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WHITE PAPER

COMBATING CORROSION IN HIGH RELIABILITY CONNECTORS

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The buildup of an insulating film on the surface of a connector (corrosion) is responsible for most failures of low voltage, low current, signal level circuits in computers and telecommunication equipment. Corrosion is a chemical process that gradually deteriorates the surface of a metal by oxidation or chemical reaction. Metal contact surfaces are subject to corrosion in the form of galvanic attack, which takes place when high humidity and ambient trace chemicals combine to form an adsorbed electrolyte on the contact surface.

The occurrence of corrosion, however, also depends on the integrity and chemical activity level of the connector's metal surface. If the contact surface must remain stable for a long period of time (a necessity for telecommunication connectors), the surface is coated with a precious metal such as gold through electroplating or cladding. Using and maintaining the appropriate surface coating can help prevent corrosion.

UNDERSTANDING GALVANIC ATTACK

Galvanic attack is an electrolytic process similar to the action in a battery cell. Therefore, these four elements must be present for galvanic corrosion to occur: an electrolyte, an anode, a cathode and a current path. The degree of corrosion depends on the following conditions:

- Ambient temperature
- Environment
- Humidity
- Type of metal product
- Type of corrosion product

Two environmental conditions—relative humidity in excess of 60 percent and the presence of ambient gases such as chlorine, nitrous oxide and sulfur dioxide—are the chief catalysts for creating an electrolyte. High humidity levels allow water vapor that contains the dissolved gasses to condense on the connector surface, creating a mild conductive acid.

Local anodes and cathodes are provided by breaches or pores in the contact surface coating. The exposed base metal at the bottom of the pore becomes the anode; the precious metal coating forms the cathode.

Finally, because the coating, the interface, the base metal and electrolyte are conductive, the current path is complete.

Metallic Coatings Corrosion

Galvanic Corrosion

- Anode Reaction – Oxidation (Corrosion of Base Metal)
- Cathode Reaction – Reduction (Precious Metal Coating)
- Must Have a Current Path
- Must Have Liquid for Electrolyte (Absorbed H_2O)

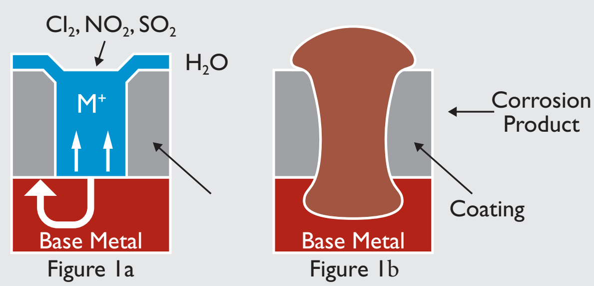

Figure 1. Four conditions must be met for galvanic corrosion to occur. There must be an electrolyte, an anode, a cathode and a current path.

The rate of corrosion is a function of the corrosion product. Copper corrosion products are very porous, allowing continuous water penetration. Also, they react with water to form additional compounds, promoting rapid and continuous corrosion. Products from nickel corrosion are impervious to moisture and adhere tenaciously to the metal surface, forming a moisture barrier. As a result, galvanic attack from nickel tends to be self-limiting.

Ultimately, corrosion will occur if all four requisite conditions are present, regardless of the surface coating. To combat corrosion, at least one of the four conditions must be eliminated. Because manufacturers can control the quality of the surface coating, they can decrease the potential for anode and cathode formation.

MAINTAINING SURFACE COAT INTEGRITY

The most common source of a breach in the surface coating is porosity, defined here as a discontinuity in the coating that exposes the substrate. A breach can occur during the manufacture of the coating, during the coating process, or during me manufacturing, handling and testing of the connector.

Both electroplated and clad metals are subject to excessive porosity. For electroplated metals, this condition results from foreign particles or poor surface finish on the substrate; contaminated electroplating solution; uneven plating due to surface roughness; internal stresses that cause the coating to self-destruct in high tension regions; and brittleness that renders the surface vulnerable to cracking during forming operations or rough handling.

Clad metals, on the other hand, are more malleable and maintain their integrity during forming. Porosity will more likely result from foreign particles on the surface of the substrate or excessive surface roughness. However, clad coatings are subject to false porosity readings caused by interdiffusion.

