



NEMI Sn Whisker Project

JISSO/PROTEC Forum

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Japan

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Tin Whisker Committees

- ***Tin Whisker Test Standards Committee (Test Group)***
 - ***First committee formed***
 - ***Objective to develop tests/test criteria for tin whiskers***
 - ***Subject of Today's report***
- ***Tin Whisker Modeling Group (Modeling Group)***
 - ***Formed to gain fundamental understanding of whisker formation***
- ***Tin Whisker Users Group (Users Group)***
 - ***Formed by large companies with high reliability products to look at mitigation techniques***

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NEMI Committee Structure

- ***Tin Whisker Test Standards Committee (Test Group)***
 - 42 companies including two governmental organizations
 - Nick Vo (Chair) – Motorola
 - Jack McCullen (Co-Chair) – Intel
 - Mark Kwoka (Co-Chair) – Intersil

- ***Tin Whisker Modeling Group (Modeling Group)***
 - 13 companies including one government organization.
 - George Galyon (Chair) – IBM
 - Maureen Williams (Co-Chair) – NIST
 - Irina Boguslavsky (Co-Chair) – NEMI Consultant

- ***Tin Whisker Users Group (Users Group)***
 - Recently started in late 2002
 - 10 companies
 - George Galyon (Chair) – IBM
 - Richard Coyle (Co-Chair) – Lucent

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Test Team Members

- *Agilent*
- *Alcatel*
- *Allegro Microsystems*
- *AMD*
- *Analog Devices*
- *Boeing*
- *ChipPAC*
- *Cooper Bussmann*
- *Delphi Delco*
- *Engelhard Clal*
- *Enthone*
- *FCI Framatome*
- *Flextronics*
- *HP*
- *IBM*
- *Indium*
- *Infineon AG*
- *Intel (Co-Chair)*
- *Intersil (Co-Chair)*
- *IPC*
- *ITRI Soldertec*
- *Kemet*
- *Lockheed Martin*
- *Microchip*
- *Micro Semi*
- *Molex*
- *Motorola (Chair)*
- *NASA Goddard*
- *NIST*
- *NEMI*
- *On Semi*
- *Philips*
- *Raytheon*
- *Soldering Tech.*
- *Shipley*
- *Solectron*
- *ST Micro*
- *SUNY Binghamton*
- *SUNY Buffalo*
- *Technic*
- *Texas Instruments*
- *US Army*

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Test Committee Goals

- ***Objective:***
 - To identify an accelerated test method for whiskering by evaluating various known test methods.
- ***Scope of Work:***
 - ✓ Collect all existing test methods for whiskers
 - ✓ Evaluate theory behind whisker formation
 - ✓ Devise a test or tests to detect whisker formation
 - ✓ Evaluate the test method with known good and “bad” processes to prove suitability
 - Develop a test specification and provide it to IPC/JEDEC for release as an industry standard

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Summary of Phase 1 DOE

- **Samples (brass coupons and 8 lead SOICs) were prepared with bright Sn along with SnPb (control)**
- **Whiskers formed only on the bright Sn-plated coupons, and were few in number - much less than expected**
- **There were two possible explanations of low whiskering**
 - **the level of impurities and/or contamination were maintained very low (samples plated in the lab) and thus helped to retard whisker growth**
 - **when the terminations were formed the plating cracked reducing stress in the finish and thus helped to retard whisker growth**
- **The results of the Phase 1 study were inconclusive**

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Summary of Phase 2 DOE

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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) for 5 months
 - Temperature + humidity exposure
 - (30 C/90%RH and 60 C/95%RH) for 4 weeks
 - Thermal cycling (500 cycles; -55 C to 85 C, 20 min cycle with 7 min dwell)
 - And a combination of all of the above conditions

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Phase 2 DOE Matrix

Legs	Temp Cycle	Temp	Humidity	Plating Site	Remarks
6	-	60	95	Supplier A	Temp&Humidity
7	-	60	95	Supplier B	Temp&Humidity
8	-	30C (Amb)	90	Supplier A	Humidity
9	-	30C (Amb)	90	Supplier B	Humidity
10	-55 to 85	30C (Amb)	90	Supplier A	Sequential T/C & Humidity
11	-55 to 85	30C (Amb)	90	Supplier B	Sequential T/C & Humidity
12	-55 to 85	Amb	Amb	Supplier A	Test T/C
13	-55 to 85	Amb	Amb	Supplier B	Test T/C
14	Amb	Amb	Amb	Supplier A	Ambient
15	Amb	Amb	Amb	Supplier B	Ambient

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Samples Tested in DOE 2

- A = 50-100 microinch 100% Matte Sn (Sulphate) on OLIN 194 Cu SOIC Molded/singulated
- B = 500-600 microinch 100% Matte Sn (Sulphate) on OLIN 194 Cu SOIC Molded/singulated
- C = 50-100 microinch 100% Bright Sn plate brass coupon
- D = 500-600 microinch 90Sn/10Pb on OLIN 194 Cu Molded/Singulated (control)
- E = 50-100 microinch 100% Matte Sn (MSA) on OLIN 194 Cu SOIC Molded/singulated
- F = 500-600 microinch 100% Matte Sn (MSA) on OLIN 194 Cu SOIC Molded/singulated

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Plating Bath Control for Suppliers A and B

Supplier A										
Contaminations, ppm	Pb		Fe		Cu		Zn		Ni	
	t_o	t_e	t_o	t_e	t_o	t_e	t_o	t_e	t_o	t_e
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

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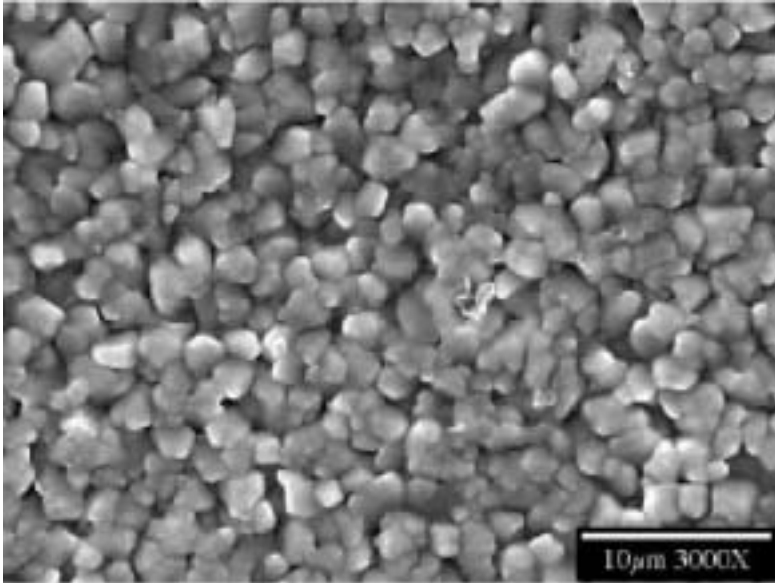
SEM Inspection Protocol: Report

