DuraMAT
Durable Module Materials Consortium

SAND2020-4270PE

# Field-Aged Module Library Technical Update

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Energy Materials Network
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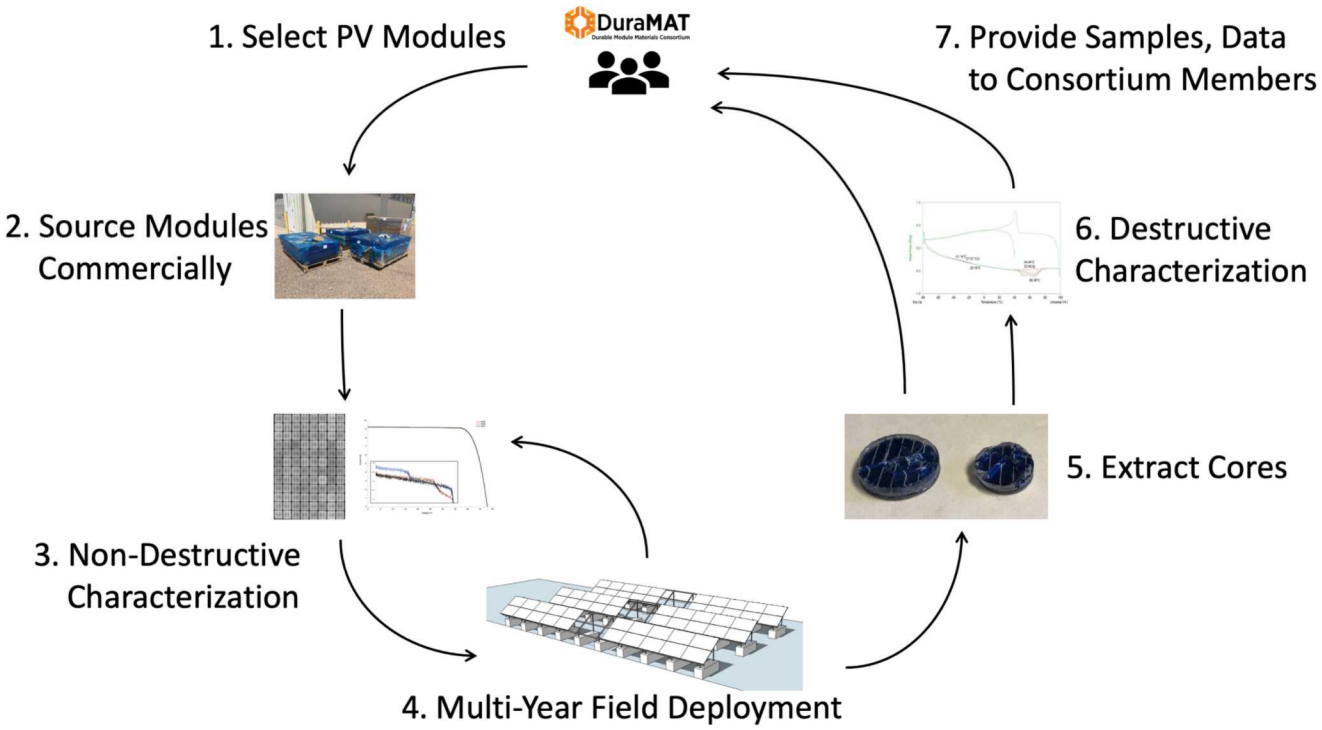
SLAC NATIONAL ACCELERATOR LABORATORY

