ELECTRONIC PACKAGING & SPACE PARTS NEWS

EEE Links

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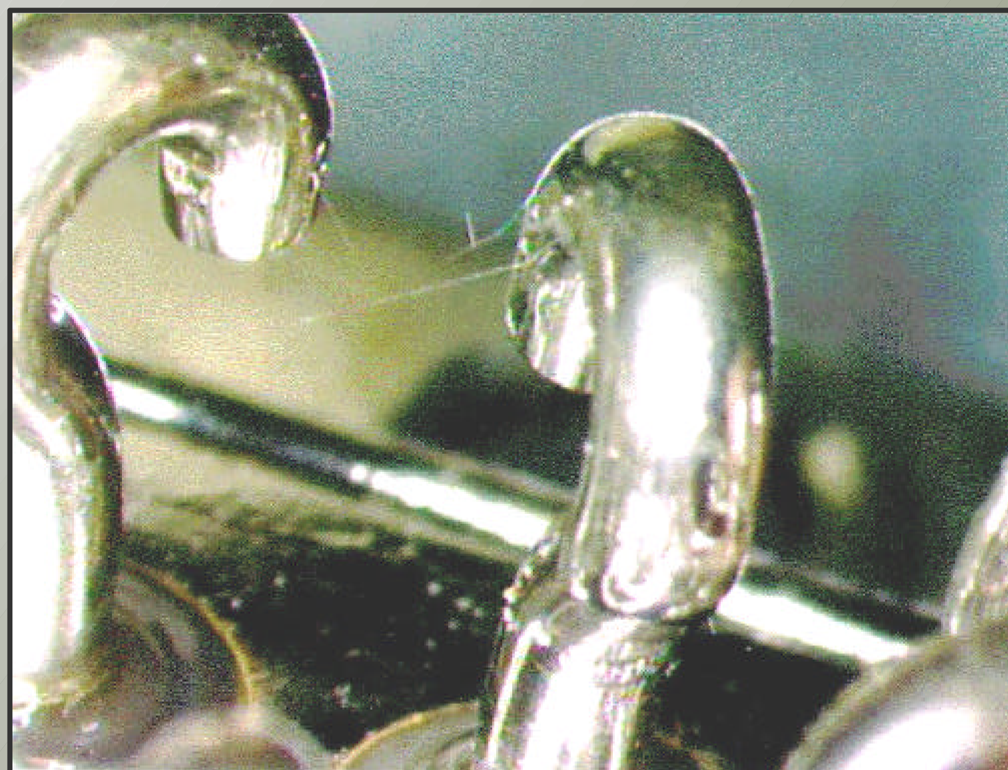

- ***Solid-State Non-Evaporable Getters to Maintain Vacuum in Hermetic MEMS Device Packages for Space Applications*** used to explain each process from stripping the fiber through polishing, and then inspection and testing of the completed assembly.

To learn more about these classes or any of the other many classes currently offered, call the Training Center at (301) 286-8632 or visit our web site at

http://arioch.gsfc.nasa.gov/312/train.htm

Tin Whiskers: Revisiting an Old Problem

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Recent events have reminded the space community of the potential risks associated with the use of pure tin-plated finishes on electronic components and assemblies. Pure tin finishes are susceptible to the spontaneous growth of single crystal structures known as ***tin whiskers***. Tin whiskers are capable of causing electrical failures ranging from parametric deviations to catastrophic short circuits. Although the tin whisker phenomenon has been documented for decades and is reasonably well understood, it is still a reliability hazard that warrants special attention.

This article does not provide a complete explanation of the tin whisker growth mechanism; numerous (often contradictory) publications have attempted this task. The intent is to provide a comprehensive explanation of generally accepted understandings of tin whiskers along with some suggestions for how to reduce the risk of tin whiskers on spaceflight hardware. In addition, Goddard Space Flight Center is maintaining a Tin Whisker Information Homepage to provide regular updates to facts and findings as they become available. This homepage can be found at the following URL:

http://misspiggy.gsfc.nasa.gov/ctre

WHY TIN?

