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IPC-9691A

User Guide for the IPC-TM-650, Method 2.6.25, Conductive Anodic Filament (CAF) Resistance Test (Electrochemical Migration Testing)

IPC-9691A

August 2007

A standard developed by IPC

Supersedes IPC-9691
October 2005

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Developed by the Electrochemical Migration Task Group (5-32e) of the
Cleaning and Coating Committee (5-30) of IPC

Supersedes:

IPC-9691 - October 2005

Users of this publication are encouraged to participate in the
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Acknowledgment

Any document involving a complex technology draws material from a vast number of sources. While the principal members of the Electrochemical Migration Task Group (5-32e) of the Cleaning and Coating Committee (5-30) are shown below, it is not possible to include all of those who assisted in the evolution of this standard. To each of them, the members of the IPC extend their gratitude.

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User Guide for the IPC-TM-650, Method 2.6.25, Conductive Anodic Filament (CAF) Resistance Test (Electrochemical Migration Testing)

1 SCOPE

This document is the product of the IPC Electrochemical Migration (ECM) Task Group. It was drafted to provide guidance regarding how the IPC-TM-650, Method 2.6.25, Conductive Anodic Filament (CAF) Resistance test can best be used for evaluating the effects of mechanical stress, laminate material fracturing, ionic contamination, moisture content prior to press lamination, and other material processing characteristics on conductive anodic filament (CAF) resistance test method results. This CAF test method provides a proven standard for determining the risk of temperature, humidity and bias (THB) failure within rather than on the surface of printed circuit boards (PCBs), typically filament formation along the boundary between the resin and laminate reinforcement.

2 BACKGROUND

Conductive anodic filament formation was discovered in 1976 simultaneously by researchers at Bell Labs and Raytheon. Bell labs researchers [1, 2] testing flexible epoxy substrates showed that under temperature, high humidity and voltage conditions, catastrophic failure can occur due to “through substrate shorts” and surface to surface shorts. Der Marderosian at Raytheon [3] examined only through substrate shorts and termed the failure mode the “punch thru” phenomenon. It was not until 1979 that this failure mode was named conductive anodic filament (CAF) growth. [4]

CAF growth is a conductive copper-containing salt created electrochemically that grows from the anode toward the cathode subsurface along the epoxy/glass interface. More recently CAF reliability concerns in the industry have increased as board designs have advanced in terms of decreasing dimensions and/or higher voltages.

The mechanism for CAF is the transfer of copper (Cu) ions and the deposition of Cu salts in the presence of moisture and voltage bias influenced by concentration and pH gradients. The conductive path is the growth from the anode by a salt, as compared to dendrite formation on the surface of the board where metal ions deposit on the cathode [5]. CAF is associated primarily with mechanically drilled holes where the mechanical drilling disrupts the glass reinforcement fibers in glass bundles permitting the absorption of subsequent processing chemistry between the fibers and epoxy.

The user of this document is encouraged to become familiar with IPC-9201, *Surface Insulation Resistance Handbook* so as to understand the factors which affect electrochemical migration.

3 PURPOSE

This user guide addresses test issues regarding determining pass/fail criteria based on knowledge of three product goals:

- What are the long term reliability requirements?
- What is the closest spacing required for a given voltage differential?
- What is the maximum safe voltage differential between features with a given spacing?

4 INTRODUCTION

Where large conductive filament growth is visible under a microscope, often there is some adjacent laminate material fracturing or defect that contributed to its formation. Examples of such visible filament growth follow. Only Figure 4-3 may show a true atacamite filament, however all examples shown in Figures 4-1, 4-2 and 4-3 would fail the temperature, humidity, and bias conditions selected to determine multilayer board reliability between internal features.

The high magnification photo, Figure 4-1 below, shows a PCB with layer 1 (top layer) removed, revealing a near shorting condition between the plated through hole and layer 2 ground plane.

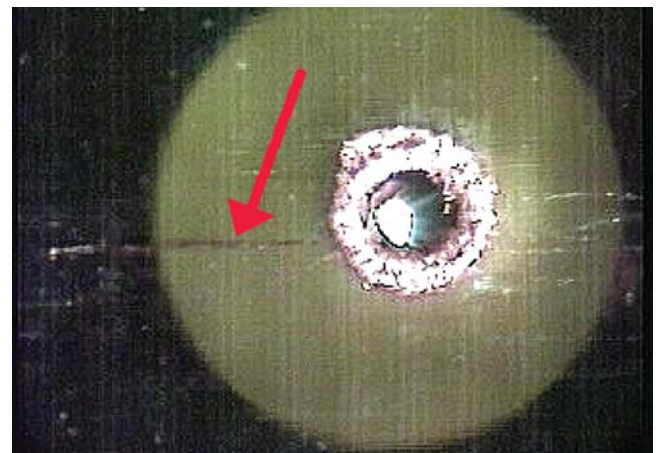


Figure 4-1 Conductive Filament Example^a

Poor press lamination and/or defective prepreg material may contribute to conductive filament formation.

test failure if the resin/reinforcement bonding strength and resistance to mechanical stress is reduced.

