Solder Flux Residue – Part 1

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Introduction

Solder flux residue left on printed circuit board assemblies often results in corrosion, electro-chemical migration, electrical leakage, and short circuit faults. SEM/EDS analysis of these residues has shown us that various flux chemistries and levels of corrosion can lead to a variety of elemental signatures. This paper investigates what conclusions can be drawn from the EDS data for solder flux residue.

EDS Data

Fig. A shows elemental composition of solder flux residue on average for various samples (N = 35) that had been suspected of failing due to ionic electrical leakage between otherwise isolated signal nodes on printed circuit board assemblies.

Element	Average	St. Dev.
C	71.05%	4.30%
O	22.80%	2.42%
Al	0.30%	0.56%
Si	0.70%	0.71%
P	0.00%	0.01%
S	0.27%	0.16%
Cl	0.09%	0.11%
Ca	0.44%	0.37%
Ti	0.27%	0.45%
Fe	0.01%	0.01%
Ni	0.27%	0.43%
Cu	0.23%	0.35%
Br	0.30%	0.37%
Ag	0.27%	0.85%
Sn	2.48%	1.07%
Ba	0.50%	0.57%

Fig. A - EDS data for solder flux residue on various samples in atomic percentage (N = 35).

Potential sources for the elemental constituents found in solder flux residue are shown in Fig. B. The primary three constituents most commonly observed are carbon, oxygen, and tin. Bromine and chlorine are normally considered to be flux activators, though these can also be due to brominated epoxy (e.g. FR4 laminate) or chlorine in polymers (e.g. parylene conformal coating). Other constituents are thought to be indicators of corrosion (e.g. copper, silver, & nickel).

Carbon (C) - resin or rosin in solder flux - polymers	**Oxygen (O)** - resin or rosin in solder flux - oxides of metallic constituents
Chlorine (Cl) - solder flux activator - chlorinated water	**Titanium (Ti)** - TiO_2 constituent in silk screened ink - MLCC barium titanate dielectric
Bromine (Br) - solder flux activator - brominated epoxy (FR4)	**Aluminum (Al)** - Al_2O_3 in solder mask, alumina substrates, or polishing compound in X-sect
Sulfur (S) - constituent in LPI solder mask - sulfur in rinse water - sulfur in atmosphere	**Silicon (Si)** - SiO_2 in solder mask - SiC in grinding abrasive in X-sect
Tin (Sn) - Sn-Ag-Cu solder alloy	**Phosphorus (P)** - Ni-P barrier plating on components - Ni-P alloy from ENIG finish
Copper (Cu) - component mounting pads - Sn-Ag-Cu solder alloy	**Iron (Fe)** - iron in tap water - possible steel or ferrite part(s) on PCBA
Nickel (Ni) - nickel barrier plating on MLCCs - Ni-P alloy from ENIG finish	**Calcium (Ca)** - calcium oxide or carbonate filler in potting material - calcium in tap water
Silver (Ag) - silver thick film layer on MLCCs - Sn-Ag-Cu solder alloy	**Barium (Ba)** - constituent in LPI solder mask - MLCC barium titanate dielectric

Fig. B - Potential sources for the elemental constituents found in solder flux residue.

Analysis of EDS Data

This section illustrates by example how we can analyze EDS data of flux residues on PCBAs. This example involves suspect QFN devices that were mechanically pried off of the board so that entrapped flux residue under the devices on the board surface could be examined.

The majority of the carbon in the solder flux residue was assumed to be due to no-clean flux resin, which is often pentaerythritol benzoate (C33H28O8). Sn, SnO, SnO_2, and SiO_2 were included as candidate contributors to the EDS spectrum since C, O, Si, & Sn represent ~ 99 at% of the EDS spectrum. Finally, a mass balance was set up to solve for mole fractions of the proposed constituents such that the atomic percentage of each element matches the experimental data from the EDS spectrum (see Fig. C below). The results confirm that pentaerythritol benzoate no-clean flux resin fits the EDS data fairly well within a margin of error equal to ~ 0.2 %. The no-clean flux resin represents the bulk of the residue. Metallic Sn and Sn-oxides are the next largest component. The SiO_2 is likely due to glass or silicone in the solder mask beneath the residue as the e-beam can penetrate through thin residue layers.

Constituent	Mole%
NC Resin	92.62%
SnO_2	2.79%
SnO	1.13%
Sn	1.12%
SiO_2	2.34%

Fig. C – Mole fraction (%) of constituents from mass balance using EDS data

Summary

This paper introduces some of the approaches available to analyze EDS data for solder flux residue, which is often associated with printed circuit board assemblies that failed due to corrosion, electro-chemical corrosion, and dendritic growth. Additional approaches will be developed and discussed in subsequent sections to be added to this paper in the future.