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Working with Surface Mount Adhesives

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In SMT, surface mount adhesives are used with both the wave soldering and reflow soldering processes to maintain component positioning on the printed circuit board (PCB). Adhesive is required only between device placement and solder application to ensure that the component is not displaced in transit through the assembly line or during the soldering process.

Wave soldering is used on PCBs that include a mixture of surface mount devices and throughhole components. As illustrated in Figure 1, the adhesive is dispensed directly onto the PCB substrate between the solder pads; the component is placed onto the adhesive dot; the adhesive is heat cured; through-hole components are inserted into the board; the assembly is flipped 180° and then put through the wave soldering process.

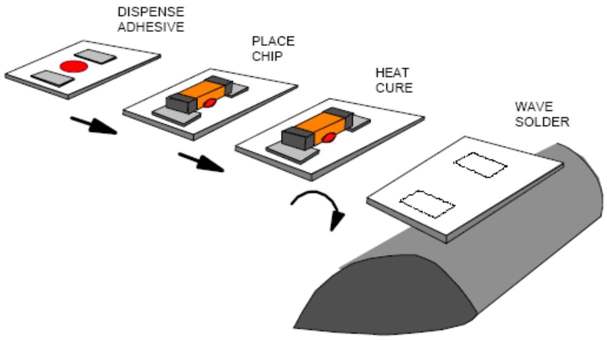

Figure 1

Reflow soldering is used on single and double sided PCBs that have surface mount device attachments. Next, solder paste is stenciled onto the solder pads on the PCB; adhesive is dispensed onto the substrate; the component is placed; the heat cure and reflow processes occur in the same heating step; for double sided boards, the board is then flipped and the top side is similarly processed.

After the device is placed, the uncured adhesive must have sufficient wet or "green" strength to hold the device in position until the adhesive cures. The cured adhesive joint needs only enough strength to hold the component to the underside of the PCB while passing through the soldering station. (At this point, forces on the joint are quite low, typically less than 2N for a flat chip.) The adhesive’s biggest challenge is surviving thermal shock experienced as the joint moves from the preheat section into the solder operation. This requires a combination of good adhesion, strength and flexibility.

Once the soldering process is completed and the solder joint is permanent, the adhesive no longer serves a useful purpose. However, because the cured adhesive remains on the PCB for the remainder of the board’s working life, it is important that it does not undergo any degradation that may compromise the integrity of the working circuit, especially when exposed to extreme temperatures and humidity. The cured adhesive must offer good cured electrical characteristics, and must be tested to IPC specifications for corrosion and surface insulation resistance under extreme environmental conditions.

Adhesive Attributes

The majority of surface mount adhesives used in PCB assembly are epoxies, although acrylic adhesives are still used for specific niche applications. Epoxies were established as the more prevalent adhesive technology worldwide after high speed dispensing versions were introduced and the industry learned how to work with relatively short shelf life products. Epoxies generally provide outstanding adhesion to a wide range of substrates, offer very high bond strength, and excellent electrical properties. Since epoxies are heat sensitive, they have to be stored under refrigerated conditions (5°C) to ensure maximum shelf life.

Epoxy surface mount adhesives are formulated to provide a range of benefits to the end user, including excellent dispensability, consistent dot profile and size, high wet and cured strength, rapid cure, flexibility, and resistance to thermal shock. These adhesives allow for high speed dispensing of very small dots, and offer excellent on-board cured electrical properties. They are non-stringing and will not slump during the heat cure cycle.

Surface mount adhesives must be easy to detect against typically green or brown substrates using visual detection or automated equipment. As automated vision control systems have become increasingly popular, red and yellow have emerged as the two basic colors for surface mount adhesives, although the ideal color for an application depends on the visual contrast between the board and the adhesive.

Epoxy surface mount adhesives are cured by heat. Typically, heat cure takes place in-line in an IR tunnel oven. While the minimum temperature to initiate cure is 100°C, in practice, cure temperatures range from 110°C to 160°C. Using cure temperatures above 160°C will give faster process times, but is likely to result in a brittle joint.

