Creating Reliable Flip Chip Assemblies

Precise Control of Underfill Deposition is Critical to Stable On-Board Attachment Technologies

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The demand for denser assemblies in recent years has led to increased use of flip chip ball grid array (FCBGAs), direct chip attach (DCA), chip scale package (CSP) and chip-on-flex (COF) technologies to reduce footprint and thickness of the chip assembly (as much as 50 percent thinner than wire-bonded chip packages).

Equally important is improving the reliability of packaged devices, and increasing processing speeds. In fact, PCB assemblers utilize one of these newer assembly methods for almost all PCBs in order to meet the demand for smaller, more portable electronic products.

Unlike previous techniques for chip attachment, which utilized glob-top and dam-and-fill dispensing methods to encapsulate electrical connections (small leads wire-bonded on top of the chip), flip chip technologies complete electrical connections on the underside of chips, which are then mounted either inside a BGA package or directly on the substrate.

However, flip chip technologies carry a new set of production challenges and issues, primarily related to durability. Precise deposition of underfill materials is necessary for stabilizing flip chips against shock, heat, moisture and connectivity disruptions. Dispensing too much underfill material can impact the integrity of the die in BGA packages, destroy the chip, or denigrate adjacent components. Dispensing too little material leads to uneven coverage and a potentially unstable situation, such as the overheating that can occur in a flip chip with an underfill air pocket. Thus, precise control of underfill material deposition is critical to creating reliable flip chip assemblies and reducing the number of boards and packages requiring rework.

Protecting Chip Integrity

The primary concern with underfill dispensing operations is protecting the silicon edges of the chip and the integrity of the die during material deposition. During the underfill process, a dispensing system deposits specialized epoxy resins along one or more sides of the chip, the substrate and the dispensing needle are heated to enhance material flow, and the material runs under the chip to encapsulate connections through capillary action. Finally, a fillet can be dispensed along one or more sides of the chip, sealing the underfill material and protecting the chip.

Underfill material deposition requires a far greater degree of placement accuracy than the glob-top and dam-and-fill, in which material covers the entire die. During underfill, the dispensing needle is positioned anywhere from 2-5 mils from the chip edge and 2-8 mils from the substrate. For all intents and purposes, contacting the chip with the dispensing needle during underfill material deposition, also known as "clipping" the chip, will destroy or severely compromise the die. Also, getting material on top of the chip can adversely affect the longevity of the die.

Precise control of the location of the dispensing needle during material deposition is critical to creating reliable flip chip assemblies. If the needle is too far away from the die, the material may not adequately "fill" the underside of the assembly, it may migrate to adjacent component locations, or may create an excessive fillet. If the needle location is too high from the substrate surface and bottom side of the die, it can cause insufficient material flow, air voids, and material overflow on the top side of the die surface.

Yet, precise control of the location of the dispensing needle is not the only key to successful underfill dispensing operations. The viscosity of the underfill material and the rate at which it is applied can also impact whether underfill material deposition successfully stabilizes or potentially jeopardizes flip chip assemblies.

Controlling Viscosity

Because the capillary action of the epoxy resins actually "fills" the underside of a flip chip assembly, controlling the viscosity of the underfill material is another important challenge for creating reliable flip chip assemblies. If the material is too thick, it will not "crawl" under the assembly and fill the underside of the chip. If the material is too "runny," it may travel beyond the assembly, impacting adjacent components, "wick" up the sides of the needle, or leave voids beneath the chip. All of those scenarios are unacceptable. Typically, the substrate is heated to 70-100° C and the encapsulating material is pre-heated to 40-60° C via a material or syringe heater, if required.

Once material viscosity is controlled, the rate at which the material is dispensed becomes the determining factor for successful underfilling of flip chip assemblies. Normally, material is dispensed at a very slow rate to achieve optimal material flow for the viscosity of the material and the location of the dispensing needle relative to the die.
With three different factors — needle location, material viscosity and dispensing rate — affecting the reliability of underfill dispensing operations, semiconductor manufacturers, and PCB assemblers need an automated means for monitoring, adjusting, and managing all three variables in concert to achieve optimum flip chip underfill.

Automated Material Deposition

Automated dispensing control systems can eliminate most of the trial and error associated with underfill dispensing. For example, a traceable glass plate procedure can ensure needle location accuracy to within 1 mil. Software maps the location of each gantry position and automatically adjusts the system for needle location inaccuracies in X and Y positioning. The system can also automatically compensate for discrepancies in material viscosity by adjusting material volume and flow rate, and eliminate drip via a positive shut-off valve.

Because such closed-loop systems have innate intelligence, detecting and compensating for deviations in needle location and material viscosity, they automatically control underfill material deposition, ensuring that the same successful process runs over and over again.

With the potential for significantly reducing the height of electronics packages, advanced material deposition technologies are a necessity for meeting consumer demand for smaller electronics products. Likewise, semiconductor manufacturers and PCB assemblers need automated underfill dispensing techniques to continue to address the demand for denser assemblies. Fortunately, closed-loop systems that manage the critical elements for successful underfill material deposition (e.g., needle location, material viscosity, and flow rate) can automate the process, reducing package rework while enhancing the reliability of flip chip assemblies.

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