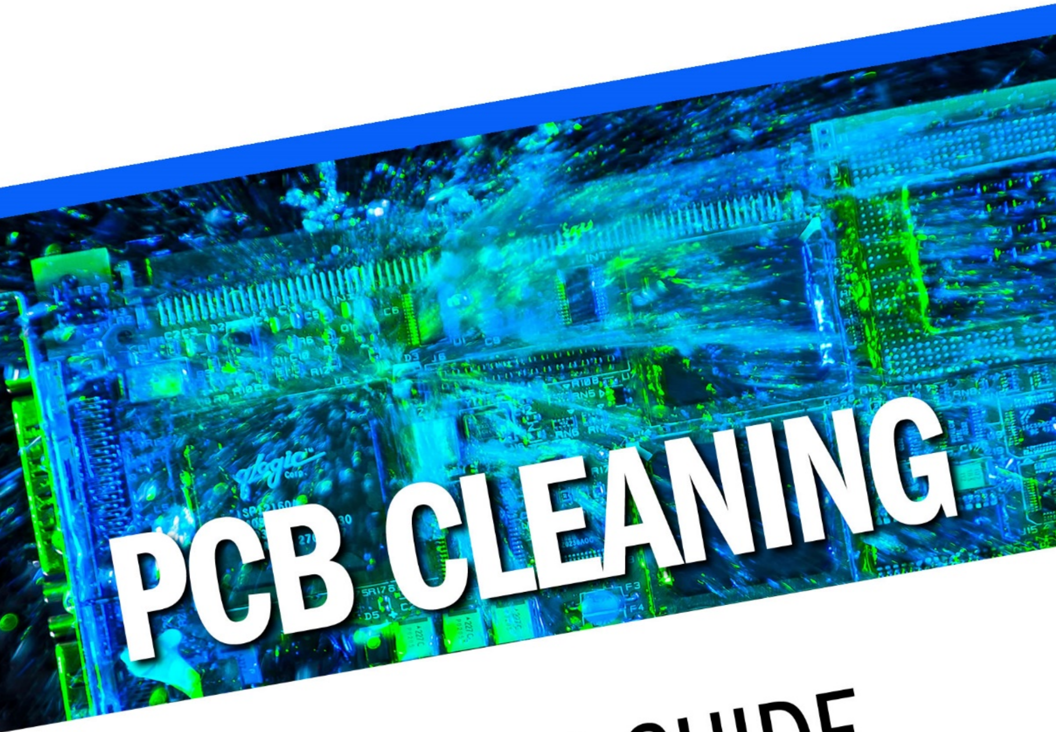

PCB CLEANING

APPLICATION GUIDE

CONFORMAL COATING

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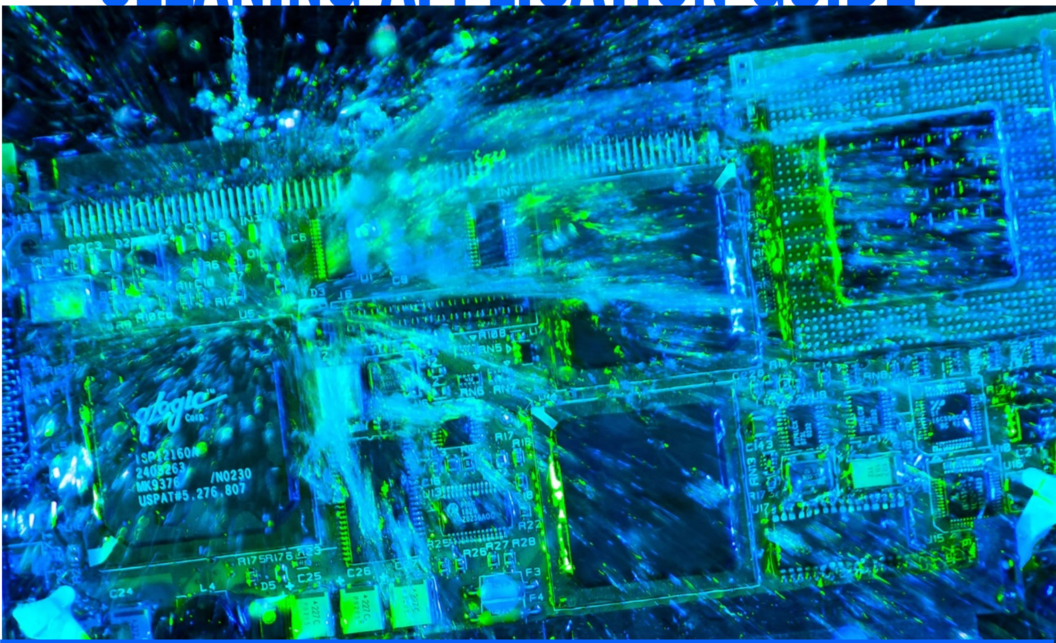


In the process of assembling, reworking or repairing printed circuit boards (PCB) for electronic devices, the discussion inevitably turns to whether or not to clean the PCB. Cleaning adds time and expense to the process, and doing it wrong can cause more harm than good. This guide will walk you through the reasons to clean PCBs, and the best practices for electronics cleaning.

Why Clean a Printed Circuit Board (PCB)?

Since cleaning PCB's is not always required and adds time and cost to the production or repair process, some justification may be required.

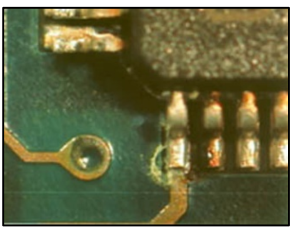
Improve Aesthetic Appearance of PCB
If you are a contract manufacturer of PCB's, the visual appearance of the board reflects on your work. A clear, greasy-looking residue around a solder joint may raise flags for your customer's incoming QC inspectors. If the flux residue chars and forms spots on the solder joints, it may look like a true defect like a solder joint void or "blow hole". If the flux residue is from a rework process, it acts as a fault tag in the rework area, calling attention to the work even if there shouldn't be a concern.

