Mitigation Strategies for Tin Whiskers

Prepared by M. Osterman CALCE-EPSC

Outline

Introduction

The drive to eliminate lead (Pb) from electronics has resulted in an interest in the use of pure tin (Sn) finishes as an economical lead-free (Pb-free) plating option; many already have, or are in the process of transitioning. The re-emergence of tin-plating has renewed concern over the threat of failure due to tin whiskering, first reported in the 1940s [Levine, 2002]. Due to the threat of tin whisker induced failure and the concern for the reliability of electronics that perform mission critical services and have long operation periods, CALCE Consortium has posted an alert, warning manufacturers of electronic hardware that tin whiskers represent a current failure risk, that must be addressed [TIN WHISKER ALERT, 2002]. Tin whiskers have been identified or are highly suspected in the costly failure in a number of electronic systems. Although new plating processes have been developed that appear to reduce the risk of tin whisker growth, there is currently no industry-accepted test for determining the propensity of tin whiskers to grow on a finished surface. At present, new electronic systems may be at risk due to the introduction of parts with pure tin finishes. To address the threat of tin whiskers, a review of mitigation strategies for tin whisker is presented. Much of the technical information needed to eliminate or significantly mitigate the risk imposed by tin whiskers remains unknown and will require extensive additional research. This paper presents an interim guide to help makers and users of high reliability products/systems understand the various mitigation strategies and methods currently in use or being considered, along with the relative risks associated with each. In this presentation, the pros and cons of each strategy will be presented and the supporting documentation of the effectiveness of each strategy will be provided. It must be borne in mind that the effectiveness of the various strategies discussed has not been demonstrated.

Risks Related To Tin Whiskers

Tin whiskers pose a serious reliability risk to electronic assemblies that are specific to the product that incorporates pure tin plating. The general risks fall into four categories:

1. **Stable Short Circuits In Low Voltage, High Impedance Circuits.**
   In such circuits there may be insufficient current available to fuse the whisker open and a stable short circuit results. Depending on a variety of factors including the diameter and length of the whisker, it can take more than 50 milliamps (mA) to fuse open a tin whisker.
2. **Transient Short Circuits**
   At atmospheric pressure, if the available current exceeds the fusing current of the whisker, the circuit may only experience a transient glitch as the whisker fuses open.
3. **Metal Vapor Arcing (Plasma) in Vacuum**
   In vacuum a much more destructive phenomenon can occur. If currents of above a few amps are available and the supply voltage is above approximately 12 V, the whisker will fuse open but ***the vaporized tin may initiate a plasma that can conduct over 200 amps!*** An adequate supply of tin from the surrounding plated surface can help to sustain the arc until the available tin is consumed or the supply current is interrupted such as occurs when a protective fuse element interrupts.
4. **Debris/Contamination**
   Whiskers or parts of whiskers may break loose and bridge isolated conductors remote from the original site of whisker growth. In addition, whisker debris may interfere with optical surfaces or the smooth operation of microelectromechanical structures (MEMS).

A Brief Description Of Tin Whiskers

- Whiskers are elongated single crystals of pure tin that have been reported to grow to more than 10 mm (250 mils) in length (though they are more typically 1 mm or less) and from 0.3 to 10μm in diameter (typically 1 - 3 μm).
- Whiskers grow spontaneously without an applied electric field or moisture (unlike dendrites) and independent of atmospheric pressure (they grow in vacuum).
- Whiskers may be straight, kinked, hooked or forked and some are reported to be hollow. Their outer surfaces are usually striated.
- Whisker growth may begin soon after plating. However, initiation of growth may also take years. The unpredictable nature of whisker incubation and subsequent growth is of particular concern to systems requiring long term, reliable operation.

