

NEMI Tin Whisker Test Group
Phase 2 DOE Results
IPC - 2002

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Test Group Phase 2 DOE Experimental Parameters

- **Finishes**
 - Matte pure tin plated from MSA and Sulfate baths
 - 90Sn/10Pb alloy as a control
- **Plating done on production line and in laboratory**
- **Samples**
 - Production type components (OLIN 194 Cu SOIC)
 - Passives (fuses)
 - Brass coupons (flat)
- **Test Conditions (modified conditions from Phase 1)**
 - Ambient exposure (30 C)
 - Temperature exposure + humidity exposure
 - (30 C/90%RH and 60 C/95%RH)
 - Thermal cycling (-55 C to 85 C, 20 min cycle with 7 min dwell)
 - And a combination of all of the above conditions



Phase 2 DOE Matrix

Legs	Temp Cycle	Temp	Humidity	Plating Site	Sample Size	Remarks
1	-55 to 85C	-	-	Samples from P1	30ea of A0,B0 &D0	Test to be run at Motorola: Check a different test condition using the samples from P1
2	-	60	95	Samples from P1	30ea of A0,B0 &D0	
3	-55 to 85C	60	95	Samples from P1	30ea of A0,B0 &D0	
4	-40 to 90C	50	85	S	2 strips ea of A1,B1,C1& 1 strip of D1, 2 coupons of G1	Confirm results from Phase 1
5	-	50	85	S	2 strips ea of A1,B1,C1& 1 strip of D1, 2 coupons of G1	Confirm results from Phase 1
6	-	60	90	X	AMD = 3 strips ea of A,B,E&F, 20 coupons ea of Cx & Cy, Motorola = 3 strips ea of E&F, TI/Shipley = 24 coupons of Sample G1, ChipPAC = 5 strips of D	Temp&Humidity
7	-	60	90	Y		Temp&Humidity
8	-	30C (Amb)	90	X		Test humidity
9	-	30C (Amb)	90	Y		Test humidity
10	-55 to 85	30C (Amb)	90	X		Sequential T/C & Humidity
11	-55 to 85	30C (Amb)	90	Y		Sequential T/C & Humidity
12	-55 to 85	Amb	Amb	X		Test T/C
13	-55 to 85	Amb	Amb	Y		Test T/C
14	Amb	Amb	Amb	X		Ambient
15	Amb	Amb	Amb	Y		Ambient

Slide Courtesy of Prasad Swaminath at ChipPAC

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Test Samples:

- A0= SAMPLES FROM PHASE 1. 50-100 microinch 100% Bright Sn (MSA) plate OLIN 194 Cu SOIC Molded/singulated
- B0 = SAMPLES FROM PHASE 1. 500-600 microinch 100% Bright Sn (MSA) plate OLIN 194 Cu SOIC Molded/singulated
- D0 = SAMPLES FROM PHASE 1. 500-600 microinch 90Sn/10Pb SOIC 8ld OLIN 194 Cu Molded/Singulated
- A1 = REPLICATION OF PHASE1. 50-100 microinch 100% Bright Sn (MSA) plate OLIN 194 Cu SOIC Molded/singulated
- B1 = REPLICATION OF PHASE 1. 500-600 microinch 100% Bright Sn (MSA) plate OLIN 194 Cu SOIC Molded/singulated
- C1 = REPLICATION OF PHASE 1. 50-100 microinch 100% Bright Sn (MSA) plate brass coupon
- D1 = REPLICATION OF PHASE 1. 500-600 microinch 90Sn/10Pb SOIC 8ld OLIN 194 Cu Molded/Singulated
- A = 50-100 microinch 100% Matte Sn (Sulphate) plate OLIN 194 Cu SOIC Molded/singulated
- B = 500-600 microinch 100% Matte Sn (Sulphate) plate OLIN 194 Cu SOIC Molded/singulated
- Cx = 50-100 microinch 100% Matte Sn (Sulphate) plate brass coupon
- Cy = 50-100 microinch 100% Matte Sn (MSA) plate brass coupon
- D = 500-600 microinch 90Sn/10Pb SOIC 8ld OLIN 194 Cu Molded/Singulated
- E = 50-100 microinch 100% Matte Sn (MSA) plate OLIN 194 Cu SOIC Molded/singulated
- F = 500-600 microinch 100% Matte Sn (MSA) plate OLIN 194 Cu SOIC Molded/singulated



Plating Bath Control for Suppliers A and B

Supplier A										
Contaminations, ppm	Pb		Fe		Cu		Zn		Ni	
	<i>t_o</i>	<i>t_e</i>	<i>t_o</i>	<i>t_e</i>	<i>t_o</i>	<i>t_e</i>	<i>t_o</i>	<i>t_e</i>	<i>t_o</i>	<i>t_e</i>
Sulfate (samples A and B)	6	6.3	9.7	11.9	0.4	0.6	0.4	0.5	0.44	0.5
MSA (samples E and D)	N/A	N/A	5.2	5.2	0.7	0.7	0.6	0.7	0.41	0.48
Supplier B										
MSA (samples E and D)	8.2	8.3	13.9	15	0.3	0.3	0.3	0.3	10	13

t_o – before plating

t_e – after plating



SEM Inspection Protocol

courtesy of P. Bush, SUNY at Buffalo

- Three packages randomly chosen from the test sample mounted in upright, inverted and inverted rotated positions

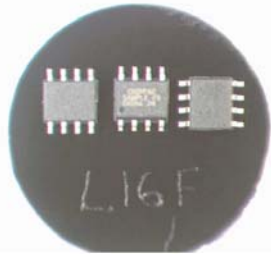


Fig. 1 Packages mounted for SEM observation.

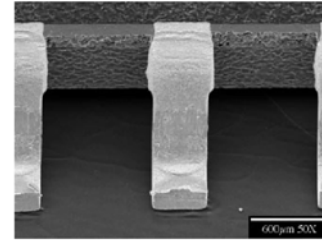


Fig 2. View of top side of lead

- At 300x or greater, inspect all lead surfaces with the stage at normal incidence. Image and measure the longest whisker found.
- Collect three randomly located fields at 300x from a) underside of lead, b) top of lead and c) side of lead (representative of the overall condition of the parts as determined by the first inspection).
- Measure and record the longest whisker in each field, using higher magnification if necessary.
- Record one image at 3000x from an undisturbed region of plating to estimate grain size.



SEM Inspection Protocol: Report

- Average number of whiskers from the three fields
- The length of the longest whisker found in those fields.
- The the length of longest whisker found during 300x inspection of entire leadframe surfaces on all three devices/coupons.
- The estimated grain size range of the deposit. Include
- In all reports include:
 - the date of plating;
 - The date, duration, and conditions of accelerated test/storage
 - the date of inspection.