Improve Reliability of PCB

Reliability requirements are generally driven by the nature of the final product. For a disposable product like a computer keyboard, nobody loses their life if it stops working. In that case, an EMS supplier may use no-clean flux and forgo the cleaning process. On the other end of the scale, requirements for pacemaker electronics, where board failure could directly lead to death, are going to be much stricter. In that example, cleaning will be required after assembly and any subsequent rework, and the process will be thoroughly tested for effectiveness and repeatability. Long-life durable goods may fall somewhere in-between, with cleaning a requirement, but without the rigid testing and controls.

Prevent Corrosion on Components and PCB

Flux residues left on electronic circuit boards are acidic. If they aren't removed with a cleaning process, the residues can draw in ambient moisture from the air and lead to corrosion of component leads, and PCB contacts.



Corrosion on failed assembly in QFP area
(photo courtesy of Foresite)

Avoid Adhesion Problems with Conformal Coating

Most people understand that when painting something, the surface must be prepared so it is absolutely clean. Otherwise, the paint will quickly lift off the surface and peel off. The same logic applies to conformal coating, even when the contamination is from no-clean flux. "No-clean" refers to the amount of ionic material left after soldering. It has nothing to do with whether or not coating can stick to it.

When there are flux residues left on the PCB before the coating process, it is common to see the coating lift or delaminate from the surface of the board. This is evident when the pockets are isolated around solder joints rather than the overall surface (the exception being the bottom of a wave soldered PCB).

To make matters worse, coatings are generally semi-permeable, so breathe to a certain extent. Moisture can enter and soak into the flux residue, and potentially lead to corrosion.

Flux residues causing coating uplift
(photo courtesy of NPL)

Prevent Dendritic Growth from Ionic Contamination

Polar or Ionic particles left from flux residue and other sources, when exposed to moisture from the ambient air and when current is applied, can link into a chain or branch called a dendrite (fig 1). These dendrites are conductive, so form an unintended trace that cause current leakage or, over a longer period of time, even a short circuit.

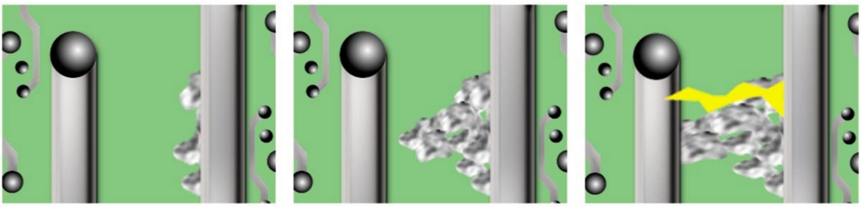
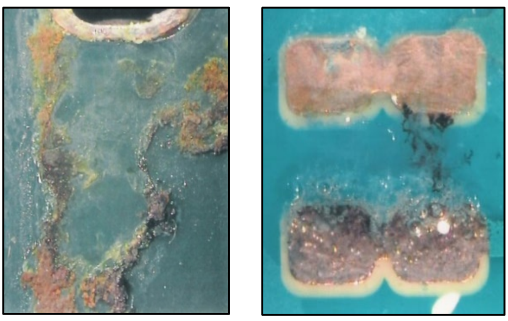


Fig 1 – dendrite formation



Dendritic grown between solder pads, caused by ionic contamination
(photos courtesy of Foresite)

What are the Different Methods of Cleaning Electronic Circuit Boards?

PCB flux removal can either happen at the benchtop, which generally requires a manual cleaning method. This is common for low volume electronic PCB assembly, rework, and repair. Manual cleaning methods are generally more laborious and less repeatable, so results may vary from operator to operator. For higher volume assembly or reduced variability, more automated cleaning methods are used.

Manual Flux Removal Methods

- **Aerosol** – Aerosol flux removers have the advantage of a sealed system, which ensures fresh solvent every time, and agitation provided by the spray pressure and pattern. A straw attachment is generally included to spray into areas with greater precision.
- **Aerosol w/brush attachment** – A brush can be added to the aerosol nozzle, so the solvent sprays through the brush as you scrub.

- **Trigger spray** – Trigger spray bottles are more common for water-based cleaners and isopropyl alcohol (IPA), but not for aggressive solvent cleaners.
- **Liquid immersion** – The PCB can be immersed into a tray or bucket of solvent cleaner, with cleaning tools like swabs and brushes used as needed for tenacious soils. Cleaning performance can be further improved by heating the solvent, but this should only be done with nonflammable flux removers.
- **Spot cleaning with a swab** – A cotton or foam swab can be saturated with a mild solvent like isopropyl alcohol, often from a pump dispenser or “dauber”.
- **Presaturated wipes** – For added convenience, wipes and swabs are available presaturated with a mild solvent like isopropyl alcohol.

Automated or Semi-Automated Flux Removal Methods

- **Ultrasonic** – Ultrasonic cleaning equipment use sound waves to create implosions within the flux residue, breaking it apart and lifting it off the PCB. Most equipment have the option of heating the solvent to increase cleaning performance. Only use this option with a nonflammable flux remover. Cross contamination can be a concern, so change solvent regularly. Ultrasonic cleaning might be too rough on sensitive components like ceramic-based resisters.
- **Vapor degreaser** – Vapor degreasing is the go-to process for the highest precision cleaning, like used for aerospace and medical electronics. PCBs can be submerged in a sump of boiling solvent, in a rinse sump with ultrasonics, and rinsed in solvent vapors. Special solvents need to be used that are azeotropes or near-azeotropes, so will not change as the solvents are boiled off and reconstituted in a continuous cycle.
- **Batch flux remover** – Basically a dishwasher for electronic circuit boards. PCBs are stationary in a rack, and the flux remover (usually water-based) is sprayed over the assembly. The PCB stays in place as the machine goes through the wash, rinse and finally dry cycle.
- **Inline flux remover** – An inline washer is more like a carwash for electronic circuit boards. PCBs travel on a conveyor through wash, rinse and dry zones. Water-based flux removers are used.

