表面贴装技术已成为使用焊膏的同义词。焊膏的开发是为了向越来越复杂的印刷电路板（PCB）组装提供高产量和高产出率。但是，焊膏在用于焊接通孔元件时有局限性。焊膏过厚往往会引起不规则的焊锡珠，而且通过增加模板厚度来增加焊膏量可降低印刷质量。在表面贴装过程中焊膏量不足以焊接通孔元件时，焊料预成型能提供一种高产出率的选择。

Solder Preforms in Circuits Assembly

Mitch Holtzer

New solutions for old problems.

Surface-mount technology has become synonymous with the use of solder paste. Paste was developed to provide a high throughput and yields to increasingly complex printed circuit board (PCB) assemblies. However, solder paste has limitations when used to solder through-hole components. Overprinting paste often results in random solder balls, and increasing paste volume by increasing stencil thickness can compromise print definition. Solder preforms offer a high yield alternative when solder paste volume is inadequate to solder through-hole components in a surface-mount process.

Many surface-mount applications still require the use of one or more through-hole components. A common example is a multiple lead connector. The process viability may be limited by the volume of solder paste that can be printed. The minimum solder volume required is specified in IPC-A-610 B—at least 75% of the volume between the through hole and the lead pin should be filled with solder; at least 270° fill without gaps. A more common specification is 100% fill and the presence of a solder fillet on the top and bottom of the board. The process engineer has to determine if a wave soldering step is required or if enough paste volume can be printed in and around the through hole.

Wave soldering involves a second thermal cycle and a costly additional process step. Assuming that exposing an assembly to only one solder reflow cycle is ideal, wave soldering is often ruled out. Wave soldering is required as a final step if the through-hole component/connector cannot withstand the peak temperature of the surface-mount reflow oven. If wave soldering is eliminated, the process engineer must establish the volume of solder required to provide a void-free solder joint using some combination of paste and possibly a solder preform.

Commonly, the stencil design can be altered in two ways to increase solder paste volume. One is to make the stencil thicker; the other is to increase the diameter of the stencil aperture. Of course, combining the two offers greater potential for maximizing solder volume, if paste is the only source of solder used.

If the paste volume demand is localized to the through-hole section of the board, step stencils can be used in lieu of increasing the thickness of the entire stencil. Steps of 0.001 to 0.004 are common but, in many cases, do not offer enough solder volume. For example, if a 0.050 in. aperture in a 0.006 in. thick stencil is stepped to 0.010, the total paste volume is increased from 1.18e-5 in^3 to 1.97 e-5 in^3 (66%) (Figure 1). However,

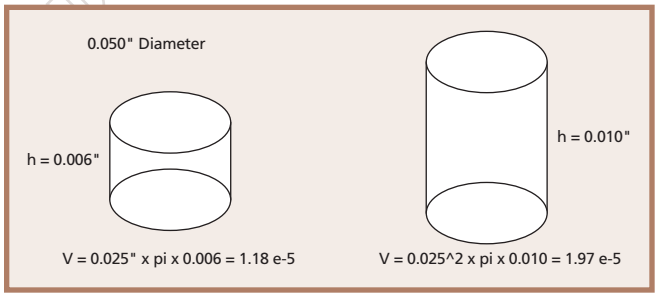

FIGURE 1: If a 0.050 in. aperture in a 0.006 in. thick stencil is stepped to 0.010, the total paste volume is increased from 1.18e-5 in^3 to 1.97 e-5 in^3 (66%).

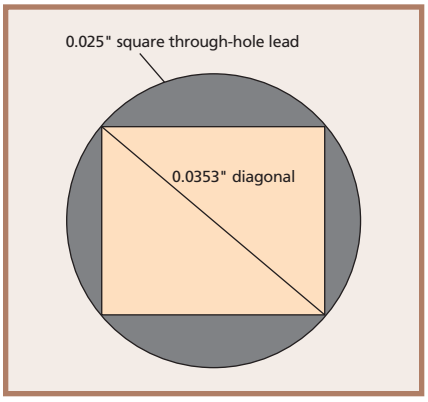

FIGURE 2: If the process involves a standard (0.063 in. thick) board, with a 0.025 in. square through-hole pin and a 0.0353 in. diameter through hole, the volume of paste required to fill the volume between the through hole and the square pin is 2.25 e-5 in^3.

solder paste formulations designed for printing are approximately 50% solder and 50% non-metallic additives. Therefore, using a 10-mil step yields a volume of 9.85 e-6 in^3 (1.97 e-5 x 50%).

