The Effect of Florida and Accelerated Weathering Exposures on Photovoltaic Backsheets

A. Lefebvre, G. O'Brien, L. Fang, G. Moeller

2014 NREL Module Reliability Workshop

February 25-26, 2014

ARKEMA
INNOVATIVE CHEMISTRY

Introduction

- **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.**
  - IEC 61215 UV preconditioning test: Preconditions modules – but does not measure durability. Total UV exposure (15 kWh/m2 280-385 nm) is less than 3 months direct exposure in Miami, FL.
  - A weathering durability test is needed for UL and IEC standards

- **Long PV module lifetimes are supported by incorporating materials with proven, long term weatherability into the module.**

KYNAR® BY ARKEMA

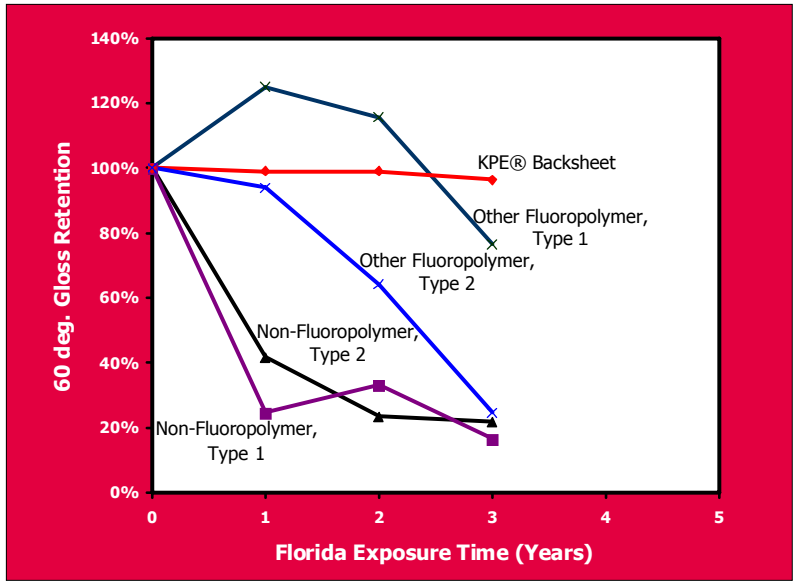
Weathering Study Details

- **Arkema initiated a study to examine effects of FL outdoor exposure on backsheets.**
  - Photo-degradation monitored by gloss retention, optical and SEM microscopy, chalking evaluation, and FTIR spectroscopy.
  - Compare results with accelerated weathering using QUV A.
- **Florida Outdoor Testing Conditions:**
  - Samples located in Miami, FL.
  - Samples oriented south facing at 45 degree angle facing the sun.
- **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/m2 or 4.91 MJ/m2 in 24 hrs.
  - Backsheets are facing the lamp.
  - 1300 hrs exposure has equivalent UV radiation to 12 months direct exposure in Florida.
  - In the Field - Backsheet exposure is a percentage of direct exposure (25% - 10%) .
- **Backsheet Materials Tested:**
  - KPE® Backsheet – Kynar® Film/ PET /EVA backsheet
  - Other fluoropolymer film based backsheet
  - Non-fluoropolymer based backsheets