Bond strength is critical to the performance of a surface mount adhesive, and is determined by several factors, including level of adhesion to the component, degree of adhesion to the PCB, size and configuration of the adhesive dot, and degree of cure. The most common causes of poor bond strength are inadequate adhesive cure, insufficient adhesive application, and poor adhesion.

Dot Profile

An adhesive's flow behavior or rheology affects the way a dot of adhesive is formed, as well as its shape and size. Surface mount adhesives are formulated to allow rapid and controlled dispensing and to form adhesive dots of a defined shape. To ensure that well-defined dot profiles are achieved and maintained post-dispense, adhesives are engineered to be thixotropic, thinning upon agitation and thickening at rest. The viscosity of surface mount adhesives decreases when shearing stress is applied during dispense, allowing easier flow. When the adhesive reaches the PCB surface, it quickly restructures and recovers viscosity.

Dot profile is influenced by thixotropic recovery rate, viscosity at zero shear rate, and other factors. The actual shape of the dot may be peaky-conical or rounded hemispherical. However, the dot profile is defined by non-adhesive parameters such as dot volume, dispense needle diameter and stand-off height. For a given adhesive grade, it is possible to produce exaggeratedly high, narrow dots and low, wide dots by adjusting these parameters.

After chip placement, the dot must have a diameter smaller than the space between the solder pads and be high enough to bridge the gap between the PCB surface and the body of the device, but not so high as to interfere with the placement head. The adhesive gap is defined by the height of the solder pad above the PCB solder mask surface and the gap created by the difference in end metallization and body thickness of the device. This can vary from less than 0.05mm for flat chips to more than 0.3mm for large SOs and QFPs.

Dispensing tall dots ensures good adhesive coverage on the underside of components with high stand off, yet allows adhesive to be squeezed out between low stand-off components without risking pad contamination. Often, two sets of dispense parameters are used side by side for a single adhesive grade, one producing a high, large volume dot for high stand-off components and the other producing moderate height and volume dots for flat chips and MELFs.

The size of the adhesive dot is also controlled by the internal diameter/stand-off height ratios of the nozzles selected. Typically, dot width to height ratio will range from 1.5 : 1 to 5 : 1 (h/w = 0.2 to 0.6), depending on the dispensing system parameters and adhesive grade. These ratios can be optimized for any given component by adjusting machine settings.

Void Avoidance

Moisture in an adhesive dot will boil during curing and cause voids that weaken the joint and allow paths for solder to penetrate under the device, which may cause shorting of the circuit due to solder bridging. In a syringe, adhesives have an insignificant level of moisture; however, if left in an uncured state exposed to ambient conditions, the adhesive may absorb moisture, particularly in humid environments. Moisture absorption is a particular problem with pin transfer dispensing because of the large exposed surface area presented by open baths of adhesive. However, it can also occur in syringe dispensing applications where there is a long delay between dispensing and curing or where ambient conditions are very humid. Most surface mount adhesives are formulated with raw materials that have low moisture pick-up properties in order to minimize this effect.

Void problems may be solved by using a slow, lower temperature cure with a long warm up time to help moisture escape before cure takes place, trapping the water in the joint. Moisture can be eliminated from the substrates to be bonded by storing components in a cool dry location, or conditioning the materials in a moderate temperature drying oven before use. By avoiding process stoppages before the adhesive cures and using a special grade adhesive that absorbs minimal moisture, voiding problems can also be dramatically reduced.

Dispense Methods

Surface mount adhesives may be applied to a PCB using syringe dispense, pin transfer, or stencil printing. Used in less than 10 percent of total surface mount applications, pin transfer dispensing uses an array of pins, which are dipped into a tray of adhesive. The suspended adhesive drops are then transferred as a unit to the board. Pin transfer systems require a lower viscosity adhesive with good resistance to moisture absorption since the adhesive is open to ambient conditions in the bath. Factors critical to controlling pin transfer dispense include pin diameter and design, adhesive bath temperature, depth the pins are dipped into the adhesive, and the length of the dispense cycle including delays before and during pin contact with the PCB. Bath temperature, which controls viscosity of the adhesive and the quantity and form of the adhesive dot, should typically be set between 25° and 30°C.