# DuraMAT Field-Aged Module Library

*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

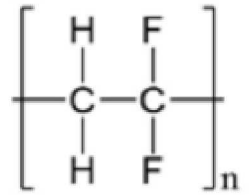


# Fielded Modules

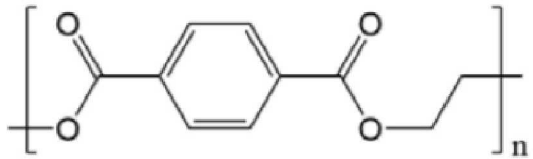
| Group | Manufacturer | Model | Cells | Cell Type | Status | Flash | Inverter |
|---|---|---|---|---|---|---|---|
| 1 | Jinko | JKM270PP-60 | 60 | Multi-Si | Installed | 273 ± 1.0 | IQ7+ |
| | Canadian Solar | CS6K-300MS Quintech | 60 | Mono PERC | Installed | 300 ± 1.7 | IQ7+ |
| | Hanwa Q-Cells | Q.Peak-G4.1 300 | 60 | Mono-Si | Installed | 302 ± 1.2 | IQ7+ |
| | LG | LG320N1K-A5 | 60 | Mono N-type | Installed | 319 ± 0.6 | IQ7+ |
| | Panasonic | VBHN330SA17 HIT | 96 | HIT N-type | Installed | 330 ± 0.4 | IQ7X |
| 2 | Mission Solar | MSE300SQ5T | 60 | Mono PERC | Installed | 292 + 1.1 | IQ7+ |
| | ITEK | 350 SE | 72 | Mono P-type | Installed | 355 ± 0.8 | PVI |

# Initial FT-IR Results

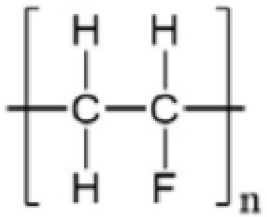
| Manufacturer | Model | # mods | Backsheet Outer layer Material |
|---|---|---|---|
| Canadian Solar | CS6k300MS | 10 | PVDF (blended with PMMA) |
| QCells | Q.Peak-G4.1 300W | 10 | PET |
| Mission Solar | MSE300SQ5T | 10 | PET |
| Panasonic | N325SA16 325W | 10 | PET |
| LG | LG320N1K-A5 | 10 | PET |
| Jinko | JKM260P-60 | 10 | PVF |




PVDF




PET




PVF

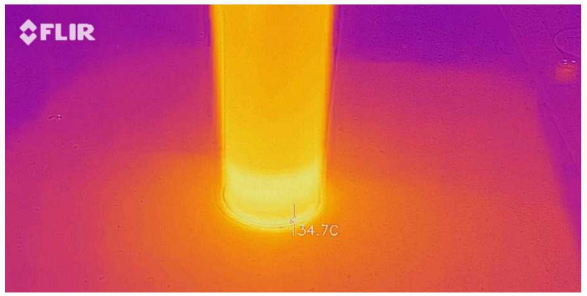
Agilent 4300 Handheld FTIR

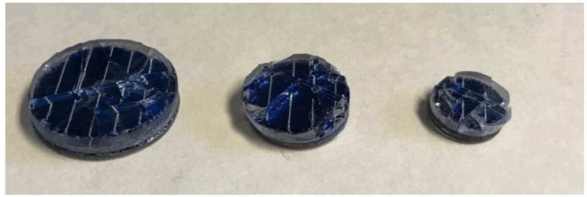
# Automated Coring Process

*Developed capability to extract samples from modules for destructive characterization*

- High throughput to handle large number of modules being processed
- Minimize damage to polymeric packaging materials during extraction

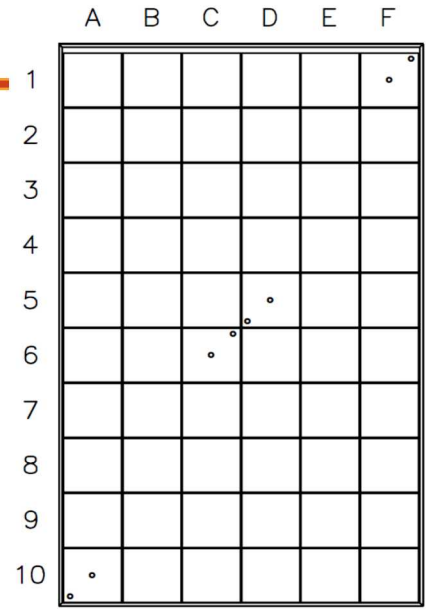
- Modified CNC plasma cutter
- Precise, repeatable sampling location
- Tight process control to avoid overheating, sample damage
- ½” – 1” samples
- ~ 2 samples/hour
- Minimizes operator involvement



# Materials Observations

- Cores collected from unaged modules at distinct locations (right)
- Core samples were split to gather information about each layer in the laminate



