Method and device for encapsulating electronic components using underpressure

The invention relates to a method for encapsulating electronic components mounted on a carrier using underpressure, comprising the processing steps of: A) placing an electronic component for encapsulating in a mould cavity connecting to the carrier, B) heating encapsulating material such that it becomes liquid, C) displacing the encapsulating material to the mould cavity enclosing the electronic component by exerting pressure on the liquid encapsulating material, D) filling the mould cavity with encapsulating material, and E) at least partially curing the encapsulating material in the mould cavity. The invention also relates to a device for encapsulating electronic components mounted on a carrier, comprising mould parts which are displaceable relative to each other and which in a closed position define at least one mould cavity for enclosing an electronic component, feed means for liquid encapsulating material connecting to the mould cavity and provided with at least one plunger, and an extractor connecting to the mould cavity for extracting gas from the mould cavity.

In the encapsulation of electronic components, more particularly the encapsulation of semiconductors mounted on a carrier (such as for instance a lead frame), use is made of the so-called "transfer moulding process". The carrier with electronic components is herein clamped between mould parts such that mould cavities are defined around the components for encapsulating. Liquid encapsulating material is then introduced into these mould cavities, after at least partial curing of which the mould parts are moved apart and the carrier with encapsulated electronic components is removed. The feed of encapsulating material usually takes place by means of one or more plungers with which pressure can be exerted on a supply of encapsulating material. The plunger is displaceable in a housing into which the encapsulating material is also carried. The encapsulating material is usually placed in the mould in a non-liquid state in the form of a pellet, in the form of a package enclosed with film material, or introduced as a granulate. It is however also possible to introduce the encapsulating material in liquid form. The encapsulating material normally consists of a thermocuring epoxy or resin incorporating a filler. The plunger exerts a pressure on the encapsulating material which is simultaneously heated, as a result of which heating the encapsulating material becomes liquid. In response to the pressure applied by the plunger the liquid encapsulating material flows to the heated mould cavity and fills it with encapsulating

material. For the purpose of displacing the encapsulating material, the encapsulating material is heated, after which it cures at least partially in the heated mould cavity as a result of chemical bonding (also referred to as cross-linking). In order to increase the quality of the encapsulation it is possible to apply a determined underpressure (i.e. a gas pressure lower than the ambient air pressure) in the mould cavity before starting feed of the encapsulating material. This method is applied in practice, although the quality of the encapsulation leaves something to be desired, particularly in the processing of relatively thin carriers and in the manufacture of larger encapsulations.

The object of the present invention is to provide a method and a device for an improved controllable encapsulation of electronic components using underpressure, and to improve the quality of a thus manufactured encapsulation.

The invention provides for this purpose a method of the type stated in the preamble, wherein the underpressure in the mould cavity is actively controlled during at least one of the processing steps B) - D). More particularly, the underpressure in the mould cavity is actively controlled during processing step D). Active control of the underpressure is here understood to mean a dynamic control, whereby a determined gas pressure is obtained in the mould cavity as a result of direct control of the underpressure. This active control of the underpressure in the mould cavity prior to the start of and/or during the feed of the encapsulating material forms an alternative to passively allowing the underpressure to vary as a result of process variables, wherein an initially prevailing underpressure only decreases as a result of the feed of encapsulating material, evaporation of the encapsulating material and/or leakage from the mould cavity. Through active control of the underpressure it is possible to select the optimum gas pressure during different phases of filling of the mould cavity with encapsulating material, and the quality of the encapsulation of electronic components can increase. The underpressure will usually very between 900 mbar and 10 mbar.

The underpressure control can comprise of conditioned increase of the underpressure during at least one of the processing steps B) - D). Increasing the underpressure is understood to mean reducing the absolute gas pressure; for this purpose gas must be removed from the mould cavity (or at least the remaining part of the mould cavity not yet filled with encapsulating material). Particularly in the case of very thin carriers, a

great underpressure in the mould cavity before a substantial quantity of encapsulating material is introduced into the mould cavity can result in unwanted lifting of the carrier; this can for instance result in damage to the product for encapsulating and/or the desired dimensional accuracy of the encapsulation to be manufactured may not be achieved. It is likewise possible for the underpressure control to comprise of conditioned reduction of the underpressure during at least one of the processing steps B) - D). Reducing the underpressure is understood to mean increasing the absolute gas pressure. Increasing the relative gas pressure before and/or during filling of the mould cavity with encapsulating material may for instance be desirable in order to discharge gas present in the encapsulating material, in order to prevent too rapid a displacement of a flow front, as a result of which voids occur, in order to prevent foaming (formation of bubbles) of the encapsulating material, which can for instance result in “wire sweep”, and/or in order to prevent lifting of the carrier of the product for encapsulating. Increasing the pressure during the final part of the filling of the mould cavity may be desirable in order to thus prevent encapsulating material (or a thinner fraction of the encapsulating material) flowing out of the mould cavity through the extraction opening (also referred to as bleeding). By means of the method according to the invention it is moreover also possible to manufacture thin, relatively large encapsulations in which large numbers of electronic components can for instance be placed simultaneously in a single encapsulation.

