MATERION

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TECHNICALTIDBITS

MATERION PERFORMANCE ALLOYS

We have clearance, Clarence. – Under high enough electrical stress, even electrical insulators have their breaking points.

- **Volume Resistivity (Bulk Resistivity)**
- **Surface Resistivity (Sheet Resistivity)**
- **Electromigration**
- **Electrochemical Migration**
- **Dendrites**
- **Tracking**
- **Comparative Tracking Index**
- **Clearance**
- **Creepage**

The next issue of Technical Tidbits will discuss ferroelectric and piezoelectric materials.

SURFACE-RELATED FAILURES OF DIELECTRIC MATERIALS

The last issue of Technical Tidbits described how dielectric materials (intended to be electrical insulators) can break down and conduct current through their internal volume. This occurs when the applied electrical potential gradient through the material exceeds a certain critical value (dielectric strength) that depends on material thickness, quality, temperature, humidity, frequency and duration of the applied field, geometry, etc. However, dielectric materials can also fail by allowing the formation of conductive paths across their surfaces.

Electrical resistivity can be measured two ways. One is **volume resistivity**, also known as **bulk resistivity**, which is the inverse of electrical conductivity. It determines how much an applied voltage is required to allow a given quantity of current to flow through the material.

Surface resistivity (also known as **sheet resistivity**) describes the resistance to current flowing across the surface of a material. This can be very different from the resistance to current flowing through the material. For a perfectly clean, undamaged surface on a dielectric, the surface and volume resistivity should be equivalent. Surface contamination (especially if it contains carbon) can conduct electricity, thus reducing the effective surface resistivity far below its design value. Often, a dielectric material is used to separate conductive circuit elements, so a high surface resistivity is important in order to avoid short circuits.

Electromigration is the tendency for atoms of a conductor to move under the influence of an applied electrical current. An electrical current will naturally move through conductor such as silver or copper when a voltage is applied. As the electrons that make up said current are moving through the conductor, they may transfer some of their momentum to the atoms within the conductor. These atoms will appear to be drawn to areas of positive charge and away from areas of negative charge. Since the current is more intense in areas of reduced cross section, the effect is intensified there. Over time, this can result in voids appearing in the middle of circuit traces.

Something similar can happen to dielectric materials. **Electrochemical migration** also occurs under the influence of a potential between separate conductors across the surface of a dielectric or other insulating material. However, moisture and surface contamination is required for this reaction (unlike electromigration within conductors). The surface does not have to be visibly wet; atmospheric humidity may be sufficient to start the reaction. Atoms of copper, silver, or other conductor materials can dissolve into solution with moisture, and can be drawn toward a conductor of opposite charge, before effectively electroplating out on the surface of the dielectric. The "replated" copper or silver deposits form tree-like growths (called **dendrites**) that grow out of one conductor across the surface of the dielectric material. These branches grow until they bridge the surface between two such conductors, resulting in a short circuit.

Tracking is the formation of a conductive path between such charged conductors across the surface of the insulator. Unlike electrochemical migration, tracking does not involve the movement of conductive atoms from inside the conductors. It forms a conductive path from surface contaminants. This contamination could come from any number of sources, such as human skin contact, residual flux residue from soldering, deposition of corrosive substances from air or liquid contact, etc. It usually involves interaction between the surface contamination, moisture, and the surrounding air. When two are more conductors are bridged, high current can flow through the short. If the underlying dielectric is a polymer, it can be effectively "burned" by the subsequent heat, resulting in a highly conductive path of carbon.

The tendency to form tracking on the surface is measured by the **comparative tracking index**. This test involves placing electrodes on a clean dielectric, and dropping 50 drops of an electrolytic solution onto the dielectric between the electrodes. When tracking occurs, the measured current between the electrodes will greatly increase. The voltage threshold at which failure occurs is the comparative tracking index.

SURFACE-RELATED FAILURES OF DIELECTRIC MATERIALS (CONTINUED)

Often, you will hear the terms "creepage" and "clearance" used when distances between conductors on a printed circuit board, or between adjacent contacts in an electrical connector. These terms are used to describe the required distances necessary to prevent failure by one of the modes discussed above under given circumstances.

Clearance is the linear distance, through the air, of adjacent conductors. (See Figure 1). When talking about clearance, you are primarily concerned about the potential for failure by electrical arcing between the conductors. The clearance must be large enough so that the potential between the conductors is larger than the breakdown voltage for that distance. Higher potential differences between the conductors require larger clearances, while lower voltages allow for smaller clearances.

Creepage is the shortest distance between two conductors along the surface of a dielectric (also shown in Figure 1). The creepage path is where failure by tracking or by electrochemical migration is most likely to occur. Is Conductors can be spaced closer together on dielectric materials with higher comparative tracking indices, so shorter creepage is allowed. If the comparative tracking index is lower, then the creepage must be increased. Similarly, lower voltage allows for shorter creepage distance, while higher voltage requires greater creepage.

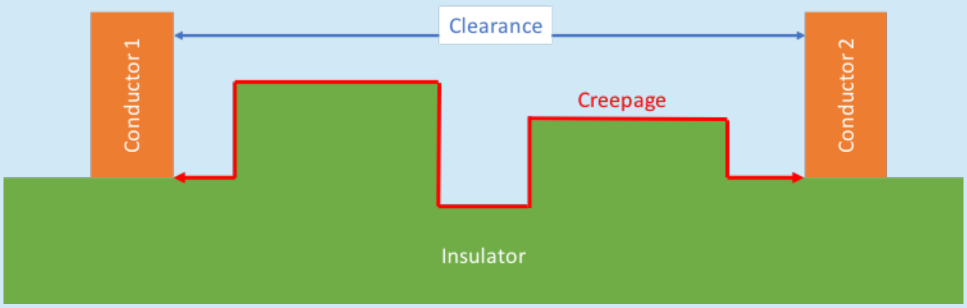

Figure 1. Creepage and Clearance.
Clearance is simply the straight-line distance through the air between two adjacent conductors, as shown in the blue line above. Creepage is the distance across the surface of the insulator, as shown by the red line. The IEC has specific rules about how to calculate this distance, depending on the exact geometry of the insulator between the conductor. For example, for sufficiently narrow grooves, the current path may be across the top of the groove, bypassing the walls and floor of the groove.

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IEC 60664-1:2007 Insulation coordination for equipment within low-voltage systems - Part 1: Principles, requirements and tests ©2007 IEC

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