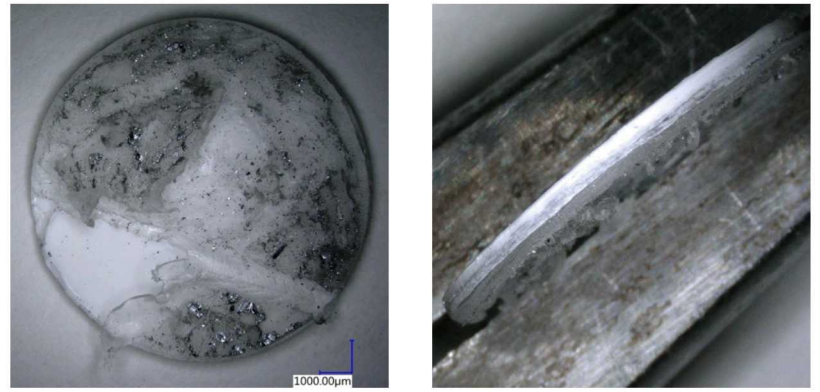

Mission Solar

Black inner layer, BS layer or encapsulant?
Same seen on LG modules

Panasonic

Extremely thin encapsulant layer
Ribbon pressed deep into BS

Q-Cells



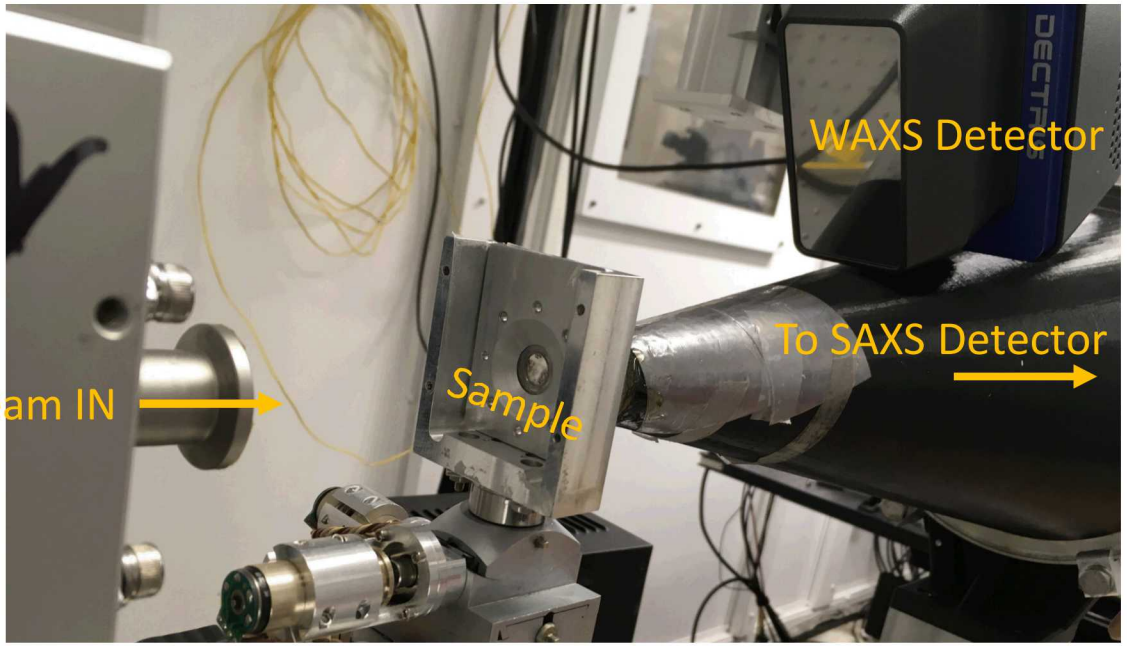
Representative of remaining modules
All white BS + distinct clear encapsulant

# Overview: Recent Results

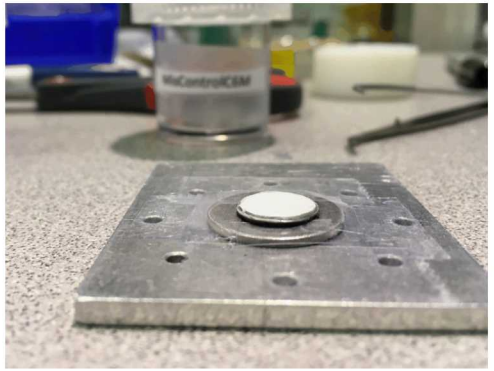
- Additional characterization completed of cores from the unaged module set:
  - X-ray scattering of backsheets at SLAC
  - Imaging of anti-reflection coatings
- Year 1 nondestructive characterization is complete
  - EL imaging
  - Flash testing
- Year 1 modules are being cored this week

