Research & Development
Technical Paper

Analysis Topic:	Tin Plated Electrical Contacts: Study of Tin Whisker Formation & Mitigation Process		**Author:** Mr. Sumit Shukla B.E, Mechanical Engineering P.G. Tool Engineering
Analysis Mode:			
Simulation provider:	NA		
Date:	28th Dec 2018		
Simulation	-	Tel.: - +91 7066447587	
Costumer, Project:	-		
Device / Part:	-		MAT-no.: -

Type of study: ☐ FEA Analysis ☐ Mold flow analysis ☐ CFD

☐ Tolerance ☐ Temperature management ☒ Theory and Practical References

Status of Analysis: Status: ☐ released ☒ released with condition ☐ rejected

Topic:

Tin Plated Electrical Contacts: Study of Tin Whisker Formation and Mitigation Process

1. ABSTRACT

The choice of using a non-noble alternate to gold should be based upon rational engineering criteria as well as cost factors. Tin and tin alloy coatings are attractive electrical contact finish choices because of their low cost, low contact resistance, and good solderability.
The use of tin and tin alloy coatings is limited by their low durability characteristics and susceptibility to fretting corrosion. These limitations may be circumvented by using tin or tin alloy coatings only in applications where a relatively low number of mating cycles are required, and by using appropriate contact design and lubrication (as needed) to reduce susceptibility to fretting corrosion. [1]

The following technical paper is a showcase of theoretical aspects, practical failure cases and discussion of the criteria which need to be considered when determining if the use of tin and/or tin alloy coatings would be appropriate for an electrical contact design.

2. INTRODUCTION

The drive to eliminate lead (Pb) from electronics has resulted in an interest in the use of pure tin (Sn) finishes as an economical lead-free (Pb-free) plating option; many already have or are in the process of transitioning. [2]

"Lead-Free" Movement

Electroplated and dip-coated finishes are applied to electronic components primarily to protect the base metal (conductor) from corrosion and to enhance solderability. The benefits of many tin and tin alloy electroplating processes also include excellent control and uniformity of plating thickness (especially critical in miniaturized, fine-pitched components), good electrical conductivity, and non-toxicity. In addition, tin finishes, especially "bright" finishes, which use organic additives in the plating bath, maintain an aesthetically pleasing shiny surface. For these purposes, a wide assortment of electroplated finishes has been used with much success, including many tin-lead based alloys (ranging from 2% - 50% Pb) as well as 100% pure tin.

Despite all its benefits, there is one major impediment to an across-the-board adoption of pure tin as the solution to pending Pb-free legislative requirements: ***many pure tin electroplates develop tin whiskers.***
This possibility, in combination with the lack of accepted methods for testing whisker growth susceptibility, gives rise to major reliability concerns! [3]

Perhaps the greatest reliability issue to come out of the Restriction of Hazardous Substances (RoHS) Directive is tin whiskers. This residual effect of RoHS is nothing new to electronics manufacturing. Tin whiskers were first being reported in the 1940s and credited with taking down satellites and military planes, causing critical failures to pacemakers and space shuttle systems and even the shutdown of a nuclear power facility. [4]

Introduction to Tin Whiskers

Tin whiskers are electrically conductive, crystalline structures of tin that sometimes grow from surfaces where tin (especially electroplated tin) is used as a final finish. Tin whiskers have been observed to grow to lengths of several millimeters (mm) and in rare instances to lengths more than 10 mm. Numerous electronic system failures have been attributed to short circuits caused by tin whiskers that bridge closely-spaced circuit elements maintained at different electrical potentials. [5]

People sometimes confuse the term "whiskers" with a more familiar phenomenon known as "dendrites" commonly formed by electrochemical migration processes. Therefore, it is important to note here that whiskers and dendrites are two very different phenomena. A "Whisker" generally has the shape of a very thin, single filament or hair-like protrusion that emerges outward (z-axis) from a surface. "Dendrites", on the other hand, form in fern-like or snowflake-like patterns growing along a surface (x-y plane) rather than outward from it. The growth mechanism for dendrites is well-understood and requires some type of moisture capable of dissolving the metal (e.g., tin) into a solution of metal ions which are then redistributed by electromigration in the presence of an electromagnetic field. While the precise mechanism for whisker formation remains unknown, it is known that whisker formation does NOT require either dissolution of the metal NOR the presence of electromagnetic field. [5]

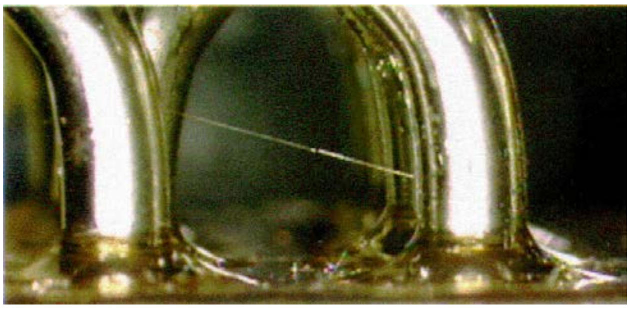


Fig 1: Tin "Whisker" shown above growing between pure tin-plated hook terminals of an electromagnetic relay

Fig 2: "Dendrites" shown above are NOT the same phenomenon as "whiskers"

Tin Whiskers Growth occurs over time by accretion of metal ions at the base NOT the tip

- LENGTH: Log-normally distributed Rarely up to 10 mm or more (Typically ~1mm or less)
- THICKNESS: Range 0.006 to >10 um (Typical ~ 1 um)

Fundamental theories for growth mechanism DO NOT enable prediction of the time-dependence of whisker density, whisker lengths or thicknesses. [6]

