APEX 2004

Jetting of Underfill and Encapsulants for High-Speed Dispensing in Tight Spaces

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Abstract
The underfill process has become common practice in the assembly of flip chip and CSP devices and the practice of area array assembly has been adopted by many board designers and component assemblers. The range of devices underfilled has been greatly expanded and now includes everything from very small silicon devices to stacked die assemblies, MEMS and display devices. All of these applications have the common problem of smaller amounts of space restrictions/area, etc. that underfill materials can be applied to. Additionally, in a number of applications, underfill materials are not allowed to contact die surfaces, adjacent wirebonds or components.

This increased demand to limit underfill flow onto adjacent components has put pressure on dispensing companies to develop techniques for putting down small fillets of underfill in a highly controlled manner. A high degree of control of a dispensing needle tip usually involves slowing the dispensing system down so that a small needle can maneuver into position and dispense into a tight space. This slows down throughput, therefore a new method of delivering underfill fluids in tight spaces is required.

This paper will describe the work done to develop a jet capable of dispensing abrasive underfill materials, producing smaller fillets and high throughput.

Introduction
Jetting of epoxies and other materials is going to change the way people do dispensing. For the last twenty years, dispensing has evolved from pushing fluid through a needle using air pressure to a highly automated production process with linear positive dispensing pumps. Controlling fluid deposition, needle position and dispensed volume accuracy has dramatically improved in recent years. Additionally, speed has increased while software has simplified operational control. Now, jetting has become practical and it is going to have as large an impact on the electronics assembly industry that Ink Jet printing has had in the office / home environment.

Underfill

Conventional underfill dispensing uses an auger or linear positive displacement pump with a needle to apply underfills around a flip chip or chip scale package. In both cases, the needle has to be positioned alongside the die with typically a 125-micron gap between the chip component and the side of the needle. The needle is also positioned in Z to be at a mid-point between the board and the top of the chip component. The goal is to dispense enough material in the wetted area next to the component, to completely underfill the die and form a fillet around the edges. Fluid on top of the component or clipping the die corner isunsatisfactory. It is also not desirable to coat adjacent components with underfill, otherwise they cannot be reworked.

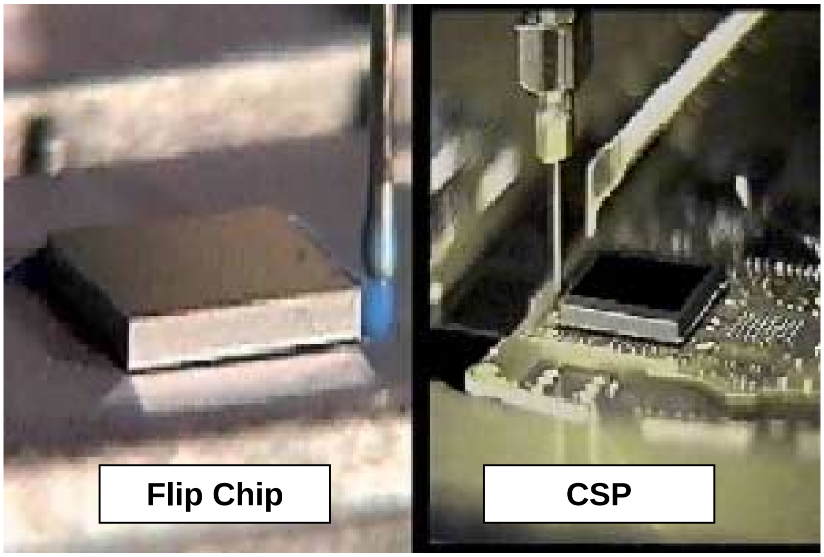

Figure 1

When using a needle to dispense underfill for the glass die, (as shown in Figure 2) it can be seen that the wetted area where the needle deposited underfill material extends out from the die 1.25mm. If the underfill fluid is allowed to self-fillet and a seal pass is not employed, the finished fillet size for all sides of the die is approximately 0.5mm wide. If the chip had components placed within the wetted zone, they would be coated with the underfill material. Some companies use this effect and place two die to be underfilled next to each other and use one pass of the dispense needle to underfill both die.

