

Flow Front and Mold Bleed Control System and Method

Field of the Invention

[0001] The present invention relates to semiconductors packaging. In particular, the invention relates to a molding method and system for encapsulating semiconductor device with flow front and mold bleed control.

Background

[0002] In semiconductor packaging, multiple IC dies are generally mounted and wire bonded on one substrate, such as single row lead-frames, matrix lead-frames and high-density matrix lead-frames, and molds for packaging the IC dies are often designed for loading more than one substrate. These molds include encapsulant extrusion-ports, runners and cavities/compartments, which are designed to correspond with the substrate layouts. It is possible that the mold is designed to encapsulate multiple IC dies within one mold cavity/compartment, or to have dedicated mold cavities/compartments for each IC die.

[0003] In a molding process, improper control of encapsulant flow within the mold cavities/compartments often results in defective encapsulation. It is therefore a challenge for mold makers to design a mold having cavities and runners that provide consistent and balance flow of the encapsulant. During the mold design, designers often need to simulate the encapsulant flow as design aid to optimize the design before casting the mold.

[0004] One known problem in the semiconductors packaging is the imbalance flow and uneven filling within mold cavities due to the differences in cross sectional areas or gates between top mold cavities, where the IC dies are positioned, and bottom mold cavities. Such problem often causes blockage to the air vents resulting in the formation of internal, external voids or incomplete filling.

[0005] The flow patterns and speeds are often affected by the following features: die size and thickness relative to cavity size and height; gate configuration, such as gate depth, gate angle, top gating or bottom gating; and die pad size or down-set of lead frame. However, it is not possible for a single or unique mold design to cater for myriad of factors mentioned above.

[0006] In matrix layout lead-frame packages molding, there exist a “Christmas tree” filling pattern **610** as shown in FIG. 6a. The “Christmas tree” effect can often be reduced by varying runners and branches sizes and angles and/or varying gate sizes of the cavities.

[0007] Bleed/flash effect is common in exposed-pad packages **625** as shown in FIG. 6b. The exposed-pad packages **625** loaded on the mold **629** are not firmly secured thereon. When the encapsulant compound resin **624** is transferred into the mold cavities **621**, the flow of encapsulant compound **624** often shifts, lifts or tilts the exposed-pad packages **625**, thereby, causing the encapsulant compound to slip (circled portion **622**) under the exposed-pad packages **625**.

[0008] One way of dealing with the bleed/flash effect is to use film-assisted molding method, where the exposed portion of the pad sits on a film with a soft surface during the molding process to obtain a flash-free exposed-pad package. Alternatively, the mold cavity can be designed to have an interface for adapting a down-set of the lead-frame die pad for preventing the bleed/flash effect. Yet another alternative is using vacuum suction to hold and keep the die pad against the cavity face to produce a flash-free exposed die pad.

[0009] However, for mold to perform film-assisted molding, relieves must be etched into the mold surfaces to cater for the film thickness. In such case, the mold is not universal and unable to run without film. Further, when the alternative method is used, there is no consistency in the flash free condition achieved as tolerance of the cavity depth and down-set of the lead-frame die pad varies for different type of substrate. Further, the vacuum holes used to hold and keep the die pad in place are prone to blockage in the event of any bleed out of the encapsulant compound.

[0010] The bleed/flash effect too occurs between lead-frame and tape in QFN packages. In QFN packages molding, be it for wire bonded or flip-chip, requires flash-free at leads and contact pads. Usually, these surfaces are pre-taped with high-temperature polyimide tape to prevent mold resin seeping to these surfaces. Further, most QFN packages are molded in map and matrix on a panel substrate and the panel substrate is often clamped only along its peripherals. However, there is no room on the leads for clamping to prevent bleed/flash.

[0011] The bleed/flash effect can be addressed by increasing adhesive strength of the polyimide tape and/or using strip vacuum to hold down the lead frame onto the bottom mold. The vacuum also functions as a media to relax the tape and aid the purging of air within the mold cavity. However, when the adhesive strength of the polyimide is increased, the amount of tape residue after the tape is removed from the lead frame increases accordingly. Additional cleaning process is required to remove the tape residue.

