

PREVENTING WHITE RESIDUE BY CONTROLLING UPSTREAM AND DOWNSTREAM PROCESS CONDITIONS

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ABSTRACT

White residue formation after soldering is one of the most complex problems in cleaning electronic assemblies. The visual appearance of flux residue has much to do with the flux composition and solder profile. White residue is affected by a wide range of electronic assembly materials including all flux types, heat exposure during soldering and before cleaning, component spacing and pitch, solder masks, cleaning agent, wash processing conditions and mechanical cleaning energy. The ideal state, specifically for no-clean processes, is a clear translucent solid, with active ingredients fully reacted and benign. White residue left after the cleaning process is commonly the result of extracting and removing only some soluble ingredients of the residue while leaving behind an insoluble white crystal.

The most effective method for preventing white residue is controlling the upstream soldering process, post soldering heat exposure before cleaning and optimizing cleaning process variables. Over-heating the assembly during and after the soldering process can burn, char, cross-link and eventually polymerize flux residues. Changing the residue properties can lead to partial cleaning. The second key factor that contributes to white residue is the wash process. The critical variables for controlling the process are the cleaning agent, wash time, wash temperature, wash concentration, and impingement energy. The purpose of this research paper is to provide participants with an improved understanding of how controlling the assembly process and wash parameters reduce the occurrence of white residue.

KEY WORDS

Cleaning, Flux Residue, Defluxing, White Residue, Over Heating, Wash Parameters, High Density Interconnects

INTRODUCTION

Most think of cleaning as a chemical. In reality, cleaning is a process that must take into account multiple factors which may affect soil properties and their ability to be removed (cleaned). Cleaning is the removal of undesired materials from surfaces without changing the surface in an unacceptable manner.

Cleaning is performed to remove soils that may impact product reliability over the end product's functional life. Printed circuit boards increase in value as a part of the overall product in which the technology is employed. Cleaning is not so much due to the value of the circuit board itself, but due to its place in the overall system.

In the age of highly dense interconnected circuit boards and packages, products are smaller, lighter and make use of advanced technologies. Military, defense and law enforcement agencies rely on products performing on demand. Aerospace continuously rely on products that improve operational efficiencies while avoiding hardware and air traffic disasters. Medical devices improve the quality and extend life while reducing health care costs. Automotive electronics improves operating efficiencies, reduces pollution, and provides entertainment and comfort. Information technologies find its backbone on electronic circuitry that has changed the way people interact, communicate and work.

The world in which we live has come to depend on products that function through electrical interconnects. Disruptive forces continually challenge assemblers to build, faster and higher functioning devices. These trends increase the importance of cleaning. Value added may only be appreciated by factoring in the costs of not cleaning or under cleaning at a particular step within the process.

ELECTRONIC ASSEMBLY RESIDUES

Residues left on electronic assemblies' decreases reliability with device miniaturization, closer spacing between conductors, and increased electrical fields. Process and service related contaminants create the potential to accelerate device failures. When corrosion forms as a result of these residues it can significantly decrease product functionality and reduce service life.

Proper cleanliness levels on assemblies' built with highly dense component placements, component configurations (low clearance with flux bridging conductors) and miniaturized components has become more difficult to achieve. Increased cleaning difficulty arises from higher heat transfer and lower clearance gaps shielding the residue under the component. Assemblers must better understand the long term effects of these assembly residues. Current industry standards for cleanliness may be inadequate for highly dense interconnected board assemblies.

How clean is clean enough is more challenging to answer as conductors and circuit traces converge. What is acceptably clean for one segment of the industry may be unacceptable for more demanding segments. The issue is that most assemblers have no background in chemistry, chemical interactions and quantitative test methods that define acceptable residue levels. In addition, most do not know how to measure or define cleanliness, nor can they recognize process problems related to residues.

Residues can be classified into three categories:

1. Polar or Ionic
2. Non-polar or nonionic
3. Particulate

Examples of residues that fit these categories are listed in tables 1, 2, and 3.

Category 1: Polar or Ionic Contaminants
• Flux activators
• Soldering salts
• Fingerprints and handling
• Residual plating salts
• Neutralizers
• Organic amines

Table 1: Polar Residues

Polarity refers to a separation of electric charge leading to a molecule having an electric dipole.² A polar ion readily dissolves in water with the anion bonding with hydrogen ion and the cation bonding with hydroxide ion. The dipole-dipole attraction from the positive and negative ions with water creates an electrolyte.

Polarity results from an ion in which the total number of electrons in the valence shell is not equal to the total number of protons, giving it a net positive or negative charge.¹ Ions are commonly referred to as anions and cations. An anion is an ion with more electrons than protons, giving it a net negative charge since electrons carry a negative charge. A cation is an ion with fewer electrons than protons, giving it a net positive charge.

The most common type of ionic bonding is seen in compounds of metals and non-metals. Metals are characterized by an excess of electrons in the valence shell. Metals have a tendency to lose these extra electrons in order to attain a stable configuration thus resulting in an electro-positive ion. Non-metals are characterized by a valence shell with a few electrons short of a stable configuration resulting in an electro-negative ion.

When an electro-positive metal is combined with an electro-negative non-metal, the extra electrons from the metal ion are transferred to the electron-deficient non-metal ion. This reaction produces an ionic bond between the metal cation and non-metal anion.