- **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.**
- **In all reports include:**
 - **The date of plating**
 - **The date, duration, and conditions of accelerated test/storage**
 - **The date of inspection**

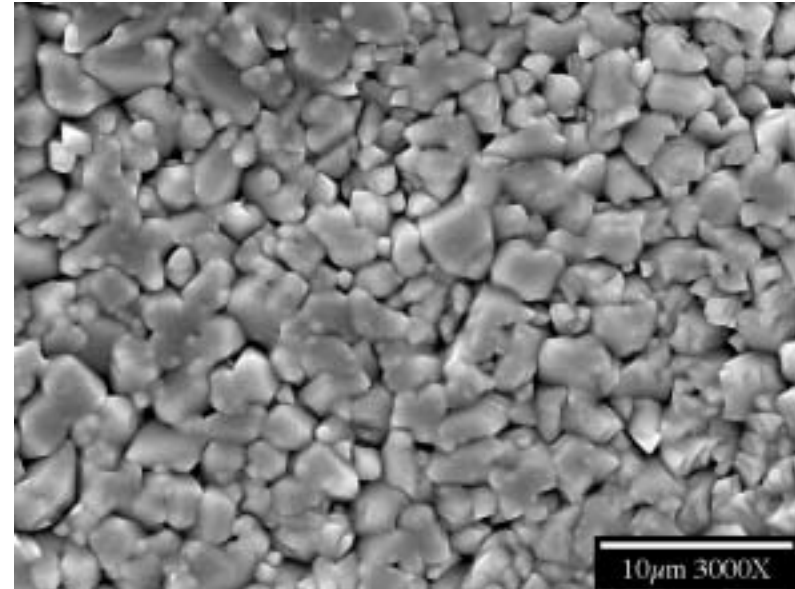
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Effect of Deposit Thickness on Morphology



50-100 microinch deposit



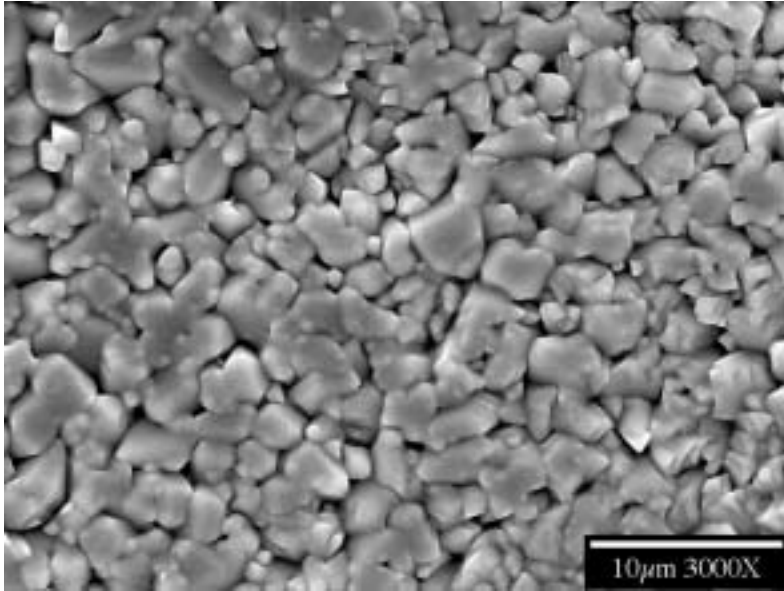
500-600 microinch deposit

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

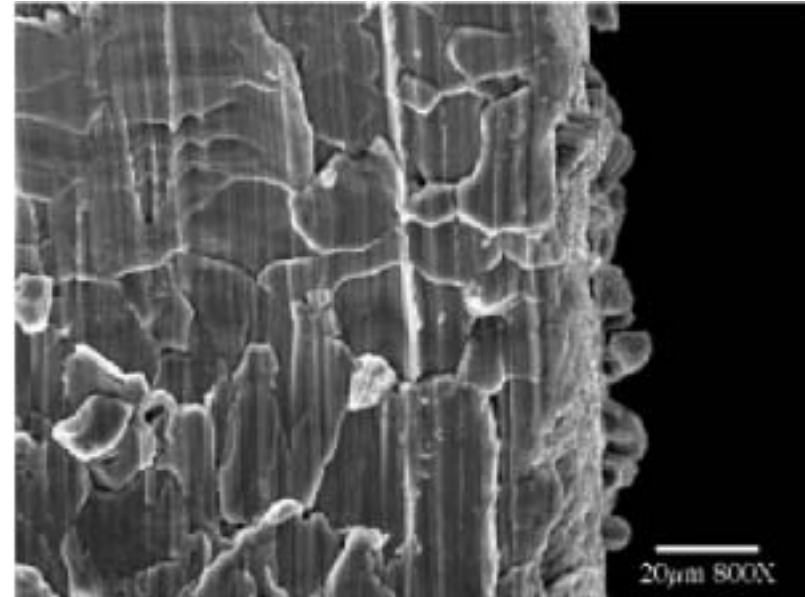
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Recrystallization in the Damaged Area



