Moisture Ingress Protection by Combined Backsheet and Encapsulant Constructions

K. Terwilliger, M. Kempe,
G. Jorgensen, C. Kennedy

Background

- Moisture ingress occurring along the edges of a module or through a soft backsheet can cause premature failure of a PV module
- By studying the combined effects of backsheets and encapsulants, we are working to identify packages which will reduce the damage caused by moisture ingress

Outline

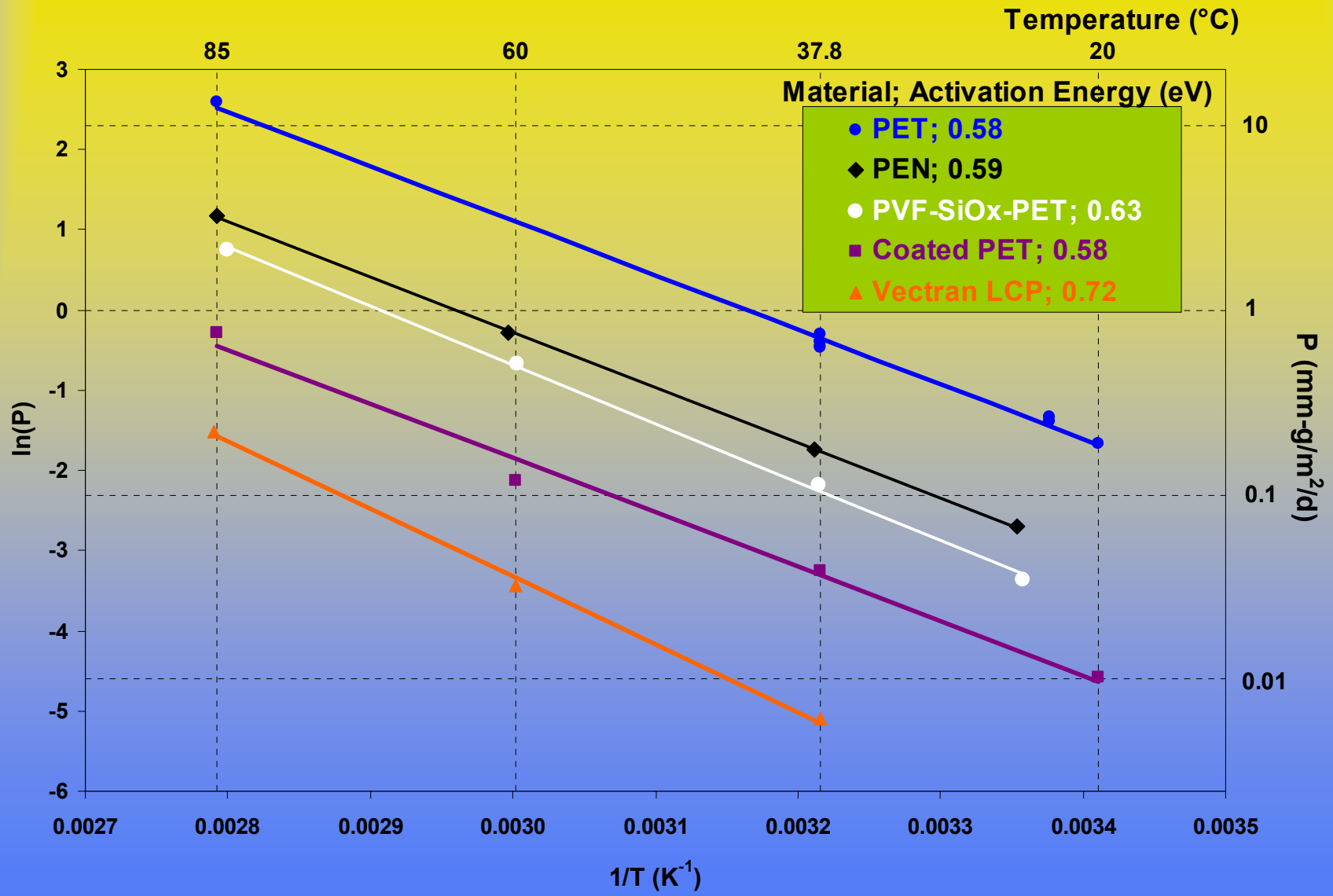
- Updates on Water Vapor Transmission Rates (WVTR)
  - Values for new backsheets
  - Challenges associated with measuring barrier coatings
  - Updates on new barrier coated PET
- Updates on combined backsheet/encapsulant moisture ingress and aluminum corrosion prevention test
  - Use of light box for backlighting of samples
  - EVA, BRP, and silicone encapsulant test results
  - True Seal solar edge tape test results
  - Bead blast test results

Updates on Water Vapor Transmission Rates (WVTR)

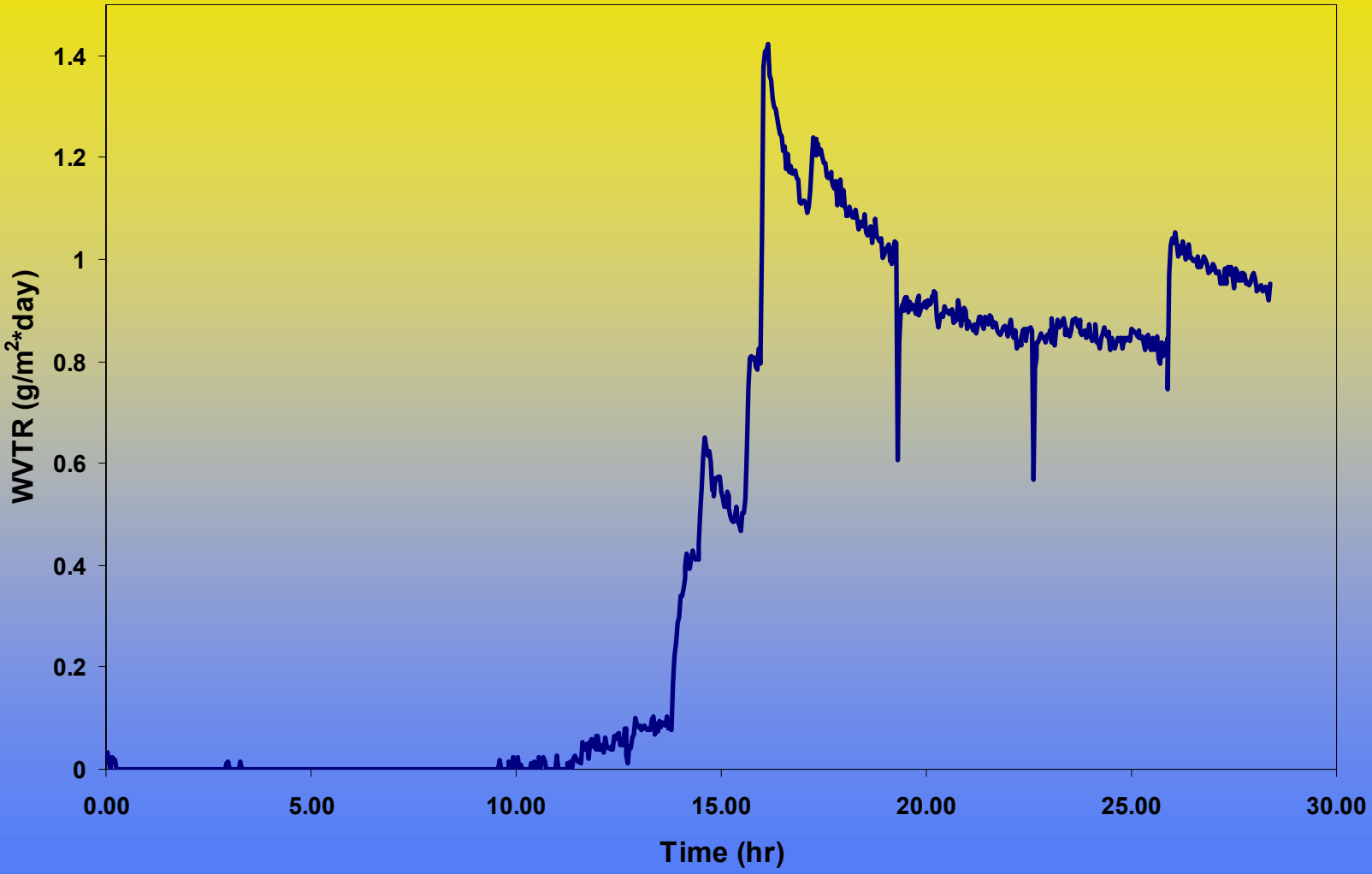
New Backsheet Results

Name	Description	Supplier	Thick (mm)	Temp (°C)	WVTR (g/m^2*day)	Permeability ($mm*g/m^2*day$)
Mylar D	PET	Dupont	.1778	25	1.81	.322
				37.5	3.98	.708
				60	13.75	2.448
				85	69.53	12.362
Kaladex 2000	PEN	Dupont	.1016	25	0.66	.067
				38.2	1.74	.177
				60.5	7.4	.752
				85	31.62	3.213
EL1152 Exp. Lam.	PEN-Al-PET	Stan Levy	.1143	85	<.05	<.006
Icosolar 2116	PVF-Al-PET	Isovolta	.1778	85	<.05	<.009
Icosolar 2836	PVF-SiOx-PVF	Isovolta	.1397	24.7	0.25	.035
				37.9	0.8	.112
				59.9	3.65	.510
				84.1	15.10	2.109
Vectran V200P	LCP	Ticona	.0381	37.8	0.16	.006
				60	0.85	.032
				85.3	5.76	.219

