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Requirements for a Standard Test to Rate the Durability of PV Modules at System Voltage

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This presentation does not contain any confidential material

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Motivation

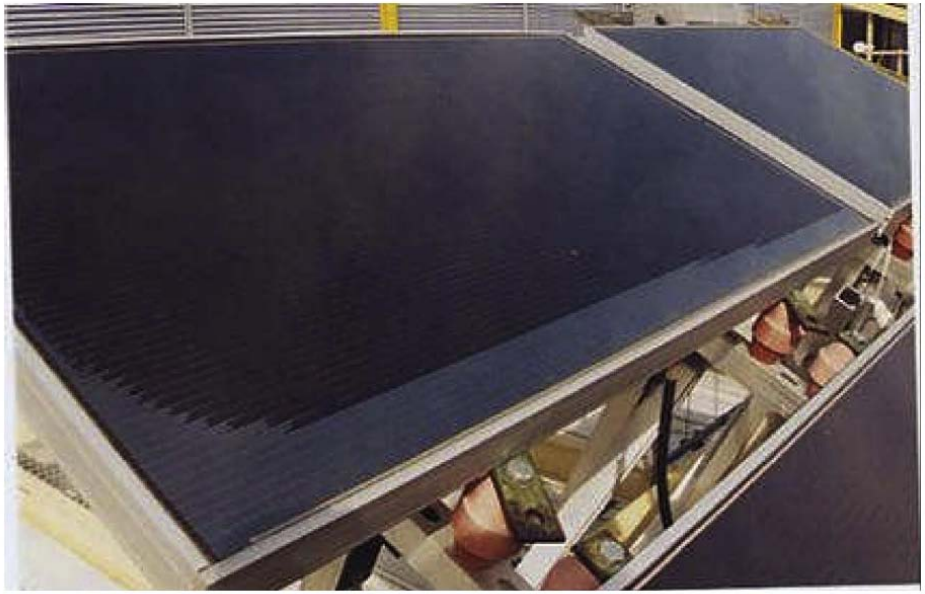
Over the past decade, there have been observations of module degradation and power loss because of the stress that system voltage bias exerts. This results in part from qualification tests and standards not adequately evaluating for the durability of modules to the long-term effects of high voltage bias that they experience in fielded arrays.

> "*Oh no! our modules are down 40%, we think it is potential–induced degradation*"
>
> *-anonymous module manufacturer, 2010*

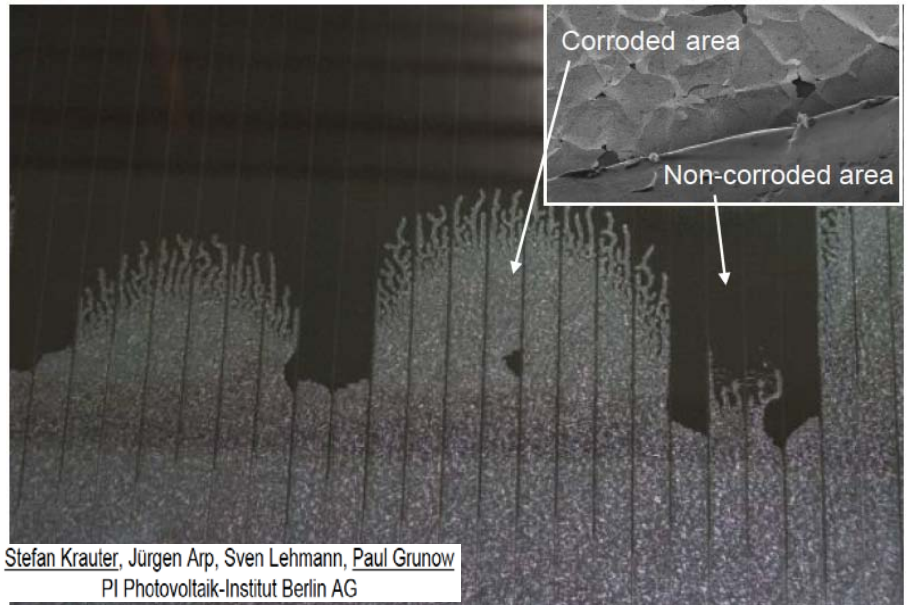
Three degradation modes - overview

1. Ionic motion in the packaging of the active layer leads to accumulation of charge or charged ions over the semiconductor surface
   - Charge influences surface field of semiconductor active layer
   - In severe cases, accumulation of mobile ions such as Na in the glass leads to delamination
2. Ionic motion also takes place within the active layer, degrading semiconductor junction properties and causing shunts
3. Usually in the presence of humidity in the packaging, electrolytic corrosion occurs and macroscopic transport of ionized conductor metal is observed.