The electronics industry has utilized pure tin plated finishes for decades. Tin forms an excellent protective coating that resists oxidation and corrosion and also provides good solderability. In addition, pure bright tin finishes (those which use chemicals called "brighteners" in the plating bath) maintain an aesthetically pleasing shiny surface even when exposed to air and moisture. Tin is also preferred by manufacturers over tin-lead plating because lead in waste streams increases the cost and complexity of disposal. These are a few reasons why pure tin plating has become a common termination finish for Commercial-Off-The-Shelf (COTS) components.

PURE TIN PROHIBITION IN THE MILITARY SPECIFICATION SYSTEM:

Following a series of tin whisker related failures in the late 1980's and early 1990's the U.S. Military sought to eliminate pure tin from its systems. Between 1992 and 1993, language was introduced into most of the MIL EEE part specifications to specifically prohibit the use of pure tin plating. Notable exceptions were the specifications for electromechanical relays. Two of these specifications, MIL-R-6106 and MIL-R-83536, did not prohibit tin on external surfaces until they were converted to performance specifications (PRF) in 1997.

In some Military EEE part specifications, pure tin finishes are still a specifiable option (i.e., the user can choose pure tin finishes and clearly identify this option by a character in the part number). One example of this situation exists with ceramic chip capacitors made in accordance with MIL-PRF-55681.

A BRIEF DESCRIPTION OF TIN WHISKERS:

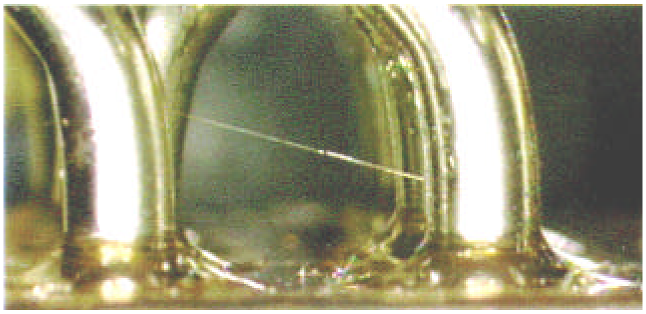
The following list describes some of the generally accepted characteristics of tin whiskers and their formation:

Whiskers are elongated single crystals of pure tin that have been reported to grow to more than 4 mm (160 mils) in length and from 0.3 to 10 µm in diameter (typically ~1 µm).

Whiskers grow spontaneously without an applied electric field or moisture (unlike dendrites) and independent of atmospheric pressure (they grow in vacuum).

They may be straight, kinked, hooked or forked and some are reported to be hollow. Their outer surfaces are usually grooved.

Whisker growth may begin soon after plating or may take years to initiate.



An example of a tin whisker growing between pure tin plated hook terminals of an electromagnetic relay similar to MIL-R-6106 (LDC 8913)
Photo Courtesy of Andre Pelham (Intern)
Goddard Space Flight Center

TIN WHISKER GROWTH MECHANISM:

The mechanism(s) by which tin whiskers grow has been studied for many years. A single accepted explanation of this mechanism has not been established but there are some commonly agreed upon 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 most susceptible due to the high current densities involved in the plating process.
- 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
- The change in lattice spacing that occurs from the formation of intermetallic compounds such as those between copper and tin.
- Whiskers appear to grow more readily at temperatures approaching 50°C. Whiskers growth appears to cease at temperatures higher than about 140°C and lower than around –40°C.
- Bright tin finishes (shiny) seem to be worse than matte finishes due to some influence of the organic compounds used as brighteners.

POTENTIAL RISKS OF TIN WHISKERS:

Tin whiskers pose a serious reliability risk to electronic assemblies. Several instances have been reported where tin whiskers have caused system failures. The general risks fall into four categories:

(a) Whiskers or parts of whiskers, may break loose and bridge isolated conductors or interfere with optical surfaces

(b) In low voltage, high impedance circuits, there may be insufficient current available to fuse the whisker open and a stable short circuit results. Depending on the diameter and length of the whisker, it can take more than 50 milliamps (mA) to fuse one open. More typical is ~10 mA

(c) At atmospheric pressure, if the available current exceeds the fusing current of the whisker, the circuit only experiences a transient glitch as the whisker opens.

