iNEMI Tin Whisker Accelerated Test Project
Test Method for Evaluating Tin Whisker Growth on Plated Surfaces

06/17/04 - Revision 6.1

Disclaimer

Based on a variety of testing and data review from around the globe, three test conditions have been identified that appear to be suitable for monitoring tin whisker growth. These test conditions include two isothermal conditions with controlled humidity and a thermal cycling condition, as described in Section 3. However, at the time of writing, the fundamental mechanisms of tin whisker growth are not fully understood and acceleration factors have not been established. This document is not a qualification standard. The document contains a suite of recommended whisker growth tests. If these common tests are adopted, then the industry can collect common and comparable data that may improve the understanding of the fundamentals of whisker growth and allows comparisons between technologies. Tests in this document may be changed in the future as a better understanding of the mechanisms causing tin whisker growth is developed.

Introduction

The predominant terminal plating metallurgies on electronic components have been Sn-Pb alloys. As the industry moves toward Pb-free components and assembly processes, the predominant terminal plating metallurgies will be pure Sn and dilute alloys of Sn, including Sn-Bi and Sn-Ag. Unfortunately, pure Sn and Sn-based alloy Pb-free electrodeposits and solder-dipped finishes may grow tin whiskers, which could electrically short across component terminals. Currently there are no widely accepted test conditions for monitoring the propensity of a given tin coating process to grow tin whiskers.

1 Scope

This document specifies three different test conditions for evaluating tin whisker growth from platings containing a predominance of tin (Sn).

1.1 Purpose

- Provide test methods to aid in the evaluation and development of platings.
- Provide an industry-standardized suite of tests, for comparison of whisker propensity for different plating chemistries and processes.
- Provide a consistent inspection protocol for tin whisker examination.
- Provide a standard reporting format.

1.2 Normative Reference

JEDEC – JESD22-A104 Temperature Cycling

1.3 Definitions

1.3.1 Sample: Any samples with tin-based plating may be evaluated, including experimentally plated coupons or components, or production-plated electronic components. This test method

was designed for the evaluation of tin-based platings. However, it may be appropriate for other whisker-forming platings, such as Zn or Cd platings.

Note 1. Coupons may not be representative of finished product.

1.3.2 Whisker: a spontaneous columnar or cylindrical filament, which rarely branches, usually of mono-crystalline metal, emanating from the surface of a plating finish. See Appendix A for pictures of tin whiskers. For the purpose of this document, whiskers have the following characteristics:

- Have an aspect ratio (length/width) >2
- Can be kinked, bent, twisted
- Usually have a uniform cross-sectional shape
- Typically consist of a single columnar filament that rarely branches
- May have striations along the length of the column and/or rings around the circumference of the column

Note: Whiskers are not to be confused with dendrites: fern-like growths formed as a result of electro migration of an ionic species (see appendix A-2 for a typical dendrite picture).

1.3.3 Whisker growth: Measurable changes in whisker length and whisker density after exposure for a certain duration or number of cycles to a whisker test condition.

1.3.4 Whisker density: The number of whiskers on a single lead or coupon area.

1.3.5 Axial whisker length: The distance between the plating surface and the tip of the whisker. For tin whiskers that bend and change directions, the total axial length may be estimated by adding all of the straight subdivisions of a whisker.

2 Equipment

2.1 A two-chamber, air-to-air temperature cycling furnace capable of cycling from –55(+0/-10)°C to +85(+10/–0)°C or from –40(+0/-10)°C to +85(+10/–0)°C.

2.2 Temperature humidity chambers capable of 60±5°C, 93 + 2, -3 %RH and 30 ± 2°C, 60± 3%RH

2.3 Optical stereomicroscope with adequate lighting capable of 50X – 150X magnification capable of detecting whiskers with a minimum axial whisker length of 10 microns or less.

