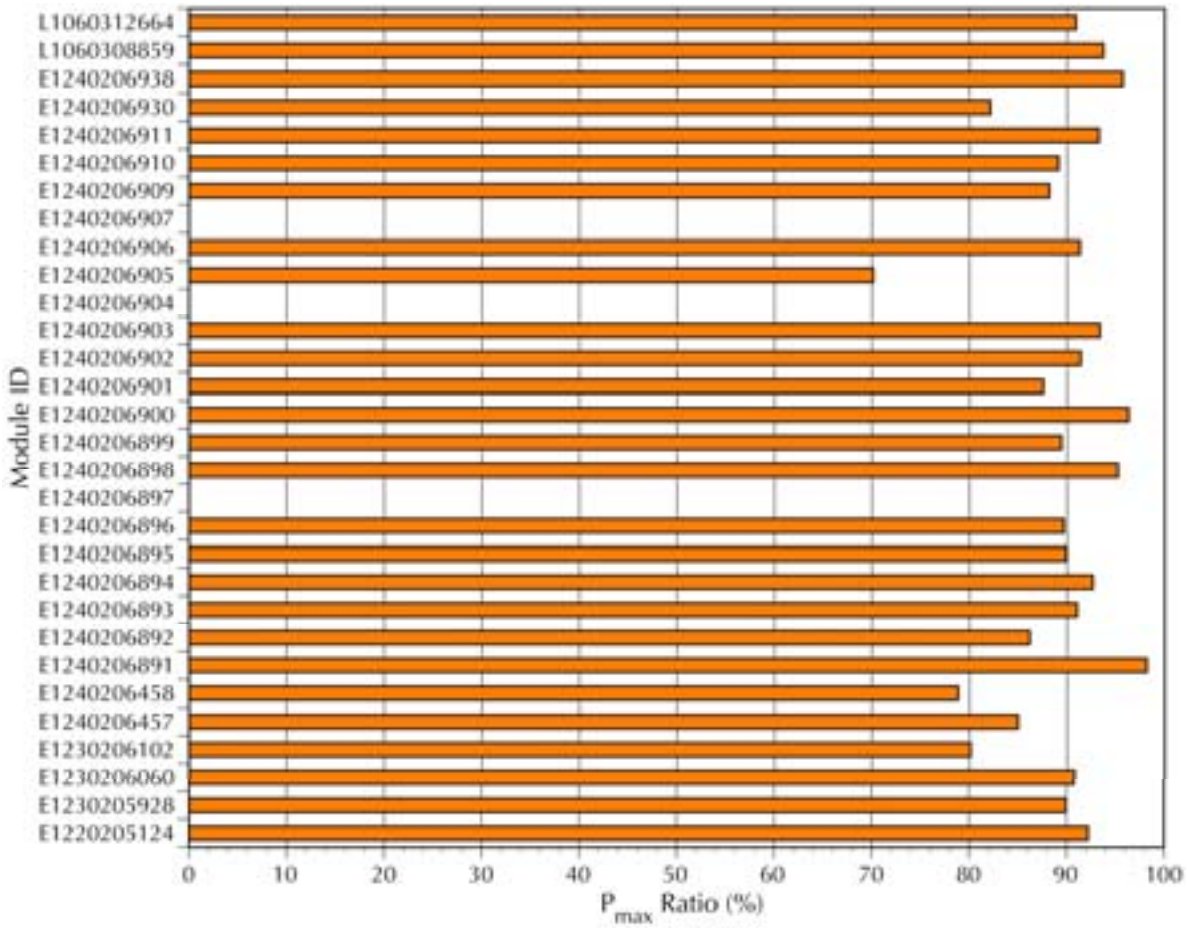
- Module/array power logged real-time
- Monthly multiple linear regressions to PTC equation
- PTC ratings – 1000 W/m^2, 20°C ambient, 1 m/s wind speed
- Linear fit gives degradation rate
- Important for true LCOE