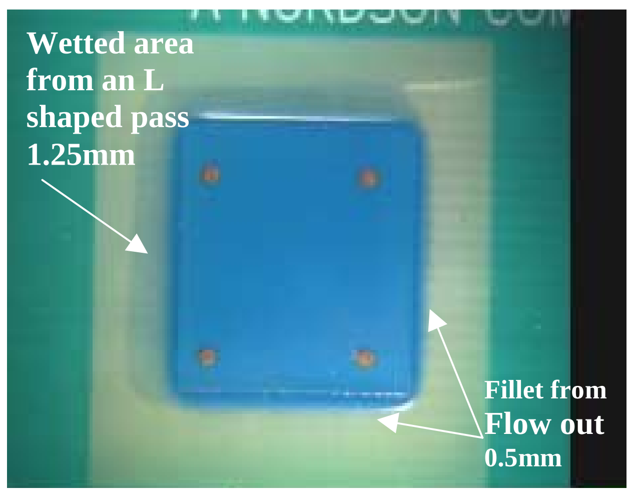

Figure 2

Adjacent Passive Components

Adjacent passive components near a CSP or flip chip can affect the throughput and quality of the underfill operation. All underfill materials will flow to some extent. If a passive component touches the wetted area near a component under which underfill has been dispensed, it can rob the underfill from the active device, increasing the amount of underfill fluid required, or causing voids to develop under the active device. Capillary flow will not discriminate between an active chip component and a passive one. While no detrimental effect has been reported on passives, which are in contact with the underfill, it does require a greater amount of material to be dispensed if the active device is to have adequate underfill. Capillary flowrequires more timethus increasing throughput times, and wasteof underfill materials.

As designs get tighter between the die and passive components, it becomes increasingly difficult to insert a dispensing needle between the components. Designs of some boards have spacing as small as 0.8mm. With gaps this small, a 25-gauge needle would be required, with an outside diameter of 0.5mm. The maximum flow rate of fluid through a 25-gauge needle is less than 10 mg per second at 100 psi pressure in the pump. If the device being underfilled required 30mg of material, it would therefore take 3 seconds to dispense the underfill. A 20- gauge needle, with an OD of 0.9 mm, has a flow rate of 50 mg per second. If this size needle could be used, the dispense time would be cut in one third. Hence, dispensing time is considerably impacted by the gap between the chip and passive component. Figure 3 shows the problem on board.

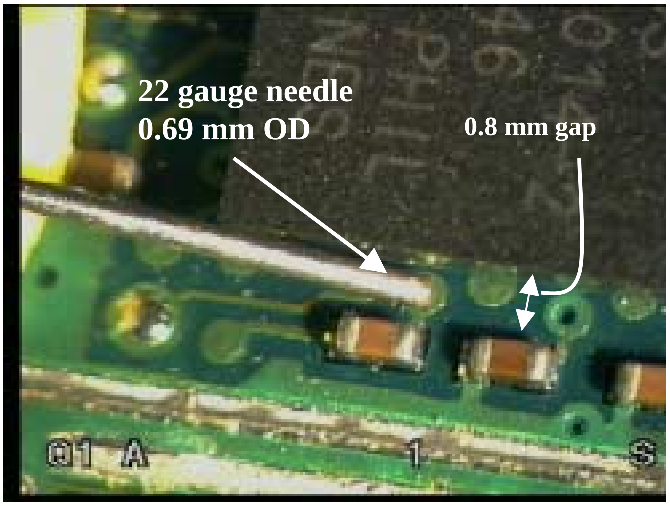

Figure 3

Why Dispense Jets

It has long been realized that employing ink jet technology to dispense fluids used in electronic assembly could provide a very flexible tool. Unfortunately, ink jets used in printing cannot dispense the typical fluids used in electronics assembly (those with viscosities of 1000 to over 100,000 centipoise, and in many cases highly filled with abrasive particles). Computer ink jets use either rapid thermal heating of the ink to dispel a droplet from the jet or peizo traducers to impart energy to dispel a droplet of ink. The jet developed for this work uses a mechanical action to move the fluid. A typical computer inkjet drop is on the order of a few pico-liters, the droplets from the mechanical jet are a few nano-liters, depending on specific gravity of the fluid, approximately 0.02mg / shot.

Dispense Jet Theory of Operation

The Jet uses a pneumatic needle with a ball tip, to push fluid through a narrow orifice at the jet nozzle see figure 4. Air pressure raises the needle, which allows a fluid to flow around the needle ball and into the nozzle. Spring pressure returns the needle to the nozzle seat when the air is removed. As the ball on the end of the needle engages in a nozzle seat, the fluid is energized to shoot a droplet from the end of the jet. The nozzle orifice and several other factors control the size of the droplet. As the droplet leaves the jet is approximately on 100 microns in diameter. ????The DisperseJet can deposit over two hundred drops per second. This stream of underfill can be positioned very close to the edge of a die, and in some cases can be directed at an angle to shoot at the die board interface. By moving and dispensing simultaneously, lines are formed, and no artifacts of

