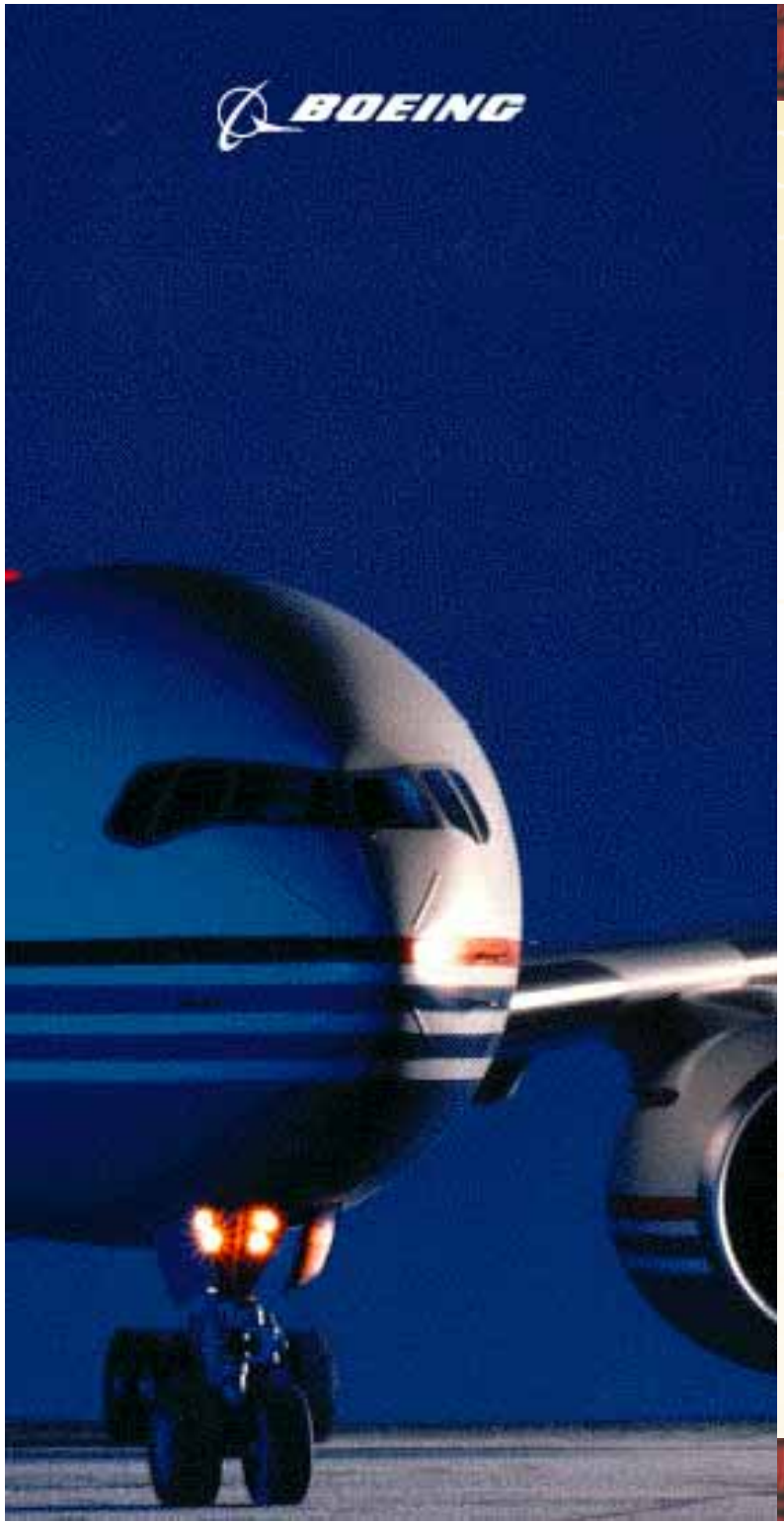

Evaluation of Conformal Coatings as a Tin Whisker Mitigation Strategy

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IPC/JEDEC 8th International Conference on Lead-Free Electronic Components and Assemblies
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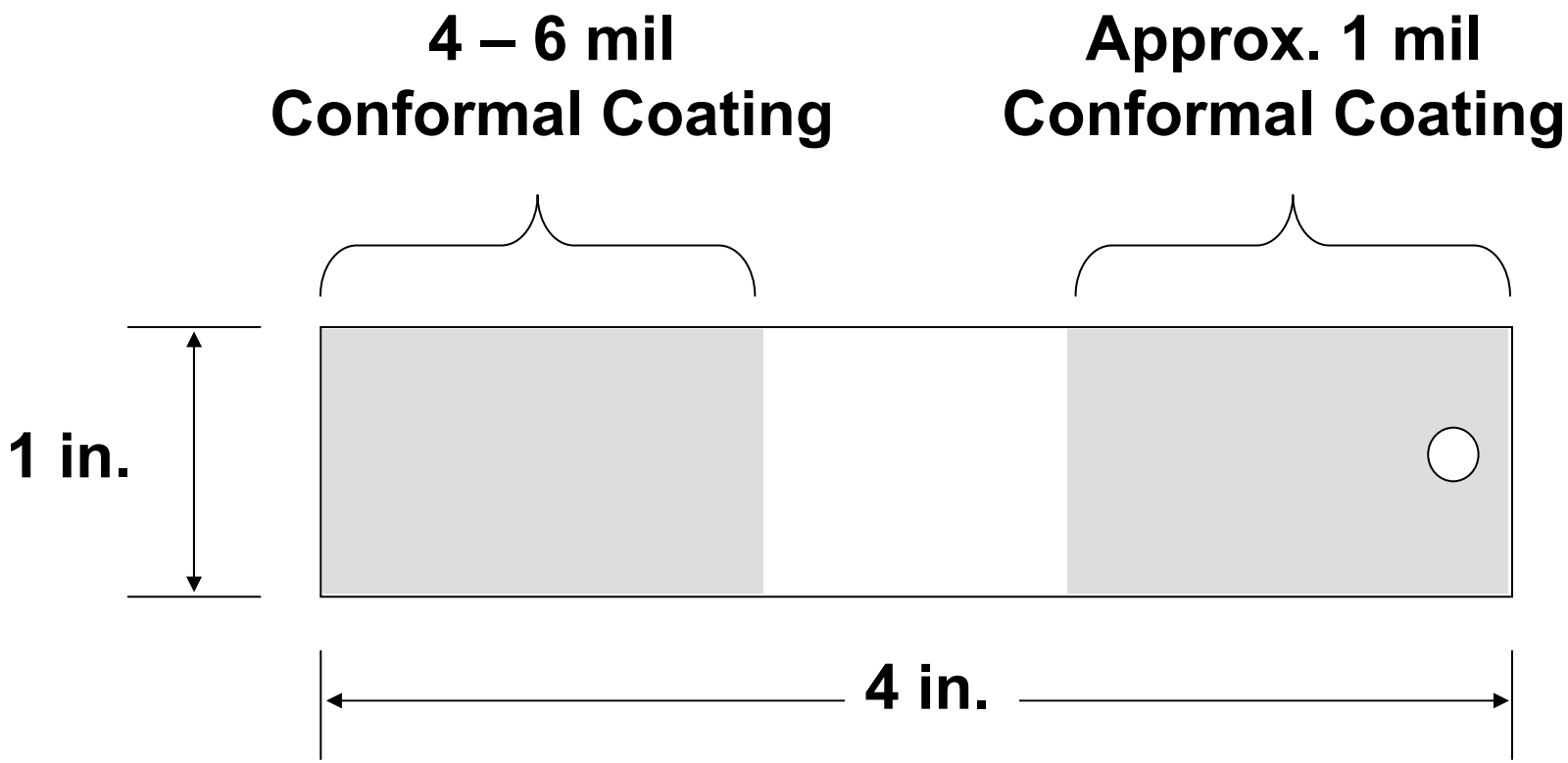
Objective

- Evaluate conformal coatings for mitigation of whisker formation and growth.
  - ✓Conformal coating application is one area that can be controlled by OEMs.
  - ✓Hard, stiff coatings might be able to mechanically suppress whisker formation.
  - ✓Permeability of the coatings to water vapor/oxygen may play a role.
  - ✓If whiskers do grow, the coatings might trap them.

Approach

- The test coupons were designed to grow whiskers as fast as possible (bright Sn over brass).
- The coupons were coated with 6 conformal coatings and then aged.
  - ✓278 days at ambient conditions
  - ✓Then 419 days at 50°C/50%RH
- The coupons were inspected periodically using optical or scanning electron microscopy.

Test Coupon (Brass 260 Plated with 154 Microinches of Bright Tin)

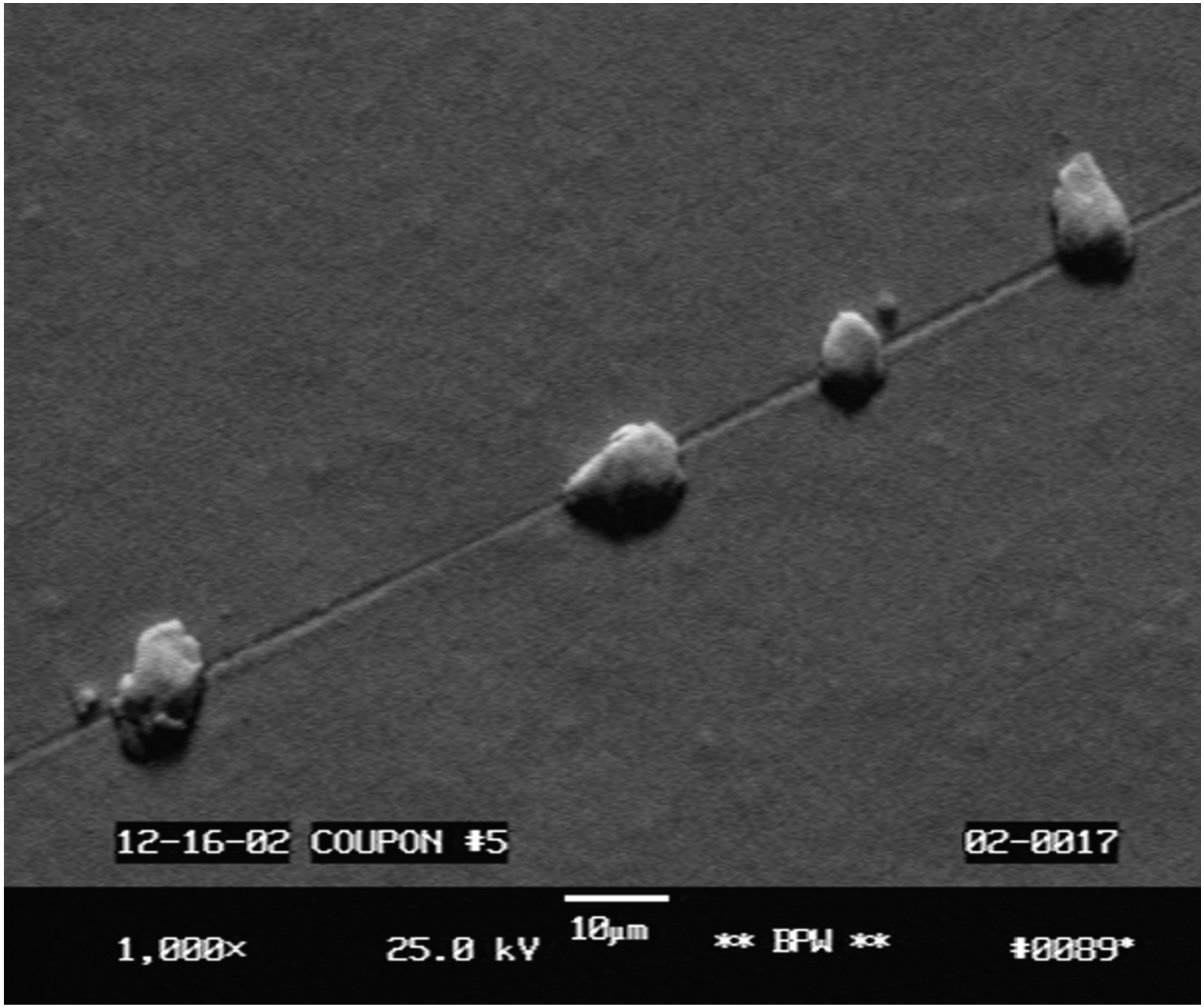


Physical Properties of the Conformal Coatings

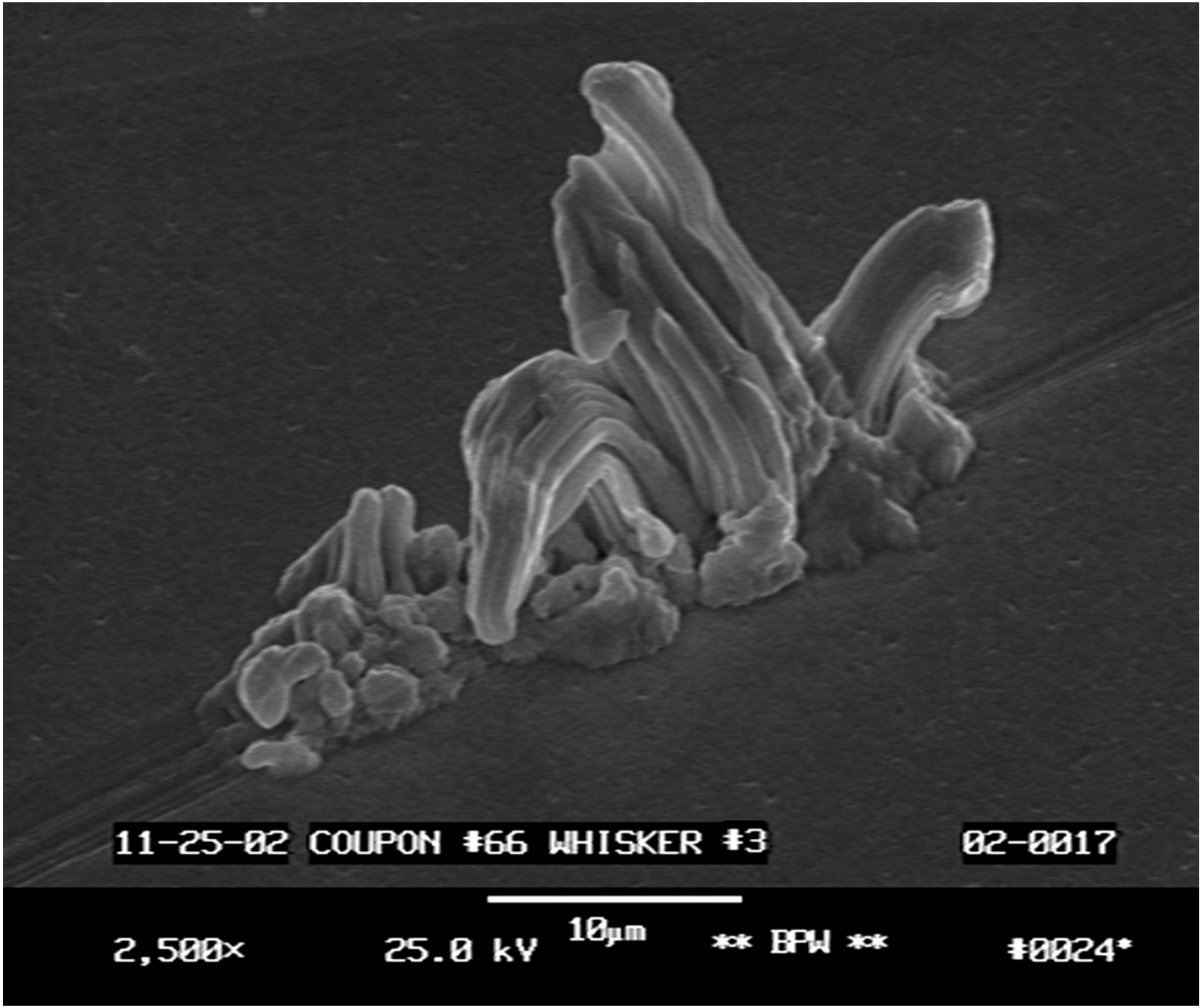
	Coating A (Urethane Acrylic)	Coating B (Silicone)	Coating C (Acrylic)	Coating D (Urethane Acrylic)	Coating E (Urethane Acrylic)	Parylene C
Young's Modulus (psi)	700	900*	1000	60,000	178,000	400,000
Tensile Strength (psi)	250	435		6,000	3,500	10,000
Elongation @ Break (%)	200	30		5	9.5	200
Hardness	Shore A55	Shore D24		Shore D80	Shore D70	Rockwell R80 (approx. Shore D75)
Oxygen Permeability at 25°C (cm^3 (STP)•mil/(100 in^2/day•atm)	200*	50,000*		200*	200*	7.2
Water Vapor Transmission at 90%RH, 37°C (gm•mil/(100 in^2•day)	2*	5*		2*	1.8	0.21