Sample Set A: Sulfate Chemistry, 50-100 μ inch, Olin 194 SOIC Molded/Singulated

Leg #	Test sequence	Average density	Max. length in field	Max. length on 3 SOIC's	Grain size
4	TC: -40C to 90C; 50C/85% RH for 4 weeks				
5	No TC; 50C/85% RH for 4 weeks				
6	No TC; 60C/95% RH for 4 weeks				
7	No TC; 60C/95% RH for 4 weeks				
8	No TC; 30C/90% RH for 4 weeks	0	0	0	1-4
9	No TC; 30C/90% RH for 4 weeks	-	-	-	-
10	TC: -55C to 85C; 30C/90% RH for 4 weeks	0	0	0	1-4
11	TC: -55C to 85C; 30C/90% RH for 4 weeks	-	-	-	-
12	TC: -55C to 85C; Amb/Amb for 4 weeks	0	0	0	1-4
13	TC: -55C to 85C; Amb/Amb for 4 weeks	-	-	-	-
14	No TC; Amb/Amb	0	0	0	1-4
15	No TC; Amb/Amb	-	-	-	-

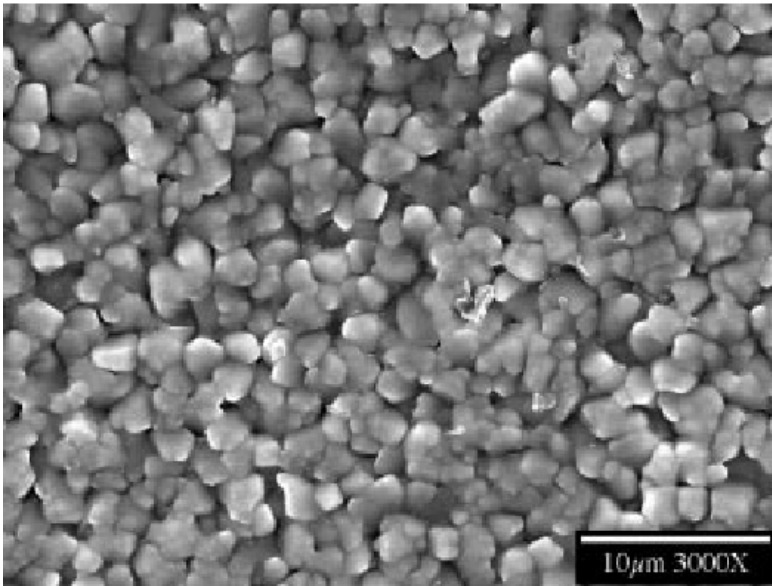


Sample Set B: Sulfate Chemistry, 500-600 μ inch, Olin 194 SOIC Molded/Singulated

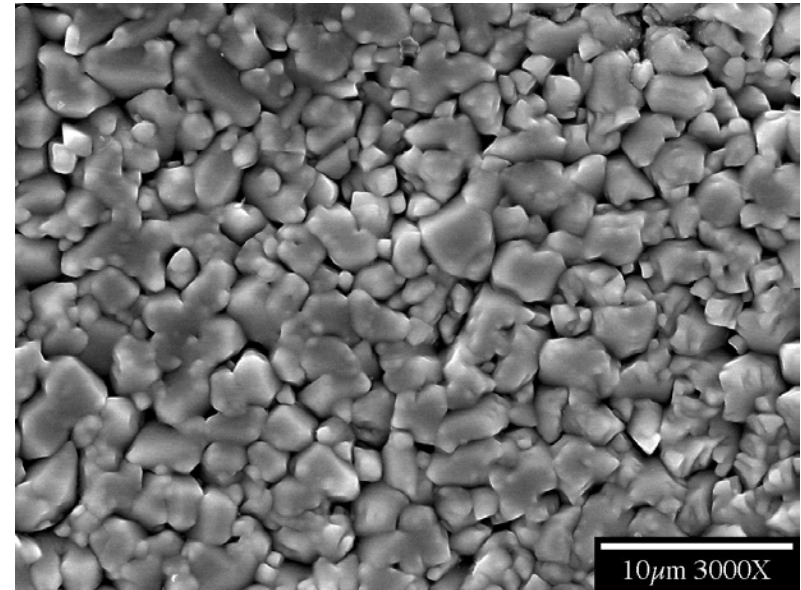
Leg #	Test sequence	Average density	Max. length in field	Max. length on 3 SOIC's	Grain size
4	TC: -40C to 90C; 50C/85% RH for 4 weeks				
5	No TC; 50C/85% RH for 4 weeks				
6	No TC; 60C/95% RH for 4 weeks				
7	No TC; 60C/95% RH for 4 weeks				
8	No TC; 30C/90% RH for 4 weeks	0	0	0	1-4
9	No TC; 30C/90% RH for 4 weeks	-	-	-	-
10	TC: -55C to 85C; 30C/90% RH for 4 weeks	0	0	10	1-4
11	TC: -55C to 85C; 30C/90% RH for 4 weeks	-	-	-	-
12	TC: -55C to 85C; Amb/Amb for 4 weeks	0	0	10	1-4
13	TC: -55C to 85C; Amb/Amb for 4 weeks	-	-	-	-
14	No TC; Amb/Amb	0	0	0	1-4
15	No TC; Amb/Amb	-	-	-	-



Effect of Deposit Thickness on Morphology



50-100 microinch deposit

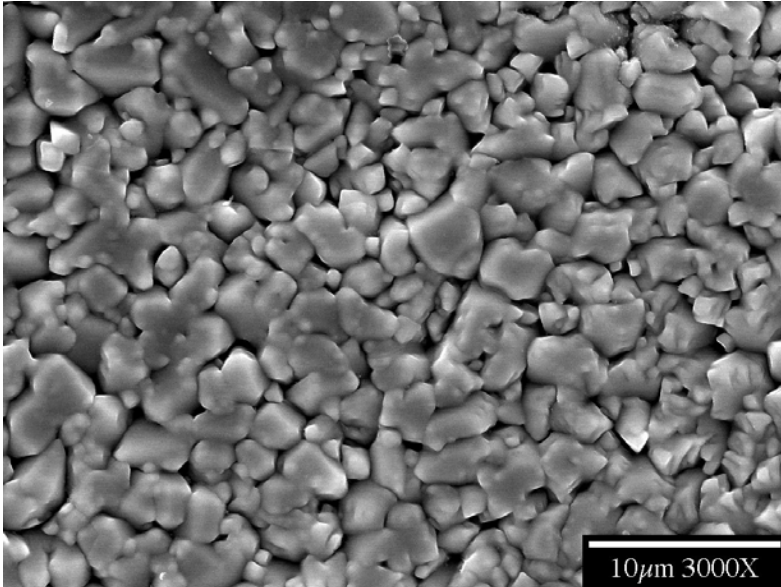


500-600 microinch deposit

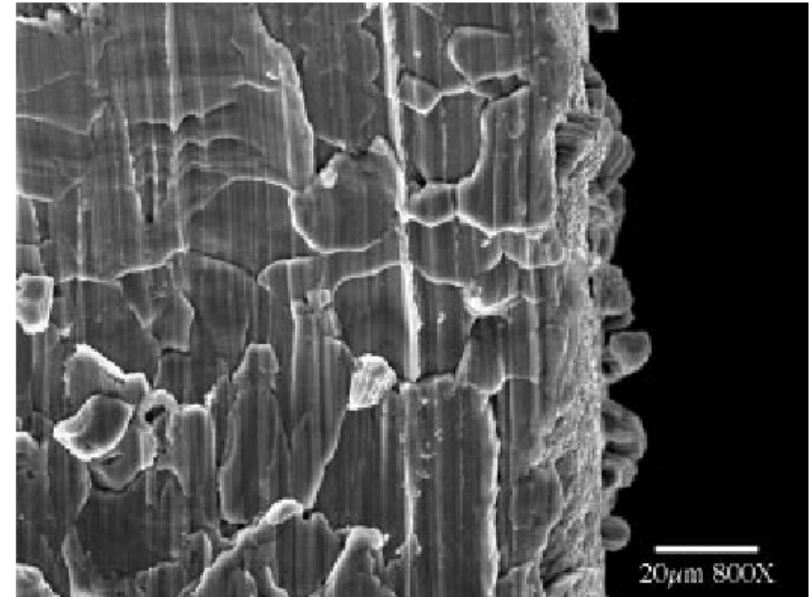
**Sulfate chemistry, supplier A, after TC -55C to 85C and 30C/90%RH
(legs 10A and B)**



