

Method and device for encapsulating electronic components using a reduction material which undergoes a phase change

The invention relates to a method for encapsulating electronic components mounted on a carrier, comprising the processing steps of: A) placing an electronic component for encapsulating into a mould cavity connecting to the carrier, B) filling the mould cavity with liquid encapsulating material, and C) at least partially curing the encapsulating material in the mould cavity. The invention also relates to a device for performing such a method.

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In the encapsulation of electronic components, more particularly the encapsulation of semiconductors mounted on a carrier (such as for instance a lead frame), use can be made of different types of encapsulating process such as, among others, transfer moulding, compression moulding, injection moulding or a combination of these encapsulating processes. It is noted here that semiconductors are interpreted broadly here such that, in addition to chips, they also include other electronic components such as for instance Light Emitting Diodes (LEDs). The carrier with electronic components is clamped here between mould parts such that mould cavities are defined around the components for encapsulating. A liquid encapsulating material is fed 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 encapsulating material usually consist of a thermocuring epoxy or resin incorporating a filler. Pressure is exerted on the encapsulating material, which is usually also heated, as a result of which heating the encapsulating material, to the extent it is not already liquid, does become liquid. The liquid encapsulating material fills the (usually heated) mould cavity and the liquid encapsulating material cures at least partially in the mould cavity, for instance by means of chemical bonding (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. The mould cavity is here usually brought to underpressure through suction channels (ventings) which enable the discharge of gases during filling of the mould cavity. It is of great importance to completely fill the mould cavity with encapsulating material. A problem in the encapsulation of electronic components is that, depending on the specific conditions, the mould cavities are not always completely

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filled with encapsulating material, whereby openings (voids) remain in the encapsulations to be produced. This phenomenon occurs particularly at the front of the flow front of the encapsulating material in the mould cavity, where (small) air bubbles or released gases may be enclosed in the encapsulating material.

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The present invention has for its object to provide a method and device for encapsulating electronic components, wherein the chance of voids occurring in the encapsulation of electronic components is reduced.

- 10 The present invention provides for this purpose a method of the type stated in the preamble, wherein a reduction material is introduced into the mould cavity before the mould cavity is wholly or partially filled with encapsulating material, which reduction material undergoes a phase change during filling of the mould cavity with the encapsulating material such that the volume of the reduction material decreases. It is
- 15 possible here for the reduction material to at least condense from the gas phase during filling of the mould cavity with the encapsulating material, although it is also possible for the reduction material to transpose from the gas phase to the solid phase, or for the reduction material to condense as (optionally superheated) vapour or to transpose to a solid substance. For the purpose of performing the method the reduction material can be
- 20 carried actively into the mould cavity in gas phase and/or as mist, wherein a more specific option is to actively feed the reduction material as superheated steam. It is on the other hand also possible for the reduction material to be in liquid phase or in solid phase when it is actively carried into the mould cavity. What is relevant is that, under the conditions prior to feeding of the encapsulating material to the mould cavity, the
- 25 reduction material has a relatively large volume (low mass density) and that, under the conditions in which the encapsulating process takes place, the reduction material undergoes a phase change. Not only is the temperature relevant here, the pressure increase also plays an important part since the temperature at which the phase change occurs is very much dependent on the pressure. Encapsulation takes place in a
- 30 temperature range of [150-200] °C and at a pressure of [50-100] Bar, more particularly at [60-90] Bar. In order to obtain a maximum reduction in the volume of the reduction material (i.e. the greatest possible compression factor) it is further desirable that the molecular weight of the reduction material is as small as possible.

The invention also provides a method wherein a film material is arranged between the carrier with electronic components and the mould cavity connecting to the carrier, the liquid encapsulating material is fed between the carrier and the film material and the reduction material is carried between the film and the mould cavity. The reduction material is thus separated from the electronic components for encapsulating, from the carrier and from the encapsulating material. To the extent that the presence (of relatively small quantities) of the reduction material could damage the encapsulating process, these drawbacks can be prevented. The reduction material is in this way after all situated on the side of the film material facing away from the carrier with electronic components, while the carrier with electronic components (and later, during the encapsulating process, the encapsulating material as well) is on the contrary situated on the opposite side of the film (i.e. the side of the film material facing toward the carrier with electronic components).

