

NEMI Sn Whisker Project

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INTRODUCTION

Many IC suppliers are evaluating and implementing lead (Pb) free finishes acting in accordance with the industry movement to eliminate Pb in the use of electronics. There are several commercially available tin-based finishes that are being considered as replacement finishes to the current SnPb finish. These include: tin (Sn), tin-bismuth (SnBi), and tin-copper (SnCu). Sn-based finishes are being considered because they provide good corrosion protection and a solderable surface. However, a drawback of Sn-based finishes is whisker growth. Although this phenomenon was observed and studied (quite extensively) in the past when pure Sn was the prevailing component finish, standard whisker test methods were never established. Now that Sn and its alloys with low content of the alloying element are being considered to replace SnPb, the concern for whisker propensity has raised a need for standard test methods. Standard test methods will help the industry move more quickly in the evaluation and development of Sn-based Pb-free finishes. In addition, standard tests will: permit meaningful comparison of whisker propensity for different plating systems and processes; provide a consistent inspection protocol for tin whiskers examination; and provide a standard method to compare and report results.

Under the auspices of NEMI, a team was formed to identify an accelerated test method for whiskering by evaluating various known methods. At the writing of this paper over 40 companies were participating in different capacities on this committee. The project was initiated with a benchmark study to collect all existing methods for growing whiskers. Also, the team identified and discussed theories behind whisker formation in order to compare test method to whisker growth mechanism and fundamentals. The fundamentals of whisker growth proved to be more complex than anticipated and a separate committee was formed to evaluate different whisker growth theories. However, the test standard committee proceeded with evaluations of test methods which members reported to have resulted in whisker growth. Four principal methods were reported to successfully grow whiskers, which were: storage at ambient office conditions; storage between 50 and 85C; storage at high relative humidity (85-95%); and -55C/85C air-to-air temperature cycling.

Two phases of testing have been completed. In Phase 1, samples (brass coupons and 8 lead SOICs) were prepared with bright Sn along with SnPb (control). Based on past literature, bright Sn is more prone to whisker growth, so it was chosen to improve the likelihood of whisker growth. The samples were then subjected to assorted combinations of the four environments identified. The results of the Phase 1 study were inconclusive. Whiskers formed only on the bright Sn-plated coupons, and were few in number - much less than expected. It is speculated that because the samples were plated in a lab the level of impurities and/or contamination were maintained very low and thus helped to retard whisker growth. A second speculation is that when the terminations were formed the plating cracked reducing stress in the finish and thus helped to retard whisker growth.

Because the results of the Phase 1 study were inconclusive, the team felt it was necessary to perform an additional study of the test methods using parts plated at an assembly house using production baths.

EXPERIMENTAL

Two IC suppliers volunteered and plated 8-lead SOIC samples for the Phase 2 study. One supplier (Supplier A) provided samples plated with a Methane Sulfonic Acid (MSA) bath and samples plated with a Sulfate-based electrolyte. The second supplier (Supplier B) only provided samples plated with a MSA bath. Thick (10-12 micron) and thin (2-3 micron) Matte Sn samples, as well as, SnPb samples were included in the evaluation. The list and the description of the samples are presented below.

- 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

The samples were subjected to slightly different combinations of the four environment conditions which are presented in Table 1.

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

Table 1. Test conditions and sample description for whisker test.

EQUIPMENT

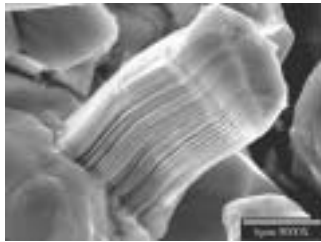
An air to air temperature cycling equipment capable of cycling from $-55(+0,-10)^{\circ}\text{C}$ to $+85(+10 -0)^{\circ}\text{C}$ was used to carry out thermal cycling procedure. A temperature humidity chamber capable of $60^{\circ}\text{C}/90\pm 5\% \text{RH}$ and $30^{\circ}\text{C}/90\pm 5\% \text{RH}$ exposures was utilized for temperature/humidity experiments. Ambient storage was defined as $\sim 23^{\circ}\text{C}/\sim 30-60\% \text{RH}$ conditions. Scanning Electron Microscope (SEM) was used for whisker inspection.

TIN WHISKER DEFINITION

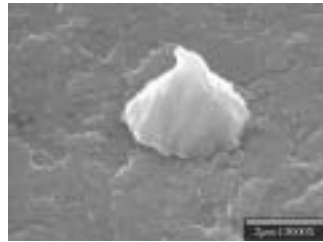
The following definition of a whisker was developed: a spontaneous columnar or cylindrical filament, which rarely branches, of mono-crystalline tin emanating from the surface of a plating finish. See Figure 1 for pictures of tin whiskers. For the purpose of this study, tin whiskers have the following characteristics:

- An aspect ratio (length/width) >2
- Can be kinked, bent, twisted
- A consistent cross-sectional shape
- Rarely branch
- May have striations/rings around it

