NIST
Polymeric Materials Group
Engineering Laboratory

Accelerated Laboratory Tests Using Simultaneous UV, Temperature and Moisture for PV Encapsulants, Frontsheets and Backsheets

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INTRODUCTION

The use of simultaneous multiple stresses (temperature, moisture, UV radiation) for the accelerated laboratory testing is critical to the development of reliable laboratory test methods that correlate to field test.

In this study, the NIST SPHERE *(Simulated Photodegradation via High Energy Radiant Exposure)* was used for accelerated laboratory testing of PV encapsulants, including ethylene vinyl acetate (EVA), fronsheet fluoropolymers, and polyvinyl fluoride /polyester/EVA (PVF/PET/EVA) backsheet materials. The outdoor exposure was also carried out in Gaithersburg, Maryland. Multiscale chemical, optical, mechanical and morphological measurements were performed to follow changes during accelerated laboratory and outdoor exposures. The degradation mechanism and failure mode of PV materials and components were studied.

Linking Laboratory and Outdoor Exposures

Reliability-based Methodology

Accelerated Laboratory Exposure (to study effects of simutaneous UV, temperature and moisture on degradation mechanism of PV materials/modules)

Outdoor Exposure (with monitored weather parameters)

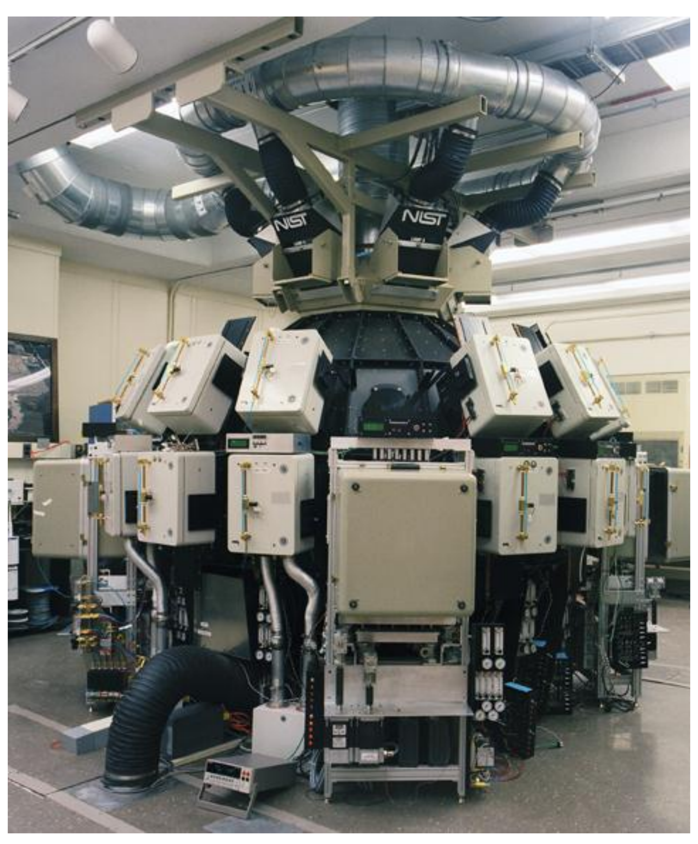
Cumulative Damage Prediction Model

Failure Mode Analysis

➢ To develop reliable accelerated laboratory test methods that correlate to field test.