***Estimated**

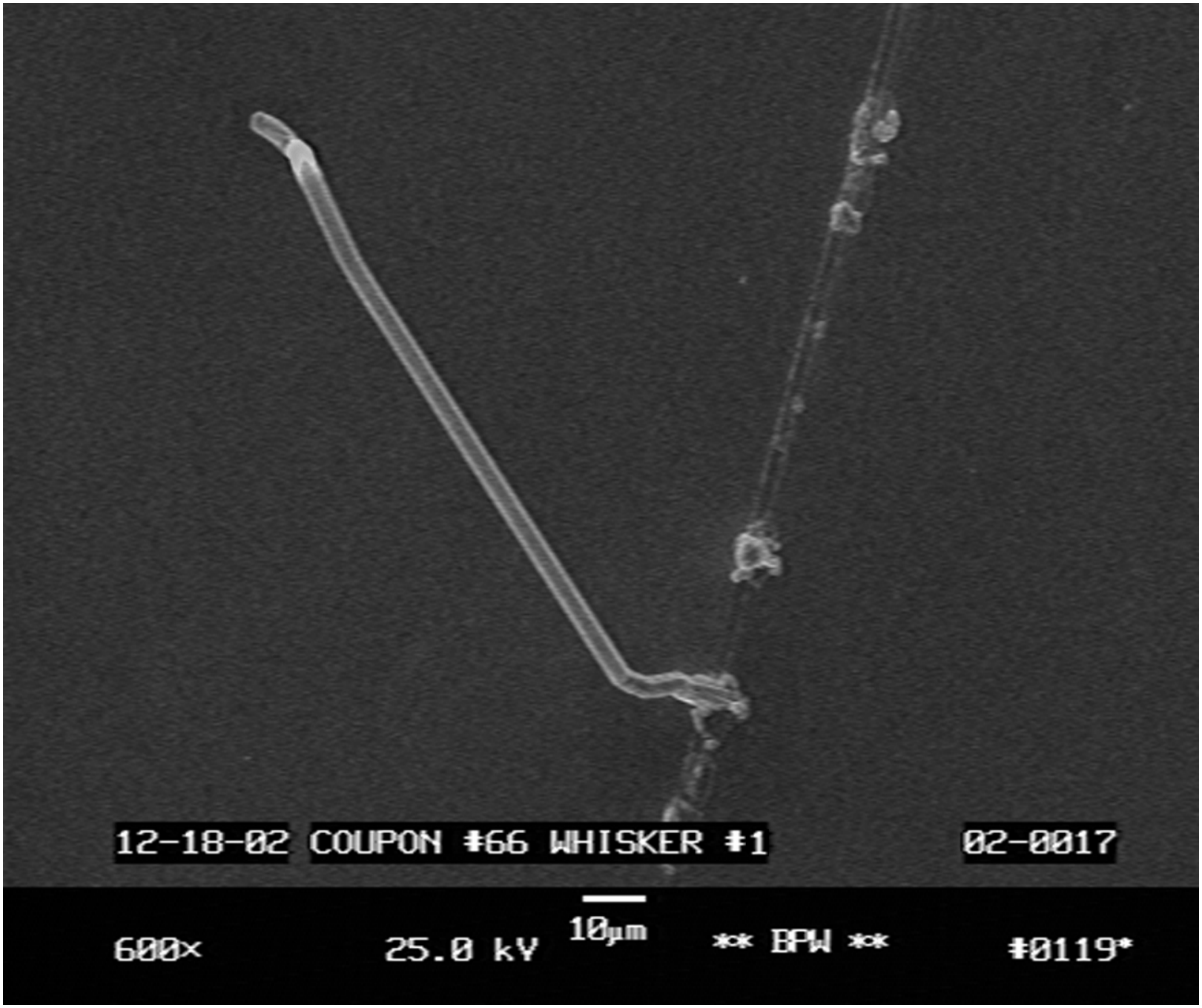
Nodule



Odd Shaped Eruption (OSE)

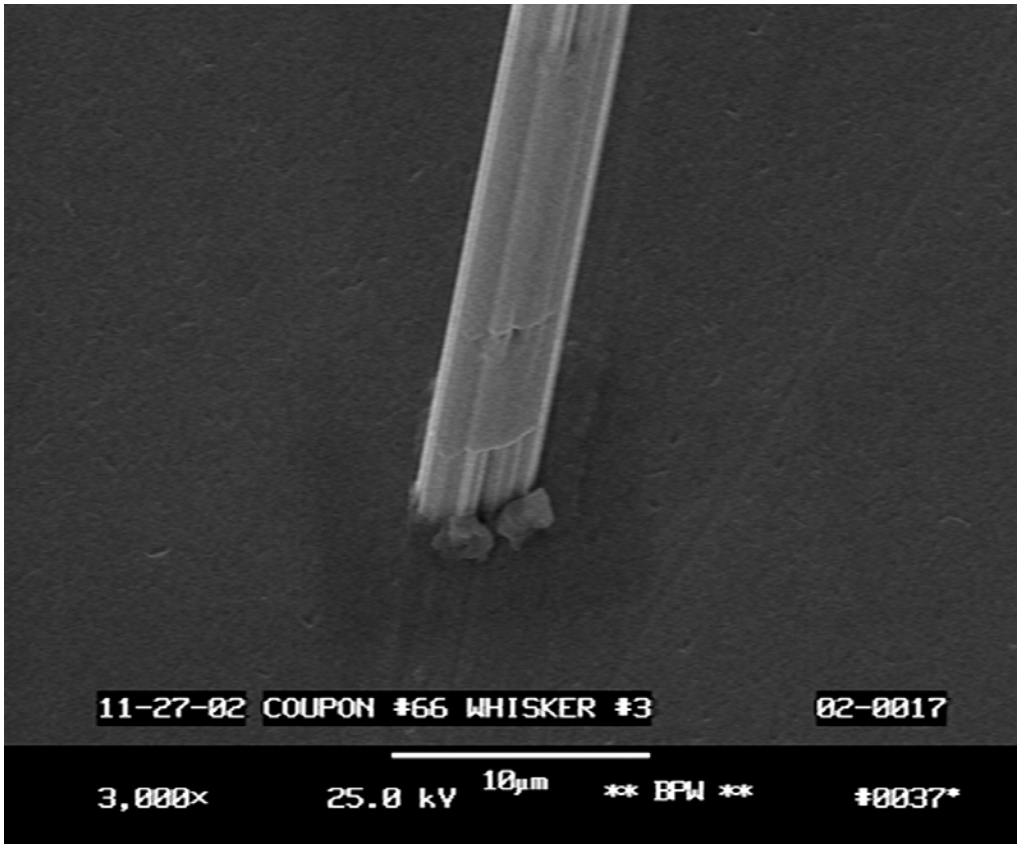


Whisker

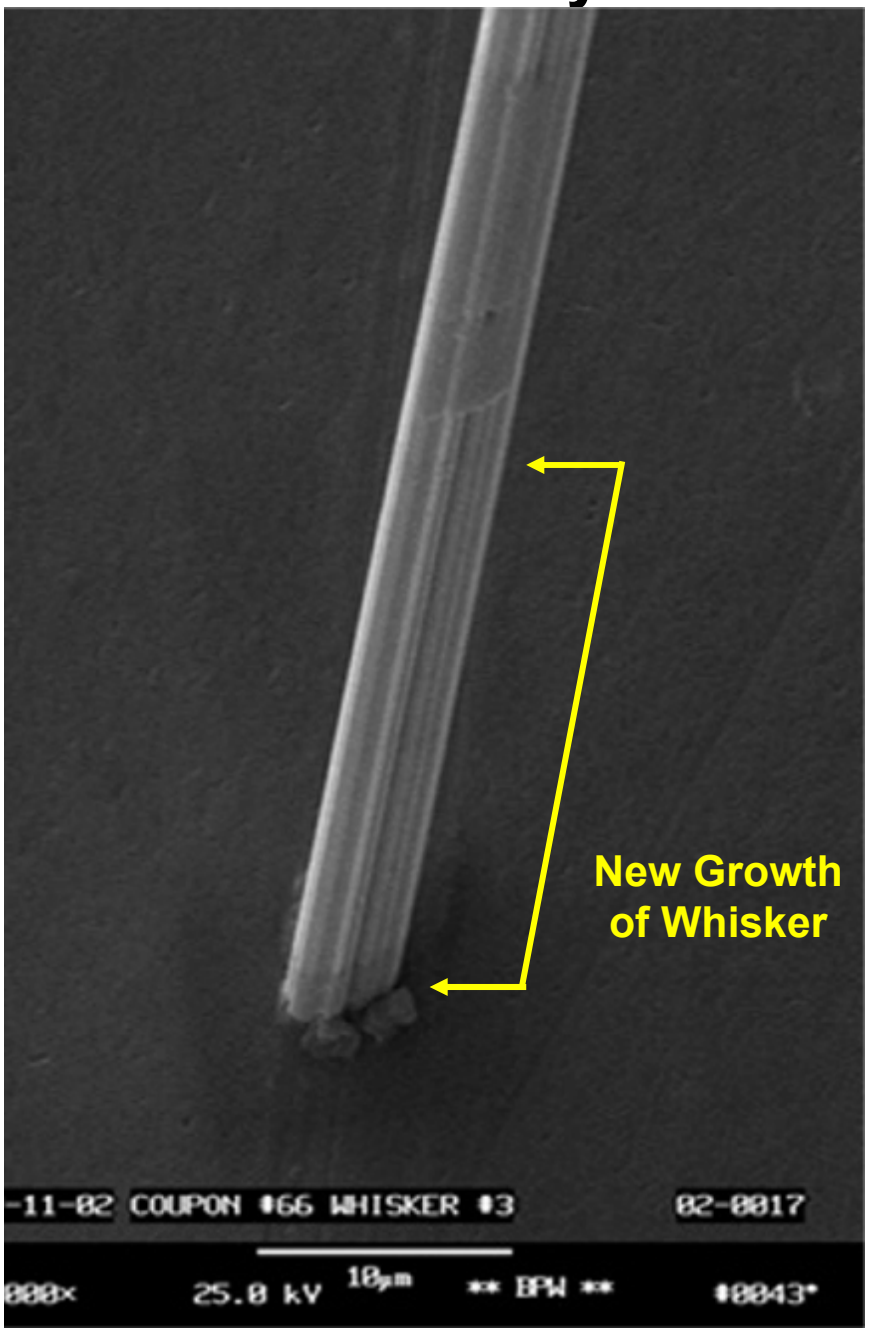


Note: This coupon was not coated with a conformal coating

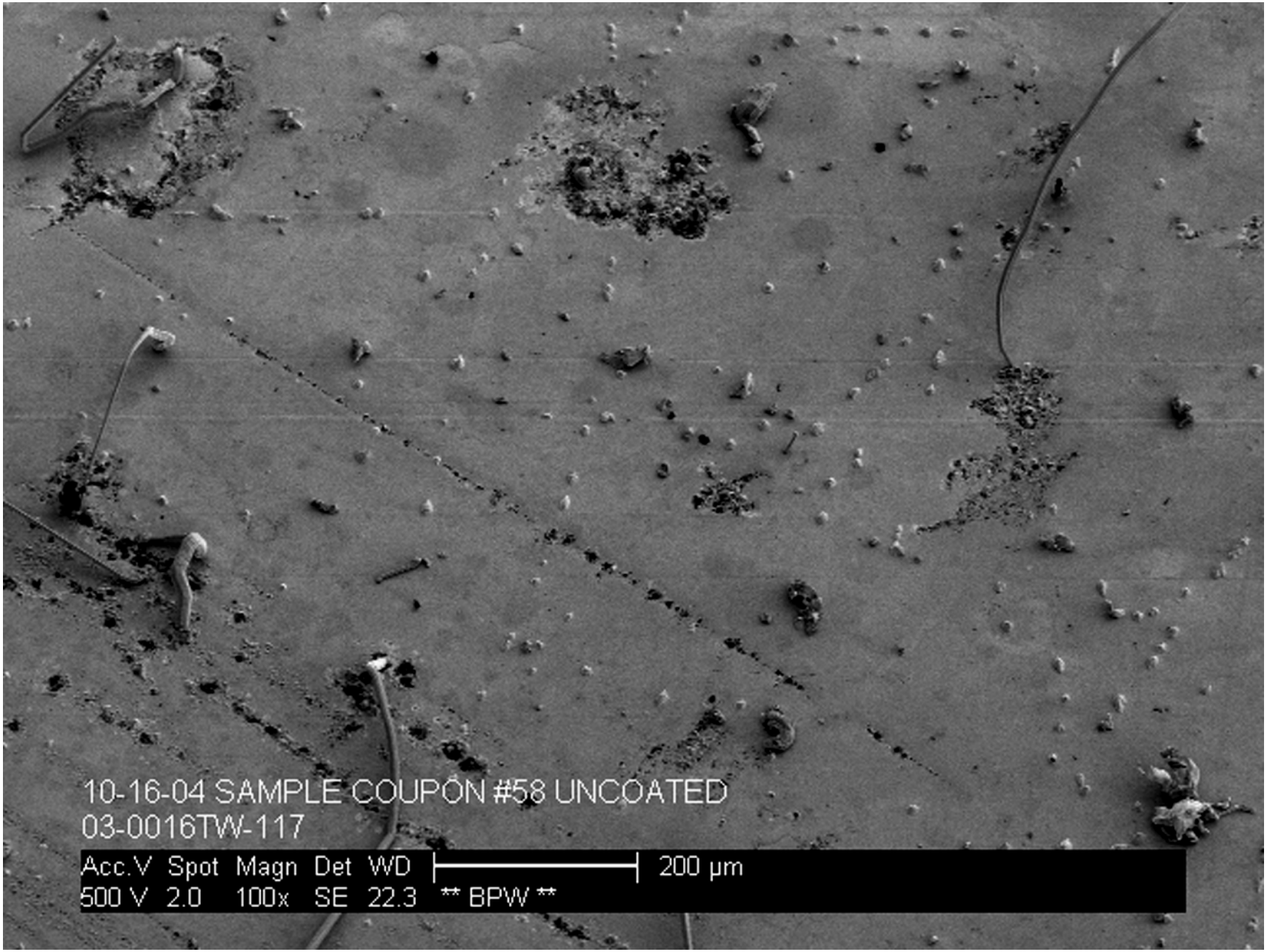
Organic? Material on Whisker



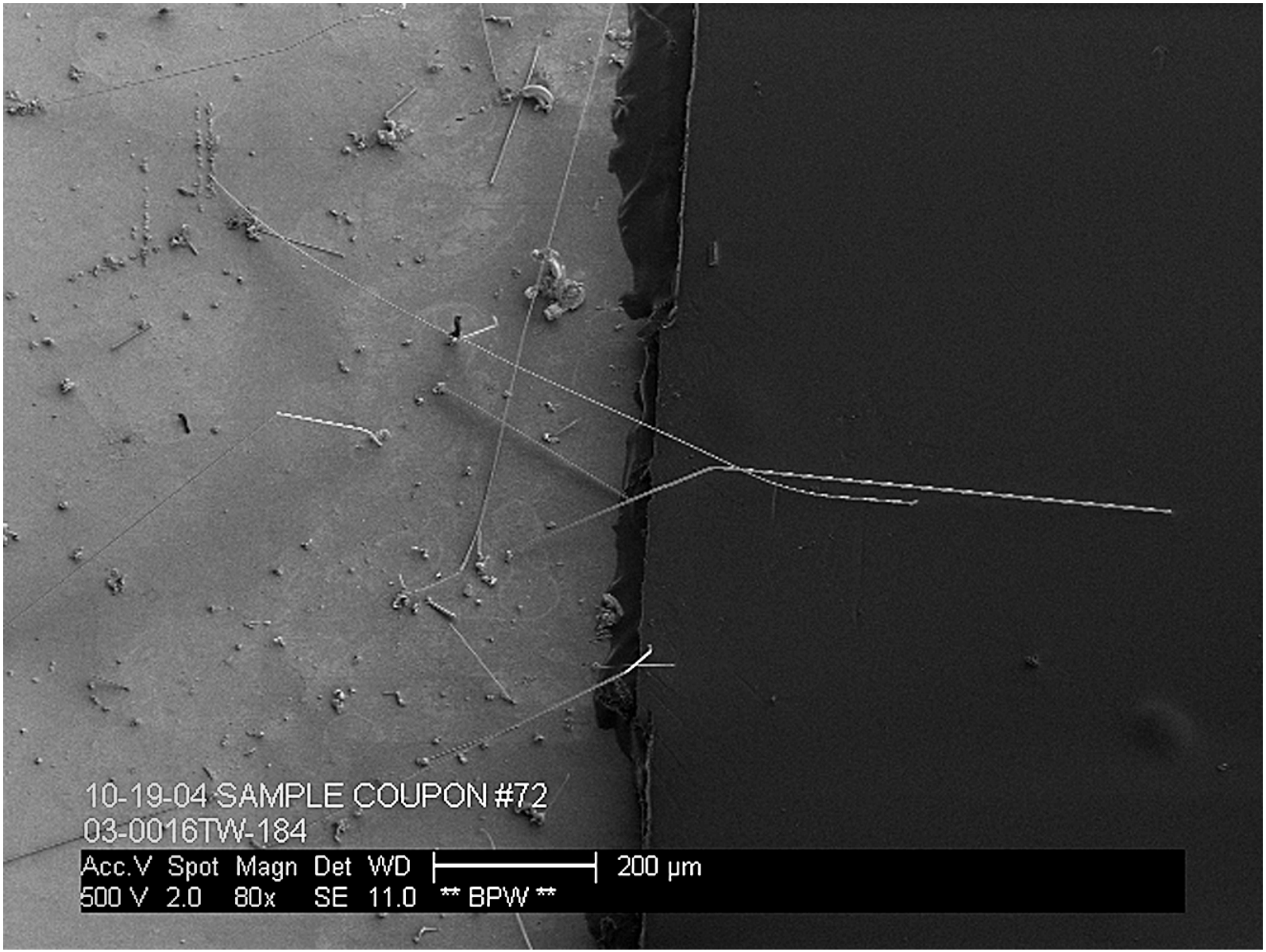
New Growth of Same Whisker after 14 Days



