Ranking PV Materials for Weathering Performance

Greg O'Brien, Amy Lefebvre, Steven Hahn, Anthony Bonnet

PV Module Reliability Workshop - Silicon
February 28, 2012

PV Module Reliability

- PV module's return on investment is directly related to the module's lifetime and performance.
- Photovoltaic power can only truly be considered "green" when modules can produce safe and reliable electricity for very long periods of time.
- Module makers should be able to select component materials of construction that have proven long lasting performance.
- Current certification standards (UL and IEC) are focused on safety and short term output performance.
- Long term weathering durability for materials of construction support long PV module lifetimes.

Module Makers Cannot Wait 25 Years for Materials Selection

- Without 25 year weatherability and performance data, the PV industry can utilize accelerated testing to evaluate the effect of UV light with oxygen, temperature cycles, and humidity cycles on materials of construction.

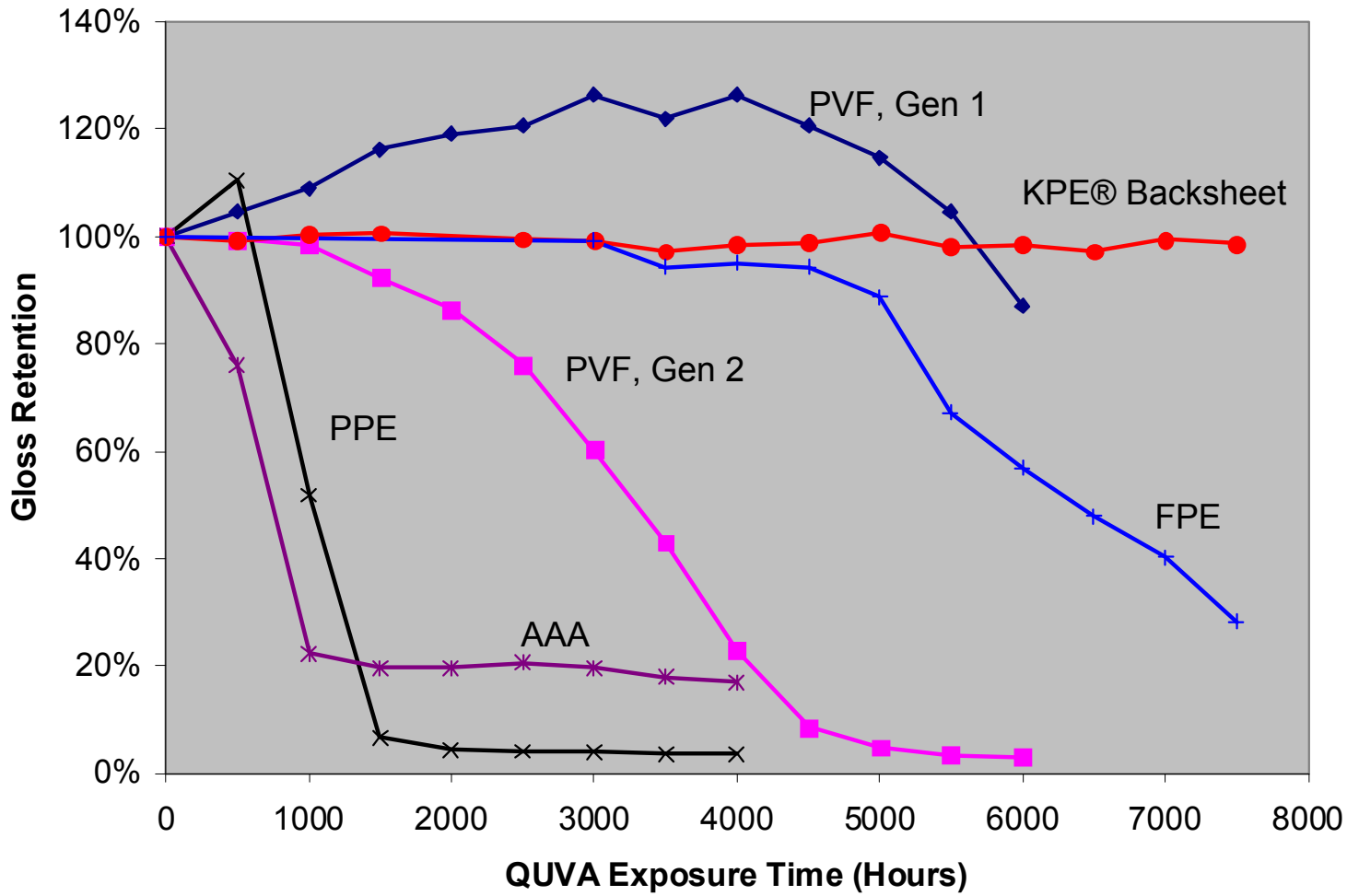
- Long term exposure to these elements stresses the polymer components and can shorten their lifetime.