Thin Film P_{max} 0-y Data

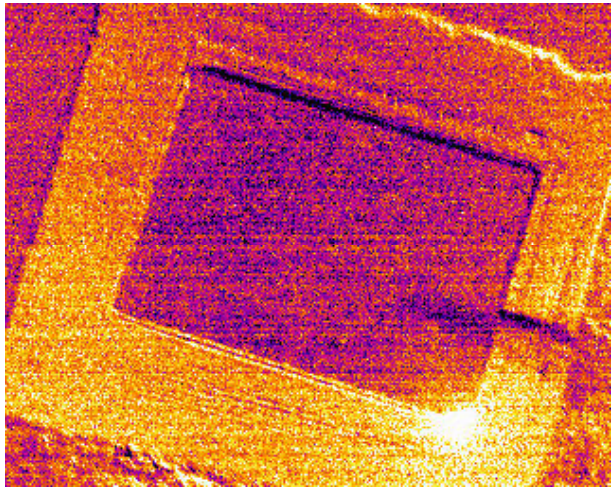


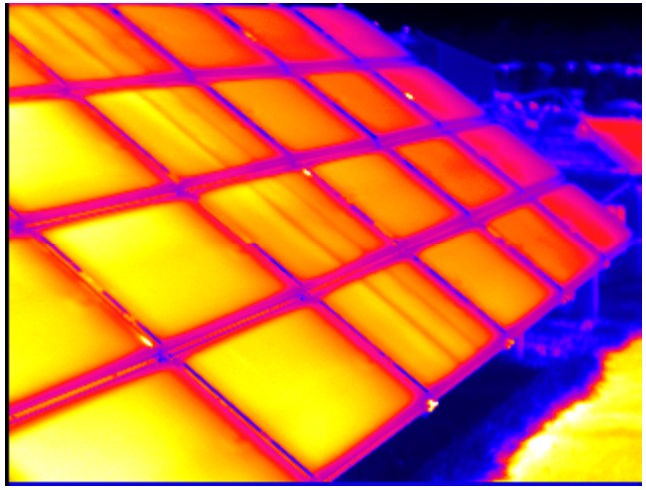
Thin-Film P_{max} 5-y Data

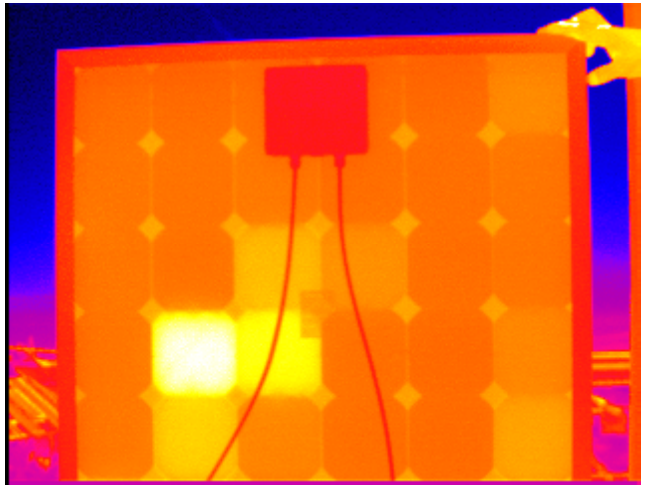


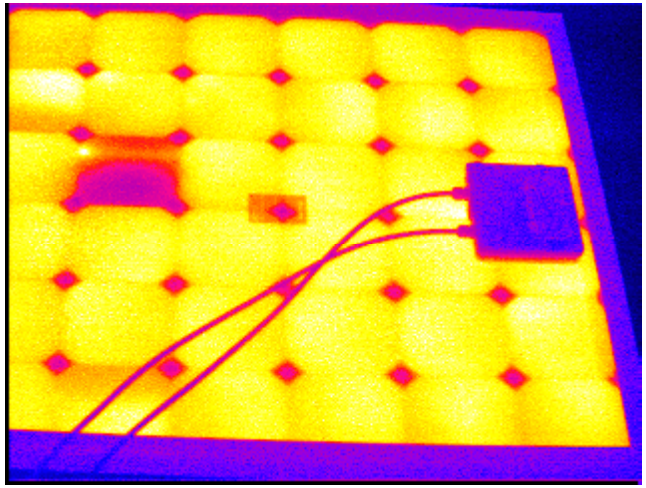
IR Camera Diagnostics

Cells to Systems, 0.2 to 50 □C





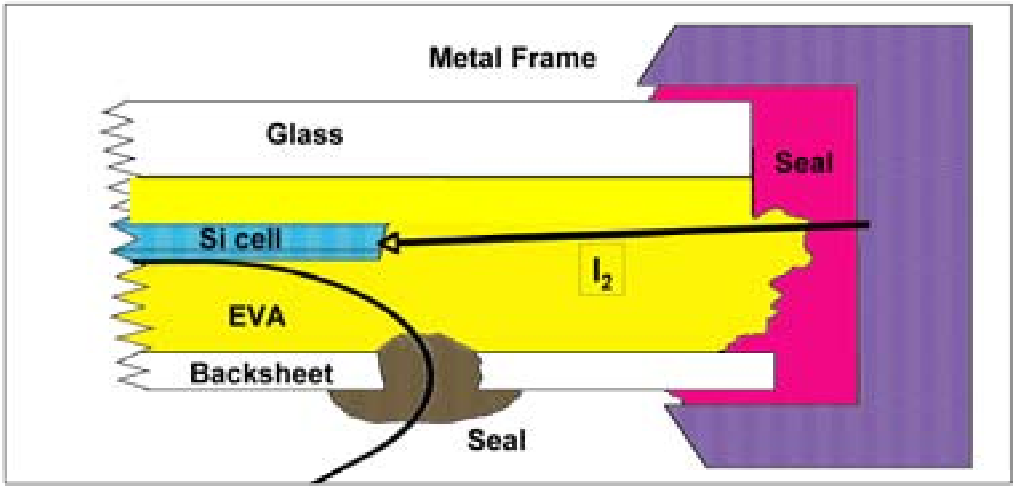


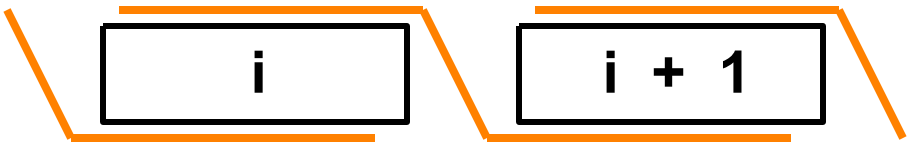


NREL Packaging Team Capabilities

- Characterization
  - Adhesion, cohesion, and toughness; peel, butt and lap shear strength, and torque vs angle
  - Electrical conductivity; surface and bulk
  - WVTR; water transmission, solubility, diffusion
  - Rheology; modulus
- Accelerated tests
  - UV, temperature, damp heat, acceleration factors
- Module and cell diagnostics
  - IR imaging, individual cell shunt, coring , transient currents, internal resistance
- Modeling
  - Moisture ingress and egress
  - Cell-to-frame leakage current
  - Device(AMPS) and Module(PSpice)

