FORESITE
ISO 9001:2008

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FORMERLY CSL INC.

Cleanliness Investigation

BEST
Project #:1818-30

March 6, 2012

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Rolling Meadows, IL 60008

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1992

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Surface Mount Technology Association

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Cleanliness Investigation
Project # 1818-30
Bob Wettermann

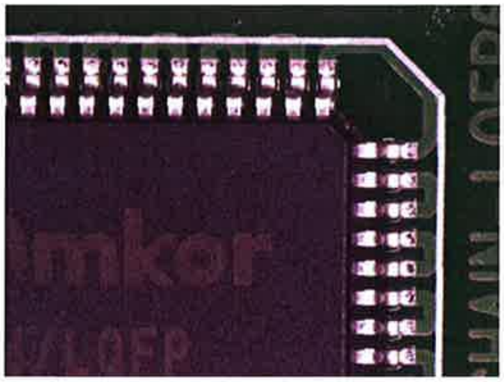
PROJECT GOAL

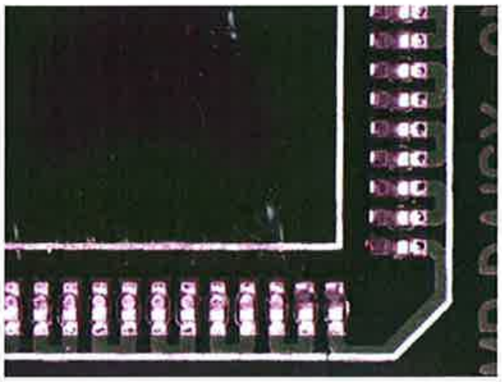
The purpose of this project was to determine if adhesive residues from rework stencil operation are detrimental to the assembly. All residues in this evaluation were characterized using Ion Chromatography per IPC-TM-650, method 2.3.28.

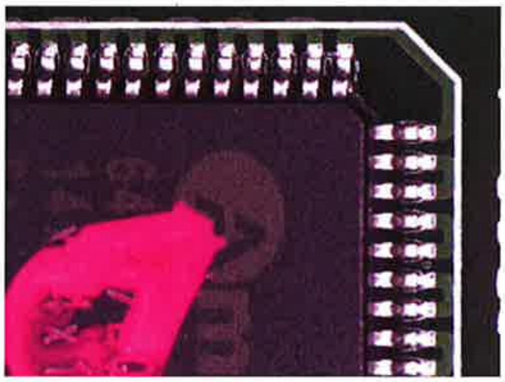
SAMPLE DESCRIPTION AND PROCESS HISTORY

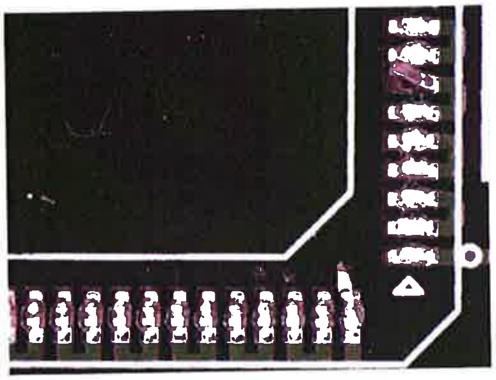
10 boards reworked using stencil with adhesive "A"
10 boards reworked using stencil with adhesive "B"
10 boards reworked using standard hand soldering rework process

