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Sample Preparation for Mitigating Tin Whiskers in Alternative Lead-Free Alloys

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ABSTRACT. As lead-free alloys shift into high reliability electronics, the issue of tin whisker growth remains a primary concern among those in the industry. Current research shows that there is no perfect alloy for all cases of electronic usage. Industry leaders and researchers continue to study and search for a lead free alloy that is able to withstand harsh environments while maintaining high reliability.

INTRODUCTION. This study looks at one of the many concerns regarding lead-free solder in high reliability electronics. The work in this paper has been accumulated over time with some of the initial work released in 2010. Since most of the tin whisker issues in modern electronics have been tin plating related, testing has been geared toward this type of whisker growth. While some did, most of the established tin whisker testing revealed alloys that did not grow whiskers.

TEST METHOD. A simple test was developed to test solder. A copper wire of approximately 0.03" standard house wiring is fluxed and coated by hot dipping with solder. The solder coating is approximately 300 um thick. The wire is allowed to cool. After all samples are prepared, 10 of each alloy are then placed in an arbor press and bent into a U. The bent samples are then placed in a chamber at 60°C /87RH (initial runs were prepared using two other conditions, however it was determined this condition would be used for all future testing). The U shaped wire was then placed in a holder that stands them up.

Figure 1. Bent Samples

EXPLANATION. Lead-free alloys grow whiskers at different rates. S(Sn) A(Au) C(Cu) is consistently the worst, however Sn63 is a control that does not grow whiskers. This initial test was run with nine lead-free alloys. Subsequent research was done where 30 different alloys were tested.

TEST RESULTS. Tin whiskers always grow in the same region of the bend as shown below in Figure 2.