Ionic residues form based on the strength of the ion-dipole forces of attraction with water and the strength of the interionic bond. When the ion-dipole forces between water and the ionic compound are greater than the ionic bond strength, the ions dissolve in water. Water dipoles surround the ionic compound. The negative end of the water dipole is attracted to the ionic compound's positive dipole and the positive end of the water dipole is attracted to the ionic

compound's negative dipole. If the force of attraction is stronger than the ionic compounds interionic bond, the interionic bond will be broken and hydrated by water molecules.

Ionic residues create a reliability risk when the interionic bond is hydrated with monolayers of water. Consider a flux that contains an amine hydrochloride activator. Monolayers of water overcome the interionic bond. The chloride's negative charge is attracted to the positive hydrogen ion within the water dipole. Hydrogen chloride forms a weak acid which dissolves trace metals present on conductors. The metal ion carries a positive charge. When the circuit is powered up, the positive metal is attracted to the negative cathode (Figure 1). Over time the metal plates until it reaches the anode, from which a dead short can occur.

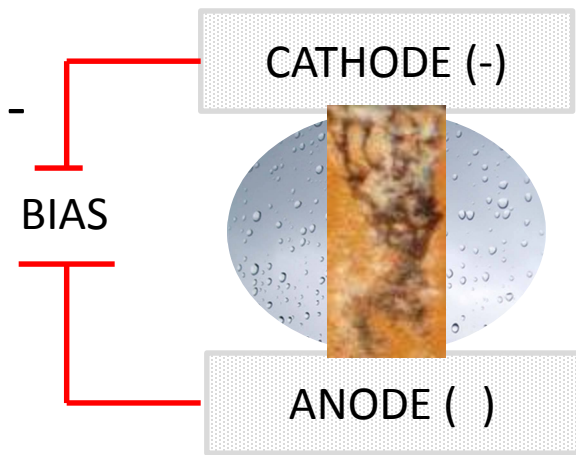


Figure 1: Ionic Residue Migration

Water soluble flux formulations use di-or tri-functional organic acids such as succinic acid, citric acid, adipic acid, etc. which are soluble in polar solvents.³ Water soluble flux formulations also include other vehicles such as glycol, polyglycol, surfactants and glycerol. The major difference between water soluble and rosin fluxes is their fluxing activity. The aggressive activators used in water soluble fluxes are highly ionic. When exposed to water the interionic bonds are broken and hydrated. These post soldering residues are corrosive and must be totally removed.

Category 2: Nonpolar / Nonionic Contaminants
• Rosin flux
• Flux resins
• Synthetic polymers

• Wax
• Polyglycols
• Hand Creams
• Lubricants
• Silicone
• Nonionic surfactants
• Conformal coating

Table 2: Nonpolar / Nonionic Contaminants

Rosin fluxes are commonly formulated with activators. Rosin fluxes carry designations based on their activity level. Pure rosin (R), rosin mildly activated (RMA) and rosin highly activated (RA) represent product classifications based on the levels of halide and organic acids present. Pure rosin and rosin mildly activated are considered non-corrosive and on many designs not cleaned. One of the issues with rosin flux residues is their sticky nature and propensity to attract contaminants from handling and environmental conditions. As spacing between conductive paths decrease, these sticky residues bridge conductors, which increases the importance of cleaning.

Low residue “no-clean” fluxes are formulated with modified rosins (resins). The flux compositions are formulated to leave behind low residue and ionic levels. Activators formulated into the compositions improve wetting and oxidation removal with the benefit of decomposing during soldering. One of the key principles behind low residue fluxes is the soldering temperature at which the flux reacts with metal oxides and then volatilizes and decomposes.

Non-polar no-clean flux residues are excellent insulators. However, the residues can interfere and make it difficult to test probe assemblies. To address this limitation, polymers can be added to the flux composition. The polymers soften the residue structure and improve electrical contact needed to conduct functional tests.

No-clean residue left on the board may cause poor conformal coating adhesion. Most conformal coatings do not achieve permanent curing and adhesion for days or weeks after being applied.⁴ Bubbles, voids and milky appearance can result from incomplete curing. Flux residues under the coating can interact with chemicals present in the conformal coating, which can compound adhesion issues. To avoid these issues, the board surface should be cleaned before conformal coating is applied.

Nuisance contaminants such as hand creams, lubricants, silicones and non-ionic surfactants can be present on assemblies.⁵ The use of ethanol-based hand sanitizers has become a common practice. The use of hand creams and sanitizers creates the risk of transferring fragrances, oils, and emollients contaminants to the assembly. Assemblers

must be aware to these contaminants and the potential risk of transferring these solutions/agents to the surface of the assemblies as a contamination material.

Even though non-polar contaminants do not form corrosive ions in the presence of moisture, the smaller conductive spacing for components placed on highly dense interconnects creates a condition where residues can bridge conductors. These residues may create a path for leakage currents, which may affect signal integrity.

