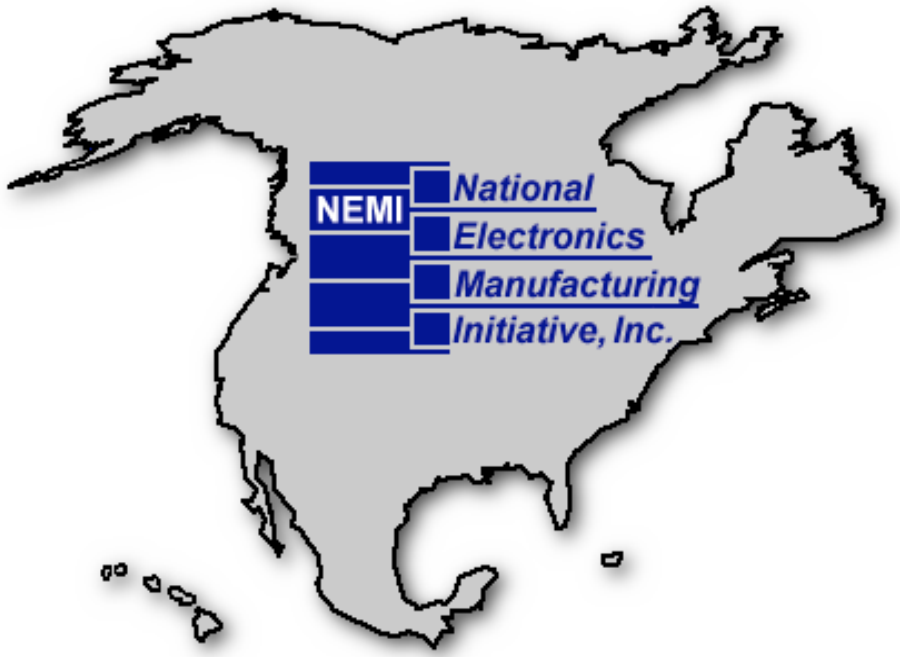


NEMI Tin Whisker Test Project

SMTA International

Irina Boguslavsky, NEMI Consultant
Chicago, IL
September 25, 2003

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*

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) – EFECT, NEMI Consultant

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

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*

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

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

Summary of Phase 2 DOE

Connect with and Strengthen Your Supply Chain

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

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

Samples Tested in DOE 2

A: 2 to 3µm, Matte Sn (Sulphate) on OLIN194 Cu SOIC molded/singulated

B: 10 to 12µm, Matte Sn (Sulphate) on OLIN194 Cu SOIC molded/singulated

C: 2 to 3µm, Bright Sn on brass coupon

D: 10 to 12µm, 90Sn/10Pb on OLIN194 Cu SOIC molded/singulated (control)

E: 2 to 3µm, Matte Sn (MSA) on OLIN194 Cu SOIC molded/singulated

F: 10 to 12µm, Matte Sn (MSA) on OLIN194 Cu SOIC molded/singulated

Plating Bath Control for Suppliers A and B

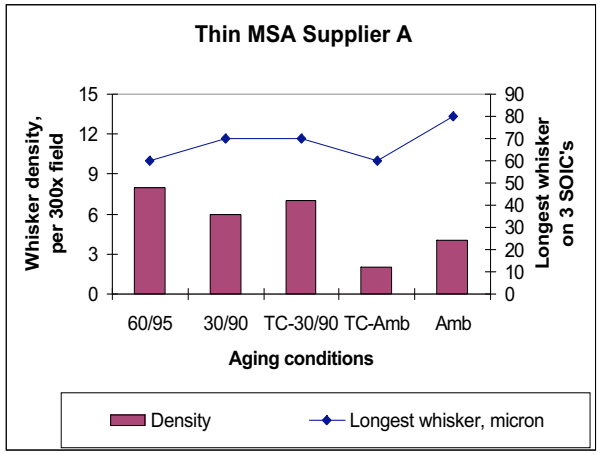
Supplier A										
	Pb		***Fe***		***Cu***		***Zn***		***Ni***	
Contaminations, ppm	t_o	t_e	t_o	t_e	t_o	t_e	t_o	t_e	t_o	t_e
Sulfate (samples A and B)	6	6.3	9.7	11.9	0.4	0.6	0.4	0.5	0.44	0.5
MSA (samples E and D)	N/A	N/A	5.2	5.2	0.7	0.7	0.6	0.7	0.41	0.48
Supplier B										
MSA (samples E and D)	8.2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

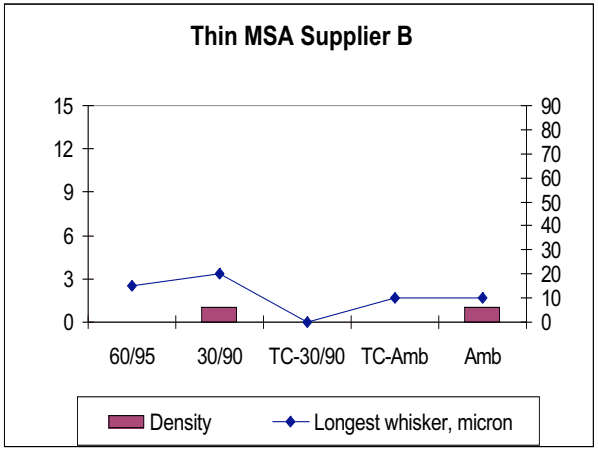
t_o – before plating
t_e – after plating

