SOLAR CELL/MODULE DEGRADATION AND FAILURE DIAGNOSTICS

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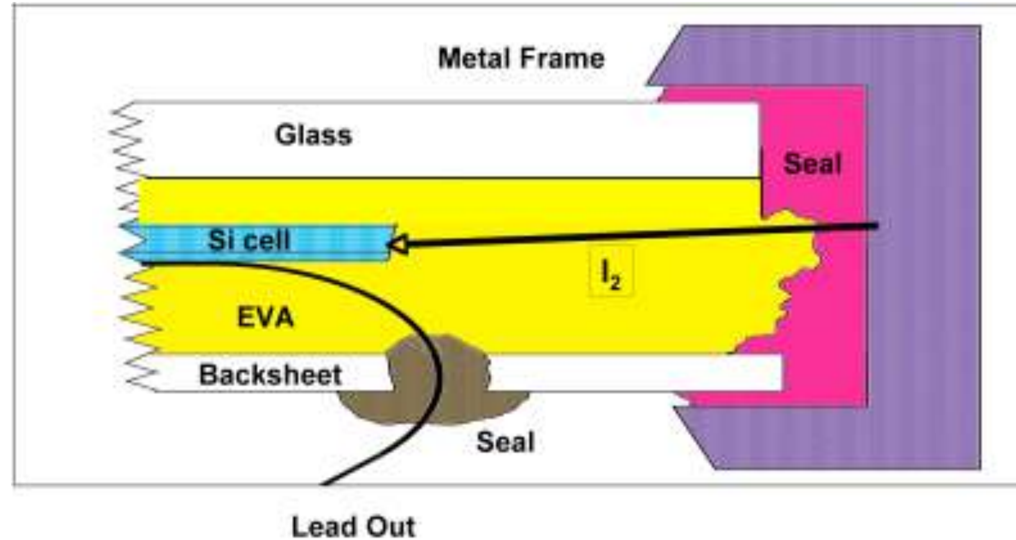
Purpose

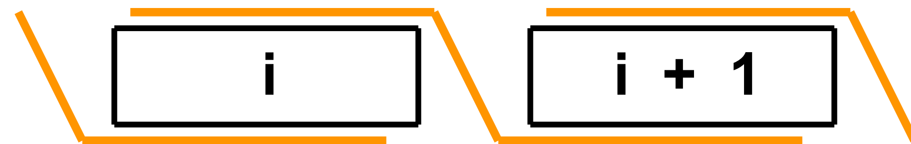
- **Review of solar cell/module degradation and failure diagnostic tools.**
- **Coring technique to acquire samples and evaluate interface toughness.**
- **Accelerated testing and failure mechanisms in PV.**

Outline

- Basic Module Types
- Diagnostics
- Distributed vs localised
- Definition of reliability
- Accelerated testing in PV
- Failure mechanisms
- Summary