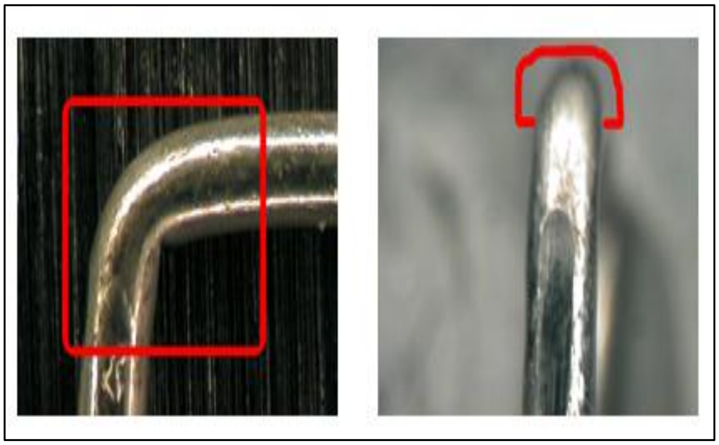

Figure 2. The Bend

Figure 3. Typical Whisker Growth

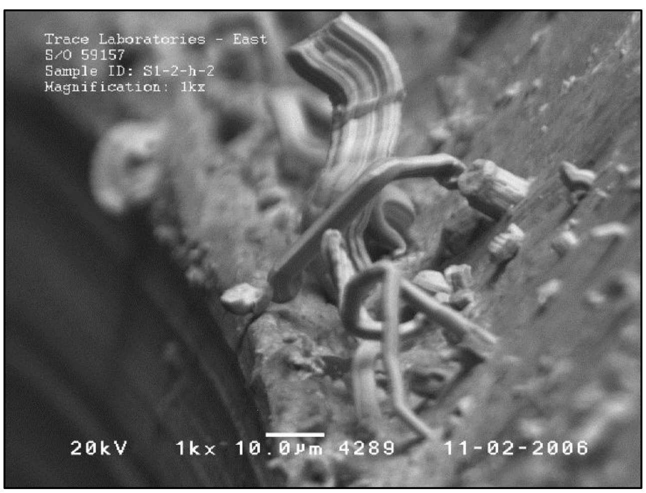

Figure 4. Typical SAC305 Whiskers

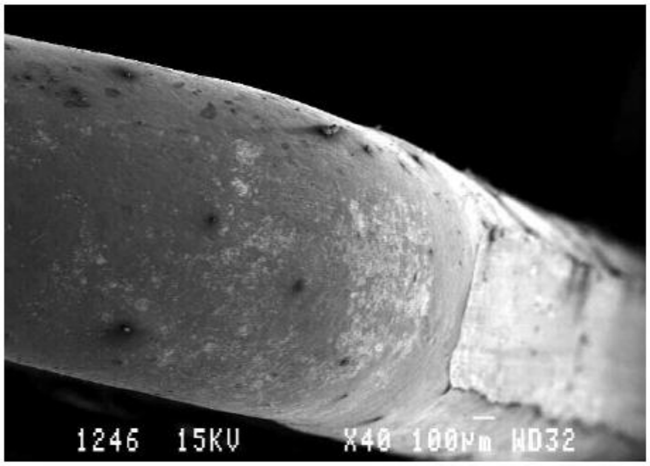

Figure 5. Sn63

If a leaded device is solder coated and bent, or scratched, there is a possibility of whisker growth from standard lead-free alloys. Shown in figure 6, is a typical gull wing device illustrating the potential growth zone at the bend.

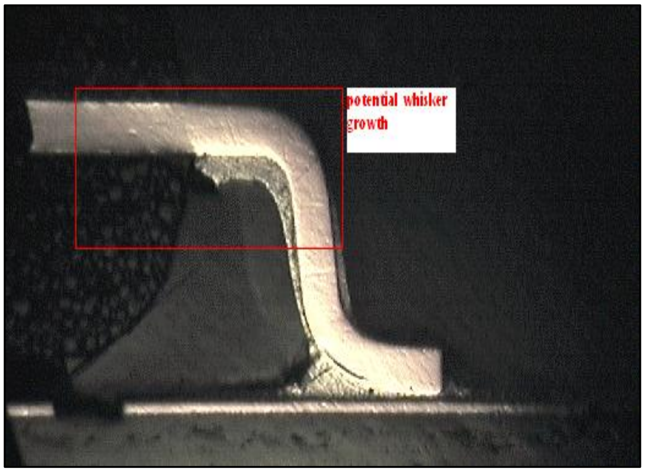

Figure 6. Potential Whisker Growth

Developmental Alloys #41, #60, & #61 all mitigate whisker growth as evidenced in Figures 7, 8 & 9.

