The Resurgence of Cleaning

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Why are many high-quality assemblers making the move from no-clean back to cleaning?

During the past few years, global demand for the cleaning of electronics assemblies has been steadily increasing. This phenomenon is of particular peculiarity since no-clean manufacturing processes have successfully been used for over 10 years. On closer examination, however, a rising number of current leakage and other board reliability issues has been observed, frequently on coated assemblies, which seems to be a significant contributor.

The term *no-clean* was chosen as a synonym for achieving identical product quality at a lower overall process cost through elimination of cleaning as a formerly integrated process step. To assess a genuine process cost comparison, one must first take a closer look at the specifics of both processes. A product with a no-clean label is not always a guarantee for a properly installed and performing no-clean process.

To fulfill all paste-specific advantages, ensuring correct soldering profiles to warrant the full encapsulation of organic activators is necessary (Figure 1). Thus, in spite of remaining residues, one theoretically should create electrical cleanliness. Unfortunately, however, results often turn out more problematic than initially anticipated.

For example, the optimization of the reflow profile typically does not coincide with the objective of full encapsulation of organic activators. This unclean variation of the no-clean process can only be sufficient for end-product applications that are not exposed to climatic stressors or for scenarios where field failures are actually anticipated and/or welcomed. For most other applications, one has to be made fully aware of the above-mentioned conflict between soldering and proper encapsulation. In other words, to achieve the cleanliness levels required for the elimination of leakage currents and condensation phenomena, additional costs do arise. These costs range from procurement to production, storage and disposal. Due to the high degree of variation among manufacturing processes, the desirable quantification of individual cost positions becomes difficult.

To compare no-clean processes to "clean" manufacturing, this study examines technological as well as cost-related aspects in a comprehensive manner.

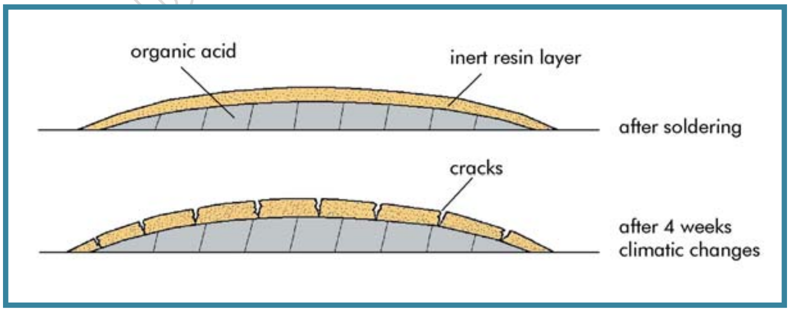

FIGURE 1: Encapsulated activators exposed to climatic stressors.

Clean vs. No-Clean

Main cost contributors for clean processes are the investment in equipment and cleaning products. Additionally, the chemical and water waste costs are often overlooked as much as the simple availability of deionized (DI) rinsing. The footprint usually only causes problems when equipment has to be installed retroactively.

Of significant importance for no-clean manufacturing is the soldering under an inert atmosphere (N_2). Cost factors to consider range from material to transport and storage. The consumption of nitrogen, even for the most modern oven systems, often reflects one of the main consumable cost contributors of the overall process—sometimes exceeding solder paste and water usage! Especially in light of lead-free solders, the usage of nitrogen will be even less expendable with promoted oxidation due to the generally higher soldering temperatures.

Soldering mainly serves to create soldered and reliable connections, which is not necessarily a trivial process according to many companies surveyed for this study. The incorporation of a cleaning process step does introduce additional flexibility through the incorporation of more activated solder pastes and/or fluxes. A significantly extended process window for the soldering process

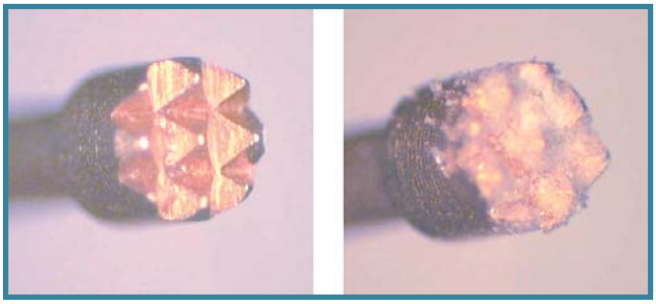

FIGURE 2: Close up of ICT needle contaminated with no-clean resin.