Additionally, an unavoidable or unwanted capacitance between the parts of an electronic component or circuit can occur from both non-polar and polar residue that is in the proximity of adjoining circuits.⁶ High levels of voltage can render electrical interference from closely spaced circuits. Signal integrity can be interrupted due to unwanted or parasitic capacitance between two components. Parasitic capacitance can distort high frequency signals due to residues interfering with wave paths, which may result in disrupted signal integrity.⁷

Category 3: Particulate Contaminants
• Resin / Fiberglass board particles
• Dust
• Lint
• Packing materials
• Hair / skin

Table 3: Particulate Contaminants

Circuit boards, components and work-in-process should be stored in clean conditions, controlled temperature, and humidity. Category 3 contaminants can be picked up from handling during assembly, transferring boards through process steps, inspection, rework and packaging. Contaminants such as finger oils, perspiration, flaking skin, hand creams, body fluids, lint or debris from gloves, and assorted dust and dirt can present reliability and cleaning problems. Work place practices and procedures need to be clearly defined and followed to limit Category 3 contaminants.

HEAT EXPOSURE

An important factor to consider when designing a cleaning process is to understand the nature of the soil. Processing conditions, such as the reflow profile, can change the nature of the soil. In some cases, processing conditions can render the soil uncleanable. Understanding the do's and don'ts is critical to cleaning repeatability and reproducibility.

As circuit assemblies increase in density, more and smaller components are assembled onto a circuit card. Industry soldering material companies estimate that more than 80% of assemblers are building their boards with no-clean (low residue) solder pastes. To render the residues left from the soldering process non-conductive, the flux composition must be totally reacted. Often times, this requires a longer soak time during the reflow soldering process. In combination with higher lead-free reflow temperatures, the soils can cross link and polymerize. These chemical reactions can render a cleanable solder paste non-cleanable (Figure 1).

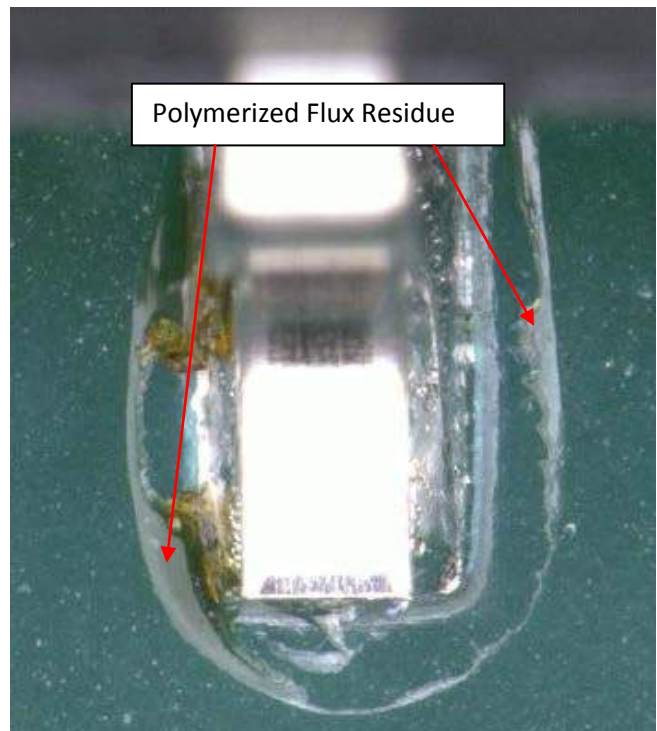


Figure 1: Cross-Linked Flux Residue Example

Similar to cleaning agent advances, solder paste companies are continuously improving their products to achieve assembly yields. Highly dense interconnects are prone to latent defects such as cold solder joints, grapping, head-in-pillow, and tin whisker propagation. For assemblers who do not clean, a soft residue that allows for print probability and elasticity once probing takes place is desired. One way to improve yields is to formulate higher molecular weight oxygen barriers into the rosin or resin vehicles to allow for long soak and heat exposures during the reflow soldering process. These polymers and other functional additives used

to provide a print probable residue can change cleaning properties.

Figure 2 illustrates a board that was reflowed with a print probable solder paste. During reflow, the flux both wets and spreads away from the solder joint. At the fluxes thinnest point, heat from solder reflow both hardens, and in some cases, polymerizes the residue. When this occurs, the residue forms a long chain molecule that no longer dissolves in the cleaning agent. The more important point is to understand the impact that heat has on changing the chemical structure of the residue. If a flux is susceptible to chemical change with heat, controlling and understanding those limits is critical to achieving a cleanable residue.

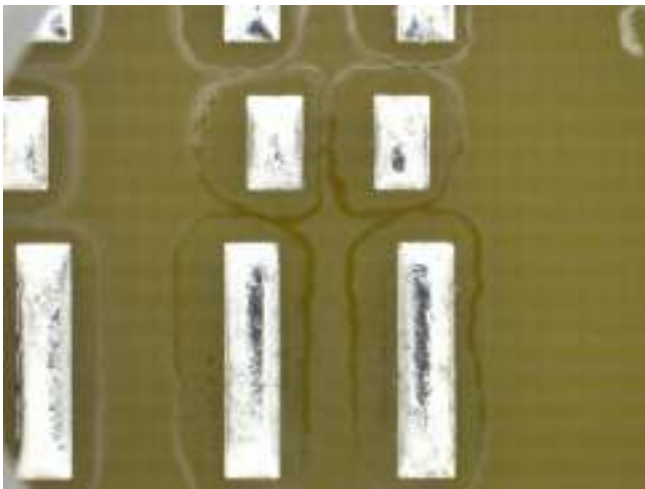


Figure 2: Over Heated Flux Residue

When designing solder pastes, cleaning is not a high consideration since a large segment of the market still runs a “no-clean” process. Cleaning material companies have closely followed solder paste innovations, and continuously improve their products to clean “no-clean” solder paste residues. The added benefit for assemblers is that they can select one solder paste for products that do not require cleaning and for those that do require cleaning. When cleaning issues arise, the remaining partially cleaned flux residue leaves a “white” hygroscopic residue at the base and under components (Figures 3&4).