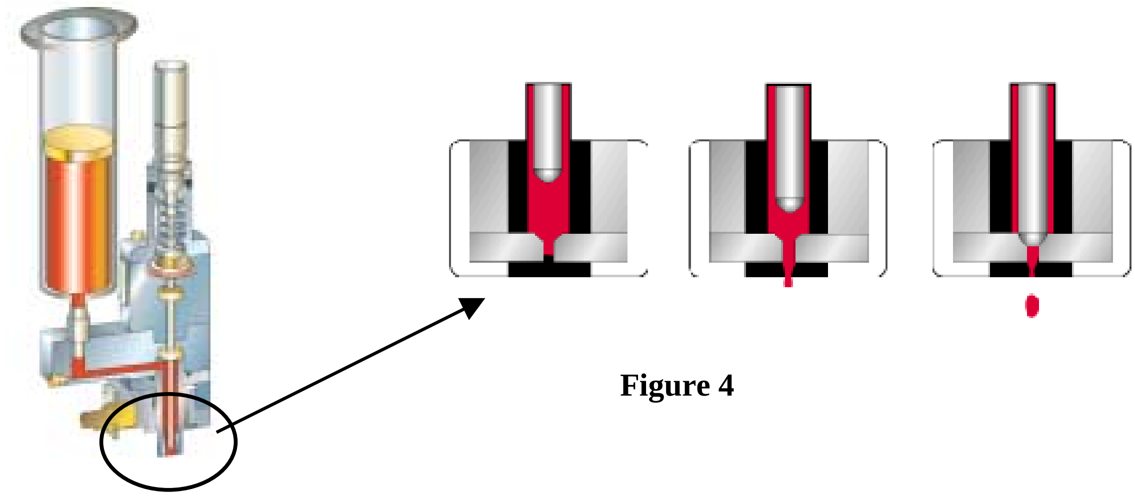

Figure 4

the dispense method can be discerned between needle or jet dispensing.

Jetting Modes

There are several modes of operation for jetting fluids onto a part. The simplest method, to move into position and fire a dot, and this is typically used for surface mount adhesives (SMA) where precise round dots are required. Other types of materials, such as silver epoxy for die bonding, wirebond encapsulation and underfills do not require precise round dots, and oblong shapes can be tolerated. In this case, the head is moved as dots of adhesive are fired from the jet to form a line of fluid, this is known as jetting on the fly. This requires the system software to be able to make predetermined, precise moves, timed to firing the jet, in order to place a line of underfill in a defined position. Figure 5 shows four different modes of jet dispensing "on the fly." The four modes are distance based, time based, fixed number of dots in a line and finally the fastest mode is a continuous line with breaks. In this mode, the head does not stop moving between the end of the first line to the start of the second line.

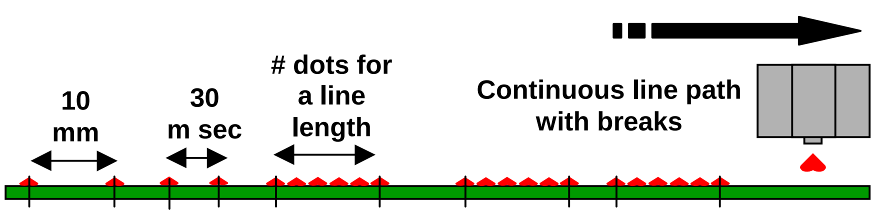

Figure 5

Dispensing Speed / Throughput

With needle dispensing it is necessary to ensure a consistent gap between the needle and the dispensing surface, to eliminate strings and blobs to ensure consistent quality. Therefore,with needle dispensing numerous heights senses are required on boards with multiple chip sites. Height sense measurements take approximately 1 second-- which may not seem like a long time, but these can add up to a significant portion of the overall dispensing time. Jets shoot from 0.5 to 3mm above the board. A single height sense measurement is taken on a board and no further height senses are required. A series of throughput test was conducted to compare the needle and jet dispensing throughputs. The volume of fluid was calculated for several die sizes and a dispense pattern developed for each die size. A comparison test was run between a positive displacement pump and a jet on the same platform. As can be seen in Figure 6, the jet throughput was consistently higher throughout the range of the test…