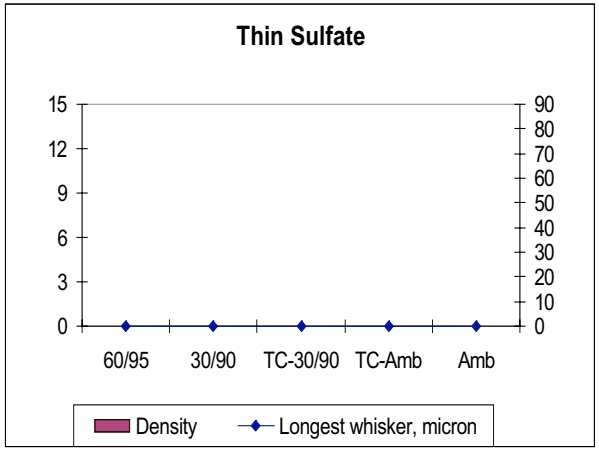
SEM Inspection Protocol: Report

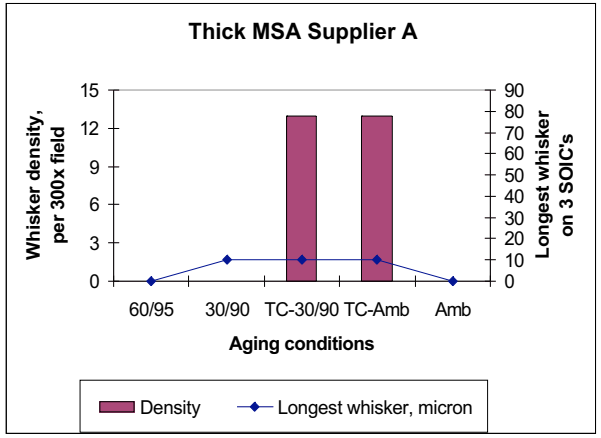
- Average number of whiskers from the three fields
- The length of the longest whisker found in those fields
- The the length of longest whisker found during 300x inspection of entire leadframe surfaces on all three devices/coupons
- The estimated grain size range of the deposit.
- In all reports include: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

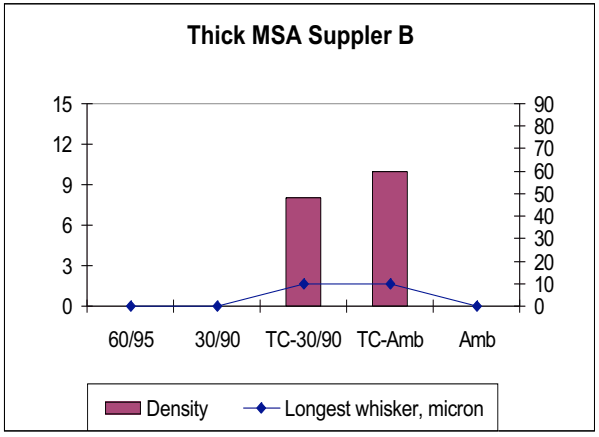
Effect of Bath Chemistry (*SOIC's*)