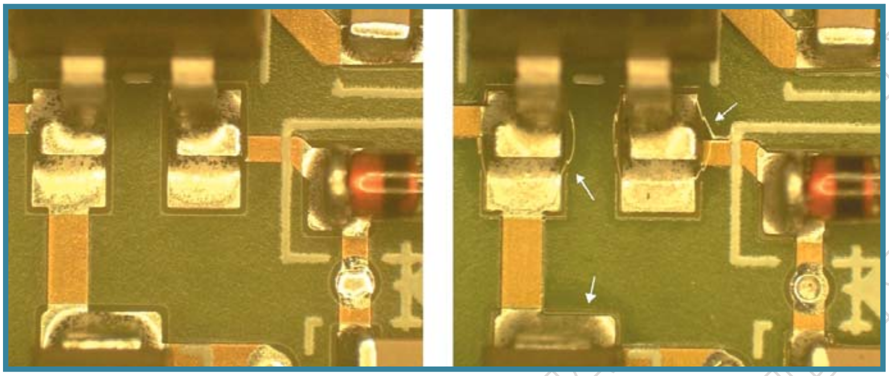

FIGURE 3: Contrast impairment due to contamination; cleaned (left), uncleaned (right).

can result, which can cause shorter soldering profiles and improved tolerances for process fluctuations.

Besides the appropriate soldering conditions, the cleanliness levels of assemblies have to be considered as the second priority for no-clean processes. In general the process window for no-clean processes can be affected as early as during the printing process. For example, the usage of minimum solder paste is typically preferred for a no-clean process, which, in turn, compromises objectives for coplanarity. In comparison, processes with an integrated cleaning process allow for significantly more degrees of freedom. Here, the functionality—soldering result—of each process step is most important, which increases the output and reduces superfluous rework steps.

Another drawback of no-clean processes is that the operator has to ensure that cross contamination during the handling steps is minimized or eliminated. Contamination such as dust and fingerprints can be reduced with increasing automation or through precautionary measurements such as protective gloves. However, using the latter is cumbersome and costly long term.

Both processes require various media and specific logistics. For clean processes, cleaning agents are required. The increasing usage of water-based products in the industry surely reduces transport and storage costs. For no-clean processes, on the other hand, the handling of nitrogen tanks is more cumbersome. Storage and transportation are more restricted and, therefore, less cost effective.

Additional hidden cost factors can also be found with the procurement of components and bare boards. By using more strongly activated fluxes, the limits for storage and processing ability of assemblies and printed circuit boards (PCBs) can be further reduced for clean processes, which then allows companies to reduce their material costs through acquiring larger quantities. Furthermore, climate and humidity-controlled storage, as well as expensive protective packaging, can be abandoned.

Other savings with clean processes are the elimination of any material specification with regard to contamination. As these guarantees are often paid for, the company will also profit from a reduction in failure rates by taking full advantage of the cleaning process.

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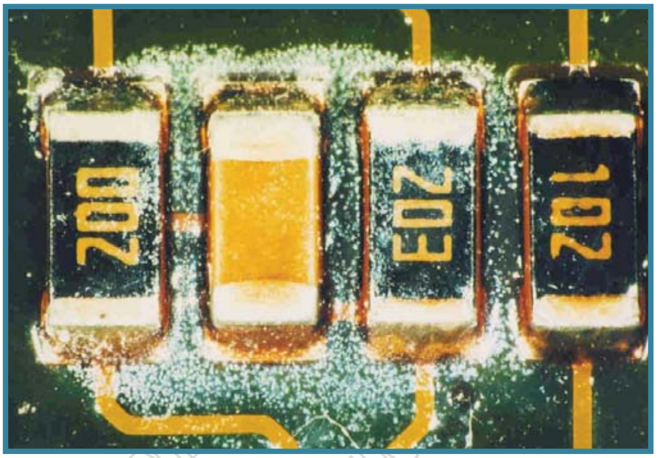

FIGURE 4: Blister-type delamination around chip components caused by hygroscopic contaminants.

Questions with regard to material compatibility for processes with integrated cleaning steps have become less frequent, especially due to the reduction of switches and/or relays. Material compatibility has often been a concern in the past and continues to be, especially for cleaning processes using obsolete cleaning technologies.

In-circuit testing (ICT) and automated optical inspection (AOI) systems are typically most relevant to cost considerations. As mentioned above, the no-clean process should ideally encapsulate all soils and residues to render them ineffective against corrosion and leakage currents. On the other hand, these hardened films can impact ICT. The defect rate of ICT measurements has been found to significantly decrease with a proper contact on residue-free surfaces. Furthermore, these films often lead to faulty measurements, contaminated test needles (Figure 2) and increased needle wear-and-tear, which adversely contributes to overall process costs.