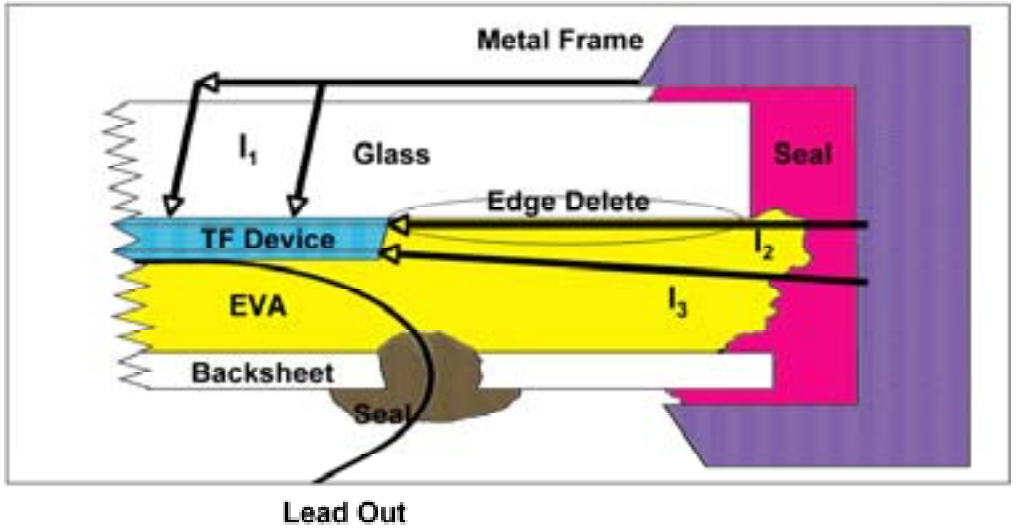
Wafer Type Module

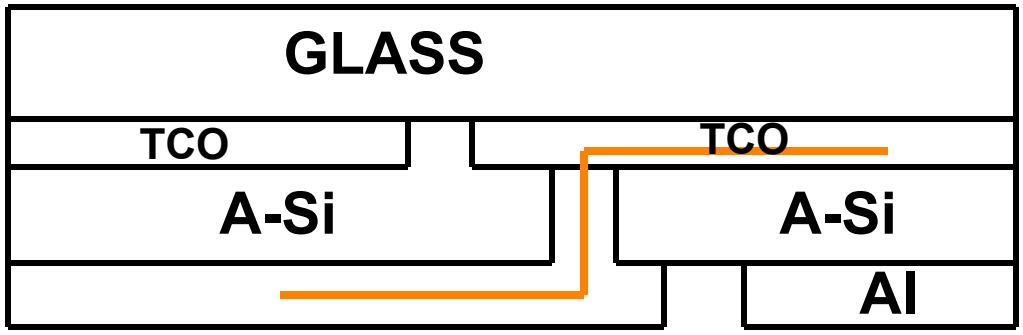




Cell Interconnect

Thin-Film Type Module

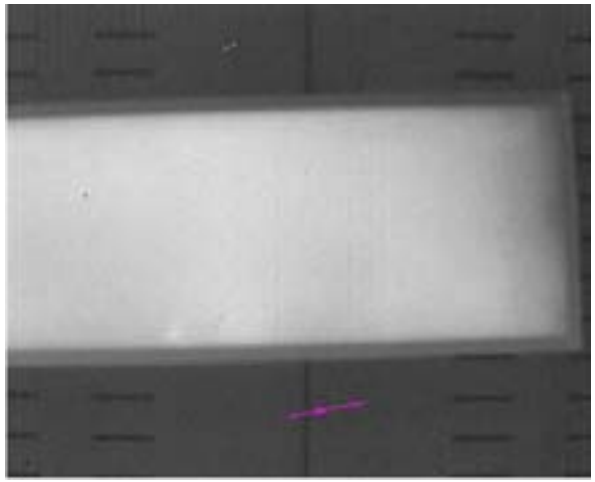




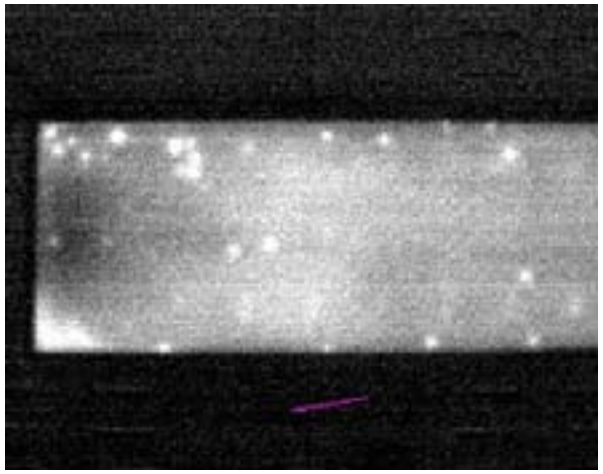
Cell Interconnect

