The Mask From Hell

Foresite Inc.

In working with Foresite, you may someday hear us talk about “the mask from Hell” incident. A manufacturer of a low-end commercial product was experiencing a wide spread failure during burn in testing. The failure mechanism was excessive leakage currents and an almost instantaneous metal migration situation. The bare board fabricator held Omegameter readings which showed the bare boards to be in the 2-5 microgram of NaCl equivalence per square inch. This would be considered clean by conventional standards. The manufacturer was using a halide-free low solids (no-clean) flux and was not doing any post-reflow soldering. Conventional wisdom says if you have a clean board, a clean process, and a halide free flux, you should have a good product. Similar products had been produced acceptably on this no-clean line for the past five years. What was the cause of the failures?

The materials used in the product were, in all cases, “bargain basement” quality. Cheap laminate, cheap mask, cheap plating, punched edges rather than routed, etc. However, in the world of low-end consumer electronics, you can’t afford top-of-the-line gold plated contacts and remain competitive. The failed assemblies had two things in common: the specific solder mask used and two board fabricators.

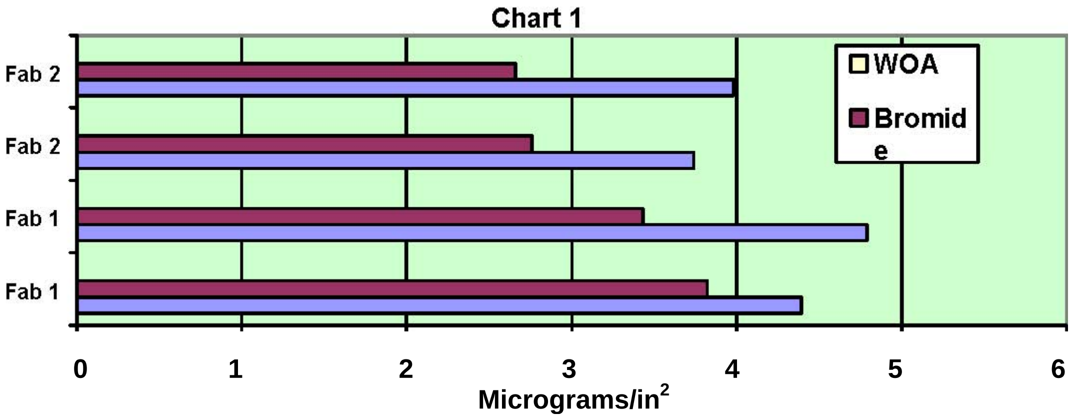
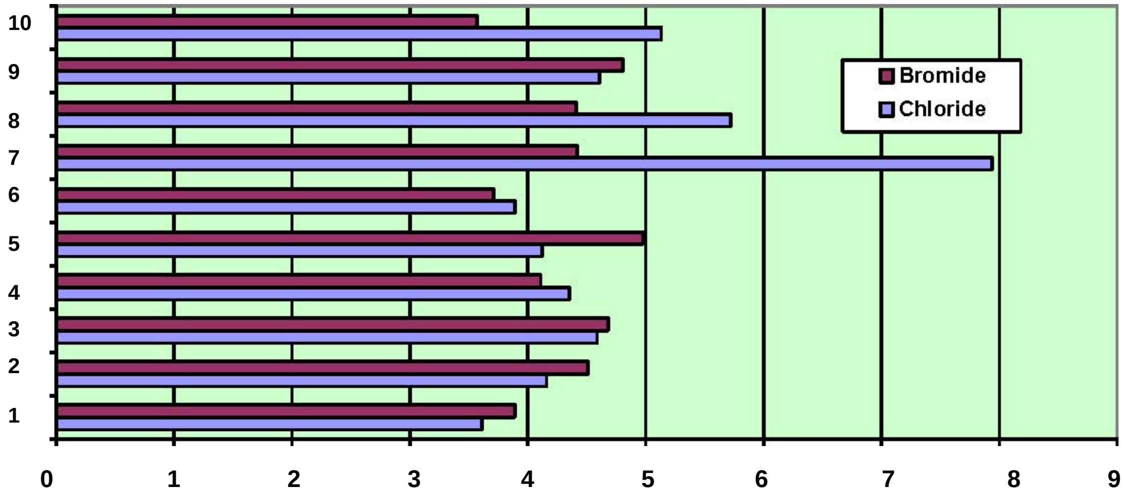


Chart 1 shows the bare board cleanliness level for these two fabricators. In both cases, the bromide levels were slightly elevated for the laminate (CEM), but could be explained by the punched edges of the boards, which naturally results in higher levels of extracted bromide. We did not equate these bromide levels with corrosive or metal migration failures.

The chloride levels on the bare boards for both fabricators were unacceptably high for a no-clean process. We recommend less than 2.0 micrograms per square inch and all bare boards exceeded 3.5. While the values were high, and therefore undesirable, we did not feel that the levels were so high as to correlate to the rampant metal migration. Accelerated testing (temperature and humidity) on the bare boards, or boards taken from any point in the processing prior to wave solder, did not show the high incidence of metal migration experienced in the final assembly. It was only after wave soldering that the units failed at a high rate. Chart 2 shows the chloride residues carrying through to the final assemblies. Chart 3 shows the levels of weak organic acids (WOAs) found on the finished assemblies (typical levels for a spray fluxer).

To make a long series of analysis short, we arrived at the following failure scenario. The solder mask was a cheap material with limited thermal resistance and high levels of porosity. A water soluble flux, charged with chloride, was used in the tin-lead deposition. The HASL process opens the solder mask polymer matrix, and the mask absorbed high levels of the water-soluble flux. The contact with the molten solder effectively heat sealed the flux inside the mask. Conventional Omegameter testing did not pick up the presence of the flux since it could not be effectively removed by the low energy extraction method. Ion chromatography detected some of the flux due to the higher energy extraction. Ionic testing by the fabricator or assembler did not pick up the flux as the flux was not mobile at this point. When the boards passed through the wave solder, the mask pores opened up, freeing the flux and chlorides to mix with moisture to initiate and support metal migration. Since this was a no clean process, there was no chance to remove these harmful materials.

Chart 2



One of the useful techniques we developed in this investigation was the use of a “heated control”. This was a bare board, with no components, which was run over the wave without any applied flux. For a good clean board, there should be only a slight elevation in bromide content, due to thermal effects, and a slight decrease in chloride level due to the “washing” action of the wave. In this study, we saw huge levels of chloride (30-50 micrograms per square inch or more) and large jumps in bromide, which had to be removed. This helped us eventually nail down the problem. At the end of the manufacturing process, the solder mask had ceased to be an effective material in any sense of the word.

The manufacturer worked with the bare board fabricator to help get the fabrication process under control. A series of evaluations was done on some alternative (much higher quality) solder mask formulations. The newer masks had much more thermal resistance (at least 5 reflow exposures) and were able withstand the HASL and assembly wave solder processes without absorbing flux. The heated control was used to demonstrate the mask's resistance to the flux. Without the entrapped flux residues, there was nothing to fuel the electrochemical migration during accelerated testing. The problem was solved.