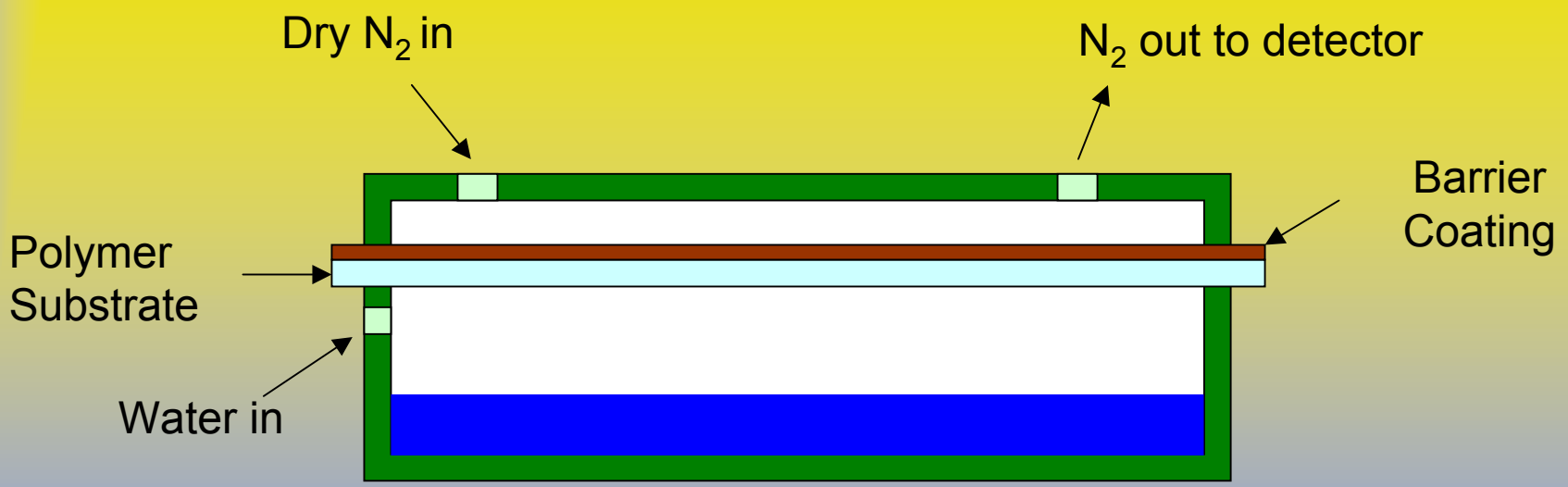
Arrhenius Plot of Permeability



WVTR vs. Time for Barrier Coated PET (25°C/100%RH)

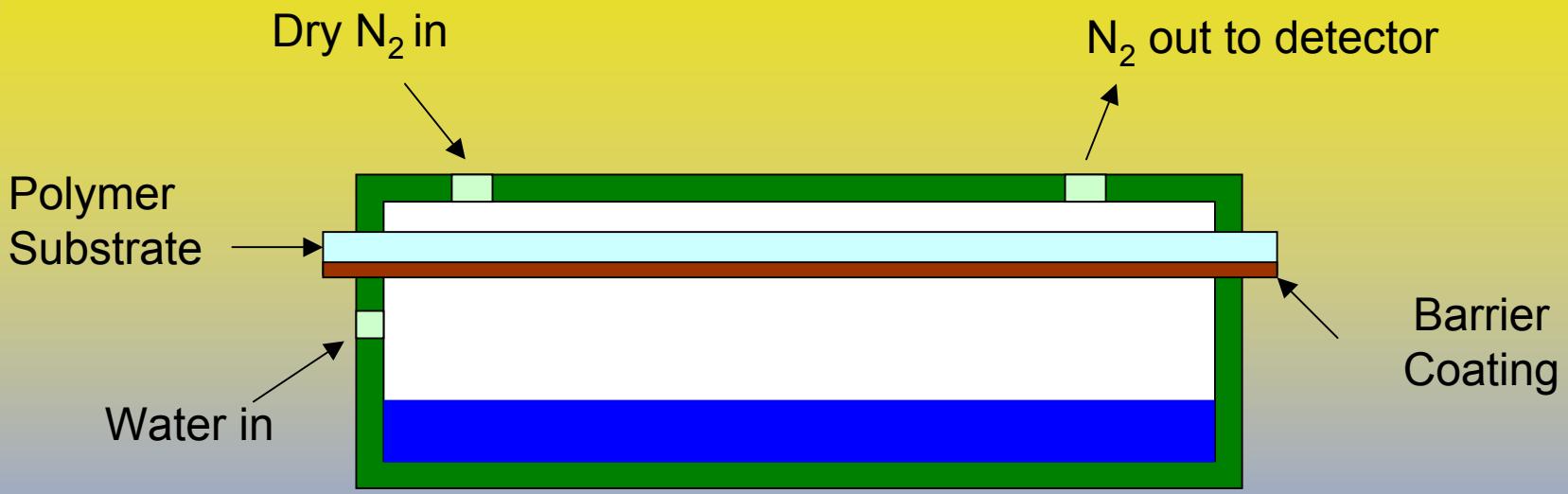


Measuring Coating with Barrier to Dry N_2 Gas



- Allows build-up of moisture at the barrier/polymer interface

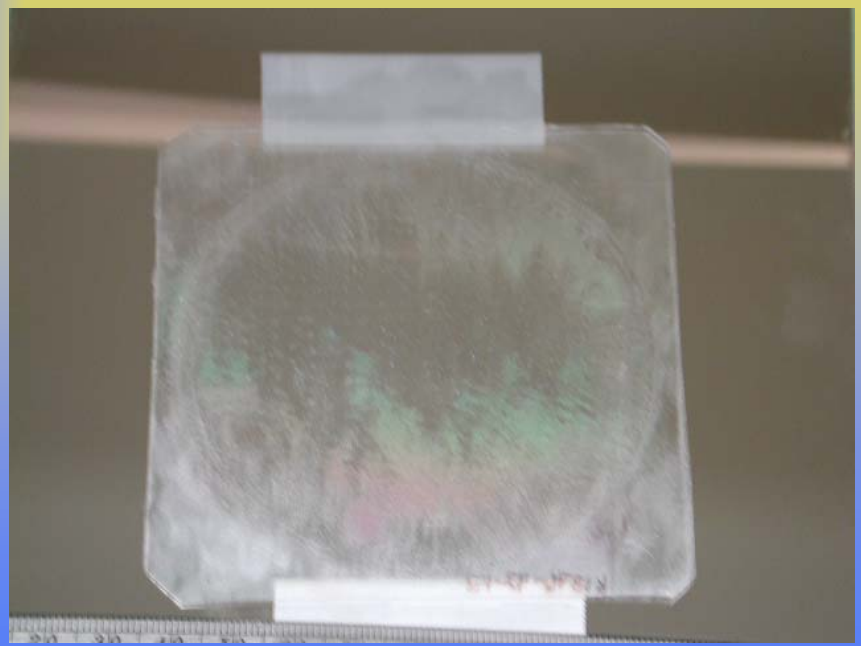
Measuring Coating with Barrier to Moisture



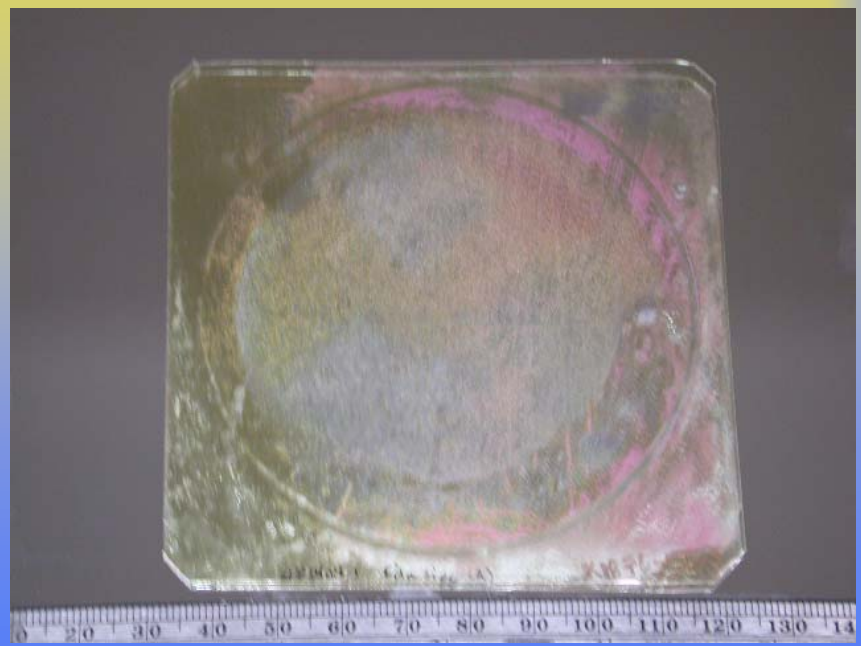
- If the barrier is moisture sensitive, can be destructive

Pictures of Barrier Coatings Damaged During Measurement

Sample tested with barrier to N_2



Sample tested with barrier to Moisture



Barrier Coated PET Results

Red: measured with barrier to dry N2

Blue: measured with barrier to moisture

Name	Description	Supplier	Thick (mm)	Temp (°C)	WVTR (g/m^2*day)	Permeability ($mm*g/m^2*day$)
Mylar D	PET	Dupont	.1778	25	1.81	.322
				37.5	3.98	.708
				60	13.75	2.448
				85	69.53	12.362
PECVD #1	SiOxNy/PET	NREL	.1778	25	1.10	.196 (10hours)
PECVD #2	SiOxNy/PET	NREL	.1778	37.8	3.75	.667 (40hours)
PECVD #3	SiOxNy/PET	NREL	.1778	37.8	3.7	.658 -----
PECVD #4	SiOxNy/PET	NREL	.1778	37.8	0.2	.035
				59	0.5	.089
				85	13.45	2.391 -----
PECVD #1	SiN/PET	AKT	.1778	37.8	<.05	<.009
				60	10	1.778 (10hours)
PECVD #3	SiN/PET	AKT	.1778	60	12.25	2.178 -----
PECVD #10	SiON/PET	AKT	.1778	37.8	4.25	.756 -----

Barrier Coated PET Results

Blue: measured with barrier to moisture

Name	Description	Supplier	Thick (mm)	Temp (°C)	WVTR (g/m^2*day)	Permeability ($mm*g/m^2*day$)
Mylar D	PET	Dupont	.1778	25	1.81	.322
			.1778	37.5	3.98	.708
			.1778	60	13.75	2.448
			.1778	85	69.53	12.362
Icosolar 2836	PVF-SiOx-PET	Isovolta	.1397	24.7	0.25	.035
				37.9	0.8	.112
				59.9	3.65	.510
				84.1	5.10	.712
FG300	Oxide-Acrylate (3x)/PET	PNNL	.1778	60	0.1	.0178
				84	27.47	4.884 (20hours)
FG500	Oxide-Acrylate (5x)/PET	PNNL	.1778	60	<.05	.009
				85	31.9	5.672 (35hours)

Updates on Combined Backsheet/ Encapsulant Moisture Ingress and Corrosion Prevention Test

