The Industry's Only Dedicated Surface Mount Technology Resource

SMT®

Celebrating 20 Years

January 2005
www.smtmag.com
PennWell

INSIDE:

Maximize Lead-free Wetting

SMT 101: Board Design

Lead-free: WEEE and RoHS Issues

Jet Dispensing

The Underfill Solution

By Todd Woods and Steven J. Adamson

Human-implantable medical devices need to be as small as possible to avoid user discomfort. At the same time, new features and functions are being added to the design of implantable devices. This puts pressure on the use of the substrate area of these types of systems. To improve board utilization, one company* investigated the use of jet dispensing technology to dispense underfills for medical devices.

The underfill process has become a common practice in the second-level assembly of flip-chip and CSP devices. Medical devices that use these types of area array components have common problems. The use of a wide range of device types and the limited real estate in which underfill materials can be applied causes iterative development.

In many applications, underfill materials cannot contact die surfaces, adjacent wire bonds or components. This puts severe pressure on dispensing companies to develop techniques for placing small fillets of underfill or encapsulants in a controlled manner. Achieving precision movement of a dispensing needle tip usually involves slowing the dispensing system down so that small needles can move into position and dispense in tight spaces, reducing throughput times. There also are limits as to how small of a needle can be used. Jet dispensing overcomes this and enables assembly designers to meet compact design requirements.

This article describes the work done to develop a jet that can dispense underfill materials to produce smaller fillets for underfill and controlled encapsulant dispensing. It also examines how jetting was used in the assembly of medical devices to enable efficient manufacturing of difficult assemblies.

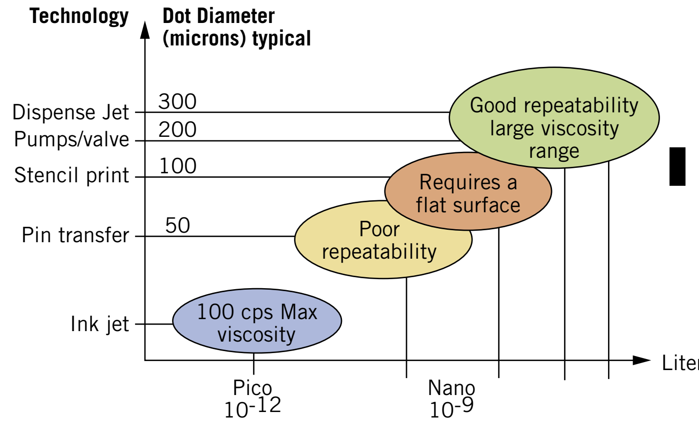

Figure 1. Ink jets have limited fluid sets they can deposit.

Dispensing Technology

Many designers know that using ink jet technology to dispense fluids in electronics assembly would offer a flexible tool. Unfortunately, ink jets used in printing cannot dispense the typical fluids used in electronics assembly — those with viscosities from 1000 to over 100,000 centipoise and, in many cases, filled with abrasive particles. However, ink jets used in computer printers can deposit dots of fluid as small as 2 pl and can create unlimited dispensed patterns on a substrate.

When reviewing the technologies for discretely depositing small dots of fluid, how they relate to each other and their inherent limitations and capabilities can be seen. Ink jets can dispense small dots of any technology, but have a limited fluid set of materials that they can deposit (Figure 1).

Pin transfer has been used to develop small dots. Unfortunately, fluids need to be spread into a thin film on a plate. A pin is dipped into the fluid film to pick off a layer. The pin then touches down onto the work piece surface to transfer fluid to the substrate. The surface tension of the pin to the fluid and the substrate can impact the success of the operation. In addition, when the fluid is spread thin, it has a tendency to dry out and change the surface tension to the pin as well as the characteristics of the fluid deposition on the substrate.

Stencil printing is a popular method used to deposit small dots onto a surface. Stencils have an advantage because the fluid needs only to move through the thickness of the stencil instead of being pushed through the length of the needle. Stencil printing also is a quick way to make several dots. Stencils, however, require a flat surface, and assembled PCBs are not flat.