In a preferred variant the underpressure control is linked to the degree of filling of the mould cavity. This is understood to mean that the underpressure at the specific degree of filling (for instance a 50% degree of filling of the mould cavity) is determined at a specific value. Depending on the degree of filling, the same gas pressure will therefore be repeatedly present in the mould cavity in successive encapsulating processes. The encapsulation of the electronic components mounted on a carrier is thus standardized. An invariable coupling can for instance be realized by choosing as a variable the position of a plunger with which the encapsulating material is urged to the mould cavity, whereby the underpressure in the mould cavity is controlled. Conversely, a direct measurement of the pressure in a space or channel connecting to the mould cavity can also take place.

The control of the underpressure is for instance possible by varying the action of an extractor connecting to the mould cavity. A more intense operation of the extractor can thus result in a higher underpressure, and a less intense operation of the extractor (or even stopping of the extractor) will result in a lower underpressure. The extractor can for instance be formed by a pump or by a venturi system. The venturi can then be powered with air pressure, through control of which the underpressure can be created in very inexpensive manner by means of a proportional pressure control valve.

For dynamic control of underpressure in the mould cavity it is desirable that the size of the minimum passage opening of an extraction channel connecting to the mould cavity is varied. The minimum passage opening of an extraction channel connecting to the mould cavity requires a determined minimum size for the purpose of dynamic pressure control. The drawback of an extraction channel with a minimum passage opening of considerable size is however that encapsulating material can hereby leave the mould cavity (also referred to as “bleed” and “flash”). The invention therefore also provides the option of varying the size of the minimum passage opening of an extraction channel connecting to the mould cavity. This is for instance possible by giving a segment of the extraction channel connecting to the mould cavity a displaceable, more preferably rotatable form. With a larger size of the minimum passage opening it will be possible to realize the dynamic control of the pressure in the mould cavity, and with a reduced size of the minimum passage opening the outflow of the encapsulating material can be prevented. The displaceable wall part can be embodied in practice such that the passage is not fully closed in order to thus also be able to allow escape from a mould cavity of the gas that is present during filling of the final part of a mould cavity. Another advantage of a variable size of (a part of) the extraction channel is that very viscous encapsulating material can thus also be processed. Yet another advantage of the variable size of (a part of) the extraction channel is that dispersal of cleaning material or gases released during cleaning can hereby be prevented during cleaning of the mould cavity. It is otherwise noted that the channel of variable size can also be fully closed if, in addition to this channel, at least one discharge channel of limited dimensions, which is continuously open, also connects to the mould cavity. This will be further elucidated hereinbelow.

In yet another advantageous application of the present method the underpressure control is menu-controlled subject to process variables. The process variables to be entered into the menu can for instance consist of: the type of encapsulating material, the processing temperature, the type and the thickness of the carrier material, the ambient pressure, the desired processing speed, position of components, minimum quality level and so on. Depending on the entered variables, the menu will cause the underpressure in the mould cavity to vary during feed of the encapsulating material in accordance with an associated (and preferably optimized) pattern. Only entering of the variables therefore makes it possible to control the underpressure.

The invention also provides a device of the type stated in the preamble, wherein the device is provided with a control with which the underpressure in the mould cavity can be actively controlled. Active control is herein understood to mean a dynamic control option such that more and less underpressure prevails in the mould cavity as desired during the feed of encapsulating material. As already explained above on the basis of the method according to the invention, a variable can in this way be controlled with which improved control of the encapsulating process becomes possible. This will of course result in an improved quality of the encapsulated electronic components. The control will normally consist of an intelligent control unit. The control can intervene directly in the operation of the extractor with which the underpressure in the mould cavity is generated. It is thus also possible for the control to be coupled to an extractor, which can be embodied as a pump or as a venturi system. A venturi system has the advantage that structurally it can be take a very inexpensive form.

In another advantageous embodiment variant the device is provided with an extraction channel which connects the mould cavity and the extractor, and a wall part of which can be displaced such that the minimum passage opening of the extraction channel can be changed. This displaceable wall part can for instance be embodied as a rotatable wall part. By displacing the wall part the extraction channel with which the extractor connects to the mould cavity can be obstructed to a lesser or greater extent. Such a displaceable wall part is of simple construction and can be given an operationally reliable form. For the purpose of displacement the extractor can be moved by a motor forming part of the control, for instance an electric motor or a pneumatically or hydraulically driven motor.