Undamaged area



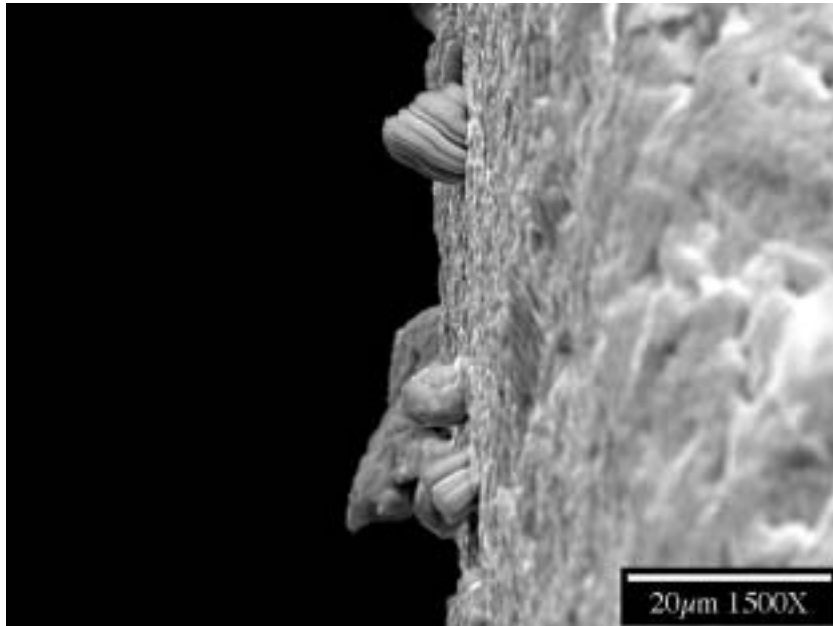
Damaged area

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

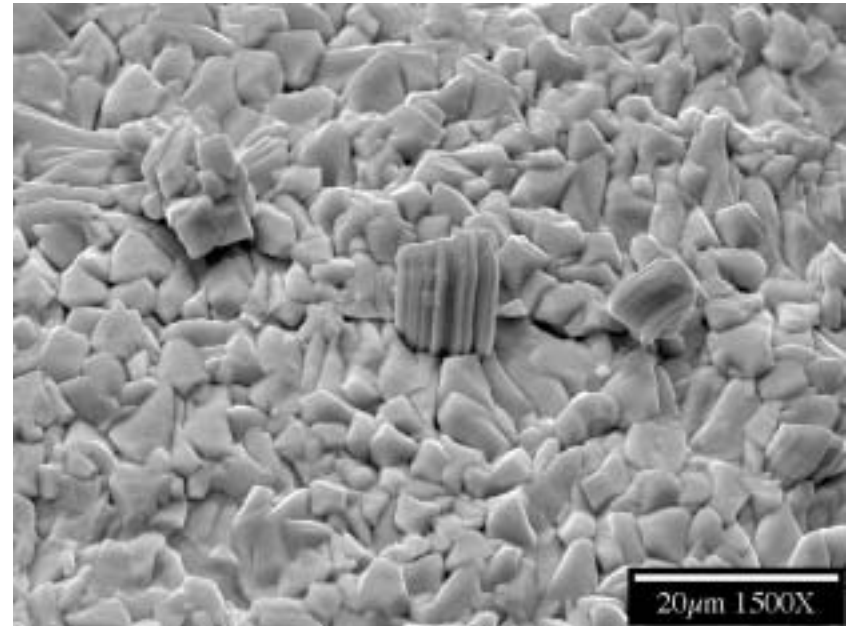
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Temperature-cycled Thick Sulfate



Leg 10 B early whisker growth

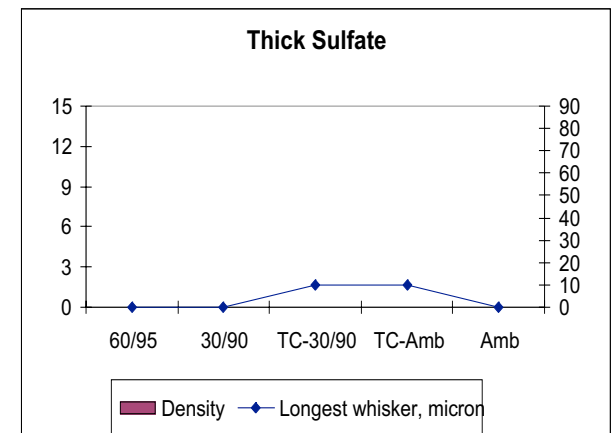
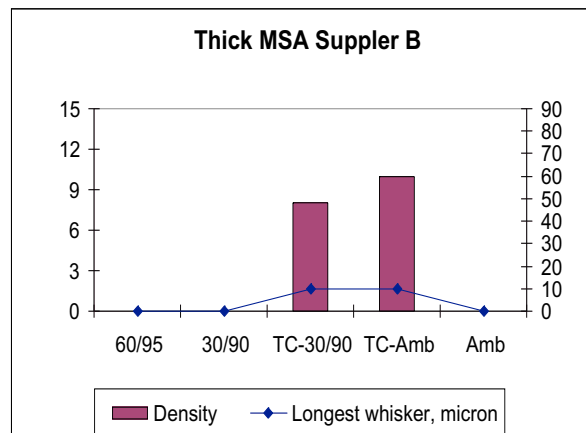
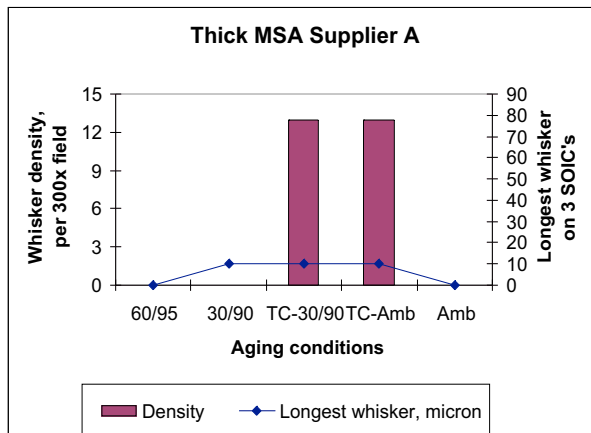
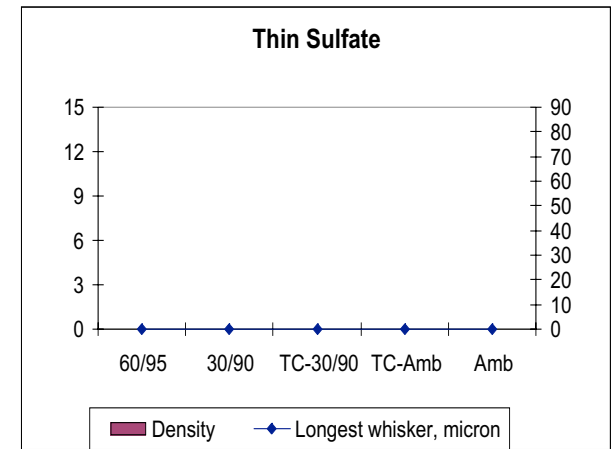
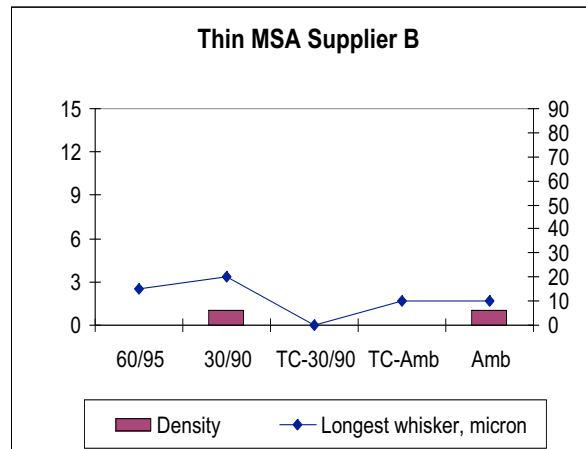
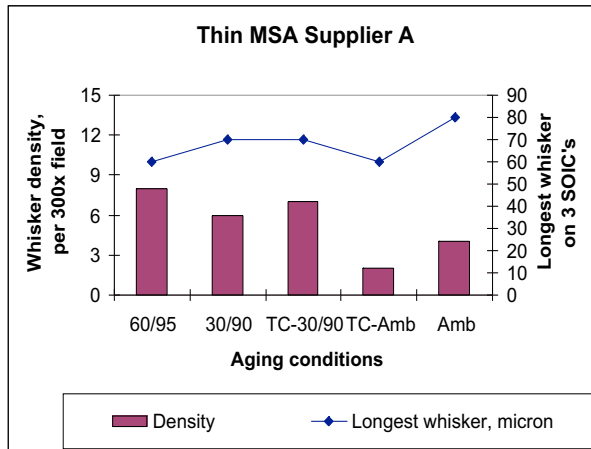


