

Is Cleaning Really Worth the HASL – Part 2

Quantity of wash cycles does not compensate for quality
Foresite Inc.

Introduction

In Part 1 of this series, we examined how a fabricator's post-HASL cleaning process, despite its seeming proficiency visually or "on paper", can be ineffective against hot air solder leveling (HASL) flux residues. In this article, we present a failure analysis evaluation that exemplifies the consequences of allowing the transfer of excessive HASL flux residue to finished assemblies.

Outlining the Evaluation

Concerned about failures from a water drop test, an assembler tasked us to evaluate the ionic cleanliness on three bare boards and three finished assemblies. The failures were predominantly associated with wave soldered assemblies built approximately one week prior. The bare boards and assemblies in this evaluation were the same part number and fabricated with CEM-1 punched laminate, an epoxy solder mask, tin/lead HASL metallization, and mixed component technology (surface mount and through hole). The assembly process used a low solids (no clean) flux for surface mount and wave soldering. We subjected each board to Ion Chromatography (IC) testing per IPC-TM-650, method 2.3.28. Tables 1 & 2 summarize the IC data, measured in units of $\mu\text{g}/\text{in}^2$.

TABLE 1. Bare Board Ion Chromatography Data (in $\mu\text{g}/\text{in}^2$)

Sample #	Sample Description	Chloride	Bromide	Sulfate	WOA
1	Sample #1	8.43	19.71	3.78	0.00
2	Sample #2	9.05	19.36	3.88	0.00
3	Sample #3	7.16	19.24	0.67	0.00
	MEAN	8.21	19.44	2.78	0.00

Table 2: Assembly Ion Chromatography Data

Sample #	Sample Description	Chloride	Bromide	Sulfate	WOA
4	Sample #1	8.511	20.46	0.00*	3.83
5	Sample #2	7.86	20.00	0.00	3.33
	Sample #3	9.14	20.00	0.00*	4.70

Analyzing the Data

As stated in Part 1, bromide levels can vary depending upon the amount of fire retardant the laminate manufactured. In this case, CEM-1 was added. We attribute levels below $7.0 \mu\text{g}/\text{in}^2$ to the fire-retardant material found in CEM-1 laminates and exposure to reflow temperatures. Neither of these do we consider a threat for electrochemical failures.

We also know that a serious threat for electrochemical failures exists when we can attribute the bromide levels to flux residues since they tend to be corrosive. For bare boards, these bromide residues most often come from HASL fluxes. Our experience with circuit boards constructed of CEM1 laminate has shown that bromide levels above $7.0 \mu\text{g}/\text{in}^2$ on circuit boards typically represent corrosive flux residues.

The data in Table 1 shows bromide levels on the bare boards that far exceed this recommended guideline, and therefore are attributable to the use of a bromide-activated HASL flux. Furthermore, Table 2 clearly shows that these residues transfer in whole to the finished assembly. The assembly process evaluated does little to add to the overall levels of bromide nor is it capable of removing them since the assembly process uses no clean flux.

In Part 1, we stated that tolerable levels of chloride for finished bare boards depend upon the type of assembly process that they will eventually encounter. For this evaluation in which the assembly process implemented low solids (no clean) materials, we applied our recommended maximum guideline of 2.0 $\mu\text{g}/\text{in}^2$.

Table 1 shows that the three bare boards far exceed our recommended guideline. Although chloride has many sources in fabrication, we attributed these high chloride levels to the HASL flux that contained not only bromide but also chloride activators. As was the case with bromide, Table 2 reveals that these chloride residues transfer in whole to the finished assembly, and once more the assembly process contributes little to these overall levels. Consequently, each bare board and assembly sample is at risk of developing electrochemical failures.

Sulfate is a good measuring stick for assessing the effectiveness of a fabricator's cleaning process. Sulfate in sufficient quantities can be detrimental to reliability. The level of sulfate on two of the three bare board samples in Table 1 exceeds our 3.0 $\mu\text{g}/\text{in}^2$ guideline. We attribute the difference in the sulfate levels between Sample #3 and the other two samples to variations in the fabrication process. High sulfate levels indicate that the cleaning process is not effective. Consequently, these bare boards are at risk of developing electrochemical failures on finished assemblies. *NOTE: When this study was initially performed, sulfate and weak organic acids came out at the same point in the chromatogram, and were inseparable. Table 2 identifies this with an asterisk in the sulfate column, indicating that the result for WOA is actually a combination of WOA and sulfate residues. With advances in chromatography equipment, sulfate and WOAs can now be differentiated.*

Finally, we detected the presence of WOAs (weak organic acids) on the assemblies, as we would expect. WOAs serve as activator compounds in many fluxes, especially no-clean fluxes, and are typically not a threat to the long-term reliability of finished assemblies. Since WOAs are not relevant to the PCB fabricator's process, for the sake of completeness we will mention that the WOA levels remaining after assembly operations as presented in Table 2 are trace and therefore not detrimental.

What does all of this mean?

In the end, we advised our client to consider optimizing the fabrication cleaning process using the list of recommendations presented in Part 1. We concluded that the leakage failures produced during the water drop testing were the result of the moisture-absorbing characteristics of fabrication residues, particularly chloride and bromide (HASL) residues. The HASL process loosens the solder mask polymer matrix, allowing the mask to absorb high levels of these residues. Subsequently, these residues percolated to the board surface during wave soldering. As the customer reported, the bulk of the leakage failures occurred on assemblies processed through the wave soldering operation.

This evaluation is another example of just how much influence a PCB fabricator has on the reliability of any finished assembly. Regardless of the HASL flux used, it is imperative that a fabricator's post-HASL cleaning be effective at removing sufficient amounts of process residues, particularly if the boards eventually enter an assembly process devoid of cleaning. Most fabricators neglect to ask important questions of the customer regarding the type of assembly process (i.e., water soluble, no clean, etc.) and the type of product being assembled on a particular board. Answers to these questions dictate how well a fabricator's process must work in order to produce sufficiently clean product for any given assembly process.

It goes without saying, "The HASL process is only as good as its subsequent cleaning process."