The device can also be embodied with at least one extraction channel connecting the mould cavity and the extractor and provided with a displaceable wall part, and at least one extraction channel connecting to the mould cavity and having a fixed wall structure. The extraction channel with the fixed wall structure (for instance a standard "venting") can then be embodied with a relatively small passage, such that no encapsulating material can leave the mould cavity therethrough, while the extraction channel with the displaceable wall part can provide a large passage in order to enable the dynamic pressure control in the mould cavity, while the extraction channel can also be given a fully sealable form. The limited amount of gas which still has to be extracted from the mould cavity during the final phase of filling of the mould cavity can then take place through the (smaller) extraction channel with the fixed wall structure.

In yet another embodiment variant the plunger is provided with a position detector, this position detector connecting to the control. Provided the starting position is known, the position of the plunger forms an accurate measure for the filling level of the mould cavity. The position of the plunger can be readily determined by means of position detectors. External measurement (i.e. a measurement outside the mould cavity) is thus representative of the filling level. It is otherwise noted here that is also possible to measure the pressure in the mould cavity by a direct measurement of the pressure in a recess connecting to the mould cavity.

The present invention also provides a mould part for application in an encapsulating device according to the invention, which mould part is provided with at least one extraction channel with a displaceable wall part as described above. Using such an extraction channel a rapid and dynamic pressure control of the pressure in the mould cavity is made possible, while a limitation of the extraction channel can still be set at the desired moments, this with the advantages as described above.

The present invention will be further elucidated on the basis of the non-limitative exemplary embodiments shown in the following figures. Herein:
figure 1 shows a schematic view of a device according to the invention,

figure 2 shows a graph of the gas pressure in the mould cavity of an encapsulating device plotted against the degree of filling of the mould cavity as can be realized by means of the method according to the invention, and

figure 3A shows a perspective view of a rotatable wall part of an extraction channel as forms part of an embodiment variant of the device according to the invention, in an opened position,

figure 3B is a perspective view of the rotatable wall part as shown in figure 3A, here however in a substantially closed position,

figure 3C is a perspective view of a drive of the displaceable wall part as shown in figures 3A and 3B.

Figure 1 shows a device 1 for encapsulating electronic components 3 mounted on a carrier 2. The carrier is clamped between two mould parts 4, 5 such that electronic components 3 are here received in a mould cavity 6 which is left clear in top mould part 4. An encapsulating material 8 which has become liquid due to heating can be urged through a runner 9 to mould cavity 6 by means of a plunger 7. In order to now obtain the proper filling of the mould cavity with encapsulating material 9, gas (generally air, possibly with gases released from encapsulating material 9) can be extracted via an extraction chamber 11 and an extraction channel 12 to the environment (see arrow P_1) by activating a pump 10.

Device 1 is further provided with an intelligent control 13, here shown in the form of a computer, which can preferably be programmed with a plurality of menus in order to implement, subject to determined parameters to be entered, a dynamic control of the underpressure in mould cavity 6 appropriate for the relevant conditions. The intelligent control 13 is connected, optionally wirelessly, to a sensor 14, which transmits the position of plunger 7. The degree of filling of mould cavity 6 is after all directly dependent on the position of plunger 7 (making use of known initial values of the quantity of encapsulating material 8 and of the starting position of plunger 7 at the start of the process). The intelligent control 13, supplied with the relevant variable(s) for the selection of a specific item in respect of the dynamic underpressure pattern and supplied with the measurement values from sensor 14, will control the underpressure in the mould cavity, as for instance shown in this figure by direct control of pump 10.

Figure 2 shows in graph 20 an example, in the form of line 21, of a profile of the pressure which can occur in a mould cavity (6, see figure 1). On X-axis 22 the degree of filling of the mould cavity (or the position of a plunger (7, see figure 1) directly corresponding therewith) is plotted against the absolute value of the pressure in the mould cavity on Y-axis 23. It can be clearly seen that initially (i.e. in the case of a mould cavity not filled with encapsulating material, or filled only to a very limited extent) the pressure in the mould cavity is relatively high (i.e. the pressure in the mould cavity is only a little below atmospheric pressure). As the mould cavity becomes further filled, the pressure can decrease further because the chance of lifting of the carrier as a result of the prevailing underpressure in the mould cavity is small due to the encapsulating material already being present. In a subsequent part of the graph the pressure rises again, this in order to suppress the tendency of the encapsulating material to begin "foaming" at that moment. As the mould cavity then becomes even further filled, the pressure can be reduced very considerably, eventually to possibly even only several tens of mbar above vacuum.