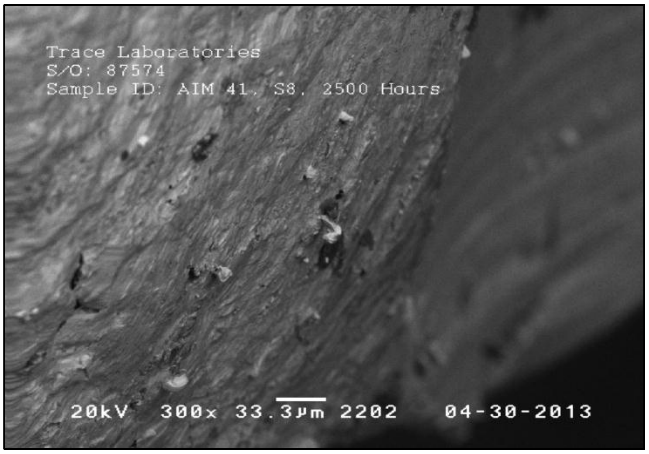

Figure 7. #41

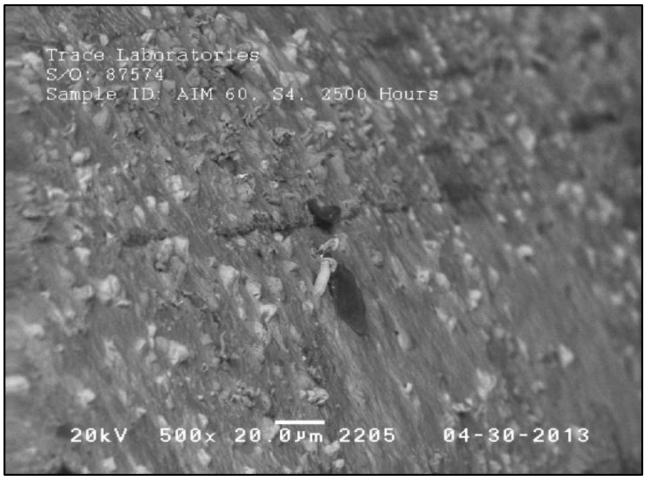

Figure 8. #60

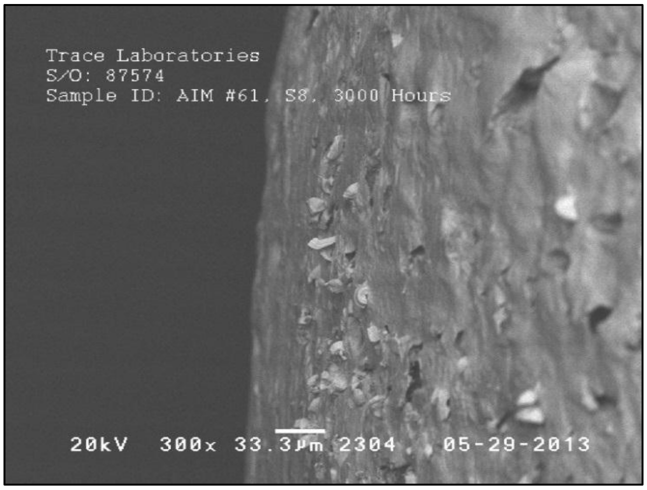

Figure 9. #61

Recent work has shown that the above alloys contain micro additions, and in conjunction with other low percentage elements, do mitigate whisker growth. These alloys were studied for grain size and shape, DAC (Should this be DSC), dip wetting (wetting balance), spread testing, tensile, hardness, and percent elongation.

The following pictures examine the grain structure of the different alloys.

Alloy #41 exhibits a very different grain structure with only 500 ppm of an addition. Alloy #60 is with 2000ppm of an element and Alloy #61 that has two additions, one at 600ppm and one at 2000ppm. (Can any indications be given on the type of alloying additions used).

