Cross-sectional Characterizations of PV Backsheets and Non-Destructive Tests of PV Modules

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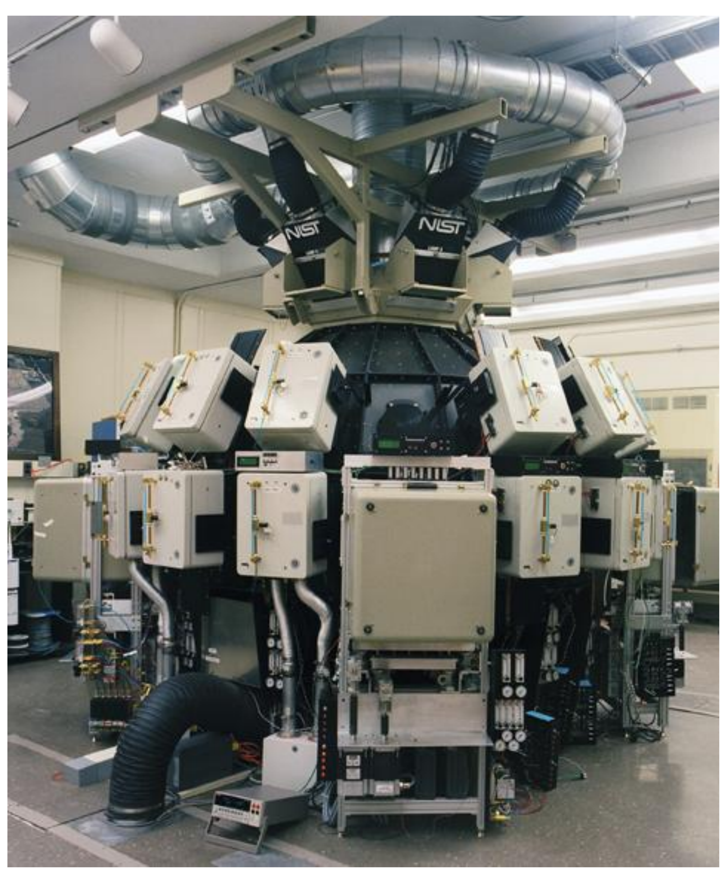
INTRODUCTION

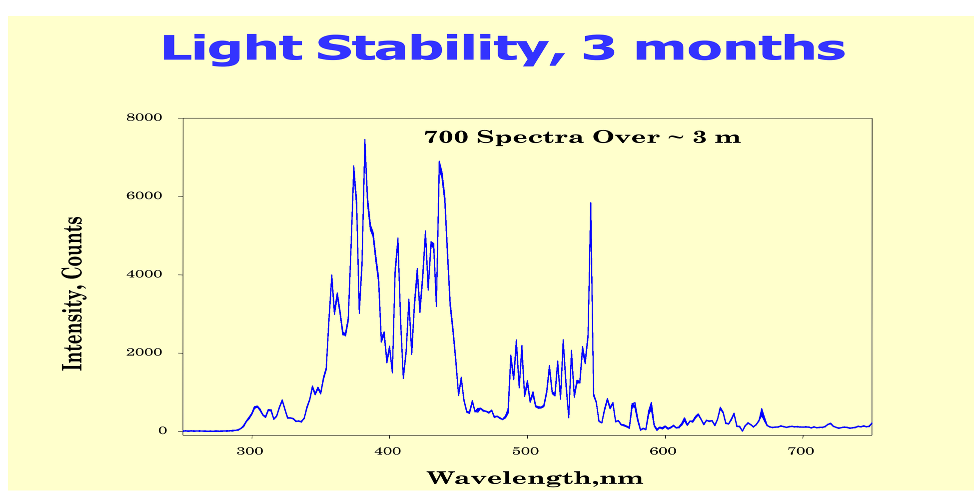
Cross-sectional characterization is a unique technique to provide structural and property changes of multilayered backsheets during exposure to their service environments. Non-destructive chemical imaging of PV modules also enable a better understanding of the changes of material properties during exposure. In this study, the chemical and mechanical cross-sectional characterizations of the aged and unaged polyvinyl fluoride/polyester/EVA (PVF/PET/EVA) backsheets were carried out using Raman microscopy and laser scanning confocal microscope. The NIST SPHERE was used for the accelerated exposure of the PV backsheet materials. For non-destructive chemical mapping of a PV mini-module, the Raman confocal microscopy was used.

