Multi-functional Dispensing for Semiconductor Back-end Packaging

Evolving beyond Traditional Dispensing

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Liquid dispensers have long played an essential role in printed circuit board (PCB) assembly. In meeting the weight, size and performance requirements of devices such as cell phones, pagers and handheld computers, for instance, designers continue to be faced with the challenge of packaging higher densities of components on available real estate.

The manufacturing processes for these increasingly dense packages are becoming more reliant on next generation dispensers because of their unique ability to deposit micro-volumes of conductive materials and adhesives in extremely precise patterns. Some dispensers are even evolving beyond the traditional dot dispensing, such that they are able to handle multi-functional applications that require placement coupled with the application of a fluid material. Systems with these designed-in capabilities are being integrated into the manufacture of such devices as: stacked packages, flip chip ball grid arrays (FCBGAs), plastic ball grid arrays (PBGAs), and system in packages (SiPs).

Why dispensers? The answer is simple: only dispensers can deposit precisely controlled micro-volumes of electrically and thermally conductive adhesives, pastes and encapsulants in simple and complex patterns. Due to the layout and configuration of semiconductor packages, the ability to program the dispensing system for the individual requirement is considered a significant benefit for ensuring accuracy and reliability. The more advanced dispensing platforms today are multi-functional, in that they offer programmable gantry motion that incorporates pick-and-place capability as well as dispensing.

Stacked Packages

Stacked die packages are the result of the demand for lower power consumption and higher transfer rates in the smallest possible footprint. Stacked two-die chip scale packages (CSPs) housed in a single package are reportedly achieving silicon efficiencies (ratio of total IC area to package area required to house the die) approaching 200 percent.

Results of this package could put 3GB of memory in less than 0.5 in^2. Multiple levels of die can be stacked, the limitation being that of the permitted height for the end product or package.

Stacked die are complex to manufacture, but with appropriate equipment, a repeatable product can be achieved. The dispense system comes into play as one of the final steps in "assembling" the package when conductive material is precisely deposited to connect the multi-levels. This effectively replaces the more common wire-bonded dies and reduces total footprint by eliminating the need for bond pads. Connecting the stacked die with a conductive adhesive also allows the same size die to be stacked within a package.

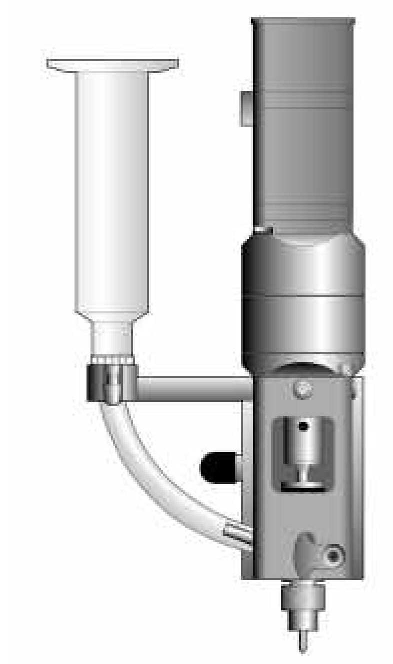

Figure 1. Dispensing system with auger pump

The first hurdle in applying the conductive material is designing custom fixturing capable of presenting all interconnect sides to the dispense tip. Even with articulated fixturing, advanced programming features in the dispenser are required. The stacked assembly must rotate in a controlled motion that results in a specific angle to the dispensing needle optimal for depositing the conductive material. The correct process angle, coupled with the needle movement, results in the material being "pushed" between the layers to provide adequate material coverage over the internal interconnect points.

Precise X-Y alignment of the top and bottom of the stacked die is essential, as is locating the top and bottom surfaces along the Z-axis. Depending on the build, the stacked die can have a variance of up to ± 0.015” over a package height of 0.500”. Vertical lines of interconnect material (the conductive adhesive) must also be precise in placement and consistent in width, typically ± 0.005” with a line pitch of 0.020”. If the dispensed line varies in width outside of the specific tolerance, neighboring lines can join, thus, causing a short or an otherwise defective interconnect. Auger technology is unique in that flow characteristics can be controlled by the design of the auger and its sleeve; and with closed-loop feedback, the auger rotational speed is regulated to ensure consistent and proper material flow (Figure 1).

Dispensing needles are also an important consideration, as a chamfered tip (Figure 2) allows the needle to be positioned optimally to the dispense surface. Conventional needle tips need to be farther away from the surface by a distance

Figure 2. Chamfered needle tip

equal to the thickness of the needle wall. Also, with a conventional tip, material can accumulate on the end of the needle, which can result in paste or adhesive migrating to improper locations.

