Tantalum Applications - Reply to General Question

*Moisture - An Old and Known Nemesis of Tantalum Caps*

**Elimination of CFCs**

The problems of moisture penetration into plastic molded packages developed with changing solder processes in the late 80’s and early 90’s. The CFC based flux cleaners may have masked problems with this packaging for years, but these “problems” were not application induced moisture penetration. The devices were tested to humidity and moisture environments that may have been exaggerated of actual application conditions, but the plastic coating packages did well in passing the test of these exposures.

Environmental concerns led the industry to seek alternatives to the CFC laden cleaning solutions that were prevalent in the industry. The two competing flux systems were based on “no-clean” and “water-wash.” Based on concerns for leaving traces of the flux as a permanent residue on the boards, as well as improved solderability, led the initial majority of the environmentally concerned to water wash.

The water wash introduced for many of the board mounted components a new and highly concentrated exposure to water. In some cases the water was heated and mixed with surfactants as detergents and the board was exposed to this solution as a spray or immersion as part of the solder process. Early problems of this process generated the term “popcorn” effect to the surface mount industry.

**Popcorn Effect**

The popcorn effect was most noted with plastic encapsulated ICs, when these devices were cleaned after each solder thermal exposure, and then returned for additional exposures. The plastic packaging offers a mechanically consistent container for high-speed or tightly controlled pick-and-place surface mount equipment. As a molded package, the encapsulation of the electronic devices presented a reasonable high-speed process step to the component manufacturers. It has been in use across many component types for years. The packaging was neat and high speed, but was not a moisture proof package. The plastic material itself, though we use it for tarps and raincoats, is not moisture impenetrable. It breathes, and it absorbs moisture; but this is not the main thrust of the problem.

The thermal process exposes the plastic and the internal materials to a high temperature exposure that created mismatches in expansions. Invariably the internal components are metal or ceramic with coefficients of thermal expansion (CTEs) in the range of 7 to 30 PPM/°C; while the plastic encapsulant is in the range of 60 to 200 PPM/°C. Even from the mold presses, the fit of plastic to metal was not a perfect bond. Small gaps that may have been present between the plastic and the metal leads extending out of the package may be increased through the solder thermal exposure.

The introduction of water into the process soon pointed out how imperfect these bonds were. If the devices were warm when introduced to the water, this would create a sucking action within the gaps - water literally being sucked into the package. As the package cools with time, the gaps narrow and trap the water within. With time, the water penetrates into the deepest crevices of the package.

Because the mounting process may have involved two-sided board population, a second solder thermal excursion was needed. The water within the package is trapped to some degree. Once its temperature exceeds 100°C, it now becomes steam. The steam cre-
ates a high pressure within the package, and eventually tears the package apart at as it attempts to escape. The ruptures of the plastic packaging, expanding the package outward from within, had some resemblance to popcorn -- thus the term “popcorn” effect!

This popcorn effect was not noted to the same degree in the different packages. The IC’s were the packages that had long walls of thin plastic that were most susceptible to this phenomenon; but this effect was also noted in capacitors and other components. The fix for this problem was a combination of treatment of the lead frame materials, modifications of the mold compound materials, stricter process controls. Control of the process, establishing proper solder profiles, as well as cool-down and rise constraints probably had a larger influence on eliminating this problem to minute occurrences. The biggest influence on diminishing this industry failure mechanism to extremely minor incidents was the switch from water-wash to no-clean flux systems.

Moisture and Capacitors

Two committees that studied the problems of moisture penetration with capacitors were the IPC and the EIA components sub-committee in 1989. The EIA committee released a document “PN-2208: Packaging Material Standards for Moisture Related Sensitive Items.” This document dealt with moisture proof packaging and inclusion of desiccant materials. The IPC document (IPC-SM-786) deals with this issue from a user’s perspective.

At KEMET, we observed a sudden increase in turn-on failure rates, that predated the rush of failures with water-wash systems; but it wasn’t until the water-wash system failures, that we found the culprit to be moisture. When water was pointed out as a common factor to the new step increase in failure rates, a review of the earlier unresolved failures revealed a common trait to the sites reporting these failures: they were “island” or “island-like” countries - Singapore, Hong Kong, England, and Malaysia. High humidity countries where another common thread involved long term storage of the capacitors in facilities with poor or no temperature controls. Our theory suggested that water was penetrating into the plastic package, leading to turn-on failures; though not to the point of creating cracks within the case.

We believed that the silver ions were being carried into the pellet structure through the pores with the moisture. There are sites within the vast area of Ta₂O₅, where a neck-down of the channel can lead to exposed dielectric, which can have defects within it. These sites can be bare, or thinly connected with only a film of the MnO₂.

In a biased condition, this movement cannot take place because the electric field locks up the silver ions to the outermost regions of the pellet. Yet in an unbiased state, these ion-laden penetrations would then connect fault sites that were not connected previously or through such thin MnO₂, that they were not effectively healed and sealed. Initial power application could not activate a healing mechanism of the MnO₂ because it wasn’t there or was insufficient to cover the site.

The predicament we observed was that the plastic could never stop the moisture penetration. (Even today, many IC manufacturers recommend a bake-out under vacuum process be used prior to in-

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**Moisture Fault Potential**

![Moisture Fault Activation](image)

<table>
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<td>Ionic laden moisture establishes contact to fault -- No MnO₂ healing mechanism!</td>
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KEMET Electronics Corp.
sersion and reflow for their parts. The moisture doesn’t always get in along the gaps, but is present in sufficient quantity within the plastic itself -- reflow causing the steam to be driven out of the plastic to the outside, or accumulate along the surface of the component within.) We could never devise a scheme to effectively circumvent what most of our customers were exposing these packages to. Since we couldn’t stop the moisture ingress along the lead frame or within the plastic, we focused on the internal package, the anode, instead.

**Moisture Barrier**

We wanted to eliminate the penetration of moisture into the anode. The mechanism for failure was thought to include the mobilization of silver ions activated by the increased moisture in an unbiased capacitor. As such, we wanted to establish a barrier mechanism between the silver application and the remainder of the anode. This was found to be much more effective than an application over the silver coat, which could have been an easy step as the silver coat is the last step prior to encapsulation. This point of application also presented us with a predicament that the barrier had to prevent the movement of the silver ions, but not inhibit the electrical conductivity between the silver and the remainder of the anode.

Our focus was to create a film or impediment to the silver ion penetration. The film coverage was dismissed as impractical because the material would have to be conductive, and conductive ions like silver, were thought to be the root of the problem. As unlikely a candidate as it might seem, an insulative material of fine individual molecules with a propensity to chain, was chosen as the answer. It had excellent penetration properties that we wanted to utilize. By allowing the material to penetrate into the channels or pores of the anode, following the same path as the MnO₂ cathode plate material, the material could form a channel block mechanism. The moisture barrier treatment is applied to the anode before the silver application. The silver ion is a large ion, and we were attempting to restrict the movement of this ion into the deeper regions of the anode.

The results were phenomenal. We dramatically reduced the effects of early moisture exposure. Increases in leakage were only observed after a thousand hours of exposure in a high humidity chamber. In 1992, we began implementation of the moisture barrier with the 7343 chip (KEMET “D” and “X” case). In the following months we’d included the moisture barrier application to all surface mount case sizes.

We still get occasional instances where excessive water treatments in the solder process brings out higher failure rates, but these instances are very rare and can usually be eliminated through modifications of the assembly process.