Tin Whisker Growth Mechanism

The mechanism(s) by which tin whiskers grow has been studied for many years. No single, widely accepted explanation of this mechanism has been established but there are some commonly agreed factors involved in tin whisker formation. Tin whisker growth is primarily attributed to stresses in the tin plating. These stresses may be from many sources including:

- Residual stresses in the tin resulting from the plating process. Electrodeposited finishes are considered most susceptible due to stresses built into the finish as a result of the plating process.
- Formation of intermetallic compounds (i.e. Cu_6Sn_5) especially within the tin grain boundaries
- Compressive stresses such as those introduced by torquing of a nut or a screw
- Bending or stretching of the surface after plating
- Scratches or nicks in the plating introduced by handling

- Coefficient of Thermal Expansion mismatches between the plating material and substrate
- Historically, elevated temperature storage (approximately 50°C) has been reported to be the optimum environment for whisker growth to occur. However, very recent studies by international consortia have produced contradictory findings. Further studies are attempting to quantify the effects of environmental conditions such as temperature cycling, elevated temperature and humidity and even prolonged ambient storage.

Bright tin finishes (shiny) seem to be worse than matte finishes due to some influence of the organic compounds used as brighteners and/or their smaller grain size structure.

Mitigation Strategies

Before describing the various technical strategies for mitigation, a business approach along the following lines may prove worthy of consideration. Companies may avoid some potential tin whiskers issues by conducting a continuous and consistent effort to maintain as many possible sources (alternatives on the flow chart below) of high reliability components as possible. To do this, they must first find out if their suppliers intend to switch to pure tin electroplating or lead free soldering. Those who indicate such an intent should be provided with information intended to convince them to either reconsider switching or to maintain the capability to produce high reliability components in parallel with lead free components. Arguments include:

(a) There will always be a market for high reliability components in military, aerospace and medical products;
(b) There is no pending US legislation mandating lead free electronic products and if it does arise, the military, aerospace and medical equipment manufacturers will likely be exempt, as is the case with the European legislation (WEEE);
(c) The soldering and finishing process uses so little lead compared with the rest of the industry (less than 0.5%), that the impact on environment is insignificant;
(d) High reliability military, aerospace and medical equipment have little probability of ending up in a landfill and causing pollution;
(e) Most solder materials in lead free components are many times more toxic than the current SnPb compound;
(f) It is in our national interest to have high reliable military, aerospace and medical products.

The uncertainties associated with tin whisker growth make it extremely difficult to predict if/when tin whiskers may appear. There are currently no industry-accepted accelerated test methods to judge a particular product's propensity to form whiskers. In fact, the historical literature on tin whiskers frequently reports contradictory experiences regarding the effects of various forms of environmental stresses on whisker growth. At present, a number of organizations are working on understanding the whisker growth phenomenon and attempting to develop methods to test and model the propensity for whisker growth.

Nonetheless, the industry is currently faced with the prospect of dealing with pure tin finishes in electronic products. As such, a mitigation approach is needed to address the failure risk posed by tin whiskers. A flowchart chart to assist in mitigating the risk of tin whiskers is presented in Figure 1. Due to the difficulties in predicting tin whisker growth, it may not be possible to completely eliminate tin whiskers as a failure risk.