Leg 12 B early whisker growth

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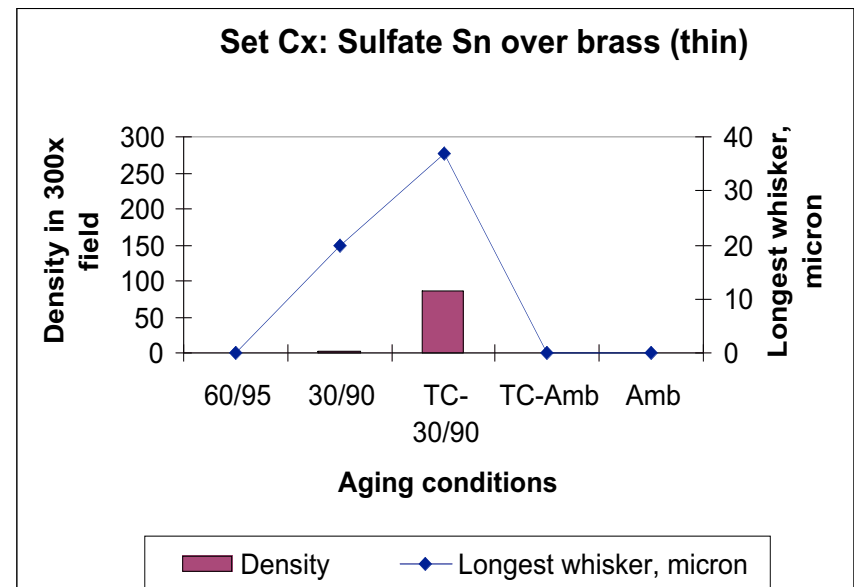
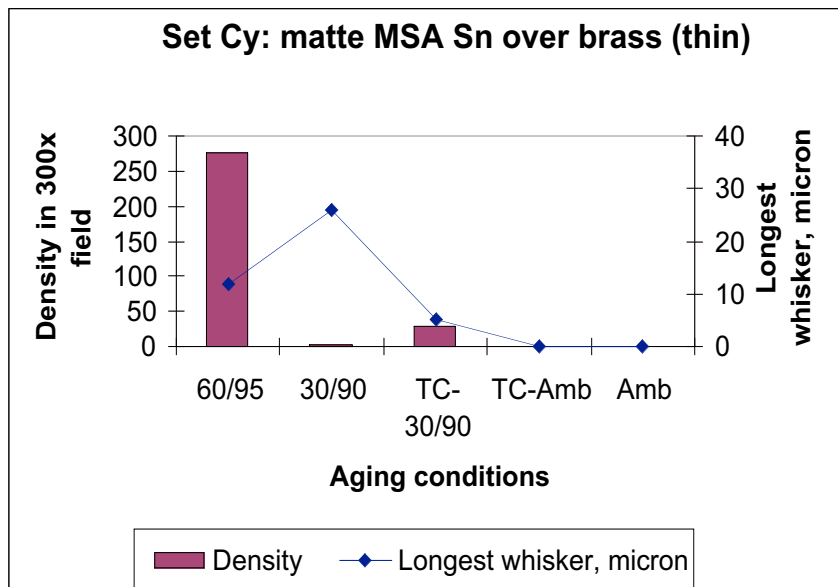
Effect of Bath Chemistry (SOIC's)



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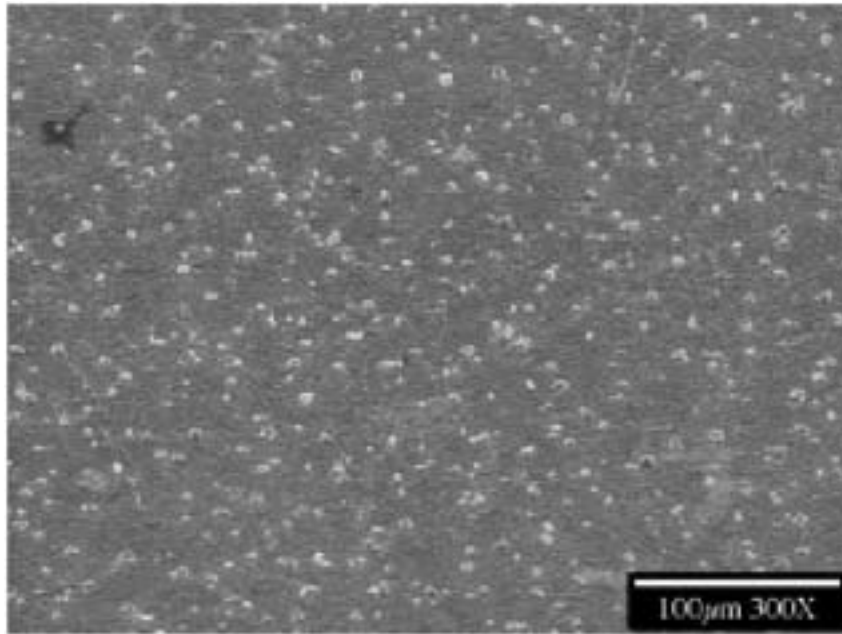
Effect of Bath Chemistry (*brass coupons*)



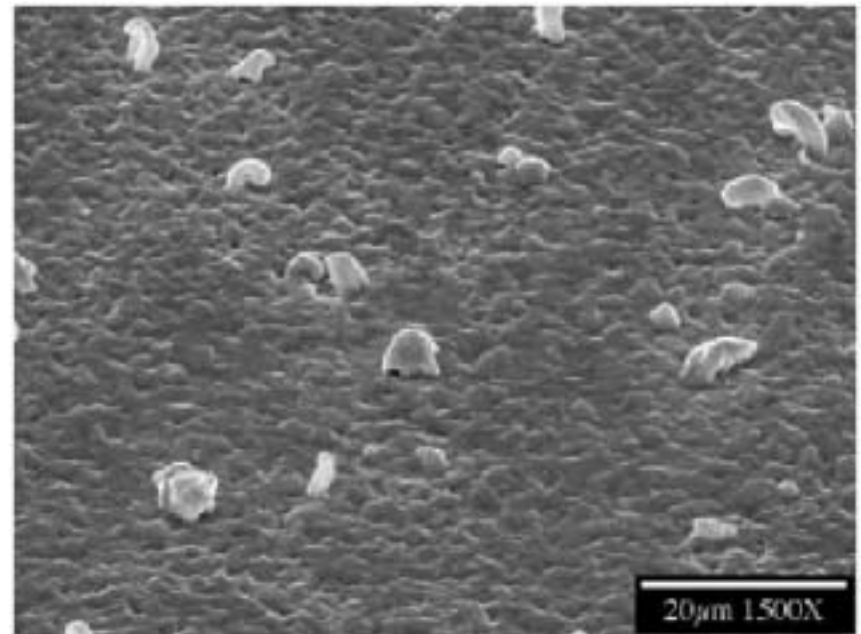
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Sample Set Cy