Recrystallization in the Damaged Area



Undamaged area

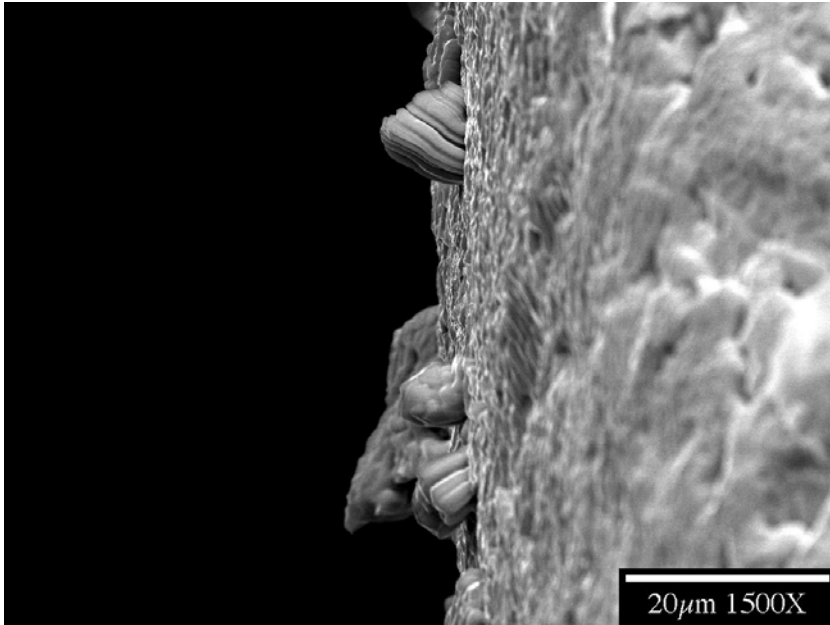


Damaged area

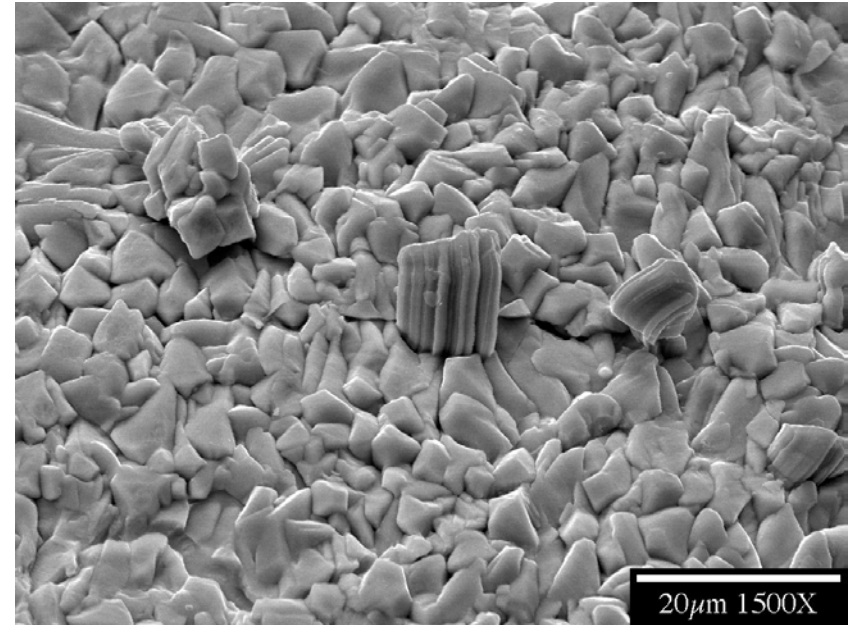
Sulfate chemistry, supplier A, after TC -55C to 85C and 30C/90%RH (leg 10B)



Temperature-cycled Thick Sulfate



Leg 10 B early whisker growth



Leg 12 B early whisker growth



Thick vs. Thin Sulfate

Conclusions: Only early whisker growth observed in temperature-cycled thick deposit.



Sample Set E: MSA Chemistry, 50-100 μ inch, Olin 194 SOIC Molded/Singulated

Leg #	Test sequence	Average density	Max. length in field	Max. length on 3 SOIC's	Grain size
4	TC: -40C to 90C; 50C/85% RH for 4 weeks				
5	No TC; 50C/85% RH for 4 weeks				
6	No TC; 60C/95% RH for 4 weeks (supplier A)	8	50	60	1-5
7	No TC; 60C/95% RH for 4 weeks (supplier B)	0	0	15	1-5
8	No TC; 30C/90% RH for 4 weeks (supplier A)	6	50	70	1-5
9	No TC; 30C/90% RH for 4 weeks (supplier B)	1	6	20	1-5
10	TC: -55C to 85C; 30C/90% RH for 4 weeks (supplier A)	7	50	70	1-5
11	TC: -55C to 85C; 30C/90% RH for 4 weeks (supplier B)	0	0	0	1-5
12	TC: -55C to 85C; Amb/Amb for 4 weeks (supplier A)	2	40	60	2-10
13	TC: -55C to 85C; Amb/Amb for 4 weeks (supplier B)	0	0	10	5-15
14	No TC; Amb/Amb (supplier A)	4	40	80	2-10
15	No TC; Amb/Amb (supplier B)	1	10	10	5-15



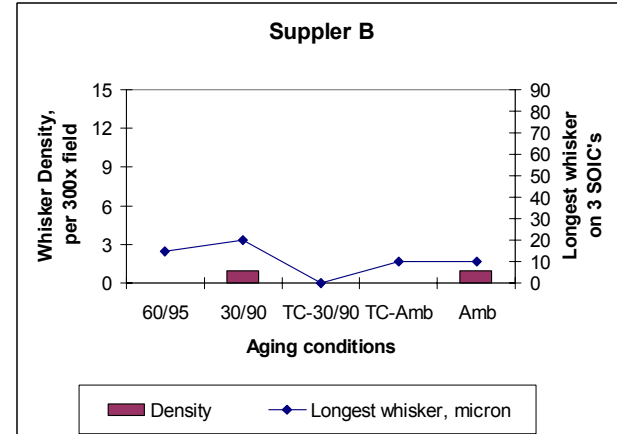
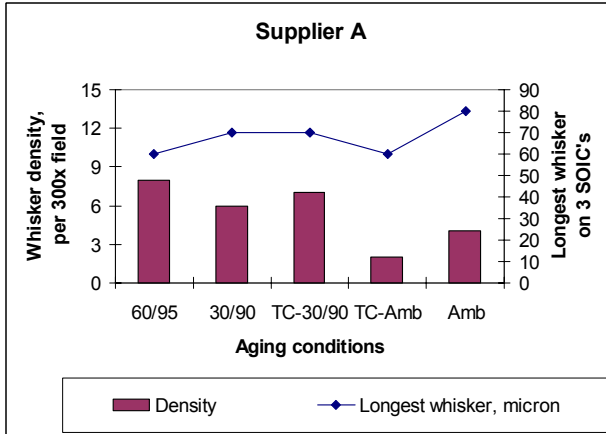
Sample Set F: MSA Chemistry, 500-600 μ inch, Olin 194 SOIC Molded/Singulated

