

**Mould for encapsulating electronic components, insert for such a mould,
method for producing an insert and method for encapsulating electronic
components**

- 5 The invention relates to a mould for encapsulating electronic components mounted on a carrier, comprising at least two mould parts which are displaceable relative to each other, at least one of the mould parts with a mould cavity recessed in a contact side, which mould parts are configured to engage with the mould cavity round the electronic components to be encapsulated. The invention also provides a
- 10 method for encapsulating electronic components mounted on a carrier using such a mould, comprising the processing steps of: a) positioning a carrier carrying one or more electronic components between two mould parts such that the electronic components face a mould cavity, b) moving the mould parts towards each other, such that the mould parts are clamping the carrier between the mould parts, the at
- 15 least one mould cavity is enclosing the electronic components to be encapsulated and the insert contacts at least one of electronic components; c) bringing a moulding material in the mould cavity; and d) moving the mould parts apart from each other, and removing the carrier with moulded electronic components from the mould parts, thereby also releasing the insert from the electronic components.
- 20 Furthermore an insert to be used in the mould and method according the present invention are provided, as well as a method to produce such insert.

The encapsulation of electronic components mounted on a carrier, also commonly called a "substrate", with a moulding material is a known art. On an industrial scale

25 such electronic components are provided with an encapsulation, usually an encapsulation of a curing epoxy or resin to which a filler material is added. There is a trend in the market toward simultaneous encapsulation of larger quantities of electronic components with various dimensions and with still increasing accuracy demands. This may result in products having heterogeneous combinations of

30 electronic components in a single package. Electronic components may be envisaged here such as semiconductors (chips, although LEDs are in this respect also deemed semiconductors) which are generally becoming increasingly smaller. Once the moulding material has been arranged the collectively encapsulated electronic components are situated in an encapsulation (package) which is

35 arranged on one but sometimes also two sides of the carrier. The moulding or

encapsulation material often takes the form of a flat layer connected to the carrier in which layer the electronic components are full or partially embedded/encapsulated. The carrier may consist of a lead frame, a multi-layer carrier - manufactured partially from epoxy - (also referred to as board or substrate and so on) or another
5 carrier structure.

During the encapsulation of electronic components mounted on a carrier, usually use is made according to the prior art of encapsulating presses provided with at least two mould halves, into at least one of which is recessed one or plural mould
10 cavities. After placing the carrier with the electronic components for encapsulating between the mould halves, the mould halves are moved towards each other, e.g. such that they clamp the carrier. A, normally heated, liquid moulding material may then be fed to the mould cavities, usually by means of transfer moulding. As an alternative it is also possible to bring the moulding material in the mould cavity
15 before the closure of the mould parts; this alternative process for transfer moulding is called compression moulding. After at least partial (chemical) curing of the moulding material in the mould cavity/cavities, the carrier with encapsulated electronic components is taken out of the encapsulating press and the encapsulated products may be separated from each other during further
20 processing. Foil may be used during the encapsulating process to, among others, screen off a part of the electronic components and so to prevent the foil covered parts of the electronic component to be covered by the moulding material. The partial with moulding material covered electronic components (not over moulded electronic components are referred to as "bare die" or "exposed die" products) may
25 be used in various applications; like for instance various types of sensor components, ultra-low packages or heat dissipating components. This method of encapsulation is practised on large industrial scale and enables well controlled encapsulation of partially uncovered electronic components. A problem of the prior art encapsulation processes of electronic components that result in partially
30 uncovered electronic components is that the process is only suited for the encapsulation of larger quantities of electronic components with identical height of flat areas on the electronic components to be left uncovered. The flexibility in the areas of the electronic components to be left uncovered and the possibilities for the simultaneous partial uncovered encapsulation of electronic components with
35 various heights is limited.

The present invention has for its object to provide an alternative mould and method for encapsulating electronic components that enable the partial uncovered encapsulation of electronic components with various dimensions and/or with
5 variation in the shape of the uncovered parts of the electronic component.