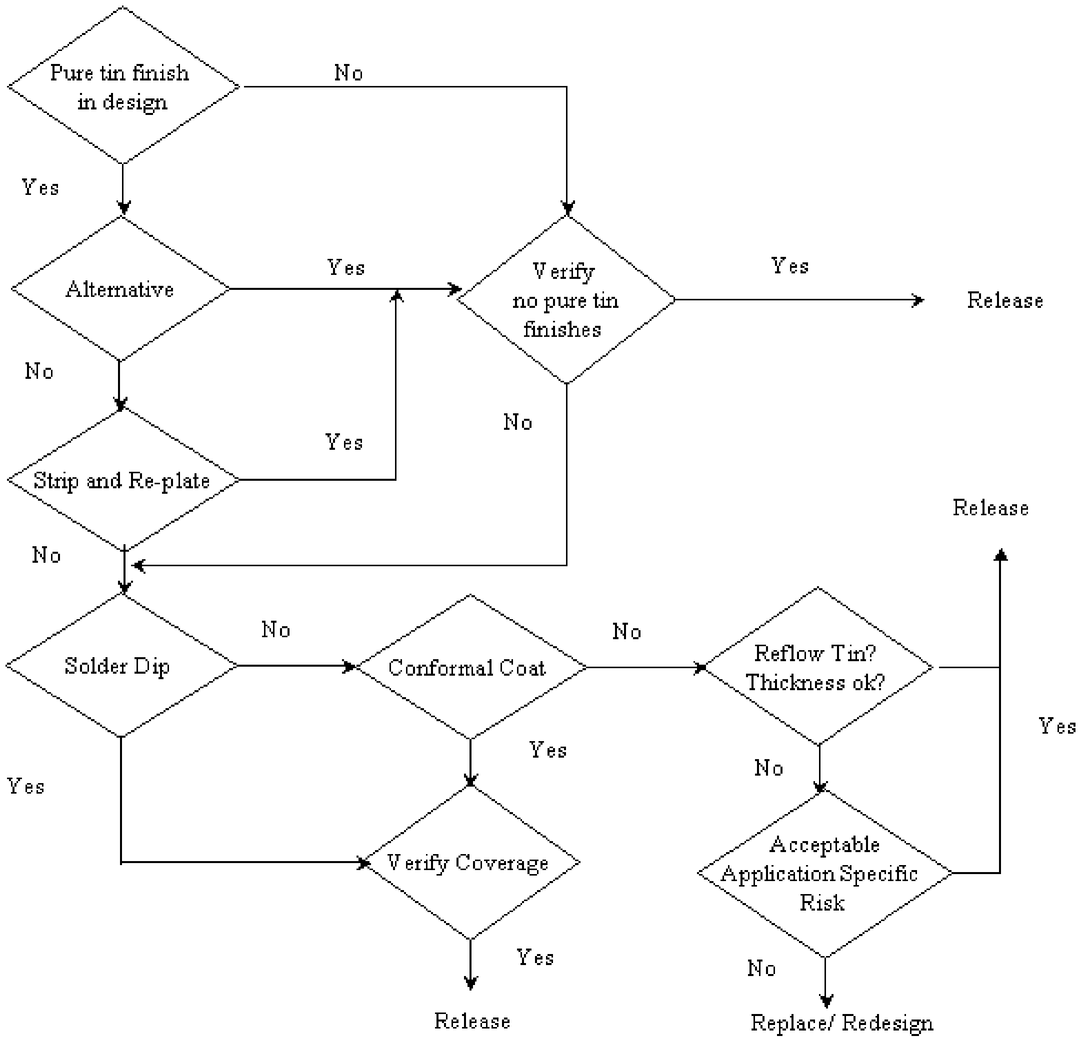

Figure 1. Mitigation Process

Below is a discussion of the individual mitigation strategies presented in the flowchart, as well as other information that may help engineers reduce the risk of failure due to tin whisker formation. Each discussion provides a description of the strategy with the advantages (Pros) and disadvantages (Cons) of the strategy as well as any supporting evidences of the effectiveness of the method.

Avoid Tin Plated Parts

The best strategy to prevent tin whisker induced failure of electronic hardware is to avoid using pure tin plating on any of the parts used in the construction of the electronic hardware, such as lead finishes, RF shields, mounting hardware, and electronic enclosures. In particular, bright tin finishes have been show to be particularly prone to whisker formation. Utilization of procurement specifications that have clear restrictions against the use of pure tin plating is highly recommended. Most (but not all) of the commonly used military specifications currently have prohibitions against pure tin plating. Studies have shown that alloying tin with a second metal can reduce the propensity for whisker growth. Alloys of tin and lead are generally considered to be acceptable where the alloy contains a minimum of 3% lead by weight. However experimenters have reported whisker growth from tin-lead (SnPb) alloys. In the case of whiskers on SnPb alloys, the observed whiskers have also been reported to be dramatically smaller than those from pure tin plated surfaces and may be sufficiently small so as not to pose a significant risk for the geometries of today's microelectronics.

