As originally published in the SMTA International Conference Proceedings.

NEXT GENERATION PoP PASTES FOR ELECTRONICS ASSEMBLY

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ABSTRACT

Package-on-package (PoP) technology allows two or more electronic components to be stacked vertically, which saves space and allows our portable gadgets to continue getting smaller year after year. A relatively new form of solder paste called “PoP Paste” has been developed specifically for this application.

There are fundamental differences between PoP pastes and the traditional solder pastes, which are designed for printing applications. This paper will highlight the differences between these solder pastes and talk about the characteristics needed by PoP pastes to increase transfer efficiency, eliminate head-in-pillow defects, and provide excellent solder wetting. If these three criteria are met, solder joint reliability will follow.

INTRODUCTION

The PoP assembly process involves placing a bottom component in a traditional SMT (surface mount technology) fashion, dipping a second component in solder paste or flux, and then placing it on the bottom component, which has solderable pads on its top side. These bottom components are shown in figure 1. PoP paste is a relatively new form of solder paste which has been developed specifically for this application.

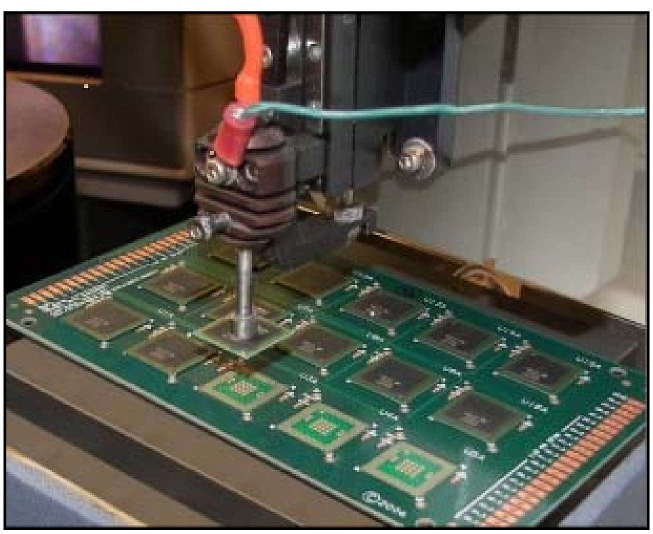

Figure 1: PoP test board and components

IMPORTANT CHARACTERISTICS

Challenges for PoP assembly are similar to those found in traditional SMT processes, although they are exaggerated by the structure of the PoP components. In order for these component stacks to have an overall low profile, the individual packages are designed to be as thin as possible. Consequently, mismatches in the coefficient of thermal expansion for the package material can cause the thin components to curl [1]. The curvature of the PoP components has been known to cause the solder spheres on the package to lose contact with the pads during reflow. This is especially apparent on corner interconnects.

Solder pastes that excel in dipping applications share some common properties. The properties that help PoP pastes transfer over 100% more solder than printing pastes are formulation, particle size, and metal loading. These properties affect tack, viscosity, and, ultimately, the amount of solder that can be transferred by the dipping paste. Optimizing transfer efficiency helps increase solder joint reliability by maximizing solder volume and minimizing the occurrence of head-in-pillow defects [2]. Fortunately these properties also result in a paste material that can be easily leveled in a flux reservoir and applied by normal dipping processes, which are common for tacky type fluxes.

The formulation of a flux vehicle is the most important characteristic in determining the paste’s ability to be applied efficiently to form a reliable solder joint. Luckily, the chemists that develop these formulations have learned a great deal from solder paste printing and dispensing applications. This traditional SMT background is not enough, however. An understanding of the unique PoP application needs has made this newest generation of materials for component dipping especially notable. This advancement has also led to improvements in dipping applications, outside of PoP assembly, for BGA/CSP rework and pin transfer.

Optimizing solder particle size in a PoP paste is a balancing act. Solder powder must be sufficiently fine to maximize the volume of metal that is transferred onto each BGA sphere. However, finer solder particles have more surface area per mass and more opportunity to oxidize, which can decrease the ability of a paste to form a quality solder joint. Highly controlled powder size and purity specifications are critical if a solder paste is to differentiate itself from all the other PoP dipping paste on the market.