What Factors Cause Difficulty Cleaning Flux Residues from PCBs?

Any process engineer will tell you that the key to designing a repeatable process is to control the variables. When removing flux from electronic circuit boards, there are a number of variable that can drastically change the cleaning performance of a cleaner and process:

- **Flux type** – The type of flux can have a big impact on the cleaning process. R, RA and RMA fluxes are generally easier to remove with standard flux removers and isopropyl alcohol. No-clean fluxes are intended to stay on the PCB, so can be more difficult to remove. They may require a more aggressive solvent flux remover, additional agitation like brushing, or a heated solvent. Aqueous fluxes are generally designed to be removed in a batch or inline cleaning system with straight deionized water or water with a saponifier. Alcohol-based or specially formulated solvents can also be used to clean aqueous fluxes, but the same cleaners may have mixed results on other types of fluxes.

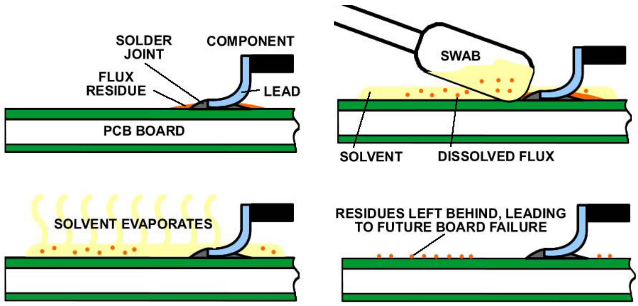
- **Higher solids flux** – Cleaning a PCB made with a mix of soldering technologies can be a particular challenge. Tacky fluxes or other types with a high level of solids can be more challenging to clean, require more cleaning time, soak time, or additional agitation.
- **Amount of flux** – A thicker layer of flux residue is more soil to remove, and can also create flux dams under low stand-off components. This prevents flux remover from fully penetrating under the component.
- **Soldering temperature** – Higher temperatures have a greater tendency to bake-on flux residues, making them more difficult to remove. High temperature soldering may require more cleaning time, soak time, or additional agitation.
- **Lead-free solder** – Lead-free soldering generally requires higher soldering temperature and more highly activated fluxes. Flux residues left from a lead-free soldering process may require more cleaning time, soak time, or additional agitation, and you may actually have to consider a more aggressive flux remover that is engineered for lead-free processes.
- **Time between soldering and cleaning process** – It is not unusual to finish the assembly on Friday, come back on Monday to clean and be surprised with white flux residues. As flux residues sit on the PCB, volatiles continue to flash off and it becomes more difficult to remove.

If you are suddenly surprised by white residues or some other clear evidence of a cleaning problem that didn't exist before, step back and look at your process before calling for help. Has anything changed? That will be the first question a technician will ask, and necessary to know before you can identify and solve the problem.

How do you clean a PCB after soldering?

The most common way to clean flux residues from a repair area is to saturate a cotton or foam swab with isopropyl alcohol or another cleaning solvent, and rub it around the repair area. While this may be adequate for no-clean flux, where the goal is a visually clean PCB, this may not be clean enough when more heavily activated fluxes are involved, like RA or aqueous.

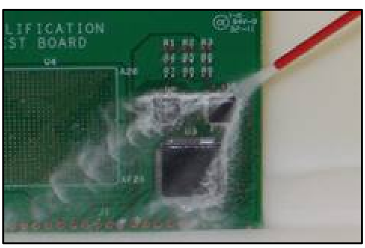
The dirty little secret is that flux residues will not evaporate along with the solvent. You may dissolve the flux, and some of the residues will soak into the swab, but most of the residues will settle back onto the board surface. Many times these white residues are more difficult to remove than the original flux.



Flux residues don't evaporate along with the solvent.

One quick and easy improvement to this process is to rinse the board after swabbing around the repair area. While the solvent is still wet, spray over the entire board with an aerosol flux cleaner. Hold the PCB at an angle to allow the solvent to flow over the board and run off, along with any residues that are picked up.

The straw attachment that comes with aerosol flux removers is a good way to increase the spray force and penetrate under the components.



Aerosol with straw good for cleaning under components

Chemtronics offers an aerosol brush attachment with many of their flux removers. The cleaning solvent sprays through the brush, so agitation can be increased by scrubbing while spraying. To absorb the flux residues, a lint-free poly-cellulose wiper can be placed over the repair area, and the spraying and scrubbing can occur over the material. Then remove the wipe and brush attachment, and spray over the board for the final rinse.

Aerosol brush attachment over a wiper dissolves and absorbs flux residues at the same time.

Which are Better: Water- or Solvent-Based Cleaners?

Solvent Cleaners
All solvents work by dissolving the soil; breaking it down into smaller particles and carrying it into the solution and away from the surface being cleaned. Many solvents offer an advantage of a quick cleaning, so the soils dissolve and flow off of the substrate without needing extended prep time, processing time or drying time.

Solvent-based cleaners remain popular in industrial applications due to their cleaning power; they remove thick, baked on oils, dirt, containments, solder flux, and greases. Some examples of strong cleaning solvents are acetone, methyl ethyl ketone, toluene, nPB, and trichloroethylene (TCE). Common mild solvents include isopropyl alcohol, glycerin, and propylene glycol. In this case, the terms “strong” and “mild” are arbitrary designations. Solvent strength depends not only on the soils being removed, but also on the amount of soil to be removed and the level of cleanliness that is required.