300X



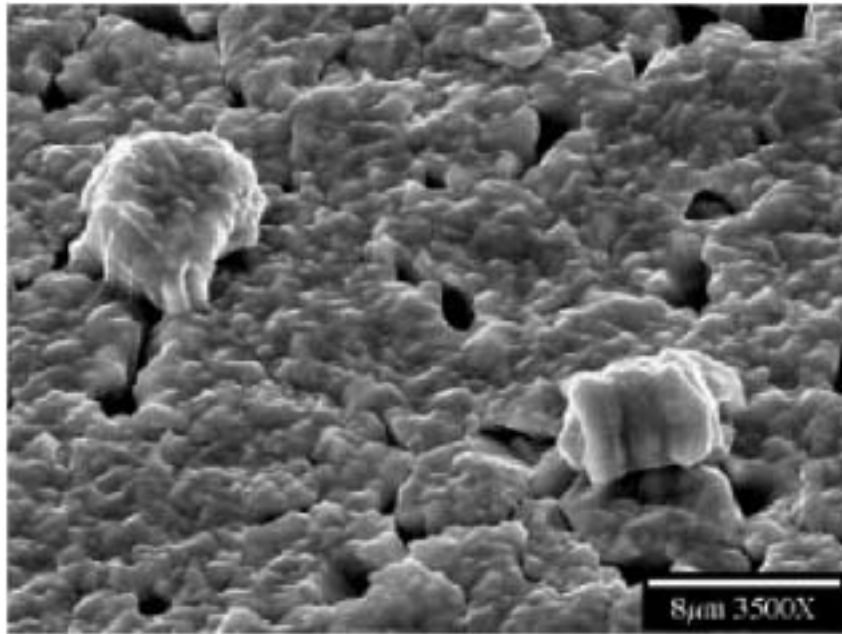
1500X

Leg 6 Cy 300+ small whiskers

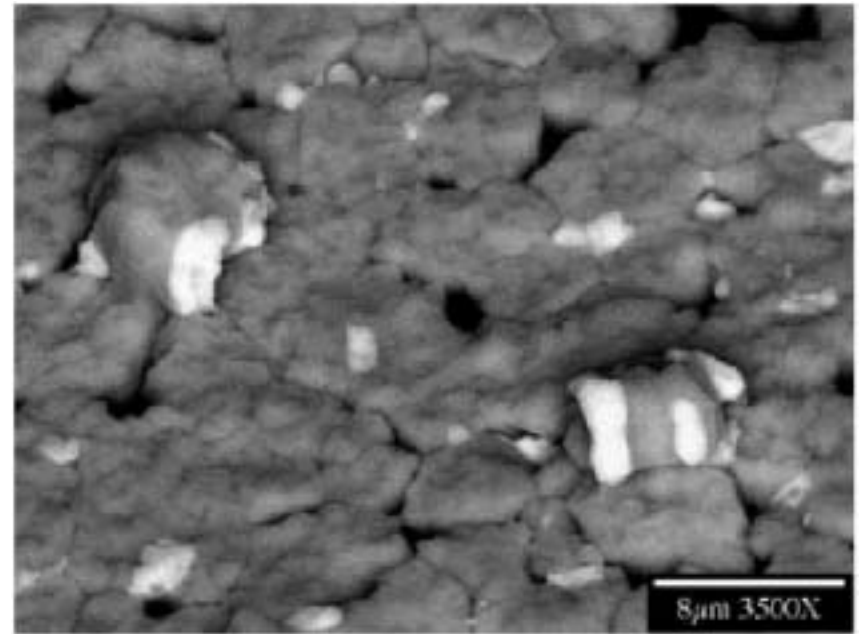
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Sample Set D: SnPb – No Whiskers



Secondary Electron Image



Backscattered Electron Image

Leg 13 D

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Initial Findings

- In general, more whiskers grew with the -55C/85C temperature cycle method, followed by 60C/90%RH storage; some whisker growth was also observed with the ambient environment
- 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
- All these observation may indicate that there are some unknown factors that have influence on whisker growth comparable with aging conditions
- Another conclusion maybe made that whisker growth phenomenon is multi-factorial event and the theory/model describing it should take into consideration numerous parameters

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Recommended Test Method

- *Prepare whisker test method for release by JEDEC.*
- *Purpose:*
 - Provide test method to aid in the evaluation and development of plating finishes.
 - Provide an industry-standardized test for comparison of whisker-propensity for different plating systems and processes.
 - **Not intended for use in reliability assessment or qualification.**
- *Recommended Test Methods:*
 - **-55°C (+0, -10) / 85°C (+10, -0) air-air temperature cycle (20minutes/cycle)**
 - **60°C, 90±5%RH temperature / humidity storage**
 - **Ambient storage (~23°C, %RH to be determined)**
 - **All three tests are to be performed using separate samples**

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Future Work and Concerns

- *Future work:*

- Prepare whisker test method document for release by JEDEC.
- Validate and verify recommended test methods.
- Perform tests to extended durations (establish end points for recommended test methods).
- Attempt to identify test methods which can be correlated to application life (to attempt to define reliability and qualification tests).

- *Concerns:*

- How do we correlate whisker tests to application life (proof of quality & reliability)?
- How do we to utilize fundamental understanding to define an accelerated test?
- Are the proposed mitigation techniques effective?

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Phase 3 DOE – Validate and Verify

- **Tests:**
 - -55°C (+0, -10) / 85°C (+10, -0) air-air temperature cycle (20minutes/cycle)
 - 60°C, 90±5%RH temperature / humidity storage
 - Ambient storage (~23°C, ~60%RH)
- **Samples:**
 - Leaded packages from assembly contractors
 - Sn, SnBi, SnCu and SnPb (control) finishes
 - Copper CDA194, copper 7025, and Alloy42 leadframes
 - For comparison include cells with
 - Ni underplating (both matte and bright Sn)
 - Fused (confirm melting) and/or annealed Sn
 - Hot-dipped Sn
 - JEITA test vehicle

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Phase 3 DOE

Tentative milestones

- Complete design of experiment (DOE) matrix **May 30**
- Prepare samples **Jun 27**
- Perform initial SEM **Jul 18**
- Storage and temp cycle and regular inspections **Sep 26**
- Analyze the data **Oct 17**
- Prepare report **Nov 14**

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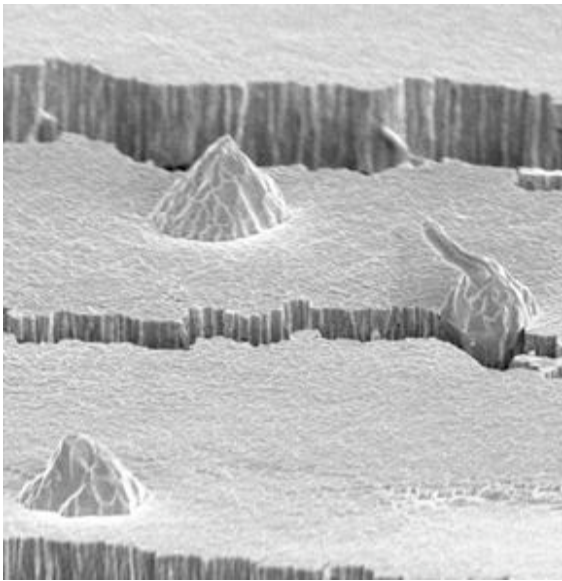
Whisker Definition

