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DuraMAT
Durable Module Materials Consortium

Discover, Develop, and De-Risk module materials, architectures, accelerated testing protocols,data analytics, and financial models to reduce the LCOE of solar energy

Field-Aged Module Library

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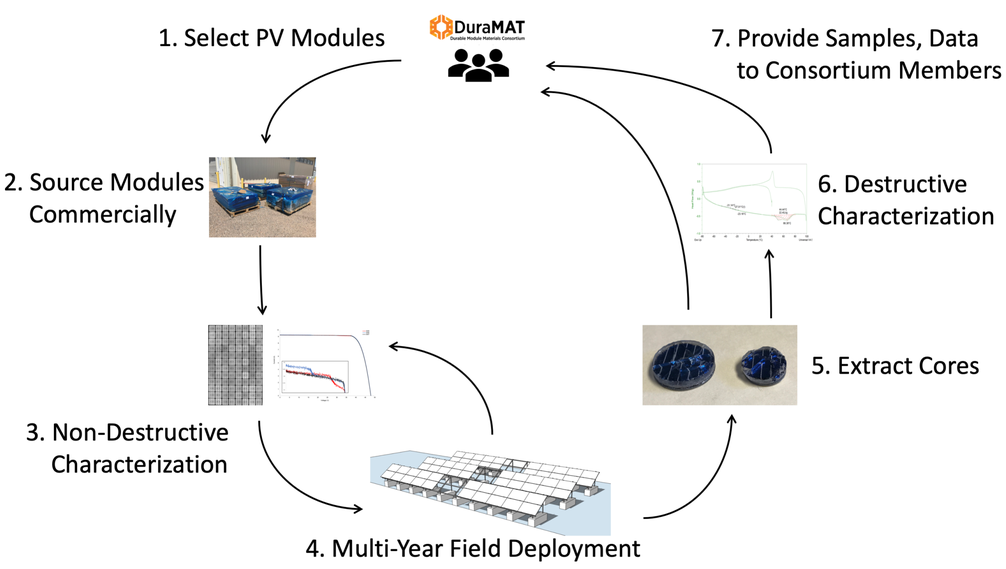
Characterize material degradation from natural aging in commercially relevant PV modules

Approach

- 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
Itek (Silfab)	360 SE	Mono P-type
Jinko	JKM270PP-60	Multi-Si
LG	LG320N1K-A5	Mono N-type
Mission Solar	MSE300SQ5T	Mono PERC
Panasonic	VBHN330SA17 HIT	HIT N-type



Characterization Methods

Laboratory Non-Destructive
- Indoor Flash Test
- Electroluminescence
- Infrared thermography
- Visual

ND Field Forensics
- FT-IR
- Yellowness Index (YI)
- Gloss

Laboratory Destructive
- Differential Scanning Calorimetry (DSC)
- FT-IR
- Thermal Gravimetric Analysis (TGA)
- Raman Spectroscopy

Non-Destructive Laboratory

Year-over-Year Power Rating (W) and Degradation

Mfg	Rating	Initial	Year 1		Year 2		Year 3	
			Power	%/yr	Power	%/yr	Power	%/yr
Canadian	300	300 ± 2	295 ± 1	-1.6	293 ± 1	-1.1	284 ± 2	-1.5
Q-Cells	300	302 ± 1	295 ± 1	-2.2	293 ± 1	-1.5	292 ± 1	-0.9
Itek	360	358 ± 1	351 ± 1	-2.2	339 ± 8	-2.2	-	-
Jinko	270	273 ± 1	268 ± 1	-1.8	264 ± 1	-1.6	260 ± 1	-1.4
LG	320	319 ± 1	316 ± 1	-0.9	314 ± 1	-0.8	311 ± 6	-0.7
Mission	300	292 ± 1	289 ± 1	-1.0	286 ± 1	-1.0	282 ± 2	-1.0
Panasonic	330	330 ± 0	330 ± 1	0.0	328 ± 1	-0.3	324 ± 3	-0.5

- All fielded modules are brought inside annually for recharacterization
- Most modules display a 1-2%/year power degradation during the first year that stabilizes to ~ 1%/year in subsequent years
- Trends are consistent with expectations from larger arrays of the same modules on -site at Sandia