- Early indicators of photo-degradation of white polymeric materials are
  - Gloss Loss
  - Chalking
  - Oxidation of the polymer chains

Backsheet Weathering Study

- Arkema initiated a weatherability study to establish ranking of backsheets.
  - Based on accelerated weathering QUV A.
  - Photo-degradation monitored by gloss retention, SEM microscopy, chalking evaluation, and FTIR spectroscopy.
  - Compare with outdoor weathering results – Florida Exposure.
- QUV A - Accelerated Testing Conditions:
  - Irradiance of 1.55 at 340 nm, 8 hrs light at 60°C and 4 hrs dark at 50°C with condensation (ASTM G154 Cycle 6).
  - UV irradiance 295 – 385 nm = 85 W/m^2 or 4.91 MJ/m^2 in 24 hrs
  - 6000 hrs exposure has equivalent UV radiation to 48 months in Florida.
  - Backsheet exposure is a percentage of direct exposure.
- Backsheet Materials Tested:
  - KPE® sheet – Kynar® Film / PET / Kynar® Film backsheet
  - PVF, Gen 1 - PVF Generation 1/PET/PVF Generation 1 backsheet
  - PVF, Gen 2 - PVF Generation 2/PET/PVF Generation 2 backsheet
  - FPE - Partially fluorinated coating based backsheet
  - PPE - Weatherable polyester backsheet
  - AAA - Polyamide based backsheet

