TECHtips

Electronics Manufacturing Insights from ACI Technologies, Inc.

Tin Whiskers: Mitigation with Conformal Coatings | Part II

One of the two basic risks of employing the commercially accepted, Restriction of Hazardous Substances (RoHS) compliant, lead-free (Pb-free) electronics is the threat to the electronics reliability from the growth of tin whiskers. The other basic risk deals with Pb-free solder joint reliability.

Although the risk of whisker-generating electroplated pure tin is commonly found in commercial off the shelf (COTS) electronic hardware, it is showing up in military electronic assemblies at an alarming rate. Because of this "inconvenient truth" (as the tin whisker risk has been called) many attempts at mitigation of these risks have been made. An example of a tin whisker event on the NASA Space Shuttle is depicted in Figure 1.

It should be noted that these Space Shuttle tin whiskers were not growing from tin plated electrical components, since the Space Shuttle avionics pre-dated the RoHS law by a significant time, but from tin plated beryllium copper card guides, and may have been growing for years. Today's lead free electronics would be expected to have far more tin whisker susceptible components, since any tin plated component could be a source of whiskers.

An analogy can be drawn between unwanted tin whisker growths in electronics and weeds in a lawn. Generic strategies for elimination of weeds involve studying the biological growth mechanism for the weed phenomenon, identifying the critical biological contributors to the growth, and eliminating or arresting these key biological factors as needed to circumvent the growth and not simultaneously harm wanted phenomena (e.g. your lawn).

In the case of tin whiskers, the metallurgy of tin must be studied to identify the critical parameters for tin whisker growth and then eliminate as many of the key metallurgical factors as needed to circumvent the growths (without simultaneously harming the electronics, or the environment, in the case of Pb-free electronics).

It is commonly accepted that whisker growth follows a two part mechanism:

1. diffusion of tin from anywhere in the tin plate to the site of the whisker, and
2. incorporation of the tin atoms into the crystal lattice of the tin whisker.

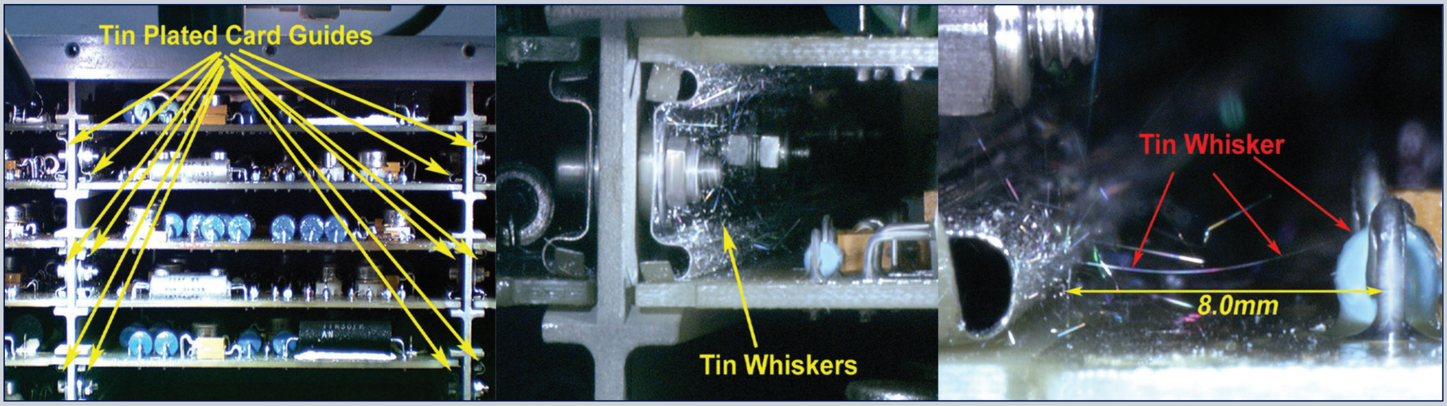

Figure 1: Tin whiskers growing on NASA Space Shuttle avionics hardware documented in April 2006. These photographs appear courtesy of NASA.

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Diffusion is encouraged by:

1. a temperature high or low enough to be a significant fraction of the melting temperature at the high end, and absolute zero at the low end, and
2. a stress gradient whereby the tin atom diffuses from a place of high free energy (compressively stressed tin plated surface finish) to low free energy (a perfect crystal of β tin) within the tin whisker.

Neither of the diffusion enhancing/impeding parameters can be readily mitigated. First, temperatures at which electronics operate are rarely high or low enough to affect the diffusion coefficient of tin (melting point 231°C) appreciably.

Second, even though the internal compressive stress in the plated tin can be eliminated or caused to become tensile at the initial deposition of the tin coating film, the long term generation of intermetallic compounds in the tin coating on any of the electronic component leadframe alloys can eventually, often over very extended times, re-generate internal compressive stress in an initially stress-free tin finish coating. Diffusion is not something that can be controlled on a practical, long term basis.

The second half of the mechanism for whisker growth – incorporation of the tin atom into the whisker crystal – could possibly be prevented by coating the whisker, or the recrystallized grain of the tin plate that provides the first few layers of perfect crystal in the whisker, with a conformal coating of a high elastic modulus material. If the elastic modulus of the conformal coat is higher than the modulus of tin, then the incorporation of the additional tin atoms may not be possible, because the elastic modulus of pure tin would have to be exceeded to add additional tin atoms (and therefore whisker crystal volume, to the whisker) thus "stretching" the coating. Of course, the elastic modulus of the standard conformal coating materials (acrylics, silicones, epoxies, Parylene, and urethanes) is thousands of times lower than tin. Only ALD Cap is documented to exhibit higher elastic modulus than tin metal applied to the completed circuit card assembly as a conformal coating by Atomic Layer Deposition. The ALD Cap is a ceramic material with a much higher elastic modulus than tin metal.

A third approach possible to mitigate whisker risk is to conformally coat the electronics with a tough viscoelastic conformal coating that tents the growing tin whisker and causes Euler buckling of the whisker rather than allowing the growing whisker to puncture the coating. Tin whiskers have been shown to puncture and grow through all standard conformal coatings in a matter of months or a few years.

Both Whisker Tough P1 and ALD Cap conformal coatings show promise in mitigating tin whiskers, and ACI Technologies has evaluated a number of conformal coatings for electronics.

ACI Technologies can help determine the coating solution that is right for your specific application. Put our expertise in lead free technology and mitigation to work for you. We offer an array of analytical services including solder analysis, help with processing issues and development of lead free control plans. Contact the Helpline at 610.362.1320 or email helpline@aciusa.org.

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