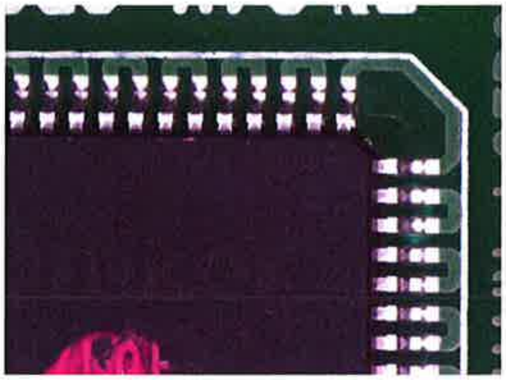
Visual Observations

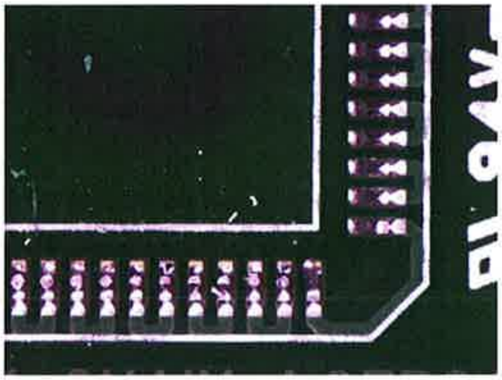

Sample A Component level


Sample A Board level


Sample B Component level


Sample B Board level


Sample C Component level


Sample C Board level

BEST

Project #:	1818-30	Address:	3603 Edison Place
Date:	March 6, 2012		Rolling Meadows, IL 60008
Contact:	Bob Wettermann	Phone:	847.797.9250
P.O. Number:	Trade	E-Mail:	bwet@solder.net

Cleanliness Investigation

	all values are in µg/in^2 unless noted	Ion Chromatography						
Foresite ID#	**Sample Description**	Cl^-	NO_2^-	Br^-	NO_3^-	PO_4^{2-}	SO_4^{2-}	WOA
Foresite recommended limits for bare boards		2.0	3.0	6.0	3.0	3.0	3.0	n/a
Foresite recommended limits for components		1.0	3.0	6.0	3.0	3.0	3.0	n/a
Foresite recommended limits for no-clean SMT		3.0	3.0	12.0	3.0	3.0	3.0	25.0
Foresite recommended limits for cleaned		6.0	3.0	12.0	3.0	3.0	3.0	25.0
1818-30-01	Sample A #1	1.21	0.01	0.71	0.06	0.24	0.84	25.03
1818-30-02	Sample A # 2	0.97	0.02	0.72	0.11	0.85	1.15	26.62
1818-30-03	Sample A #3	0.91	0.02	0.64	0.10	0.23	0.71	26.62
1818-30-04	Sample A #4	1.21	0.02	0.69	0.07	0.20	0.81	23.63
1818-30-05	Sample A #5	1.91	0.03	0.68	0.07	0.28	0.86	22.99
1818-30-06	Sample A #6	1.78	0.02	0.70	0.09	0.36	0.70	25.20
1818-30-07	Sample A #7	1.25	0.03	0.57	0.08	0.26	0.75	26.50
1818-30-08	Sample A #8	1.66	0.02	0.62	0.07	0.29	0.73	27.91
1818-30-09	Sample A #9	1.61	0.02	0.63	0.08	0.28	0.67	28.46
1818-30-10	Sample A #10	1.31	0.02	0.59	0.09	0.26	0.77	27.89
1818-30-11	Sample B #1	1.57	0.02	1.08	0.08	0.26	0.56	21.03
1818-30-12	Sample B #2	1.72	0.03	1.11	0.04	0.22	0.63	18.06
1818-30-13	Sample B #3	2.18	0.03	1.29	0.06	0.17	0.76	49.81
1818-30-14	Sample B #4	2.10	0.02	1.13	0.08	0.19	0.64	21.25
1818-30-15	Sample B #5	3.59	0.02	1.04	0.11	0.26	0.92	33.65
1818-30-16	Sample B #6	2.68	0.03	1.31	0.09	0.41	0.80	21.96
1818-30-17	Sample B #7	2.25	0.02	1.12	0.08	0.26	0.70	22.62
1818-30-18	Sample B #8	2.96	0.02	1.36	0.06	0.25	0.82	22.55
1818-30-19	Sample B #9	2.61	0.03	0.93	0.09	0.26	0.73	28.54
1818-30-20	Sample B #10	2.18	0.03	1.08	0.06	0.23	0.62	21.70
1818-30-21	Sample C #1	2.22	0.04	1.00	0.15	0.32	0.76	19.11
1818-30-22	Sample C #2	1.22	0.05	0.54	0.09	0.37	0.99	12.27
1818-30-23	Sample C #3	1.44	0.06	0.64	0.10	0.44	1.01	10.19
1818-30-24	Sample C #4	1.41	0.04	0.66	0.12	0.41	1.02	52.72
1818-30-25	Sample C #5	1.47	0.05	0.88	0.10	0.37	0.89	24.93
1818-30-26	Sample C #6	1.27	0.05	0.55	0.09	0.41	1.03	11.61
1818-30-27	Sample C #7	1.41	0.04	0.83	0.09	0.35	0.81	13.25
1818-30-28	Sample C #8	1.46	0.05	0.75	0.09	0.35	0.96	18.42
1818-30-29	Sample C #9	1.99	0.05	0.63	0.13	0.34	0.85	11.36
1818-30-30	Sample C #10	1.59	0.04	0.78	0.11	0.39	0.96	16.96