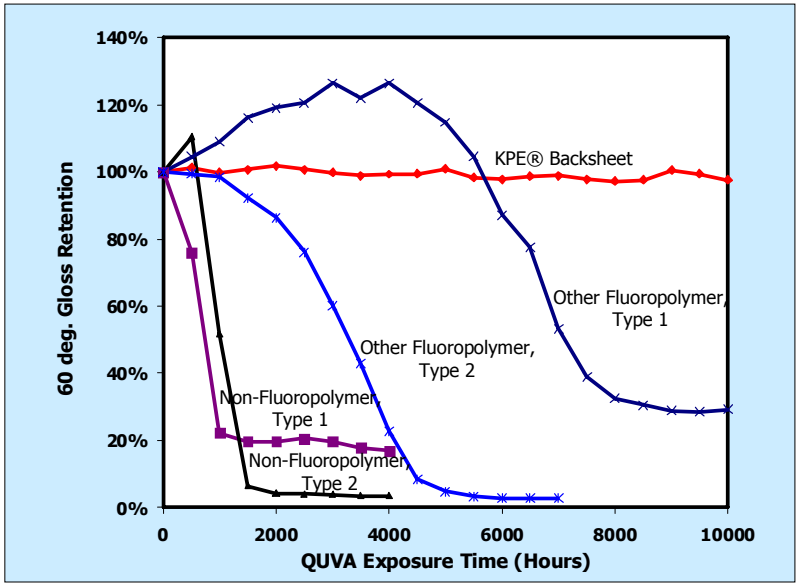
KYNAR® BY ARKEMA

Surface Degradation of Backsheets

Florida Exposure



QUV A Exposure

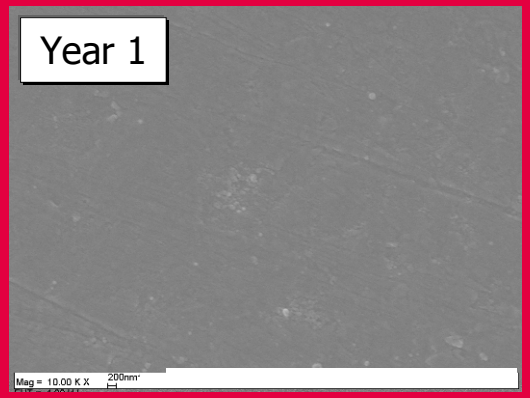


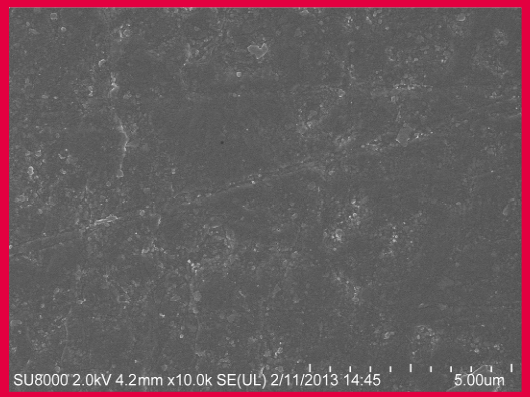
- 1300 hrs. QUV A exposure has equivalent UV radiation to 1 year direct exposure in FL.
- The decreasing gloss retention trends observed in realtime Florida exposure are the same as observed after QUV A accelerated weathering exposure just at slower rates due to the decreased amount of UV radiation.
- We expect Florida exposure results to continue following the trend seen in accelerated QUV A results.