Accelerated UV-A Weathering Study: Degradation of Backsheets: Gloss Retention

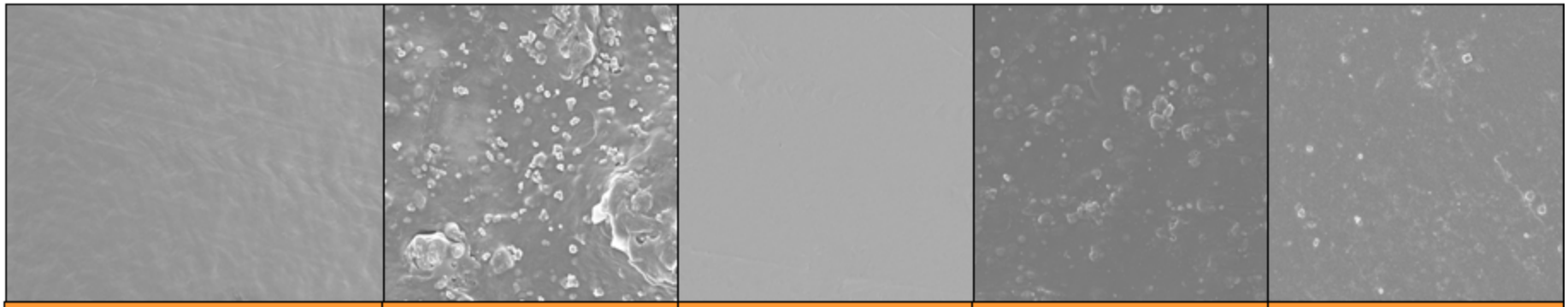


QUV Accelerated Weathering Conditions
QUVA: Irradiance = 1.55 at 340 nm

ARKEMA

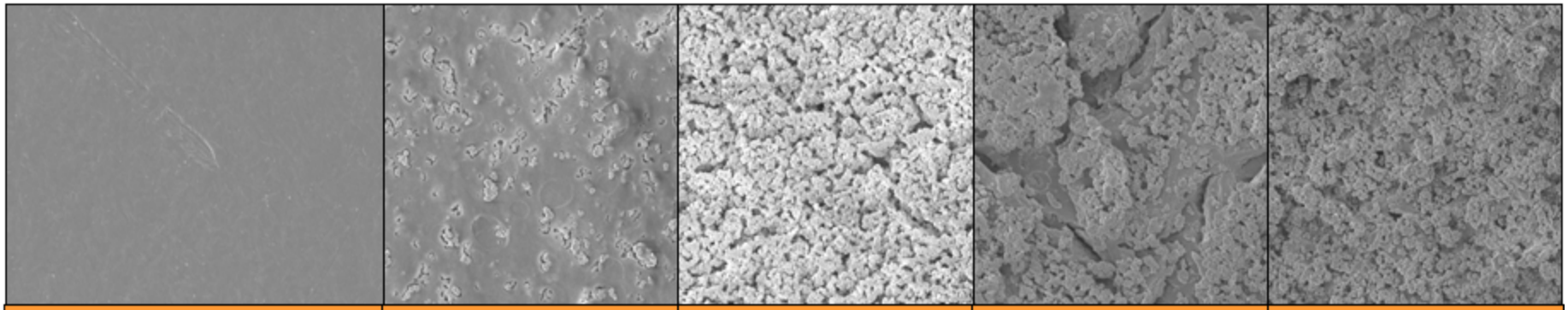
UV Stability of Backsheets: SEM Images

Before Exposure



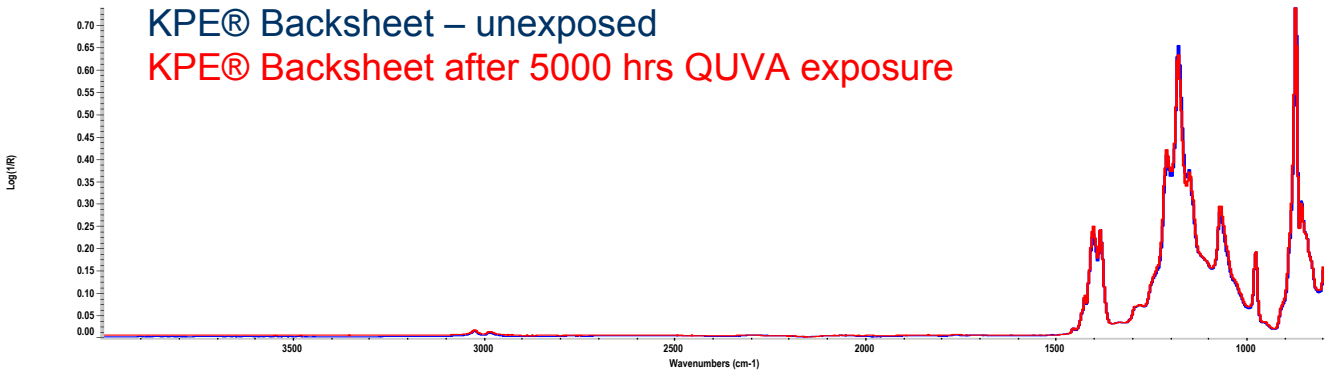
KPE® Backsheet Unexposed	PVF, Gen 1 Unexposed	FPE Unexposed	PPE Unexposed	AAA Unexposed

After QUVA Exposure

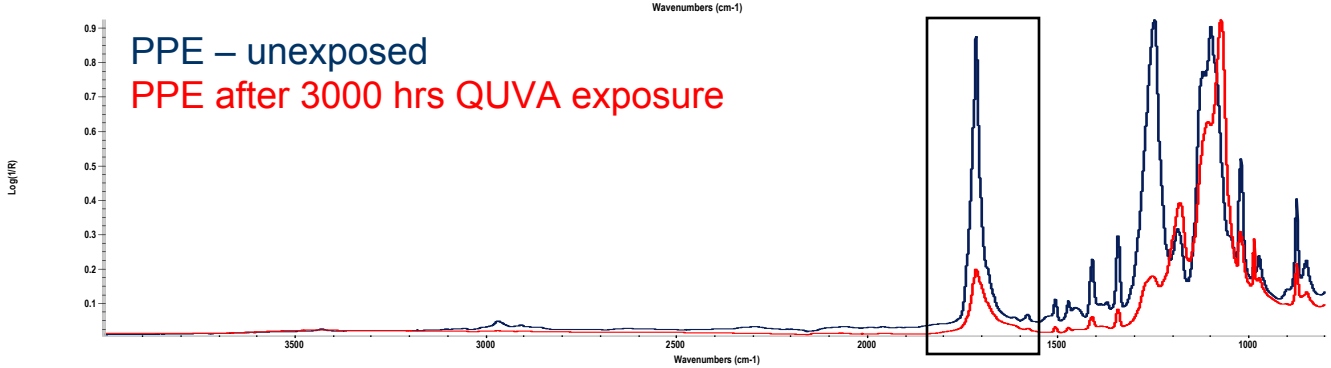


KPE® Backsheet After 5000 hours	PVF, Gen 1 After 5000 hours	FPE After 5000 hours	PPE After 3000 hours	AAA After 3000 hours

