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Raiders of the lost arc - A continuing overview of arcing between contact surfaces in separable electronic connectors.

- **Metal Transfer**
- **Welding**
- **Activation**
- **Contact Bounce**

The next issue of Technical Tidbits will summarize coatings for electrical contacts.

The Effects of Arcing

Last month's edition of Technical Tidbits described how and why electrical arcs occur. Now that the causes have been discussed, it is time to move on to effects. If arcing were completely harmless, there probably would not be much interest in studying this phenomenon. Since so much time and effort is spent on the subject, it is reasonable to assume that arcing has several negative consequences. This assumption would turn out to be correct.

One of the effects of arcing is the generation of electromagnetic interference. Any electrical noise in a device can be detrimental to its functionality. If arcing cannot be prevented, the interference can be minimized by shielding and filtering the affected circuits.

Metal transfer is another consequence of arcing. As mentioned in last month's edition, electrons will pass from the cathode to the anode during an arc. In turn, the anode may release positive ions from its surface, which travel to the cathode. This would result in transfer of metal from the anode to the cathode. This is usually the case. However, in certain circumstances the direction of metal transfer may be reversed. The direction depends on the anode and cathode materials, and the length of the arc. (Shorter arcs will tend to show transfer from the cathode to the anode.) In AC circuits, the polarity of the contacts continuously changes, so the instantaneous direction of transfer depends on which of the contacts happened to be the anode and cathode at the moment of interruption. Over time, however, the net transfer will be approximately zero.

Welding may occur on contact closure. The heat created by the arcing may cause the contact surfaces to melt. If the contacts were to close on the molten metal, they may weld together. If the opening force is sufficient, the weld will be ruptured when the contacts are opened, resulting in some mechanical damage to the contact surfaces. If the opening force is insufficient, the contacts may not separate, and the separable interface will suddenly become a permanent bond. It also is important to note that welding can occur without arcing, since the sudden inrush of current upon making contact can be substantially higher than the steady state current, resulting in temporary melting of the interface. Silver tin oxide, silver cadmium oxide, and silver carbon composites have high melting temperatures and are less likely to weld than pure silver contact surfaces.

In switches, the energy of impact can damage the contact surfaces. Over many cycles, small fatigue cracks will appear and grow at the interface. This results in mechanical wear of the contact surfaces over time. The total erosion of the contact interface is a combination of material transfer, material vaporization, and mechanical damage from impact, fatigue, and separation of welded surfaces. As stated in Electrical Contacts, Principles and Applications, the amount of wear that occurs on each contact cycle depends on many factors including the current level, arcing time, size of the contact gap, the gasses present in the gap, opening and closing velocity, contact stress, the number of bounces on closure, movement of the arc on the contact surfaces, and the contact size, shape, and material.

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The Effects of Arcing (continued)

The high energy of arcing will result in the formation of corrosion products such as oxides, chlorides, sulfides, nitrides, and carbon on the surface of the contacts. This will cause the electrical resistance of the contact interface to increase over time. Carbon deposits also are much more susceptible to arcing than standard contact materials. Arcs therefore will form more readily and last longer. This is referred to as **activation** of the contact surface.

Contact bounce has a significant effect as well. A closure arc begins the sequence, followed by an impact, then an opening arc as the contacts separate, and the cycle repeats until bounce subsides. In this case a single contact closure results in multiple arcs and impacts. In order to minimize the wear of the contacts, it is necessary to minimize the number and height of the bounces. This can be achieved by reducing the impact velocity, increasing the energy absorption upon impact, increasing the contact force, and reducing the inertia of the contact. A reduction in impact velocity implies a reduction in opening velocity, which will increase the duration of opening arcs. Soft contact materials will absorb more energy during impact, but are more susceptible to mechanical wear than hard contact materials. However, arcing will heat and soften the contact surfaces, which increases the amount of energy absorbed at impact and improves the damping rate of the bounces. Unfortunately, this may make the surfaces more susceptible to welding. Bouncing therefore can best be controlled by using small, strong, stiff contacts with low inertia and high contact force, and by using contact materials that are most resistant to arc formation and wear.

Another way to control the damage due to arcing is to minimize the arcing duration. This can be accomplished by increasing the contact gap as quickly as possible. This may make the contact more likely to bounce, but an arc of sufficient strength and duration can completely vaporize the contact! Therefore a balance must be found that minimizes the combined damage of opening arcs and contact bounce.

Arcing will become increasingly important as the automotive industry implements higher voltage architectures for electric and hybrid electric vehicles. These voltage levels are certain to create arcs. Therefore, contacts must be designed with arcing in mind. Care must be taken to optimize the contact velocity, and to use the appropriate contact materials. The cost of plating will probably become a larger percentage of connector cost than the base metal. Therefore, it is best to select the materials which allow easy miniaturization of the connectors (high strength and good formability), and which are resistant to high current levels and heat (high conductivity, good stress relaxation resistance). High performance alloys like copper beryllium thus become much more cost effective in these cases.

Written by Mike Gedeon of Materion Brush Performance Alloys Customer Technical Service Department. Mr. Gedeon's primary focus is on electronic strip for the telecommunications and computer markets with emphasis on Finite Element Analysis (FEA) and material selection.

TECHNICAL TIDBITS

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References:

**Slade, Paul G.
Electrical Contacts Principles and Applications
1999 Marcell Dekker, Inc. New York**

Please contact your local sales representative for further information on arcing or other questions pertaining to Materion or our products.

Health and Safety

Handling copper beryllium in solid form poses no special health risk. Like many industrial materials, beryllium-containing materials may pose a health risk if recommended safe handling practices are not followed. Inhalation of airborne beryllium may cause a serious lung disorder in susceptible individuals. The Occupational Safety and Health Administration (OSHA) has set mandatory limits on occupational respiratory exposures. Read and follow the guidance in the Material Safety Data Sheet (MSDS) before working with this material. For additional information on safe handling practices or technical data on copper beryllium, contact Materion Brush Performance Alloys