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The Importance of Having a Clean Slate in the SMT Assembly Process for High-Density and Fine-Pitch Applications

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ABSTRACT

The miniaturization of electronics and globalization of the SMT industry have introduced a number of challenges to the manufacturing process. Despite improvements to many aspects of SMT manufacturing, one of the crucial components of a smooth and efficient process is often overlooked. The industry strives to minimize the number of voids and defects that can occur during production and starting with a clean surface on the PCB is an important step in accomplishing this.

This generation of SMT manufacturing has seen the introduction of nearly microscopic chips and components that populate PCBs at higher densities than ever before. The smallest bit of debris can cause major problems and interfere with the solder pads that have been screen printed over it. Hair and dust contribute to voids and errors during the reflow process. PCB manufacturing has become a major point of growth on a worldwide scale. The number of PCBs being produced continues to grow and the technology of the boards also advances. This mass production of bare boards has led to losses of quality control resulting in a rise of cases where excess of substrate material debris is being left on the PCBs. That loose material, if left on the surface, can interfere with printing and burn up during reflow. There is no guarantee that the PCB is completely free of contaminants when it enters into production.

Implementing a method of cleaning the PCB surface before it enters the screen-printing machine is an ideal step in Process Control. This step ensures that the PCB surface is free from debris & contaminants, and prepares the surface of the pads to make clean contact with the solder.

The white paper will cover an experiment and evaluation conducted by a well-known Japanese manufacturer of automotive electronics to improve upon the defect ratio of their PCB assembly process by utilizing a bare board cleaner before the paste printer. The evaluation will depict the conditions of their assembly process before using the cleaner and results after testing with cleaning system. This study will cover the effects and observations of reflowing PCBs, while comparing the results of the effectiveness of using a bare PCB surface cleaner.

Key words: PCB cleaner, bare board cleaning, dust and particulate removal

INTRODUCTION

Surface Mount Technology (SMT) production is a dynamic field that continually evolves to meet the demands of the electronics industry. Several trends have been shaping SMT production in recent years:

1. Miniaturization: Electronics are becoming smaller and more compact, driving the need for smaller components and tighter component placement on PCBs. Miniaturization trends include the development of smaller surface mount components, such as 0201 and 01005 passive components, as well as ultra-fine pitch ICs.
2. Higher component density: As electronic devices become more feature-rich, SMT production is incorporating higher component density on PCBs. Advanced assembly techniques and machinery are used to accommodate a greater number of components in smaller spaces.
3. Automation: Automation in SMT production is growing, reducing labor costs and improving efficiency. Automated pick-and-place machines, solder paste dispensing, and inspection systems are becoming more sophisticated and capable of handling a wide range of component types and sizes.
4. Advanced materials: SMT production is adopting advanced materials for PCB substrates, solder pastes, and coatings. These materials improve thermal management, increase reliability, and enhance the performance of electronic assemblies.
5. Environmental sustainability: There is a growing emphasis on sustainable and eco-friendly manufacturing practices in SMT production. Manufacturers are using lead-free solder alloys and implementing more efficient waste management and recycling processes. Also included in this is the need to reduce the waste caused by misprints and invalid production PCBs. Reliability & quality assurance has become an integral part of ensuring that waste is not created.

Taking a look at these trends, we must do what we can to assure that the manufacturing process is running at its optimal specifications with an emphasis on efficiency and quality. This starts with having a “clean slate”, or a clean PCB in the manufacturing process.

THE IMPORTANCE OF A CLEAN PCB

Having a clean Printed Circuit Board (PCB) before the screen-printing process is important for several reasons:

1) Solder paste adhesion: Solder paste is a critical component in SMT assembly, as it serves as the adhesive that holds the components in place before reflow soldering. If the PCB surface is contaminated with dust, oils, or other contaminants, the solder paste may not adhere properly, leading to weak solder joints or solder defects.
2) Solder joint quality: Contaminants on the PCB surface can lead to solder joint defects, such as solder ball formation, solder bridging, voiding and insufficient solder volume. These defects can compromise the reliability and functionality of the electronic assembly.
3) Component alignment: During the screen-printing process, a stencil is used to apply solder paste onto specific areas of the PCB. If there are particles or residues on the PCB surface, they can interfere with the precise alignment of the stencil, leading to misalignment and inaccurate solder paste deposition.
4) Electrical Performance: Contaminants on the PCB can also affect its electrical performance. Residues and debris may create unintended electrical paths or shorts between components or traces, potentially causing electrical failures or malfunctions.
5) Consistency & reproducibility: Cleanliness is essential for achieving consistent and reproducible results in the PCB assembly process. In manufacturing, consistency is key to producing high-quality electronic products with low defect rates. Cleaning the PCB ensures that each assembly receives the same starting conditions, leading to uniform soldering and component placement.
6) Long-term reliability: Clean PCBs are more likely to have reliable and durable solder joints. In applications where long-term reliability is critical, such as aerospace, medical devices, and automotive electronics, ensuring clean PCBs is essential to minimize the risk of premature component failure.
7) Environmental considerations: Some solder paste and flux residues can be environmentally hazardous. Cleaning the PCB before screen printing can help reduce misprints & invalid PCB waste, making the assembly process more environmentally friendly and compliant with regulations.

