REACTIVITY OF NO-CLEAN FLUX RESIDUES TRAPPED UNDER BOTTOM TERMINATED COMPONENTS

Bruno Tolla, Ph.D., Jennifer Allen, Kyle Loomis
Kester
Itasca, IL, USA
btolla@kester.com

Mike Bixenman, DBA
KYZEN Corporation
Nashville, TN, USA
mikeb@kyzen.com

ABSTRACT

The standoff gap of Bottom Terminated Components is commonly less than 50µm. As components reduce in size, the flux residue formation during the reflow soldering process is altered which can impact the reliability of the final assembly. As the flux residue build-up, there are several factors that can cause failure:

(1) The outgassing channel under bottom terminations is compromised
    a. Solvents don't evaporate, which results in chemically active residues comprised of polar and hygroscopic solvents acting as a media for Electrochemical migration and corrosion
    b. Gaseous decomposition products are trapped underneath the components
(2) Local thermal transfer effects
    a. Shallow flux layers trapped between large thermal masses do not experience the expected reflow profile and reach a partially activated state, which present different properties than fully reflowed activators.

If the residues trapped under the component terminations are active and can be mobilized with moisture, there is a potential for electrochemical migration, which will compromise the reliability of the final assembly.

The test board designed for this study has sensors placed under the components bottom termination. The component types selected are µBGAs, QFNs and resistors. Four solder pastes with different activator systems will be studied. Surface Insulation Resistance and Ionic contaminants of the residues trapped under the component termination will be measured. The DOE matrix calls for various reflow profiles and cleaning conditions (uncleaned, partially clean and thorough cleaning cycle). Inferences from the data findings, conclusions and process recommendations will be reported.

Key words: Bottom Terminated Components, QFNs, No-Clean Solder Paste, Flux Outgassing, Cleaning

INTRODUCTION

As electronic devices increase functionality in smaller form factors, there will be limitations, obstacles and challenges to overcome. Advances in component technology can create issues that may have time delayed effects. One such effect is device failure due to soldering residues trapped under bottom terminated components. If the residues trapped under the component termination are active and can be mobilized with moisture, there is the potential for ion mobilization causing current leakage.

Leadless components can block flux outgassing channels due to low standoff gaps, a high number of interconnects and large ground pads. When venting channels are compromised, flux residues accumulated under the components bottom terminations present different chemical characteristics, which affect their reactivity in the end-use environment. No-clean flux residues that do not have a channel to outgas can still contain solvents and activators. Massive components present similar challenges, as they induce thermal sinks which affect the properties of the residue. With power and ground in close proximity, it only takes a small level of moisture to create leakage currents and ultimately dendritic growth.

No-clean solder pastes are engineered to leave a benign post soldering residue. Solvents are designed to decompose and outgas at specific temperatures during reflow. Activators remove metal oxides needed to improve solderability through a fluxing reaction. Remaining activators and fluxing by-products are designed to be encapsulated in non-polar rosin and resins or to yield an inert residue. When adequately exposed to proper heat profile temperatures, the residue is non-ionic and poses minimal reliability risks.

PROBLEM STATEMENT

The miniaturization of modern electronics decreases conductor widths, which can create higher risks to insulation failure. As distances between conductors reduce, electronic hardware is more vulnerable to insulation failure due to higher voltage gradients and trapped contamination. To achieve acceptable soldering yields, higher fluxing capacity

may be needed. Residues trapped under bottom terminations that do not reach proper activation temperatures may still be active. The potential for failure is very real and the effects of failure can be costly when products are exposed to harsh environments.

PURPOSE STATEMENT

The purpose of this research is to evaluate four solder paste formulas for their reliability under bottom terminated components in function with the assembly process conditions. The board was designed so that all response factors can be studied independently for each component type (BGA, resistor, QFN). The process window is investigated by submitting the boards to disparate reflow profiles, one involving a direct ramp-to-spike while the second introduces a soak stage before liquidus. The cleanability aspects are also taken into consideration: A portion of the test boards were uncleaned, a subset cleaned at a process condition leaving residues under the bottom terminations, and a subset is thoroughly cleaned until no residues are left.

RESEARCH HYPOTHESES

The following research hypotheses will be tested:

H_1: Flux residues trapped under the bottom termination create the potential for ion mobilization and current leakage
H_2: Flux activators can be designed to reduce current leakage potential
H_3: Process optimization helps to reduce current leakage as longer profiles promote the conversion of activators into inert residues
H_4: Partial cleaning can expose flux constituents that can increase leakage potential
H_5: Total cleaning reduces current leakage potential

TEST BOARD

A non-standard, highly-customized, test board was designed to study the surface insulation resistance responses to fluxes and process parameters directly under the components. The test board design features include:

1. Board surface finish: OSP
2. Resistivity sensor traces placed under various low standoff devices
3. Copper weight: 1 oz. copper
4. Vias under QFNs: 20 mils or smaller non plated
5. Solder mask: LPI, 8µm min
6. 3 Fiducials, 50mils
7. Board thickness: 62mils

Several low standoff devices were selected to study the effects of components architectures. The selected devices were:

- BGA100 with 0.8mm pitch
- 2512, 1210 & 0805 Resistors
- QFN44's and QFN100's

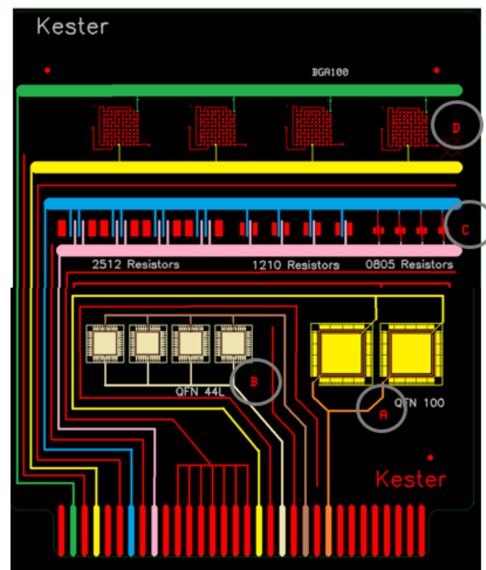

Figure 1: SIR Flux Reliability Test Board

The pin out shown was designed for compatibility with a 4 channels B24 connector wiring harness (A, B, C, D). This mitigates the risks of cross-contaminations from hard-wiring the board with flux core solder wires, as we have experienced in the past.