	all values are in µg/in^2 unless noted	Ion Chromatography					
Foresite ID#	**Sample Description**	**Li+**	**Na+**	**NH4+**	**K+**	**Ca+**	**Mg++**
Foresite recommended limits for bare boards		3.0	3.0	3.0	3.0	N/A	N/A
Foresite recommended limits for components		3.0	1.0	3.0	3.0	N/A	N/A
Foresite recommended limits for no-clean SMT		3.0	3.0	3.0	3.0	N/A	N/A
Foresite recommended limits for cleaned		3.0	3.0	3.0	3.0	N/A	N/A
1818-30-01	Sample A #1	0	1.56	2.54	1.61	1.93	0.10
1818-30-02	Sample A # 2	0	1.29	2.44	1.70	2.05	0.09
1818-30-03	Sample A #3	0	1.60	2.47	1.34	1.86	0.07
1818-30-04	Sample A #4	0	1.26	2.47	1.65	1.82	0.08
1818-30-05	Sample A #5	0	2.42	2.39	2.08	1.81	0.10
1818-30-06	Sample A #6	0	2.30	2.52	1.81	2.00	0.11
1818-30-07	Sample A #7	0	1.73	2.53	1.50	1.73	0.10
1818-30-08	Sample A #8	0	1.72	2.54	1.78	1.86	0.09
1818-30-09	Sample A #9	0	1.82	2.49	1.78	1.83	0.10
1818-30-10	Sample A #10	0	1.65	2.48	1.64	1.89	0.10
1818-30-11	Sample B #1	0	1.91	2.84	1.51	2.40	0.08
1818-30-12	Sample B #2	0	1.97	2.91	1.63	2.37	0.07
1818-30-13	Sample B #3	0	2.29	2.75	1.96	1.95	0.19
1818-30-14	Sample B #4	0	1.69	2.92	1.80	2.10	0.07
1818-30-15	Sample B #5	0	2.99	2.40	1.36	2.32	0.11
1818-30-16	Sample B #6	0	2.18	2.98	2.39	2.99	0.09
1818-30-17	Sample B #7	0	2.16	2.96	1.97	2.29	0.10
1818-30-18	Sample B #8	0	2.47	2.88	2.50	2.46	0.09
1818-30-19	Sample B #9	0	2.22	2.43	2.70	2.31	0.10
1818-30-20	Sample B #10	0	2.11	2.81	2.22	2.21	0.09
1818-30-21	Sample C #1	0	2.18	1.42	2.64	1.83	0.41
1818-30-22	Sample C #2	0	1.33	1.27	2.40	1.74	0.45
1818-30-23	Sample C #3	0	1.66	1.32	2.64	2.26	0.47
1818-30-24	Sample C #4	0	1.64	1.23	2.42	1.58	0.81
1818-30-25	Sample C #5	0	1.49	1.40	2.22	2.07	0.52
1818-30-26	Sample C #6	0	1.65	1.27	2.57	2.14	0.49
1818-30-27	Sample C #7	0	1.09	1.35	2.44	2.09	0.44
1818-30-28	Sample C #8	0	1.98	1.32	2.45	2.12	0.48
1818-30-29	Sample C #9	0	2.24	1.21	2.51	1.82	0.41
1818-30-30	Sample C #10	0	2.35	1.46	2.45	2.11	0.48

- All testing was performed on a Dionex ICS 3000 ion chromatography system using Chromeleon software
- Controls and blanks were performed on the Dionex ICS 3000 ion chromatography system before the test began. *NOTE: Foresite used NIST-traceable standards for all system calibrations*
- A 1.5mL sample of each test samples' extracted solution was analyzed using a 1.7mM sodium bicarbonate/1.8mM sodium carbonate eluent.

CONCLUSIONS

Group A results were the best overall of the three groups tested. The weak organic acid levels were at or marginally above the Foresite recommended limits, but they were by far the most consistent group across all species tested.