Pros: By removing tin-plating, the threat of tin whiskers is eliminated.
Cons: May not be able to find suitable alternative. Other lead free alternatives may have engineering issues that make them unsuitable for use based on the product's life cycle. User will need to evaluate the overall impact of any new material being introduced into their product.
Effectiveness: The elimination of pure tin finishes from surfaces in an electronic assembly removes the threat of tin whisker formation. However, it can be dangerous to rely on the part manufacturer's certification that pure tin plating was not used in the production of the product supplied. Several instances have been reported where the user procurement specification required "No Pure Tin", but the product supplied was later determined to be pure tin. In some of these instances, tin whisker growths were also discovered. Users are advised to analyze the plating composition of the products received as an independent verification.
Note: Current and anticipated laws and regulations (foreign and domestic) and marketing pressures ('green' products sell) are major factors driving the switch to lead-free products. While coordinated, concerted efforts are needed to 1) exempt military, space and other producers/users of high reliability systems from lead-free regulations and 2) convince part manufacturers that a sizeable market for tin-lead products still exists, these efforts are not addressed in this paper.

Strip and Replate

If alternatives to tin plated parts cannot be obtained, the tin finish may be removed. The ability to remove the tin plating from the effected surfaces and refinish the effective surfaces must be made based on cost risk analysis. Such processes should be reviewed to determine the potential for affecting the reliability of the original product (e.g., chemical attack on component materials). If eutectic solder 63Sn37Pb is used to replate the lead, a eutectic solder paste should be used in the reflow process. Experimental evidence exists that suggests using a Pb-free solder paste, such as a Sn-Ag-Cu (SAC) paste, with SnPb finished land or lead can reduce durability to temperature cycling. A NiPd or a SAC finish may be considered if a SAC paste and process will be used for assembly.

Pro: May be able to push responsibility to parts suppliers.
Cons: May not completely remove tin finish. Parts may be damaged by process. May be cost prohibitive.
Effectiveness: No information available.

When simple avoidance of pure tin plating is not a viable option such as in cases where no alternative finishes are available or its use is discovered late in system integration/test, then the following approaches may also be considered to reduce (but not eliminate) risk.
Most of these strategies have not been thoroughly evaluated through monitored experiments/field studies and should therefore be considered as "suggestions" and not "remedies".

Solder Dip the Plated Surfaces Sufficiently Using a Tin-Lead Solder

If strip and re-plate is not an acceptable risk mitigation alternative, a solder dip process may be considered. If a solder dipping process is implemented, several precautions are required to prevent damage to the parts. Possible damage to parts from the solder dip process can include package cracking or loss of hermeticity resulting from thermal shock, popcorning of plastic packages, solder bridging between leads on fine pitch packages, solder bridging between leads and solderable package surface materials, and handling damage such as bent or non-coplanar leads, electrostatic discharge, etc. Solder dipping as a tin whisker risk mitigation approach may have limited success depending upon the capabilities of the specific process that is used to coat the entire exposed tin plated lead surface. Potential risk from thermal shock damage to the package will increase with the reduction of the solder dip standoff distance to the package body. Again, if a Pb-free assembly process is being used, a SnPb finish may reduce the ability of the solder interconnect to resist fatigue failure. A SnPb finish should only be used with a SnPb assembly process.

Pro: May keep whiskers under the coat thus eliminating whisker particles and preventing local shorting.
Cons: May not cover all surfaces. May damage parts. If a lead-free solder paste and process is being used, this process may degrade solder joint durability
Effectiveness: If the pure tin surface is completely covered by the solder dip, the threat of tin whisker growth should be effectively eliminated.