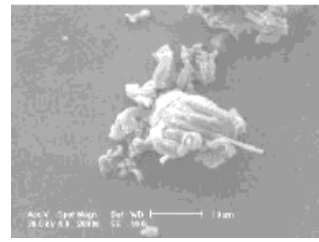
Whisker Types



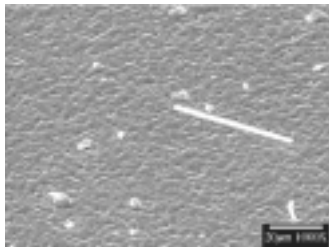
Column



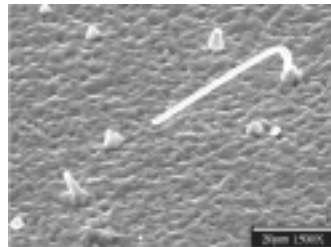
Hillock



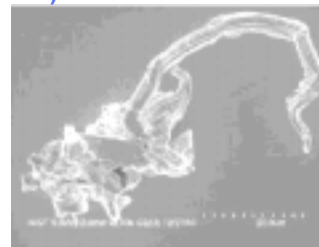
Flower or Odd Shaped Eruption (OSE)



Needle

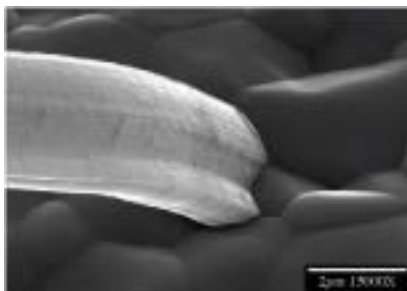


Needle growing out of hillock

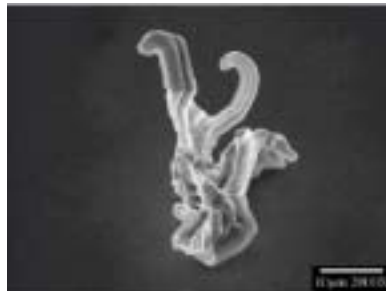


Needle growing out of OSE

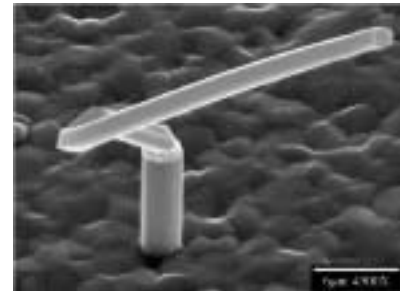
SEM photos – courtesy of P. Bush, SUNY at Buffalo



Striations on the whisker and consistent cross-section



Very rarely, whiskers may branch



Kinked whisker

Figure 1

INSPECTION PROCEDURE

The inspection protocol outlined here has been used to inspect numerous samples of the types described. Example images are included to illustrate the typical results of the method.

Leaded Packages

Three packages randomly chosen from the test sample mounted in upright, inverted and inverted rotated positions. Carbon tape or paint may be used to create conductive paths, or carbon may be evaporated on the parts if inspection is to be made immediately. At 300x magnification, inspect three randomly located fields from a) underside of lead, b) top of lead and c) side of lead (Figure 2). The stage should be tilted to 45 degrees for the latter two images. The fields should be selected as representative of the overall condition of the parts as determined by the first inspection.

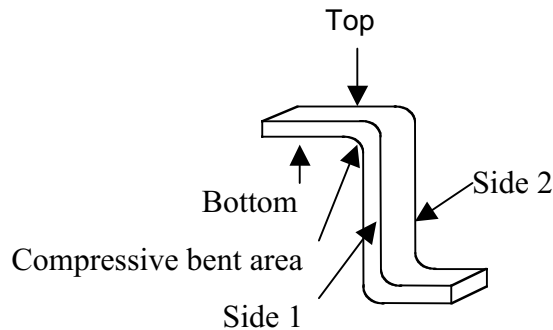


Figure 2

Coupons

On each of 3 coupons randomly selected from the test samples, collect at least three images at 300x and record data as above. Similarly, collect image at 3000x for grain size determination.

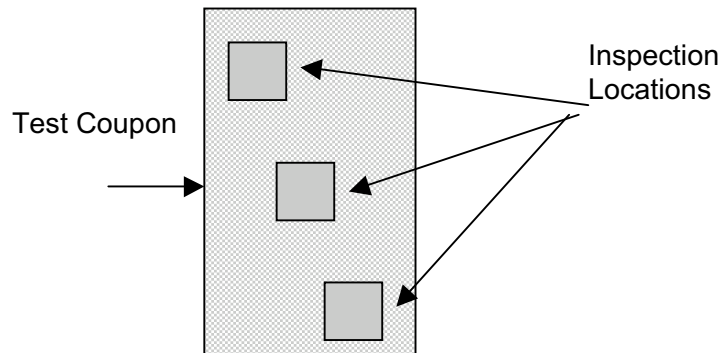


Figure 3

Passive components

Mount three samples in a similar manner to the leaded packages, and record and measure fields as described.

