

(19) World Intellectual Property  
Organization  
International Bureau



(43) International Publication Date  
24 February 2005 (24.02.2005)

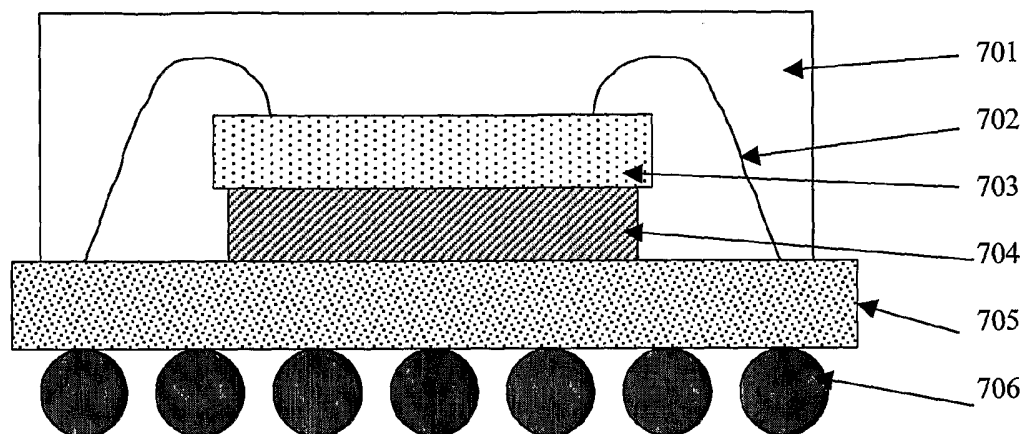
PCT

(10) International Publication Number  
WO 2005/017995 A1

- (51) International Patent Classification<sup>7</sup>: H01L 21/56, 23/31, 21/58
- (21) International Application Number: PCT/US2004/025050
- (22) International Filing Date: 29 July 2004 (29.07.2004)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data: 60/493,857 8 August 2003 (08.08.2003) US
- (71) Applicant (for all designated States except US): **DOW CORNING CORPORATION** [US/US]; 2200 West Salzburg Road, Midland, MI 48686-0994 (US).
- (72) Inventors; and
- (75) Inventors/Applicants (for US only): **CHENG, Tammy** [US/US]; 1323 Colorado Court, Midland, MI 48642 (US). **DOBRZELEWSKI, Mark** [US/US]; 3292 East Shady Ridge Lane, Midland, MI 48642 (US). **WINDIATE, Christopher** [US/US]; 2198 Fraser Road, Kawkawlin, MI 48631 (US). **SOLOMON, Daniel** [US/US]; 1361 Poseyville Road, Midland, MI 48640 (US).
- (74) Agent: **BROWN, Catherine, U.**; Patent Department - Mail CO1232, 2200 West Salzburg Road, Midland, MI 48686-0994 (US).
- (81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.
- (84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).
- Declarations under Rule 4.17:**
- as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii)) for all designations
  - as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii)) for the following designations AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU,

[Continued on next page]

(54) Title: PROCESS FOR FABRICATING ELECTRONIC COMPONENTS USING LIQUID INJECTION MOLDING



(57) Abstract: A process for fabricating an electronic component includes a liquid injection molding method for overmolding a semiconductor device. The liquid injection molding method includes: i) placing the semiconductor device in an open mold, ii) closing the mold to form a mold cavity, iii) heating the mold cavity, iv) injection molding a curable liquid into the mold cavity to overmold the semiconductor device, v) opening the mold and removing the product of step iv), and optionally vi) post-curing the product of step v). The semiconductor device may have an integrated circuit attached to a substrate through a die attach adhesive.

WO 2005/017995 A1



LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, UZ, VC, VN, YU, ZA, ZM, ZW, ARIPO patent (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG)

— of inventorship (Rule 4.17(iv)) for US only

**Published:**

— with international search report

— before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

PROCESS FOR FABRICATING ELECTRONIC COMPONENTS USING LIQUID  
INJECTION MOLDING

**DESCRIPTION**

5

Technical Field

[0001] This invention relates to a process for fabricating electronic components. More particularly, this invention relates to a process for fabricating electronic components that includes a liquid injection molding method. The liquid injection molding method may be used to provide an overmold over a semiconductor die, such as an integrated circuit, on a substrate.

10

Background

[0002] Several methods for overmolding an integrated circuit include stencil or screen printing, dam and fill, and transfer molding. However, overmolding methods known in the art suffer from drawbacks. For example, the stencil or screen printing method may be slow and may generate high waste, for example, as much as 70%. The dam and fill method is a two step process and may result in lower throughput. Transfer molding methods may have high waste, for example, as much as 50 to 70% of the molding material. There is a continuing need for methods of fabricating electronic components having higher efficiencies, lower temperatures, and lower waste production.

15

20

Summary

[0003] This invention relates to liquid injection molding method and a process for fabricating an electronic component using the liquid injection molding method.

Detailed Description of the Invention

[0004] All amounts, ratios, and percentages are by weight, unless otherwise indicated. The following is a list of definitions, as used herein.

25

*Definitions*

[0005] "M" means a monofunctional siloxane unit of the formula  $\text{RSiO}_{3/2}$ , where R represents a monovalent group such as an organic group, hydroxyl group, or hydrogen atom.

[0006] "D" means a difunctional siloxane unit of the formula  $\text{R}_2\text{SiO}_{2/2}$ .

30

[0007] "T" means a trifunctional siloxane unit of the formula  $\text{R}_3\text{SiO}_{3/2}$ .

[0008] "Q" means a tetrafunctional siloxane unit of the formula  $\text{SiO}_{4/2}$ .

[0009] "Silicone" and "siloxane" are used synonymously herein.

[0010] "Wire sweep" is movement of wires out of the designed shape, *e.g.*, arc. If wire sweep is too extreme, it can result in either wire breakage or wire contact, or both. Either of these will result in a defective electronic device.

*Methods of this Invention*

5 [0011] This invention relates to a method for fabricating an electronic component. The method comprises liquid injection molding a curable liquid over a semiconductor device, where the curable liquid cures to form an overmold. The curable liquid fills the voids in the semiconductor device and forms a hermetic seal over the substrate protecting it from environmental exposure. The semiconductor device may comprise a substrate on which a  
10 semiconductor die will be mounted, a semiconductor die mounted on a substrate, where the semiconductor die has yet to be electrically connected to the substrate, or a semiconductor die mounted on a substrate, where the semiconductor die is electrically connected to the substrate. When the semiconductor device includes a semiconductor die, the semiconductor die may be attached to a substrate through a die attach adhesive by any convenient means.

15 [0012] For example, the semiconductor die may be attached to the substrate by a process comprising:

- a) applying a die attach adhesive composition to a substrate,
- b) attaching a semiconductor die to the die attach adhesive composition, and
- c) curing the die attach adhesive composition to form a die attach adhesive.

20 [0013] Alternatively, the semiconductor die may be attached to the substrate by a process comprising:

- a) applying a die attach adhesive composition to a substrate,
- b) curing the die attach adhesive composition to form a die attach adhesive,
- c) plasma treating a surface of the die attach adhesive,
- 25 d) plasma treating a surface of the semiconductor die, and
- e) contacting the plasma treated surface of the semiconductor die with the plasma treated surface of the die attach adhesive.

[0014] These methods may optionally further comprise the step of electrically connecting the semiconductor die to the substrate after the semiconductor die is attached to the substrate  
30 through the die attach adhesive. Electrically connecting the semiconductor die to the substrate may be performed, *e.g.*, by wire bonding, when the die attach adhesive does not provide an electrical connection between the semiconductor die and the substrate.

[0015] The semiconductor die is overmolded by injection molding a curable liquid over the semiconductor die, which may or may not be wire bonded.

*Applying Die Attach Adhesive Composition*

[0016] The die attach adhesive composition may be applied to the substrate by any convenient means, such as a printing process exemplified by screen printing and stencil printing. The die attach adhesive composition may comprise a curable silicone composition that cures to form a silicone, a curable silicone-organic composition that cures to form a silicone-organic copolymer, or a curable organic composition that cures to form an organic die attach adhesive.

*Die Attach Adhesive*

[0017] The die attach adhesive composition cures to form a die attach adhesive. The mode of cure of the die attach adhesive composition is not critical, and can include cure mechanisms such as condensation reactions; addition reactions; ultraviolet radiation initiated reactions, and free radical initiated reactions. The method of curing the die attach adhesive composition is not critical and may include, for example heating, exposure to radiation, or combinations thereof.

