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Technical Report

The Tin Commandments: Guidelines For The Use Of Tin On Connector Contacts

TIN COMMANDMENTS

TIN OR TIN ALLOY COATINGS ARE COST EFFECTIVE AND RELIABLE ALTERNATIVES TO GOLD IF USED ACCORDING TO THE FOLLOWING GUIDELINES:

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

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ABSTRACT

Tin and tin alloy coatings are frequently considered as low cost options to gold on electrical connector contacts. With appropriate design considerations, they may often be successfully utilized as cost effective, and reliable alternatives to gold. In particular, special attention must be directed toward such attributes as normal force, mechanical stability, and state of lubrication. A set of guidelines has been formulated to assure acceptable performance of tin and tin alloy coated electrical contacts.

INTRODUCTION

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.

The following is a 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 a particular electrical contact design. These guidelines are similar to recommendations discussed previously by Whitley[1], but have been modified to reflect current thinking on the matter. A listing of the ten guidelines is given on the preceding page.

GUIDELINES

The following ten guidelines have been developed to successfully apply tin and tin alloy coatings to electrical contacts:

1. Tin Coated Contacts Should Be Mechanically Stable In The Mated Condition [2]

Relative motion of the contact interface during its service life is the most prevalent cause of failure of tin and tin alloy coated contacts. This failure mechanism is defined as fretting corrosion and is caused by small amplitude relative motion (fretting) at the contact interface in an oxygen bearing environment. The amplitude of this fretting motion generally falls between 10-200 micrometers (and may be in the form of either mechanical disturbance (e.g., vibration, shock, etc.) or differential thermal expansion (DTE). If the contact is coated with a non-noble metal, fretting repeatedly disrupts any pre-existing protective oxide surface layer exposing unoxidized metal to the environment. As fretting continues, the freshly exposed metal oxidizes, and oxide debris accumulates at the contact interface. In addition, metal transfer and wear of the contact can occur. This sequence of events often leads to a rapid and dramatic increase in contact resistance. Noble metals, such as gold, do not oxidize and are not susceptible to fretting corrosion.

The severity of contact resistance degradation of non-noble metal contacts subjected to fretting motion has been clearly demonstrated. For example, clean tin coated contacts with an initial resistance of 1 milliohm developed a resistance in excess of 1 ohm in less than 20 minutes when fretting action continued at a rate of 10 cycles per minute. However, no change in contact resistance during the same test was observed with tin coated contacts treated with antifretting lubricant.

For tin and tin alloy coated contacts, the most effective way to limit fretting is to minimize relative mechanical motion of the contact interface whether the motion is rotational, translational, or rocking in nature. There are several ways to improve mechanical stability. High contact forces can promote mechanical stability. Large interface areas also tend to increase the mechanical stability of the contact interface and protect particularly well against rocking and rotational motion. Additionally, a contact interface with two or more discrete contact areas spaced apart from each other improves mechanical stability.

Motion due to differential thermal expansion (DTE) of the various connector components is an important driving force for fretting motion which is often overlooked. DTE occurs when connector materials having different coefficients of expansion undergo temperature changes. The detrimental effect of DTE can be minimized by designing a connector so that the DTE is accommodated somewhere other than at the contact interface. For example, the effects of DTE often can be reduced by allowing the electrical contacts to mechanically float within the housing.

2. Tin Coated Contacts Need At Least 100 Grams Contact Normal Force [3,4]

In order to establish a stable electrical contact, a minimum of 100 grams (3.53 ounces) of normal force is recommended. Higher forces are desirable whenever possible. Limitations on the high force side are usually determined by:

A. Total force required to engage/disengage multiple-circuit connectors

B. Wear on the coating due to a large number of durability cycles (50 or more)

C. Physical size and strength of contact spring members

D. Spring deflection requirements (Resilient springs with large deflections are sometimes required in order to accommodate maximum and minimum dimensional tolerances between mating contacts. These requirements may be incompatible with the need for high contact force in 'worst-case' mechanical stability situations)

3. Tin Coated Contacts Need Lubrication [5]

When it is not possible to achieve mechanical stability -- that is, freedom from any motion of the contact interface, protective lubrication is necessary. A thin liquid lubricant film protects contact surfaces from the detrimental effects of disturbance or fretting motions by:

A. Reducing friction and generation of wear particles due to motion;

B. Protecting the surface from atmospheric oxidation, in and around the contact interface; and

C. Preventing fretting corrosion.

As contact forces approach the minimum recommended level of 100 grams (3.53 ounces), it becomes more important for lubrication to be used to prevent fretting corrosion. The lubricant can act to reduce wear, seal off the interface from the environment, and/or inhibit corrosion of the interface material as it is exposed by the fretting action. On the other hand, with higher contact forces lubrication may be necessary to reduce friction and wear during insertion cycling of the connector. In this respect, lubrication would permit the use of higher contact forces than would otherwise be allowed by frictional insertion force considerations.

Lubrication may be applied to only one side of a connector pair. However, it is recommended that both sides be lubricated whenever possible. Sufficient lubricant is normally transferred during engagement of the connector to provide fretting corrosion resistance to a contact. However, not enough lubricant is transferred to protect against overall chemical corrosion of the unlubricated part.