These are only some of the advantages of having a clean PCB in preparation for SMT manufacturing. Next, we'll look at the kinds of contaminants commonly found on PCB substrates.

CONTAMINANTS COMMONLY FOUND ON PCBS

Printed Circuit Board (PCB) substrates can be exposed to various contaminants during the manufacturing process and in their operational environment. These contaminants can negatively impact the performance and reliability of the PCB and the electronic components mounted on it. Common contaminants found on PCB substrates include:

1) Dust, hair and particulate matter: Dust, hair and airborne particles can settle on the PCB surface during manufacturing or while the board is in use. These particles can interfere with component operation and lead to voiding, short circuits or other electrical issues.
2) PCB substrate material: During the production, routing, cutting and/or packaging process, there may be microscopic shaving and pieces of substrate material left with the PCBs. The material can be embedded in the holes/routed area of the PCB and knocked loose during the SMT process. The process of moving the PCBs from the packaging to the carrier/racks can also dislodge debris from the edges of the substrates. Substrate material can interfere with the solder pads and cause voiding and misprinting.
3) Oxidation and corrosion: PCB substrates and copper traces can be exposed to moisture and environmental factors that lead to oxidation and corrosion. Oxidized copper can result in poor solderability and increased electrical resistance.
4) Grease, oils & fingerprints: Grease, oils, and other hydrophobic substances may come into contact with the PCB during handling, assembly, or maintenance. These contaminants can hinder solder adhesion and create electrical issues. Handling PCBs with bare hands can transfer oils and contaminants from skin to the board's surface. Fingerprints may not be visible but can create surface tension issues during soldering and affect the adhesion of conformal coatings.
5) Chemical & flux residues: Some chemicals used during PCB manufacturing, such as cleaning solvents and adhesives, can leave behind residues if not thoroughly rinsed or cleaned. These residues can affect soldering and component reliability. Components with pre-applied solder flux or leads coated with solder can introduce flux residues onto the PCB during assembly. These residues need to be removed to prevent reliability issues.

To mitigate the impact of contaminants on PCB substrates, manufacturers often employ cleaning processes, conformal coatings, and proper handling procedures. Cleaning methods can include ultrasonic cleaning, vapor phase cleaning, and aqueous cleaning, among others, to ensure that contaminants are removed from the PCB's surface. Conformal coatings, such as acrylics or silicone coatings, can also protect the PCB from environmental factors and contaminants, enhancing its reliability in challenging operating conditions. These practices are effective ways of preventing/cleaning oxidation, corrosion, oils and chemical substances. The following pictures (Photo 1 & 2) show the effects of contaminants and debris on the PCB during production. Photo 3 shows various remnant debris left on the PCB:

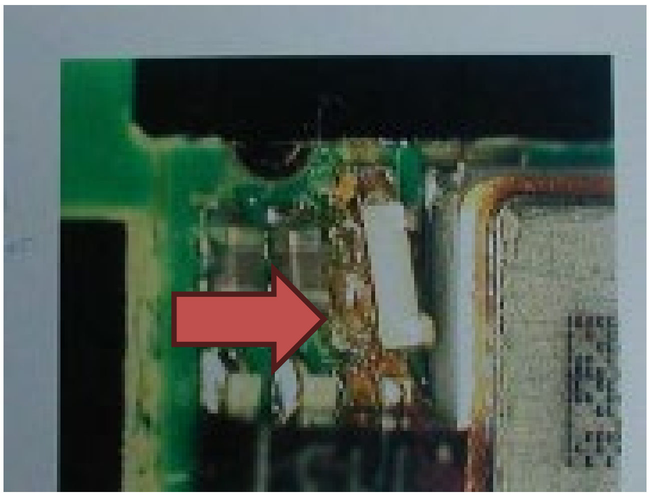

Figure 1 - Burnt contaminant post reflow)