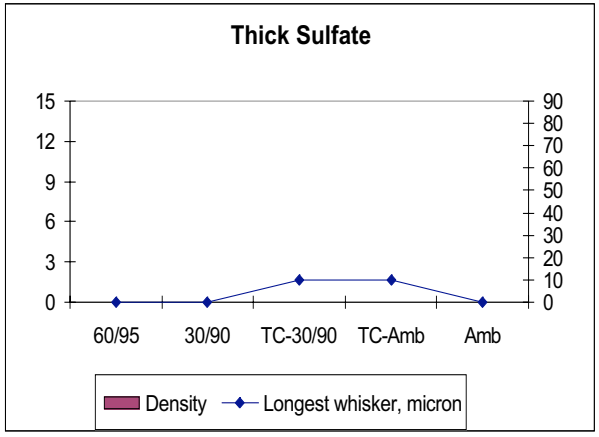




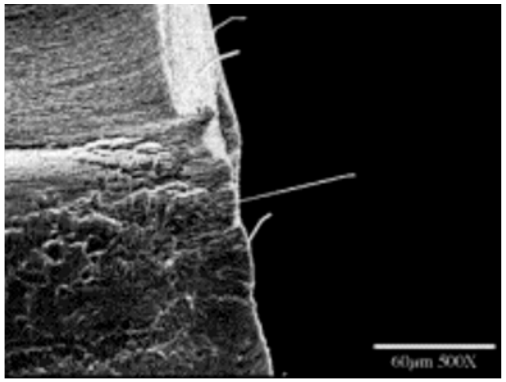




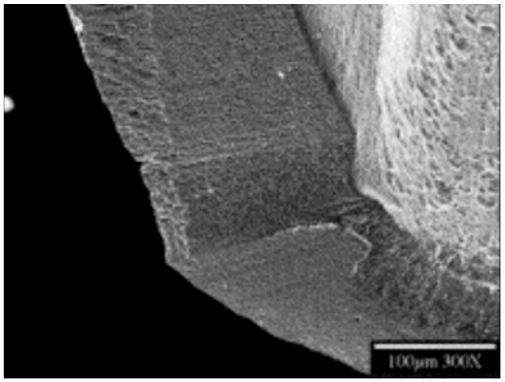




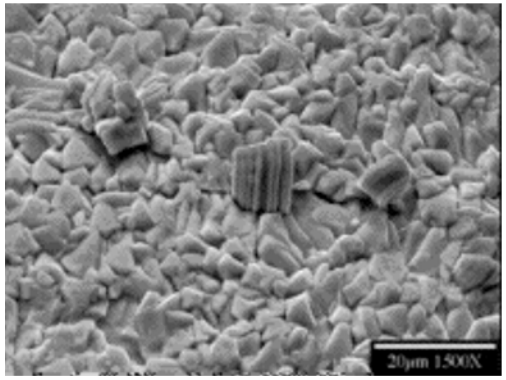
Types of Whiskers on DOE 2 Samples



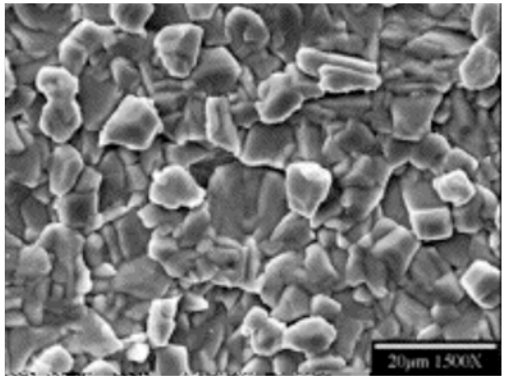
Thin MSA, Supplier A
long whiskers
(60°C/95%RH storage only)



Thin MSA, Supplier B
no whiskers
(60°C/95%RH storage only)

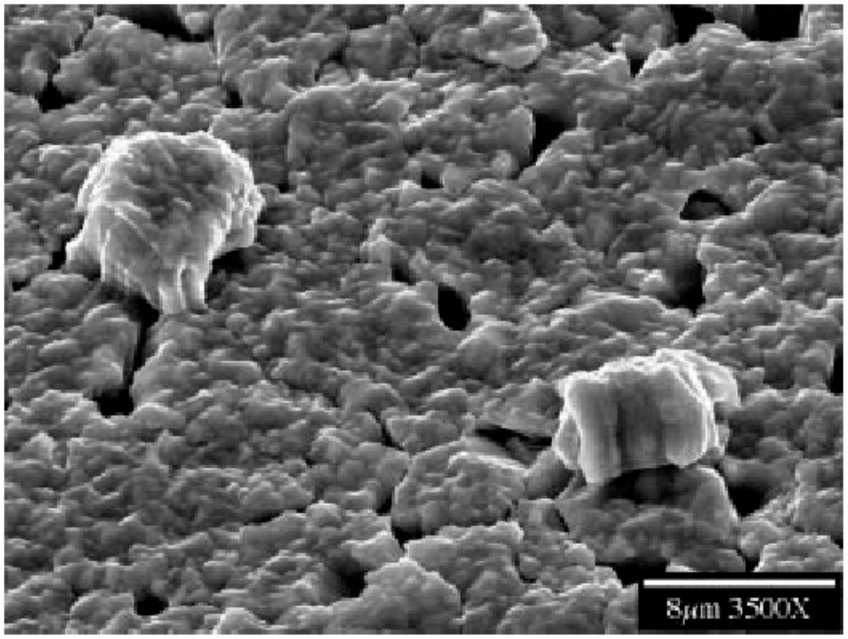


Thick Sulfate
short whiskers
(temp cycle + ambient)

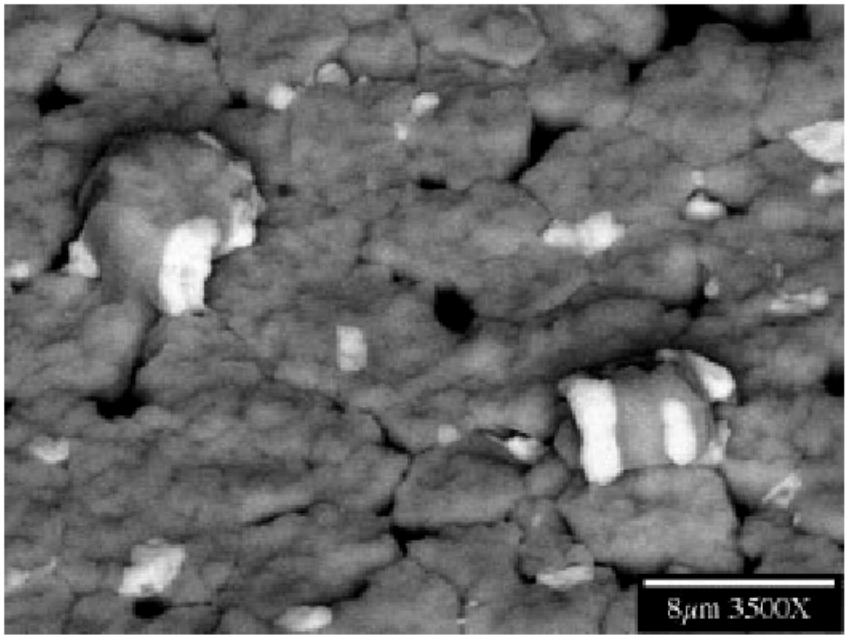


Thick MSA, Suppler A
many short whiskers
(temp cycle + 30°C/90%RH)