Note 1. It is recommended that the ability of the optical equipment be assessed by using both an optical stereomicroscope and an SEM to analyze at least one sample with whiskers (ranging from 10 microns to 50 microns in length). If whiskers of any length are detected in SEM, but not with the optical microscope, then the lighting, magnification, and/or viewing angle may need to be adjusted or the operator may require more training. A minimum whisker length of 10 microns must be detectable with the optical system used for inspection.

2.4 Scanning Electron Microscope (SEM)

3 Test Conditions

For any plating evaluated, all three test conditions are required. These test conditions are described in Section 3.2-3.4. In addition, each test condition is to be performed independently on separate samples.

3.1 Sample Size: For finished components, a total of at least 90 terminations/leads on at least six samples are required for each test condition at each inspection read out. For coupons; a total area of at least 75 mm^2 on at least 3 coupons is required for each test condition. Larger samples to satisfy internal statistical requirements or for characterization are acceptable.

The same 6 samples or 3 coupons for each test condition may be evaluated at all sequential read outs, including the final duration. Hence, to evaluate a single plating, 18 samples are required to complete the three test conditions. Alternatively, the test may be started with sufficient samples to inspect 6 different samples or coupons at each read out. In this case, the number of samples required will be a minimum of 18 and will increase depending on the expected duration of the test and number of read out points. (For example, if a plating is evaluated in temperature cycling for 2000 cycles and read outs are performed at 500, 1000, 1500, and 2000 cycles, then 24 samples are required just for the thermal cycle test condition.)

3.2 Temperature Cycling

3.2.1 Condition: -55 +0/-10°C to 85 +10/-0°C or -40 +0/-10°C to 85 +10/-0°C of air-to-air temperature cycles per JEDEC-JESD22-A104, Test condition A, soak mode 3 (10 minutes), typically 3 cycles/hour.

3.2.2 Number of cycles: The total number of cycles will be specified in the appropriate test plan.

3.2.3 Readouts: Unless otherwise specified readouts should be every 500 cycles.

3.3 Ambient Temperature/Humidity Storage

3.3.1 Condition: 30 $\pm$ 2 °C and 60$\pm$ 3% relative humidity (RH)

3.3.2 Duration: The total number of hours will be specified in the appropriate test plan.

3.3.3 Readouts: Unless otherwise specified readouts should be every 1500 hours.

3.4 High Temperature/Humidity Storage

3.4.1 Condition: 60 $\pm$ 5 °C and 93 $\pm$ 3 % RH

3.4.2 Duration: The total number of hours will be specified in the appropriate test plan.

3.4.3 Readouts: Unless otherwise specified readouts should be every 1500 hours.

4 Whisker Inspection Procedure

The whisker inspection procedure includes three parts, the initial pre-test inspection, the screening inspection, and the detailed inspection. The initial inspection should be performed once before the samples are exposed to any test condition. The screening inspection should be performed at each read out. If whiskers are detected in the screening inspection, then the detailed inspection should be performed at that read out.

4.1 Handling

When handling samples, care must be taken to avoid contact with the electroplated finish. Contact with the finish may detach whiskers. For SEM, a conductive material to attach the sample to the SEM work holder to prevent charging is recommended. If the same samples will be inspected and returned to the test condition for further exposure, then conductive plating such as C, Pt, or Au should not be deposited for SEM inspection. If samples will not be returned to the test condition, then conductive plating may be used to reduce charging.

4.2 Initial Pre-test Inspection

Prior to any test condition exposure, an initial optical inspection should be conducted and documented to determine if whiskers are present prior to testing. The same procedure used for the screening inspection, described in Section 4.3, shall be followed.

4.3 Screening Inspection

The screening inspection shall be performed at each read out, following exposure to one of the three test conditions.

4.3.1 Components

A minimum of 90 leads from a minimum of 6 samples are to be screened using either an optical stereomicroscope or an SEM. If the screening inspection is performed with an optical stereomicroscope, a minimum scanning magnification of 50x is required. For whisker verification, a higher magnification is recommended. If the screening inspection is performed with an SEM, a minimum magnification of 250x is required. If whiskers are not detected during the screening inspection, then a further inspection is not required at that read point. If whiskers are detected during the screening inspection, then three leads from each sample that appear to have the longest tin whiskers should be identified. These three leads from each sample should be evaluated following the detailed inspection procedure in Section 4.4.

