Tin Whiskers - The old but new major drawback of Tin circuitry

Simtal coating Ltd. August 2010

What are Tin Whiskers?

Tin whiskers are single crystals of tin that spontaneously grow from the surface of tin and tin alloy plating. They are extremely thin, typically 1-2uM, and grow as single crystals of tin - straight, kinked, or spiral.

Because of their current carrying ability and low electrical resistance, whiskers are a threat to electronic circuits. The fact that tin whiskers were causing electronic circuit problems was discovered back in 1951when many sudden failures and intermittent problems were associated with tin whiskers, mostly due to their ability to short-circuit closely spaced electronic circuits. Whiskers were found to grow across circuit connections and due to their thin, brittle nature, would break free and lodge across circuits.

Numbers:

- Whiskers can take many shapes and grow to lengths as long as 9mm (3/8”).
- They are known to carry 10mA of current before burning up.
- The electrical resistance of a 3mm (1/8") long tin whisker is approximately 50 Ohms
- Tin whiskers caused the failure of the Galaxy IV space shuttle back in 1998.

How do tin whiskers occur?

The mechanism behind metal whisker growth is not fully understood, but seems to be encouraged by compressive mechanical stresses including:

- Residual stresses caused by electroplating
- Mechanically induced stresses
- Stresses induced by diffusion of different metals
- Thermally induced stresses

It is known that a whisker grows from its base, and that the tin around the base does not thin out as it grows, this leads us to believe that the energy for growth is derived from micro-strains present in the tin or from externally applied pressure. Tin atoms appear to diffuse along screw dislocations within the tin and are pushed outwards by stresses .

The growth rate of tin whiskers varies tremendously. It may be irregular, with growth spurts or steady and whiskers can develop in minutes or take decades to form .

צומת בית זרזיר - גבעת אלה ת.ד. 92 תמרת 23840
Givat Ella - Zarzir Junc Timrat P.O. Box 92 ISRAEL 23840
Tel: +972-4-6041036 Fax: +972-4-6041035 tal@simtalltd.com www.simtalltd.com

Factors affecting tin whiskers growth

The following list is partial and many experiments show contradictory results for these factors:

- **Pressure** - an obvious factor affecting whisker growth is pressure. High-compression pressure from bolts or screws will always produce whiskers in tin deposits.
- **Surrounding medium** – the growth of tin whiskers is not directly related to the surrounding medium.
- **Oxygen and carbon** - In the past few years, it has been suspected that the presence of oxygen and carbon endorse tin whiskers growth as well.
- **Humidity** - Whiskers will grow in low or high humidity
- **Temperature** has some effect on the rate of growth
- **Thickness** of tin deposits affects whisker density
- **Plating process and chemistry** - current density, bath agitation and bath temperature, tin purity, use of "brightness" incorporated hydrogen
- **Deposit characteristics** - grain size and shape, crystal direction, deposited thickness and tin oxide formation

Parylene C for prevention of tin whiskers

Mechanical stress

It is well established that tin whiskers grow proportionally to pressure induced on the printed circuit board (PCB). Hence conventional conformal coatings have become a necessity to all electronic devices .

It is a well-known phenomenon that four out of five authorized conformal coating chemicals established at MIL-I 46058-C (Urethane, Epoxy, Silicone, Acrylic, and Parylene) introduce mechanical forces onto the PCB or other devices. Parylene is the only known conformal coating, due to its coating mechanism and system used for its deposition and coating, i.e. CVD (Chemical Vapor Deposition), that will not introduce any type of mechanical forces or deformations into or onto a coated PCB.

On the MIL-SPEC, there is even a remark stating the following: "***special attention should be taken if glass diodes are being used on the electronic device since the mechanical forces that are being introduced during curing of different Epoxies and different Urethanes may break these diodes***". The MIL SPEC rules out Parylene (Type XY) from this remark.

צומת בית זרזיר - גבעת אלה ת.ד. 92 תמרת 23840
Givat Ella - Zarzir Junc Timrat P.O. Box 92 ISRAEL 23840
Tel: +972-4-6041036 Fax: +972-4-6041035 tal@simtalltd.com www.simtalltd.com

Chemical aspects

Even though it has not yet been proven that oxygen and carbon will endorse the tin whiskers growth - Parylene is a great "sealer" and protector. Considered the best on the market it seals and protects the electronic tin pads from interacting with these gasses as well as with humidity.

Studies on tin whiskers and Parylene C

Significant studies have been done on methods to moderate/reducing tin whisker formation.

One study by Woodrow and Ledbury investigated the potential for conformal coatings in moderating / reducing tin whisker growth. It tested six different coatings for tin whiskers formation under different aging conditions. In their conclusions they stated that "Parylene C was the best coating for suppressing the formation of OSE's and whiskers. In addition, Parylene C will completely and uniformly coat component leads, unlike other coatings applied by spraying."

Another study by William Fox and Linda Woody showed that Parylene required half the thickness in coating layer when compared with other coatings, to prevent tin whisker induced tenting following the 5.5 years of environmental exposure to 50°C and 50% RH.

More about tin whiskers...

Should you require further data on tin whiskers, please see the links below:

1. NASA - Basic info on Tin Whiskers
2. NASA - Whiskers Home-page
3. IBM eSG Group - History of Tin Whisker Theory: 1946 to 2004

צומת בית זרזיר - גבעת אלה ת.ד. 92 תמרת 23840
Givat Ella - Zarzir Junc Timrat P.O. Box 92 ISRAEL 23840
Tel: +972-4-6041036 Fax: +972-4-6041035 tal@simtalltd.com www.simtalltd.com