# X-ray Scattering at SLAC

- Core samples were split to separate the back polymer layers from the cells
- Simultaneous small and wide-angle X-ray scattering conducted in transmission
- Motorized stage allowed quick collection from 6 locations top-to-bottom, 3 exposures each

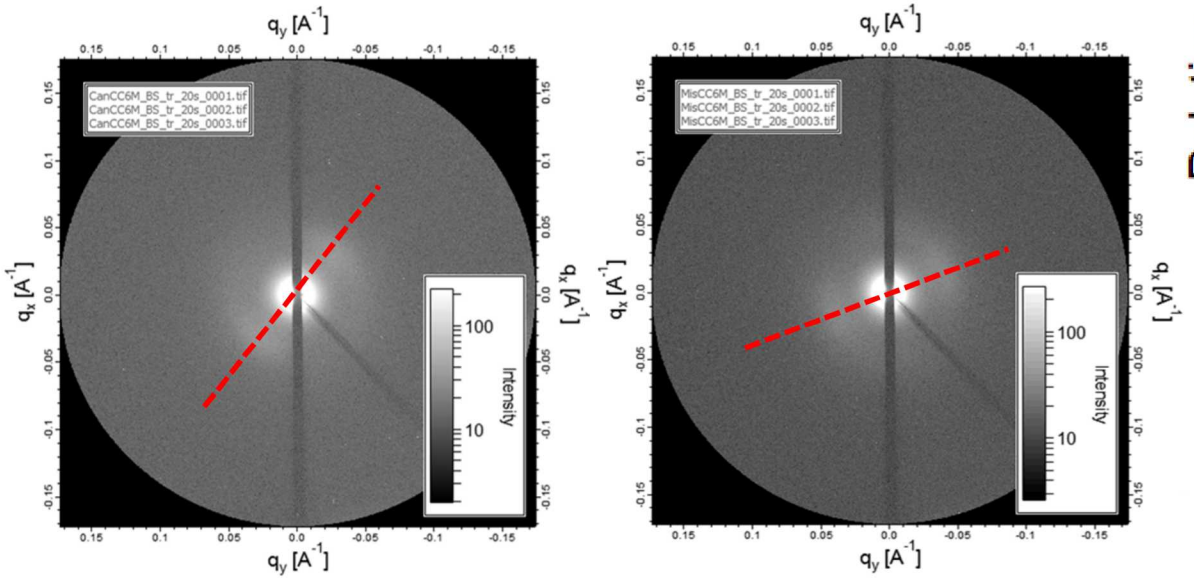