4.3.2 Coupons

A minimum of 3 coupons shall be screened using either an optical stereomicroscope or an SEM. On each of these three coupons, a minimum area of 25 mm^2 shall be screened, including at least two edges. For small coupons, more coupons shall be screened, such that the total area screened is a minimum of 75 mm^2. If the screening inspection is performed with an optical stereomicroscope, a minimum magnification of 50x is required. For whisker verification, a higher magnification is recommended. If the screening inspection is performed with an SEM, a minimum magnification of 250x is required. If whiskers are not detected during the screening inspection, then a further inspection is not required at that read point. If whiskers are detected during the screening inspection, then three areas of 2.5 mm^2 on each coupon that appear the longest tin whiskers shall be identified. These three areas from each sample should be evaluated following the detailed inspection procedure in Section 4.4.

4.4 Detailed Inspection

The detailed inspection shall be performed on leads or areas identified in the screening inspection. If whiskers are not observed in the screening inspection, Section 4.3, then the detailed inspection is not required. For samples that exhibit whiskers, this means 3 leads or three areas per sample and a minimum of 6 components or 3 coupons shall be inspected. More

samples may be required if there are fewer than 3 leads or terminations. A scanning electron microscope shall be used for the detailed inspection with a minimum magnification of 300x. For whisker measurement, a higher or lower magnification may be required. Moreover, for whisker measurement, it is recommended that the whisker approximately fill the field of view at the selected magnification for measurement.

4.4.1 Leaded Packages

A minimum of 18 leads on a minimum of 6 samples shall be inspected with SEM. The top and 2 sides of each identified lead shall be inspected. The top and 2 sides of the lead are depicted in Figure 1. If leads are round then the surface that is the top _ of the diameter should be inspected. Whiskers on the two sides may be easier to identify and measure if the component is mounted upside down in the "dead bug" position. For each inspected lead, the maximum whisker length and the whisker density shall be recorded as described in Section 4.5.

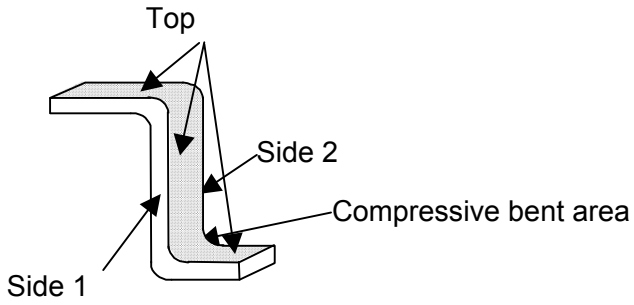


Figure 1

Figure 1. A schematic exemplifying a component lead and the top and 2 sides of the lead that should be inspected.

4.4.2 Leadless Components, Passive Chip Capacitors or Resistors

A minimum of 18 terminations on a minimum of 6 samples shall be inspected with SEM. If there are fewer than three terminations on each sample, then more than 6 samples must be inspected to reach the requirement of 18 terminations. The top and 3 sides of each identified termination shall be inspected. The top and 3 sides of the termination are depicted in Figure 2. . For each inspected termination, the maximum whisker length and the whisker density shall be recorded as described in Section 4.5.

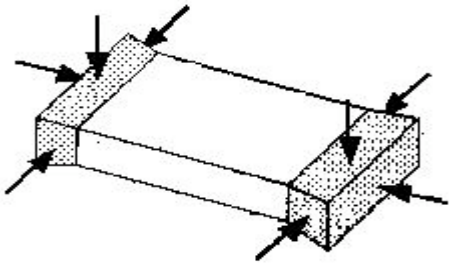


Figure 2. A schematic exemplifying a leadless component and the top and 3 sides of the terminations that should be inspected.

