Avoiding FLUX RESIDUE in Advanced PCB Designs

Today's advanced PCB technologies demand more aggressive steps in cleaning up residues left by conventional no-clean flux cleaning processes.

By Zulki Khan, President and Founder
NexLogic Technologies, Inc.

The PCB world is seeing more technology advancements today than ever before. With so much attention given to a growing number of PCB design, fabrication, and manufacturing concerns introduced by these new technologies, it is no surprise that little consideration is given to board cleanliness on the manufacturing floor. To make matters worse, today's PCB cleaning agents are lackluster at best. As a result, there is a high probability of leaving residues on the board, ultimately leading to undesirable performance. That is a key reason for placing special emphasis on cleaning no-clean fluxes.

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Residues and contaminants left over on PCBs could be ionic contaminations or non-ionic contaminations. Typically, these are non-conductive, organic species that are left over due to fabrication and assembly handling. These residues result mostly from resins, oils, greases, hand lotions, or silicone, and they don't change a cleaning solution's conductivity. However, these need to be cleaned after the board is assembled.

Conversely, ionic contaminations are ones containing molecules or atoms, which are conductive when a cleaning solution is applied to it. Moisture or ionic residues can completely dissociate into negative or positive particles, which change the overall conductivity of the solution. Therefore, if certain solution-like water is applied, it becomes either positive or negative. These are ionic contaminants or residues.

Some examples of ionic residues are ionic surfactants, flux activators, human perspiration, and plating chemistries, which are the ones that get charged during PCB fabrication. By taking a positive or negative ion charge, these residues change the cleaning solution's conductivity, thereby making the cleanliness process different from what it should be.

These scenarios make it imperative that the EMS Provide or CM must not be complacent in its PCB regular cleaning process. Rather, extraordinary steps must be taken in assuring the correct cleaning technologies or techniques are applied based on a PCB's application.

Otherwise, unexpected reactions can be created, resulting in subsequent board damage when inappropriate or non-compatible cleaning agents are used with fluxes and solder pastes.

The right cleaning agents are required to remove flux residues, especially when higher-reliability mil/aero and medical electronics PCB applications are involved. Proper cleaning agents improve the integrity of the process such as bonding and conformal coating. Residues can also cause improper adhesion of a bond that can lead to failures such as heel liftoff of certain gull wing components. During the coating process, if these residues are left in poor wetting or de-lamination, they can cause assembly failures and ultimately lead to field failures. These reliability risks are extraordinarily high, especially when using lead-free solder paste.

Switch to No-Clean Paste

Up to now, using water-soluble paste for cleaning PCBs has been the predominant method. However, today, increasing numbers of EMS providers and contract manufacturers (CMs) are switching to no-clean paste due to greater usage of quad flat no-leads (QFN) packages and flip-chip devices on the PCB, which are better assembled using no-clean paste. In those cases, special chemistries and aqueous batch cleaning take on a more important role compared to de-ionized water.

There are two main reasons for using no-clean paste for QFN and flip chip device-populated PCBs. One, it provides better wetting processes. Two, it is more aggressive and compatible with those packaged devices in that no-clean paste penetrates through tight and tiny board packaging areas and crevices, which, otherwise, is not completely possible with water-soluble paste. Plus, no-clean paste offers better solder ability with fine-pitch BGAs and CSPs.

From a broader perspective, the challenge is to use no-clean paste and flux and still be able to clean the board and components to 99.5% - 99.9% level of cleanliness. Due to their tenacious nature, residues left behind by no-clean flux are especially difficult to clean even with special cleaning agents. In some cases, even some residues remain, which produce