ACCELERATED LABORATORY EXPOSURE DEVICE

NIST Integrating Sphere-based UV Chamber



NIST-Patented 2-meter SPHERE



- High UV radiant exposure (8400 W UV)
- 95% exposure uniformity
- Visible and infrared radiation mostly removed
- Temperature and relative humidity around specimens precisely controlled (25-85 °C; 0-95% RH)
- Capability for mechanical and electrical loadings
- Exposure conditions of 32 chambers can be individually controlled (UV, RH,T)

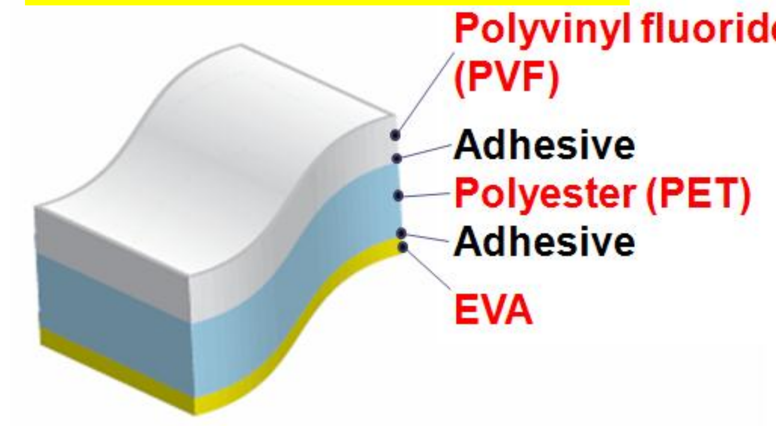
• *Chin et al, Review of Scientific Instruments (2004), 75, 4951; Martin and Chin, U.S. Patent 6626053*

OBJECTIVE

To develop test methods for PV backsheet cross-sectional characterization and non-destructive test of PV module encapsulant.

EXPERIMENTAL

PVF/PET/EVA Backsheet

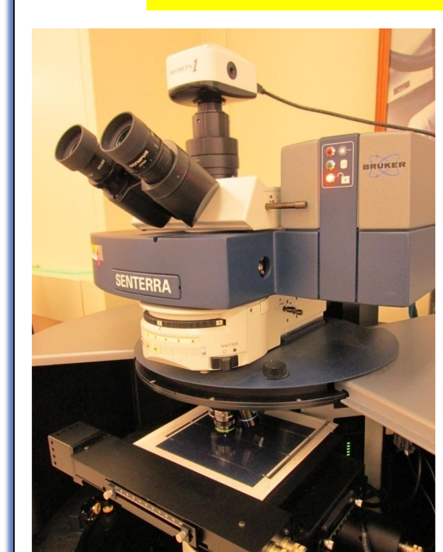


SPHERE Exposure

UV/T/RH in combination:

- UV Irradiance *(200 W/m², 295-480 nm)*
- Temperature = *55 ℃*
- Different RHs *(0% and 75%)*
- Different sides of backsheet *(PVF side or EVA side)*