- **Purpose:**
To specify the physical and visual characteristics of a tin whisker **for use in inspection** (not intended as a metallurgical definition)
- **Tin Whisker:**
A spontaneous columnar or cylindrical filament, which rarely branches, of tin emanating from the surface of a plating finish.
- **NOTE, For the purpose of inspection tin whiskers have the following characteristics:**
 - *an aspect ratio (length/width) > 2;*
 - *can be kinked, bent, twisted;*
 - *generally have a consistent cross-sectional shape;*
 - *rarely branch;*
 - *and may have striations/rings around it.*

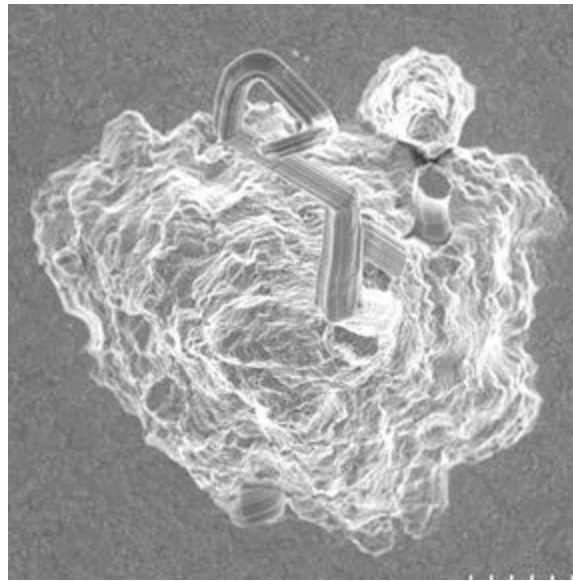
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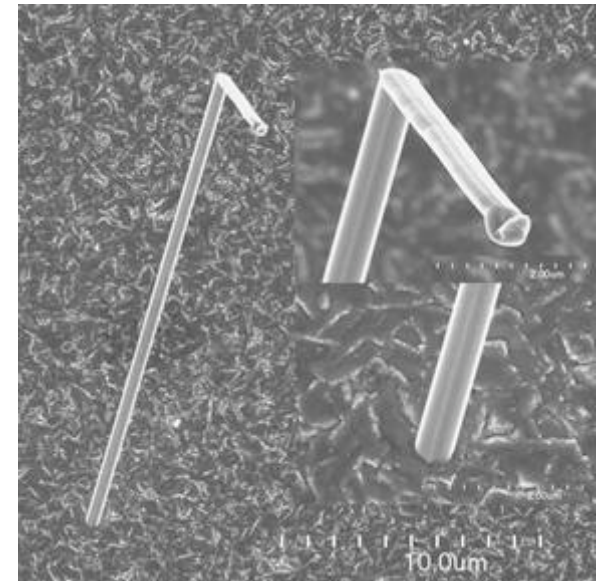
Whisker Examples



**Hillocks
(Lumps)**



**Odd-Shaped
Eruptions (OSE)**

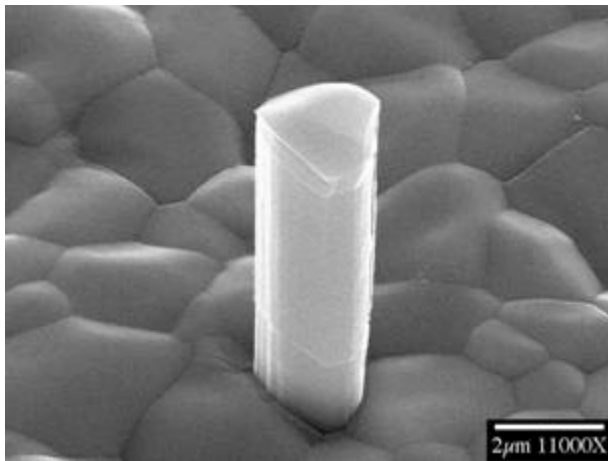


Whisker

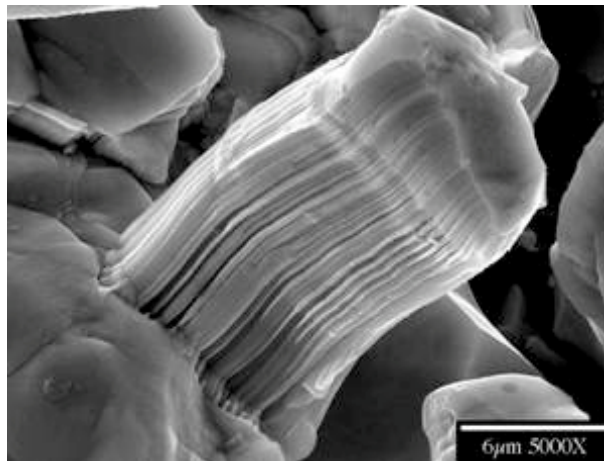
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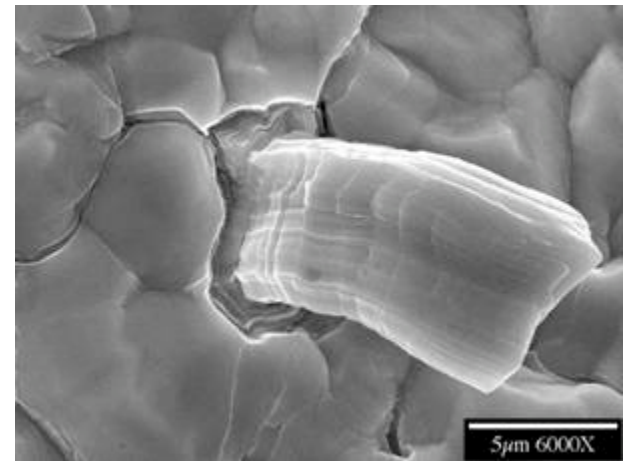
Whisker Examples



