The Influence of the PV backsheet on the Formation of Snail Trails

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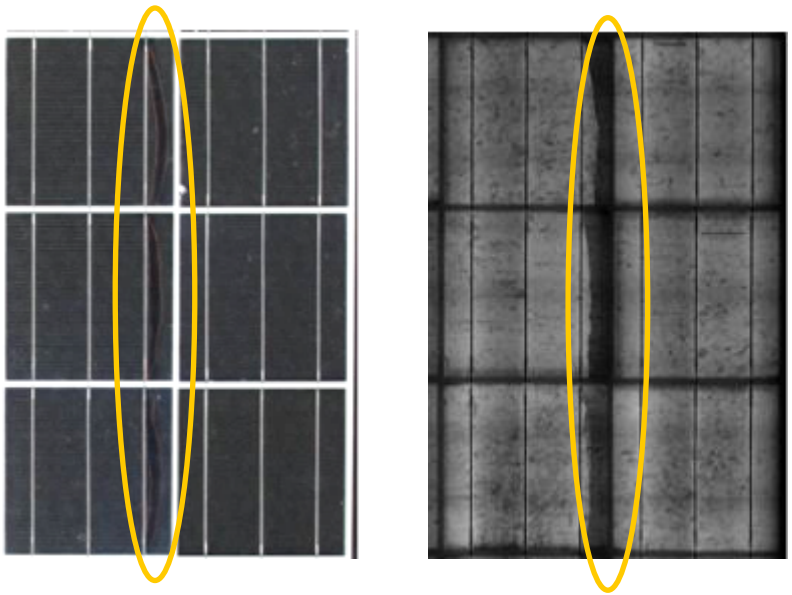

NREL reliability workshop

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This presentation contains no confidential information.

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Snail Trails: Introduction

- The solar industry is investigating so-called 'snail trails' – small, dark lines that have begun to crop up on modules starting around 2006. [1]
- The phenomenon affects modules from several manufacturers in the U.S., Europe and Asia. [1]
- There is discussion around the exact causes, but researchers suspect a chemical reaction of the silver metallization fingers occurring when moisture penetrates cells due to micro cracks. [2]

[1] Ines Rutschmann, Unlocking the secret of snail trails, Photon International, 01-2012

[2] Köntges et al., Schneckenspuren, Snail Tracks, Worm Marks und Mikrorisse, TÜV Rheinland, 8. Modul-Workshop 2011

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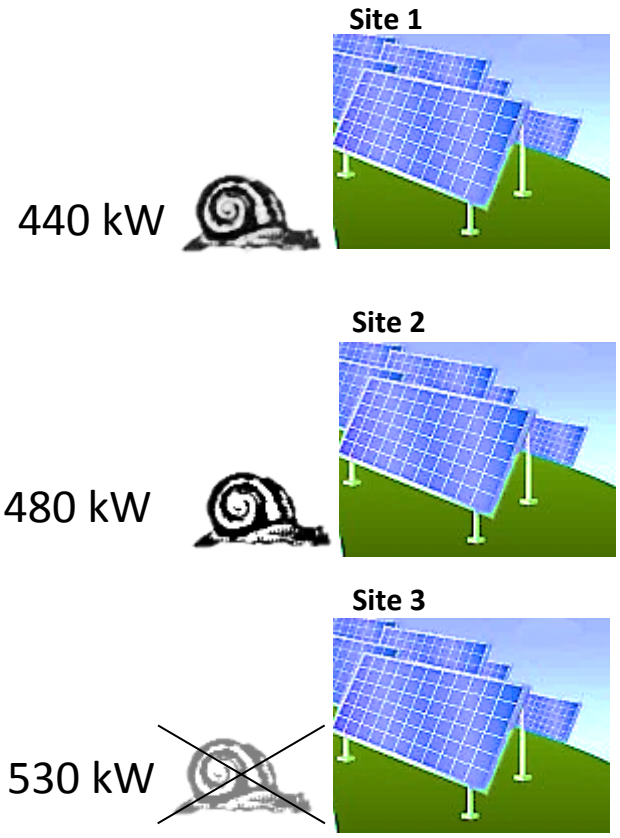
Snail Trails: Introduction

- Snail trails do not emerge in modules stored indoors.
- When applying damp heat to modules stored indoors, snail trail like effects can develop but disappear again.
- Snail trails appear to develop quicker in humid and hot climates and slower in dry and cold climates, for the same module type.
- Irregular snail trails appear to be an indication for inhomogeneous temperature distribution.
- Snail trails develop to a certain width. After that they either stop growing or appear to grow very slowly.
- Degree of EVA cross linking does not correlate with snail trails.

Köntges et al., Snail Tracks (Schneckenspuren), Worm Marks und Micro Cracks, International Energy Agency, IEA PVPS Task 13 Workshop, 27th EU PVSEC, 2012

Project background / approach

- 3 sites having the same PV module model installed within 2.5 years in New England were analyzed.
- 2 out of 3 sites showed snail trails.
- From each site 5 fielded modules and 1 module out of storage were analyzed.
  - Crack analysis
  - Visual snail trail detection
  - I-V under STC
  - Core sampling
    SEM, FTIR



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Crack analysis using electroluminescence imaging

- Distribution of crack location.
- Each field in the matrix represents a cell position. The numbers represents the total number of cracks at that specific position.
- In general there is no apparent pattern in the location of the cracks.