Sample Set D: SnPb – No Whiskers



Secondary Electron Image



Backscattered Electron Image

Leg 13 D

Connect with and Strengthen Your Supply Chain

Crystal Orientation

- Crystal orientation of tin deposits is perceived to be an important factor affecting whisker growth
- The combination of certain grain orientations may create conditions favorable for whisker formation
- Volume fractions of various orientations define deposit texture
- Highly textured deposits with one preferred orientation representing a large volume fraction suggested to be less prone to whisker due to low concentration of crystalline defects
- Crystal orientation can be characterized by Preferred Orientation Factor (P)

Preferred Orientation Factor

$$P(hkl) = \frac{I(hkl)/\ I_o(hkl)}{(1/n)\ ?\ [I(hkl)/\ I_o(hkl)]}$$

Where

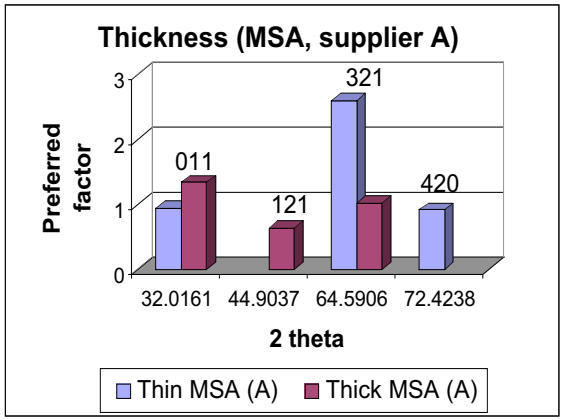
P(hkl) = Preferred Orientation Factor

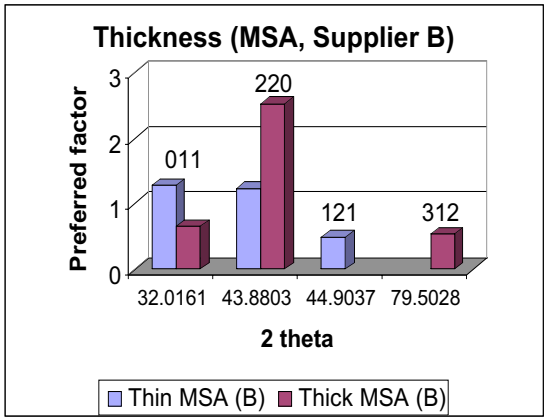
I(hkl) = measured intensity ofhkl reflections

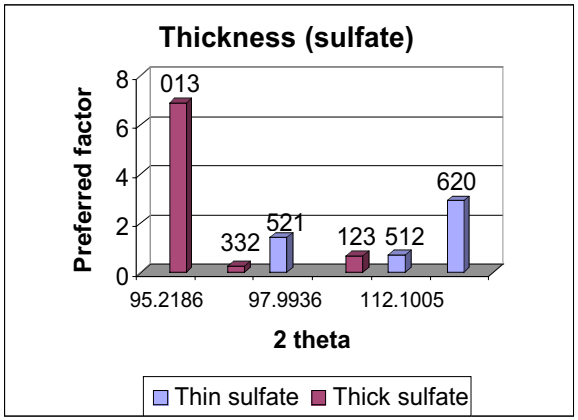
I_o(hkl) = theoretical intensity ofhkl reflections

n = number of reflections used in analysis

Effect of Bath Chemistry and Thickness







Types and Volume Fractions of Various Preferred Orientations

	MSA Supplier A		MSA Supplier B		Sulfate	
	Thin	Thick	Thin	Thick	Thin	Thick
Preferred Orientation	[321]	[011]	[011]	[220]	[620]	[013]
% of highest Preferred Orientation Factor	58	45	43	68	58	88

Whisker Test for Passive Components

- Chip fuses were tested as passive components by a supplier of passives
- Fuses were barrel plated with nickel barrier layer (2.54-12.7 µm thick) and pure tin (2.54-15.24 µm thick)
- Test conditions
  - Thermal cycling –40ºC to +90ºC followed by 60ºC/90%RH
  - Thermal cycling –40ºC to +90ºC followed by ambient
  - Temperature+humidity: 60ºC/90%RH
  - Ambient
- No whiskers were found after 4 weeks of ambient and 60ºC/90%RH exposure
- Whiskers of similar length and density were found after thermal cycling followed by both ambient and 60ºC/90%RH exposure

Chip Fuse Whisker Test Results

Plating Group #	After 500 Temp Cycles (-40°C to 90°C)		After 500 Temp Cycles (-40°C to 90°C) & 4wks storage (60°C & 90%RH)	
	Whisker Frequency 200µm x 260µm area	*Max Length (µm)*	*Whisker Frequency 200µm x 260µm area*	*Max Length (µm)*
1	223	31	159	22
2	54	44	66	25
3	137	28	144	38
4	66	34	93	34
5	6	9	3	9

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

Future Work and Concerns

- *Future work:*
  - 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?