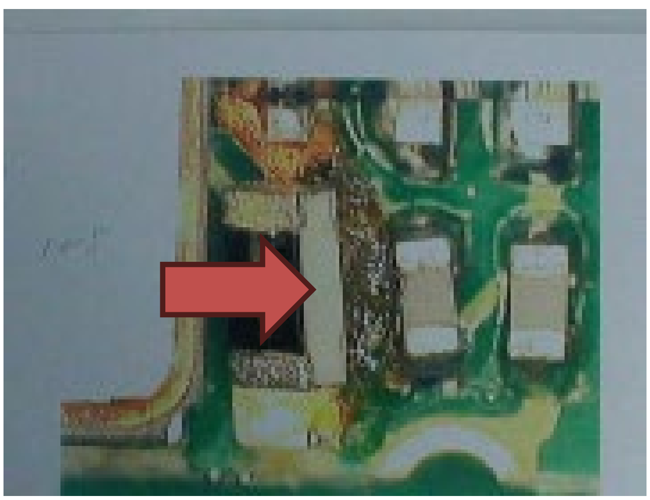

Figure 2 - Burnt contaminant post reflow)

Figure 3 - Substrate material left on PCB)

What can be done to ensure the PCBs are free of dust, debris and particulate matter right before screen printing?

We will explore the use of a contact cleaner, placed just before the screen-printer in the SMT line.

CONTAMINANT & DEBRIS CLEANING STUDY

In a partnership with a well-known Japanese manufacturer of automotive electronics, UNITECH Co, Ltd. conducted a study to measure the effectiveness of the use of a PCB cleaning system placed just before the paste-printing process. The goal was to minimize the number of PCB failures caused by debris and contaminants on the PCB.

Table 1- TEST LOT

	# of PCBs	Defects Found (AOI)
Without Cleaning	155	2
With Cleaning	150	0

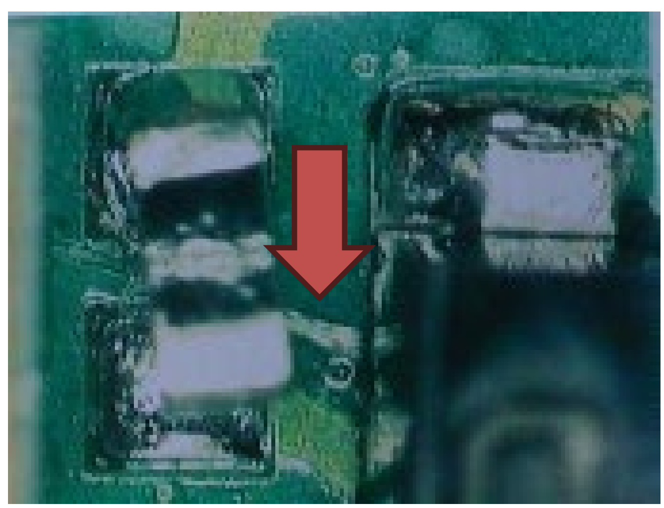

Figure 4 - Substrate material left on PCB)

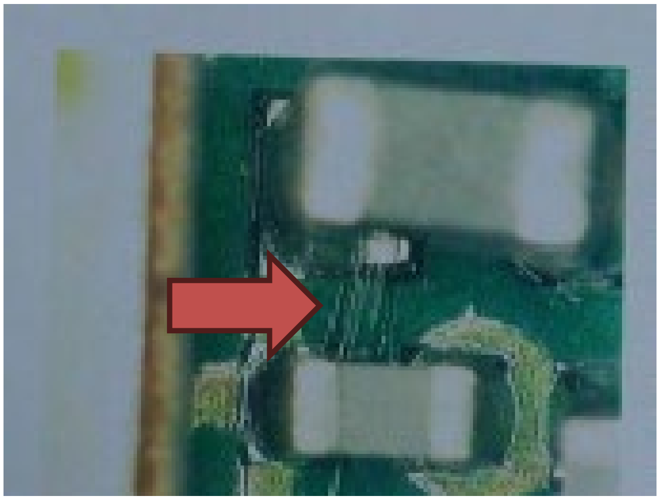

Figure 5 – Contaminant material left on PCB)

Table 2 - TEST LOT

	# of PCBs	Defects Found (Visual)
Without Cleaning	350	8
With Cleaning	334	0

A study was conducted using 2 production lots of PCBs. As you can see in the data, the first lot of PCBs yielded 2 defects caught by optical inspection (shown in Photo 4 & 5) on the PCBs that were not cleaned. Test lot 2 yielded and additional 8 defects caught by optical inspection on uncleaned PCBs. The PCBs that were cleaned before screen-printing, yielded 0 defects optically.