Select a Matte or Low Stress Tin Finish

While all pure tin finishes have the potential for whisker growth, bright-electroplated tin finishes have been found to have the highest density and longest whiskers. A poorly controlled plating process can lead to early formation of whiskers. Process parameters that effect whisker formation include excessive brighteners concentration, high current densities, and/or low operating temperatures. In considering Sn plated finishes for parts, component manufacturers are using updated plating processes with chemistries to reduce the residual stress in the plated Sn. AMP has reported no growth of whiskers on pure tin plated connectors that have been subjected to over a year at 50C. Zhang et al. [Zhang 2002] also reported a pure tin finish called Satin Bright that showed no substantial growth of whiskers in a 10-month period.

Pro: Has been shown to significantly reduce the growth of tin whiskers. The part manufacturer performs the plating.
Con: Mechanical damage or life cycle loads may produce compressive loads that precipitate whisker growth. Long-term data needs to be developed to determine if new plating processes are sufficient to prevent whisker formation.
Effectiveness: While evidence of removal of compressive residual stress has been shown to significantly reduce the on set of tin whisker formation, it is not clear that whiskers will not be an issue in 10 to 30 years. Mechanical damage due to handling may induce sufficient compressive stress to initiate whisker growth.

Select Underplating (Barrier layer) to Reduce Intermetallic Formation

It has been suggested that the formation of intermetallics in the base metal below the pure tin plating create stresses that promote the growth of tin whiskers. Based on this assumption, it has been suggested that using barrier layer (such as Nickel) between the base metal and the pure tin finish can reduce the likelihood of tin whisker growth. A recent study [Brusse 2002] presents data that indicates that tin whiskers can grow on parts with nickel underplating. However, the part reviewed in that study had a nickel undercoat applied over silver, which was in turn applied over a ceramic material. In another study [Zhang 2002], a nickel barrier layer of 1.5 μm over a copper base material significantly reduced the growth of tin whiskers on a low stress tin finish.

Pro: Use of nickel underplating on copper substrates has been shown to reduce the tin whisker growth. May be able to have part supplier provide desired underplate.
Con: The base material has been shown to contribute to whisker growth despite the application of a barrier layer. May be cost prohibitive if part user needs to have parts re-plated. Another plating process that must be controlled.
Effectiveness: The effectiveness of the underplating appears to depend on the base material as well as the process parameters used to deposit the pure tin finish. At present, it is not clear whether the underplating will permanently stop whisker formation. However, nickel is reported as being the underplate of choice when using a pure tin finish.

Vary Thickness of Tin Plating

Thin plating (less than 1 μm) or thicker plating (greater than 20 μm) may reduce the tin whisker formation. Unfortunately, the thin plating may reduce the ability of the finish to serve other necessary functions such as to resist corrosion. On the other hand, while higher thickness may reduce internal stress in the plate, mechanical damage and/or long term growth of intermetallics may still initiate whisker formation.

Pro: May be able to push responsibility to parts suppliers
Cons: Due to the geometry of surfaces that would have tin finishes; it is unlikely that plating thickness could be adequately maintained. For thick plating, bridging may occur. This would be a particular problem with fine pitch packages. If the plating is too thin, other functions provided by the plating may be compromised.
Effectiveness: Multiple references indicate that increased plating thickness can reduce or eliminate tin whisker growth. Again, the substrate material will also play a role in determining the effectiveness of increasing the plating thickness.

Reflow Of Pure Tin Plated Surfaces

The melting point of tin is approximately 232^{o}C. It has been reported that reflowing or "fusing" pure tin plating is an effective means to reduce whisker formation. Again, the limitations of this approach have not been identified; the effect could be time dependent, affected by the substrate, the environment, or by any number of other potential variables. It has been observed that scratches on pure tin finishes can become sites of whisker growth. In addition, bending a tin finished surface in such as way as to cause a compress load in the finish has been observed to increase whiskers formation. Therefore, handling the parts after reflow may compromise the effectiveness of this mitigation strategy. Parts that are attached in a reflow process see the temperature exposure as part of the assembly process. If these parts are subjected to reflow temperatures prior to the reflow assembly process, the ability to form reliability solder joints may be comprised.

