Process Control and Qualification of Cleanliness Issues

New tool for localized extraction aids in process qualification

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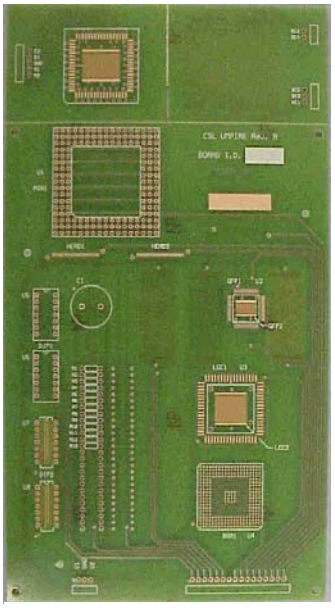
The qualification of a process includes a variety of testing and assessment techniques. Each industry and reliability classification has their proven sets of product tests and performance parameters for all the functionality of the product. In this study, we will only focus on the issues of process cleanliness and the impact on product performance.

The qualification of a process for cleanliness is three fold:

- Electrical assessment of the residues in high humidity environments
- Ionic analysis that separates and quantifies the ionic and organic residues left on the board surface and under the components
- Surface analysis using a process control tool that differentiates between good and bad residues.

The tools used to assess the electrical performance of a process are only as good as the samples built for assessment. Using a test coupon that only includes the primary paste and reflow, or wave soldering processes gives only ½ the residue picture. The secondary processes such as repair and rework, and then localized cleaning or cleaning issues are just as important and must be evaluated as well. Electrical assessment of residues from the process must be evaluated on an assembly at the pad to pad and hole to hole relationship. This is difficult to do on a functional assembly, and is the reason that different test boards have been developed for electrical and mechanical assessments of the processes.

One test coupon that we will discuss in this study is called the Umpire test board. Using this test assembly, both through hole and reflow top and bottom processes can be evaluated. The assembly process uses the chipbonder glue attachment to bottom side SMT parts 0402, 0805, 1206 along with IPC B-24 combs patterns with and without soldermask. Using the through hole vias, BGA, DIP packages and the Bellcore electromigration pattern, the Umpire board provides a good assessment of entrapment of residues on the bottom side of an assembly. The topside (primary side) of the Umpire uses IPC B-36 (68 pin LCC components – 2) and a variety of newer components that use a 10 mil spacing on an 80 pin TQFP, and a 256 ball BGA. Besides the paste and reflow, glue cure and then wave solder processes (either cleaned or not cleaned), we have areas to hand solder, perform localized cleaning and to use temporary soldermask blocking during primary wave soldering.



Umpire Test Coupon

The Umpire test coupon is a double sided FR-4 assembly that has the soldermask and metallization of the board fabricator you use to build your bare boards. We recommend that you have your fabricator take the Gerber files and fabricate the test coupon using the materials that are used on the production boards. Now, you start with a test coupon that is the same as your product. This helps create the same incoming cleanliness issues and board porosity that your typical product sees.

When building the Umpire test coupon, we also recommend that a few current production boards are built and ionically tested to document the ionic similarities of the processed

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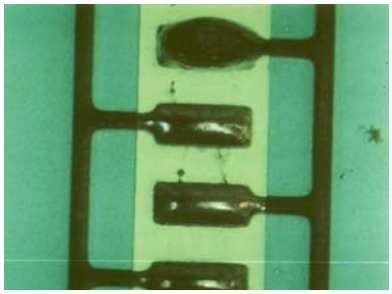
assemblies and test coupons. This approach can be done on different chemistries at the same time to screen and down-select different materials and processes.

Using the IPC J-STD-001 process qualification parameters of SIR (surface insulation resistance), 10 processed test coupons and 3 unprocessed bare control coupons are the minimal number of samples required. We recommend that 5 current production boards with bare boards from the same supplier be submitted at the same time to evaluate the assembly cleanliness.

