

Appendix D1

ESEM and SEM/EDS Data for Test #2, Day-16 Fiberglass in High- and Low-Flow Zones

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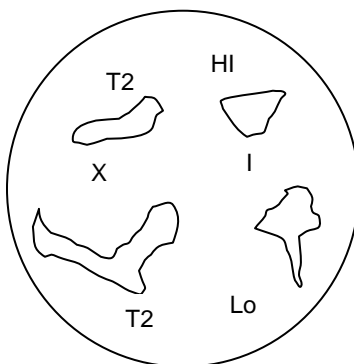
The debris accumulated on fiberglass in the ICET tests is of great interest because it may contribute to additional head loss during recirculation of the coolant following a LOCA. To evaluate these potential debris accumulations, fiberglass samples submerged in high- and low-flow zones in the tank were examined by ESEM and SEM/EDS.

In this appendix, images and data are presented for fiberglass samples that were extracted on February 21, 2005 (Test #2, Day 16). Both exterior and interior locations on the fiberglass samples were examined for material that had been placed in both high- and low-flow locations. Microprobe SEM was used to examine the fiberglass samples after they were air dried at room temperature and then coated with gold/palladium. Low-vacuum ESEM examinations were performed on hydrated material without any required coating to avoid sample modifications that might occur during the drying process. Microprobe SEM/EDS and ESEM analyses of Test #2, Day-16 fiberglass samples were obtained on February 25 and March 4, 2005, respectively. Accompanying EDS results provide a semiquantitative elemental analysis of the debris deposited on the fiberglass under both low- and high-flow conditions.

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Transcribed Laboratory Log

ESEM laboratory session from March 4, 2005



Instrument Conditions: 20-kV, 12-mm Working Distance, Low-Vacuum Mode (80 Pa)

T2 High-Flow Exterior

Image:	T2HIX1	90 ×	BSE Image Overview	Figure D1-1
	T2HIX2	350 ×	On center of image T2HIX1 (above)	Figure D1-2
	T2HIX3	1000 ×		Figure D1-3
	T2HIX4	350 ×	Another sample area	Figure D1-4

T2 High-Flow Interior

Image:	T2HII5	90 ×	Overview	Figure D1-5
	T2HII6	1000 ×	Same area as image T2HII5 (above)	Figure D1-6
	T2HII7	550 ×	Another area	Figure D1-7

T2 Low-Flow Exterior

Image:	T2LOX8	90 ×	Overview	Figure D1-8
	T2LOX9	500 ×	Upper left of image T2LOX8 (above)	Figure D1-9

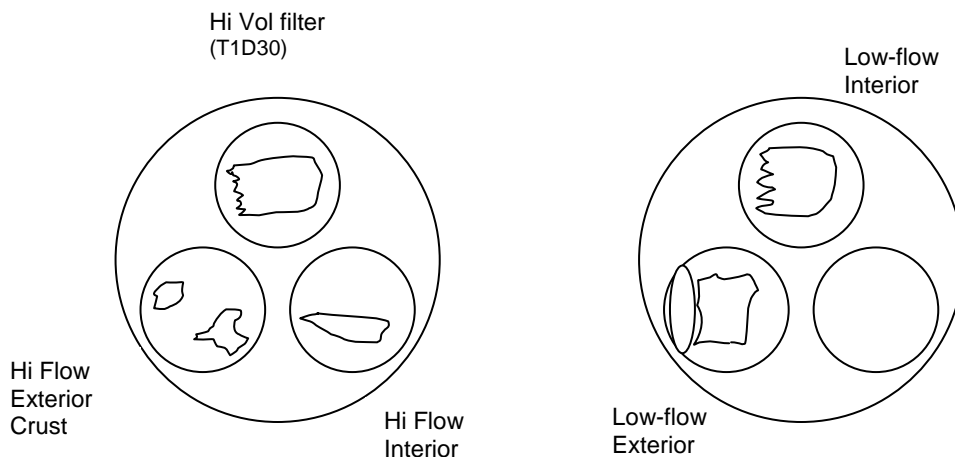
T2 Low-Flow Interior

Image:	T2LOI10	90 ×	Overview	Figure D1-10
	T2LOI11	500 ×	On center of image T2LOI10 (above)	Figure D1-11

Transcribed Laboratory Log

Microprobe laboratory session from February 25, 2005

T2D16 Samples plus high-volume filter from T1D30



Conditions: 15-kV, 1 nA

High-Flow Exterior Crust

Image:	HI_flow_ex_crust_001	40 ×	Overview (Charging)	Figure D1-12
	HI_flow_ex_crust_002	40 ×	Overview the same as 001	Figure D1-13
	HI_flow_ex_crust_003	60 ×	Zoom in on crust	Figure D1-14
	HI_flow_ex_crust_004	150 ×	Zoom in on crust	Figure D1-15
EDS:	Hiflow_excrust_EDS1		Area of picture 004—deposit	Figure D1-16
Image:	HI_flow_ex_crust_005	270 ×	Zoom in on different region	Figure D1-17
EDS:	Hiflow_excrust_EDS2		Area of picture 005—deposit	Figure D1-18
Image:	HI_flow_ex_crust_006	40 ×	Overview of another area	Figure D1-19

Laboratory Session March 6, 2005

High-Flow Interior (T2D16)—(after sputtering again to get better pictures)

Image:	Hiflow-interior001	40 ×	SE overview image	Figure D1-20
	Hiflow-interior002	80 ×	SE image	Figure D1-21
	Hiflow-interior003	65 ×	SE image—pretty clean fibers	Figure D1-22
	Hiflow-interior004	300 ×	SE image—deposits	Figure D1-23
	Hiflow-interior005	5000 ×	SE image—zoom in on deposits on fiberglass	Figure D1-24

Low-Flow Interior (T2D16)

Image:	Lowflow-interior001	55 ×	SE overview image	Figure D1-25
	Lowflow-interior002	120 ×	Close-up of Lowflow-interior001	Figure D1-26
	Lowflow-interior003	3500 ×	SE image zoom in on deposits	Figure D1-27
	Lowflow-interior004	370 ×	SE image zoom in on deposits	Figure D1-28
	Lowflow-interior005	85 ×	SE overview image	Figure D1-29
	Lowflow-interior006	370 ×	Zoom in	Figure D1-30
	Lowflow-interior007	100 ×	SE image	Figure D1-31

General Observations: Low-flow interior looks cleaner than high-flow interior.
No crusts, only small particles.
Images Lowflow-interior001 through 004 taken on the same region

Low-Flow Exterior (T2D16)

Image:	Lowflow-exterior001	43 ×	SE overview image	Figure D1-32
	Lowflow-exterior002	120 ×	Close-up (charging)	Figure D1-33
	Lowflow-exterior003	600 ×	Zooming on deposits	Figure D1-34
	Lowflow-exteriorEDS1		Particle on fiberglass (pic 003)	Figure D1-35
	Lowflow-exteriorEDS2		Particle on fiberglass (pic 003)	Figure D1-36

General Observations: Although sputtered again, some problems with charging remain.

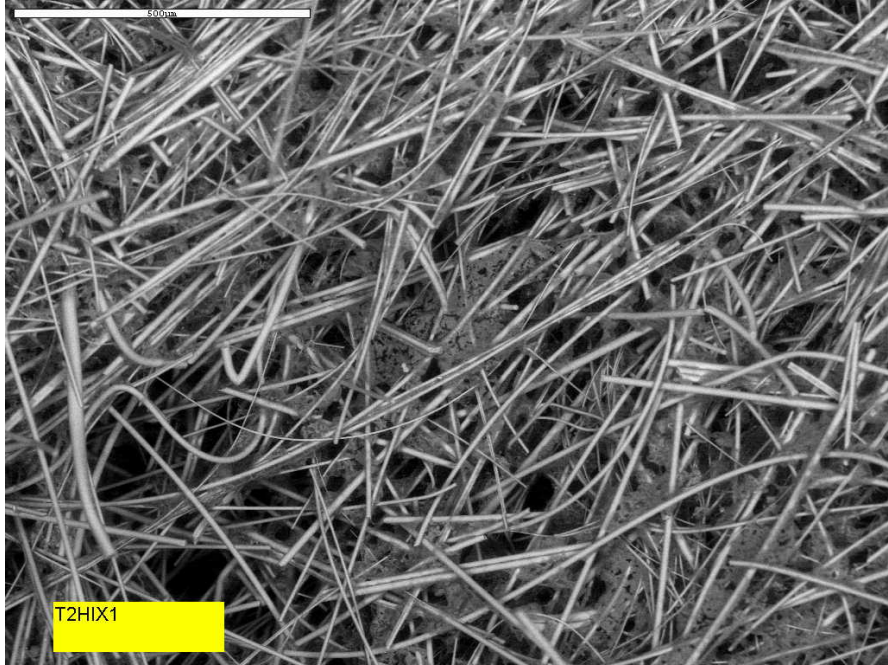


Figure D1-1. Back-scattered electron (BSE) image overview. (T2HIX1)

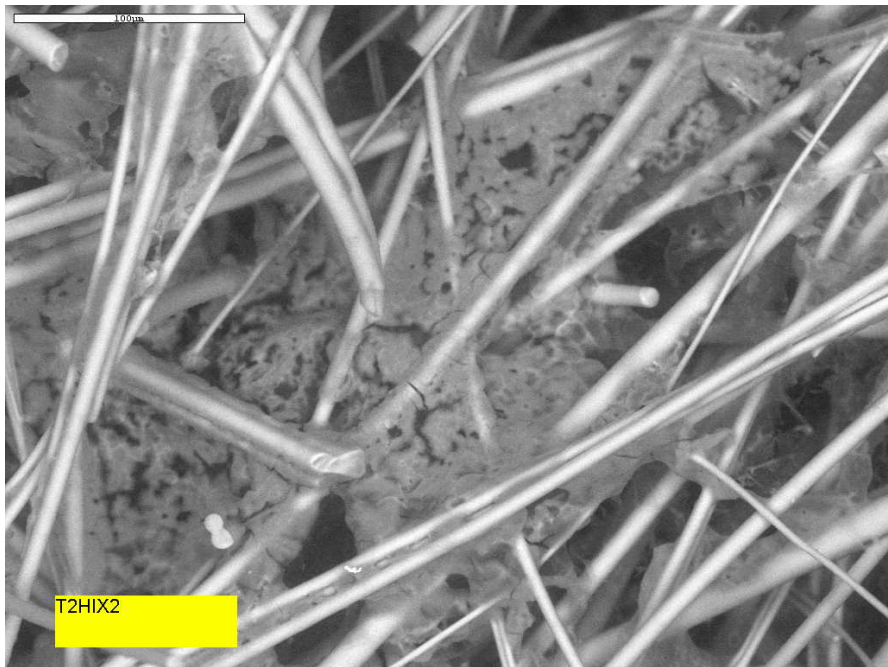


Figure D1-2. BSE image on center of Figure D1-1. (T2HIX2)

