

## SEMICONDUCTOR DEVICE PACKAGE AND METHOD OF MANUFACTURE

### Background of the invention

- 5 The present invention relates to a method of packaging a semiconductor device. It finds particular utility with devices such as image sensors, MEMs, and pressure sensors.

Semiconductor sensor packages generally include a semiconductor die part  
10 which is mounted on a substrate made of metal and/or plastic, with the die and substrate being enclosed within a plastic material. However, since sensor semiconductors must be capable of being exposed to e.g. light, in the case of optical sensors, or, a fluid, in the case of pressure sensors, the active die surface must be left exposed, or at least accessible, after the die and  
15 substrate have been enclosed.

### Description of the Prior Art

Prior art packaging techniques often use a ceramic substrate material, which is preconfigured with a cavity to accept the die. Such ceramic substrates are  
20 in single unit form, and cost more than substrates made of metal and/or plastic.

Once the die is attached to the substrate, a cap is applied to protect the die surface and seal the unit. Prior art techniques attach a cap to the substrate,  
25 the leadframe or the die surface. The cap is held in place using an adhesive. The adhesive is usually in the form of a paste, or is dispensed from a tape. However, the application of adhesive in either form is difficult, prone to result in adhesive being erroneously applied to the die surface and requires lengthy periods for the adhesive to cure.

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Another technique which is used to protect the die surface while the package is enclosed in a moulding material uses a soft deformable insert which is placed over the die while moulding material is injected to enclose the entire package. Later, once the moulding material has set, the insert is removed,

leaving a raised edge of moulding material around the die. However, there is a risk that the delicate die surface can be damaged by the insert either at the preparation or the removal stage. Insertion and removal are also additional steps in the manufacturing process which require more time, additional  
5 machinery and increase the opportunity for error.

### **Summary of the Invention**

According to a first aspect of the present invention, there is provided a semiconductor package including:

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- a substrate;
  - a semiconductor die attached to said substrate;
  - a housing part attached to said substrate and arranged to surround said semiconductor die; and
- solidified moulding material arranged around said housing and adhering to  
15 said substrate to secure said housing in position on said substrate.

Preferably, said semiconductor die is attached to said substrate by means of an adhesive substance.

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- Preferably, the substrate includes a channel arranged on its upper surface for receiving a portion of the housing part.

Preferably, a portion of the housing part is arranged to penetrate the substrate.

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- Preferably, the substrate is formed from an epoxy material. In a preferred form, the epoxy is FR4/5 or BT, although other epoxies may be used.

Alternatively, metal, ceramic or other materials may be used as required.

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- Preferably, the housing part is formed from a thermoplastic or thermosetting material. Other materials may be used as required, with the proviso that the

melting temperature of the chosen material should be higher than the temperature of the moulding material used.

5 Preferably, the package additionally includes an insert for attachment to said housing part.

Preferably, the insert is provided with a screw thread for co-operation with a complementary thread provided in the housing part.

10 Alternatively, the insert is arranged to provide a snap-fit connection with the housing part.

Preferably, the insert includes a lens, and said lens is arranged such that it is positioned above said semiconductor die.

15 Preferably, the insert includes a channel for allowing the through-flow of a fluid such that said fluid is able to contact an active portion of said semiconductor.

20 Preferably, the active portion of said semiconductor is sealed from the remainder of said housing by a sealing material.

25 Preferably, the insert is provided with a channel for allowing the through-flow of a cooling material and said insert is arranged to be thermally coupled to said semiconductor to facilitate the cooling of said semiconductor.

Preferably, the insert includes a thermally conductive material and includes a plurality of cooling fins, and said insert is thermally coupled to said semiconductor.

30 Preferably, the portion of said housing part which contacts said substrate is substantially flat and includes a channel inscribed in said flat portion.