Widely accepted for solder paste application, stencil printing is now being used for dispensing adhesives as well. Although less than two percent of surface mount adhesives are currently stencil printed onto PCBs, interest in this method has increased and new equipment developments are overcoming some of the technique's earlier limitations. Correct stenciling parameters are critical for good results; for example, on-contact printing (zero snap off) may require a delay cycle to allow good dot formation. In addition, off-contact printing (approximately 1 mm gap) with a polymer stencil requires optimum squeegee speed and pressure. Metal stencil thickness is typically 0.15 to 0.20mm, and should be slightly greater (+0.05mm) than the maximum gap between the device and the PCB. Polymer stencils are typically thicker, 0.25 to 0.35 mm.

More than 90 percent of all surface mount adhesives used are currently dispensed by syringe. Syringe dispensing can be further divided into two subgroups: pressure-time systems and volumetric systems. As pressure-time syringe dispensing is the most common method used, the remainder of the discussion in this article refers to this dispense method. Syringes can dispense up to 50,000 dots per hour, and are highly adjustable to meet changing production needs.

Dispensing Defects

There are several dispense challenges that, unaddressed, may lead to final process defects. They include stringing, inconsistent dot size, missed dots, and satellite dots.

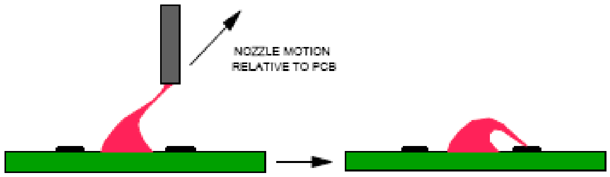

Figure 2

As illustrated in Figure 2 adhesive stringing can result in pad contamination and poor solder connection. The adhesive must have the ability to break quickly and cleanly from the nozzle as it is retracting. Even adhesive grades formulated specifically for high speed dispense can string if the dispensing parameters are incorrect. Risk of stringing is high when the dispense volume of adhesive is too small for the nozzle diameter and stand-off height, resulting in a very tall thin dot. A smaller needle diameter/stand-off height combination can solve the problem. However, stringing can also be caused by several non adhesive-related parameters such as electrostatic charge on the board, directional/random stringing caused by incorrect Z-stroke adjustment height, and board warpage or insufficient board support.

When adhesive dots are missing, devices will not be placed properly on the PCB. Missing dots can occur for one of two reasons. When line pressure is insufficient to enable dispense, the line pressure or system compressor may not be adjusted properly for dispensing. If there is insufficient pressure at the back of the syringe to dispense adhesive consistently, the machine dispense pressure may need to be increased.

Inconsistent dot sizes affect the overall strength of the bond between the board and the component, and can occur for several reasons. If the nozzle's standoff post is landing on the solder pads, a replacement nozzle with a different standoff post location will solve the problem. If insufficient time is allotted for adhesive recovery, recovery will take place during the dispense cycle, affecting dot size. By simply increasing the delay sequence, recovery problems are solved.

If there is insufficient pressure-on time to complete the dispense cycle, or if the adhesive level has decreased as the syringe empties, increasing the pressure-on/cycle time (typically expressed as a percentage of maximum) will correct dot size inconsistency.

As satellite dots are imprecisely located, they can result either in pad contamination or insufficient bond strength. When nozzle standoff height is too large for the dispensed dot, a reduction in standoff height will eliminate satellite dots. If dot volume is too large for the nozzle being used, reducing pressure or using a larger I.D. nozzle will also solve the problem.

