

Method for encapsulating electronic components with a controllable closing force

The present invention relates to a method for encapsulating electronic components mounted on a carrier with encapsulating material, comprising the processing steps of:

- 5 A) placing an electronic component for encapsulating on a mould part, B) moving a number of mould parts toward each other with a closing force such that the electronic component for encapsulating is enclosed by a mould cavity and the carrier is clamped between the mould parts, C) exerting pressure on a liquid encapsulating material with at least one plunger such that encapsulating material is displaced to the mould cavity
- 10 enclosing the electronic component, D) filling the mould cavity with encapsulating material, and E) at least partially curing the encapsulating material in the mould cavity.

According to the prior art, the closing force is constant irrespective of the process situation, or control of the closing force takes place at two different levels; a lower

15 pressure level while the mould cavity is being filled with encapsulating material (the feed situation) and a higher pressure level with greater closing force when the mould cavity is completely filled with encapsulating material and at which moment the filling pressure is also higher than in the feed situation. The moment of transition from the (detected) lower pressure to a (detected) higher pressure is generally determined by a

20 plunger, with which the encapsulating material is supplied, reaching a determined position. A drawback of the pressure control on the basis of a position of one (or more) plunger(s) is that such a control is inaccurate and unreliable. Such a control does not for instance take into account of, among other factors, variations in the weight/volume of the pellets of encapsulating material to be displaced with the plunger and of variations

25 in the volume of the mould cavities to be filled (for instance due to the presence of more or fewer electronic components for encapsulation). The existing control can be realized in simple and reliable manner, but the quality of the encapsulation of electronic components placed on a carrier requires further improvement. Particularly the carriers, also referred to as boards or substrates, of softer quality and lower compression strength

30 are susceptible to overload and deformation during the encapsulating process. Not only can this have adverse consequences for the carrier, the process conditions can also be adversely affected as a result; the passage for encapsulating material and the passage for venting can thus be affected, this resulting in uncontrollable process conditions (and therefore also uncontrollable process results).

The present invention therefore has for its object to provide an improved method for encapsulating electronic components mounted on a carrier with encapsulating material, with less waste and an improved quality of encapsulation.

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The invention provides for this purpose a method as stated in the preamble, wherein the pressure on the encapsulating material is measured by at least one force sensor, and the closing force with which the mould parts are urged toward each other and the pressure exerted on the encapsulating material are dynamically dependent on each other over
10 time. The pressure on the encapsulating material is preferably measured with a pressure sensor connecting to the encapsulating material or with a force sensor connecting to the plunger. The advantages of the method according to the invention are related to the resultant of the pressure the encapsulating material exerts on the mould parts in the mould cavity and the closing force with which the mould parts are urged toward each
15 another. This is because this resultant has now become readily controllable. The resultant determines the pressure exerted on the carrier by the mould parts. A good controllability of the force exerted on the carrier can prevent the resultant (also referred to in practice as the board pressure) exceeding a determined maximum. Undesirable damage and deformation of the carriers can thus be prevented. It is hereby also possible
20 to prevent the resultant falling below a determined minimum during an encapsulating process, thereby preventing undesirable leakage of liquid encapsulating material outside the mould cavity (so-called flash and bleed). The present method thus results in an improved encapsulating result (for example a better compaction of the encapsulation/housing manufactured from encapsulating material); less damage to the
25 carrier and less contamination of the carrier.

The pressure on the encapsulating material is measured with a force sensor which can for instance consist of a pressure sensor connecting to the encapsulating material. One or more of these sensors can measure the pressure on the encapsulating material very
30 precisely, and are here in contact with the encapsulating material. The sensor must then be chosen such that it does not fail as a result of curing encapsulating material and that the presence of the sensor does not have a negative effect on the encapsulating process. An alternative method of measuring the pressure on the encapsulating material consists of measuring a force with a force sensor connecting to the plunger. The force sensor can

then function at a distance from the encapsulating material, and there is therefore no (or less) danger of contamination caused by curing encapsulating material.