The invention provides for this purpose a mould for encapsulating electronic components mounted on a carrier according the introduction wherein at least a part of the mould cavity is formed by an insert having a flexible three-dimensional
10 moulding surface for facing the electronic components. Flexibility of the insert moulding surface is herein to be interpreted as being flexible relative to the inflexible structure of the mould parts. Such an insert, that may also be referred to as a "liner", enables to realise a contact surface with any shape desired. The moulding surface of the insert is thereto commonly shaped to closely adhere to the
15 shape of the electronic components to be encapsulated. As a contact surface with any desired shape may be realised, the mould according the invention enables far more freedom in the shape of the moulded electronic components, wherein it becomes possible to make the inset fit combinations of various sized electronic components as well as to fit combinations of identical sized electronic components
20 with different "cover rate" demands. For instance various electronic components within a single package having differing heights may be "bare die" moulded leaving for instance the upper surface of a small electronic component as well as the surface of a high electronic component exposed. The flexible three-dimensional moulding surface of the insert is hereto configured to contact during moulding those
25 parts of the electronic components to be left exposed. It is also possible that the insert is configured to contact (part of) the carrier in addition to or instead of contacting one or more of the electronic components such that a part of the carrier remains exposed. Such an exposed part of the carrier may function as a connector and/or as a mounting surface for future mounting of one or more components. Also
30 variations in local heights of the cured moulding material may be realised through the topology of the moulding surface of the insert. Moreover, due to the flexibility of the insert moulding surface, the insert may through deformation compensate for height tolerances of the electronic components. This way, no excessive pressure forces are exerted on the electronic components during moulding, even if the

flexible three-dimensional moulding surface does not fully fits to the shape of the electronic components.

5 The three-dimensional moulding surface of the insert may in a common instance be formed by a continuous surface configured to cover multiple electronic components. Said multiple electronic components are hereby typically mounted on the same carrier. For the moulding surface to cover multiple electronic components, the surface itself has to be large enough, as well as being adapted to the layout of said multiple electronic components. As a benefit of being able to cover multiple
10 electronic components with the same three-dimensional moulding surface, larger quantities of electronic components can be encapsulated simultaneously. Due to the three-dimensional moulding surface, which topology matches with that of the electronic components mounted on the carrier, the electronic components can thereby have various dimensions (and in particular various heights).

15 The three-dimensional moulding surface of the insert may moreover comprise multiple contact areas for contacting at least a part of an upper surface of an electronic component, wherein the distance of said contact areas to a side of the insert opposing the three-dimensional moulding surface differs between at least two
20 of said contact areas. The distance of the contact areas to the side of the insert opposing the three-dimensional moulding surface corresponds with the height or thickness of the insert at the location of the concerning contact areas. This distance or height determines the distance over which the insert moulding surface protrudes into the mould cavity. The distance of the contact areas to the side of the insert
25 opposing the three-dimensional moulding surface is chosen such that during moulding, wherein the carrier is clamped between the mould parts and the moulding material is brought into the mould cavity, said contact areas each contact at least a part of an upper surface of an electronic component. This is achieved by choosing the distance of the contact areas to the side of the insert opposing the
30 three-dimensional moulding surface based on the height of the electronic component to be covered by said contact areas. The upper surface parts of the electronic components covered by the contact areas are as a result hereof left free of moulding material. Due to the fact that the distances of the contact areas to the side of the insert opposing the three-dimensional moulding surface mutually differ,
35 it becomes possible to simultaneously mould multiple electronic components

having different heights, and preferably all electronic components mounted on one or more carriers. In a common instance, the multiple contact areas are each formed by a flat surface oriented substantially parallel to the upper surface of the electronic component to be covered by the concerning contact area. Generally, this means
5 that the multiple contact areas are oriented parallel to the side of the insert opposing the three-dimensional moulding surface.

In addition to said contact areas, the moulding surface may comprise further areas that are configured not to contact the electronic components. By varying the
10 distance of said further areas to a side of the insert opposing the three-dimensional moulding surface, the thickness of the layer of moulding material at the location directly underneath said further areas can be controlled and varied accordingly.