Figure 3: Visible White Residue after Cleaning

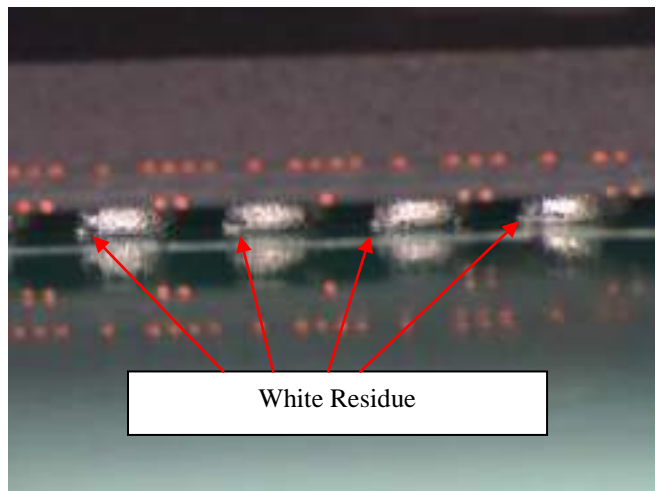


Figure 4: White Residue Post Cleaning

Understanding the nature of the flux residue and how its properties change when exposed to the soldering process is a critical property to know when it comes to cleaning. No clean flux technologies are designed to react and form a non-polar / non-conductive residue. As miniaturization increased cleaning importance, an understanding of the processing conditions must be taken into consideration to assure that these residues are cleanable.

Organic acid, “water-soluble”, flux designs are highly polar and readily hydrogen bond with water. Similar to no-clean flux designs, the residues from organic acid fluxes change when exposed to elevated temperatures. Overheating these residues creates a crystalized salt that is no longer soluble in water (Figure 5). Aqueous cleaning agents’ that wet and

react with these residues may improve the ability to clean over heated water soluble residues.

Water soluble fluxes tend to be more aggressive at removing metal oxides. By nature, their residues are corrosive when compared with the encapsulated “no-clean” residues. Therefore it is more critical that they be completely cleaned to ensure product reliability.

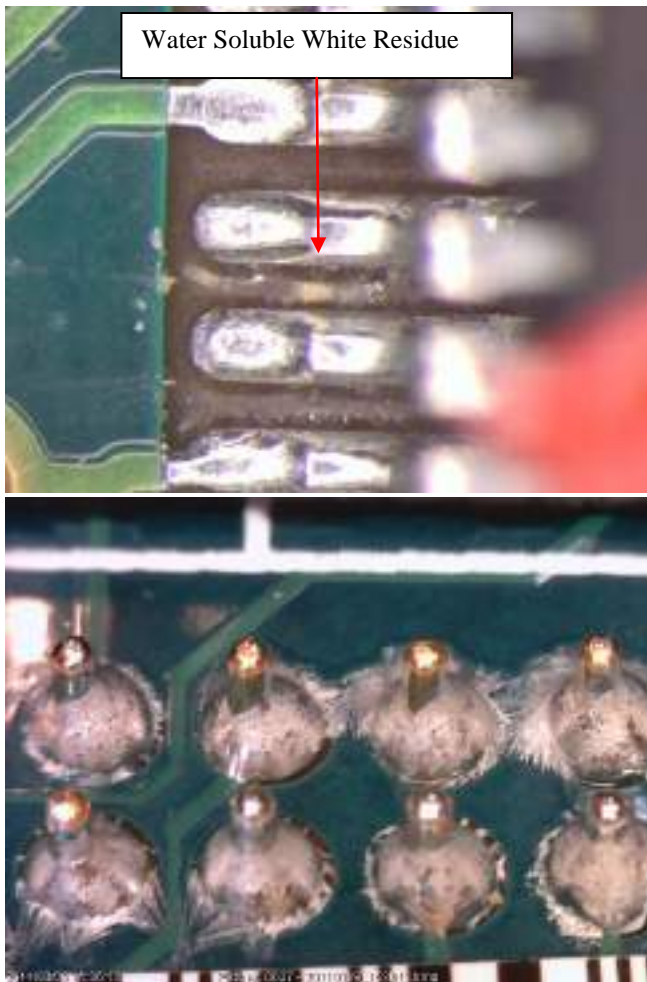


Figure 5: Overheated Water Soluble Flux Residues

COMPONENT SPACING AND PITCH

The distances between conductors, and the underneath clearance gaps from the board to the bottom of the components on printed circuit boards, are smaller due to miniaturization. Smaller spacing increases the probability that flux residues or surface contamination will be sufficient to bridge all or most of the under clearance gap between conductors. Flux bridging conductors opens the pathway to form a conductive cell between two points on the board assembly.