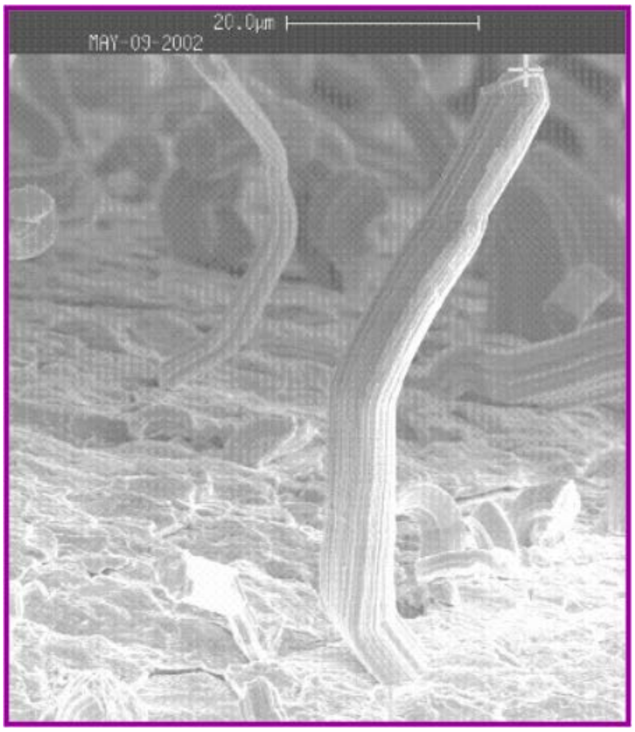


Fig 3.1: Tin Whiskers on Tin-Plated Ceramic Chip Capacitor

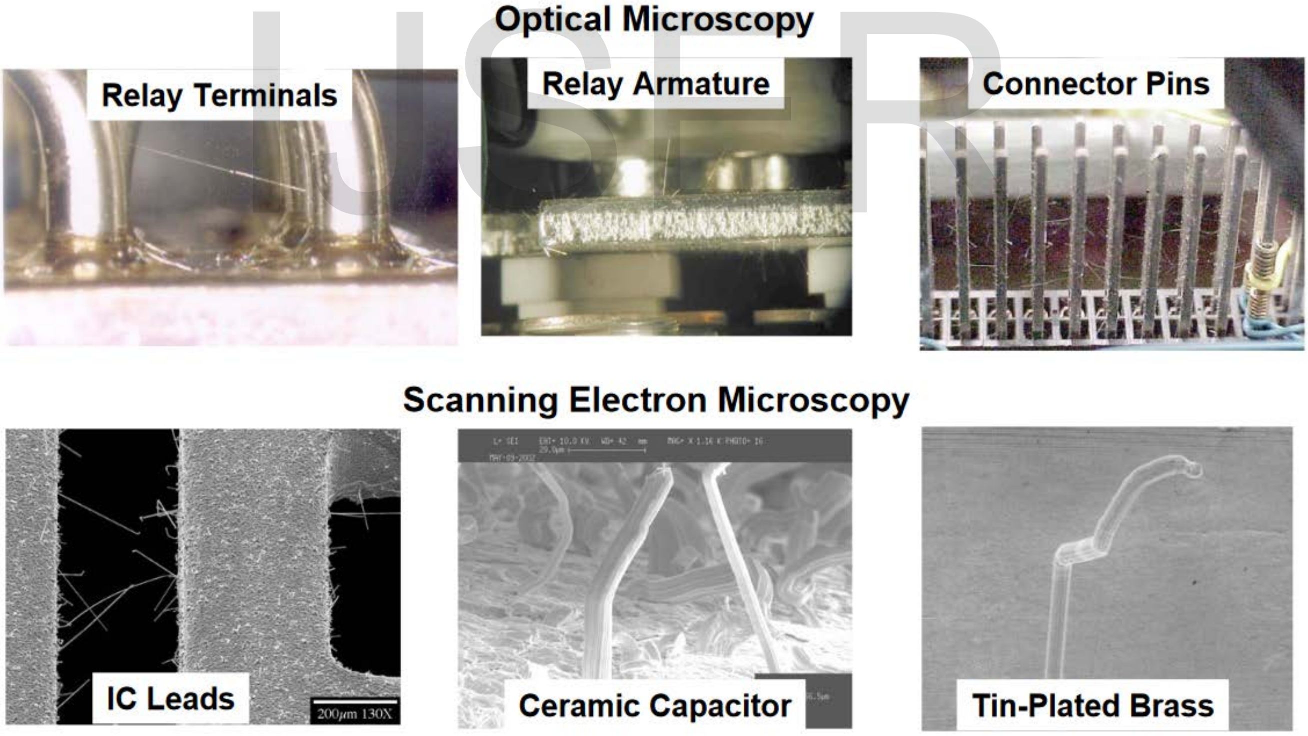
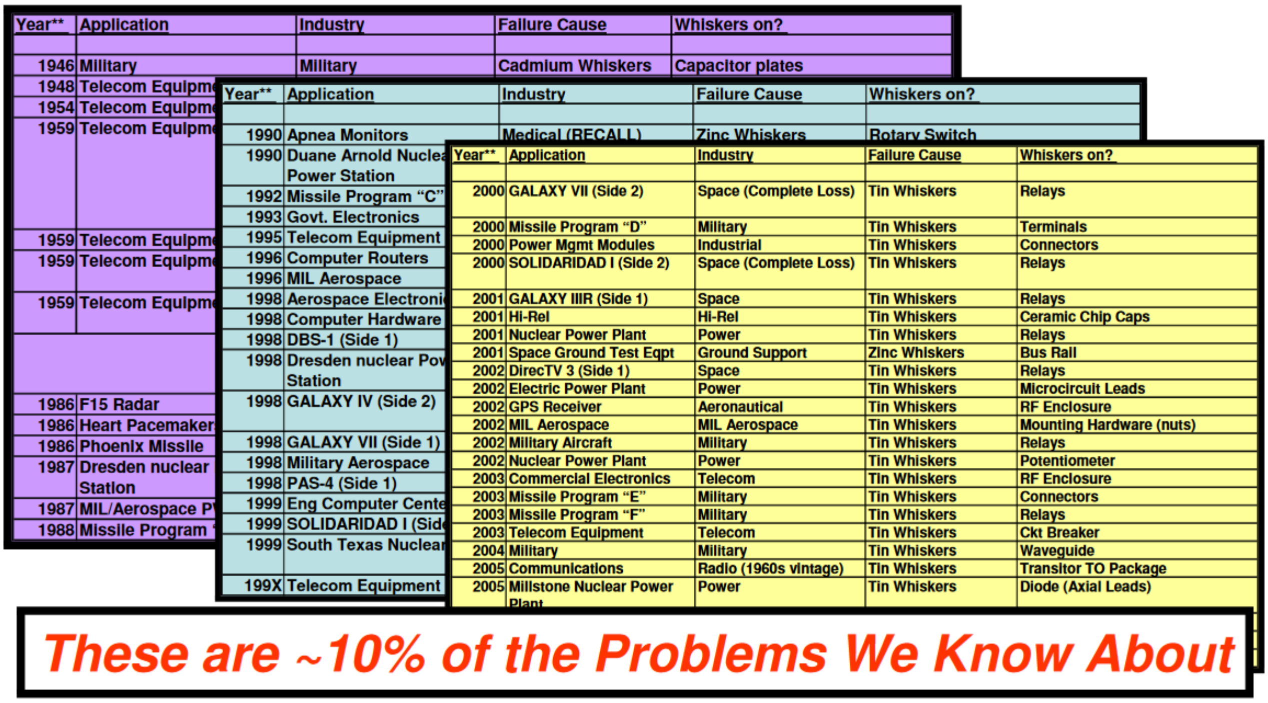


Fig 3.2: Tin Whiskers on Components



Year**	Application	Industry	Failure Cause	Whiskers on?
1946	Military	Military	Cadmium Whiskers	Capacitor plates
1948	Telecom Equipme			
1954	Telecom Equipme			
1959	Telecom Equipme			
1959	Telecom Equipme			
1959	Telecom Equipme			
1959	Telecom Equipme			
1986	F15 Radar			
1986	Heart Pacemaker			
1986	Phoenix Missile			
1987	Dresden nuclear Station			
1987	MIL/Aerospace P			
1988	Missile Program			

Year**	Application	Industry	Failure Cause	Whiskers on?
1990	Apnea Monitors	Medical (RECALL)	Zinc Whiskers	Rotary Switch
1990	Duane Arnold Nuclea Power Station			
1992	Missile Program "C"			
1993	Govt. Electronics			
1995	Telecom Equipment			
1996	Computer Routers			
1996	MIL Aerospace			
1998	Aerospace Electroni			
1998	Computer Hardware			
1998	DBS-1 (Side 1)			
1998	Dresden nuclear Pow Station			
1998	GALAXY IV (Side 2)			
1998	GALAXY VII (Side 1)			
1998	Military Aerospace			
1998	PAS-4 (Side 1)			
1999	Eng Computer Cente			
1999	SOLIDARIDAD I (Sid			
1999	South Texas Nuclear			
199X	Telecom Equipment			

Year**	Application	Industry	Failure Cause	Whiskers on?
2000	GALAXY VII (Side 2)	Space (Complete Loss)	Tin Whiskers	Relays
2000	Missile Program "D"	Military	Tin Whiskers	Terminals
2000	Power Mgmt Modules	Industrial	Tin Whiskers	Connectors
2000	SOLIDARIDAD I (Side 2)	Space (Complete Loss)	Tin Whiskers	Relays
2001	GALAXY IIIR (Side 1)	Space	Tin Whiskers	Relays
2001	Hi-Rel	Hi-Rel	Tin Whiskers	Ceramic Chip Caps
2001	Nuclear Power Plant	Power	Tin Whiskers	Relays
2001	Space Ground Test Eqpt	Ground Support	Zinc Whiskers	Bus Rail
2002	DirecTV 3 (Side 1)	Space	Tin Whiskers	Relays
2002	Electric Power Plant	Power	Tin Whiskers	Microcircuit Leads
2002	GPS Receiver	Aeronautical	Tin Whiskers	RF Enclosure
2002	MIL Aerospace	MIL Aerospace	Tin Whiskers	Mounting Hardware (nuts)
2002	Military Aircraft	Military	Tin Whiskers	Relays
2002	Nuclear Power Plant	Power	Tin Whiskers	Potentiometer
2003	Commercial Electronics	Telecom	Tin Whiskers	RF Enclosure
2003	Missile Program "E"	Military	Tin Whiskers	Connectors
2003	Missile Program "F"	Military	Tin Whiskers	Relays
2003	Telecom Equipment	Telecom	Tin Whiskers	Ckt Breaker
2004	Military	Military	Tin Whiskers	Waveguide
2005	Communications	Radio (1960s vintage)	Tin Whiskers	Transitor TO Package
2005	Millstone Nuclear Power Plant	Power	Tin Whiskers	Diode (Axial Leads)