Leg #	Test sequence	Average density	Max. length in field	Max. length on 3 SOIC's	Grain size
4	TC: -40C to 90C; 50C/85% RH for 4 weeks				
5	No TC; 50C/85% RH for 4 weeks				
6	No TC; 60C/95% RH for 4 weeks (<i>supplier A</i>)	0		0	2-8
7	No TC; 60C/95% RH for 4 weeks (<i>supplier B</i>)	0		0	5-15
8	No TC; 30C/90% RH for 4 weeks (<i>supplier A</i>)	0		10	2-8
9	No TC; 30C/90% RH for 4 weeks (<i>supplier B</i>)	0		0	5-15
10	TC: -55C to 85C; 30C/90% RH for 4 weeks (<i>supplier A</i>)	13	10	10	2-15
11	TC: -55C to 85C; 30C/90% RH for 4 weeks (<i>supplier B</i>)	8	10	10	5-15
12	TC: -55C to 85C; Amb/Amb for 4 weeks (<i>supplier A</i>)	13	10	10	2-10
13	TC: -55C to 85C; Amb/Amb for 4 weeks (<i>supplier B</i>)	10	10	10	5-15
14	No TC; Amb/Amb (<i>supplier A</i>)	0	0	0	2-10
15	No TC; Amb/Amb (<i>supplier B</i>)	0	0	0	1-5 15

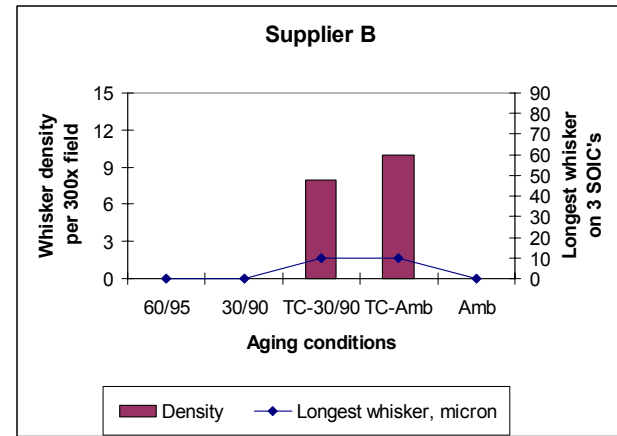
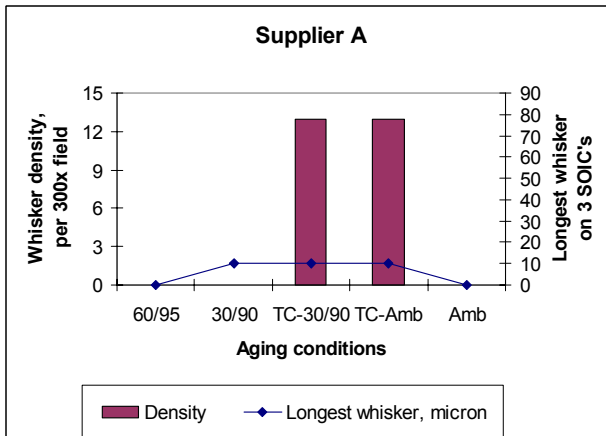
Connect with and Strengthen Your Supply Chain



Sets E and F: Comparison of Aging Conditions



Set E: 50-100 microinch matte Sn, MSA based chemistry

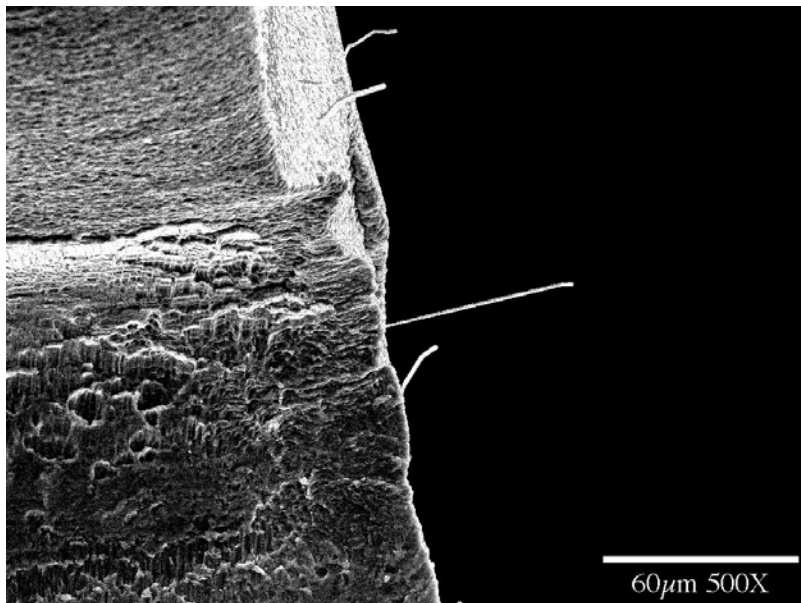


Set F: 500-600 microinch matte Sn, MSA based chemistry

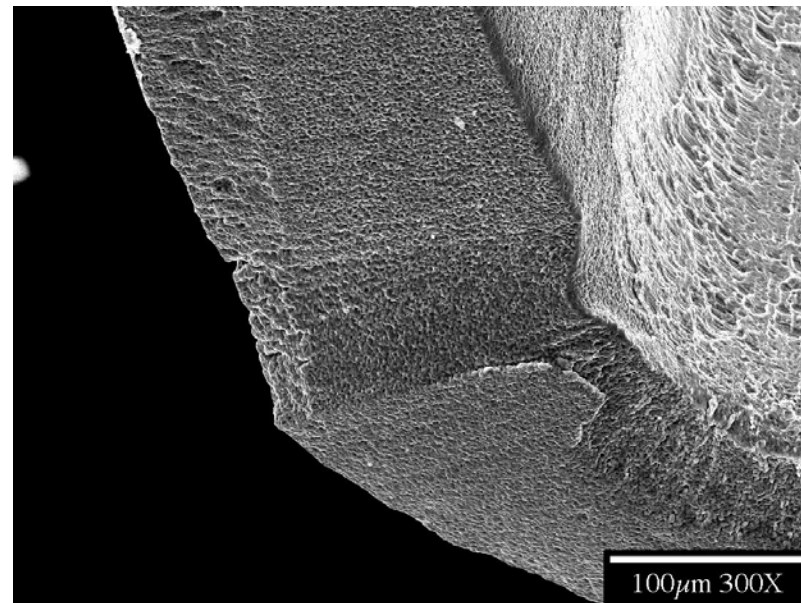
Connect with and Strengthen Your Supply Chain



Sample Set E: MSA Chemistry, 50-100 μ inch, Olin 194 SOIC Molded/Singulated



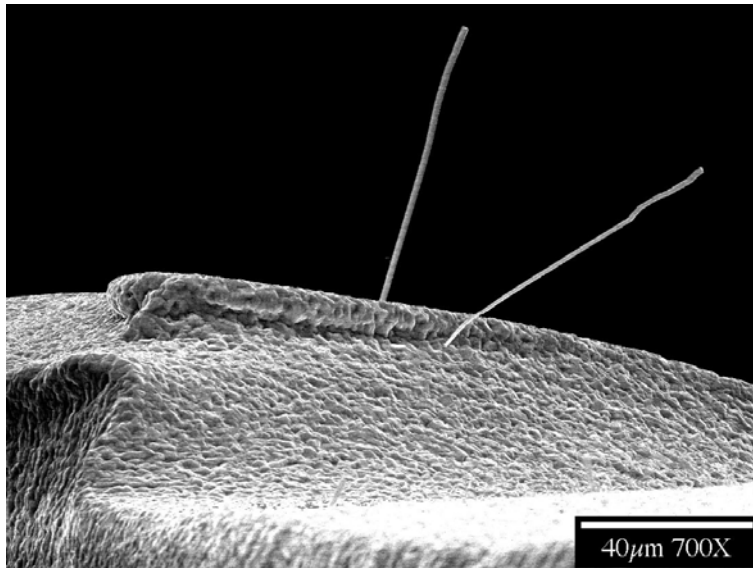
**Leg 6 E Supplier A, no TC
60/95 T/RH**