It is also important for a solder manufacturer to optimize the percentage of powder that is used in a dipping paste. Early tests have shown that lower transfer efficiencies are the result of higher metal loads, while reflow defects are more common with lower metal loads.

These characteristics can be evaluated using a few simple tests:

Transfer Test

As mentioned earlier, optimizing solder paste transfer efficiency helps increase solder joint reliability by maximizing solder volume and minimizing the occurrence of head-in-pillow defects. It seems natural then, to measure the amount of solder that is transferred by different pastes in order to compare next generation materials to other dipping and printing solder pastes.

The test to evaluate solder paste transfer for PoP pastes is quite simple:
1) Weigh and record the component mass.
2) Set the paste reservoir height. This is generally 0.3-0.5 times the sphere diameter.
3) Lower the component into material reservoir until it reaches the bottom of the reservoir.
4) Raise the component out of the material.
5) Repeat steps 1-3 for a confident sample size.
6) Weigh the samples using an appropriate scale.
7) Record the measurements.

This information can be used to compare potential pastes with respect to the components you are using. From the trials done with 0.5mm and 0.4mm components (see Figure 2), transfer seems to be proportional. For example, if paste C has the highest transfer efficiency for component X, it also had the highest transfer efficiency for component Y.

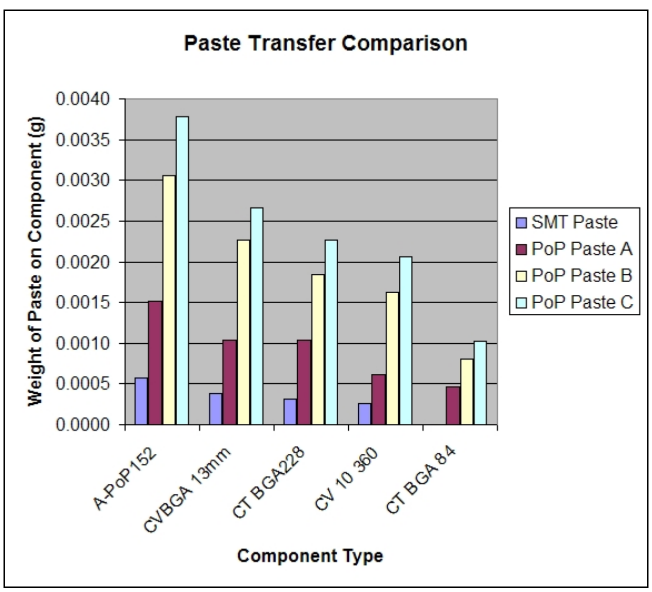

Figure 2: Paste transfer comparison

This transfer test included a printing version of one of the solder pastes to demonstrate the effect of proprietary mixing procedures used to make PoP solder pastes. Figure 2 also shows how the different solder pastes transferred vastly different amount of solder paste per component. The paste labeled *SMT Paste* is a very modern printing solder paste, which used type 3 powder (25 – 45µm). This paste was also blended using a standard metal load for printing applications. This mixture uses a higher metal load, which helps during printing, but not necessarily during dipping. Paste A had a similar chemistry, although the powder size and metal load were optimized specifically for the dipping process. This material performed well in functional testing and in customer applications, transferring greater amounts of solder that the SMT Paste. Paste B was chemically formulated especially for PoP applications. Tests showed that this material transferred roughly twice as much solder as Paste A, which was an exciting advancement. Paste C represents an overall improvement in almost every aspect of Paste B, exhibiting better wetting characteristics, higher yield, wider process window, and higher transfer efficiency.

Wetting Test

A simple IPC wetting test [3] will adequately compare PoP pastes; however, you may also want to expand this testing to incorporate other surface finishes or alloys that may be used in future designs. Although this is not necessary, it will give you a better feel for the paste's activity and operational range.