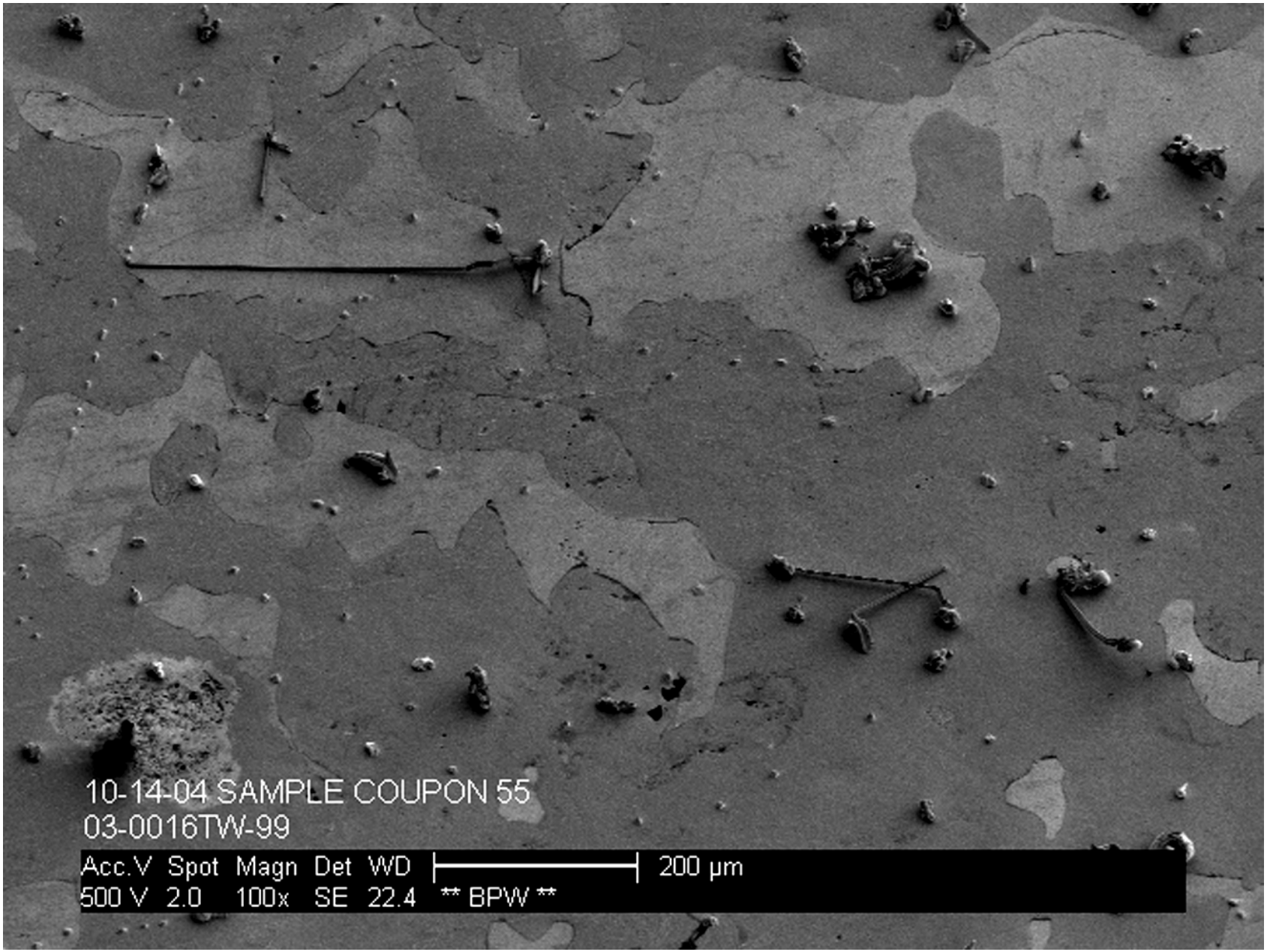
Control Area for Coating A (278 Days at Ambient + 419 Days in 50°C/50% RH)



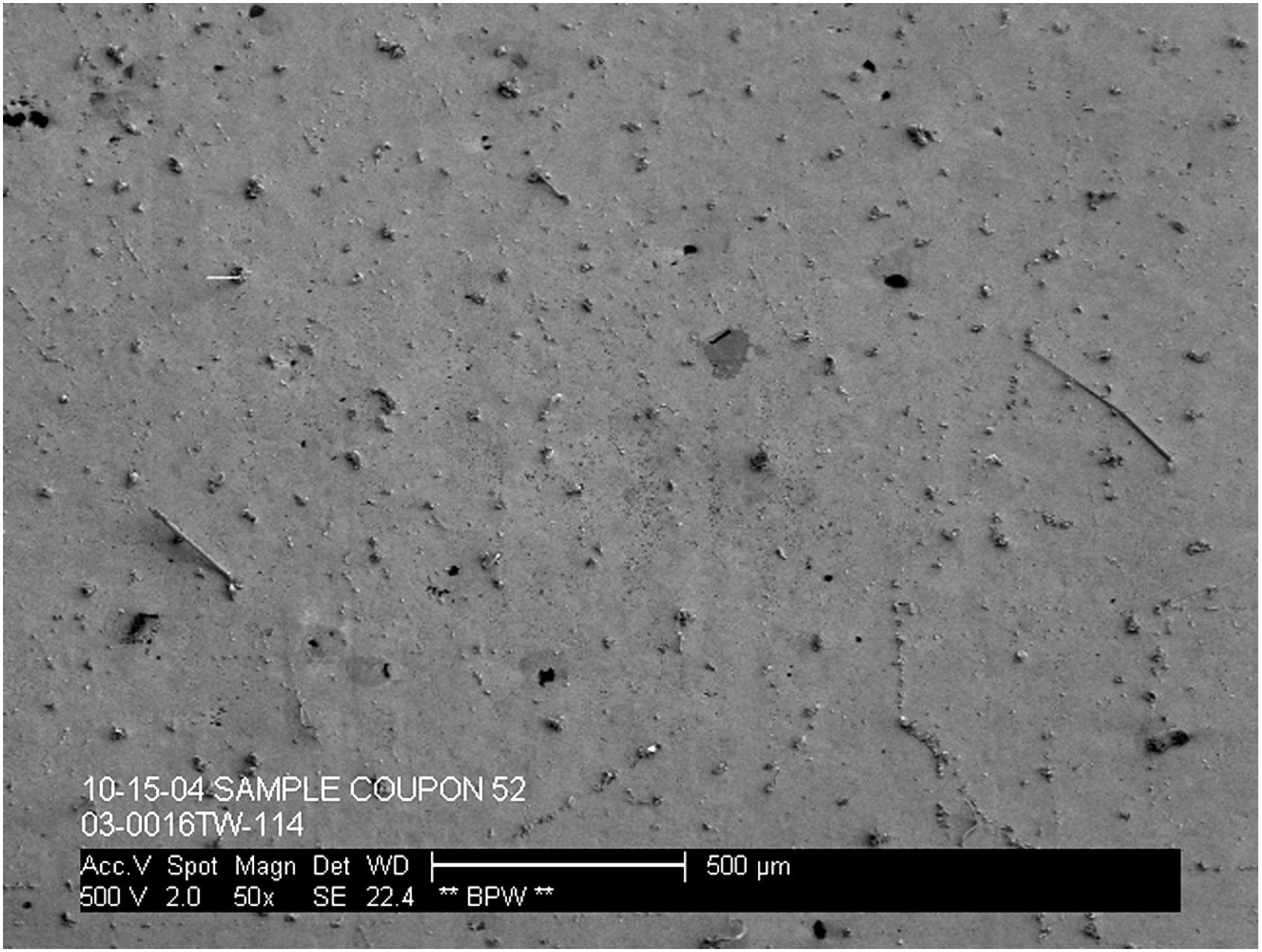
Coating B – Demarcation Line between Uncoated Control Area and Coated Area (1.5 Mils) (278 Days at Ambient + 419 Days in 50°C/50%RH)



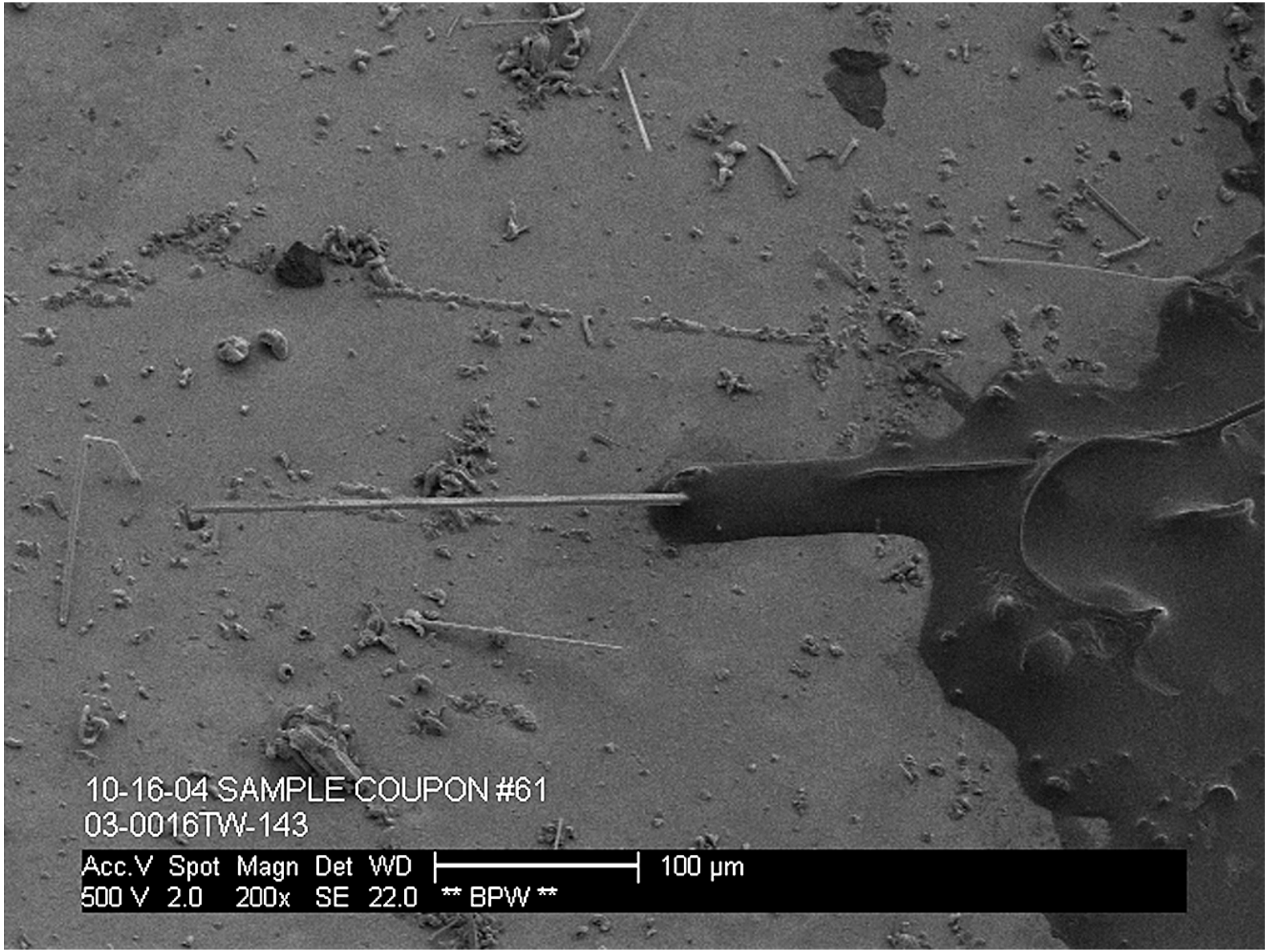
Control Area for Coating C (278 Days at Ambient + 419 Days in 50°C/50%RH)



Control Area for Coating D (278 Days at Ambient + 419 Days in 50°C/50%RH)

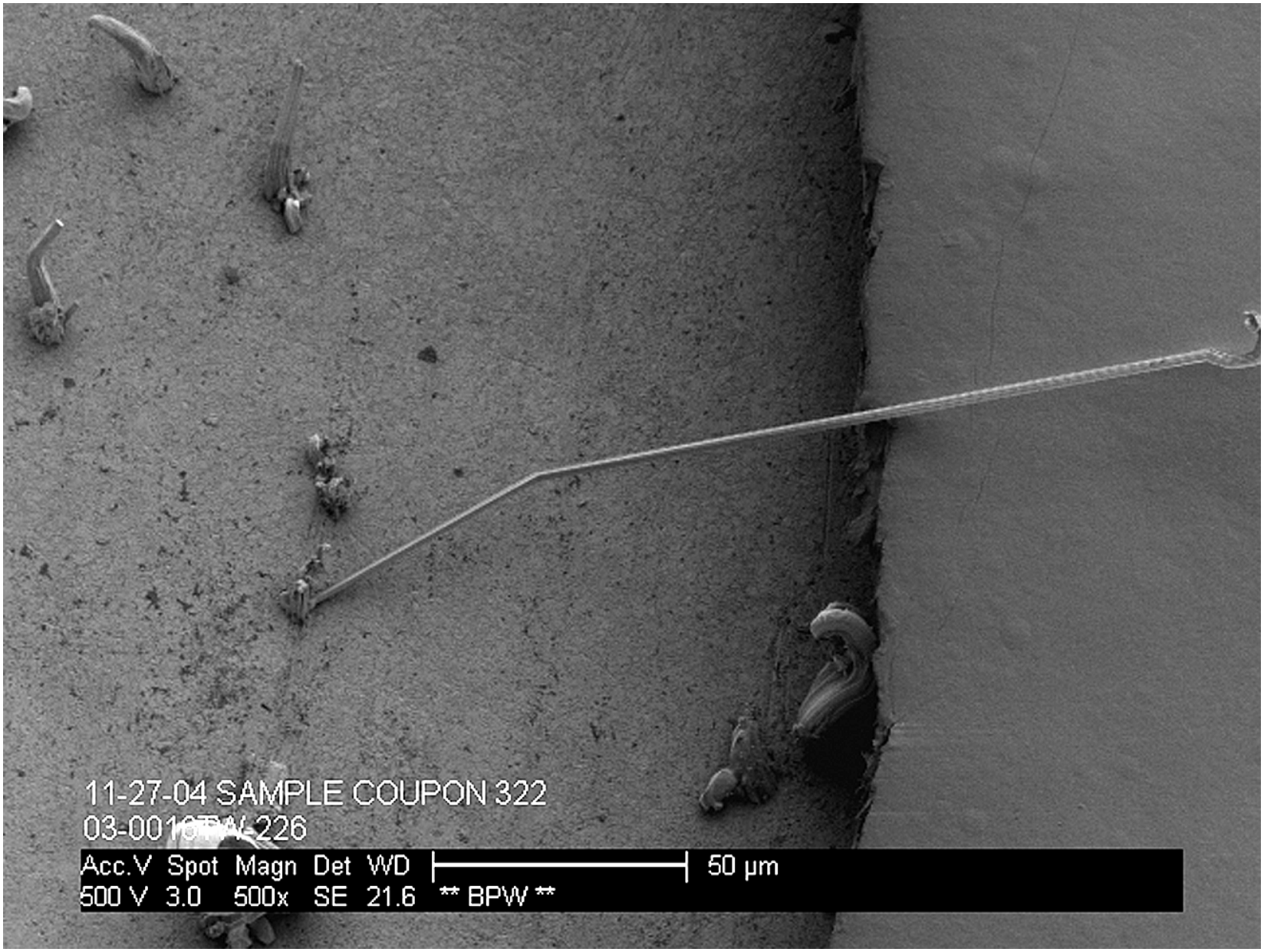


Control Area for Coating E (278 Days at Ambient + 419 Days in 50°C/50%RH)



Uncoated Side **Coated Side**

Control Area for Parylene C – Chemically Etched but not Coated (177 Days at Ambient + 84 Days in 50°C/50%RH)