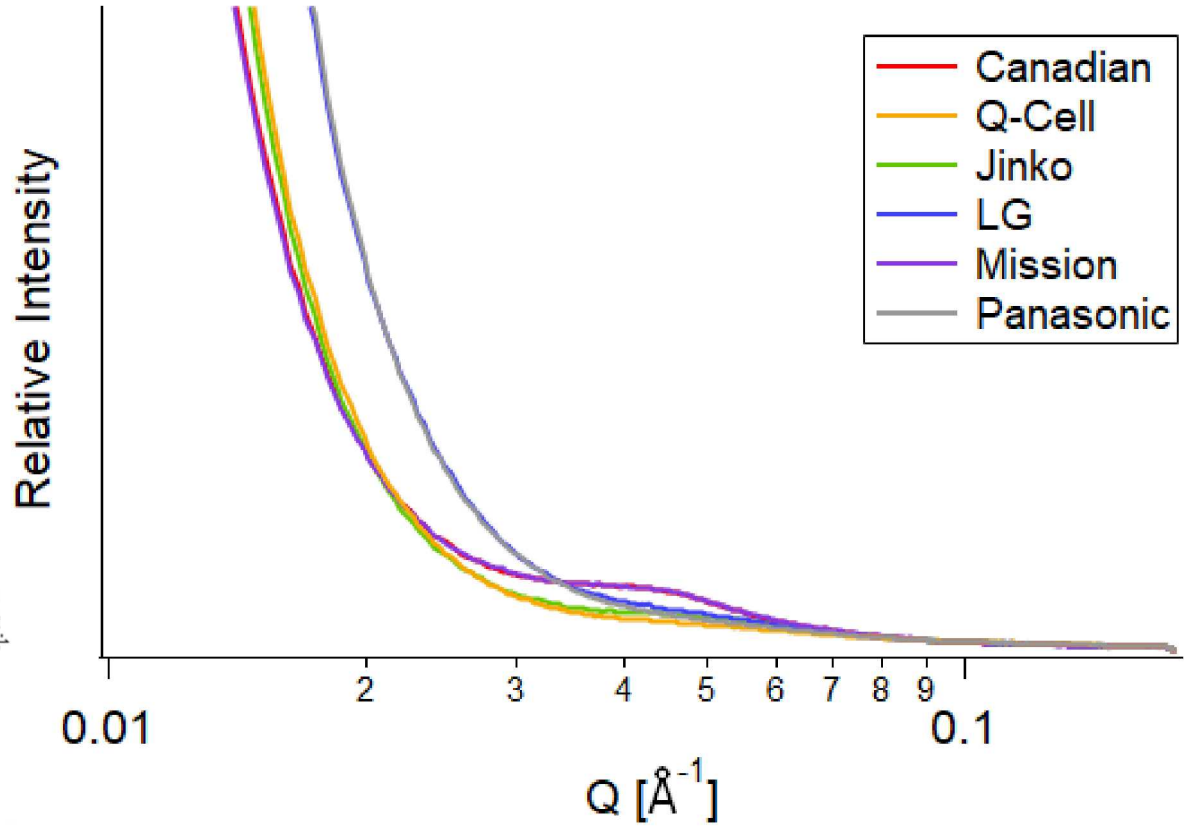

Sample mounted w/ air side (BS) towards detectors



# Small Angle X-ray Scattering at SLAC

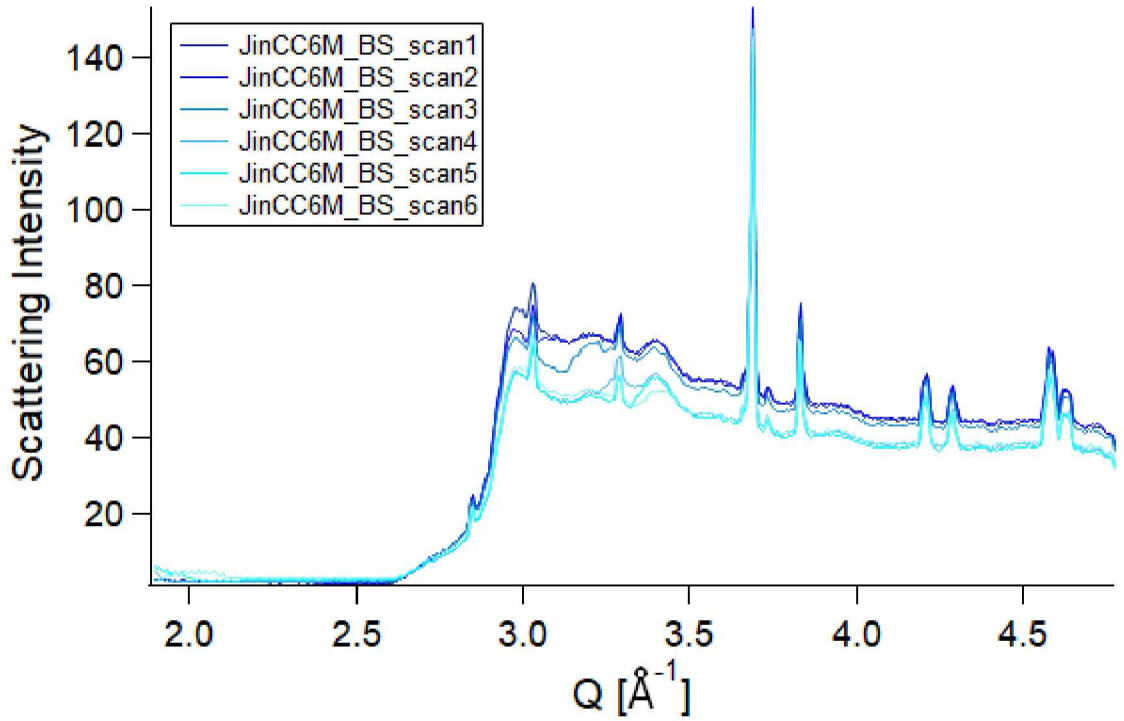
- Features in SAXS are produced from polycrystalline domains
- Canadian Solar and Mission Solar samples have anisotropic scattering due to alignment of domains along an axis