Mode 1 : Na ions moving to glass TCO interface



J. H. Wohlgemuth et al. "**LONG TERM RELIABILITY OF PHOTOVOLTAIC MODULES**", WPSEC-4 (2006) p. 2050



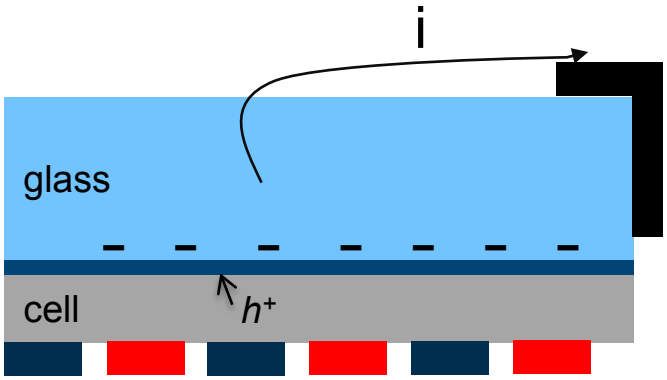
Reported by BP Solar…

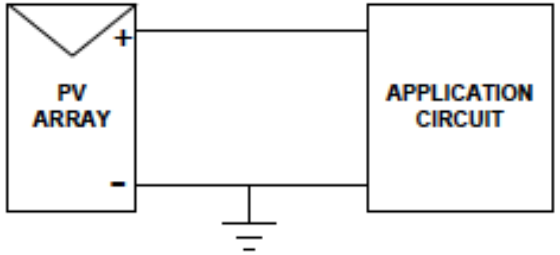
- a-Si modules
- - 600V bias
- 12 mo. in the field

- Sodium ions migrating to the TCO/glass interface causes delamination of the TCO, electrochemical corrosion
- Key drivers are:
  - *Negative cell polarity* vs. ground
  - Moisture ingress
  - Temperature
  - Na content in glass

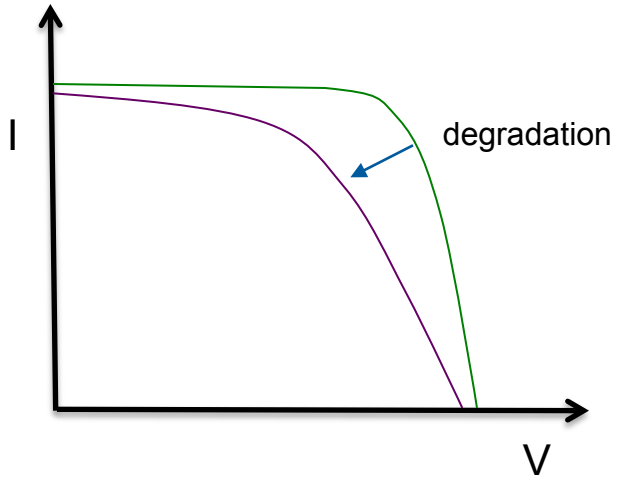
Mode 1 : Na ions moving away from active layer

SunPower reports 'surface polarization' in modules in 2005

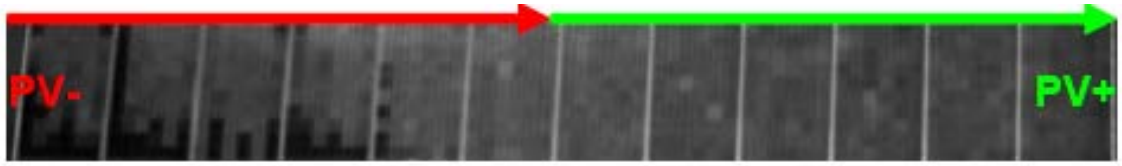




- *Positive bias* string leads to leakage current through glass to ground, leaving negative charge on cell surface, degrading effectiveness of the n^+ front surface field of the n^+/n structure
- Minority carriers (holes) recombine at front surface, leading to degraded cell performance