During annealing—a part of the cladding process—atoms from thee substrate material will migrate through the grain structure of the substrate and the coating material (Figure 2). This diffusion leaves regions of base- metal-rich alloys at grain boundary junctions on the surface of the connector material. Porosity testing will show these regions as pores, usually measuring less than 0.003" dia. This is not true porosity and should be ignored.

For plated materials, migration along grain boundaries presents an additional source of corrosion. Electroplated hard gold is about 10 percent organic material. These organics tend to widen the grain boundaries, giving corrosive elements an easier path to the substrate (Figure 3).

For both clad- and plated-metal systems, extreme surface roughness promotes porosity, but placed surfaces tend to be more vulnerable. Plating accumulates more readily on the peaks and valleys of rough surfaces. A normally acceptable average thickness may be poorly distributed, leaving breaches in the surfaces (Figure 4). When measuring the plating thickness with x-ray fluorescence—a procedure that determines the average coating thickness—a poor coating distribution will go undetected.

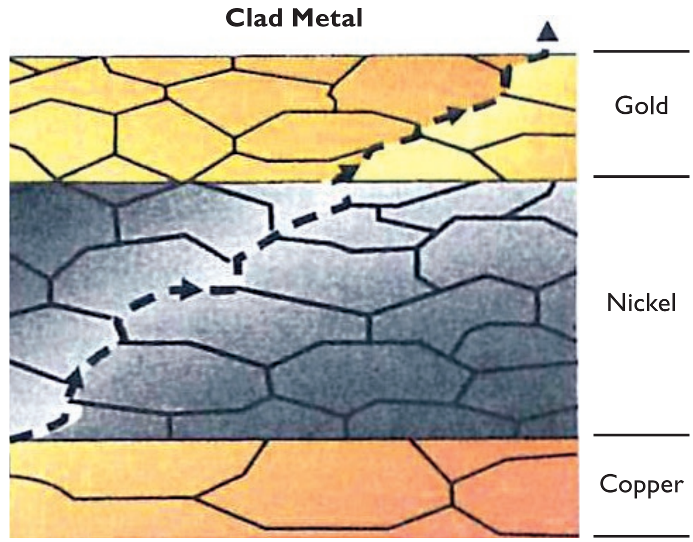

Figure 2. Nickel barrier tends to be thicker in clad products. Longer diffusion paths inhibit base-metal migration to the surface.

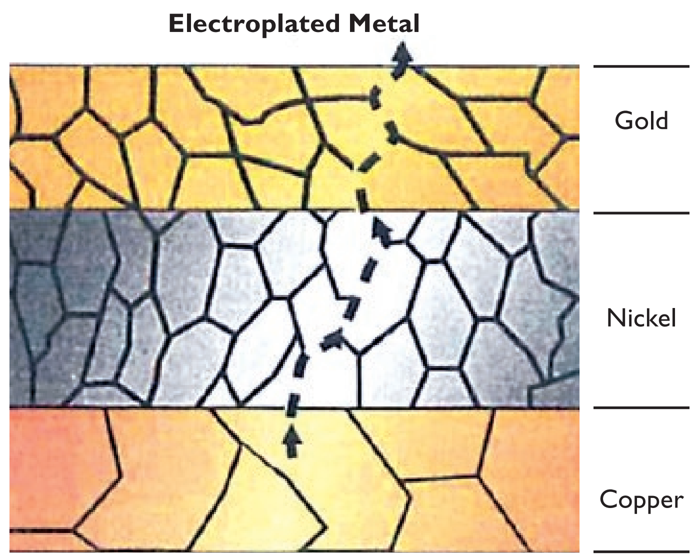

Figure 3. Cobalt-organic complex widens the grain boundaries, helping base metals diffuse more easily to the contact surface. The diffusion path is shorter and more direct in electroplated-metal systems.

Surface roughness also contributes to adhesive and abrasive wear. The basis for increased wear is twofold. First, wear initiates at surface high spots. Second, the uneven distribution of plated gold on rough surfaces makes them more susceptible to excessive wear. For example, the plated connector for an automobile safety component exhibited unacceptable porosity after five wear cycles, even though it passed x-ray florescence testing. Although normal life-cycle usage of this component would only be a few wear cycles, routine assembly and diagnostics required an estimated 10 cycles. The specification called for 50 cycles to provide an acceptable margin of safety.

