

Understanding the effects of solder flux residues is critical to matching the cleaning agent to the residue, and matching the cleaning agent to the residue is key to effective and efficient cleaning. This article introduces the process cleaning rate theorem, discusses the characterization of both cleaning agents and flux residues, and explores how to determine the best fit properties of multi-component compositions, ultimately providing a method for selecting cleaning agents that saves both cost and time over the trial-and-error method.

The move toward lead-free soldering and miniaturization represents two force fields converging that increase cleaning complexities.¹ Higher lead-free melting temperatures requires the use of fluxes with greater thermal stability. The problem: lead-free alloys exhibit poorer wetting properties, which require higher flux capacity and strength to improve wetting and flow. Flux technology also plays an important role in reduced voiding by increasing the need for high oxidation resistance, oxygen barrier capability, high thermal stability and low volatility.

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Miniaturization requires the flux to be more stable at peak reflow to prevent oxidation, which requires a higher content of rosin or resin (modified or synthetic rosin, resins and/or polymers). Reducing flux volatility results in greater amounts of circuit assembly flux residue. Halide free flux materials require higher levels of weak organic acids, which increase the level of ionic materials that can form an electrochemical cell.

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Watch a video on the process cleaning rate theorem on Global SMT TV online at <http://pcrt.gl-obalsmt.net>

Flux residue variation impacts the electronic assembly cleaning process. Understanding the effects of the solder flux residues is critical to matching the cleaning agent to the residue. The thermal phases during the soldering process influence the flux residue cleaning parameters. The number of heat excursions and time above alloy liquidus can cause flux burn off, polymerization, and hardening of the flux residue. These harden flux residues when partially cleaned form white residue, which represents one of the most complex problems in electronic assembly. White residue left after the cleaning process is commonly the result of extracting and removing soluble flux residue ingredients while leaving behind an insoluble ionic white powder.

With the wide acceptance of no-clean soldering processes, boards may see multiple reflow cycles (top side, bottom side, through-hole, and selective soldering), since the residue was not designed to be cleaned. This was made possible in large part due to no-clean flux technology advances. Each consecutive reflow exposure hardens the rosin/resin translucent film by driving out solvent molecules. As a result, the flux residue forms a hard shell that is increasingly difficult to dissolve and clean.

Lead-free soldering and miniaturization complicates this process due to increased melting temperature and component density.² The surface tension of SAC (tin-silver-copper) alloys is roughly 20% higher than eutectic tin-lead, which results in poorer wetting. This wetting deficiency needs to be compensated with improved flux compositions that lower surface tension and increase thermal stability. Additionally, miniaturization aggravates the flux burn-off factor due to the need for lower volatility and greater oxidation resistance. Reduced volatiles mean a greater amount of flux residue, with a higher molecular weight.

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Additionally, new flux compositions may contain more oxidation resistant chemical bonds that change cleaning properties. To prevent tombstoning, a longer soak period is needed for lead-free soldering, which may cause greater cleaning difficulty. White residue formation of these flux residues is more prone to formation in high temperature soldering conditions. As a result, lead-free and miniaturization creates a condition where high thermal heat is generated making the flux more difficult to clean and prone to white residue formation.³

Process cleaning rate theorem

The process cleaning rate theorem holds that the static rate (solubility of the flux residue in the cleaning agent) plus the dynamic rate (thermal and mechanical energy) equals the process cleaning rate.⁴ The static cleaning rate is a key indicator for predicting the cleaning agent that best matches up to the flux residue. Static testing is performed using low thermal and mechanical energy forces. Cleaning agents that dissolve flux residues under these conditions exhibit high levels of cohesive energy for the residue. The basic principle is that "like dissolves like." Cleaning agents that do not match up to the soil do not usually dissolve the soil.

