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Assembly Cleanliness Evaluation

Purchase Order #: 000111
PAL Report Number: 1000-003

A Good Company
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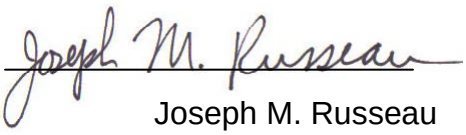
Date: June 21, 2011

Approved By:



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Process Analyst

Objective

The purpose of this study was to evaluate the ionic residues remaining on four printed board assemblies (PBA's). The analysis of the assemblies was conducted in accordance to IPC-TM-650, method 2.3.28.

Known Information: No date codes could be found.

No information was provided with respect to the materials or processing conditions that were used for assembling the boards. All four boards were processed in a no clean assembly environment. All four boards contained a hot-air solder leveled (HASL) surface finish.

Sample Identification: PC-789110000 REV 00

1000-003-01: S/n 1111 (0X-0045) ODT34A1; RESHA; D/C 2111
1000-003-02: S/n 1112 (0X-0047) ODT34A1; D/C 1111
1000-003-03: S/n 1011 (0X-0047) ODT34A1; D/C 1111
1000-003-04: S/n 1012 (0X-0045) ODT34A1; RESHA; D/C 2121

Photo Documentation: (Sample sent by the client)

Photo of the client's sample placed here

Equipment and Materials Used:

- Dionex Ion Chromatographs with Chromeleon software
- 18 Megohm-cm Deionized Water
- NIST Traceable Anion Standards (PAL Lot #: PAL-AN5-197)
- NIST Traceable Organic Acid Standards (PAL Lot #: PAL-AN5-197)
- NIST Traceable Cation Standards (PAL Lot #: PAL-CA3-047)
- Clean 3cc Syringes
- 99.9% HPLC Grade Isopropanol (PAL Lot #: PAL-EX-1040)
- Heat-sealable pouches
- High Temperature Circulating Water-bath
- Clean powder-free Vinyl Gloves
- Dionex analytical column / guard column / Self-Regenerating Suppressor
- Dionex analytical column / guard column / Self-Regenerating Suppressor
- Sodium Carbonate / Sodium Bicarbonate Anion Eluent (Lot #: AN-EL-1103)
- Sulfuric Acid Eluent (PAL Lot#: CA-EL-1032)

Procedure:

Ion Chromatography

1. The samples were handled with ionically clean powder-free vinyl gloves.

2. The samples were removed from their protective packages, visually inspected, and one sample was photo documented.

3. The samples were placed into clean Kapak heat-sealable pouches.

4. Two hundred milliliters (200 mL) of 75% of isopropyl alcohol and 25% deionized (DI) water (v/v) was added to each Kapak pouch containing the samples. The entire are of the board was extracted. The surface area of the samples was estimated as follows:

   For Samples 1 - 4: Assemblies

   Surface Area (in^2) = [(11.56 in)(7.00 in)][2 sides][1.1 population factor] = 178.02 in^2

5. The samples were extracted in an 80^oC circulating water bath for one hour.

Procedure – Continued:

6. After the hour expired, the Kapak pouches were removed from the water bath and the solution and samples were allowed to return to ambient temperature.

7. The samples were then removed from their respective Kapak pouches and allowed to air dry.

8. The Ion Chromatograph was calibrated using NIST traceable chromatography standards as described previously.

9. The anion and cation calibrations were verified for accuracy using validation solutions.

10. Three milliliters of the sample extract solution was drawn into ionically clean syringes and injected into the ion chromatograph for analysis per IPC-TM 650, method 2.3.28.

Ion Chromatography Data:

Table #1: PAL Recommended Guidelines for Bare Board and Assembly Cleanliness – Anions

Condition	Chloride Cl^-	Bromide Br^-	Nitrate NO_3^-	Phosphate PO_4^{3-}	Sulfate SO_4^{2-}	Organic Acids
Bare Board (Non-HASL)	< 1.0	< 12.0	< 3 - 5.0	PI	< 3 - 5.0	PI
Bare Board (HASL)	< 2.0	< 12.0	< 3 - 5.0	PI	< 3 - 5.0	PI
No Clean Assembly						
Surface Mount Only	< 2.5	< 12.0	< 3 - 5.0	PI	< 3 - 5.0	5 - 20.0
Mixed Technology	< 2.5	< 12.0	< 3 - 5.0	PI	< 3 - 5.0	20 - 50.0
Through Hole Only	< 2.5	< 12.0	< 3 - 5.0	PI	< 3 - 5.0	50 - 100.0
Post-Assembly Cleaning						
Surface Mount Only	< 4 - 5.0	< 12.0	< 3 - 5.0	PI	< 3 - 5.0	5 - 20.0
Mixed Technology	< 4 - 5.0	< 12.0	< 3 - 5.0	PI	< 3 - 5.0	20 - 50.0
Through Hole Only	< 4 - 5.0	< 12.0	< 3 - 5.0	PI	< 3 - 5.0	50 - 100.0

