EnviroSense Corporation
Project TM02
26 March 1998
Mark Palmer

Bare Board Cleanliness Evaluation

Goal of the Project

The goal of this project was to evaluate the process residues remaining on bare boards. In this evaluation, we will:

- Determine the type and quantity of process residues
- Identify possible source(s) of harmful residues
- Recommend corrective action that can help to reduce or eliminate harmful residues.

All residues in this evaluation were characterized using ion Chromatography per IPC-TM-650, method 2.3.28.

Process History

A quantity of six bare boards was provided for analysis. Three boards were tested "As Received" and three boards were cleaned in a Marseco in-line board cleaner. The bare board information and cleaning conditions were as follows:

Board Information

Board Size:	~7.0 mm by 19.3 mm
Laminate:	FR4
Solder mask:	green LPI (SMOBC)
Surface metalization:	HASLed over base copper
Assembly process:	none
Part number:	none
Date code:	808-12/B

Cleaning Conditions

Water Quality:	D.I. water (10 Meg) wash and rinse
Saponifier:	EnviroGold 816 @ 2.5%
Belt speed:	5 ft/min.

Test Procedure

1. Each test board was placed into a clean Kapak (heat sealable polyester film) bag. A volume of isopropanol (75%) and deionized water (25%) was introduced into each bag, immersing the test sample. Each bag was heat sealed, but each bag contained a vent hole.

2. Each bag/test sample was placed into an 80^{o}C water bath for one hour. After one hour, the bags were removed from the water bath and the test samples removed from the bags. The test samples were allowed to air dry.

3. A 3 ml sample of each extract solution was analyzed using a Dionex ion chromatography system and a sodium bicarbonate eluent.

Data Discussion - Ion Chromatography

1. The data for this evaluation is shown on the attached data page and graph. The ion chromatography data is shown as micrograms of the residue species per square inch of extracted surface $\mu g/in^2$ unless otherwise noted. This measure should not be confused with micrograms of sodium chloride equivalent per square inch, which is the common measure for most ionic cleanliness test instruments.

2. For this project, ion chromatography detected the following anion residues: bromide (Br) sulfates (SO_4^{-2}), and chloride (CL). Each residue is discussed in greater detail below.

3. **Bromide** is generally attributable to the bromide fire retardant added to epoxy-glass laminates to give fire resistance, and which is subsequently extracted in the ion chromatography analytical procedure. Bromide can also sometimes come from solder masks, marking inks, or from fluxes which have a bromide activator material. Bromide, when from the fire retardant, is not a material considered to degrade long term reliability of electronic assemblies. If bromide is from a flux residue, then the bromide can be corrosive as other halides can be. The level of bromide can vary depending on the porosity of the laminate and/or mask. The degree of over/under cure of the laminate or mask, or the number of exposures to reflow temperatures.

4. Bromide levels of 0-7 $\mu g/in^2$ inFR-4 laminate can be attributable to the fire retardant. Levels can rise as high as 12 $\mu g/in^2$ with several exposures to reflow temperatures. When bromide levels begin to rise appreciably above 12 $\mu g/in^2$, we look for the use of a brominated flux. It should be noted that different laminates have widely variable levels of bromide additives. Sometimes the use of a brominated flux or excessive thermal conditions is detected in large increases in observed bromide level at various points in the assembly process.

5. All test samples exhibited bromide levels which are within the 0-7 $\mu g/in^2$ range for FR-4 laminate, and so the bromide was attributable solely to the fire retardant. Therefore, we would not consider the observed levels of bromide to be detrimental. Cleaning with a saponifier and DI water reduced the extractable level of bromide.

6. **Sulfates**, when present in sufficient quantity, can be harmful materials for electronic assemblies. Sulfates can come from a variety of sources, such as contact with sulfur-bearing papers or plastics, acid processes in fabrication, but these residues most often come from tap water rinsing/cleaning.