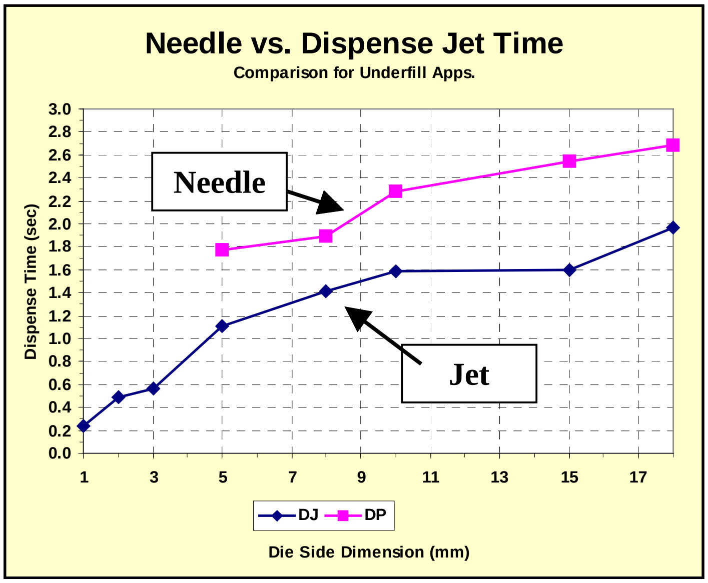

Figure 6

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

Applications

Staked Die

In stacked die applications, where it is not desirable to get underfill epoxy on top of wirebonds or the die, the jet can dispense much closer to the die than a needle. In this

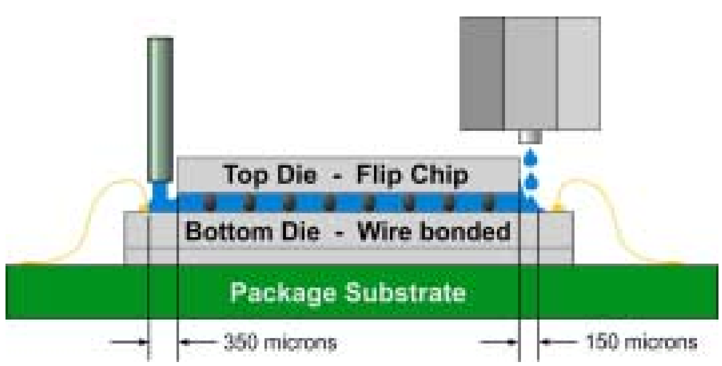

Figure 7

instance, the Jet can be positioned for the stream of epoxy to be dispensed very close to the die. Typically, the center jet stream can be placed at 125 microns as compared to 350 microns for a needle. There is no wall thickness of the needle to allow for and because the epoxy is shot from a jet positioned over the die there is no chance of clipping the die with a needle. When dispensing with a needle into tight spaces and there is a need for high positional accuracy, it is often necessary to slow down the speed of the robot. However, with a jet flying over the top of a die, it is fairly easy to obtain an accurate X-Y positional accuracy and not have to worry about Z height accuracy. Therefore, the dispensing operation can run at higher speeds and increasing throughput.
In a stack die application for one customer, the throughput was increased from 600 units per hour to over 2000.

Adjacent Components

In many designs of cell phones and other portable electronic devices, the circuit density is very high, chip resistors and capacitors are placed very close to CSP devices. It is often difficult to place a needle in the gap between the chip components and a CSP. In this case, a small nozzle can be used to give highly controlled small fillets of material, without bridging the gap between the two components, and flooding underfill over the adjacent resistors. Needles also have a problem where a blob of underfill forms on the bottom of the needle and is released as the needle is moved to the edge of the CSP device, thus, often coating everything that the blob touches.

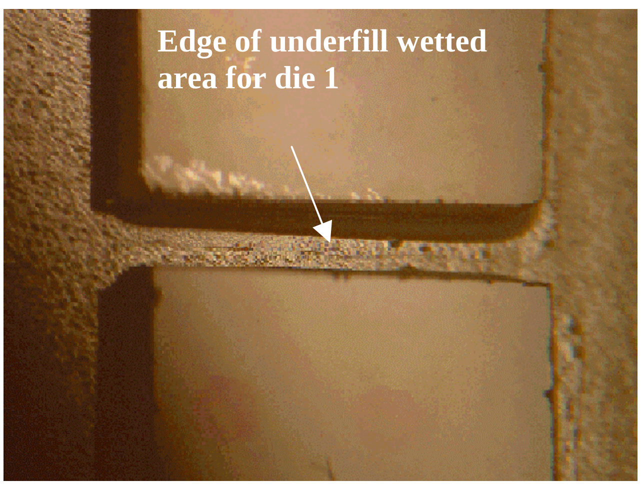

Figure 8

In figure 8, two die have been placed with a 1 mm separation between them. The underfill material for one die is dispensed in the gap, along the edge of the die. As can be seen, the fluid did not bridge over to the adjacent die. Fillets / wetted area have been dispensed as small as 125 microns wide.

Summary

During the last twenty years, dispensing of epoxies and other materials for electronic assembly has used needle dispensing. In this time, dispensing technology has moved from simple air over fluid to auger pumps, highly accurate linear positive displacement pumps and now the era of jet dispensing has arrived. Jets will allow denser circuitry to be developed at the package and board level, while offering a greater degree of process control at faster speeds than needle dispensers. Jetting also offers the ability to make patterns with materials that are just not possible with needles.