Low-residue “no-clean” flux residues are considered as benign residues. When the pitch between conductors narrows, this benign no-clean residue wets and underfills the bottom side of the component. With the residue bridging conductors, a path exists for leakage currents and potential corrosion (Figure 6). As a result, higher density board designs increase reliability risks, which are commonly mitigated by cleaning all flux residues and ionic contamination on the surface and under components on the assembly.



Figure 6: Flux Residue Bridging Conductors

Cleaning flux residues from under component gaps has become extremely challenging due to

- The changing nature of the flux residue
- Under component clearance from the board to the bottom of the component
- Time required for the cleaning agent to penetrate the gap
- The cleaning agents ability to solvate and break the flux dam needed to create flow channels
- The mechanical energy needed to deliver the cleaning agent to the flux residue.

Flux residues that form a hard shell require longer wash times to dissolve in the cleaning agent, thus requiring increased time to clean these residues under the component gaps (Figure 7). In order to remove residues under tight gaps both solvency and high energy spray channels are needed. A

cleaning agent that is closely matched to the soil increases the rate of dissolution. Highly targeted spray channels move the cleaning agent to the soil. Once the soil reaches break through, a flow channel is achieved. Flow channels are critical for dissolving and removing all remaining flux residues.

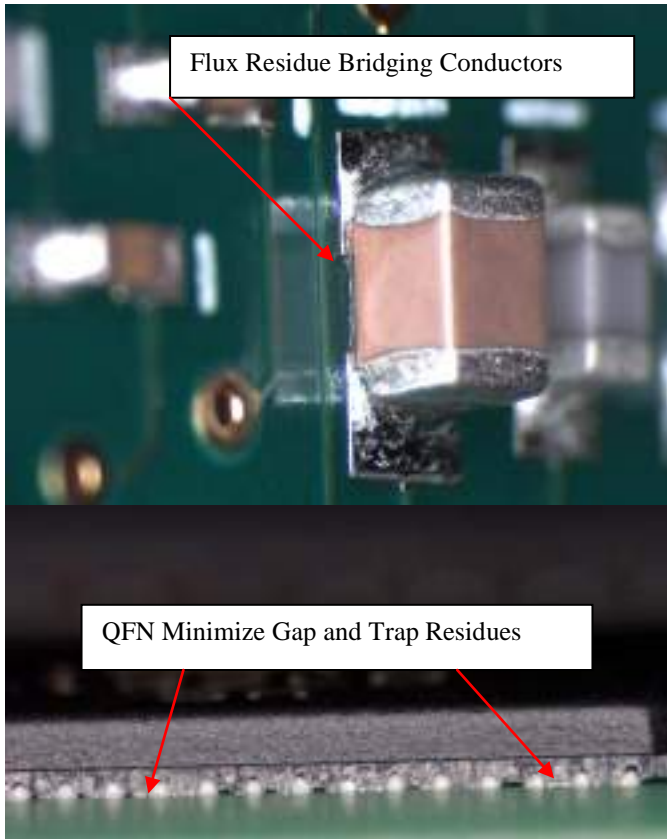


Figure 7: Tight Gaps Require Solvent and Energy

CLEANING AGENTS

Solubility of the contaminant into the cleaning agent is becoming a bigger challenge. Higher molecular weight flux ingredients in combination with higher soldering temperatures and heat cycles change soil properties. These changes may require more aggressive cleaning agents, increased wash time, increased wash temperatures and stronger mechanical forces.

Solubility is the ability to dissolve the soil(s) into the cleaning chemistry. The opposite of solubility is insolubility, with an example being sand in water. In solution, all ingredients are uniformly distributed.

Cleaning agents are engineered with a range of materials designed to remove a specific subset of soils. Past researchers developed predictive models that help users understand the science of cleaning. Suitability of a cleaning for removing the soil(s) applies the following theorems:

1. Coulomb’s Law
2. Van Der Waal’s Forces
3. London Dispersive Forces
4. Hildebrand Solubility Model
5. Hansen Solubility Model
6. Match the Cleaning Agent to the Soil Model

Polar flux residue soils, most notably organic acids, activators, fingerprints etc., are best cleaned with polar cleaning agents. Aqueous cleaning agents are the most logical choice when cleaning polar residues. An acidic flux residue is attracted to a mildly alkaline aqueous cleaning agent. The positively charged acid flux is attracted to the negatively charged aqueous cleaning agent (Figure 8). Functional additives engineered into the cleaning agent in combination with the cleaning equipment provide for a highly efficient and repeatable process.

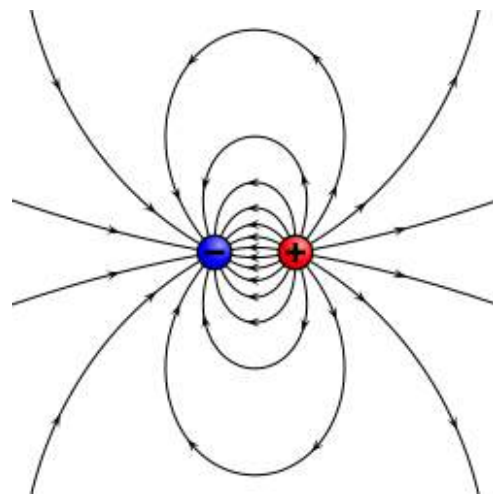


Figure 8: Positive Flux Residue attracted to Negatively Charged Cleaning Agent

The dielectric constants for rosin and low residue “no-clean” flux residues are low. The residue structures, by design, are non-ionic and covalent in nature. Solvent-based cleaning agents, most notably chlorinated vapor degreasing fluids, were used to dissolve these resinous structures. Due to ozone-depleting, toxicity, and worker safety concerns, aqueous cleaning agents have gained popularity.