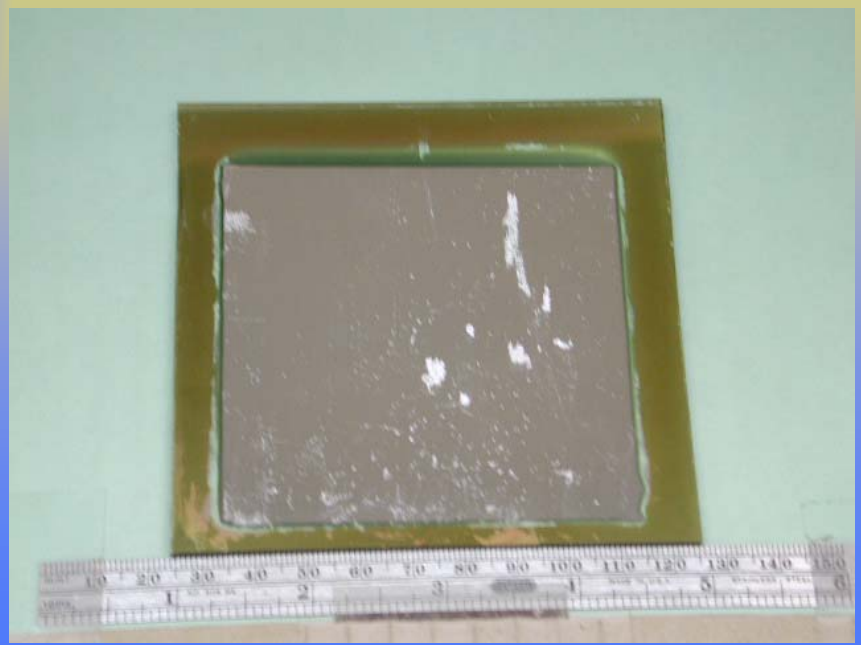
Testing the Effectiveness of Packages on Small Scale Devices

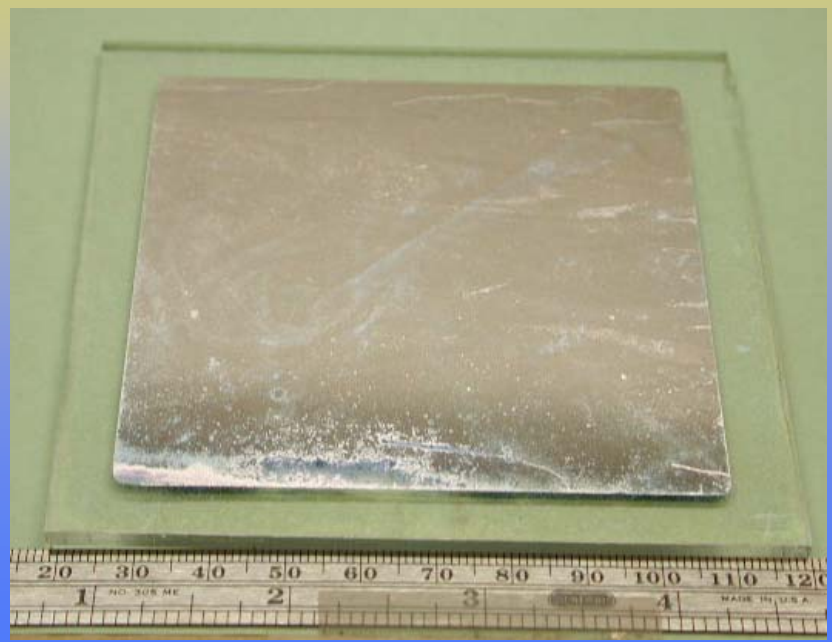
- Small scale PV devices are difficult to characterize without compromising the integrity of the protective package because of the wire leads
- Difficult to obtain a large set of replicate devices for comparison testing

Testing the Effectiveness of Barrier Coatings on Aluminized Glass

- Historically oxide films have been tested by coating aluminized glass substrates and subsequent exposure to damp heat has shown aggressive aluminum corrosion

Sputtered coatings after 24 hours of damp heat exposure (85^{o}C/85% RH)





Testing the Effectiveness of Packages on Aluminized Glass

- By replacing the device with a thin film of aluminum we can characterize the package by the amount of visual corrosion observed during testing

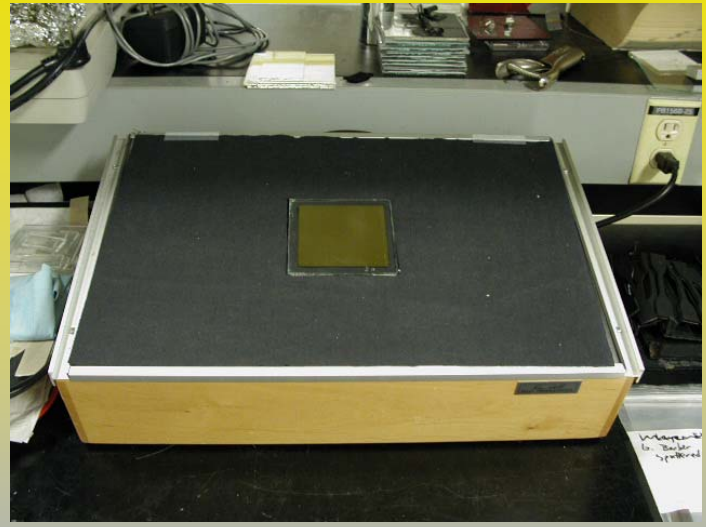
Experimental Design

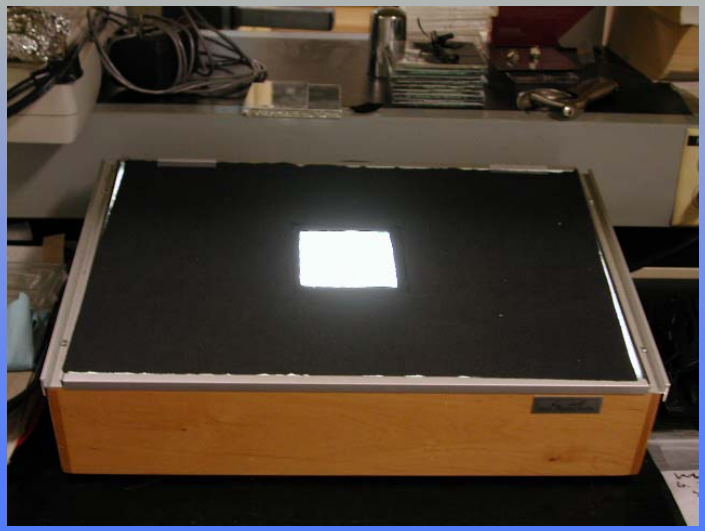
- Superstrates: Soda Lime, Borosilicate Glass
- Encapsulants: EVA, BRP, LAF, Silicone (primers)
- Backsheets: Glass, TPE, PET, PEN/Al/PET
- Edge Seal: Solar Edge Tape from True Seal
- Edge Deletes: Bead blast with various cleaning methods

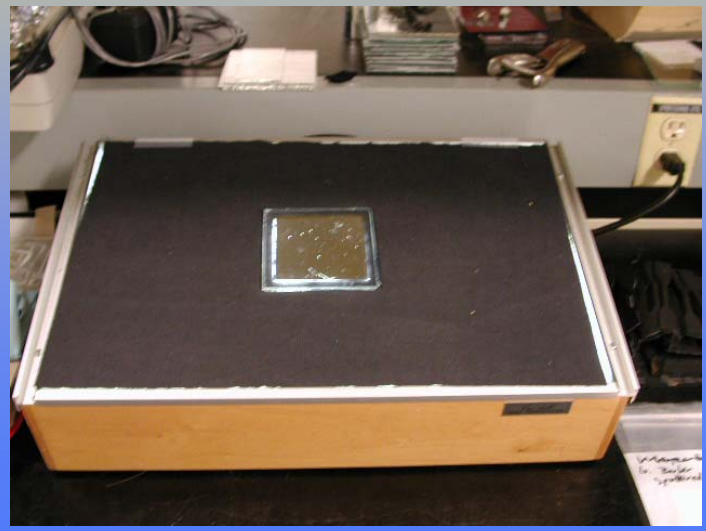
Sample Preparation

- Glass (4”x4”) is cleaned by using:
  - Isopropyl Alcohol
  - Bilco pH 5.9
  - DI water
- 80nm Al deposited to glass
  - Pulsed DC sputtering
- Samples are laminated and exposed to damp heat for 1000 hours
- Test periodically suspended for visual observations and digital imagery