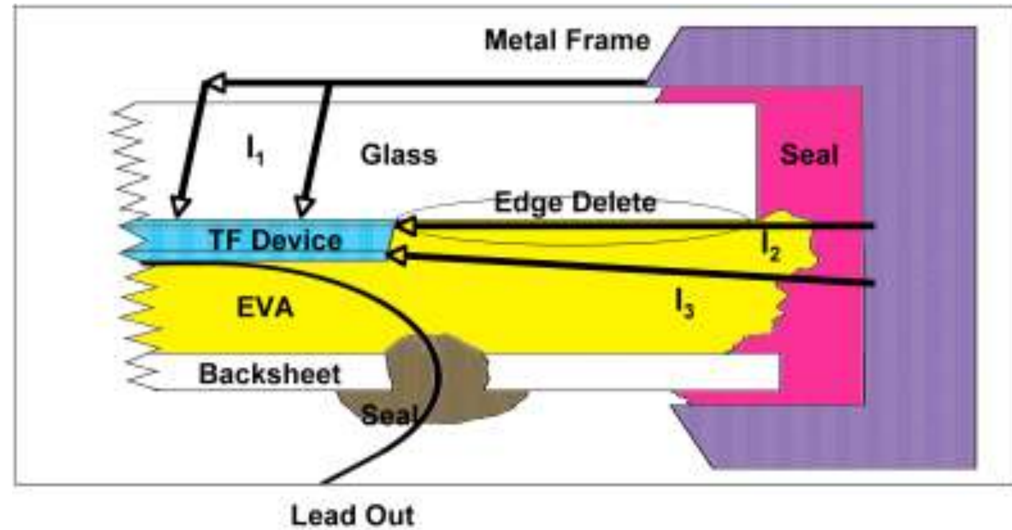
Wafer Type Module

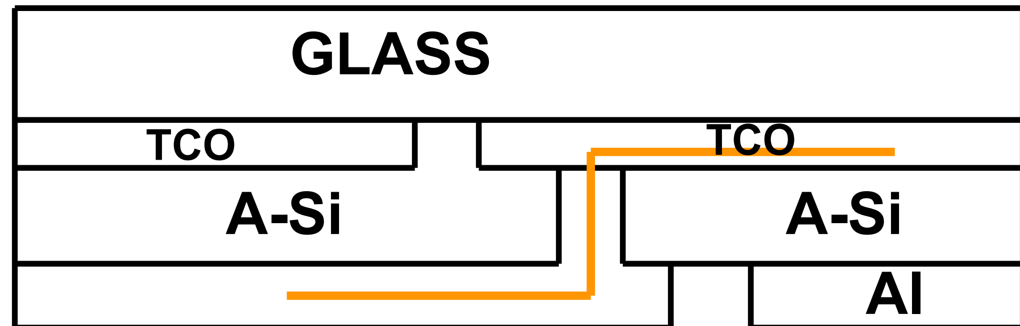




Cell Interconnect

Thin-Film Type Module

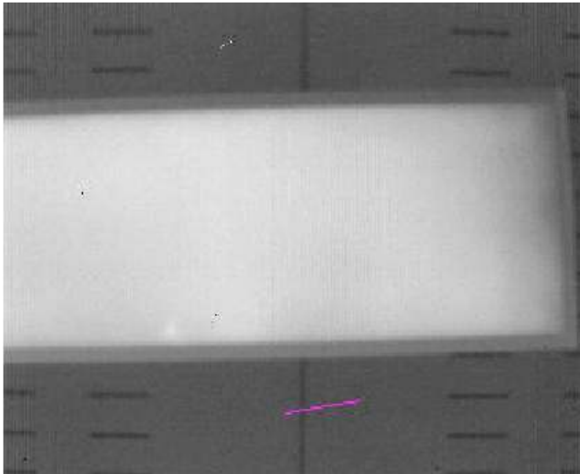




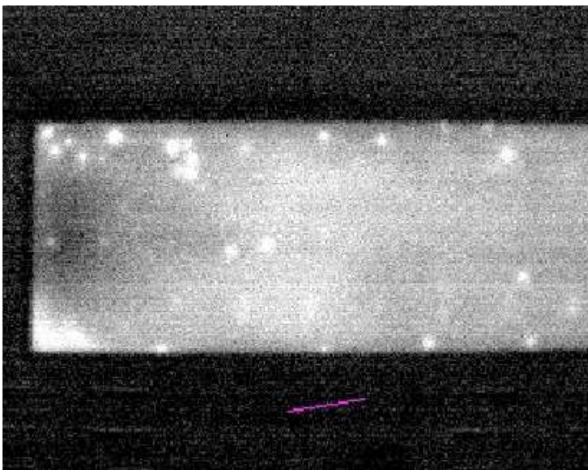
Cell Interconnect