Observations

	Coating A (Urethane Acrylic)			Coating B (Silicone)		Coating C (Acrylic)		
Average Coating Thickness (mils)	No Coating	1.4	6.0	No Coating	1.5	No Coating	0.6	3.9
Coating Thickness Range (mils)	No Coating	1.2 - 1.7	5.4 - 6.5	No Coating	1.4 - 1.6	No Coating	0.4 - 1.0	3.1 - 4.3
After 278 Days at Ambient	Small Nodules on Fine Scratches	Small Nodules on Fine Scratches	Small Nodules on Fine Scratches	Scattered Small Nodules	No Growths	Small Nodules on Fine Scratches; **2 Short Whiskers**	Small Nodules on Fine Scratches	Small Nodules on Fine Scratches; **1 Short Whisker**
After 278 Days at Ambient + 63 Days in 50°C/50%RH	Nodules on Scratches; **Scattered Whiskers**	Nodules on Scratches	Nodules on Scratches	Nodules on Scratches; **Scattered Whiskers**	Nodules on Scratches	**Many Whiskers**	OSE's + **Some Whiskers**	**Many Whiskers Tenting Coating**
After 278 Days at Ambient + 119 Days in 50°C/50%RH	**Many Whiskers**	Many OSE's (Some in Bubbles)	Many OSE's (Some in Bubbles)	**Many Whiskers**	Nodules	**Many Whiskers**	**Coating Penetrated by Whiskers**	**Many Whiskers Tenting Coating**
After 278 Days at Ambient + 336 Days in 50°C/50%RH	**Many Whiskers**	Many OSE's in Bubbles	Many OSE's in Bubbles; **Short Whiskers in Bubbles**	**Many Whiskers**	A few OSE's in Bubbles; **Coating Penetrated by Whiskers**	**Many Whiskers**		**Many Whiskers Tenting Coating**

Observations (cont'd)

	Coating D (Urethane Acrylic)			Coating E (Urethane Acrylic)			Parylene C	
Average Coating Thickness (mils)	No Coating	1.1	4.6	No Coating	1.3	4.0	Etched But Not Coated	0.8
Coating Thickness Range (mils)	No Coating	1.0 - 1.2	2.7 - 6.7	No Coating	1.1 - 1.5	3.2 - 4.5	Etched But Not Coated	0.8 - 1.0
After 278 Days at Ambient	No Growths	No Growths	No Growths	Nodules; **Whiskers**	Scattered Small Nodules	Scattered Small Nodules		No Growths
After 278 Days at Ambient + 63 Days in 50°C/50%RH	**Many Whiskers (Some Very Long)**	Small Nodules on Scratches	Small Nodules on Scratches	**Many Whiskers**	**Scattered Whiskers (Some Very Long)**	**1 Whisker**	**Many Whiskers** (after 177 Days at Ambient + 84 Days in 50°C/50%RH)	No Growths
After 278 Days at Ambient + 119 Days in 50°C/50%RH	**Many Whiskers**	Many OSE's in Bubbles; **Coating Penetrated by OSE's and Whiskers**	**1 Whisker under Coating**					No Growths
After 278 Days at Ambient + 336 Days in 50°C/50%RH	**Many Whiskers**		Many OSE's in Bubbles; **Short Whiskers in a Bubble**	**Many Whiskers**	**Coating Penetrated by OSE's and Whiskers;** a Few OSE's in Bubbles	Many OSE's and **a Few Whiskers;** a Few OSE's in Bubbles		**Very Few Whiskers but Coating was Penetrated**

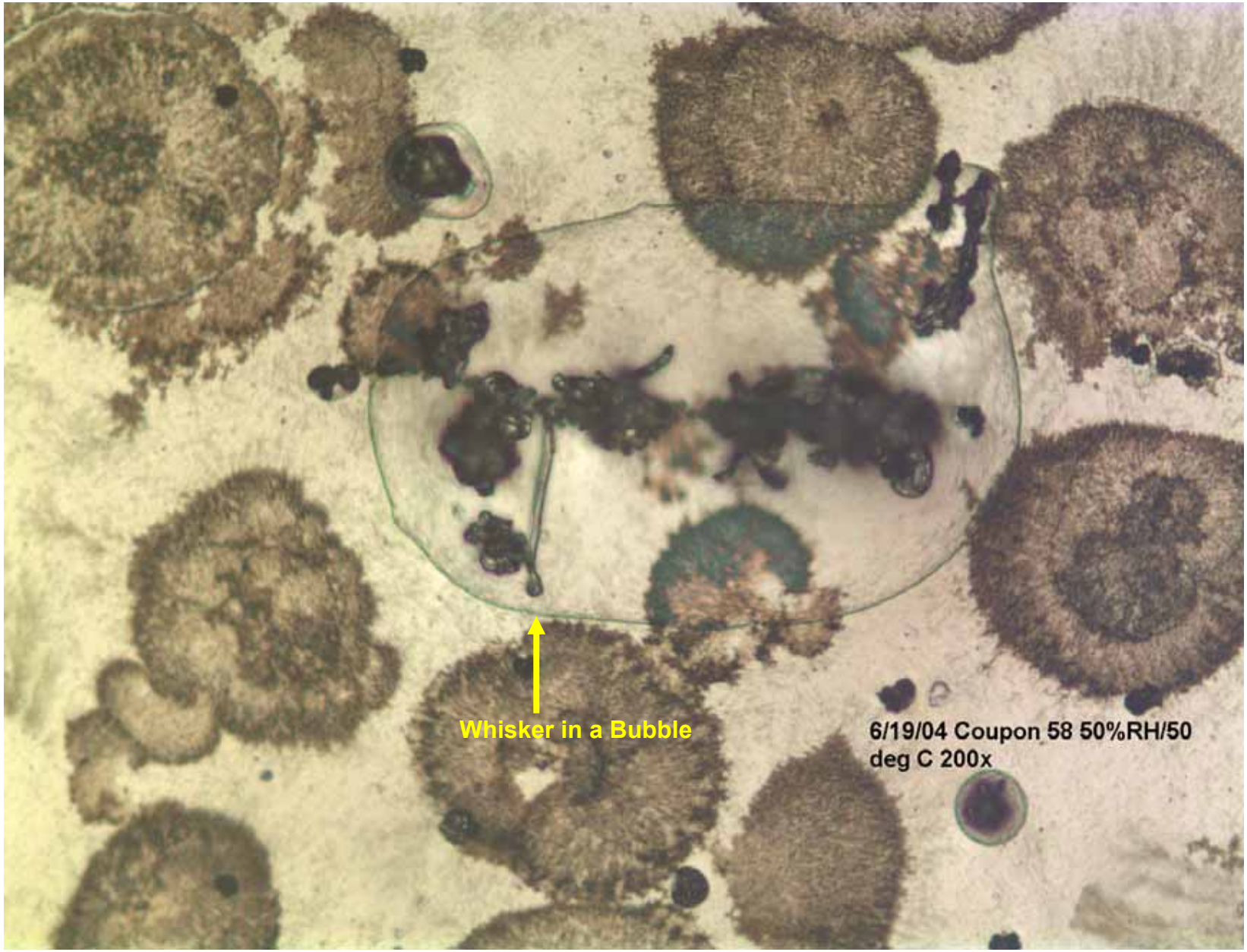
Summary

- Parylene C suppressed OSE and whisker formation the longest. The silicone was also effective at suppressing growths.
- The acrylic was least effective at suppressing OSE and whisker formation.
- Once whiskers did begin to grow, all of the thinner coatings (approx. 1 mil) were penetrated (except Coating A).
- None of the thicker coatings (3.9 – 6.0 mils) were penetrated.

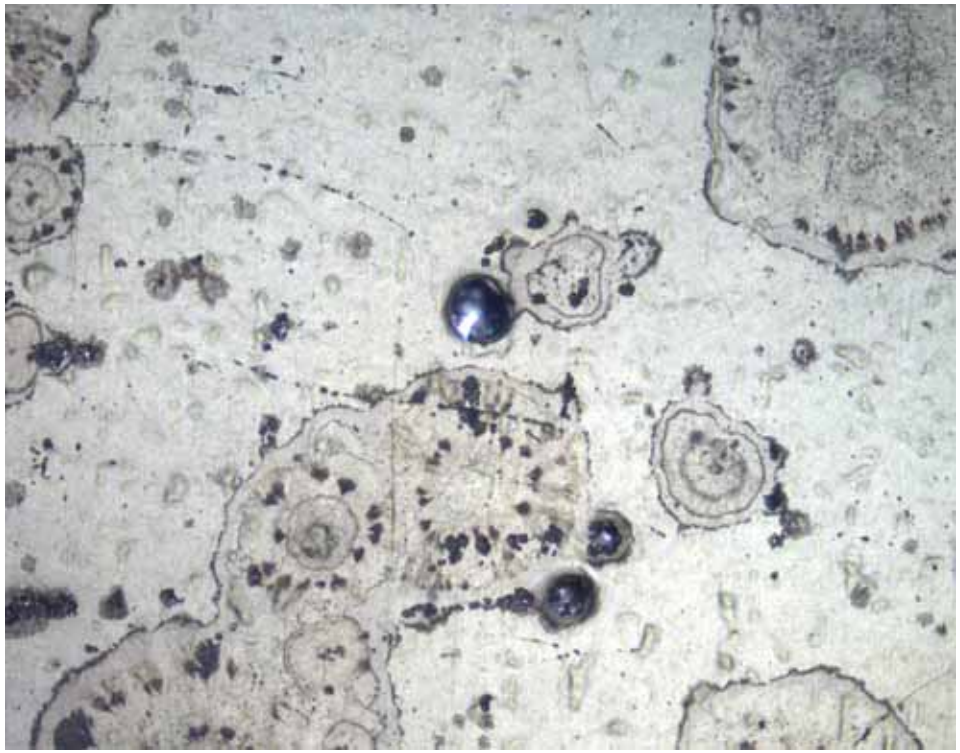
Summary (cont'd)

- There was no obvious correlation between modulus, tensile strength or hardness and ability to suppress growths (compare Parylene C and the silicone).
- There was no obvious correlation between oxygen or water vapor permeability and ability to suppress growths (compare Parylene C and the silicone).

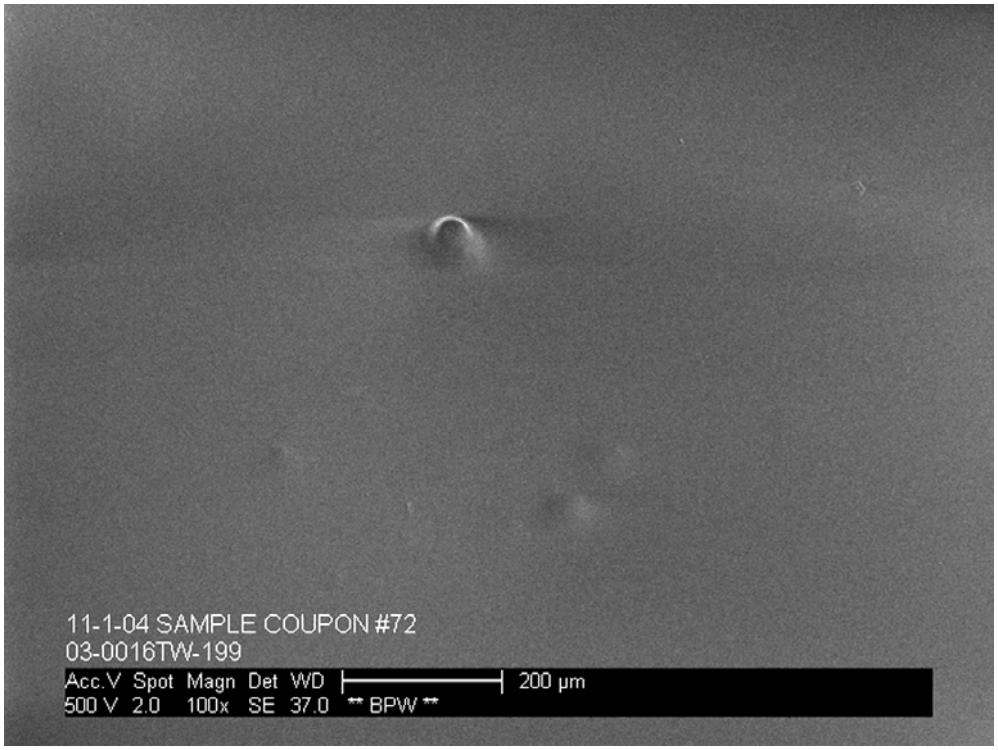
Coating A – 6.0 Mils (278 Days at Ambient + 336 Days in 50°C/50%RH)



Optical Microscope Image of Coating B Showing Example of OSE's in Bubbles – 1.5 Mils (278 Days at Ambient + 419 Days in 50°C/50%RH)



SEM Image of Same Area

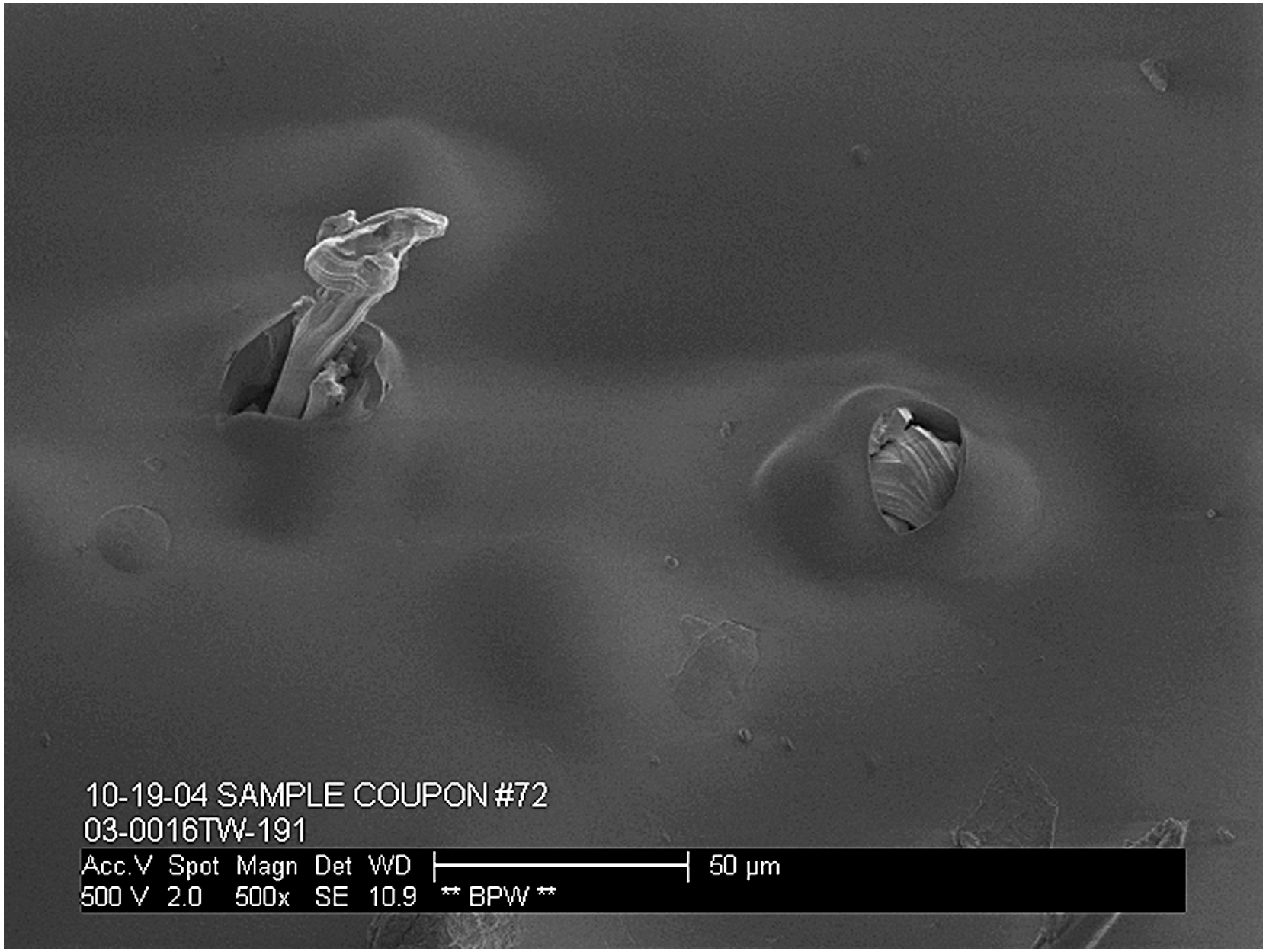


Coating B – 1.5 Mils (278 Days at Ambient + 336 Days in 50°C/50%RH)