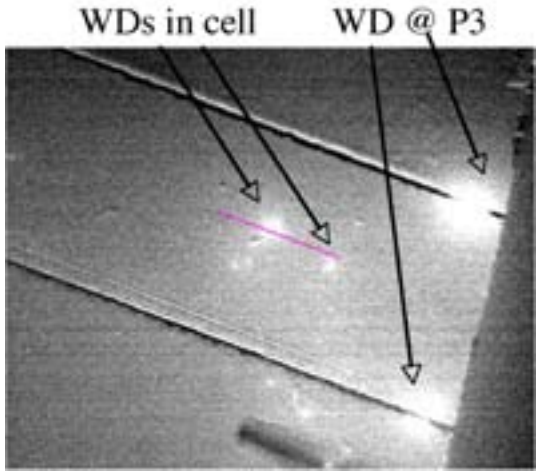
Thermal Imaging, Forward Bias

0 y @ NREL



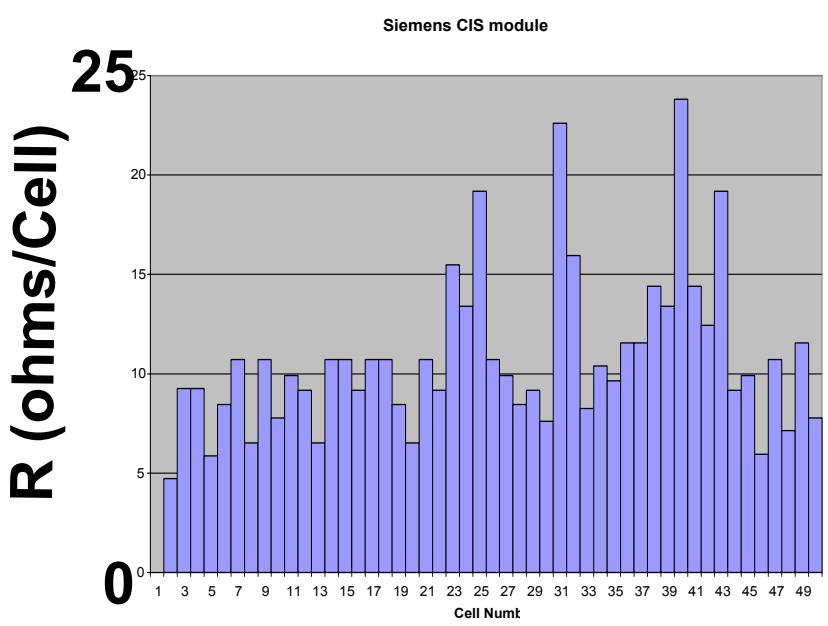
5 y @ NREL





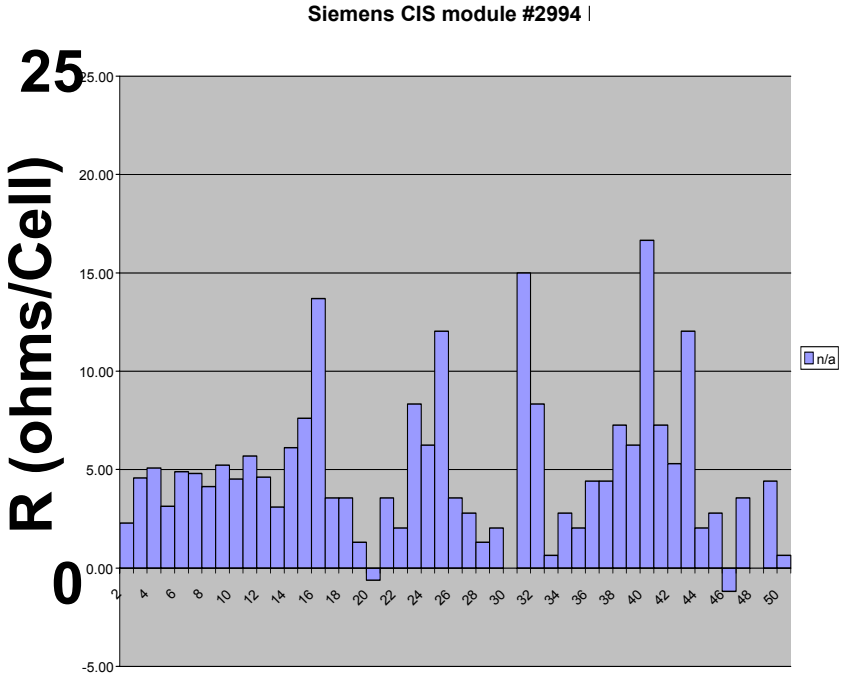
Two-Terminal, Non-destructive Shunt Resistance Technique