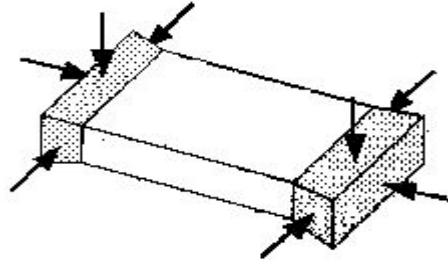


Figure 4

REPORT

Count and record all whiskers in the three fields. Measure and record the longest whisker in each field, using higher magnification if necessary. Finally record one image at 3000x from an undisturbed region of plating. Report the estimated grain size range of the deposit. Report average number of whiskers from the three fields and the length of the longest whisker found in those fields. Include the date of plating; whisker test conditions (duration, temperature, humidity, number of cycles, etc.) and the date of inspection.

BATH CONTROL

Each plating bath was maintained at the optimum conditions specific for each process. Level of metallic contamination was measured by Atomic Absorption Analysis prior to plating (t_0) and after the plating was complete (t_e). The results for both suppliers are presented in the table below.

Supplier A										
Contaminations, ppm	Pb		Fe		Cu		Zn		Ni	
	t_0	t_e	t_0	t_e	t_0	t_e	t_0	t_e	t_0	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

Table 2. Level of impurities (in ppm) in the plating baths

WHISKER TEST RESULTS

The results of whisker test for various samples and all test conditions are shown in Figure 5. The average amount of whiskers in the field of view at 300x magnification is presented as columns and the length of the longest whisker is shown as a line.

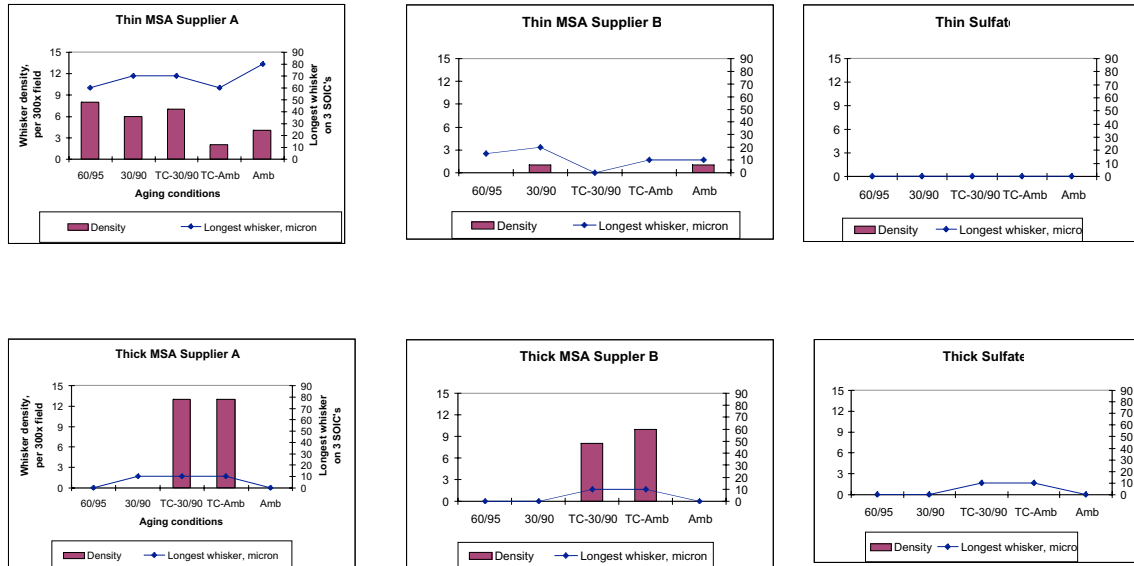


Figure 5. Whisker test results for various test conditions, deposit thickness and bath chemistries

CONCLUSION

The Phase 2 results were more conclusive. 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. Also, based on the results of the Phase 2 experiment we did not see a difference in whisker performance within the deposit thickness range tested. However, the results seem to show that the bath chemistry/plating process has the most significant influence on whisker growth. There appears to be substantial difference between the two MSA-based processes from the suppliers; and in general the sulfate-based chemistry seems to have better whisker performance over the MSA-based bath but only slightly better performance over a good-practice MSA bath.

FUTURE WORK

A Phase 3 experiment is currently in the planning stage to verify the results of the Phase 1 and 2 evaluations. One of the goals of the Phase 3 evaluations is to show that the three recommended tests can consistently produce whiskers with similar samples. A second goal of the evaluations is to confirm that it is applicable for other Sn-based (SnBi and SnCu) finishes and possibly other sample types (connectors, special design coupons, etc.). The tests will be carried out to extended durations to determine appropriate end points for each test method. The endpoints will be defined by the saturation of growth (growth saturation definition to be determined).

An attempt to correlate the test methods to application life will also be examined. Since the mechanism for whisker growth is not known, subjecting samples which have been produced with Sn (and/or Sn-based Pb-free) finishes to the recommended test methods may provide some correlation to application life (risk) in applications where these current Sn-plated products are used.

Work is also continuing in the NEMI Whisker Fundamentals Group to develop a better understanding of whisker formation which may lead to better test methodology or validate that these are the best tests that can be carried out.