7. In general, sulfate levels on bare boards of 0 - 0.1 $\mu g/in^2$ represents aqueous cleaning with RO water and a good DI water rinse. Sulfate levels in the 0.1 - 1.0 $\mu g/in^2$ represent tap water cleaning with a marginal quality rinse. Increasing sulfate levels represent a decrease in cleaning efficiency. Levels above 3.0 $\mu g/in^2$ should be considered as detrimental and often represent acid residues.

8. Overall, the sulfate levels were above 1.0 $\mu g/in^2$ and were variable amongst the six samples. These observations suggest that the cleaning stage is not effective. In this particular case, the unsaponified RO wash water is not sufficient enough to maintain sulfate levels at or below 0.1 $\mu g/in^2$, which is indicative of an effective aqueous cleaning with RO water (1 MW or better) and a good water rinse (preferably deionized water). Saponifier cleaning reduced the levels of sulfates to below our recommended level.

9. **Chloride** is one of the more detrimental materials found on printed circuit assemblies. Chlorides can come from a variety of sources, but is most often attributable to flux residues. Chlorides will generally initiate and propagate electrochemical failure mechanisms, such as metal migration and electrolytic corrosion, when combined with water vapor and an electrical potential.

10. The amount of allowable chloride on a bare board is difficult to assess. If the boards will go into an assembly process which incorporates cleaning, then a higher level of chloride can be tolerated. If the bare board is intended for a no-clean assembly process, then a lower chloride level is required.

11. For bare boards, we recommend maximum chloride levels of less 1.0 $\mu g/in^2$ for a nickel/gold coated, solder-masked sample intended for a no-clean process. This recommended maximum does not presently appear in any nationally accepted specifications or standards, but is based on our failure analysis efforts with numerous customers.

12. Based on our standards for chloride, all samples exhibited unacceptable levels of chloride. As with sulfates, we observed variability amongst the six samples as well. High levels of chloride and sulfate residues collectively on a bare board are usually a result of an ineffective cleaning process. Here we apply the same rationale as we did for sulfates: improving the bare board cleaning by using an RO water rinse with a recommended saponifier and deionized water rinse.

13. For halide residues, it is recommended that you consider “acceptability” as a sliding scale. The higher you go with halide residues, the greater the risk of electrochemical failures (metal migration, corrosion, electrical leakage). Reducing halide residues gives a greater margin of electrochemical safety and yields a more reliable circuit.

Conclusions

1. All uncleaned samples exhibited unacceptable levels of chloride (less than 2.0). We suspect that the final rinse is not effective enough.

2. All samples exhibited acceptable levels of bromide and sulfate and, therefore, are not detrimental.

Recommendations

1. If you intend to use RO water, we recommend that you maintain a resistance of at least 1 megohm to ensure optimal rinse water quality.

2. We recommend that you consider implementing a saponifier as part of your cleaning regimen. We have found that a 2-5% solution of EnviroGold 816 in deionized water (140-150^{o}F), followed by deionized water (140^{o}F) in an in-line cleaner works best.

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Anion Data

All values are in µg/in^2, unless otherwise noted

Ion Chromatography

CSL ID	Sample Description	Chloride	Bromide	Sulfate
	Bare Boards As Received			
TM01-01	Sample 1	4.96	1.35	1.17
TM01-02	Sample 2	6.31	1.28	1.21
TM01-03	Sample 3	5.22	2.65	2.28
	Mean	**5.50**	**1.76**	**1.55**
	Bare Boards After Cleaning in a Marseco Board Cleaner Using 2.5% EnviroGold 816 Saponifier			
TM01-01	Sample 1	0.37	0.34	0.19
TM01-02	Sample 2	0.18	0.39	0.22
TM01-03	Sample 3	0.26	0.46	0.17
	Mean	**0.27**	**0.40**	**0.19**

Ionic species tested for: Anions: Chloride, Nitrate, Bromide, Phosphate, Methane Sulfonic Acid, Fluoride, Sulfate, Weak Organic Acid (WOA), Carbonate, Succinate, Glutarate, and Acipate