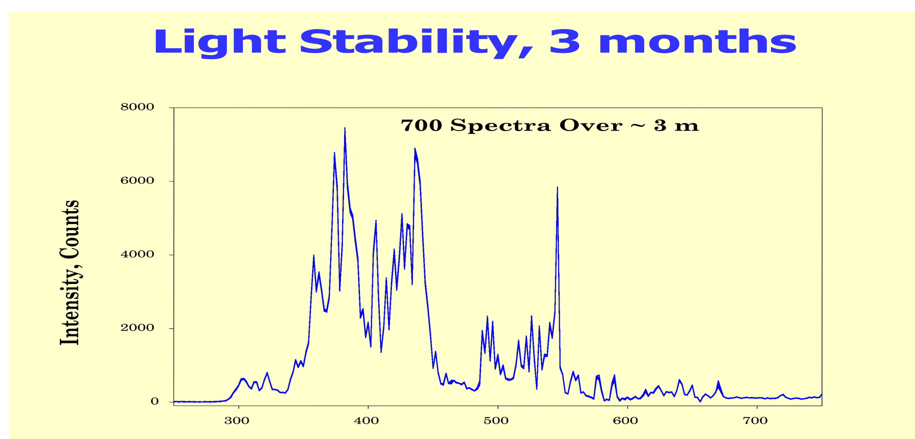
ACCELERATED LABORATORY EXPOSURE DEVICE

NIST Integrating Sphere-based UV Chamber



NIST-Patented 2-meter SPHERE

(*S*imulated *P*hotodegradation via *H*igh *E*nergy *R*adiant *E*xposure)



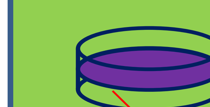
- High UV Radiant Exposure (8400 W UV)
- 95% exposure uniformity
- Visible and infrared radiation mostly removed
- Temperature and relative humidity around specimens precisely controlled (25-75°C; 0-95% RH)
- Capability for mechanical and electrical loadings
- Exposure conditions of 32 chambers can be individually controlled (UV, RH,T)

• Chin et al, Review of Scientific Instruments (2004), 75, 4951; Martin and Chin, U.S. Patent 6626053

EXPERIMENTAL

Materials

(A) EVA



CaF_2 Substrate *(for FTIR , UV-visible and AFM)*

(B) Frontsheet * fluoropolymers

(C) PVF/PET/EVA backsheets

SPHERE Exposure

UV/T/RH, individually or in combination, under

- UV Irridiance *(200 W/m², 295-480 nm)*
- Different Temperatures *(25-85℃)*
- Different RHs *(0-75%)*