4.4.3 Coupons

A minimum of 9 areas on a minimum of 3 coupons shall be inspected with SEM. These areas are 2.5 mm^2 each and should have been identified during the screening inspection. An example of inspection areas are depicted in Figure 3. For each inspected area, the maximum whisker length and the whisker density shall be recorded as described in Section 4.5.

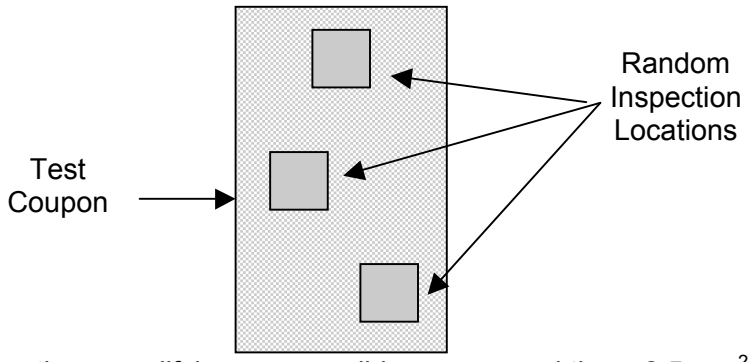


Figure 3. A schematic exemplifying one possible coupon and three 2.5 mm^2 areas identified for inspection.

4.5 Recording procedure (Note: Refer to Tin Whisker Tests Standard Report Format in Appendix B)

4.5.1 General Information

- the date of inspection
- test condition and cumulative exposure time, or # of cycles
- sample number or other identification
- sample type (package, chip cap, coupon, leadframe, etc)
- substrate (copper C194, copper 7025, Alloy 42, etc)
- underplating (material & thickness), if applicable
- plating bath vendor and type (chemistry and matte or bright; example: matte, MSA)
- finish type (100% tin, tin-copper, tin-bismuth)
- plating thickness
- date of plating or date code
- any post plating treatment (none, reflow, 1 hr 150°C anneal, etc)
- Any preconditioning prior to testing, e.g. 255 °C reflow
- Grain size
- Plating condition and plating contamination levels
- Underplating conditions

4.5.2 Recording of detailed inspection

For each lead, termination, or coupon area that is inspected during the detailed inspection, the following information should be recorded.

4.5.2.1 Whisker density range

For each lead, termination, or coupon area identified for detailed inspection, a whisker density range shall be determined using the following procedure. An SEM with a minimum of 250x shall be used for the whisker density measurement. A higher magnification may be used if it produces a field of view which captures the entire width of the lead, including the two sides of

the lead. Note tin plating should fill as much of the field of view as possible, including the two sides of the lead. To assess the whisker density, a minimum of three independent regions of the lead or test coupon shall be examined. For formed leads or coupons, it is suggested that convex, concave and planar region of the lead be examined. If the tests are being done on coupons, then three fields of view shall be examined for each 2.5 mm^2 area identified for inspection. The number of whiskers should be counted in each field of view. Counting may be stopped when the total number of whiskers counted in the three fields of view exceeds 45 whiskers. The total number of whiskers counted in the three areas per lead, termination, or coupon area shall be used to classify the whisker density range, according to Table 1.

Table 1. Lists whisker density ranges that can be determined based on the number of whiskers observed in three fields of view per lead, termination, or coupon area

Whisker density range	**Total number of whiskers measured in three fields of view per termination or area**
Low	< 10 whiskers
Medium	10-45 whiskers
High	> 45 whiskers

4.5.2.3 Maximum axial whisker length: Record the maximum whisker length measured on each lead, termination, or coupon area during the detailed inspection. Whisker axial length is measured from the termination/electroplate surface to the whisker tip. For tin whiskers that bend and change directions, the total axial length may be estimated by adding all of the straight subdivisions of a whisker. In Figure 4, there are two examples that depict estimating the axial whisker length when the whisker is segmented.

