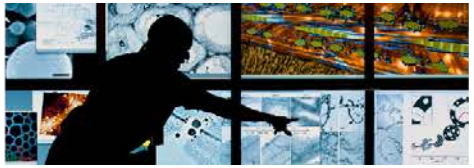
NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Group 3:
Humidity, Temperature and Voltage

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2013 Thin Film PV Reliability Workshop

Colorado School of Mines: Golden, CO

NREL/PR-5200-59294

Introduction

- **Group 3 is chartered to develop accelerated stress tests that can be used as comparative predictors of module lifetime versus stresses associated with humidity, temperature and voltage.**
- **The tools we have to utilize are:**
  - **Outdoor test results**
  - **Accelerated stress tests results**
  - **Modeling**

Where we stand today

- **The module qualification test sequences IEC 61215 and IEC 61646 contain a 1000 damp heat test (85 °C at 85% RH).**
- **This stress test appears to do an excellent job of screening out module designs and materials that would fail in the field in short time periods.**
- **So Group 3 must look to find field failures that are not identified in the 1000 hour damp heat test, but are limiting the lifetime of PV modules.**

Group 3 Efforts

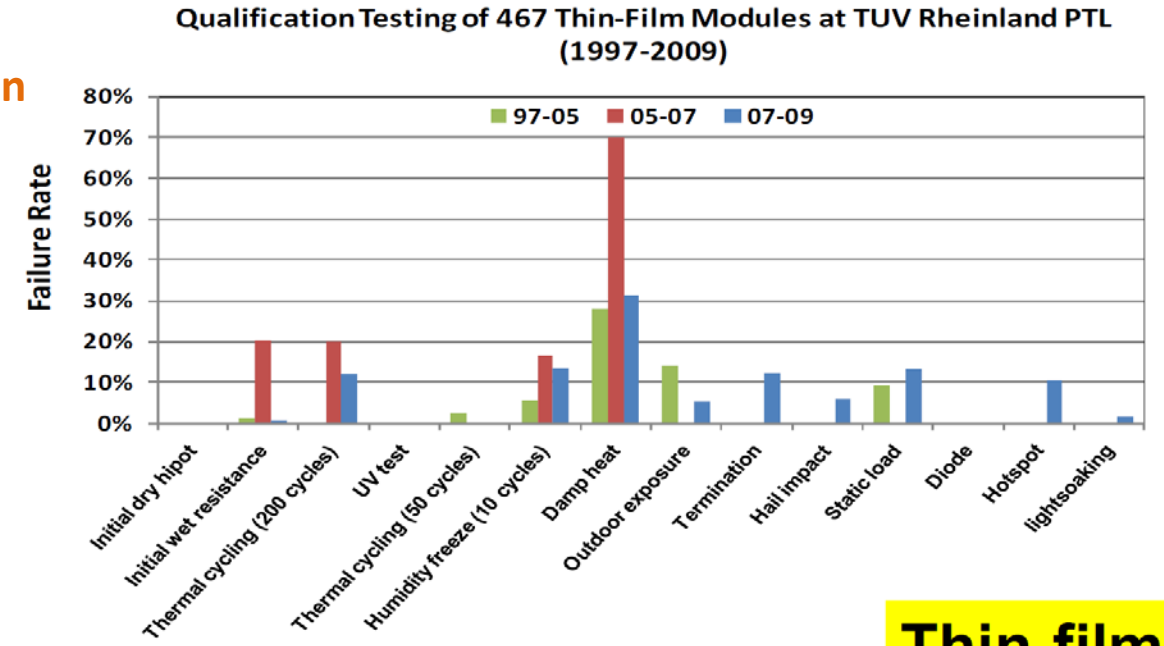
- Making observations of field failures related to humidity
- PID Testing – Adding voltage to H and T
- Modeling to understand conditions within module
- Effectiveness of Qualification Test
- Look at results of testing beyond qualification

Thin Film Susceptibility to Humidity

Observed Field Failures

- If you don't do something about it, the number one field failure mode for CdTe and CIGS appears to be due to moisture ingress.
- For a-Si humidity, temperature and voltage can lead to delamination of TCO from glass.
- Many of today's most successful thin film products are designed to keep moisture out.