Channel D: Collects local SIR data under the BGA components. The board layout complements the internal daisy chain of each BGA to form the SIR electrical gap between selected balls under the devices (Figure 2).

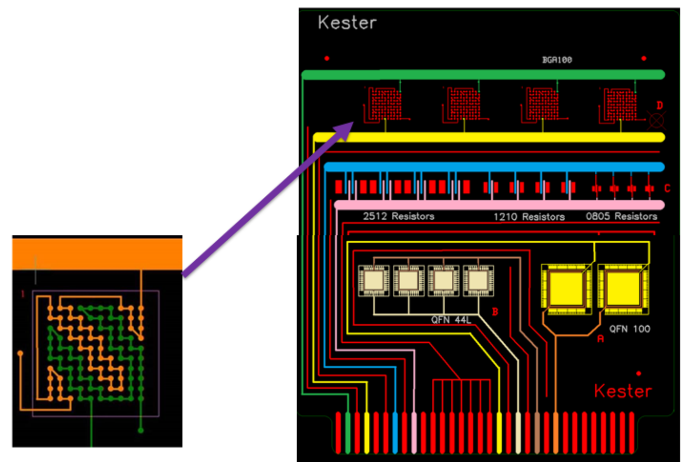

Figure 2: BGA Daisy Chain

Channel C: Collects local SIR data under the Resistors. Sensors are made of interdigitated traces located under the central body of the 12 passive devices. Solder paste was deposited on the sensor traces in addition to the resistor terminations, in order to ensure flux connections between the traces (Figure 3).

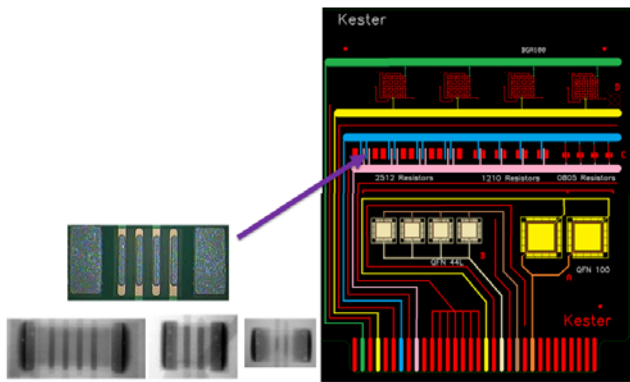

Figure 3: Passive Sensor Traces

Channel B: The looped sensors under each QFN44 devices are located in the space between the center thermal pad and the perimeter I/Os (Figure 4). The loop is biased against the I/O and against the center pad.

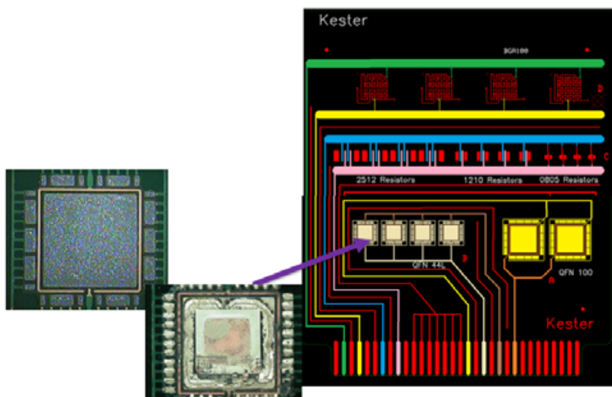

Figure 4: QFN 44 Sensor Traces

Channel A: Similar set up as Channel B to measure the local SIR values in the spacing under each QFN100 device, except for a more complex sensor loop geometry to insure a voltage gradient in the same range as other devices under test (Figure 5).

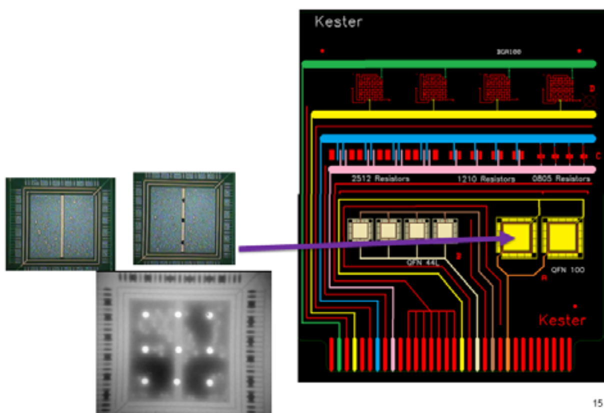

Figure 5: QFN 100 Sensor Traces

The IPC SIR Test method for open format B24 test boards (IPC-TM-650 §2.6.3.7) directs the user to apply an electrical bias of 25 V/mm (DC) between adjacent parallel traces. Since a broad range of line spacing and pitches is found on our customized board, the bias voltage had to be optimized to reach an acceptable range across components, while keeping the ability to study the impact of voltage gradients (Figure 6).