These are ~10% of the Problems We Know About

Fig 4: 2006- NASA GSFC Presented A Partial History of Documented Metal Whisker Problems

3. MECHANISM OF TIN WHISKERS FORMATION

The mechanisms by which tin whiskers grow have been studied for many years. A single accepted explanation of the mechanisms has NOT been established. Some theories suggest that tin whiskers may grow in response to a mechanism of stress relief (especially "compressive" stress) within the tin plating. Other theories contend that growth may be attributable to recrystallization and abnormal grain growth processes affecting the tin grain structure which may or may not be affected by residual stress in the tin-plated film. [7]

Those advocating "stress" as crucial for metal whisker formation point to some commonly accepted factors that can impart additional residual stress:

1. **Residual stresses** within the tin plating caused by factors such as the plating chemistry and process. Electroplated finishes (especially "bright" finishes) appear to be most susceptible to whisker formation reportedly because bright tin plating processes can introduce greater residual stresses than other plating processes.
2. **Intermetallic Formation:** The diffusion of the substrate material into the tin plating (or vice versa) can lead to formation of intermetallic compounds (such as Cu6Sn5 for a Sn over Cu system) that alter the lattice spacing in the tin plating. The change in lattice spacing may impart stresses to the tin plating that may be relieved through the formation of tin whiskers.
3. **Externally Applied Compressive Stresses** such as those introduced by torquing of a nut or a screw or clamping against a tin-coated surface can sometimes produce regions of whisker growth.
4. **Bending or Stretching of the surface after plating** (such as during lead-formation prior to mounting of an electronic component)
5. **Scratches or nicks** in the plating and/or the substrate material introduced by handling, probing, etc.
6. **Coefficient of Thermal Expansion** Mismatches between the plating material and substrate

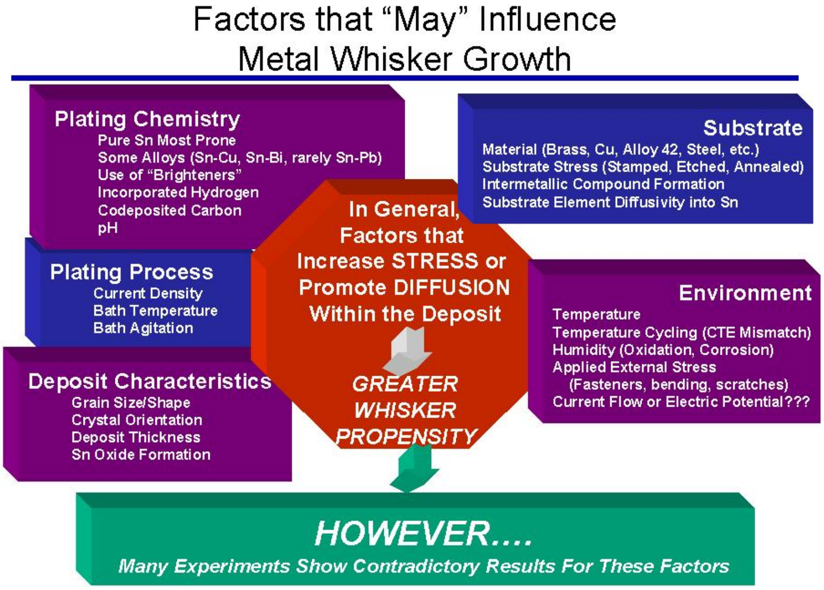
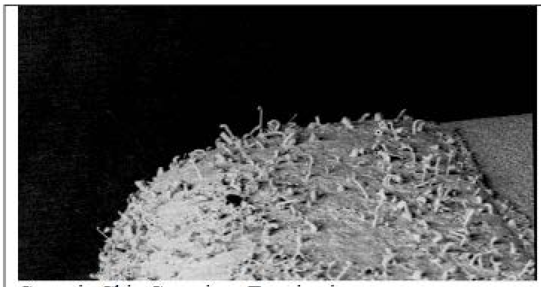


Fig 5: Factors which 'may' influence Metal Whisker Growth

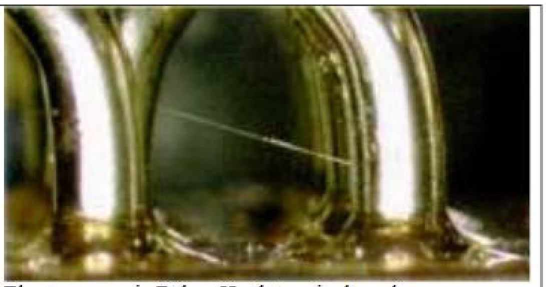
4. RISK RELATED TO TIN WHISKERS

Tin whiskers present two reliability issues for equipment manufacturers and users. The first is electrical shorting. Whiskers can grow between adjacent conductors of different potential and cause either a transient short as the whisker is burned open, or a permanent short. Second, whiskers can be broken loose from their substrate and as debris cause mechanical problems with slip rings, optical devices, microelectromechanical devices (MEMS) and similar components.

Many types of pure tin coated components have been shown to be susceptible to spontaneous growth of tin whiskers. Given time (days or months to years) whiskers may grow to lengths capable of causing electrical shorts in densely packed circuits. [8]



Ceramic Chip Capacitor: Termination
(>0.2 mm long)



Electromagnetic Relay: Hook terminals and case
(>2.0 mm long)

Terminal Lug: Inside crimp barrel
(> 0.25 mm long)

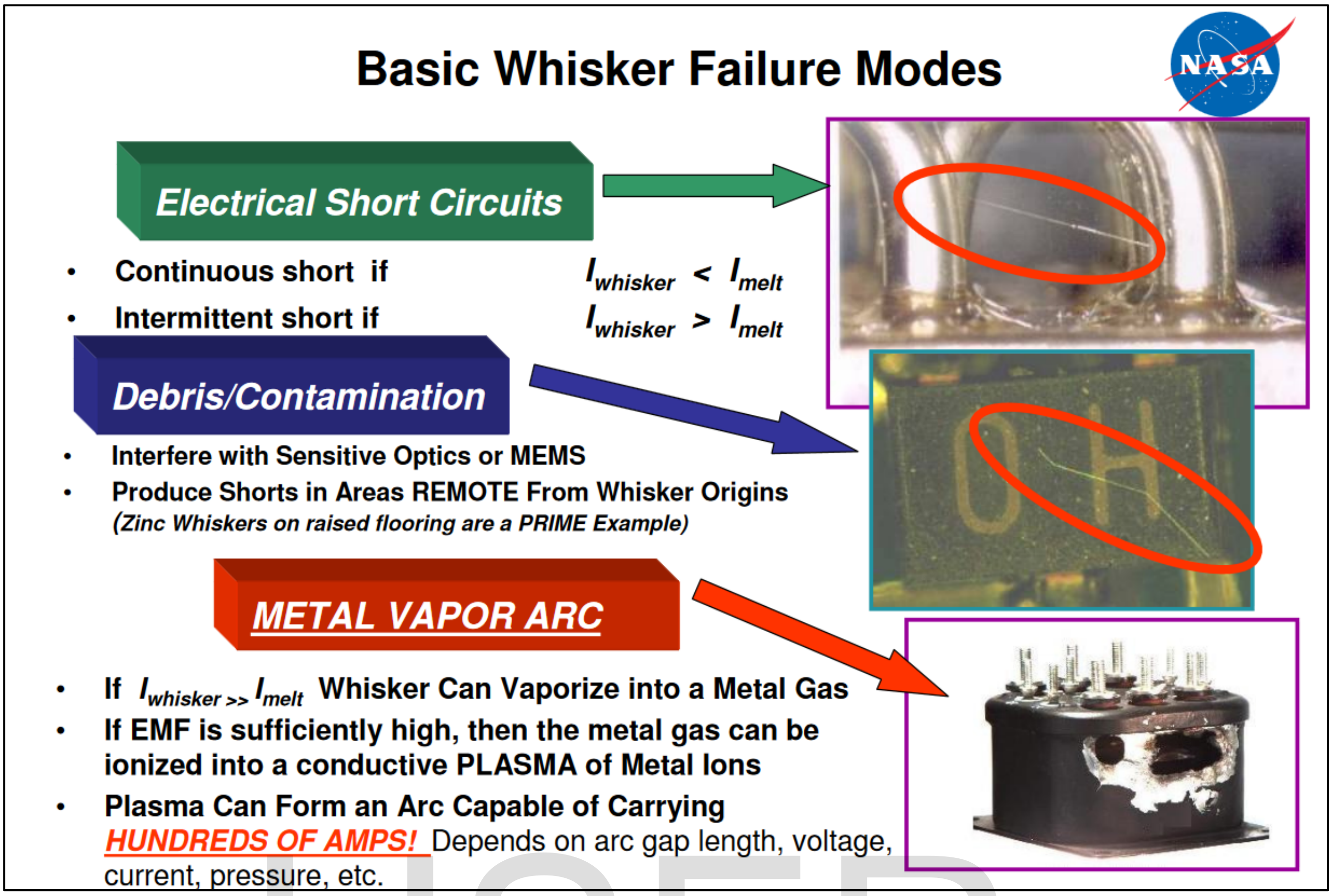
Hybrid Microcircuit: Package Lid
(> 2 mm long also reported)