5 y @ NREL



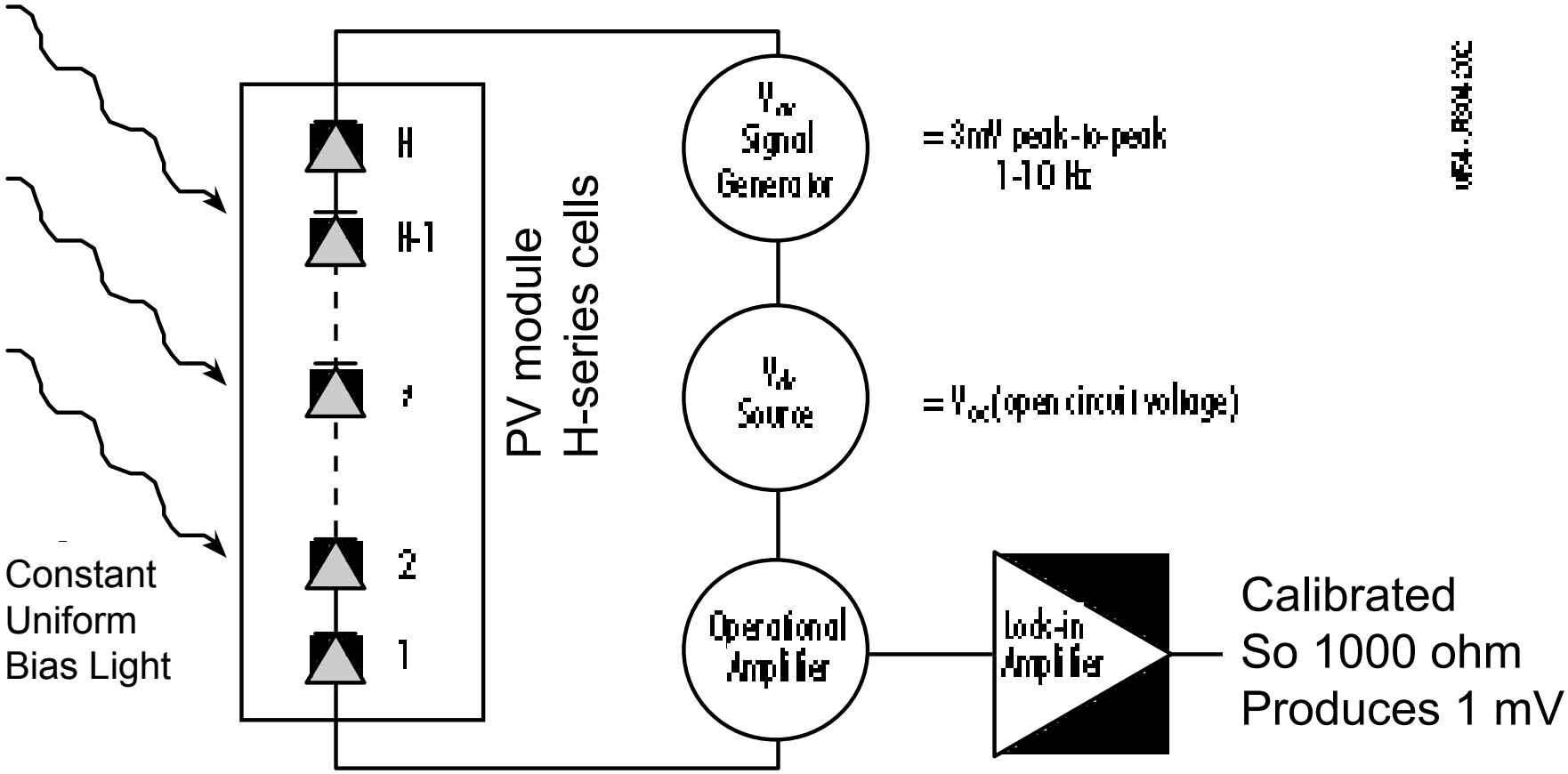
Cells 1 thru 48

7 y @ NREL

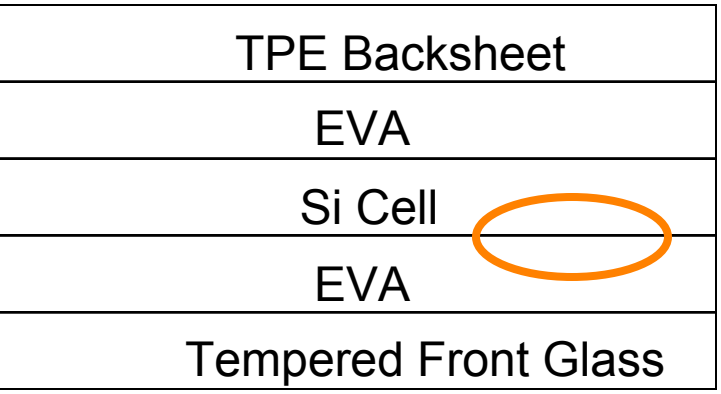


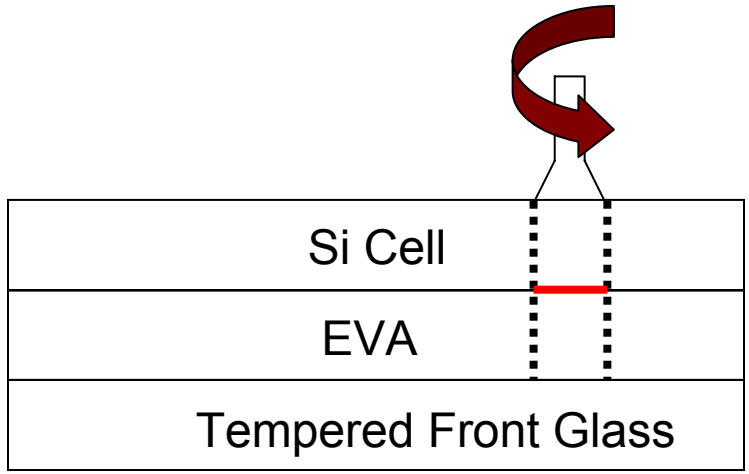
Cells 1 thru 48