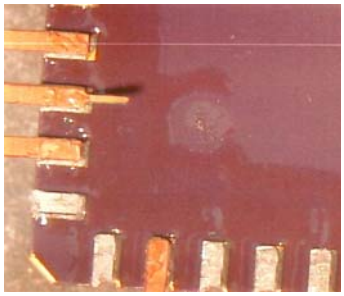
IPC SIR testing is done per the IPC TM 650 2.6.3.3a which states that the test coupons must be exposed to a non-condensing environmental exposure of 85ºC at 85% RH with a 50 volt bias and a 100 volt measurement after one minute of electrification, then a reading is taken using a micrometer 617 from Keithley Instruments, or an autoSIR from Concoat, or an equivalent system. Data acquisition is in 5 sets for each test area, initial ambient, 24, 96, 168 hour and ambient final. The pass / fail criteria for the IPC J-STD-001 is any value at 168 hours or final that is below the 1.0 e 8 ohms of resistance, or visible evidence at 10x magnification that electrochemical migration (dendrites) were present to cause a short, and then broken (blew apart due to the amount of current driving the short). All test areas are visually inspected for debris and shorts. The unprocessed controls are used to assess the chamber cleanliness and quality. The unprocessed control, if clean, should not fail electrically. We suggest that one of the three controls is a clean control that we provide as a background proven clean board.

Here is a data set from a typical umpire board process qualification (failed) evaluation of a water soluble flux and water only cleaning.

3% E816	**Umpire Board**		**Initial**	**24 hours**	**96 hours**	**168 hours**	**Final**	Visual	**Grade**
WSF Cleaned	Component Area		(ambient)	(85/85)	(85/85)	(85/85)	(ambient)		Pass* / Fail**
SMT	**LCC**	**Leads**	1.74E+11	9.77E+08	1.20E+09	4.68E+09	6.92E+11	No Dendrites	Pass
	LCC	**Comb**	2.57E+11	1.91E+08	4.37E+09	1.74E+10	2.40E+12	No Dendrites	Pass
	TQFP	**Leads**	3.24E+12	1.20E+09	7.59E+09	1.62E+10	7.24E+11	No Dendrites	Pass
	TQFP	**Comb**	3.89E+12	4.57E+08	2.57E+09	2.14E+10	1.17E+12	No Dendrites	Pass
	BGA	**Balls**	1.23E+12	1.17E+09	5.75E+09	9.33E+10	4.37E+11	No Dendrites	Pass
PTH	**DIP**	**U6**	3.89E+12	1.15E+09	1.05E+10	4.79E+11	3.39E+12	No Dendrites	Pass
hand solder	**DIP (brush)**	**U7 (cleaned)**	3.80E+12	6.31E+08	1.17E+10	4.07E+12	3.98E+12	No Dendrites	Pass
	PGA	**U1**	2.82E+12	8.71E+08	2.57E+09	9.33E+09	5.25E+11	No Dendrites	Pass
Bottom	**B-24--1**	**No mask**	3.89E+12	1.20E+09	5.50E+09	9.77E+09	2.57E+12	No Dendrites	Pass
	B-24--2	**Masked**	3.24E+12	6.17E+10	2.29E+10	1.48E+11	1.20E+12	No Dendrites	Pass
	B-24--3	**Crossed**	3.89E+12	1.62E+09	5.37E+09	1.82E+10	1.10E+12	No Dendrites	Pass
Resistor* **	1206	**bottom**	Good	Good	Good	Good	Good	No Voids	Pass
	805	**bottom**	Good	Good	Good	Good	Good	No Voids	Pass
	402	**bottom**	Good	Good	Good	Good	Good	No Voids	Pass
	402	**top**	Good	Good	Good	Good	Good	No Voids	Pass



LCC area with heavy water soluble flux residues trapped under the 5 mil standoff of the 68pin LCC.



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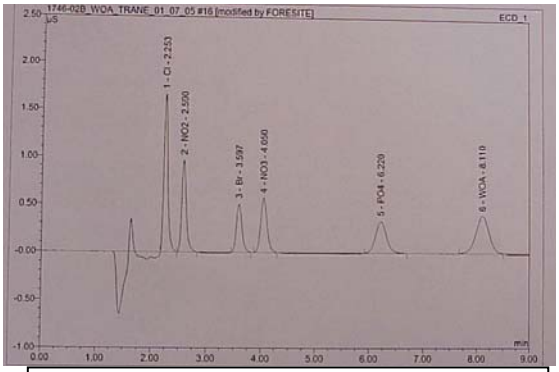
This data set is from the samples cleaned with a 3% EnviroGold Saponifier run at the same time.