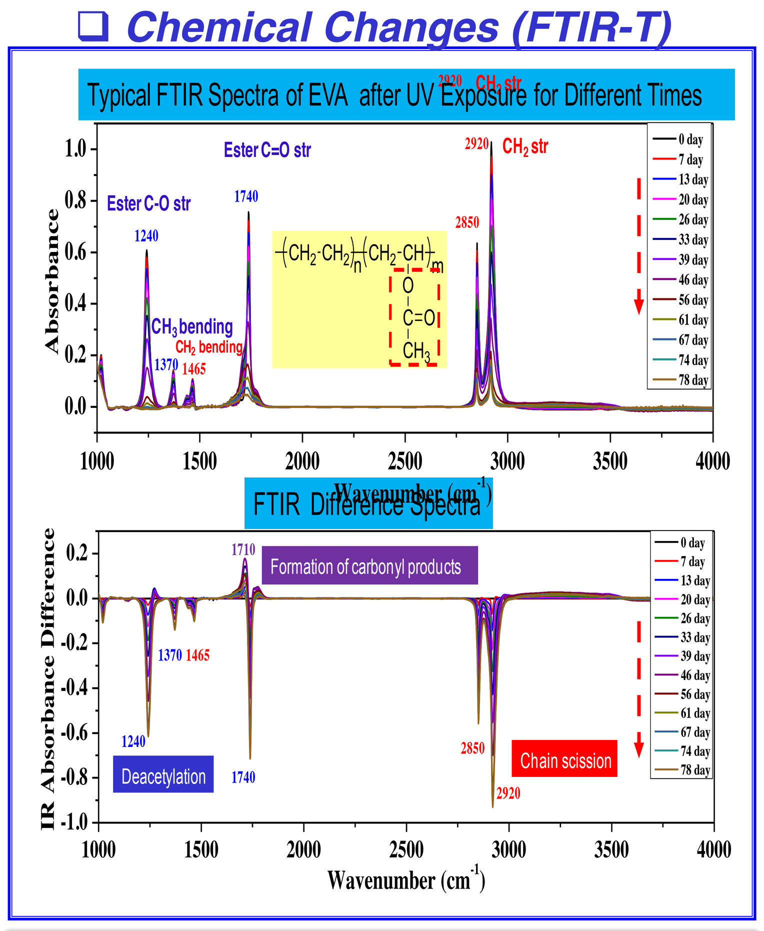
Outdoor Exposure

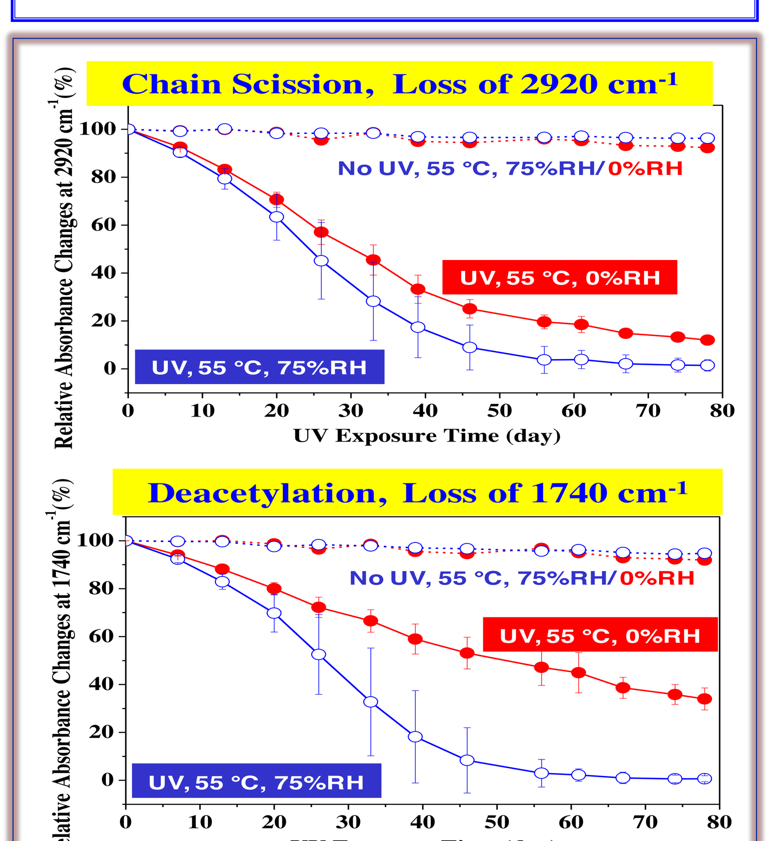
Gaithersburg, MD

RESULTS FROM LABORATORY EXPOSURE

Effect of Simultaneous UV/T/RH on Degradation of EVA