Solvent-based cleaners can be fast evaporating or slow evaporating, high in odor or low in odor, plastic safe or very aggressive. The variety of solvents lends to being able to create very specific cleaning chemistries for removing specific soils from substrates. Some cleaners are capable of removing a specific ink on a plastic substrate while leaving others completely untouched.

Water-based Cleaners
Water-based cleaners remove soils not only by dissolving contaminants, but they can also chemically react with the contaminants and make them more readily dissolvable in water. For example, some materials will react with or dissolve more readily into an acidic solution (pH of 7 or lower). Some common acidic materials can be found in lemons (citric acid), vinegar (acetic acid), soft drinks (carbonic and phosphoric acid) and car batteries (sulfuric acid).

Other materials are more readily reacted with or dissolved into a solution with a pH above 7. These solutions are caustic, or alkaline. Some common caustic materials are ammonia, bleach (sodium hypochlorite), lye (sodium hydroxide), and oven cleaners (more sodium hydroxide).

Most aqueous cleaners contain a variety of other components to enhance the cleaning profile. These other materials can include:

- **Detergents or surfactants –** materials that have wetting and emulsifying properties, and can carry soils into a solution that would not otherwise go.
- **Builders** – materials that increase the efficacy of detergents in water by adding alkalinity to solutions.
- **Emulsifiers** – liquids that can carry oils into water solutions, creating a liquid in liquid solution.

- **Saponifiers** – materials that will react with fatty acids and other carboxyl groups to form water-soluble soaps that can dissolve into the water solution.
- **Sequestering agents** – bind with calcium, magnesium and other metals in hard water that detract from the overall cleaning ability of the cleaner. Sequestering agents can bind with more than one metal ion at a time.
- **Chelating agents** – similar to sequestering agents, but bind to one metal ion only.

The combination of water, solvents, surfactants, and saponifiers can be as effective as solvent cleaning, but often requires a change in the cleaning process. In a high precision application where residues cannot be tolerated, a rinsing process is often required with water-based chemistries. Batch or in-line cleaning systems generally have rinse and dry cycles to overcome these issues.

Which Is Best For You?
Both cleaning technologies have the potential to be very effective in terms of performance – however, the cleaning ability depends on what is being cleaned off of the surface, the substrate being cleaned, and the process constraints and requirements. All three parameters must work in tandem for the best cleaning results.

To choose between an aqueous cleaner vs. a solvent, one must evaluate your unique application, requirements, and goals. Then, you must consider safety, performance, and cost of the solution. A good cleaning agent that is made specifically for removing handling soils may not remove machine greases, a cleaner that works well on stainless steel may not be compatible with glass lenses, and a cleaner that removes machining oil may not be clean enough for a liquid oxygen line.

The bottom line is that it’s impossible to make an overall credible judgment of the superiority of solvent or water-based cleaners without evaluating the unique situation of the user. Luckily, even with the ever-mounting regulations, there's still an array of choices that include both solvents and water-based cleaners.

How Do I Decide Which Flux Remover Is Best For My Application?

Like when selecting any other product, there are a number of options available, and trade-offs to consider. It’s tempting to jump right to the lowest price, but there are a number of other factors that can have a big impact on performance and safety:

- **Flammability** – Many commercially available degreasers contain alcohols and hydrocarbon solvents, which are very flammable. They are economical and generally effective cleaners, but can pose a safety hazard without proper ventilation, and if there are open flames, sparks, or hot surfaces nearby. Nonflammable degreasers are available to avoid these safety issues, but may be offered at a premium price. Some nonflammable cleaners also have significant toxicity concerns, and may contain toxic materials such as perchloroethylene (perc), trichloroethylene (TCE) or n-propyl bromide (nPB). High flashpoint (often called “high flash”) solvents are still flammable, but the vapors are less likely to combust in normal ambient temperatures (say below 140°F/60°C).

GHS (Global Harmonized System) pictogram for flammable materials, as found on product labels and SDS.