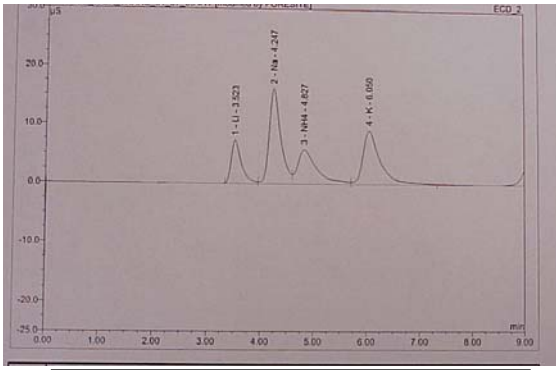
DI water WSF Cleaned	Umpire Board Component Area		Initial (ambient)	24 hours (85/85)	96 hours (85/85)	168 hours (85/85)	Final (ambient)	Visual	Grade Pass* / Fail**
SMT	**LCC**	**Leads**	1.51E+11	**8.91E+05**	**8.91E+05**	**8.91E+05**	**9.33E+05**	dentrite	Fail
	LCC	**Comb**	6.92E+11	**9.33E+05**	**8.91E+05**	**8.91E+05**	6.46E+08	dentrite	Fail
	TQFP	**Leads**	2.69E+12	**9.12E+05**	**1.02E+06**	**9.55E+05**	3.89E+09	dentrite	Fail
	TQFP	**Comb**	1.51E+11	**9.12E+05**	**9.55E+05**	**9.33E+05**	3.72E+09	dentrite	Fail
	BGA	**Balls**	1.24E+11	**8.91E+05**	**8.91E+05**	**8.91E+05**	8.91E+05	dentrite	Fail
PTH hand solder	**DIP**	**U6**	3.80E+12	1.10E+09	1.32E+10	1.95E+10	1.74E+11	No Residue	Pass
	DIP (brush)	**U7 (cleaned)**	3.72E+12	1.32E+09	1.66E+09	3.24E+09	2.45E+10	No Residue	Pass
	PGA	**U1**	2.95E+12	1.48E+08	2.29E+08	9.77E+09	1.86E+10	dentrite	Fail
Bottom	**B-24--1**	**No mask**	3.63E+12	1.62E+09	3.47E+09	1.58E+10	8.91E+10	No Residue	Pass
	B-24--2	**Masked**	8.91E+11	9.77E+09	9.55E+09	5.50E+10	9.77E+10	No Residue	Pass
	B-24--3	**Crossed**	3.39E+12	1.29E+09	1.86E+09	7.41E+09	1.20E+10	No Residue	Pass
Resistor* **	1206	**bottom**	Good	Good	Good	Good	Good	No Voids	Pass
	805	**bottom**	Good	Good	Good	Good	Good	No Voids	Pass
	402	**bottom**	Good	Good	Good	Good	Good	No Voids	Pass
	402	**top**	Good	Good	Good	Good	Good	No Voids	Pass

The SIR data from the water soluble study shows the umpire has a variety of electrical test sites that give good indications if the process is leaving residues that are causing performance problems. This customer found that the electrical performance of 10 assemblies gave passing criteria electrically and visually with the 3% saponified cleaned water soluble flux, but how clean were the boards that passed compared to the boards that failed?

Using Ion Chromatography to identify the cleanliness of the assemblies allows us to understand the effects from different processes. The cleanliness testing is done per the IPC TM-650 test method for ionic analysis TM-650 2.3.28. Using a Dionex ICS 2000 system with the AS4A-SC column and guard, the 1.7mM sodium bicarbonate/1.8mM sodium carbonate eluent for anions and the CS12A column and guard for cations with 0.075 mM sulfuric acid as a mobile phase will allow for good separation of the ionic species in less than ten minutes.