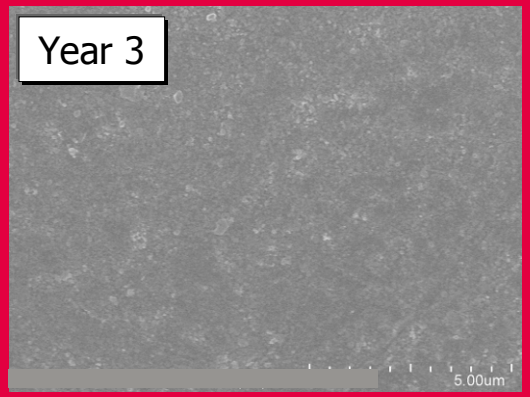
KYNAR® BY ARKEMA

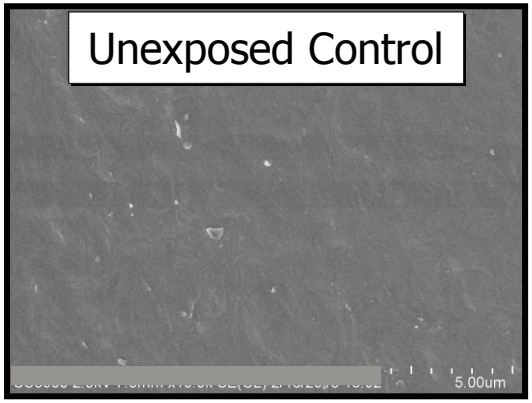
SEM Images of KPE® Backsheet

Florida Exposure









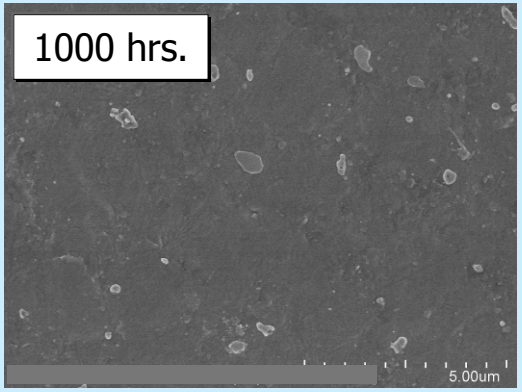
Florida Exposure:

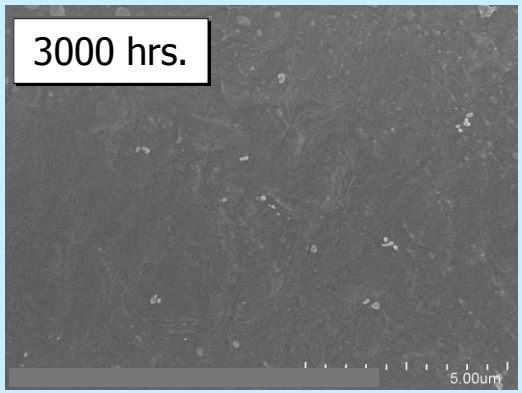
- Year 1, no degradation or cracking of backsheet occurring.
- Year 2, no degradation or cracking of backsheet occurring.
- Year 3, still no degradation or cracking of backsheet occurring.

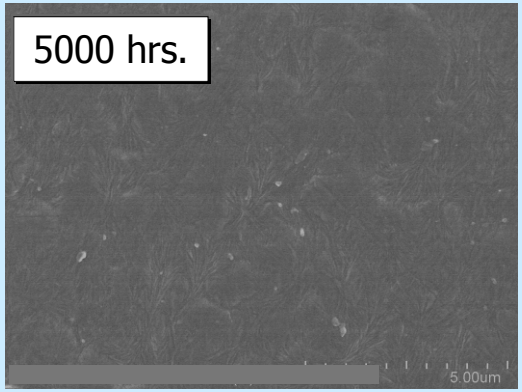
QUV A Exposure:

- 1000 hrs, no degradation or cracking of backsheet occurring.
- 3000 hrs, no degradation or cracking of backsheet occurring.
- 5000 hrs, still no degradation or cracking of backsheet occurring.