Site 1
Σ 5 modules

4	2	1	4	13	2
8	5	0	0	2	2
1	3	0	5	14	1
4	11	3	3	8	4
6	17	8	11	10	4
5	10	10	11	13	4
5	21	6	1	17	2
7	20	6	2	5	2
3	3	1	2	3	3

Site 2
Σ 5 modules

1	1	1	4	1	4
0	7	5	1	4	4
11	7	1	3	2	2
9	12	1	3	3	1
4	5	6	3	4	1
12	11	4	3	7	6
10	32	6	14	1	5
14	15	8	6	7	1
8	11	7	9	1	2

Site 3
Σ 5 modules

0	0	2	2	0	2
2	2	1	4	1	4
1	1	1	2	4	2
6	1	4	0	5	2
6	4	3	2	3	2
5	1	1	2	1	6
4	4	3	3	1	0
1	1	2	1	2	1
7	3	1	1	6	4

Unfielded
1 module

1	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	1	0	0
0	0	0	0	0	0
0	4	0	0	0	0
0	0	0	0	0	0

Unfielded
1 module

0	0	0	0	0	0
0	0	0	0	0	0
1	0	0	0	1	0
1	0	0	0	2	0
0	0	1	0	0	0
0	1	0	0	0	1
0	0	0	0	0	0
0	1	0	0	1	0
0	0	0	0	0	1

Unfielded
1 module

2	1	0	0	0	1
0	2	0	0	2	0
1	0	5	2	2	1
2	0	0	0	2	0
2	6	0	0	0	0
1	1	0	0	0	0
0	0	0	0	1	0
0	0	0	1	0	0
0	0	0	0	0	1

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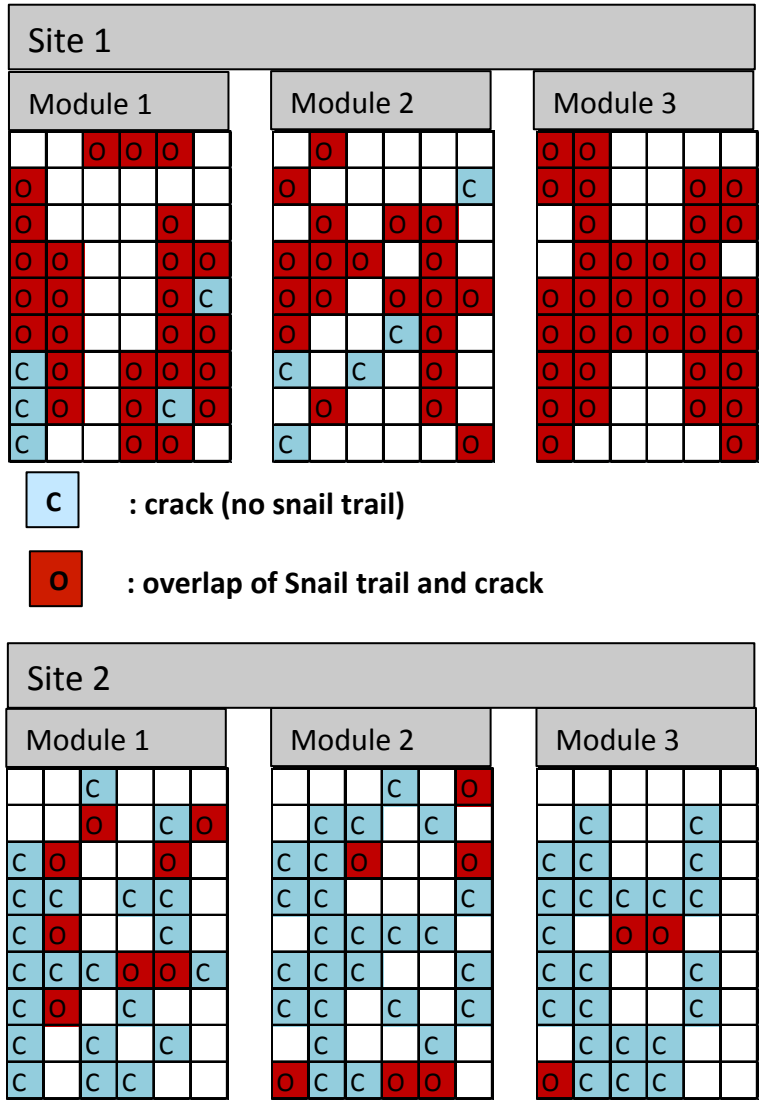
Snail Trail and Crack Correlation

- Nearly 100 % of the snail trails are correlated with cracks in the cells (red fields in matrix).
- Not every crack can be correlated with a snail trail, but this may change over time.