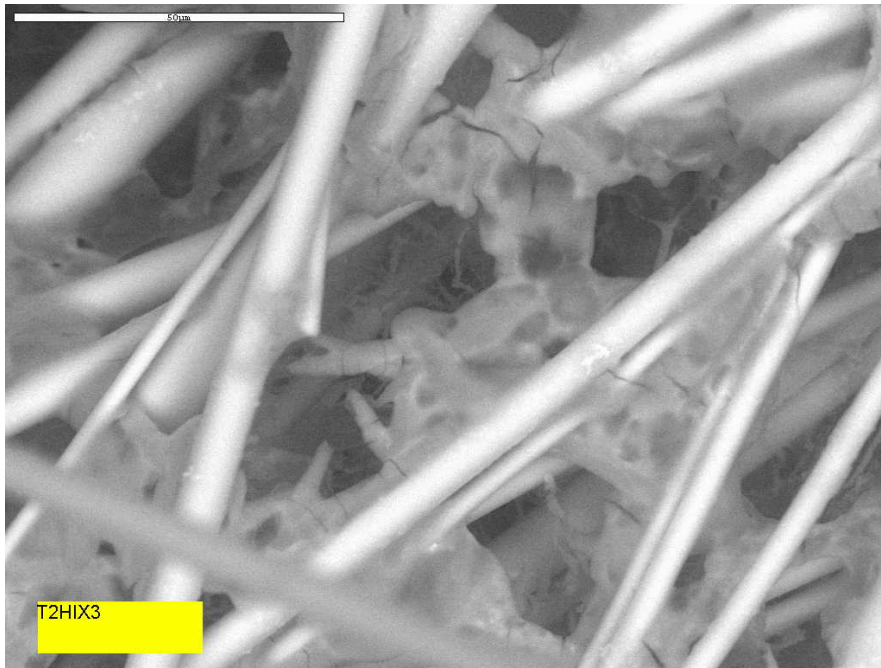


Figure D1-3. BSE image at 1000 times magnification. (T2HIX3)

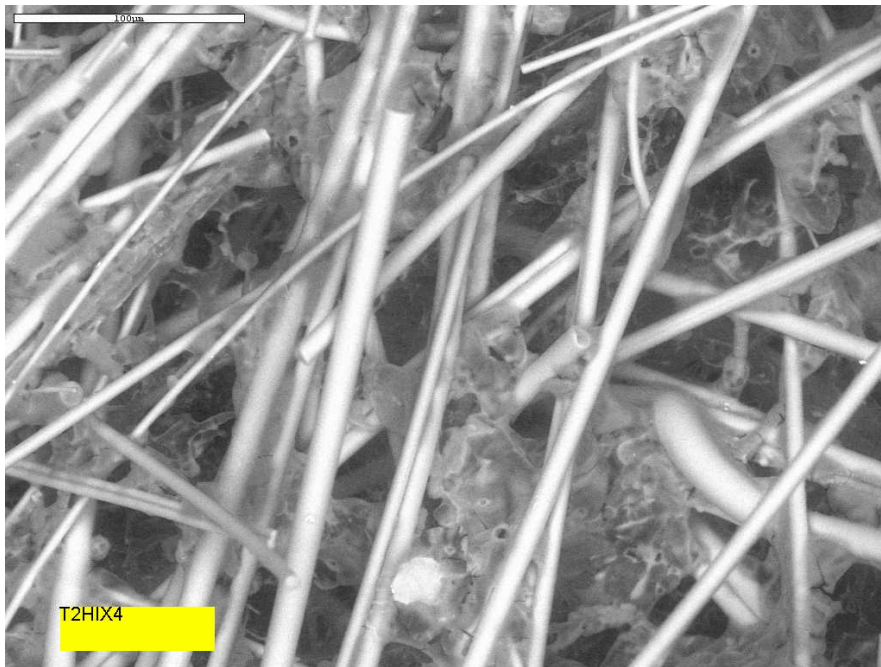


Figure D1-4. BSE image at another angle on the center of the image. (T2HIX4)

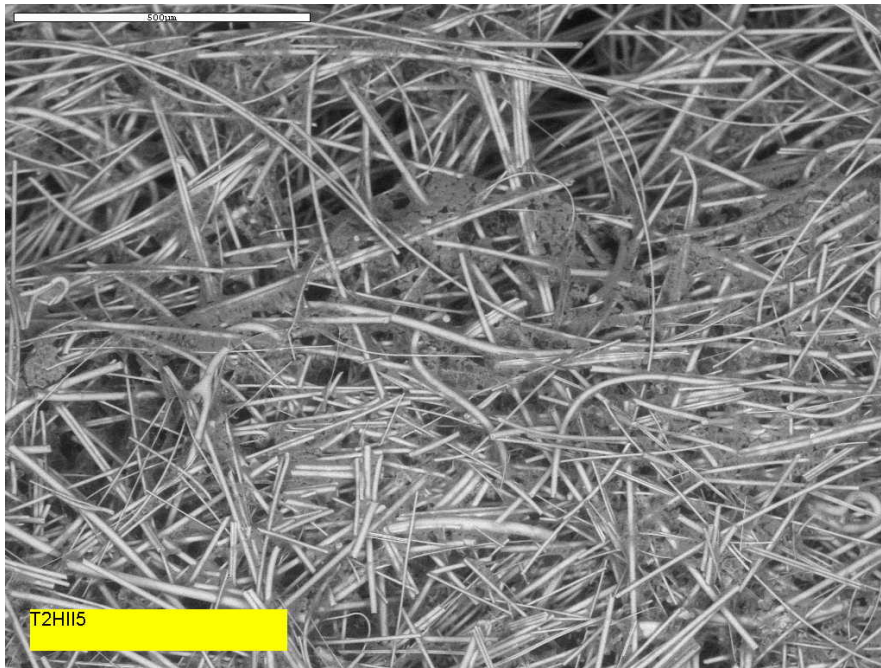


Figure D1-5. SEM image overview for interior of high flow. (T2HII5)

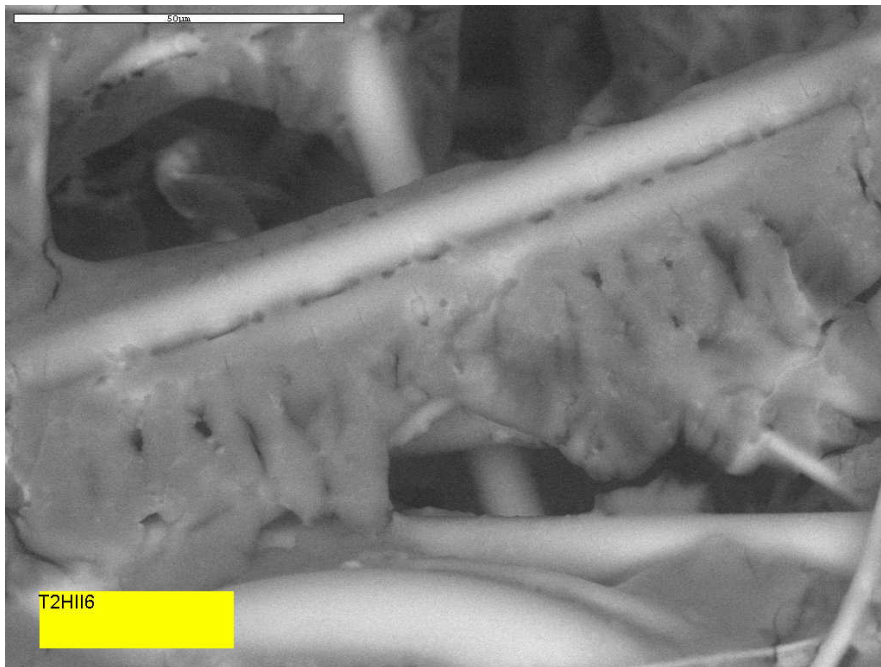


Figure D1-6. SEM image of Figure D1-5 at 1000 times magnification. (T2HII6)

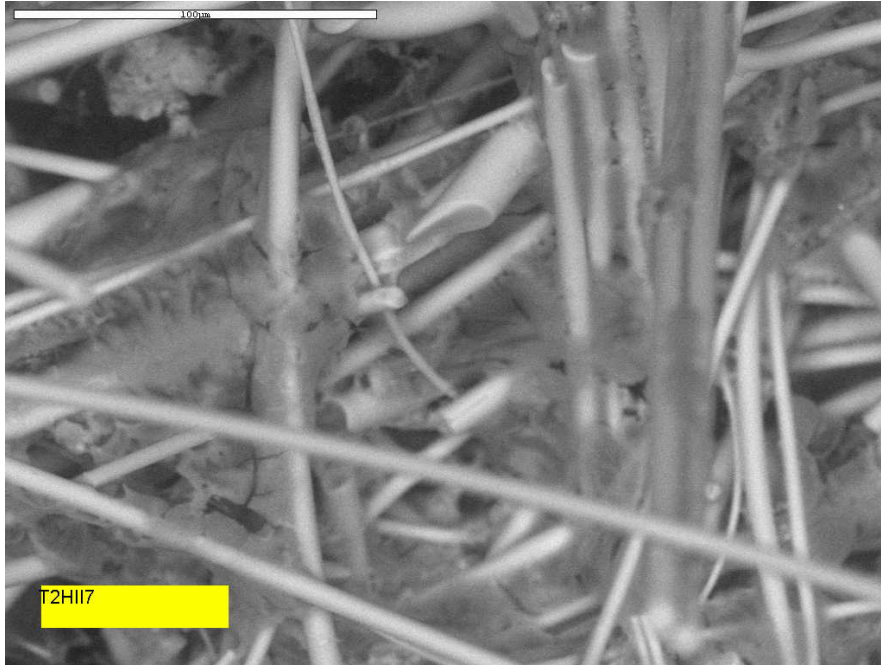


Figure D1-7. SEM image of high-flow interior for another sample area. (T2HII7)