Phase 3 DOE – Validate and Verify

- *Tests:*
  - -55°C (+0, -10) / 85°C (+10, -0) air-air temperature cycle (20minutes/cycle) up to 3000 cycles (500 cycles check points)
  - 60°C, 90±5%RH temperature / humidity storage 9000 hrs (~1 year) with 1000 hr check points
  - Ambient storage (~23°C, ~60%RH) up to 18000 hours (~2 years) with 1000 hr check points
- *Samples:*
  - Leaded packages from assembly contractors (64 LQFP)
  - Sn, SnBi, SnCu and SnPb (control) finishes
  - Copper CDA194 and Alloy42 leadframes
  - For comparison include cells with
    - Matte Ni underplating
    - Fused (confirm melting) and/or annealed Sn
    - Hot-dipped Sn
    - JEITA test vehicle

Whisker Definition

- *Purpose:*

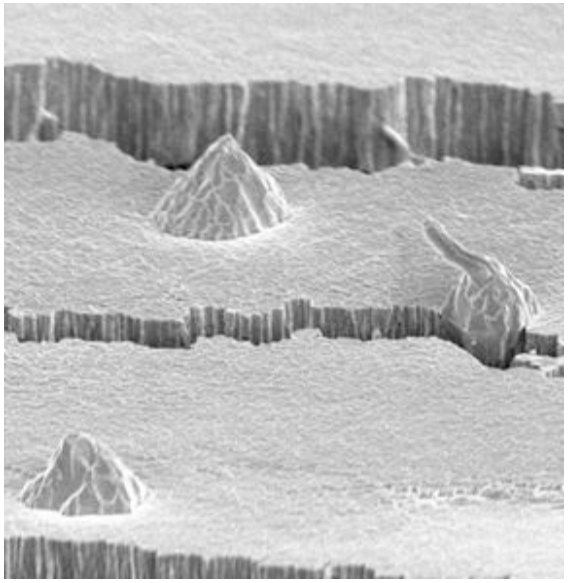
  To specify the physical and visual characteristics of a tin whisker for use in inspection (not intended as a metallurgical definition)

- *Tin Whisker:*

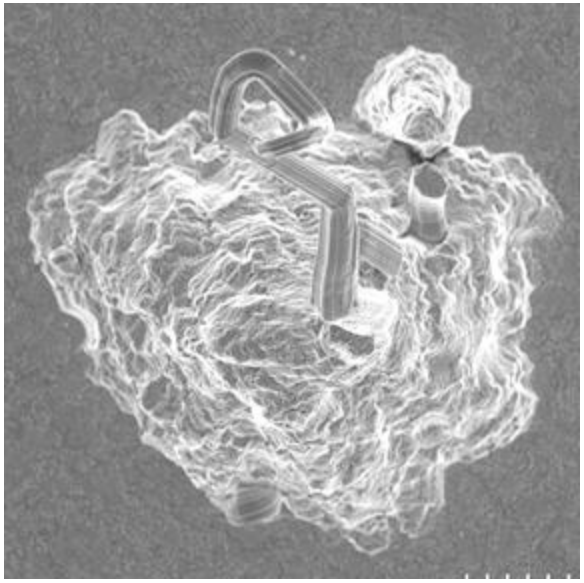
  A spontaneous columnar or cylindrical filament, which rarely branches, of tin emanating from the surface of a plating finish.

- **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.*

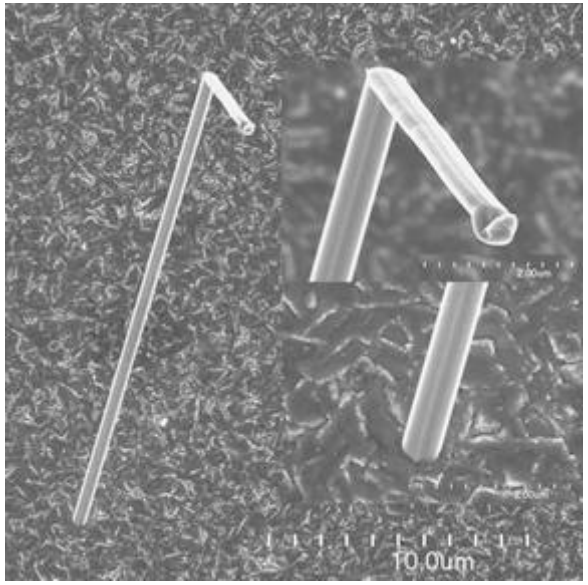
Whisker Examples



Hillocks (Lumps)

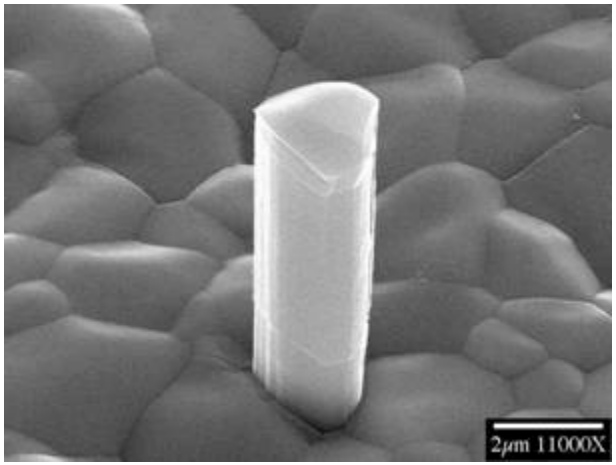


Odd-Shaped Eruptions (OSE)