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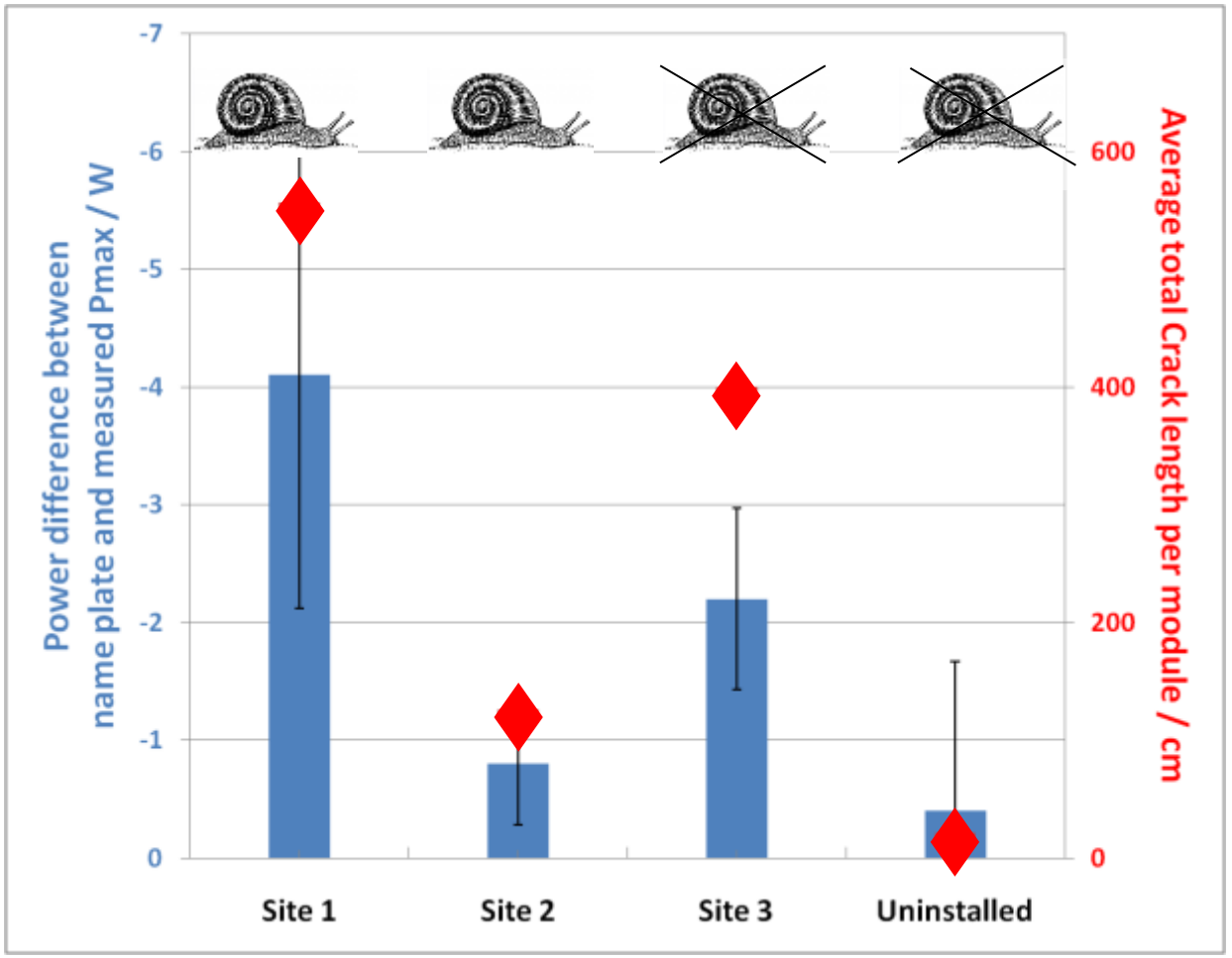
Solar Simulator Performance Testing

Module power loss appears to correlate with the number of cracks, rather than with the number of visible snail trails.



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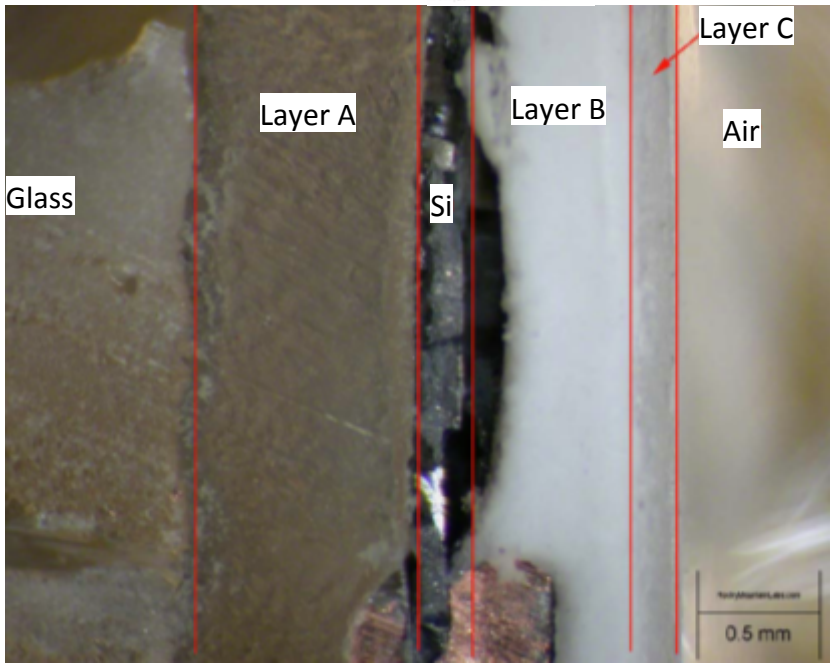
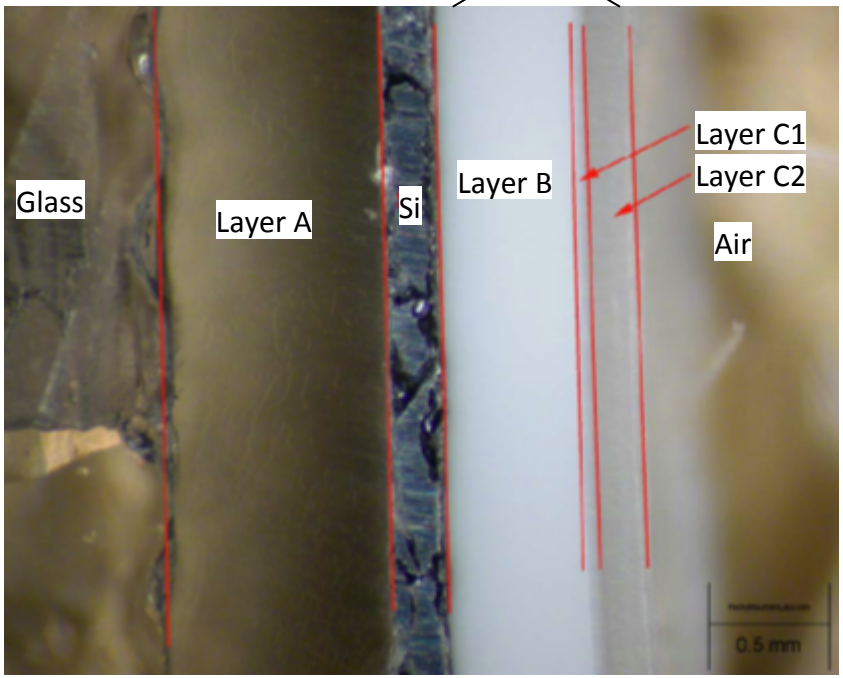
Core sampling