[0012] Yet another known problem is flow front unevenness and “wrapping” effect in array and stack die packages. When molding array packages, whether single die or stack die, flow front unevenness is particularly evident when die size/die surface area is large and gap for resin flow between die surface and cavity surface is small. Flow front of the mold resin flow faster where there is less resistance (for example, more space). As shown in circled portions **630** FIG. 6c, the faster flow fronts **632** are wrapping over to the slower flow fronts **634**. In view of this problem, the mold design is customized to provide a gate layout for a particular die array. As in the case of panel substrate molding, such dedicated design is not suitable for all die array or matrixes, and the method is not able to effectively control the flow pattern, flow front unevenness and “wrapping” effect. This is particularly evident with large die, stack die and also where gap for resin flow between die surface and cavity surface is small and narrow.

[0013] Vacuum assisted molding method and system has been suggested for controlling the mold resin flow. For example, see, US patent no 5,603,879. However, evaluations on the vacuum-assisted molding apparatus have shown that, it creates a

“drag” and further worsen the flow front unevenness, which does not address the problem with “wrapping” effect. Further, there is no evident that air trap can be purged if these gases remain within the encapsulant compound throughout the transfer process. FIG. 6d is a photo showing a cured encapsulant on a matrix lead-frame substrate molded with a conventional method as described above. The photo shows that the encapsulant flow front **640** is uneven and defective.

[0014] It can thus be seen that there exists a need for a simple and robust way for a method and system that can overcome the disadvantages of the existing prior art.

Summary

[0015] In accordance with one aspect, the present invention provides a process for encapsulating semiconductors comprising loading a substrate having at least one IC die mounted and wire bonded thereon, on a mold having a cavity adapted to correspond with the at least one IC die; providing positive pressures into the cavity; extruding encapsulant compound into the cavity for encapsulating the IC dies, wherein the extruded encapsulant compound has a flow direction against the positive pressures; terminating the positive pressures; and curing the encapsulant compound.

[0016] In accordance with one embodiment, the positive pressure may continuously exert until the cavity is filled with the encapsulant compound.

[0017] In accordance with another embodiment, the process may further comprise controlling the positive pressures before terminating the positive pressures.

[0018] In accordance with another embodiment, the process may further comprise sealing the mold fluidly after loading the substrate on the mold.

[0019] In accordance with yet another embodiment, wherein the positive pressures may be a fluid pressure. It is possible that the fluid is gas. Further, the gas may be nitrogen gas.

[0020] In accordance with yet another embodiment, the mold may comprise a plurality of cavities adapted to correspond with the IC dies.

[0021] Yet, in another embodiment the positive pressure may be exerted from a plurality of location into the cavity. It is possible that the encapsulant compound is extruded from a plurality of location into the cavity.

[0022] In accordance with another aspect, the present invention provides a molding apparatus for encapsulating a semiconductor substrate having a plurality of IC dies mounted and wire bonded thereon, said apparatus comprising a mold having a cavity for loading said substrate, wherein the cavity is adapted to correspond with the IC dies; a pressures pump for providing positive pressures into the cavity; and an encapsulant extrusion port for extruding encapsulant compound into the cavity for encapsulating the IC dies, wherein the extruded encapsulant compound has a flow direction against the positive pressures.

[0023] In accordance with one embodiment. the pressures pump may operable to exerts the positive pressures continuously until the cavity is filled with the encapsulant compound.

[0024] In accordance with another embodiment, the positive pressure may be controllable by the pressures pump while exerting the positive pressure into the cavity.

[0025] In accordance with yet another embodiment, the apparatus may further comprise sealing member for fluidly sealing the mold cavity.

[0026] In accordance with yet another embodiment, the positive pressures exerted by the pressures pump may be a fluid pressure. It is possible that the fluid is gas. Further, the gas may be nitrogen gas.

[0027] In accordance with yet another embodiment, the pressures pump may operable to exert positive pressures into the cavity from a plurality of location.

[0028] Yet, the encapsulant extrusion port may be operable to extrude encapsulant compound into the cavity from a plurality of locations.

[0029] Yet, the mold may comprise a plurality of cavities adapted to correspond with the IC dies in accordance with one embodiment.