Light Box (Backlighting) Used for Visual Observations



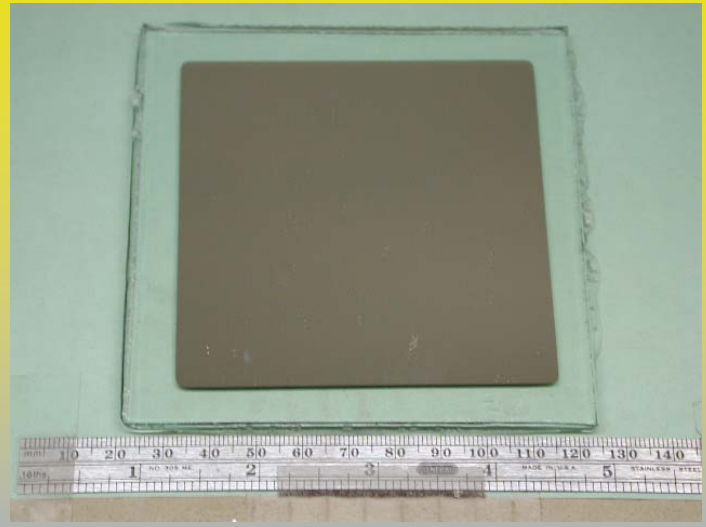




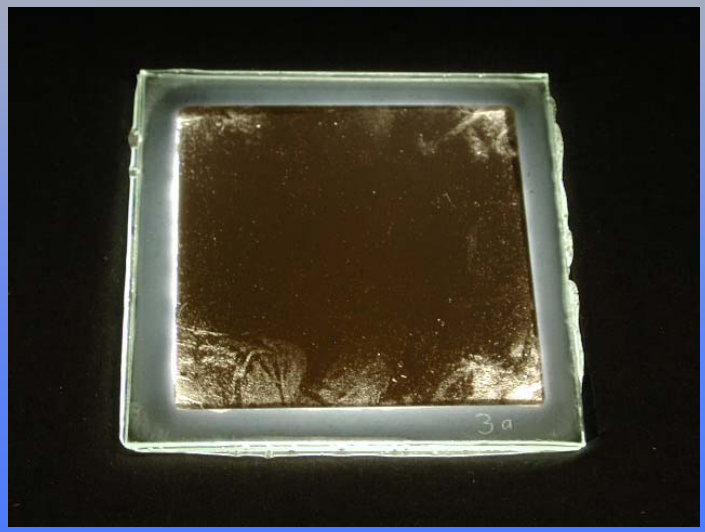
Improved Observations from Light Box

Light box Initial

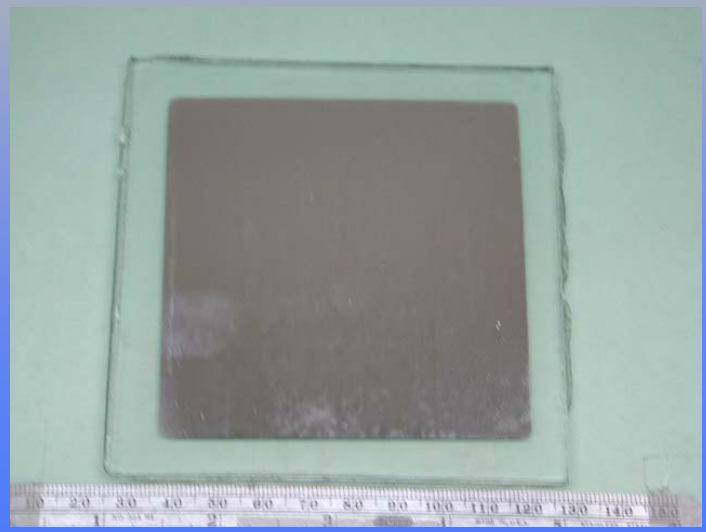
Front Light Initial



Light box 700hrs



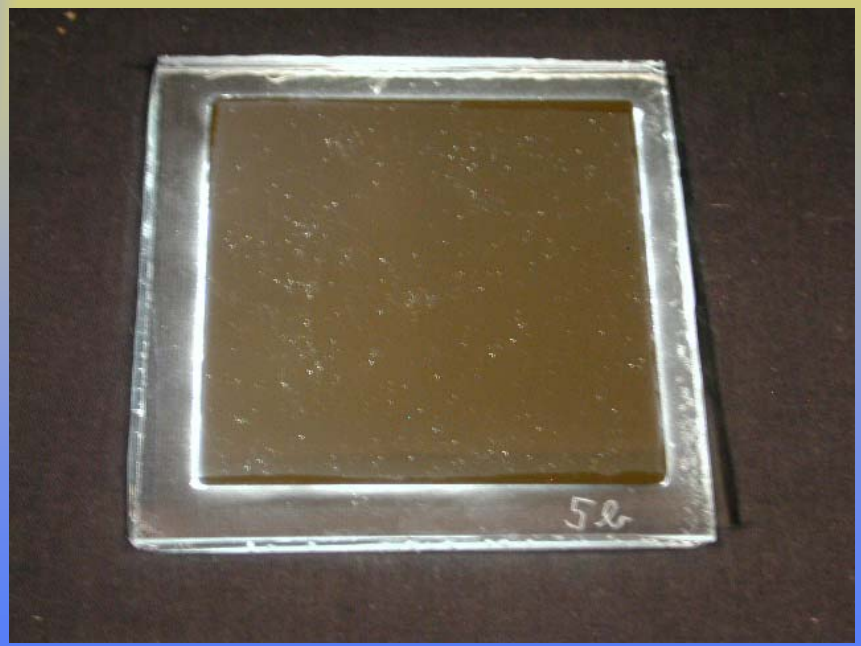
Front Light 700hrs



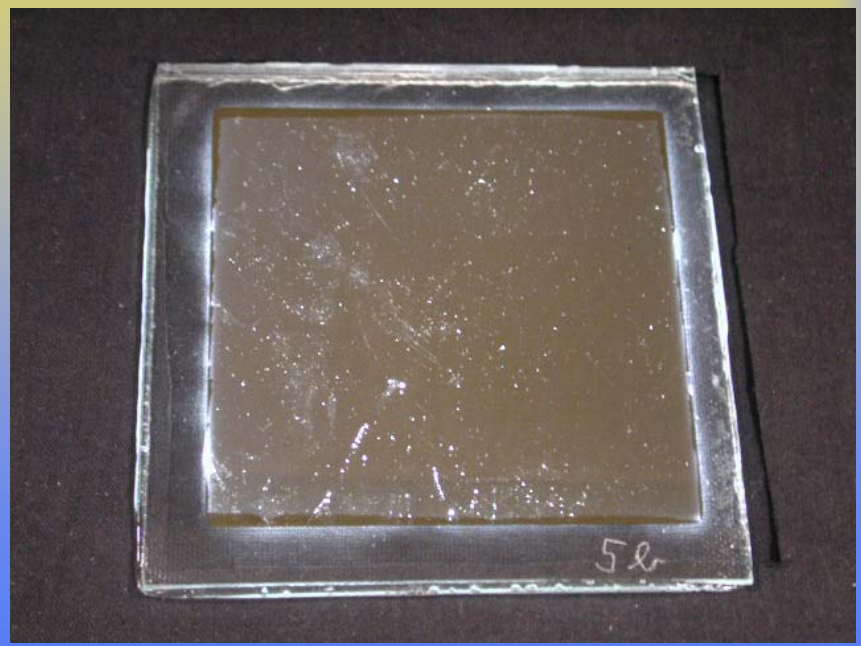
EVA with No Backsheet

- Slight corrosion

Initial



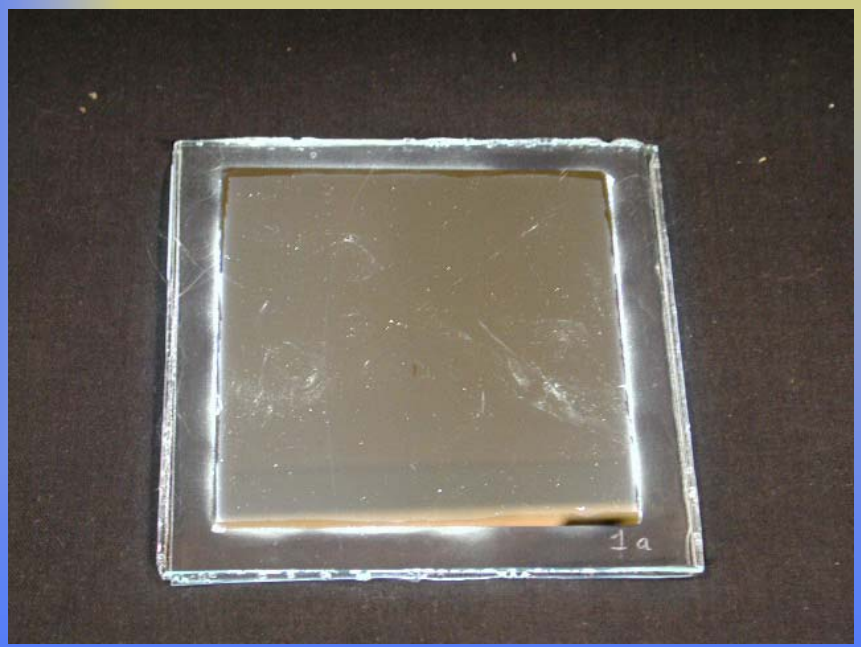
700 hours of exposure



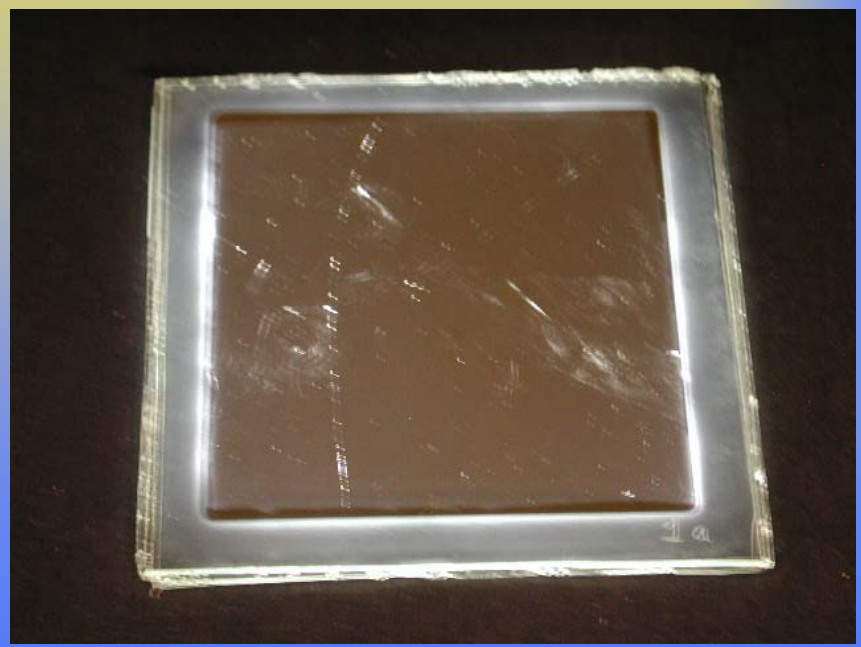
EVA with PET Backsheet

- Slight corrosion

Initial



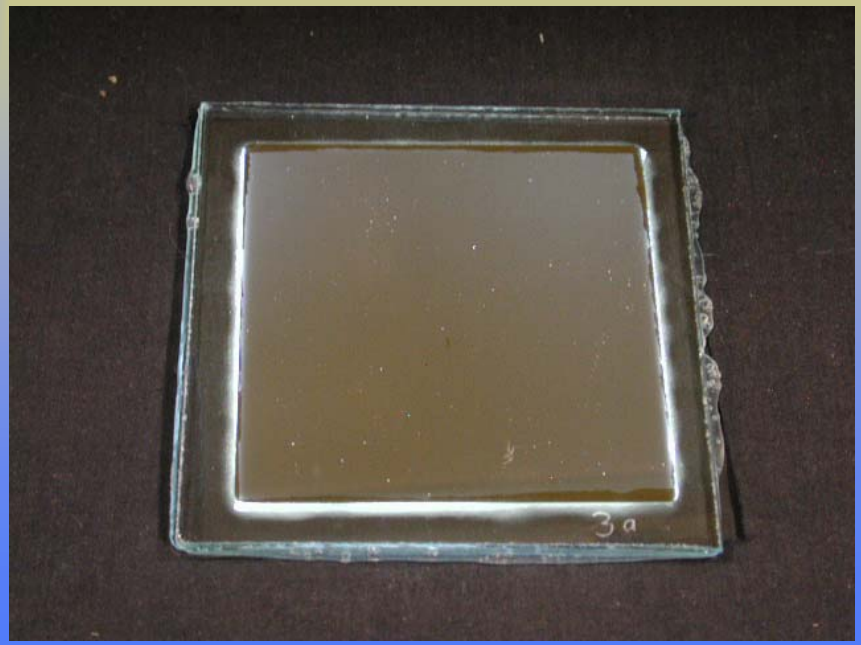
700 hours exposure



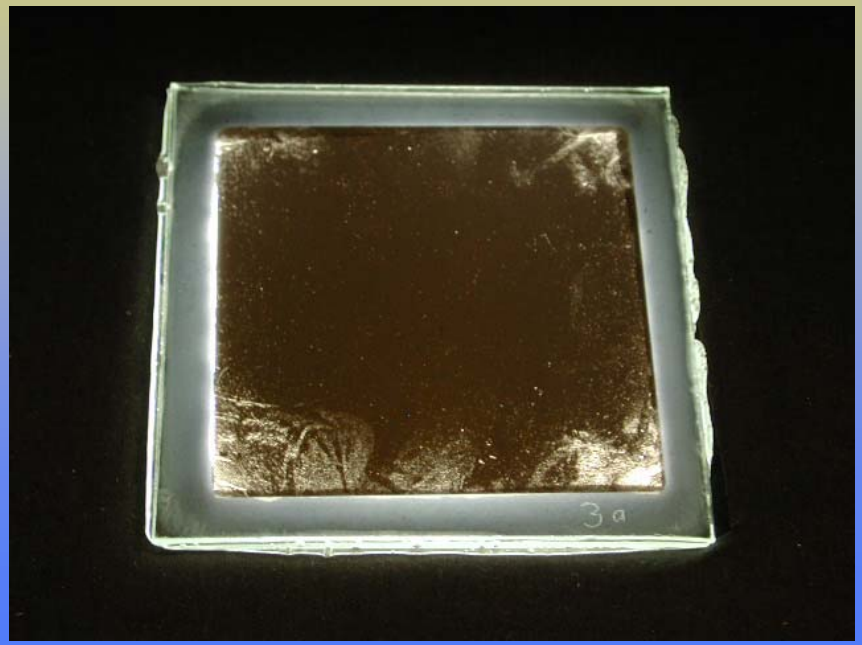
EVA with Glass Backsheet

- After 250 hours, moisture will penetrate to center
