Breakout session:
Moisture sensitivity of thin films

Discussion leaders: Ryan Gaston & Mike Kempe

8:00 – Kent Whitfield (Miasole) – Common Failure Modes for Thin-Film Modules and Considerations Toward Hardening CIGS Cells to Moisture

8:30 – D.J. Coyle, H.A. Blaydes, J.E. Pickett, T.R. Tolliver, and R.A. Zhao (GE Global Research) – Packaging Requirements for ITO-Hardened CIGS

9:00 – Discussion: After Hardening, What Protection Do We Need?

9:30 – Break

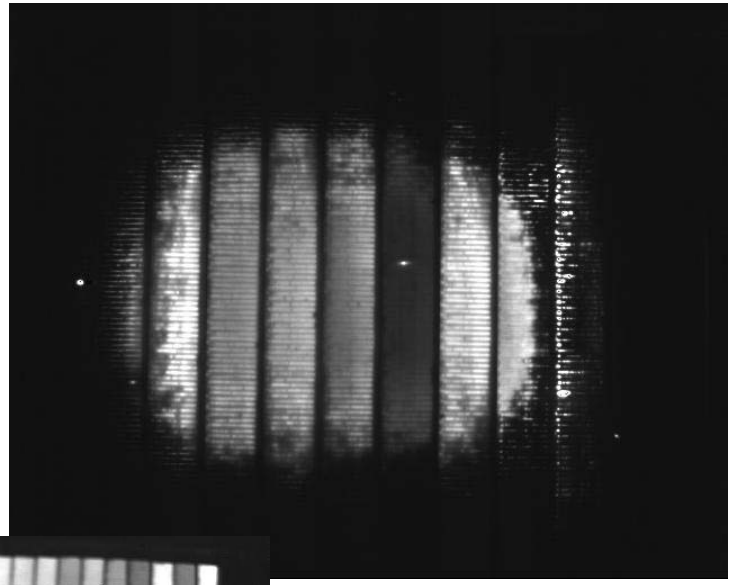
10:00 – Arrelaine Dameron (NREL) – Methods for Measuring Moisture Ingress and Requirements for Protecting Moisture Sensitive Cells

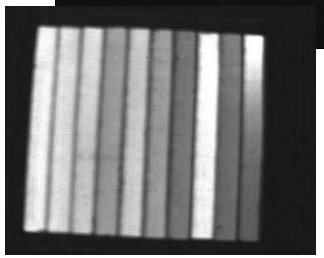
10:30 – Samuel Graham (Georgia Tech) – Approaches to Barrier Coatings for the Prevention of Water Vapor Ingress

11:00 – Discussion: Which aspects of the problem are solved? Where is more work needed?

What to look for

- Moisture ingress almost always leaves very perceptible signs





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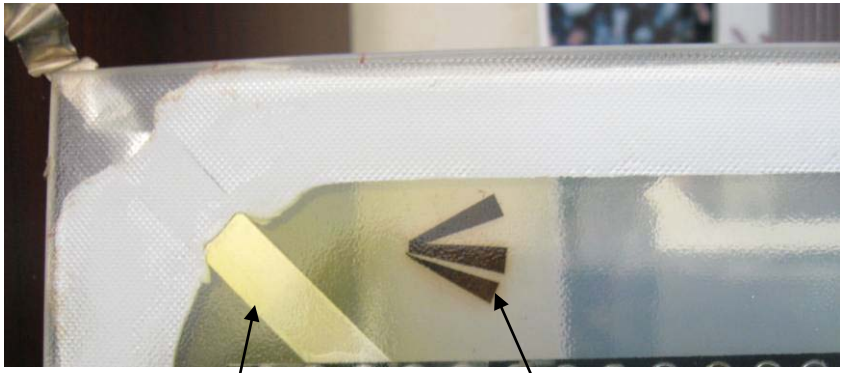
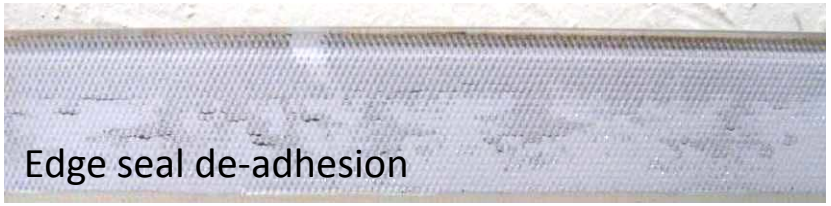


Metallic corrosion
(in this case yellowing)