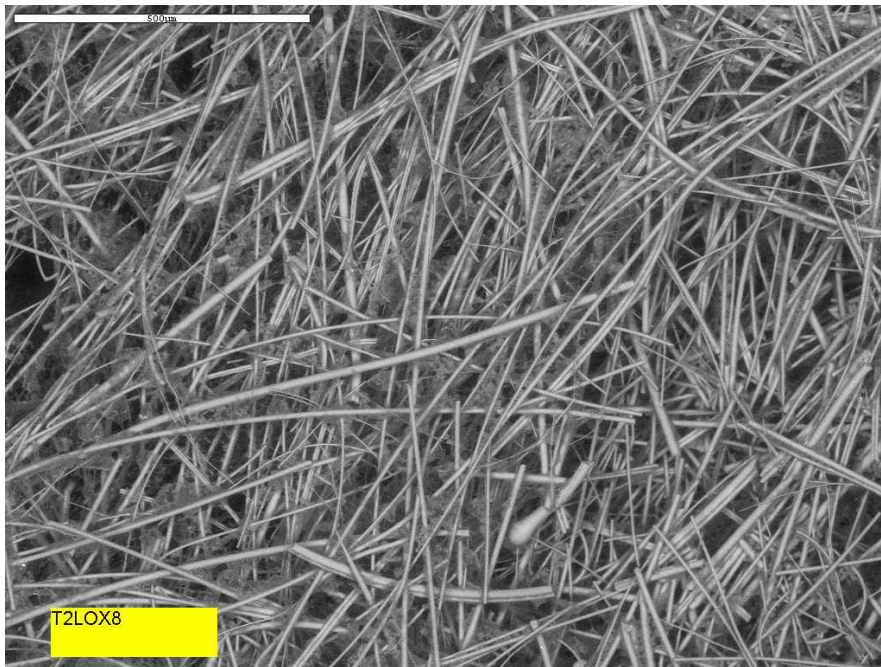


Figure D1-8. SEM image overview for exterior of the low-flow sample. (T2LOX8)

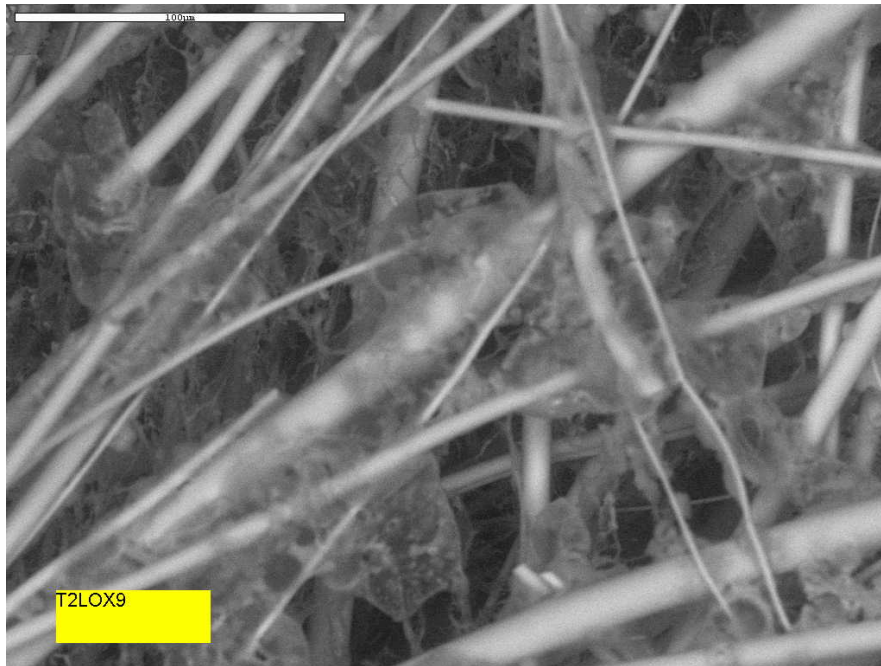


Figure D1-9. SEM image of the upper left portion of Figure D1-8, low-flow exterior. (T2LOX9)

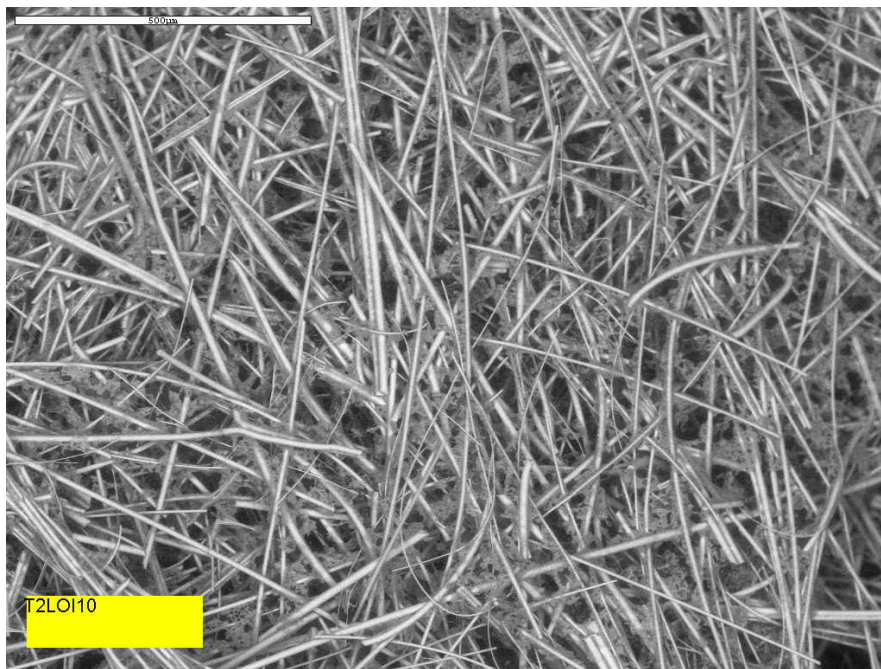


Figure D1-10. SEM image overview for interior of the low-flow sample. (T2LOI10)

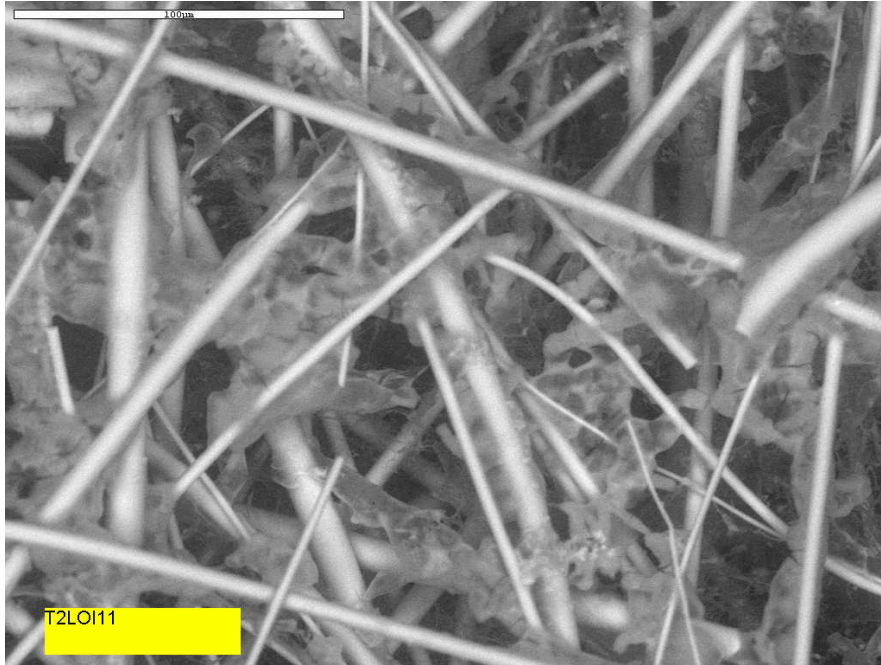


Figure D1-11. SEM image on the center of Figure D1-10, low-flow interior. (T2LOI11)

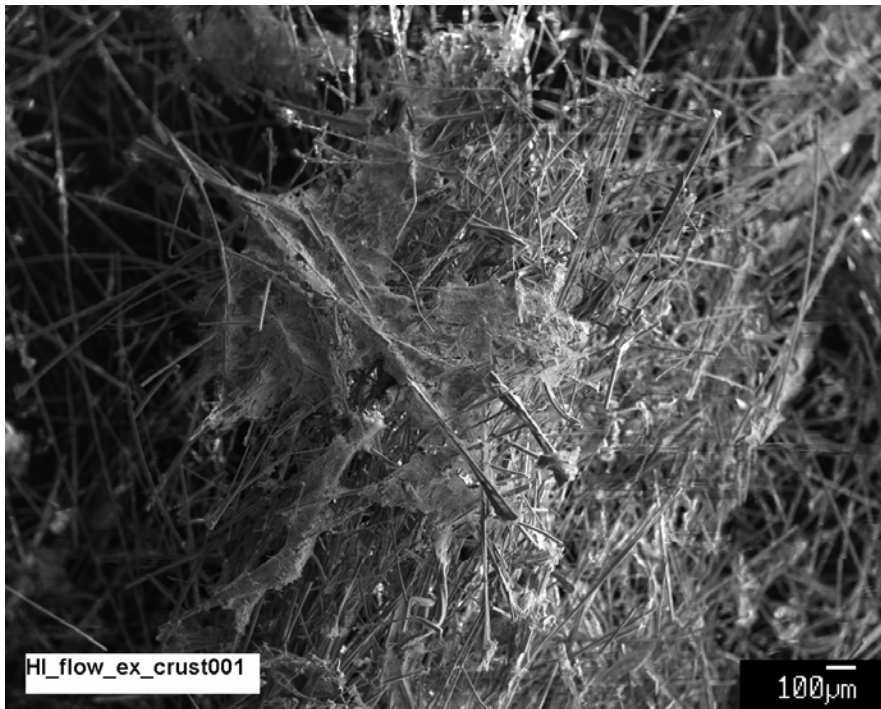


Figure D1-12. SEM image overview of exterior crust. (HI_flow_ex_crust001)