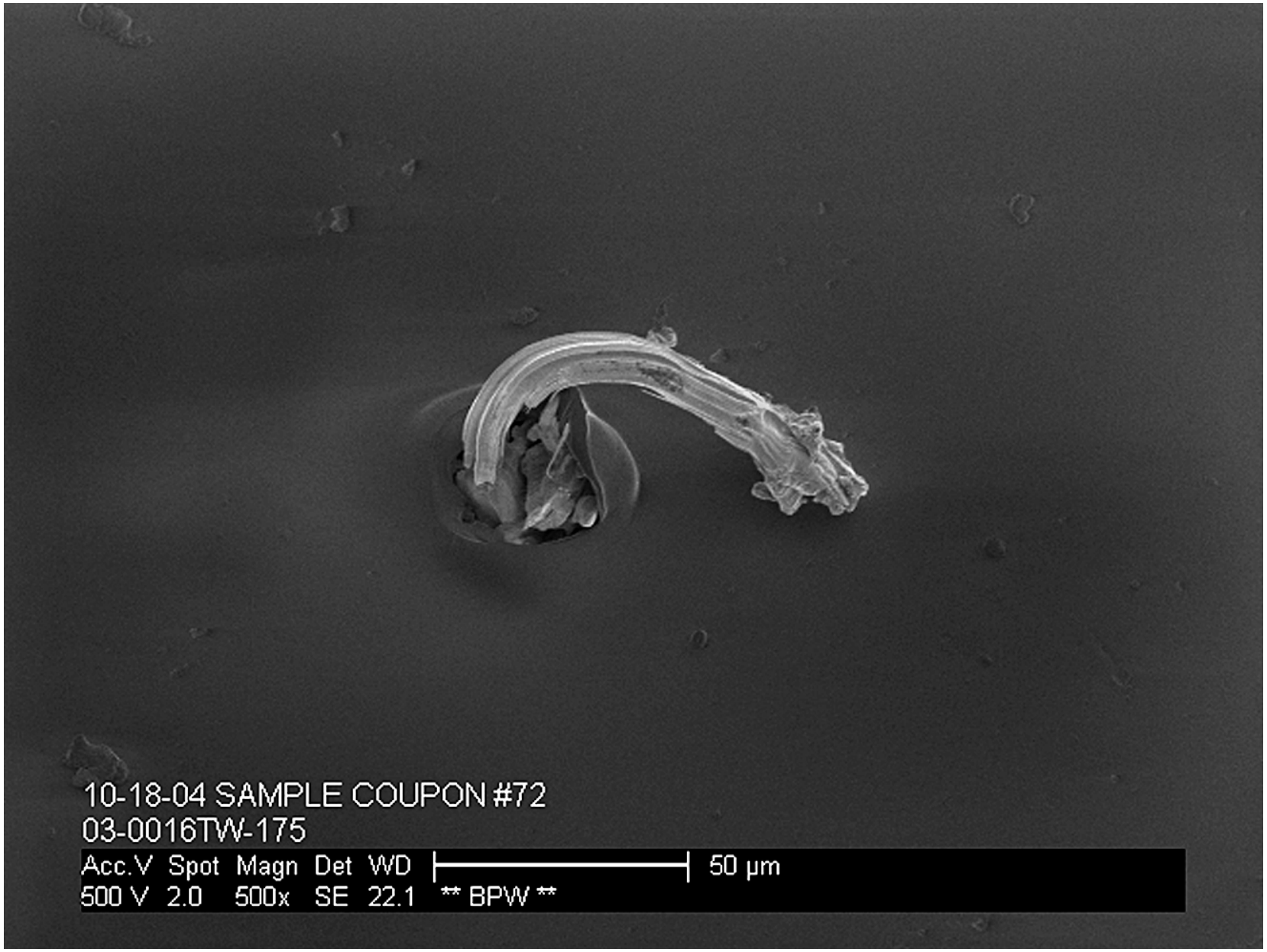
Coated Side

Uncoated Side

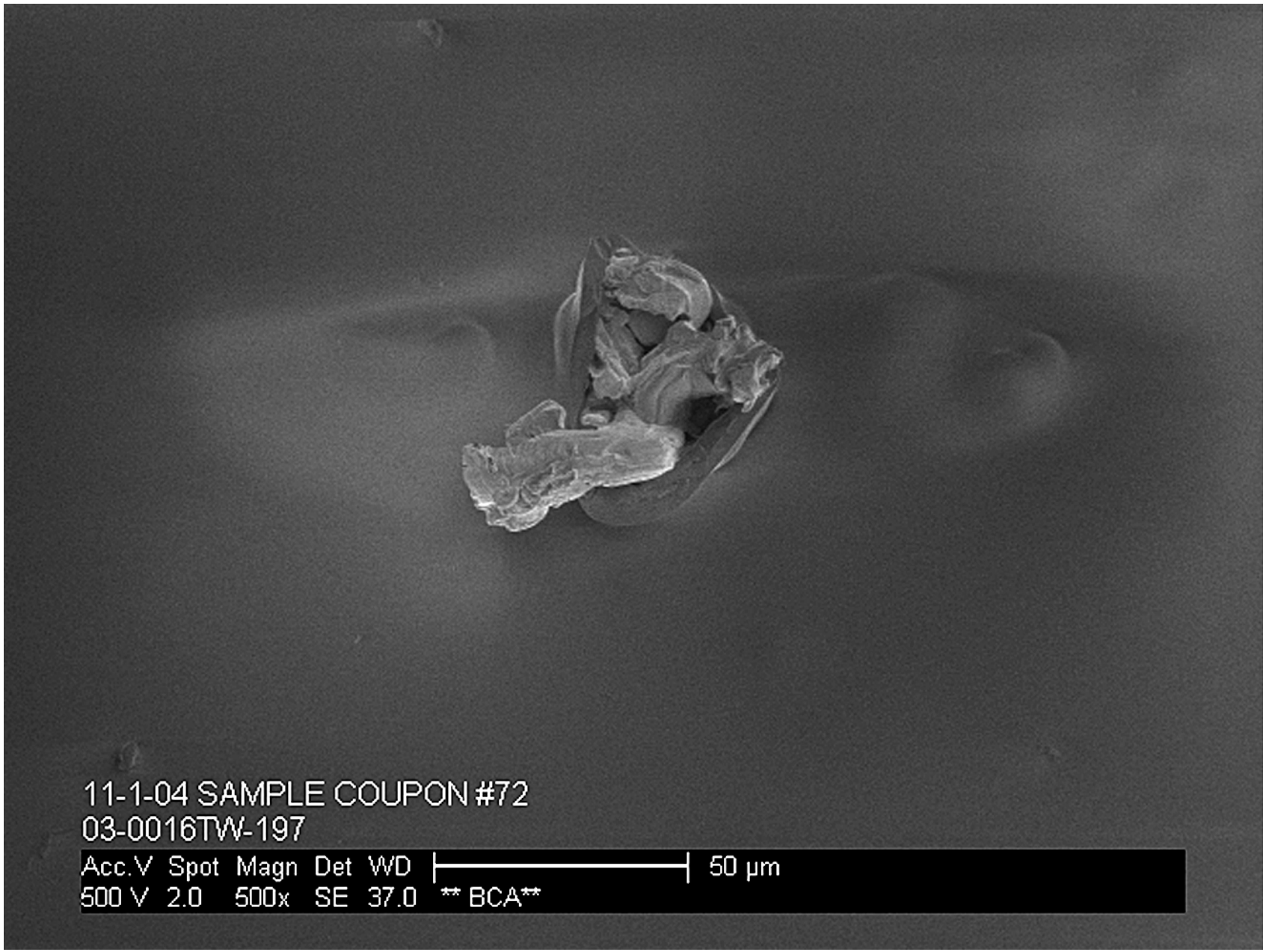
Whisker Penetrating Coating B – 1.5 Mils (278 Days at Ambient + 419 Days in 50°C/50%RH)



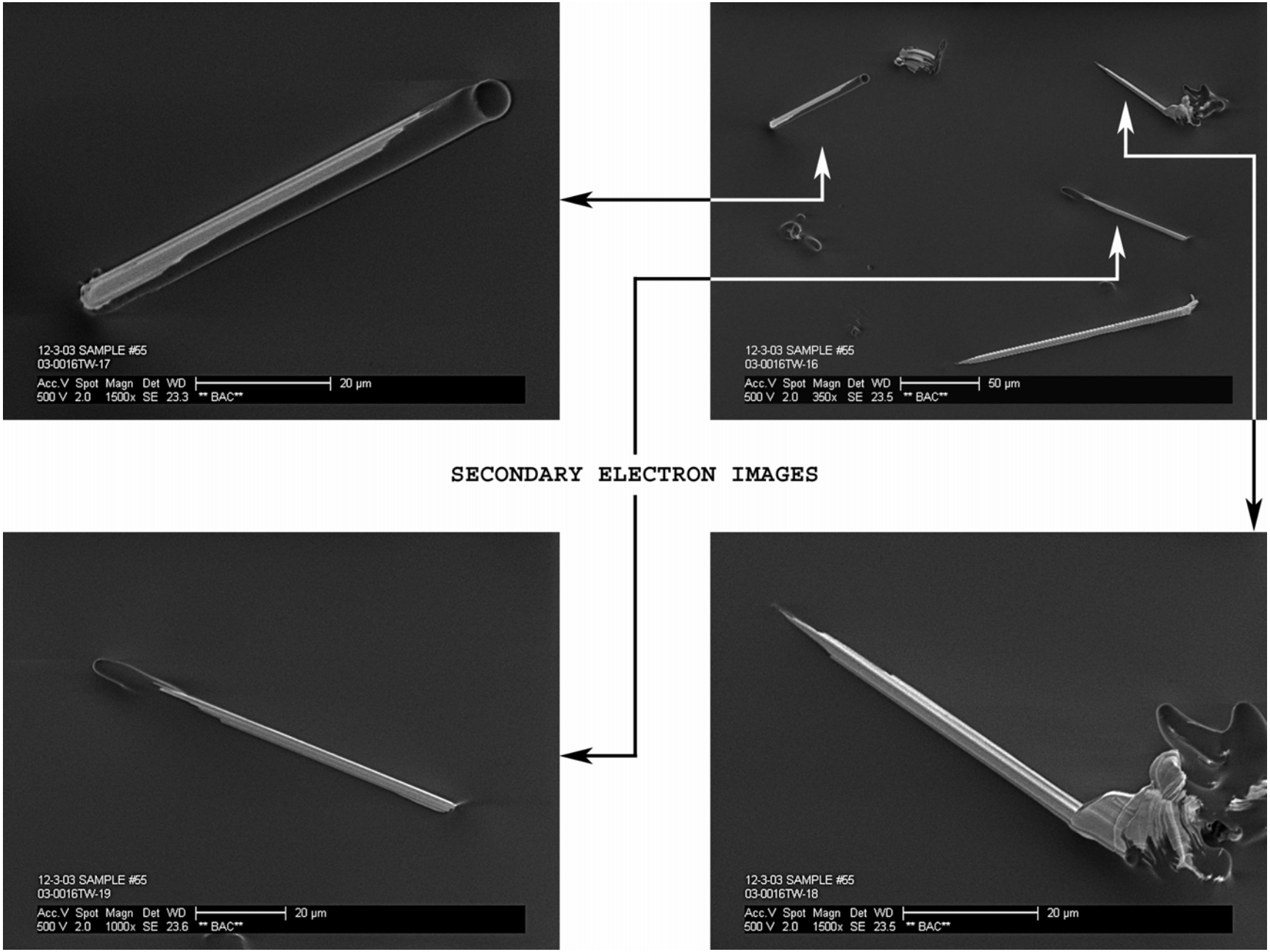
Whisker Penetrating Coating B – 1.5 Mils (278 Days at Ambient + 419 Days in 50°C/50%RH)



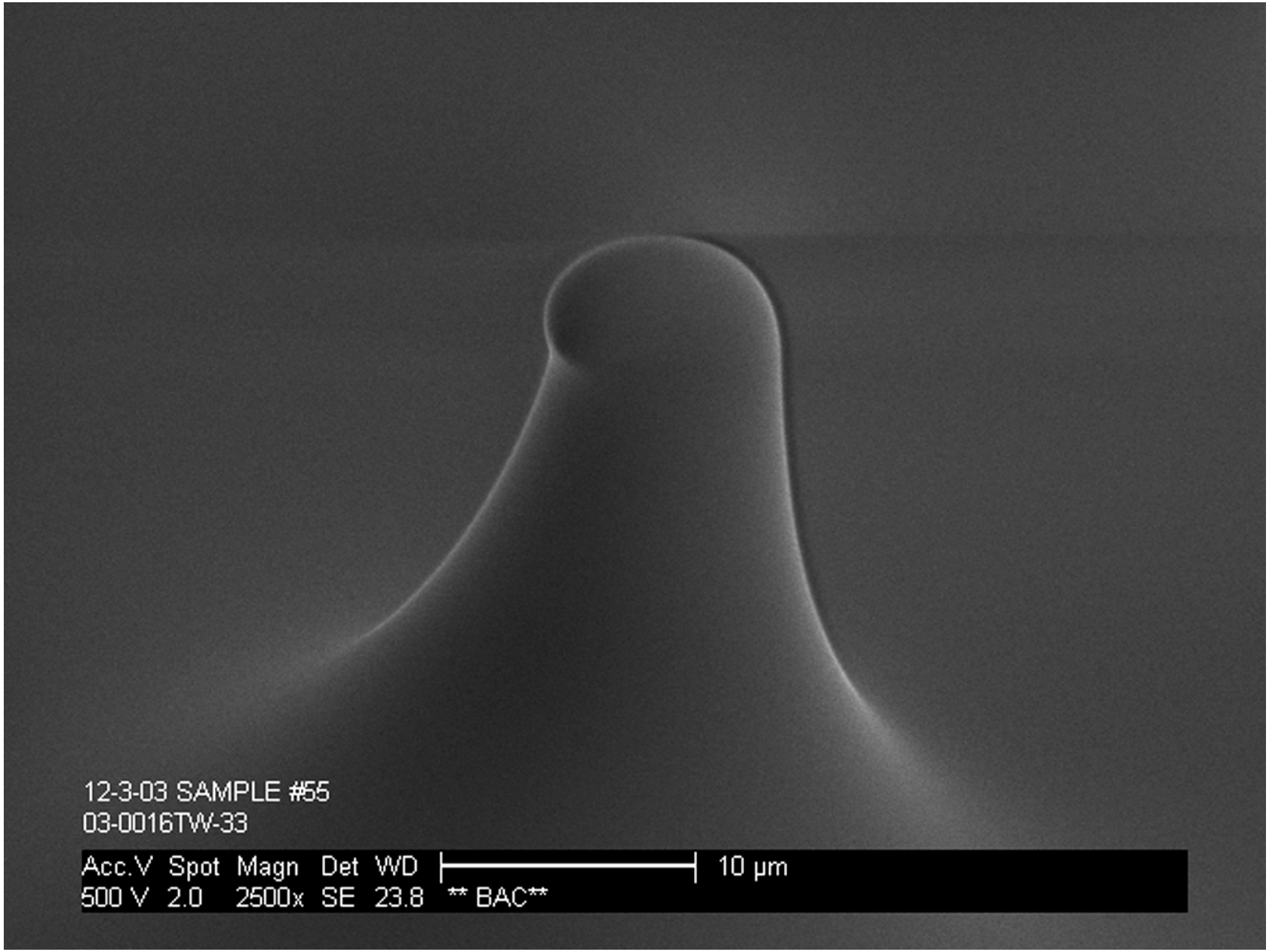
Whisker Penetrating Coating B – 1.5 Mils (278 Days at Ambient + 419 Days in 50°C/50%RH)



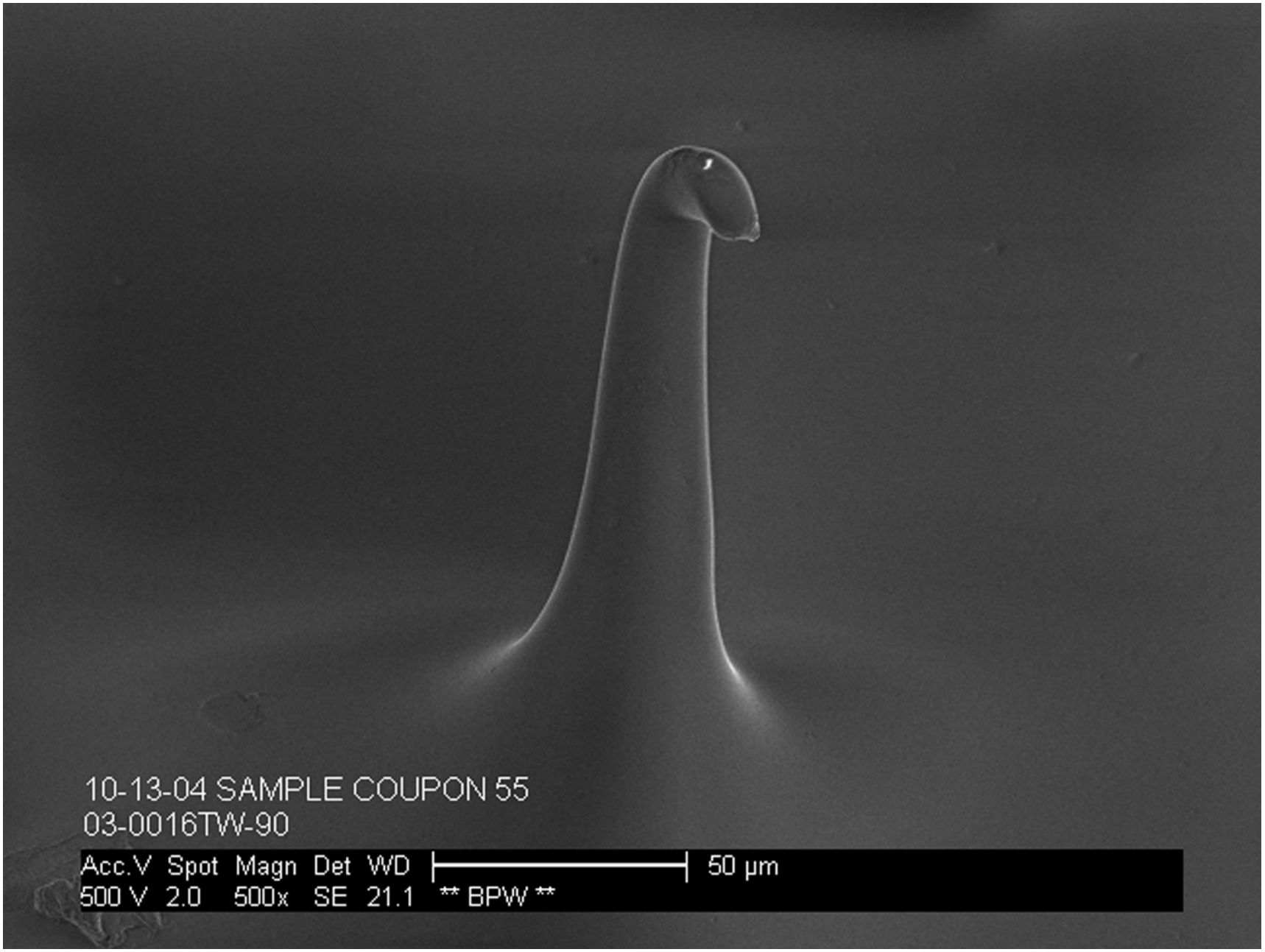
Whiskers Penetrating Coating C – 0.6 Mils (278 Days at Ambient + 119 Days in 50°C/50%RH)