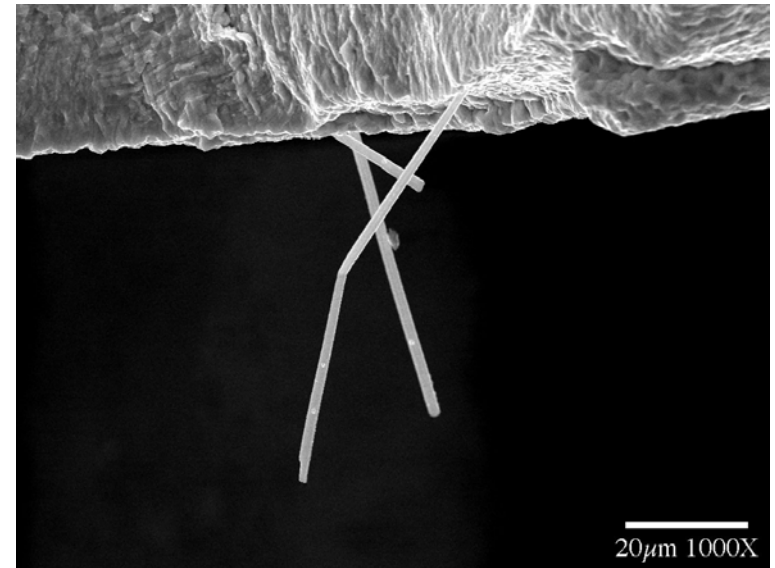
**Leg 7 E Supplier B, no TC
60/95 T/RH**



Set E: Longest Whiskers Observed



Ambient (80 micron)

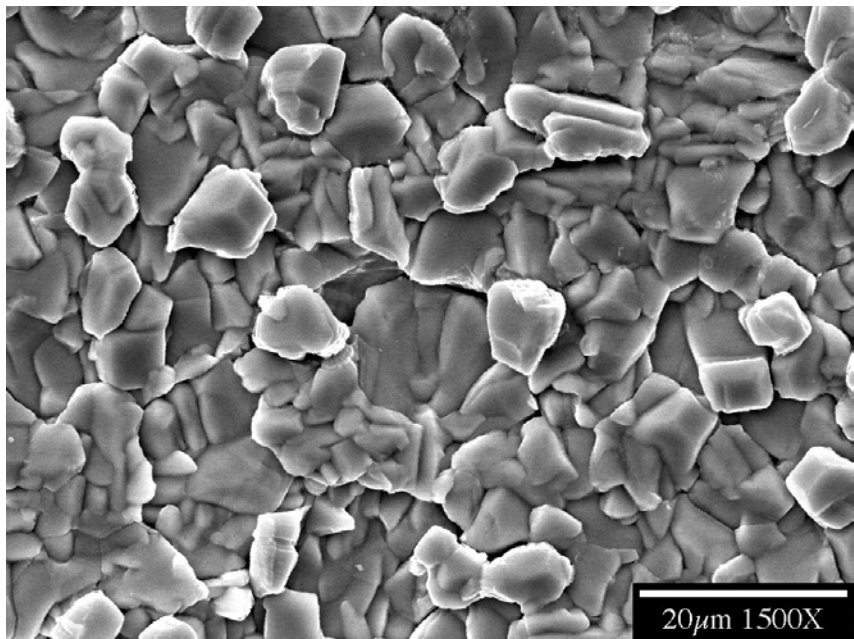


*TC: -55C to 85C; 30C/90%RH for 4 weeks
(70 micron)*

Thin MSA tin from Supplier A

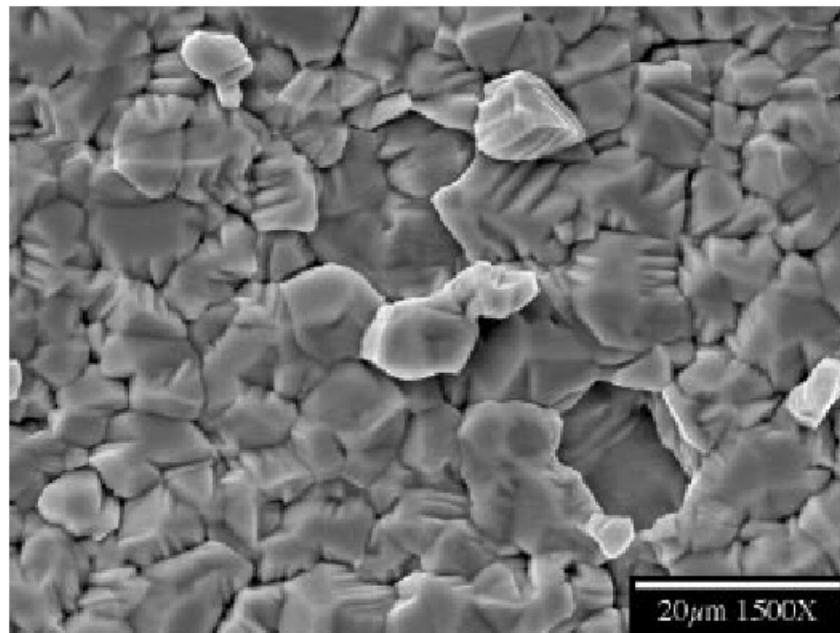


Sample Set F: MSA Chemistry, 500-600 μ inch, Olin 194 SOIC Molded/Singulated



Leg 10 F. Very short, but unmistakable growths.

Supplier A



Leg 11 F. Short growths and sunken adjacent grain.