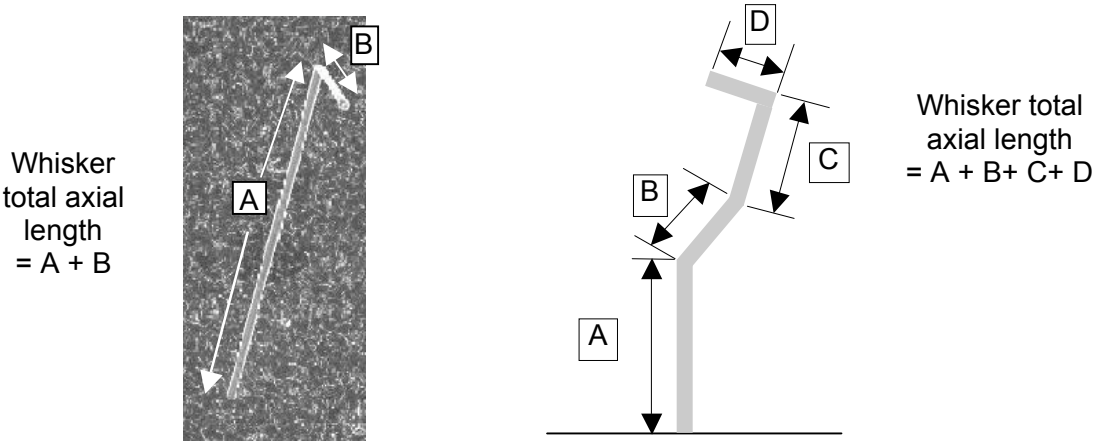
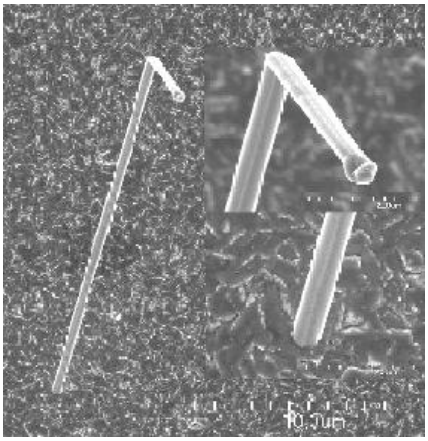
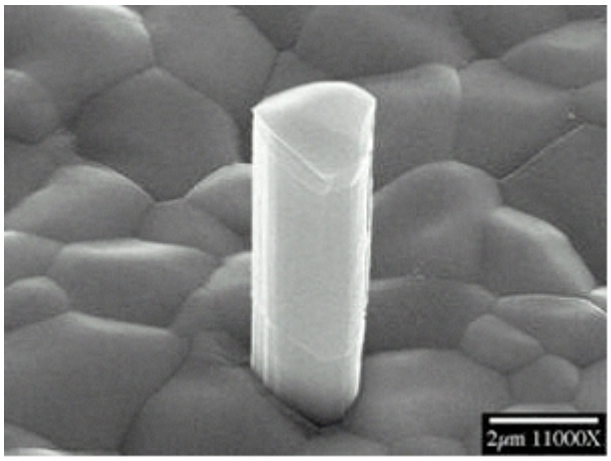


Figure 4. Two examples depicting the estimation of axial whisker length that is made by adding all of the straight subdivisions or segments of a whisker.