“Tenting” of Coating C – 3.9 Mils (278 Days at Ambient + 137 days in 50°C/50%RH)

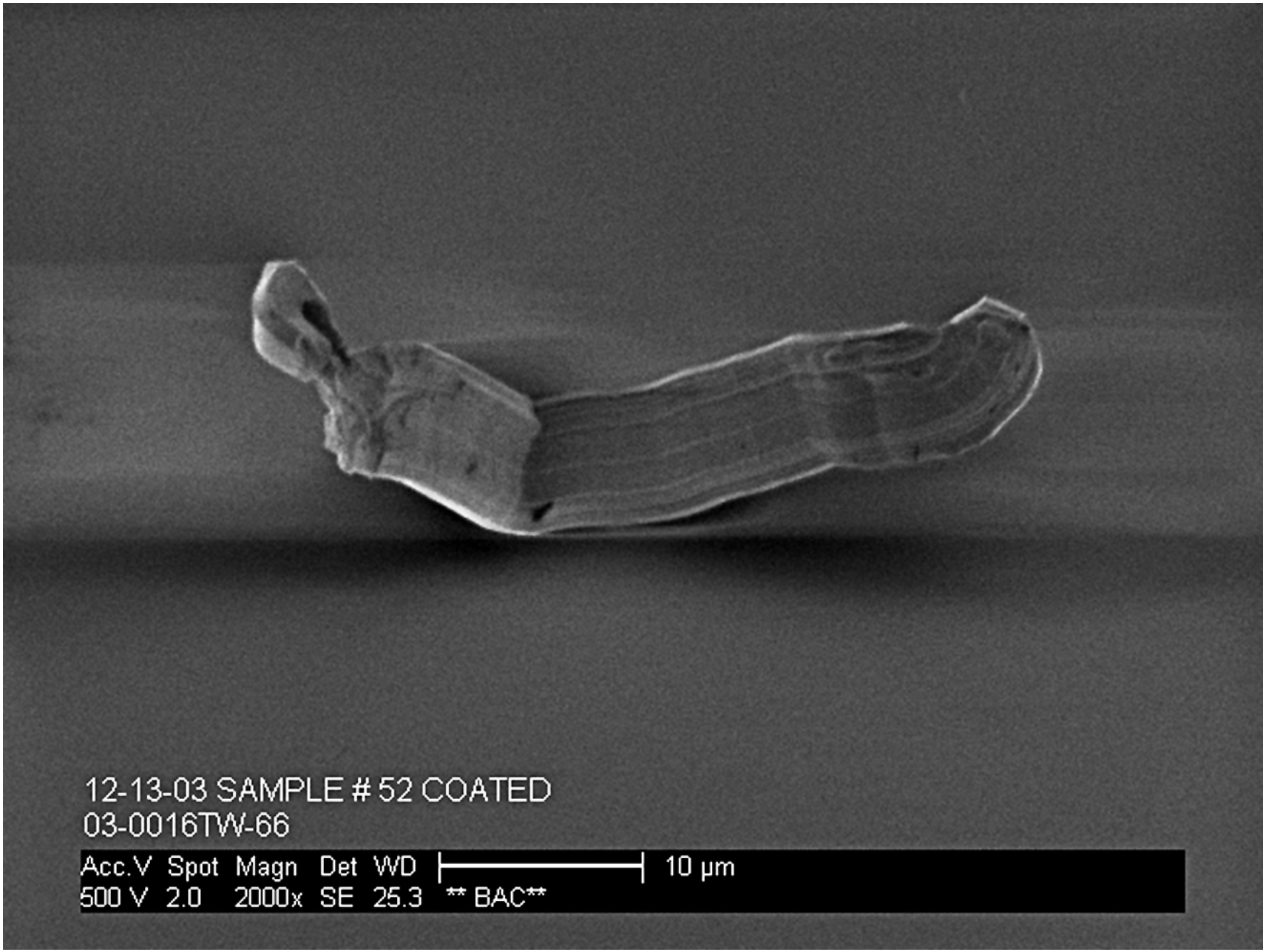


Coating C – 3.9 Mils (278 Days at Ambient + 419 Days in 50°C/50%RH)



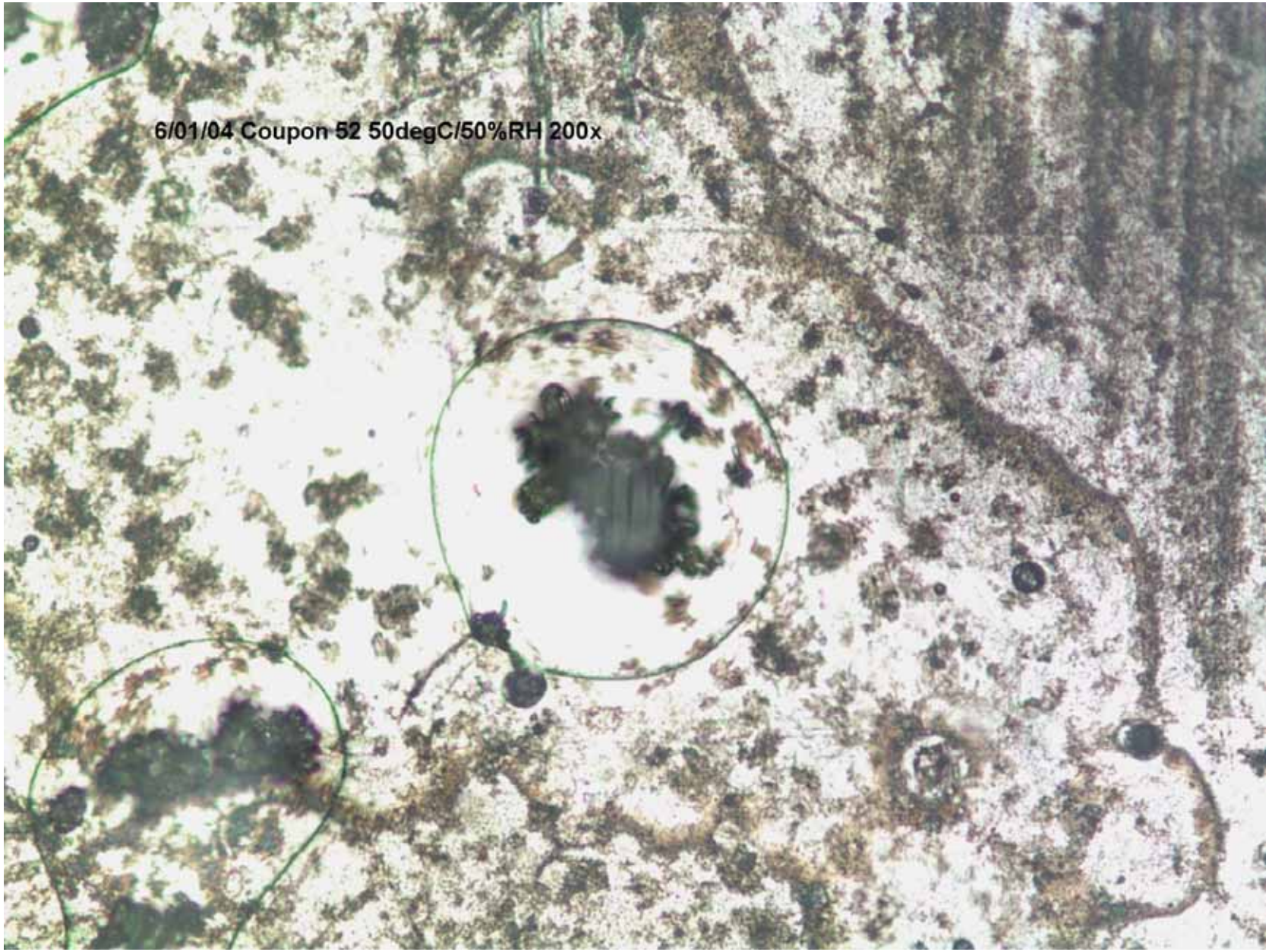
Coating C – 3.9 Mils (278 Days at Ambient + 336 Days in 50°C/50%RH)

Whisker Penetrating Coating D – 1.1 Mils (278 Days at Ambient + 147 Days in 50°C/50%RH)



OSE's and Whiskers Erupting through Coating D – 1.1 Mils (278 Days at Ambient + 147 Days in 50°C/50%RH)

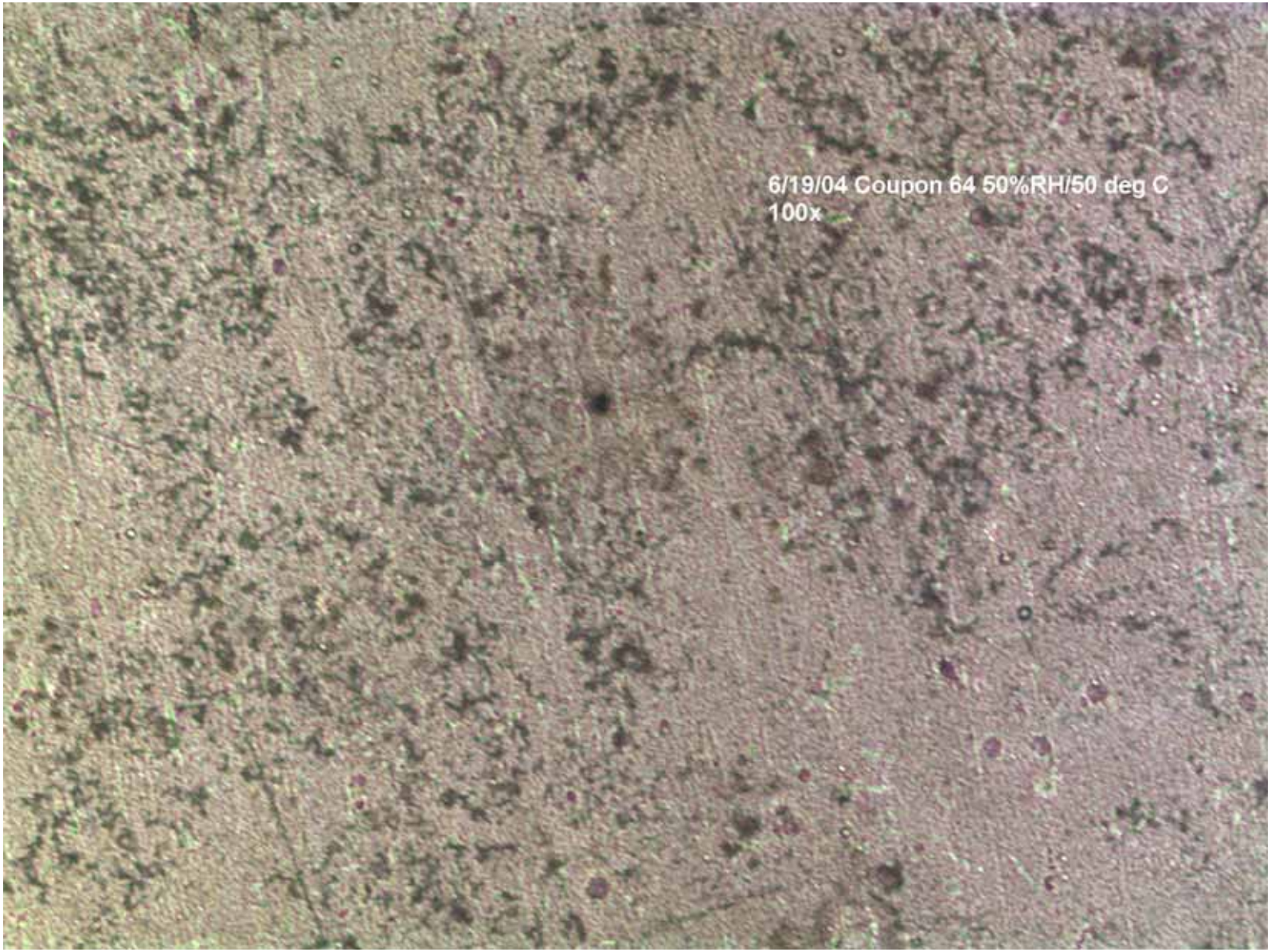
Coating D – 4.6 Mils, OSE's and Whisker in a Bubble (278 Days at Ambient + 318 Days in 50°C/50%RH)



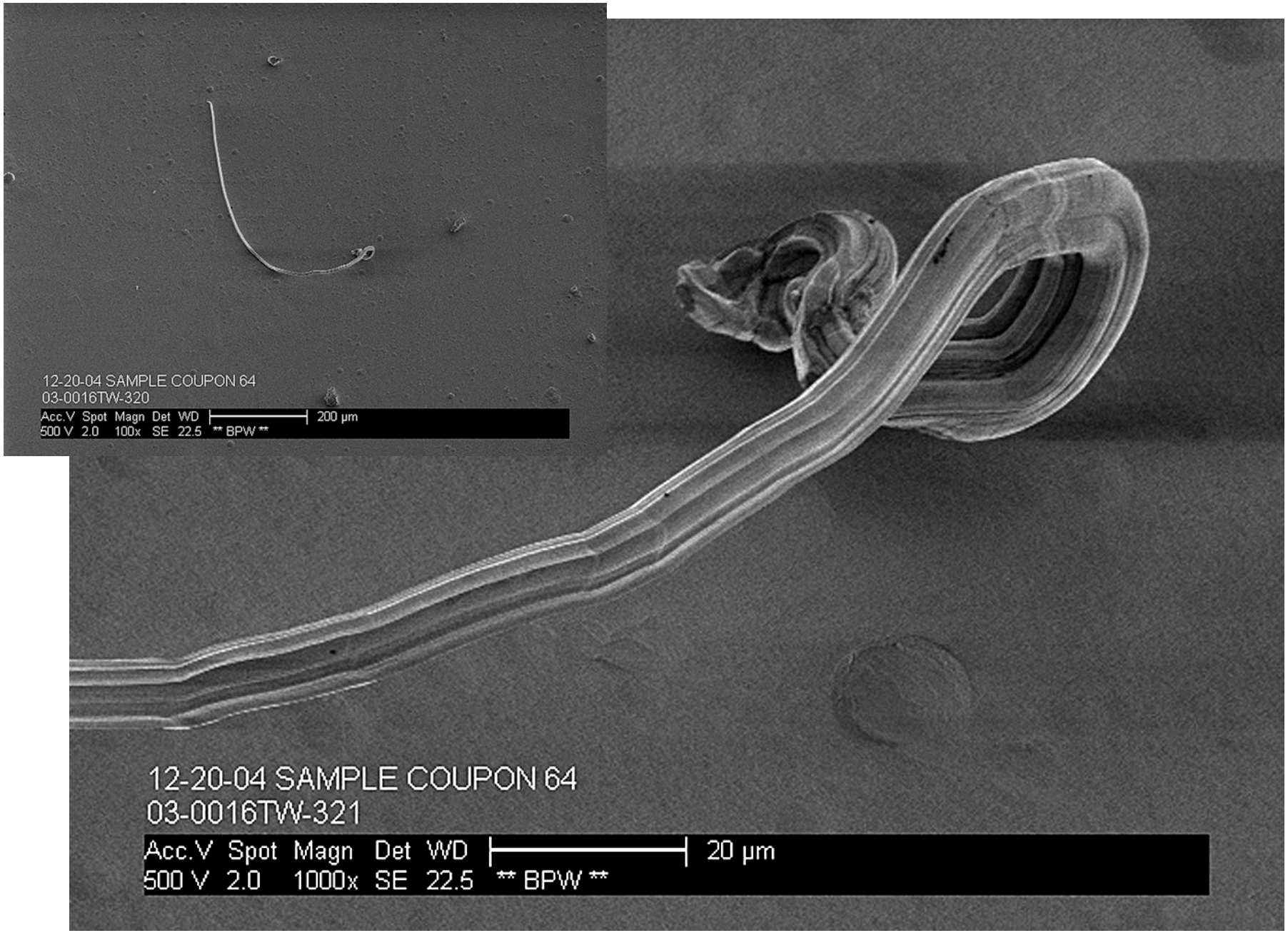
Whisker Penetrating Coating E – 1.3 Mils (278 Days at Ambient + 419 Days in 50°C/50%RH)