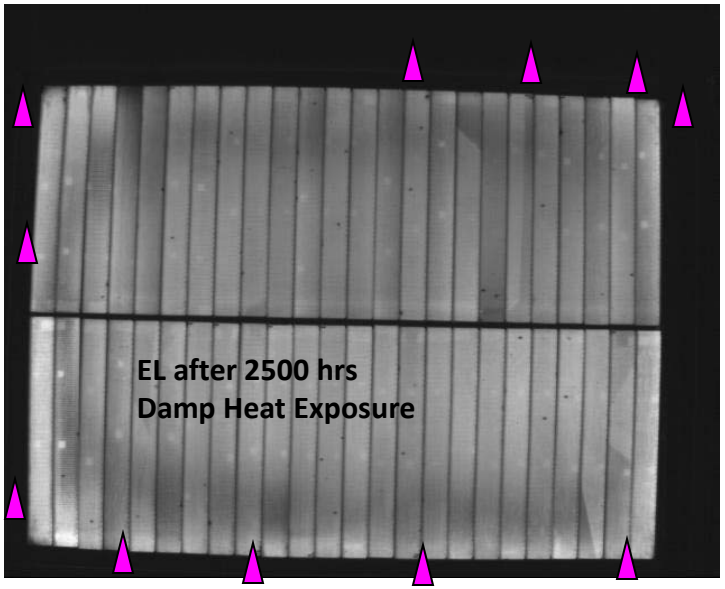
Color change
indicator



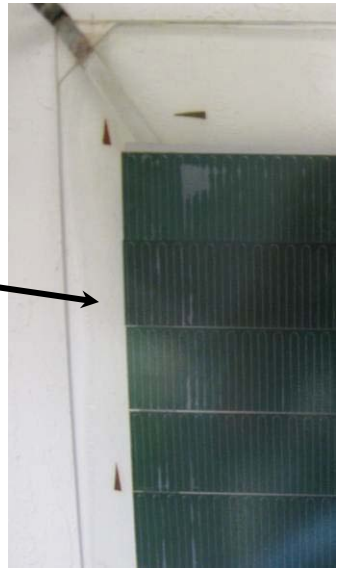
Edge seal de-adhesion

Whitfield summary

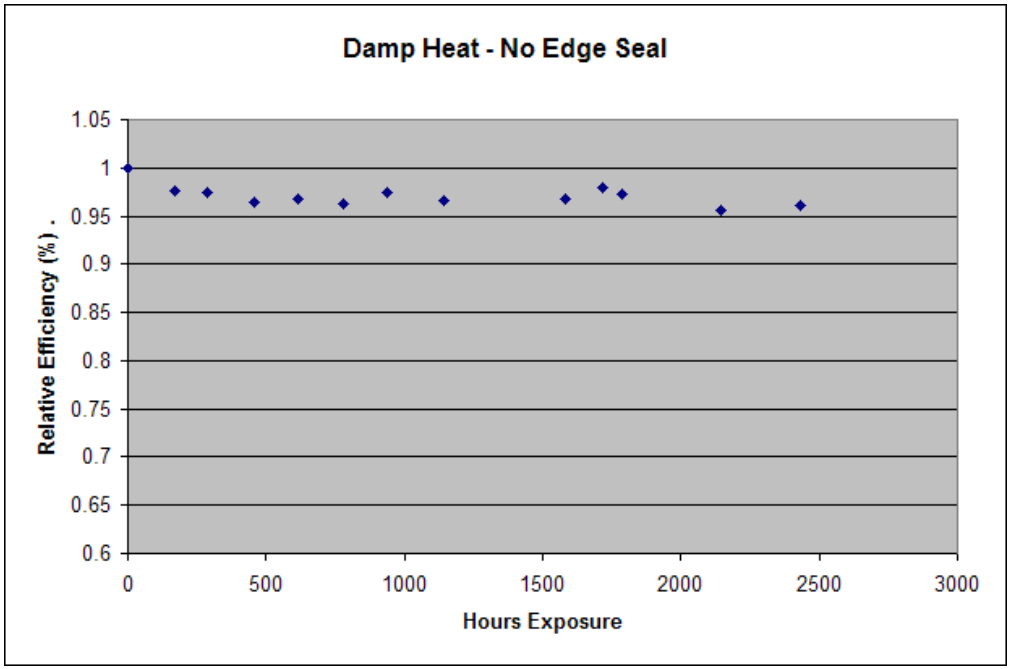
Can CIGS be Moisture Hardened?



