

## TODAYS CHALLENGES WITH STATE OF THE ART SMT PRODUCTION

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*As demand increases for advanced PCBAs across a wide range of industries, so has the need for innovative manufacturing solutions that enable the next generation of SMT production. The emergence of electric vehicles, bio-medical monitoring and increasing speed and bandwidth requirements for telecommunications infrastructure, are all contributing to the need for advanced PCBA designs.*

Over the past decade, the growing complexity of PCBA products has become evident [1]. Pin counts have more than doubled, with as many as 4,200 terminations. Minimum termination pitches of 16 mils have become commonplace, with some designs in production today having a pitch of 12 mils. Electronic Manufacturing Services (EMS) companies and OEM's continually work to define design rules that support higher performance requirements, while still being manufacturable.

For automotive applications, engineers at EMS companies have developed expertise in material selection and processing to manage high power and high voltage devices in electric and hybrid vehicles. These materials optimize thermal conductivity while simultaneously providing isolation for high power. The Internet of Things and bio-medical monitoring have driven the need for smaller connected sensors. These sensors require very high levels of reliability and sensitivity, necessitating the selection of new materials and higher levels of cleanliness.

Another driver is speed, increasing power and mixed signal integration, with power and ground pins for different power domains. Also, PCB designers want passive components as close to a chip's power and ground pins as possible to improve decoupling. PCB technology is being driven to minimize chip-to-chip spacing in order to increase speed and signal integrity. Increasing performance at a lower cost drives demand for bottom terminated components (BTC). Designs with tighter chip and component spacing, however, present challenges if rework is required.

Some of the key technology challenges OEMs and EMS providers have been working to solve include: selection and processing of specialized materials, cleaning PCBAs, minimizing voids in BTCs, reducing the pitch between components while reserving sufficient space for rework, eliminating head-on-pillow defects in connections and building PCBAs for mission critical applications. These issues continue to drive extraordinary advances in SMT processes as the number of terminations increase and pad pitch decreases. Some of the latest SMT technology challenges currently being addressed include:

### HIGH POWER DEVICES REQUIRE EXPERTISE WITH UNIQUE MATERIALS

High power applications common in hybrid cars, electric automobiles and high-power LED lighting require specialist materials expertise to select and process substances used in manufacturing. Power management integrated circuits (ICs) are used in inverters, converters, chargers and powertrain systems. Typically, high power applications require 1,000 to 4,000 volts and these high voltages give rise to die temperatures approaching 170°C in some devices. It is critical to have good thermal conductivity between the device and the PCBA to transfer the heat efficiently and to allow it to dissipate through heat sinks. However, because of the very high voltages, good insulation is also required. The characteristics of the material chosen to connect high power devices to a PCBA must include good thermal conductivity and good dielectric properties. Automotive applications present the most pronounced challenge. Unique components on the leading edge of technology used in some applications require expertise in selecting the most suitable material to optimize thermal conductivity, dielectric properties as well as manufacturability. Dispensing, processing and curing these materials during the manufacturing process presents critical challenges. For example, materials with both good thermal conductivity and insulation properties often have abrasive characteristics. When the material is pushed through dispensing equipment, it can reduce equipment lifetime. More importantly, air trapped during the dispensing process can create an arcing problem in the high power device. Vacuum mixing methods have been developed to dispense the material in a uniform layer and eliminate the possibility of trapped air.

### VERY SMALL LEAKAGE CURRENTS PRESENT CLEANING CHALLENGES

Advanced electronic designs in telecommunications, automotive and medical applications require PCBs having extremely small leakage currents. Sensors worn on the human body, high speed telecommunications and high power automotive applications require very high levels of insulation. Today's leading edge designs require insulation levels measured in  $10^{12}$  ohms, whereas insulations of  $10^8$  ohms were sufficient several years ago.

No-clean fluxes used in most SMT assembly processes leave weak organic acid (WOA) residues. These residues can reduce surface insulation levels. As a result, the cleaning and measurement of cleanliness on PCBAs has become a critical process requiring high precision and repeatability.

Components with stand-off height from the substrate as low as 2 mils pose a technical challenge for cleaning. With this very low profile, it is difficult to expel the water from under the device. Solutions have been developed using a Saponifier to reduce the surface tension of the water and allow it to flow out from under devices with very low profiles. However, maintaining optimal concentration of the chemical for effective cleaning while reducing its adverse effect continues to be a critical challenge.

There are a number of methods used to measure PCBA cleanliness. Ion chromatography is used to find and quantify anions, cations and WOAs. It measures ion concentration on the PCBA after cleaning. Surface Insulation Resistance (SIR) measures the resistivity on the surface of the PCBA. Typically, SIR is continually monitored over a period of seven days, while humidity is maintained at 85 percent. Both of these measurement methods are complementary and are used as part of qualification and validation to verify that the SMT production process is capable of achieving the high levels of cleanliness and surface insulation resistance required.

### REDUCING VOIDING IN BTCS

PCBs with BTCs are increasingly common, as BTCs have the advantage of offering good performance-both in signal integrity and thermal performance at a relatively low cost. However, increasing pin count, package size and reduced pitch on BTCs creates production challenges. The increased pin count allows more functionality and manufacturing faces new challenges in producing reliable contacts with these large-surface-area devices. The biggest challenge with BTC packages is thermal pad voiding. During the solder reflow process, chemicals or air can be trapped in the solder, creating voids that may impact thermal conductivity or solder joint reliability. BTCs are used for very high speed switching. The devices can increase in temperature very quickly. Large voids restrict heat dissipation, causing an increase in temperature to the point where transient failures can occur. Thermal pads present a unique challenge during reflow, as the pads are typically larger and connected to large copper areas within the PCB. Therefore, they require proper solder volume control and optimized reflow profiles to ensure adequate solder coverage with minimum voiding. Stencil



design techniques, soldering materials, new processes and design for manufacturability practices have been developed and fine-tuned to minimize voiding. Vacuum reflow has also been developed as a solution and is now used in volume production.