Irrespective of its state (i.e. whether or not it has been reduced), the reduction material does not therefore affect the condition of the carrier with electronic components and the encapsulating material; contact is after all prevented. An advantage of the encapsulation of electronic components, wherein a film material is applied in combination with application of a reduction material, is that the advantages of applying encapsulating material (for instance no chance of adhesion of the encapsulating material to the mould cavity) can thus be realized without structural measures having to be taken in order to enable degassing of the mould cavity. In the encapsulation with film material it is thus not necessary to make provision for preventing the buildup of overpressure in the mould cavity. Particularly in higher mould cavities (to be applied in combination with LEDs, for instance for wholly or partially encapsulating and/or manufacturing optical lenses) the overpressure can rise high, whereby the risk of damage to the film material (mini-cracks) increases. Discharge channels are usually arranged for this purpose in the mould part in which the mould cavity (or the mould cavities) are arranged. The presence of the reduction material makes such a provision unnecessary because a volume reduction occurs as a result of the phase change in the reduction material such that a degassing (venting) of the mould cavity or cavities has become unnecessary. Not only does this make the mould part with the mould cavity or cavities easier to manufacture but, perhaps more importantly, it thus also makes a simpler mould part less susceptible to malfunction during operation. This is because degassing provisions connecting to a

mould cavity can become easily clogged with dirt or, for instance in the case that a film separation does not function properly, with encapsulating material. Cleaning such a mould part with clogged degassing provision is labour-intensive and can impede the progress of production. Another advantage of the superfluity of a degassing provision is that it hereby becomes possible to apply smooth or even polished mould cavities for the purpose of manufacturing encapsulations with specific possible applications. The invention makes it unnecessary to guide enclosed gas to a venting via surface roughness of the mould cavity. It thus becomes possible for instance to manufacture lenses using encapsulating material.

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Yet another sought-after property of the reduction material is that it does not already undergo a reducing phase change before the pressure is increased; premature condensation of the reduction material for instance is in this way prevented. This is not only important because the desired effect (substantial volume reduction of the reduction material during the encapsulating process) no longer occurs in the case of for instance premature condensation; the condensate can also impede good encapsulation. On the other hand, a phase change of the reduction material before the encapsulating process begins is however permitted if it is an expanding phase change. If a reduction material is introduced in for instance liquid phase or solid phase into the mould cavity but the reduction material expands before the actual encapsulating process takes place, this does not have to be a problem. The reason is that the evaporation of the liquid or solid before the beginning of the encapsulating process causes the reduction material to then also be voluminous (i.e. have a very low mass density Δ) before the encapsulating process begins. The volume reduction of the reduction material can be very considerable due to condensation. Owing to this volume reduction little volume of possible (small) air bubbles enclosed in the encapsulating material will thus remain; the enclosed compartments hereby become so small that they need no longer be qualified as enclosed spaces. Due to this effect the encapsulating material nevertheless completely fills the encapsulating space, despite the initial inclusions. The air or other gases which were present according to the prior art in the mould cavity during the feed of encapsulating material will of course be compressed as a result of the increasing pressure, although this compression factor is directly proportional to the increase in the (gas) pressure. The enclosed compressed gas does therefore result in the formation of inclusions (voids) in the encapsulating material, which is particularly undesirable. This

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will be illustrated below on the basis of a specific embodiment. The presence of the reduction material which undergoes a phase change will enable an improved product quality to be realized; particularly in the case of electronic products which are relatively difficult to encapsulate completely. It is for instance possible here to envisage larger products, flip chips and other stacked electronic components wherein intermediate spaces are present between which it is difficult for the encapsulating material to flow. Application of less liquid encapsulating material and a good filling over the whole surface of a (larger) mould cavity can likewise be realized using the method according to the present invention.