5 The closing force of the mould parts and the pressure on the encapsulating material are dynamically dependent on each other, i.e. in continuous manner over time and correcting both positively and negatively, in other words not just one or more discrete levels has/have been defined on the basis of which the relative adjustment of pressures is controlled in accordance with a fixed pattern. No, the adjustment takes place in continuous manner and can not only follow a preprogrammed model but, subject to the
10 measured values, will result in a random positive or negative adjustment of the variable(s) to be controlled. Such a free control of the pressure on the encapsulating material and the closing force also has the advantage that the closing pressure at the start of encapsulation (i.e. as long as the mould cavity is not yet fully filled with encapsulating material), when the pressure on the encapsulating material is still
15 relatively low, can likewise remain limited. This has the result that the connections to the mould cavity (the feed for encapsulating material and the gas discharge) will remain relatively large and that the space in the mould cavity, particularly the space between the electronic components for encapsulating and the walls of the mould cavity, is also relatively large. This is a consequence of the relatively low closing pressure during the
20 start of the encapsulating process, i.e. during filling of the mould cavity with encapsulating material, whereby the mould parts are not closed so tightly that they deform the carrier to a considerable extent. The resulting process advantage is that the feed of encapsulating material and the degasification can take place relatively easily, and that due to the additional space in the mould cavity the flow of the encapsulating
25 material also takes place more easily and with less chance of deformation of for instance connecting wires (wire sweep). Not only is the processed result hereby improved, but the feed of encapsulating material and the pressure buildup later during a processing cycle, when the mould cavity is fully filled with encapsulating material, can also be accelerated.

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The pressure on the encapsulating material is preferably measured, on the basis of which the closing force of the mould parts is controlled. In this situation the pressure on the encapsulating material, also referred to as the filling pressure, is the leading variable (master) on the basis of which the closing force of the mould parts is controlled (slave).

It is however also possible for the closing force of the mould parts to be measured, on the basis of which the pressure on the encapsulating material is controlled. In this second situation the closing force is the leading variable (master) on the basis of which the pressure on the encapsulating material is controlled (slave). It is however also
5 possible for both variables, closing force and the pressure on the encapsulating material, to be interactively related to each other.

It is also possible to vary the passage of a gas discharge connecting to the mould cavity on the basis of the measured pressure. This is possible by controlling a variable passage
10 opening, for instance by rotating a channel segment (V-pin) or displacing a wall part of a discharge channel for gas coming from the mould cavity. Another option is dynamic control of the underpressure on the gas discharge such that this is dependent on the variation of the pressure on the encapsulating material detected with the pressure sensor. Reference is made for this purpose to, among others, the patent publications NL
15 1026739 and NL 2000488.

In order to further enhance the reliability of the present method it is desirable that at least one value is determined for the pressure on the encapsulating material, upon detection of which the clamping force is increased to a determined minimum value if
20 this value has not yet been reached. A safeguard is in this way introduced. This is because, if the pressure on the encapsulating material acquires a determined minimum value, the closing pressure of the mould parts will also have to increase. In the unlikely event the dynamic control were to fail, serious problems such as loss of products, contamination of the mould parts and so on can in this way be prevented.

25 According to yet another further improvement, the pressure of the mould parts on the carrier is also measured, and the closing force with which the mould parts are urged toward each other and the pressure exerted on the encapsulating material are then dependent over time on the pressure measured on the mould parts. This measurement of
30 the pressure exerted on the carrier represents a direct measurement of a variable which can be critical. Particularly in the case of the processing of a carrier at a level of surface load at small distance to which the carrier is sensitive, an additional safeguard against overload can thus be prevented.

It is also possible using the improved method to still detect the plunger position and, when at least one predetermined position is reached, to modify the clamping force to a determined value if this value has not yet been reached. An additional safeguard is incorporated in this way. A calamity can in this way be prevented if for instance a
5 pressure sensor, with which the pressure on the encapsulating material is measured, fails and does not transmit any correct values.

The present invention also provides a device for encapsulating electronic components mounted on a carrier, comprising: at least two mould parts displaceable relative to each
10 other and provided with a mould cavity for defining, in a position urged toward each other, a mould cavity enclosing the electronic component on a carrier clamped between the mould parts, feed means connecting to the mould cavity and provided with at least one plunger for the purpose of exerting pressure on a liquid encapsulating material such that the encapsulating material is displaced to the mould cavity enclosing the electronic
15 component, at least one force sensor for detecting the pressure on the liquid encapsulating material, drive means for mutually displacing and urging the mould parts toward one another with a controllable pressure, an intelligent control connecting to the force sensor and the drive means of the mould parts, this intelligent control being adapted to control the drive means of the mould parts dynamically over time at least
20 partially subject to the measured values detected with the force sensor. The intelligent control connecting to the force sensor and the drive means of the mould parts is preferably coupled to the feed means for encapsulating material for the purpose of controlling the pressure exerted by the plunger on the encapsulating material. The force sensor can comprise a pressure-sensitive sensor connecting to the mould cavity, but can
25 also connect to the plunger. It is further advantageous if the intelligent control is provided with a control system, wherein an increasing pressure on the encapsulating material results in an increasing pressure exerted by the drive means of the mould parts in a direction toward each other. The advantages of the encapsulating device according to the present invention have already been described with reference to the method for
30 encapsulating electronic components according to the present invention.