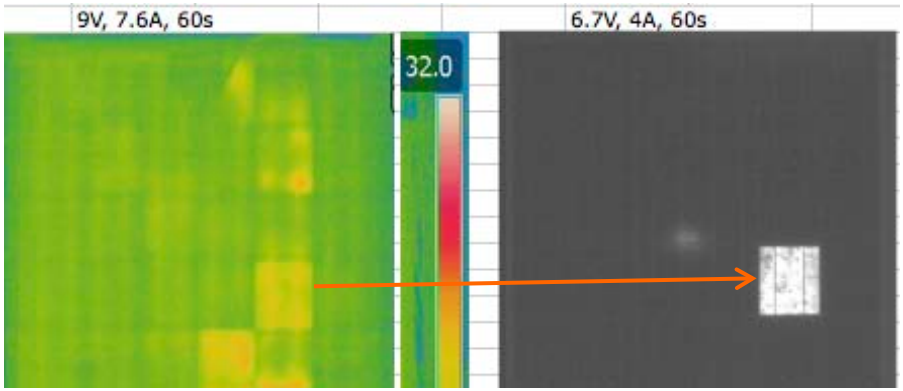


Mode 2: Ionic motion into active layer – pn junction shunt



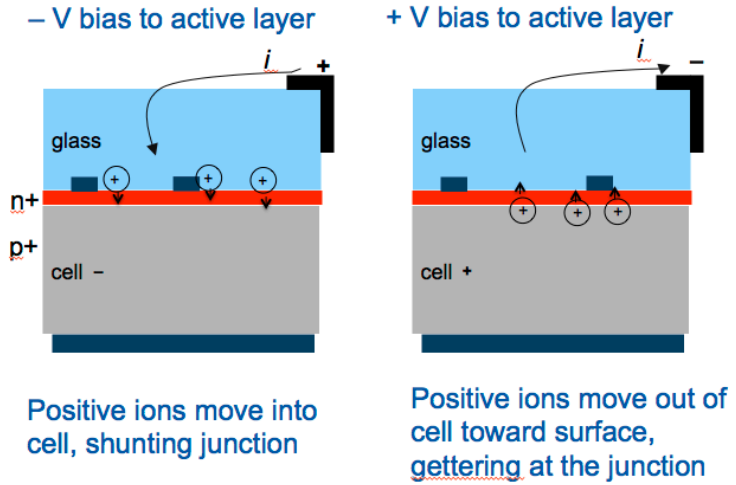
- Electroluminescence of mc-Si module strings indicating shunting in the negative portion of a center mounted or floating string *

Shunting indicates junction degradation



Thermography EL

Proposed model

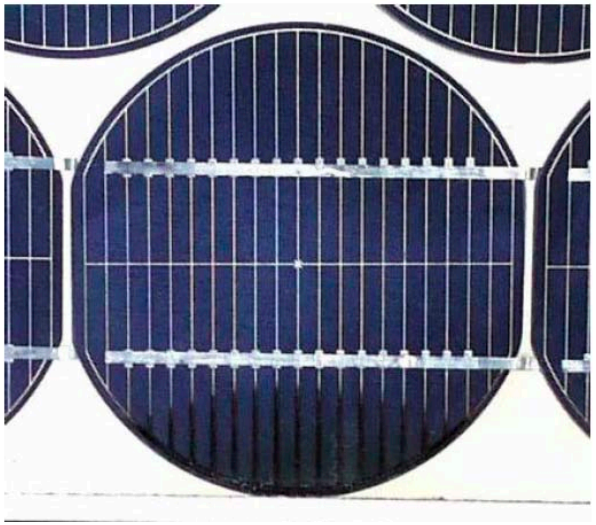


ionic motion within active layer of thin film devices also active

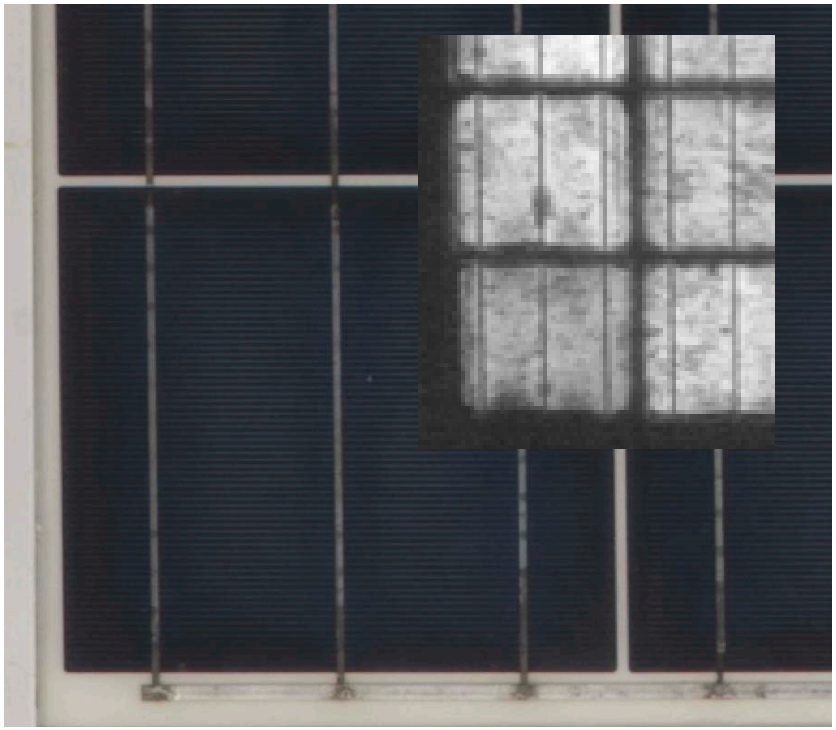
* S. Pingel, O. Frank, M. Winkler, S. Daryan, T. Geipel, H. Hoehne and J. Berghold SOLON SE, Presented at 35th IEEE PVSC, 2010