For years, auger pumps have been used in the dispensing industry. The smallest dots of electronic assembly fluids, such as silver epoxies, are made using auger pumps. Recently, a hybrid technique of wetting the end of a needle with the auger pump then touching the needle to a substrate (similar to a pin transfer) has been reported to produce dots of silver epoxy in the 125-micron range.

Augers need to be adjusted periodically as fluid viscosities change over time and the components wear. The needle tip also needs to be held at a precise distance from the PCB surface to get a consistent dot size.

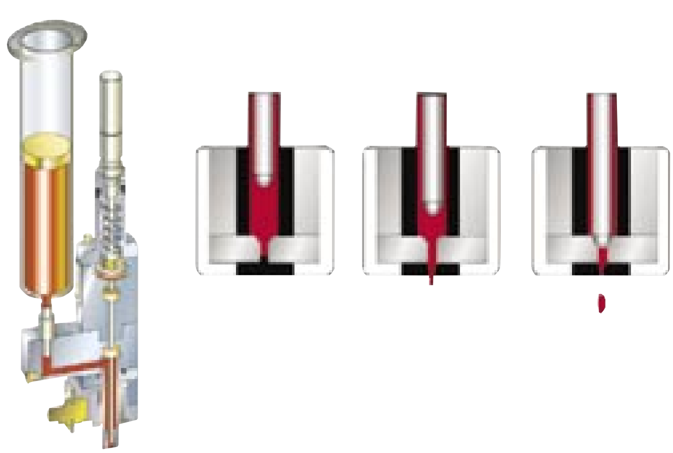

Figure 2. The ball-tip end of this technology pushes fluid through a narrow hole at the jet nozzle.

Dispensing Theory of Operation

One dispensing jet technology** uses a pneumatic piston with a ball-tip end to push fluid through a narrow hole at the jet nozzle tip (Figure 2). Air pressure raises the piston, which allows fluid to flow around the piston and into the nozzle. Spring pressure returns the piston to the nozzle tip when the air is removed. As the ball tip on the end of the piston engages in a seat at the nozzle, the fluid is energized to shoot a droplet

Reprinted with revisions to format, from the January 2005 edition of **SURFACE MOUNT TECHNOLOGY**

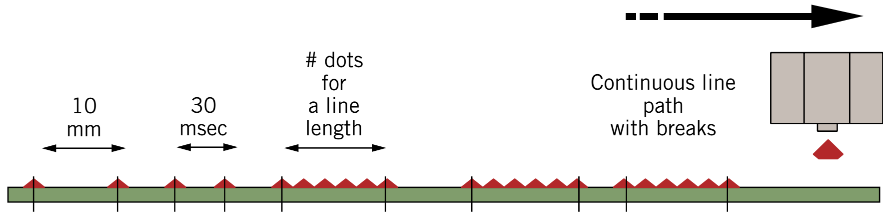

Figure 3. Four modes of jet dispensing "on the fly."

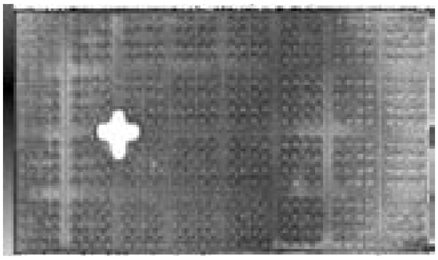

Figure 5. Non-standard pattern with pitch in the X direction and some clusters with a diagonal pitch.

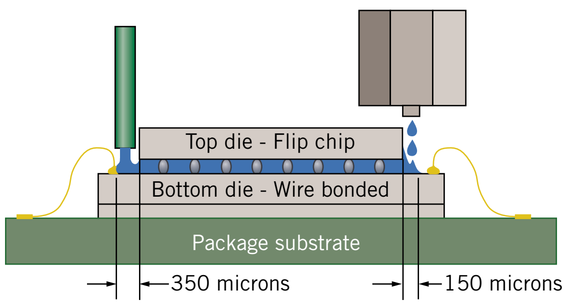

Figure 4. When Z movement of the dispense head is eliminated, the process speeds up.

from the end of the jet. The nozzle hole and several other factors control the size of the droplet. Because typical fluids change viscosity with temperature, it is necessary to control the tip temperature to ensure consistent operation. Several drops of fluid can be deposited in the same location to get a larger dot. This method can deposit more than 100 drops per second.