- Corrosion from the edges
- Previous experiment compared borosilicate and soda lime glass with no discernable differences

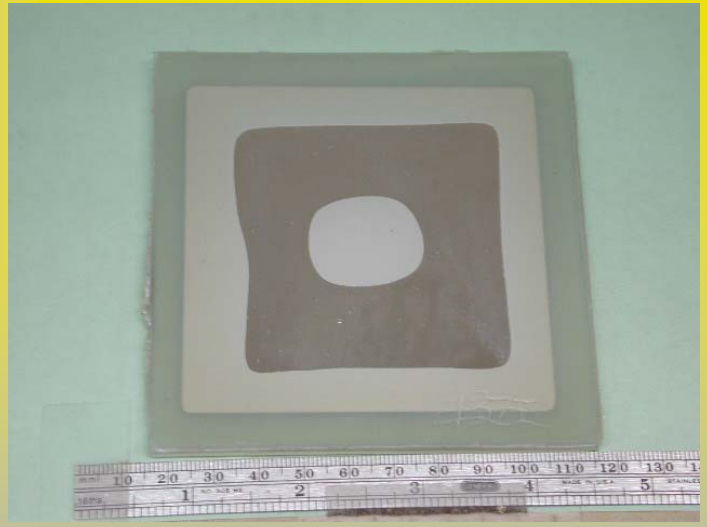
Initial



700 hours exposure

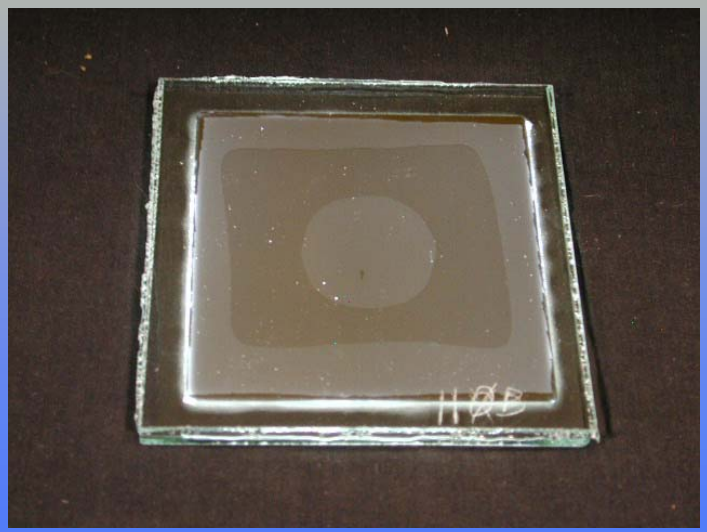


EVA with Glass Backsheet

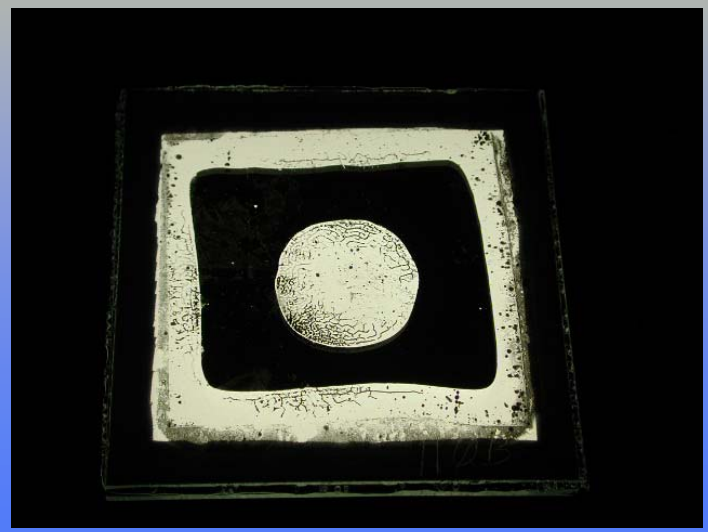


- Extreme corrosion where EVA is in contact with aluminum

Initial



700 hours exposure

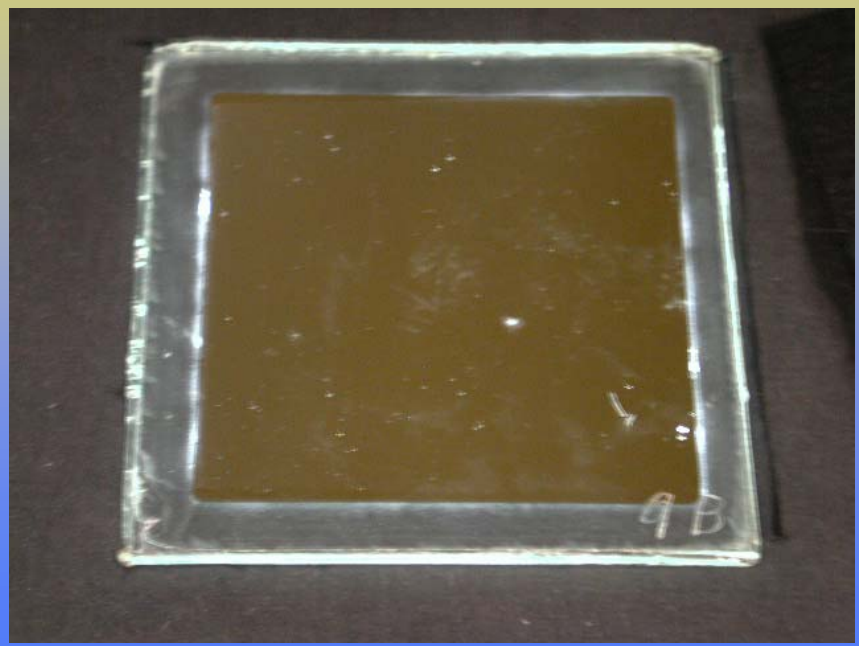


EVA with PEN-Al Foil-PET Backsheet

- Backsheet removed after 1000 hours
- Slight corrosion

Initial

1000 hours exposure

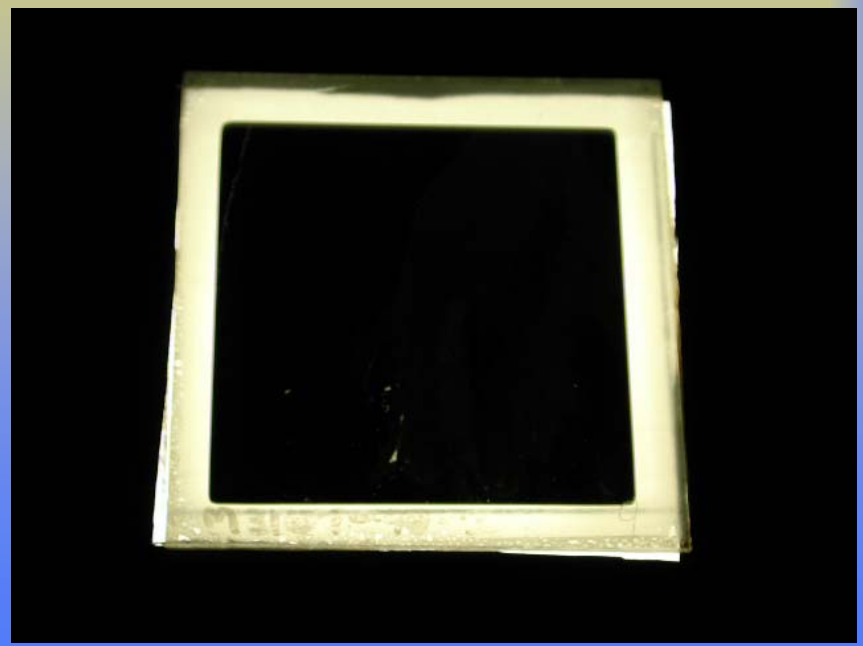


BRP with no Backsheet

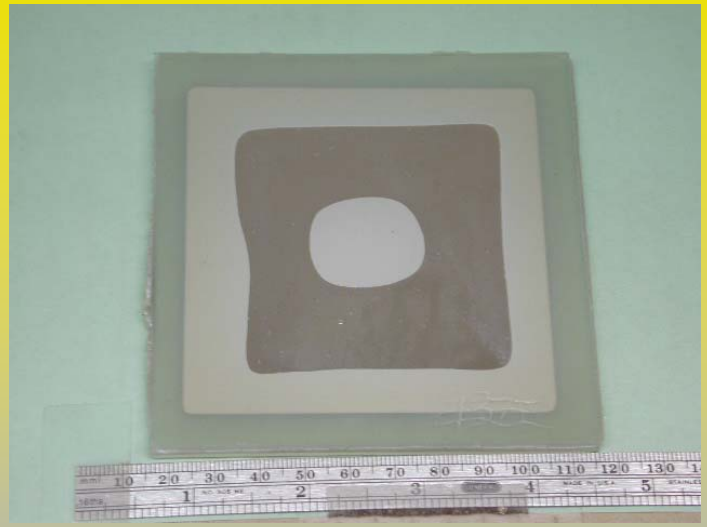
- BRP is a semi-transparent encapsulant
- Provides excellent protection against aluminum corrosion