In a second aspect of the present invention, there is provided a method of manufacturing a semiconductor device, including the steps of:

- attaching a semiconductor die to a substrate;
  - positioning a housing part on the substrate, in a position surrounding the die;
  - positioning a mould over the housing part such that an upper surface of the housing part abuts against an inner surface of the mould; and
- 5 injecting into the mould a moulding material.

Preferably, the method further includes the step of wire bonding the semiconductor die to selected pads on the substrate.

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Preferably, the step of attaching a semiconductor die to a substrate includes the step of applying an adhesive substance to the substrate prior to applying the semiconductor die.

- 15 Preferably, the step of injecting a moulding material includes the step of bringing the moulding material to a temperature in the range of 160°C-185°C and a pressure of 75bar ( $\pm 10\%$ ) before it is injected into the mould.

Alternatively, different temperatures and may be required, depending on the

20 choice of housing and moulding materials.

Preferably, the step of positioning the housing includes positioning the housing in a channel which surrounds the semiconductor die.

- 25 Preferably, the step of positioning the housing includes the step of part of the housing penetrating part of the substrate.

Preferably, the inner surface of the mould is arranged to be deformable such that a tight fit against the upper surface of the housing is achieved.

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**Brief description of the drawings**

For a better understanding of the present invention and to understand how the same may be brought into effect, the invention will now be described by way of example only, with reference to the appended drawings in which:

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Figures 1a and 1b show top plan and side views of two substrate configurations according to embodiments of the invention;

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Figures 2a-e show the steps in the assembly of a packaged semiconductor according to an embodiment of the invention;

Figure 3 shows a partially assembled semiconductor package prior to being placed in a mould;

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Figures 4a-e show the steps in the assembly of semiconductor packages in accordance with embodiments of the invention;

Figure 5a-d show housing terminations in accordance with embodiments of the invention;

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Figures 6a-d show side, top plan and bottom plan views of housings according to embodiments of the invention;

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Figures 7a-c show steps in the assembly of a matrix of semiconductor packages in accordance with an embodiment of the invention;

Figure 8 shows a top plan view of matrix of semiconductor packages produced by the process shown in Figures 7a-c;

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Figure 9 shows an embodiment of the invention including a screw-mounted insert;

Figure 10 shows an embodiment of the invention including a snap-fit insert;

Figures 11a) – e) show various embodiments of the invention including a filter element, and also an alternative mounting means using a flexi-circuit;

5 Figure 12 shows an embodiment of the invention including an insert for allowing fluid sensing;

Figure 13 shows a further embodiment of the invention including an insert for allowing fluid sensing;

10 Figure 14 shows an embodiment of the invention demonstrating the artefacts of ejector pins used in the moulding process;

Figure 15 shows a still further embodiment of the invention including an insert for allowing fluid sensing;

15 Figure 16 shows an active thermally cooled embodiment of the invention;

Figure 17 shows a passive thermally cooled embodiment of the invention; and

20 Figure 18 shows a further passive thermally cooled embodiment of the invention.

#### **Description of the preferred embodiments**

25 Figure 1a shows a top plan and side view of a substrate 100 including an attached semiconductor die 200. The substrate is composed of an epoxy material such as FR4/5 or BT. The semiconductor die 200 is attached to the surface of the substrate using a suitable adhesive such as an epoxy based adhesive. Immediately surrounding the semiconductor die 200 is a series of electrical contact pads 110. The pads 110 are arranged to be electrically  
30 connected in a manner which ultimately allows electrical signals to be sent and received by the semiconductor die. The pads may, for instance, be connected to a series of solder balls on the lower surface of the substrate which are arranged to allow the package to be secured to a circuit board. Toward the outer edge of the substrate 100 surface, outside the pads 110, is

a shallow channel 105. This channel 105 is intended to receive the lower surface of a housing part which is added to enclose the semiconductor die 200. The side view of Figure 1a is shown taken along line 150.

- 5 Figure 1b shows a similar top plan and side view of a further substrate. In this embodiment, the square channel 105 is supplemented at each corner by a hole 115 which completely penetrates the substrate 100.