Raman Microscope

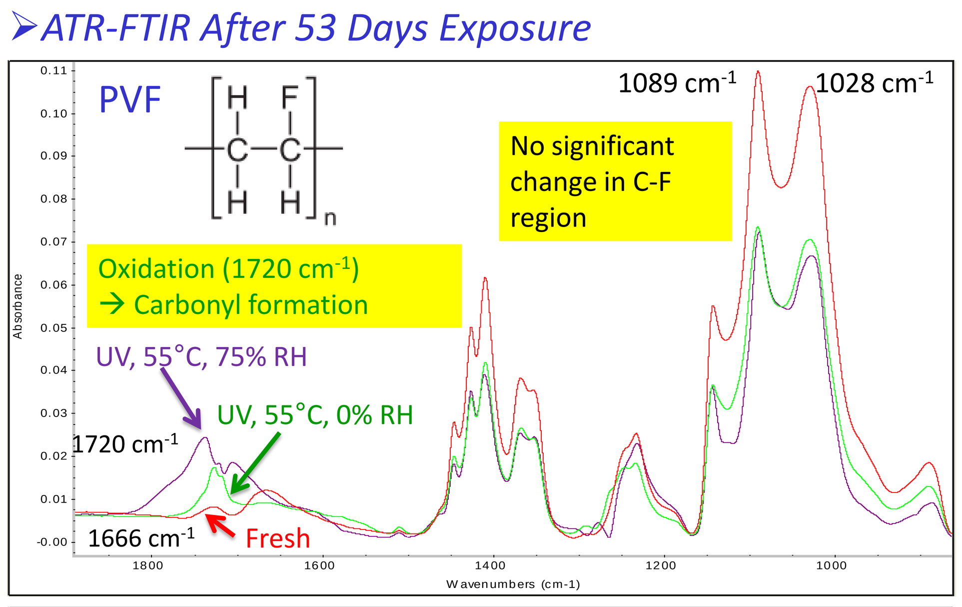


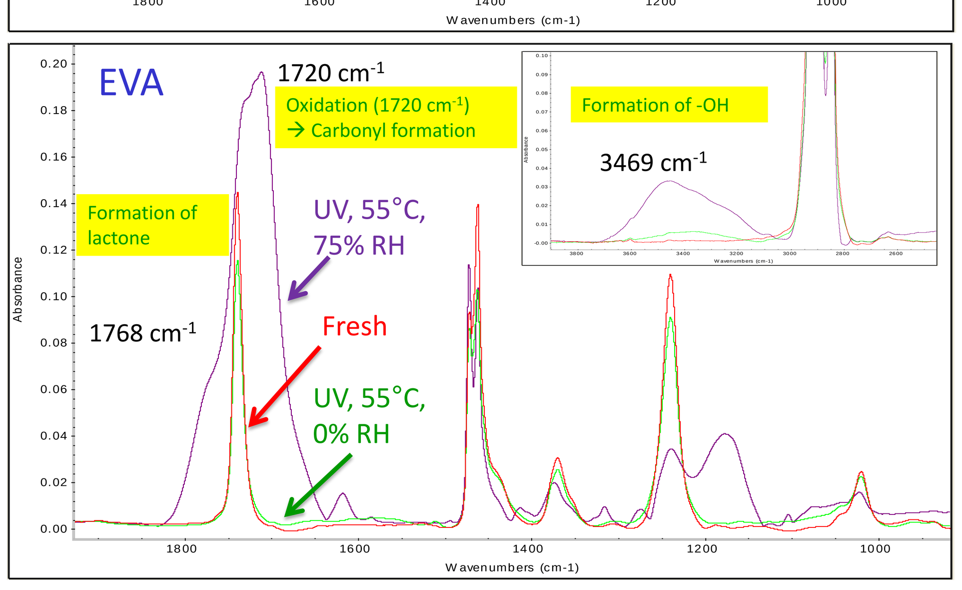
- Instrument: Senterra, Bruker
- Laser λ: 532 nm and 785 nm
- Maximum power: 100 mW
- Objective lens: 20X, 50X, 100X (with near field 50X and 100X)
- Aperture: slit and pinhole
- Z-mapping function equipped for 3D mapping