Fig 6: A few examples of pure tin-plated components that have exhibited tin whisker growth, courtesy of NASA-Goddard.

Tin whiskers pose a serious reliability risk to electronic assemblies. The general risks fall into four categories: [9]

1. **Stable short circuits in low voltage, high impedance circuits.**
   In such circuits there may be insufficient current available to fuse the whisker open and a stable short circuit results. Depending on a variety of factors including the diameter and length of the whisker, it can take more than 50 milliamps (mA) to fuse open a tin whisker.
2. **Transient short circuits.**
   At atmospheric pressure, if the available current exceeds the fusing current of the whisker, the circuit may only experience a transient glitch as the whisker fuses open.
3. **Metal Vapor Arc**
   If a tin whisker initiates a short in an application environment possessing high levels of current and voltage, then a VERY DESTRUCTIVE phenomenon known as a Metal Vapor Arc can occur. The ambient pressure, temperature and the presence of arc suppressing materials also affect metal vapor arc formation. In a metal vapor arc, the solid metal whisker is vaporized into a plasma of HIGHLY CONDUCTIVE metal ions (more conductive than the solid whisker itself). This plasma can form an ARC capable of carrying HUNDREDS OF AMPERES. Such arcs can be sustained for long duration (several seconds) until interrupted by circuit protection devices (e.g., fuses, circuit breakers) or until other arc extinguishing processes occur. This kind of arcing is happening in the metal vapor. When an arc quenching agent (e.g., air) is present, more power must be installed into the event to replace power lost to the non-interesting processes happening in the quenching agent. Therefore, as air pressure is reduced, less power is required to initiate and sustain a whisker-induced metal vapor arc. For example, past experiments** have demonstrated that at atmospheric pressures of about 150 torr, a tin whisker could initiate a sustained metal vapor arc where the supply voltage was approximately 13 Volts (or greater) and supply current was 15 Amps (or greater). Tin (or other materials) from the adjacent surfaces can help to sustain the arc until the available material is consumed or the supply current is interrupted. Metal vapor arcs in vacuum are reported to have occurred on at least three commercial satellites resulting in blown fuses that rendered the spacecraft non-operational.

4. **Debris/Contamination.**
   Whiskers or parts of whiskers may break loose and bridge isolated conductors or interfere with optical surfaces



Basic Whisker Failure Modes

Electrical Short Circuits

- **Continuous short if** $I_{whisker} < I_{melt}$
- **Intermittent short if** $I_{whisker} > I_{melt}$

Debris/Contamination

- **Interfere with Sensitive Optics or MEMS**
- **Produce Shorts in Areas REMOTE From Whisker Origins**
  (Zinc Whiskers on raised flooring are a PRIME Example)

METAL VAPOR ARC

- **If** $I_{whisker} >> I_{melt}$ **Whisker Can Vaporize into a Metal Gas**
- **If EMF is sufficiently high, then the metal gas can be ionized into a conductive PLASMA of Metal Ions**
- **Plasma Can Form an Arc Capable of Carrying *HUNDREDS OF AMPS!*** Depends on arc gap length, voltage, current, pressure, etc.

Fig 7: Basic Whisker Failure Modes

Case Study: **Field Failures Due to Tin Whiskers on "Bright" Tin-Plated Circuit Breaker Contacts [10]**

The images below depict tin whiskers growing on the "bright" tin-plated copper contacts inside of a circuit breaker. Two to three years after deployment of these components into (terrestrial) service, the user began to experience field failures in multiple locations across Europe. Failure analysis identified the root cause of failure to be tin whisker induced short circuits across contact pairs that are normally open circuit. During failure analysis the user observed that the density and length of whiskers were greatest in the areas of the contacts exposed to highest electric field in operation (i.e., between the separated contact pairs having 50V potential difference).

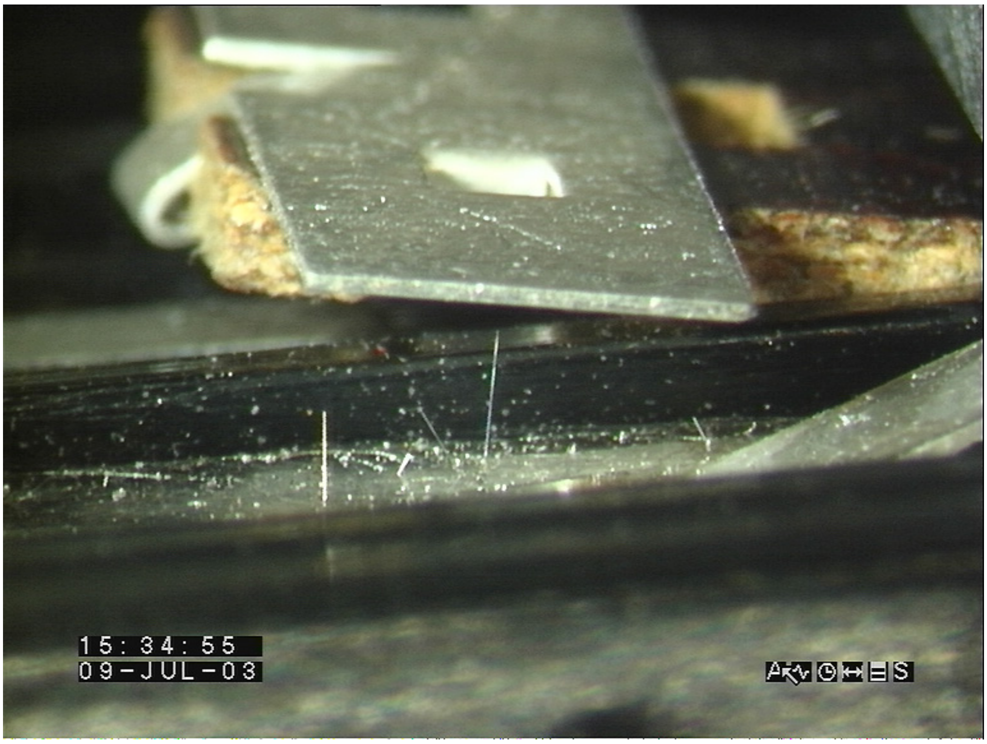


Fig 8: Tin Whiskers Growing on "Bright" Tin-Plated Copper Contacts Inside a Circuit Breaker