The side view is a split view with the left half showing a view along line 155,  
10 while the right side shows a view along line 160.

Figure 2 shows some of the steps involved in the assembly of a complete semiconductor package according to an embodiment of the invention. Figure 2a shows a substrate 100 with a channel 105 as previously described in  
15 relation to Figure 1a. Using automated pick and place machinery, a semiconductor die 200 is attached to a central portion of the substrate 100 using an adhesive 205. The adhesive 205 may be pre-applied to the substrate in the form of a film, or may be dispensed in paste or liquid form prior to the placing of the die 200. The next stage, shown in Figure 2b shows the  
20 attachment of bonding wires 210. These are again placed using known automated processes. The bonding wires are connected between the pads 100 on the substrate and similar pads on the upper surface of the die. The bonding wires may be gold, copper or any other suitably conductive material.

- 25 Figure 2c shows the positioning of the housing 300. The particular product illustrated in Figure 2 is an optical sensor. Figure 2c shows that the housing 300 includes an adaptor 350 which further includes a lens 355. The housing and adaptor are placed such that the lower surface 305 sits in the channel 105 in the substrate surface. The housing is merely placed in the channel at  
30 this stage and is not attached using adhesive.

Figure 2d shows the introduction of a mould 500 which fits tightly over the housing 300 such that the upper surface of the housing 300 abuts against the inner surface of the mould 500. The inner surface 505 of the mould may be

composed of a different material to the rest of the mould so that it may deform slightly to ensure a tight fit. Once the mould is securely in place, a molten moulding material 400 is injected in to the mould. A suitable material 400 is a thermosetting plastic material, and it may be injected at a temperature of approximately 160°C - 185°C and a pressure of approximately 75bar. The housing 300 and adaptor 350 are composed of a material having a suitably high melting point to ensure that they are not damaged by the moulding process.

Figure 2e shows the completed package once it is removed from the mould 500. The adaptor 350 is shown in a slightly raised position from that in which it entered the mould. The adaptor 350 is raised or lowered using the integral screw thread as shown. The moulding material 400 forms a solid enclosure for the adaptor which has the effect of securing the housing 300 to the substrate 100.

During the moulding process, the inclusion of the adaptor 350 in the housing 300, ensures that no moulding material 400 can contaminate or damage the sensitive die surface 200.

Figure 3 shows a detailed view of the mould 500 being positioned above the semiconductor device. The depth of the mould is selected carefully to ensure that a tight fit around the housing 300 is achieved. The portion 505 of the mould which abuts directly against the upper surface of the housing 300 may be formed from a different material to the rest of the mould 500 such that it deforms slightly to ensure a tight fit. A suitable material for this portion 505 of the mould is a silicone or rubber material, while the main body of the mould 500 may be formed from hardened steel with a chromium plating.

Figures 4a-e show the assembly of two different package types according to embodiments of the invention. Figures 4a and 4b correspond directly to Figures 2a and 2b described previously. Figure 4c shows two different packaging options for a sensor, such as a pressure sensor, which, unlike the

previous example, is completely enclosed by a housing 301 or 302. Housing 301 is similar to the housing 300 of Figure 2 in that it is designed to sit solely within a channel 105 in the substrate. Alternative housing 302 is designed to completely penetrate the substrate in at least one location 115, in the manner described in relation to Figure 1b.

Figure 4d shows the alternative housings 301 and 302 in position within the mould 500. Figure 4e shows the two corresponding completed packages encased in the solid moulding material 400.

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Figures 5a-d show alternative end portions 306, 307, 308, 309 for housing parts 300, 301 which are arranged to sit in a shallow channel 105 in the substrate 100.

15 End part 306 has a substantially L-shaped cross-section, with the lower flat surface including a pair of concentric grooves. When the moulding compound 400 comes into contact with the housing 300, if any excess moulding material attempts to enter the interior of the housing 300, it will be trapped in one or both of the grooves, thus protecting the interior of the housing and the delicate semiconductor die.