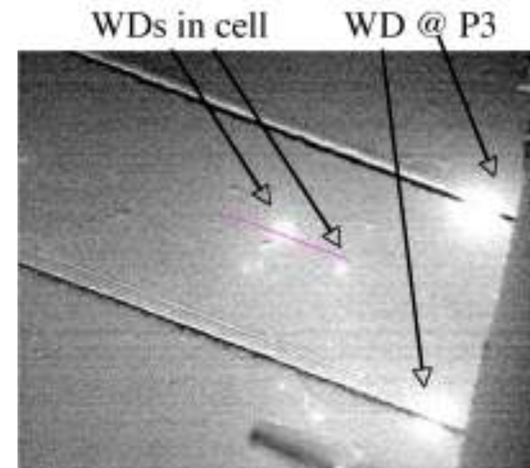
Thermal Imaging, Forward Bias

0 y @ NREL



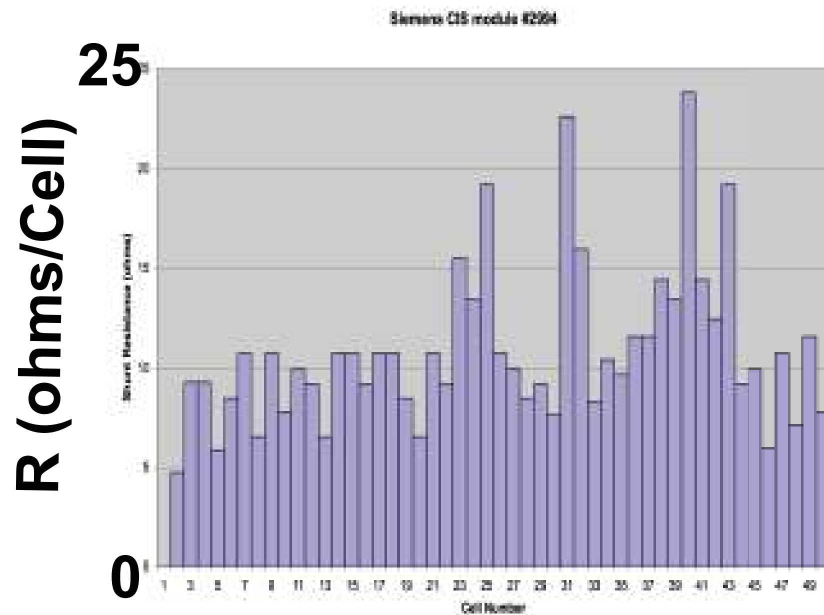
5 y @ NREL





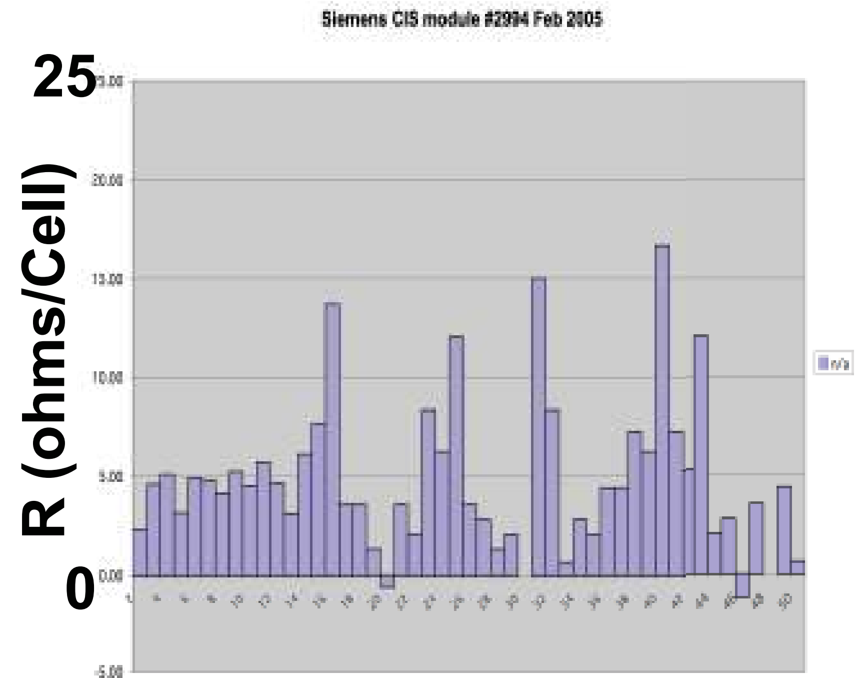
Two-Terminal, Non-destructive Shunt Resistance Technique