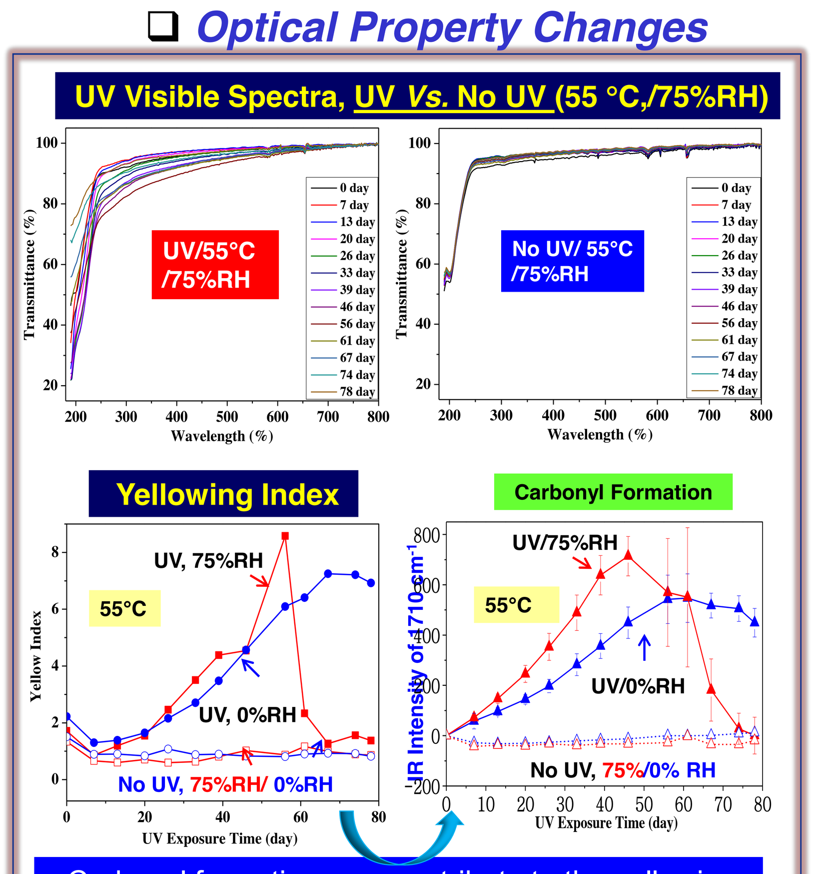
❑ *Chemical Changes (FTIR-T)*





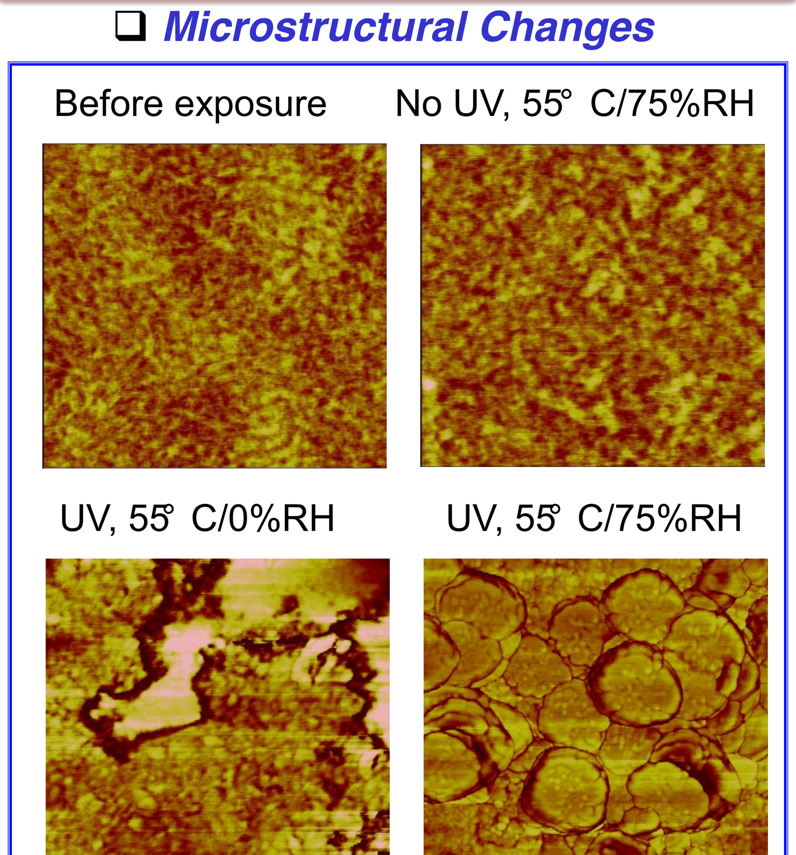
- Both UV and RH are important factors.
- Synergistic effect between UV and RH.