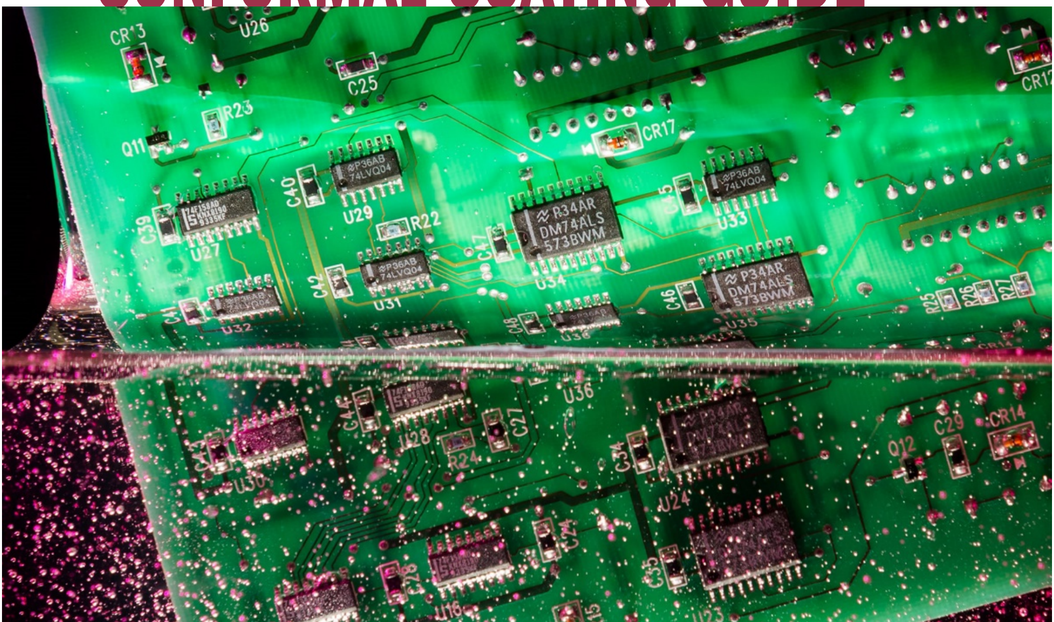
- **Plastic / rubber compatibility** – While not a concern for metal cleaning, plastic packaging and components, along with rubber gaskets need to be watched closely as a new cleaning process is implemented. If the solvent used in a flux remover is incompatible with the plastic, it can craze (create small cracks), embrittle, or soften the material. Rubber seals may swell, shrink or even dissolve if exposed to a harsh solvent. A new cleaner should always be tested before being used extensively on your new (and expensive) assemblies.
- **Surface Tension** – Surface tension is a measurement of a liquids ability to wet a surface or its ability to pull together into a cohesive droplet. The lower the surface tension of a material, the greater the ability for the material to wet a surface, and lay down a thin even coat. When the surface tension is high, the liquid tends to pull together to form droplets. In general, solvents tend to offer lower surface tension than water-based cleaners, providing the ability to permeate into tight clearance areas to remove soils, without being entrapped.
- **Toxicity** – n-propyl bromide, trichloroethylene and perchloroethylene are toxic chemicals commonly used in degreasers to provide cleaning performance in a nonflammable formula. There are cited examples where workers suffered major health effects when exposed to high levels of these chemicals. Workers reported headaches, dizziness, and even loss of full body control. Further studies have shown a possible link to reproductive problems and cancer. These risks have prompted maintenance facilities to rethink their solvent choices, especially with manual cleaning when exposure tends to be higher than the more automated cleaning processes.

GHS pictograms for acute *(short-term, left)* and chronic *(long-term, right)* hazards.

- **Environmental issues** – In the past, ozone depletion was a concern with contact cleaners containing chlorofluorocarbons (CFCs) like the Freon of old, and hydrochlorofluorocarbons (HCFCs) like AK-225. Since those solvents are no longer available on the commercial market in North America, concerns have turned to volatile organic compounds (VOCs), solvents that add to smog, or solvents with high global warming potential (GWP). Some state (e.g. CARB or California Air Review Board), municipal, and even industry-specific regulations restrict the use of high VOC or high GWP materials.

- **Cleaning performance** – Whether or not a flux remover adequately cleans is dependent on many variables, the most important being the type of flux and the cleaning requirements. In general, natural rosin-based fluxes (R, RA, RMA) are easier to clean by a broad array of chemistries. No-clean and halide-free fluxes, that often contain a mix of synthetic materials, can be more difficult to remove. Partial removal can leave behind white residues, that are often more difficult to clean than the original flux residue. No cleaner supplier can provide an exact match to your specific requirements. It is important to qualify a new cleaner using as close of a match to the soil and cleaning process as possible.
- **Cost** - When evaluating a cleaning solution based on cost, it is important to consider the total cost of the cleaning process (e.g. materials + time, energy, floor space, etc.). This takes into account the trade-offs previously mentioned. A high performance cleaner will work more quickly, require less material, and few consumables (wipes, swabs, etc.). A flammable product will require more robust ventilation and storage systems. A highly toxic product will require more stringent use of PPE (personal protection equipment) to maintain safe exposure levels.

CONFORMAL COATING GUIDE



With continued miniaturization of electronics and their circuitry, the necessity of conformal coating has skyrocketed. And choosing the ideal type of coating and application method for your application is crucial. But weeding through the vast amount of information online is daunting.

Conformal coating is a specialty polymeric film forming product that protects circuit boards, components, and other electronic devices from adverse environmental conditions. These coatings ‘conform’ to the irregular landscape of the PCB providing increased dielectric resistance, operational integrity, and protection from corrosive atmospheres, humidity, heat, fungus, and airborne contamination such as dirt and dust.

Conformal Coating Types

There are a number of options for coating technologies, and the best option should depend mainly on the protection required. Application method and ease of rework are also important factors, but should generally be considered secondary to the protective performance needed.

Traditional Conformal Coatings

What we are calling "traditional" conformal coatings are 1-part systems that have a resin base, and may be diluted with either solvent or (in rare cases) water. Traditional coatings are semi-permeable, so do not fully water-proof or seal the coated electronics. They provide resistance to environmental exposure, which increases PCB durability while still keeping application and repair processes practical.

These categories are based on the basic resin of each coating. The chemistry determines the major attributes and functions of the conformal coating. Choosing the proper conformal coating for your application is determined by operational requirements of the electronics.

- **Acrylic Resin (AR)** – Acrylic conformal coating provides fair elasticity and general protection. Acrylic conformal coating is recognized for its high dielectric strength, and fair moisture and abrasion resistance. What generally distinguishes acrylic coating from other resins is ease of removal. Acrylic coatings are easily and quickly removed by a variety of solvents, often without the need of agitation. This makes rework and even field repair very practical and economical. On the other hand, acrylic coatings do not protect against solvents and solvent vapors, for example that might be typical for pumping equipment. Acrylic coatings can be considered basic entry-level protection, because they are economical and protect against a broad-level of contamination, but not best-in-class for any characteristic except possibly dielectric strength.
- **Silicone Resin (SR)** – Silicone conformal coating provides excellent protection in a very wide temperature range. SR provides good chemical resistance, moisture and salt spray resistance, and is very flexible. Silicone conformal coating isn't abrasion resistant because of its rubbery nature, but that property does make it resilient against vibrational stresses. Silicone coatings are commonly used in high humidity environments, like outdoor signage. Special formulations are available that can coat LED lights without color shift or reduction of intensity. Removal can be challenging, requiring specialized solvents, long soak time, and agitation like from a brush or an ultrasonic bath.
- **Urethane (Polyurethane) Resin (UR)** – Urethane conformal coating is known for its excellent moisture and chemical resistance. They are also very abrasion resistant. Due to this and their solvent resistance, they are also very difficult to remove. Like silicone, full removal generally requires specialized solvents, long soak time, and agitation like from a brush or an ultrasonic bath. Urethane conformal coating is commonly specified for aerospace applications where exposure to fuel vapors is a common concern.