The presence of remaining flux residues can even affect the visibility. Especially during the automated inspection of soldered connections, various reflections and contrast impairments are a major concern (Figure 3). According to a leading AOI systems provider, a lower defect rate—less rework—is achieved with the use of clean processes.

The missing link between in-field failure rates and climatic and leakage current measurements for electronics assemblies has not yet been established. The actual weather conditions are unfortunately not adequate to simulate in-field conditions, and the existing microclimate at a particular assembly location is strongly influenced by site-specific factors. The documentation of microclimatic conditions such as probability of condensation for electronics assemblies has only recently been possible, due to newly developed sensor technologies. During the last two years, such efforts have been seen in the automotive sector, particularly in areas plagued by high failure rates such as electronic switches.

Studies on the long-term behavior of no-clean encapsulations show that the integrity of these films can easily be compromised. This phenomenon mainly depends on the quality of the encapsulation during the soldering step and on the degree of actual in-field temperature fluctuations known as cycling (Figure 1). Some resin systems also embrittle through simple oxidation reactions and, therefore, ensure protection for a limited period only.

Additional measures to prevent the onset of age-induced leakage currents, such as random sampling or final quality control procedures, will surely increase overall manufacturing costs.

Post-soldering applications such as the use of protective coatings should also be included into the discussion of clean vs. no-clean manufacturing processes. As mentioned earlier, remaining residues (no-clean) on surfaces can affect the degree of cross-linking, which results in poor adhesion of protective coatings.

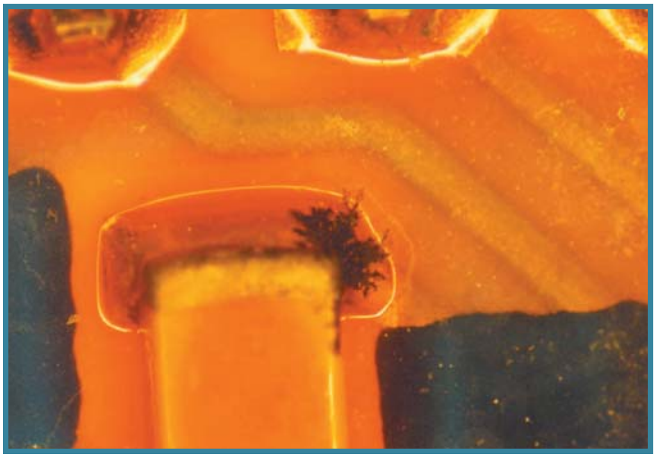

FIGURE 5: Electrochemical migration underneath protective coating due to insufficient adhesion.

During commissioned customer studies, delamination and electrochemical migration were documented underneath coatings with up to 0.4 inches of thickness (Figures 4, 5).

To make matters worse, consideration must also be given to increasing bleed from within assemblies and components, which can also limit the long-term adhesion of coatings and underfill materials. Unfortunately, these critical precipitations are generally undefined, hard to characterize or predict, and not monitored. Deteriorated signal integrity will, therefore, be neither explainable nor reproducible. A clean process could certainly accomplish the removal of this type of non-production-related deposits as well. Alternatively, the only solution to this particular occurrence would be higher quality materials at increased procurement costs.

Especially for high-end applications, a well-established company image is priceless. With the onset of globalization, however, cost and logistical considerations affecting time-to-market are becoming more prominent for companies to remain competitive. However, required long-term reliability tests are either not available or feasible, which, in turn, severely exposes products to quality impairments. These conflicting trends can only lead to the integration of cleaning processes, which is an investment seemingly well worth it.

Conclusion

For many companies and production purposes, the no-clean process has not only proven itself effective but will continue to play a dominant role. Until more experience and knowledge are gathered, however, we are currently witnessing numerous high-quality assembly producers reverting to cleaning.

At the same time, cleaning techniques with regard to cleaning efficiency, cost, processing windows, material compatibility and worker safety have been continuously improving. Today's user should compare the latest technologies in detail to fully understand their capabilities according to the above-mentioned criteria.

Cleaning often behaves similarly to coating. If it is introduced late in the process setup, it becomes not only unnecessarily expensive, but optimal process setups are often hard to achieve. Rework is always more cost intensive than the proper integration of cleaning processes during the development and design stages. Retrofitting a cleaning process due to customer requirements bears considerably more risk. Procrastination or ignorance toward cleaning can easily affect companies' global competitiveness. If the cleaning philosophy is, however, consistently taken into account during procurement, design and production, it can generate cost savings potential. ■

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