Tin Whisker Management Guidelines, Part 2

By Joe Smetana and Ron Gedney

Sunday, 01 January 2006

How 40 µm was found to be the maximum acceptable whisker length for high-rel product, and recommended strategies for mitigation.

Ed.: Part one was published in December.

Sample size. To ensure a consistent plating process, testing (using the three test conditions) should be done on three different plating finish lots with different date codes and plated at least one week apart, or plated on different plating lines. Data show that, in some cases, it is necessary to look at a minimum of 200 leads to find issues with tin whiskers. The final sample sizes recommended were a tradeoff to accommodate user needs without being an excessive burden to suppliers.

Table 3 shows iNEMI recommendations for number of samples and sample preparation. The proposed JESD 201 modifies the sample sizes slightly.

(Click here to see tables.)

Preconditioning. Preconditioning samples prior to test condition exposure helps simulate actual use conditions. Data show quite a difference in actual performance of finishes not preconditioned with a reflow cycle versus those that were. Three different preconditions are recommended. The two reflow conditions (described below) require an initial four weeks at ambient.

1. No conditioning: Components sit for a minimum of four weeks at room temperature. This precondition represents components in storage, prior to use, and serves as a baseline reference for other tests. Four weeks permits the effect of intermetallic growth (such as Cu_6Sn_5) to be seen. Intermetallic thickness grows at half power (square root) of time, thus the percentage increase in the thickness of the intermetallic is:

1-2 wks., the increase is 41%.

2-3 wks., the increase is 20%.

3-4 wks., the increase is 17%.

Although growth will continue beyond four weeks, the intermetallic growth is substantial enough after a month to see the effect during subsequent test conditions. Longer durations would further extend the total test time and were, therefore, not considered viable.

2. Reflow simulation at 215°C, which is representative of SnPb assembly.

3. Reflow at 255°C, which represents components assembled with Pb-free SnAgCu solder.

Whisker Length

Because testing for whisker growth is critical, and in most cases some amount of whisker growth occurs during testing, it is necessary to determine what whisker length can be tolerated. To determine end-item requirements, a number of questions need to be answered:

1. What is the maximum whisker length we can permit without a short?
2. What happens if a tin whisker breaks off? Where does it go?
3. What whisker length can be permitted without an adverse affect on RF/high-speed performance?
4. What are the sources of error in testing, and what safety factor is required to accommodate for these errors in setting final length requirements?

The iNEMI Tin Whisker User Group took these questions into consideration in developing recommendations. Two aspects were considered in determining the maximum whisker length that could be tolerated by system designers: mechanical performance, looking at the gap or spacing between leads; and electrical performance, considering the point at which the effects of whiskers become significant enough to cause concerns about RF/high-speed performance.

In the worst case, which assumes that two whiskers grow directly toward each other from either side, the maximum allowable whisker length is equal to half the distance from one lead to another, or to a lead on another component, or 1x the distance to the nearest trace on the PCB. **Table 4** provides an example of the analysis of mechanical spacing of typical components.

(Click here to see tables.)

With regard to electrical analysis, the effect of whisker length on circuit performance was modeled by Alcatel's Microwave Group. It is a complex function of whisker length, whisker density and operating frequency. The negative effect starts at 6 GHz RF or higher or roughly t_{rise} of 58 psec (or less in a digital circuit). The susceptibility to degradation associated with tin whiskers increases with frequency. To simplify the test requirements for whisker growth, it was determined that if the maximum whisker length could be kept below 75 µm, the effect was negligible. The maximum frequency analyzed to arrive at this limit was 20 GHz.

As stated, several factors confound whisker acceptance testing. The test conditions cannot be related to actual field conditions; the variability in

whisker measurement is significant; and we cannot ensure that the maximum whisker length observed in the test conditions, even if saturation occurs, is representative of the actual longest whisker length. As a result, a safety factor between the test requirements and the maximum allowable whisker length is a critical consideration for reliability. This safety factor should reflect both the variability in the testing and measurement and the lack of correlation of the test conditions to field conditions. Thus, when whiskers actually occur in the field, there is greater margin, based on the acceptance test criteria, before they actually result in failures.

After evaluating the data available for both mechanical and electrical performance, the iNEMI team determined that 40 µm was the maximum acceptable whisker length for high reliability (typically class 2) applications. This was roughly based on a 2:1 safety factor for both electrical and mechanical considerations. As shown in Table 4, compromises in the 2:1 safety factor were made for components with lead pitches below 0.65 µm to permit a 40 µm whisker length to be acceptable in test.

Industry discussions have led to a minor adjustment of iNEMI's original recommendation. The maximum length in the JESD 201 draft remains 40 µm for the two isothermal conditions, but has been increased to 45 µm for the thermal cycling condition where, according to data, saturation is expected.

Ongoing Monitoring

Manufacturers need to establish a system to periodically monitor processes for whisker generation. The specifics of this system are left to the producer; however, the following minimum guidelines are suggested:

A representative sample of components should be taken for each designated time period (at least monthly).

Storage conditions for these components should include a relative humidity of 60% or greater.

Samples should be inspected for whiskers six months from the date of plating.

Results should be compared to baseline measurements. If exceeded, the manufacturer should take appropriate corrective actions.

Tin whiskers can potentially have a major impact on the reliability of electronics systems. Properly managed, the exposure can be minimized and the result will, hopefully, be transparent to the end-user. Although industry still lacks a full understanding of the fundamentals of whisker growth, good engineering judgment has been applied to develop a series of specifications and working practices that will reduce risks for end-product designers. One JEDEC specification has been issued, and two more nearing release will provide much needed guidance. Meanwhile, the iNEMI recommendations can serve as interim guidelines.

Bibliography

1. G.T. Gaylon and Ron Gedney, "Avoiding Tin Whisker Reliability Problems," C*ircuits Assembly*, August 2004.
2. Joe Smetana, "Minimizing Tin Whiskers," *SMT*, August 2005.

All iNEMI documents can be found at **inemi.org/cms/projects/ese/tin_whisker_activities.html**.

Joe Smetana is principal engineer, advanced technology, Alcatel (**alcatel.com**), a distinguished member of the Alcatel Technical Academy, chair of the iNEMI Tin Whisker User Group and a member of the JEDEC and IPC tin whisker standards committees; **joseph.smetana@alcatel.com**. **Ron Gedney** is a consultant to iNEMI Pb-free and tin whisker projects; **rgedney@nemi.org**.