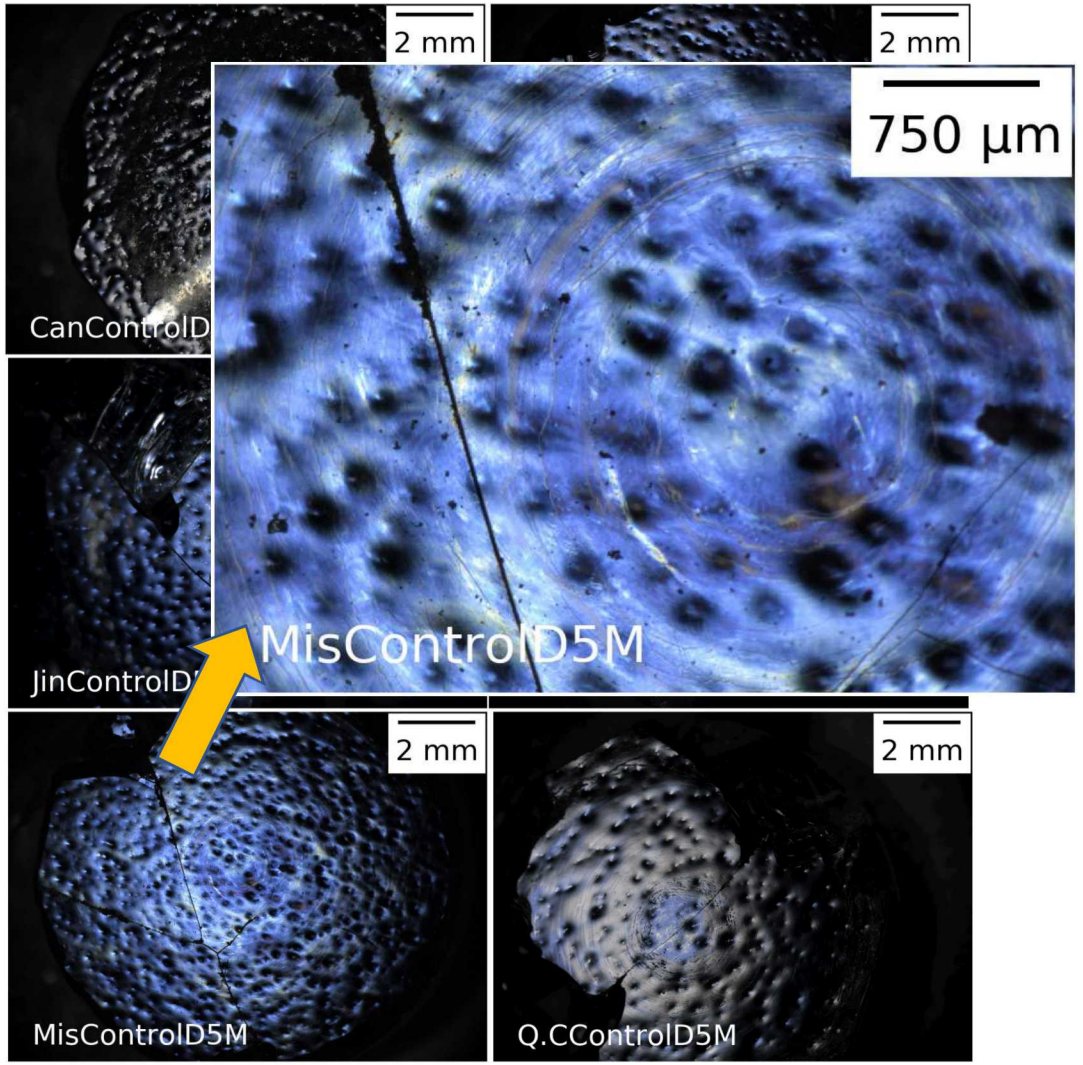
# Wide Angle X-ray Scattering at SLAC

- Data shown for Jinko sample, very similar across all modules
- Sharp scattering peaks associated with $TiO_2$ used as white pigment in backsheets