QUV A Exposure

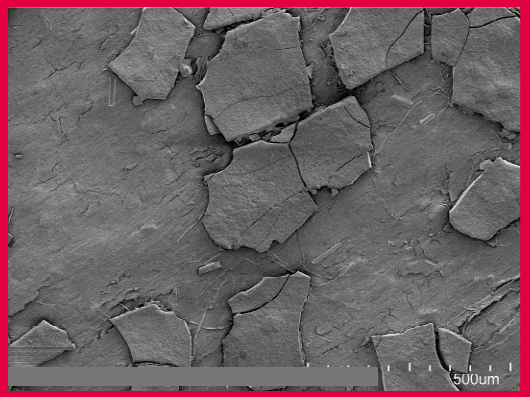


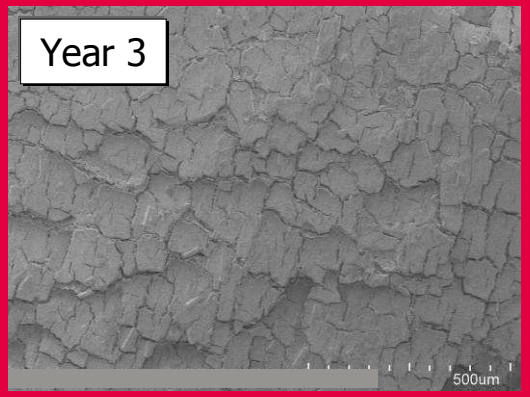


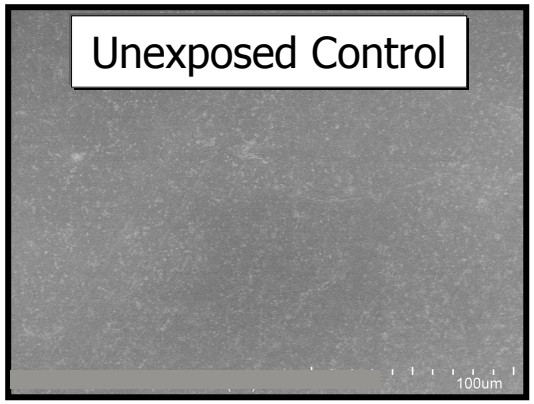


SEM Images of Non-Fluoropolymer Backsheet, Type 1

Florida Exposure







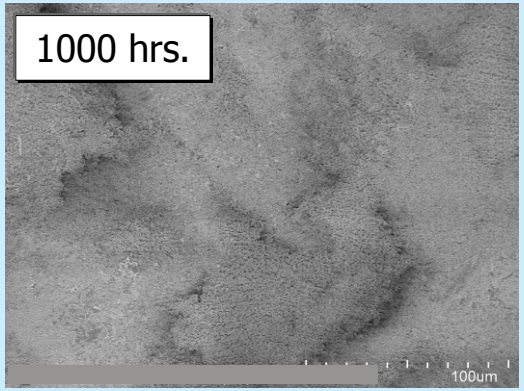
Florida Exposure:

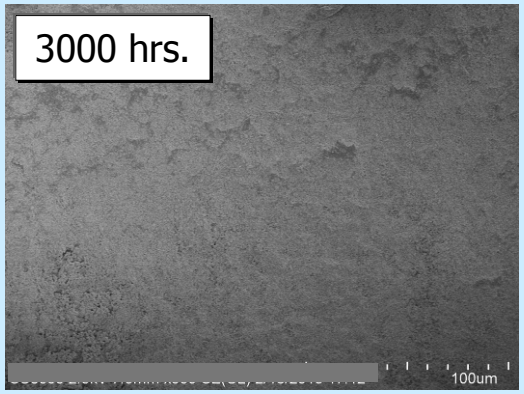
- Year 1, top layer of backsheet is cracking.
- Year 2, outer layer of backsheet is falling off and middle layer is beginning to crack.
- Year 3, middle layer is cracking.

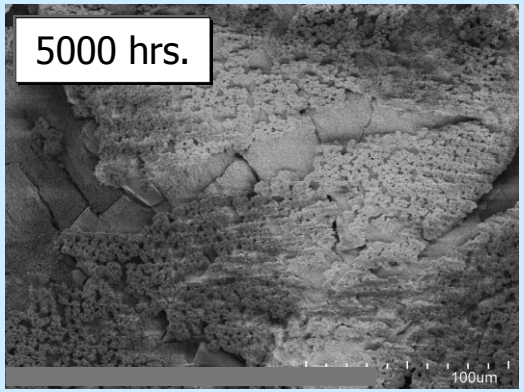
QUV A Exposure:

- 1000 hrs, polymer matrix is degrading leaving pigment particles on the surface.
- 3000 hrs, pigment particles cover the surface.
- 5000 hrs, some of the pigment particles have fallen off the surface revealing that the backsheet is cracking.