Optical image of a cross section

Site 1



Site 3



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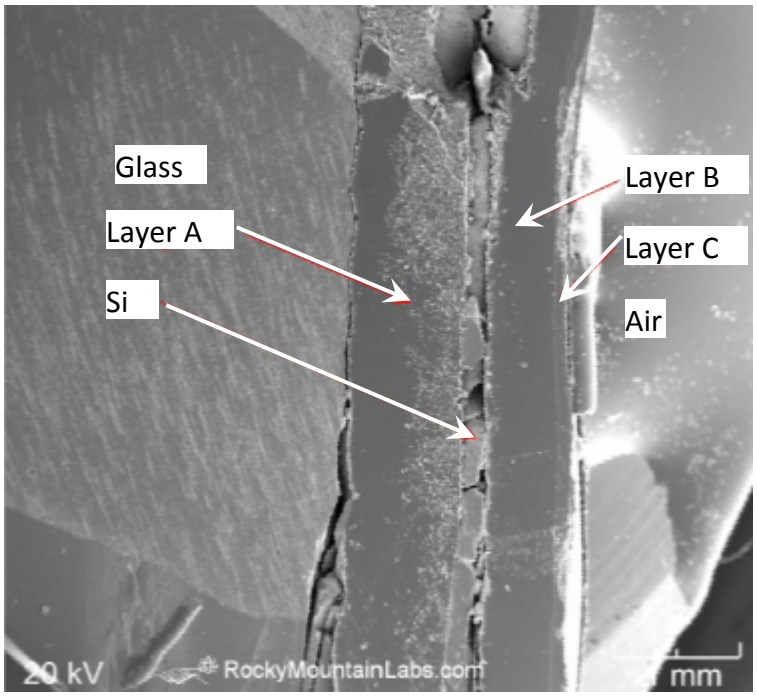
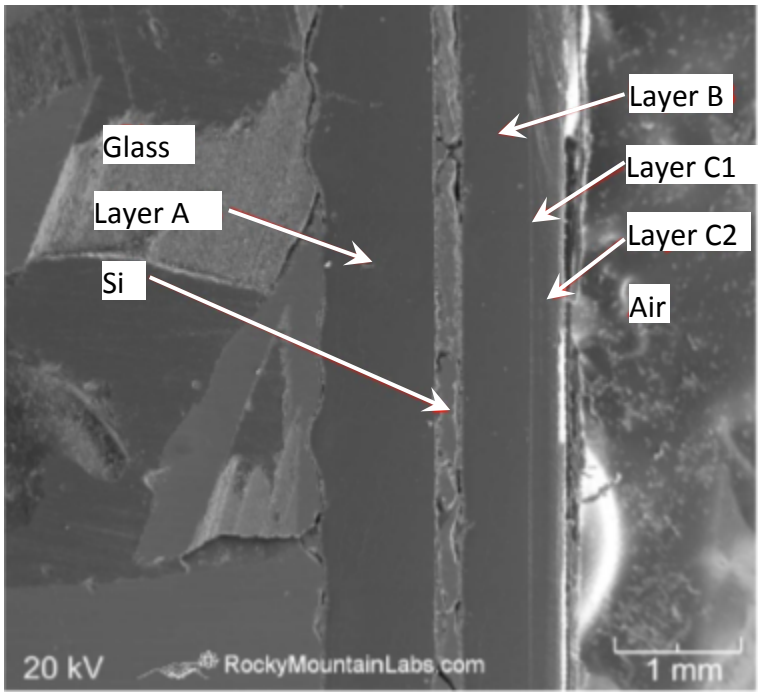
Core sampling