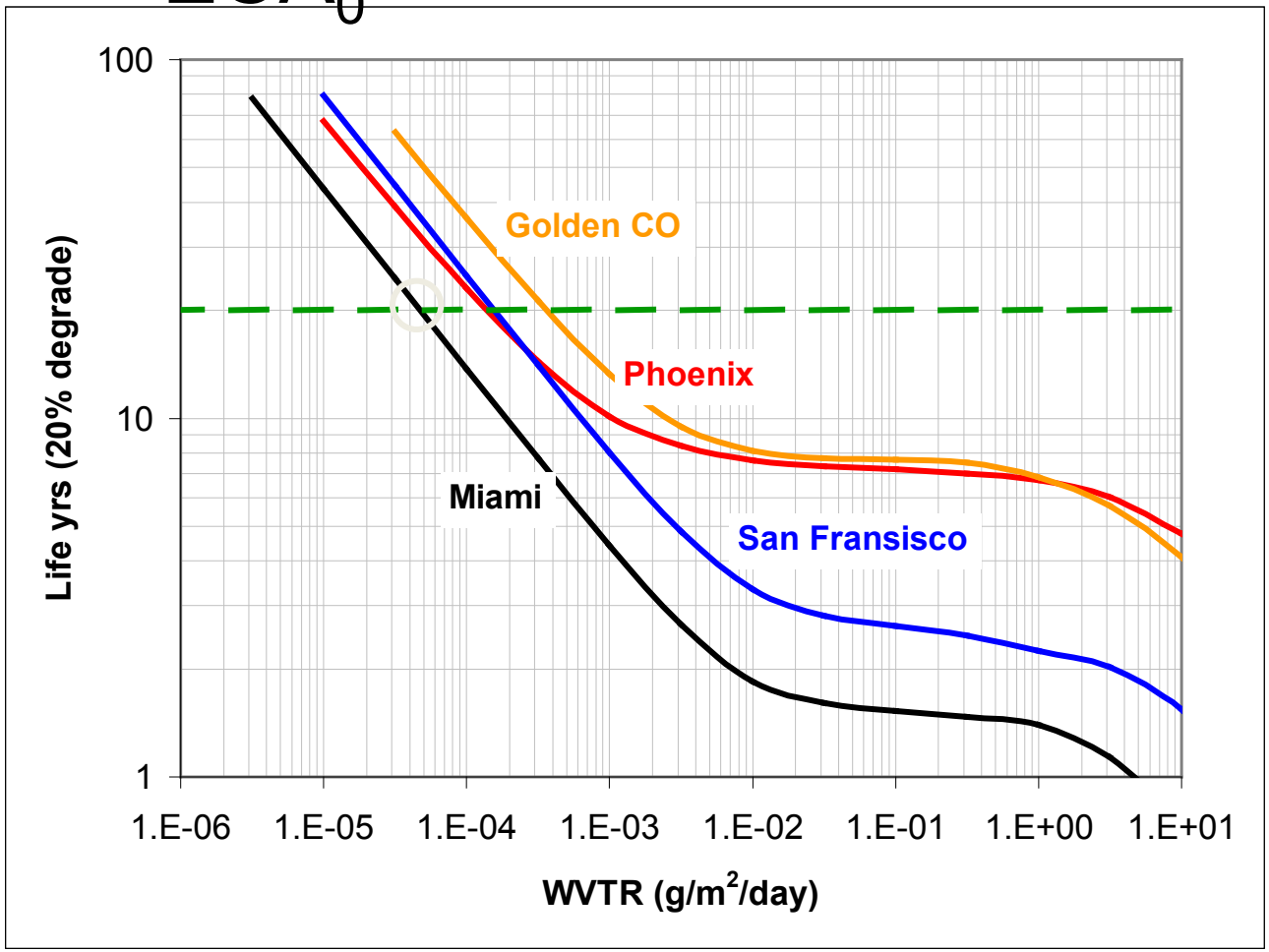
- Yes, but there are tradeoffs.
- I know that's unfulfilling, but that is the limit to what I can say…



No edge-seal



Life vs. Barrier: ITO-ECA$_0$



Need ~ 4×10^{-5} g/m^2/day package ~ 20 yr life

Conclusions, Plans & Acknowledgements

Conclusions

- AZO vs ITO CIGS degradation kinetics quantified – 25X
- Life model and accelerated test scaling developed
- Diffusion-controlled: Life ~$(t_c/R_D)^{1/2}$ or ~(diffusion-time*degrade-time)$^{1/2}$
- Significant moisture barriers required for 20 yr life – even for ITO
- Acceleration factor for damp heat smaller than assumed, highly nonlinear!
- Methodology can predict life for any moisture-sensitive module (once kinetic constants are measured)

Future Plans

1. Critical experiments to test model predictions
2. Experimental validation – Miami, FL & Arizona

Acknowledgements

Mike Kempe NREL

Steve Hegedus IEC

This work was supported by:

U.S. Department of Energy

Award DE-FC36-07GO17045

GE Global Research

GE Energy

Discussion summary – How far can the cells be hardened?