## REWORK CHALLENGES RISE AS COMPONENTS SPACING DECREASES

OEMs are focused on functionality and performance. The use of decoupling capacitors for noise reduction leads to designs with more interconnects and smaller components with tighter component spacing. New designs, with more demanding signal integrity requirements, can result in conflicts between layout requirements and what can be manufactured. With the conflicts between design requirements and process capability, rework is becoming a challenge. For some high performance computing and communications PCBAs produced at Sanmina, the cost of a single PCBA may be over \$15,000. Therefore, it is imperative that the assembly is not damaged during rework. Furthermore, adequate spacing between components is also required to ensure that heat used for rework does not damage the solder joints of adjacent components, or the components themselves. While IPC standards do not provide strict requirements for component spacing, and current SMT assembly processes can accommodate tight spacing, experience has shown that at least 100 mils of space should be left around large ball-grid arrays to allow for rework. This is a major reduction from the 200 mils clearance requirements of five years ago. OEMs are now placing decoupling capacitors as close as 17 mils in order to optimize noise performance. Because some components lose functional performance when exposed to temperatures exceeding 120oC, tighter spacing constrains the ability to perform rework. Complex and sophisticated thermal isolation schemes have been developed for these applications, but this rework technology is costly. EMS companies are working with equipment manufacturers to develop processes, robotic soldering solutions, cleaning systems and rework tooling that make reliable, repeatable rework possible, without inducing secondary reflow or additional rework of adjacent components. Although current solutions exist for keep-out space values well below 100 mils, additional process development and tooling enhancements are necessary to accommodate repair with tighter component spacings.

In addition to the mechanics of soldering and navigating rework equipment in the confines of tight dimensions, metallurgy is an important aspect of repair. In the Tin-Silver-Copper solder alloy system, repair can potentially introduce weak metallurgical interfaces as a result of spalling [2]. This can cause a weakened interface over time between the component and the PCB

and result in long term reliability issues in the field. Components should be designed with materials suitable for repair. Including a high copper content on component terminations is one approach.

## CHIP PACKAGE WARPAGE

To minimize cost, ICs are often mounted in plastic packages. However, plastic is thermally less stable than ceramic. When plastic packages are exposed to high temperatures during reflow, the package can warp 2-10 mils or more, depending on the substrate, plastic material properties, die size, package thickness and package size. A combination of package and PCB substrate dynamic warpage, along with PCB pad solderability issues and variations in printed solder paste volume, can result in solder defects between a device and the PCB. Two common defects are head-on-pillow (HOP), or non-wet open (NWO) type defects. While NWO defects create solder joints with no electrical continuity, HOP defects can be partial opens with intermittent connections. Current screening methods for HOP defects involve expensive 3D X-Ray inspection. However, this method is not advanced enough to be 100 percent effective. It is also time-consuming and resource-intensive. The best solution to the HOP issue is prevention by adopting a tighter specification for warpage.

The JEDEC specification for package warpage, revised in 2005 and republished in 2009, allows for a maximum of 8 mils of co-planarity at room temperature. Component suppliers usually provide specifications for room temperature coplanarity, using either the seating plane or regression plane measurement method. As long as the value is under 8 mils, the co-planarity is deemed within specification. Empirical data suggests that the JEDEC specification is no longer adequate [3]. For high pin count packages with small pads and lower solder volumes, production data suggests that component warpage exceeding 3.5 mils can cause problems during reflow, with a high potential for HOP defects. Manufacturers of consumer devices may discard or recycle defective boards, but this is not an option for an advanced computing or communications PCBA costing over \$20,000. EMS providers will continue to drive changes -- advocating for improved plastic material compounds and working with JEDEC to tighten the standard warpage specification to 3.5 mils for high pin count devices.

## BUILDING PCBAS FOR MISSION CRITICAL ENVIRONMENTS

Industries such as oil and gas use electronic assemblies in very demanding environments. Drilling and exploration tools used two to three miles below the earth's surface can cost upwards of \$2 million and operate in environments with temperatures up to 170oC at 50 Atm pressure. The solder material used in these assemblies

requires temperatures above 290oC in order to reflow. In the absence of mass reflow options for high melting temperature solder alloys, hand soldering has become the only alternative for such applications.

The medical, automotive and aerospace industries are highly regulated. Advanced technology designed into electronic systems used in these industries requires sophisticated SMT manufacturing techniques. However, the manufacturing process used must also comply with stringent regulatory requirements. Regulatory compliance typically requires manufacturing process validation, ensuring that each PCBA is produced according to the design and manufacturing process specifications. Validation is a significant undertaking requiring the leadership of validation engineers as well as cross functional involvement of process engineers, equipment engineers and test engineers. Master validation plans need to be developed, validation protocols written and the volume of documentation for the validation process can require thousands of pages.

## LOOKING AHEAD

Advanced PCBA designs driven by superior signal integrity, miniaturization, higher densities and increasing I/O counts will continue to push the competing technical boundaries in SMT production. High power applications and requirements for lower leakage current will continue to pose new manufacturing challenges. This will lead to the development of new technology, including automation and special handling solutions. New expertise in the selection and processing of chemicals and polymers to achieve isolation and conductivity goals will also be essential. The environment in which SMT production takes place will become increasingly important. Vacuum reflow is now in volume production and it is likely that going forward, more and more high density SMT assembly will have to be done in clean rooms.

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