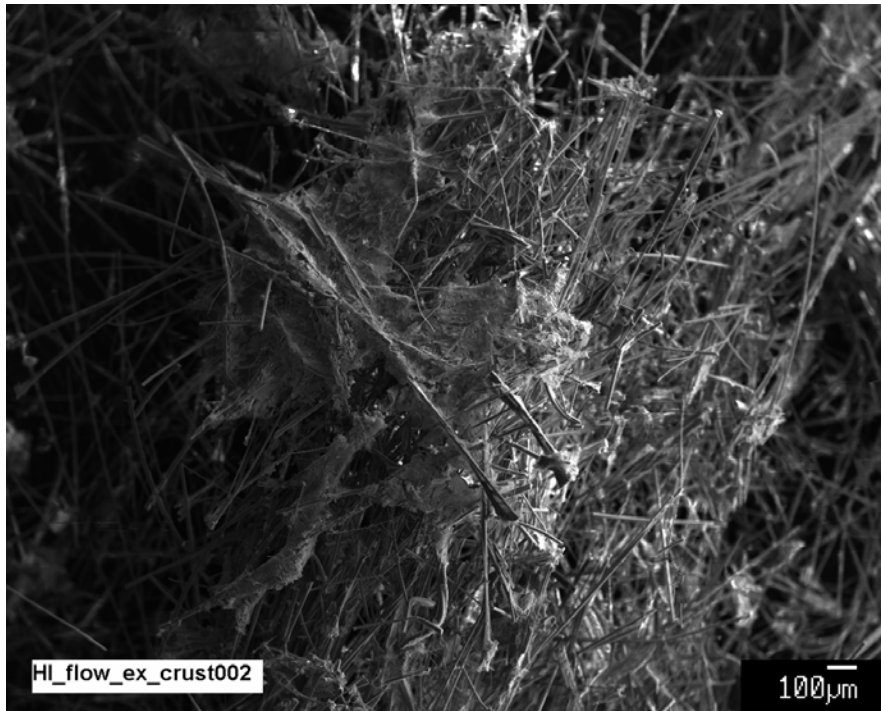


Figure D1-13. SEM image overview of the same area of Figure D1-12. (HI_flow_ex_crust002)

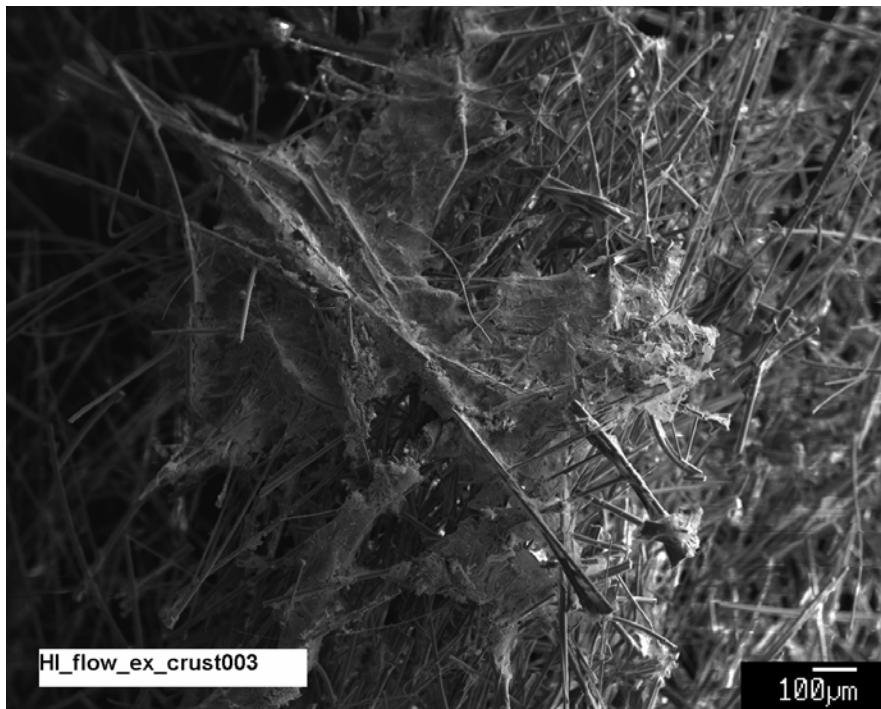


Figure D1-14. SEM image close-up view of crust. (HI_flow_ex_crust003)

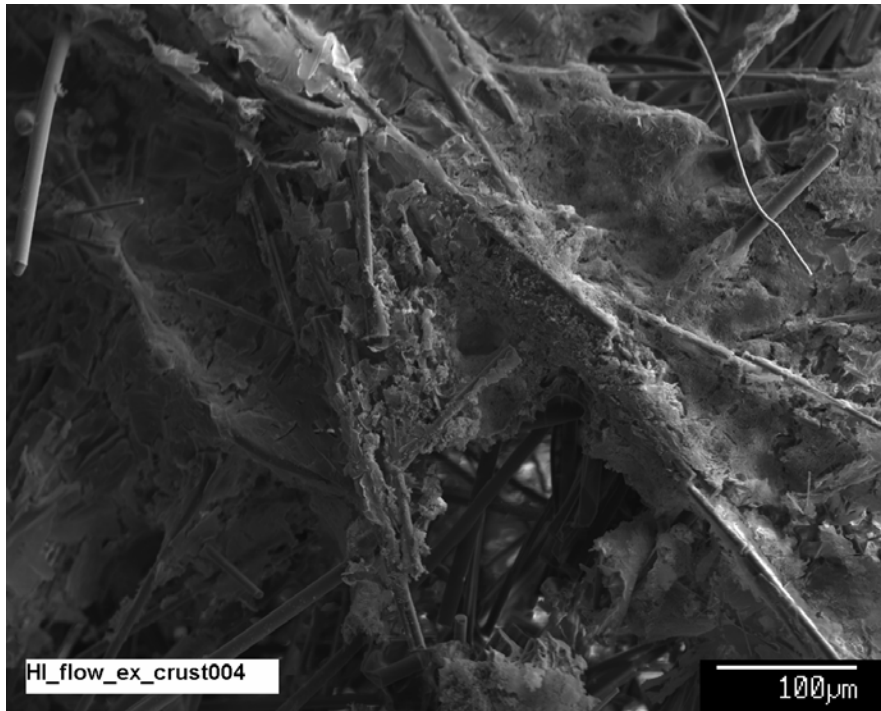


Figure D1-15. SEM image of crust at 150 times magnification. (HI_flow_ex_crust004)

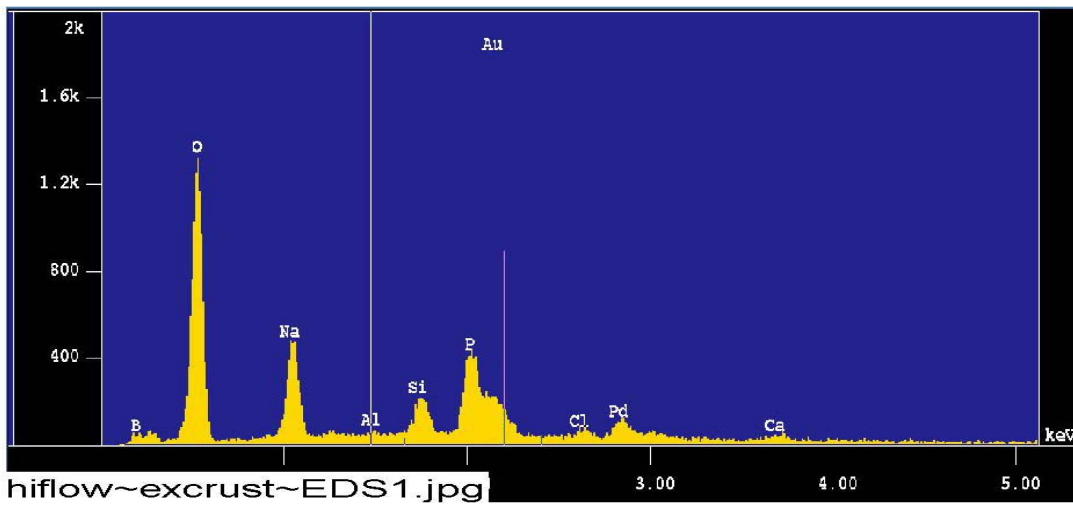


Figure D1-16. Counting spectrum image of the deposit area in Figure D1-15. (hiflow~excrust~EDS1)

The results from the chemical composition analysis for hiflow~excrust~EDS1 are given Table D1-1.

Table D1-1. The Chemical Composition for hiflow~excrust~EDS1 (Figure D1-16)

Feb 25 11:07 2005 /tmp/eds_pout.log Page 1

```

Group       : NRC
Sample      : Hiflow_excrust ID# : 1
Comment     : deposit picture4
Condition   : Full Scale : 20KeV(10eV/ch,2Kch)
              Live Time  : 60.000 sec Aperture # : 2
              Acc. Volt  : 15.0 KV Probe Current : 1.002E-08 A
              Stage Point : X=55.412 Y=74.945 Z=11.147
              Acq. Date  : Fri Feb 25 10:59:03 2005
    
```

Element	Mode	ROI (KeV)	K-ratio(%)	+/-	Net/Background
O K	Normal	0.25- 0.77	34.5490	0.0043	10752 / 46
Al K	Normal	1.26- 1.78	0.0857	0.0006	126 / 114
Si K	Normal	1.50- 2.07	1.0405	0.0012	1534 / 150
Ca K	Normal	3.40- 4.30	0.4471	0.0054	349 / 27
Na K	Normal	0.83- 1.28	3.7139	0.0097	3635 / 40
P K	Normal	1.75- 2.38	5.2367	0.0043	3892 / 132
Cl K	Normal	2.34- 3.06	0.9080	0.0010	749 / 48

 Chi_square = 15.4770

Element	Mass%	Atomic%	ZAF	Z	A	F
O	69.992	80.1268	0.7836	0.9917	0.7902	1.0000
Al	0.265	0.1798	1.1962	1.0046	1.1939	0.9974
Si	2.944	1.9201	1.0946	0.9924	1.1082	0.9953
Ca	1.156	0.5280	0.9997	1.0065	0.9932	1.0001
Na	11.074	8.8224	1.1534	0.9963	1.1562	1.0013
P	11.995	7.0932	0.8861	1.1964	0.7411	0.9993
Cl	2.574	1.3297	1.0964	1.0507	1.0440	0.9996

 Total 100.000 100.0000
 Normalization factor = 2.5852

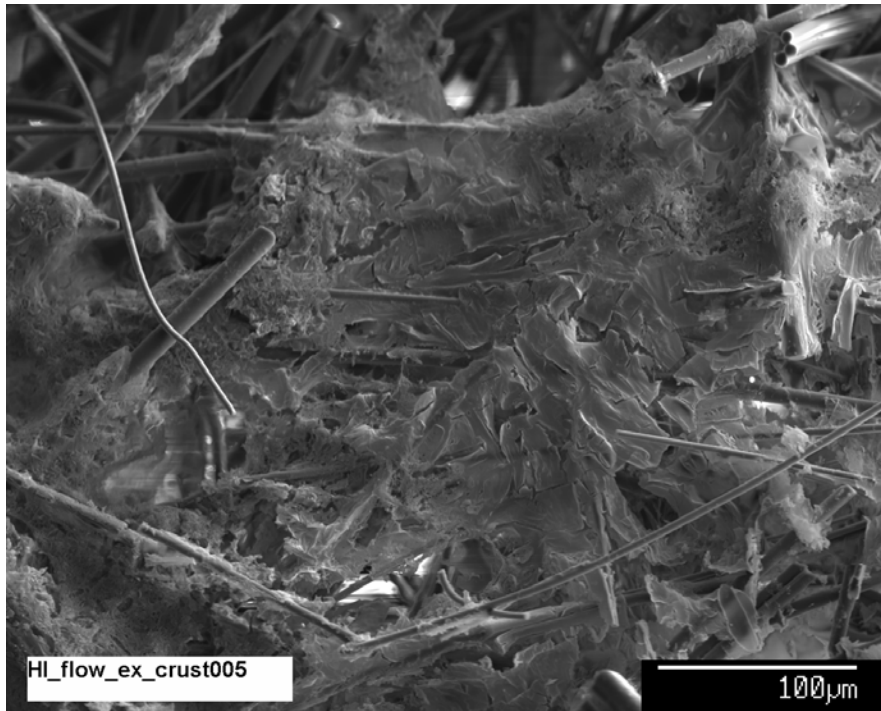


Figure D1-17. SEM image of a new exterior crust area at 270 times magnification. (HI_flow_ex_crust005)