Sensor	Gap [mm]	Field Strength [V/mm]			
reference, IPC B24	0.50	25.0			
reference, IPC B25	0.32		31.5		
2512	0.50	25.0	20.0	16.0	10.0
1210	0.34	36.6	29.3	23.4	14.6
0805	0.18	70.3	56.2	45.0	28.1
BGA100	0.35	35.7	28.6	22.9	14.3
MLF44 loop-I/O	0.13	93.0	74.4	59.5	37.2
MLF44 loop-center	0.14	91.6	73.2	58.6	36.6
MLF100 loop-I/O	0.29	43.8	35.0	28.0	17.5
MLF100 loop-center	0.29	43.7	35.0	28.0	17.5
Bias Voltage, VDC=		12.5	10	8	5

Figure 6: Local field strengths under components for various applied voltage biases

EXPERIMENTAL

DoE Factors

- Bottom Terminated components
  - BGA100 with 0.8mm pitch
  - Resistors 2512, 1210 and 0805
  - QFN44's and QFN100's
- No-Clean Activator Packages
  - Activator 1: High-reliability Zero Halogen package
  - Activator 2: Standard Zero Halogen package
  - Activator 3: Activator 1 package doped with halogenated organic compounds
    (Doping level: 4,500 ppm of covalent Bromine)
  - Activator 4: Activator 1 package doped with halides
    (Doping level: 10,000 ppm of ionic Chloride)
- Reflow Profiles (Figure 7)
  - Ramp-to-Spike
    Lower duration and peak temperatures
  - Soak
    Longer duration and higher peak temperatures
- Cleaning Conditions (Figure 8)
  - No-Cleaning
  - Partial Cleaning
    Inline spray-in-air, 2 FPM, 3 min wash
  - Total Cleaning
    Inline spray-in-air, 0.5 FPM, 10 minute wash

The reflow conditions were applied with the intent to subject the flux residues to various thermal stresses, in order to establish a relationship between the thermal stability of the activator packages and the reliability response.

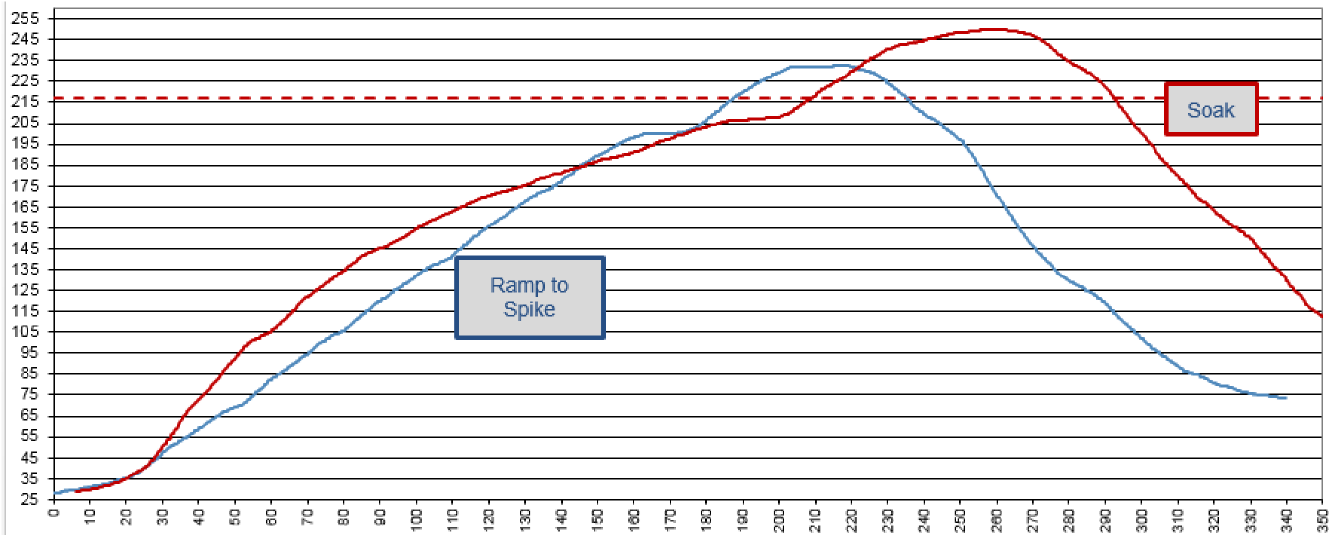

Figure 7: Reflow Profiles

Cleaning Tool Setup

The cleaning equipment was a customized inline cleaning machine designed to wash, rinse and dry circuit assemblies. Coherent and fan nozzles were intermixed in the wash section to provide needed deflection energy to penetrate and create a flow path under component terminations. The wash pressure was 70 psi for top manifolds and the wash temperature being set at 65°C. The aqueous wash chemistry is a material designed to clean lead-free no-clean solder paste flux residues. The wash chemistry was run at 15% concentration. To achieve a total clean, a belt speed of 0.5 feet per minute was run, while partial cleaning conditions used a faster belt speed of 2.0 feet per minute.

