

DuraMAT Fielded Module Study

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PVRW 2021

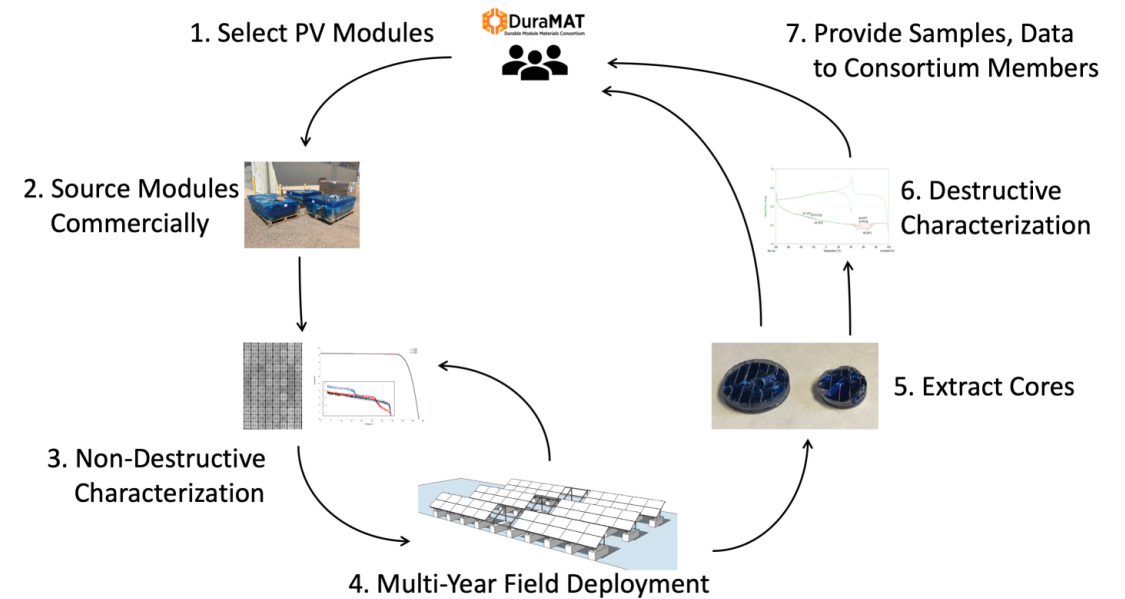


Project Overview

Characterize material degradation from natural aging in commercially relevant PV modules.

- Acquire commercially available PV modules from independent vendors
- Deploy alongside existing operational systems for extended timeframe (upwards of 10 years)
- Remove single modules of each type at a fixed interval for destructive characterization to track changes in packaging materials
- Utilize breadth of modules to develop and validate new field forensics methods

Manufacturer	Model	Cell Type
Canadian Solar	CS6K-300MS Quintech	Mono-Si
Hanwa Q-Cells	Q.Peak-G4.1 300	Mono-Si
Jinko	JKM270PP-60	Multi-Si
LG	LG320N1K-A5	Mono (N)
Mission Solar	MSE300SQ5T	Mono PERC
Panasonic	VBHN330SA17 HIT	HIT N-type



Status:

- Seven systems are operational
- Original six systems have accumulated two years of exposure
- Year 2 electrical characterization is in process; core extraction planned for March, 2021



Characterization Methods

Traditional non-destructive

- Indoor light IV (flash test)
 - YoY STC parameters
 - Series and shunt resistance
 - Fill-factor
- Outdoor light IV (2-axis tracker)
 - the above, plus
 - Temperature coefficients
 - Diode factor
 - Spectral response
 - Surface reflectivity/AOI
- Electroluminescence
- Infrared thermography (MWIR, LWIR)
- Visual

ND Field Forensics

- FTIR
 - Backsheet identification
- UV Fluorescence
 - Encapsulant degradation
 - Oxidation, diffusion
- Reflection Spectroscopy
 - Backsheet Yellowing
- Gloss
- *Field Raman*
- *Near IR spectroscopy*