To align surfaces accurately in a 3D environment, an enhanced vision system is needed to optically enlarge and focus on a precise alignment point of the stacked die. The ability to optically zoom to the desired location and focus on a single alignment point allows for stacked die alignment. Such a process is not possible with conventional field-of-view, fixed-focal-point vision cameras. A close-coupled device (CCD) camera with a motorized zoom and focus lens controlled by software, on the other hand, ensures that the correct device is focused on and results in higher accuracy.

An added advantage to a programmable zoom and focus vision system is being able to align on a single object in a field or matrix of similar points. The matrix is difficult for many vision systems to cope with, since they are unable to decipher the appropriate point alignment. The vision software should also be able to store the alignment pattern, along with "taught" vision parameters for later recall and use during processing.

FCBGAs and PBGAs

Thermally enhanced FCBGAs and PBGAs are similar applications, in that the end result is a BGA component ultimately placed by a standard SMT placement system and reflow soldered on a board. Both packages require dispensers in multiple aspects of production.

An FCBGA is essentially a flip chip that has been mounted to a carrier substrate, which has a heat dissipater attached for increased performance. The reason for placing the flip chip on an additional substrate is to increase the footprint and interconnect pitch/size, allowing standard placement systems to place a high-IO count component, in effect, a flip chip. Flip chips by themselves are difficult for many placement machines due to the presentation method and the fine pitch of the interconnects. However, where placement is possible, a second challenge occurs, that of underfilling the chip to secure it to the board. Most packaging lines do not have this capability, as dealing with a pre-packaged product is easier. The second advantage of a packaged flip chip over the bare flip chip is that the packaging helps to dissipate heat faster than a bare, underfilled flip chip on a board, thereby increasing performance.

In the manufacture of FCBGAs, dispensers are used in three specific processes, and dispensers with enhanced capabilities can perform a fourth process as well. In the first process, once a flip chip has been placed on a singulated substrate and reflowed, a capillary underfill is required. The next two processes are the application of adhesives and thermal greases that connect the heat dissipater to the substrate and flip chip. For dispense systems with multi-functional capability, the fourth process is the placement of the heat dissipater.

Capillary underfill compensates for differing expansion rates between the flip chip and substrate, and is applied using a specialized dispense system equipped with heat and a dispense pump. Again, auger technology is used for capillary underfill materials, and such pumps reportedly yield dispense results better than ±1 percent at 5.5 mg (Figure 3).

Valve control must be completely integrated. For such pumps, motor controls are enhanced by a high-count, closed-loop encoder attached to the drive motor. Closed-loop encoder feedback lets the computer control and monitor rotational speed, acceleration and deceleration of the auger and the number of increments, or degrees for dispense. By monitoring the rotational speed, the computer compensates for changes in material viscosity inherent with capillary underfills. The monitoring process is somewhat similar to cruise control in an automobile, in that controlled power is automatically applied when needed and reduced when not needed.

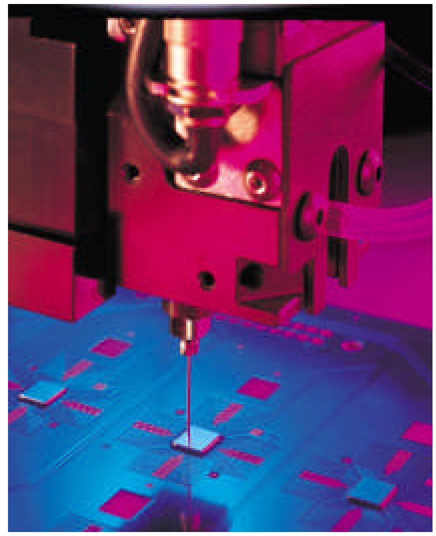

Figure 3. Auger pump dispensing underfill

An additional motor control enhancement useful in dispensing underfill is the ability to reverse rotate the auger, which allows pressure buildup at the needle tip to be relieved into the material supply pathway within the pump rather than out of the needle tip. An additional enhancement to material control is a computer-monitored vacuum on the material syringe. When the dispensing stops, a vacuum is introduced to the syringe to prevent material flow due to gravity. The vacuum is carefully monitored to avoid pulling air through the needle tip.