Microtome

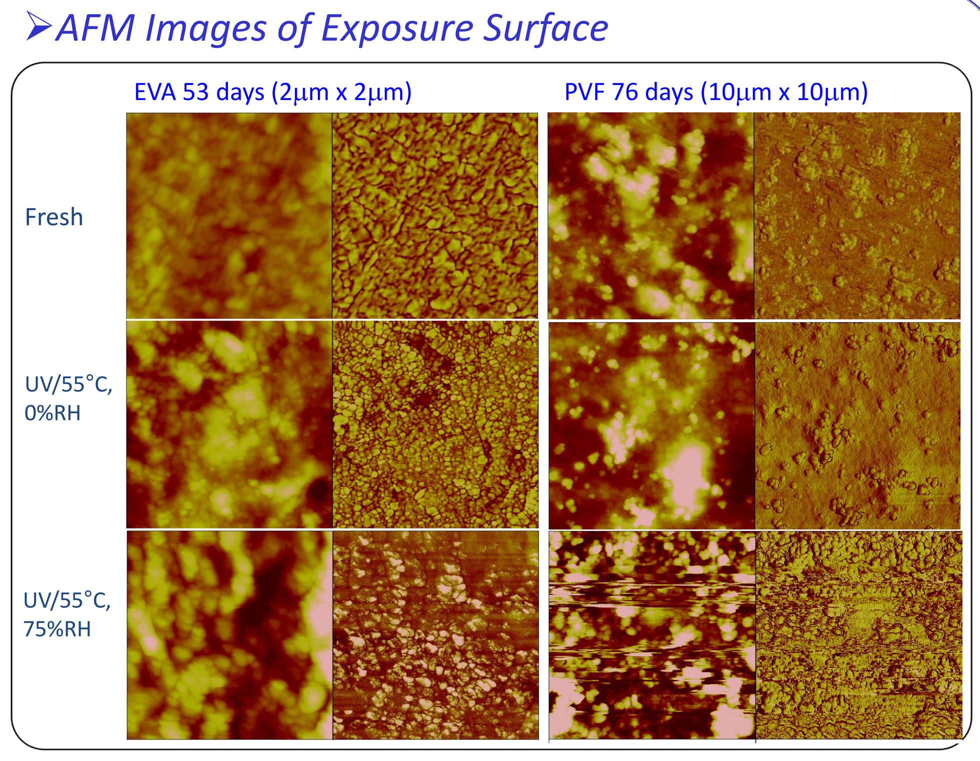
RESULTS OF BACKSHEET CHARACTERIZATION

➢ATR-FTIR After 53 Days Exposure



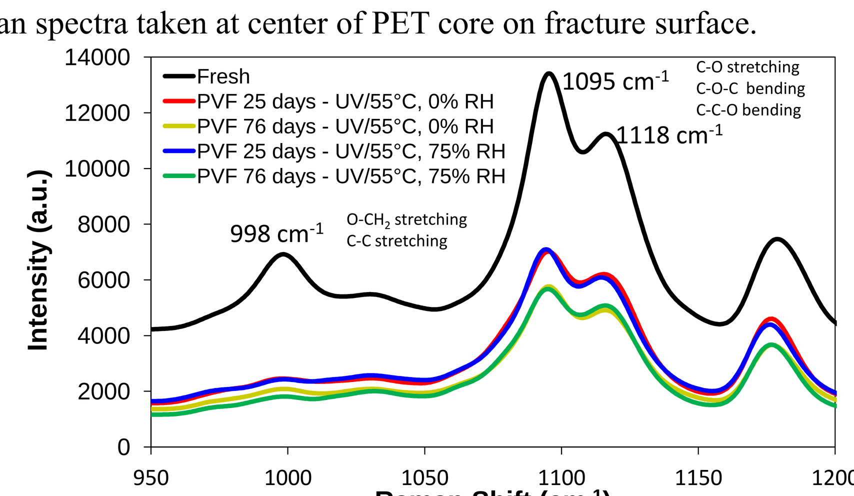


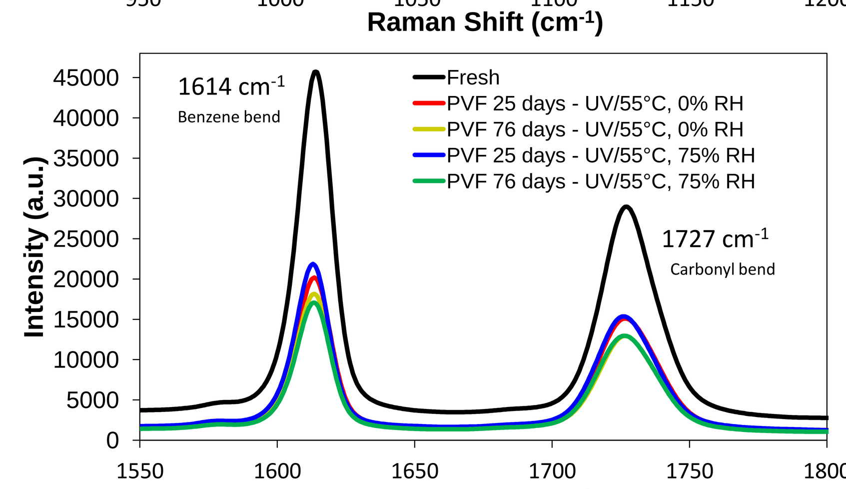
➢AFM Images of Exposure Surface