Table #1: All values in the table are in micrograms per square inch (µg/in^2). Non-HASL refers to ENIG, immersion Ag, immersion Sn and OSP board finishes. PI means the component is treated as a process indicator, as no industry guidelines currently exist. ***Please note that the various residue levels shown in the table are only a recommended starting point, they should not be construed as industry limits.***

Table #2: PAL Recommended Bare Board and Assembly Cleanliness Guidelines - Cations

Condition	Lithium Li^+	Sodium Na^+	Ammonium $NH4^+$	Potassium K^+	Magnesium Mg^{2+}	Calcium Ca^{2+}
Bare Boards	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Assemblies	< 1.0	< 2.0	< 2.0	< 1.0	< 1.0	< 1.0

Table #2: All values in the table are in micrograms per square inch (µg/in^2). ***Please note that the various residue levels shown in the table are only a recommended starting point, they should not be construed as industry limits.***

Table #3: Numerical Anion Chromatography Data - Samples

Sample Number	Sample Description	Fluoride F^-	Chloride Cl^-	Bromide Br^-	Nitrite NO_2^-	Nitrate NO_3^-	Phosphate PO_4^{3-}	Sulfate SO_4^{2-}	Fluoride F^-
1000-003-01	S/n 1111	0.00	4.20	1.67	0.00	0.25	0.00	0.17	1.02
1000-003-02	S/n 1112	0.00	2.79	1.88	0.00	0.24	0.00	0.45	0.69
1000-003-03	S/n 1011	0.00	2.79	1.75	0.00	0.36	0.00	0.28	0.71
1000-003-04	S/n 1012	0.00	8.11	1.65	0.00	0.46	0.24	0.46	1.43

Table #3: All ion values reported in the table are in micrograms per square inch (µg/in^2). All bag blank contaminants have been subtracted from the sample amounts.

Table #4: Numerical Cation Chromatography Data - Samples

Sample Number	Sample Description	Lithium Li^+	Sodium Na^+	Ammonium $NH4^+$	Potassium K^+	Magnesium Mg^{2+}	Calcium Ca^{2+}
1000-003-01	S/n 1111	0.00	1.79	1.88	1.09	0.25	0.38
1000-003-02	S/n 1112	0.00	1.16	2.16	0.76	0.39	0.48
1000-003-03	S/n 1011	0.00	1.06	1.87	0.68	0.44	0.44
1000-003-04	S/n 1012	0.00	1.62	1.93	1.10	0.30	0.49

Table #4: All ion values reported in the table are in µg/in^2. All bag blank contaminants have been subtracted from the sample amounts.

IC Data Discussion and Comments:

Residue Background

Tables 1 and 2 show (as a quick reference) the recommended residue levels that PAL suggests for the cleanliness of incoming boards with different plated finishes, as well as, the values for different flux designations for different assembly operations. The following is a brief overview and description of those values found in that table.

Most industry data relating residues to reliability have focused on the role of halides (Cl, Br) and selected mineral acid residues (SO_4) as initiators and contributors to electrochemical failure mechanisms. IPC-HDBK-001, the companion to J-STD-001, gives suggested evaluation criteria of 2.5 micrograms per square inch (µg/in^2) of chloride when low residue fluxes are used, and 4.0-5.0 micrograms of chloride for RMA and water-soluble fluxes.

For incoming boards with a HASL finish it is recommended that chloride levels not exceed 2.0 µg/in^2 of surface area. For boards with a non-HASL finish, such as ENIG, PAL recommends that chloride not exceed 1.0 µg/in^2.

Published studies on bromide suggest that it is not a problem until found in amounts above 12.0 µg/in^2. This value applies to both assemblies and incoming bare boards.

To the best of our knowledge, there is no published information on the amount of nitrate, which represents an electrochemical hazard. Most published work concentrates on the harmful amounts of chloride, bromide, sulfate and organic acids. If we assume that nitrate has similar electrochemical properties to sulfate, we would recommend a target level of 3-5 µg/in^2.