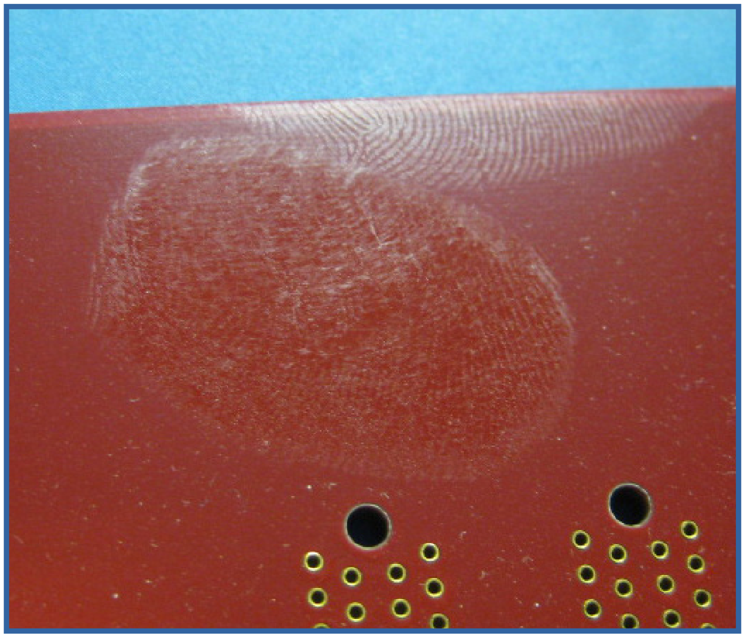
Fig. 1. *Ionograph tester for checking ionic contamination after batch cleaning is finished.*

undesirable results on extra high-speed PCBs, like improper eye diagrams.

If the proper cleaning agents aren't applied, a board may still have flux and solder paste residues that are trapped inside the small cavities, which will hinder the board's optimal performance since transmission and return signals are not 100% clean, especially with high-speed designs. When this occurs, assembly personnel have to resort to another cleaning cycle and then use an ionograph machine, as shown in Fig. 1, to assure targeted cleanliness is performed to a satisfactory level, which can be quantitatively proven.

It's also worth noting that no-clean paste means PCBs cannot be cleaned with de-ionized water. The reason is the chemistry of no-clean flux doesn't gel well with water. As a result, it leaves white residue on the PCB that is not attractive to the eye; plus, these boards are difficult to clean. Special chemistries are needed because composition of that chemistry effectively gels with the chemistry of the no-clean flux. This way, PCBs can be cleaned properly to eliminate flux residues.

Fig. 2. *PCB with red solder mask shows fingerprints from handling of this board.*



In this instance, there are flux residues that not only contaminate a board, but also have some fingerprints, which have human body oils, as shown in Fig. 2. All these residues and contaminants can get stuck in different portions of a board's surface and cause undesirable performance. Those performance symptoms can show up within a short time period; others can linger and subsequently emerge as major system flaws in the field.

For example, conformal coatings may fail, creating a huge issue. If no-clean flux residues are left, voids within the conformal coating are created, resulting in air gaps or pockets. This is a major issue, especially when these improperly cleaned PCBs are exposed to a harsh and rugged environment. Conformal coating deteriorates when incorrect chemistries adversely react with the conformal coating material. Also, bonding or encapsulation may deteriorate due to highly active flux ingredients.

The reaction in this case would be such that they break hermetically sealed packaging, which is intended to keep moisture or humidity from entering and damaging the circuitry it houses. If such a thing happens, moisture seeps in and assembly joints may be compromised and may get damaged. Also, flux residues can cause corrosions and dendrite growth, which often causes intermittent failures. Similar in nature to tin whiskers, dendrite growth comprises tiny conductive metal filaments that extend between PCB pads or bridge across tracks to cause short circuits.

Problems at High Frequency & High Voltage

Flux residues cannot be tolerated in high-voltage PCBs. Leftover and undesired flux residues have the highest probability of creating a spark between two points and short the circuit. For example, a flux residue may adversely affect analog or digital conversion in A/D circuits. This is especially true with extremely high-speed digital signals. If there are flux residues, rosins or gooey types of agents left on the PCB and device packaging, they will hinder the A/D conversion process. It will not optimally occur as it is intended, especially at high-speed levels when flux and paste residues are left over.

Also, the higher the frequency, the cleaner the PCB surface has to be. Both transmit and return paths need to operate at high-speed levels, which must be very clean of any contaminations. Even the slightest speed transfer change in the return path compared to the transmit path can have a devastating effect on performance. If improper, non-compatible cleaning agents are used, undesirable residues and rosins will hinder signal propagation at those high-speed levels.