- Yes – cells can be hardened, but not a single solution, depends on packaging and location
- Window layers have a large impact on hardening of CIGS devices (ITO vs AZO)
- Some discussion on an industry acceptable level of degradation and percentage of samples allowed to fail – no consensus

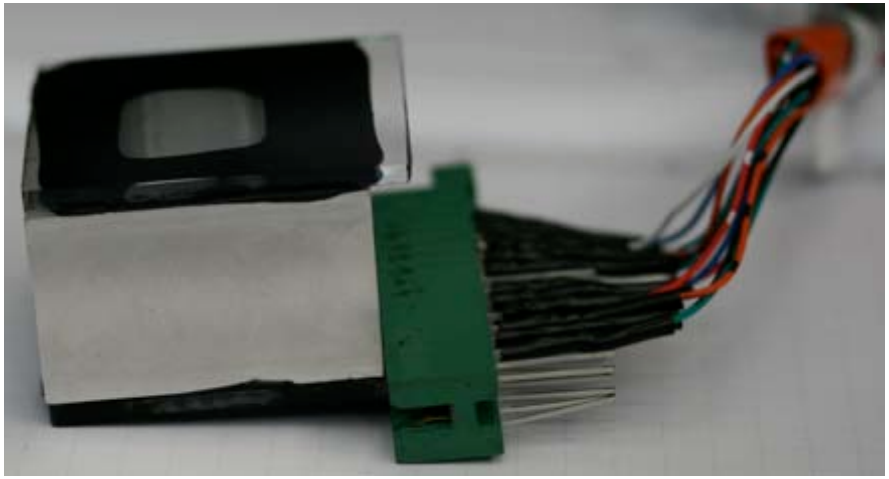
NREL's Ca Test

- Electrical Ca Test (0.1 mΩ resolution)

- Easily configurable test card & edge connector assembly
  - fast setup
  - no need to deposit Ca onto the barriers

- 16 tests simultaneously = high throughput

- Variety of environmental conditions possible

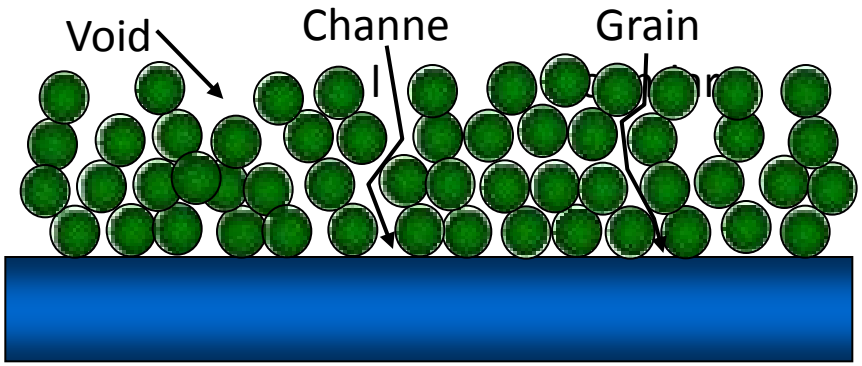


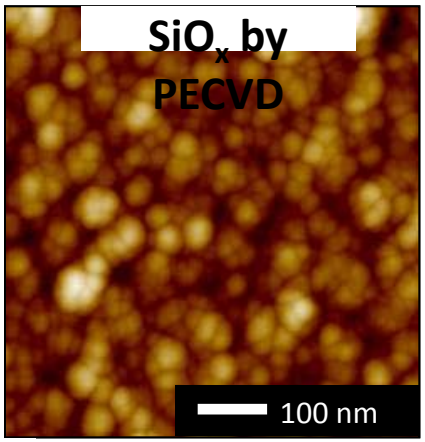
Conclusions

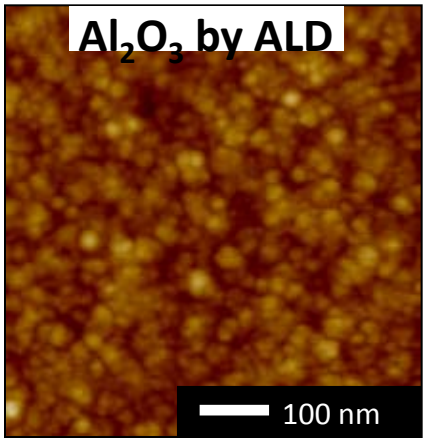
- There are several techniques to quantifiably measure moisture permeation through thin films