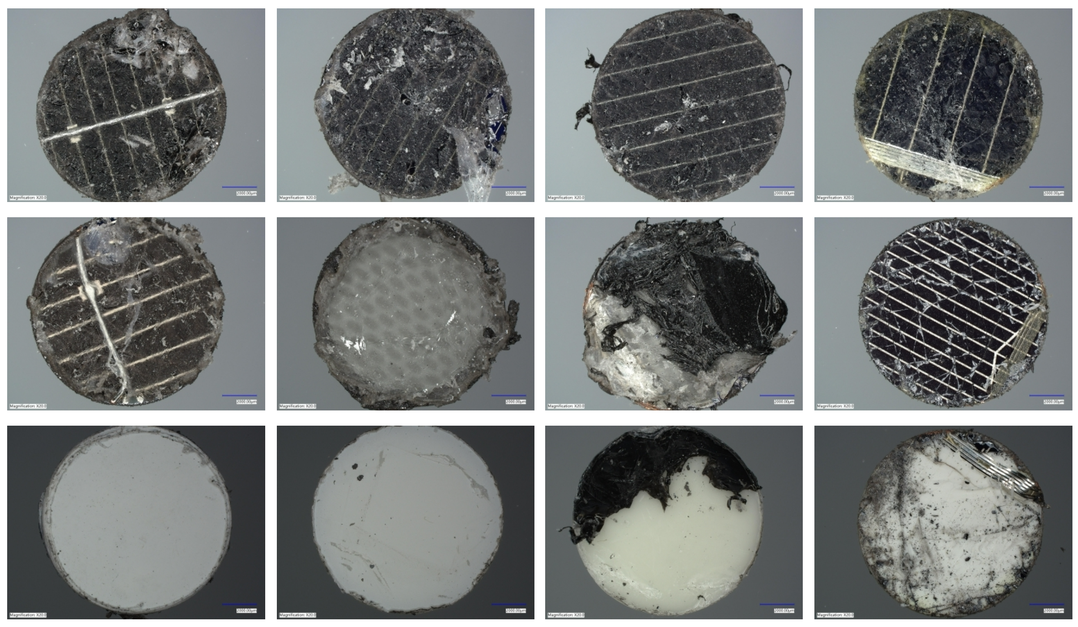
Non-Destructive

Mfg	Backsheet	b*	60° Gloss
Canadian	PVDF	0.98	15
Q-Cells	PET	-1.66	69
Itek	PET	4.3	65
Jinko	TPT	0.38	12
LG	PET	0.04	66
Mission	PET	-1.69	70
Panasonic	PET	0.95	63

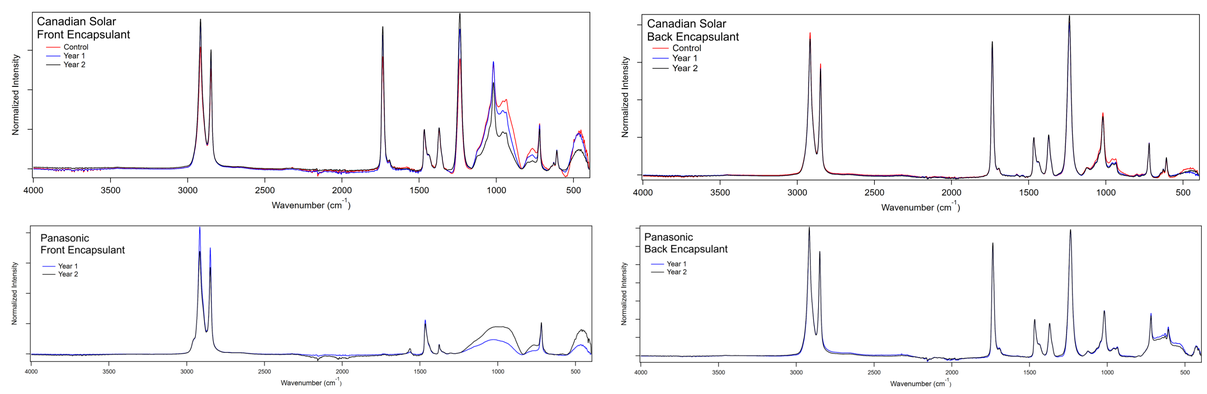
- FTIR peak comparison to known backsheets was used to classify composition
  - Most modules in this study use a PET backsheet
- Yellowness (b*) was not clearly correlated to backsheet type
- Gloss was strongly correlated to backsheet
  - PET consistently medium-high while fluorpolymers were matte

Coring and Sample Extraction

- Core samples are extracted using a modified CNC table and diamond core drill
- Core samples were split to gather information about each layer in the laminate



Laboratory Destructive



- Most modules feature EVA front and rear encapsulants
- Panasonic used TPO front and EVA rear encapsulant
- Rear EVA encapsulants were generally stable
- Front EVA from a few modules showed broader, more intense peaks in the range of 1100 – 800 cm^{-1} that varied with year of sampling
  - Possible indication of silane adhesion promoters or glass contamination

Final Activities

- Extract final year core samples
- Complete FTIR analysis
- Complete DSC and Raman characterization
- Transition remaining fielded modules to maintenance mode