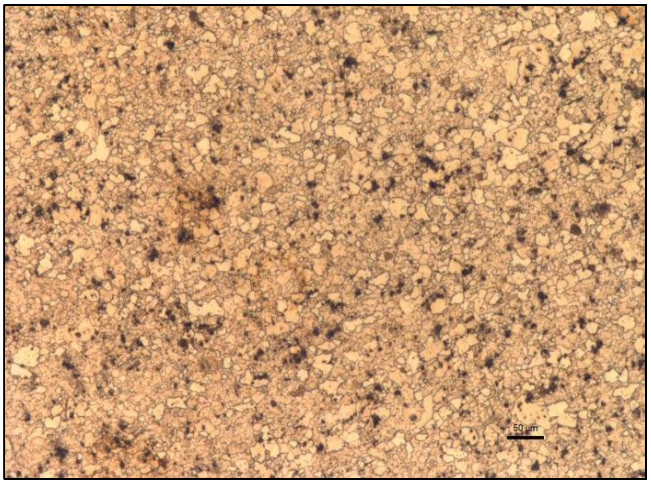

Figure 10. Alloy #41

Figure 11.Alloy #60

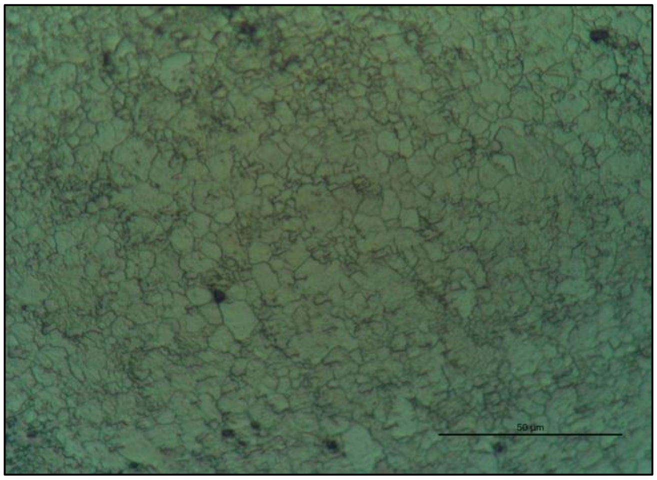

Figure 12. Alloy# 61

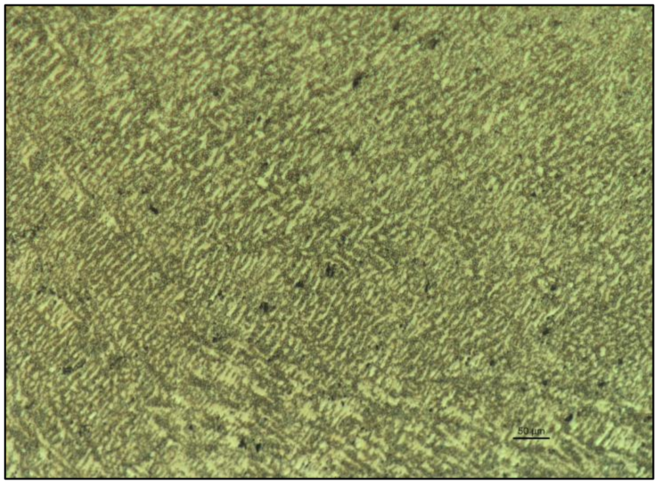

Figure 13.SAC305

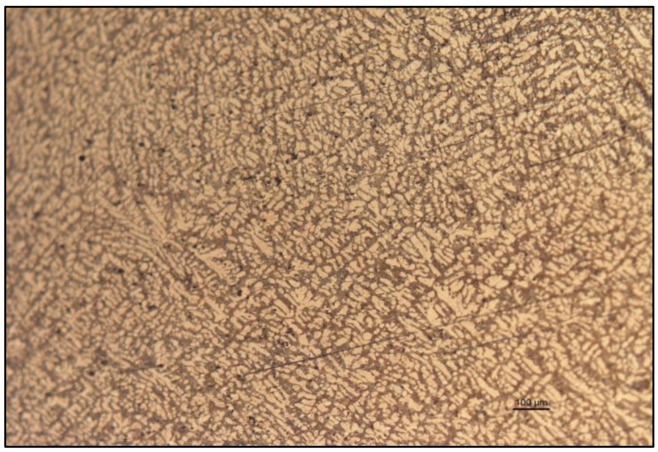

Figure 14. Sn/0.7Cu

The below chart is of several alloys that have been developed. Some have been tested for whisker growth and some are still in testing. From the properties, one can see that hardness, tensile, and percent elongation all have been affected by these additions.

Summary results

Alloy	T[illegible](°C) (Heating)	Pasty range (°C)	Wetting Time, ta (s) (300C)	Wetting force (mN) (300C)	Hardness (HV10)	Tensile strength (Mpa) (aged 96hr 125C)	Elong. (%)
#41	226	11	0.82	3.15	7.5	24.1	40.3
#60	201	24	0.6	3.63	15	77	26
#61	216	17	0.64	4.54	16	28.1	37.2
#69-2	204	21	0.56	4.77	25	82	21.5
#71	206	20	0.74	4.82	21	-	-
#81	204	20	0.79	4.8	-	-	-
SAC0607	217	18.5	0.49	4.66	15	35.1	39
SAC305	217	13	0.57	4.88	17.7	35	46.7
#82	205	20	0.58	4.8	-	-	-
#84	227	12	0.67	4.4	15	-	-
#69-6	210	18	0.58	4.63	14	-	-
#69-7	210	21	0.64	4.41	20	64	21.3
#69-8	210	20	0.55	4.17	19	63	23.5

Figure 15. Alloy Chart (Can this figure be separated into 2 tables to make it easier to read)

As previously mentioned, there is no “one” alloy that offers an absolute solution. Some of the alloys that had the best whisker mitigation had some of the worst wetting. This can be seen in the wetting balance coupon inspection.