5 y @ NREL



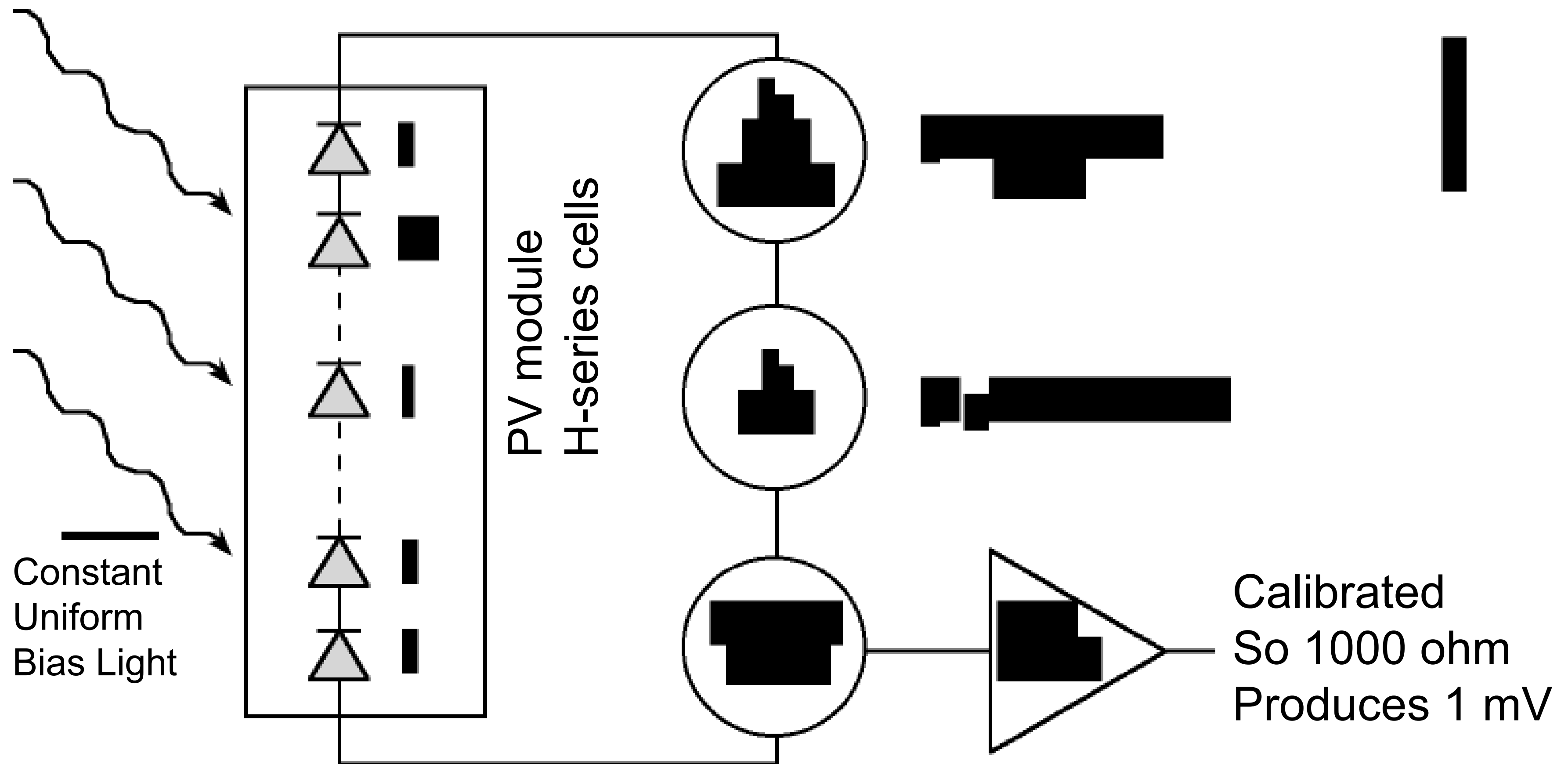
Cells 1 thru 48

7 y @ NREL

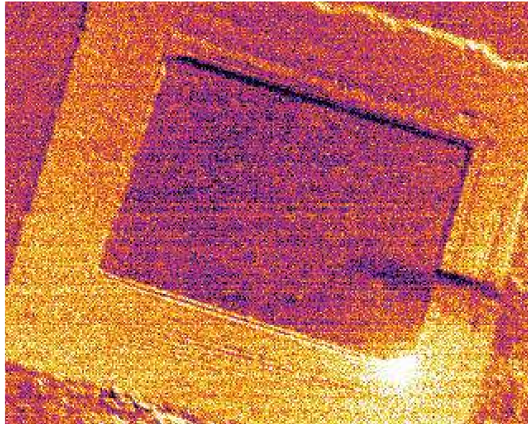


Cells 1 thru 48

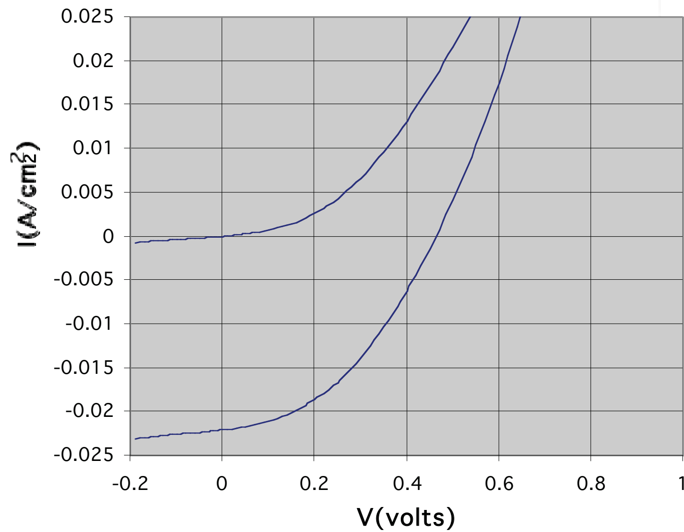
Two-Terminal, Non-destructive Shunt Resistance Technique



CdTe cell Weak Diode: IR and IVs



1225 h at Voc at 100 °C



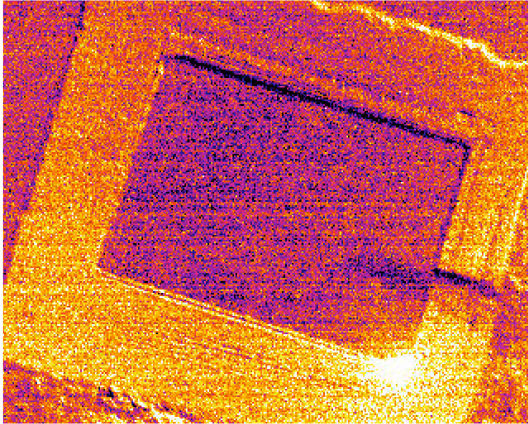
4.5 - 6 % after stress.

Hot in forward bias.