Fusing or heat-treating parts that have pure tin plating is thought to increase grain size and reduce internal stresses that may induce the growth of tin whiskers.

Pros: May be able to push responsibility to parts suppliers. Limited evidence that the method reduces the risk of tin whisker formation.
Cons: Added process step. Tin whiskers have been observed to occur on heat-treated tin-plated surfaces. May damage temperature sensitive devices. Solderability may be compromised.
Effectiveness: Some documentation appears to show that growth to is reduced by this process [Dunn 1987 by McDowell 1993]. Some documentation shows that tin whiskers will grow in fused tin [Cunningham 1990]

Annealing

As opposed to reflow, there are some references to the use of annealing (below the melt temperature of tin) as a mitigation strategy. Annealing involves heating and cooling a structure in such a manner as to: (1) soften a cold-worked structure by recrystallization or grain growth or both; (2) soften an age-hardened alloy by causing a nearly complete precipitation of the second phase in relatively coarse form; (3) soften certain age-hardenable alloys by dissolving the second phase and cooling rapidly enough to obtain a supersaturated solution; (4) relieve residual stress. There has been speculation that heating parts to 125^{o}C for a few seconds may reduce the risk of tin whisker growth. Unfortunately, like many other aspects of tin whiskers, all of the factors related to effectiveness of annealing on whisker formation are not known/studied. At present, the author is not aware of exact conditions such as temperature, hold time, and heating and cooling rates that are required to sufficiently remove the residual stress in tin plated finishes. Some information on this matter has been documented (Zhang 2002 and Sabbagh 1975). Zhang et al. was postulating that high temperature annealing could affect intermetallic compound (IMC) formation between tin (plating) and copper (substrate). Experimental results suggest that with "annealing" the IMC grows uniformly and not preferentially along grain boundaries thus imparting very limited stress. Formation of a SnCu IMC layer may also serve as a barrier for diffusion of substrate elements into the tin deposit, which might be stress inducers. Zhang et. al. notes that the SnCu IMC grown under ambient has different morphology and tends to grow into grain boundaries causing more stress. However, Sabbagh notes evidence of whiskers from specimens annealed at high temps. At present, factors regarding Time/Temperature, type of plating, thickness, substrate, and barrier metals have not been adequately studied to provide sufficient guidelines for applying annealing to mitigate tin whisker formation. For semiconductor parts, surface finishes are subjected to various forms of annealing, such as cure bakes and burn-ins. It is possible that these processes have mitigated whisker formation on existing SnPb finishes.

Pro: Has been shown to significantly reduce the growth of tin whiskers.
Con: Exact anneal processes for all tin finishes have not been adequately studied. Mechanical damage or life cycle loads may produce compressive loads that precipitate whisker growth.
Effectiveness: While evidence of removal of compressive residual stress has been shown to significantly reduce the on set of tin whisker formation, it is not clear that whiskers will not be an issue in 10 to 30 years. Mechanical damage and other factors may induce compressive stresses sufficient to initiate whisker growth.

Avoid Applying Compressive Loads on Plated Surfaces

If pure tin finished parts are used, additional care should be made to avoid mechanical damage to tin finished surfaces. Compressive stress with the tin plating is considered one of the primary causes of tin whisker formation. Compressive loads can be induced in plating by mechanical bending operations. Scratches and gouges may also be induced by handing hardware or from electrical probes used to test the equipment. The promotion of whisker growth by application of a compressive load has been recently demonstrated in an experiment [Zhang 2002].

Pro: Experimental evidence exists to show that compressive stress in pure tin finishes promotes whisker growth.
Cons: It is unclear that mechanical damage can be completely eliminated from the manufacture and assembly of electronic hardware.
Effectiveness: Multiple references indicate that mechanical damage that induces stress on pure tin finishes promotes whisker formation. However, it is unclear whether such mechanical damage can be completely eliminated from the manufacture and assembly process.