Supplier B

Test conditions: -55C to 85C; 30C/90% RH for 4 weeks

Connect with and Strengthen Your Supply Chain



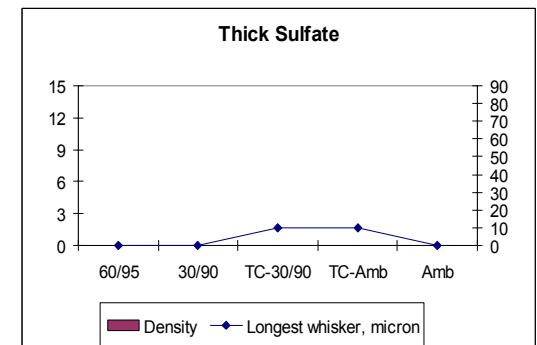
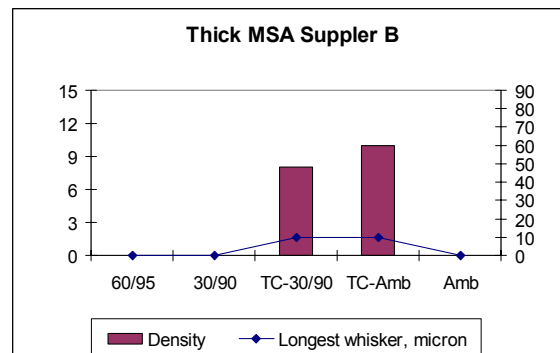
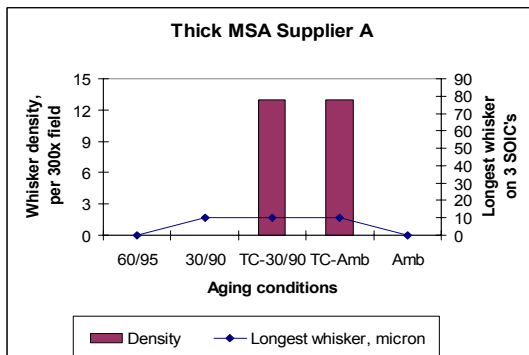
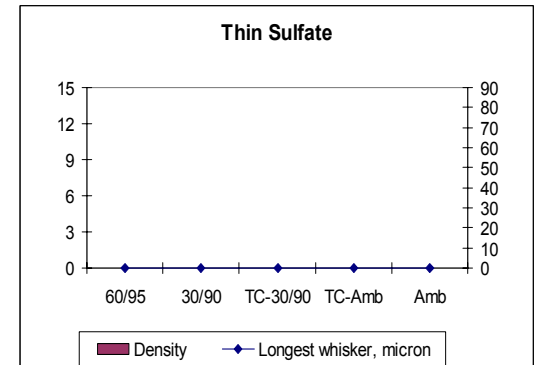
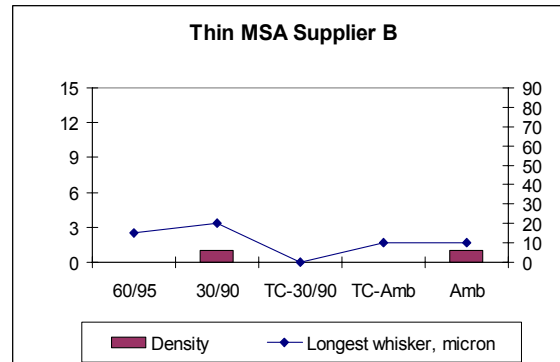
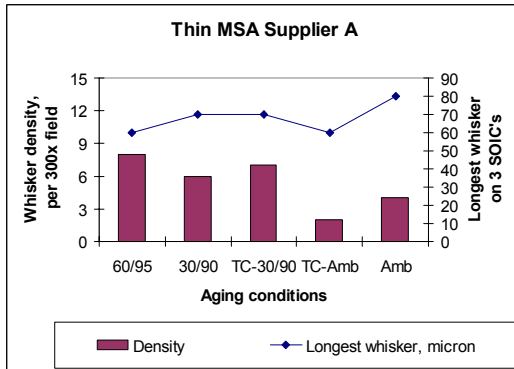
Sample Sets E and F: *Thin and Thick Tin, MSA Chemistry*

Conclusions:

- **Principal difference in whisker density was supplier related for thin deposit**
- **Temperature cycling did not significantly accelerate growth of thin deposits**
- **For thicker deposit, only temperature-cycled legs showed signs of short growth**



Effect of Bath Chemistry (SOIC's)





Sample Sets Cx and Cy: *thin matte tin over brass coupon*

Cx: sulfate bath

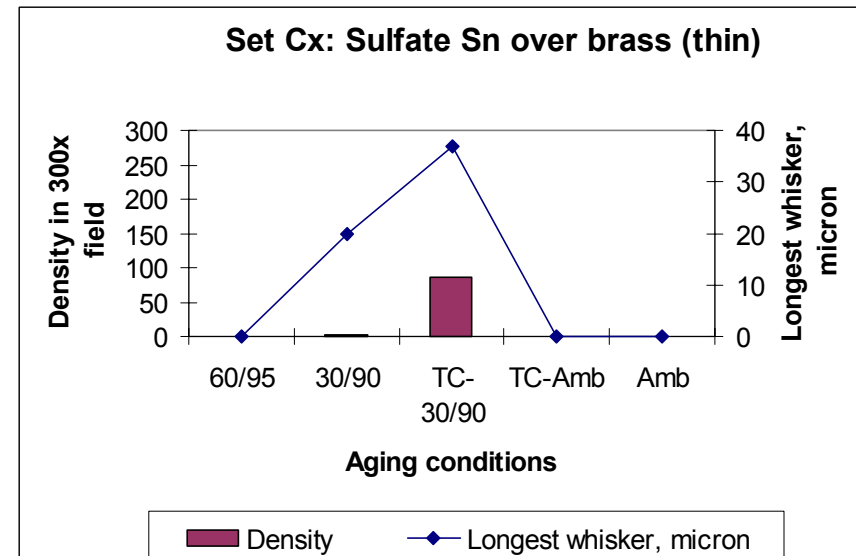
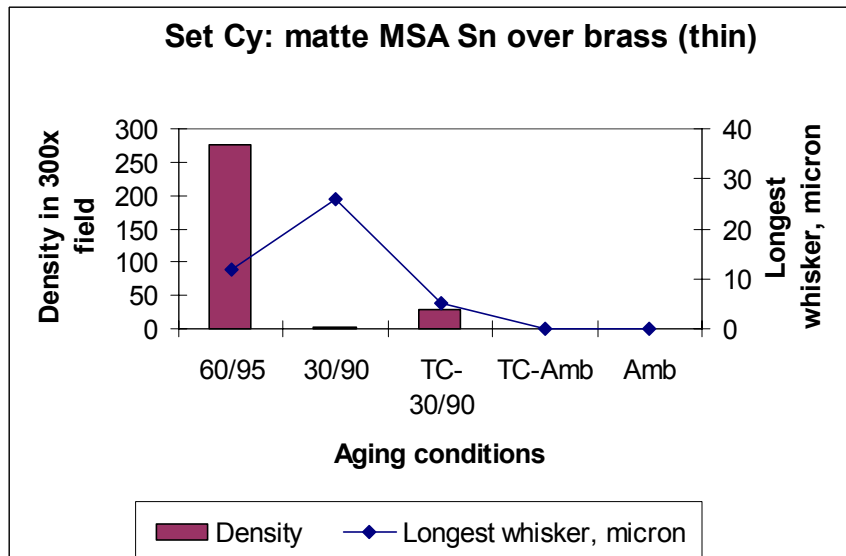
Leg #	Test sequence	Average density	Max. length in field	Grain size
6	No TC; 60C/95% RH for 4 weeks	0	0	1-3
8	No TC; 30C/90% RH for 4 weeks	3	20	1-3
10	TC: -55C to 85C; 30C/90% RH for 4 weeks	85	37	1-3
12	TC: -55C to 85C; Amb/Amb for 4 weeks	0	0	1-3
14	No TC; Amb/Amb	0	0	1-3

Cy: MSA bath

Leg #	Test sequence	Average density	Max. length in field	Grain size
6	No TC; 60C/95% RH for 4 weeks	275	12	1-3
8	No TC; 30C/90% RH for 4 weeks	2	26	1-3
10	TC: -55C to 85C; 30C/90% RH for 4 weeks	28	5	1-3
12	TC: -55C to 85C; Amb/Amb for 4 weeks	0	0	1-3
14	No TC; Amb/Amb	0	0	1-3