DATA DISCUSSION - ION CHROMATOGRAPHY

The attached page(s) show the data for this evaluation. The data table lists the ion chromatography data in micrograms of the residue species per square inch of extracted surface (μg/in^2), unless otherwise noted. One should not confuse this measure with micrograms of sodium chloride equivalent per square inch, which is the common measure for most ionic cleanliness test instruments.

Chloride (Cl^-)

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.

Chloride on Bare Boards

The amount of allowable chloride on a bare board is difficult to assess. If the board enters an assembly process that incorporates cleaning, then one can tolerate a higher level of chloride. If the bare board enters an assembly process void of cleaning (no-clean), then a more stringent level of acceptable chloride is necessary.

Foresite recommends a maximum chloride level of no more than 2.0 μg/in^2 for bare boards used with either a no clean or water-soluble flux. With this low level of contaminants on the incoming bare boards, the process can be optimized to deal with the assembly flux residues.

Chloride on Components

Foresite recommends a maximum chloride level of no more than 1.0 μg/in^2 for plastic plated components. Although this recommended maximum does not presently appear in any nationally accepted specifications or standards, years of failure analysis experience dealing with Foresite's numerous customers serves as a basis or starting point.

Chloride on Assemblies

The tolerance for chloride on an assembly depends on the flux chemistry that an assembler uses. An assembly processed with high-solids rosin fluxes (RA or RMA) can tolerate higher levels of chloride due to the encapsulating nature of the rosin. Water-soluble fluxes and no-clean fluxes, which flux manufacturers typically formulate using resins or very low levels of rosin, do not have this encapsulating protection. Therefore, they require lower levels of flux on final assemblies.

Bromide (Br^-)

Bromide is generally attributable to the bromide fire retardant added to epoxy-glass laminates for fire resistance and is subsequently extracted in the ion chromatography analytical procedure. Bromide can also come from solder masks, marking inks, or fluxes that have a bromide activator material. When from the fire retardant, bromide is not a material that typically degrades the long-term reliability of electronic assemblies. If bromide comes from a flux residue, it can be as corrosive as other halides. The level of bromide varies 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.

Bromide on Epoxy-Glass Laminate Boards

For epoxy-glass laminate, bromide levels typically fall within the range of 0 - 7 $\mu g/in^2$, depending upon the amount of fire retardant the laminate manufacturer has added. Exposure to reflow conditions tends to increase the porosity of the laminate and mask. With several exposures to reflow conditions, bromide can reach levels as high as 10 - 12 $\mu g/in^2$. Foresite does not presently consider bromide levels less than 12 $\mu g/in^2$ to be detrimental on organic printed wiring boards. However, we consider levels between 12 $\mu g/in^2$ – 20 $\mu g/in^2$ to be a borderline risk for failures if attributable to corrosive flux residues. Furthermore, we consider levels above 20 $\mu g/in^2$ to be a significant threat for failures if attributable to corrosive flux residues.

Bromide on Cyanate-Ester Modified (CEM) Laminate Boards

For cyanate-ester modified (CEM) laminate, bromide levels can range anywhere from 0 - 3 $\mu g/in^2$ depending on the amount of bromide fire retardant the laminate manufacturer has added. Exposure to reflow conditions tends to increase the porosity of the laminate and mask and so bromide levels can go as high as 5 - 7 $\mu g/in^2$ with several exposures to reflow conditions.

Bromide on Polyimide Laminate Boards

For polyimide resin materials, either as rigid laminate or as a flex circuit, bromide levels can range anywhere from 0 - 3 $\mu g/in^2$ depending on the amount of bromide fire retardant the laminate manufacturer has added.

The higher glass transition temperature of polyimide usually means that the resin manufacturer has to add less bromide to gain the same flame-retardant characteristics. If bromide levels rise appreciably above 8 - 10 $\mu g/in^2$, then we suspect the use of a brominated flux or similar fluid.

Sulfate (SO_4^-)

Sulfate, 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.

When sulfate levels start rising appreciably above 3.0 μg/in^2, we look for a sulfate-bearing chemical in the process, such as sodium/ammonium persulfate or sulfuric acid. As a conservative stance, Foresite considers sulfate levels above 3.0 μg/in^2 to be corrosive and detrimental to circuit reliability. As nitrate has approximately the same electronegativity as sulfate, the sulfate recommendations also apply to nitrate residues.