❑ *Optical Property Changes*



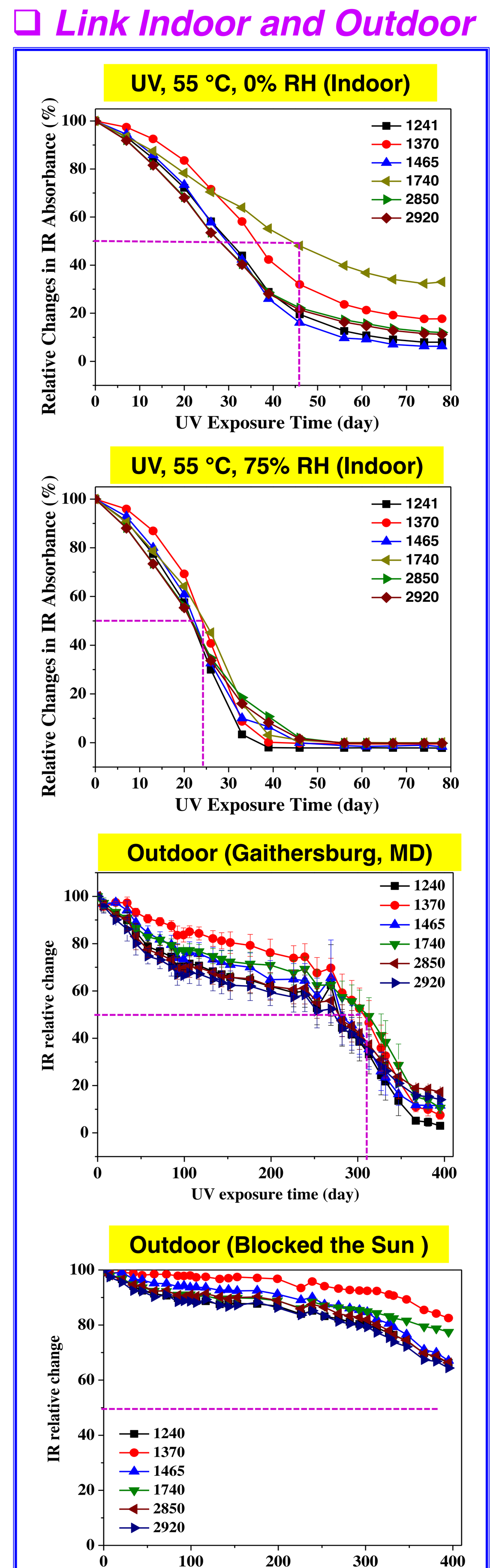
- Carbonyl formation may contribute to the yellowing.