The die attach adhesive may be a cured organic such as a cured organic resin, a cured organic elastomer, a cured organic polymer, or combinations thereof. Suitable cured organic resins include cured epoxy resins. Suitable cured organic elastomers include polyurethane.

Suitable cured organic polymers include epoxy, polyimide, polyimide copolymers, and combinations thereof. Alternatively, the die attach adhesive may be a silicone-organic copolymer such as a poly(diorganosiloxane/organic) block copolymer exemplified by poly(diorganosiloxane/amide) copolymer, and silarylene.

[0018] Alternatively, the die attach adhesive may be a cured silicone, such as a cured silicone resin, a cured silicone elastomer, a cured silicone rubber, or combinations thereof. Suitable cured silicone resins include T, DT, MT, MQ resins, and combinations thereof.

[0019] Plasma treating a surface of the die attach adhesive may be carried out by any convenient means, such as those disclosed in WO 2003/41130. "Plasma treating" means exposing a substrate to a gaseous state activated by a form of energy externally applied and includes, but is not limited to, corona discharge, dielectric barrier discharge, flame, low pressure glow discharge, and atmospheric glow discharge treatment. The gas used in plasma treatment can be air, ammonia, argon, carbon dioxide, carbon monoxide, helium, hydrogen,

krypton, neon, nitrogen, nitrous oxide, oxygen, ozone, water vapor, combinations thereof, and others. Alternatively, other more reactive gases or vapors can be used, either in their normal state of gases at the process application pressure or vaporized with a suitable device from otherwise liquid states, such as hexamethyldisiloxane, cyclopolydimethylsiloxane, 5 cyclopolyhydrogenmethylsiloxanes, cyclopolyhydrogenmethyl-co-dimethylsiloxanes, reactive silanes, and combinations thereof.

**[0020]** Die attach may be carried out by

- a) plasma treating a surface of the die attach adhesive,
- b) plasma treating a surface of the semiconductor die, and

10 c) thereafter contacting the plasma treated surface of the semiconductor die with the plasma treated surface of the die attach adhesive. The die attach adhesive may be contacted with the the semiconductor die as soon as practicable after plasma treatment. Alternatively, the method may optionally further comprise: storing the die attach adhesive after step a) and before step c), or storing the semiconductor die after step b) and before step c), or both.

15 **[0021]** Steps a) and b) may be carried out concurrently or sequentially in any order. Plasma treatment can be carried out on all or a portion of the surface of the die attach adhesive or the semiconductor, or both.

**[0022]** The die attach adhesive can be stored for at least 0, alternatively at least 1, alternatively at least 2 hours after plasma treatment. The die attach adhesive can be stored for 20 up to 48, alternatively up to 24, alternatively up to 8, alternatively up to 4 hours after plasma treatment. The same storage conditions can be used independently for the die attach adhesive and the semiconductor.

**[0023]** Adhesion can be obtained by carrying out step c) for a few seconds at room temperature. Alternatively, step c) may be carried out at elevated temperature, elevated 25 pressure, or both. The exact conditions selected for step c) will depend on various factors including the specific use of the method. However, temperature during the contacting step can be at least 15 °C, alternatively at least 20 °C, alternatively at least 100 °C. Temperature during contacting can be up to 400 °C, alternatively up to 220 °C. Pressure during contacting can be up to 10 megaPascals, alternatively up to 1 megaPascal. Pressure during contacting is 30 at least 0.1 megaPascal. Contact time can be at least 0.1 second, alternatively at least 1 second, alternatively at least 5 seconds, alternatively at least 20 seconds. Contact time can be

up to 24 hours, alternatively up to 12 hours, alternatively up to 30 minutes, alternatively up to 30 seconds.

[0024] The integrated circuit may be electrically connected to the substrate by any convenient means, such as through use of an electrically conductive die attach adhesive or by wire bonding. Wire bonding methods are known in the art, for example, see Charles A. Harper, Ed., "Package Assembly Process," Electronic Packaging and Interconnection Handbook, 2<sup>nd</sup> ed., pp. pp. 6.66 – 6.77, McGraw-Hill, New York, 1997.

*Compositions for Liquid Injection Molding*

[0025] The semiconductor die is overmolded using a liquid injection molding method. The semiconductor die may be overmolded using a curable liquid organic composition, a curable liquid silicone-organic copolymer composition, or a curable liquid silicone composition. The type of curable liquid composition selected depends on various factors including the type of die attach adhesive used. Without wishing to be bound by theory it is thought that adhesion may improve when the die attach adhesive contains reactive groups with which the curable liquid used for moldmaking reacts. For example, when a silicone die attach adhesive is used, it is preferable for liquid injection molding to use a curable liquid silicone-organic copolymer composition, or a curable liquid silicone composition, having the same or similar cure mechanism such that groups reactive with the curable liquid for liquid injection molding are present in the die attach adhesive. Alternatively, when a silicone die attach adhesive is used, a curable liquid silicone composition is more preferred for liquid injection molding.

[0026] Examples of suitable curable liquid organic compositions include curable liquid epoxies, curable liquid cyanate esters, and combinations thereof. Examples of suitable curable liquid silicone-organic copolymer compositions include curable liquid compositions that cure to form poly(diorganosiloxane/organic) block copolymers such as poly(diorganosiloxane/amide) copolymers.

[0027] Suitable curable liquid silicone compositions include condensation reaction curable liquid silicone compositions; addition reaction curable liquid silicone compositions; ultraviolet radiation initiated curable liquid silicone compositions, and free radical initiated curable liquid silicone compositions.

[0028] Addition reaction curable silicone compositions may be used to minimize by-products formed when curing, as compared to the other types of curable liquid silicone compositions. The addition reaction curable liquid silicone composition may comprise (A)

an organopolysiloxane having an average of at least two alkenyl groups per molecule, (B) an organohydrogenpolysiloxane having an average of at least two silicon atom-bonded hydrogen atoms per molecule, and (C) a hydrosilylation catalyst. The addition reaction curable liquid silicone composition may further comprise one or more optional ingredients selected from (D) a filler, (E) a treating agent for the filler, (F) a catalyst inhibitor, (G) a solvent, (H) an adhesion promoter, (I) a photosensitizer, (J) a pigment, (K) a flexibilizer, and combinations thereof.

**[0029]** Component (D) is a filler. Suitable fillers include reinforcing fillers such as silica (*e.g.*, fumed silica, fused silica, and ground silica), titania, and combinations thereof.

Alternatively, component (D) may be thermally conductive, electrically conductive, or both. Alternatively, component (D) may comprise a combination of conductive and nonconductive fillers. Component (D) may comprise DRAM grade filler or a mixture of DRAM grade filler and filler of a lesser purity than DRAM grade filler. Component (K) may comprise a long chain alpha-olefin, *e.g.*, an olefin with 14 or more carbon atoms.

The curable liquid may be a one-part composition or a multiple-part composition such as a two-part composition. When an addition reaction curable liquid silicone composition is formulated as a one-part composition, a hydrosilylation catalyst inhibitor (F) may be included. When an addition reaction curable liquid silicone composition is formulated as a multiple-part composition, any Si-H containing ingredients are stored separately from any hydrosilylation catalyst.

The curable liquid is formulated to have a viscosity that will minimize wire sweep under the liquid injection molding conditions. Without wishing to be bound by theory, it is thought that viscosity that is too high will contribute to wire sweep, however, viscosity that is too low may allow the curable liquid to leak from the mold. For some addition reaction curable liquid silicone compositions viscosity may be 80 to 3,000 Poise.

The curable liquid may be formulated to have a cure speed that will minimize wire sweep under the liquid injection molding conditions. Without wishing to be bound by theory, it is thought that a cure speed that is too fast may contribute to wire sweep, however, cure speed that is too slow may render the process inefficient. For some addition reaction curable liquid silicone compositions, cure speed may be 30 to 120 seconds at 80 to 240 °C, alternatively 30 to 60 seconds at 80 to 180 °C, alternatively 30 to 60 seconds at 80 to 150 °C.