Observed Qualification Test Failures



Tamizhmani 2010
PVMRW

Thin-film

Crystalline Silicon Findings

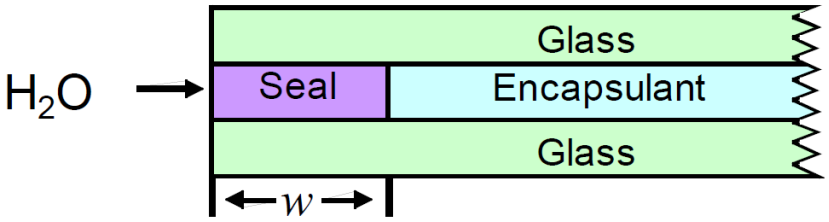
- At present time group 3 does not believe that damp heat testing beyond 1000 hours is justified.
- Looking for combined sets of stresses that can lead to delamination. Possibilities
  - UV and temperature
  - Dynamic mechanical loading/thermal cycling/humidity freeze.
- We are looking for:
  - Older arrays exposed in hot/humid environments to visit.
  - Reports on and samples of product returns that appear to be humidity and temperature related.

How do the cry-Si findings apply to Thin Films?

- Likely that the damp heat test results and field failures due to moisture are more closely related to the packaging than the technology that is inside.
- Lets look at 3 different cases:
  - Packages that keep moisture out.
  - Flexible package where device is exposed to moisture.
  - PID

Package that keeps moisture out

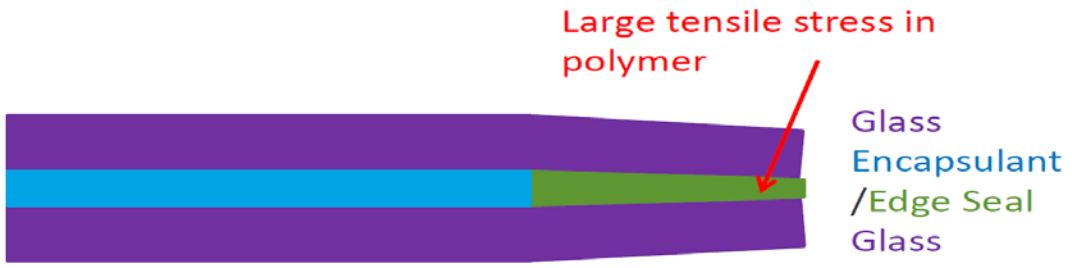
- **A module that relies on sealing out the moisture (glass-glass with an edge seal) is not likely to fail an 85/85 test, but you are not likely to learn much about its long term durability from such a test either.**



- **What we should be developing are tests that stress the package before performing the 85/85 test.**
- **Kempe (2012 NREL PVMRW) reported that a combination of edge pinch and UV exposure resulted in loss of adhesion of the edge seal and subsequent ingress of moisture into the package.**