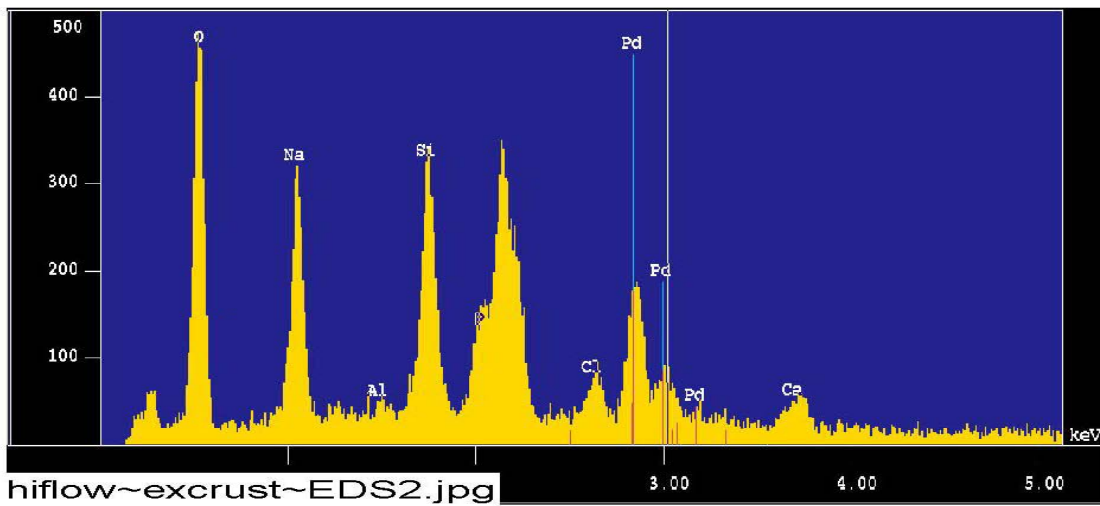


Figure D1-18. Counting spectrum image of the deposit area in Figure D1-17. (hiflow~excrust~EDS2)

The results from the chemical composition analysis for hiflow~excrust~EDS2 are given in Table D1-2.

Table D1-2. The Chemical Composition for hiflow~excrust~EDS2 (Figure D1-18)

Feb 25 11:18 2005 /tmp/eds_pout.log Page 1

```

Group       : NRC
Sample      : Hiflow_excrust ID# : 2
Comment     : deposit picture5
Condition   : Full Scale : 20KeV(10eV/ch,2Kch)
              Live Time  : 60.000 sec Aperture # : 2
              Acc. Volt  : 15.0 KV Probe Current : 1.001E-08 A
              Stage Point : X=55.001 Y=74.845 Z=11.147
              Acq. Date  : Fri Feb 25 11:13:54 2005
    
```

Element	Mode	ROI (KeV)	K-ratio(%)	+/-	Net/Background
O K	Normal	0.25- 0.77	13.1976	0.0028	4103 / 40
Al K	Normal	1.26- 1.78	0.1087	0.0005	160 / 122
Si K	Normal	1.50- 2.07	1.6773	0.0013	2470 / 108
Ca K	Normal	3.40- 4.30	0.4860	0.0055	379 / 20
Na K	Normal	0.83- 1.28	2.1936	0.0079	2145 / 31
P K	Normal	1.75- 2.38	0.6450	0.0030	479 / 162
Cl K	Normal	2.34- 3.06	1.2020	0.0010	990 / 40

Chi_square = 13.2170

Element	Mass%	Atomic%	ZAF	Z	A	F
O	63.140	74.8335	0.8873	0.9904	0.8959	1.0000
Al	0.704	0.4946	1.2005	1.0030	1.2008	0.9967
Si	9.996	6.7486	1.1053	0.9908	1.1175	0.9982
Ca	2.633	1.2457	1.0047	1.0045	1.0001	1.0001
Na	13.248	10.9272	1.1201	0.9948	1.1246	1.0012
P	3.262	1.9970	0.9380	1.1944	0.7868	0.9981
Cl	7.017	3.7533	1.0828	1.0488	1.0332	0.9992

Total 100.000 100.0000
Normalization factor = 5.3920

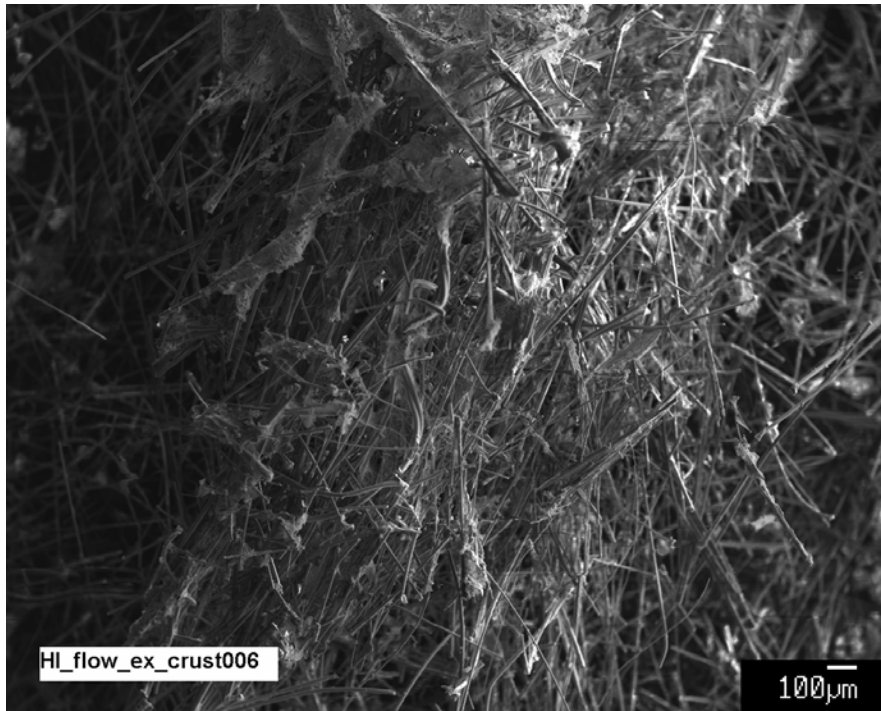


Figure D1-19. SEM image overview of another area for the exterior crust. (HI_flow_ex_crust006)

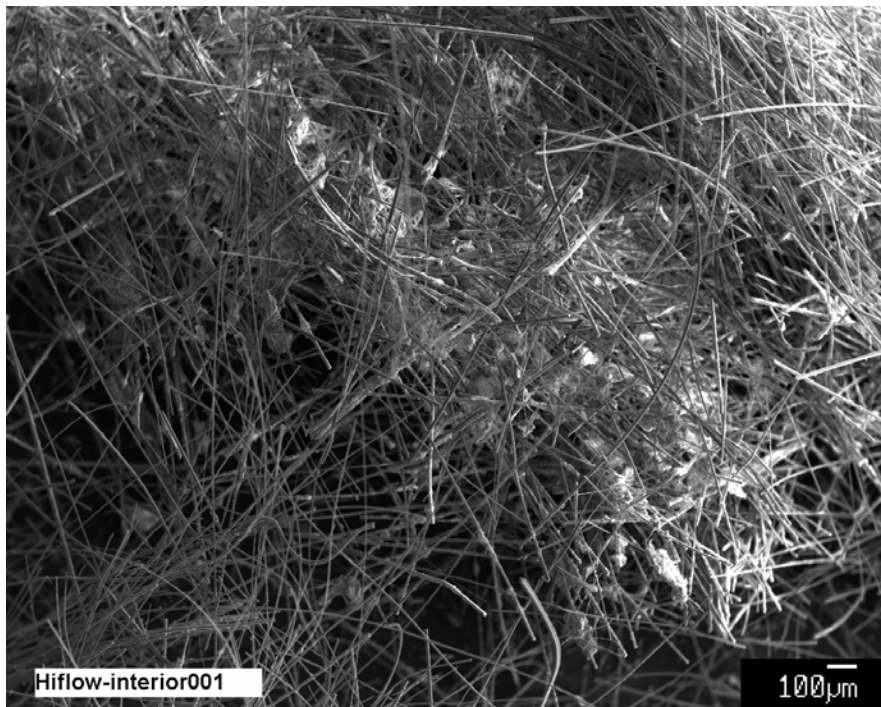


Figure D1-20. Test #2, Day-16 SEM image overview. (Hiflow-interior001)

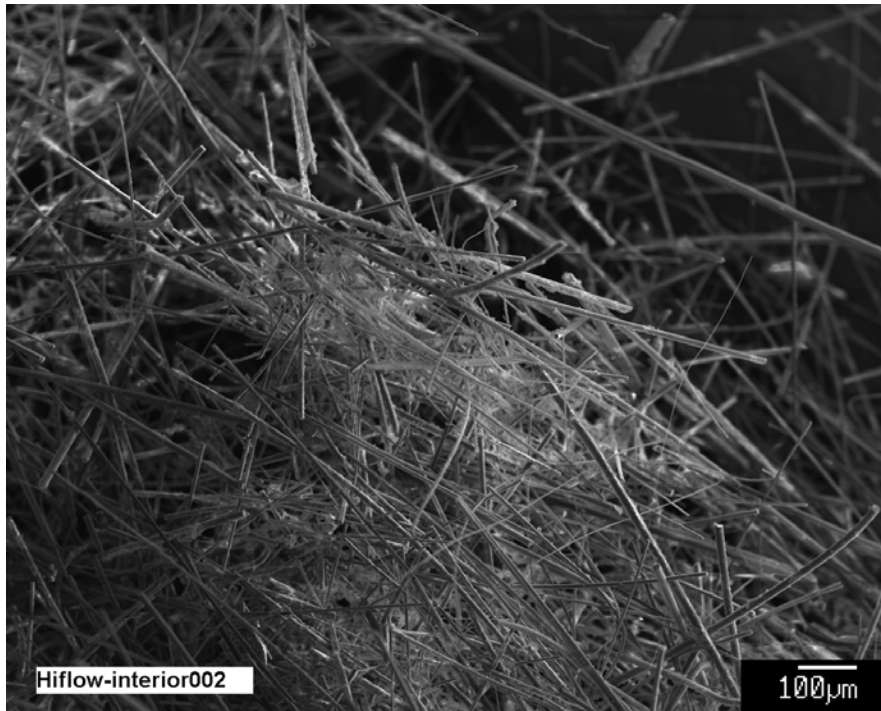


Figure D1-21. Test #2, Day-16 SEM image for high-flow interior. (Hiflow-interior002)

