Immersion Tin and Tin Whisker growth

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Abstract

The kinetics of whisker growth on pure, electroplated tin layers is known since many years and common knowledge to industry. This whisker effect is being well described in literature and topics of several published papers.

In order to check reliability, in terms of whisker growth, special test methods have been used in industry (e.g. Bellcore – GR-78-CORE/R13.2.7, IPC TM 650 2.6.3.3 and IPC TM 650 2.3.14). Common for those tests are environments with increased temperature (40-85°C) to which the specimens are exposed. These common tests are state of the art and industrial standards.

As far as seen today, immersion tin layers do meet the actual requirements as a lead-free finish for soldering and for press-fit technology. Since the mid-nineties immersion tin is used in industry with a strong increase in assembly volume.

During introduction of immersion tins, OEMs as well as PCB-manufactures and chemical vendors did substantial tests regarding its reliability. Part of these test matrixes was in-depth testing on the formation of whisker growth. According to Bellcore and IPC the tested layers were found to be whisker free.

With beginning of the year 2002, European OEMs reported formation of whiskers while inspecting not-assembled PCBs plated with immersion tin.
These boards were stored and exposed to ambient temperature for several months.
Regardless of the chemistry vendor, all immersion tin coated PCBs showed strong whisker growth.
Nevertheless, soldered and assembled PCBs staid whisker free, even after storage of more than 2 years.

Getting notice of that defect, a joint project between a European OEM and immersion tin vendors was started to avoid whiskers on PCBs plated with immersion tin. Within this project a substantial development and test program was carried out.

As result of this, a modified immersion tin process was released. These modifications are based on additives controlling and inhibiting whisker growth.

Introduction

The use of Hot Air Solder Levelling (HASL) as a solderable finish for printed circuit boards has been common for many years. However the ever-increasing circuit complexity and component density has stretched the capabilities of even horizontal solder levelling systems to their limits.

As lead pitch becomes finer than 0.64 mm, placement of soldermask dams between lands becomes more and more challenging. Solder levelling the boards without dams creates a need to trade off with increased solder shorts and reduced solderability due to intermetallic growth from insufficient solder thickness.

Clearly HASL represents a process limitation as component pitches become finer. In addition to the technical limitation of coplanarity, the need for a thin coating by using press fit technology becomes more challenging if 2.5 mm or thicker boards are being used.

Either vertical or horizontal applied HASL creates solder knees at the centre of the holes, which leads to a change in hole diameter. Thus damaging press fit pins and squeezing HASL from the centre of the hole as a filament to the surface of a printed circuit board, creating an electrical short.

Besides technical limitations HASL faces a worldwide environmental legislation ban due to the hazardous lead component.
Representatives from the electronics industry in Japan, the United States and Europe have agreed to halt lead soldering by 2005 to safeguard the environment (Global Lead-free Soldering Roadmap).
However market forces are clearly driving this to happen before that date and several Japanese OEMs have already taken the initiative, that they are lead free since yearend 2000.

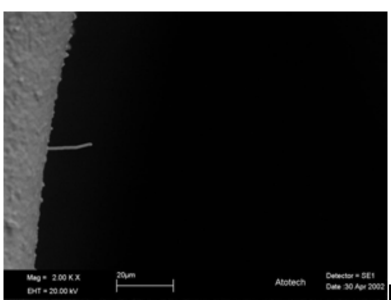
As alternative to HASL, tin coatings have been around for several years now, both electrolytic and immersion processes. There have been however recurring issues with both systems. These include whiskers and dendrites, variability caused by poor process control and solderability issues created by high levels of copper / tin intermetallic compound (IMC). These all impact the performance of the tin coating.

Tin Whisker

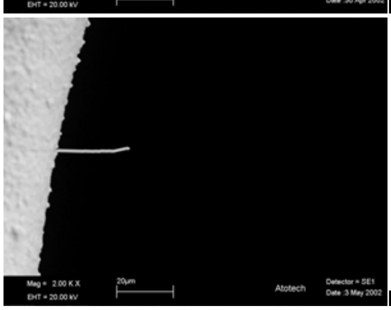
The kinetics of whisker growth on pure, electroplated tin layers, have been well known for many years and common knowledge within the industry.