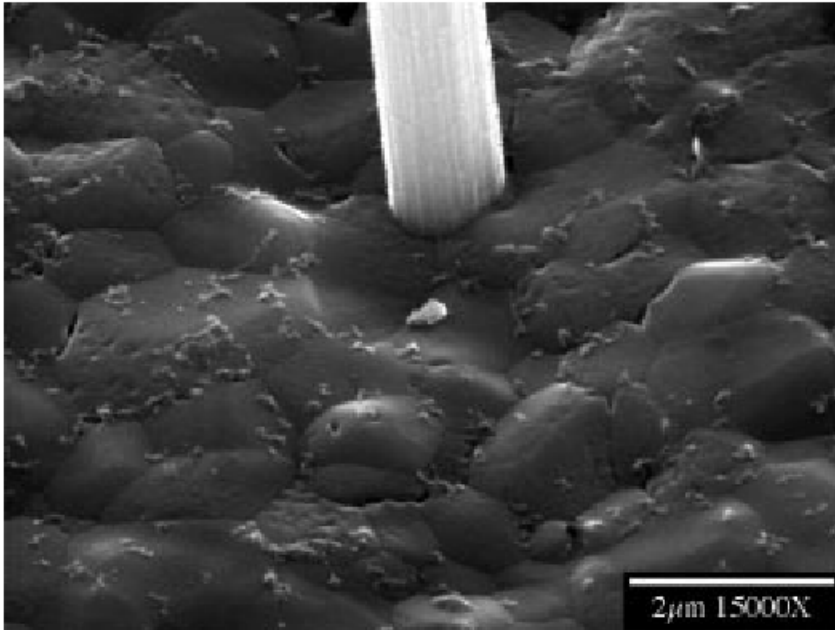


Effect of Bath Chemistry (brass coupons)

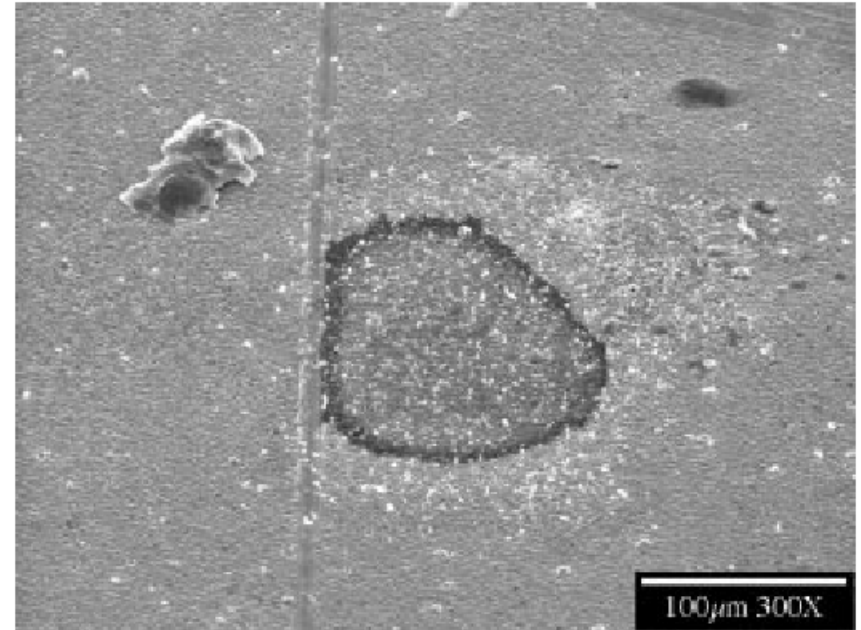




Sample Sets Cx and Cy



Leg 8 Cx particles on surface

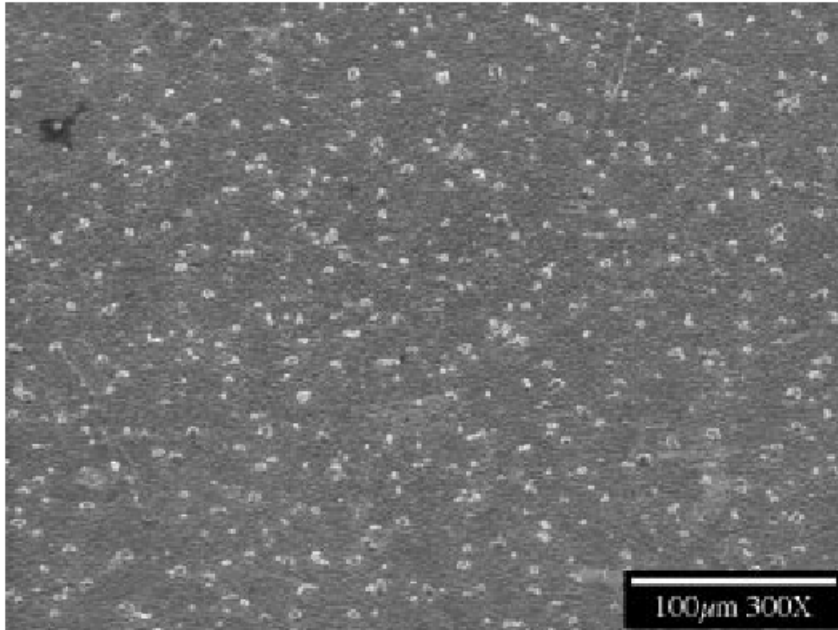


Leg 10 Cy Increased population of whiskers around contamination spot

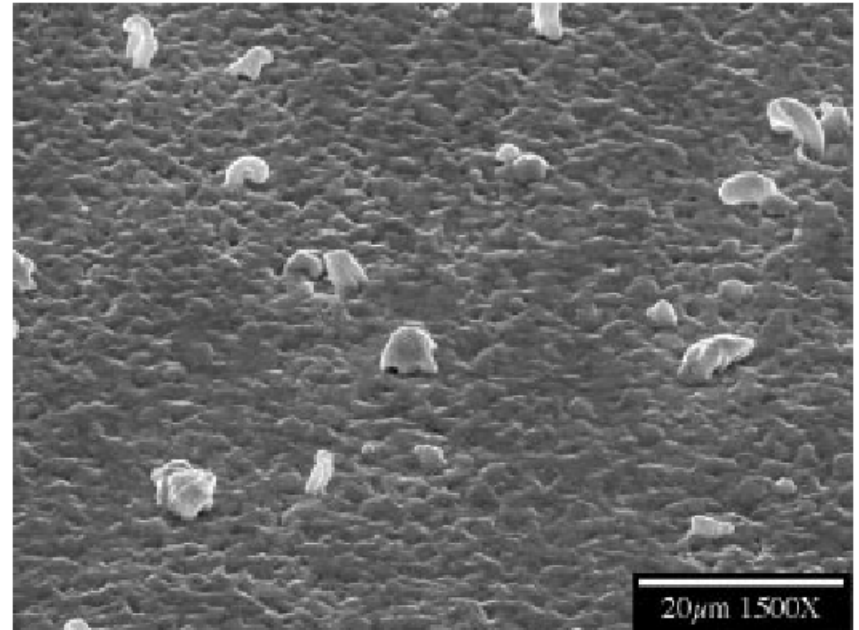
Thin matte Sn (Cx – sulfate, and Cy – MSA) over brass coupons