In an embodiment of the mould according to the invention the three-dimensional
15 moulding surface of the insert is made from a polymer material, for instance from a vulcanized synthetic rubber, or more specific a fluor-elastomer. In a regular variation, the insert comprises a FKM-type of rubber. The benefit of using a vulcanized synthetic rubber, and specifically a fluor-elastomer for the three-dimensional moulding surface of the insert is that this type of material is
20 temperature resistant at the temperatures the moulding material is processed while also being flexible and resistive to chemicals. The temperature resistance is required as normally a processing temperature between 100-200 °C is applied during bringing the moulding material in the mould cavity. Fluor-elastomers normally are even more heat and chemical resistant.

25 The insert may be detachably connectable to the mould part to allow inserts to be exchangeable. This allows for the encapsulation of electronic components with different layouts between production runs without changing the mould parts and for exchange of worn inserts.

30 As further solution for increasing the versatility of the mould, the mould may comprises multiple flexible inserts having three-dimensional moulding surfaces for facing the electronic components. The three-dimensional moulding surfaces of each of the inserts may hereby have a different layout such that electronic
35 components with different layouts may be moulded concurrently in the same mould.

However, if groups of electronic components to be packaged are to be moulded to packages with identical shape form, the moulding surfaces of the inserts may have similar shapes. An additional benefit of using multiple inserts is that the inserts may, in the case of e.g. wear or failure, be replaced independent of each other.

5

As yet another way of increasing the versatility of the mould, the mould may comprise at least two mutually opposing mould parts with a mould cavity recessed in a contact side thereof, wherein said mould cavities are at least partially formed by an insert having a flexible three-dimensional moulding surface. By providing the contact sides of two mutually opposing mould parts with a mould cavity, a space may be left between the carrier and/or the electronic components on opposing sides of the carrier to be filled with moulding material during moulding. It hereby becomes possible to encapsulate (parts of) the carrier and/or electronic components situated on opposing sides of the carrier simultaneously. Moreover, as both mould cavities may at least partially be formed by an insert having a flexible three-dimensional moulding surface, the freedom in the in the shape of the moulded electronic components and the capability to compensate for height tolerances of the electronic components applies to electronic components mounted on opposing sides of the carrier.

20

Alternatively, one of the mutually opposed flexible three-dimensional moulding surfaces of a pair of mutually opposing inserts may function as a compliant support surface for the electronic components that may or may not be packaged on one side of the carrier, while the other of the mutually opposed flexible three-dimensional moulding surfaces may form at least part of the mould cavity enclosing the electronic components on the other, opposite side of the carrier. The flexible three-dimensional moulding surface that acts as the support surface hereby preferably has a topology that follows the topology of the electrical components and carrier to be supported. A benefit of using the flexible three-dimensional moulding surface of the insert as a support surface is the freedom in the shape of the surfaces that may be supported by said support surface. Moreover, the flexible three-dimensional moulding surface acting as a support surface is able to compensate for dimensional tolerances in the surface that is supported, which is especially useful if the supported surface comprises already encapsulated electrical components. With this embodiment of the mould according to the invention, the

35

electrical components on only one side of a carrier may be encapsulated while said carrier may have electrical components mounted on opposing sides thereof. It is hereby possible that the electrical components on one side of the carrier are left unpackaged. It is however also possible that the electrical components on opposing
5 sides of the carrier are hereby packaged subsequently, wherein the carrier is turned upside down after the first moulding operation.

