SAE Aerospace
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AEROSPACE INFORMATION REPORT

SAE AIR4129

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Metallic Whiskers

RATIONALE

AIR4129 has been reaffirmed to comply with the SAE five-year review policy.

1. SCOPE

This AIR presents an abbreviated review of the metallurgical phenomena known as whiskers. It is not all encompassing, but rather it is intended to introduce the design engineer to the technical issues of metallic whiskers and the problems they can cause.

2. REFERENCES

There are no referenced publications specified herein.

3. DEFINITION

A whisker is a tiny needle or hair-like crystal growth, emanating from the surface of mostly pure metallic surfaces. Numerous metallic whiskers are known, the most prevalent are tin, zinc, cadmium, indium, and antimony. Whiskers grow from the base to the tip. Whiskers are not foreign particles or substances, rather they grow via a metallurgical diffusion mechanism from the metallic surface outward. The metallurgical principles upon which they exist are well founded and understood. Their growth mechanisms are currently being debated. Their presence can have serious consequences.

4. APPEARANCE AND EFFECTS

4.1 Metallic whiskers are electrically conductive and as such have been noted to cause electrical short circuits in microelectronic and integrated circuit devices. Whiskers pose a substantial reliability risk to electronic assemblies and result in equipment failures leading to aircraft and aerospace accidents which have occurred. The diameter of metallic whiskers have been observed anywhere from 0.5 to 10 µm. The length of these whiskers have been observed from 1 to 2 mm to over 10 mm in length. The name whisker was applied to this metallurgical phenomena as indeed its appearance under a microscope closely resembles a whisker. In electrical devices where the voltage (EMF) and current are relatively high, whiskers are usually not a problem as they are harmlessly vaporized and they are not capable of sustaining electrical flow high enough or long enough to cause a short circuit at STP (standard temperature and pressure). However, in space-based applications or systems under vacuum, such whisker vaporization can create a plasma (metal vapor arc) capable of supporting substantial current flow (analogous to plasma arc welding). Whisker formation is not a new phenomenon, having been observed in the 1940s, if not earlier. The precise reason for whisker formation and growth is still debated.

4.2 Formation and Growth Mechanisms

4.2.1 Whiskers apparently grow via a diffusion process within the finish or on the surface. Whiskers may grow in response to residual stresses, especially compressive stress within the metallic plating. Other theories state that whisker growth is attributable to recrystallization and grain growth affecting the grain structure of the metallic plating.

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4.2.2 Residual stress within the plate is a result of the plating bath chemistry, plating parameters such as current density, plating time, and other control factors. The presence of organic brighteners in the plating bath appear to promote whisker formation. Bright metallic plating can induce higher residual stresses within the plating.

4.2.3 The diffusion of substrate material into the metallic plating has been observed to lead to the formation of intermetallic compounds that alter the lattice spacing of the plating. The deformation in the crystal lattice may impart sufficient stress to the plating that may be relieved by the actual formation of whiskers.

4.2.4 Externally applied compressive stresses from clamping, bending, stretching, or torquing of fasteners have been observed as providing sufficient stress to induce whisker formation

4.2.5 Surface damage such as nicks or scratches can result in whisker formation.

4.2.6 Thermal forces resulting from a differential thermal expansion between substrate and metallic plating has been observed as sufficient to induce whisker formation.

4.2.7 Elevated temperature, humidity, and imposed current flow can accelerate whisker formation.

5. MORPHOLOGY

5.1 Shapes and Size

Whiskers can be straight, kinked, hooked or forked. Their outside surfaces are often grooved. Some may form as nodules or pyramid structures. The length can be as long as several millimeters. Some whiskers up to 10 mm in length have been reported. The diameter can range up to 10 µm.

5.2 Incubation and Growth

The incubation period may range from days to years. Growth rates from 0.03 to 0.9 mm per year have been reported. Whisker growth rates have been observed under accelerated research test conditions approaching 1 mm per day. Growth is highly variable depending on plating bath chemistry, plating thickness, substrate material, grain structure and environment.

5.3 Environmental Factors

There is conflicting data regarding how environmental factors affect whisker formation and growth. Elevated temperature (greater than 50 °C) may accelerate growth. It appears that whisker growth ceases above 150 °C. Pressures in the range of from vacuum to atmospheric can accelerate whisker growth. Moisture and humidity above 85% RH may accelerate growth. Thermal cycling may accelerate nucleation and growth. To date there appears to be no universally reproducible laboratory test method to accelerate whisker formation so as to help determine precisely how a plating bath's control factors influence later whisker formation potential.

6. CURRENT CONCERNS

6.1 Current regulatory efforts underway around the world to limit the use of potentially hazardous materials such as lead, is driving the electronics industry to consider alternatives to the widely used tin-lead alloy for metallic plating. The EU (European Union) has enacted legislation, effective June 2006, to eliminate most of the lead used in electronic equipment. Lead is believed to act as a doping agent, inhibiting whisker growth tendencies in tin-lead plating and solders. Many electronic manufacturers are not aware of the problem of whiskers and therefore may have not evaluated the potential for this problem in their designs.

6.2 Research is underway to more thoroughly examine the causes of whisker formation, explore reliable accelerated test methods, and develop recommendations to minimize the risk of whisker nucleation and growth.