Capillary Underfill

Successful Application Method

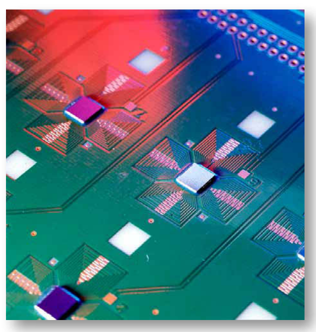
Encapsulate the Underside of Silicon Die

Application

The Capillary Underfill process is used to encapsulate the bottom side of a silicon die. The word “encapsulation” typically means to cover a top surface where fragile interconnects are located, but in this case, the fragile interconnects are on the underside of the die. The device to be underfilled is either a “flip chip” or a BGA.

Underfill is used to compensate for the differences in thermal expansion rates of two dissimilar materials: solder bumps and flex circuit or FR4, for example. Without underfill, the life expectancy of a product with a flip chip would be greatly reduced due to cracking of the interconnects. Underfill adds rigidity to the product; that is, underfill gives it the ability to survive high impact shock without fracturing or separating completely from the substrate.

A successful underfill process results in complete encapsulation of the bottom side of the die, keeping it free of trapped air, with an even meniscus on all 4 sides. If bubbles are present in the encapsulation, they could cause a defect during normal operating temperatures due to the expansion of the gas in the void.



Process

The basic steps to an underfill process are:

1) Pre Heating from ambient to 80 degrees Celsius.
2) Vision alignment of the die to be underfilled.
3) Locate surface to dispense (Z axis).
4) Dispense fill pass. Multiple passes may be required.
5) Dispense the fillet pass. This step may not be required, depending on chip size or underfill material selection.
6) Post-heating is product dependent.

Inline systems are recommended for underfill due to the ability to use pre- and post-heaters. Pre-heating quickly increases product temperature from ambient temperature to process temperature. Different methods of pre-heating are available. The most common heating method is the use of a custom contact vacuum fixture. This method offers the quickest and most uniform heat transfer.

Another common heating method utilizes forced air. Forced air allows any substrate to be heated regardless of geometry or size, but this method requires more heating time versus contact heating. To ensure substrates are not overheated, a temperature monitoring system is employed. When a substrate reaches operating temperature, heat is removed and the substrate is transported to the work area.

Post-heating is used after the dispense process to continue the flowing process. Depending on the application, the post-heater may be used to gel an underfill to hold it in place before the next step.

After preheating, the substrate is transported to the work area where alignment of each die begins. The system scans all die to determine unit orientation and which units to process. Accurate alignment of each die is necessary to keep the dispensed material within the allowed wetted areas.

The alignment process can be very tricky when silicon dies are used because the surface texture and finish can vary from unit to unit or lot to lot. It is these variations that can make finding a die using a standard illumination system very difficult. By using FullView Illumination, which is a combination of a low angle dark field with an on-axis source, any die can be found.

FullView Illumination

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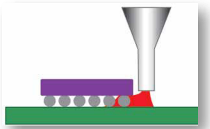
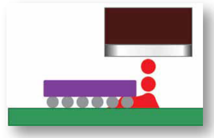
Capillary Underfill

The majority of the material that will flow under the die is deposited during the fill pass. The pattern for dispensing the material is also key for a successful process. In most cases, the "L" pattern is the best choice. The "L" starts on the longest side of the die and turns the corner to the shorter side.



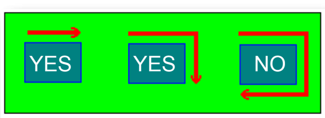
First Fill Pass with Volumetric Pump



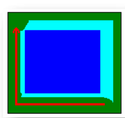
First Fill Pass with Jetting Pump

Depending on die size, this pass could be all the material required to complete the underfill. Once the material is dispensed, it flows under the flip chip via capillary action. If all the material disappears and there is no fillet or meniscus at the sides of the die, then either:

1) More material is required on the first fill pass,
2) An additional fill pass is needed, OR
3) A fillet pass is required.



Fill Pass Patterns



Fillet Pass

In many cases, the fillet pass is required. The fillet pass is used to "finish" the process by applying enough material to create the sealing joint. In an optimized process, all fill passes are dispensed first, and then after the material flows, a fillet pass is dispensed. Dispensing all the fills first gives the material enough time to flow under the die. Note that a multiple fill pass process takes longer but the cosmetics of the finished product are excellent. In some very high volume applications, a large quantity of material is dispensed in a single pass with no fillet. The cosmetics of this process show a large wetted area to one side of the die but the functional results are acceptable. Additional process control is achieved through volumetric feedback that comes from an integrated weight scale. During the calibration process, the weight scale monitors the amount of material dispensed over a period of time. If the amount of material varies from expectations, the system adjusts the dispense parameters to ensure consistent dispense quantity. This calibration routine compensates for material changes over time (pot life) and batch-to-batch variations.

Equipment

GPD Global® recommends the MAX Series or DS Series in either a stand-alone or inline configuration. All of these systems are equipped with work area heat to maintain substrate operating temperature, typically 80 degrees C. This elevated temperature reduces underfill viscosity, thus facilitating material flow. Material with a lower viscosity flows more quickly and easily below the die reducing the chances of voids. Additional features: optional pre- and post-heating, pump and needle heat, and closed loop process calibration.

GPD Global® utilizes proven auger technology that yields excellent process results and is easy to clean. Valve maintenance is minimal; a valve can be cleaned and rebuilt in 7 minutes. The dispense valve is attached to the system with the GPD Global® exclusive toolless Taper-Lock™ mounting hardware.

Standard Features

Unibody Frame on MAX II - *extremely stable platform for precise dispensing.*

ClearVu™ Vision - *programmable zoom and focus for accurate alignment of small features.*

FullView Illumination - *combination of on-axis with dark field illumination; individually controlled to view any surface.*

Illuminator Intensity Control - *controls illuminator brightness for hard-to-find fiducials. Intensity values are stored with the fiducial pattern and are automatically adjusted when a program is executed.*

Precision Laser Surface Sensing - *accurately locates substrate surfaces without contact.*

Taper-Lock™ Mounting Hardware - *allows valves and tools to be removed from the system without Allen wrenches or other tools.*

Toolless Pump Cleaning - *valves are designed for disassembly without tools, making for easy valve maintenance.*

Jetting Technology - *high speed, non-contact dispensing.*

Automatic Needle Calibration - *standard feature that makes the system automatically calibrate the position of a dispense tip. Complete process takes approximately 30 seconds.*

Auto Nozzle Cleaning - *cleans a needle or nozzle before dispensing. Ensures a good dispense process.*

FLOware® Software - *proprietary software makes programming substrates and converting data easy. Additional process monitoring features allow system and operator productivity to be monitored and saved for later recall.*

Temperature Monitoring - *monitors the temperature of a substrate in the pre-heater for precise process control.*

Non-Contact Work Area Heat available - *allows one fixture to be used for a variety of substrates as long as the package dimensions do not change.*

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