Brief Description of the Drawings

[0030] This invention will be described by way of non-limiting embodiments of the present invention, with reference to the accompanying drawings, in which:

[0031] FIGs. 1a-d illustrate cross sectional views of a molding apparatus for encapsulating in various operation stages in accordance with an embodiment of the present invention;

[0032] FIGs. 1e-g illustrate a mold layout and an encapsulant flow of the molding apparatus of FIGs. 1a-d;

[0033] FIG. 2 illustrates a flow diagram of a molding process in accordance with one embodiment of the present invention;

[0034] FIG. 3a illustrates a cross sectional view of the molding apparatus having a mold in accordance with an alternative embodiment of the present invention; FIG. 3b illustrates a partial layout and an encapsulant flow of the mold of FIG. 3a;

[0035] FIG. 4 is a cross sectional view of a mold for encapsulating exposed pad semiconductors in accordance with another alternative embodiment of the present invention;

[0036] FIG. 5a is a cross sectional view of a mold in accordance with yet another alternative embodiment of the present invention; FIGs. 5b-d illustrate a partial layout of the mold of FIG. 5a and its encapsulant flows in various stages;

[0037] FIGs. 6a-d illustrate various encapsulant flows occurred in various known molding methods;

[0038] FIG. 7 is a photo showing a cured encapsulant formed on a matrix lead frame substrate molded in accordance with one embodiment of the present invention.

Detailed Description

[0039] In line with the above summary, the following description of a number of specific and alternative embodiments is provided to understand the inventive features of the present invention. It shall be apparent to one skilled in the art, however that this invention may be practiced without such specific details. Some of the details may not be described at length so as not to obscure the invention. For ease of reference, common reference numerals will be used throughout the figures when referring to the same or similar features common to the figures.

[0040] The present invention provides a molding method and apparatus for encapsulating semiconductors with flow front and mold bleed control. The method and apparatus operable to provide pressures into mold cavities while encapsulant compound is flowing into the mold cavities.

[0041] FIGs. 1a-g show cross sectional views of a molding apparatus **100** in various operation stages in accordance with one embodiment of the present invention. The molding apparatus **100** is a multipot molding system adapted to perform transfer molding for encapsulating semiconductor devices. The molding apparatus **100** includes two opposing parts, a top mold section **120** and a bottom mold section **110**, adapted for aligning and coupling with each other. The top mold section **120** is a static part and the bottom mold section **110** is a movable part. In operations, when the bottom mold section **110** is aligned with the top mold section **120**, the bottom mold section **110** can be brought to couple with the top mold section **120** and the transfer molding can be performed therein. The molding apparatus **100** is in an opened position in FIG. 1a. It should be understood by one skilled in the art that a molding system featuring a static top mold section and a movable bottom mold section will work equally well.

[0042] In FIGs. 1a-c, the bottom mold section **110** includes a bottom mold base **117** having bottom sidewalls **118** for removably holding a bottom mold **111**. A row of pots **115**, aligning along the center of the bottom mold **111**, extending through the bottom mold **111** from the bottom mold base **117** for containing encapsulant

compound. Each pot **115** has an opening top exposes on a surface **119** of the bottom mold **111** and a closed bottom sealed by an upwardly oriented plunger **116** for extruding the encapsulant compound. A plurality of cavities **112**, arranging in rows to the sides of the pots **115**, are defined on the surface **119**. Each cavity **112** includes a bottom vent groove **114** extending away from the corresponding pot **115** towards the sidewall **118**. The top mold section **120** includes a top mold base **127** having top sidewalls **128** for removably holding a top mold **121** downwardly facing the bottom mold **111**. The top mold base **127** is attached to a machinery conveyer (not shown) that operationally brings the top mold section **120** to align and to couple with the bottom mold section **110**. The downwardly facing surface **129** of the top mold **121** defines a row of channels **125** at the center of the surface **129** and each channel **125** corresponds to a pot **115** provided on the bottom mold **111**. Each channel **125** has a circular profile bigger than the opening of the pot **115**. The surface **129** further defines a plurality of cavities **122**, arranging in rows to the sides of the channels **125**. The cavities **122** are adapted to couple with the corresponding cavities **112** to form blocks of mold compartments. The surface **129** further defines runner grooves **126** for connecting each of the cavities **122** with a corresponding channel **125**. Each cavity **122** further includes top vent grooves **124**, extending away from the channel **125** towards the top sidewalls **128**. The bottom mold **111** and the top mold **121** are adapted for encapsulating single row lead-frame.