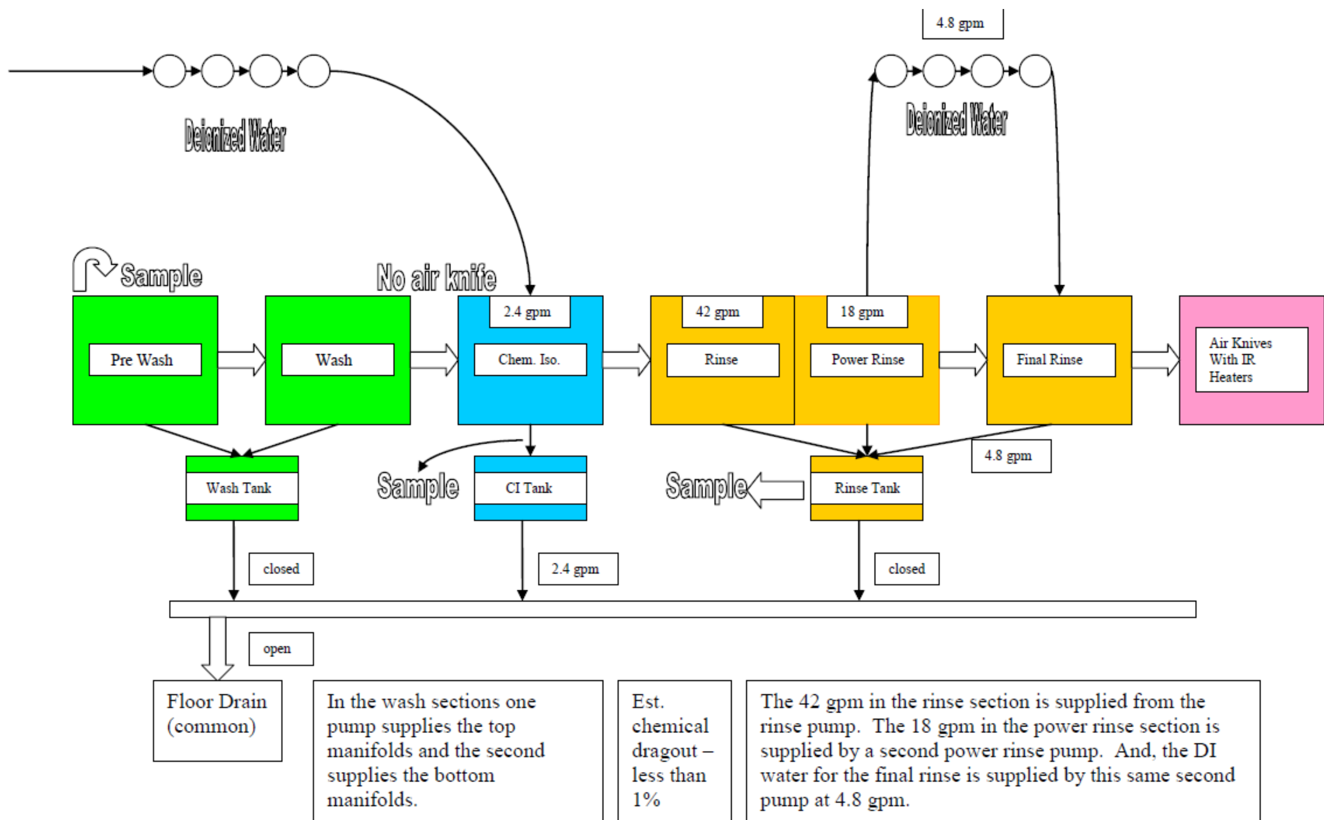

Figure 8: Inline Cleaning Machine Setup

SIR Test Parameters

- Test Coupon: Customized Test Board
- Bias: 8 Volts
- Test Voltage: 8 Volts
- Temperature: 85°C
- Humidity: 85% RH
- Measurement Interval: Every 20 minutes
- Test Duration: 7 Days (168 hours)

Temperature is ramped before humidity is elevated to avoid condensation. The inverse approach is applied to the recovery ramp down, following the same principles.

Responses

- Surface Insulation Resistance
- Residues Visual Inspection
- Ion Chromatography

RESULTS AND DISCUSSION

Surface Insulation Resistance Measurements

A wide variety of readings were obtained across the 96 unique DoE combinations of solder paste activators, sensors, components, reflow profiles and cleaning methods (Figure 9), which shows the discriminating power of the method.

Figure 9: SIR Values from all Factors and Levels Tested

A pattern showing the effect of the cleaning conditions on the SIR response plotted on a logarithmic scale is shown on Figure 10.

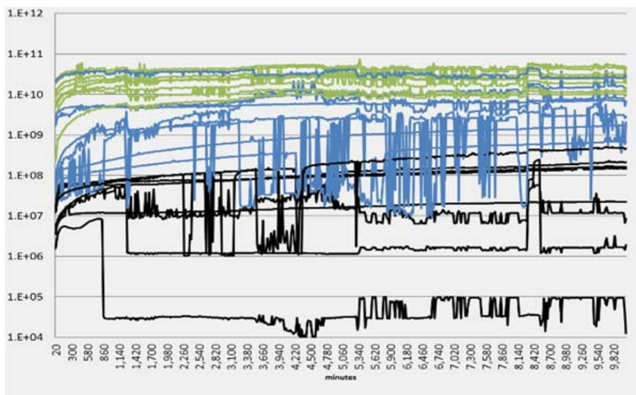

Figure 10: The Effect of Cleaning on SIR Responses
Green=Full Clean / Blue=Partial Clean / Black = No Clean

Comparing the cleaning response by the two reflow profiles, the soak profile shows generally lower readings on the uncleaned samples (Figures 11 and 12). The cleaning operation then tends to level these differences. This is an illustration of the ability of post-reflow cleaning to widen the process window.

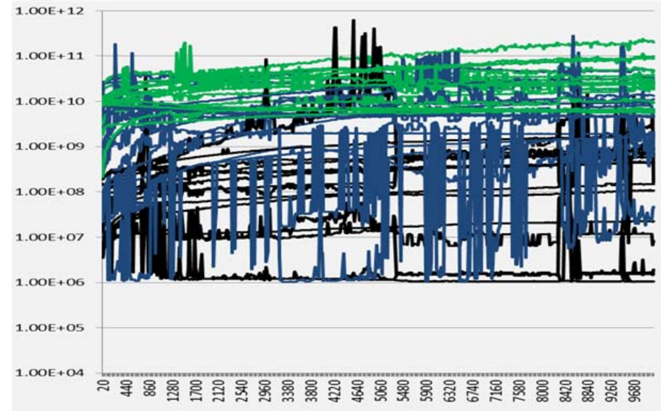

Figure 11: Ramp Reflow Profile

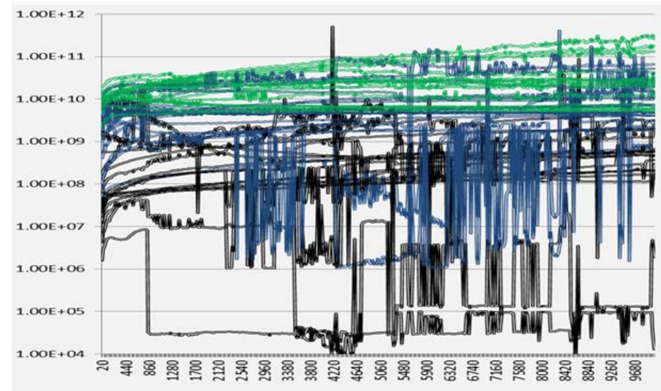

Figure 12: Soak Reflow Profile

Given the large variety of data generated during these experiments, the analyses were first broken down by components. Similar trends were found, but the sensitivities vary: The Quad Flat No-Lead packages gave the greater responses to flux chemistries and processing parameters. Therefore, we will narrow the scope of the following discussion to the evaluations under the QFN100 components. The SIR readings data most dramatically shows the benefit of cleaning under these very low standoff devices (Figure 13).