Initial

1000 hours of exposure

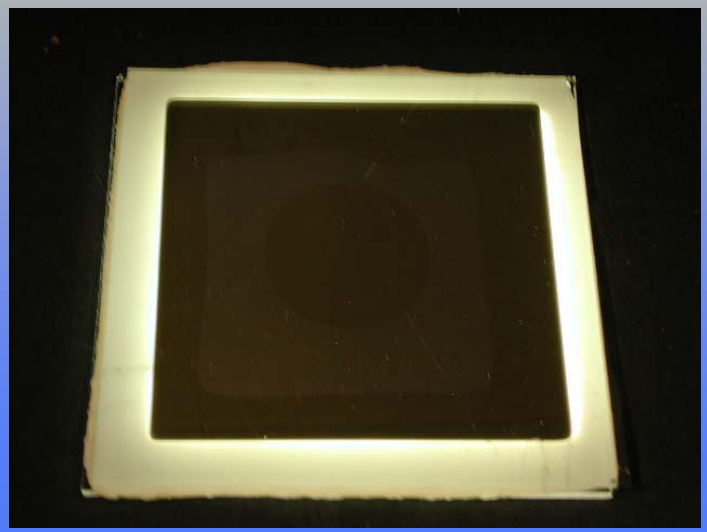


BRP with Glass Backsheet

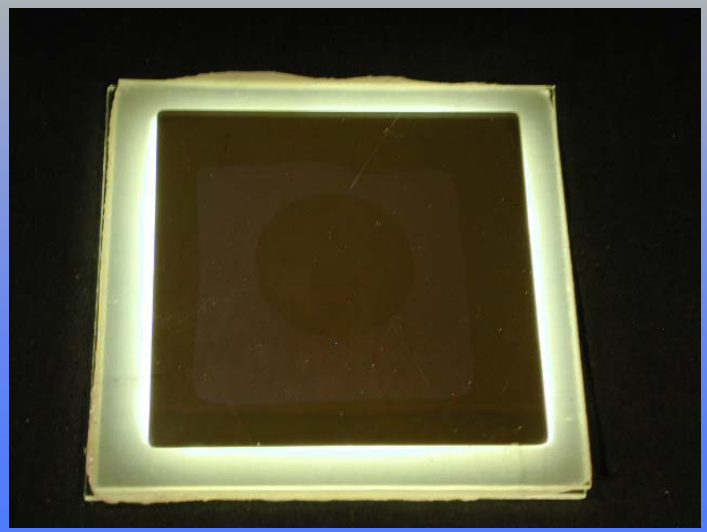


- After 100 hours, moisture will penetrate the edges
- Provides excellent protection against aluminum corrosion

Initial

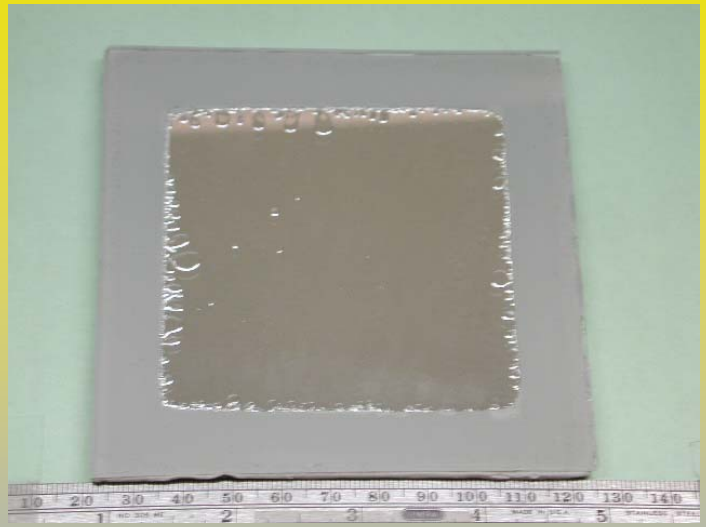


700 hours exposure



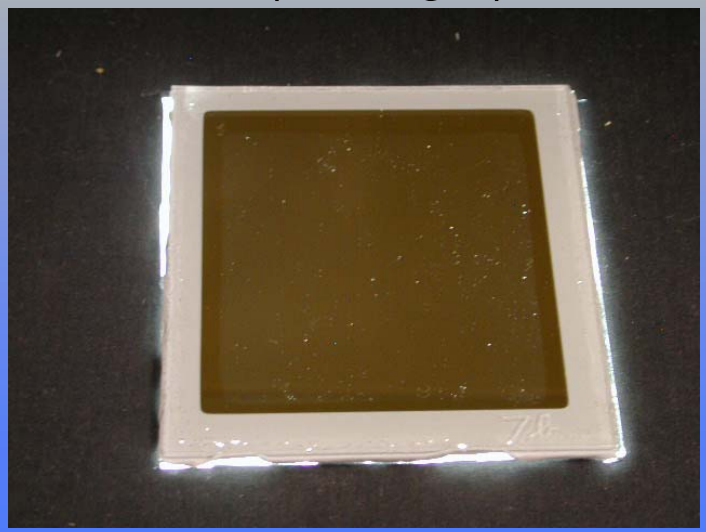
EVA (1x) + Solar Edge Tape with Glass Backsheet

Initial (backside)

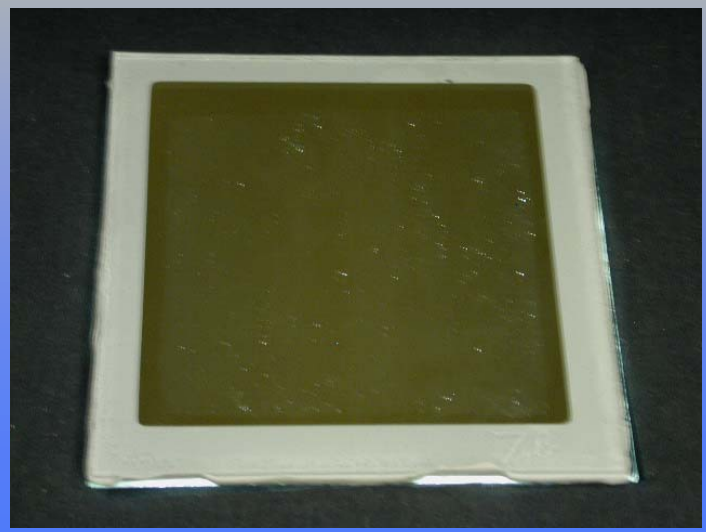


- 1x EVA thinner than solar edge tape
  - Proper seal provides excellent protection of aluminum layer

Initial (backlight)



700 hours of exposure

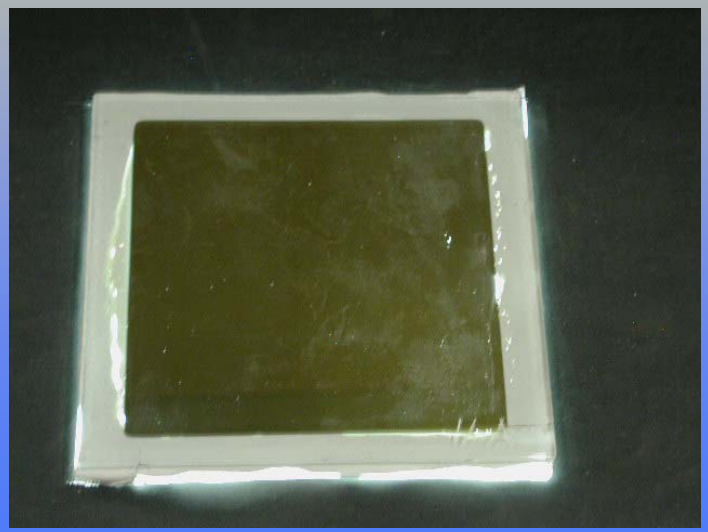


EVA (2x) + Solar Edge Tape with Glass Backsheet

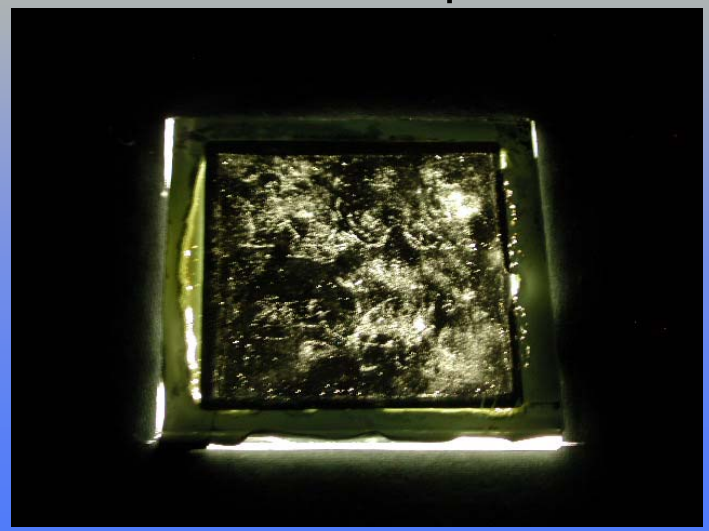
Initial

- 2x EVA thicker than solar edge tape
  - Mismatch causes poor seal, leads to extreme corrosion