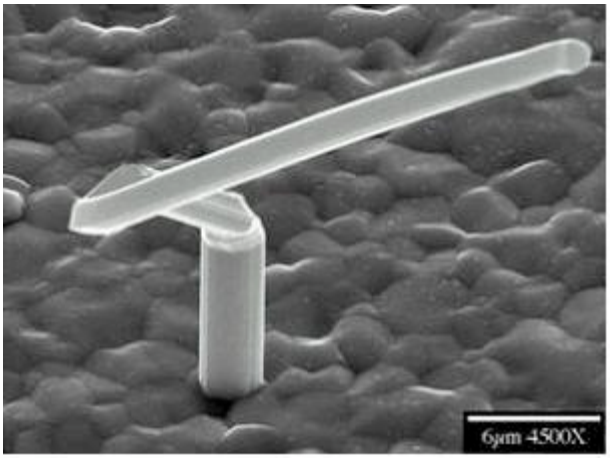
Appendix A: Tin Whiskers Examples



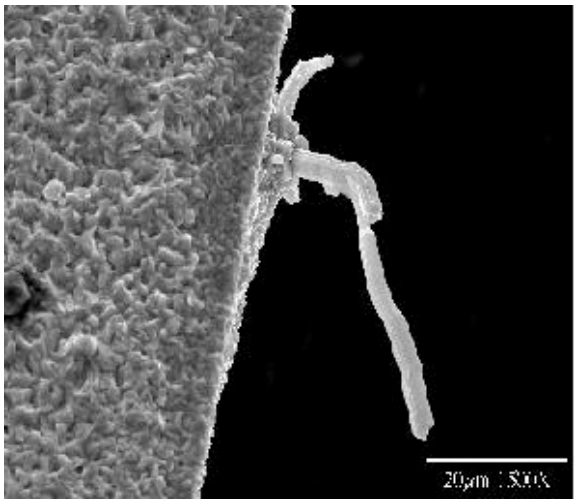
Tin whisker filaments
Photo courtesy of M. Williams, NIST



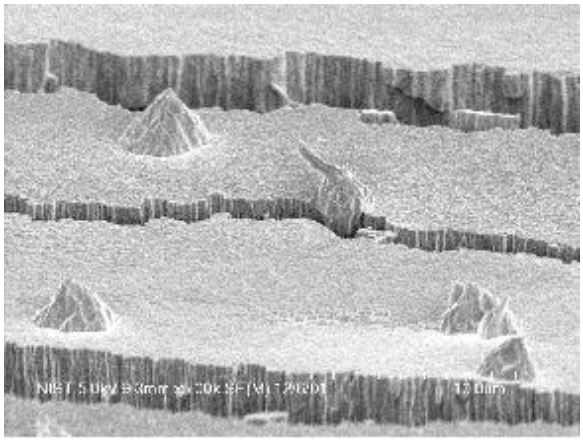
Whisker with a consistent cross section
Photo courtesy of P.Bush, SUNY, Buffalo



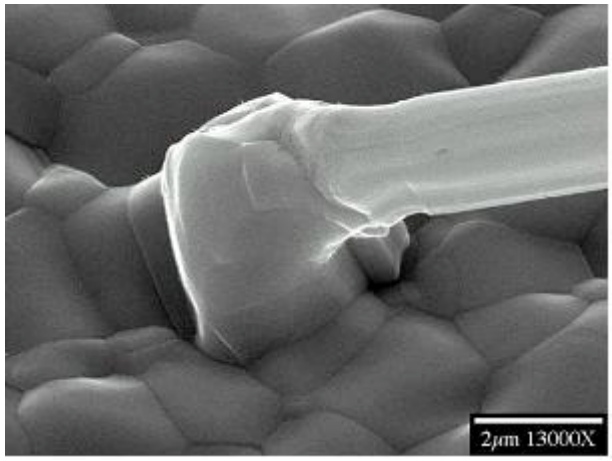
Kinked whisker
Photo courtesy of P.Bush, SUNY, Buffalo



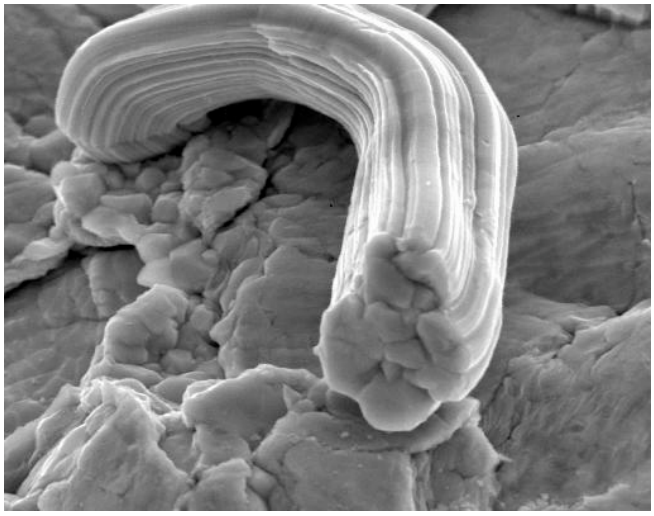
Kinked whiskers growing from a nodule
Photo courtesy of Peter Bush, SUNY