QUV A Exposure

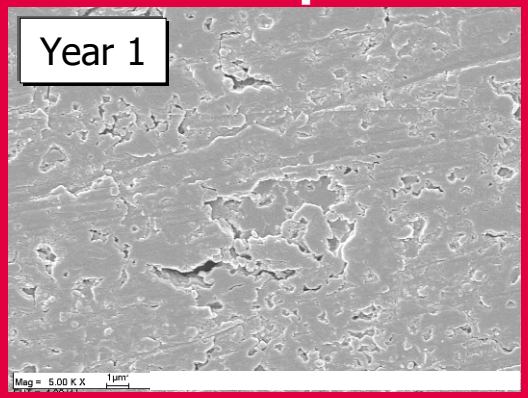


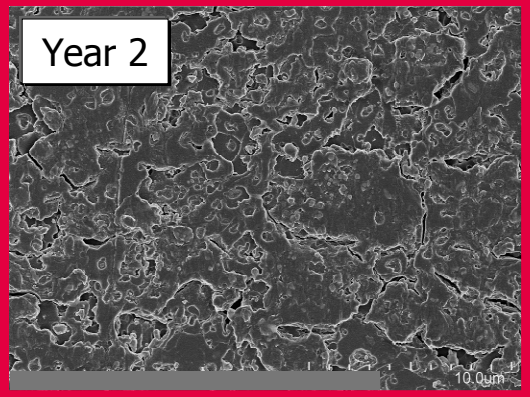


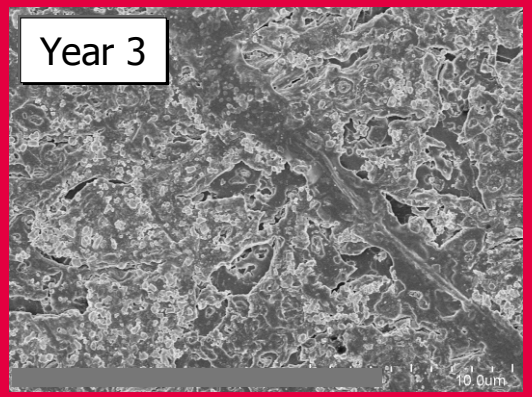


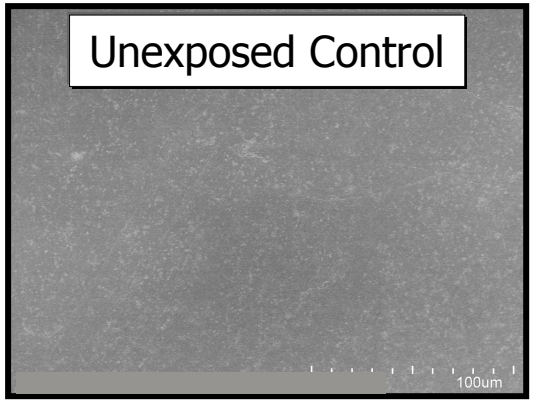
SEM Images of Non-Fluoropolymer Backsheet, Type 2

Florida Exposure









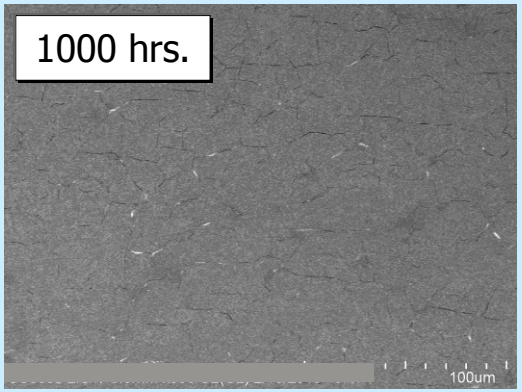
Florida Exposure:

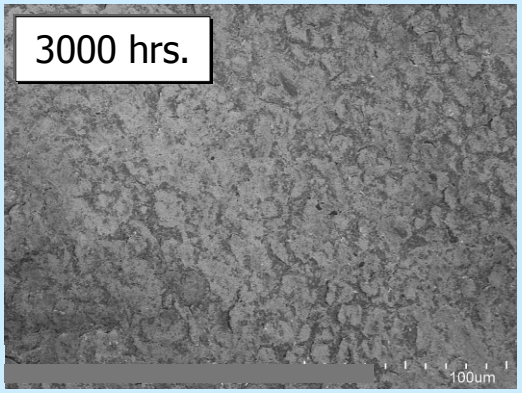
- Year 1, small cracks are appearing and polymer matrix is degrading.
- Year 2, more cracks are forming as the backsheet continues to degrade.
- Year 3, degradation of the polymer matrix is continuing.