In a preferred embodiment of the mould according to the invention the three-dimensional moulding surface of the insert has a ASTM D2240 type A hardness
10 between 70 - 100 Sh-A, preferably between 80 - 90 Sh-A. It is found that a mould surface within this hardness range provides a proper balance between flexibility and dimensional stability. The insert moulding surface should be provided with sufficient flexibility to be compliant with dimensional tolerances of the electronic components. Through its flexibility, the moulding surface is able to contact various
15 parts of the electronic components intended to be left bare after packaging without exerting a high pressure onto the electronic components. On the other hand, the insert moulding surface should have a sufficient rigidity to remain dimensionally stable during the moulding process and especially during insertion of the moulding material in the mould cavity. The moulding surface should hereby adhere closely
20 onto the parts of the electronic components to be kept exposed and thus clear (bare) of moulding material. This ensures that the moulding material will encapsulate the electronic components only there where required.

The insert may comprise an inflexible coupling part carrying the flexible three-dimensional moulding surface. The inflexible coupling part may hereby be made
25 from a substantially rigid material such as a metal. Normally the inflexible coupling part will be provided at the opposite side of the side facing the electronic components to be moulded. An inflexible coupling part of the insert will provide controlled support to the flexible moulding surface. This benefits the dimensional
30 stability of the insert. Furthermore the inflexible coupling part may facilitate coupling of the insert to the mould. For easy coupling to a mould part the inflexible coupling part may be provided with coupling means.

In order to ensure that the moulding material inserted into the mould cavity is
35 retained inside the mould cavity and does not leak away via the insert, it is

preferred that the three-dimensional moulding surface of the insert is impermeable for moulding material. By making the moulding surface of the insert impermeable for moulding material, no additional covering of the insert, e.g. in the form of a cover sheet or foil, is necessary to achieve a good seal of the mould cavity.

5

In a further embodiment of the mould according to the invention, the mould part comprising the mould cavity and configured for receiving the mould insert comprises an opening. Said opening hereby connects the mould cavity and therewith the insert with an outside of the mould. This opening may be connected
10 to underpressure means to create a partial vacuum inside the mould cavity, and in a particular instance at the flexible three-dimensional moulding surface of the insert. In order to connect the opening to said insert moulding surface, a space may be left between the insert and a side of mould cavity recessed in one of the mould parts. Alternatively or additionally, the insert may be provided with suction holes
15 running from the moulding surface to a rear side of the insert opposing the moulding surface. If a foil layer is inserted between the three-dimensional moulding surface of the insert and the electronic components to be encapsulated, an under pressure applied between the moulding surface and the foil layer will suck the foil layer over the moulding surface. This ensures that the foil layer will follow the three-
20 dimensional topography of the moulding surface. Said foil layer may - amongst others - be applied to facilitate release of the moulded electronic components from the mould cavity.

The invention further relates to an insert for use in a mould according to the
25 invention comprising a flexible three-dimensional moulding surface, the benefits of which are already explained above in relation to the mould according the present invention.

The invention also relates to a method for producing an insert according to the
30 invention, comprising vulcanizing a polymer material onto an inflexible coupling part by moulding the polymer material together with a curative between the inflexible coupling part and a counter mould. By vulcanizing the polymer material onto the inflexible coupling part, a strong bond between the flexible three-dimensional moulding surface and the inflexible coupling part may be realised. During
35 vulcanisation, crosslinks between the polymer chains are formed that significantly

increase the strength and durability of the polymer material and thus the flexible three-dimensional moulding surface of the insert. Post-curing processes such as autoclaving may however be required to achieve an optimum cure.

- 5 Finally, the invention relates also to a method for encapsulating electronic components mounted on a carrier using a mould according to the invention, comprising the processing steps of: a) positioning a carrier carrying one or more electronic components between two mould parts such that the electronic components face a mould cavity, b) moving the mould parts towards each other,
10 such that the mould parts are clamping the carrier between the mould parts, the at least one mould cavity is enclosing the electronic components to be encapsulated and the insert contacts at least one of the electronic components and/or the carrier, c) bringing a moulding material in the mould cavity, and d) moving the mould parts apart from each other, and removing the carrier with moulded electronic
15 components from the mould parts, thereby also releasing the insert from the electronic components. By performing this method, a packaged product is obtained wherein the electronic components and the carrier are at least partially covered with moulding material except for the at least one location where the insert contacted the electronic components and/or the carrier during moulding. As was
20 already mentioned previously, due to the use of a flexible insert moulding surface, the insert may by limited deformation compensate for height tolerances in the dimensions of the electronic components. This will prevent excessive pressure forces to be exerted onto the electronic components during moulding. With the use of an insert according to the invention height tolerances up to 50 µm may even be
25 compensated.