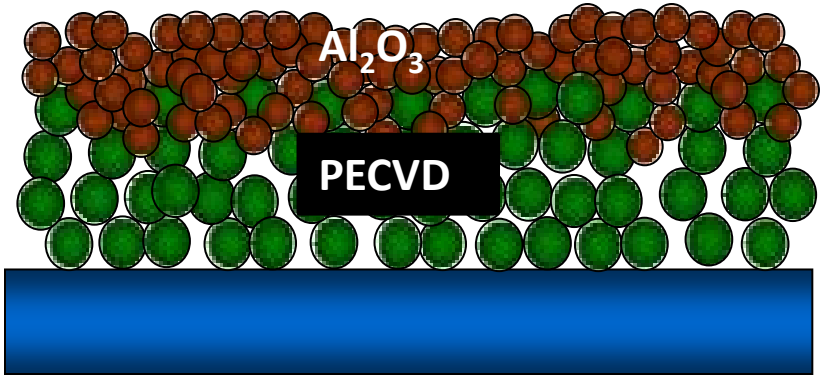
- At NREL we are working to improve existing barrier evaluation methods and developing routes to evaluate and compare edge seal materials in their applied environment

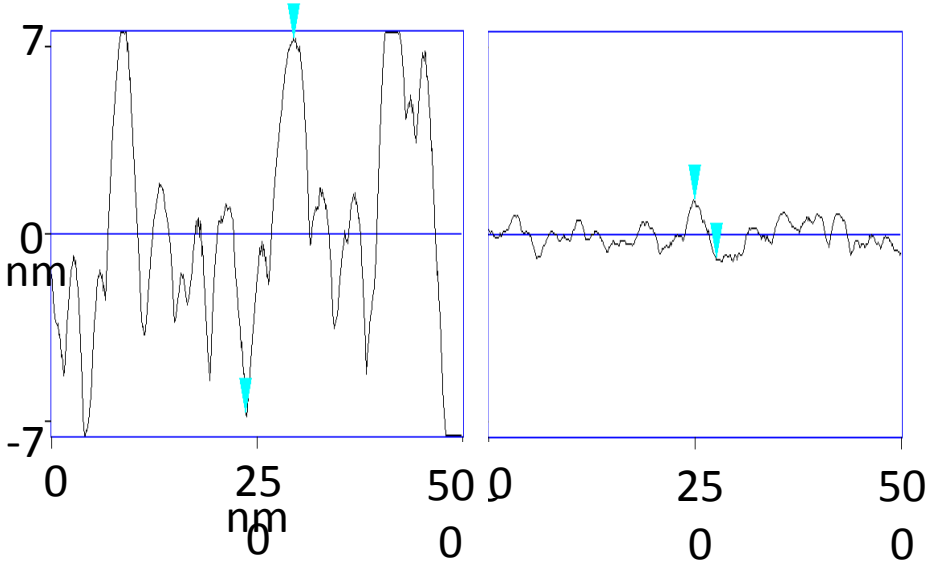
Combine rapid low temperature deposition by PECVD with high quality atomic layer deposition to simplify barrier architecture.











SiOx by PECVD Al2O3 by ALD

■ Multilayer Encapsulation

- Defect structure and solubility of polymer layer control laminate performance

- Reporting WVTR and lag time may be necessary for understanding barrier performance.

■ Hybrid Encapsulation

- Simplified Architecture provides ultralow barrier performance

- Promising opportunities exist for further reductions in processing time.

■ Device Integration

- Successful direct encapsulation of OPVs by hybrid thin films

■ Future Efforts

- Development of Edge Seals important for the packaging toolbox.

- Accelerated testing under harsh environments including light soaking!

Discussion summary – Moisture ingress – problem solved?

- Many potential solutions were discussed from multilayer vs single layer. ALD is a promising technology for eliminating pins holes and defects
- Commercial ALD technology exists and is being scaled up to roll to roll
- New testing methodologies allow for faster estimation of very low WVTRs and higher throughput
- Lag Times effects can be considerable and needs to be understood before a steady state WVTR can be calculated
- ~50% of the room believes that a commercially viable flexible CIGS based product with 20+ year lifetimes will be a reality within 5 years