Apply a Conformal Coat

If pure tin finished parts cannot be avoided, the application of a conformal coating may be used to retard tin whisker growth, to contain whisker growth within the coat, and to prevent whiskers from shorting exposed conductors. Some experiments using conformal coat or foam encapsulation over top of whisker prone surfaces have shown beneficial results but the limitations of this strategy are not completely understood. NASA Goddard experiments suggest that use of Uralane 5750 conformal coating can provide some benefit by reducing the whisker growth rate, but tin whiskers can grow through a conformal coating and, once exposed, can then short to other tin whiskers or other exposed surfaces. It has also been demonstrated experimentally that conformal coating can restrict the availability of tin sufficiently to minimize the risk of plasma formation. However, coating material and the minimum thickness of coating necessary to prevent whisker growth or preclude plasma formation has not been determined. Similarly, it has been shown that foam can prevent sustained arcing but the effects of foam type, foam density, pore size etc. have not been evaluated. Conformal coating reduces the risk of a whisker creating a short between adjacent conductors.

In an on-going NASA study [Kadesch and Brusse 2002], whiskers growing from a 5 μm thick bright tin was plated on 0.8 mm thick brass substrates have not been able to penetrate a nominal 50 μm thick Uralane 5750 conformal coat after >3 years ambient storage and 50^{o}C storage. In this same study, whisker nodules have penetrated thinner coatings (12.5 μm thick) and then launched longer filaments from the exposed nodule and a substantial density of nodules has formed under the 50 μm thick coating. It should be noted that monitoring of the test specimens is continuing to understand how some of these growths may/ may not be able to escape the coating. For uncoated areas of the test specimens, substantial whisker growth (a few >2mm) has occurred. By comparison, the conformal-coated side has substantially "retarded" the whisker growth rate (less than 50 μm) after 3 years.

The use of a conformal coat to mitigate risk with tin whiskers contains a number of unknowns that are partially dependent on the conformal coating material chosen. In addition, other engineering considerations are necessary to properly select and apply a conformal coat. Conformal coats have been found to fracture package bodies, particularly fragile glass body diodes and damage package to board interconnects. Focusing on conformal coat to mitigate failure due to tin whisker formation, one should also consider adhesion strength and material toughness in combination with application thickness. If conformal coat is too thin or does not have sufficient properties to contain or retard whisker grow then whiskers may grow straight through the material to intersect another conductive surface.

If the conformal coating fails to contain whisker formation, the effectiveness of a conformal coat in providing protection against electrical leakage and corrosion will be compromised. A puncture site may provide an increased opportunity for excessive leakage currents that can produce transient or permanent failures. Another concern related to whisker formation is the potential for whiskers to produce minor delamination of the conformal coating from the circuit board, the resulting capillary space could provide a void for condensation of the water vapor molecules that slowly diffuse through the coating material. This creates the slim possibility of galvanic corrosion, though it may not be of consequence. Further, emerged whiskers that break loose may break off could end up in other areas of your hardware that is vulnerable to conductive debris. Ground planes (where they mate to trays or heat sinks), are not allowed to be coated, and may be susceptible to tin whisker induce failures. Tin plated fasteners and other assembly hardware that is not conformally coated may also produce failures. However, this risk is substantially reduced compared to the scenario of not using a conformal coat.

For certain parts, conformal coat may not provide effective protection due to the inability of the conformal coat to completely cover all exposed plated surfaces. For instances pin grid arrays (PGAs), ball grid arrays (BGAs), CSP, connectors, and other low profile devices may have uncoated surfaces even after a conformal coat is applied. When comformal coating is performed in a spray process, high profile parts and other structures can produce shadow areas where either no or limited conformal coating occurs. Dip application of conformal coat, where the complete assembly is submerged in a bath of conformal coat may provide a more complete coverage. However, even dip may be insufficient to provide complete coating of all finished surfaces. In general, neither dip or spray applications of conformal coats provide complete coverage.