[0033] The curable liquid may be formulated to cure to form an overmold having a modulus and coefficient of thermal expansion (CTE) that will enable the electronic device to pass a minimum of Moisture Resistance Testing, Level 2A, as defined by JEDEC Standard J-STD-020B. The curable liquid may be formulated to cure to form an overmold having a modulus and CTE that will further enable the electronic device to pass JEDEC Temperature Cycle Test as defined by JEDEC Standard JESD22-A, 104-B, Condition B, and to provide adequate protection for the wires in a wire bonded semiconductor die after fabrication of the semiconductor device is complete. Without wishing to be bound by theory, it is thought that if modulus is too low, the wires may not have sufficient protection after fabrication of the electronic component is complete. For some addition reaction curable liquid silicone compositions, modulus may be 25 to 1,000 megaPascals. For some organic curable liquid compositions, modulus may be up to 3,000 megaPascals. It is also thought that if CTE is too high and modulus is too low, the wires may not have sufficient protection after fabrication of the electronic component is complete. Furthermore, it is thought that if CTE and modulus are both too high, stress on the wires may be too high, resulting in reduced reliability. For some addition reaction curable liquid silicone compositions, CTE may be 80 to 300 ppm/ °C, alternatively 80 to 150 ppm/ °C, alternatively 80 to 100 ppm/ °C. For some curable organic compositions, such as liquid epoxies, CTE may be 10 to 30 ppm/ °C.

*Liquid Injection Molding Method*

[0034] The liquid injection molding method of this invention comprises:

- i) placing a semiconductor device, described above, in an open mold,
- ii) closing the mold to form a mold cavity housing the semiconductor device,
- iii) heating the mold cavity,
- iv) injection molding a curable liquid described above into the mold cavity to overmold the semiconductor device,
- v) opening the mold and removing the product of step iv), and
- optionally vi) post-curing the product of step v).

[0035] Step ii) may be performed by applying a clamping force to the mold. Without wishing to be bound by theory, it is thought that if clamping force is too high, the semiconductor device may be damaged during liquid injection molding, however, if clamping force is too low, the curable liquid may leak out of the mold. For some addition reaction curable silicone compositions, step ii) may be performed by applying a clamping force of 1 to

80, alternatively 1 to 27 tonnes to the mold, alternatively 10 to 25 tonnes. Step iii) may be performed at a time and temperature of 30 to 120 seconds at 80 to 240 °C, alternatively 30 to 60 seconds at 80 to 180 °C, alternatively 30 to 60 seconds at 80 to 150 °C.

5 [0036] Step iv) may be carried out at an injection speed sufficient to provide a pressure of 0.3 to 7.0 MPa in the mold cavity. Step iv) may be performed using commercially available liquid injection molding equipment, such as a liquid injection molding apparatus, Model No. 270S 250-60, from Arburg, Inc., of Newington, CT, U.S.A with a mold available from Kipe Molds, Inc., of Placentia, CA, U.S.A. The exact configuration of the liquid injection molding equipment depends on various factors including the exact configuration of the mold and the  
10 semiconductor device.

[0037] Figure 1 is a schematic representation of liquid injection molding process equipment 100 for use in the method of this invention. The liquid injection molding process equipment 100 includes a feed system 101 for the two parts of a two part curable liquid silicone composition, as described above. The two parts are fed from the feed tanks 102, 103 to static  
15 mixer 104, which mixes the two parts. The resulting curable liquid silicone composition enters extruder 105 and is forced into a mold 106 through an inlet 107 to a sprue and runner system (not shown). The mold 106 may have various configurations, as discussed below and shown in Figures 2a-4b, which represent cross sectional views taken along cross section line  
20 108 and Figures 5-6, which represent cross sectional views taken along cross section line 109.

[0038] Alternatively, a one part curable liquid can be fed directly into extruder 105 from feed tank 102 (bypassing the static mixer 104).

[0039] Figure 2a is a cross sectional view taken along line 108 of a mold 106 for use in the liquid injection molding process equipment 100 in Figure 1. Figure 2a shows the mold in its  
25 open position. The mold 106 is a three part mold in which the first section 201 houses the inlet 107 and the sprue 210. The second section 202 houses the runner system 211. The third section is a mold retainer 203 that holds the substrate 204 having semiconductor dice 205 attached to the surface of the substrate 204 in mold cavities 206. The curable liquid enters the mold cavities 206 at the tops of the semiconductor dice 205 through gates 207. Figure 2b  
30 is the mold 106 in Figure 2a shown in its closed position. The mold 106 in Figures 2a and 2b includes heaters (not shown) for the runner system 211.

[0040] Figure 3a is a cross sectional view taken along line 108 of an alternative mold 106 for use in the liquid injection molding process equipment 100 in Figure 1. Figure 3a shows the mold in its open position. The mold 106 is a two part mold in which the first section 301 houses the inlet 107, sprue 310 and runner system 311. The second section is a mold retainer 5 303 that holds the substrate 304 having semiconductor dice 305 attached to the surface of the substrate in mold cavities 306. The curable liquid enters the mold cavities 306 at the tops of the semiconductor dice 305 through gates 307. Figure 3b is the mold 106 shown in Figure 3a in its closed position. The mold 106 in Figures 3a and 3b has coolers, *e.g.*, a refrigerated water system, (not shown) for the sprue 310 and runner system 311.

10 [0041] Figure 4a is a cross sectional view taken along line 108 of an alternative mold 106 for use in the liquid injection molding process equipment 100 in Figure 1. Figure 4a shows the mold 106 in its open position. This mold 106 is a two part mold in which the first section 401 houses mold cavities 406 and the runner system (not shown). The mold retainer 403 holds the substrate 404 having semiconductor dice 405 attached to the surface of the substrate 15 404 in mold cavities 406. The mold retainer 403 houses the inlet 107 and the sprue 410. Figure 4b shows the mold 106 in Figure 4a in the closed position.

[0042] The curable liquid may be gated in different configurations using the mold 106 in Figure 1. For example, the curable liquid may be gated at the side of the chip as shown in Figure 5 or on top of the chip as shown in Figure 6.

20 [0043] Figure 5 is a cross sectional view taken along line 109 of a mold 106 according to Figure 1. The mold 106 includes a sprue 410, runners 411, and gates 407. The gates 407 introduce the curable liquid into the mold cavity 406 at the side corner of each semiconductor die (not shown) within the mold cavity 406.

[0044] Figure 6 shows a cross sectional view taken along line 109 of a mold 106 according to Figure 1. The mold 106 includes a sprue 410, runners 411, and gates 407. The gates 407 25 introduce the curable liquid into the mold cavity 406 on the top of each semiconductor die (not shown) within the mold cavity 406.

[0045] The exact configuration of the mold used in step iv) depends on various factors including the type of semiconductor device and the curable liquid selected. Without wishing 30 to be bound by theory it is thought that the molds having gates configured to introduce curable liquid into the mold cavity onto the middle of the top of each semiconductor device in the mold cavity are suitable to use when the semiconductor device is a semiconductor die

wire bonded to a substrate, such as the semiconductor device shown in Figure 7. Without wishing to be bound by theory it is thought that the molds having gates configured to introduce curable liquid into the mold cavity at the side corner of each semiconductor device in the mold cavity are suitable to use when the semiconductor device is a semiconductor die is not wire bonded to a substrate, such as the semiconductor device shown in Figure 8.

5 [0046] Figure 7 shows an electronic component 700 fabricated by the process of this invention. The electronic component 700 includes an integrated circuit 703 attached to a surface of a circuit board 705 through die attach adhesive 704. The integrated circuit 703 is electrically connected to the circuit board 705 through wires 702. Liquid injection molding is performed on the integrated circuit 703 using a curable liquid that cures to form an overmold 10 701. Solder balls 706 are attached to the surface of the circuit board 705 opposite the die attach adhesive 704.

[0047] Figure 8 shows an alternative electronic component made by the process of this invention. The device 800 includes an integrated circuit 803 both attached and electrically connected to a surface of a circuit board 805 through die attach adhesive 804. The die attach 15 adhesive 804 contains electrically conductive materials 802, which electrically connect the integrated circuit 803 to the circuit board 805. Liquid injection molding is performed on the integrated circuit 803 using a curable liquid that cures to form an overmold 801. Solder balls 806 are attached to the surface of the circuit board 805 opposite the die attach adhesive 803.

20 [0048] Figure 9 shows an alternative electronic component 900 fabricated by the process of this invention. The electronic component 900 includes an integrated circuit 903 attached to a surface of a circuit board 905 through die attach adhesive 904. The integrated circuit 903 is electrically connected to the circuit board 905 through wires 902 in an alternative configuration to that shown in Figure 7. Liquid injection molding is performed on the 25 integrated circuit 903 using a curable liquid that cures to form an over mold 901. A separate encapsulant 910 is used to protect the wires from damage. Solder balls 906 are attached to the surface of the circuit board 905 opposite the die attach adhesive 904.

#### *Substrate*

30 [0049] The substrate used in the method described above is not specifically restricted. The substrate selected will depend on the various factors including the use of the method described above, *e.g.*, the type of semiconductor device to be fabricated. The substrate can be

any material used in the fabrication of an electronic device or an electronic device package, such as a circuit board (e.g., printed circuit board, PCB or PWB). The substrate can be, for example a ceramic substrate, a flexible substrate, or a rigid substrate commonly used in electronic device packaging. Examples of suitable substrates include a ceramic, a metal, a metal-coated surface, a polymer, and combinations thereof.