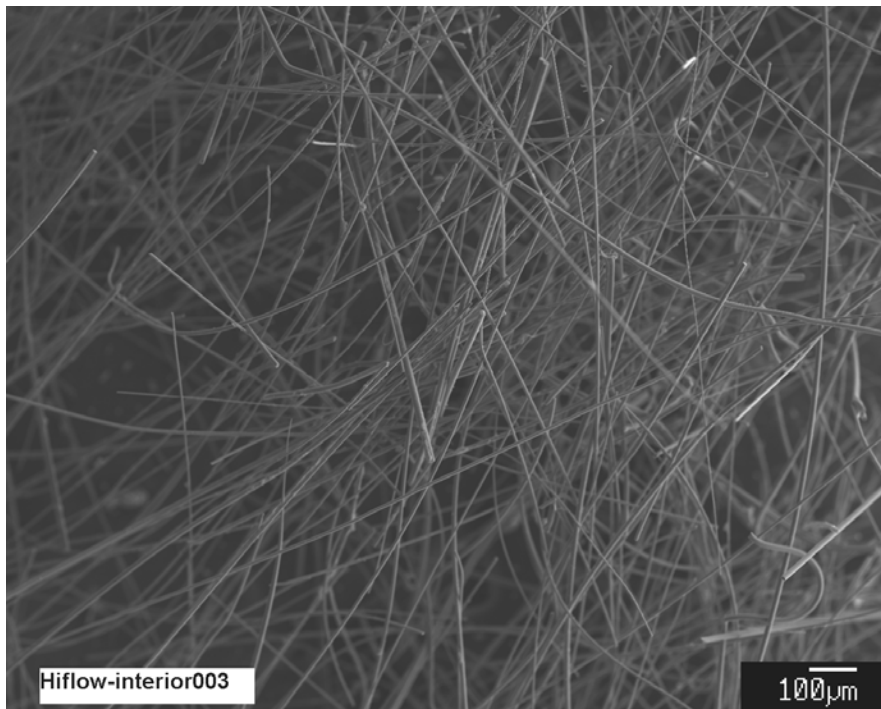


Figure D1-22. Test #2, Day-16 SEM image showing clean fibers. (Hiflow-interior003)

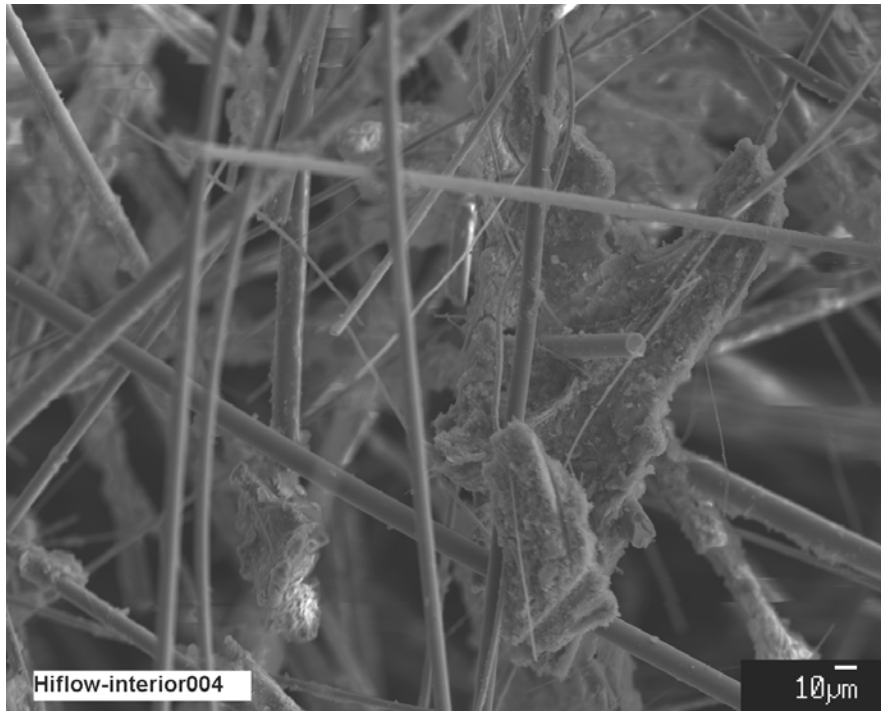


Figure D1-23. Test #2, Day-16 SEM image of deposits for high-flow interior. (Hiflow-interior004)



Figure D1-24. Test #2, Day-4 SEM image zoomed in on deposits on fiberglass, magnification 5000 times. (Hiflow-interior005)

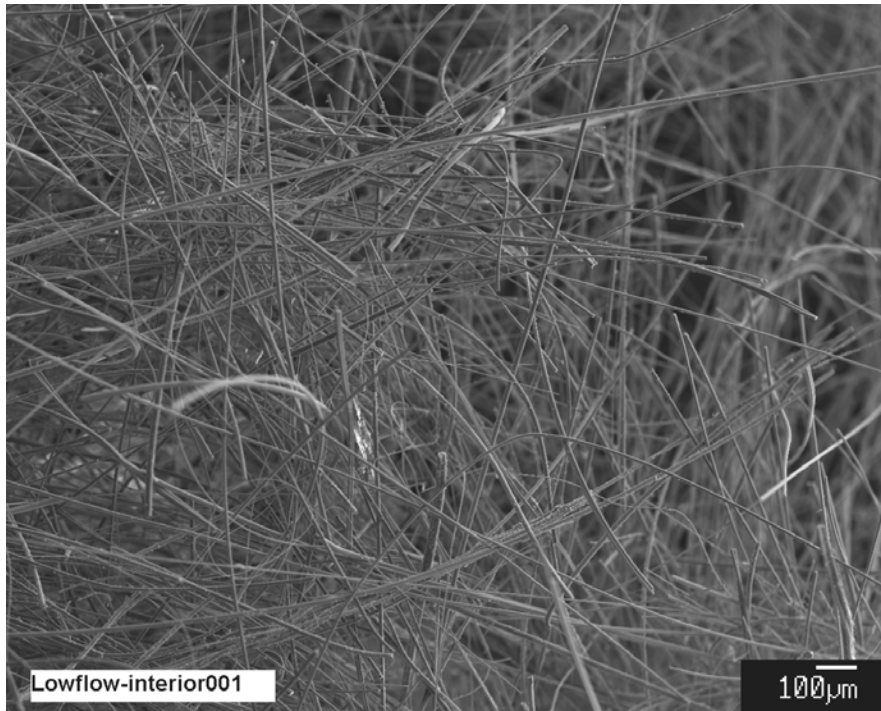


Figure D1-25. Test #2, Day-16 SEM image overview for low-flow interior. (Lowflow-interior001)

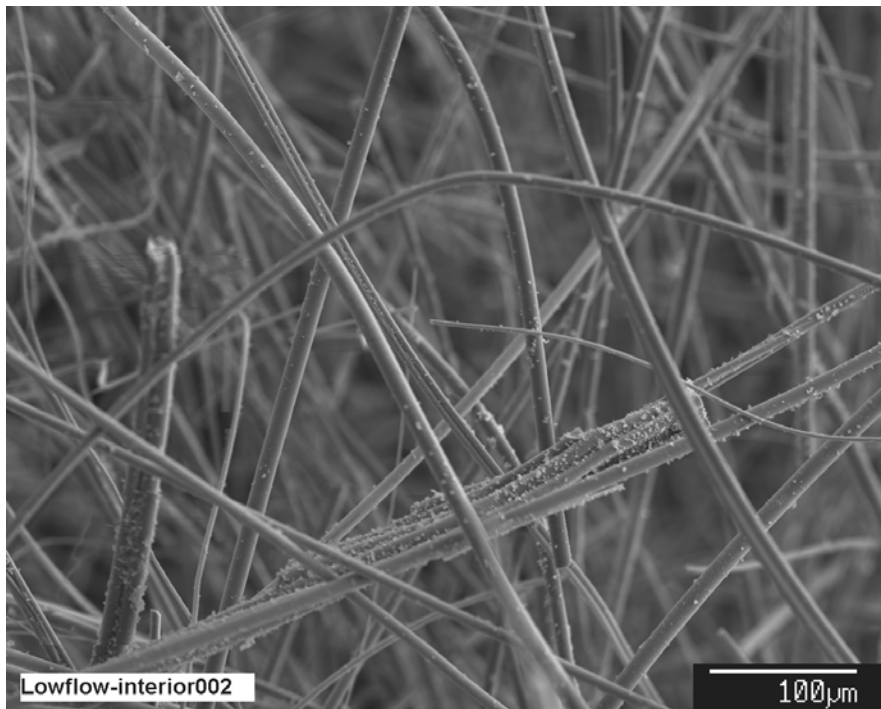


Figure D1-26. Test-2 Day-16 SEM close-up image of Figure D1-25. (Lowflow-interior002)