SEM (Scanning electron microscope) image of a cross section

Site 1



Site 3



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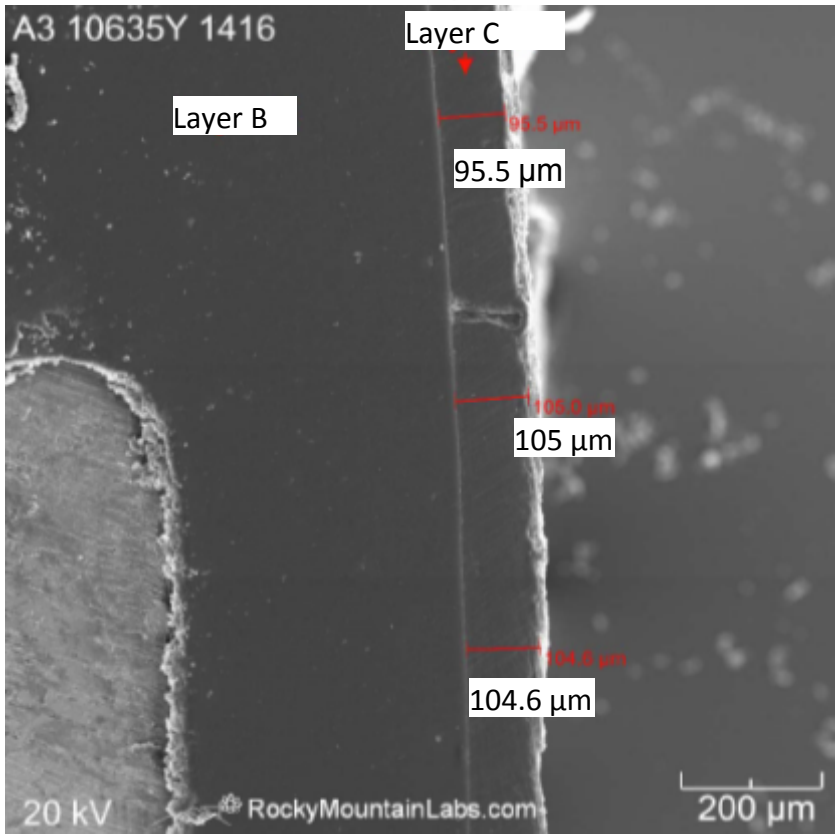
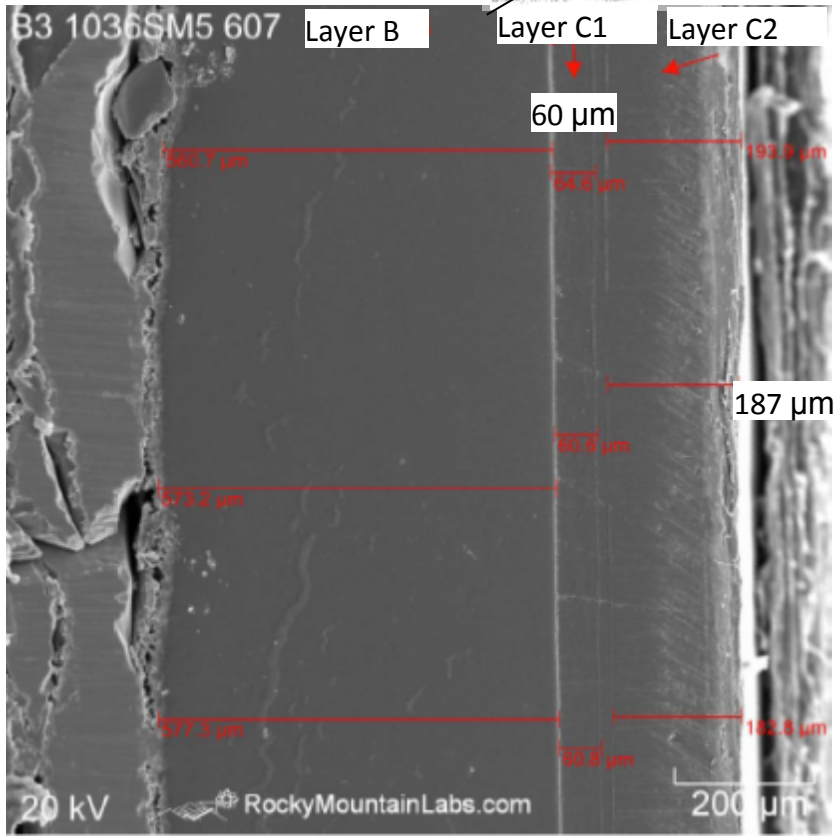
Core sampling

SEM (Scanning electron microscope) image of a cross section

Site 1



Site 3



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Core sampling

Thickness of the layers determined using SEM at cross section

Site 1 

Layer	Meas. 1	Meas. 2	Meas. 3	Avg.	
A	909.5	864.0	897.2	890.2	Front encapsulant
B	547.0	533.3	584.3	554.9	Rear encapsulant
C	95.5	105.5	104.6	101.9	Back sheet

Site 3 

Layer	Meas. 1	Meas. 2	Meas. 3	Avg.	
A	882.1	926.3	879.2	895.9	Front encapsulant
B	560.7	573.2	577.3	570.4	Rear encapsulant
C1	64.6	60.6	60.8	62.0	Back sheet
C_{Extra}	15.3	16.8	16.3	16.1	Back sheet
C2	193.9	186.9	182.8	187.9	Back sheet