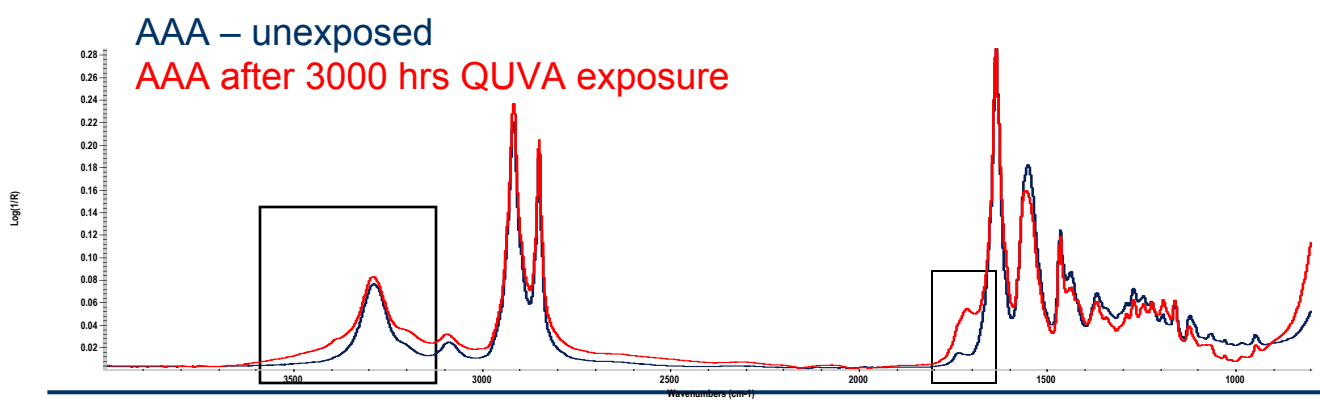
Accelerated UV-A Weathering Study
Degradation of Backsheets: FTIR ATR Analysis of Oxidation



- No spectral changes KPE® Backsheet Surface
- No sign of degradation

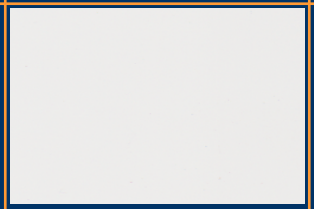
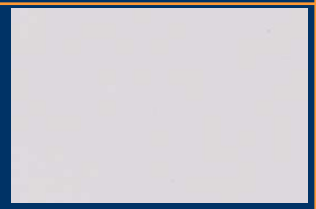
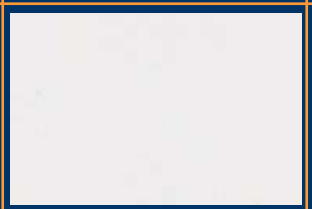
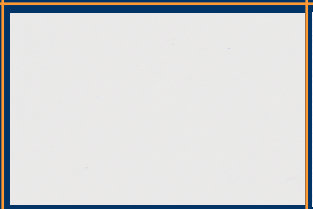
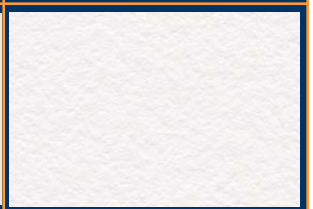


- Spectral changes in PPE indicate degradation
- C=O band has decreased substantially



- Changes in spectrum indicate degradation
- NH/OH spectral region indicates increasing OH

Real-time Weathering Study
Degradation of Backsheets: 1 Year South FL Exposure Results

	KPE® Sheet	PVF, Gen 1	FPE	PPE	AAA
Before Exposure					
After 1 Year South Florida Exposure, unwashed					
Gloss Retention	101%	105%	97%	42%	25%
Chalking* **(ASTM D4214-07 D)**	2	2	2	3	6

Gloss retention after outdoor FL exposure is showing the same trend as gloss retention after QUVA exposure

*Chalking rating: 2 is no chalking and 6 is high level (2 – 7)

ARKEMA

Gloss Retention for Weathering Ranking of Materials

Backsheet	Gloss Retention %, 3000 Hr.	Gloss Retention %, 6000 Hr.	Time to 50% Gloss Retention (Hrs.)	Weathering Ranking (Best =1)	Weathering Class
KPE® Backsheet	100	99	**> 7500**	**1**	**A**
PVF, G1	126	87	**> 6500**	**2**	**A**
FPE	99	56	**6400**	**3**	**B**
PVF, G2	60	3	**3300**	**4**	**C**
PPE	4	NA	**1100**	**5**	**D**
AAA	20	NA	**750**	**6**	**D**

QUV Accelerated Weathering Conditions
QUVA: Irradiance = 1.55 at 340 nm

Proposal for Ranking Backsheets Based Upon Accelerated Weathering Testing

- Utilize QUV A Accelerated Test.
  - Includes UV light, oxygen, and humidity to simulate worst conditions
  - Gloss loss easiest indicator to monitor
  - Common and relatively inexpensive weatherometer
- Propose 3 Class Rankings.
  - Based on time to Gloss Retention using ASTM G154 Cycle 6
    - Class A – minimum 80% retention after 6000 hrs of exposure
    - Class B – minimum 80% retention after 4500 hrs of exposure
    - Class C – minimum 50% retention after 3000 hrs of exposure
    - Class D – less than 50% retention after 3000 hrs of exposure
- Same trends observed with Outdoor Weathering.
  - After one year south Florida exposure– gloss loss for Class D is evident
  - Surprising finding: Mold growth on some backsheets.
- Weatherability is one axis of backsheet performance. Other testing is needed for a complete evaluation.

Kynar® is a registered trademark of Arkema, Inc.. KPE® is a registered trademark of Arkema France.