[0050] Metals and metal coatings include aluminum, chromium, copper, gold, lead, nickel, platinum, solder, stainless steel, tin, titanium, alloys thereof, and combinations comprising more than one metal.

[0051] Ceramics include aluminum nitride, aluminum oxide, silicon carbide, silicon oxide, silicon oxynitride, combinations thereof, and others; alternatively aluminum nitride, aluminum oxide, silicon carbide, silicon oxynitride, and combinations thereof.

[0052] Polymers include benzocyclobutene, bismaleimide, cyanate, epoxy, polybenzoxazole, polycarbonate, polyimide, polymethylmethacrylate, polyphenylene ether, polyvinylidene chloride, and combinations thereof.

#### *Semiconductor*

[0053] The semiconductor device used in the method described above is not specifically restricted. Semiconductors are known in the art and commercially available; for example, see J. Kroschwitz, ed., "Electronic Materials," Kirk-Othmer Encyclopedia of Chemical Technology, 4th ed., vol. 9, pp. 219-229, John Wiley & Sons, New York, 1994. Common semiconductors include silicon, silicon alloys, and gallium arsenide. The semiconductor device can have any convenient form, such as a bare die, a chip such as an integrated circuit (IC) chip, or a wafer.

#### Examples

[0054] These examples illustrate the invention to one skilled in the art and are not intended to limit the scope of the invention set forth in the claims.

#### *Reference Example 1 – Injection Molding Equipment*

[0055] An Engel Silicone Liquid Injection Molding Machine (M/N: CC-90), which can operate between 1 and 90 tonnes clamping pressure with a 28 mm screw diameter is used for injection molding. This and comparable equipment are commercially available from ENGEL Machinery Inc., 3740 Board Road, Rd. #5, York, Pennsylvania, U.S.A.

*Reference Example 2 – Injection Molding Equipment*

[0056] An Arburg Silicone Liquid Injection Molding Machine (M/N: ALLROUNDER 270S 250-60), which can operate between 1 and 27 tonnes clamping pressure with a 18 mm screw diameter is used for injection molding. This equipment is commercially available from  
5 ARBURG, Inc., 125 Rockwell Road, Newington, CT 06111, U.S.A.

*Reference Example 3 – Mold*

[0057] A standard mold base (Catalogue: 812A-13-13-2) manufactured with Number #2 steel from D-M-E Co., 29111 Stephenson Highway, Madison Heights, MI 48071, USA is fabricated by Kipe Molds, Inc., 340 East Crowther Avenue, Placentia, CA 92870, U.S.A. to  
10 accommodate 1 x 6 array package. The mold is designed as a hot runner system.

*Reference Example 4 – 1 x 6 BGA Strip*

[0058] An electronics BGA strip with a 1 x 6 array strip and the following dimensions is fabricated: Length= 187.5mm, Width= 40.0mm, Height = either 0.36mm or 0.61mm.

*Examples 1-3*

15 [0059] Samples 1-3 are evaluated with the equipment in Reference Example 2, the mold in Reference Example 3, and the BGA strip in Reference Example 4. The samples are cured in the mold between 10-27 tonnes clamping pressure, with curing times of 30-240 sec at a temperature of 120 °C. The results are in Table 1.

Table 1

Sample	Processability, Injection	Adhesion
1	YES	POOR
2	YES	GOOD
3	YES	POOR

20

[0060] Sample 1 is a resinous silicone matrix, which cures via hydrosilation. It forms an optically clear material upon cure. Sample 1 is a combination of 97 parts by weight of Resin/Crosslinker A and 3 parts by weight Catalyst/Inhibitor A. Resin/Crosslinker A is a combination of 81 parts vinyl-terminated silsesquioxane resin, 17 parts 1,4-  
25 bis(dimethylsilyl)benzene, 1 part of a reaction product of hydroxy-terminated dimethyl,methylvinylsiloxane, with (glycidoxypropyl)trimethoxysilane, and 1 part product(s) from the reaction of ethylene glycol and tetraethylorthosilicate. Catalyst/Inhibitor A is a combination of 3.6 parts divinyltetramethyldisiloxane and triphenylphosphine platinum

complexes, 93.3 parts toluene, 3.0 parts triphenylphosphine, and 0.1 part tetramethyldivinylsiloxane.

[0061] Sample 2 is a commercially available addition reaction curable liquid silicone composition; DOW CORNING® 6820 Microelectronic Encapsulant, which is commercially available from Dow Corning Corporation of Midland, Michigan, U.S.A.

[0062] Sample 3 is a combination of 40 parts of the composition in sample 1 and 60 parts of fused silica.

[0063] Samples 1-3 show that different liquid silicone compositions are suitable for the liquid injection molding process. Sample 2 shows that adhesion can be obtained.

**DRAWINGS**

[0064] Figure 1 is a schematic representation of liquid injection molding process equipment for use in the method of this invention.

5 [0065] Figure 2a is a cross sectional view taken along line 108 of a mold 106 for use in the liquid injection molding process equipment 100 in Figure 1. Figure 2a shows the mold 106 in its open position. Figure 2b is the mold 106 shown in its closed position.

[0066] Figure 3a is a cross sectional view taken along line 108 of an alternative mold 106 for use in the liquid injection molding process equipment 100 in Figure 1. Figure 3a shows the mold in its open position. Figure 3b is the mold 106 in its closed position.

10 [0067] Figure 4a is a cross sectional view taken along line 108 of an alternative mold 106 for use in the liquid injection molding process equipment 100 in Figure 1. Figure 4a shows the mold in its open position. Figure 4b shows the mold 106 in the closed position.

[0068] Figure 5 is a cross sectional view taken along line 109 of a mold 106 according to Figure 1.

15 [0069] Figure 6 shows a cross sectional view taken along line 109 of a mold 106 according to Figure 1.

[0070] Figure 7 shows an electronic component 700 fabricated by the process of this invention.

20 [0071] Figure 8 shows an alternative electronic component made by the process of this invention.

[0072] Figure 9 shows an alternative electronic component 900 fabricated by the process of this invention.

*Reference Numerals*

100	liquid injection molding process	109	cross section line
101	feed system	201	first section
102	feed tank	202	second section
103	feed tank	203	mold retainer
104	static mixer	204	substrate
105	extruder	205	semiconductor dice
106	mold	206	mold cavities
107	inlet	210	sprue
108	cross section line	211	runner system

301	first section	902	wires
303	mold retainer	903	integrated circuit
304	substrate	904	die attach adhesive
305	semiconductor dice	905	circuit board
306	mold cavities	906	solder balls
307	gates	910	encapsulant
310	sprue		
311	runner system		
401	first section		
403	mold retainer		
404	substrate		
405	semiconductor dice		
406	mold cavities		
407	gates		
410	sprue		
411	runners		
700	electronic component		
701	overmold		
702	wires		
703	integrated circuit		
704	die attach adhesive		
705	circuit board		
706	solder balls		
800	electronic component		
801	overmold		
802	electrically conductive materials		
803	integrated circuit		
804	die attach adhesive		
805	circuit board		
806	solder balls		
900	electronic component		
901	overmold		

**CLAIMS**

1. A method comprising:
  - a) applying a die attach adhesive composition to a substrate,
  - b) curing the die attach adhesive composition to form a die attach adhesive,
  - 5 c) plasma treating a surface of the die attach adhesive,
  - d) plasma treating a surface of a semiconductor die,
  - e) contacting the plasma treated surface of the semiconductor die with the plasma treated surface of the die attach adhesive,
  - optionally f) wire bonding the semiconductor die to the substrate,
  - 10 g) injection molding a curable liquid over the product of step f),
  - optionally h) forming solder balls on a surface of the substrate opposite the die attach adhesive.
  
2. The method of claim 1, where the die attach adhesive comprises a silicone die attach  
15 adhesive.
  
3. The method of claim 1, where the curable liquid comprises a silicone composition.
  
4. The method of claim 3, where the silicone composition cures to form an over mold  
20 having a modulus of 25 to 1,000 megaPascals, and where the silicone composition has a viscosity of 80 to 3000 Poise and a curing profile such that the silicone composition cures in 30 to 120 seconds at a temperature of 80 to 240 °C.
  
