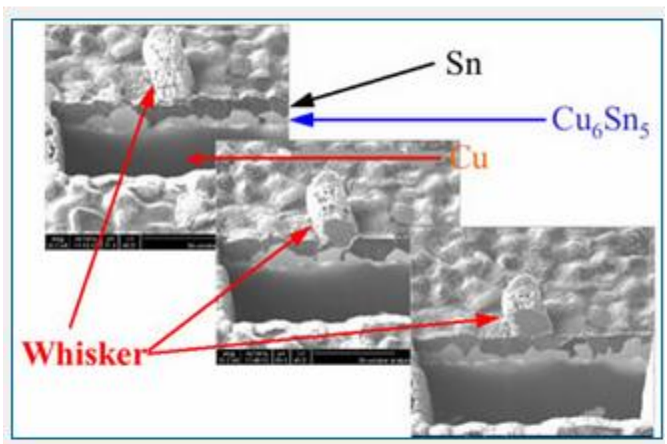
**RELIABILITY ISSUES AND FAILURE MECHANISMS-Tin whiskers**

Whiskers are spontaneous filamentary growths which can occur on a variety of metals, including tin, cadmium, zinc, iron and nickel. They are single crystal structures that are reported to reach lengths of up to 9mm with diameters up to 5µm, and to be able to carry 10mA of current. Whiskering becomes a hazard when the whiskers become long enough to bridge across leads. In high-voltage, high-current circuits, any shorts caused by tin whiskers are quickly burnt out, and may not pose as serious a threat as in low-power circuits, where they will cause intermittent failures.

Figure 1: Focused ion beam (FIB) images taken at various stages of cutting through a matt tin whisker on a copper substrate




“Tin whiskers are a fascinating and confounding subject” was Jay Brusse’s1 conclusion after four years reviewing the literature and carrying out research. Many conflicting test results have been reported, but the consensus is that whiskering is a result of stresses within the plated deposit. This is the basis for the belief that reflowing the surface during board/component manufacture, and exposing the plating to high temperatures during board assembly, will both alleviate stress in the finish and thus reduce the potential for whiskering.

Jay Brusse (QSS Group, Inc. at NASA Goddard) posting to IPC TechNet on 20 June 2002. The NASA public web site (http://nepp.nasa.gov/whisker) has a useful collection of reference materials and photographs.

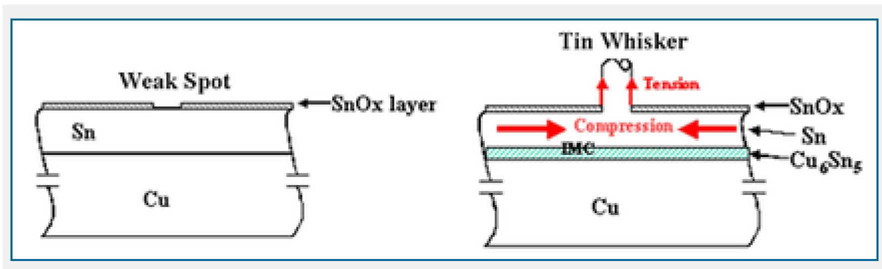
As indicated in Figure 2, the start is a point of weakness in the SnOx layer; two ongoing mechanisms then generate the internal compressive stress in the tin layer that is the major driving force for whisker growth:

diffusion of copper into the tin and the formation of Cu6Sn5 intermetallic compound (IMC);

self-diffusion of tin along its grain boundaries to the root of a whisker, supplying more tin atoms to push the whisker upwards.

Whisker growth is affected by a number of factors that include the introduction of stresses through handling, assembly and application environment. It is argued that external stresses will enhance the initiation and growth of the whisker if they are compressive, or reduce the reliability risk if they result in tension.

Figure 2: Tin whisker driving forces and failure mechanisms




Source: John Lau

Tin whiskers have an incubation period, so that a coating that has appeared to be whisker-free can develop the problem days, months or even several years later. It is this incubation period that distinguishes whiskers from plating nodules, which may be roughly similar in appearance but will be present on the surface immediately after plating.

Whiskers are sometimes also confused with electromigration (see Electromigration topic), but have a number of key differences:

Whiskers are single filaments, driven by internal stress, and can occur in any environment

Electromigration tracks are tree-like (dendritic), driven by applied voltage, and need at least humidity in the environment, probably enough to create a very thin layer of water on the surface of the material.

Tin whiskers will grow from almost all surfaces containing tin, depending on the environmental conditions.

The worst whiskering appears to occur with pure tin, which can exhibit a high density of whiskers varying in length from 100s of microns to millimetres!

Whiskers occur with tin alloys containing lead, copper and bismuth, but these are generally very short (few 10s of microns) and grow in small numbers.

The higher stresses inherent in the bright tin plating process mean that the incidence of whiskering is lower with matt tin coatings, but Brusse reports matt tin plated ceramic chip capacitors with tin whiskers up to 240µm long, despite a 5µm nickel under-layer

It is normally recommended that bright tin plate should be avoided because the co-deposited organics used to make the surface level and bright increase the internal stress, but there are drawbacks:

A bright surface finish is cosmetically very attractive.

There is no easy non-destructive test for the co-deposited compounds.

It is not possible to distinguish visually between coatings which are naturally bright because of organics and those that have been reflowed.

For a matt tin plate finish, Lau and Liu suggest (Global Trends in Lead-free Soldering, Part 1, by John Lau and Katrina Liu, Advanced Packaging, January 2004) that ways of reducing the tin whisker reliability risk are:

To use a larger grain size

To use a thicker plating (8 µm minimum, 10 µm preferred)

To reflow components immediately after plating to form a thicker IMC layer

To anneal the components (150°C for 2–3 hours, or 170°C for 1 hour) immediately after plating

To use a nickel barrier under-plate (0.2–2 µm) to block the copper diffusion that forms the IMC

To incorporate a second element such as bismuth

All these approaches work by providing fewer pathways and thicker barrier layers, so reducing build-up of compressive stress in the tin layer. The last method is preferred by most of the Japanese companies; lead was previously used for whisker suppression, but bismuth is a more environmentally-friendly choice. One also suspects that a key to success lies in combining the correct plating additives, an appropriate selection of materials and operating parameters, and stringent process controls.

Until recently there have been no industry-accepted test methods for judging whether whiskering is likely to occur in a given situation. However, supported by a background of experimental work, NEMI have proposed a set of tin-whisker acceleration tests that are in process of becoming a JEDEC standard. These involve:

High temperature/humidity test: 1,008 hours minimum at 60°C±5°C and 93%RH+2/−3%RH

Thermal cycling test: 1,000 minimum 20-minute cycles between −55°+0/−10°C and 85°C+10/−0°C

Ambient storage test:1,008 hours minimum at 20–25°C and 30–80%RH

As with much work in this area, criticisms have been levelled that many of the criteria are as yet undefined, and no definitive acceleration factors and acceleration models have been agreed.

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**Source: http://www.ami.ac.uk/courses/topics/0153_whsk/index.html**