Other methods, as available

Laboratory destructive

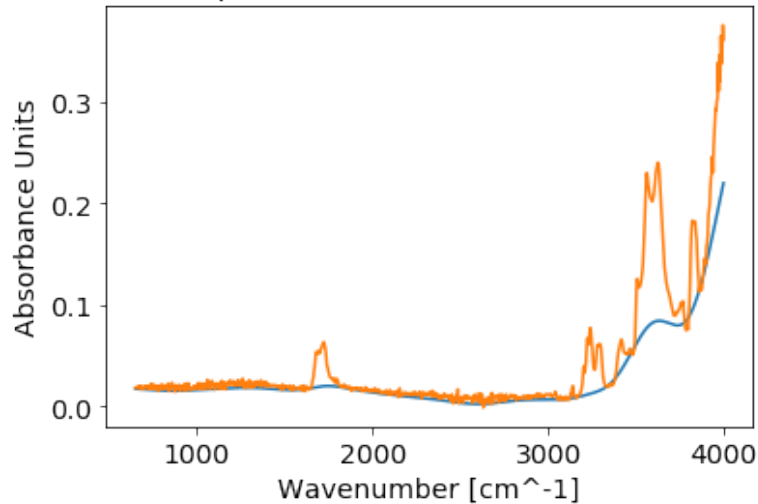
- Raman Spectroscopy
 - Chemical identification
 - Polymeric structure - Degree of cross-linking
- Differential Scanning Calorimetry
 - Endothermic/Exothermic transitions
 - Glass transition temperature
 - Melting and freezing points
 - Heat of fusion
- FTIR
- TGA
- X-ray Fluorescence
- SAXS/WAXS (SLAC)
- Coatings Characterization
- SEM – inorganics, EDS, WDS



FTIR Classification: Baseline Correction and Correlation

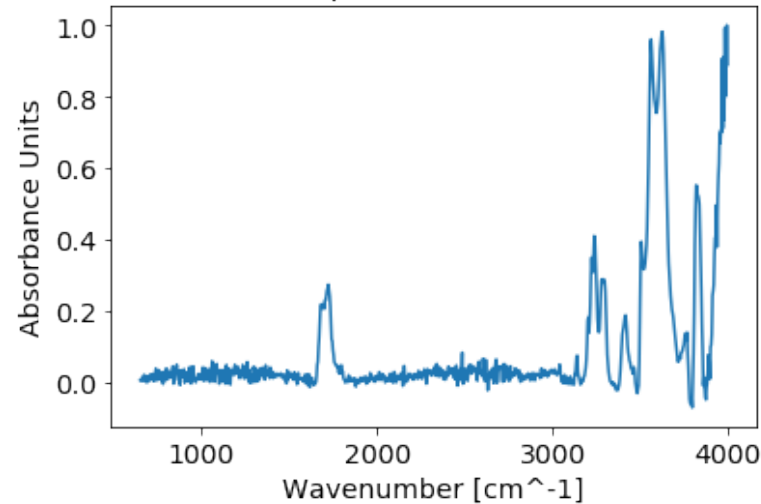
Before Correction

TPT spectrum and baseline correction

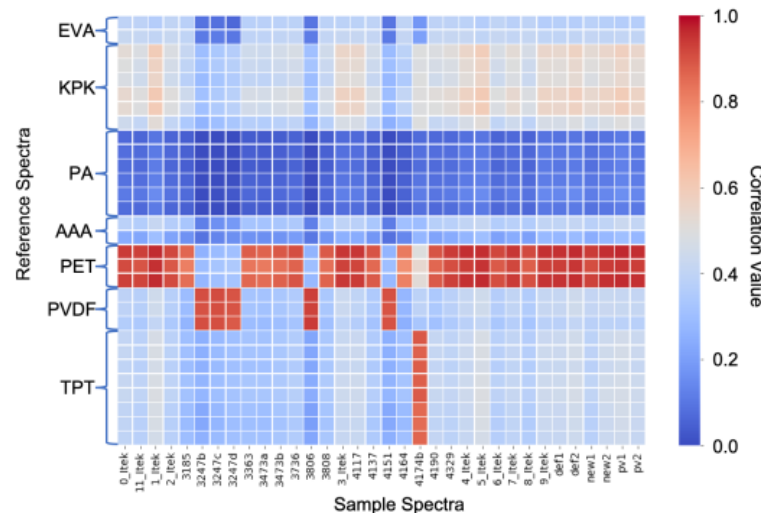
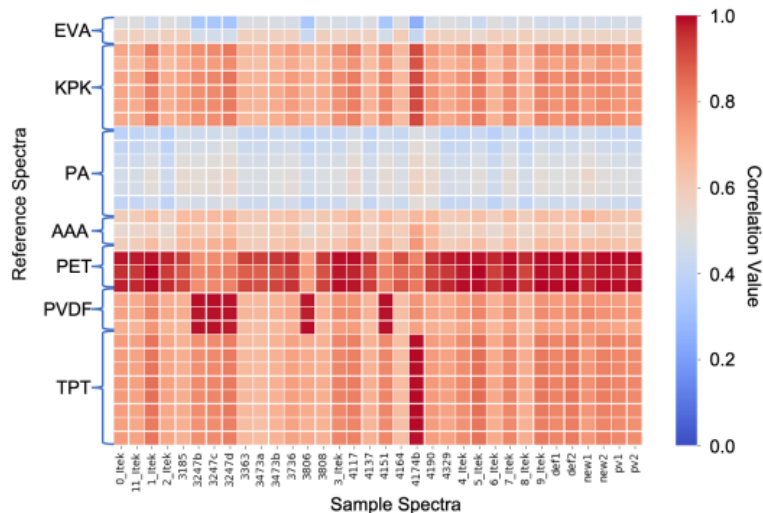