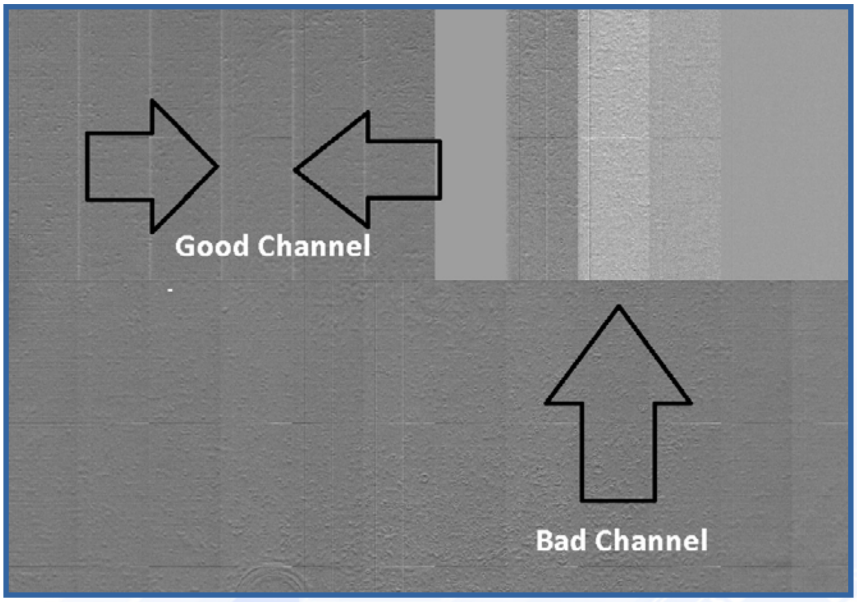


Fig. 3. *A clean video link channel may be distorted as a result of miniscule flux residues on a PCB. compromising that product.*

In particular, flux residues can have a damaging effect on image processing based applications for medical device markets. Take for example oncology products, where a clean video link channel, as shown in Fig. 3, may be distorted as a result of miniscule flux residues on a PCB, ultimately compromising that product. Due to that distortion, an inaccurate reading can mislead a healthcare giver using such a product, or worst case, medical specialists aren't able to determine healthy versus cancerous cells in the video link because channel transmission is not clean. Therefore, flux residues can prevent PCB circuitry from achieving optimal results.

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Difficult to Remove

Residues from no-clean paste and fluxes are more difficult to remove than water-soluble-based ones. At times, a special batch cleaning process with certain chemistries is required to prevent these residues and contaminations. A word of caution; using too strong a chemistry for cleaning the PCB may cause creepage of chemical agents into the solder mask, thus jeopardizing solder integrity, as shown in Fig. 4.

Creep corrosion occurs from electro-chemical oxidation of metals in reaction to an oxidant such as oxygen.

The advantage of cleaning is to prevent electrochemical migration from one side of the board to another, or so-called “creep corrosion,” either by stopping it or preventing it from happening altogether. Creep corrosion occurs from electrochemical oxidation of metals in reaction to an oxidant such as oxygen. It is difficult to mitigate due to the very nature of the corrosion, i.e. reaction between metal contents in no-clean flux and oxygen.

To mitigate corrosion, control leakage currents and improve in-circuit testing (ICT) yield by improving the cleanliness in a batch cleaning process using special chemistry instead of de-ionized water. Also, this provides a better point of contact for flying probe testing so that the probe points can effectively touch pads on the board when there is no obstruction due to flux or high chemical residues. Moreover, when boards are clean, there is improved conformal coating and underfill adhesion.

Two other factors playing a part in improved cleaning include better point of contact for testing and improved underfill conditions. De-ionized (DI) water alone