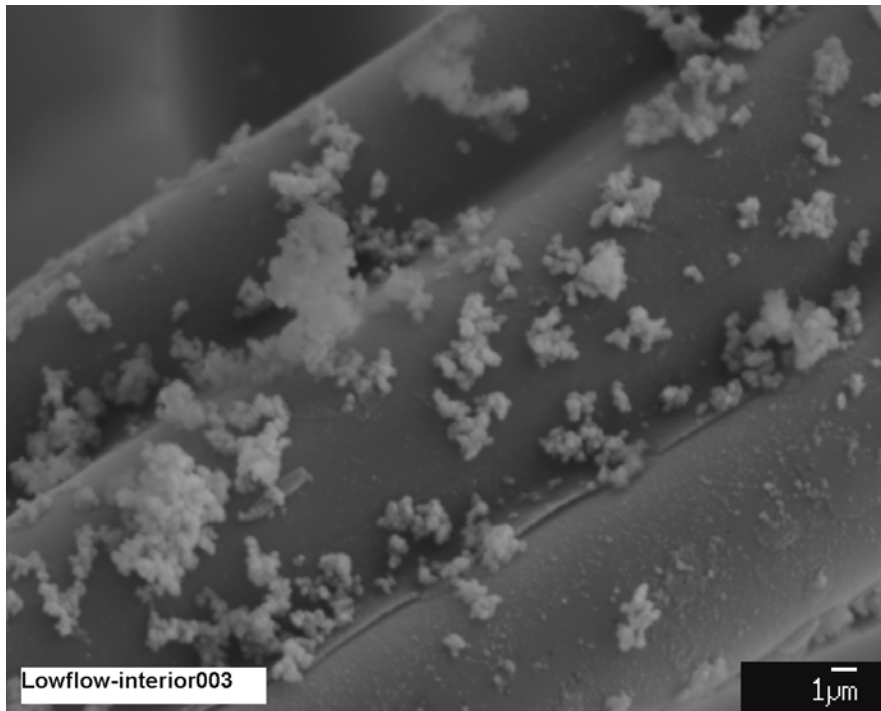


Figure D1-27. Test #2, Day-16 SEM image at 3500 times magnification of deposits shown in Figure D1-26. (Lowflow-interior003)

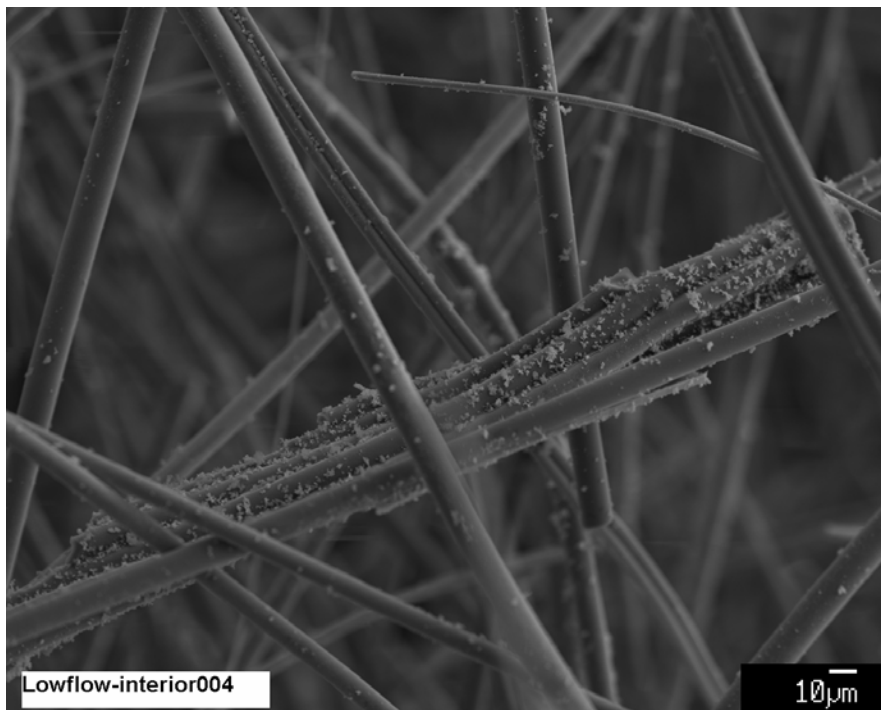


Figure D1-28. Test #2, Day-16 SEM image at 370 times magnification showing close-up of deposits in Figure D1-26. (Lowflow-interior004)

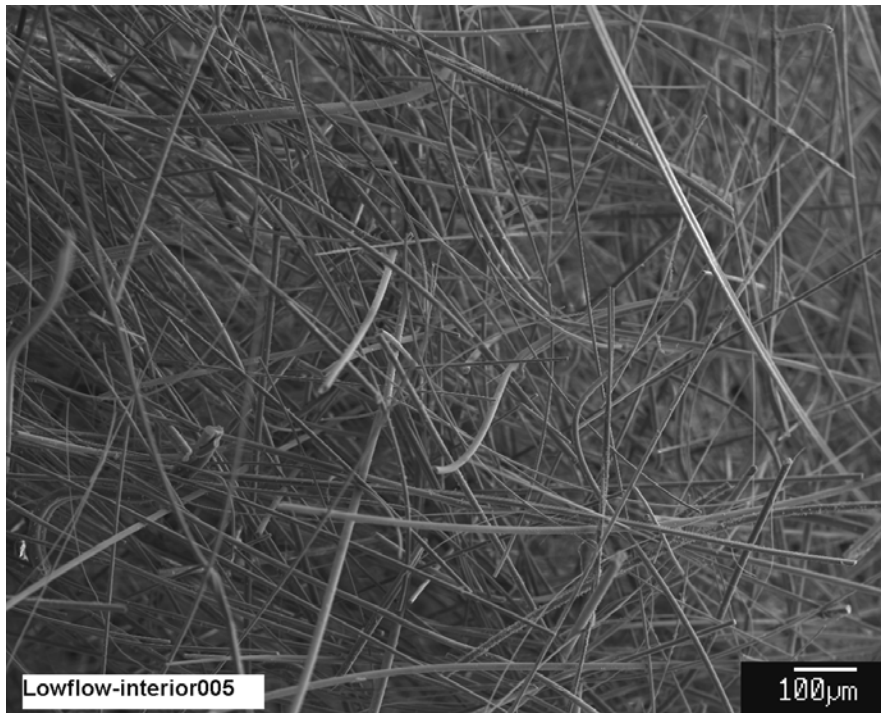


Figure D1-29. Test #2, Day-16 SEM image overview of a new sample area. (Lowflow-interior005)

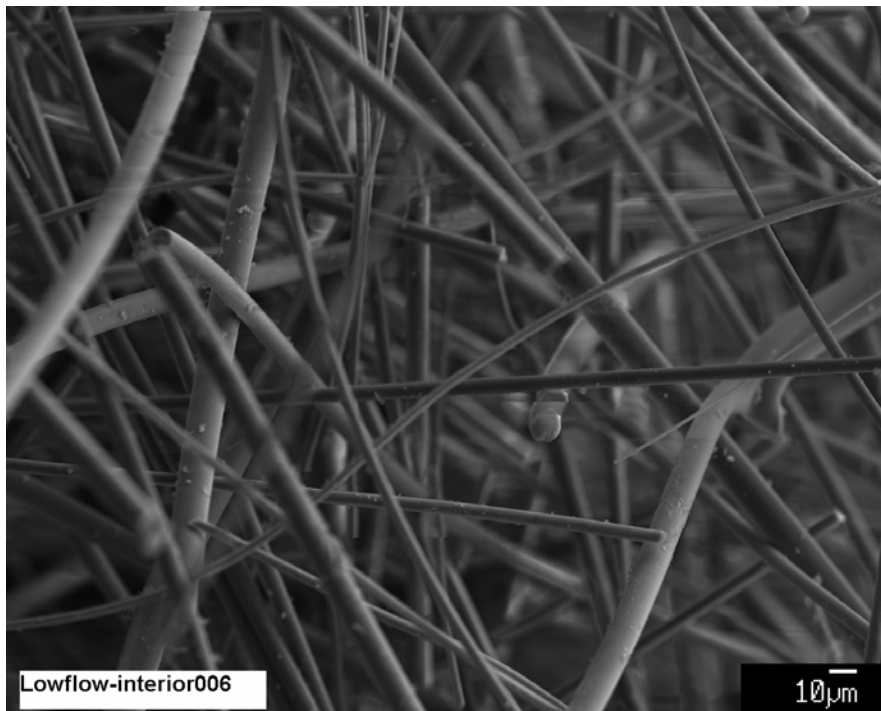


Figure D1-30. Test #2, Day-16 SEM image zooming in on Figure D1-29. (Lowflow-interior006)

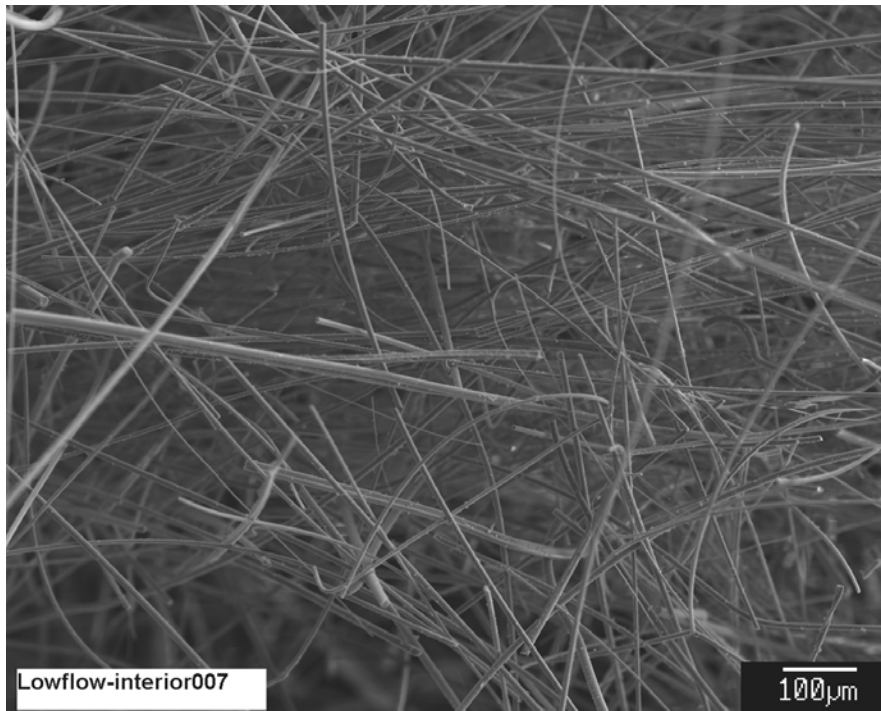


Figure D1-31. Test #2, Day-16 SEM image showing a cleaner appearance than seen in some high-flow interior samples. (Lowflow-interior007)



Figure D1-32. Test #2, Day-16 SEM image overview for low-flow exterior. (Lowflow-exterior001)