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Kinetic energy forces applied to cleaning agents that exhibit a high cohesive energy for the soil opens the process window. For many flux residues, temperature is a key driver, as flux residue softens when heat is applied. Mechanical energy, properly applied, moves highly effective cleaning agents to constricted areas resulting in flux removal under low gaps components. Boundary cleaning agents that are poorly matched to the soil require higher energy levels and longer wash time to remove the soil. For non-water soluble flux residues, mechanical energy works only when the cleaning agent dissolves the residue. Poor cleaning agent performance can rarely be overcome with stronger mechanical forces.

Matching the cleaning agent to the flux residue solubility parameters

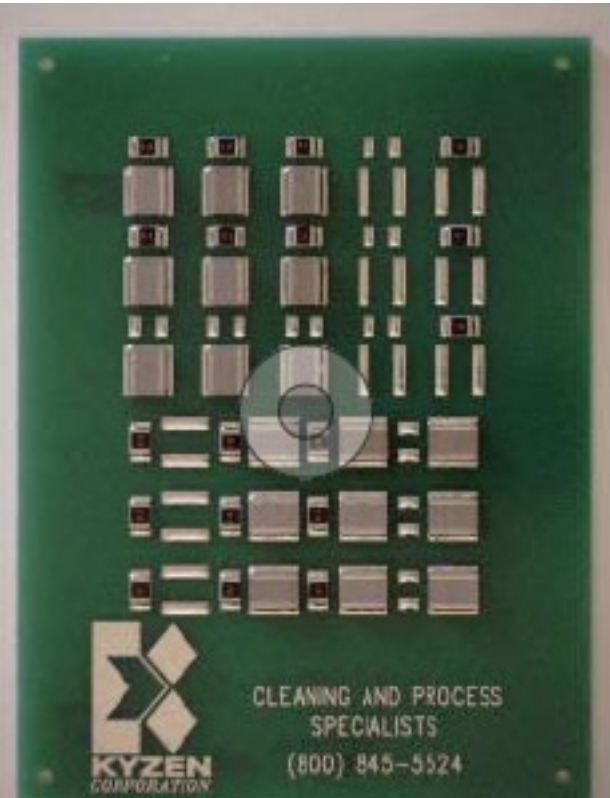
Choosing the best fit cleaning agent for removing a specific flux residue requires characterization of both cleaning agents and the flux residue. Solubility parameter characterization can be used for single and multiple component compositions for both the soil composite and the cleaning agent blend. The solubility characteristics of multiple component compositions can be compared to known values just as similar values of solvents and polymers are compared to determine if the cleaning agent can dissolve the flux residue.

To characterize the solubility parameters of the cleaning agent for the soil, similar tests are run on the soils at their various concentrations, temperature, and time levels. The goal is to identify differences at the lowest applied levels for concentration, temperature, and time. When testing selected cleaning agent candidates using elevated levels for concentration, temperature, and time, solubility differences can be clearly identified. This methodology helps the investigation more closely match the solubility characteristics of the cleaning agent to the soil. The testing also identifies optimal process parameters for wash time, temperature, and concentration.

To illustrate, consider the need to clean lead-free water soluble flux residues. Due to higher reflow temperatures, and the need to improve thermal stability and wetting, many lead-free water soluble flux residues do not completely clean with DI water cleaning agent. To better understand the cleaning agent that best matches up with lead-free soils, a cleaning study was conducted. Over 50,000 data points were generated from this study. The objective was to match up water soluble flux residues to with best technology based cleaning agent. The test boards were populated with 1210 and 1815 chip cap resistors (*Figure 1*). Following cleaning, the components were removed and the level of flux residue under the chip caps graded and analyzed statistically.

Global SMT and Packaging - Matching the cleaning agent to the flux residue

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- Size: 3.0" x 4.0" x 0.60 mil print
- FR-4 with LPI Solder Mask
- IPC Specified pad sizes and geometries
- Chip caps utilized
 - ◊ 1210 SMR ~ 0.5 mil gap
 - ◊ 1825 SMC ~ 1.0 mil gap
- Caps place bi-directional
- Caps positioned to:
 - ◊ Minimal shielding
 - ◊ One-side shielding
 - ◊ Two-side shielding

Interaction Plot for Water Soluble Study

Data Means