Another possible source of high sulfate may be the solder mask itself. Some solder mask formulations use sulfur-bearing compounds as fillers, dyes, and matting agents. When the bare board is subjected to the ion chromatography extraction procedure, the sulfates are pulled from the mask. As with bromide, when the sulfate residues are from within the mask itself, they are not detrimental.

Weak Organic Acids (WOAs)

Weak organic acids, such as adipic, malic, glutaric or succinic acid, serve as activator compounds in many fluxes, especially no-clean and water soluble fluxes. WOAs are typically benign materials and are therefore not a threat to long-term reliability. In order to avoid formulation disclosure difficulties with flux manufacturers, we group all detected weak organic acid species together and refer to them collectively as WOAs.

Weak Organic Acids on Assemblies

WOA levels vary greatly, depending on the delivery method (e.g. foam vs. spray) and the preheat dynamics. In general, water-soluble fluxes have a much lower WOA content than do low-solids (no-clean) fluxes, and the amount of residual WOA is proportional to the amount of residual flux. Bare boards typically do not contain WOA residues. When WOA levels are under 25 for SMT / hand soldering and wave at 150 μg/in^2, the residues are generally not detrimental.

Excessive WOA amounts (appreciably greater than 25 or 150 μg/in^2) present a significant reliability threat for finished assemblies. An excessive amount of flux can produce the situation in which the thermal energy of preheat is spent driving off the solvent thereby not allowing the flux to reach its full activation temperature. Unreacted flux residues readily absorb moisture that promotes the formation of corrosion and the potential for current leakage failures.

Sodium (Na^+)

Sodium is found in nature only as a compound and never as the free element. Sodium reacts exothermically with water: small pea-sized pieces will bounce across the surface of the water until they are consumed by it, whereas large pieces will explode. While sodium reacts with water at room temperature, the sodium piece melts with the heat of the reaction to form a sphere, if the reacting sodium piece is large enough. The reaction with water produces very caustic sodium hydroxide and highly flammable hydrogen gas. These are extreme hazards (see *Precautions* section below). When burned in air, sodium forms sodium peroxide Na_2O_2, or with limited oxygen, the oxide Na_2O (unlike lithium, the nitride is not formed). If burned in oxygen under pressure, sodium superoxide NaO_2 will be produced.

In electronics manufacturing it is found is some fluxes, as the counter ion to the acid activator such as sodium succinate. It is also found in the soldermask as absorbed residues and can be conductive through or on top of the mask. With levels less than 3.0 ug/in2 we have good field performance and good SIR test results.

Ammine (NH_4^+)

Amines are organic compounds and a type of functional group that contain nitrogen as the key atom. Structurally amines resemble ammonia, wherein one or more hydrogen atoms are replaced by organic substituents such as alkyl and aryl groups. An important exception to this rule is that compounds of the type $RC(O)NR_2$, where the C(O) refers to a carbonyl group, are called amides rather than amines. Amides and amines have different structures and properties, so the distinction is chemically important. Somewhat confusing is the fact that amines in which an N-H group has been replaced by an N-M group (M = metal) are also called amides. Thus $(CH_3)_2NLi$ is lithium dimethylamide. Much of the amines used in electronic assembly are in board fabrication as etchants, HASL flux residues and some water soluble fluxes and solder paste material. The amines are found in many of the water soluble fluxes and solderpaste.

Potassium (K^+)

Potassium compounds generally have excellent water solubility, due to the high hydration energy of the K^+ ion. The potassium ion is colorless in water. Potassium may be detected by taste because it triggers all the types of taste buds, according to concentration. Dilute solutions of potassium ion taste sweet (allowing moderate concentrations in milk and juices), while higher concentrations become increasingly bitter/alkaline, and finally also salty to the taste. Potassium in electronics is found in the dry film soldermask materials. The amount of potassium found is electronics is typically low but we have seen levels greater than 3.0 ug/in2 cause leakage problems.

Calcium (Ca^+) and Magnesium (Mg^+)

These ions are typically found in the soldermask as fillers and rarely come into solution or cause electrical leakage and corrosion problems. The amount of ionic residue on the surface of the assembly is low and poses a minimal risk of leakage and corrosion.