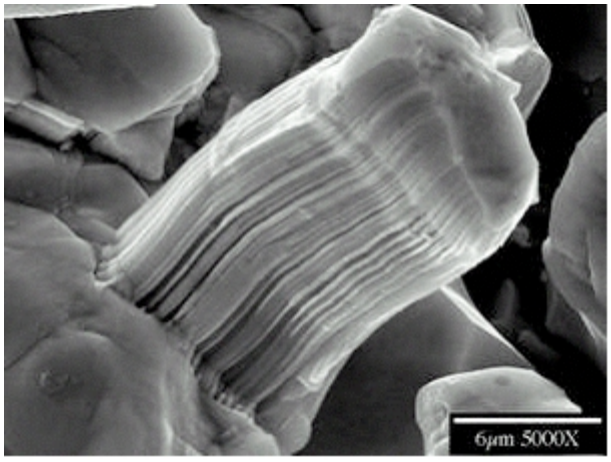
Hillocks
Photo courtesy of M. Williams, NIST



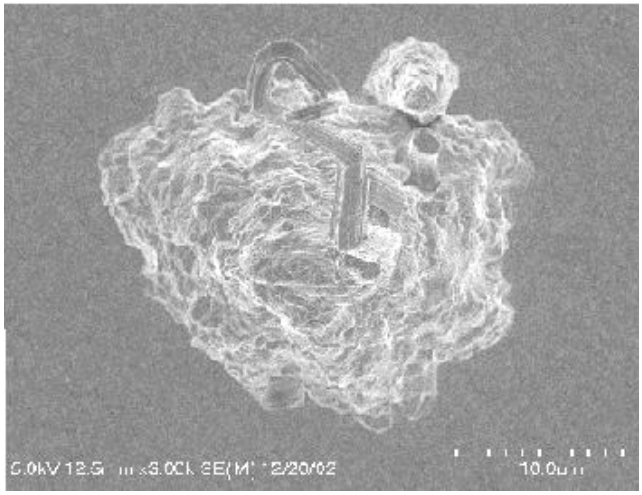
Whisker initiating from a hillock
Photo courtesy of P. Bush, SUNY, Buffalo



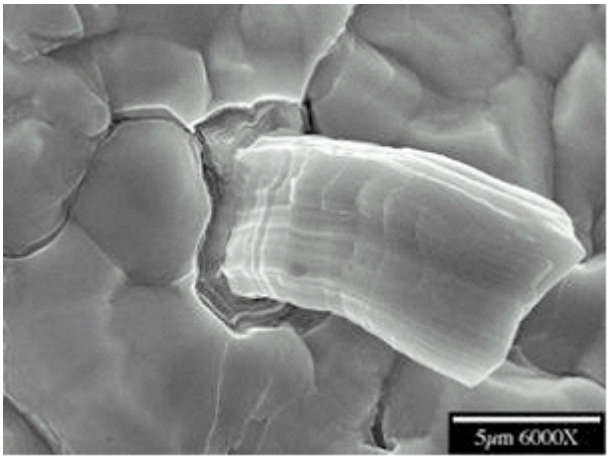
Tin whisker filament with striations
Photo courtesy of Rudy Wagner, KEMET