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End part 307 includes a flat lower surface, and a perpendicular element which protrudes out from the vertical wall of the housing. The perpendicular element extends part or all of the way around the exterior wall of the housing 300.

25 When the moulding material 400 is applied in the mould, the material fills the gap between underneath the protruding element and forms a 'key' which tends to attach the housing more securely to the substrate 100.

30 End part 308 has a lower flat surface, and a vertical wall which is located to the interior of the lower flat surface. This particular design has the advantage that more of the surface of the substrate is exposed to the moulding material, thus enhancing the bond between the moulding material, the housing and the substrate.

End part 308 operates on the same principle as end part 306 in that there is a single groove, of relatively large volume compared to end part 306, running around the lower part of end part 309. Any excess moulding material which enters the housing will be trapped in the groove.

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Figures 6a-d illustrate some possible housing designs. The top left figure in each case is a side view; the lower left figure is a bottom plan view; and the lower right figure is a top plan view.

- 10 Figure 6a shows a closed housing which is generally square in plan view. Such a housing may be used for a pressure sensor where the semiconductor die does not need to come into direct contact with the sensed parameter.

Figure 6b shows an open housing which is generally square in plan view.

- 15 Such a housing benefits from assembly according to embodiments of the invention in that the open upper surface abuts the interior of the mould and so protects the delicate die. A cap or other closure may be fitted after moulding if required.

- 20 Figure 6c shows a semi-closed housing is generally square in plan view. Extending from the square surface is a raised cylindrical portion which is open at its upper surface. Such a housing may be useful for optical sensors or other sensors where physical access is required to the die surface.

- 25 Figure 6d shows an open housing which is generally circular in plan view. In other respects, this housing is similar to the housing of Figure 6b.

- 30 Figures 7a-c illustrate how embodiments of the invention may be used to create arrays of semiconductor packages. Figure 7a shows a cross-section through a 4x4 array of individual packages based around the housing 300 described in Figure 2. The individual housings 300 are positioned as previously on a substrate. All sixteen housings and associated components are then positioned inside a large mould 501 as previously described. Molten moulding material is injected as shown in Figure 7b. Once the moulding

material has solidified, as shown in Figure 7c, the mould may be removed to reveal a matrix of packaged sensor devices. A top plan view of the arrangement is shown in Figure 8, where the semiconductor dies 200 are visible through the solidified moulding material 400 on substrate 100, prior to the introduction of adaptors 350.

Further embodiments of the invention are presented in Figures 9 –18. Figure 9 illustrates the housing 300 already described, and shows how insert 350 including a lens is attached by means of co-operating screw threads. Such an arrangement allows simple attachment of lenses of different types without any need to alter the basic housing 300.

Figure 10 shows an alternative means of attaching an insert 351. In the illustrated embodiment, the insert is a simple plug to seal the housing 303, but other inserts including a lens, for instance, may also be provided. The insert 351 includes one or more recesses about it's perimeter. Provided on an inner portion of the housing 303 are one or more projections 304 which co-operate with the recesses 352 to ensure a snap-fit connection between the insert 351 and the housing 303.

Figures 11a) – e) illustrate various embodiments of the invention. In each case, the upper left view is a side view. The upper right view is a top plan view, and the lower left view is a cross-sectional side view.

Figures 11a) – d) show how a filter 800 may be incorporated into the package. Certain die types are susceptible to certain wavelengths of radiation, particularly infra-red (IR) radiation. Each of the embodiments shown in Figures 11a) – d) incorporate a filter adapted to prevent or limit the ingress of IR radiation. In each embodiment illustrated, the filter 800 is incorporated into the housing before the moulding process described previously.

Figures 11a) – d) also illustrate the solder balls 810 which are used to fasten the completed package onto a printed circuit board. Individual solder balls

allow electrical contact to be made with corresponding contacts on the semiconductor die.

Figure 11e) illustrates a further embodiment of the invention, where rather than using solder balls 810 to secure the package to a circuit board, a length of flexible circuit 820 is provided which can then be attached either directly to a PCB, or via a socket arrangement.

