Corner Bond Dispensing for BGAs
The underfill process was designed to improve the reliability of flip-chip packages, specifically the fatigue resistance of C4 interconnect bumps during thermal cycling. The mismatch in the coefficient of thermal expansion (CTE) between the chip and the substrate induced stress on interconnect bumps. It was later adopted for direct flip-chip attach to circuit boards to improve not only resistance to fatigue, but also reliability during bending and mechanical shock. BGA packages were designed with larger interconnection bumps (interconnection balls), so fatigue during thermal cycling was not an issue.

When BGA packages entered use in portable electronics, most notably in mobile phones, it was found that many BGA packages were not reliable during mechanical shock, such as dropping a phone. Faced with a reliability crisis in the late 1990s, the industry began underfilling BGA packages at the board level. In some cases, underfill was also used on PCBs that were subjected to bending during assembly and shipment, such as circuit boards used in PCs and gaming consoles. The process was to underfill BGA packages after reflow and cure the underfill material prior to final assembly. Additional dispensing equipment and cure ovens added undesirable cost to assembly, but it was necessary to achieve the required reliability.

### Corner Bonding BGAs

Underfilling BGAs provides more reliability than needed for many products, so the industry began to explore less costly alternatives. The corner-bond (sometimes called corner-glue) process was developed. In this process, adhesive similar to surface mount adhesive (SMA) is placed on the PCB in dots at the corner of BGA attachment points prior to placing the BGA. When the circuit board is re-flowed, the material cures and provides additional shock and bending resistance to the assembly. To increase reliability, alternate...
patterns, such as “L” shapes at the corner, have been developed (Figure 1).

Although these materials are similar to SMAs, they have been designed specifically to accommodate interconnect collapse and self-alignment during reflow. The principle advantages of this process are that additional cure ovens are not required and existing SMA dispensing equipment could be adapted to make underfill material compatible with the fluid reservoir, tracking of the working life, and equipment that can be cleaned quickly and easily.

Pre-dispense heat station brings the board up to temperature for underfilling. The pre-heat station must accommodate specific temperature ramp rates and/or dual-sided heating techniques to meet production-speed requirements without inducing thermal expansion stress.

Heated dispense station holds the board at an optimal temperature during underfill.

Automated vision alignment systems: depending on board layout and package density, systems with edge-detection algorithms may be needed for precise material placement.

Many underfill materials are abrasive to dispensing equipment, so equipment must be designed to accommodate this.

Underfill material often has a limited working life, which requires temperature management of the fluid reservoir, tracking of the working life, and equipment that can be cleaned quickly and easily.

Limited working life also implies material rheology changes during production, which must be accommodated by calibration.

Depending on package size, board layout, and density, underfill equipment may need to accommodate multiple dispensing steps that are timed precisely to optimize material fill width and prevent void formation.

If the package is covered with an RF shield, jetting is preferred so that the material can be applied through a hole in the shield after it is placed.

While many of these features may not be required, they are justified through cost of ownership (COO) calculations that show reduced production cost by improving production speed, material savings, or yield. For example, using jetting technology instead of needle dispensing can reduce material consumption by 35% and improve production rates as much as 400%. Figure 2 illustrates the cost of ownership reduction that can be obtained by a modest improvement in yield.

Equipment Requirements for Underfill

Underfill processing requires dispensing equipment and a cure oven. Underfill can be done manually, however, medium- to high-volume production runs and/or high-value components demand automated dispensing. Typical dispensing equipment for underfill features:

- Pre-dispense heat station brings the board up to temperature for underfilling. The pre-heat station must accommodate specific temperature ramp rates and/or dual-sided heating techniques to meet production-speed requirements without inducing thermal expansion stress.
- Heated dispense station holds the board at an optimal temperature during underfill.
- Automated vision alignment systems: depending on board layout and package density, systems with edge-detection algorithms may be needed for precise material placement.
- Many underfill materials are abrasive to dispensing equipment, so equipment must be designed to accommodate this.
- Underfill material often has a limited working life, which requires temperature management of the fluid reservoir, tracking of the working life, and equipment that can be cleaned quickly and easily.
- Limited working life also implies material rheology changes during production, which must be accommodated by calibration.

Equipment Requirements for Corner Bonding

As mentioned, corner bonding can be accommodated with most SMA equipment. The following characteristics are differentiated from the requirements of underfilling:

- Board heating is not required, eliminating pre-dispense heat and dispense heat stations, and potentially allowing for a dispenser with a smaller footprint to reduce floor space and COO.
- Corner-bond material may not be abrasive, which can relax requirements on wetted parts inside the fluid-delivery device.
- Corner-bond material typically has a longer working life, reducing cleaning and accommodation of rheology changes.
- Multiple dispensing steps and timing algorithms are not required.
Precision in the placement and volume of material for corner bonding can be critical. The process is new, but guidelines are available. Bonding material is placed prior to component placement and reflow. For high reliability, the bonding material must not interfere with the reflow process. Therefore, it must be placed in a precise position, with the correct volume, and in the correct shape, so that it captures the edge of the package without touching any of interconnect balls. Features such as jetting technology, material quantity calibration, and data logging of critical process parameters can reduce COO by increasing production speed and yield.

Equipment Requirements for Edge Bonding
Although edge bonding takes place at a different point in the assembly process, equipment requirements for dispensing edge-bond material are similar to that of corner bonding, with these exceptions:
- Edge-bond materials that are UV-curable must have fluid handling and dispensing systems compatible with UV-cure chemistries.
- The shape and height of the edge-bond material is critical to the reliability of the final package. Unlike corner bond or underfill, the bonding material often stays in the shape in which it is dispensed. Therefore, technologies such as jetting can help provide flexibility with high production rates.
- If the edge-bond process is designed so that the material partially flows under the package, board heating may be required.
- Since the material is applied after reflow, an additional curing step is required. If UV-cure chemistry is used, a UV-cure oven typically is faster and requires less production space than heat-cure ovens.

As with corner bonding, edge-bonding reliability depends on the shape and placement of the bonding material. It is desirable to minimize the “footprint” of the edge bond, or the area past the edge of the package that is required for bonding. In this case, jetting technology can provide a speed and material profile advantage.

Conclusion
The goal of corner- and edge-bonding processes is to improve board assembly reliability at a cost less than underfill. The drive to reduce production costs can tempt manufacturers to purchase the lowest-cost equipment. Yield and reliability should be considered in the process’s total cost of ownership. If the choice of equipment further reduces reliability, it is possible to lose the intrinsic savings in material, production time, or floor space.

REFERENCES
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Al Lewis, director of marketing and applications, Asymtek, may be contacted at (760) 930-3379; alewis@asymtek.com.