After Correction

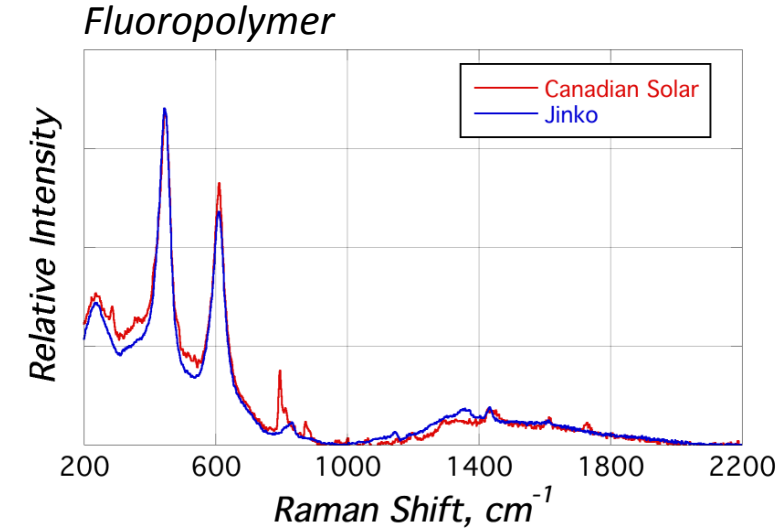
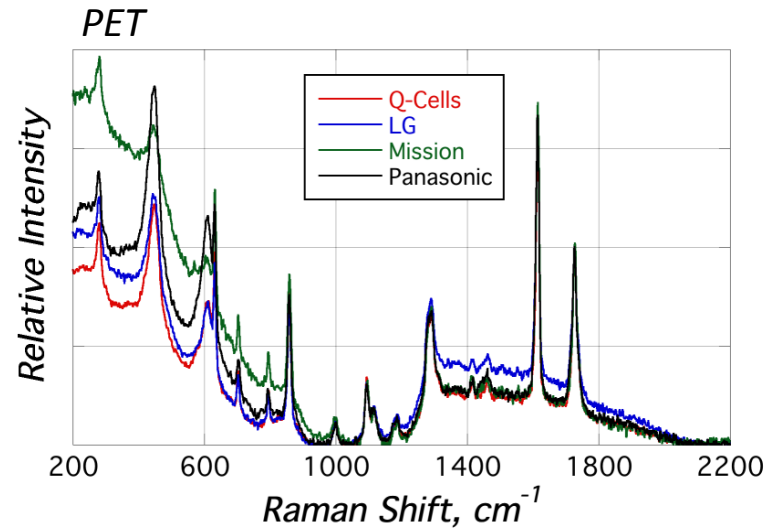
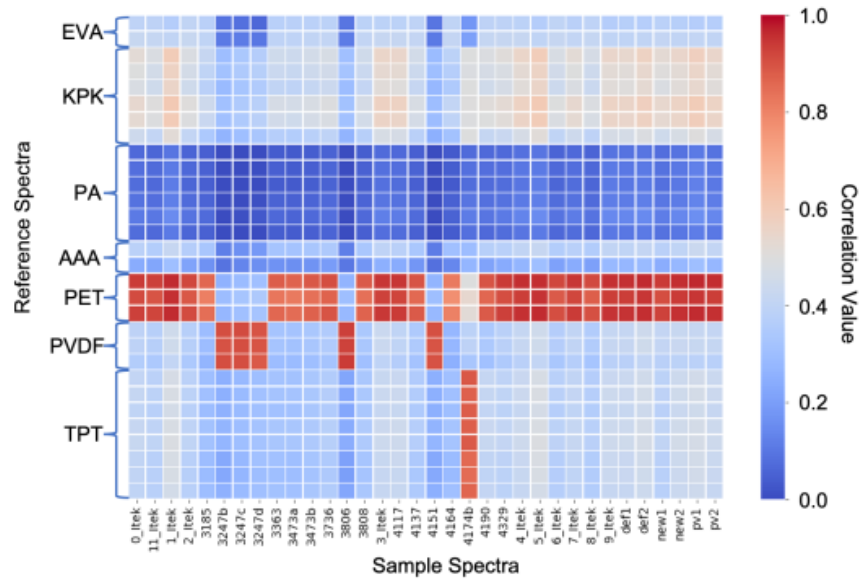
TPT spectrum corrected