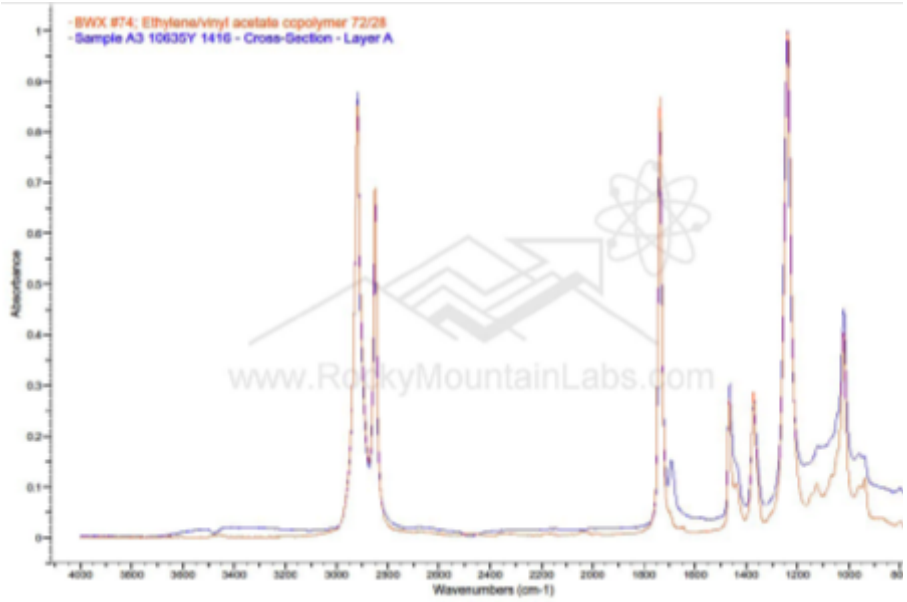
Core sampling

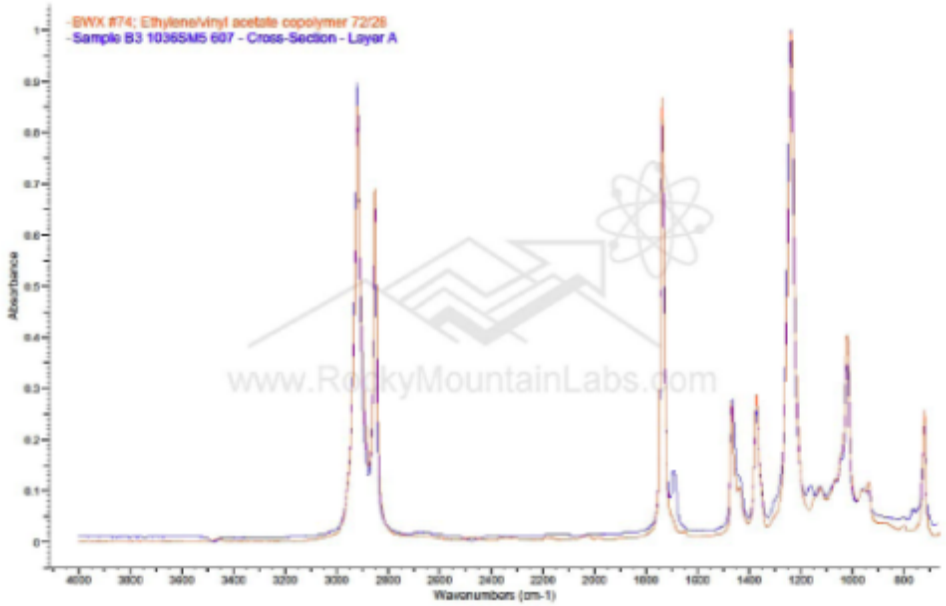
FTIR spectrum of Layer A (front encapsulant)

FTIR spectrum of Layer A (front encapsulant), compared to a library reference spectrum of Ethylene/Vinyl Acetate Copolymer (EVA)

Site 1 

Site 3 





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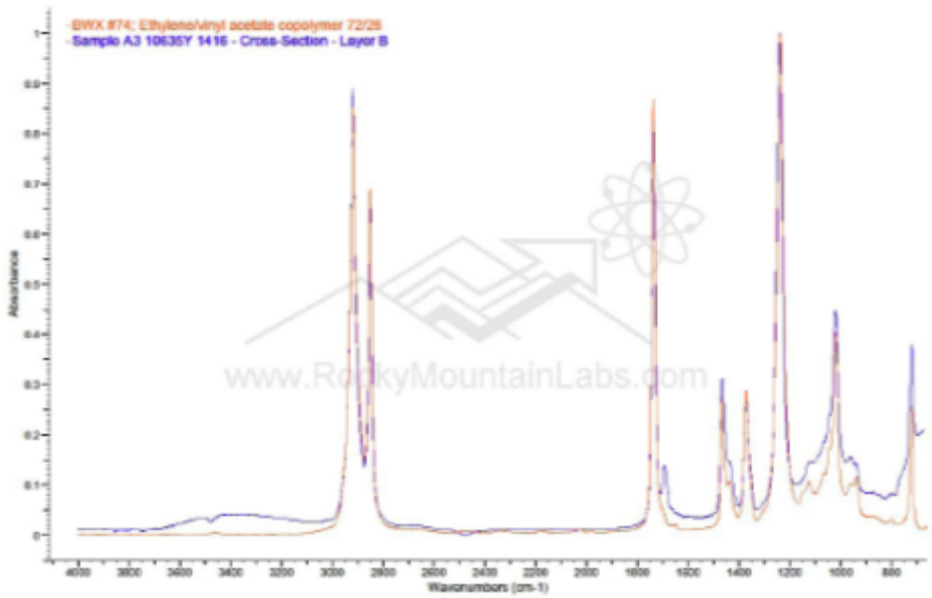
Core sampling