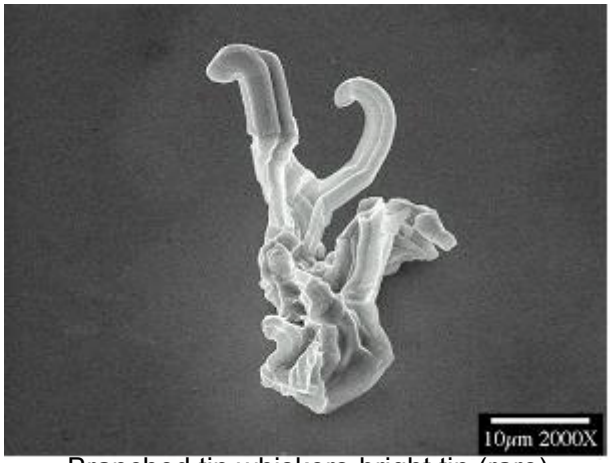
Tin whisker filament with striations
Photo courtesy of P.Bush, SUNY, Buffalo



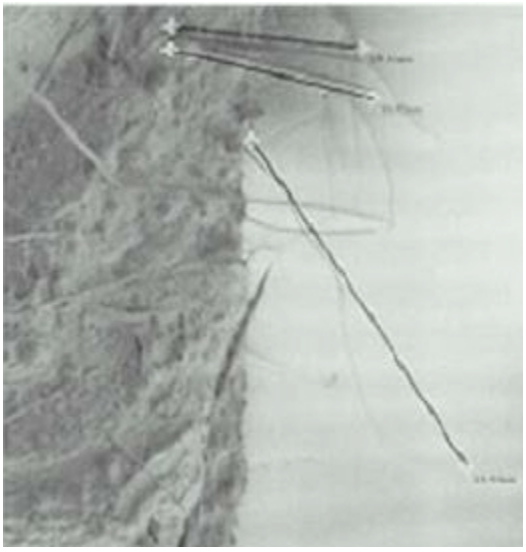
Kinked whisker on odd-shaped eruptions
Photo courtesy of M. Williams, NIST



Tin whisker with rings
Photo courtesy of P.Bush, SUNY, Buffalo



Branched tin whiskers-bright tin (rare)
Photo courtesy of P. Bush, SUNY, Buffalo



Tin whisker filaments 1500X
Lengths: 14-34 um
Courtesy TI

APPENDIX A-2

DENDRITES ARE NOT TIN WHISKERS

Dendrites are fern-like growths formed as a result of electro migration of an ionic species. They are not whiskers.

APPENDIX B

Tin Whisker Test Standard Report Format

Table below is broken up into sections because it is too long. Changes planned for a more cohesive future table.

					Substrate/Leadframe	
Date of Inspection	Test Condition	Exposure Time or # of cycles	Sample Number	Sample Type (pkg, coupon, chip, etc)	Material or alloy (copper, CDA194,alloy 42, etc)	Temper (1/2 hard, etc)

	Plating Information													
Electroplating date	Bath type (Matte/MSA, Bright/H2SO4)	Plating time	Amps	Voltage	Temp	Current Density (Amps/dm^2)	Carbon in deposit (percent)	Hydrogen in deposit (percent)	Contaminant level of Ag (ppm or percent-specify)	Contaminant level of Pb (ppm or percent - specify)	Contaminant level of Fe (ppm or percent - specify)	Contaminant level of Cu (ppm or percent - specify)	Contaminant level of Zn (ppm or percent - specify)	Contaminant level of Ni (ppm or percent - specify)

Finish (Sn, SnCu, SnBi, etc.)	Alloying content in bath (g/l or ppm)	Alloying content in plated deposit (percent)	Finish thickness (micron)

Underplating									
Type (Ni, Ag, Cu, other)	Bath type (e.g. sulfamate Ni)	Plating time	Amps	Voltage	Current Density (amps/ dm^2 or amps/ft^2)	Bath Temp	Bath pH	Thick ness	Under-plating date

Post Plating Treament (none, reflow, anneal 1hr@150C etc.)	Type of whisker	Axial Length of longest whisker (micron)	Whisker density	Grain size (microns)	Comments/Exceptions