Factors That Affect Dispensability

Good dispensing does not depend on adhesive qualities alone. For pressure-time syringe dispensing, a number of machine related factors influence dispensability and dot formation. The inner diameter of the needle is critical to dot formation, and must be significantly smaller than the diameter of the dot on the board. As a rule, the ratio should be 2:1; for example, dot sizes of 0.7 to 0.9mm require an inner diameter of 0.4mm; dot sizes 0.5 to 0.6mm require an inner diameter of 0.3mm. Equipment manufacturers typically provide specifications and guidelines to produce the desired dot sizes and configurations.

As illustrated in Figure 3 PCB to needle stand-off or stopper height controls the height of the dot produced, and must be appropriate for the quantity of adhesive being dispensed and the needle's inner diameter. For a given adhesive volume, the height to width ratio of the adhesive dot will increase with stopper height. Typically, maximum stopper height is half the needle's inner diameter. Beyond this point, inconsistent dispensing and stringing will occur.

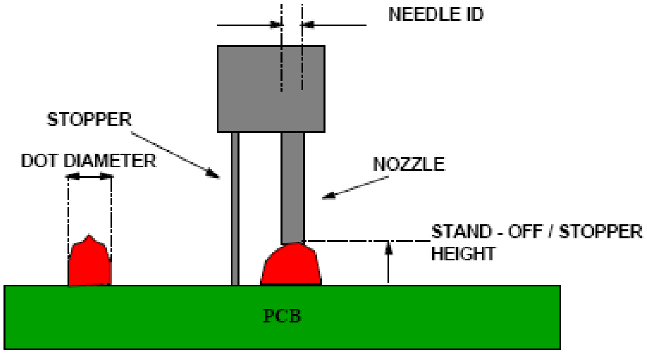

Figure 3

Current high speed dispense equipment uses dispense cycles where the pressure can be timed to start before the nozzle is in position. The speed at which the nozzle retracts, the retraction height, and the delay between dispensing and nozzle retraction will all affect dot shape and stringing.

Finally, temperature will also affect viscosity and dot shape. Most modern dispensers rely upon a temperature control device on either the dispense nozzle or dispense chamber to maintain the adhesive's temperature above ambient. However, dot profile can also suffer if the temperature of the PCB is elevated from previous processing.

Maintenance

Dispense needles and stoppers that get damaged, bent or worn can detrimentally affect dispensing. Excess adhesive on the outside of the needle can interrupt the smooth and consistent formation of a dot. In extreme cases, adhesive may bridge over to the stopper pin and totally disrupt dispensing. Therefore, the nozzle exterior should be kept as clean as possible.

Cleanliness of the inner surfaces of the nozzle is also a common source of dispensing problems. Adhesive build up can occur on the inner diameter and restrict flow. Adhesive also may partially cure in the nozzle if left for long periods in a warm environment or incompatible solvent. Changing adhesive grades can cause cross-contamination and nozzle blockage. Needle blockages due to cured or partially cured adhesive should be cleared using a drill bit before solvent cleaning. Needles should be regularly inspected, but cleaned only when a dispensing problem becomes apparent, as cleaning can increase the frequency of problems experienced with attaching the empty nozzle to the syringe.

Leaving dirty needles to soak in baths of solvent is a common but inefficient cleaning method. When soaking needles, use a compatible solvent, but do not rely upon soaking alone to remove all the uncured adhesive from the needle. A "jet spray" can be used to blast the uncured adhesive out of the needle bore with a compatible solvent. The needle is then dried by blowing through the bore using dry compressed air.

An alternative cleaning approach involves an ultrasonic or static bath. Uncured adhesive should be mechanically removed using a blunt tool for any larger cavities and a drill bit or piano wire of appropriate diameter for the needle bore. Immerse items to be cleaned in a reservoir of fresh solvent. For an ultrasonic bath, set the bath at maximum power for 3 minutes at 40°C. For a static bath, agitate the items in the bath until solvent has become stained from the adhesive. Rinse the parts in fresh solvent to confirm cleanliness. For needles with very small bores or cavities, follow with a jet spray, then dry parts and blow through bore using dry compressed air.