

Essential cleaning for electronics assemblies

Cleaning is an essential process within electronics manufacture and has been used for many years to remove potentially harmful contaminants during PCB manufacture. Such contaminants include flux, solder and adhesive residues, and other more general contaminants such as dust and debris present from other manufacturing processes. The purpose of cleaning, specifically within the rapidly expanding electronics industry, is to essentially improve product lifetime by ensuring good surface resistance and by preventing current leakage leading to PCB failure. This developing market sees modern and future electronics becoming smaller and smaller and the requirement for high performance and reliability is stronger than ever. In order to achieve good insulation resistance, the cleanliness of the electronic assemblies is essential. This can only be achieved by manufacturers of fluxes/adhesives, cleaning chemicals, cleaning equipment and electronics engineers, all working together to ensure optimal cleaning performance is reached.

There are many stages where cleaning is required; prior to stencilling and soldering in order to remove contaminants from the many previous production stages, after stencilling to remove excess adhesive, and after soldering to remove corrosive flux residues and any excess solder paste. In industry today, many manufacturers are turning to 'no clean' processes, implying that cleaning is not required after soldering. In the 'no clean' process the solids content of the flux is lower than traditional types, however they still contain rosin and activator which are not removed prior to the next process, such as coating or encapsulating of the PCB. Such residues, along with any other unwanted elements collected due to the missing cleaning stage, could cause issues with adhesion and possibly affect the performance of the protecting media applied. It can therefore be stated that even with advances in new technologies, such as 'no clean' fluxes, cleaning is still an essential multi-stage process within the electronics industry. Finally, there are also cleaning stages required for the removal of coatings and adhesives when re-work is necessary, for the cleaning of actual components and for maintenance of the production line.

There are two main categories of cleaner currently available, solvent based and water based. Traditionally, solvent based cleaners such as 1,1,1-trichloroethane and 1,1,3-trichlorotrifluoroethane dominated the market; however, due to their ozone depleting potential, they have been replaced by a more diverse range of solvent cleaners. This category is now typically divided into three sub-sections; flammable solvent cleaners, non-flammable solvent cleaners and non-flammable halogenated solvent cleaners such as HFCs and HFEs. All three types have their advantages and disadvantages but overall solvent cleaners can be described as fast evaporating, single stage cleaners. However, they require specialist equipment and extraction to protect against toxicity and other possible hazards.

Water-based cleaners were also developed to replace ozone depleting chemicals as well as offering a solution to reduce solvent emissions. Water-based cleaning has several advantages over solvent based cleaners including non-flammable properties, low odour, low/non-VOC and very low toxicity. There are many applications for cleaning, all of which depend on the type of equipment available. Whether it be ultrasonic, spray under immersion or dishwasher type application, identifying the correct water-based cleaner for the specific job is essential. Water-based cleaners tend to be much more complex than their solvent based counterparts. They utilise surfactant technology to assist the removal of contaminants from a PCB by reducing the interfacial tensions and suspending or emulsifying them in solution. Alternatively, water-based flux removers work by saponification, neutralising the flux acids. The only major disadvantage of water-based cleaners is that they require multiple stages to complete the cleaning process, including a two-stage rinse process and a final drying stage. Finally, there is also a newer type of surfactant-free water based cleaner. Based on glycols, these cleaners combine the advantages of water based and solvent based cleaners with only minimal rinsing required.

With the cleaning market continually developing to meet the demands of industry expansion it is important that the level of cleanliness required is clearly defined. A significant proportion of potentially damaging flux residues and contaminants are not visible to the naked eye or even with the aid of magnification. It is therefore vitally important that the correct method is used to determine that the level of cleanliness achieved meets the standard specified by the electronics engineer. There are two types of residues; ionic and non-ionic and there are a number of methods that can assess the level of contamination after cleaning and accurately describe the term 'clean'.

Non-ionic residues including rosin, oils and grease are non-conductive and are usually organic species that remain after board fabrication or assembly. They have insulative properties which are a problem where plug-in contacts or connectors are utilized on assemblies. These can cause poor adhesion of solder mask, conformal coating and potting compounds as well as encapsulate ionic contaminants and foreign debris.