[0043] Still referring to FIGs. 1a-c, the molding apparatus **100** further includes a pressure pump **130** having pipes **132** connecting to vents **134** of the top sidewalls **128**. The vents **134** extend into the top mold **121** through the top sidewalls **128**. The molding apparatus **100** is configured in a manner that, when the top mold section **120** is coupled with the bottom mold section **110**, i.e. the molding apparatus **100** is in a closed position as shown in FIGs. 1b-d, it forms a fluid path from the pots **115** to the pressure pump **130**, via the channels **125**, the runner grooves **126**, the cavities **112** and **122**, the bottom vent grooves **114** and the top vent grooves **124**. The molding apparatus **100** is also provided with seal members **150** near its marginal edges as gaskets for preventing fluid leakage in the fluid path.

[0044] FIG. 2 is a flow diagram showing the process of molding substrate in accordance one embodiment. Details of the process will be illustrated in conjunction with the FIGs. 1a-d. The process include the steps of loading and placing substrates in step **210**; soft-closing the molding apparatus **100** in step **220**; starting the pressure pump **130** in step **230**; hard-closing the molding apparatus **100** in step **240**; extruding pre-heated encapsulant compound in step **250**; stopping the pressures pump in step **260**; curing encapsulant compound in step **270**; and removing encapsulated substrates in step **280**.

[0045] Referring back to FIG. 1a, a plurality of substrates **200** are loaded on both sides to the pots **115** at step **210**. Each substrate **190** having a row of IC dies **192** attached and wire bonded thereto. The cavities **112** and **122** are adapted to provide one molding compartment for encapsulating one IC die **192**.

[0046] Referring now to FIG. 1b, when the substrates **190** are properly loaded and aligned, the pots **115** are filled with a predetermined amount of encapsulant compound **180**. The encapsulant compound **180** is pre-heated before loading into the pots **115**. When the substrates **190** are loaded onto the bottom mold **111** and the encapsulant compound **180** is loaded in the pots **115**, the molding apparatus **100** performs a soft-close or partial-close at step **220**, where the top mold section **120** is brought to a position that the top sidewalls **128** is slightly in contact with the seal members **150** for sealing the bottom side walls **118**. At step **230**, the pressures pump **130** starts applying positive pressure along the fluid path within the molding apparatus **100** as shown by arrow **135**. The positive pressure first passes through the pipe **132** and flows into the vent grooves **114** and **124** via the vents **134**. The positive pressure enters into the mold compartment formed by cavities **112**, **122** and then fills up the channels **125** via the runner grooves **126**.

[0047] Referring now to FIG. 1c, where the molding apparatus **100** is closed firmly at step **230**. At this stage, the top mold section **120** is brought closer towards to the bottom mold section **110** and the sealing members **150** on the bottom sidewalls **118** deform as they are pressured by the top sidewalls **128**. The top mold section **120** is brought close enough to ensure no fluid leakage. The pressures pump **130** continues to

provide positive pressure into the fluid path. At step **250**, the plunger **116** start moving upward (as shown by arrow **136**) to transfer the encapsulant compound **180** into the channels **125**.

[0048] Referring now to FIG. 1d, as the plunger **116** is moving upward, the encapsulant compound **180** starts filling up the channels **125**. Once the channels **125** is filled-up, the encapsulant compound **180** flows into the runners grooves **126** until it reaches the mold compartments formed by the cavities **112** and **122** as shown in FIG. 1e. The encapsulant compound **180**, instead of flowing freely and unevenly within the mold compartments, will be controlled by the positive pressure exerted by the pressure pump **130** to fill-up the backward cavities, thus distributing flow fronts **185** evenly during the molding process. FIG. 1f (and FIG. 1d) shows that the encapsulant compound **180** has filled-up half of the mold compartments, whilst the flow fronts **185** remain evenly distributed. FIG. 1g shows the encapsulant compound **180** has filled up the entire mold compartments, and when it is so, the pressure pump **130** stops supplying positive pressure in step **260**. The molding apparatus **100** remains at the closed position until the encapsulant compound **180** is cured and hardened after curing at step **270**. The encapsulated substrate **490** will be removed from the molding apparatus **100** at step **280** for singulation.