5. The method of claim 4, where step g) comprises:
  - 25 i) placing the product of step e) or the product of step f) in an open mold,
  - ii) closing the mold to form a mold cavity,
  - iii) heating the mold cavity,
  - iv) injection molding a curable liquid into the mold cavity to overmold the semiconductor die on the substrate,
  - 30 v) opening the mold and removing the product of step iv), and
  - optionally vi) post-curing the product of step v).

6. An electronic component prepared by the method of claim 1.
7. A method comprising:
- i) placing a semiconductor device in an open mold,
  - 5 ii) closing the mold to form a mold cavity,
  - iii) heating the mold cavity,
  - iv) injection molding a curable liquid into the mold cavity to overmold the semiconductor device,
  - v) opening the mold and removing the product of step iv), and
  - 10 optionally vi) post-curing the product of step v).
8. The method of claim 7, where the semiconductor device comprises a substrate, a die attach adhesive, and an integrated circuit, wherein the integrated circuit is attached to a surface of the substrate through the die attach adhesive, and where the integrated circuit is
- 15 wire bonded to the surface of the substrate,
9. The method of claim 7, where step ii) is carried out by applying a clamping force of 1 to 27 tons.
- 20 10. The method of claim 7, where the curable liquid comprises a silicone composition.
11. The method of claim 7, where step iii) is performed at a temperature of 80 to 180 °C.
12. The method of claim 7, wherein step iv) is carried out at an injection speed sufficient
- 25 to provide a pressure of 0.6 to 2.0 MPa force in the mold cavity.
13. The method of claim 10, where the silicone composition has a viscosity of 80 to 3000 Poise.
- 30 14. The method of claim 10, where a cured product of the silicone composition has a modulus of 100 to 1,000 megaPascals.

15. A method comprising:

- a) applying a die attach adhesive composition to a substrate,
- b) attaching a semiconductor die to the die attach adhesive composition,
- c) curing the die attach adhesive composition to form a die attach adhesive,
- 5 optionally d) wire bonding the semiconductor die to the substrate, and
- e) injection molding a curable liquid over the semiconductor device formed as the product of step c) or step d), wherein injection molding is carried out by a method comprising

- 10 i) placing the semiconductor device in an open mold,
- ii) closing the mold to form a mold cavity,
- iii) heating the mold cavity,
- iv) injection molding a curable liquid into the mold cavity to overmold the semiconductor device,
- v) opening the mold and removing the product of step iv), and
- 15 optionally vi) post-curing the product of step v).

16. A method comprising:

- a) attaching a semiconductor die to a substrate to form a semiconductor device, and
- b) injection molding a curable liquid over the semiconductor device by a method

20 comprising

- i) placing the semiconductor device in an open mold,
- ii) closing the mold to form a mold cavity,
- iii) heating the mold cavity,
- iv) injection molding a curable liquid into the mold cavity to overmold the
- 25 semiconductor device,
- v) opening the mold and removing the product of step iv), and
- optionally vi) post-curing the product of step v).

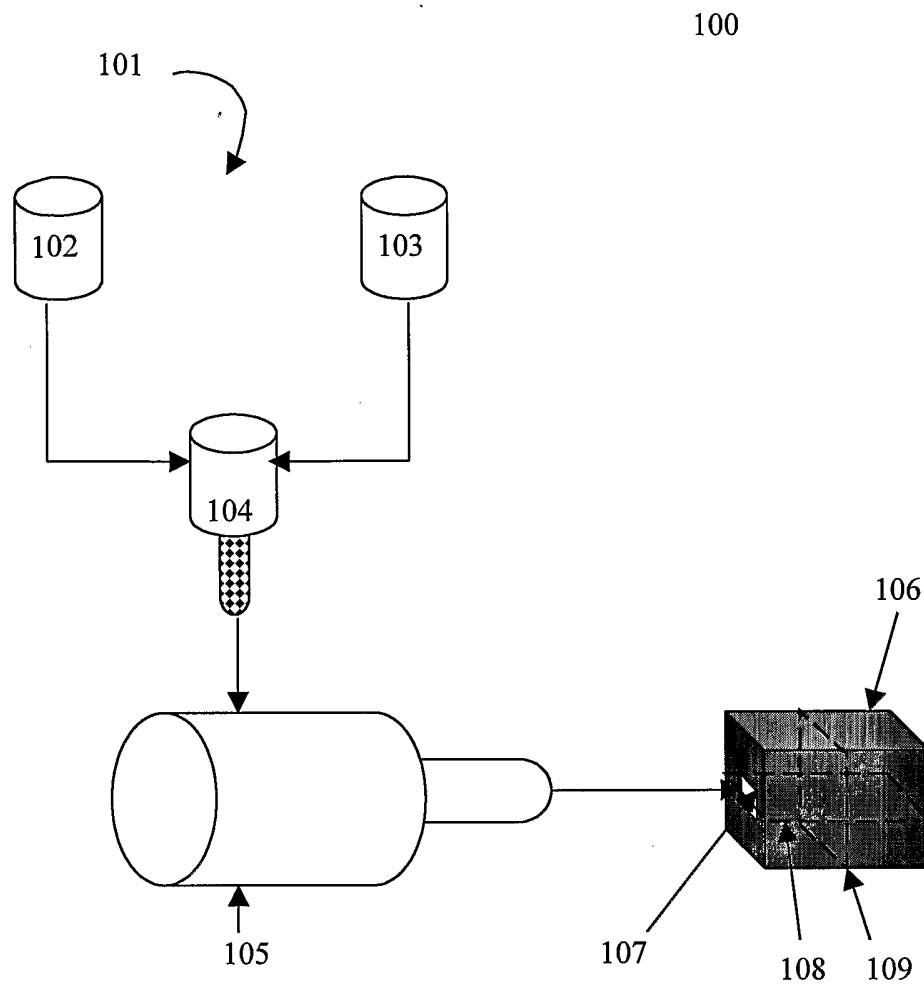


Figure 1

Figure 2a

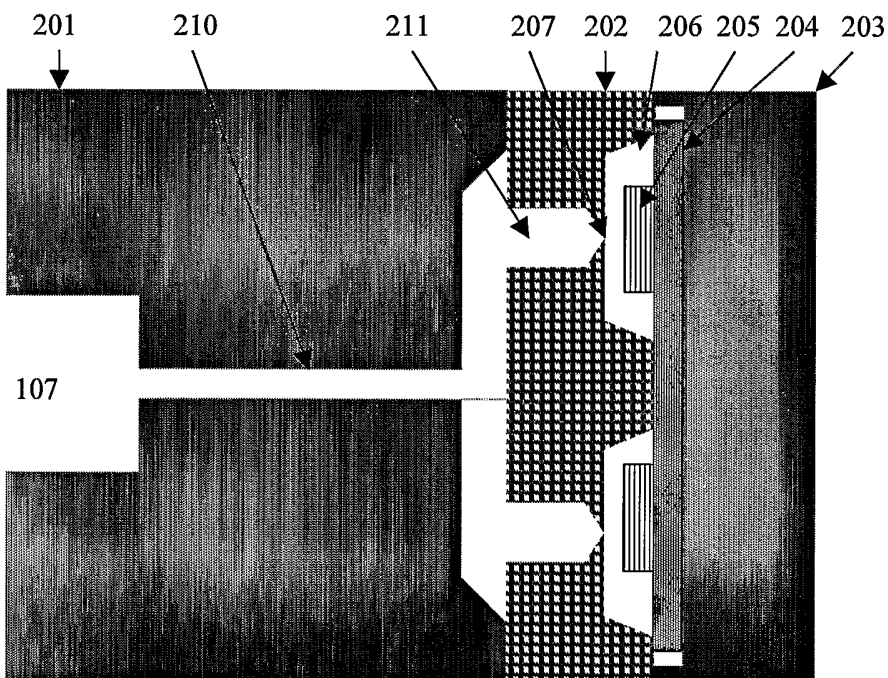
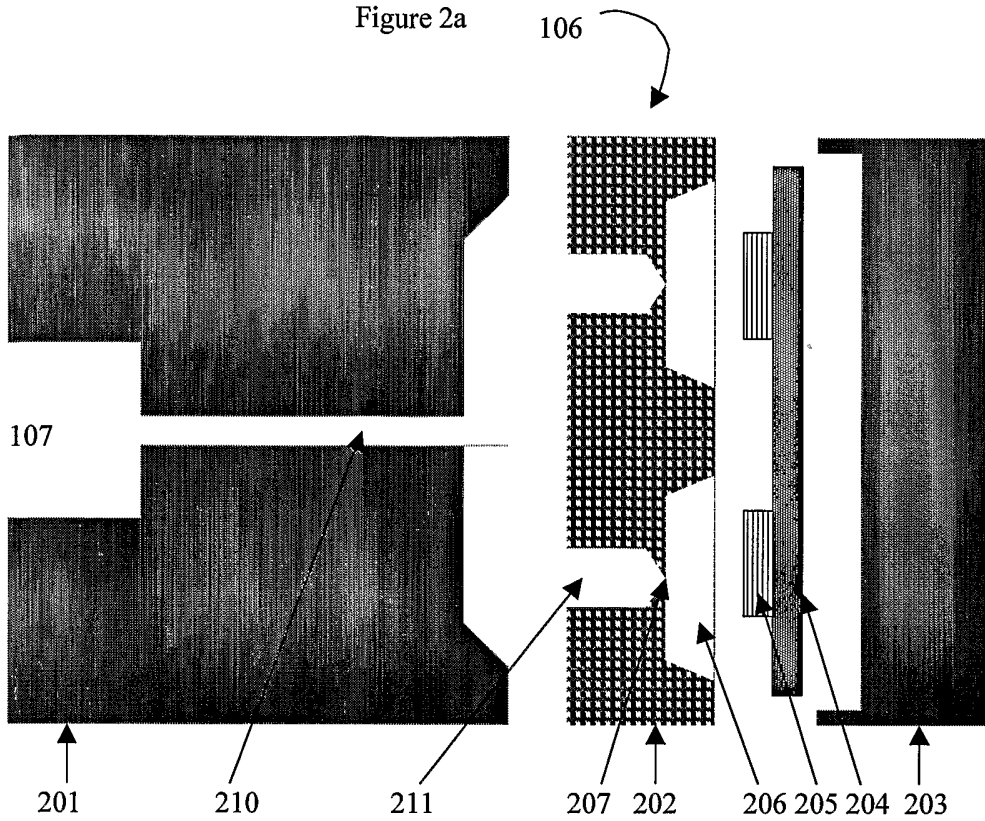