The growth of a single grain of tin due to inherent stresses in the surface layer leads to the growth of a needle like structure known as Tin Whisker.

Whisker growth over eight days



Day 10



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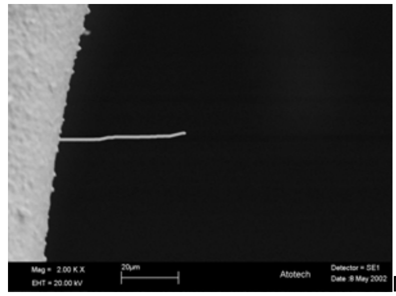
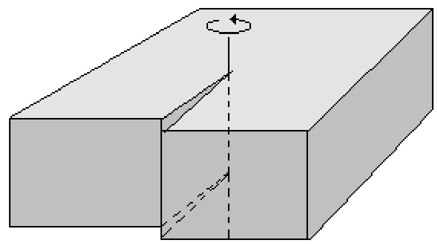


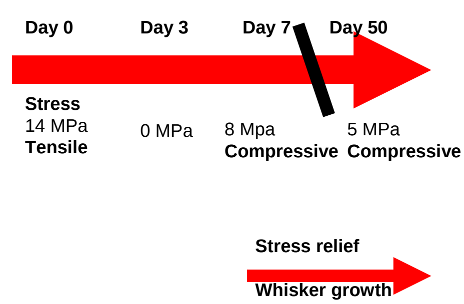
Day 18 Immersion Tin Whisker – a single grain of tin that grows due to internal stresses in the immersion tin layer

Directly after plating, Immersion tin contains tensile stress that changes to compressive stress as the intermetallic copper/tin phase grows. This stress is relieved by whisker growth.
The primary site for whisker growth is at a Screw Dislocation.



Screw Dislocation

Explanation of whisker growth



Whiskers can grow to several mm in size if enough stress is present to drive the growth. As the surface finish is only 1 µm thick the tin atoms have to travel to the point of growth to form the whisker. This occurs along the grain boundaries.
Whiskers are a potential problem in PCB production due to whiskers being able to bridge fine track and gap distances thus shorting out the panel during subsequent use.

This whisker effect has been well described in literature and topics of several published papers.
In order to check reliability, in terms of whisker growth, special test methods have been used in industry (e.g. Bellcore – GR-78-CORE/R13.2.7, IPC TM 650 2.6.3.3 and IPC TM 650 2.3.14). Both tests have in common environments with increased temperature (85 °C) to which the specimens are exposed. These common tests are state of the art and industrial standards.

SIR / IPC TM 650 2.6.3.3.
85°C @ 85%r.h. for 4 days @ 50V bias

Electromigration / IPC TM 650 2.3.14.
85°C @ 85%r.h. for 7 days @ 10V bias

IPC B-24 380/520µm lines/spaces

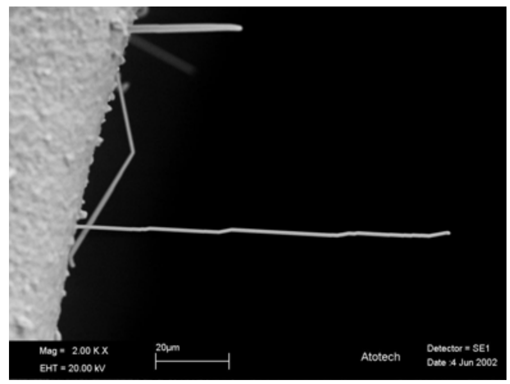
SIR - Electromigration / GR-78-CORE / R13.2.7
85°C @ 85%r.h. 96h stabilization period, without bias 85°C @ 85%r.h. for 500h @ 10V bias

IPC B-25 250/380µm lines/spaces

From the industry standard tests above, immersion tin layers do meet the actual requirements as being whisker free.

