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Electronics Manufacturing Insights from ACI Technologies, Inc.

Tin Whiskers: Risks with Lead Free | Part I

Tin (Sn) metal displays the characteristic of growing "tin whiskers" from pure tin coatings (most actively on relatively thin, electrodeposited or immersion tin coatings), usually months or years from the initial deposition of the tin. Tin whiskers are electrically conductive, filamentary, single crystals of white (beta phase) tin. These filaments of single crystal tin are usually one to five microns in diameter, and a few microns up to several tens of millimeters long, that grow spontaneously from the tin coatings. Alloying additions of several percent (by weight) of lead (Pb) prevents these electrically conductive tin whiskers from growing. Pb alloyed into the Sn was discovered to prevent the occurrence of tin whiskers in electronic assemblies in the 1950s as the Bell Laboratories solution to the problem of tin whiskers. The alloying of the tin with lead has thus quietly averted incalculable losses from short circuits in electronic equipment for the last 60 years.

Sixty years ago, the most commonly used surface finish for electronic components and printed wiring boards was tin-lead solder. The composition of this solder was most often "eutectic," or 63% tin and 37% lead, by weight. This composition was ideal for the soldering process and the Pb virtually eliminated tin whisker growth on the tin-lead coated electronic hardware.

In 2006, the European Union (EU) passed the law called Restriction of Hazardous Substances (RoHS) that restricted lead to 0.1% or less, by weight, in any commercial electronic equipment offered for sale on the European market. Responding to this law, printed wiring board (PWB) and electronic component vendors changed the surface finish for electronic components to pure tin, and the PWB finish to immersion tin, immersion silver, or immersion gold plating.

Unfortunately, both the electroplated pure tin (now predominantly coated on components) and the immersion tin now applied to Pb-free PWBs (for the sake of RoHS compatibility) are susceptible to the electrically conductive tin whisker growths. Since the tin whiskers are documented to conduct several milliamps of electrical current without fusing (melting), they have caused short circuit failures of both military and commercial electronics (e.g. satellites, radars, and heart pacemakers) that utilize tin coated parts (Pb-free electronics). Tin whiskers can also vaporize at higher currents and voltages creating a tin plasma that can conduct many tens or hundreds of amperes, causing catastrophic damage to the power supply.

Even though the military is not bound by the RoHS law, the military must use, in many cases, the same type of tin-plated components demanded by the vastly larger commercial electronics customer base. Thus, many tin-lead plated components are becoming less and less available from the component and PWB vendors as the vendors convert to pure tin plating. Since military uses of electronics constitute such a small fraction (one to two percent in North America) of the component vendor customers, the military does not have the economic leverage to influence the type of surface finishes offered by the vendors. Tin whisker growth has thus become a prime source of risk with the switch to pure tin plating for lead free (RoHS compliant) component terminals and circuit boards.

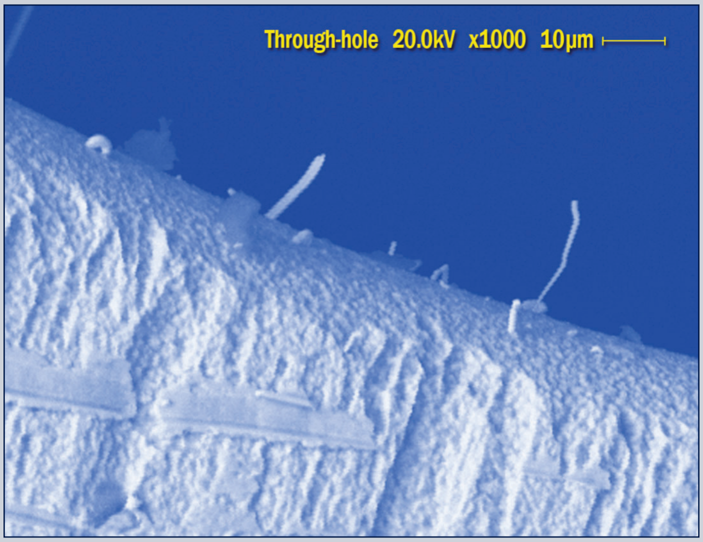

Figure 1: Scanning electron micrograph of tin whiskers grown on an immersion tin coating after five days of storage at ACI Technologies.

There are two areas of tin surface finish that pose a much more severe risk for the long product life, high-reliability Department of Defense (DoD) applications than for the relatively short product lifetime

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commercial electronics world. While product lifetimes for military systems are routinely 30 to 40 years, there are few commercial products expected to last as long as 10 years, with averages nearer to three years.

The first area of concern is the tendency of tin whiskers to grow for extremely long periods of time, long past the obsolescence (and replacement) timeframe of commercial electronics. Figure 1 is an electron microscopic picture of a circuit board surface having immersion tin plating (a common lead-free alternative finish) after five days of room temperature storage at ACI Technologies. Note the small, 10 to 20 micron tin whiskers that are present. These whiskers are too small to be a serious risk, even for fine pitch circuitry. Figures 2 and 3 show the same sample after 2.5 to five years of storage (a long time for a commercial application, but a short time for a DoD application) showing some tin whiskers that have grown to over 150 microns (long enough to electrically short closely spaced modern electronic circuits). How long will these whiskers be in 10 or 20 years?