[0049] In accordance with the above embodiment, the pressures pump **130** is configured to exert positive pressures in a direction opposite the flow of the encapsulant compound. The pressure can be any kind of fluid pressure, which includes gas pressure, such as nitrogen gas. The positive pressures within the cavities control the encapsulant compound to reduce the flow speed differences of the flow front within the mold cavities caused by the gate differences, thereby reducing the wrapping effect and the uneven flow front. In addition, the positive pressures further compact the encapsulant compound to reduce porosity of the encapsulant thereby to provide flow front with smoother edge. Further, the positive pressures also exert pressure on the substrate **190** to sit firmly within the mold cavities. When appropriate, the positive pressures may be varied by controlling the pressures pump **130** during the encapsulant process to provide better control of the encapsulant compound flow.

[0050] FIG. 3a is a cross sectional view of the molding apparatus **100** in a closed position in accordance with an alternative embodiment of the present invention. The molding apparatus **100** includes a mold **301** suitably adapted for encapsulating substrates **390**. The mold **301** is divided into two parts, a bottom mold **311** and a top mold **321**, each having a surface opposing the other. A row of pots **315**, aligning along the center of the bottom mold **311**, extending through the bottom mold **311** for containing encapsulant compound. Each pot **315** has an opening top exposes on the surface of the bottom mold **311** and a closed bottom sealed by an upwardly oriented plunger **316**. The plunger **316** operationally slides within the pot **315** for transferring the contents of the pot **315** therefrom. The top mold **321** has channels **325** defining along the center of the top mold **321**. Each of the channels **325** corresponds to one pot **315**. The mold **301** further includes rows of compartments **310**, formed by corresponding cavities defining on the surfaces of the bottom mold **311** and top mold **321**, aligning to each side of the channels **325**. The top mold **321** further defines runner grooves **326** on its surface for fluidly joining the mold compartments **310** to the corresponding channel **325**.

[0051] FIG. 3b shows a partial layout **350** of the mold **301** of FIG. 3a. The mold **301** is a multipot mold adapted for encapsulating substrates **390** of twelve IC dies **392** arranged in a 3 by 4 matrixes arrangement. The partial layout **350** includes one of the channels **325** having a circular profile larger than the opening of the pot **315**; twelve mold compartments **311**, located to the left of the channel **325**, having an arrangement adapted to correspond with the IC dies **392**; runner grooves **326** extend from the channel **325** and branch to each of the mold compartments **311**; and vent grooves **314** extend from the mold compartments **311** away from the channel **325** toward the pressures pump **130**. The cavities defined on the mold **301** (i.e. the channel **325**, the runner grooves **326**, the mold compartments **311** and vent grooves **314**) established a fluid path from the pot **315** to the pump **130**. In operation, when the substrate **390** is loaded onto the mold **301**, the pressures pump **130** starts exerting positive pressure, and the plunger **316** forces the encapsulant compound within the pot **315** to flow into the channel **325**. The positive pressure continuously pressurizing and compacting the encapsulant compound to fill up the channel **325**. When the channel **325** is filled up with the encapsulant compound, the encapsulant compound flows into the runner

grooves 326. When the encapsulant compound reaches the branches of the runner grooves 326, the compound flows into the rows mold compartments 311 succeedingly as the positive pressure forcing against the compound flow. The pressures pump 130 stops when all the mold compartments 311 are filled with the encapsulant compound.

[0052] FIG. 4 is a cross sectional view of a mold 490 for encapsulating exposed pad semiconductors in accordance with one embodiment of the present invention. The mold 490 defines a plurality of mold compartments 410. The cavities 411 have a depth when a substrate 490 is loaded on the bottom mold 411, the exposed pads 495 abut on the bottom surface of the corresponding cavities 411. During the die encapsulating process, a pressure pump (not shown) exerting positive pressures toward the pot 415 through the mold compartments 410 and vent grooves 414 as shown by arrow 435. The positive pressures within the mold compartments 410 further exert force to push the exposed pad 495 against the bottom surfaces of the mold compartments 410. A molding compound 480 flows from pots 415 into the mold compartment 410 to fill up the cavities 411. As the positive pressure is exerting forces within the mold compartments, the exposed pads 495 are secured against the bottom surface of the cavities 411 for preventing “bleeds” of the encapsulant compound.