It was found that temperature treatment of panels relieves the internal stresses in the immersion tin layer. If a panel is heated the internal stresses are relieved to such an extent that whisker growth is prevented. The Standard whisker tests involve heating the panel during the test. This reduces the internal stresses, reducing the likelihood of creating whiskers.
For this reason, the issue of ambient temperature tin whisker growth was not found until recently.

During introduction of Immersion Tin, OEMs as well as vendors performed substantial testing regarding its reliability. Part of these test matrices was in-depth testing on the formation of whisker growth. According to Bellcore and IPC the tested layers were found to be whisker free.
During investigation it was discovered that all PCB’s pass these tests regardless of if they have whiskers evident or not. This is for two reasons.
Firstly the magnification used to inspect the panels is not great enough to see even larger whiskers. Whiskers in the 50 µm+ range still cannot be seen with a magnification of 30x as specified in the industrial standards outlined above.
Secondly, it was found that PCB’s that had been assembled did not suffer from whisker growth. This was found to be due to the reduction of internal stresses during soldering and the healing of lattice defects by annealing.



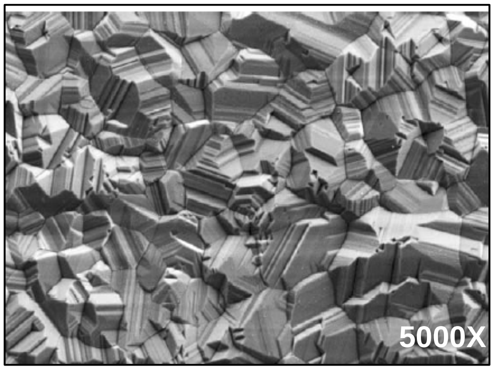
Heating a panel plated with immersion tin reduces the internal stresses by the movement of tin atoms. As the growth of whiskers is dependent on these internal stresses, whisker growth is prevented. However, the growth of the intermetallic layer is not acceptable to the PCB industry due to solderability issues and storage. A panel heated to prevent whisker growth would have the same characteristics as a panel that has been on extended storage.
Although the annealing process does prevent whiskers, it is not an acceptable solution to the issue.

As result of this, a modified Immersion Tin process was released. These modifications are based on additives controlling and suppressing whisker growth.
In co-operation and during this joint project, the resulting immersion tin layers plated with whisker controlling and suppressing additives were qualified regarding all aspects of soldering, press fit technology and whisker growth.

Due to an immersion tin Additive, the process is meeting the severe requirements for electronic systems in the automotive industry, as the only whisker free immersion tin.

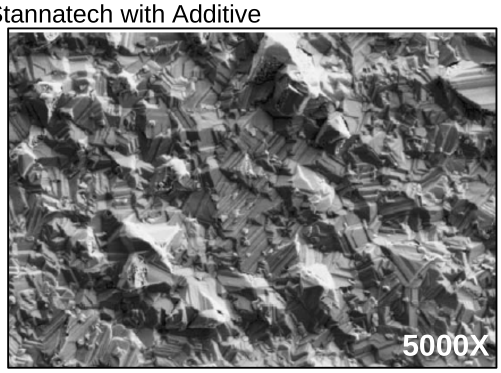
Preventing atomic diffusion along the grain boundary prevents the whiskers forming. This can be done, by adding an agent that blocks the tin atoms path along the grain boundaries.

Immersion Tin



Immersion tin structure prone to whisker growth

Stannatech with Additive



Whisker suppressing immersion tin structure

Summary

Directly after plating, Immersion tin contains tensile stress that is relieved as the intermetallic copper/tin phase grows.
The formation of this intermetallic phase produces internal compressive stress in the boundary tin layer. If this stress is not relieved, the potential of whisker growth exists.
The primary site for whisker growth is at a Screw Dislocation.

Preventing atomic diffusion along the grain boundary prevents the whiskers forming. This can be done, by adding an agent that blocks the tin atoms path along the grain boundaries.

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