The scope of the rest of this article is concerned mainly with what we call "traditional" conformal coatings, but we'll cover other coating types here to provide a complete picture of the available options.

Specialized Coatings

- **Epoxy Resins (ER)** – Epoxy-based coatings are usually available as two-part compounds and create a very hard coating. The epoxy conformal coating provides very good humidity resistance and isn't generally permeable like conformal coatings are. They also have high abrasion and chemical resistance. Typically, they are very difficult to remove once they are cured, and are not as flexible as the other materials. Epoxy coatings are common in potting compounds, which in contrast to conformal coatings, completely covers the electronics in a solid and level layer of material.
- **Parylene (XY)** – Parylene conformal coatings is a unique type of coating applied by vapor phase deposition. It provides excellent dielectric strength and superior resistance to moisture, solvents and extreme temperatures. Because of the vapor deposition method, parylene coatings can be applied very thin and still provide excellent circuit board protection. Removal for rework is very difficult, requiring abrasion techniques, and without access to vapor phase deposition equipment, recoating with parylene is impossible.
- **Thin Film / "Nano" Coatings** - A coating is dissolved in a fluorocarbon-based carrier solvent and applied with a spray or dip method to create a very thin coat, although not nanometer scale as the nickname suggests. They are commonly used to provide a minimal amount of hydrophobicity, which may prevent shortages from very quick exposure to water. This type of coating does not offer the level of the surface protection of other coating methods.

Coating Application Methods

Once the coating type is selected, the next question is how to apply the conformal coating? That decision should be based on the following variables:

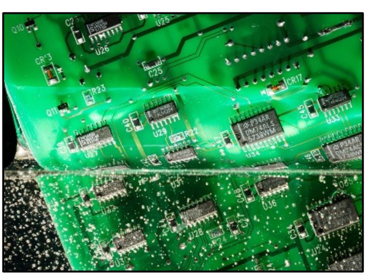
- **Production throughput requirements** – The prep work needed, the speed of the coating process, and how quickly the boards can to be handled after the coating process.
- **Board design requirements** – Connector laden designs, solvent sensitive components, and other issues impact your decision.
- **Equipment requirements** – If a coating is only sporadically required, tying up capital and floor space with additional equipment may not make sense.
- **Pre-coating processing** – Some processes require masking or taping before coating.
- **Quality requirements** – Mission critical electronics that require a high degree of repeatability and reliability will generally move you to more automated application methods.

The following are the application methods for traditional conformal coatings:

- **Manual spraying** - Conformal coating can be applied by an aerosol can or handheld spray gun. It is generally used for low volume production when capital equipment is not available. This method can be time-consuming because areas not requiring coating need to be masked. It is also operator dependent, so variations are common from board to board.
- **Automated spraying** - Programmed spray system that moves the board on a conveyor under a reciprocating spray head that applies a conformal coating.
- **Selective coating** - An automated conformal coating process that uses programmable robotic spray nozzles to apply the conformal coating to very specific areas on the circuit board. This process is used in high volume processes and can eliminate the need for masking. An applicator may have a built-in UV lamp to cure coating immediately after it is applied.

Selective spray system
(photo courtesy of PVA)

- **Dipping** - The circuit board is immersed then withdrawn from the conformal coating solution. Immersion speed, withdrawal speed, immersion time and viscosity determine the resulting film formation. It is a common conformal coating technique for high volume processing. A great deal of masking is generally required before the coating process. Dipping is only practical when coating on both sides of the board is acceptable.



Dipping process

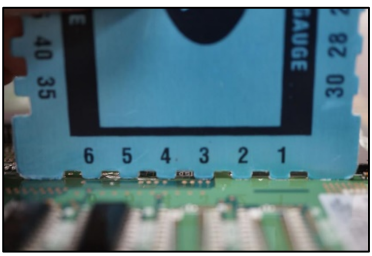
- **Brushing** - Brushing is a simple application technique used mainly in repair and rework applications. The conformal coating is applied with a brush to specific areas on the board. It is a low cost but labor intensive and highly variable method, best suited for small production runs.

How Do I Measure Coating Thickness?

Conformal coatings are usually applied as very thin coatings, providing the maximum protection possible using the thinnest about of material. This minimizes heat entrapment, additional weight, and a variety of other concerns. Normal thickness with most conformal coatings is anywhere between 1 to 5 mils (25 to 127 microns) with some coatings applied at an even thinner level. Anything greater than this thickness is usually an encapsulate or a potting compound, which typically provide more mass and thickness to protect the boards.

There are three primary ways to measure the thickness of a conformal coating:

- **Wet film thickness gauge** - Wet film thickness can be measured directly by using the appropriate gauge. These gauges incorporate a series of notches and teeth, each tooth has a known and calibrated length. The gauge is placed directly onto the wet film to take the film measurement. This measurement is then multiplied by the percent solids of the coating to calculate the approximate dry coating thickness.