The invention is further elucidated on the basis of the non-limitative exemplary embodiments shown in the following figures. Herein:

figure 1 shows a schematic representation of an encapsulating device according to the invention,

figure 2 shows a schematic representation of an alternative embodiment variant of an encapsulating device according to the invention, and

- 5 figure 3 shows three graphs with the variation of the pressure on the encapsulating material, the force with which the mould parts are urged toward each other and the resulting pressure on the carrier.

Figure 1 shows a schematic representation of an encapsulating device 1 provided with
10 two mutually displaceable mould parts 2, 3 into which mould cavities 5 are recessed on the mutually facing contact sides 4. Incorporated in the lower mould part 3 is a plunger 6 with which a pellet (not shown in this figure) of encapsulating material (for instance epoxy) can be pushed upward after it has been heated such that the encapsulating material, which has thus become liquid, flows to mould cavities 5 through channels
15 arranged for this purpose in mould parts 2, 3. For the relative displacement of mould parts 2, 3 the lower mould part 3 forms a stationary assembly with a frame 7 and upper mould part 2 is coupled to frame 7 via drive means in the form of a cylinder 8. It is noted that the drive means can also be formed by an electromechanical drive or a pneumatic/hydraulic pressure-increasing drive. Mould parts 2, 3 can be displaced
20 relatively by cylinder 8 and urged with a determined pressure against each other. The displacement of plunger 6 for the encapsulating material takes place by operating a servomotor 9 with which a spindle 10 is rotated. The rotation of spindle 10 results in a vertical displacement of a table 11 along vertical guides 12, on which table 11 the plunger 6 supports and thus co-displaces with table 11.

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A force sensor 13 (load cell) is placed between table 11 and plunger 6. Force sensor 13 can thus generate a measurement value which, as long as the encapsulating material is liquid, is representative of the pressure on the encapsulating material. Force sensor 13 is connected via a signal line 14 to an intelligent control 15. Intelligent control 15 is also
30 supplied with information coming from servomotor 9 (see signal line 16 with which for instance position-dependent information of plunger 6 can be transmitted) and information coming from cylinder 8 (see signal line 17 with which for instance position and pressure-dependent information from cylinder 8 can be transmitted). Intelligent control 15 can further also be supplied by a signal line 18 with information from a

machine control 19. Machine control 19 is connected with a control line 20 to a control 21 for a pump 22 with which the displacement of cylinder 8 is controlled. Intelligent control 15 acts via respective control lines 23, 24 on servomotor 9, with which plunger 6 is displaced, and a control 25 with which the operation of cylinder 8 is controlled. The pressure on the encapsulating material is thus controlled by the displacement of plunger 8 and the closing pressure of mould parts 2, 3 by cylinder 8, these being adapted to each other in dynamic and continuous manner.

Figure 2 shows an alternative embodiment variant of an encapsulating device 30 in which the components corresponding to the components of encapsulating device 1 as shown in figure 1 are designated with identical reference numerals. At variance with the above shown encapsulating device 1, the encapsulating device 30 shown here is provided with a pressure sensor 31 which is received in a mould cavity 5 recessed into lower mould part 3 such that the detection surface of pressure sensor 31 forms a part of the wall of mould cavity 5. The pressure on the encapsulating material situated in mould cavity 5 can hereby be detected directly with pressure sensor 31. The thus recorded measurement values are sent via a signal line 32 to intelligent control 15. Pressure sensor 31 forms an alternative to force sensor 13 under plunger 6 as forms part of encapsulating device 1.

Figure 3 shows three graphs 40, 41, 42 showing the parallel variation of the pressure over a period of time for respectively the pressure (F_{transfer} , graph 40) exerted on the encapsulating material by a plunger, the force (F_{clamp} , graph 41) with which the mould parts are urged toward each other, and the resulting pressure (F_{board} , graph 42) on the carrier of the electronic components which is clamped between the mould parts. The top graph 40 shows that the pressure F_{transfer} exerted on the encapsulating material remains limited for a longer period of time during filling of the mould cavity with encapsulating material, and then suddenly increases quickly as soon as the mould cavity is fully filled with encapsulating material. The middle graph 41 shows that the pressure F_{clamp} with which a carrier (board) is clamped between the mould parts, after having been at a constant level for a longer period of time (again while the mould cavity is being filled with encapsulating material), suddenly increases rapidly to a higher level. Due to the mutual dependence of F_{transfer} and F_{clamp} , which is controlled by intelligent control 15 as shown in figures 1 and 2, the resulting force which acts on the carrier (F_{board}) remains