Dependent on the soil chemical make-up, aqueous cleaning agents are designed with hydrophilic (water-loving) and hydrophobic (oil-loving) properties within the engineered cleaning agent. The carboxylic acid rosin structure is weak negative dipole and can be easily cleaned with a mildly alkaline aqueous cleaning agent. The rosin flux is attracted to the alkaline aqueous cleaning agent due to the opposite partial charges of neighboring induced dipoles. These forces commonly referred to as Van der Waals Forces, facilitate dissolution of rosin flux in aqueous cleaning agents (Figure 9).

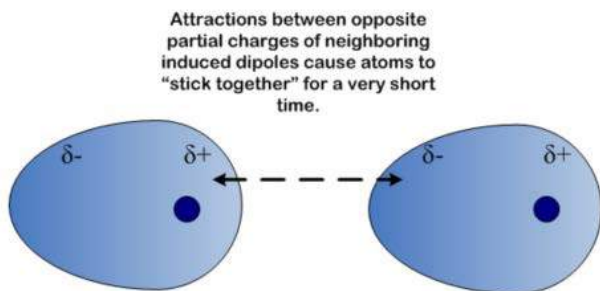


Figure 8: Aqueous Di-pole Attractions Facilitate Dissolution

Low residue “no-clean” flux residues are formulated with modified resins and polymeric compounds. Low residue fluxes are designed to leave minimal flux post soldering and to encapsulate reacted activators and metal salts. The residue type is non-conductive.

When traces were wider, the residues did not bridge conductors. As circuit assemblies decreased in size and greater levels of functionalities increased, highly dense interconnects with smaller pitch were designed. These highly dense components required changes to the solder reflow profiles and flux compositions. Additionally, the move to lead-free SAC alloys required increased oxygen barriers to be formulated into flux compositions.

In order to clean these residues in aqueous cleaning agents, the engineered formulation requires a combination of solvency and low reactivity. The solvents are selected based on their ability to match-up to the resin structure (hydrophobic by nature). Polar-based solvents that are hydrophilic (water loving) by nature are needed to induce a di-pole on the covalent flux residue. This induced dipole-dipole interactions, commonly referred to as “London Dispersive Forces”, facilitates dissolution in aqueous

cleaning agents (Figure 11). This reaction occurs by distorting the positive charge on the flux residue. The electric field forms a temporary bond dipole that facilitates dissolution.

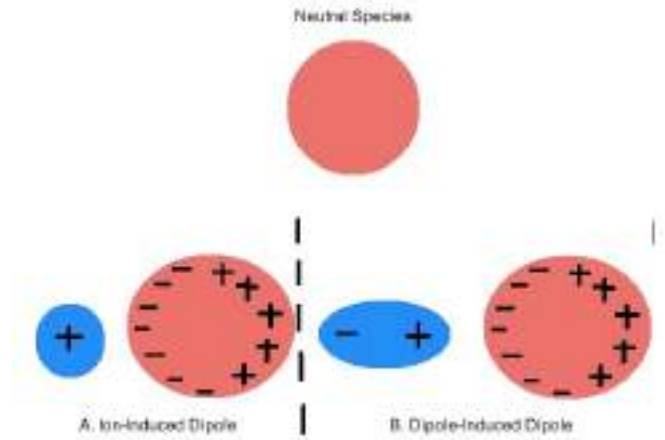


Figure 11: Reactivity in Aqueous Cleaning Agents Induces a Dipole-Dipole Interaction that Facilitates Dissolution

The cleaning agent design must be matched to the flux residue type in order to clean the soil. A poorly matched cleaning agent will not remove the residue, even in the presence of higher mechanical energy (Figure 12). Poorly matched cleaning agents remove partial levels of the flux residue. The remaining residue forms a white residue, which contains the insoluble portion of the resin and polymeric structures. The white residue may also expose activators and metallic salts.

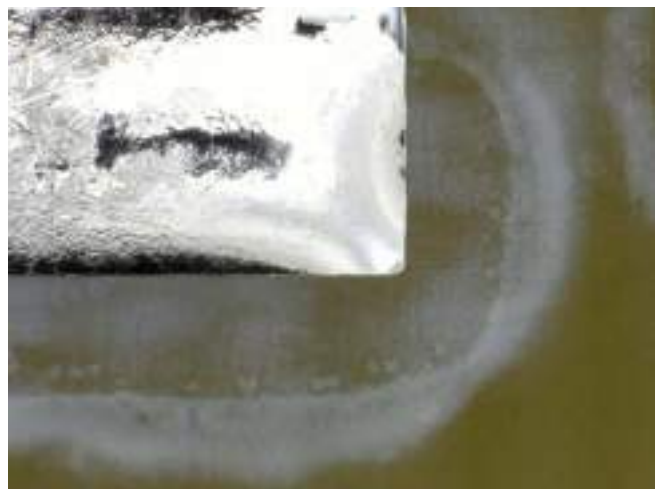


Figure 12: Partially Cleaned Flux Residue

Conversely, cleaning agents that are closely matched to the residue successfully removed low residue “no-clean” flux residues. Aqueous cleaning agents that are engineered to clean low residue flux residues in combination with properly designed aqueous cleaning machines are effective at cleaning highly dense interconnects (Figure 13).

