FACTORS WHICH ENHANCE CONDUCTIVE ANODIC FILAMENT FORMATION

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There is a need for a fundamental understanding of the interaction of fusing fluids, soldering fluxes and cleaning agents with printed wiring board substrates. This need is driven by two factors. (1) The increased density of today's electronic products creates voltage gradients which are high enough to enhance degradation modes which are not important for less dense circuitry, and (2) the elimination of chlorofluorocarbons (CFCs) and other ozone depleting cleaning agents has lead to a proliferation of new soldering fluxes and cleaning agents whose interactions with the printed wiring board (PWB) are not well characterized.

Water soluble fluxes have been effectively used in high volume electronic manufacturing operations for a number of years. Their use has increased dramatically as they provided an opportunity to eliminate CFCs in the cleaning process. They provide excellent soldering with low defect levels and with a proper cleaning process can produce highly reliable electronic circuits. However, some water soluble flux and fusing fluid formulations contain ingredients which can have deleterious effects on the reliability of a product under certain operating and use conditions.

Printed wiring boards (PWB) consist of epoxy-glass composites with copper or copper/tin/lead metallized circuitry. The most commonly used substrate is "FR-4," a 0°/90° woven e-glass - epoxy composite with copper circuits. Under high humidity conditions, this composite may respond to an applied voltage by developing subsurface deposits of copper salts emanating from the anode (Figure 1). These deposits, termed conductive anodic filaments (CAF), were first identified in the mid-1970's at Bell Labs.[1-4] This failure mode involves a de-bonding of the epoxy - e-glass interface and the formation of a conductive filament which grows along this interface from anode to cathode.

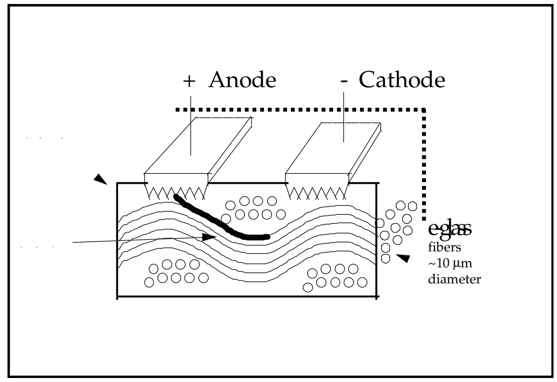

Figure 1.

Schematic representation of surface track to surface track CAF in FR-4 PWB.

Bell Labs focused their CAF studies on unprocessed FR-4 PWBs. This work has investigated the effect that flux and substrate choice have on the formation of CAF. Both FR-4 epoxy-glass and MC-2 substrates were used in this study. While FR-4 consists of many layers of 0°/90° woven glass fiber with epoxy, MC-2 substrates have a layer of polyester with random, chopped glass fibers sandwiched between a single-ply 0°/90° woven e-glass - epoxy composite face sheets at the top and bottom of the PWB.

The test coupon for this study was the IPC-B-24 coupon which has four interdigitated comb patterns on the surface. The coupons were processed with 7 different water soluble fluxes and cleaned. The comb patterns were wired to electrical measuring equipment which was used to place the combs under a bias of 100V and to measure the surface insulation resistance across the combs on a daily basis. These readings were taken over a period of 28 days while the coupons were in an environmental chamber set at 85°C/85% RH to accelerate any electrochemical degradation that might occur.

It was postulated that flux or moisture uptake by the processed laminate could be related to a tendency for CAF formation. Thus, coupons to be processed with each flux were weighed before and after the flux/soldering/cleaning process and data compared with control boards which were heated to soldering temperatures but not exposed to flux. In addition, moisture uptake during temperature/humidity exposure was also measured and compared across the fluxes and substrates examined.

Optical microscopy (Figure 2) and SEM/EDS data (Figure 3) were used to determine if CAF had formed and to identify the chemical nature of the filament. Finally, contact angle measurements of the wetting of water drops placed on the laminate surface were used to assess the change in surface energy due to processing.

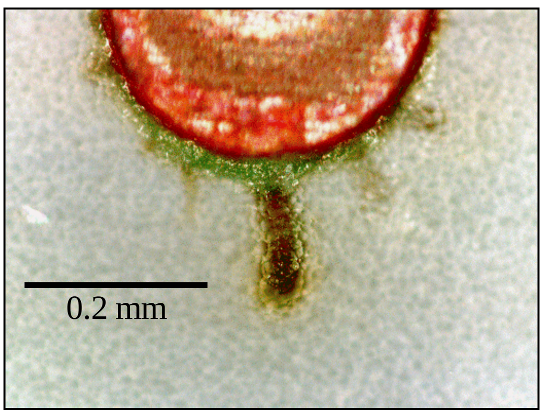

Figure 2.

Optical micrograph showing a well delineated CAF that formed on the anodic tip of a comb pattern on an FR-4 PWB.

On the basis on this research, we conclude that MC-2 is highly susceptible to CAF formation under high humidity conditions even when no flux is present. For FR-4, CAF formation was enhanced by those flux formulations which contained polyglycols. However, not all polyglycol-containing fluxes were equally aggressive in CAF formation. In addition, the fluxes which did not contain polyglycols did not create CAF on the FR-4 test coupons under study.

While SIR electrical measurements were used to assess the interaction of residues with the PWB, it did not provide electrical evidence for the presence of CAF. Only optical microscopic examination using back lighting was a suitable detection method for detecting this failure mode.

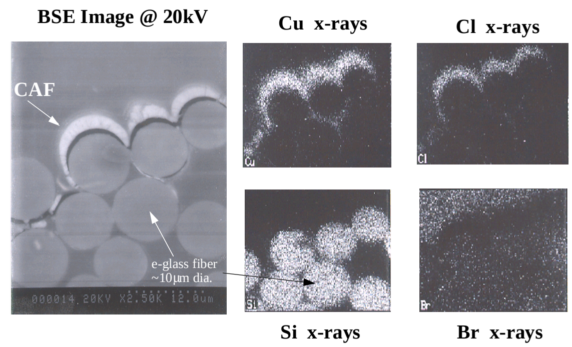

Figure 3.

CAF revealed in SEM micrograph (above left) as traveling along the separated fiber / epoxy interface. EDS elemental map (above right) of CAF shows that it is copper and chlorine containing.

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1 Boddy, P.J., Delaney, R.H., Lahti, J.N. and Landry, E.F., "Accelerated Life Testing in Flexible Printed Circuits" ***14th Annual Proceedings of Reliability Physics***, pp. 108-117 (1976).

2 Lando, D.J., Mitchell, J.P., and Welsher, T.L. "Conductive Anodic Filaments in Reinforced Polymeric Dielectrics: Formation and Prevention." ***17th Annual Proceedings of Reliability Physics***, pp. 51-63 (1979).

3 Lahti, J.N., Delaney, R.H., and Hines, J.N. "The Characteristic Wearout Process in Epoxy-Glass Printed Circuits for High Density Electronic Packaging." ***17th Annual Proceedings of Reliability Physics***, pp. 39-43. (1979).

4 Welsher, T.L., Mitchell, T.L., and Lando, D.J., "Conductive Anodic Filaments (CAF): An Electrochemical Failure Mechanism of Reinforced Polymeric Dielectrics." ***Annual Report of the Conference on Electrical Insulation and Dielectric Phenomena***, pp. 234-238. (1980).