5. COMMONLY REPORTED CHARACTERISTICS OF TIN WHISKERS

The vast disparity in the observations reported by different experimenters is evidence of the complications associated with understanding and controlling tin whiskers. The following list is intended to provide a very basic overview of some of the observed characteristics of tin whiskers. [11]

1. **Shapes:** Whiskers may be straight, kinked, hooked or forked. Their outer surfaces are often grooved. Some growths may form as nodules or pyramidal structures.
2. **Incubation (Dormancy) Period:** Experimenters report the incubation period may range from days to years. This attribute of whisker growth is particularly concerning because meaningful experiments to determine the propensity for a particular process to form whiskers may need to span very long periods of time.
3. **Growth Rate:** Growth rates from 0.03 to 9 mm/yr have been reported. Growth is highly variable and is likely to be determined by a complex relationship of factors including plating chemistry, plating thickness, substrate materials, grain structure and environmental storage conditions.
4. **Whisker Length:** Whiskers as long as a few millimeters are not uncommon with some experimenters observing whiskers in excess of 10 mm (400 mils) in length. Only a few researchers have measured the distribution of whisker lengths for specific specimens. Invariably, these researchers report the length distribution fits a lognormal distribution.
5. **Whisker Diameter:** Typical diameters are a few microns with some reports in excess of 10 um and rarely less than 100 nm.

6. **Environmental Factors:** There is a great deal of contradictory information regarding environmental factors that might affect whisker formation. Several organizations are attempting to devise accelerated test methods to determine a particular plating process's propensity to form tin whiskers. However, to date, there are no accepted test methods for evaluating whisker propensity. Indeed, much of the experimental data compiled to date has produced contradictory findings regarding which factors accelerate (or retard) whisker growth.
    - **Temperature:** Some experimenters report that ambient temperatures of approximately 50°C are optimal for whisker formation, while others observe that room temperatures (22°C to 25°C) grow whiskers faster. Reportedly, whisker growth ceases at temperatures above 150°C
    - **Pressure:** Whiskers will grow in vacuum as well as earth based atmospheric pressure.
    - **Moisture:** Some observe that whiskers form more readily in high humidity (85% RH) whereas others report moisture is not a contributing factor
    - **Thermal Cycling:** Some experimenters report that thermal cycling increases the growth rate of whiskers, but others report no effect due to thermal cycling.
    - **Electric Field:** Whiskers grow spontaneously without requiring an applied electric field to encourage their growth. Some recent observations of tin whisker induced field problems in the commercial sector seem to suggest that an electric field could stimulate whisker growth, but more analysis is required to confirm these effects (if any). GSFC has demonstrated that whiskers can bend due to the forces of electrostatic attraction thus increasing the likelihood of tin whisker shorts

7. **Whisker Prone Processes:** There is tremendous debate in the industry regarding which plating processes are prone to whisker formation. Most of the literature agrees that "pure tin" electroplated surfaces (especially those that employ brighteners in the plating process) are the most susceptible to whisker formation. There are also reports that tin-lead plating can grow whiskers; however, such whiskers are generally reported to be less than 50um long.

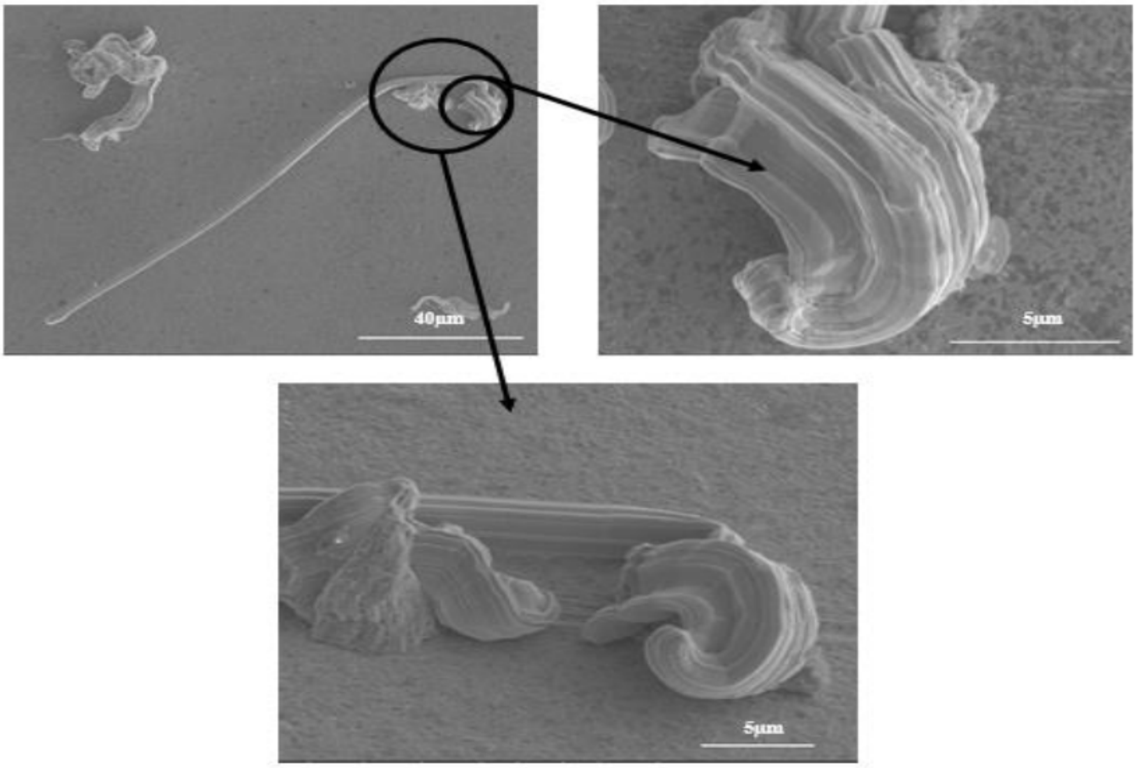


Fig 9: Tin whisker profiles with various geometries shown at different magnifications

6. TIN WHISKERS MITIGATION PLAN

Connectors with a pitch of less than 1 mm should not be un-annealed, pure tin, either, because "whiskers" can grow between the contacts. Whiskers, or small hairs, can form perpendicular to the metal itself and cause short circuits with neighboring metal. In high-frequency circuits, whiskers can act like antennas. Annealing, coatings, lubricants, and metal alloys can mitigate whiskering. Gold is less susceptible to whiskering, but can still create them, although of much smaller size. For a long time, lead (Pb) was introduced into solder to reduce the chance of whiskers. However, electronics waste that introduced unacceptable levels of lead (and other dangerous elements) into the environment, leading to the Restriction of Hazardous Substances (RoHS). RoHS restricts substances "that are hazardous to the environment, and pollute landfills, and are dangerous in terms of occupational exposure during manufacturing and recycling." [12]

The stresses that drive whiskering derive from five sources: [13]

1. Base metal (intermetallic formation)
2. Base metal (differences in coefficient of thermal expansion)
3. Bulk plating conditions
4. Oxidation/Corrosion
5. External pressure

Whiskering occurs when one or more of these sources induce stresses of a sufficient magnitude. The magnitude of these stresses can be fixed at the time of production or can evolve over time.

1. Base metal (intermetallic formation)

Because of significant differences in the diffusion rate of copper (Cu) through tin (Sn) grains and grain boundaries at room temperature, copper-tin intermetallic (Cu_6Sn_5) will tend to grow preferentially into the grain boundaries. The volumetric expansion of 58% (molar volume of Cu and Sn compared to Cu_6Sn_5), will result in large compressive stresses within the plating.

The use of an underplate such as nickel (Ni) prevents interdiffusion of the Sn and Cu and thus formation of the Cu_6Sn_5 intermetallic. The resulting Sn and Ni intermetallic compound, Sn_3Ni_4, is relatively thin, uniform, and is self-limiting due to the low dissolution rate of Ni in Sn compared to Cu[2]. This morphology does not create compressive stresses in the tin plating and actually induces a slight tensile stress. For this reason a Ni underplate of > 1.2 micrometers is often used to mitigate growth of tin whiskers.