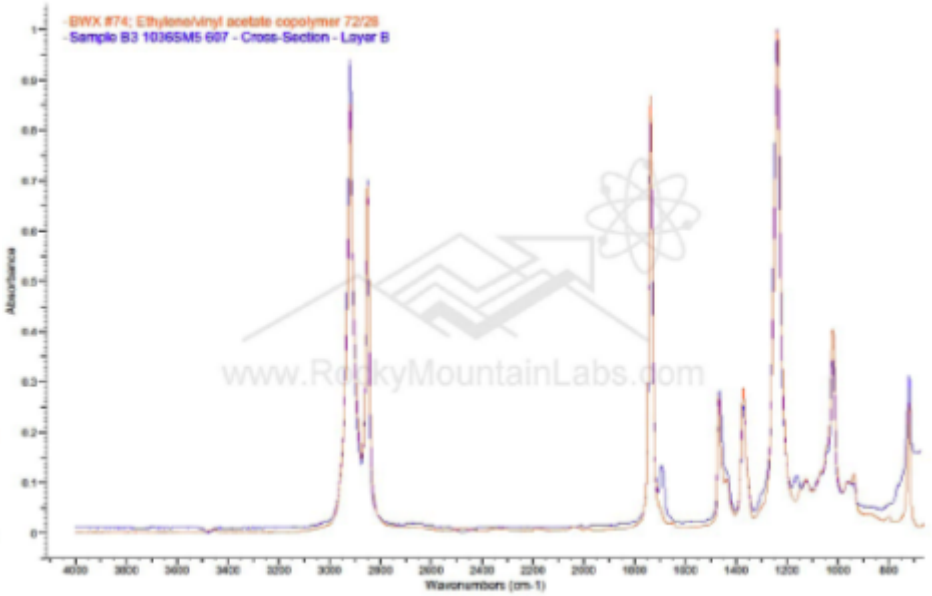
FTIR spectrum of Layer B (rear encapsulant)

FTIR spectrum of Layer B (rear encapsulant), compared to a library reference spectrum of Ethylene/Vinyl Acetate Copolymer (EVA)

Site 1 

Site 3 





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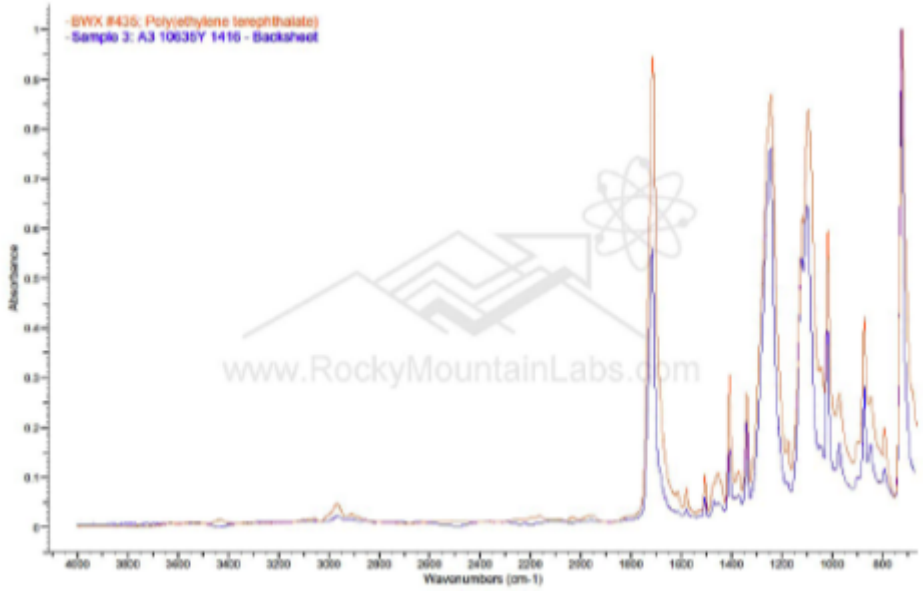
Core sampling

FTIR spectrum of Layer C (back sheet)