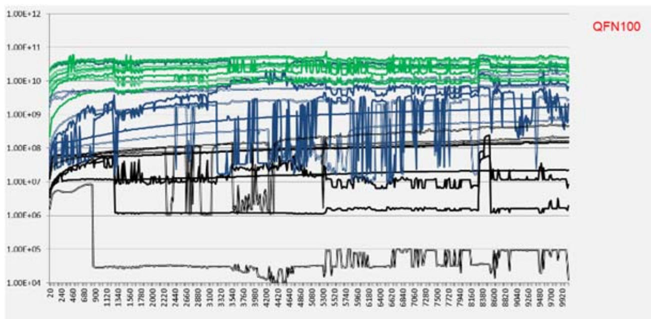

Figure 13: QFN100's Cleaning Effect
Green=Full Clean / Blue=Partial Clean / Black = No Clean

The QFN100 data can be further broken down by the various solder paste no-clean activator packages, with activator 2 showing the largest variation (Figure 15).

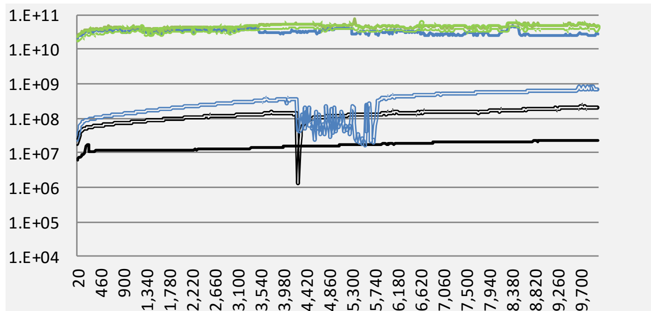

Figure 14: Activator 1 Responses for QFN100
Green=Full Clean / Blue=Partial Clean / Black = No Clean

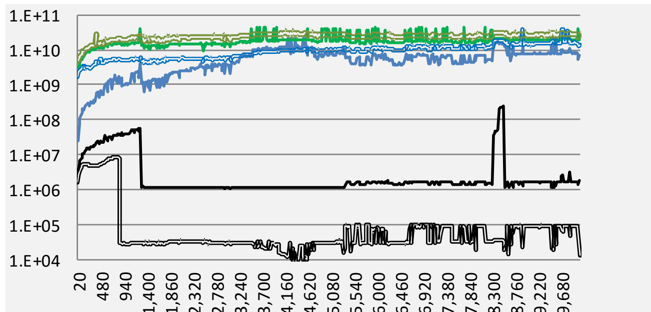

Figure 15: Activator 2 Responses for QFN100
Green=Full Clean / Blue=Partial Clean / Black = No Clean

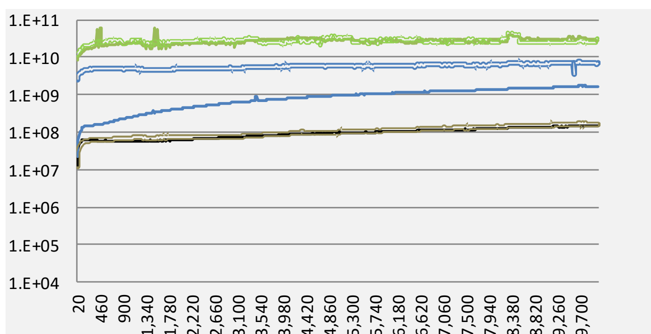

Figure 16: Activator 3 Responses for QFN100
Green=Full Clean / Blue=Partial Clean / Black = No Clean

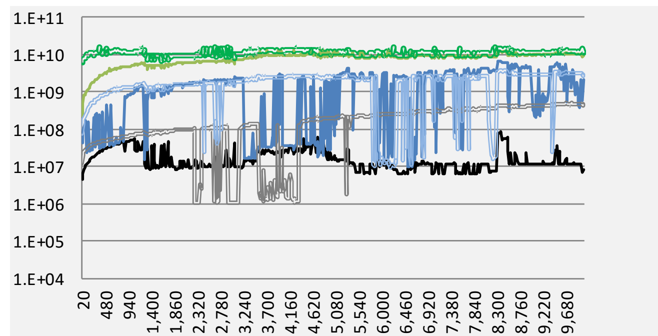

Figure 17: Activator 4 Responses for QFN100
Green=Full Clean / Blue=Partial Clean / Black = No Clean

It is remarkable that Activator 2, a zero-halogen package (meaning there are no-intentionally added halogens to this formula), presents the worse reliability performance of all activator packages in uncleaned conditions. Activators 3 and 4, which were a design variant of the high-reliability Activator 1, perform better than Activator 2 while being loaded with large amounts of halogens. The backbone structure of the formula, including solvents, additives and other types of activators (weak organic acids, organic amines, etc.), have a far more decisive impact on reliability than the "Halogen-free" label of a soldering flux, as shown in an earlier paper [1].

Looking at Activator Packages 1, 3, 4, which form a homogeneous series based on the same formulation backbone, the following comments can be made:

- Halides, an ionic form of halogens, are a significant factor of reliability (comparison Activator Packages 1 and 4). Here, the failure is identified by the SIR spikes rather than a general drop of the signal. This pattern is characteristic of electrochemical migration, where dendrites grow, short the conductors and then burn-off in a short timeframe. This is a real-life confirmation of a fundamental study we had executed in the past on this class of activators, using model tests [2]. The failure modes and mechanisms are described in detail in the referenced paper.

