Gold Verses Tin for Use in Contact Applications

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With the appropriate design, tin platings are cost effective, reliable alternatives to gold.

Gold is considered the metal of choice for highly reliable contacts. It avoids porosity, diffusion, and durability problems. However, hold is relatively expensive. In many applications, less expensive non-noble alternatives to gold are acceptable. The rational use of gold when needed and a consideration of alternatives, when feasible, will maximize both cost effectiveness and reliability.

The decision to use non-noble alternatives should be based upon sound engineering criteria as well as cost. Tin and tin alloy platings are effective finishes for contacts because of their low cost, conductivity properties, and solderability. Even major objections (i.e., durability and corrosion resistance) to tin and tin alloy platings can be overcome with proper application. If tin or tin alloy platings are used for applications that require relatively few mating cycles, their durability is not an issue. The appropriate contact design and /or use of lubricants protect the contact from oxides and corrosion.

Guidelines for the use of Tin Plate on Electrical Contacts

The motion of the contact interface during its service life is the single most important cause of failure of tin-plated contacts. This failure mechanism is defined as fretting corrosion and is driven by small amplitude relative motion at the contact interface. Fretting action generally falls in the 10 to 200 micrometer range and may be caused by either mechanical disturbance (vibration) or differential thermal expansion. Fretting action causes metal transfer and wear. If the contact is made of a base metal, oxidation of the surface and the wear debris occurs, which leads to a process defined as fretting corrosion. This often leads to rapid and dramatic increases in contact resistance. Noble metals, such as gold, do not oxidize and are not susceptible to fretting corrosion.

The severity of resistance degradation to base metal contacts subjected to fretting motion has been clearly demonstrated. In one series of tests, clean tin-plated contacts with initial resistance of 1 milliohm developed a resistance in excess of 1 ohm in less than 20 minutes when fretting action continued at the rate of 10 cycles per minute. However, lubricated tin plate and gold contacts showed no change during the same test. Lubricant formulations vary in complexity and effectiveness. They include pure mineral oil (marginal in life and efficiency) and sophisticated mixtures of natural oils, synthetic oils, and additives for optimized performance. For tin-plate contacts, the most important factor is to attain mechanical stability (i.e., the prevention of motion at the contact interface). This motion could be rocking, rotation, or translational in form. Mechanical stability can be achieved in a number of ways. For example, high contact forces can promote mechanical stability. Large interface areas tend to increase stability at the contact interface and protect, in particular, against rocking and rotational motion.

Additionally, an interface with two or more discrete contacts spaced apart from each other provides stability, especially when dealing with mechanical disturbance effects.

Motion due to differential thermal expansion of the various connector components is an important driving force for fretting motion, and is often overlooked. This risk may be assessed by subjecting the mated connector to thermal cycling. It is controlled by the choice of materials and/or by designing the connector configuration such that the expansion/contraction is accommodated somewhere other then at the contact interface. As an example, mechanical float of contacts in their housings is often able to negate the effects of differential thermal expansion.

Forces, Friction, and Lubrication

Higher normal forces are desirable whenever
It is possible to provide them. Limitations on
These high forces are usually determined by:

- Total effort required to engage/disengage multiple circuit connectors due to high friction
- Wear on the plating from large numbers of mating cycles; durability cycling requirements of 50 mating cycles or more is considered large
- Physical size and strength of contact spring members
- Spring deflection requirements; dimensional tolerances sometimes require resilient springs with large deflections so as to accommodate maximum and minimum tolerance conditions between mating contacts. This may be incompatible with high contact force in the worst-case condition

When it is not possible to achieve absolute 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. It protects the contacts by:

- Reducing friction and the generation of wear particles due to motion
- Safeguarding the surface from the atmosphere oxidation, in and around the contact interface
- Preventing fretting corrosion

As contact forces approach the minimum recommended level of 100 grams, it is important to use lubrication to protect against fretting and disturbance motions. On the other hand, with higher contact forces, lubrication may be necessary to reduce friction and wear during engage/disengage cycling of the connector. Lubrication will permit higher contact forces than would otherwise be allowed by friction force.