Figures 12 –15 illustrate embodiments of the invention which are useful in the provision of packages for sensing properties of fluids, such as temperature, flow rate, pressure or composition.

Figure 12 shows a housing part 300 formed substantially as previously described, enclosed in solidified moulding material 400 which acts to lock the housing part to the substrate as shown. The semiconductor die, located on the substrate, includes an active portion 220 which is sensitive to a particular fluid and is able to sense one or more properties of a fluid.

The housing, rather than having an optical insert as in previous embodiments, has an insert 605 for receiving a fluid (liquid or gas). The insert 605 is attached to the housing 300 by means of a screw thread. There is a channel provided in the insert which allows for a fluid to enter 600 and leave 610. The channel allows the fluid to come into contact with the active portion 220 of the semiconductor. The area around the active portion 220 is sealed using a suitable paste, gel or tape to ensure that the fluid does not enter the main body of the housing part 300.

Figure 13 shows an alternative embodiment where the fluid may be allowed to be in contact with the entire interior of the housing 310. Access to the interior is achieved via an aperture 315 in the housing 310. Semiconductor 200 is chosen to be sensitive to a property of the fluid under test. Also shown is a passive component 250. The package of Figure 13 is manufactured in substantially the same way as has been previously described.

Figure 14 shows a package including a housing part 302. The solidified moulding material includes two recesses 405 in the upper surface. These recesses are formed by ejector pins in the mould, and are used to easily remove the finished package from the mould once the moulding material has solidified.

Figure 15 shows a package including a housing part manufactured as previously described, attached to an insert 615 with a central channel for allowing a fluid 620 to contact the active portion 220 of a semiconductor. The active portion is sealed from the remainder of the housing by use of a sealing paste, gel or tape 230. Insert 615 is attached to the housing by a screw thread.

Figures 16-18 illustrate packages which are adapted to enable efficient thermal management of the included semiconductor. Many semiconductors operate at very high temperatures, or are required to be operated at a controlled temperature, and in either case, it is desirable to be able to control their temperatures. This is possible using either active or passive temperature control.

Figure 16 shows a package including a housing formed as previously described. The semiconductor 200 requires cooling in operation. The insert 705, which is attached by a screw thread, is provided with an inlet 700 and an outlet 710 through which a cooling fluid runs. The insert is thermally coupled to the semiconductor 200 via a thermally conductive tape, paste or gel 260. In this way, the heat generated by the semiconductor is dissipated in the cooling fluid and the semiconductor is able to operate at a desired temperature. Figure 16 illustrates an active control technique.

Figure 17 shows a package including a sealed housing 320 encased in solidified moulding material 400, and formed as previously described. This package utilises passive cooling. The housing 320 is formed from a thermally conductive material, such as a metal, and it is coupled via a thermally conductive material 260 to semiconductor 270. In this way, the semiconductor

is able to radiate heat via the housing 320. The semiconductor in this embodiment is a Ball Grid Array (BGA) type package, and it is noted that this type of package may be used in any of the other embodiments described herein.

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Figure 18 illustrates a further passive cooling device. In this embodiment, the housing includes a screw thread, and mounted to co-operate with said screw thread is an insert 330 formed from a thermally conductive material such as a metal. The insert includes a plurality of cooling fins which act to increase the available surface area for dissipating generated heat. The insert 330 is thermally coupled to semiconductor 200 via a thermally conductive material 260.

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Thus, embodiments of the present invention provide a modular system whereby the housing may be simply formed using a moulding system, and the same basis housing structure may be adapted to suit a variety of different sensor types.

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The present invention includes a novel feature or combination of features disclosed herein either explicitly or any generalisation thereof irrespective of whether or not it relates to the claimed invention or mitigates any or all of the problems addressed.