Mode 3 corrosion and macro - transport

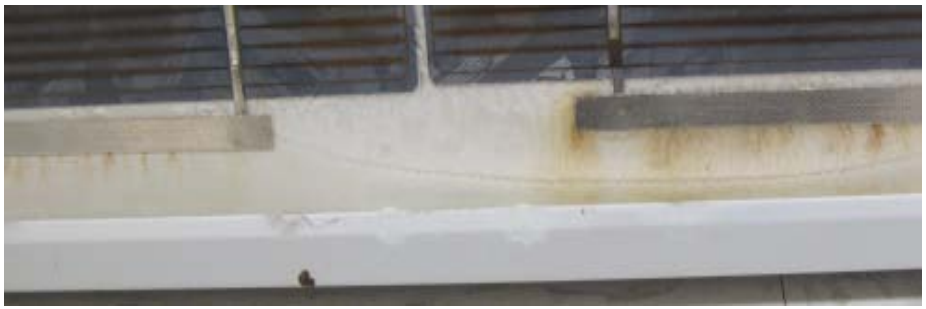
Corrosion of gridlines and Si-grid interface leading to higher series resistance evident visibly, in electroluminescence, and I-V curves



Realini (TISO)



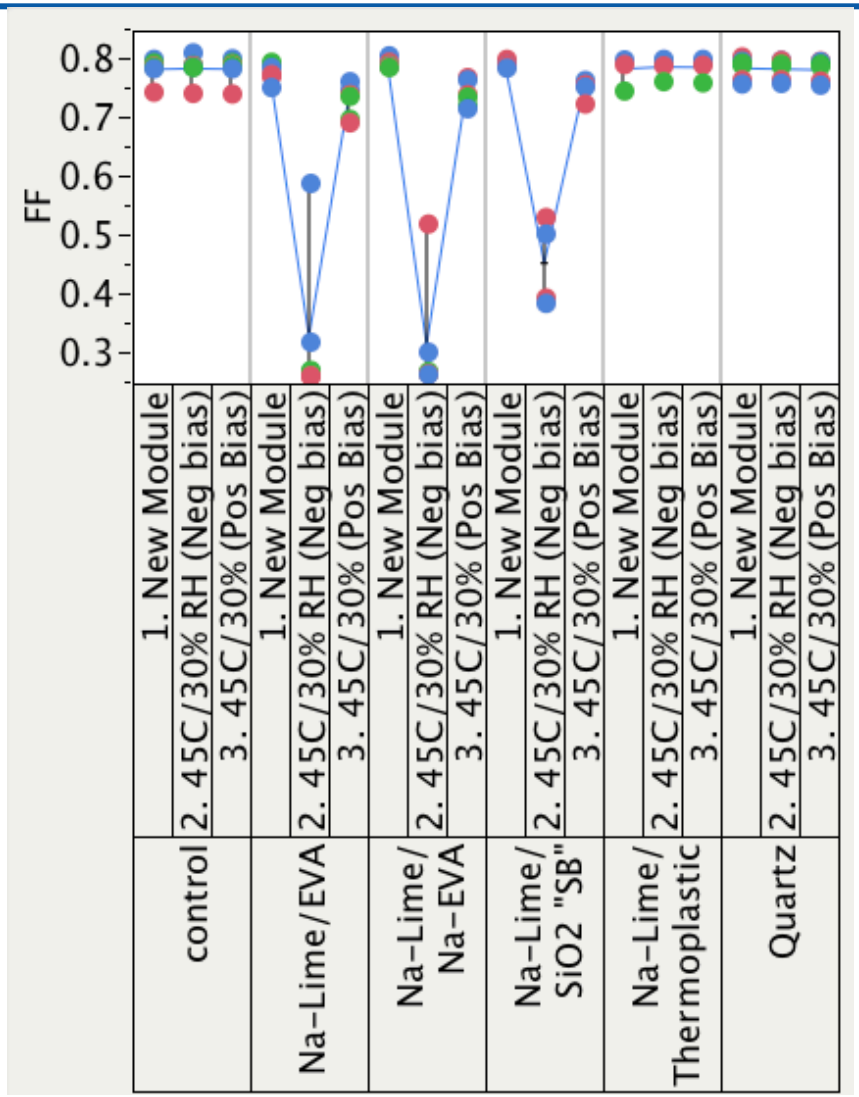
Corrosion and ionic transport at bus ribbons toward frame (positive string)