Annealing the tin coating immediately after plating at a temperature from 150 – 170°C is also commonly used to mitigate whisker growth. At temperatures over 60°C[3] the intermetallic that forms is Cu_3Sn. In addition, at temperatures above 75C[4], bulk and grain boundary diffusion rates in Sn become roughly equivalent. The resulting intermetallic morphology does not induce compressive stresses and provides a uniform layer that reduces the rate of diffusion and intermixing of Cu and Sn. It is essentially a poor man's Ni layer.

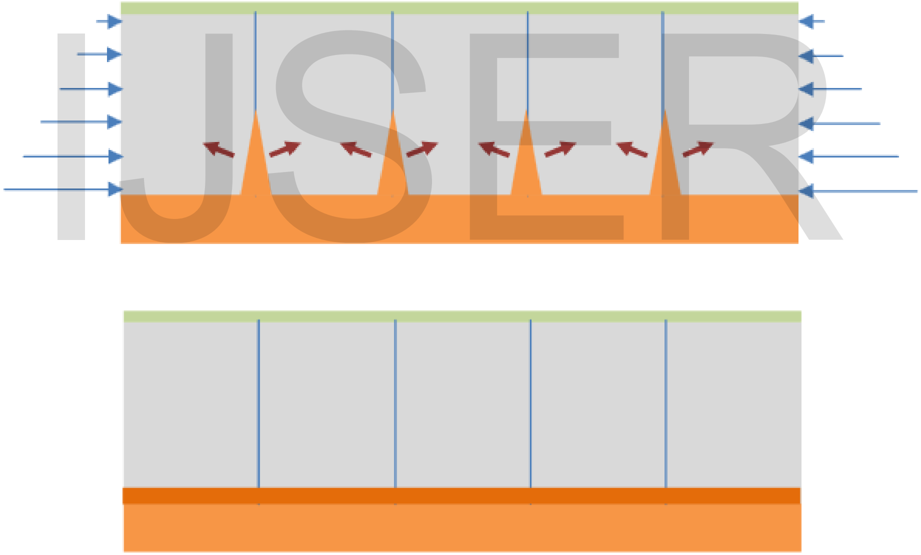
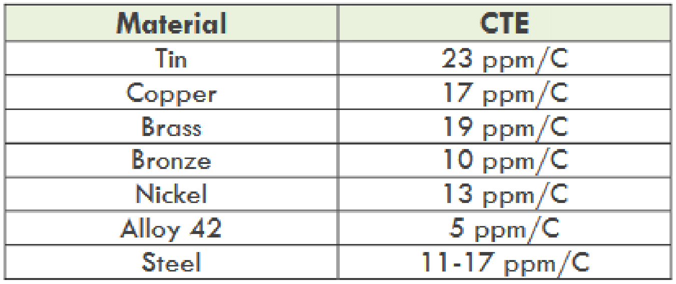


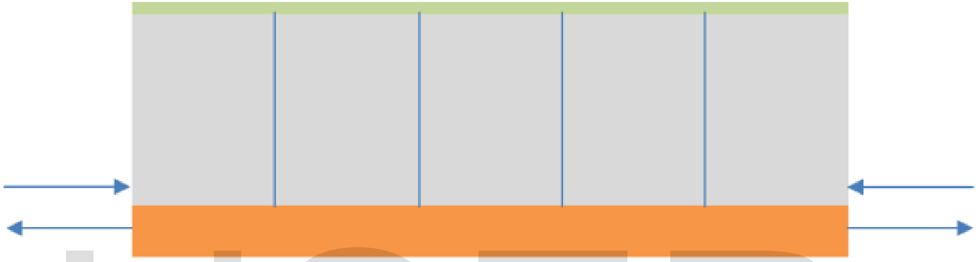
Fig 10: Base Metal (Intermetallic Formation)

2. Base metal (differences in coefficient of thermal expansion)

Compressive stresses can also arise when the base metal (copper, Alloy 42, steel) has a lower coefficient of thermal expansion (CTE) than tin plating and the plated component is subjected to repeated changes in temperature.



Material	CTE
Tin	23 ppm/C
Copper	17 ppm/C
Brass	19 ppm/C
Bronze	10 ppm/C
Nickel	13 ppm/C
Alloy 42	5 ppm/C
Steel	11-17 ppm/C

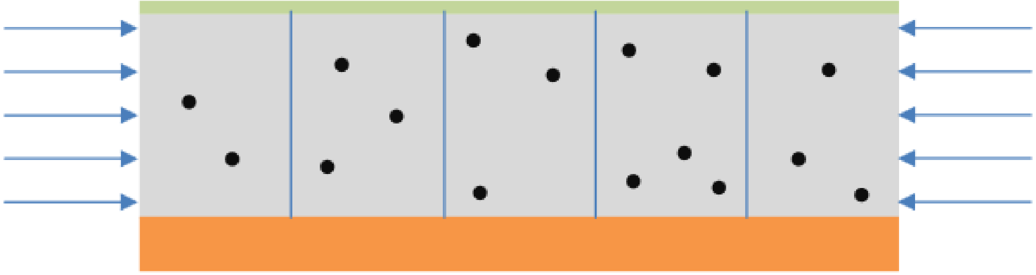


3. Bulk plating conditions

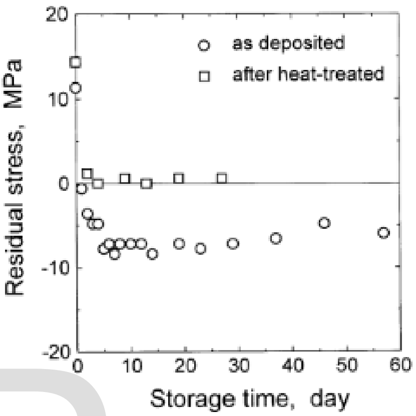
The process of plating tin can introduce compressive stresses into the bulk plating. This is typically through conditions that can cause grain texturing or the incorporation of plating elements such as organic brighteners.

Brighteners are typically used for two reasons: ensure a uniform plating surface and to reduce the grain size. Brightener is attracted to points of high electro-potential, temporarily packing the area and forcing metal ions to deposit elsewhere.
By continuously moving with the highest potential, the brightener prevents the formation of large clumps of tin, giving a smooth, bright deposition.
Organics used as brightening agents also provide a nucleation site for grain growth of tin.
Without such nucleation sites, the tin added during plating will more readily settle into its low energy state and form large grains. The smaller grains from brighteners provide a high and uniform reflectance from the plated surface.

The incorporation of the organics can cause compressive stress in the tin deposit and the smaller grains provide more grain boundaries for rapid inter diffusion of Sn and Cu and faster diffusion of Sn to form whiskers. For this reason, bright tin (grain size < 1µm) is typically not allowed on electronic components.



Intrinsic stresses can also arise simply due to variations in the plating process. While the effects of all drivers are not always well quantified, it is believed that degree of texturing plays a critical rule. Texturing is the phenomenon of preferred, rather than random, orientation of the crystal lattice of the grains. High organic brightener content and high current densities[5] can also introduce texturing into the plating. As carbon content or plating rates rise, the tin atoms are unable to rearrange to a low-energy state. This can introduce orientations that are 'whisker friendly' and increases the compressive stresses within the plating[6].



4. Oxidation / Corrosion

Just as with intermetallic formation, the process of tin oxidation can also induce compressive stress states. Because of significant differences in the diffusion rate of oxygen (O) through tin (Sn) grains and grain boundaries at room temperature, tin oxide (SnO2) will tend to grow preferentially into the grain boundaries. The volumetric expansion can result in large compressive stresses within the plating. Similarly, certain conditions can cause corrosion on the surface of the tin plating and the corrosion product will induce compressive stresses within the tin.