Figure 2b

106

2/9

Figure 3a

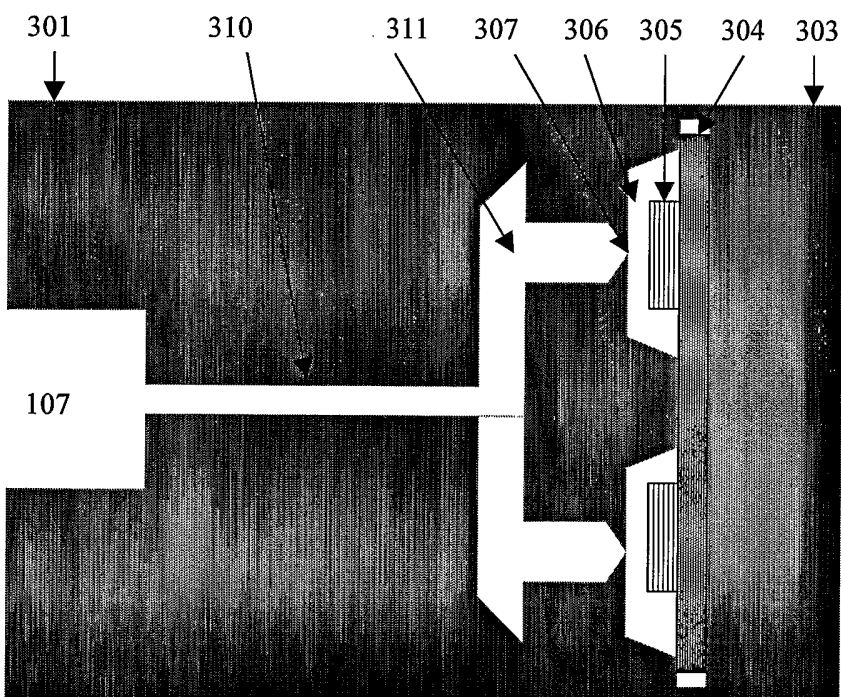
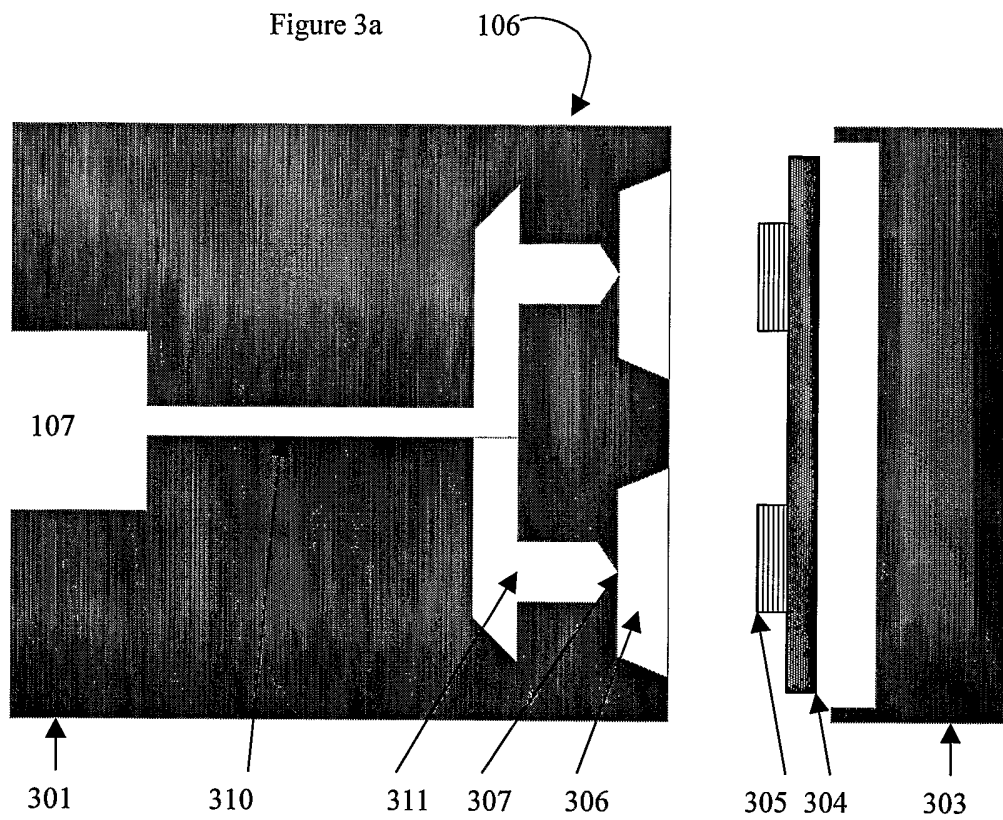