- It is possible to bring a foil layer in the mould cavity covering at least partially the flexible three-dimensional moulding surface of the insert before the carrier carrying the one or more electronic components is clamped between the mould parts. Said
30 foil layer may act as a release foil to aid in the release of the partial moulded electronic components from the mould cavity. In particular said foil layer is clamped between the insert and the electronic components and/or the carrier during processing step c) while moving the mould parts towards each other. In a preferred instance, an under-pressure is applied between the foil layer and the flexible three-
35 dimensional moulding surface of the insert via an opening in the mould part. This

under-pressure ensures that the foil layer closely follows the three-dimensional topography of the moulding surface and is retained on the moulding surface throughout the moulding process.

5 In an embodiment of the method for encapsulating electronic components mounted on a carrier according to the invention, the moulding material is brought in the mould cavity according method step c) after the mould parts are moved towards each other according method step b) by displacing liquid moulding material to the mould cavity enclosing the electronic component by exerting pressure on the
10 moulding material. This method is also known as "transfer moulding". The moulding material is hereby at least partially cured before moving the mould parts apart from each other so that the mould shaped product is not losing its shape during the release from the moulded product out of the mould. In an alternative moulding process the encapsulating material may be brought in the mould cavity according
15 method step c) before the mould parts are moved towards each other according method step b). Such moulding process is also known as "compression moulding". The present invention may be practiced independent of the specific type of moulding process. Normally the encapsulating material is heated before and/or during the moulding process but also such is not a limitation for the present
20 invention.

The present invention will be further elucidated on the basis of the non-limitative exemplary embodiments shown in the following figures, wherein:

- 25 • figure 1 shows a cross section of a mould according to the invention clamping a carrier with electronic components,
- figures 2a - 2d show a schematic representation of the method steps for encapsulating electronic components mounted on one side of a carrier using a mould according to the invention, and
- 30 • figures 3a - 3d show a schematic representation of the method steps for encapsulating electronic components mounted on two opposing sides of a carrier using a mould according to the invention.

Figure 1 shows a cross section of a mould (1) according to the invention clamping a carrier or substrate (2) carrying multiple electronic components (3) for incorporation
35 in a single package. The mould (1) comprises two mould parts (4, 5), an upper

mould part (5) in a contact side (7) of which a mould cavity (6) is recessed. The mould cavity (6) is on one side defined by an insert (8) having a flexible three-dimensional moulding surface (9) which surface (9) faces the electronic components (3). On a side opposite the three-dimensional moulding surface (9),
5 that faces the upper mould part (5), the insert (8) comprises an inflexible coupling part (10) which acts as a support for the moulding surface (9). The insert (8) is detachably connected to the upper mould part (5) by bolts (11) acting as coupling means which are thereto provided on the inflexible coupling part (10). The upper mould part (5) is furthermore provided with suction openings (12) that are one end
10 connecting to an outside of the mould (1) connected to under-pressure means (13). The openings (12) debouch inside the mould cavity (6), wherein a space that is left between the insert (8) and a side of mould cavity (6) that ensures that an under-pressure is applied between the flexible three-dimensional moulding surface (9) and a foil layer (14). Said foil layer (14) is clamped between the insert (8) on one
15 hand and the electronic components (3) and the carrier (2) on the other hand, thereby covering at least partially the flexible three-dimensional moulding surface (9). The surfaces (15) of the electronic components (3) and the surface (16) of the carrier (2) contacted by the foil layer (14) will be exposed after moulding. The foil layer (14) will act as a release foil when the carrier (2) with the moulded electronic components (3) is released from the mould parts (4, 5).
20