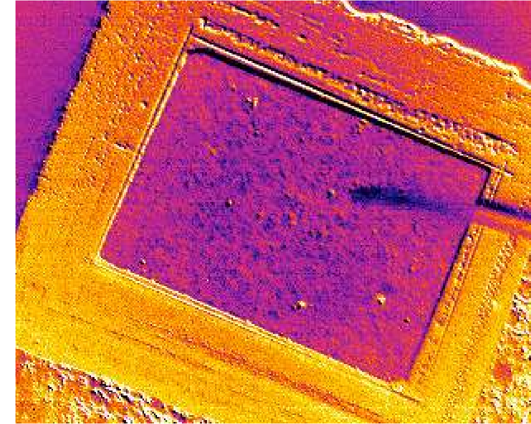
Not in reverse bias

NEDT 25 mK

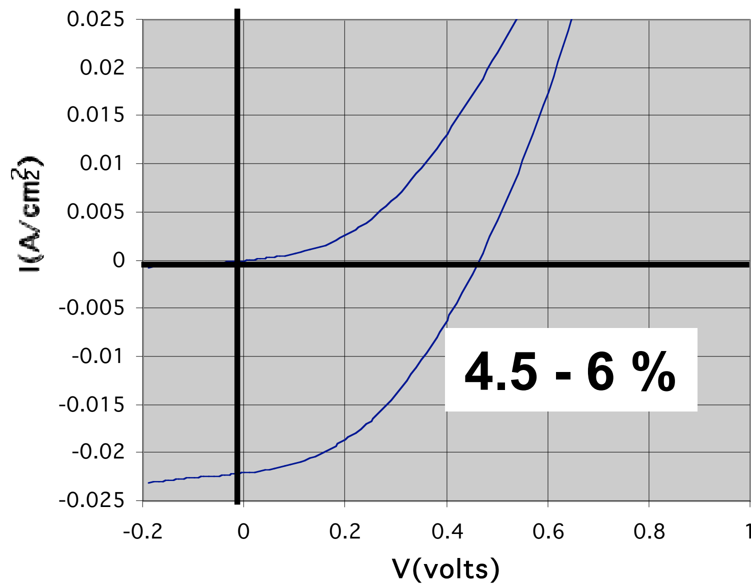
Weak Diode Removal

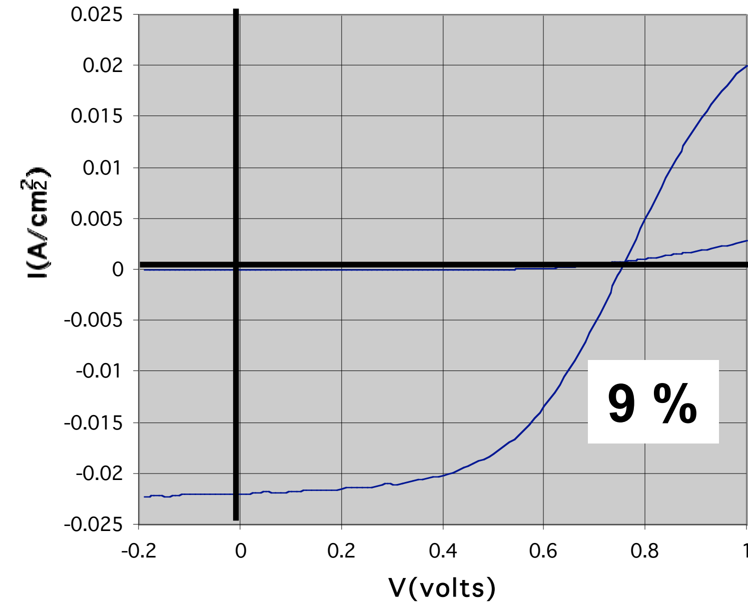


1225 h at Voc at 100 °C

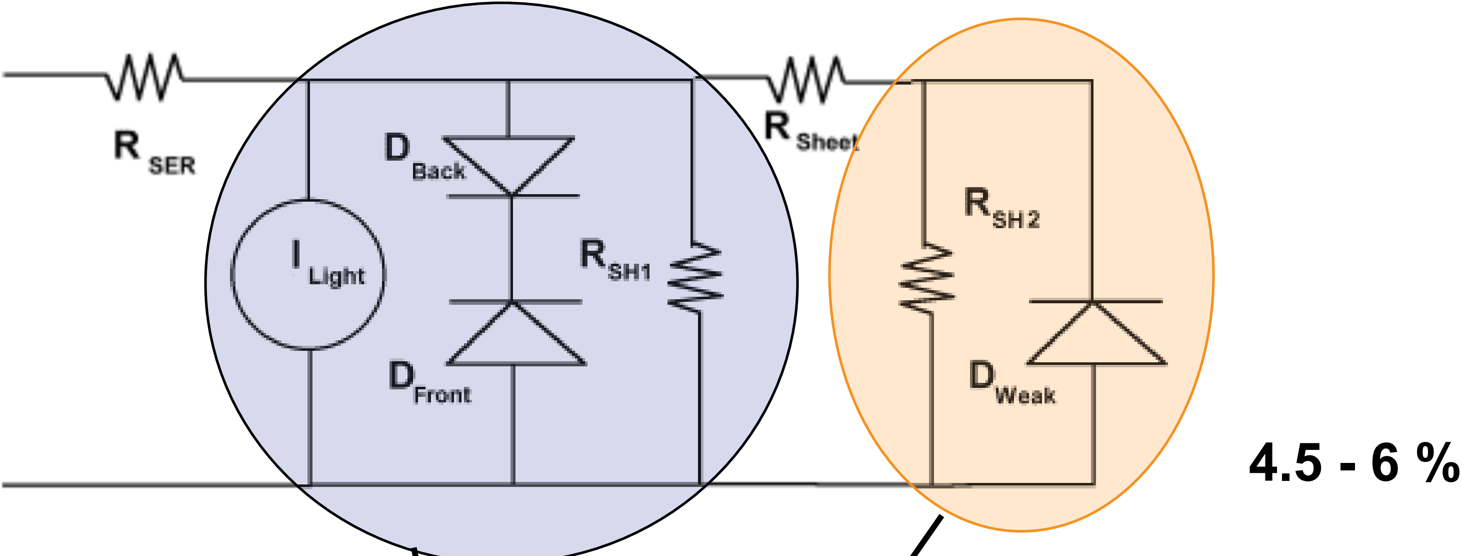


WD @ Corner Removed

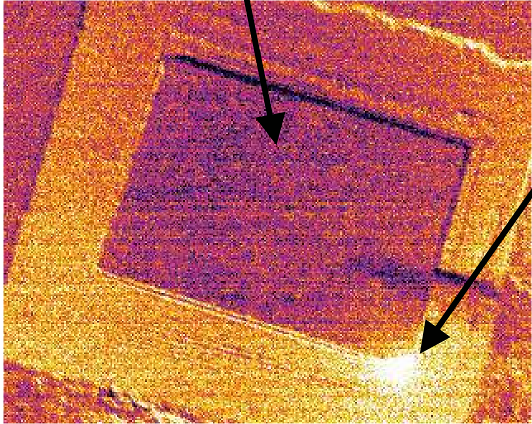