Two-Terminal, Non-destructive Shunt Resistance Technique

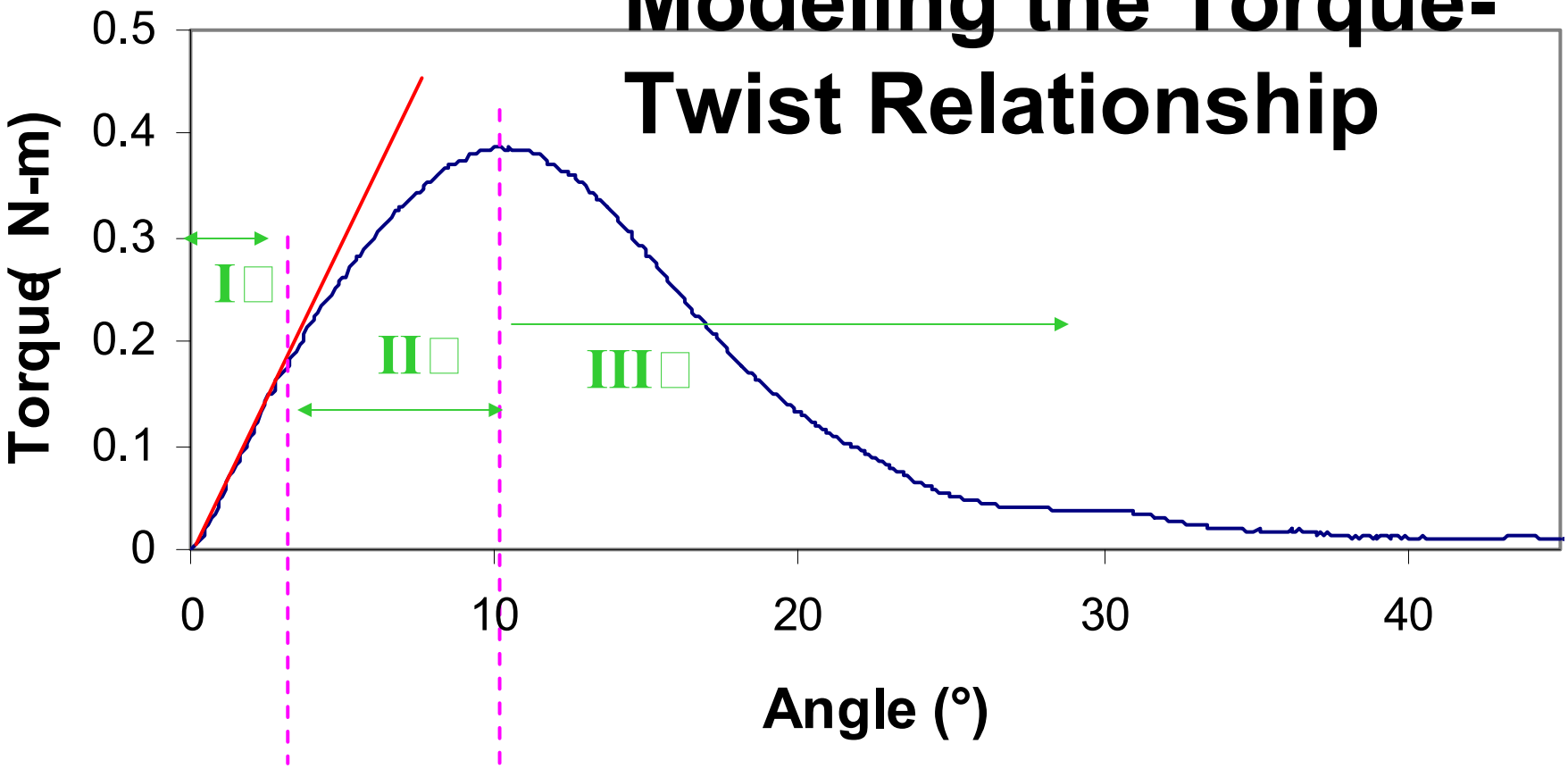


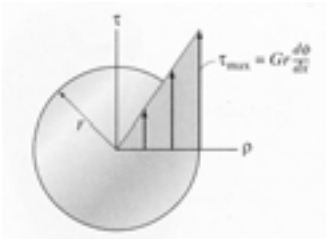
Shear Strength Measurement at Front Cell/EVA Interface