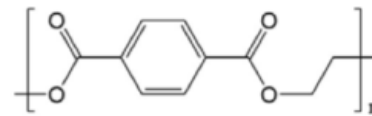
- Some materials are similar in peak location and relative intensity
- Prior method (using PCA and ML) susceptible to mischaracterization
- Baseline correction using asymmetric least squares smoothing to decrease chances of mischaracterization
- Correlation matrix - correlate reference spectra with sample spectra to identify unknowns



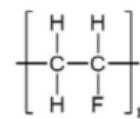
Backsheet Identification – FTIR and Raman



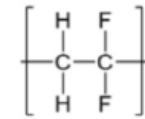
Manufacturer	Model	Backsheet
Canadian Solar	CS6k300MS	PVDF
QCells	Q.Peak-G4.1 300W	PET
Mission Solar	MSE300SQ5T	PET
Panasonic	N325SA16 325W	PET
LG	LG320N1K-A5	PET
Jinko	JKM260P-60	TPT
Itek	SE 350	PET



PET



PVF



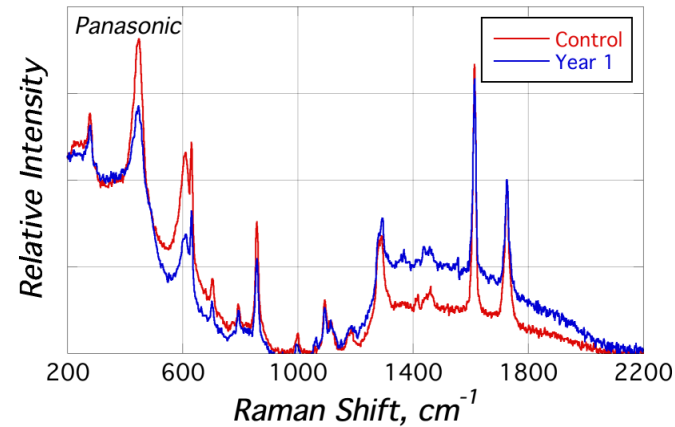
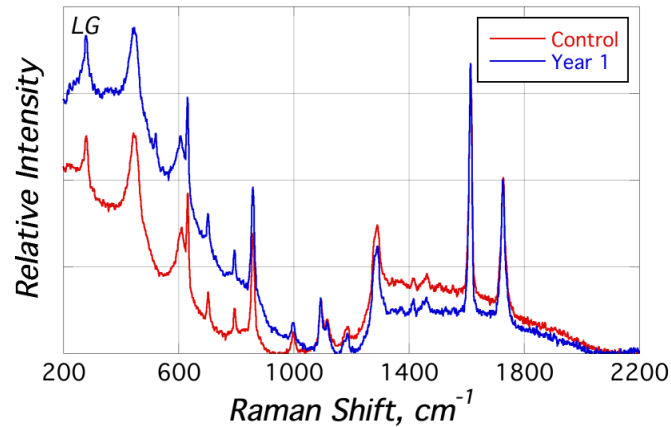
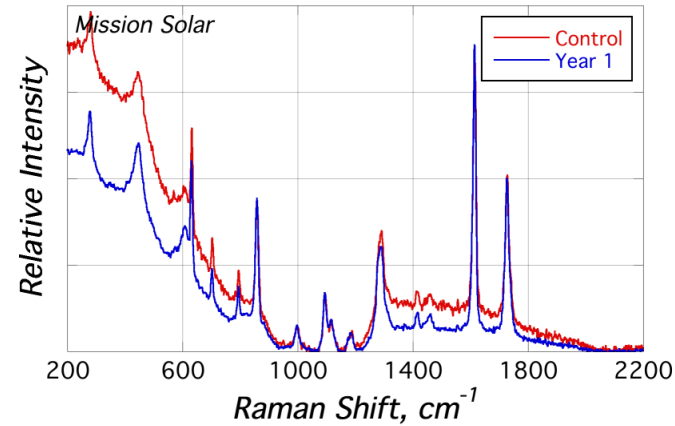
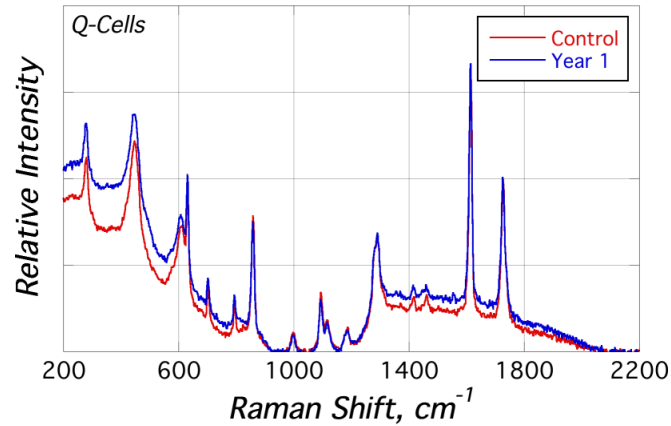
PVDF