We will assume that 100% of the printed solder paste is transferred to the circuit card after the stencil is released. The paste transfer ratio may vary based on a number of process and chemical variables, but a number less than 100% should be kept in mind when evaluating the required volume of solder.

Let us also assume that the process involves a standard (0.063 in. thick) board, with a 0.025 in. square through-hole pin and a 0.0353 in. diameter through hole, which is the smallest diameter that will accept a 0.025 in. square pin (Figure 2). The volume of the through hole is $\pi r^2 h$= 6.19 e-5 in^3. The volume excluded by the 0.025 in. square pin inserted into the through hole is 3.94 e-5in^3. The volume of paste required to fill the volume between the through hole and the square pin is 2.25 e-5 in^3.

As mentioned before, increasing the stencil aperture opening is another way to increase the paste deposit volume. Using the 0.050 in. diameter aperture over a 0.0353 in. diameter hole represents a 200% overprint—the area of a 0.050 in. diameter circle is 200% of a 0.0353 in. diameter circle. Overprinting with larger apertures is limited by the pitch of the through holes (center-to-center distance) and the tendency for solder paste to form random solder balls when printed over solder mask.

FIGURE 3: A preform washer can be placed using a nozzle that picks up the washer.

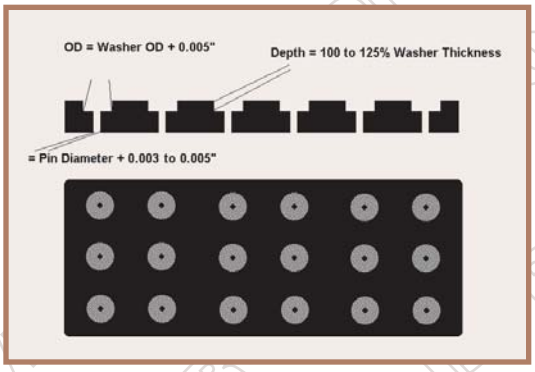

FIGURE 4: Placing the washers on connector leads is accomplished by tooling a fixture that has holes matching the pattern of the connector.

The paste volume shortage issue is exacerbated by yet another common issue. When the through-hole component (or connecter) is inserted into the card, any paste that covered the through hole will be pushed through and either bond to the tip of the lead or drip away from the assembly. The best scenario is that the paste sticks to the through-hole lead, migrates back to the through hole and becomes part of the desired solder joint during the reflow cycle.

In summary, if you have 100% paste volume transfer from the stencil to the card and no paste loss with lead insertion, and you have used a 200% overprint aperture and a 10-mil thick stencil, you will have only 44% of the required solder volume! This translates to 9.85 e-6/2.25e-5 = 44%.

The Solution to the Problem

A growing solution to this volume deficiency is the use of solder preforms in conjunction with solder paste. Preforms can be placed into printed solder paste or pre-applied to connector leads. Even preform washers can now be placed using readily available nozzles that pick up the washer (Figure 3).

Let us calculate the required dimension for a preform washer if we eliminate the step feature of the stencil (0.006 in. thick vs. 0.010 in.) and use the 0.025 in. square pin in a 0.063 in. thick via, a 0.0353 in. diameter. We will assume that a 0.050 in. aperture is used, 100% of the paste is transferred from the aperture to the board and 50% of the printed paste volume is available to form the solder joint.

Required solder volume is 2.25e-5 in^3. Solder paste volume equals π x $(0.050/2)^2$ x 0.006 = 1.18e-5 in^3. One-half of the paste volume is metal (0.59e-5), leaving a requirement for 2.25 - 0.59 = 1.66 e-5 in^3 of solder.