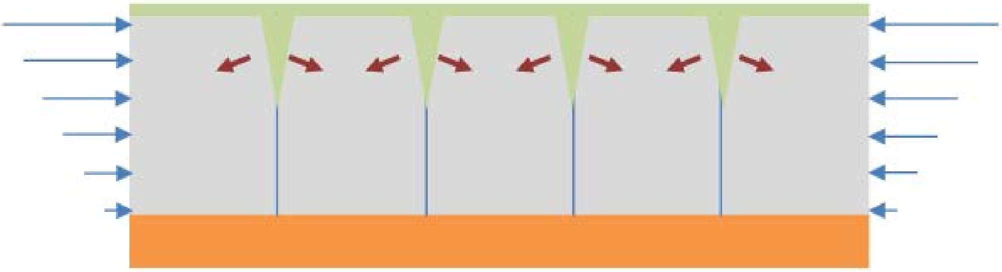


Fig 11: Oxidation / Corrosion

There are some indications that exposure to elevated temperature / humidity conditions could exacerbate this behavior by overcoming the self-limiting behavior of tin oxide at room temperature.

5. External pressure

While most sources for stresses in tin plating are intrinsic, extrinsic sources can also introduce compressive stresses into the plating.
One of the first studies on tin whiskers was triggered by a serendipitous finding that tin-plated steel mounted in a ring clamp grew whiskers and the amount of whiskering increased as the clamping pressure increased.

Common external pressure points within electronic products include connectors (on-board and press-fit), standoffs, card guides, washers/terminals, and separable shielding. Of concern is contact pressure on tin plated flexible circuits. The compliancy of the polyimide substrate results in localized areas of high contact pressures and therefore high stresses. The larger the stresses in the tin, the longer the whiskers must grow to relieve the stress.

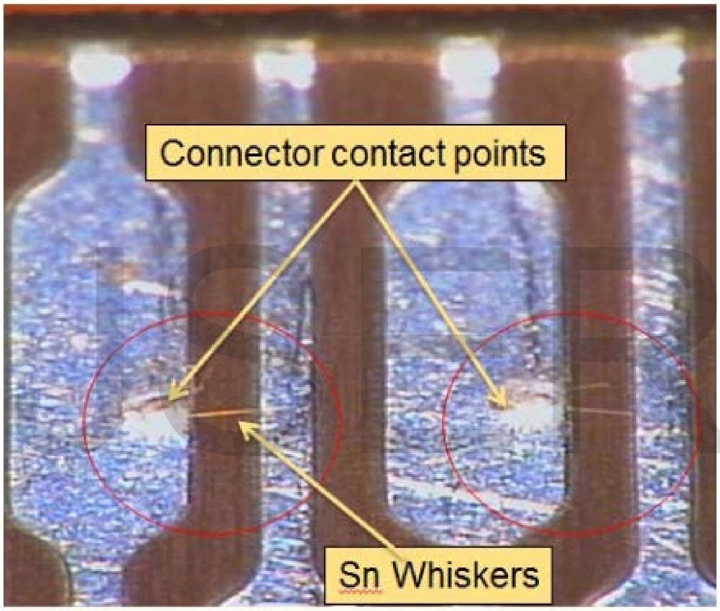


Fig 12: External Pressure

Related Checklist

Are stresses due to intermetallic formation adequately controlled?
- Yes, through annealing (150°C for an hour within 24 hours of plating)
- Yes, through use of an appropriate underplate (nickel, silver, etc.)
- Yes, the base metal is treated to limit anisotropic intermetallic growth (i.e., surface roughening)
- No

Are stresses due to differences in coefficient of thermal expansion adequately controlled?
- Yes, the base metal is copper
- Yes, the coefficient of thermal expansion is greater than or equal to nickel (13 ppm)
- No

Are stresses in the bulk plating adequately controlled?

- Requirement: The supplier measures in-plane stresses on a monthly basis and ensures the stresses are tensile or mildly compressive
- Yes, the supplier only uses low carbon/organic content tin plating
- Yes, the plating is subjected to reflow temperatures that melt the tin
- No

Are stresses due to oxidation or corrosion adequately controlled?

- Requirement: The device is not directly exposed to corrosive conditions (residual aqueous flux residues, corrosive gases, salt spray, etc.)
- Yes, the device will be used in a vacuum
- Yes, the application has sufficient power dissipation to drop the humidity below 40%RH and the application is always on
- Yes, the device is covered with conformal coating or potting material
- No

Are stresses due to external loads adequately controlled?

- Yes, the tin plating does not have separable mechanical load being applied
- No

Tin Or Tin Alloy Coatings Are Cost Effective And Reliable Alternatives To Gold If Used According To The Following Guidelines: [14]

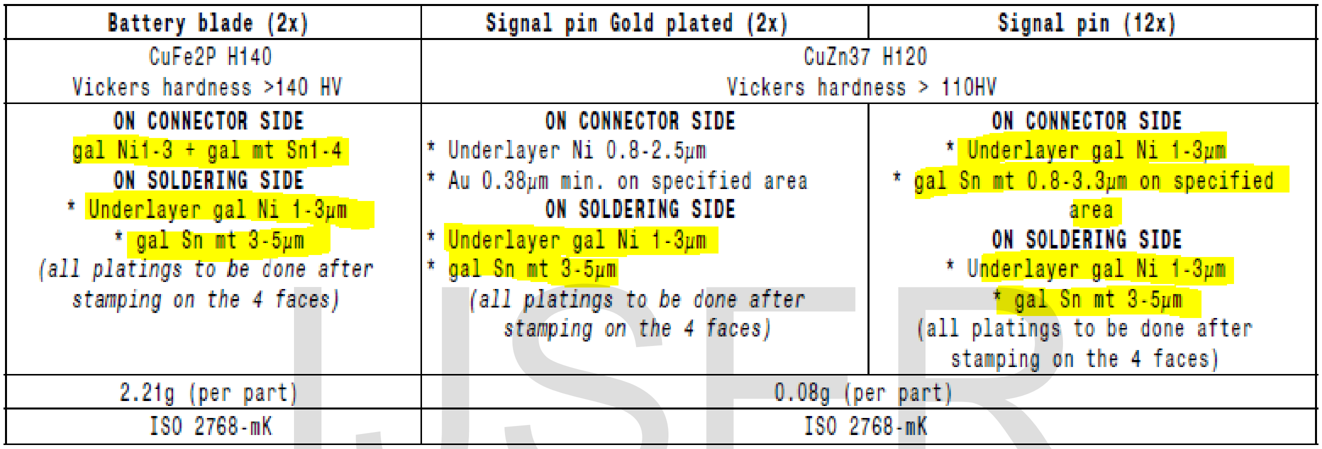
1. Tin coated contacts should be mechanically stable in the mated condition
2. Tin coated contacts need at least 100 grams contact normal force
3. Tin coated contacts need lubrication
4. Tin coating is not recommended for continuous service at high temperatures
5. The choice of plated, reflowed, hot air leveled, or hot tin dipped coatings does not strongly affect the electrical performance of tin or tin alloy coated contacts
6. Electroplated tin coatings should be at least 100 microinches thick
7. Mating tin coated contacts to gold coated contacts is not recommended
8. Sliding or wiping action during contact engagement is recommended with tin coated contacts
9. Tin coated contacts should not be used to make or break current
10. Tin coated contacts can be used under dry circuit or low level conditions

Note:

Tin coatings on brass should have a nickel undercoat to prevent zinc migration from the base metal. The main effect of zinc migration is to reduce solderability.