350 hours of exposure

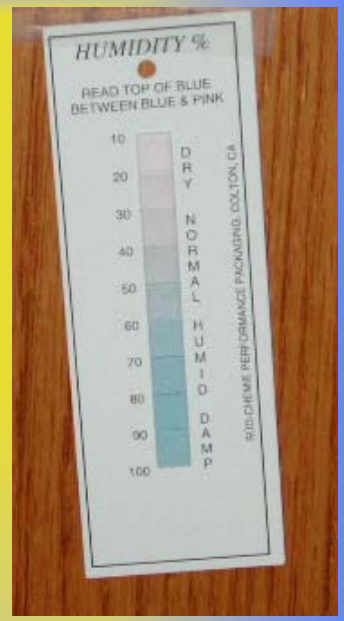


1000 hours of exposure

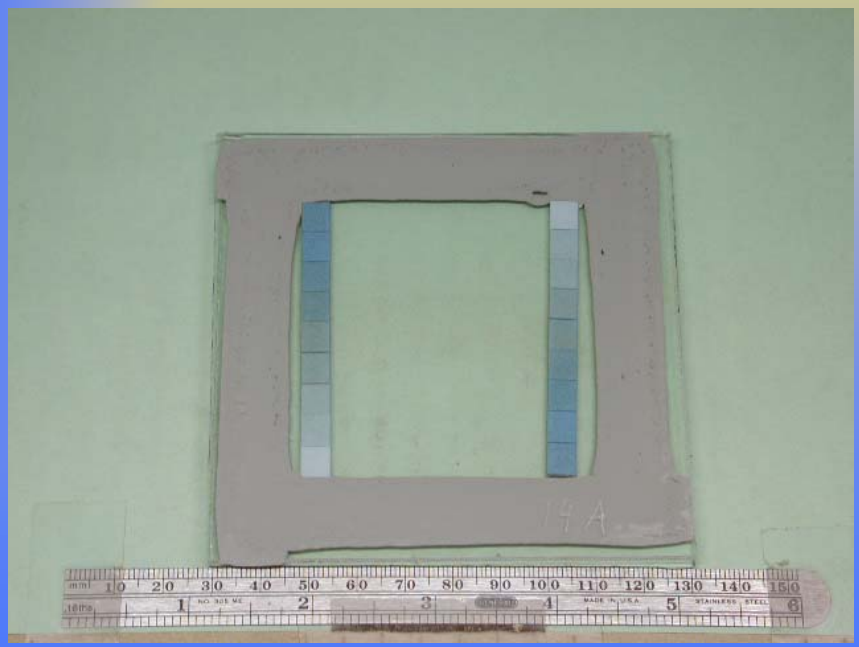


Solar Edge Tape

- Cobalt Humidity Sensors
- 700 hour of exposure
- Can provide excellent protection



Solar Edge Tape

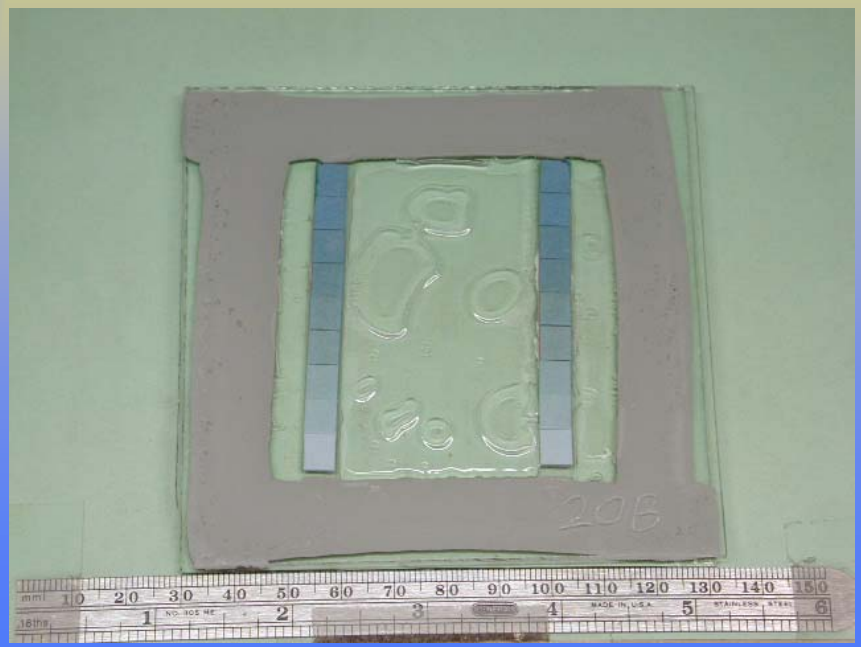


Solar Edge Tape

Solar Edge Tape

- ~700 hour of exposure
- 1x EVA thinner than solar edge tape, 2x EVA thicker than solar edge seal

Solar Edge Tape/EVA (1x)



Solar Edge Tape/EVA (2x)

Discoloration of Humidity Sensors

- Cobalt Humidity Sensors
- Should turn pink with humidity

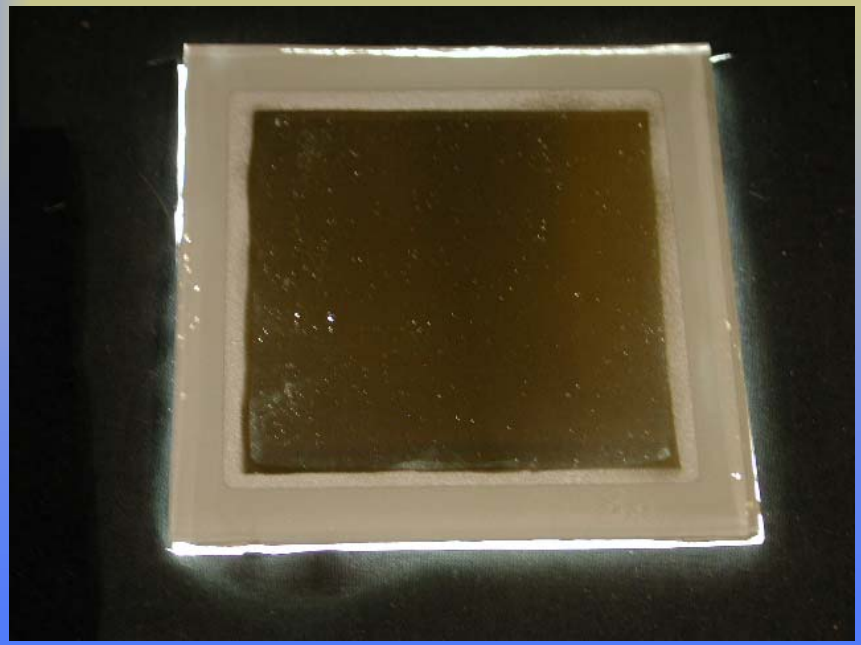
42 hours of exposure

Glass/EVA-TPE Glass/EVA-TAT

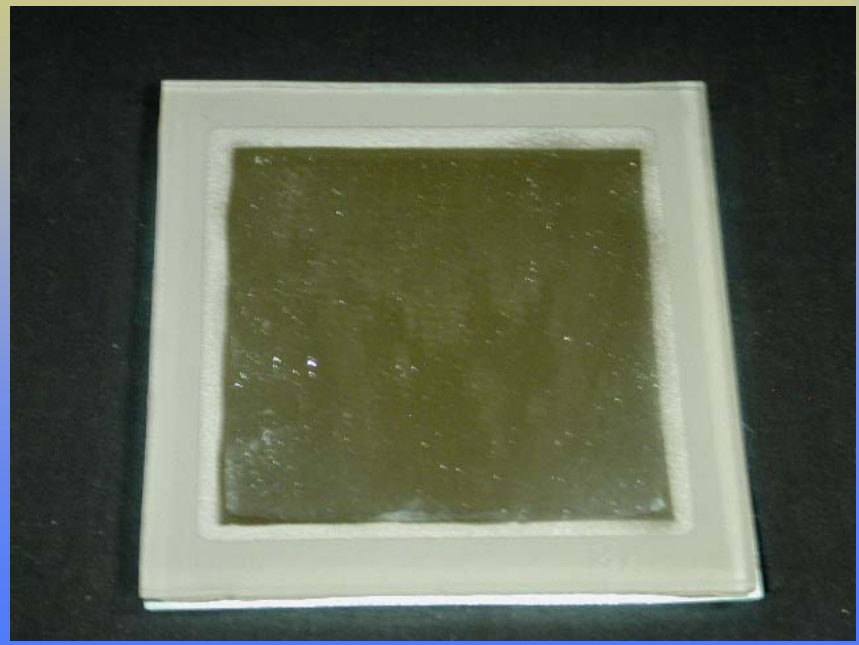
Glass(Bead Blast)/EVA (1x) + Solar Edge Tape with Glass Backsheet