Sample Set Cy



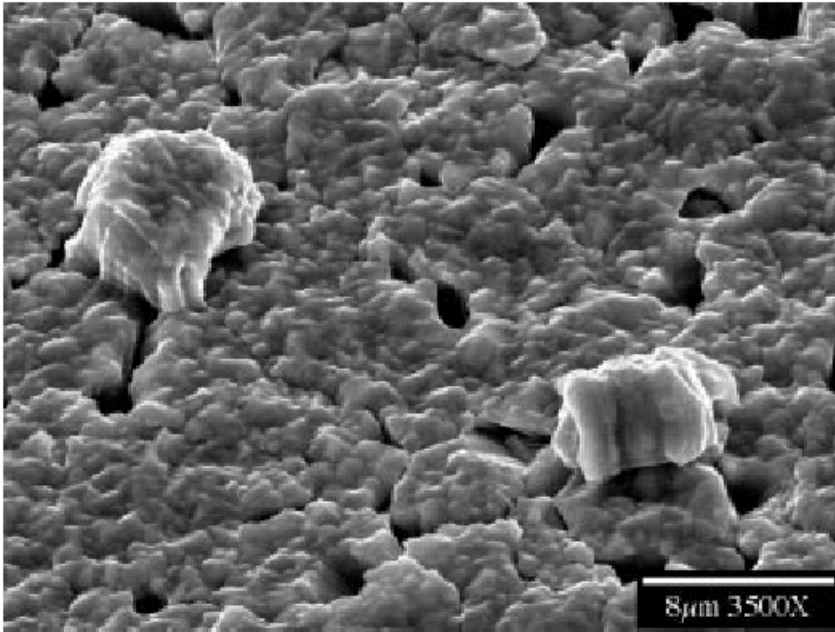
Leg 6 Cy 300+ small whiskers



Leg 6 Cy 300+ small whiskers

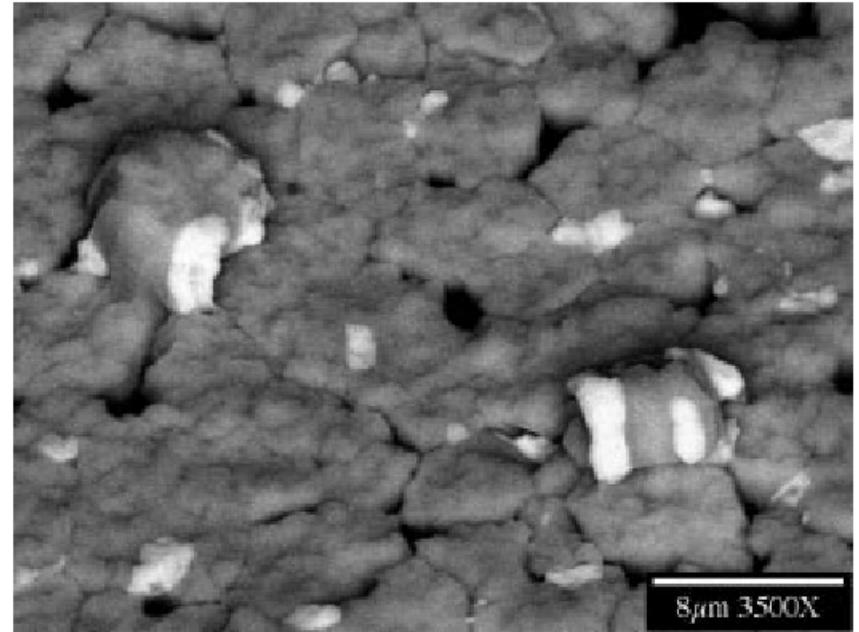


Sample Set D: SnPb – No Whiskers



Leg 13 D

SEI

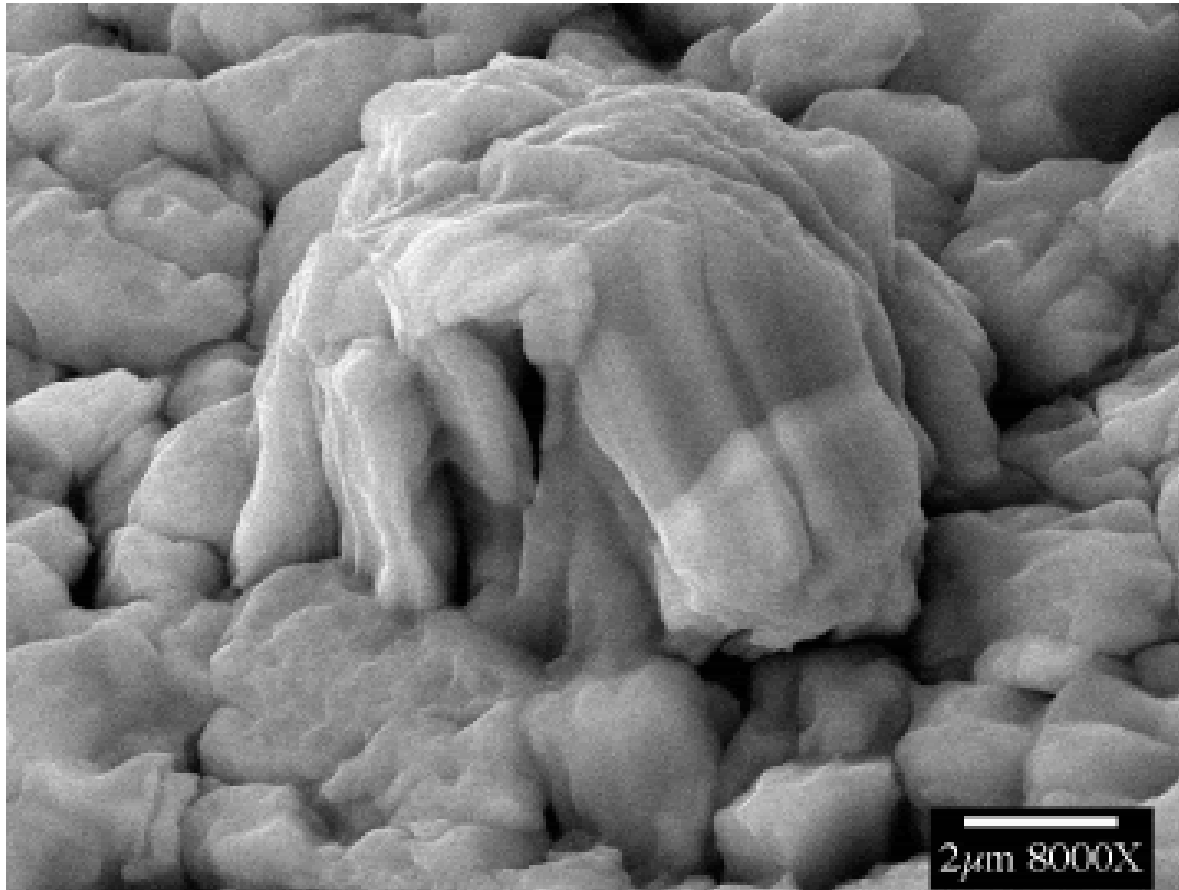


Leg 13 D

BEI



Series D movie





Initial Findings

- There is no conclusive evidence that any set of conditions tested in this experiment has the highest accelerating effect on whisker growth
- There is no indication in this experiment that thicker deposits are less prone to whisker
- Bath chemistry/plating process parameters seem to have the most significant influence on whiskering
 - Slight advantage of sulfate-based chemistry comparing to a good-practice MSA bath
 - Significant difference between two MSA-based processes from two suppliers
- Overall the results look random and maybe within experimental error/noise



Acknowledgement

NEMI Test and Modeling Groups would like to acknowledge valuable contribution made by Mr. P. Bush, SUNY at Buffalo, in developing SEM whisker inspection procedure and evaluating the results of Phase 2 DOE.