❑ *Microstructural Changes*



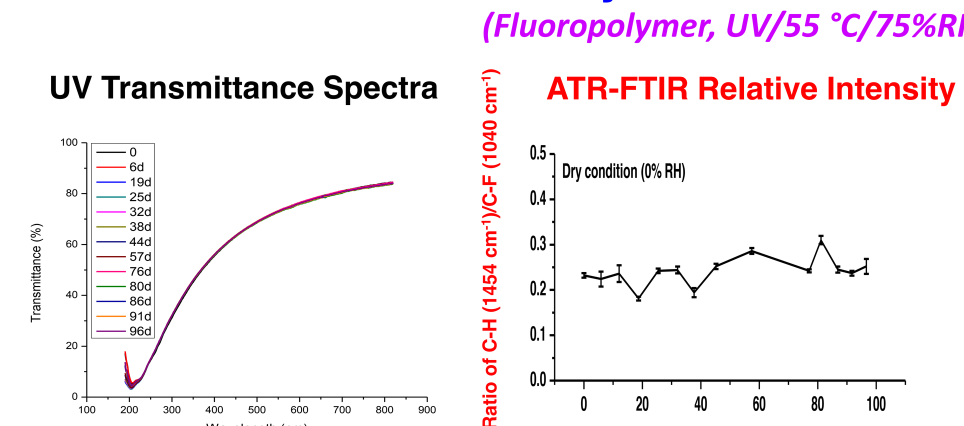
•78 days exposure **1 μm × 1 μm**

❑ *Link Indoor and Outdoor*



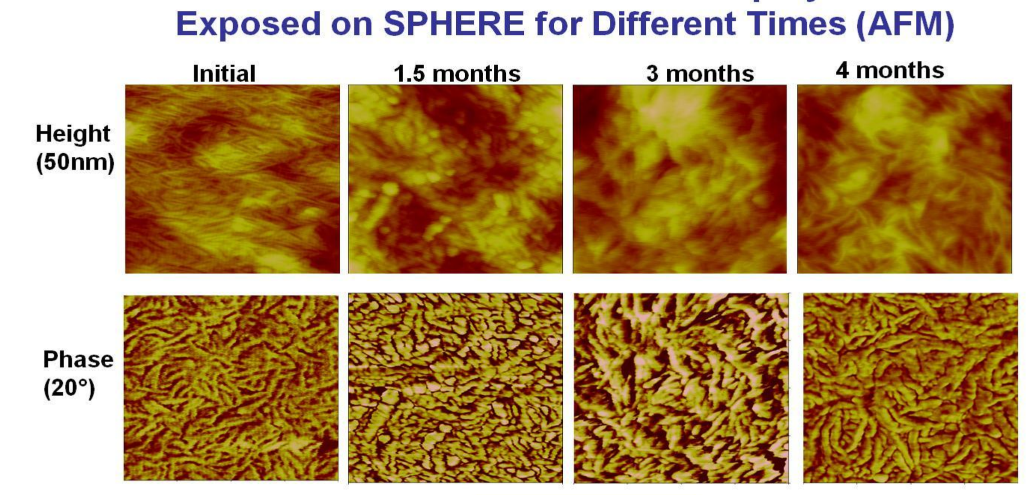
Photostability of Frontsheet Materials

(Fluoropolymer, UV/55 °C/75%RH)



➢ Little chemical, optical or morphological changes were observed for frontsheet fluoropolymers.

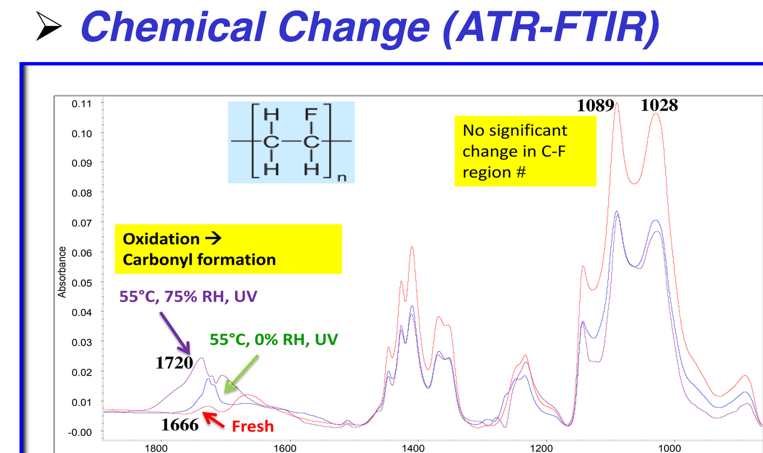
Surface Nanostructures of A Fluoropolymer Film Exposed on SPHERE for Different Times (AFM)