Jetting Modes

There are several modes of operation for jetting fluids onto a part. The simplest method, moving into position and firing a dot, is used for materials such as surface mount adhesives (SMA). SMA dispensing requires consistent round dots, accurately placed, so that when a component is placed on the dot, the adhesive does not spread onto adjacent component terminals and interfere with the electrical connection. Other types of dispensing, such as silver epoxy patterns for die bond, wirebond encapsulation and underfills do not require precise round dots. With these types, oblong shapes can be tolerated. In this case, the head is moving as dots of adhesive are fired from the jet. This requires the system software to be able to make predetermined, precise movements timed to the moment of firing the jet, to place a line of dots in a required position. Figure 3 shows the different modes of jet dispensing "on the fly." The four modes are distance based, time based, fixed number of dots in a line and a continuous line with breaks, which is the fastest mode. In this mode, the head does not stop moving between the end of the first line and the start of the second line.

Developing a new method for delivering fluid does not, in itself, make it worth using. New technology has to demonstrate that it is capable of doing something the previous technology could not do; or it should perform the operation to achieve higher manufacturing throughputs. In most cases, jet dispensing of epoxies and other fluids seems faster, and can access denser areas of board assemblies than needle dispensing techniques.

Underfill

Dispensing of underfill epoxies has been simplified. The dispensing jet is brought into position next to and above the die. This eliminates any chance of clipping the die with the needle. Z movement of the dispense head also is eliminated, speeding up the process, particularly with many small die on an array assembly (Figure 4). Depending on board or component layout, a 20% improvement in throughput can be seen, and in some cases, throughput has more than doubled.

When using a needle to dispense, often it is necessary to stroke the needle back over the line to break an epoxy string. Discrete dot dispensing of underfill with a jet does not have tail-off problems, which makes programming the end of a line easier and saves time in production.

Application Introduction

When dispensing advanced materials, whether it is underfills, epoxies, adhesives or reflow encapsulants, medical applications provide more challenges than others.

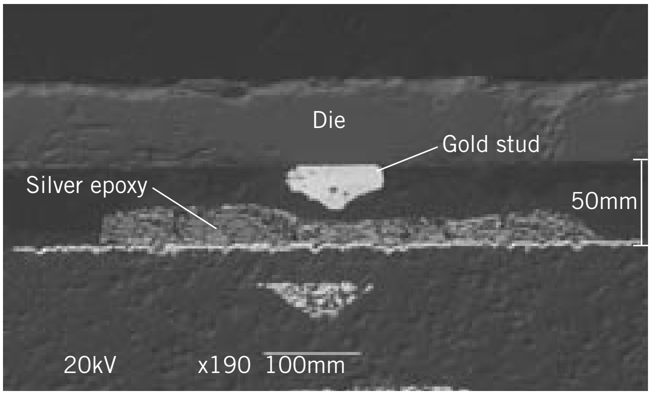

Figure 6. Small gaps in which to flow underfill material require special material to fit these tight constraints.

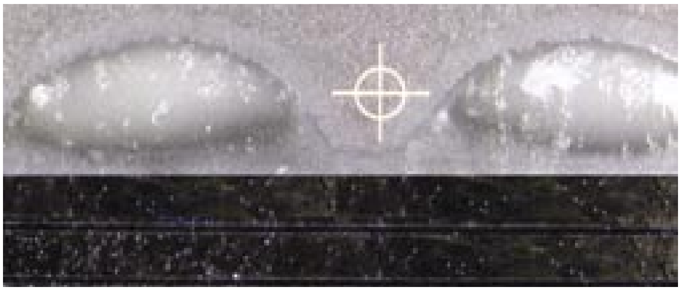

Figure 7. Normal underfill processes do not allow the accuracy needed to dispense around the fiducials without creating a void.

The applications are more varied; device scale and real estate are tighter. In addition, most devices encountered are custom designs. At times, the I/O patterns are non-standard (Figure 5) or the package types requiring underfill are widely varied. Within a specific product, there will be variations in die sizes, pitch, I/O pattern and interconnect methods that drive flexibility needs in the underfill dispense process. Other patterns include non-standards where the pitch in the X direction is 0.9 mm and 0.8 mm in the Y direction with some clusters, including a center pad with a diagonal pitch of 0.6 mm.