[0053] FIG. 5a is a cross sectional view of a mold 501 adapted for encapsulating substrates 590 within one mold cavity 510 in accordance with yet another alternative embodiment of the present invention. The substrate 590 is a matrix lead frames type substrate, where IC dies 592 are mounted and wire bonded on a panel substrate. The mold 501 further defines channels 525, each corresponds to a pair of cavities 510 via three runners grooves 526 as shown in FIGs. 5b-d. In operation, when the mold 501 is closed, the pressures pump starts applying positive pressures to the cavities 510 as shown by the arrows 535. The positive pressures also exerting forces (as shown by arrows 536) to press the substrate 590 down against the loading bay to prevent encapsulant compound 580 seep under the substrate 590. As the positive pressures is exerting on the encapsulant flow, the encapsulant compound 580 fills up the back end cavities. With the positive pressures, the encapsulant compound 580 flow is more compact and air, vapors and combustion air are pressed out from the encapsulant compound 580. Further, the positive pressures reduce the speed

differences between the flow fronts, thereby preventing wrapping effect occurs during the molding process.

[0054] FIG. 7 is a photo showing a cured encapsulant formed on a matrix lead-frame substrate molded in accordance with one embodiment of the present invention. The photo shows that the cured encapsulant has a flow front **710** that is more compact and provides smoother edges.

[0055] In accordance with one embodiment, the pressure pump provides a positive pressure that is lower than a pressure of injecting of encapsulant.

[0056] While specific embodiments have been described and illustrated, it is understood that many changes, modifications, variations and combinations thereof could be made to the present invention without departing from the scope of the invention.

Claims

1. A process for encapsulating semiconductors comprising:
 - loading a substrate having at least one IC die mounted and wire bonded thereon, on a mold having a cavity adapted to correspond with the at least one IC die;
 - providing positive pressures into the cavity;
 - extruding encapsulant compound into the cavity for encapsulating the IC dies, wherein the extruded encapsulant compound has a flow direction against the positive pressures;
 - terminating the positive pressures; and
 - curing the encapsulant compound.
2. The process according to claim 1, wherein the positive pressure is continuously exerting until the cavity is filled with the encapsulant compound.
3. The process according to claim 2, further comprising controlling the positive pressures before terminating the positive pressures.
4. The process according to claim 1, further comprising sealing the mold fluidly after loading the substrate on the mold.
5. The process according to claim 1, wherein the positive pressures is a fluid pressure.
6. The process according to claim 5, wherein the fluid is gas.
7. The process according to claim 6, wherein the gas is nitrogen gas.
8. The process according to claim 1, wherein the mold comprises a plurality of cavities adapted to correspond with the IC dies.
9. The process according to claim 1, wherein the positive pressures is exerted from a plurality of location into the cavity.

10. The process according to claim 1, wherein the encapsulant compound is extruded from a plurality of location into the cavity.
11. A molding apparatus for encapsulating a semiconductor substrate having a plurality of IC dies mounted and wire bonded thereon, said apparatus comprising:
 - a mold having a cavity for loading said substrate, wherein the cavity is adapted to correspond with the IC dies;
 - a pressures pump for providing positive pressures into the cavity; and
 - an encapsulant extrusion port for extruding encapsulant compound into the cavity for encapsulating the IC dies, wherein the extruded encapsulant compound has a flow direction against the positive pressures.
12. The apparatus according to claim 11, wherein the pressures pump operable to exerts the positive pressures continuously until the cavity is filled with the encapsulant compound.
13. The apparatus according to claim 12, wherein the positive pressure is controllable by the pressures pump while exerting the positive pressure into the cavity.
14. The apparatus according to claim 11, further comprising sealing member for fluidly sealing the mold cavity.
15. The apparatus according to claim 11, wherein the positive pressures exerts by the pressures pump is a fluid pressure.
16. The apparatus according to claim 15, wherein the fluid is gas.
17. The apparatus according to claim 16, wherein the gas is nitrogen gas.
18. The apparatus according to claim 11, wherein the pressures pump operable to exert positive pressures into the cavity from a plurality of location.

19. The apparatus according to claim 11, wherein the encapsulant extrusion port operable to extrude encapsulant compound into the cavity from a plurality of location.
20. The apparatus according to claim 11, wherein the mold comprises a plurality of cavities adapted to correspond with the IC dies.