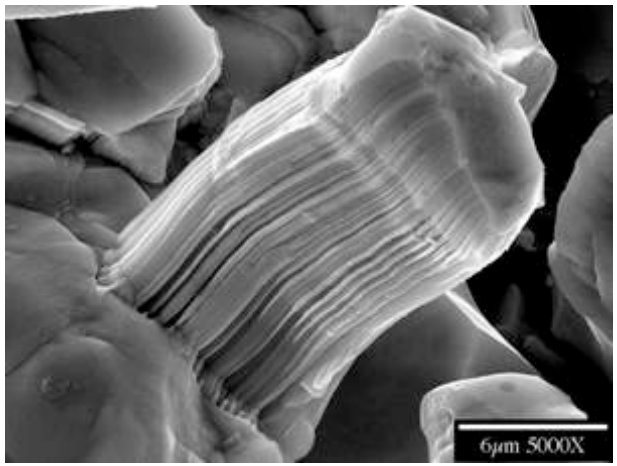


Needles

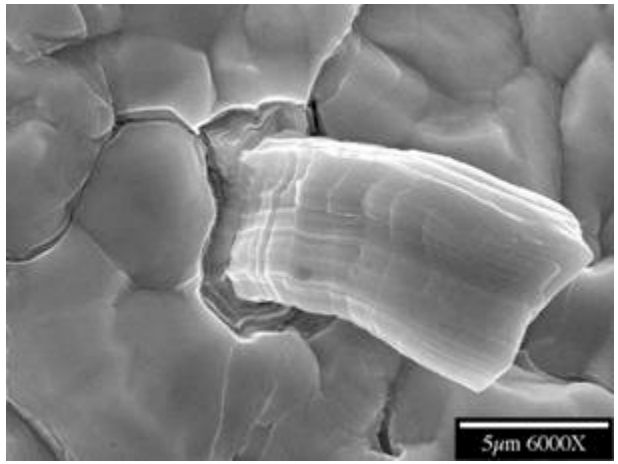
Whisker Examples



Consistent cross-section (column)

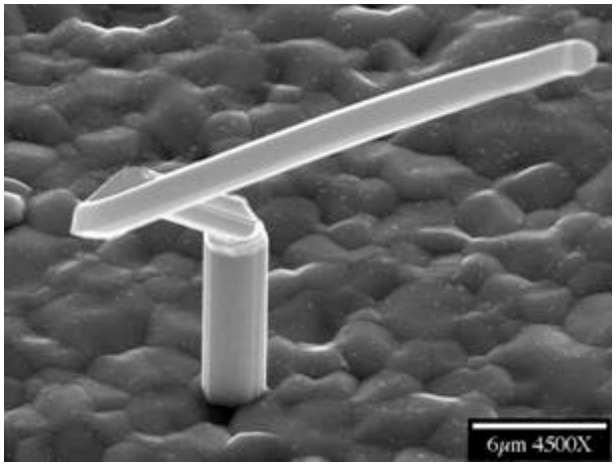


Striations

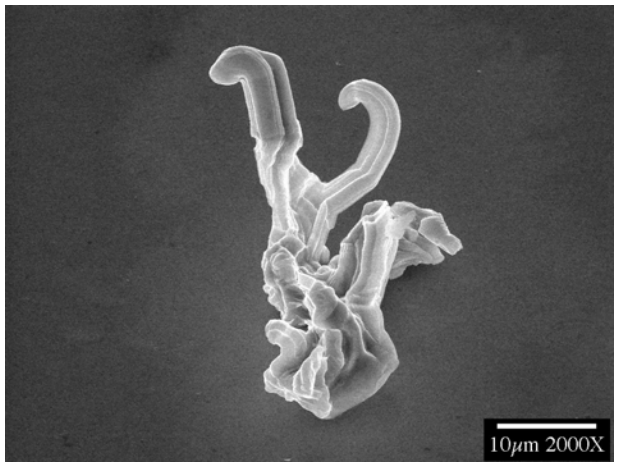


Rings

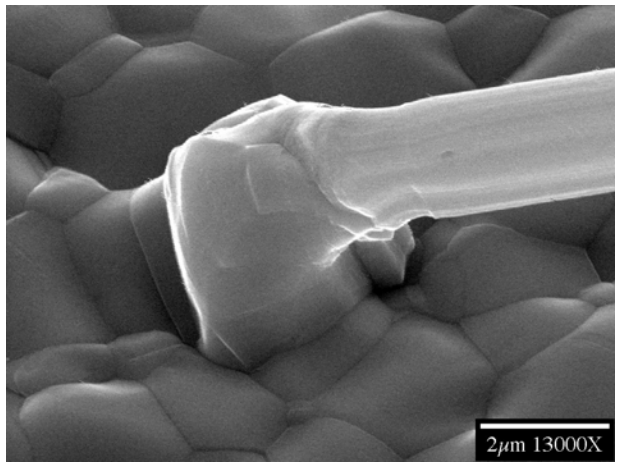
Whisker Examples



Kinked



Branched



Initiating from Hillock

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.