The results of the study showed that the manufacturer was able to considerably decrease (or eliminate) the number of defects found in their SMT process due to the presence of contaminants and debris.

METHODS OF CLEANING

For non-chemical based bare PCB cleaning, there are 3 major cleaning methods:

1) Air vacuum or brush & vacuum combination: Nylon-based brush heads are used to clean the surface of the PCB, lifting up any particulates from the surface and sucked away by a vacuum system. This method does a good job of cleaning larger particulates and debris that is in the crevices of the PCB. Minimal use of consumables.
2) Sticky roller: A silicon-based rubber roller is used to lift any debris & contaminants off the PCB, then transfers the contaminants from the rubber roller onto a sticky paper roller. This method cleans smaller particulates very well and creates an environment where less dust and particulates remain air born.
3) Blower/air-knife: An air blower is used to blow off any dust & contaminants from the surface of the PCB. The air can be ionized in order to minimize the presence of static electricity, which can attract dust & particulates to the substrate material.

Each cleaning method has its pros and cons. The following study was conducted to examine the effectiveness of the different methods.

Table 3 – Effectiveness of Cleaning Methods

	10µ	30µ	60µ	90µ	← Particle size
Rubber Roller	81	90	92	89	Removal (%)
Brush Type & Vacuum	14	45	61	70	
Vacuum Only	46	40	32	26	
Air Blower Only	39	31	28	27	

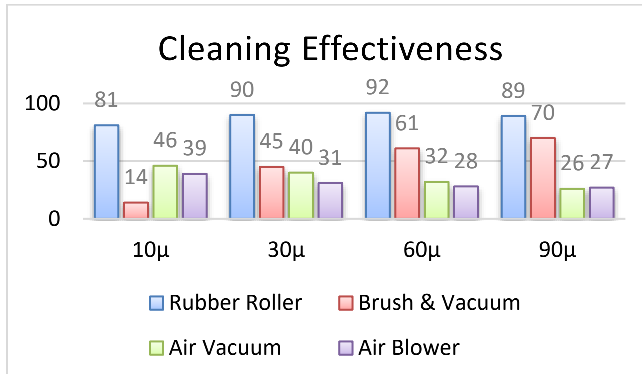

Figure 6 - Cleaning effectiveness per cleaning method

As demonstrated in the study, the rubber roller and brush/vacuum cleaning methods proved to be the most effective. An additional observation is that when a combination of methods are used, the cleaning effectiveness is also increased.

CONCLUSION

In conclusion, the need for cleaning bare PCBs (Printed Circuit Boards) in Surface Mount Technology (SMT) assembly is essential for several compelling reasons.

First and foremost, PCB cleaning is essential to ensure the integrity of the soldering process. Contaminants, such as dust, hair, leftover & routed substrate material, dirt, and other foreign particles, can interfere with the adhesion of solder paste during the screen-printing phase. Insufficient adhesion can lead to defective solder joints, including weak connections and solder bridges, jeopardizing the overall reliability and functionality of electronic assemblies. Debris and particles can burn during the reflow process, causing voiding, misalignment and dislodging of components.

Furthermore, proper cleaning of bare PCBs is critical for maintaining the quality and consistency of the SMT production process. Clean PCBs provide a uniform starting point for component placement and soldering, contributing to consistent results across production runs. This consistency is essential for achieving low defect rates and high-quality electronic products.

Clean PCBs are crucial for long-term reliability. Contaminants left on the PCB surface can lead to electrical shorts, corrosion, and compromised insulation resistance over time. By ensuring that bare PCBs are thoroughly cleaned before component placement, manufacturers can enhance the longevity and durability of their electronic assemblies.

Additionally, as environmental regulations become stricter, PCB cleaning plays a role in promoting eco-friendly manufacturing practices. Proper cleaning helps decrease the wasting of material and resources due to misprints and defective PCBs. This leads to a reduction in the environmental impact of the electronic production processes.

In summary, the need for bare PCB cleaning in SMT is driven by the importance of maintaining soldering quality, achieving production consistency, ensuring long-term reliability, and adherence to environmental standards. Embracing effective cleaning practices is a fundamental step toward producing high-quality, reliable, and environmentally responsible electronic products in the ever-evolving world of electronics manufacturing.

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