**Consistent
Cross-section**



Striations

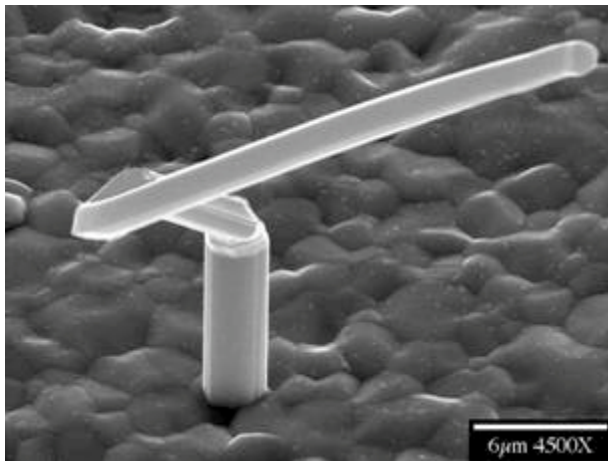


Rings

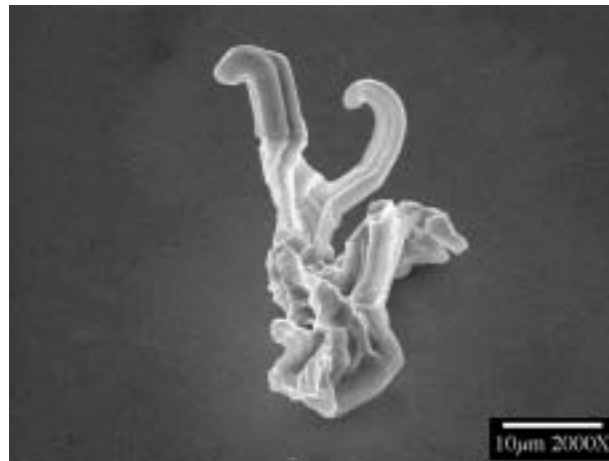
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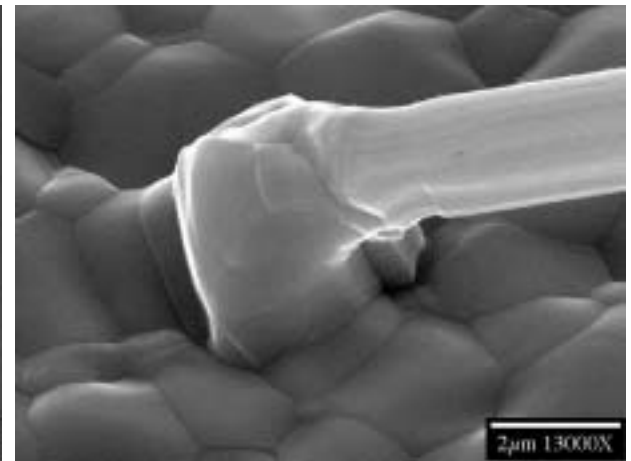
Whisker Examples



Kinked



Branched



**Initiating from
Hillock**

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Inspection Protocol

- *Scope:*
 - Establish an inspection method to quantify the propensity of an electroplated lead finish to develop tin whiskers.
 - Examples of electroplated lead finish uses: terminals of ICs and passives, connectors, printed circuit boards, etceteras.
- *Purpose:*

To recommend the equipment, locations and area of inspection, sample size and procedure for inspection.
- *Equipment:*

Scanning Electron Microscope (SEM) is recommended for whisker inspection and verification.

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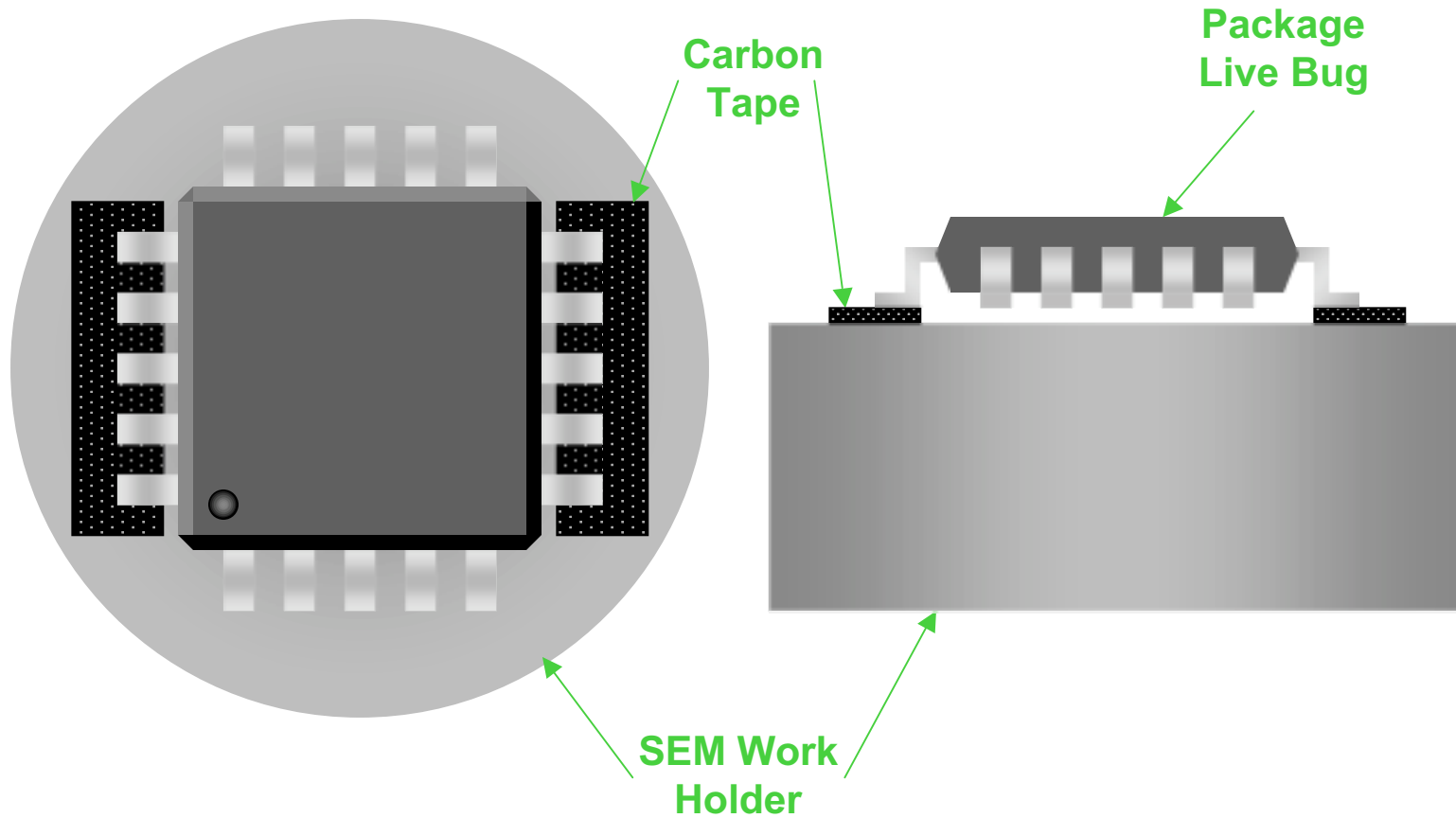
Inspection Protocol

- *Procedure:*
 - Use carbon tape, paint, or other conductive material to attach the sample to the work holder to prevent charging.
 - When handling the samples, care must be taken to avoid contact with the electroplated finish. Contact with the finish may detach whiskers.
 - Inspect each sample for whiskers at a magnification of 300X.
 - The samples should be mounted in the best position (maximize inspection areas and view of critical locations such as bends) for SEM inspection.
 - At each inspection:
 - Record the presence of hillocks, odd-shaped eruptions and whiskers (whiskers ≥ 10 microns in length or > 2 in aspect ratio).
 - Estimate and record the length of the longest whisker. Whisker length is measured from the termination/electroplate surface. Use higher power as necessary to determine length.
 - Record the whisker density representative of the level of whisker growth (number of whiskers within a $250\mu\text{m} \times 250\mu\text{m}$ area).