➢ Raman Cross-sectional Characterization

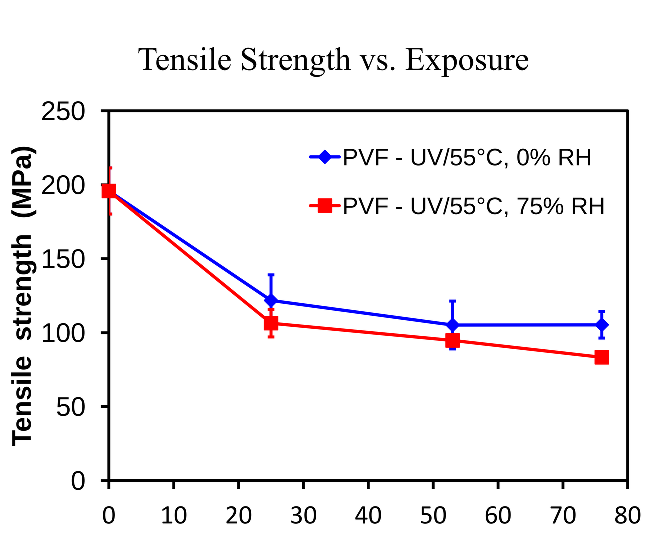
Raman spectra taken at center of PET core on fracture surface.





Raman results show crystallinity change of PET core after exposure.