Anion separation in 9 minutes



Cation Separation in 9 minutes

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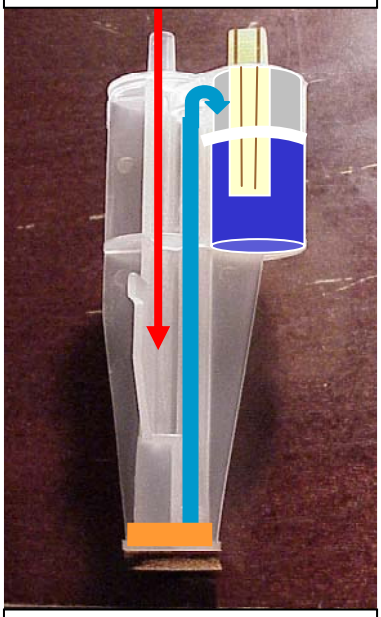
Each sample must be extracted prior to having the ion chromatography analysis conducted. We have two extraction protocols that area used in this evaluation. The first is a total board extraction **(standard extraction)** of the break away coupon with the 68 pin LCC component (top left corner of the umpire photo on page 1). The total extraction is done with a solution of IPA and DI water at 75% IPA and 25% DI water. A 10 ml volume of extraction solution is placed into a Kapak bag and the area of the board is placed in the bag and then suspended in a water bath at 80C for one hour to extract the residues from the assembly. This extraction solution is then injected directly into the Dionex ion chromatography system that has a 100 uL injection loop that will deposit in the different columns.

The second extraction (C3 localized) approach we use allows us to look at the localized area and extract from a 0.1 in^2 area around a component or comb pattern. This extraction method works using a microburst of steam. An area is isolated by the test cell, steam is then delivered to the isolated area, allowed to soak, and is then aspirated. This cycle is repeated a total of 9 times to remove ionic contaminants from the area of interest. Using the stream in 50 uL bursts, we will collect a total of 2.5 mls of extraction solution in less than 3 minutes. This solution is now ready to be injected into an ion chromatographer using a sample vial and autosampler.

3) The C3 Tester

Besides just creating a localized extraction of process residues, the C3 Tester has a second function as an electrical assessment of the extraction residue. Inside the test cell is a sacrificial electrode to electrically assess if the residues are corrosive.

C3 Test Cell
Heated Extraction Solution



Extraction Chamber
Aspiration Pathway of Solution

C3 Testing Extraction

Any production floor or analytical test for cleanliness is only as good as the technique to remove the residue from the surface of the assembly. Process cleanliness relates to the type and level of residues that are able to be brought into solution in critical areas, such as pad to pad or hole to hole on a functioning assembly. It is these residues that the C3 has been designed to assess. The extraction solution is designed to achieve effective ionic residue removal using a heated delivery system consisting of 3 stages.

1. Solution heating/delivery to the extraction site
2. Soak and ionization time
3. Aspiration of solution to collection cell

This cycle is repeated 9 times to effectively remove the surface residues from a 0.1 in^2 area, generating approximately 2.5 mls of extraction solution to be used during the testing and afterwards for additional testing.

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C3 Electrical Testing

Using a sacrificial Y-pattern electrode immersed in the extraction solution, a 10 volt bias (+/- 0.1V) is then applied to the electrode and an internal timer is started to measure the time it takes to achieve a leakage event. The system is measuring the leakage across the electrode generated by the extraction solution plus the residues extracted from the board surface. A threshold of 500 µA has been set to identify when a current leakage event has occurred. This threshold has been set using a combination of SIR and Ion Chromatography data.

The electrical measurement is determined by assessing the time it takes for the extraction solution and the 10 volt biased electrode to reach a 500 µA event. The system works under the theory that the more corrosive / conductive the residue the faster it will take to achieve this event. The less corrosive or conductive the residue the longer it will take to achieve. We have found that C3 timing results to achieve the 500 µA event in less than 60 seconds correlates to corrosive residues as set by Foresite's limits and are identified as **Dirty**. Timing events that take longer than 60 seconds have correlated to cleaner less corrosive residues and are identified as **Clean.**

A process qualification report will have the electrical performance data from the SIR testing, the cleanliness testing from the standard and localized extractions and the localized residue effects from the component areas on the processed test coupons and production boards. A typical sample matrix looks like the following:

	SIR testing	**C3 testing**	**Ion Chromatography**
Current production (5 assemblies)	0	3x5=15	3x5=**15**
Umpire Test Coupons (unprocessed)	3	3x3=9	3x3=9+3=**12**
Umpire Test Coupons (processed)	10	3x10=30	3x10=30+10=**40**

SIR Testing will be done on 15 component sites on the umpire board with 10 samples giving150 SIR readings on a variety of component styles.

Ion Chromatography will be done on both the current production in 3 locations using the C3 extractor and then on the processed and unprocessed umpire boards with 54 C3 extractions and 13 total board standard extractions.

C3 Localized Testing will be done on the three groups with a total of 54 samples.

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