- Halogens can be safely used in a flux formula, as shown with Activator package 3, provided the interplays between chemical reactions, processing conditions and end-usage environments are thoroughly understood. This can be achieved through a testing protocol modeling the application conditions (assembly materials, devices, processes and environment). The experiments presented in this paper are an example of such a test, which happens to be far more discriminative than the current industry standards.

The impact of the reflow process is represented in Figures 14 to 17 by the line shading: solid lines correspond to a ramp-to-spike while the soak profile is represented by unfilled lines. The zero-halogen packages (Activators 1 and 2) appear to be more sensitive to the reflow conditions than the activator doped with covalent Bromine (Activators 3).

This is attributed to the thermal instability of brominated organic compounds at peak temperatures: Regardless of the preheating conditions, the brominated residue is essentially decomposed, volatilized and outgassed in the Liquidus range. On the other hand, the chloride-based residues (Activator 4) display electrochemical activity independently of the reflow conditions. Dendritic growth can only be addressed by a thorough cleaning procedure as illustrated by the green curve on Figure 17.

Residues Visual Inspection

Standard Die Shear equipment (Dage Series 4000) was used to remove QFN components from a select group of test boards. Four board images were selected for our discussion:

1. QFN 44 – (Figure 18)
   a. Activator 1
   b. Soak Profile
   c. Uncleaned

The residue was in a dried condition, which indicates proper heat exposure. The residue bridged the pads but was not as thick in the spacing next to the sensor loop.

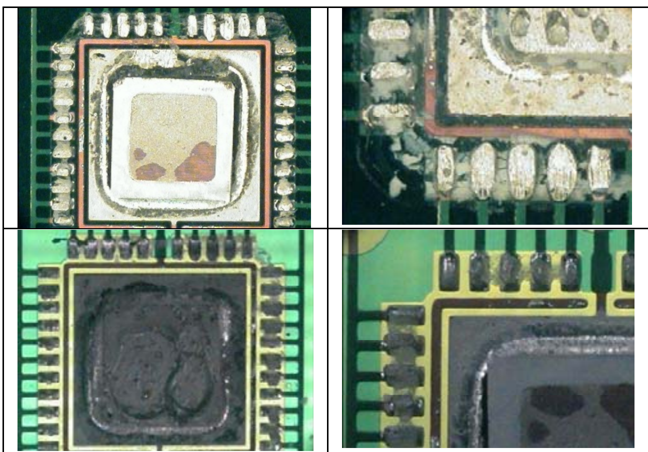

Figure 18: Control under QFN44 / Uncleaned condition

2. QFN 100 – (Figure 19)
   a. Activator 4
   b. Soak profile
   c. Uncleaned

The images show a significant level of flux bridging the pads. Where residue was present next to sensors, dendrites in the form of leakage currents propagated. The larger thermal mass of the QFN100 component relative to QFN44, combined with larger paste deposits on the center thermal pad had a significant impact of the amount and reactivity of the residues.

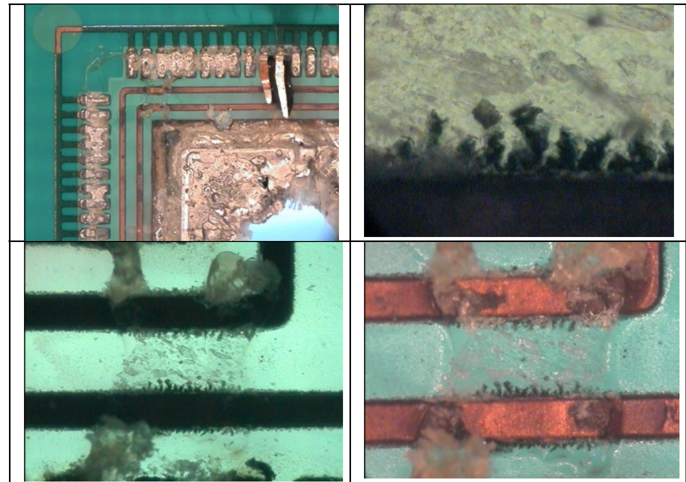

Figure 19: Activator 4 – No Cleaning – Followed SIR

3. QFN 100 – Activator 4 (Figure 20)
   a. Soak profile
   b. Partial Cleaning

For the partially cleaned components, most of the residue was removed during the cleaning process. However, in areas where residue was present, there was clear evidence of electrochemical migration. These findings indicate that quantitative residue removal is the necessary condition for reliability when highly active chemical packages are used, in agreement with the SIR results presented on Figure 17.

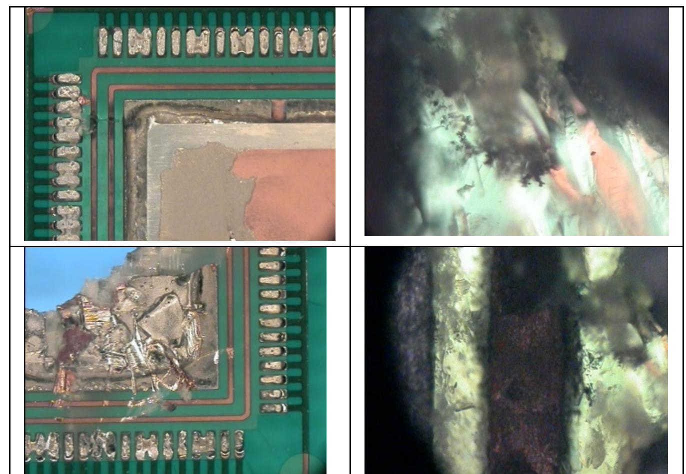

Figure 20: Effects of low residue left following SIR testing

4. QFN 100 & QFN44 – Activator 4 (Figure 21)
   a. Soak profile
   b. Total Cleaning

There was no observable dendritic growth on parts which were totally cleaned of flux residues.