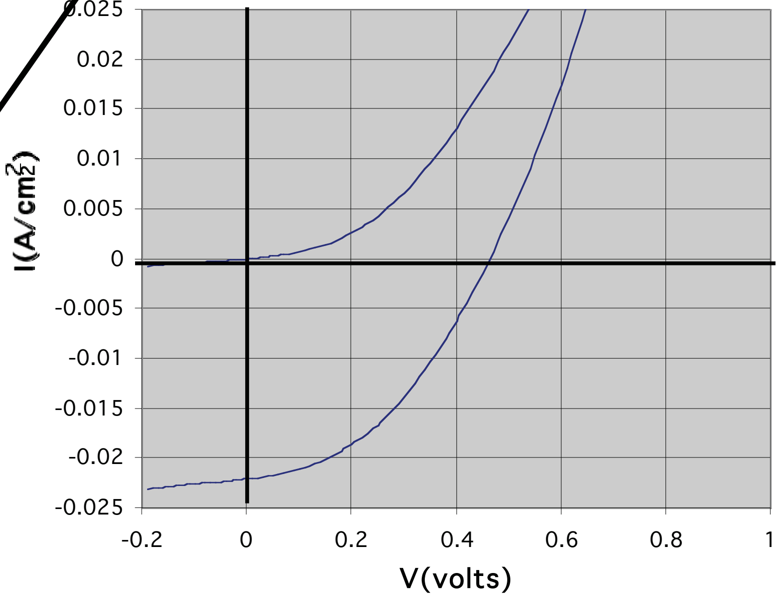


P-Spice circuit w/WD

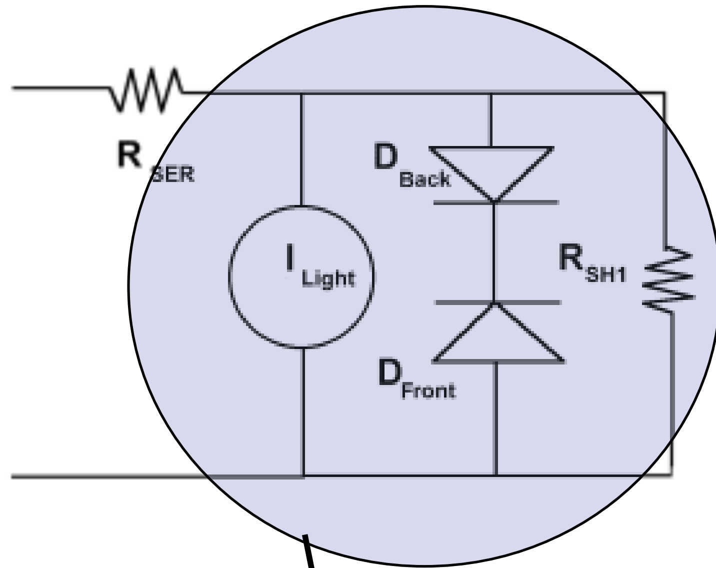


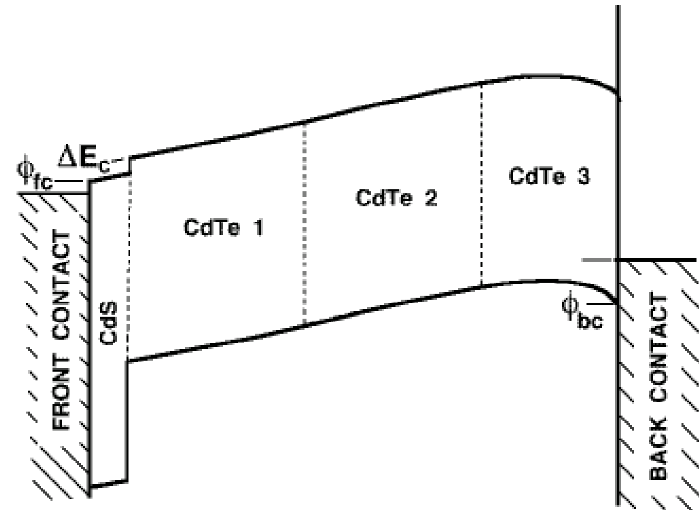
4.5 - 6 %

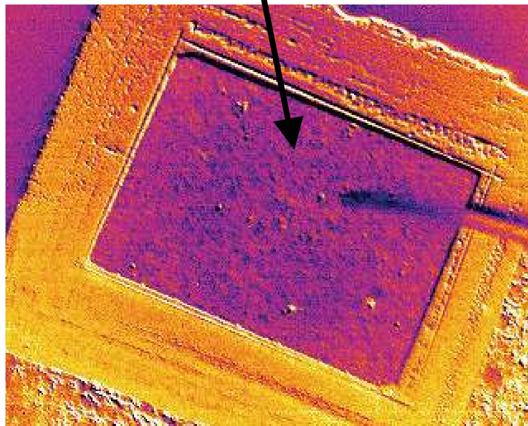


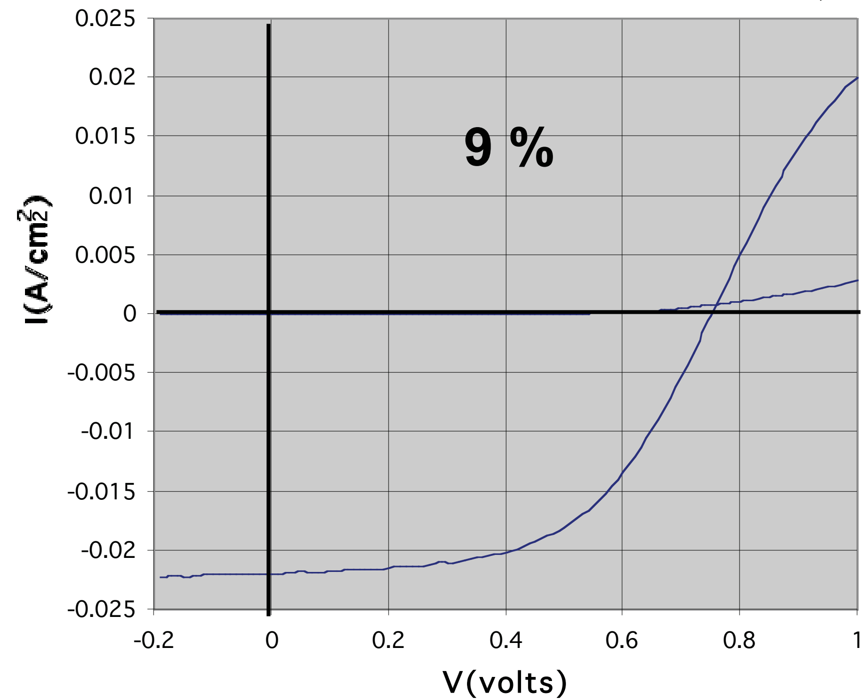


P-Spice/AMPS (crossover/rollover)

