Foresite Recommended Cleanliness Limits

For over 20 years, Foresite has studied field failures of electronics. A majority of these failures have been the result of residues on surfaces during the manufacturing process.

From these observations, we have correlated concentrations of specific contaminants with product reliability through the use of ion chromatography. This has demonstrated that the concentration of ions at or below our developed limits results in elimination of failure root causes. These causes, associated with a lack of electronics cleanliness, can be alleviated. The following table contains the recommended limits, regardless of electronic product class. When residues are present in detrimental concentrations, reliability suffers, regardless of the application. In harsher environments, these results only increase at an expedited rate.

		Fluoride	Acetate	Formate	Methanesulfonic Acid	Chloride	Nitrate	Bromide	Nitrite	Phosphate	Sulfate	Weak Organic Acid	Weak Organic Acid	Lithium	Sodium	Potassium	Ammonium	Calcium	Magnesium	C3 - IPC Class 2 & 3	C3 - IPC Class 1
		F^-	$C_2H_3O_2^-$	HCO_2^-	MSA	Cl^-	NO_3^-	Br^-	NO_2^-	PO_4^{3-}	SO_4^{2-}	SMT hand & selective	Wave direct contact	Li^+	Na^+	K^+	NH_4^+	Ca^{2+}	Mg^{2+}	time/µA	time/µA
Bare Boards	PCB Pre-mask Via or PTH Soldermask Surface SMT Pad Area Innerlayer*	3	2.5	2.5	0.5	2	2.5	2.5	2.5	2.5	3 *10	n/a	n/a	2	2	2	2.5	n/a	n/a	>120s/250µA	>60s/500µA
Component	BGA Reballed BGA Tinned IC Flip Chip Trayed Component	1	3	1	1	1	2	6	2	2	1	25	n/a	1	2	2	2.5	n/a	n/a	>120s/250µA	>60s/500µA
PCBA (no clean)	NC Via Top Solder Area NC SMT NC Wave Reworked	1	3	3	1	3	3	6	3	3	3	25	150	3	3	3	3	n/a	n/a	>120s/250µA	>60s/500µA
PCBA (clean)	NC/WSF Via Top Selective NC/WSF SMT NC/WSF Wave Rework/Misprint	1	3	3	1	6	3	6	3	3	3	25	25	3	3	3	3	n/a	n/a	>120s/250µA	>60s/500µA
Support Hardware	Heat Sink Housing/ESD Foam Thermal Material Thermal Pad Battery Housing	1	3	3	1	2	3	6	3	3	3	n/a	n/a	1	1	3	2	n/a	n/a	>120s/250µA	>60s/500µA

Foresite, Inc. • 765-457-8095 • www.foresiteinc.com

Implications of Residues

Halides

Halides present on electronic hardware have varying impacts on product performance and can be introduced throughout the manufacturing process.

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 a higher level of chloride can be tolerated. 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 less than 2.0 µg/in^2 for bare boards used in a no clean or water-soluble flux soldering process. With this low level of contamination on the incoming bare boards, the process can be optimized to deal with assembly flux residues.

Chloride on Components

Foresite recommends a maximum chloride level of less than 1.0 µg/in^2 for plastic plated components.

The recommended maximum level does not presently appear in any nationally accepted specification or standard. However, years of failure analysis experience with numerous customers suggest this to be a basis or starting point.

Chloride on Assemblies

The tolerance for chloride on an assembly depends on the flux chemistry that is used during manufacture. 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 ionic species are generally attributable to the bromide fire retardant additives that are included in the manufacture of epoxy-glass laminate circuit boards and subsequently extracted in the ion chromatography analytical procedure. Bromide can also come from solder masks, marking inks, or fluxes (that have a bromide activator). 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 with the range of 0–7 µg/in^2, depending upon the amount of fire retardant added by the laminate manufacturer.

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 µg/in^2. Foresite does not presently consider bromide levels less than 12 µg/in^2 to be detrimental on printed circuit boards.

However, we consider levels between 12–20 µg/in^2 to be a borderline risk for failures if attributable to corrosive flux residues. Furthermore, we consider levels above 20 µg/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 µg/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 µg/in^2 with several exposures to reflow conditions.

Implications of Residues

Bromide on Polyimide Laminate Boards

For polyimide resin materials, either as rigid laminate or as a flex circuit, bromide levels can range from 0–3 µg/in^2 depending on the amount of bromide fire retardant added by the laminate manufacturer.

The higher glass transition temperature of polyimide material usually suggests that the resin manufacturer can add less bromide and still maintain the same flame retardant characteristics as other circuit board materials. If bromide levels rise appreciably above 8–10 µg/in^2, then we suspect the use of a brominated flux or similar fluid.

Sulfate (SO_4^{2-})

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

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 per sulfate or sulfuric acid. Foresite considers sulfate levels above 3.0 µg/in^2 to be corrosive and detrimental to circuit reliability. As nitrate has approximately the same electro negativity as sulfate, the sulfate recommendations also apply to nitrate residues.

Another possible source of high sulfate may be solder mask. 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 removed from the mask. As with bromide, if the sulfate residues are extracted from the mask during the IC process, they are not detrimental.

Weak Organic Acids (WOA)

Weak organic acids, such as adipic, malic, glutaric or succinic acid, serve as activator compounds in many flux systems, 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 less than 25 µg/in^2 for SMT / hand soldering and below 150 µg/in^2 for wave soldering, 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. Un-reacted flux residues readily absorb moisture that promotes the formation of corrosion and the potential for current leakage failures.

Sodium (Na^+)

In electronics manufacturing, sodium is found in some fluxes, as the counter ion to the acid activator such as sodium succinate. It is also found in solder mask as absorbed residues and can be conductive through or on top of the mask. Levels less than 3.0 µg/in^2 have shown good field performance and good SIR test results.

Ammonium (NH_4^+)

Amines used in electronic assembly are from the board fabrication process, such as, etchants, HASL flux residues, some water soluble and solder paste materials.

Potassium (K^+)

Potassium in electronics is found in dry film solder mask materials. The amount of potassium found in electronics is typically low, but we have seen levels greater than 3.0 µg/in^2 that cause leakage problems.

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

These ions are typically found in the solder mask as fillers and rarely come into solution or cause electrical leakage and corrosion problems.