Addressing Flux Corrosion & Reliability Concerns Early

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ADDRESSING FLUX CORROSION AND RELIABILITY CONCERNS EARLY

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SUMMARY: The old saying “An ounce of prevention is worth a pound of cure” is very true when it comes to the assembly process and avoiding field-failure returns.

Flux corrosion is just one of the reasons an assembly might be rejected by the end customer, or worse yet, be returned from the field non-operational. Fortunately, there are steps that can be taken to minimize the risk of corrosion, even before the first component is placed.

Understanding how flux corrosion is assessed per industry standards is an important first step in selecting the correct flux-containing products for the assembly process. Additionally, understanding the different types of flux corrosion is useful in determining the best way to minimize the flux’s corrosive effects, which can be assessed using actual process chemistry on dummy circuits through testing that is termed “assembly process validation testing.” And what better way to avoid field failures than to learn from others’ mistakes? The following three case studies will provide steps for assembly process improvement.

There are two types of corrosion associated with fluxes, chemical and electrolytic. By definition, chemical corrosion is a process in which a solid, especially a metal, is eaten away and changed by a chemical action. Electrolytic corrosion, on the other hand, is an electrochemical process in which one metal corrodes preferentially to another when both metals are in electrical contact in the presence of an electrolyte.

Flux corrosion on electronic assemblies was assessed in the 1950s. Unfortunately, it is a failure mechanism still
observed today. Initially, flux materials were qualified for use on military products per MIL-F-14256. These were the days of the RMA (rosin, mildly activated) and RA (rosin, activated) fluxes. The first IPC specification, IPC-SF-818 came along in 1988, followed by a standard that was accepted by multiple organizations. Given the joint effort, it was renumbered IPC J-STD-004 (J-STD = joint standard).

Since the 1950s, the corrosive properties of fluxes have been assessed and materials have been qualified. Low solids no-clean fluxes have been added to the mix, but these are not without processing concerns. The weak organic acids typically found in many no-clean fluxes can cause corrosion if they are not fully activated through thermal exposure. The most common issues are related to an inadequate reflow profile or excessive application of flux so that all of the potentially harmful flux residues are not completely volatilized. The remaining acid could easily attack copper barrels or traces and eventually lead to an open circuit on the assembly.

On the other hand, electromigration will often occur when you have an unactivated no-clean flux residue or a water-soluble flux residue that was not completely removed. These are somewhat tough to isolate because they often lead to intermittent short circuits, as dendrites tend to form and burn off once the current flowing through the dendrite becomes too great.

IPC J-STD-004 is a current document used to classify fluxes, and any flux containing solder—solder paste, cored wire, etc. There are four tests in 004 that assess how corrosive a flux or flux residue is: copper mirror, corrosion, surface insulation resistance (SIR) and electrochemical migration (ECM). These four tests are used to establish whether the flux will be categorized as an L (low activity), an M (moderate activity), or an H (high activity). For reference, many of the L fluxes are no-cleans, while many of the H fluxes require cleaning following the soldering process. The 004 document is intended to qualify the flux material not the soldering process.

In the copper mirror test, the flux is assessed in the as-received condition. It is not refloowed before or during the test. The flux is applied to glass slides that have been coated with 50 nm of copper. The slides are placed in a chamber at 23°C/50%RH for 24 hours. Following the exposure, a visual exam is performed to assess the amount of breakthrough. You can see by the photos that the amount of breakthrough determines whether the flux is an L, an M, or an H. The final classification for the flux is determined by the highest activity level for all tests, so the flux may give an L result for one test and an M for another—in this case it would be classified as an M.

The corrosion test is different than the copper mirror test. In this test, the flux is tested af-

Figure 1: Copper mirror test. L = no breakthrough, M = less than 50% breakthrough, H = greater than 50% breakthrough.
ter reflow. A small amount of flux and solder is run through the appropriate reflow profile on a copper panel. The copper panel is then conditioned for ten days at 50°C/95%RH. Following exposure, the panels are removed and visually examined. The “no corrosion” on the left would indicate an L rating. The “minor corrosion” in the center would yield an M rating and the “major corrosion,” where a green/blue copper salt has formed, would be an H; here, the copper is being corroded by the flux.

The next two tests assess the flux’s propensity to develop leakage current across two isolated traces. This leakage current is often caused by the formation of dendrites or electrochemical migration. Again, these J-STD-004 SIR and ECM tests were developed to test the flux itself, not an assembly process. For the SIR test, the flux is reflowed on the test board. The samples are biased and exposed to 40°C/90%RH for seven days. During that time, insulation resistance (IR) measurements are taken every 20 minutes. The reason for the frequent monitoring of the IR is that dendrites tend to form and then burn off because they cannot carry the current that builds up across this fragile “circuit,” as shown in this real time video.

The 20-minute measurement interval is intended to catch the drop in IR when there is a bridge between the conductors. Fluxes that fail to meet the 1 x 10E-08 ohm requirement must be cleaned. Additionally, following the test, a visual exam is performed. Evidence of corrosion of the conductors is also considered to “not meet” the specification and the flux would have to be cleaned. There is a lot of product develop-
ment that flux manufacturers must perform to develop a product that will effectively clean the metals to be soldered, make a good quality solder joints and leave no corrosive residues.