1 μm x 1 μm

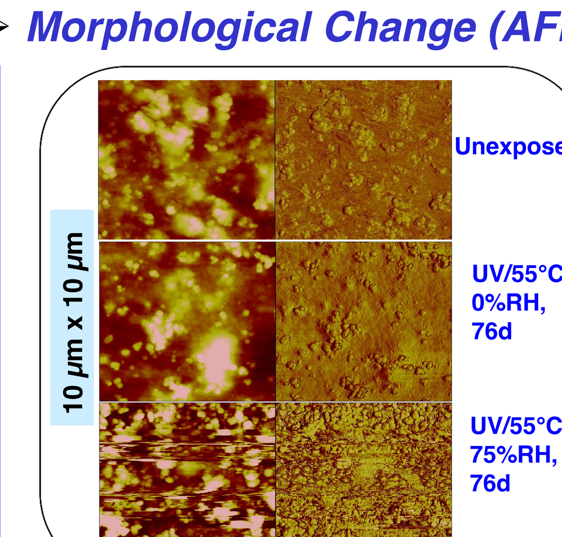
Simultaneous UV/T/RH on PVF/PET/EVA Backsheets

➢ *Chemical Change (ATR-FTIR)*

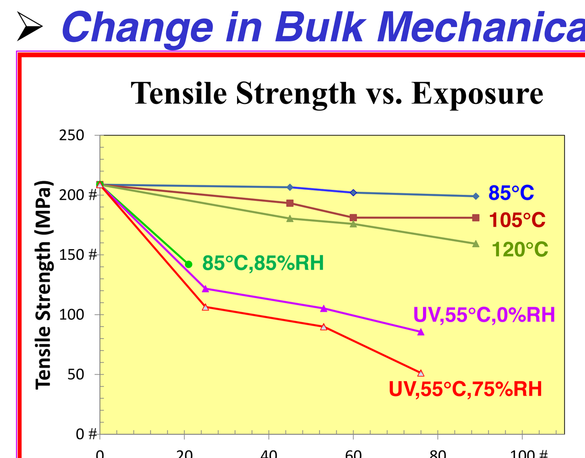


- Chemical and morphological changes are more severe with combination of UV, T and humidity.

➢ *Morphological Change (AFM)*

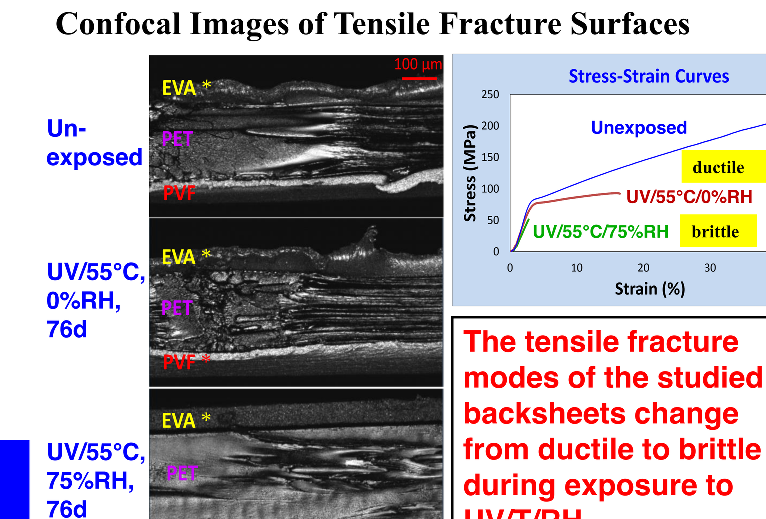


➢ *Change in Bulk Mechanical Property and Fracture Mode*



- Simultaneous UV/T/RH exposure results in greatest loss of tensile strength for backsheet materials.

Confocal Images of Tensile Fracture Surfaces



The tensile fracture modes of the studied backsheets change from ductile to brittle during exposure to UV/T/RH.

SUMMARY

➢ UV radiation was the most important factor for degradation of all studied materials. A RH/UV synergistic effect was observed for EVA and backsheet materials.

➢ A fundamental understanding of degradation mechanism under simultaneous multiple stresses is important to develop reliable standardized accelerated tests for PV materials.