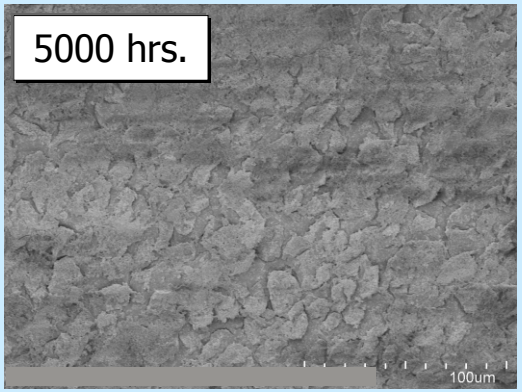
QUV A Exposure:

- 1000 hrs, backsheet is beginning to crack; polymer matrix is degrading.
- 3000 hrs, polymer degradation has progressed - pigment particles cover the surface.
- 5000 hrs, pigment particles have fallen off the surface revealing that the backsheet is cracking.

QUV A Exposure

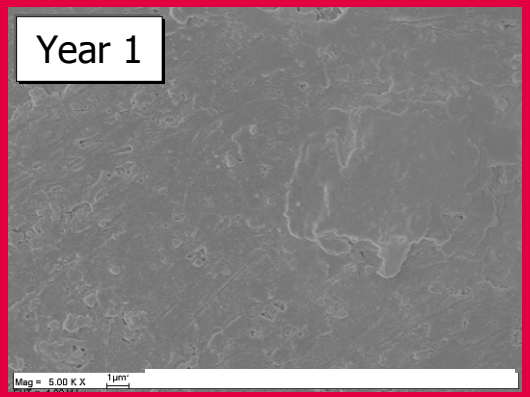


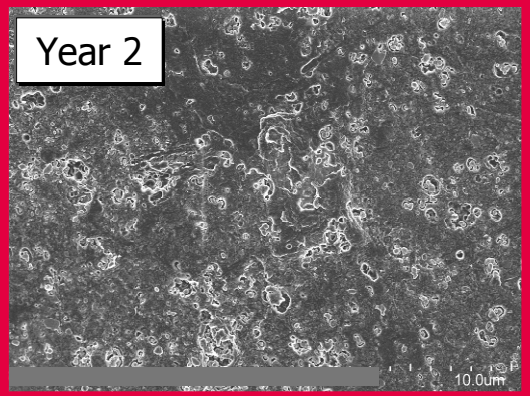


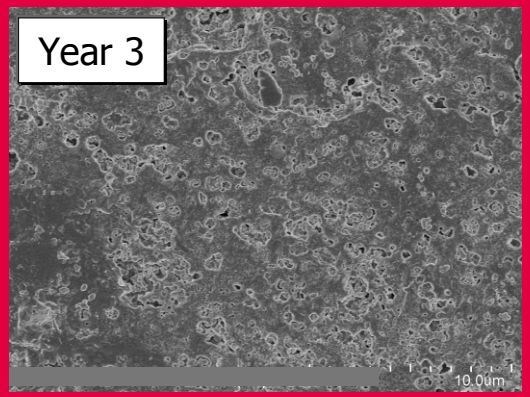


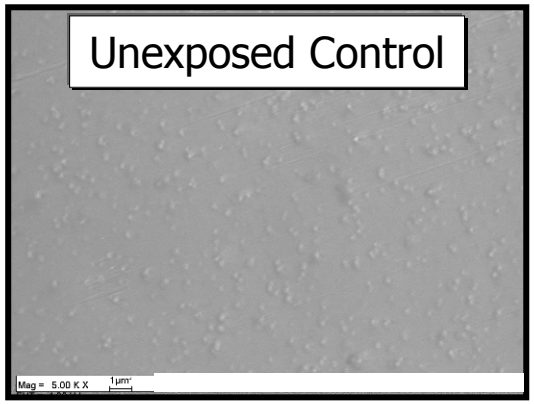
SEM Images of Other Fluoropolymer Film Backsheet, Type 1