Application I

The first application covered in this article is a large die. There are two of these die attached end-to-end to a substrate using conductive adhesive. There were several constraints on the underfill process due to the specific configurations of this product.

The stud bump height allowed for a 50-micron gap in which to flow the underfill material. This required a time-consuming development process to select a material that would flow effectively into this small gap. There are a few materials such as this available currently (Figure 6).

The application required end-to-end die placement with a maximum gap of 33 microns, making the length of flow 70 mm. The width of the die and the substrate also were identical, eliminating any possibility of a side fillet. This placed restrictions on the underfill process by allowing only an end-fill pattern of dispensing, and required a great amount of work due to the length of flow required by the material.

Normal underfill processes would not have allowed the positional accuracy needed to dispense around the fiducials without creating a void, and would have required a special travel pattern to ensure that no material would be deposited on top of the die, which increases the process time (Figure 7).

Needle dispensing operations often have issues with materials wicking up the outer diameter of the needle. This material can, in turn, drop off or be re-deposited where it is unwanted.

Application II

The second application examined is a double-sided, medical handheld product. There are over 90 devices underfilled per assembly due to severe drop-test requirements. This application required the dispensing of reflow encapsulant or "no-flow" underfill. The small volume of material, positional and volumetric accuracy and throughput requirements make this suitable for dispensing technology.

This jet dispensing technology allows for quicker changes in volume dispensed than auger methods. This was crucial because of the large variation in package types and sizes on the assembly. Volumetric differences of 450% between adjacent packages were handled. Normally, a pattern or nozzle change would be required that would impact the overall throughput of the process.

The fabrication of this PCB included through-hole vias placed near the packaged devices where the underfill material is applied. To avoid materials seeping into and through these vias, the dispense pattern was modified. This specific pattern may not have been possible using a needle dispense.

The need to dispense an accurate volume of material repeatedly, while not allowing the fillets to connect and drain one another, was critical. This dispensing technology is capable of volumetric increments as small as 12 nl. The accuracy and programmable monitoring the volume dispensed also ensured that over several thousands of units produced, the variation in volume would not impact the ability to keep material out of the vias.

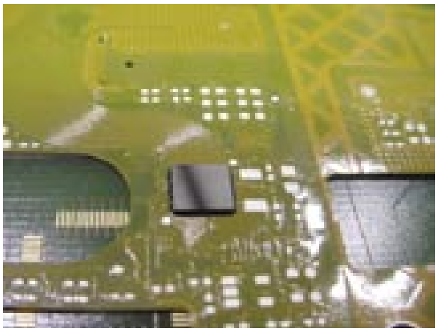

Figure 8. Because overall assembly thickness was predetermined, no material was deposited on top of the die.

Application III

The final application is a handheld drug delivery system. This application is a flip-chip-on-flex application. As with all flex-circuit applications, dispensing planes vary. With the non-contact jetting, any potential of physically contacting the substrate or die was eliminated. The product volume requires that the dispense operation is extremely fast. Dispense times for these products are <1 second per unit. The net difference in this application between jetting and needle dispensing was approximately 18%, which, over the course of one year, will increase potential revenue by 35%. The device also required that no material be deposited on top of the die as the overall thickness of the completed assembly was predetermined to fit into an enclosure (Figure 8).

Conclusion

These applications define areas where jetting technology provides an advantage over conventional methods for the underfill process. One company*** was able to deliver products to customers with very difficult dispensing and assembly requirements. Through the use of this dispensing technology, patterns could be generated with extremely thin lines and small dots in conjunction with long flow paths. Specific patterns to avoid through vias can be developed and still provide fast, void-free underfill. SMT

* Asymtek
** Dispense Jet, Asymtek
*** Plexus Corp.

Todd Woods, site engineering manager, Plexus Corporation, may be contacted at (920) 722-3451; e-mail: todd.woods@plexus.com. **Steven J. Adamson**, marketing manager, product marketing for Asymtek, may be contacted at (760) 930-7274; e-mail: sadamson@asymtek.com.