The electrochemical migration test was copied from the Telcordia GR-78-CORE specification. For manufacturers who are required to have their materials qualified to J-STD-004, as well, the GR-78 wanted one qualification procedure to cover both J-STD-004 and the Telcordia document. This method has not been modified to include frequent monitoring of the IR because the Telcordia document does not include this. Again, for this test, the flux is tested in the reflowed state. The boards are run at 65% RH for 21 days and the IR measurement at 96 hours is compared to the 500-hour measurement. A greater than 1 decade drop in IR would constitute a failure.

Again, dendrites and corrosion are reasons for failure.

There is one additional test, the Bono test, which has been run for a number of years but is not currently part of the J-STD-004 specification. The Bono test is based on a test developed by Dr. David Bono and recently modified by Dr. Laura Turbini. For the most recent study, weak organic acid (WOA) solutions including abietic, succinic, glutaric, adipic and malic acids were used to assess the best environment for assessing flux corrosion. This experiment did not use full flux chemistry, just the acid itself. The study found a 60°C/93% RH environment for 10 days was most effective in detecting differences in the WOA’s corrosivity. The J-STD-004 committee is currently considering the research being done on this method for possible inclusion in the specification. This test is a similar temperature/humidity/bias (T/H/B) test, but the amount of corrosion and the IR are measured quantitatively. The test is showing promise for being more sensitive in assessing flux corrosion.

Once the fluxes have been selected, it is important to confirm that all of the assembly process chemistries work well together and that there will not be any unexpected reactions. IPC-9202 and IPC-9203 are resource documents for this assessment. Often, a perfectly benign flux, when placed in the company of other chemistries, can cause some unexpected reactions. The IPC-B-52 board pictured below is a good tool to assess process chemistries. Test boards and dummy components may be purchased commercially or the boards may be built by the actual board supplier to assess this step, as well. It is important to use dummy components as active circuits would not allow for IR to be measured beneath the components. This board is a good tool to assess a change in assembly line chemistry. The old and the new chemistry may be run side-by-side to compare leakage current development and corrosion characteristics.

Case Studies

Case #1: An automotive audio supplier began experiencing intermittent failures in their radios. Intermittent failures can be difficult to
detect, but evidence of carbonized debris was observed (Figure 7). This debris is what remains when the dendrite sees too much current and then disintegrates.

When assessing what went wrong in the assembly process, data sheets and qualification data were reviewed for all chemicals involved. The flux supplier was asked for recent evidence of lot conformance testing and qualification data. It was discovered that the material had not undergone a full qualification in 15 years. Running an ion chromatography test on the flux confirmed that the activity level of the flux had changed, most likely due to a change in one of the raw materials.

For users of fluxes, it is important to select fluxes that are qualified per J-STD-004 or another industry standard. After selecting the soldering materials for the assembly process, it is important to ask to see the dated qualification and conformance reports. Do not rely on technical datasheets as this information can be years old. Per 004, flux manufacturers must be able to provide this data to their customers. This is most often an issue (product not tested for a very long time and out of control) in product failure analysis when the contract manufacturer (CM) or original equipment manufacturer (OEM) is using a flux supplier who does not participate in IPC or other technical conferences.

IPC has recognized this as a common issue and has begun a program called Product Vali-

Figure 7: Carbonized debris.

Case #2: The second case study involves a security company that began receiving field failure returns of their camera system. The issue was isolated to a particular BGA. You can see excessive flux residue around the suspect component.

The test engineer X-rayed the BGA to look for potential failure causes and was able to capture images of the dendritic growth projecting from the solder balls. Additionally, once the BGA was removed, there was clear evidence of excessive flux residue and dendritic growth bridging electrically isolated conductors.

These photos show the dendrites beneath the excessive flux residue with the component removed. Fourier transform infrared (FTIR) spectroscopy was run on the flux residue for comparison to reflowed flux residues of all fluxes used in the assembly process. There was a close match to a particular tacky rework flux. When reviewing the flux datasheet the following state-

Figure 8: Excessive flux residue observed surrounding BGA.
ment was found: “Meets IPC ANSI-J-STD-006 requirements for ORLO, Water Soluble.” There is a problem with this statement. J-STD-006 is the standard for the solder metal, not the flux activity level. This should be a red flag that the manufacturer may not have a complete understanding of the IPC classification system. When ion chromatography was run on the flux, it was found to be an L1 level containing halides.

Again, these are very straightforward examples of what pitfalls need to be avoided when developing the assembly process steps. Any hand soldering step—in this case rework—must be tightly controlled to make sure all flux is fully activated. Request and review actual flux data and be on the lookout for red flags. Consider performing process validation studies before the product is in a field failure return situation. Weigh your risks and potential damage to your reputation if product is recalled.

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<th>Summary of Recommendations</th>
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<tr>
<td>Use reputable flux suppliers</td>
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<td>Periodically request the most recent qualification and lot screening test results</td>
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<tr>
<td>Be sure to have controls on all stages of the soldering process</td>
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<tr>
<td>Verify assembly process through process validation studies</td>
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<tr>
<td>Control process steps that are not part of the normal process (i.e., rework)</td>
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Table 1.
an additional reflow step can give the chemicals time to dissolve the copper in the hole which can lead to an open circuit. Manufacturers appear to be more aware of this failure mode, so it is not found as often as it was few years ago.

Table 1 contains a summary of steps that may be taken to improve assembly reliability as it relates to controlling flux corrosion. **SMT**

**References**


**Case #3:** Entrapped assembly chemicals are an issue that can arise within small vias or within vias that are tented on one side of the board. Soldermask voiding and misregistration can also allow assembly chemicals to enter a via and become trapped. A board going through

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