➢ Change in Bulk Mechanical Property

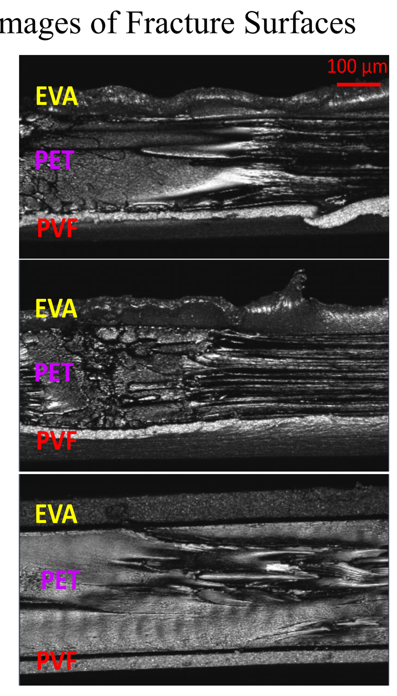


Confocal Images of Fracture Surfaces

Fresh

PVF UV/55°C, 0% RH, 76 days

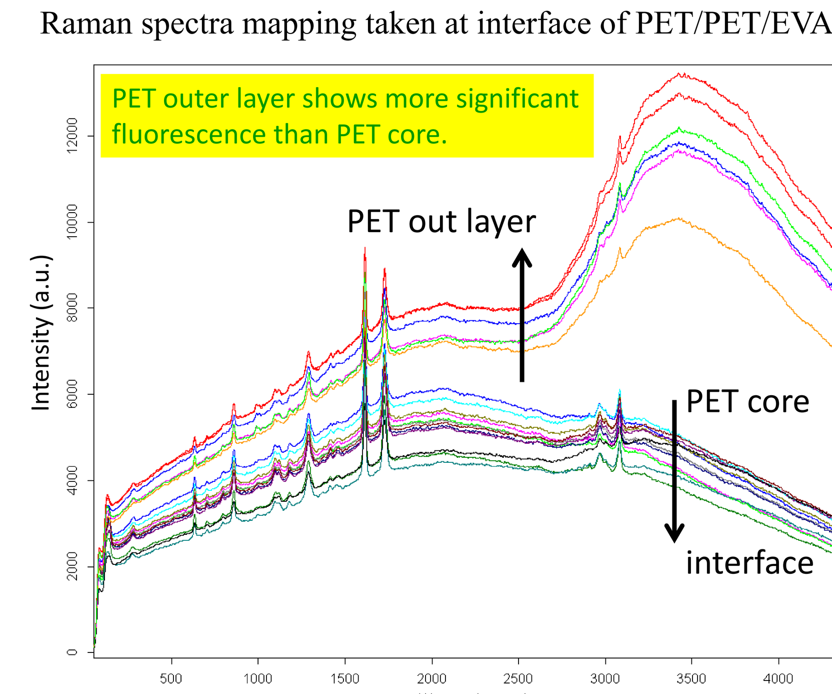
PVF UV/55°C, 75% RH, 76 days

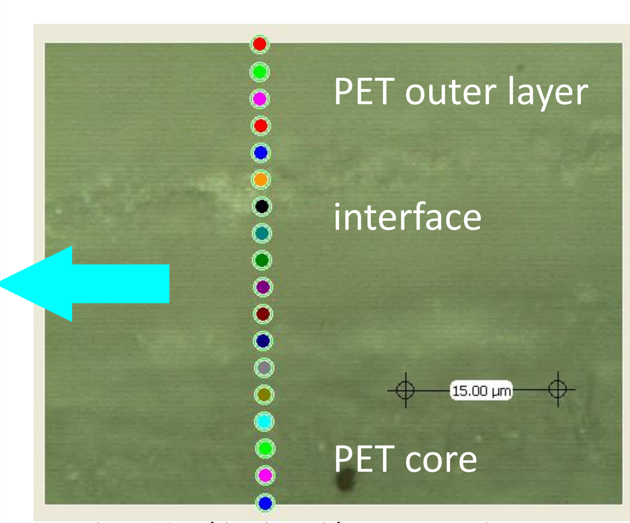


CROSS-SECTIONAL MAPPING OF BACKSHEET AND NON-DESTRUCTIVE MINI-MODULE TEST

➢Chemical Mapping of Backsheet Cross-section

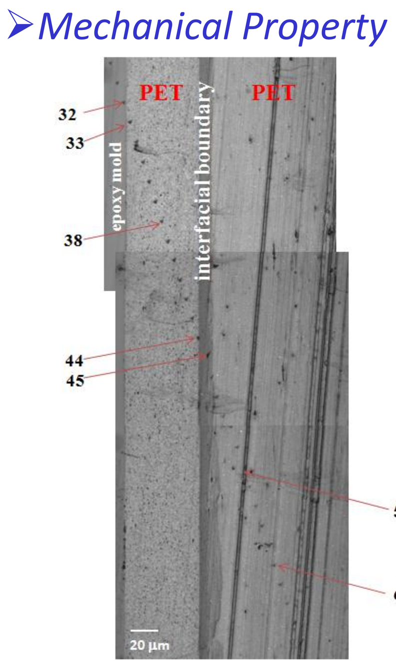
Raman spectra mapping taken at interface of PET/PET/EVA backsheet cross-sectional surface.