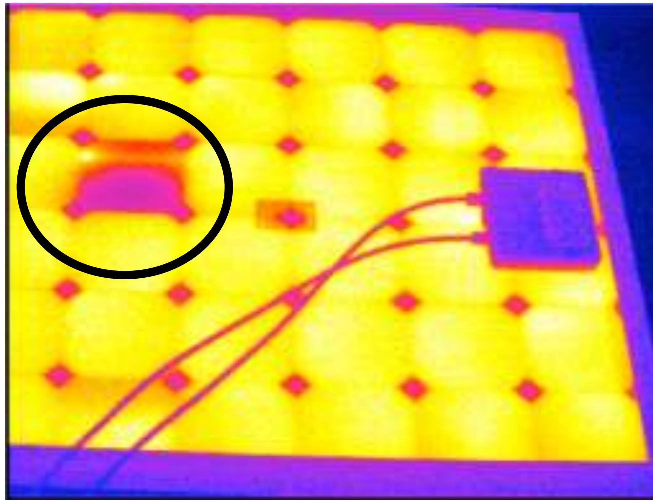




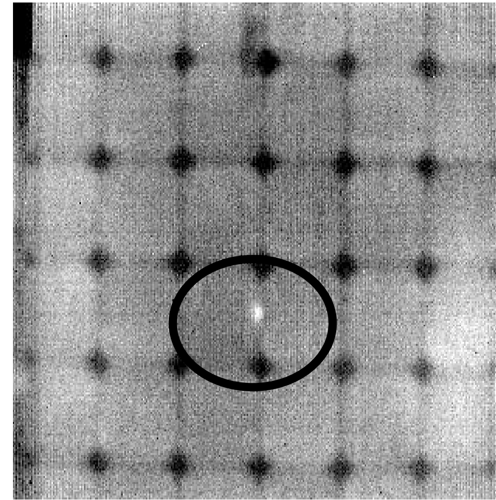




Si Wafer Modules



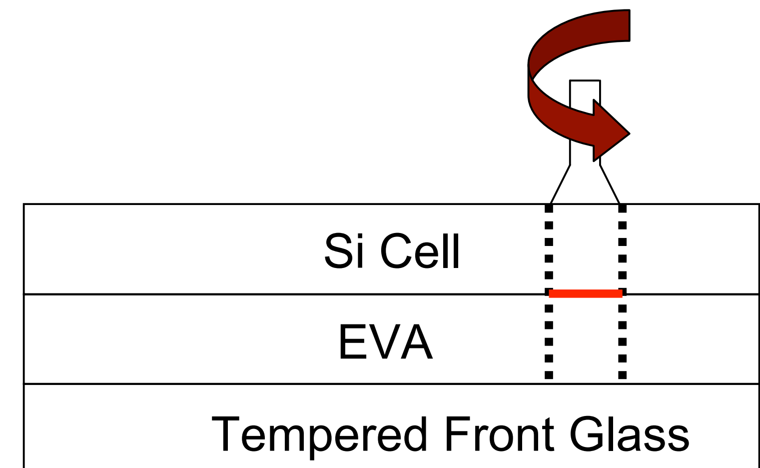
Cracked cell



Shorted interconnect

Shear Strength Measurement at Front Cell/EVA Interface

TPE Backsheet
EVA
Si Cell
EVA
Tempered Front Glass



Torque-Twist-Toughness

Torque (N-m)