Alloys #41, #60, and #61 all had poor coverage on the coupon as shown below in figures 16, 17, & 18.

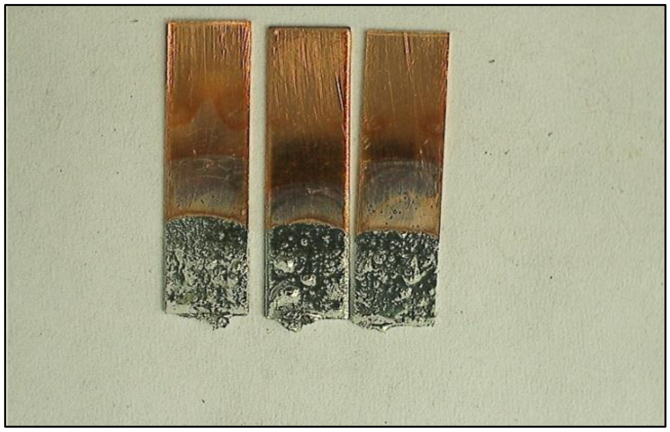

Figure 16. Alloy #41

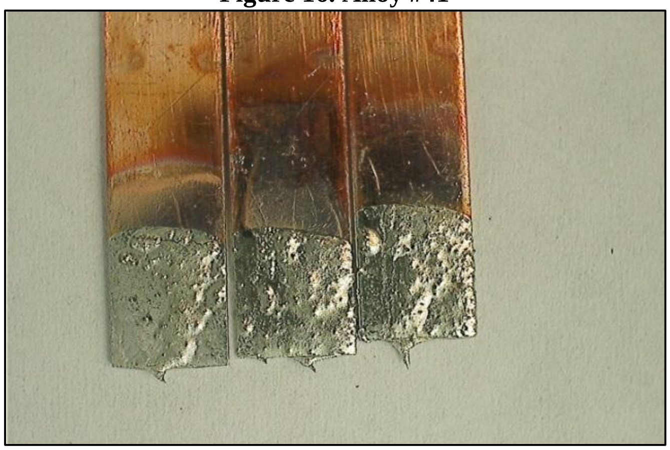

Figure 17. Alloy # 60

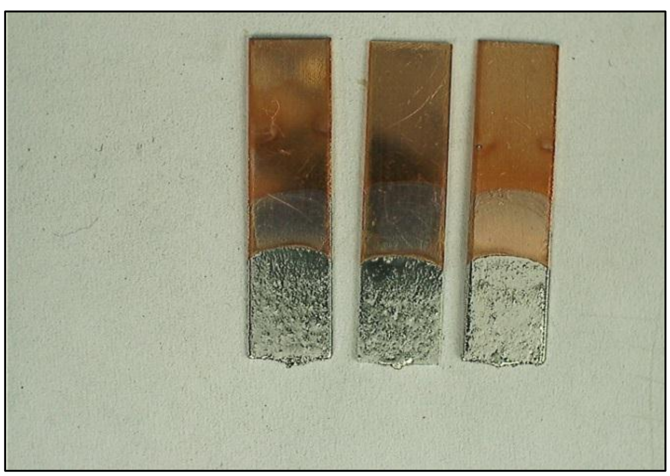

Figure 18. Alloy #61

MODIFIED ALLOY. Alloy #81 is a modified alloy with lower levels of one of the materials contained in the others. It appears to exhibit better wetting.

Figure 19. Alloy # 81

CONCLUSION. Based on the above work, further research is necessary. As evidenced in this paper, it is likely that tin whiskers can be mitigated by alloy additions and acceptable physical properties can be achieved for high reliability alloys.

ACKNOWLEDGEMENTS

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