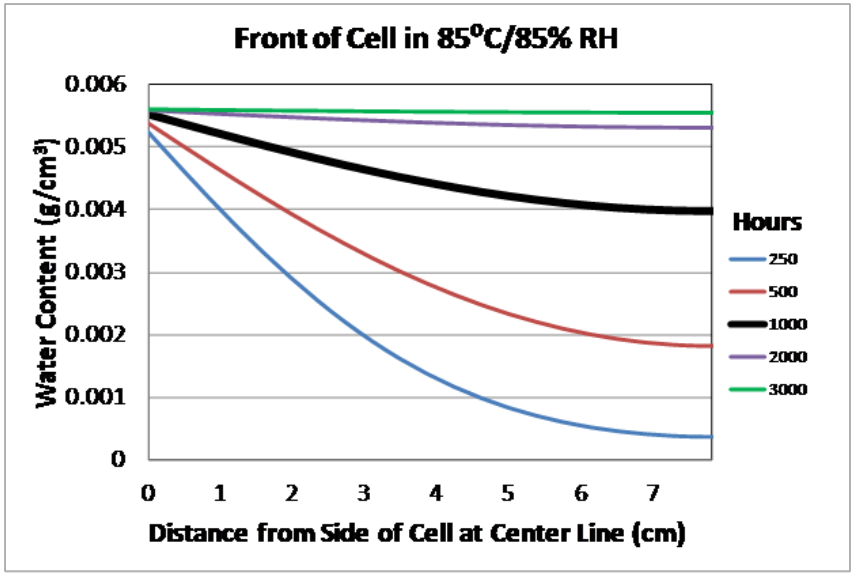
Edge Pinch

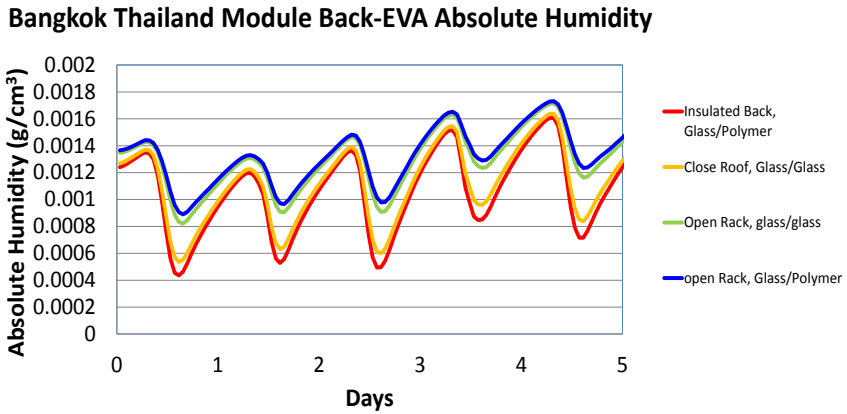
(lamination pressure cause the glass to bend around the perimeter)



Flexible PV Packages

- In flexible packages the moisture will reach equilibrium within the module in less time than in a package with one or more vapor barriers (glass, cells, etc.).
- For example modeling by Kempe shows that it takes about 1000 hours at 85/85 to mostly saturate the encapsulant between a cell and the glass.
- On the other hand with a flexible package it may only take a few hours for the humidity to reach equilibrium in the encapsulant.
- It is likely that for flexible packages 85/85 for 1000 hours is too much stress for evaluating a 25 year lifetime outdoor in most terrestrial environments.
- Can use modeling to determine a better combination of temperature and humidity where maybe using a longer (than 1000 hours) test will be a much better indicator of long term performance in most (if not all) terrestrial environments. (See Kempe paper from PVMRW 2013)

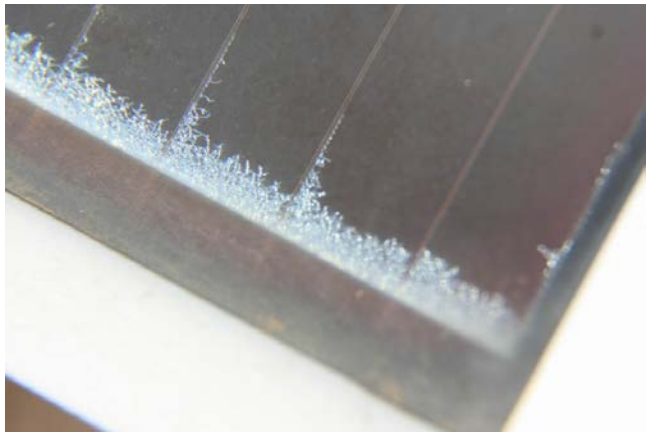




PID in Thin Films

- Remember PID was first reported in thin film products. (See Carlson et. al. PIP, 11, 2003)
- Changes to barrier layers slowed the process down considerably – it was no longer the squeaky wheel.
- However, even some a-Si modules built after the “fix” still suffer from some PID.
- PID tests developed for cry-Si modules may do a good job of identifying PID susceptible thin film product.

Electro-Chemical Corrosion of TF Module
From Neelkanth Dhere, FSEC



Later generation a-Si module

Summary

- **Accelerated stress tests for moisture related failures need to address the package more than the package's contents.**
- **Adding thin film specialists to work in group 3 will lead to development of better accelerated stress tests for temperature, humidity and voltage for both crystalline Silicon and thin film modules.**
- **Expanding the effort to increase focus on flexible packages may be useful.**