A wetting test was performed for three PoP pastes. Figure 3 shows a sample of the coupons that were used to test the wetting properties of each flux vehicle. Each paste was printed through a 0.25mm thick three-hole hand stencil with a diameter of 6.35mm per aperture. The samples were then reflowed using a standard Pb-free profile. The resulting height of each solder joint was then measured and recorded.

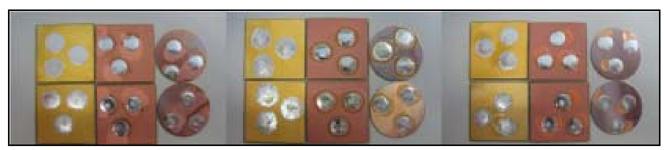

Figure 3: Wetting Test

Pastes A, B, and C had post reflow thicknesses averaging 0.2794mm, 0.3175mm, and 0.2159mm, respectively. All three pastes spread out onto ENIG, copper, and OSP surfaces well, with Paste C having the best spread characteristics.

Electrical Test

The simplest reality check is to build test boards with PoP components and materials. Most of the challenges during the PoP assembly process occur during reflow. PoP components are known to be thinner and more prone to warping, which is why solder pastes are used instead of PoP fluxes in many demanding applications. A good PoP paste can span the gap between a pad and the BGA sphere that has been lifted due to heat-related component distortion.

Fortunately, there is no need to wait for your product design to begin evaluating PoP materials. There are 'dummy' boards and components readily available for testing. A sample of an off-the-shelf test board is shown in Figure 1. The boards generally include test pads for electrical monitoring the occurrence of electrical failures. These may be designed to trace failures back-to-top or bottom interconnects, or even to more specific locations across individual components. Common test kit configurations currently feature 0.5mm pitch board-level components and 0.65mm pitch upper components with internal daisy-chain routing. These perimeter array BGA components are intended to have similar mechanical characteristics compared to real PoP components. Proper dummy components for this evaluation should have solder spheres with a similar alloy to what you will use in your actual assembly. It is also important that the packages have similar warp tendencies, so you can also evaluate this phenomenon during testing.

A separate test was performed using test boards and PoP components. Using a flip chip placement machine the base components were dipped into the paste tray with a 0.005" paste thickness, and placed on the board using the machine's vision system. The top components were then dipped the same way and placed on top of the base components, also using the vision system. This test was performed using an older PoP paste formulation, Paste B, and a newer PoP paste formulation, Paste C. Once the test boards were populated, they were reflowed in a convection oven using both P1 and P9 profiles. The P1 profile has a linear ramp-to-peak slope, with a peak temperature of ~230^{o}C, and a time-above-liquidus (TAL) of ~60 seconds, whereas the P9 profile (also linear) has a peak temperature of ~243^{o}C and a TAL of ~80 seconds.

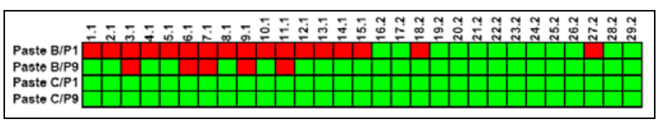

Figure 4: Test results show a vast improvement with the newer material

Proper equipment calibration is a must for this type of testing. Two boards were omitted from these test results because the paste tray was not level, which caused poor paste transfer to the components. This, in turn, caused electrical opens which were not related to the properties of the paste.

CONCLUSION

With the miniaturization of today's electronic devices and the increasing complexity of their features, the need for PoP components is increasing significantly. Although it may seem like a simple solution to just use the standard SMT solder paste that you have in-house for your upcoming PoP applications, these products are not optimal for this type of process. As our testing has shown, modern PoP solder paste materials are much better suited for the dipping process used for PoP components. Formulation, particle size, and metal loading are all key factors in the design of a PoP-specific solder paste. The time spent evaluating these new products is well spent. Electrical opens on your boards when using standard SMT materials or outdated dipping pastes can result in costly and time-consuming rework down the road. With the proper material and process, insufficient solder transfer and head-in-pillow defects can be a thing of the past.

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