- within two extreme values (between the upper and lower limits $F_{\text{board max}}$ and $F_{\text{board min}}$ shown with broken lines). This is because the force which acts on the carrier consists of the force with which the mould parts are moved toward each other minus the (counter)pressure of the encapsulating material in the mould cavity ($F_{\text{board}} = F_{\text{clamp}} -$
- 5 F_{transfer}). In the shown example the pressure on the encapsulating material is controlled dynamically and continuously; the graph of this pressure (F_{transfer}) does after all display an unpredictable pattern clearly deviating from a straight line.

Claims

1. Method for encapsulating electronic components mounted on a carrier with encapsulating material, comprising the processing steps of:
 - 5 A) placing an electronic component for encapsulating on a mould part,
 - B) moving a number of mould parts toward each other with a closing force such that the electronic component for encapsulating is enclosed by a mould cavity and the carrier is clamped between the mould parts,
 - C) exerting pressure on a liquid encapsulating material with at least one plunger such
10 that encapsulating material is displaced to the mould cavity enclosing the electronic component,
 - D) filling the mould cavity with encapsulating material, and
 - E) at least partially curing the encapsulating material in the mould cavity,wherein
 - 15 - the pressure on the encapsulating material is measured by at least one force sensor, and
 - the closing force with which the mould parts are urged toward each other and the pressure exerted on the encapsulating material are dynamically dependent on each other over time.
- 20 2. Method as claimed in claim 1, **characterized in that** the pressure on the encapsulating material is measured with a pressure sensor connecting to the encapsulating material.
- 25 3. Method as claimed in claim 1 or 2, **characterized in that** the pressure on the encapsulating material is measured with a force sensor connecting to the plunger.
4. Method as claimed in any of the foregoing claims, **characterized in that** the pressure on the encapsulating material is measured, on the basis of which the closing
30 force of the mould parts is controlled.
5. Method as claimed in any of the foregoing claims, **characterized in that** the closing force of the mould parts is measured, on the basis of which the pressure on the encapsulating material is controlled.

6. Method as claimed in any of the foregoing claims, **characterized in that** the passage of a gas discharge connecting to the mould cavity is varied on the basis of the measured pressure.

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7. Method as claimed in any of the foregoing claims, **characterized in that** at least one value is determined for the pressure on the encapsulating material, upon detection of which the clamping force is increased to a determined minimum value if this value has not yet been reached.

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8. Method as claimed in any of the foregoing claims, **characterized in that** the pressure of the mould parts on the carrier is measured, and the closing force with which the mould parts are urged toward each other and the pressure exerted on the encapsulating material are then dependent over time on the pressure measured on the mould parts.

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9. Method as claimed in any of the foregoing claims, **characterized in that** the plunger position is detected and, when at least one predetermined position is reached, the clamping force is modified to a determined value if this value has not yet been reached.

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

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- at least two mould parts displaceable relative to each other and provided with a mould cavity for defining, in a position urged toward each other, a mould cavity enclosing the electronic component on a carrier clamped between the mould parts,
- feed means connecting to the mould cavity and provided with at least one plunger for the purpose of exerting pressure on a liquid encapsulating material such that the encapsulating material is displaced to the mould cavity enclosing the electronic component,
- at least one force sensor for detecting the pressure on the liquid encapsulating material,
- drive means for mutually displacing and urging the mould parts toward one another with a controllable pressure,

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- an intelligent control connecting to the force sensor and the drive means of the mould parts, this intelligent control being adapted to control the drive means of the mould parts dynamically over time at least partially subject to the measured values detected with the force sensor.

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11. Encapsulating device as claimed in claim 10, **characterized in that** the intelligent control connecting to the force sensor and the drive means of the mould parts is coupled to the feed means for encapsulating material for the purpose of controlling the pressure exerted by the plunger on the encapsulating material.

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12. Encapsulating device as claimed in claim 10 or 11, **characterized in that** the force sensor comprises a pressure-sensitive sensor connecting to the mould cavity.

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13. Encapsulating device as claimed in any of the claims 10-12, **characterized in that** the force sensor connects to the plunger.

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14. Encapsulating device as claimed in any of the claims 10-13, **characterized in that** the intelligent control is provided with a control system, wherein an increasing pressure on the encapsulating material results in an increasing pressure exerted by the drive means of the mould parts in a direction toward each other.