Florida Exposure

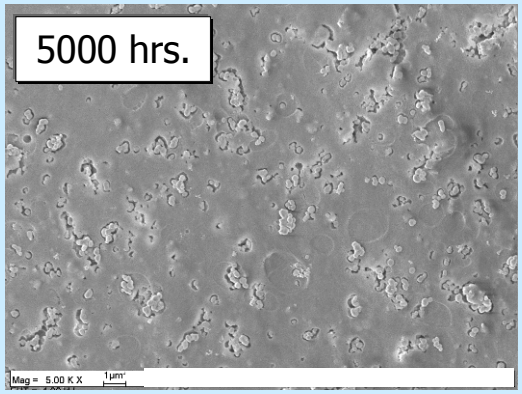








QUV A Exposure



Florida Exposure:

- Year 1, little to no degradation is occurring.
- Year 2, degradation of the polymer matrix is starting around the pigment particles.
- Year 3, degradation is continuing.

QUV A Exposure:

- 5000 hrs, polymer matrix is beginning to degrade around the pigment particles.

Conclusions

- **Gloss retention in Florida exposure correlates well with gloss retention in accelerated QUV A testing.**
- **Similar backsheet degradation mechanisms (cracking and polymer degradation) are observed in Florida and QUV A exposures.**
- **Kynar® film protected backsheets show no signs of polymer degradation or cracking after 3 years of Florida exposure.**
- **Short term Florida and QUVA exposures show significant degradation of Non-Fluoropolymer based backsheets.**
  - Non-Fluoropolymer, Type 1 backsheet shows cracking after only 1 year FL exposure. After 3 years, cracking has progressed into the middle layer.
  - Accelerated QUV A testing of Non-Fluoropolymer, Type 1 shows cracks only after long exposure, but maybe masked by pigment accumulation.
  - Non-Fluoropolymer, Type 2 backsheet shows microcracks and surface erosion in only 1 year of FL exposure. After 3 years, surface erosion is becoming more significant.
  - Accelerated QUVA testing of Non-Fluoropolymer, Type 2 shows larger cracks vs. Florida exposure after 1000 hrs.
  - Both Non-Fluoropolymer backsheets show rapid gloss loss.
- **Other Fluoropolymer Film based backsheets lose gloss with Florida and QUV A exposure.**
  - After 2 years of Florida exposure, the polymer matrix of Other Fluoropolymer, Type 1 backsheet is starting to degrade.

KYNAR® BY ARKEMA

Accelerated Weathering Test Improvements

- **Better UV Exposure test (than IEC) is needed to test products for durability over 25+ year product lifetime**
  - 5000 hrs QUV A at 1.55 Irrad. approximately equals 25 years in FL at 15% of direct irradiance.
- **Differences between weathering study exposures and use in PV modules**
  - In PV modules, backsheets have more thermal cycle/shock and mechanical stress because of laminated structure and heat build.
  - QUV has no thermal cycle/shock.
  - Florida backsheet exposure lacks applied stress.
- **Concern:**
  - Current backsheet study shows crack development in both Florida and QUV A exposures.
  - Lack of thermal cycle and mechanical stress limits the ability to test propensity for crack propagation.
- **Proposal for Improvement in Accelerated Testing**
  - Add thermal shock/cycle to testing protocol by using multiple water spray – light cycles.
    - Goal is to add many thermal cycles and stress to accelerate this phenomena.

KYNAR® BY ARKEMA