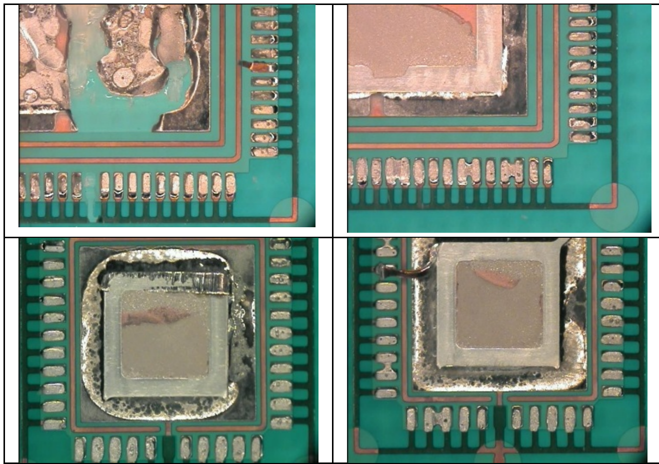

Figure 21: Effects of cleaned QFNs following SIR testing

Ion Chromatography

The ionic content in the residues was quantified by Ion Chromatography, using a Dionex ICS 1100 RFIC system equipped with a Dionex IonPac AS14 column for anion detection, Dionex IonPac CS12A cationic column for cation detection, and a conductivity detector. The residue extraction procedure followed the standardized conditions defined in IPC-TM-650 testing method §2.3.28.1. A 10µl sample was injected and eluted with a 4.5 mM Na_2CO_3 / 1.4 mM $NaHCO_3$ solution pumped at a flow rate of 1.2mL/min, the temperature being set at 30C. The data reported below compare the impact of the board cleaning conditions on ion contamination for each of the activator packages used in this study.

1. Uncleaned Boards

Only a few ions showing levels that exceeded the published cleanliness guidelines were detected on the uncleaned boards: Nitrate, Nitrite and Sulfate anions as well as Potassium cations. All these contaminants come from the board: due to the complex processes associated with PCB manufacturing, boards are a well-known source of chemical contamination, which need to be discriminated from the flux.

Looking at the flux-specific components, only significant amounts of Chlorides from Activator 4 package, Bromides from Activator 3 and Weak Organic acids from all activator packages were detected in the uncleaned residues. All these components were intentionally added in the flux formulations, so these results demonstrate the capability of the method.

Table 1: Ion chromatography data – Uncleaned Boards

	Soak Activator 1	Ramp to Spike Activator 1	Soak Activator 2	Ramp to Spike Activator 2	Soak Activator 3	Ramp to Spike Activator 3	Soak Activator 4	Ramp to Spike Activator 4
Anion IC Data								
Fluoride	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
Chloride	9.12	8.25	5.41	7.15	9.32	9.43	137.72	152.25
Nitrite	N/D	N/D	2.74	2.88	N/D	N/D	N/D	N/D
Bromide	10.28	7.68	8.84	5.57	54.29	51.38	14.82	10.08
Nitrate	6.31	7.89	5.96	6.27	6.73	6.80	6.79	8.07
Phosphate	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
Sulfate	59.15	83.94	35.58	30.95	76.60	65.64	55.11	91.19
Acetate	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
Formate	18.20	18.58	18.83	19.64	20.59	18.77	16.49	18.77
Methane Sulfonate	1.63	1.88	3.17	2.52	2.85	2.61	1.75	1.77
Phthalate	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
Total Weak Organic Acids	19.82	20.46	22.00	22.16	23.44	21.38	18.24	20.54
Cation IC Data								
Lithium	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
Sodium	9.54	11.91	7.73	9.08	13.38	11.87	10.79	13.71
Ammonium	25.40	24.69	19.02	20.20	22.75	25.94	23.19	23.88
Potassium	72.36	114.70	63.72	62.76	114.81	108.11	174.07	248.28
Magnesium	10.48	17.22	9.22	9.61	13.91	15.62	11.95	15.05
Calcium	14.23	15.17	18.88	21.30	12.13	16.93	13.83	11.73

As far as Activator 3, the halogen was added in the formulation as a covalently bonded Bromine. However, this brominated organic compound was dissociated during reflow, according to the halogen fluxing mechanisms described in another paper [2]. It was therefore expected to detect it in the flux residues in its ionic form (e.g. Bromide).

2. Cleaned Boards (Partial and Total)

The comparison of the contamination data in Table 2 and 3 shows that the Chlorides present in Activator 4 require an extensive cleaning process. Even with a quantitative wash, the detected chloride levels are still slightly above the baseline established with other components (Table 3). This is a direct consequence of the use of low stand-off components, as these species are highly soluble in water and should be easily removed in open conditions.

Table 2: Ion chromatography data - Partially cleaned Boards (1.5 fpm)

	Soak Activator 1	Ramp to Spike Activator 1	Soak Activator 2	Ramp to Spike Activator 2	Soak Activator 3	Ramp to Spike Activator 3	Soak Activator 4	Ramp to Spike Activator 4
Anion IC Data								
Fluoride	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
Chloride	4.83	4.33	3.29	5.25	3.79	4.44	14.57	18.20
Nitrite	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
Bromide	10.27	6.21	5.93	6.04	14.55	11.14	10.83	6.26
Nitrate	N/D	3.68	3.67	4.08	3.64	4.16	3.73	3.74
Phosphate	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
Sulfate	1.05	1.22	0.20	1.11	3.67	1.64	0.48	1.87
Acetate	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
Formate	17.46	17.88	16.37	16.32	17.16	16.69	17.44	17.18
Methane Sulfonate	3.36	3.86	3.83	2.98	4.21	4.01	2.70	2.52
Phthalate	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
Total Weak Organic Acids	20.82	21.74	20.21	19.30	21.37	20.70	20.14	19.70
Cation IC Data								
Lithium	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
Sodium	4.10	4.12	3.51	4.21	3.84	4.98	4.41	4.59
Ammonium	25.08	20.73	16.44	24.54	24.15	21.72	21.15	23.22
Potassium	10.98	9.16	7.02	9.49	7.86	11.29	20.93	26.13
Magnesium	5.24	7.48	4.22	7.18	4.74	6.46	4.59	6.13
Calcium	9.83	13.79	12.42	20.66	15.16	19.05	13.86	18.83

The bromide contents from Activator 3 show a similar trend. Although the final contamination levels are similar to the final chloride levels from Activator 4, our reliability study has shown that the latter are much more prone to create electrochemical migration issues.