Figure 3A shows a view of the contact side of a mould part 30 with an extraction channel 31, which connects on one side to a mould cavity 32 and on the opposite side transposes into a subsequent extraction channel 37 leading through the mould part. Situated in extraction channel 31 is a rotatably displaceable wall part 33, which is placed in this figure such that extraction channel 31 is fully opened. It is noted that mould part 30 takes a multiple form; an identical mirrored structure with another mould cavity 34, a discharge channel 35 and a rotatable wall part 36 is also shown in this figure 3A.

Figure 3B shows the rotatable wall part 33 shown in figure 3A, now however in a position in which it is rotated relative to the previously shown position. Extraction channel 31 is hereby now obstructed to a considerable extent by rotatable wall part 33. By rotating wall part 33 the outflow of encapsulated material from mould cavity 32 can thus be prevented, while a dynamic control of the underpressure in mould cavity 32 is still also possible.

Figure 3C here shows a schematic side view of extraction channel 31 and rotatable wall part 33. In mould cavity 32 encapsulating material 38 is flowing over carrier 39, on

which are placed the already no longer visible electronic components. For rotation of rotatable wall part 33 in extraction channel 31 a rotation shaft 40 connected to rotatable wall part 33 is rotated (see arrow P_2). The operation of rotation shaft 40 takes place in that a linearly displaceable operating strip 41 (see arrow P_3) is operated with a cylinder 42. Strip 41 engages on an operating tongue 42 connected to rotation shaft 40 of rotatable wall part 33. A dynamic control of the pressure in mould cavity 32 is thus also possible by actuating operating cylinder 42.

Claims

1. Method for encapsulating electronic components mounted on a carrier using underpressure, comprising the processing steps of:

A) placing an electronic component for encapsulating in a mould cavity connecting to the carrier,

B) heating encapsulating material such that it becomes liquid,

C) displacing the encapsulating material to the mould cavity enclosing the electronic component by exerting pressure on the liquid encapsulating material,

D) filling the mould cavity with encapsulating material, and

E) at least partially curing the encapsulating material in the mould cavity,

characterized in that the underpressure in the mould cavity is actively controlled during at least one of the processing steps B) - D).

2. Method as claimed in claim 1, **characterized in that** the underpressure control comprises of conditioned increase of the underpressure during at least one of the processing steps B) - D).

3. Method as claimed in claim 1 or 2, **characterized in that** the underpressure control comprises of conditioned decrease of the underpressure during at least one of the processing steps B) - D).

4. Method as claimed in any of the foregoing claims, **characterized in that** the underpressure control is linked to the degree of filling of the mould cavity.

5. Method as claimed in any of the foregoing claims, **characterized in that** the underpressure control takes place by varying the action of an extractor connecting to the mould cavity.

6. Method as claimed in any of the foregoing claims, **characterized in that** the size of the minimum passage opening of an extraction channel connecting to the mould cavity is varied.

7. Method as claimed in claim 6, **characterized in that** the passage of a connection to the mould cavity is varied by rotating a segment of an extraction channel providing the connection.

8. Method as claimed in any of the foregoing claims, **characterized in that** the underpressure control is menu-controlled subject to process variables.

9. Device for encapsulating electronic components mounted on a carrier, comprising:

- mould parts which are displaceable relative to each other and which in a closed position define at least one mould cavity for enclosing an electronic component,
- feed means for liquid encapsulating material connecting to the mould cavity and provided with at least one plunger, and
- an extractor connecting to the mould cavity for extracting gas from the mould cavity,

characterized in that the device is provided with a control with which the underpressure in the mould cavity can be controlled.

10. Device as claimed in claim 9, **characterized in that** the control connects to the extractor.

11. Device as claimed in claim 9 or 10, **characterized in that** the device is provided with an extraction channel which connects the mould cavity and the extractor, and a wall part of which can be displaced such that the minimum passage opening of the extraction channel can be changed.

12. Device as claimed in claim 11, **characterized in that** the displaceable wall part is a rotatable wall part.

13. Device as claimed in claim 11 or 12, **characterized in that** the device is provided with at least one extraction channel connecting the mould cavity and the extractor and provided with a displaceable wall part, and at least one extraction channel connecting to the mould cavity and having a fixed wall structure.

14. Device as claimed in any of the claims 9-13, **characterized in that** the plunger is provided with a position detector, this position detector connecting to the control.

15. Device as claimed in any of the claims 9-14, **characterized in that** the control comprises a motor.

16. Mould part for application in a device as claimed in any of the claims 9-15, which mould part is provided with at least one displaceable wall part as claimed in claims 11-13.