0.5
0.4
0.3
0.2
0.1
0

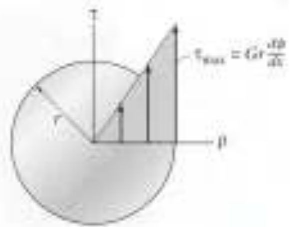
I

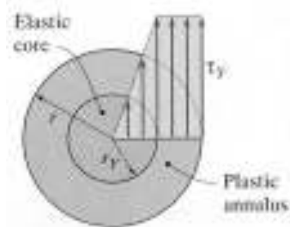
II

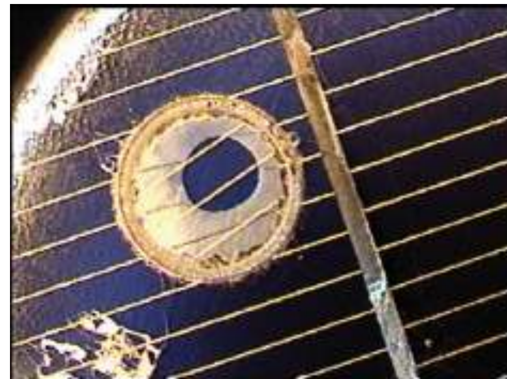
III

0
10
20
30
40

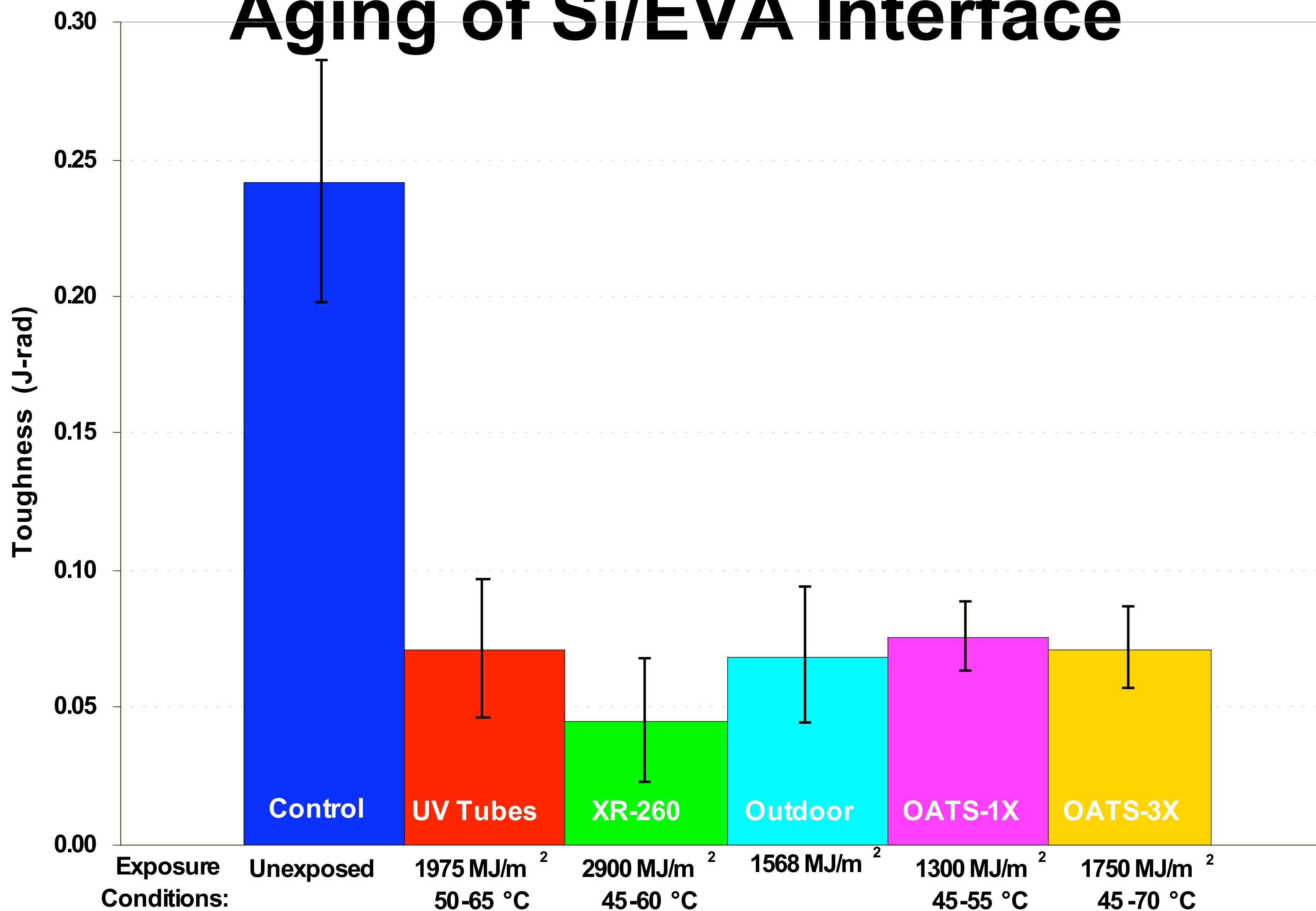
Angle (°)







Outdoor/Chamber UV Toughness Aging of Si/EVA Interface



Failure Mechanisms (FMs)

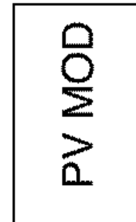
- **Packaging vs Cell**
  - **Packaging is 90% of the field returns * ^**
  - **50% of the cost**

- **Distributed vs Localised**
- **General vs Technology Specific**

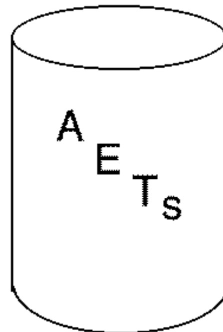
* Includes cell interconnects.

^ Failure rate and cause depend on how mature the technology is, e.g. BP Silicon is 1/4200 module year; Newbee modules are 1/10 - 1/100.

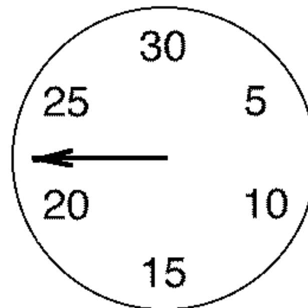
Service Life Prediction



Technology "i"
Manufacturer "j"
Process "k"



Failure Mode "l"
revealed with
acceleration parameter
for each stress.
Validate with the full
range of field conditions.



Time-To-Failure calculated
under any and all Use
Conditions, for each i, j, k,
and l.
Mixed, composite, and
competing risk models are
used to combine failure
modes as appropriate.

FMs: Modules General

Field returns and anticipated failures

- **Front Sheet/Encap failure**
- **Cell/Encap failure**
- **Back Sheet/Encap failure**
- **Stress breakage of glass/glass laminate**
- **Glass edge damage/breakage**
- **Corrosion of grid lines / ohmic contact / R_{series}**
- **Poor solder joint(string ribbons and J-boxes)**
- **By-pass diode failure**
- **Frame/mounting failure**
- **Failure of electrical safety/Hi-Pot isolation**

FMs: Modules Technology Specific

Field returns and anticipated failures

Wafer Si:

- Crack formation in thinner cells
- Solder joint degradation on cells
- Ribbon related open circuit or shunting

Thin Film:

- Flexible packaging interconnect failure
- Laser scribe interconnect failure
- De-adhesion of device layers, inc. CTOs and metal contacts
- Busbar adhesion and electrical contact
- Weak diode or shunt defects
- Decreasing ff (E-field collection or series resistance issues)
- Moisture ingress problems, esp. flexible with CIS
- Diffusion, esp. Cu in CdTe
- Staebler-Wronski, esp. single junction a-Si
- SnO_2 corrosion in superstrate cells

Conclusions

- **Artificially accelerating environmental stress on PV cells and modules is used to test for their reliability under field conditions.**
- **Failure diagnostic techniques are used to locate, identify, and evaluate resulting failure modes.**
- **A new core torque-twist technique used to evaluate module packaging durability and obtain sample specimens for failure analysis is reviewed.**
- **Proposed failure mechanisms for the different module technologies.**