Figure 3b

106

3/9

Figure 4a 106

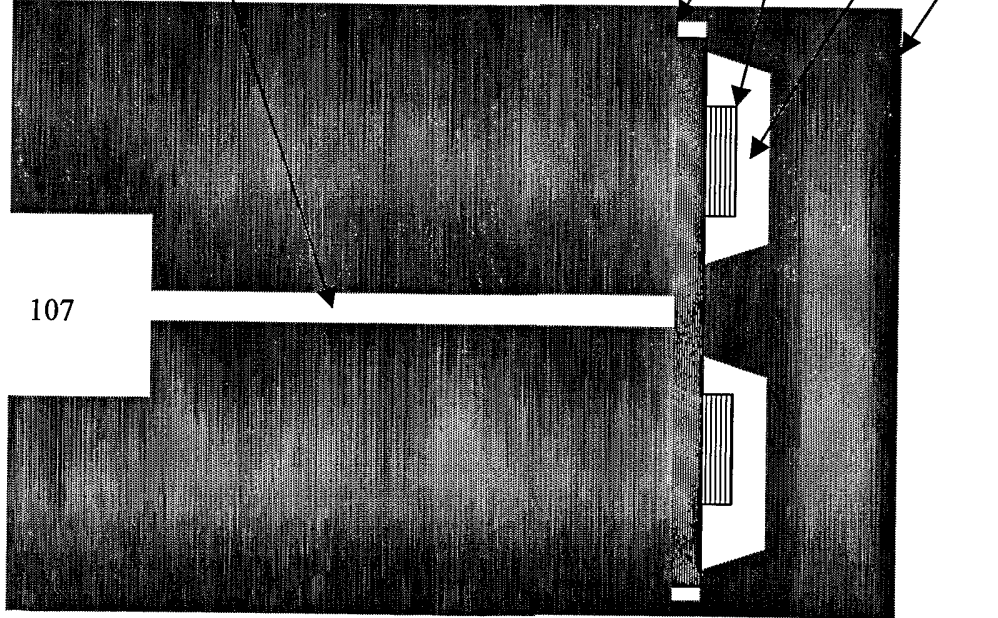
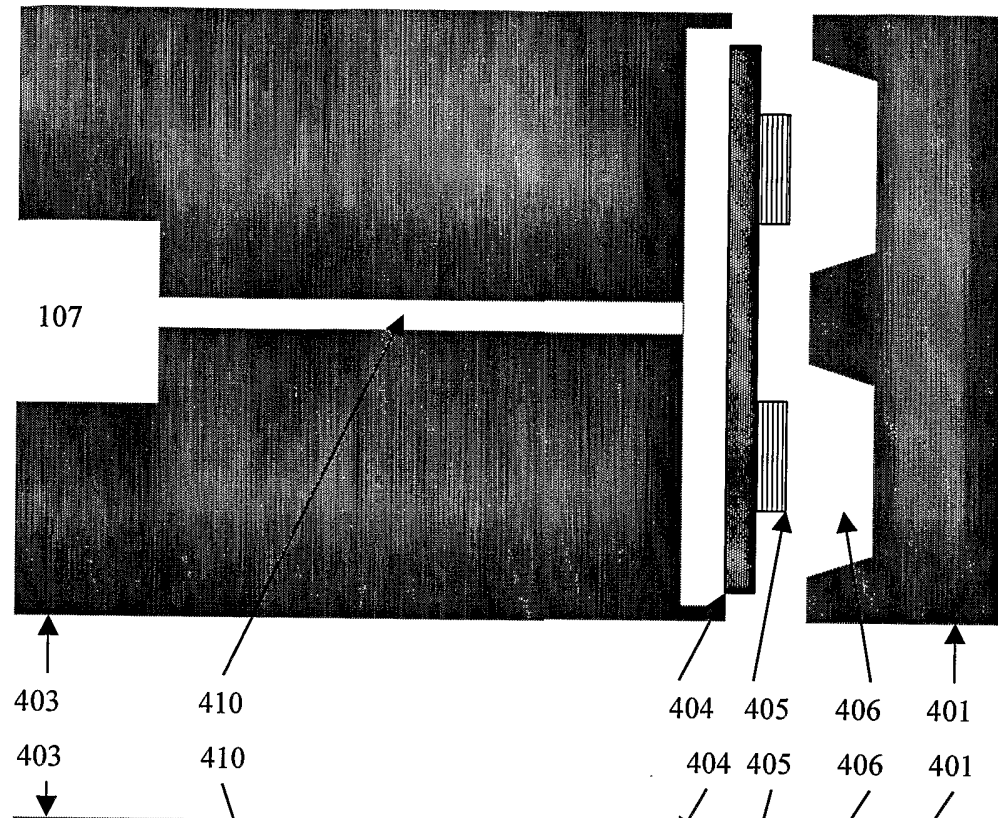