7. APPLICATIONS

Project: Connector Plate Connector Terminal Pin Plating Definition:-



Battery blade (2x)	Signal pin Gold plated (2x)	Signal pin (12x)
CuFe2P H140 Vickers hardness >140 HV	CuZn37 H120 Vickers hardness > 110HV	
ON CONNECTOR SIDE gal Ni1-3 + gal mt Sn1-4 ON SOLDERING SIDE * Underlayer gal Ni 1-3µm * gal Sn mt 3-5µm *(all platings to be done after stamping on the 4 faces)*	ON CONNECTOR SIDE * Underlayer Ni 0.8-2.5µm * Au 0.38µm min. on specified area ON SOLDERING SIDE * Underlayer gal Ni 1-3µm * gal Sn mt 3-5µm *(all platings to be done after stamping on the 4 faces)*	ON CONNECTOR SIDE * Underlayer gal Ni 1-3µm * gal Sn mt 0.8-3.3µm on specified area ON SOLDERING SIDE * Underlayer gal Ni 1-3µm * gal Sn mt 3-5µm (all platings to be done after stamping on the 4 faces)
2.21g (per part)	0.08g (per part)	
ISO 2768-mK	ISO 2768-mK	

Surface coating process

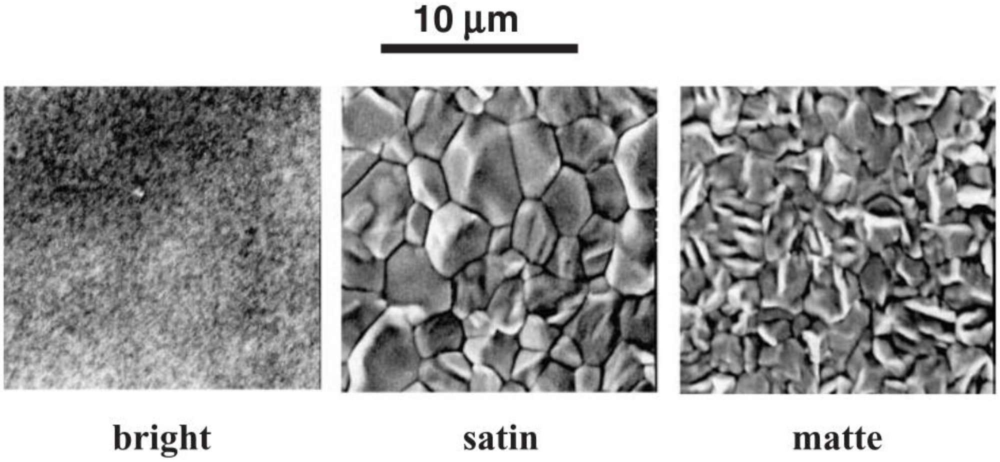
Various methods may be used to coat the contact parts:
- Electroplating: gal
- Electroplating matt: gal mt
- Hot-galvanizing: fvz

After the galvanizing process, the contact parts may be tempered (reflow method):
- Electroplated matt + reflow: gal mt ref

There are two types of electroplated pure tin: bright tin and matte tin. [15]

Bright tin is coated in electroplating solutions containing brighteners - organic additives causing formation of fine Grain structure deposit. Bright tin coating have excellent cosmetic appearance, however they are characterized by high internal stresses and contain increased amount of organics.
Matte tin coatings are made in electrolytes without additions of brighteners. Matte tin has dull appearance but the level of internal stresses in matte tin depositions is much less than in that of bright tin.

Pure tin has been used in food package applications and as cosmetic overlay.
Recently pure tin has been introduced as non-toxic replacement of lead containing solders. Maximum service temperature of pure tin solders is higher due to higher melting temperature of tin (450°F / 232°C). Matte tin (in contrast to bright tin) is characterized by low whiskers growing therefore it is used in electronics.



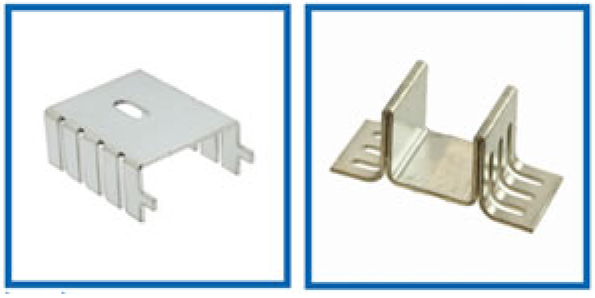
Should I use parts with a Matte finish or a Bright finish?

There are trade-offs to be considered with either finish, and the decision depends on your requirements and preferences. Parts finished with Bright tin provide a shiny, aesthetically pleasing surface finish. It also provides somewhat lower coefficient of friction for mating with other parts, boards and connectors as compared to Matte tin. For example, press-fit interconnects often use Bright tin plating to reduce the required insertion force which in turn can reduce damages of the plated through-hole in the printed circuit board (PCB). Conversely, Matte tin finish parts are better suited for solder reflow processes, and suffer less stress effects from elevated temperatures. Matte tin will also retain its original color under high temperatures, compared with Bright tin.

What is the visual appearance of Matte and Bright plating?

Matte has more of a dull, white surface, whereas Bright is more shiny and reflective. The Bright finish may also discolor towards a brown or black color when exposed to high temperatures such as those used in reflow soldering processes.

A example of two heat sinks is shown below. On the left is a Matte Tinned and on the right is a Bright Tinned with Matte on the left and Bright on the right.



(Images courtesy of connector manufacturer Assmann WSW Components)

What is the composition of Matte and Bright plating?

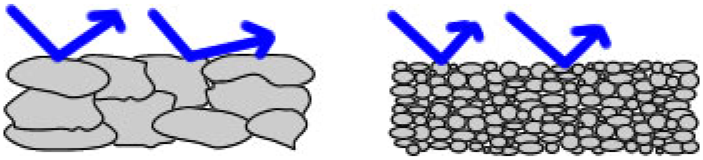
Both types are basically 100% pure tin (Sn). The differences in the chemical make-up are from the amount of co-deposit organic materials in the tin. Carbon is the predominate organic material used in plating and finishes. Matte tin contains relatively few additives, in the range of 0.005% – 0.05% by weight, and most typically around 0.015%. Bright tin has about 10 times more organic materials, in the range of 0.1% – 1.0% by weight, and most typically around 0.15%. The additives contribute to how the grains and boundaries form in the material.

How thick is the finish?

This depends on the product and usage. For electronic components and connectors, the plating is typically in the 150 micro-inch to 450 micro-inch thickness. This will vary with the manufacturer and the specific component.

If the materials are so similar, why is one dull in appearance and the other shiny?

The Matte tin has a larger grain size than Bright tin. This is nominally around 1um – 9um diameter for Matte and in the sub-micron range of 0.1um for Bright. The smaller grain size presents a more uniform surface for reflecting light, giving a shiny appearance. Below is a representation of the grains in the finish, with Matte on the left and Bright on the right.



Which is better for soldering?

Matte tin plating is suitable for lead-free reflow solder processes which has higher temperatures, typically in the range of 250C – 260C. It can also be used with all existing lead-alloy and lead-free solders and pastes, and is fully backward compatible with leader solder processes. Bright tin may discolor at the higher temperatures, and may also suffer more material stress during the reflow process.

What are the concerns regarding formation of Tin Whiskers?

Whiskers are microscopic, very thin fibers of metal which can grow from tin plated surfaces. These can grow for relatively large distances and can create short circuits between electrical components causing electrical failures. The material stress in the plating process is a root cause of whisker formation and growth.

Any final recommendations?

Many electronics suppliers are recommending using Matte finish when possible due to its better suitability with the lead-free reflow solder processing, less likelihood of whisker grow and that its appearance does not discolor under high temperatures.

Indication on Drawings

Electrodeposited matt tin coatings of 3 µm to 5 µm with an electrodeposited Ni base coat of 1 µm to 3 µm, applied prior to contact cutting.

gal Ni 1-3	gal mt Sn 3-5	***Prä***

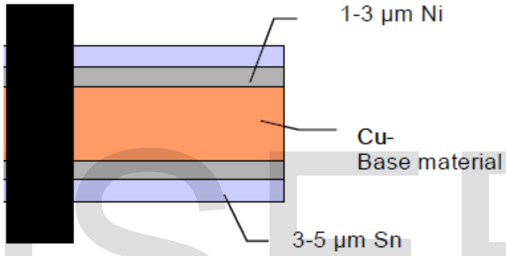


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Figure 1 & 2: Photo Courtesy of Andre Pelham (Intern)
NASA Goddard Space Flight Center

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Figure 3.1: https://nepp.nasa.gov/whisker/reference/tech_papers/2007-brusse-metal-whiskers.pdf
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