Preform washers are precision stampings with 100% metal volume. Generally, tooling determines the outer diameter (OD) and inner diameter (ID) of a washer, and the thickness can be varied based on the application requirements. In this

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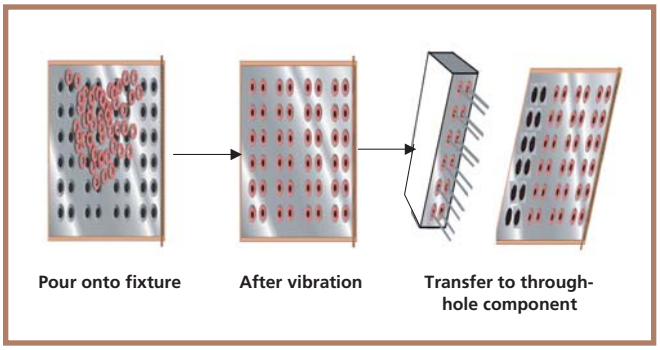

FIGURE 5: A vibratory table is used to match individual washers to the correctly drilled holes in the fixture.

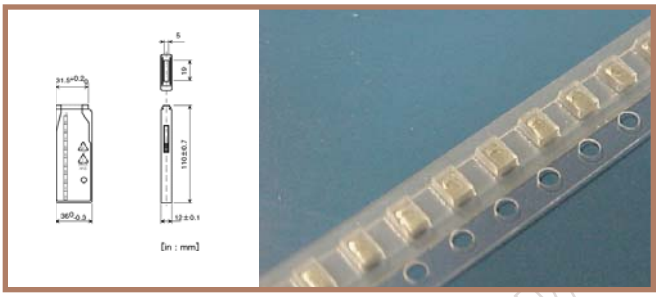

FIGURE 6: A common preform placement process is to supply the preforms using pick-and-place equipment. Paste is printed onto the through holes and the surrounding plated pads. Preforms are supplied on a tape-and-reel package or via a bulk feeder system

case, a flux-coated 0.040 in. ID x 0.058 in. OD preform washer would fit nicely over the leads and into the printed area of the paste. To obtain the 1.66 e-5 in.^{3} of volume, the 0.040 in. x 0.058 in. preform washer must be 0.012 in. thick.

A high-volume technique for placing solder preforms is to transfer washers from prefabricated fixtures onto connector lead pins. This technique is adapted from passive component manufacturing, where billions of leads are attached to capacitors, diodes and resistors each year.

Placing the washers on connector leads is accomplished by tooling a fixture that has holes matching the pattern of the connector (Figure 4). Thousands of holes may be drilled into a single fixture to match the required throughput. A vibratory table is used to match individual washers to the correctly drilled holes in the fixture (Figure 5). The connectors are then press-fit into the fixture, and, when withdrawn, solder washers are attached to the leads.

The second most common process is to supply the preforms using pick-and-place equipment. Paste is printed onto the through holes and the surrounding plated pads. Preforms are supplied on a tape-and-reel package or via a bulk feeder system (Figure 6). The preforms are sequenced and placed into the paste as if they were a passive component. Similar to passive chip-scale components, solder paste acts as a temporary binder for the preform, preventing movement during subsequent component placement and conveyance through the reflow oven. Rates of 10,000 washer placements per hour have been reported using this technique.

Rectangles may also be used to provide the required solder volume. Figure 7 shows an illustration of placing rectangular segments near the through hole.

FIGURE 7: Placing rectangular segments near the through hole.

Summary

Printing enough solder paste to provide the volume required to form a complete solder joint between a through-hole pin and a plated via may be difficult or impossible, especially when square or rectangular pins are used. Solder preform washers or rectangles can be placed into printed solder paste to provide the required volume of metal. Alternatively, solder washers may be pre-placed onto through-hole leads.

Both solutions offer the required solder volume, without random solder balls commonly associated with overprinting solder paste. Poor print definition that may occur when the stencil thickness is greater than the design limitation of the solder paste may also be eliminated. With the development of innovative pick-and-place nozzles, both preform rectangles and washers can now be used to solve this volume problem in a highly efficient manner. ■

Mitch Holtzer *is worldwide product manager with Alpha Metals, Jersey City, NJ; email: mholtzer@cooksonelectronics.com.*