Wet film thickness gauge

- **Micrometer** - Micrometer thickness measurements are taken on the board (or on a test panel) on several locations before and after coating takes place. The cured coating thickness is subtracted from the uncoated measurements and divided by 2, providing the thickness on one side of the board. The standard deviation of the measurements is then calculated to determine the uniformity of the coating. Micrometer measurements are best taken on harder coatings that do not deform under pressure.
- **Eddy current probes** - Eddy current measurement of conformal coating thickness uses a test probe that directly measures the thickness of a coating by creating an oscillating electromagnetic field. The thickness measurements are non-destructive and very accurate but can be limited depending on the availability of a metal backplane or metal under the coating, and the direct contact available of the test sample. Without metal below the test area no measurements will be made, and if the probe does not fit flat on the test area, readings will inaccurate.

- **Ultrasonic thickness gauge** – This type of gauge measures coating thickness using ultrasonic waves. It has the advantage over eddy current probes because it does not need a metal backplane. Thickness is determined by the amount of time sound takes to travel from the transducer, through the coating, bounce off the surface of the PCB, and back. A conductive medium, like propylene glycol or water, is needed to provide good contact with the surface. This is generally considered a non-destructive test unless there is a concern with the complaint affecting the coating.

Ultrasonic thickness gauge

Curing Methods

While the cure mechanism isn't a primary criterion when selecting a coating, it has a direct impact on the type of application method that will be feasible, and the production throughput that can be expected. Some mechanisms are relatively foolproof, while others are very complex and leave room for application errors when used in an uncontrolled process.

- **Evaporative Cure Mechanism -** The liquid carrier evaporates, and what is left behind is the coating resin. Although very simple in theory, circuit boards usually need to be dipped at least two times to build up an adequate coating on component edges. Whether the liquid carrier is solvent or water-based, humidity affects application parameters. Solvent systems tend to be easy to process, provide consistent coverage due to good wetting, and fast cure times. However, solvents are often flammable, so adequate ventilation and fume extraction methods are required. Using water as a carrier can eliminate the flammability concern, although they tend to take much longer to cure, and can be very sensitive to ambient humidity.
- **Moisture Cure** - Primarily found in silicone and some urethane systems. These materials will react with ambient moisture to form the polymer coating. This type of curing mechanism is often coupled with an evaporative cure. As carrier solvents evaporate, moisture reacts with resin to initiate final curing.

- **Heat Cure** - Heat cure mechanisms can be used with one or multicomponent systems, as a secondary cure mechanism for UV cure, moisture cure, or evaporative cure. The addition of heat will cause the system to polymerize, or speed the cure of the system. This can be advantageous when one cure mechanism is insufficient to gain the cure properties required or expected. However, thermal sensitivity of circuit boards and components must be taken into consideration when curing in elevated temperatures.
- **UV Cure** - Coatings that are cured by ultraviolet light offer very fast production throughputs. They are 100% solid systems with no carrier solvents. UV curing is line-of-site, so a secondary curing mechanism is needed under components and in shadow areas. UV cured coatings are more difficult to repair and rework and require UV curing equipment and UV radiation protection for workers.

Conformal Coating Removal

On occasion, it is necessary to remove a conformal coating from the circuit board to replace damaged components or perform other reworking procedures. The methods and materials used to remove coatings are determined by the coating resins as well as the size of the area and can impact the time required.

The basic methods as cited by IPC are:

- **Solvent Removal** – Most conformal coatings are susceptible to solvent removal, however, it must be determined if the solvent will damage parts or components on the circuit board. Acrylics are the most sensitive to solvents hence their easy removal; epoxies, urethanes, and silicones are the least sensitive. Parylene cannot be removed with a solvent.
- **Peeling** – Some conformal coatings can be peeled from the circuit board. This is mainly a characteristic of some silicone conformal coatings and some flexible conformal coatings.
- **Thermal/Burn-through** – A common technique of coating removal is to simply burn through the coating with a soldering iron as the board is reworked. This method works well with most forms of conformal coatings.
- **Microblasting** – Micro blasting removes the conformal coating by using a concentrated mix of soft abrasive and compressed air to abrade the coating. The process can be used to remove small areas of the conformal coating. It is most commonly used when removing Parylene and epoxy coatings.
- **Grinding/Scraping** – In this method, the conformal coating is removed by abrading the circuit board. This method is more effective with harder conformal coatings, such as parylene, epoxy and polyurethane. This method is only used as a method of last resort, as serious damage can be incurred.

If all you are doing is replacing a component or working on an isolated area, it is common to simply burn through the coating with a soldering iron. In cases when this is aesthetically unacceptable, contamination is a concern, or components are densely spaced, there are coating removers available in pen packaging.

Conformal Coating Certifications

Certifications are an important way to distinguish general purpose varnishes and shellacs from engineered coatings designed specifically for PCB protection. Although there are dozens of user and industry specifications, the two major certifications are IPC-CC-830B and UL746E. When selecting a coating, look for the availability of 3rd party test documentation, rather than coatings with the claim that it "meets the requirements". Both standards use the UL94 standard to judge flammability, with a V-0 rating signifying the lowest flammability potential.

IPC-CC-830B / MIL-I-46058C
This standard originated with the military standard MIL-I-46058C, which became obsolete in 1998. The civilian version IPC-CC-830B is nearly identically, so it is generally understood that if a board passes the IPC spec it will also pass the MIL spec., and visa versa. IPC-CC-830B is a battery of tests, some pass-fail and others that provide data that can be referenced and compared:

- Appearance
- Insulation resistance
- UV fluorescence
- Fungus resistance
- Flexibility
- Flammability
- Moisture and insulation resistance
- Thermal shock
- Hydrolytic stability

UL746E
Underwriters Laboratories (UL) is considered a credible and reliable safety certification body worldwide, and UL certification is commonly required for consumer goods. UL746E tests for electrical safety and flammable safety of the coated electronics. For electrical safety, there is a battery of tests similar to IPC-CC-830B, but with a cycling current load to constantly measure the failure of the isolative properties of the coating. The flammability test uses the UL94 standard like IPC-CC-830B, which involves attempting to light the cured coating with an open flame and observing the sustainability of the flame.