Lubricant formulations vary in complexity and effectiveness. They include pure mineral oil (marginal in life and effectiveness) and sophisticated mixtures of natural oils, synthetic oils, and additives for optimized performance. When possible, it is recommended to choose a lubricant with proven antifretting characteristics. If the presence of lubricant cannot be maintained throughout the lifetime of the connector, an alternative to lubrication such as a mechanically stable design or a noble metal coating should be considered.

4. Tin Coating Is Not Recommended For Continuous Service At High Temperatures [6]

At elevated temperatures, the performance of tin coated electrical contacts is degraded by aging effects due to a rapid increase in the rate of diffusion of copper and tin. This results in a change in the composition and effective thickness of the tin coating as a hard, brittle, non-uniform resistive layer of copper-tin intermetallic compound (IMC) grows between the tin layer and the copper base metal. It is recommended that a nickel underlayer be applied for elevated temperature applications because the growth rate of the nickel-tin IMC is lower than that of the copper-tin IMC.

In addition to the detrimental effects of IMC, tin loses a significant portion of its mechanical strength resulting in substantial creep effects at temperatures >100 °C (212 °F). Special design parameters such as high contact force, thick coatings or limited time-temperature exposure are needed to successfully avoid contact problems.

High temperature operation would impose special requirements on contact lubricants, and under this condition, the lubricant must withstand the time and temperature requirements representative of the applications.

While tin coated contacts have been used at higher temperatures on an intermittent basis, e. g, high force contacts for automotive applications, use at temperatures >100°C (212 °F) should be based on evaluation to verify acceptable performance for the intended application.

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 Contacts [1, 7, 16, 22]

The electrical performance of these various coatings is roughly equivalent.

A. Coatings with bright appearance are considered more aesthetically appealing.

B. Both bright and matte coatings are solderable; however, plated coatings brightened with organic additives can become unsolderable when plated with excessive brightener content. Matte tin should be kept clean to ensure consistent solderability. The solderability of matte tin is initially similar to that of hot air leveled tin (HALT) and reflowed tin coatings of similar thickness. However, matte tin plating solderability will deteriorate faster than that of HALT and reflowed tin.

C. 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.

6. Electroplated Tin Coatings Should Be At Least 100 Microinches Thick [8, 16, 22]

Tin and tin alloy coatings should be at least 100 microinches thick, mainly to reduce the effects of intermetallic compound growth on solderability and for increased durability. In order to minimize the effects of high coefficient of friction, the maximum recommended thickness for tin coatings is 300 microinches.

Coatings thinner than 100 microinches have been successfully used in special cases. A particular case involved pre-tinned stock with 30-80 microinches of tin applied as a hot dipped coating. This material has been used for many low cost connectors where price considerations are predominant and the product does not need to be solderable. The thinner electrodeposited coatings have generally been unsuccessful due to porosity and intermetallic growth and they do not afford good environmental protection.

7. Mating Of Tin Coated Contacts To Gold Coated Contacts Is Not Recommended [9,10,11]

Tin-to-gold interfaces are more susceptible to fretting corrosion related failures, and lubricants are not nearly as effective at stabilizing contact resistance as they are with tin-to-tin interfaces. Tin tends to transfer onto the gold surface which can ultimately lead to accumulation of tin oxide on the harder gold substrate. It is more difficult to disrupt the tin oxide on the harder gold substrate than it is to break through the tin oxide that forms directly over tin.

The warning against mating tin with gold also applies to mating tin with palladium and its alloys because the fretting behavior of tin-to-palladium and its alloys is similar to that of tin-to-gold. This warning does not apply to the case of the tin-to-silver interface because its fretting behavior is similar to that of tin-to-tin.

8. Sliding Or Wiping Action During Contact Engagement Is Recommended With Tin Coated Contacts [12]

Tin and tin alloy coated contacts should be designed with wipe during insertion to aid in breaking through the oxide surface layer to establish metal-to metal contact. Even Zero Insertion Force (ZIF) connector designs should include wipe. A less satisfactory method of assuring break-through of the oxide layer would be to design the contacting surface with sharp points to penetrate the opposing surface. The problem with incorporating these force concentrating points into the design of the contact is that they can decrease the durability of the contact. This decrease in durability is due to the fact that upon insertion, penetration of the contact surface can cause premature exposure of the underlying metal to the environment.

9. Tin Coated Contacts Should Not Be Used To Make Or Break Current [13]

Tin and tin alloys are not arc resistant because they have relatively low melting temperatures. Therefore, 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 [14,15]

As long as fretting corrosion can be controlled, there are no limits to the voltage and current levels at which these contacts may be used.

SUMMARY

The objective of these guidelines is to identify and recommend conditions under which tin and tin-alloy platings may be used to establish and maintain acceptable values of electrical contact resistance. While there are cases in which the use of gold on connector contacts is necessary, e.g., low normal force contacts and military-aerospace connectors, there are many applications in which tin coated contacts will suffice. A clear choice may not always be evident because many application conditions may be unknown. However, these guidelines should direct the selection process along rational lines.

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