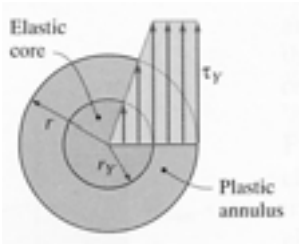


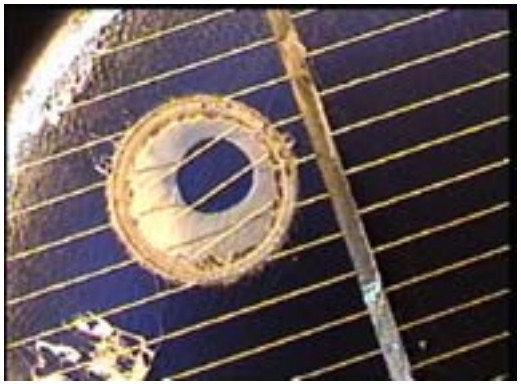


Modeling the Torque-Twist Relationship

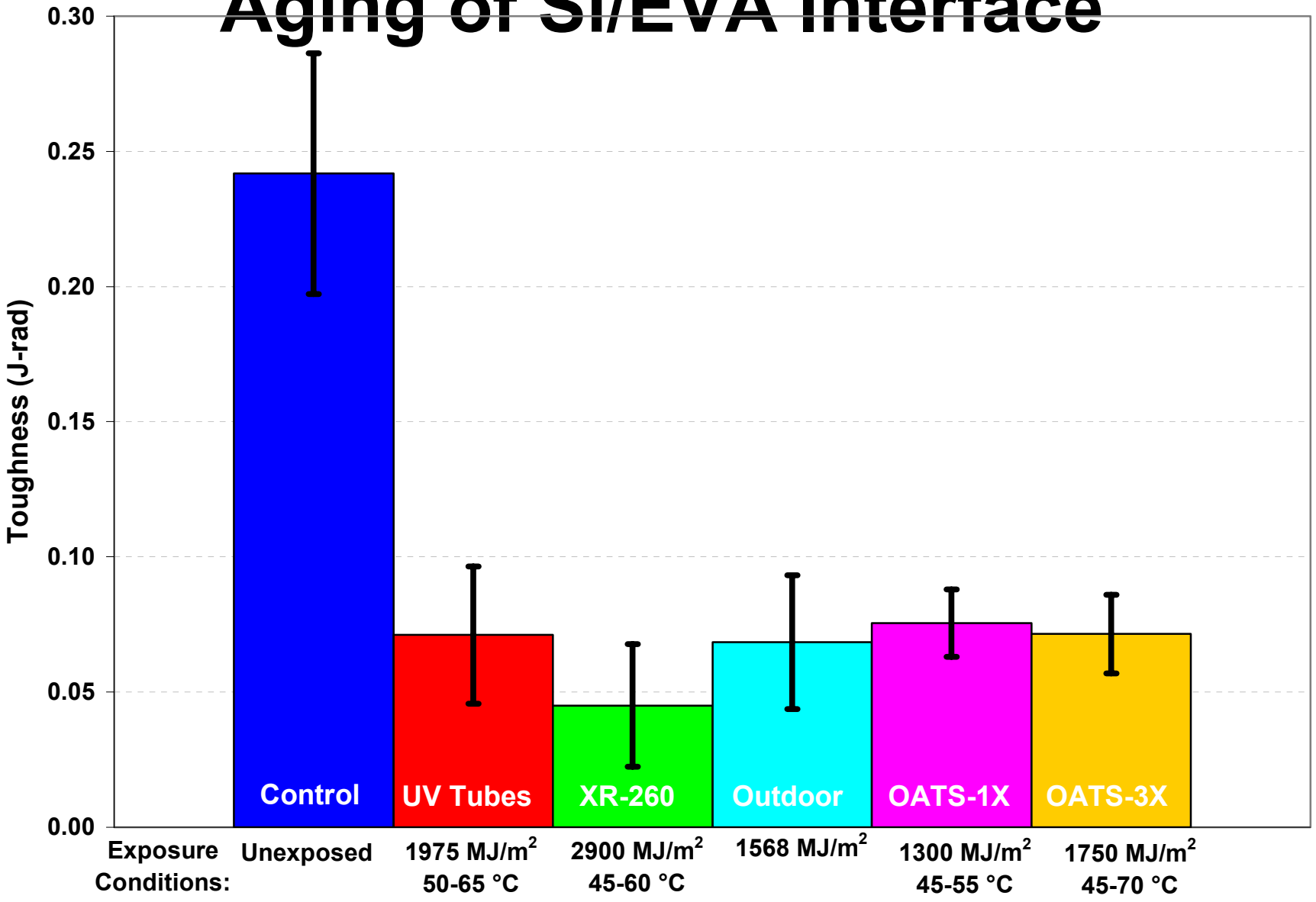




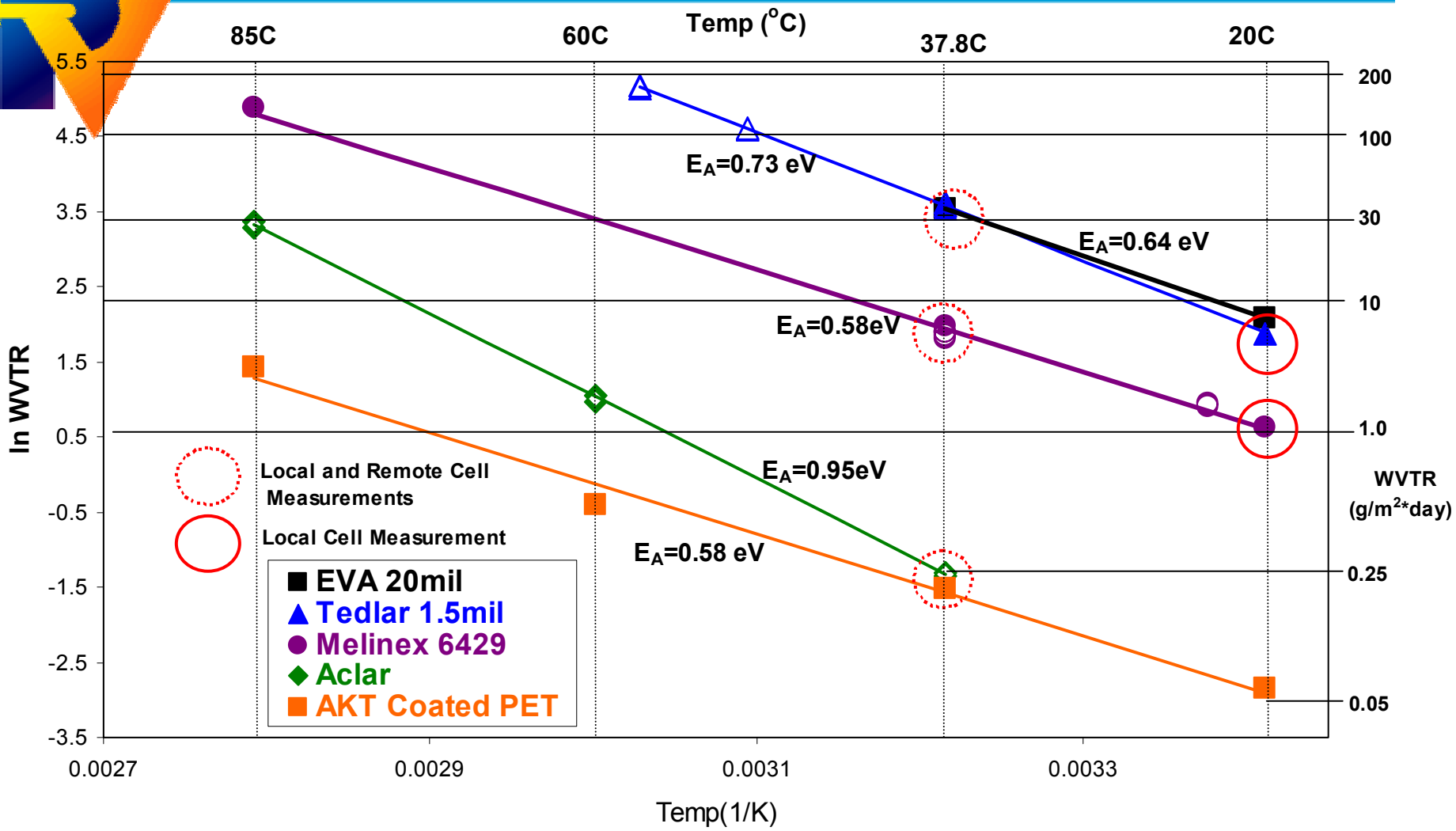