Enlargement of Same Whisker

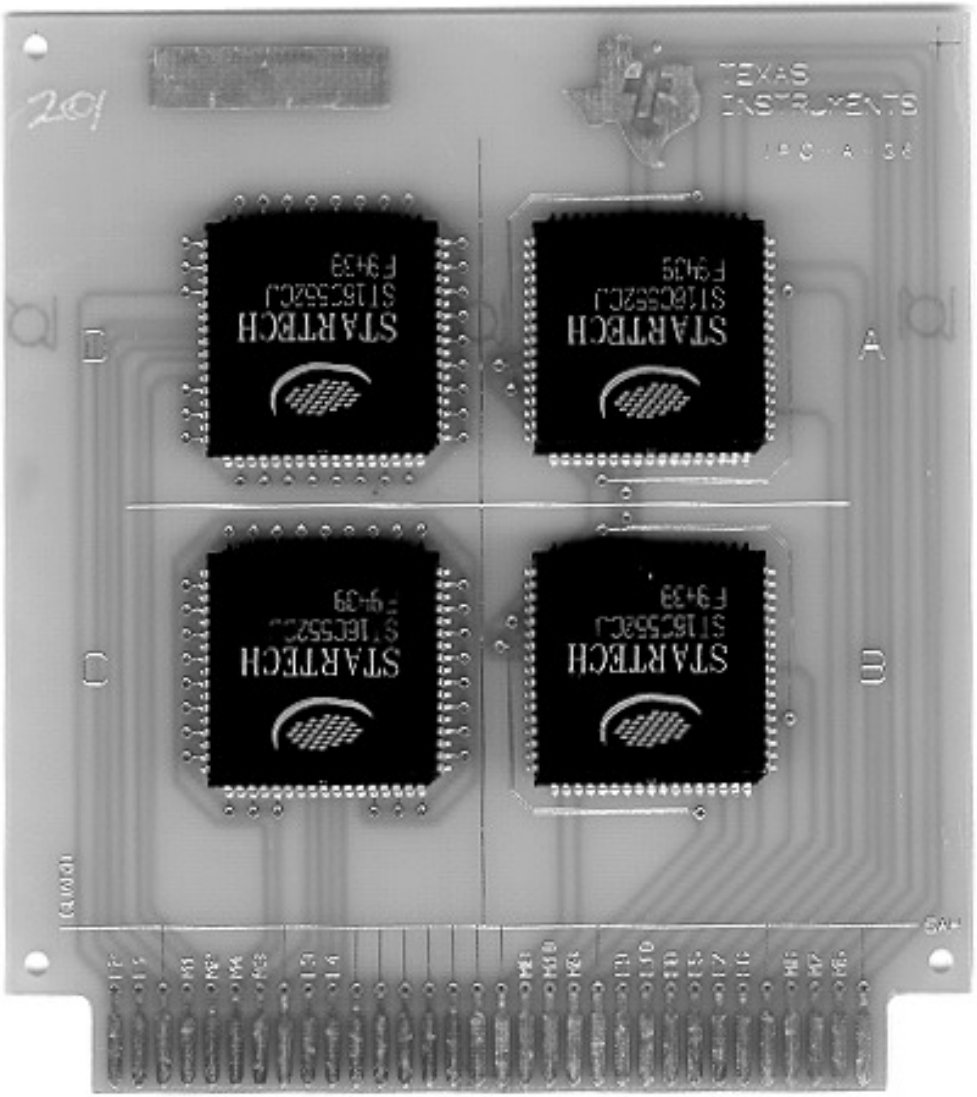
Parylene C – 0.8 Mils, Note Mottling of Tin Plating but No Growths (278 Days at Ambient + 336 Days in 50°C/50%RH)



Whisker Penetrating Parylene C – 0.8 Mils (278 Days at Ambient + 419 Days in 50°C/50%RH)



PLCC64's Used to Evaluate Conformal Coating Coverage on Leads



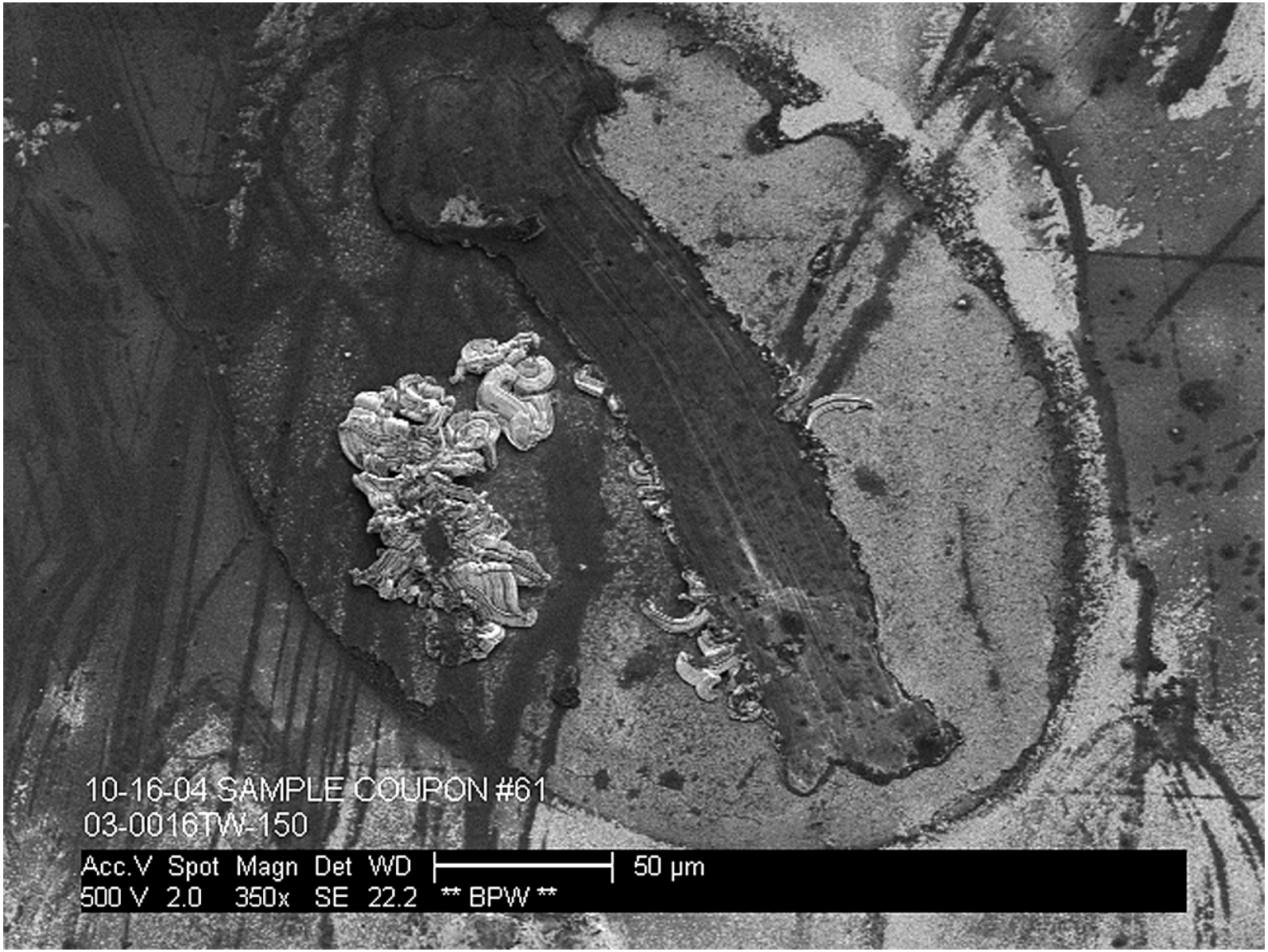
Evaluation of Lead Coverage using Resistance Measurements

	Coating D (Urethane Acrylic)	Coating E (Urethane Acrylic)	Parylene C
Measured Thickness of Coating on Flat Area of Test Board (mils)	4.6	1.8	0.85
Sufficient Coverage on Front of PLCC64 Leads?	No	No	Yes
Sufficient Coverage on Back of PLCC64 Leads?	No	No	Yes

Component Lead Coverage

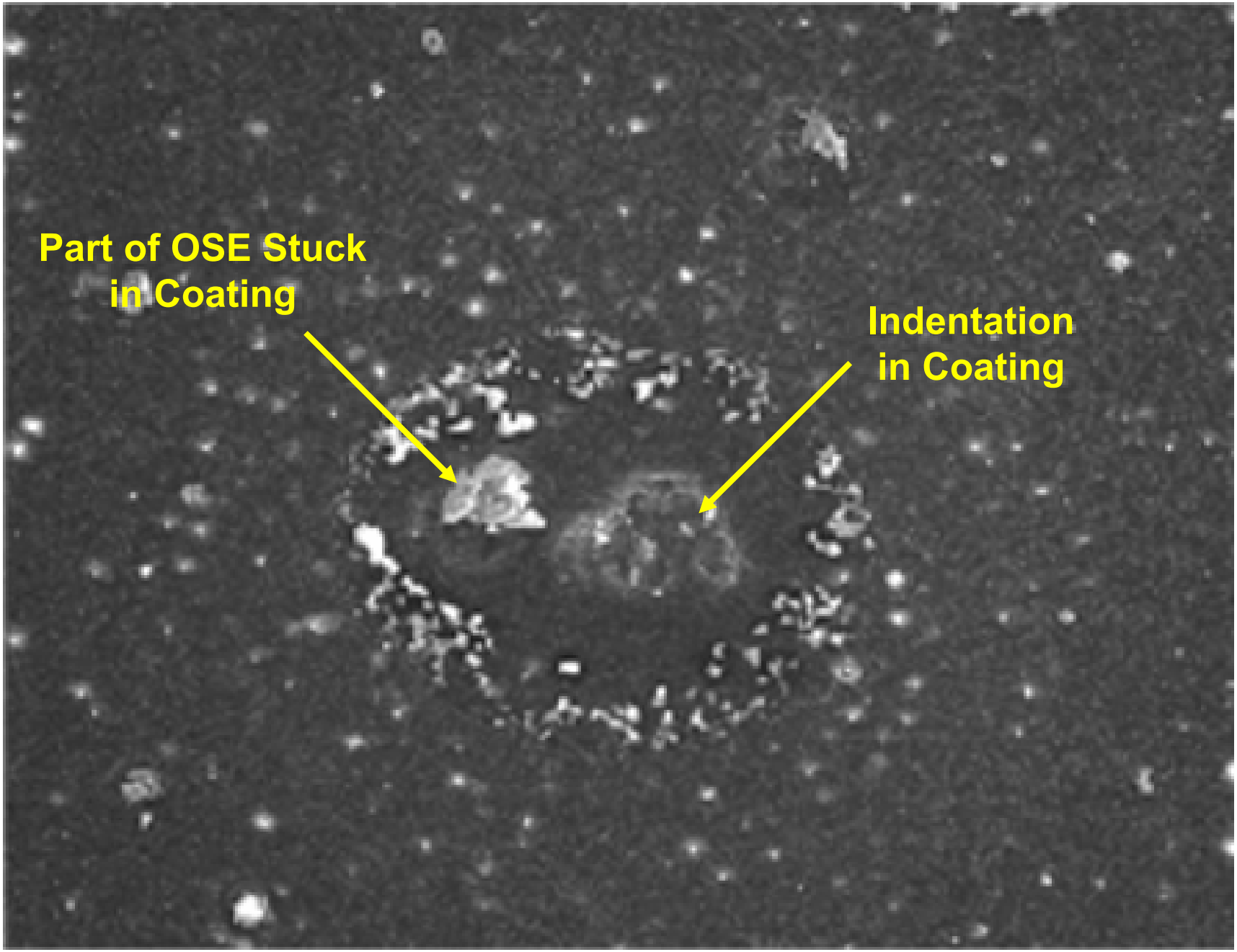
- Many sprayable conformal coatings will not effectively coat component leads.
- Parylene will completely and evenly coat component leads since it is applied by a vacuum deposition process.

Coupon after Removal of 1.3 Mils of Coating E (278 Days at Ambient + 419 Days in 50°C/50%RH), Note Oval Demarcation Line Where Bubble Was

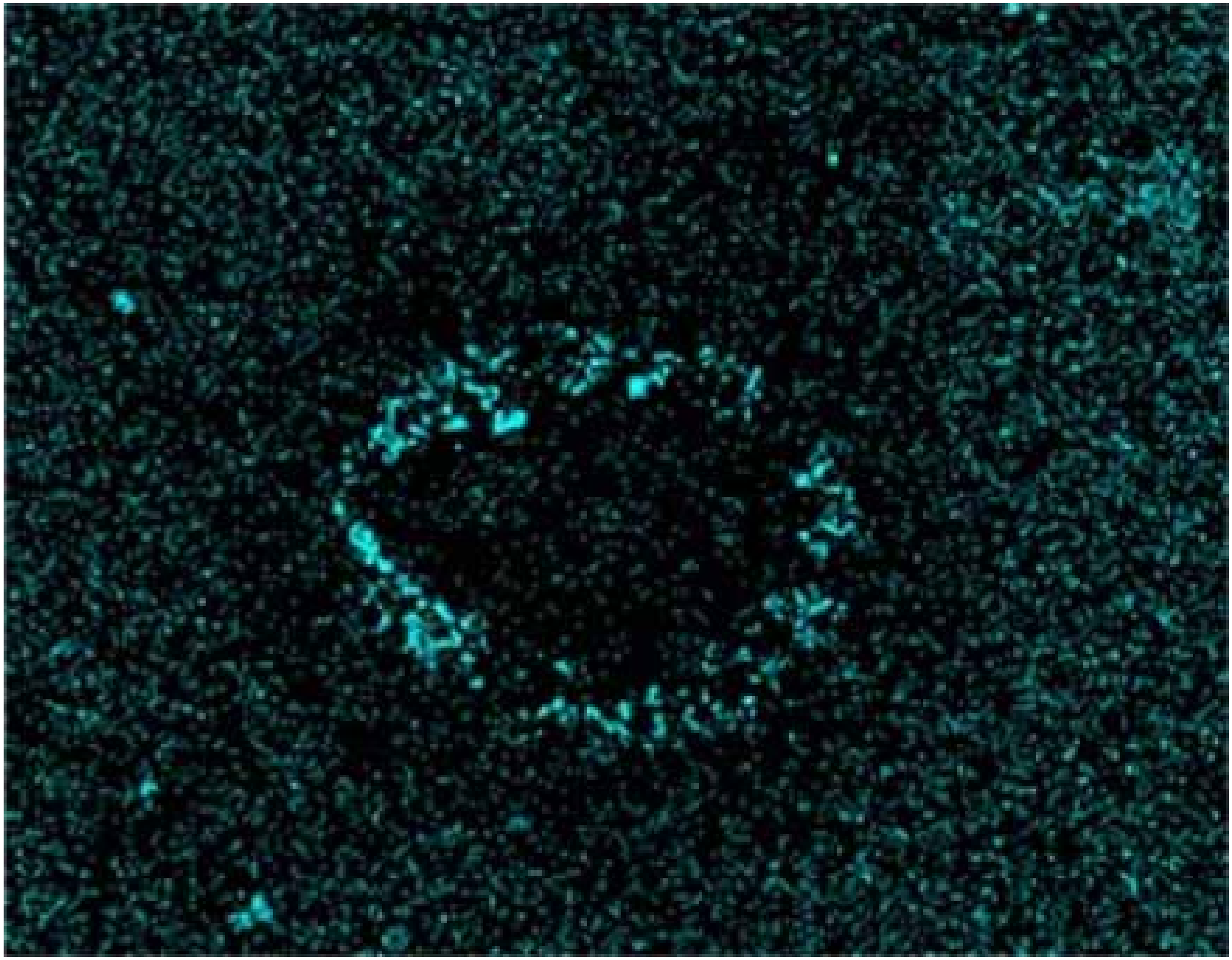


Coupon after Removal of 1.3 Mils of Coating E (Coiled Whiskers?)