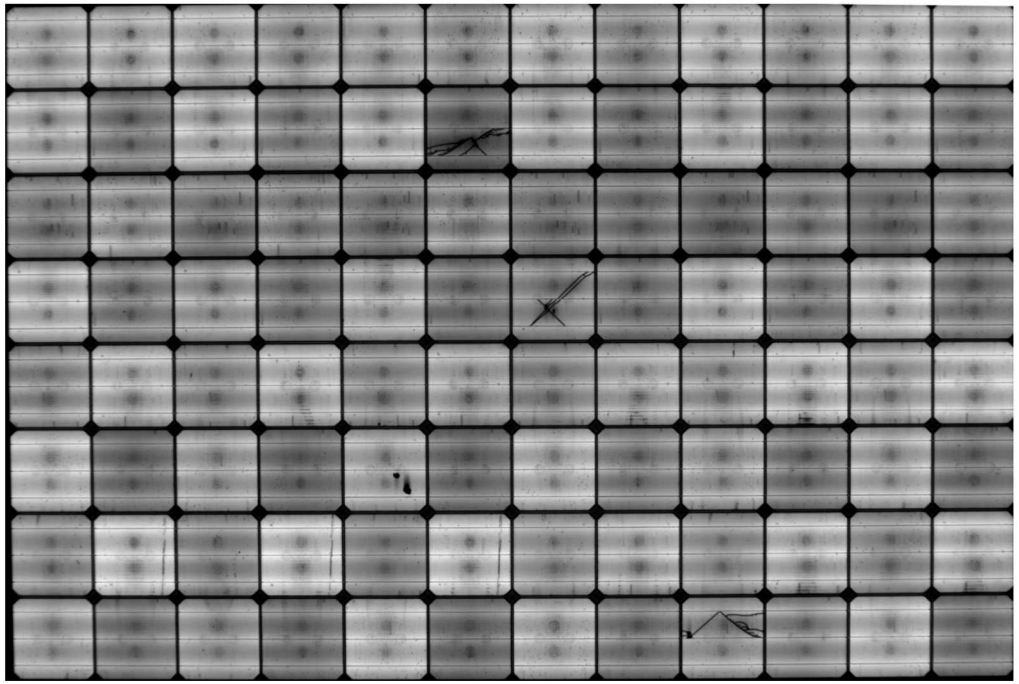
# Measurement of Anti-Reflection Coatings

- Todd Karin (LBNL) requested core samples for analysis of ARCs
- Images are taken by imaging a white LED reflected from the top glass onto an RGB camera at ~10 degrees from normal incidence.
- Issue: all samples showed loss of coating in a circular pattern → damage occurring as core breaks loose



