Comparative Performance and Reliability of Backsheets for PV Modules

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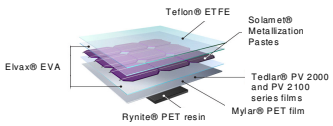
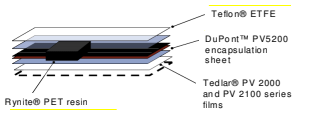
Solar Technologies – Long Life Required

- Rapid growth of commercial and utility segments
- Strong need for improved module reliability
- DuPont focused on partnerships, enabling technologies, and end market requirements
- Tedlar® film enables long-term, reliable module performance

Crystalline Si (c-Si) PV cells & modules



Amorphous Si (a-Si) thin film PV modules

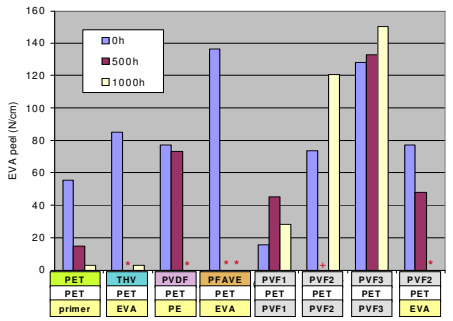


Critical Backsheet Properties Tested

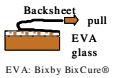
Physical Properties	*Sample Structure*	*Test Standard*
Structural Analysis	FILM	internal
Thickness	FILM	ASTM D374
Reflectance	FILM, LAMINATE	ASTM E1164
Color	FILM, LAMINATE	ASTM E308
Dielectric Breakdown Voltage	FILM	ASTM D1868
Tensile Strength (MD, TD)	FILM	ASTM D882
Elongation (MD, TD)	FILM	ASTM D882
Peel Strength to EVA (180deg, 0.2m/min peeling)	LAMINATE	ASTM D1876
Cut Susceptibility	LAMINATE	UL1703
Coefficient of Thermal Expansion	FILM	internal
Dimensional Stability (150C, 30m)	FILM	ASTM D1204
Visual Inspection	FILM, LAMINATE, MODULE	internal
Water Vapor Permeability	FILM	ASTM 1249

Exposure Tests	*Sample Structure*	*Test Standard*
Damp Heat (85C, 85%RH, 1000h))	FILM, LAMINATE, MODULE	IEC 61215
UV aging (xenon, UVA, UVB)	FILM, LAMINATE, MODULE	IEC 61345, ASTM
Thermal Cycling (50 and 200cyc, -40C, 85C)	FILM, LAMINATE, MODULE	IEC 61215
Thermal Cycling/Humidity Freeze (50 cyc, 10cyc)	FILM, LAMINATE, MODULE	IEC 61215

Backsheet Adhesion to Encapsulant After Damp Heat



Loss of EVA adhesion for PET and other fluoropolymer based backsheets

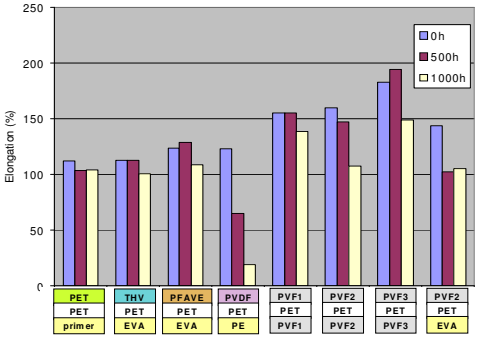


EVA: Bixby BixCure®

* Adhesion not measurable due to backsheet break
\+ EVA peel from glass indicating strong EVA/backsheet adhesion

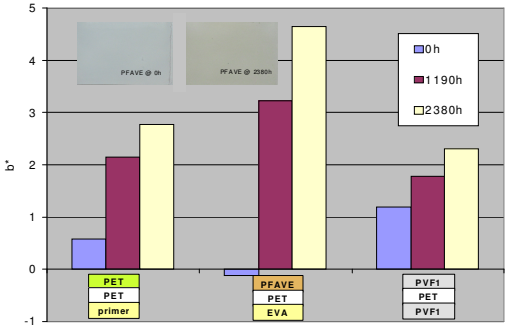
PFV1=PV2000 series
PVF2=PV2100 series
PVF3=PV2400 series

Backsheet Elongation After Damp Heat



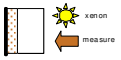
Embrittlement of PVDF based backsheet

Color Change in Glass/EVA/Backsheet Laminate



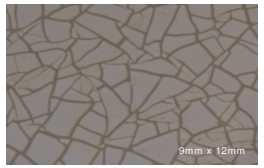
Exposed under xenon (ASTM G155) from glass side and measured from glass side of laminate

2380h xenon exposure ~630 days in Florida (< 2 years)

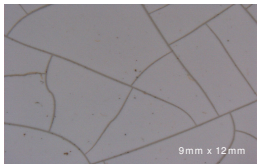


Degradation - Glass/EVA/backsheet laminate after UV Exposure (ASTM G155) at 1190h

Cracking observed on PET backsheet in laminate exposed on backsheet side



Cracking observed on PET backsheet in laminate exposed through glass



Coefficient of Thermal Expansion (CTE)

Backsheet	Direction 1 (um/°C*m)	Direction 2 (um/°C*m)
PVF1/PET/PVF1	41	29
PVF2/PET/PVF2	39	30
PVF3/PET/PVF3	41	30
PVF2/PET/EVA	116	178
PET/PET/primer	347	184
PVDF/PET/PE	82	34
THV/PET/EVA	114	28
PFAVE/PET/EVA	326	258

- CTE measured in two orthogonal directions (1 and 2) from -40°C to 90°C
- TPT structures have lower CTE and more isotropic expansion
- Other backsheets show higher CTE and more anisotropic expansion
- Two PET backsheets showed same or greater CTE as shown
- Higher expansion and anisotropy may lead to delamination, cracking and failure

Summary

- DuPont has and will continue to demonstrate its commitment to meet increasing demand for reliable backsheet materials.
- DuPont is recognized as a global leader in materials and technologies for the PV industry.
- Tedlar® PVF film based backsheet consistently outperforms alternative products.
- Tedlar® PVF film based backsheet is the only material that has successfully protected PV modules for more than 25 years.

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NREL PV RELIABILITY WORKSHOP, 2/18/2010