- Bead blast cleaned with Isopropyl Alcohol wipe
- Slight corrosion

Initial



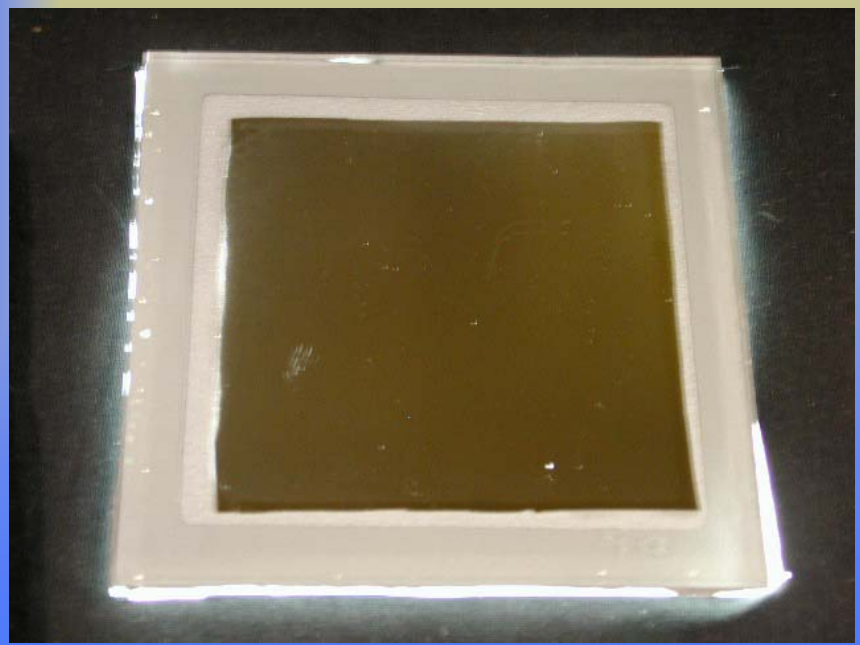
700 hours exposure



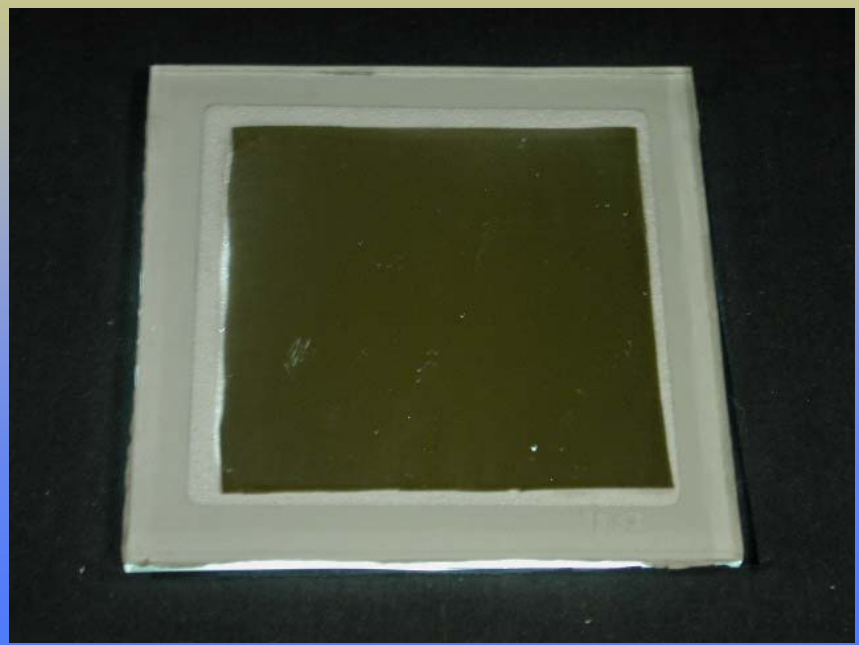
Glass(Bead Blast)/EVA (1x) + Solar Edge Tape with Glass Backsheet

- Bead blast cleaned with Isopropyl Alcohol bath in ultrasonic cleaner
- Little to no corrosion

Initial



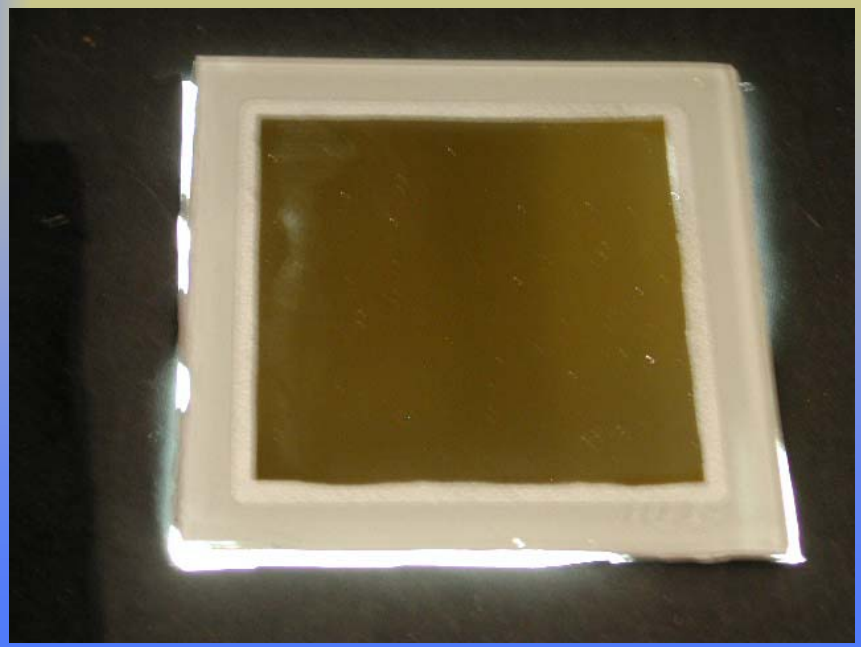
700 hours exposure



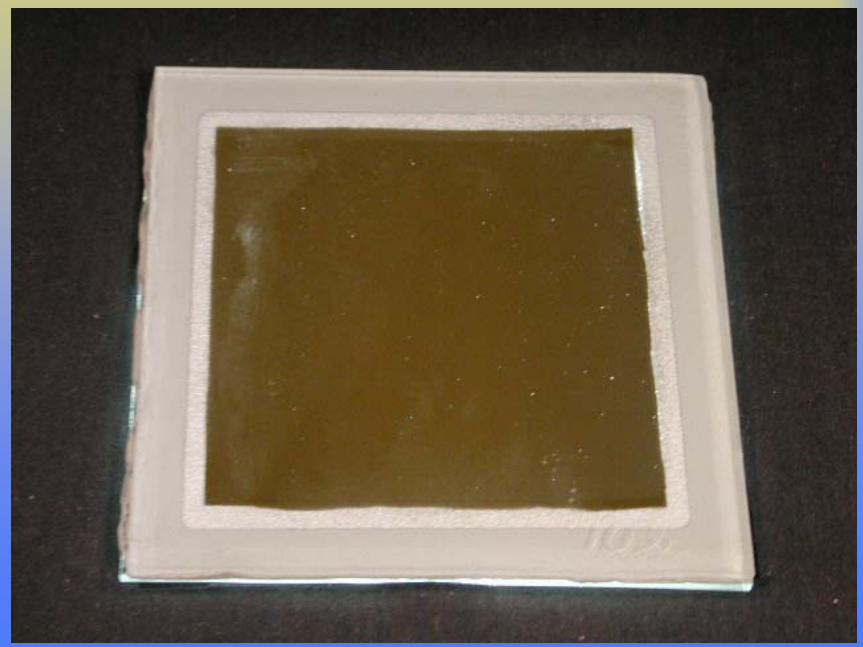
Glass(Bead Blast)/EVA (1x) + Solar Edge Tape with Glass Backsheet

- Bead blast cleaned with Isopropyl Alcohol wipe and ultrasonic cleaner
- Little to no corrosion

Initial



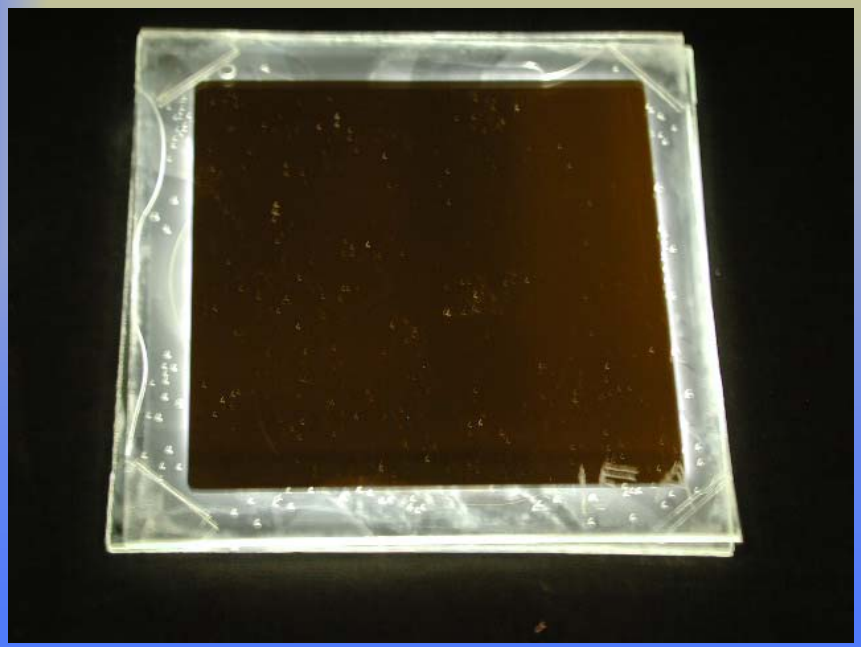
700 hours exposure



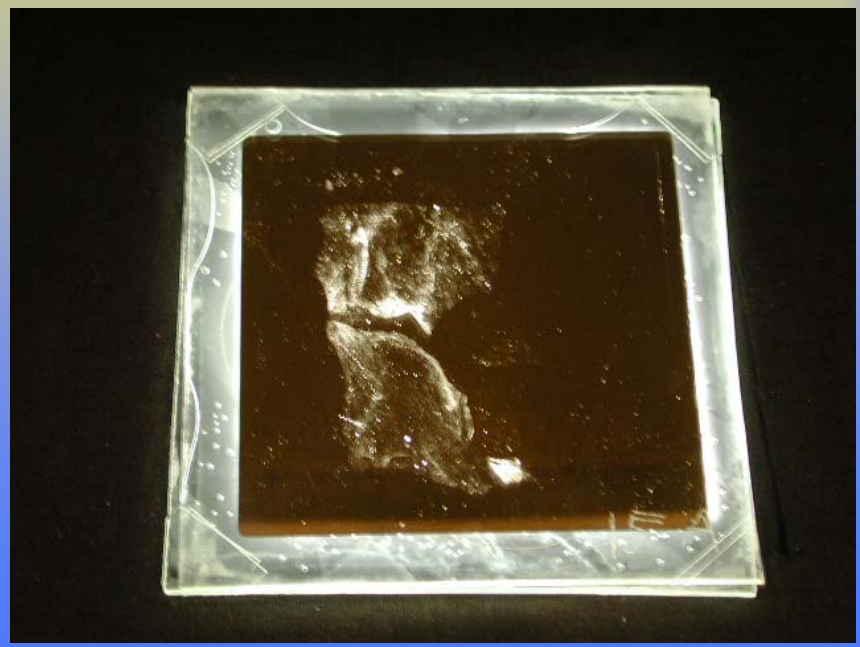
DOW Sylgaurd 184 Silicone with Glass Backsheet

- Different primers appear to be effecting corrosion
- Silicone seems to protect aluminum better than EVA
- Results are preliminary, more experiments will follow

Initial



700 hours exposure



Summary

- Continuing to examine WVTR of polymers, polymer laminates, and barrier coated polymers
- Measuring WVTR of barrier coated polymers is also a stress test
- Aluminum mirrors have been analyzed to quantify the effects of moisture ingress and corrosion for various backsheet/encapsulant constructions
  - Imbedded humidity sensors
  - Donut constructions
  - Breathable and glass backsheets
  - BRP, EVA, and Silicone encapsulants
  - Solar edge tape with/without bead blast