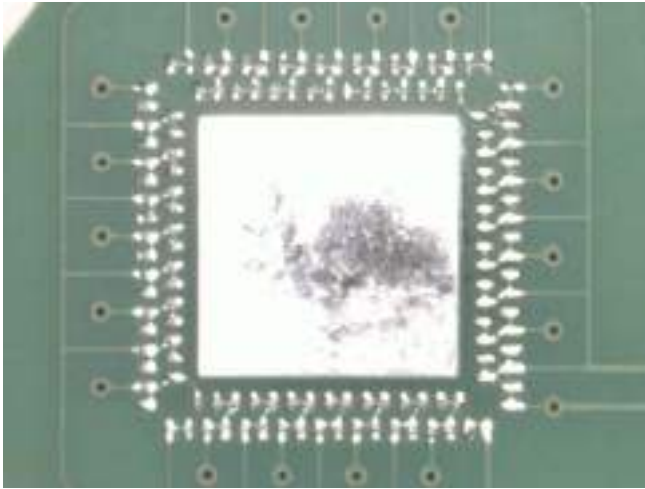


Figure 13: QFN Cleaned with Properly Designed Aqueous Cleaning Agent and Cleaning Machine

Matching the Cleaning Agent to the Soil evaluates the soil dissolution into engineered cleaning agents at various concentrations in water and temperature. This method determines the static cleaning rate, which is the rate at which the soil dissolves in the absence of mechanical energy.

When designing cleaning agents, solubility theorems are the formulator’s tool box for developing products that efficiently dissolve the soil(s) in question. The cleaning equipment design is the second critical factor that influences the cleaning agent design. The best cleaning agent designs maximize the energy effects of the cleaning equipment, cohesive temperature effects, and solubility effects. One limitation that must be factored into the cleaning process is material compatibility.

PROCESS CLEANING VARIABLES

Wash concentration, temperature, exposure time and impingement energy are significant factors in developing the process window. As a general rule, the higher wash concentrations, wash temperatures and physical energy applied to the soil, the better the cleaning results. When running the cleaning process at the high end, numerous

limitations such as material compatibility, chemical losses, and environmental effects must be considered.

Aqueous cleaning agents run at different dilution rates. The aqueous chemistry design and the soil make-up are significant factors for determining the appropriate concentration range. Polar soils, such as organic acid and activators are best cleaned with highly polar aqueous cleaning agents. Non-polar soils, such as rosin and low solids resin fluxes are best cleaned with aqueous cleaning agents that combine solvency with reactivity.

Rosin and resin flux residues soften at higher wash temperatures. As a general rule, the rate at which these soils dissolve doubles when the wash temperature rises 10°C (18°F). The opposite may be true for some organic acid based flux residues, making them more difficult to clean at higher wash bath temperatures. Contract manufacturer’s often use a mix of flux technologies (no-clean, rosin, OA) depending on a specific customer build but also need to clean all of their assemblies using the same processing equipment. Therefore, the chemical characteristics of each soil must be taken into consideration when determining the actual wash temperature process window.

Bottom termination components, board density and soil make up impact wash time. Miniaturization tightens component pitch and lowers component gaps. The net effect is that the flux residues underfill the components bottom side. To fully clean the flux residue out from under the component, the flux dam must be penetrated to create a flow channel. Additionally, low standoff gaps from the board surface to the bottom of the component require physical energy to deliver the cleaning agent to the soil. Higher molecular weight soils and process temperature cycles impact the time needed to dissolve the soil. Each of these factors requires longer wash exposure times.

Optimized mechanical impingement improves cleaning effectiveness especially on highly dense interconnects where shadowing is common. Research data indicates that fluid flow, pressure, and directional forces improve cleaning under bottom termination components.

CONTROLLING CLEANING AGENTS

Wash bath concentration varies over time due to drag-out and exhaust losses. Infrequent monitoring or the lack of wash bath control often results in the concentration drifting out of tolerance, which leads to incomplete cleaning and the

formation of white residue. Process control technologies that monitor the cleaning agent and make adjustments over time help assure repeatability and reproducibility over time and reduce the chance that white residue will form.

The critical soil loading level represents the amount of soil that the cleaning agent bath can hold before cleaning performance declines. If no cleaning solution was lost over time, the wash bath life would fit a linear model (Figure 14). In the example below, the cleaning rate will decrease above the critical soil load, requiring more exposure time or higher wash concentration to achieve the same results as before.