Failure analysis, as seen in two perspectives in Figure 4-2, show a near-shortening condition from the hole barrel to the plane on layer 3.

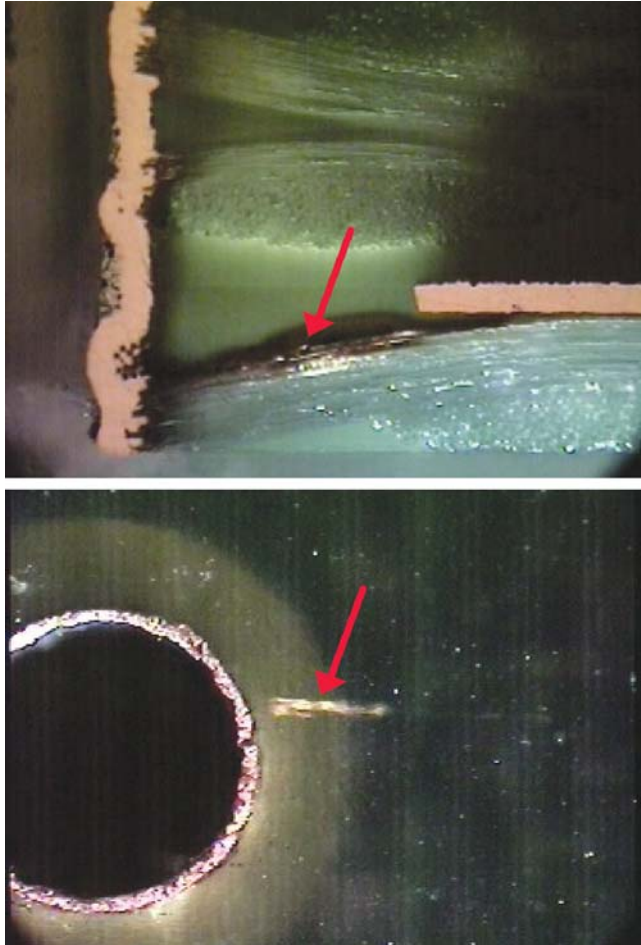


Figure 4-2 Two Perspectives of the Same Conductive Filament^b



Figure 4-3 Failure Analysis Photo Showing Suspected CAF Failure Between Very Closely-Spaced Plated Through Holes^c

During CAF testing, the use of a low bias voltage and at least 1.0 megohm current limiting resistor can facilitate, with sufficient time, formation of the larger scale CAF growths possibly detectable by microscopic examination. If the power goes out on an AutoSIR all data can be lost, so it is recommended to use an uninterruptible power source (UPS) to mitigate the effects of any short disruption in power.

5 WHAT IS CONDUCTIVE ANODIC FILAMENT GROWTH?

Work by Ready and Turbini [6] more precisely identified the nature of this compound which has semiconductor properties. Their work found that the conductive anodic filament was Atacamite, an orthorhombic structure of $\text{Cu}_2(\text{OH})^3\text{Cl}\cdot\text{H}_2\text{O}$. This was based upon transmission electron microscopy (TEM) results.

Atacamite crystals are very long and thin. Even with 1.0 megohm current limiting resistors in line with the test traces, these thin filaments can be blown and can take some time to reform. Therefore any significant drop in resistance during the THB testing should be regarded as a failure due to CAF for testing purpose, even if the resistance later returns to a high level.

Lando et al [4] showed that CAF formation follows a 2-step process: 1) Degradation and moisture debonding of the epoxy-glass interface followed by 2) The electrochemical reaction with an applied voltage. Weakening of the polymer/glass interface can be influenced by poor hole drilling, the quality of the silane agent used to enhance the glass/polymer bond, thermal cycling (soldering) due to the difference in the coefficient of thermal expansion between the polymer and glass. The electrochemical reaction follows the preferred pathway along the epoxy-glass interface.

Further research done by the University of Maryland-CALCE has shown that thermal cycling in a humid environment can also contribute to the debonding due to the difference in coefficient of thermal expansion between the epoxy and fiberglass reinforcement.

6 INCREASING CAF RISK TRENDS

CAF failure mechanism models that correlate with high temperature / humidity / bias test results show increasing risk with decreasing through-hole pin pitch, decreasing BGA, LGA, or other close escape via grid/pitch arrangements, and with increasing voltage differential between adjacent holes. Table 6-1 shows design trends at one major OEM (year shown is actual or estimated first production release for the indicated technology level).