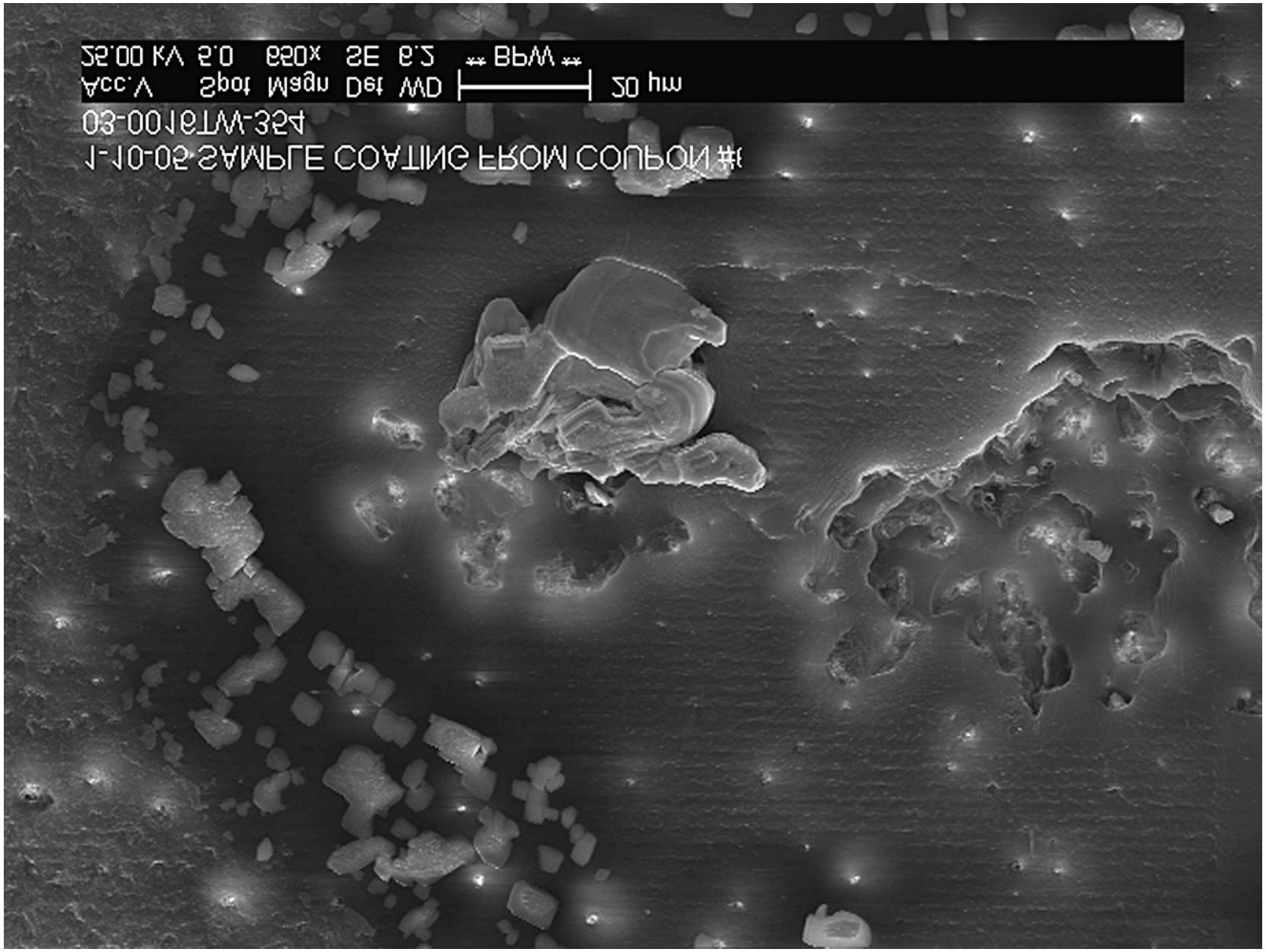
Coating E (4.0 Mils Thick) after Removal from Coupon



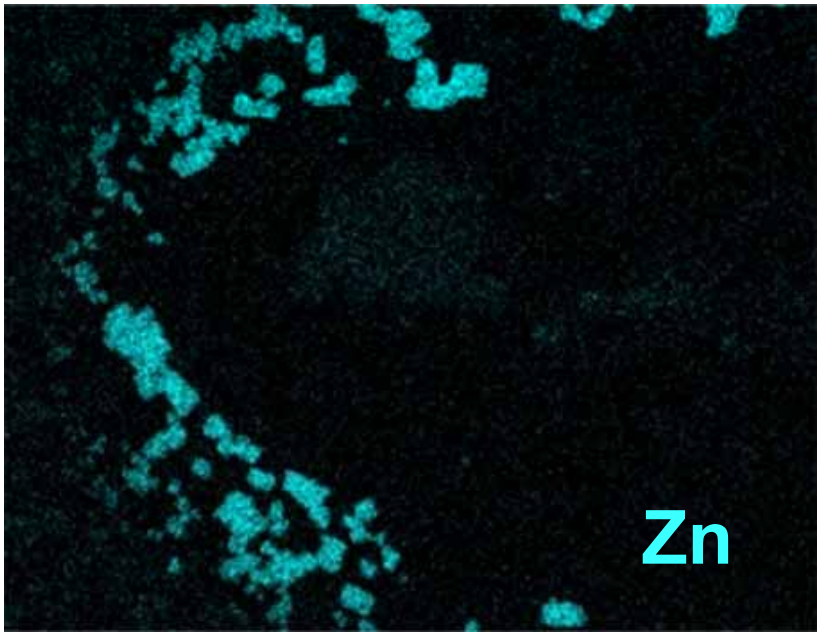
Zinc EDS Map of Coating from Previous Slide Showing “Zinc Ring”

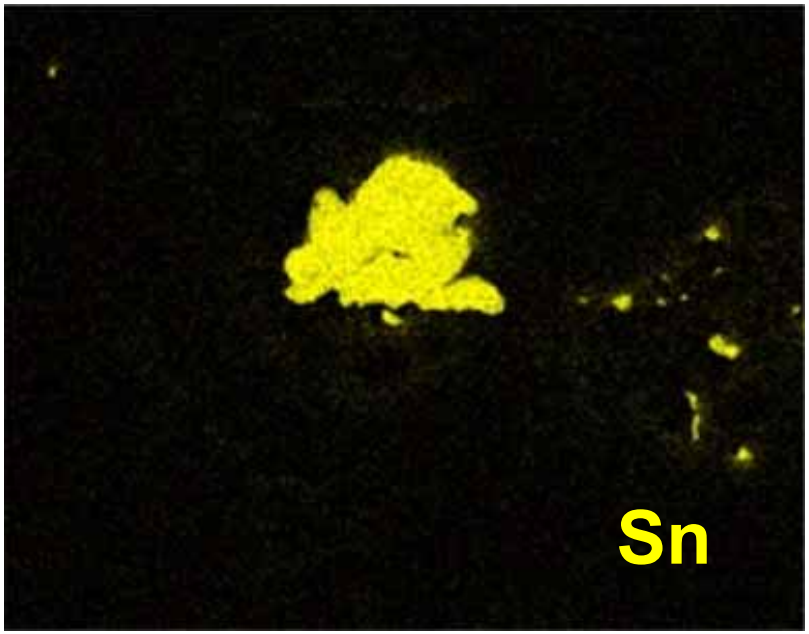


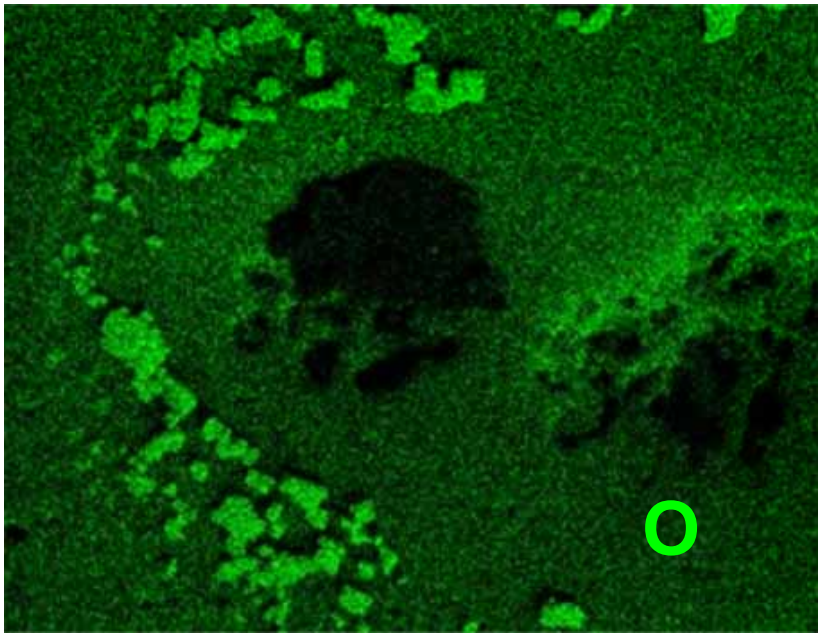
Coating E after Removal from Coupon (Same Area as Previous Slide)

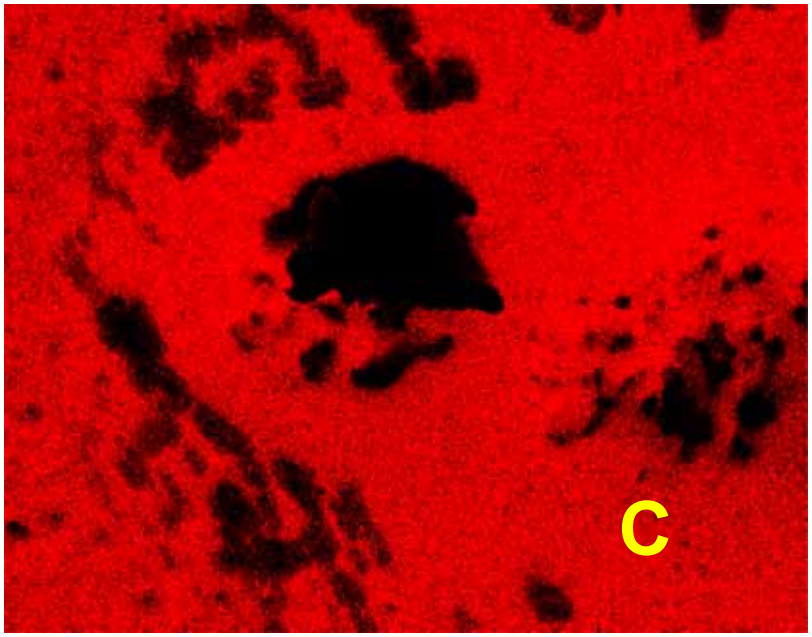


EDS Elemental Maps of Coating E after Removal from Coupon (Same Area as Previous Slide)

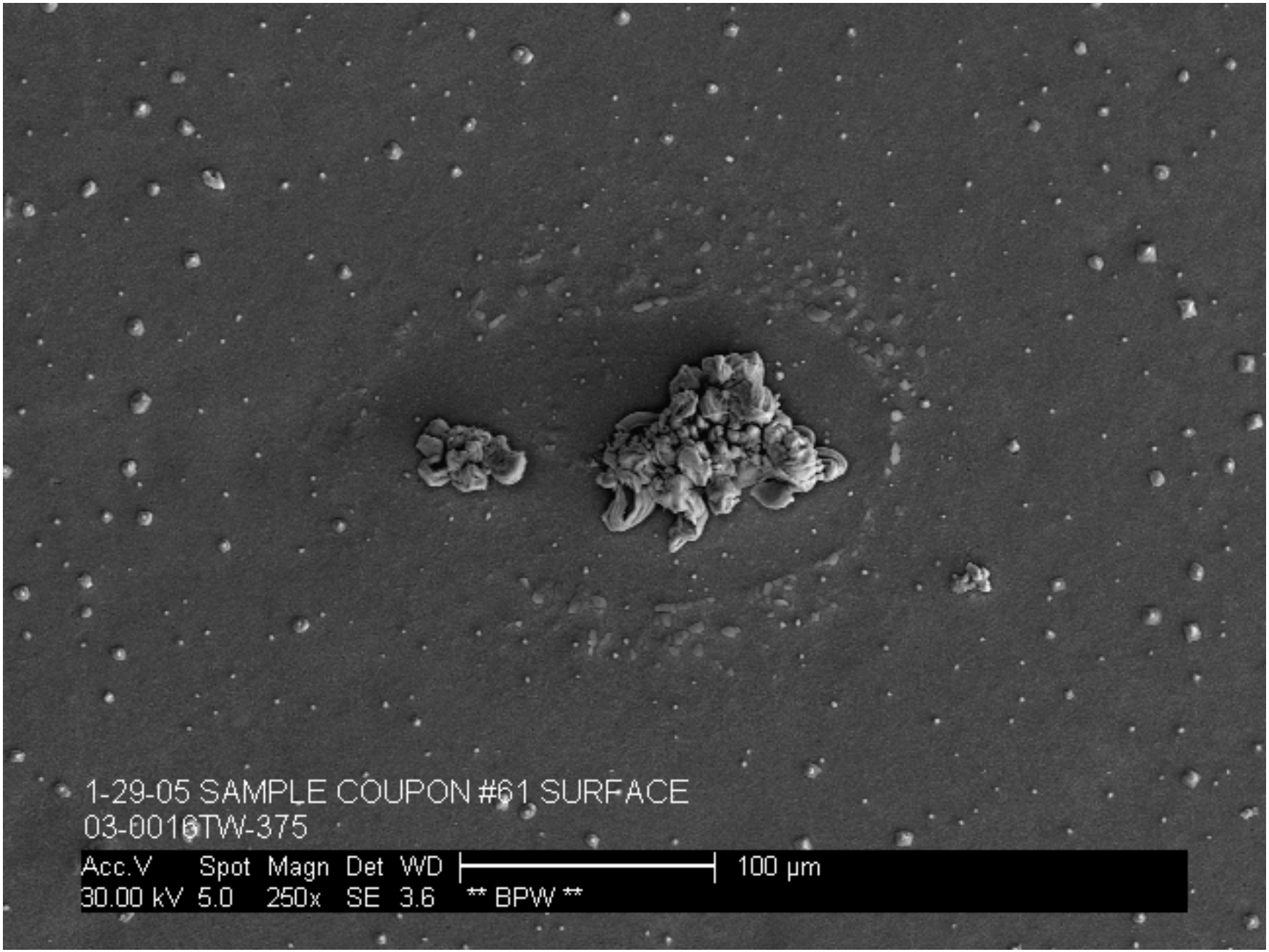




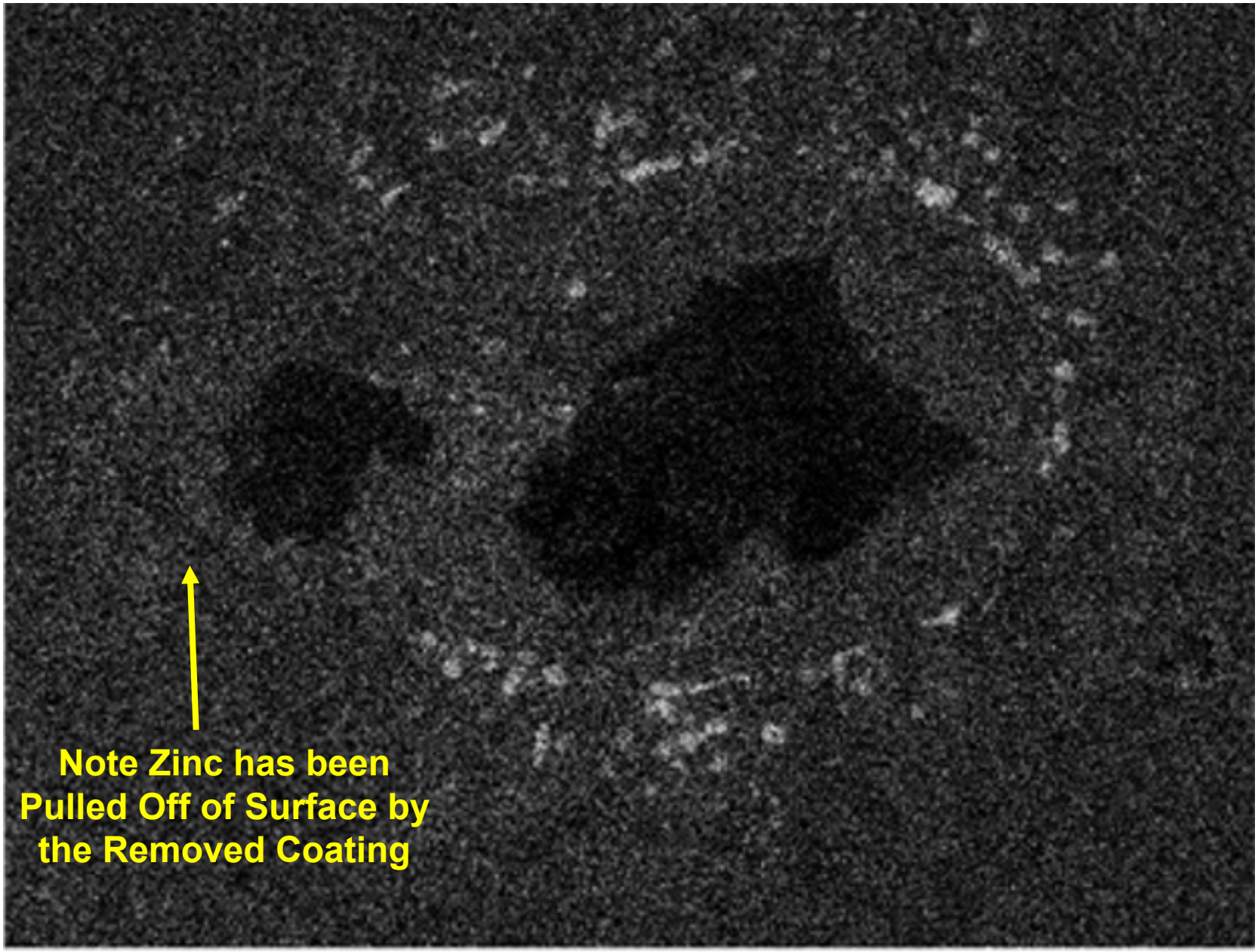




Surface of Coupon that Matches Up with Coating on Previous Slide



Zinc EDS Map of Coupon from Previous Slide Showing "Zinc Ring"



“Zinc Ring”

- Zinc migrates from brass substrate up through grain boundaries of the Sn.
- Zinc moves across surface of the Sn and gets trapped by the edge of a bubble to form a ring.
- No “zinc ring” observed on areas that were not covered with conformal coating.

Acknowledgements

Thanks to Bill Rollins and Bob Ogden of Raytheon for coating many of the test coupons.

Thanks to the members of the Tin Whisker Alert Group for their helpful suggestions.