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SEM Inspection Set-up



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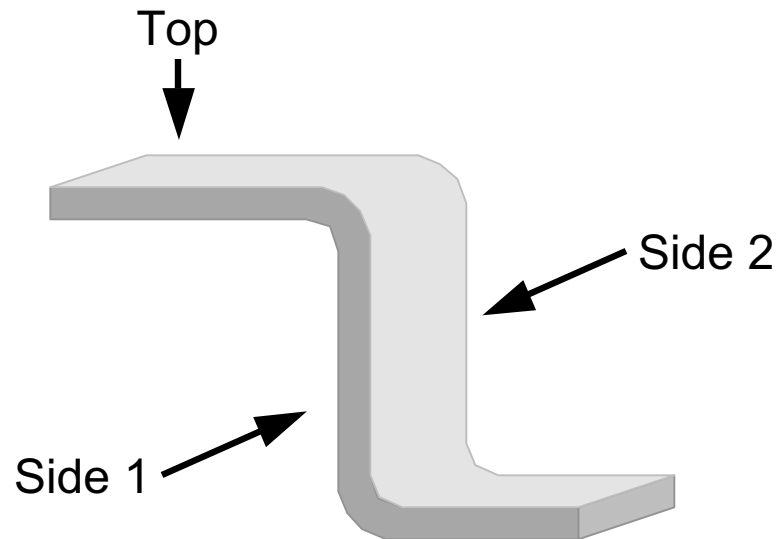


Inspection Protocol

- *Recommended Sample Sizes:*

- **Example: Leaded Packages**

Inspect all plated surfaces, as practical, of 3 leads on a minimum of 3 packages randomly chosen from the test samples.



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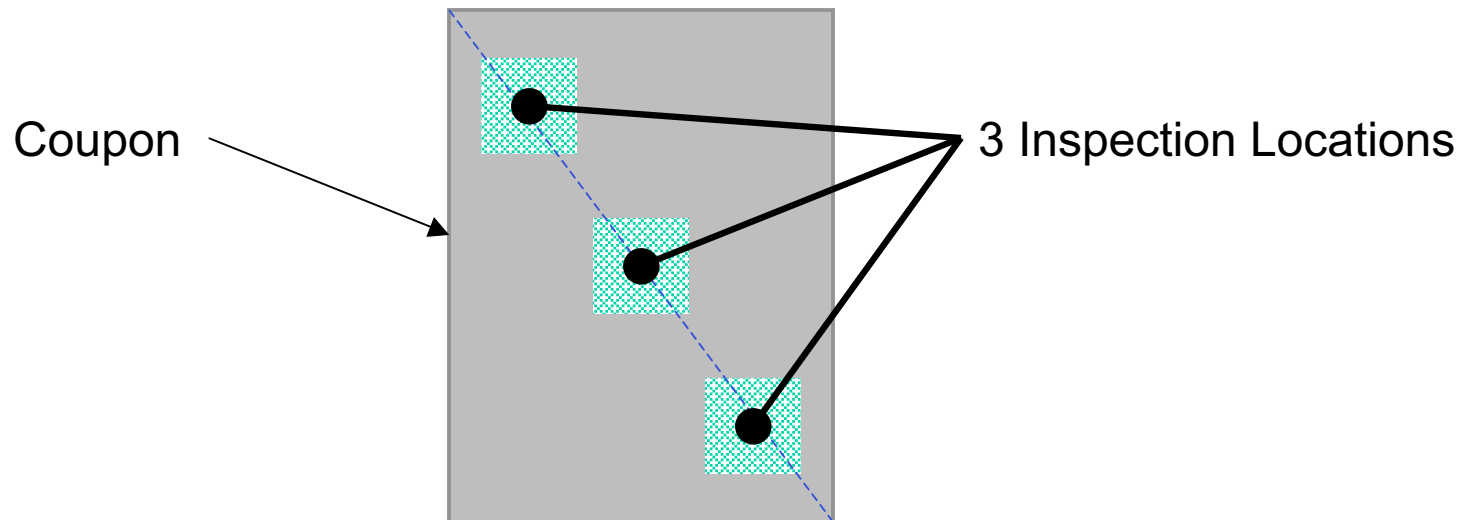


Inspection Protocol

- *Recommended Sample Sizes:*

- **Example: Test Coupons**

Inspect 3 locations on a minimum of 3 coupons randomly selected from the test samples. The area inspected at each location should be the field of view at 300x (approximate area 250 μm X 250 μm).



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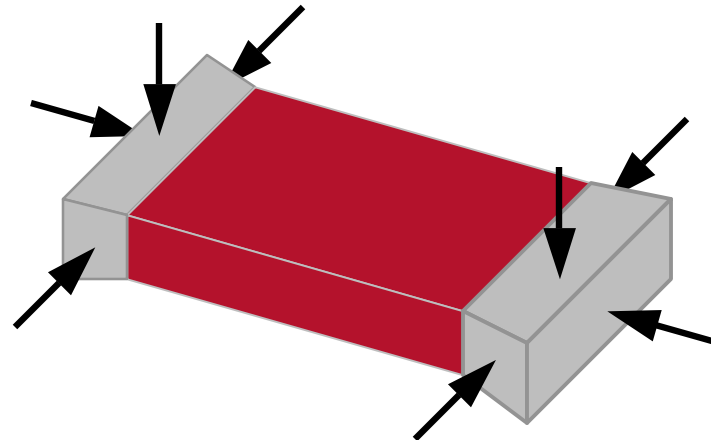


Inspection Protocol

- *Recommended Sample Sizes:*

- **Example: Passive Chipcaps/resistors**

Inspect the 3 visible sides and end of each termination on a minimum of 3 samples selected at random.



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Overview of Committee Effort

- ***Direct:***
 - Completed two comprehensive matrices, Phase 1 and 2, both for ICs and Passives.
 - Identified three test methods recommended for plating finish development and characterization.
 - Proposed a definition for whiskers.
 - Developed an inspection protocol.
 - Initiated test method document for potential release by JEDEC.
 - Preparing matrix for Phase 3 DOE (validation and verification).
- ***Indirect:***
 - Generated considerable momentum to understand whiskers and tin plating globally.

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Recommended Test Method

- *Recommended Test Methods:*
 - **-55°C (+0, -10) / 85°C (+10, -0) air-air temperature cycle (20minutes/cycle)**
 - **60°C, 90±5%RH temperature / humidity storage**
 - **Ambient storage (~23°C, %RH to be determined)**
 - **All three tests are to performed using separate samples**
- *Still need further verification, acceleration factors*

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