TESTING AND EVALUATING METAL SURFACE COATING

Connector manufacturers use two standard tests to monitor their metal coating processes: Uncontrolled direct attack, which tests for nitric acid and vapor per ASTM B-735; and controlled corrosion, electrographic testing per ASTM B-741. In addition, the tests provide an indirect method for predicting service life.

Electroplating on Rough Surfaces

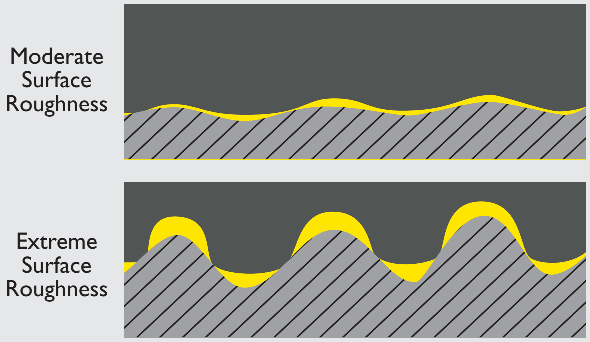

Figure 4

Figure 4. Electroplating accumulates more readily on the peaks and valleys of extremely rough surfaces, leaving breaches on the surface that invite galvanic attack.

Field exposure can be simulated using Battelle mixed flowing gas environments. Forty-eight hours of this accelerated testing simulates one year of field exposure. The Battelle test creates four classes of environments, representing a range of potential galvanic attack situations. Test classes II and III generate pure corrosion, the environments in which most signal level connectors are used. However, class III, where there are high concentrations of corrosive gases, corrosion product may be generated to the point where it begins to migrate, spreading a film over an extended area of the contact surface. This phenomenon, called "creep," can originate from pores or bare edges where the metal has been stamped. An ASTM committee is developing a specification for class II and III environments. One manufacturer has collected a large amount of data regarding corrosion resistance of a number of coated metal systems within the Battelle environments.

REDUCING POROSITY WITH GOLD

Metal coatings less noble than gold such as palladium, palladium nickel, and palladium silver, are more susceptible to galvanic attack from low levels of ambient chlorine in the atmosphere. Galvanic attack is attenuated by applying a thin coating of gold over these materials, usually 3 to 5 µin of plated gold or 10 to 20 µin of 18 carat clad gold alloys. The thicker clad coating of gold alloy exhibits much less porosity than the thinner plated gold coatings.

Numerous lab studies confirm that the clad gold coating provides a significantly higher level of corrosion protection. Moreover, there is no cost penalty because the gold alloy is less expensive than the gold used in plating.

WHAT COATING SHOULD A CONNECTOR FEATURE

Male connectors are typically electroplated because when mated, they are entirely exposed and require protection. For most applications, such as wire pins and stamped blades, the cladding process cannot be used. However, clad metals have been successfully employed in stamped and formed foldover blades.

For female connectors, the cost vs. performance of plated and clad metal materials should be evaluated on the basis of total manufacturing costs. In this situation, clad materials combat corrosion at comparable or lower costs because they may be formed after the cladding process, wheras closed end female connectors are typically preformed, plated and then finish formed to avoid cracking the coating. The extra manufacturing step adds to the cost.

Higher reliability applications require clad metal connectors manufactured for high corrosion resistance. For example, one telecommunications company has used clad metal connectors in digital switching systems for more than 15 years. During that time, more than five million pounds of pore-free material has been manufactured and shipped; none has been returned.

CONCLUSION

Galvanic corrosion can be significantly attenuated through connector design, materials selection and handling practices that maintain surface integrity and minimize connector exposure to conditions that promote galvanic attack. When selecting connectors for high reliability applications, keep in mind that a thin gold overcoating can significantly reduce corrosion. Clad gold alloy coatings also offer higher levels of protection without cost penalty for many female end connectors. For more information or to speak with an engineer, visit www.materion.com/connectors.