- Backsheet outer layers characterized using FTIR and Raman Spectroscopy
- FTIR automated classification against known backsheets
- Raman classification against published peak locations
- Classification consistent between both methods

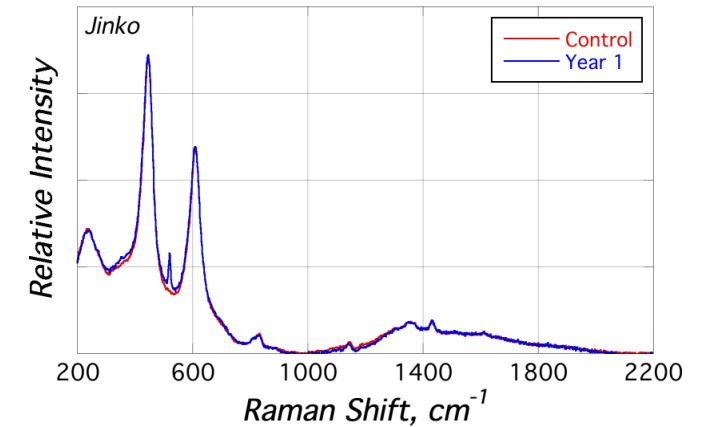
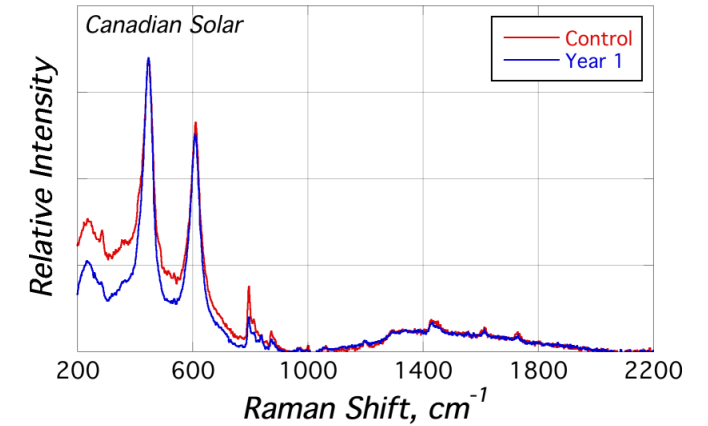


Backsheet – Year 1

PET Backsheets



Fluoropolymer Backsheets



- PET outer layers show changes in relative peak intensity and fluorescence
- Fluoropolymer backsheets show minimal changes
- TPT/PVF backsheet shows appearance of new peak at 517 cm^{-1} – possible Si contaminant



Upcoming Work

- Year 2 Characterization is in process
 - Non-destructive – February
 - Core extraction - March
- Continued destructive characterization of Year 1 samples
 - Backsheet inner layer, front and rear encapsulant
 - Raman, DSC, TGA, FTIR
 - SEM analysis of Anti-Reflective Coatings (ARCs)
- Further refinement of FTIR classification method
 - Add more "knowns" to database