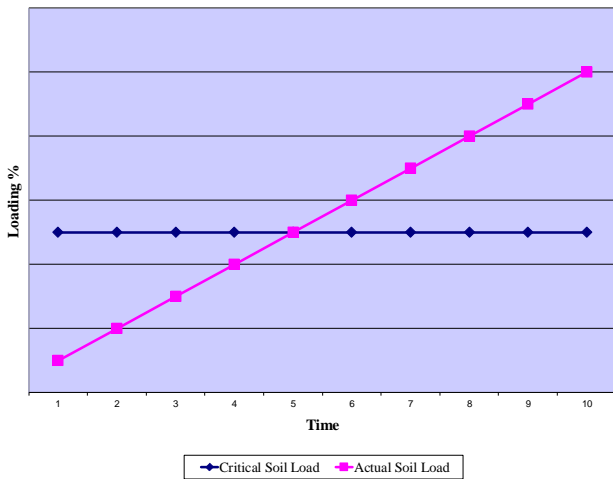


Figure 14: Critical Soil Loading Model

When process control methods are used to control the wash bath, cleaning performance can be maintained for extended periods of time. The critical metric is to consistently replenish the wash bath in the proper concentration ratio of water and cleaning agent as losses occur due to drag-out and exhaust. A steady state wash bath can be achieved when automated wash bath control is employed (Figure 15). The yellow line represents a steady state concentration, which is well under the critical soil loading level. Theoretically, when the wash bath is maintained below the critical soil loading level, the wash bath does not require change out.

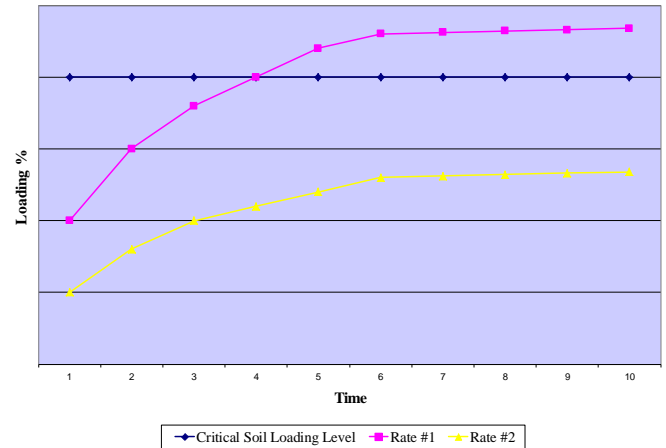


Figure 16: Wash Bath Control

Automated process control technology integrates the control of the wash tank with the cleaning equipment software (Figures 16 & 17). The system monitors the wash tank and controls the additions of fresh cleaning agent and water inputs to the tank. The cleaning process is a dynamic system; as fluid losses occur both up the exhaust stack and due to drag-out. For aqueous processes, cleaning agent losses are not linear to water losses. Typically, cleaning agent losses are less since water has a higher relative vapor pressure. The lower vapor pressure ingredients within the aqueous cleaning agent condense at a faster rate, and as such, therefore less cleaning agent is lost as vapor up the exhaust stack.

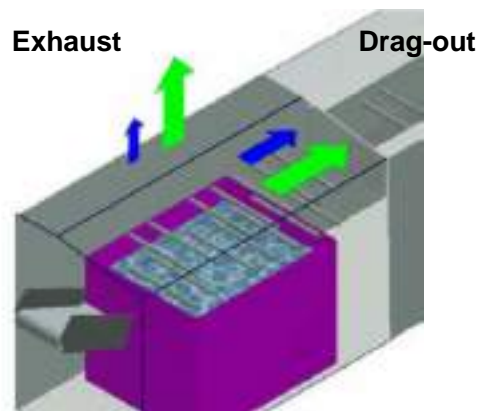


Figure 16: Wash Tank Losses

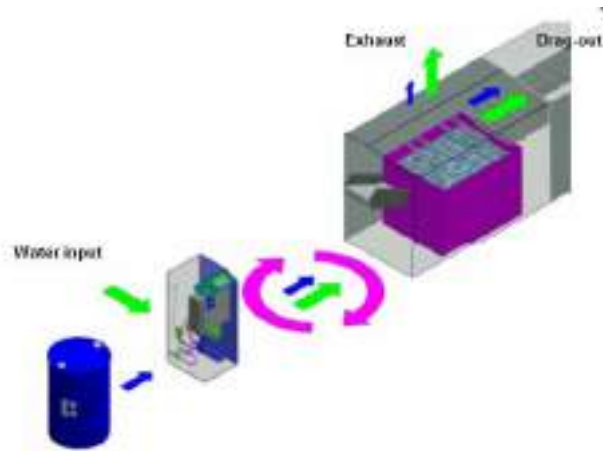


Figure 18: Process Control System

WHITE RESIDUE PREVENTION

White residue is a common occurrence during the electronic assembly manufacturing process. White residue forms when the cleaning process fails to totally remove the soil. Each of the factors discussed in this paper can be a contributing factor to white residue:

- Nature of the Soil
- Heat Exposure of the Soil
- Matching the Cleaning Agent to the Soil
- Optimizing Process Variables
- Automated Control of the Process

Cleaning is a multi-faceted process, from which a deficit in any of the factors discussed in this paper will cause white residue.

The difficulty arises from the technologies built into circuit assemblies to increase performance functionality. Highly dense interconnects require smaller components and more of them placed in reduced spaces. The second challenge is the change to SAC (tin/silver/copper) alloys which require hotter soldering temperatures. Higher density interconnects increase cleaning importance but also create a more difficult cleaning challenge.

In cases where higher temperature reflow profiles are used to mitigate soldering defects (like head in pillow) it has a side effect of over-heating thin flux residues and making them difficult to fully remove. A successful cleaning process is truly an optimized balance of the factors

discussed in this paper. Any factor out of sync reduces cleaning effectiveness, which results into white residue formation.

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