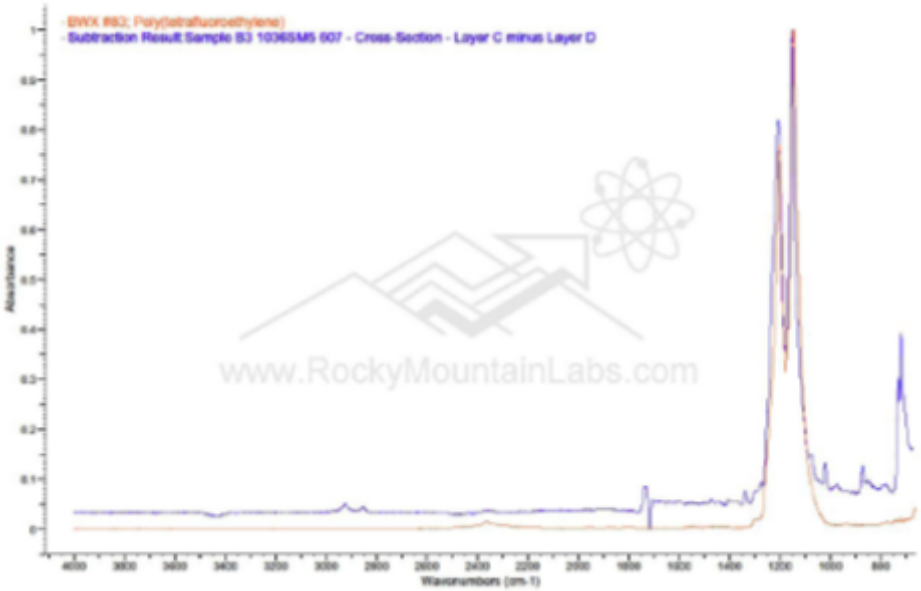
Site 1

FTIR spectrum of Layer C (back sheet), compared to a library reference spectrum of Poly(ethylene terephthalate) (PET)



Site 3

FTIR spectral subtraction result: Layer C (back sheet, part 1), compared to a library reference spectrum of Poly(tetrafluoroethylene) (PTFE)



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Core sampling

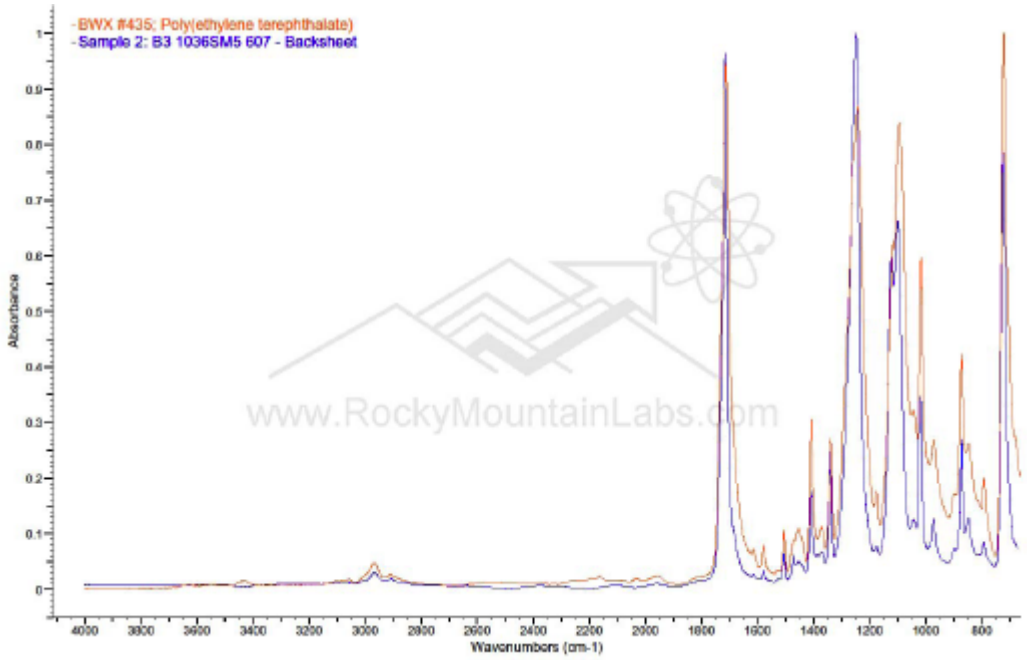
FTIR spectrum of Layer C2 (part 2 of back sheet)

Site 1 

No further layer

Site 3 

FTIR spectrum of Layer D (backsheet part 2), compared to a library reference spectrum of Poly(ethylene terephthalate) (PET)



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Core sampling

Thickness and material of the layers determined using SEM and FTIR at cross section

Site 1 

Layer	Avg. thickness	Polymer type	component
A	890.2	EVA	Front encapsulant
B	554.9	EVA	Rear encapsulation
C	101.9	PET	Back sheet

Site 3 

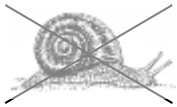
Layer	Avg. thickness	Polymer type	component
A	895.9	EVA	Front encapsulant
B	570.4	EVA	Rear encapsulation
C1	62.0	PTFE	Back sheet
C_{Extra}	16.1	--	Back sheet
C2	187.9	PET	Back sheet

Core sampling

summary:

polymer stacks in the two samples are different in the area of the backsheet

- Site 1: single layer PET backsheet (ca. **100 μm** thick)



- Site 3: three layer backsheet:
  - Layer 1: PTFE (ca. 60 μm thick)
  - Layer 2: (ca. 15 μm thick), too thin for material analysis (likely an adhesive tie layer)
  - Layer 3: PET (ca. 190 μm thick)
  - Total back sheet thickness: ca. **265 μm** thick

Conclusion

- The discoloration of the silver metallization fingers itself does not have negative consequences for module performance.
- However, the cracks behind the snail trails in the cells could be problematic.
- Modules having thinner backsheets, which are presumable more permeable for moisture and oxygen ingress, contribute to a module's susceptibility to snail trail development.

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