Testing methods – low T & RH regime

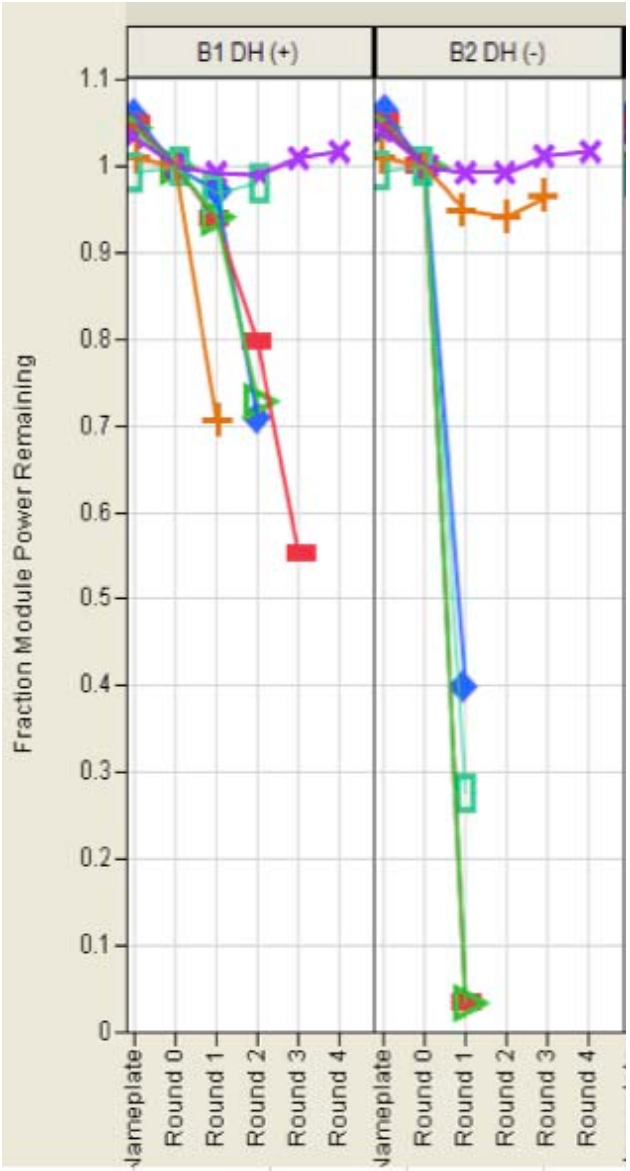
Near ambient temperature tests applying system voltage

- Saline water film, wet towel, or carbon paste act as the ground electrode to simulate wet surface, salt mist, or conductive dirty surface
- Degradation generally reversible by reversal of ionic motion
- No visible damage
- Degradation modes 1 & 2 active



1 cell mc-Si mimos, ± 1000 V bias applied to shorted leads; the module face grounded with C-paste, 120 h stress tests at 45 ° C, 30% RH

Testing methods – high T & RH regime



- 6 commercial module designs
- 85° C/ 85% RH
- 600 V system voltage

Activates modes 1,2 and 3, including corrosion, series resistance

Strongly differentiates modules' durability to system voltage bias potential-induced degradation

Summary

- Three modes of system bias potential-induced degradation
- Fielded systems showing system bias potential degradation
- Modern higher system voltages are more stressful on modules
- Increasing need to push down overall degradation rate
- Increasing variety of solar cell technologies sensitive to system bias potential (*e.g.*, selective emitter with junction closer to cell surface)
- Long-term degradation by system bias voltage is not presently captured in IEC 61215 and IEC 61646
- Tests around ambient temperature succeed reasonably well at elucidating 2 of 3 degradation modes, but higher temperature and humidity required to show durability to corrosion
- Exact, most appropriate level of stress is yet to be determined, but we shouldn't wait to implement some screening test