Figure 4b 106

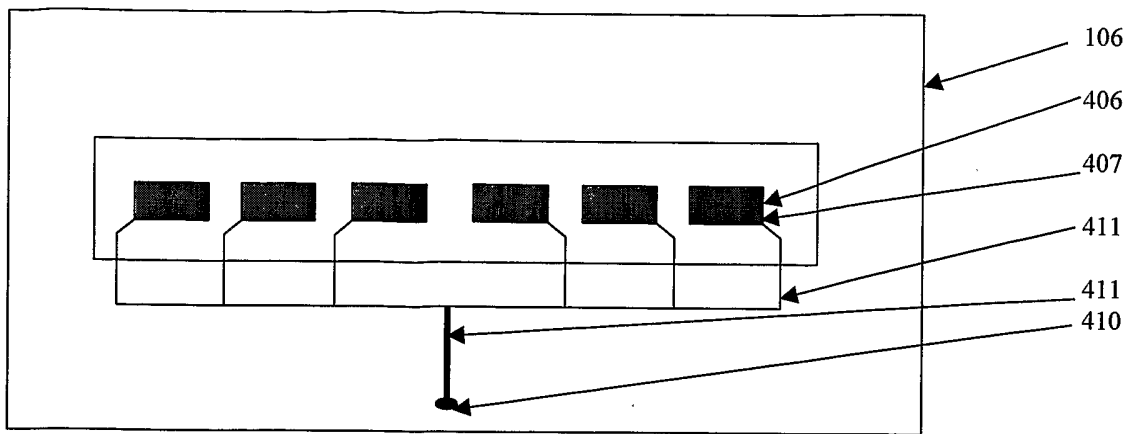


Figure 5

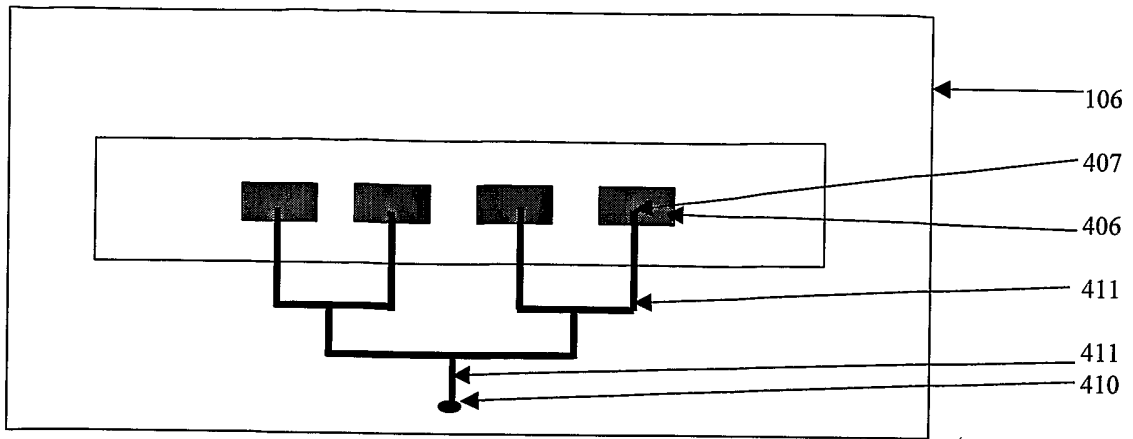


Figure 6

6/9

700

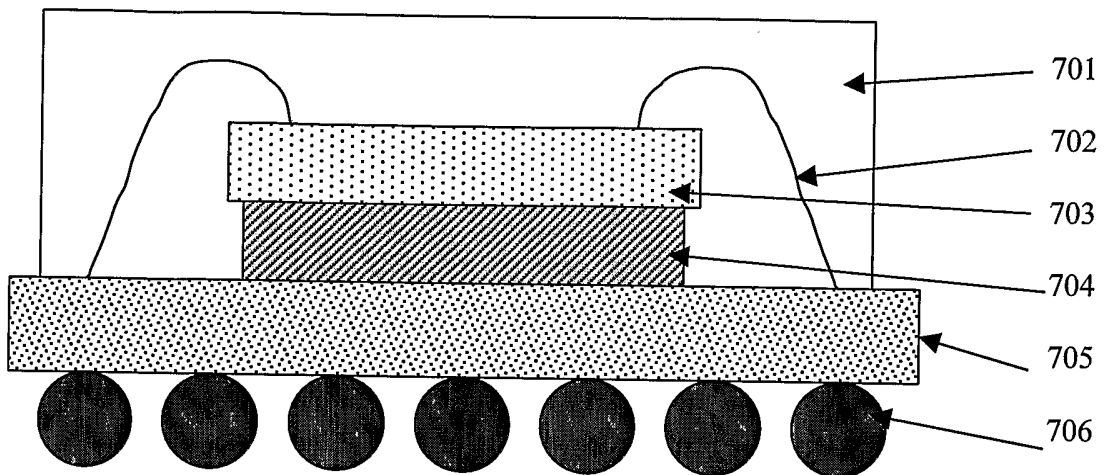


Figure 7

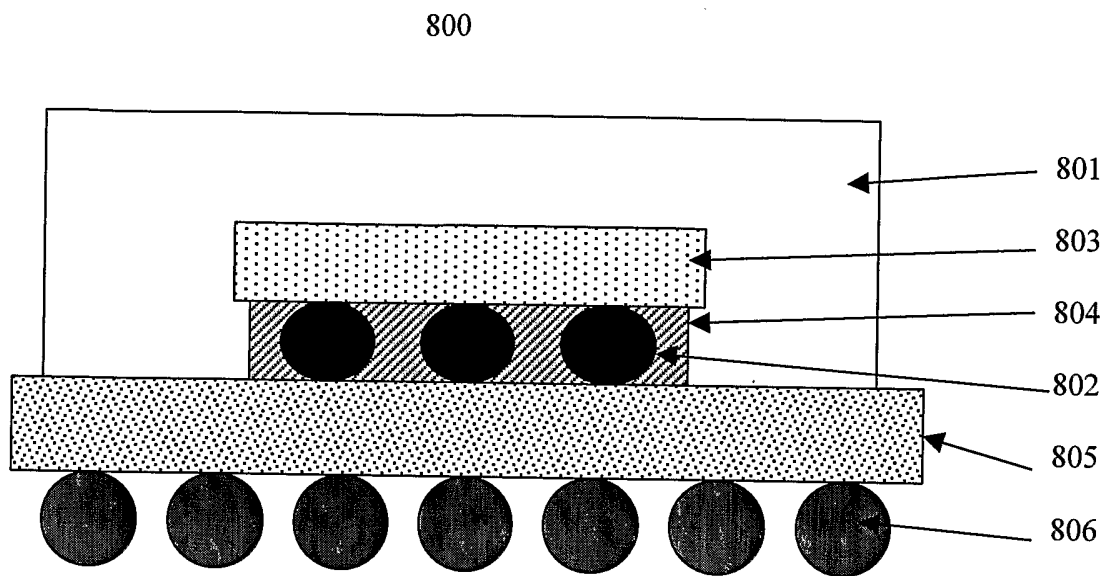


Figure 8

900

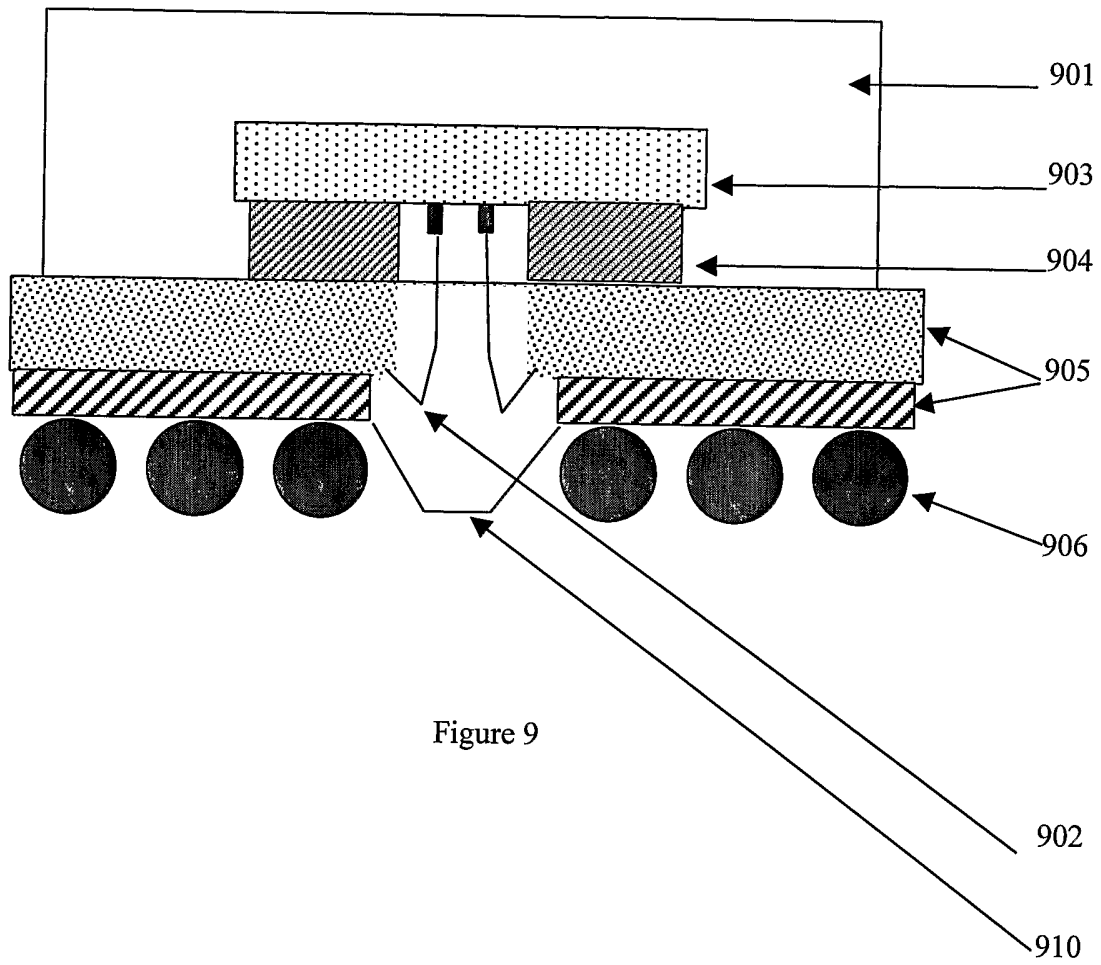


Figure 9

## INTERNATIONAL SEARCH REPORT

 Int. Application No  
 PCT/US2004/025050

 A. CLASSIFICATION OF SUBJECT MATTER  
 IPC 7 H01L21/56 H01L23/31 H01L21/58

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

 Minimum documentation searched (classification system followed by classification symbols)  
 IPC 7 H01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2003/145940 A1 (PARBHOO BHUKANDAS ET AL) 7 August 2003 (2003-08-07)	1,2
Y	paragraphs '0017! - '0070!	3-5
X	US 2002/110956 A1 (ICHIKAWA KINYA ET AL) 15 August 2002 (2002-08-15)	7,11-14, 16
Y	paragraphs '0020! - '0043!; figure 2	3-5, 8-10,15
Y	US 5 592 025 A (CLARK MINH-HIEN N ET AL) 7 January 1997 (1997-01-07) column 4, line 54 - column 5, line 44; figure 6	8-10,15
A	EP 1 149 864 A (ST MICROELECTRONICS SRL ; TOSHIBA CHEMICAL KAWAGUCHI WOR (JP)) 31 October 2001 (2001-10-31) paragraphs '0041! - '0047!	1
	-/--	

 Further documents are listed in the continuation of box C.

 Patent family members are listed in annex.

\* Special categories of cited documents:

\*A\* document defining the general state of the art which is not considered to be of particular relevance

\*E\* earlier document but published on or after the International filing date

\*L\* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

\*O\* document referring to an oral disclosure, use, exhibition or other means

\*P\* document published prior to the international filing date but later than the priority date claimed

\*T\* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

\*X\* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

\*Y\* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

\*&amp;\* document member of the same patent family

Date of the actual completion of the international search

15 December 2004

Date of mailing of the international search report

29/12/2004

Name and mailing address of the ISA

 European Patent Office, P.B. 5818 Patentlaan 2  
 NL - 2280 HV Rijswijk  
 Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,  
 Fax: (+31-70) 340-3016

Authorized officer

Edmeades, M

## INTERNATIONAL SEARCH REPORT

Interr	Application No
	PCT/US2004/025050

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2003/082845 A1 (HOFFMAN PAUL ET AL) 1 May 2003 (2003-05-01) figures 6A-E -----	1
A	EP 0 469 890 A (SHINETSU CHEMICAL CO) 5 February 1992 (1992-02-05) the whole document -----	3,10
A	GB 1 204 619 A (RCA) 9 September 1970 (1970-09-09) the whole document -----	3,7,10

## INTERNATIONAL SEARCH REPORT

Intern application No  
PCT/US2004/025050

Patent document cited in search report	Publication date	Patent family member(s)	Publication date	
US 2003145940	A1	07-08-2003	EP 1435109 A2 TW 569300 B WO 03041130 A2	07-07-2004 01-01-2004 15-05-2003
US 2002110956	A1	15-08-2002	US 2002109241 A1 JP 2004530307 T WO 02101812 A1 US 2002114144 A1 US 2004053443 A1	15-08-2002 30-09-2004 19-12-2002 22-08-2002 18-03-2004
US 5592025	A	07-01-1997	EP 0582052 A1 JP 6112354 A	09-02-1994 22-04-1994
EP 1149864	A	31-10-2001	EP 1149864 A1 AU 6591601 A WO 0183604 A1 EP 1278796 A1 JP 2003531938 T US 2002022679 A1	31-10-2001 12-11-2001 08-11-2001 29-01-2003 28-10-2003 21-02-2002
US 2003082845	A1	01-05-2003	NONE	
EP 0469890	A	05-02-1992	JP 2522721 B2 JP 4088060 A DE 69122005 D1 DE 69122005 T2 EP 0469890 A2 US 5204437 A	07-08-1996 19-03-1992 17-10-1996 20-02-1997 05-02-1992 20-04-1993
GB 1204619	A	09-09-1970	NONE	