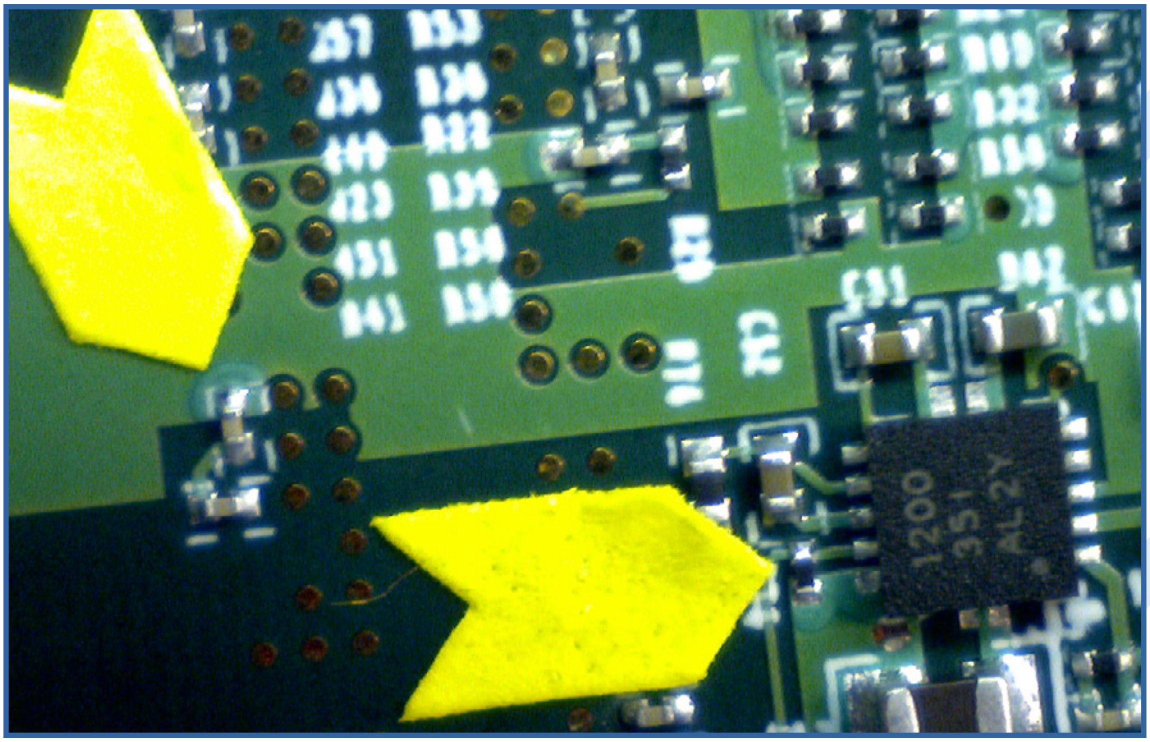

Fig. 4. *Too strong a chemistry used for cleaning a PCB may cause creepage of chemical agents into the solder mask and jeopardize solder integrity.*

cannot clean 100 percent of all the rosin in the flux. It leaves white powdery foam and the solvent saponifier chemistry is often needed to clean that foam. This increases the capital expenditure of the CM, as well as increases the cost since a special cleaner is required, along with the extended cleaning time requirements.

Consequently, equipment is needed to clean it, and additional chemistries are needed. Rosin, which is in the no-clean flux, provides inert and, in some cases, non-hygroscopic covers on the top. This coating on the top prevents ions from having an electromagnetic migration path.

Expertise on Manufacturing Floor

EMS providers and CMs are faced with a vast selection of PCB cleaning agents from a considerable number of large well-known commercial vendors. Each has different types of cleaning agents with varying kinds of chemicals in those products. There are also lesser-known, smaller vendors producing different cleaning agents with different characteristics. Some are conducive to no-clean flux cleaning, while others are not as compatible.

It's also important to know that sometimes vendors add or delete certain chemical properties from their cleaning agents. When this occurs and the changes go unannounced, it leaves the EMS provider and CM guessing as to the proper PCB cleaning mix to avoid damaging boards.

Therefore, it's highly important for the EMS provider and CM to be at the top of their game and have up-to-date knowledge, expertise, and experience about today's cleaning agents and their characteristics. This includes matching the right cleaning agents with the right PCB applications, knowledge of chemical properties in cleaning agents produced by specific vendors, understanding technical specification sheets, and making the right decisions based on precise know how. If that expertise isn't found on a PCB manufacturing floor, the chances are high that the wrong cleaning agents will be used. As a result, those boards will incur some level of damage, leading to undesirable performance and latent field failures. EE

Author Bio

Zulki Khan is the Founder and President of NexLogic Technologies, Inc., San Jose, CA, an ISO 9001:2008 Certified Company, ISO 13485 certified for medical electronics, and a RoHS compliant EMS provider. Prior to NexLogic, he was General Manager for Imagineering, Inc., Schaumburg, IL. He has also worked on high-speed PCB designs with signal integrity analysis. He holds B.S.E.E from N.E.D University and M.B.A from University of Iowa and is a frequent author of contributed articles to EMS industry publications.