Ionic contaminants are typically flux residues or harmful materials left behind after soldering. Water-soluble organic or inorganic compounds can disassociate in a solution as charged ions increasing the overall conductivity of that solution. They can degrade the reliability of the electronic components and assemblies by contributing to current leakage between the circuitry, causing corrosion and promoting dendrite growth. While ionic and non-ionic contaminations both impact the operation and reliability of the device on which they are present, ionic contamination accounts for the larger proportion of failures.

There are several methods available for monitoring the level of both ionic and non-ionic contaminants. The simplest method, suitable for monitoring both types of residue, is a visual inspection. Although this does not provide any quantitative data it should always be utilised alongside other methods. Magnification at around 10-15X should be sufficient for quality purposes and will provide information on production processes including handling and packaging and their contributions towards contamination.

Other than optical inspection, there are no simple methods of measuring non-ionic residue. Fourier Transform Infrared Spectroscopy (FTIR) is the most widely used analytical method for efficiently determining the precise identity of the contamination. High Performance Liquid Chromatography (HPLC) and UV-Vis Spectroscopy can be used to identify residual rosin. Scanning Electron Microscopy (SEM), Energy Dispersive X-ray (EDX) analysis and Auger analysis are also suitable for determination of residues and contaminants on a PCB and each has its own specific advantage. The equipment required to set up these types of experiments are costly and require a lot of maintenance and are therefore rarely used in production environments.

A common method of determining the degree of ionic contamination is to measure Resistivity of Solvent Extract (ROSE), also known as Solvent Extract Conductivity (SEC). The theory of ROSE is that as the concentration of ions in a solution increases, the resistivity decreases. Simple automated versions of ROSE testing, the Omega Meter, Ionograph or Zerolon, are used by a number of electronic assembly houses for quality control testing. The industry standard, IPC-TM-650, employs a solution of isopropanol and deionised water to extract the contaminants whilst the meter measures the change in conductivity. This type of testing is widely accepted and offers rapid results but can be restrictive. Originally designed to test residues from traditional rosin based fluxes and utilise a cheap, readily available solvent (IPA), the scope of this method is now somewhat outdated and may not alert users to possible changes resulting in non-soluble residues. The change in accepted cleanliness levels also highlights the development of the cleaning industry. Traditionally for the CFC-113 type cleaners mentioned earlier an accepted limit of $1.56\mu\text{g}/\text{cm}^2$ ($10\mu\text{g}/\text{in}^2$) equivalent NaCl is detailed as per ANSI/J-STD-001. Today, most assemblies are now achieving well below this level, typically in the region of $0-1\mu\text{g}/\text{in}^2$. This method is also only capable of measuring ionic contamination and cannot define exactly where or what that contamination is.

Two further methods provide valuable data are the measurement of Surface Insulation Resistance (SIR) and Ion Chromatography (IC). The former involves measuring the change in electrical current over time via an interleaved comb pattern PCB and is typically performed at elevated temperatures and humidity levels. The presence of contamination lowers the insulation resistance of the material between the conductors. The latter, Ion

Chromatography (IC), is a newer method for cleanliness evaluation which can be used for identifying and quantifying specific ionic species that are present on an electronic device. The test method details a specific list of ionic residues which can be removed by specific media. Subsequent analysis of the fluid can separate, identify and quantify the residue. Substrate handling and preparation are critical for this method making it particularly expensive and time consuming. Therefore it is not used for general quality control purposes but as a more specific analytical technique.

The effective cleaning of PCBs and associated components is an essential part of electronics manufacture. It increases the reliability of assemblies and allows coating and encapsulating operations to be carried out with full confidence. The type of cleaner chosen depends widely on the manufacturing conditions. Whether solvent based or water based technology is chosen, the correct application method and set up is imperative in order to achieve successful cleaning. Many specifications have been outlined for cleanliness evaluation; IPC TM-650 is the industry standard, however. It details methods for many of the cleaning tests described above, giving precise guidelines for analysis. It is clear that some methods are costly and rather time consuming, however they can provide extremely accurate data on the type, location and quantity of the residue. Other, less intense methods can be employed for fast, efficient quality control. In summary, selection of the most suitable cleaning process, which in turn provides the required level of cleanliness, is the key to ensuring maximum reliability at minimum cost.