Figures 2a - 2d show a schematic depiction of the method steps for encapsulating electronic components mounted on one side of a carrier using a mould according to the invention. Throughout these figures, similar elements are designated by similar
25 reference numbers. Like in figure 1, figures 2a - 2d show a mould insert (20) that encloses part of a mould cavity (21) of a mould (not further represented in these figures). The insert (20) comprises a flexible three-dimensional moulding surface (22) and an inflexible coupling part (23) attached to the flexible three-dimensional moulding surface (22). The inflexible coupling part (23) is configured for connecting
30 to a mould part. The flexible three-dimensional moulding surface (22) faces a carrier or substrate (24) provided with multiple electronic components (25, 26, 27) on one side thereof. Figure 2a shows that two of the electric components (26, 27) have a height difference (h), e.g. due to production tolerances and/or variation in electronic components type. Figure 2b depicts the situation after the mould parts
35 are moved towards each other, wherein the flexible three-dimensional moulding

surface (22) of the insert (20) contacts the electronic components (25, 26, 27). It can be seen from this figure that the height difference (h) is compensated for by means of the flexible moulding surface (22). After the carrier (24) and the electronic components (25, 26, 27) mounted thereon are enclosed between the mould parts, a moulding material (28) is introduced into the mould cavity (21) as shown in figure 2c, wherein the direction of insertion is indicated by an arrow (29). Following the complete filling of the mould cavity (21), the mould parts are moved apart from each other, lifting the flexible three-dimensional moulding surface (22) off the electronic components (25, 26, 27). Figure 2d shows the packaged product (30) resulting from the method according to the invention, wherein the electronic components (25, 26, 27) are now partly encapsulated by the moulding material (28). The parts of the electronic components (25, 26, 27) covered by the flexible three-dimensional moulding surface (22) during moulding are hereby left bare.

Figures 3a - 3d show a schematic representation of the method steps for encapsulating electronic components (45, 46, 47, 48, 49, 50) mounted on two opposing sides of a carrier or substrate (44) using another embodiment of a mould according to the invention. In these figures, similar elements are again designated by similar reference numbers. The method steps shown in figures 3a - 3d much resemble the method steps as shown in figures 2a - 2d. An important difference however is that the mould (which is not further represented in these figures) now comprises two mould inserts (40, 41) that each form part of a different one of two opposing mould cavities (42, 43). The mould cavities (42, 43) are hereby configured to each enclose one of two opposing sides of a carrier or substrate (44), which opposing sides each comprise electronic components (45, 46, 47, 48, 49, 50) and parts of the carrier (44) to be encapsulated. The inserts (40, 41) both comprise a flexible three-dimensional moulding surface (51, 52) and an inflexible coupling part (53, 54) attached to the flexible three-dimensional moulding surface (51, 52). Figure 3b depicts the situation after the mould parts are moved towards each other, wherein the flexible three-dimensional moulding surface (51) of one insert (40) contacts the electronic components (45, 46, 47) on one side of the carrier (44) and wherein the flexible three-dimensional moulding surface (52) of the other insert (41) contacts the electronic components (48, 49, 50) on the other side of the carrier (44). In addition, the three-dimensional moulding surface (52) of the last mentioned insert (41) contacts a part (55) of the carrier (44) that will thus be exposed after

moulding. Figure 3c shows the consecutive step of introducing a moulding material (56) in the mould cavities (42, 43), the direction of insertion being indicated by arrows (57). Following the complete filling of the mould cavities (42, 43), the mould parts are moved apart from each other, lifting the flexible three-dimensional

5 moulding surfaces (51, 52) off the electronic components (45, 46, 47, 48, 49, 50). In figure 3d the resulting packaged product (58) is depicted, wherein the electronic components (45, 46, 47, 48, 49, 50) are now partly encapsulated by the moulding material (56). The parts of the electronic components (45, 46, 47, 48, 49, 50) as well as the part (55) of the carrier (44) covered by the flexible three-dimensional

10 moulding surfaces (51, 52) during moulding are hereby exposed.