The amount of residual organic acid on a manufactured assembly varies depending on a number of factors, such as: flux composition, reflow profiles, method of flux application, level of applied flux, and assembly configuration (SMT vs. PTH). In general, a pure SMT process will have organic acid levels in the 5-20 ug/in^2 range, a mixed technology process in the range of 20-50 ug/in^2, and a pure PTH process in the range of 50-100 ug/in^2. Published research has indicated that organic acids are not "generally" electrochemical risks until the applied levels are in the hundreds of micrograms per square inch.

Additionally, we are not aware of any information correlating high levels of organic acids found on incoming boards to end-product reliability. Most of the industry data related to organic acids has been focused on the effects to assemblies. As such, we treat organic acids on incoming boards as a process indicator until we have reason to suspect they pose some risk to end-product reliability

For cations, very few studies have been published related to the role they play in electrochemical failures. As mentioned previously, most published work has focused on the effects from anions. We have developed some general guidelines for each of the cation species based on our evaluations of product considered as acceptably clean.

With these caveats in mind, we can review the data from the samples in this investigation.

IC Data Discussion

Four assemblies were provided for ion chromatography analysis to evaluate the levels of ionic residues that remained on each board's surface.

After reviewing the data, we find that samples 2 and 3 showed the overall lowest levels of ionic residues based on our recommended anion guidelines for no clean assemblies with surface mount only devices. Both samples showed chloride levels that were slightly above our recommended guideline, but were not terribly high. Sample 2 showed a slightly higher level of ammonium compared to the other three assemblies. The higher ammonium level is treated as a process indicator.

According to the client, the assemblies (samples 1 and 4) with the RESHA stickers were manufactured in Asia. The residue of most interest for those two assemblies was chloride. The measured levels on both units were high based on our recommended guidelines, with sample 4 having an excessive amount. All other residue levels were well within our recommended levels and not at levels known to cause electrochemical issues (i.e. electrical leakage, corrosion, dendritic growth, etc.).

Final Comments

The client desired to evaluate the levels of ionic residues remaining on four assemblies. Two assemblies were provided from the client's Asian facility. The other two assemblies came from the client's U.S. based facility. The client indicated that all four boards were processed in a no clean assembly environment. In addition, he indicated that the boards had a HASL surface finish. No additional information was provided with respect to the assembly materials or processing conditions or the fabrication materials or processing conditions.

In our experience, most no clean assembly environments utilize fluxes that are low halide bearing or "halide-free". The halide ions include fluoride, chloride, bromide and iodide. Chloride and bromide are the most commonly noted halides. For this evaluation, the most prominent residue common to all four assemblies was chloride. Chloride can have numerous sources from the incoming boards, to the components, to the assembly materials (i.e. flux, solder paste, etc.). Since we

would not expect the soldering materials to be halide bearing, we would focus our attention on the incoming boards. It is common practice for HASL processes to incorporate fluxes that contain either chloride or bromide activators. If the incoming boards contained high levels of chloride, then this would result in the assemblies having higher than desired levels. In our experience, a well-controlled HASL process should be able to maintain chloride levels below 2 micrograms per square inch. Additionally, there were noted differences in the date codes, which could explain the variation in the measured chloride on the two Asia assemblies. Further, if there is that much variation from one date code to the next, then we would recommend evaluating the incoming boards used by both facilities to assess their ionic residue contributions. Ideally, we would prefer the boards be from the same date or lot codes used for the assemblies in this evaluation and that the boards come from the same supplier(s).

In terms of assessing potential failure risks, it is important to note that every assembly has its own threshold for how much residue it can tolerate. Some assemblies can simply tolerate more residues than others. This makes it difficult to establish the risk for each assembly and is the reason why no industry limits currently exist. In our view, residues should be considered as a sliding scale of risk, with higher residue levels equating to a higher risk of issues in the field. The chloride level as noted on sample 4 is a cause for concern, as it is at a level known to be problematic. Sample 1 would also be considered at higher risk than samples 2 and 3.

Lastly, IC data, in order to be truly effective, must be viewed within the context of the manufacturing materials and processes used on the analyzed samples. Providing more information on the materials and processes (from fabrication and assembly) used for both sets of assemblies may allow us to give better insights into the data. In addition, we would recommend sending samples of the solder pastes used by both facilities to evaluate the types and amounts of ionic residues that are contributed from those sources.