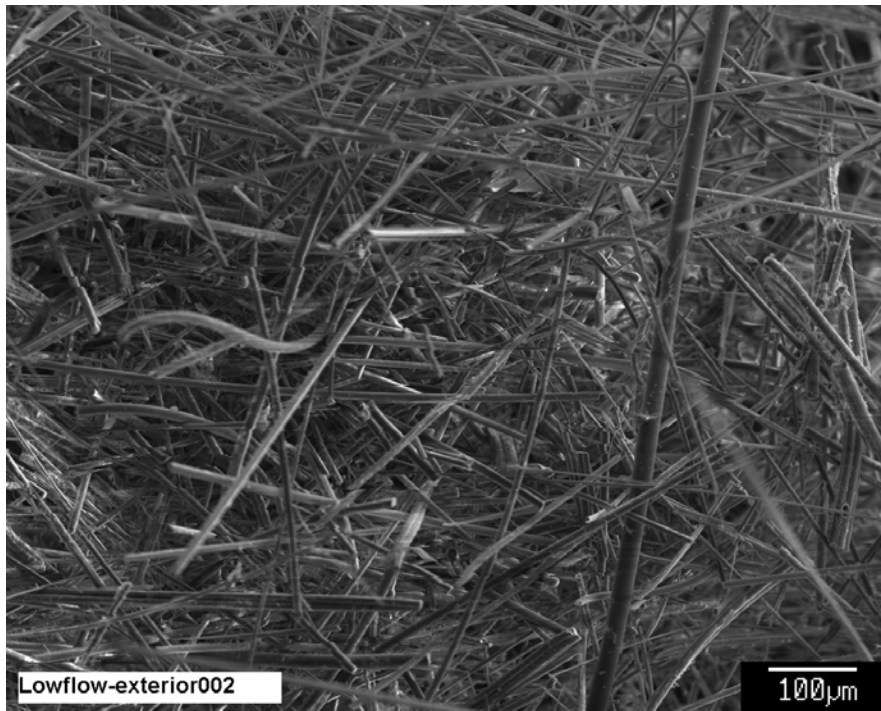


Figure D1-33. Test #2, Day-16 SEM image close-up (charging) of Figure D1-32. (Lowflow-exterior002)

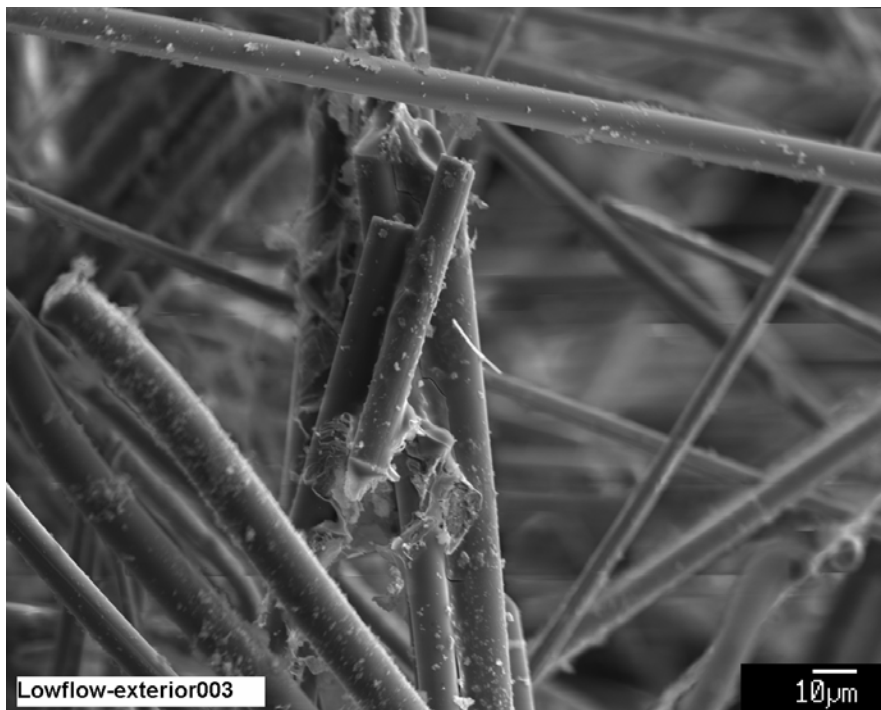


Figure D1-34. Test #2, Day-16 SEM image zooming in on deposits at 600 times magnification. (Lowflow-exterior003)

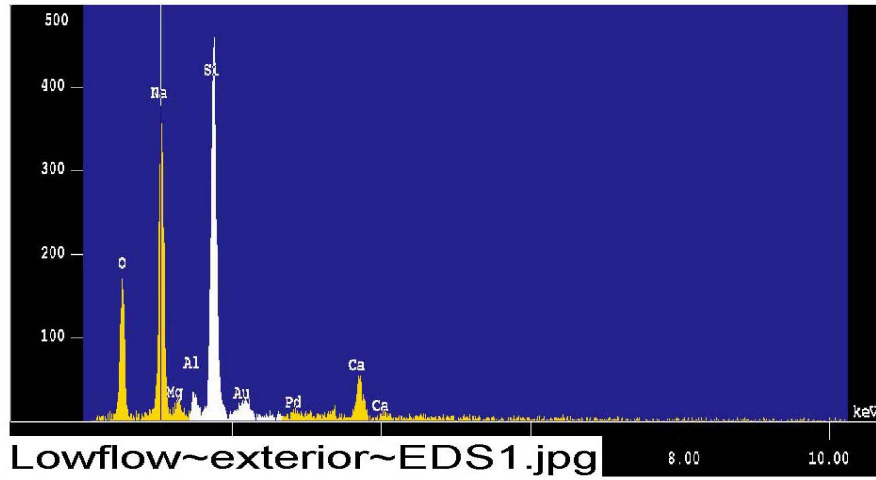


Figure D1-35. Test #2, Day-16 counting spectrum image for a particle on the fiberglass shown in Figure D1-34. (Lowflow~exterior~EDS1)

The results from the chemical composition analysis for Lowflow~exterior~EDS1 are given in Table D1-3.

Table D1-3. The Chemical Composition for EDS1

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```

Group       : NRC
Sample      : T2D16 Low-flow ID# : 1
Comment     : Exterior particle on fiberglass
Condition   : Full Scale : 20KeV(10eV/ch,2Kch)
              Live Time  : 60.000 sec   Aperture #   : 3
              Acc. Volt  : 15.0 KV      Probe Current : 2.003E-08 A
              Stage Point: X=52.122 Y=69.909 Z=12.467
              Acq. Date  : Sun Mar 6 21:42:04 2005
    
```

Element	Mode	ROI (KeV)	K-ratio(%)	+/-	Net/Background
O K	Normal	0.25- 0.77	21.1989	0.0017	1491 / 6
Na K	Normal	0.83- 1.28	13.6362	0.0082	3016 / 14
Mg K	Normal	1.03- 1.52	0.4152	0.0007	116 / 204
Al K	Normal	1.26- 1.78	0.6657	0.0004	222 / 137
Si K	Normal	1.50- 2.07	11.9355	0.0014	3976 / 24
Ca K	Normal	3.40- 4.30	3.2837	0.0042	579 / 4

Chi_square = 2.8832

Element	Mass%	Atomic%	ZAF	Z	A	F
O	41.276	53.6697	1.0489	0.9914	1.0580	0.9999
Na	24.595	22.2554	0.9716	0.9956	0.9752	1.0007
Mg	0.973	0.8323	1.2621	0.9981	1.2653	0.9993
Al	1.542	1.1892	1.2481	1.0035	1.2512	0.9940
Si	25.465	18.8616	1.1493	0.9912	1.1597	0.9999
Ca	6.149	3.1917	1.0088	1.0039	1.0048	1.0001

Total 100.000 100.0000
Normalization factor = 1.8564

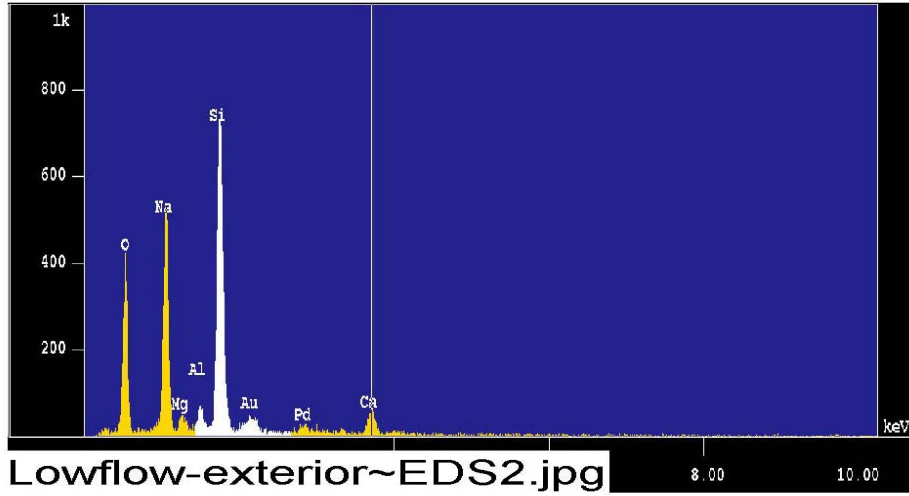


Figure D1-36. Test #2, Day-16 counting spectrum for a particle on the fiberglass shown in Figure D1-34. (Lowflow-exterior~EDS2)

The results from the chemical composition analysis for Lowflow~exterior~EDS2 are given in Table D1-4.

Table D1-4. The Chemical Composition for EDS2

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Group : NRC
 Sample : T2D16 Low-flow ID# : 2
 Comment : Exterior film on fiberglass
 Condition : Full Scale : 20KeV(10eV/ch,2Kch)
 Live Time : 60.000 sec Aperture # : 3
 Acc. Volt : 15.0 KV Probe Current : 2.003E-08 A
 Stage Point : X=52.133 Y=69.884 Z=12.467
 Acq. Date : Sun Mar 6 21:52:13 2005

Element	Mode	ROI (KeV)	K-ratio(%)	+/-	Net/Background
O K	Normal	0.25- 0.77	49.3257	0.0025	3469 / 20
Na K	Normal	0.83- 1.28	19.2296	0.0098	4252 / 22
Mg K	Normal	1.03- 1.52	1.0859	0.0010	303 / 308
Al K	Normal	1.26- 1.78	1.2414	0.0005	414 / 240
Si K	Normal	1.50- 2.07	20.6078	0.0018	6865 / 48
Ca K	Normal	3.40- 4.30	4.1927	0.0049	739 / 10

 Chi_square = 5.6127

Element	Mass%	Atomic%	ZAF	Z	A	F
O	48.657	60.9403	0.9606	0.9936	0.9668	0.9999
Na	19.974	17.4088	1.0115	0.9979	1.0129	1.0007
Mg	1.370	1.1292	1.2286	1.0005	1.2288	0.9993
Al	1.568	1.1644	1.2300	1.0060	1.2299	0.9941
Si	24.091	17.1875	1.1384	0.9937	1.1458	0.9999
Ca	4.340	2.1699	1.0081	1.0068	1.0012	1.0001

 Total 100.000 100.0000
 Normalization factor = 1.0269