Lubrication may be applied to only one side of a connector pair. However, it is recommended, whenever possible, to lubricate both halves. Enough lubricant is normally transferred during engagement of the connector to prevent fretting corrosion; but there is not enough transference to protect against overall chemical corrosion of the unlubricated part.

The softening temperature of tin is 100 degrees C. This is the temperature at which tin loses virtually all of its mechanical strength and tends to flow under the high unit pressure at the contact interface. The rate of diffusion between tin and copper increases rapidly above 100 degrees C, causing formation of tin-copper intermetallic ally, which is hard, brittle, highly resistive, and undesirable in electric contacts.

As the operating temperature approaches 100 degrees C, consideration should be given to the use of a nickel underplate. Nickel is a better diffusion barrier than copper and would mitigate the problems associated with the formation of an inter metallic. Operation at these high temperatures would impose special requirements on contact lubricants. The lubricant must withstand the time-temperature requirements of the application.

Tin Types and Coatings

Bright tin, matte tin, and tin-lead alloy platings are roughly equivalent.

- Bright tin is currently more aesthetically appealing
- Both bright tin and matte tin are solderable; however, bright tin is more sensitive to plating parameters and can easily become unsolderable. Matte tin should be kept clean to ensure consistent solderability.
- Pure tins, both bright and matte, are susceptible to tin whisker growth.
- Tin-lead coatings of solder composition (50-50, 60-40) can be soldered at lower temperatures than higher tin-to-lead ratios.
- Tin coatings on brass should have either a nickel or a copper undercoat to prevent zinc migration from the base metal; the main effect of zinc migration is to reduce solderability.

Whisker growth is a main drawback for using tins and can cause scoring and scratching. Whisker growth may be prevented or minimized by:

- Plating bath control
- Using a nickel underplate, especially for zinc-bearing alloy substrates
- Thermal annealing of the tin plate
- Reflowing
- Applying a hot tin dipped process, as compared to electroplating
- Using small amounts of alloying elements (i.e., 5% lead)

Thinner coatings have been successfully used in special cases. A particular case involves pretinned stock with 30-80 microinches of tin applied as a hot dipped coating. This material has been used for many low-end connectors where price is a consideration and the product does not need to be solderable. Light electrodeposited coatings, generally, have been unsuccessful because they tend to be porous and do not afford good protection.

Electrodeposited coatings of 60-80 microinches have been successfully used in selected applications. However, a thickness of 100 or 150 microinches minimum is recommended for separable connector systems. Thicknesses from 200 to 300 microinches have been used when better corrosion protection and wear life are needed. The tin-to-gold interface is susceptible to fretting corrosion-related failures. However, in this case, lubricants are not nearly as effective in stabilizing contact resistance as they are with the tin-to-tin interface. The mechanism is related to the transfer of tin to gold, ultimately leading to the buildup of tin oxide on the harder gold substrate. Disruption of this oxide is more difficult than for tin oxide on tin. Additionally, the tin-to-gold interface is subject to galvanic corrosion and may degrade in humid environments.

The warning concerning the mateability of tin-to-gold extends to palladium and gold flashed palladium. The fretting behavior to tin-to-palladium is similar to that of tin-to-gold. This warning would not be extended to the case of tin-to-silver; the fretting behavior is similar to that of tin-to-tin. Even the zero-entry-force type connector should incorporate some wipe. The alternative is to provide sharp points on the contact to break through the tin oxide surface film. This is a less satisfactory way of breaking though the films from the standpoint of wear life and plating penetration to the underlying base metal.

Tin and most tin alloys have relatively low melting and vaporization temperatures. They are not arc resistant; arcing quickly destroys tin plate. Tin-plated contacts should not be used to make or break currents. Under the guidelines used for the preceeding conditions, there are no limits to the voltage and current at which the contacts may be used. This includes microvolt/microamp levels as well at the volt/ampere region.