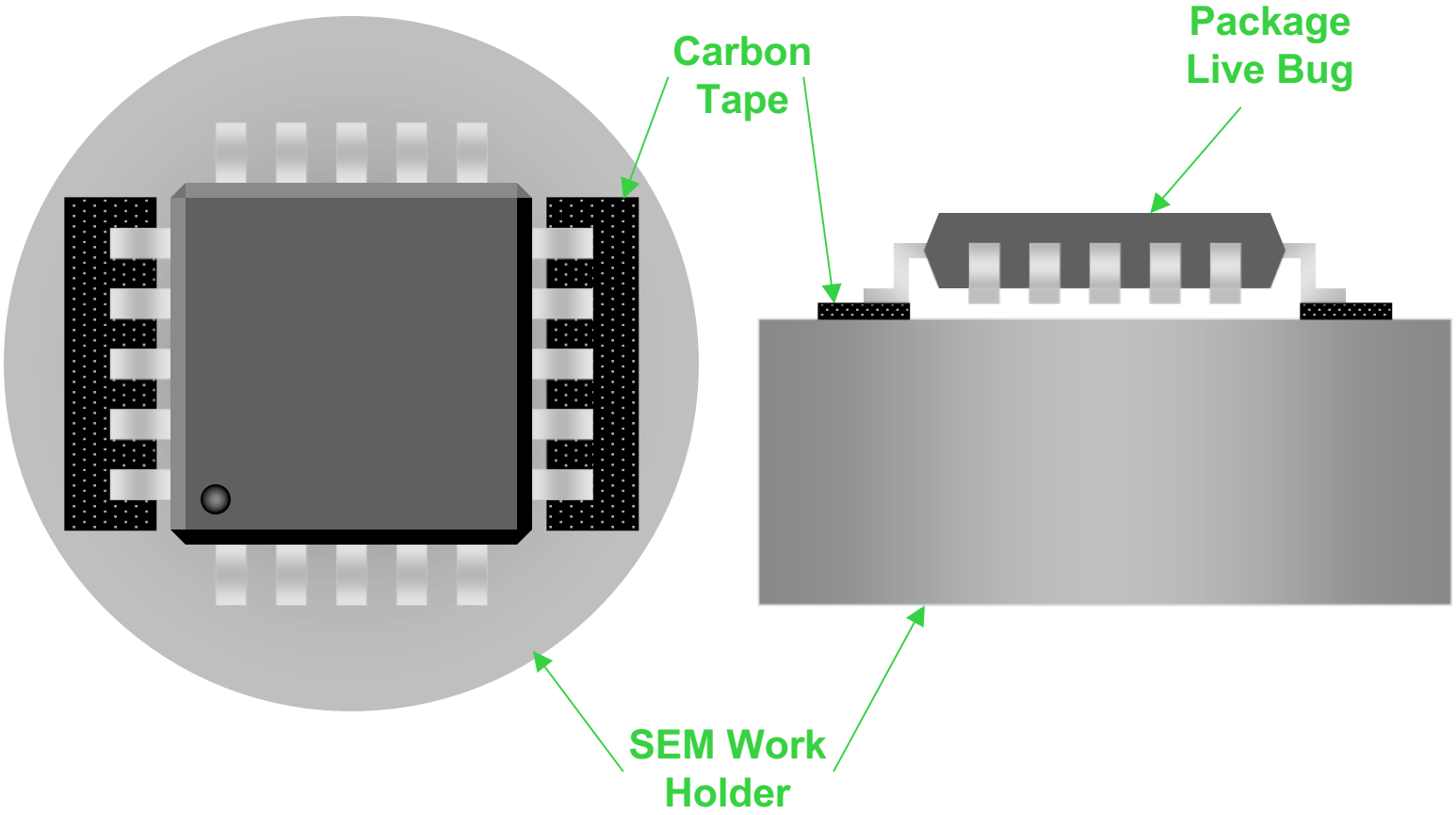
- *Equipment:*

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

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 250µm X 250µm area).