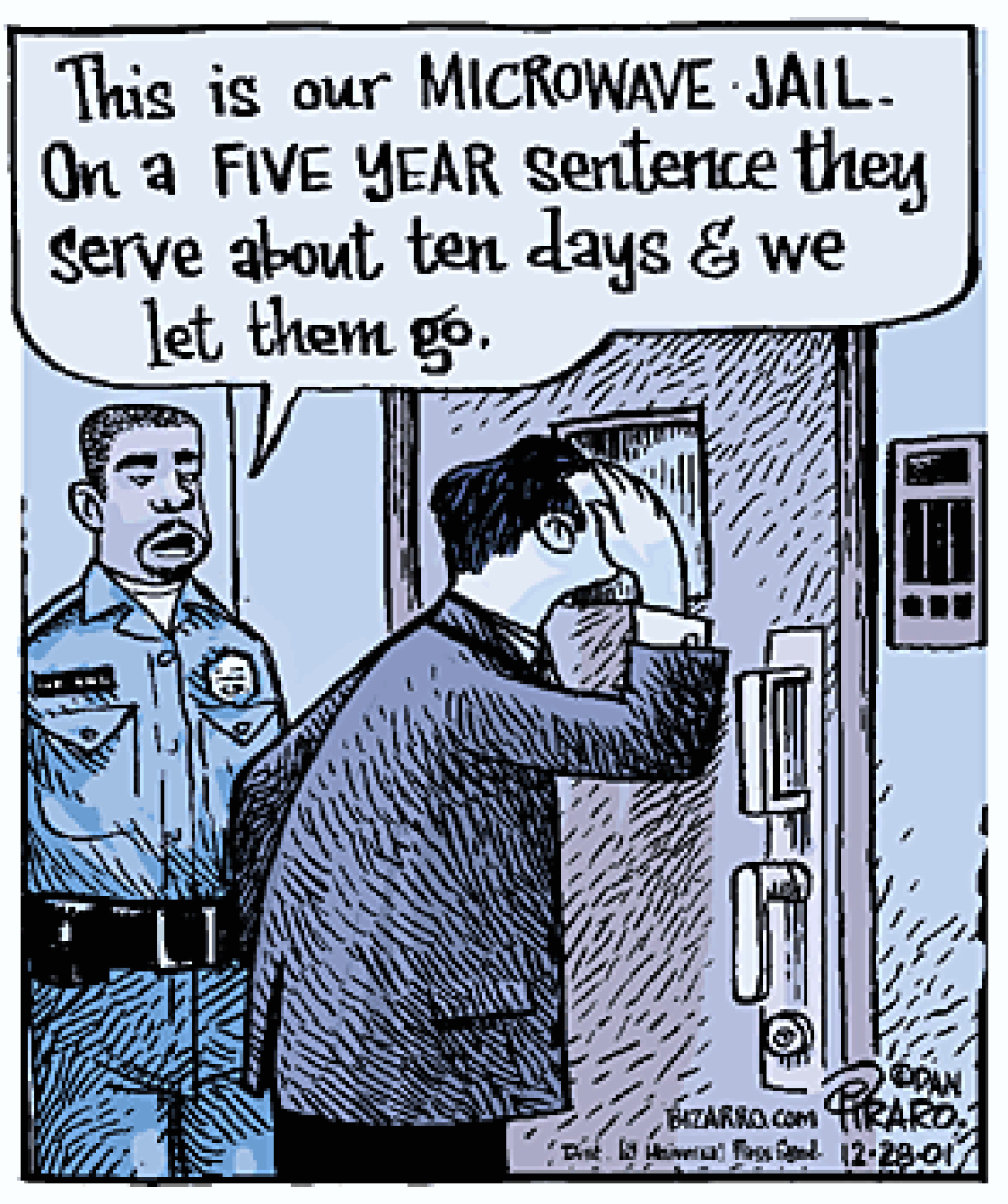


Outdoor/Chamber UV Toughness Aging of Si/EVA Interface



Arrhenius Plot of WVTR for various backsheet materials as measured on Remote Cells





The Universal Need for Correlations with Accelerated Exposures