(d) ***In space vacuum*** however, a much more destructive phenomenon can occur. If currents of above a few amps are available, 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 plated surface is necessary to sustain the arc.

OFFICIAL ALERT HISTORY:

Numerous GIDEP Alerts and Problem Advisories have been issued that cover specific occurrences of tin whisker related failures. Although these alerts and advisories show a bias towards relays and other devices typically packaged in metal cans, any surface plated with pure tin is potentially at risk for tin whisker formation.

SUGGESTIONS FOR REDUCING THE RISK OF TIN WHISKERS:

At this time, the only sure way of avoiding tin whiskers is not to use pure tin plating. Utilization of procurement specifications that have clear restrictions against the use of pure tin plating is highly recommended. Most (but probably 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 reduces the propensity for whisker growth. Alloys of tin and lead are acceptable where the alloy contains a minimum of 3% lead by weight.

If there is no alternative to using pure tin plated finishes, it is recommended to solder dip the plated surfaces sufficiently to completely reflow and alloy the tin plating. Obviously, special precautions are required to prevent thermal shock induced damage, to prevent loss of hermeticity and to avoid thermal degradation. Some manufacturers may be willing to strip the pure tin plate from finished products and re-plate using a suitable alternate plating material such as tin/lead.

Other treatments such as conformal coating and foam encapsulation appear to be beneficial but the limitations are not understood. It has been reported that tin whiskers can grow through conformal coating. It has also been demonstrated experimentally that conformal coating can restrict the availability of tin sufficiently to prevent plasma formation. However, such factors as the minimum thickness of coating necessary to prevent whisker growth or plasma formation have 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.

Additional studies and evaluations are underway to try to answer the critical open questions in order to provide more detailed suggestions in the future. For the latest available information visit the tin whisker homepage at:

http://misspiggy.gsfc.nasa.gov/ctre

Solid-State Non-Evaporable Getters to Maintain Vacuum in Hermetic MEMS Device Packages for Space Applications

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Many high sensitivity microelectromechanical systems (MEMS) need to operate in a hermetically sealed vacuum electronic package to realize their full performance. This vacuum is destroyed by outgassing of various species such as water vapor, hydrogen, carbon monoxide, nitrogen, oxygen, and carbon dioxide from the package surfaces and microleaking or permeation through the package body. The loss of vacuum is particularly serious if organic materials are used in an isolated MEMS packaging device. A getter material is needed to eliminate this problem and achieve successful MEMS device operation for long duration space applications. The term "getter" refers to materials, which chemically sorb active gases in a vacuum environment. A solution is proposed using a SAES non-evaporable high porosity getter material family (Zirconium-aluminum-iron, titanium, thorium, etc.) to solve the hermetic sealing problem associated with the micro-gyro and other similar MEMS devices where hermetic sealing is required. The getter consists of a highly porous and mechanically stable packaging component that will be installed inside the MEMS vacuum packaging chamber and activated.

A variety of sealed-off devices such as cathode ray tubes (CRT's), electron tubes, plasma displays, particle accelerators and colliders, vacuum thermal insulation, ultra-high vacuum systems for semiconductor processing, X-ray tubes, lamps, field emission displays (FEDs) require a vacuum for their successful operation. Maintaining vacuum in extremely small volume packages depends on the surface area of materials exposed to that volume that are sources for species to be outgassed and finally that will destroy the vacuum. Getters are routinely used in larger static systems and similarly getters will be needed if the desired system lifetimes of many years are to be obtained in MEMS packages for space applications.

The solid-state getters may be either planar or three-dimensional and exhibit good mechanical strength. They must be particle free under the stringent operational conditions in space and on the ground, and they should have a high active surface area that can easily be activated at low temperatures. This minimizes problems such as high ambient temperature that may be detrimental to MEMS devices during activation. High porosity combined with a large active surface area will assure excellent sorption performances at room temperature. There should not be any loss of getter particles before, during, or after activation of the getter in a packaged MEMS device