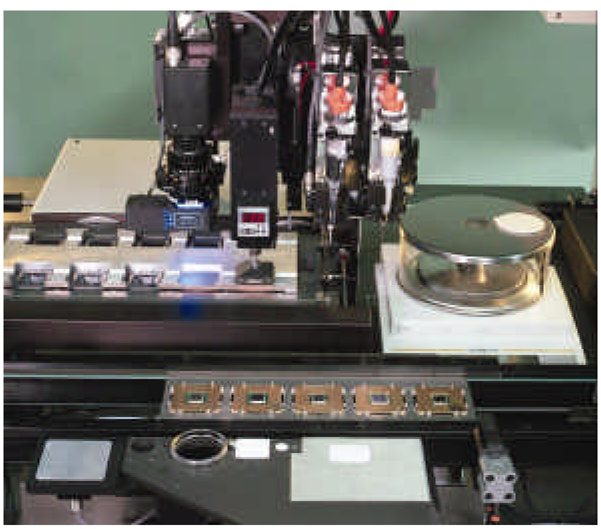

Figure 4. Heat dissipater mounted on an FCBGA package

To complete the FCBGA package, a heat dissipater must be attached (Figure 4). Two types of heat dissipaters for FCBGA are in use today: two-piece and single-piece configurations. The configuration depends on the manufacturer. The heat dissipater connects to the package in two locations: at the substrate-to-heat dissipater interface and at the flip-chip-to-heat dissipater interface. The first interface requires an adhesive, which can be dispensed in either a series of dots or a continuous line; while the second interface requires the application of thermally conductive grease directly on top of the flip chip in a rectangular fill pattern.

Placement of the heat dissipater can be handled by multi-functional dispense systems -- dispense systems equipped with placement heads that incorporate alignment for correct placement, as well as specialized feeders to present the various types of dissipaters.

A PBGA package is similar to an FCBGA package in that each employs a silicon die. The principal difference is that a PBGA utilizes a wire bonded die while the FCBGA uses a flip chip. As a result, the PBGA almost always incorporates fewer I/Os than the FCBGA.

Manufacturing a PBGA begins with a strip of components that are ultimately singulated at the completion of the production process. During manufacture, a die bonder encompasses the application of conductive adhesive and placement of the die. The accuracy of die placement is not critical, as the system attaching the wire bonds aligns each interconnect point before placement.

Once the wire bonds are made and the product cured, the strip is conveyed to a dispensing system where one or two processes may be done, depending on the dispense system type. The first process applies the adhesive to hold the heat dissipater and the second process, for multi-functional systems, places it.

The heat dissipater used in a PBGA process typically has standoffs or “bumps” at each of the corners (Figure 5). The bumps hold the dissipater off the substrate for material penetration during the molding process, while a thermally conductive adhesive holds the heat dissipater in place. Material is dispensed at the four corners where the heat dissipater bumps contact the substrate. The use of an auger-pump ensures a repeatable volume of material, which is essential for maintaining planarity in placement of the heat dissipater. Unlike placement of the die, placement of the heat dissipater is crucial to avoid a failure such as "half-mooning," which occurs when part of the dissipater shows through the molding compound, thereby creating the illusion of a half moon. As with the FCBGA package, a multi-functional dispense system can place the heat dissipater.

Figure 5. Standoffs on heat dissipater for PBGA package

SiPs

SiP covers an array of products from wireless devices to image sensors, GPS and Bluetooth to name a couple. Each product has a specific process that lends itself to a dispense system and, in many cases, those with multi-functional capability. Cameras that are now appearing in everything from pens to phones to PDA’s use a SiP in which the image device incorporates a wire bonded die and, in some cases, a flip chip with passive components.

By definition, a SiP consists of at least one flip chip or wire bonded die and at least one passive device mounted to a standard package. Dispensers are required for the underfill process as described with the FCBGA. A SiP may also use a heat dissipater to enhance the performance of the flip chip, which can also be placed by a multi-functional dispensing system. In the assembly of an image sensor, a lens and housing are mounted in accurate proximity to the image device; otherwise, a fuzzy image could appear. Multifunctional dispensers can dispense material to hold the lens (in many cases an optically clear UV adhesive) as well as place the lens accurately. To complete the process, a multi-functional system dispenses adhesive for the housing and places it.

Conclusion

While dispensing systems today feature various pump designs and capabilities, a system for back-end packaging should: certify and calibrate accuracy on the production floor, include a CCD camera system with motorized zoom and focus, and incorporate a multi-function process that enables component placement as well as dispensing.

For a complete list of references, please contact the author.

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