Once a coating has passed ULT746E, it can be registered with UL and assigned a registration number. Products certified and registered to UL746E standards can include the UL symbol (which looks like a backward "UR"). To maintain the registration, a coating much be retested annually.

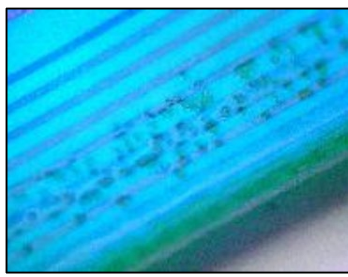
Coatings can, and often are, tested to standards that only represent a portion of the whole standard. In the case of UL94, this is helpful when flammability is the main concern. Some specialty coatings may not be tested to the entire IPC-CC-830B or UL746E because they may fail portions of the test because of the nature of the product, not a reflection of the quality of the product. For example, some coatings intended to coat LEDs leave out the UV indicator to prevent color shift, but this automatically would cause disqualification under IPC-CC-830B. In other words, it is by definition impossible to pass IPC-CC-830B and have optical clarity in the UV part of the spectrum.

How To Identify & Cure The Top 7 Coating Defects

One of the most common customer support calls we receive is to solve conformal coating application issues. Given the number of variables involved in a conformal coating process (e.g. coating formula, viscosity, substrate variations, temperature, air mix, contamination, evaporation, humidity, etc.), no wonder issues come up frequently. Let's take a look at some of the more common problems that can crop up when applying and curing conformal coatings, and the potential causes and cures. *(photos courtesy of NPL)*

1

Dewetting - This is caused by contamination on the substrate that is incompatible with the coating. The most likely culprits are flux residues, process oils, mold release, and fingerprint oils. Dewetting can be recognized simply by observing areas of good coating application next to areas where the co ating beads up and moves away from the contaminated area. Think of it as putting a drop of detergent in oily water – the oil immediately moves away from the single drop. Cleaning the substrate thoroughly prior to coating application will resolve this.



2

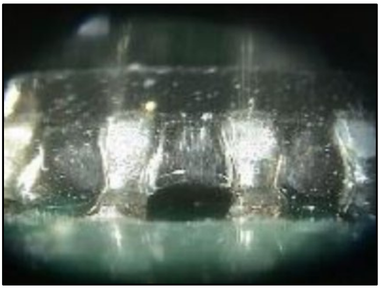
Delamination - There are a couple of common causes for this problem where an area of the coating loses adhesion to the substrate and can lift from the surface. One main cause, again, is a contaminated surface. Usually, you will only notice delamination after the part is out in the field, as it is usually not immediately observed. Proper cleaning can take care of this issue. Another cause is insufficient tack time between coats. The solvent has not had the proper time to flash off prior to the next coat. Ensuring adequate time between coats is a “must”.

3

Air bubbles - Can be caused by a coating layer not leveling and adhering to the substrate surface, causing air to be trapped. As the air rises through the coating, it creates a small bubble. Some bubbles collapse to create concentric rings in the shape of a crater (for larger caters, see "Fisheyes" section below). Another cause can occur during brushing. If the operator is not extremely careful, the brushing action can entrain air bubbles into the coating with the subsequent effect above.

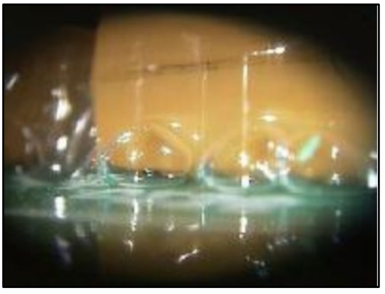
4

More bubbles and voids - The majority of bubbles are caused by a solvent that has been trapped and then vapors through the coating layers. If the coating layer is too thick, if the coating goes into accelerated (heat) cure too quickly, or if the coating solvent evaporates too quickly – all of these result in the coating surface to skin over while there is still solvent underneath that is vaporing up, causing bubbles in the top layer.



5

Fisheyes - A small circular area, highlighted by a "crater" in the center, and is seen usually during spray application or shortly thereafter. This can be caused by entrained oil or water in the sprayer air system and is commonly seen when using shop air. Prevention comes in the form of a well-maintained filtration system to scrub any oil or moisture from entering the sprayer.



6

Orange peel - This looks exactly what the term implies – an uneven, mottled appearance. Again, there can be multiple causes. If using a spray system, if the air pressure is too low, this can cause uneven atomization which can result in this effect. If using a thinner in the spray system to reduce the viscosity, sometimes the incorrect choice of thinner can cause it to evaporate too quickly. This does not allow the coating adequate time to level out properly.

Still another cause is applying too many heavy wet coats – go back and reset the sprayer parameters and adjust the spray technique accordingly.

7 **Cracking/crazing** - Highlighted by long cracks or areas of smaller cracks (crazing). This is usually caused by excessive film thickness or insufficient time between overcoats. If curing with heat acceleration, exposing the wet film to excessively high temperature can also cause this to occur. A staged evaporation rate is always desired, so a lower temperature for a longer time may be in order. Some coatings recommend a two-step accelerated cure where a lower temperature for a short amount of time is called for, followed by a time of increased temperature. This allows for the more volatile solvent to evaporate at a slower rate and then the slower ones such as the tailing solvent are flashed off at the higher temperature.

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