Table 3: Ion chromatography data - Totally cleaned Boards (0.5 fpm)

	Soak Activator 1	Ramp to Spike Activator 1	Soak Activator 2	Ramp to Spike Activator 2	Soak Activator 3	Ramp to Spike Activator 3	Soak Activator 4	Ramp to Spike Activator 4
Anion IC Data								
Fluoride	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
Chloride	4.17	3.82	3.98	4.75	4.45	4.87	7.81	9.16
Nitrite	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
Bromide	8.73	5.40	9.03	5.24	12.03	9.80	8.25	6.79
Nitrate	3.67	3.72	3.51	3.67	N/D	N/D	N/D	N/D
Phosphate	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
Sulfate	0.20	1.50	0.11	1.21	0.68	2.08	0.20	2.24
Acetate	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
Formate	17.60	16.57	17.10	16.11	15.52	17.24	16.30	17.81
Methane Sulfonate	3.42	3.12	2.80	2.77	2.81	2.64	2.62	2.33
Phthalate	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
Total Weak Organic Acids	21.02	19.69	19.90	18.88	18.33	19.88	18.92	20.14
Cation IC Data								
Lithium	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
Sodium	4.09	4.24	4.04	4.37	4.29	5.41	4.04	5.18
Ammonium	19.69	10.38	18.13	13.28	17.55	14.69	13.91	19.06
Potassium	10.02	8.71	8.78	8.59	8.97	10.35	10.65	14.97
Magnesium	5.07	6.63	4.88	7.36	5.01	6.68	5.11	6.74
Calcium	15.08	20.25	14.11	22.35	16.00	20.25	15.14	20.43

Finally, the weak organic acid levels remain stable throughout the test. Their relatively low amounts do not seem affected by the cleaning procedure, due to the presence of low stand-off components. Their residual concentration is very similar across activator packages. However, our tests have demonstrated very significant differences in the reliability of the zero-halogen chemistries based primarily on these acids (Activator packages 1 and 2). Indeed, different members of this broad class of chemicals present very different activities and moisture sensitivities. Therefore, analytical methods like Ion Chromatography need to characterize these acids accurately in order to perform meaningful risk assessments. Specific columns were designed for that matter.

Overall, the boards produced with a thorough cleaning procedure (0.5 fpm) presented anion and cation levels below the published cleanliness guidelines and excellent reliability performance under all components, regardless of the activator package in use.

CONCLUSIONS

The experimental protocols described in this paper allowed us to test 5 fundamental hypotheses constituting the original motivation for the collaboration between Kester and Kyzen:

H_1: Flux residues trapped under the bottom termination create the potential for ion mobilization and current leakage

> Accept: The data conclusively finds that flux residue trapped under the component has the potential to drop resistance and current leakage.

H_2: Flux activators can be designed to reduce current leakage potential

> Accept: the data conclusively finds that the activator has a significant effect on resistance and current leakage. Of the four activators tested, Activator 3 was by far the safest activator package should flux residue not be cleaned or if some flux residue was still present following the cleaning process.
>
> When the parts were totally cleaned, all activator types had high resistance values and no sign of current leakage.

H_3: Soak reflow profile reduces current leakage as compared to the Ramp-to-Spike profile

> Reject: The reflow effect by activator provides some interesting findings however. When the QFN100 data is reformatted to show the impact of the selected reflow profile, it can be seen that some packages are more sensitive to heat treatment than others, for the reasons explained in the discussion section.

H_4: Partial cleaning can expose flux constituents that can increase leakage potential

> We strongly believe partial cleaning can be detrimental for some classes of activators, but more experiments are required to demonstrate a degradation between uncleaned and partially cleaned conditions.

H_5: Total cleaning reduces current leakage potential

> Accept: The data conclusively finds that total cleaning improves resistance values. No SIR fails were detected on parts that were totally cleaned, regardless of the activator packages or components in use.

In conclusion, low stand-off components present dramatic impacts on the reliability of the final assembly. The design of a customized SIR flux reliability test board taking this factor into account proved to be valuable in testing solder pastes types, cleaning material effectiveness, cleaning equipment and environmental conditions. These advances in test vehicle design can provide an improved understanding of the complex interactions between assembly materials, component designs and process conditions. A testing protocol modeling the end-use environment is the best approach to mitigate the reliability risks associated with the use of chemical packages. The experiments presented in this paper are an example of such a test, which happens to be far more discriminative than the current industry standards.

REFERENCES

[1] B. Tolla. D. Jean, H. Bhavsar, Y. Shi, X. Wei, "Reactivity of no-clean flux residues in electronic assemblies: a systematic study", SMTA International Conference Proceedings, Rosemont, IL, USA, **2015**

[2] B. Tolla, Y. Shi, X. Wei, H. Bhavsar, "Chemical influences on the reliability of complex assemblies", SMTA SE Asia Conference Proceedings, Penang, Malaysa, **2015**

ACKNOWLEDGEMENTS
The authors would like to acknowledge the following individuals for their contribution to this research paper:

- Dale Lee from Plexus, for his contribution to the reliability board layout
- Denis Jean, Product Technology Manager at Kester
- Chelsea Jewell, Process Development Engineer at KYZEN Corporation to clean test boards.
- Kevin Soucy, Application Manager at KYZEN Corporation for his help in setting up the machine to run test boards.
- James Perigen, Chemist at KYZEN Corporation for running the IC analysis on test boards