This question represents the second of the two troublesome characteristics of tin whiskers. Their growth rate, and conditions that can accelerate this rate, are unpredictable. This makes the tin whisker phenomenon difficult to study. For example, the only way to assure whiskers do not grow to excessive length in a given time is to observe the whiskers for that length of time. For military applications with product lifetimes of several decades, impracticably long whisker observation times are indicated. For commercial applications, this might only be a practical span of several years. Many of the military and commercial electronic shorting failures that have been caused by tin whiskers have occurred after years or decades. Electronics in satellites, airplanes, one nuclear power plant, and even the space shuttle, have failed due to whisker growth. These tin whisker failures were impossible to predict when the electronics were manufactured and would be just as impossible to predict if built today.

The literature contains abundant misinformation about tin whiskers. Many component and PWB vendors have claimed their pure tin (RoHS compliant) coatings are immune to whisker failures because of various “mitigation” techniques. Since none of these vendors have inspected product for tin whiskers for 20, 30, or 40 years, any such claims are suspect. In fact, many of the commonly held “mitigation techniques,” such as nickel underplating of the tin, annealing of the tin plate, use of “matte” rather than “bright” tin electroplate, have all been seen to allow tin whisker growth if observed for as little as a couple of years.

The universally accepted driving force (perhaps not the only driving force) for tin whisker growth is internal compressive stress in the tin coating. Such stress might be due to the initial plating conditions used in the deposition of the tin such as current density, tin concentration in the electrolyte, and organic “brighteners” used in the electroplating process. Mechanical scratches or bending of the tin plated article or even the growing of intermetallic compounds (Cu6Sn5) as copper in the base metal diffuses into the tin coating can create compressive stress over potentially very long times.

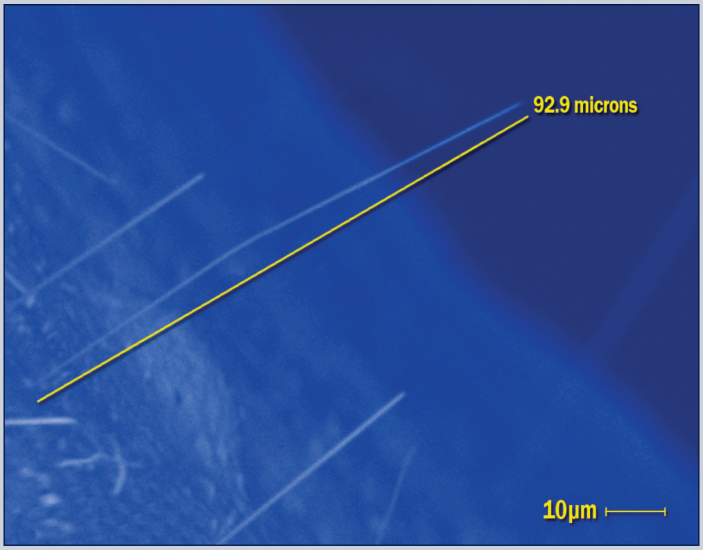

Figure 2: Scanning electron micrograph of the same sample (different field, equivalent area) after 2.5 years of storage at ambient conditions at ACI Technologies.

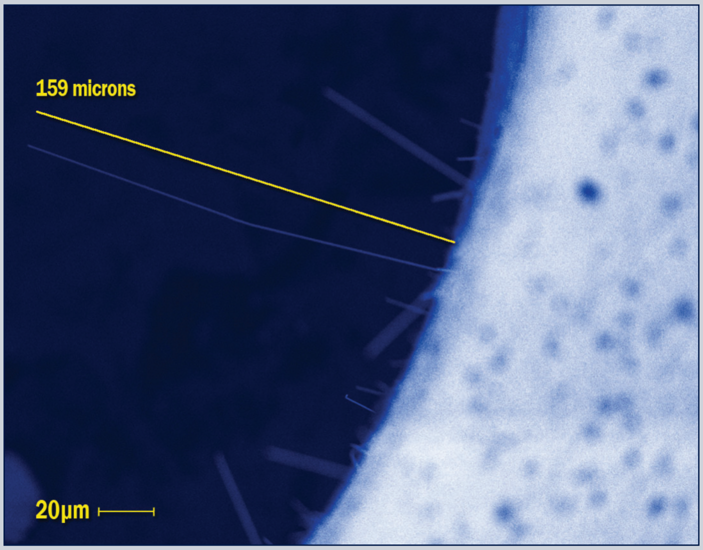

Figure 3: Scanning electron micrograph of same sample (different field, equivalent area) after five years of storage at ambient conditions at ACI Technologies.

ACI Technologies and partner organizations are working to identify valid long term mitigation or complete prevention of tin whisker growth on RoHS compatible electronic hardware, making use of commercial

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off the shelf (COTS) electronic components by the military a less risky proposition.

Put our expertise in lead free technology and mitigation to work for you. ACI Technologies can assist with RoHS compliance and lead free processes. 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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