As mentioned previously, there are multiple considerations that must be made when selecting a conformal coat. In selecting conformal coat, CTE and modulus of the material should be considered. The properties can assist in making a determination of the ability of the conformal coat to damage package bodies or package to board interconnects. Low modulus conformal coat material and low application thickness are preferred to avoid potential cracking of part bodies or damaging package to board interconnect due to life cycle loads. Another important consideration is the ability to rework conformally coated assemblies. For example, parylene is often avoided due to the difficulty or inability to rework electronics that are coated with parylene.

Properties of some potential conformal coat materials are provided in Table 1.

Table 1 Potential Conformal Coat Materials

Material	Silicone	Parylene	Urethane	Acryllic	Epoxy
Modulus (MPa)	1-4	45-75	24	8-11	14-69
Shore Hardness	80OO	Rockwell 80R	50A	NA	65-89
CTE (ppm/^{o}C)	160-190	35-70	140-510	55	20-100
Tg (^{o}C)	-45	NA	40-70	15-43	120
Temperature Range (^{o}C)	-65 to 200	NA	-65 to 125	-65 to 125	-65 to 200
Reworkable	Acceptable	Difficult	Acceptable	Good	Acceptable
Whisker Resistance	No data available. Currently not considered to have sufficient strength to contain	No data available. Likely to be able to constrain whiskers.	50 µm thick Uralane 5750 found to constrained tin whiskers from a whisker prone test	No data available	No data avaliable

	conductive whiskers.		coupon for over 3 years.		

Pro: May keep whiskers under the coat thus preventing whisker particles and local shorting.
Cons: May not cover all surfaces. May not be thick enough to prevent whisker break through. An extra process step in the manufacturing process.
Effectiveness: Some evidences exists that conformal coat can trap whiskers. Conformal coat over electrical conductors will prevent shorts from free whisker particles. At present, there is not guideline as to the thickness required to trap
tin whiskers.

Evaluate Application Specific Risks

In terms of application specific consideration, the proximately of adjacent conductors is a particular concern. For example, a 0.5 mm pitch 208 PQFP can have spacings between adjacent leads as small as 230 µm and the spacing between adjacent pads can be as small as 100 µm. For some high-density applications, the spacing between conductors has been reported as small as 76 µm. Design rules normally call for 530 µm spacing between external conductors and 500 µm between internal conductors. Whisker growth of 250 µm can easily create shorts in high-density applications and growths above 1 mm (1000µm) can induce shorts under current design rules. To remove the threat of shorts due to tin whiskers, engineers should review criticality of the system or subsystem as well as its desired life expectancy. As presented above, a variety of application specific considerations may be used to assess the risk of whisker-induced failures and assist in making "use as-is" or "repair/replace" decisions. These factors include circuit geometries that are sufficiently large to preclude the risk of a tin whisker short, mission criticality, mission duration, collateral risk of rework, schedule and cost. At present, any pure tin finished surface can be considered as having the potential to grow tin whiskers.

Summary and Conclusions

A process for mitigation the risk of failure due to tin whisker formation has been presented. Several strategies have been identified. However, other than the elimination and verification of eliminations of pure tin finishes, the effectiveness of the strategies cannot be quantified. The most obvious mitigation strategy for removing the threat of tin whiskers is to avoid parts with pure tin finishes and to be vigilant in reviewing parts received, in particular from companies that provide the same parts with pure tin finishes. If pure finished parts cannot be avoided, use pure tin finishes with low residual stresses. Annealing or reflowing the finish may reduce the stresses and promote uniform growth of intermetallics (particularly when the base material is copper). As an additional measure, apply conformal coat. A dip process for applying the conformal coat may provide better coverage than spray. However, the manufacturer should evaluate carefully evaluate the type of conformal coating material and the application process to make sure that the coating process provides adequate coverage and does not damage the product.

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Prepared by M. Osterman CALCE EPSC

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CALCE Consortium (University of Maryland)
Raytheon (Rhode Island, Massachusetts, Texas, Arizona, and California sites)
Boeing (Seattle and El Segundo sites)
Honeywell (Tucson, Minnesota, and Florida sites)
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