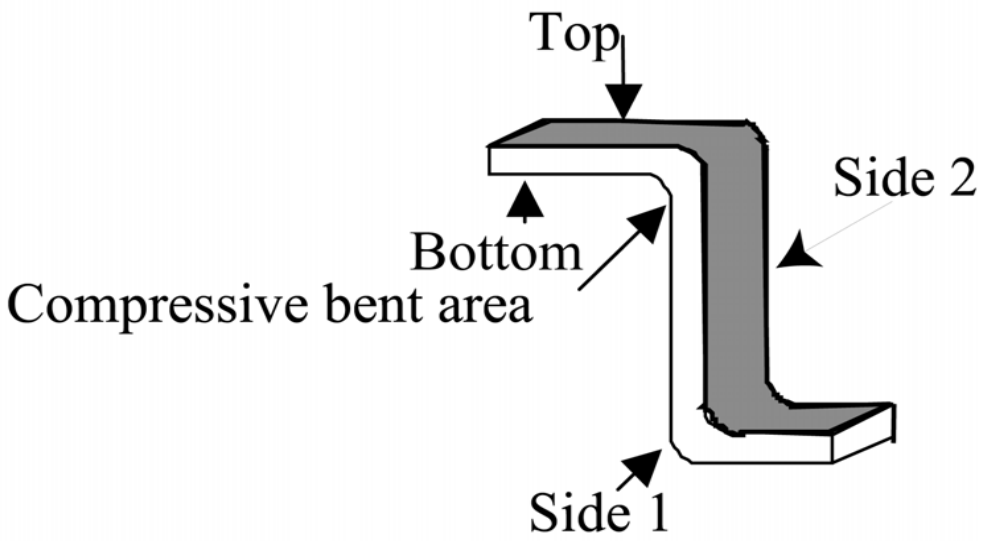
SEM Inspection Set-up



Inspection Protocol

- *Recommended Sample Sizes:*
  - **Example: Leaded Packages**

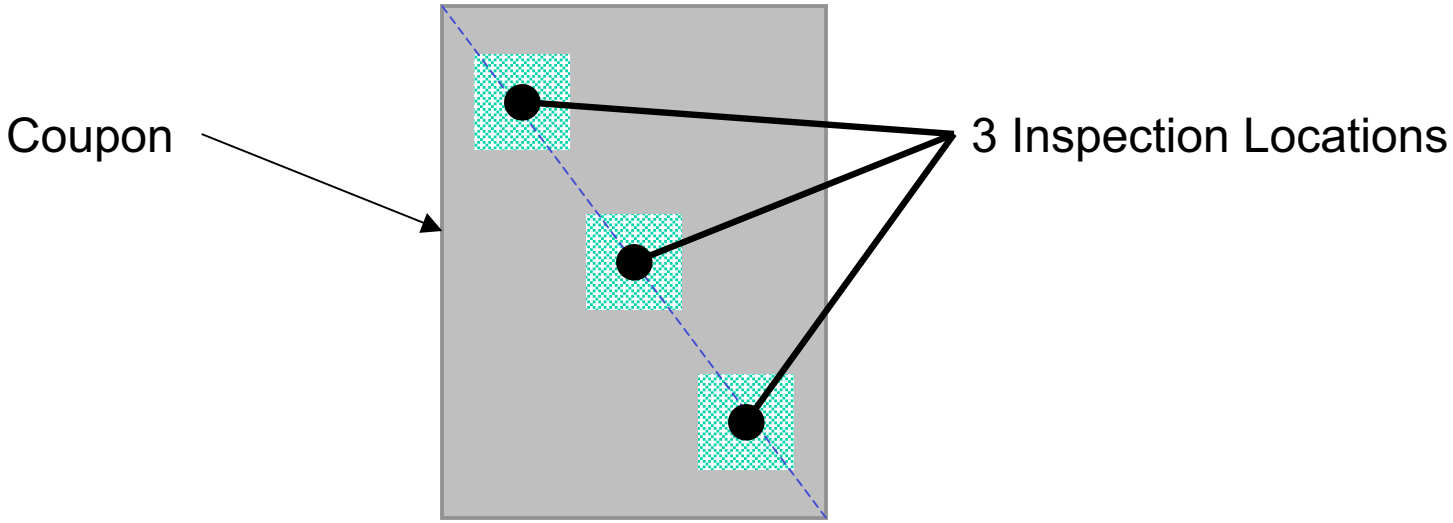
    Inspect all plated surfaces, as practical, of 3 leads on a minimum of 3 packages randomly chosen from the test samples.



Inspection Protocol

- *Recommended Sample Sizes:*
  - **Example: Test Coupons**

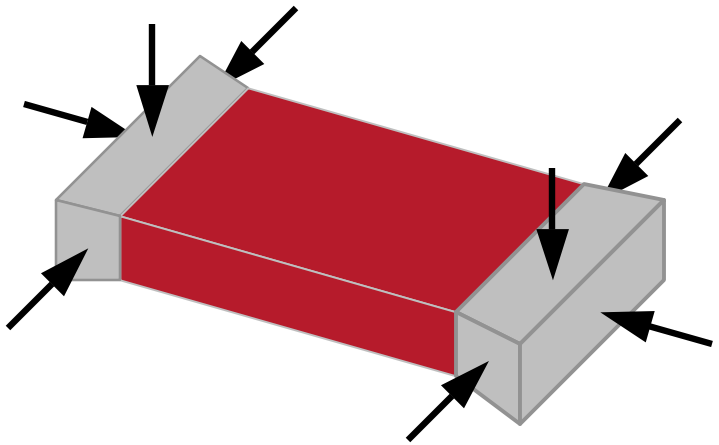
    Inspect 3 locations on a minimum of 3 coupons randomly selected from the test samples. The area inspected at each location should be the field of view at 300x (approximate area 250 μm X 250 μm).



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.



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.

Recommended Test Method

- Prepared 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 Method

- Recommended Test Methods:
  - -55°C (+0, -10) / 85°C (+10, -0) air-air temperature cycle (20minutes/cycle)
  - 60 + 5 °C, 93 +2, -3 % RH
  - 20 - 25 °C, ~30-80% RH
  - All three tests are to be performed using separate samples
  - Each test condition is to be performed independently