• using 100X objective with 1 µm spot size

➢Mechanical Property Mapping of Backsheet Cross-section

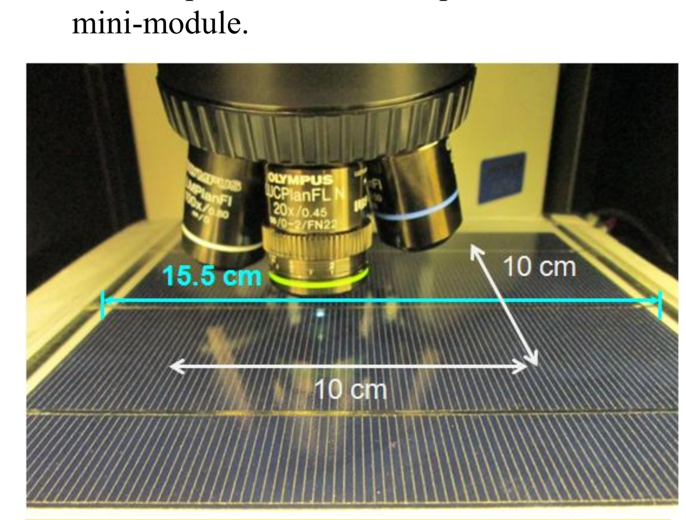


Calculation depth: 300 nm - 500 nm

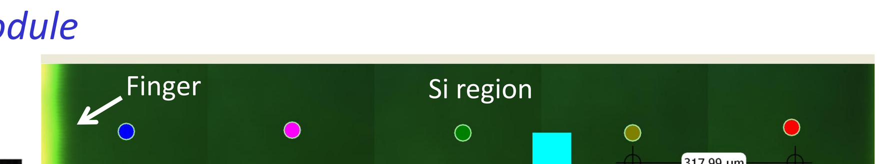
Indent #	Modulus (GPa)	Hardness (GPa)
32	4.3 ± 5.1x10^{-2}	0.21 ± 6.7x10^{-3}
33	3.8 ± 5.7x10^{-2}	0.19 ± 3.4x10^{-3}
38	4.4 ± 1.0x10^{-1}	0.24 ± 1.3x10^{-2}
44	4.6 ± 1.9x10^{-1}	0.35 ± 1.8x10^{-2}
45	4.5 ± 1.0x10^{-1}	0.29 ± 4.6x10^{-3}
51	4.7 ± 5.0x10^{-2}	0.31 ± 5.0x10^{-3}
65	5.0 ± 1.4x10^{-1}	0.35 ± 1.1x10^{-2}

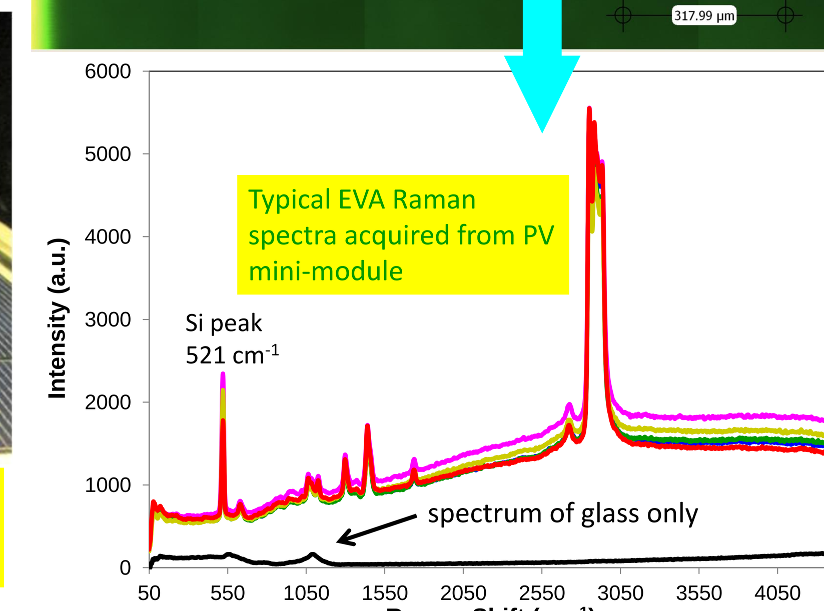
➢Non-destructive test of PV Mini-module

Raman spectra of EVA encapsulant in PV mini-module.



Raman microscope in combination with a computer-controlled x/y sample stage (x-y limit of 10 cm x 10 cm)





SUMMARY

- ➢ By means of cross-sectional characterization using Raman microscopy and microtomy, a complete study on PV backsheet materials is reachable.
- ➢ Non-destructive test method of Raman mapping provides an excellent solution for encapsulant degradation monitoring in PV module.

FUTURE WORK

- ➢ More systematic study on representative types of backsheet materials is required to understand how backsheet materials fail to protect PV encapsulant and PV module.
- ➢ To establish accelerated laboratory testing of PV mini-module and perform non-destructive test following exposure time are the next step of our investigation.