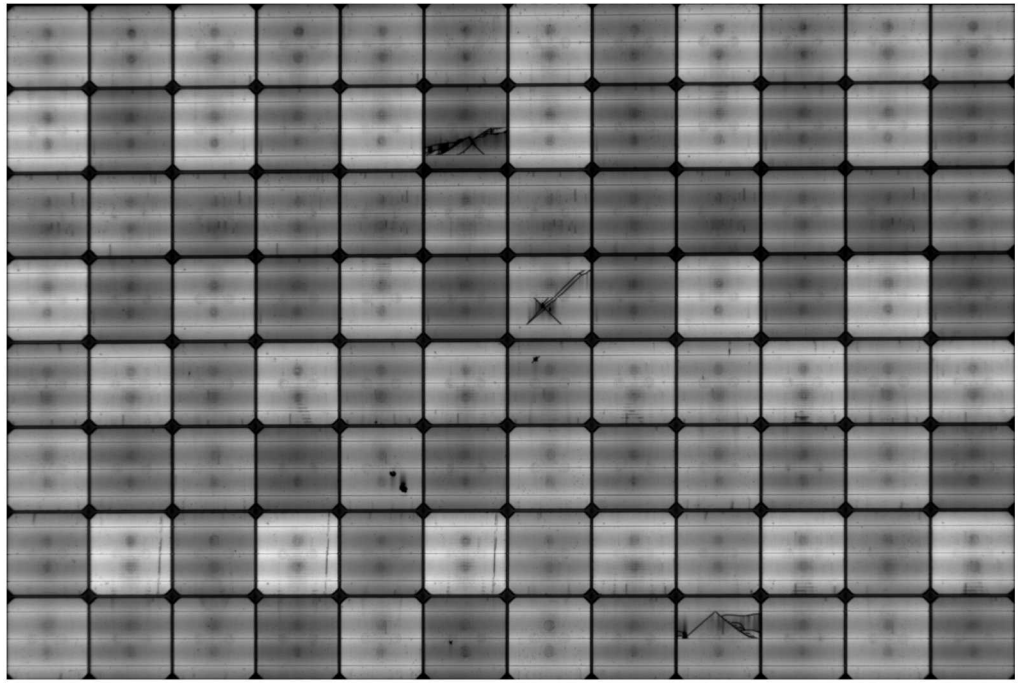
# Year 1 Nondestructive Testing

- EL imaging conducted on all modules after 1 Year in the field



Initial

**Panasonic**

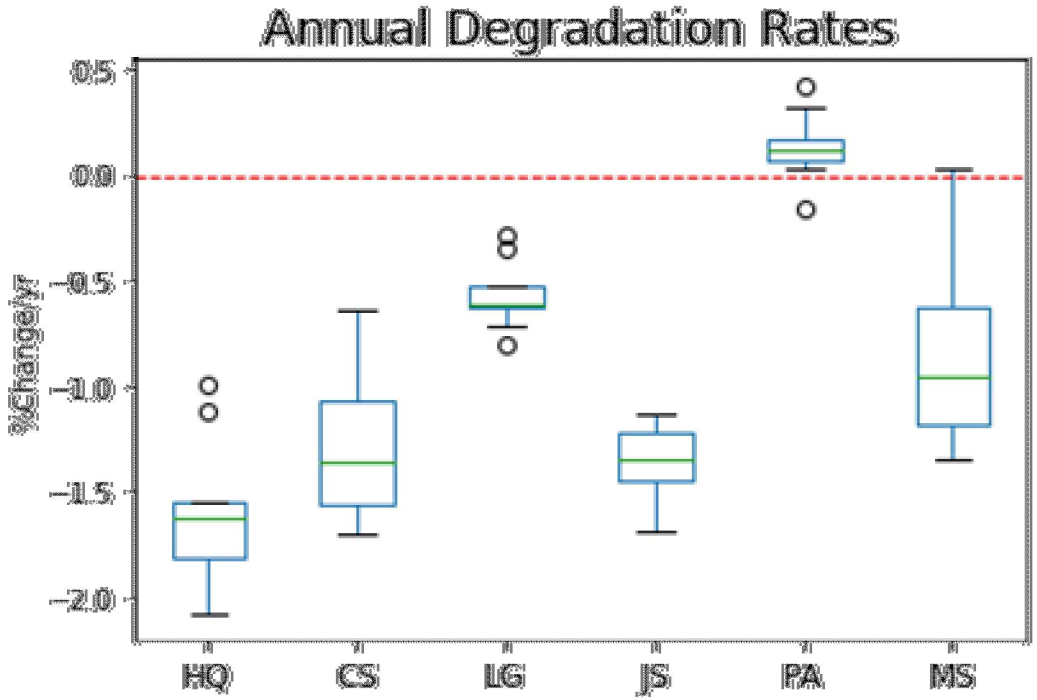


Year 1

# Year 1 Nondestructive Testing

- Indoor light IV conducted on a Spire flash tester

| Manufacturer | Rating | Initial | Year 1 |
|---|---|---|---|
| Hanwa Q-Cells (HQ) | 300 | 302 ± 1 | 295 ± 1 |
| Canadian Solar (CS) | 300 | 300 ± 2 | 295 ± 1 |
| LG | 320 | 319 ± 1 | 316 ± 1 |
| Jinko (JS) | 270 | 273 ± 1 | 268 ± 1 |
| Panasonic (PA) | 330 | 330 ± 0 | 330 ± 1 |
| Mission Solar (MS) | 300 | 292 ± 1 | 289 ± 1 |




Boxes: quartile 1 to quartile 3
Error bars: 1.5*(Q3-Q1)
Circles: outliers

# Next Steps

- Coring scheduled to be completed this week from Year 1 modules for destructive characterization
  - Including procedure to protect glass coating with tape
- Continue to build database of known backsheet reference FT-IR spectra.
- Conduct annual survey of backsheet FTIR
- Obtain NIR spectrometer to measurement the internal layers of backsheets.

- Possibility of adding two more sets of modules from PV Lifetime
  - Jinko and Trina, 3-4 years of field exposure already

- **We welcome requests for core samples to expand the impact from this collection of modules**