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**CLAIMS**

1. A semiconductor package including:

- a substrate including at least one channel arranged on a surface of the substrate;
- a semiconductor die attached to said substrate;
- a housing part received by said at least one channel of attached to said substrate and arranged to surround said semiconductor die; and
- solidified moulding material arranged around at least partially about said housing and adhering to said substrate to secure said housing part in position on said substrate.

2. A semiconductor package as claimed in claim 1 wherein said semiconductor die is attached to said substrate by means of an adhesive substance.

3. A semiconductor package as claimed in any one of the preceding claims wherein the at least one channel has a substantially rectilinear cross-section.

4. A semiconductor package as claimed in any one of the preceding claims wherein a portion of the housing part is arranged to penetrate the substrate.

5. A semiconductor package as claimed in any one of the preceding claims wherein the substrate is formed from an epoxy material.

6. A semiconductor package as claimed in any one of the preceding claims wherein the housing part is formed from a thermosetting or thermoplastic material.

7. A semiconductor package as claimed in any one of the preceding claims wherein the package additionally includes an insert for attachment to said housing part.
8. A semiconductor package as claimed in claim 7 wherein the insert is provided with a screw thread for co-operation with a complementary thread provided in the housing part.
9. A semiconductor package as claimed in any one of claims 1 to 7 wherein the insert is arranged to provide a snap-fit connection with the housing part.
10. A semiconductor package as claimed in any one of claims 7 to 9 wherein said insert includes a lens, and said lens is arranged such that it is positioned above said semiconductor die.
11. A semiconductor package as claimed in any one of claims 7 to 10 wherein said insert includes a channel for allowing the through-flow of a fluid such that said fluid is able to contact an active portion of said semiconductor.
12. A semiconductor package as claimed in claim 11 wherein said active portion of said semiconductor is sealed from the remainder of said housing by a sealing material.
13. A semiconductor package as claimed in any one of claims 7 to 12 wherein said insert is provided with a channel for allowing the through-flow of a cooling material and said insert is arranged to be thermally coupled to said semiconductor to facilitate the cooling of said semiconductor.
14. A semiconductor package as claimed in any one of claims 7 to 13 wherein said insert includes a thermally conductive material and includes a plurality of cooling fins, and said insert is thermally coupled to said semiconductor.

15. A semiconductor package as claimed in any one of the preceding claims wherein the portion of said housing part which contacts said substrate is substantially flat and includes a channel inscribed in said flat portion.

16. A semiconductor package array wherein said array includes a plurality of semiconductor packages as claimed in any one of the preceding claims mounted on a single substrate.

17. A method of manufacturing a semiconductor device, including the steps of:

- attaching a semiconductor die to a substrate, the substrate including at least one channel arranged on a surface of the substrate;
- positioning a housing part on the substrate, in a position surrounding the die, the housing part received by the at least one channel of the substrate;
- positioning a mould over the housing part such that an upper surface of the housing part abuts against an inner surface of the mould; and
- injecting into the mould a moulding material.

18. A method as claimed in claim 17 further including the step of wire bonding the semiconductor die to selected pads on the substrate.

19. A method as claimed in any one of claims 17 or 18 wherein the step of attaching a semiconductor die to a substrate includes the step of applying an adhesive substance to the substrate prior to applying the semiconductor die.

20. A method as claimed in any one of claims wherein 17 to 19 the step of injecting a moulding material includes the step of bringing the moulding material to a temperature in the range of 160°C – 185°C and a pressure of 75bar  $\pm$ 10% before it is injected into the mould.

21. A method as claimed in any one of claims 17 to 20 wherein the step of positioning the housing part includes positioning an end of the housing part in

the at least one channel which surrounds the semiconductor die, the at least one channel being of substantially rectilinear cross-section.

22. A method as claimed in any one of claims 17 to 21 wherein the step of positioning the housing part includes the step of part of the housing part penetrating part of the substrate.

23. A method as claimed in any one of claims 17 to 22 wherein the inner surface of the mould is arranged to be deformable such that a substantially tight fit against the upper surface of the housing part is achieved.