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An advantageous choice is found to be the choice for H₂O (water) as reduction material. Not only is the molecular mass of this reduction material small ($M_{\text{water}} = 0.018 \text{ kg/mol}$), it also has the desired condensation behaviour at a pressure increase from 1 to for instance 80 bar (at a constant temperature of for instance $T = 150^\circ \text{C}$). During the change occurring from the gas phase at 1 atmosphere with $\Delta_{\text{water}} = \pm 0.5 \text{ kg/m}^3$ to the liquid phase with $\Delta_{\text{water}} = \pm 900 \text{ kg/m}^3$ a volume reduction thus occurs with a factor in the order of about 1800. Heretofore it has always been a starting point according to the prior art to prevent the encapsulating process being disrupted by water. With this objective the encapsulating material is thus conditioned with extreme care according to the prior art. The unexpected and not obvious insight leading to this invention is that the presence of water in the encapsulating device can on the contrary result in an improved encapsulating result. Another option for a reduction material which condenses under the encapsulating conditions is C₂H₄OH (ethanol), $M_{\text{ethanol}} = 0.046 \text{ kg/mol}$. The increasing pressure results in a volume reduction with a factor in the order of about 350. This is still a respectable volume reduction, which can also result in a clear improvement in the encapsulating result.

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A further improvement of the desired effect is that an underpressure is applied in the mould cavity before or during filling of the mould cavity with encapsulating material as according to processing step B). This refers to an underpressure relative to atmospheric pressure, or a pressure lower than 1 atmosphere. An underpressure which can be realized in the mould cavity in simple manner amounts to 0.1 Bar absolute. The volume reduction as calculated in the previous paragraph is hereby increased by a factor 10.

- This means that, under the modified starting condition: $\Delta_{\text{water}} = \pm 0.5 \text{ kg/m}^3$ with a change to the liquid phase with $\Delta_{\text{water}} = \pm 900 \text{ kg/m}^3$, whereby a volume reduction occurs with a factor in the order of about 18,000. For ethanol this will accordingly produce a volume reduction factor in the order of about 3,500. Bringing the mould cavity to underpressure thus enhances the sought-after favourable effect even further. It is otherwise also possible to already apply an underpressure in the mould cavity during or before introducing the reduction material into the mould cavity in order to thus already largely remove the gases present (generally air). This removal of the gas initially present in the mould cavity is also possible by flushing the mould cavity with gaseous reduction material or by feeding (injecting) reduction material optionally in the form of superheated steam. After bringing the mould cavity to underpressure and subsequent flushing of the mould cavity it is desirable, as already stated above, to then once again bring the mould cavity to underpressure.
- 15 The reduction material can be added to the mould cavity separately of the encapsulating material, for instance by injecting or blowing in the reduction material, although feeding a (rapidly evaporating) small quantity of liquid (for instance liquid water) or a solid particle reduction material (ice) can likewise result in the desired conditioned starting position of the mould cavity before the actual encapsulation. It is however also possible for the reduction material to be fed in combination with the encapsulating material, this however such that the reduction material enters the mould cavity before the encapsulating material. The encapsulating material can be conditioned for this purpose by for instance adding reduction material to the encapsulating material.
- 25 The encapsulating material can be fed to the mould cavity once this latter has been positioned during processing step A) relative to an electronic component for encapsulating. It is also possible to heat the encapsulating material before it is displaced to the mould cavity, and by means of exerting pressure on the encapsulating material it can be carried to the mould cavity. Particularly envisaged here is the so-called transfer moulding process, wherein the encapsulating material is urged to the mould cavity by one or more plungers. On the other hand, the present invention can also be combined with other encapsulating processes, such as for instance also compressing the encapsulating material in the mould cavity using the closing pressure of the mould parts (compression moulding) or injecting encapsulating material into the mould cavity
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(injection moulding). The application of reduction material in the mould cavity can result in the above stated advantages irrespective of the manner of feeding of the encapsulating material to the mould cavity.

- 5 In a variant of the method according to the present invention the reduction material can be fed into the mould cavity through a suction opening for gases (eject air or venting) before the mould cavity is closed. The reduction material (for instance in the form of steam) can thus be introduced into the mould cavity in a short time, for instance within 1-3 seconds. Only then can the mould parts which define the mould cavity be brought to
10 closing pressure.

The invention also provides 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
15 component, and feed means for liquid encapsulating material connecting to the mould cavity, wherein the device is also provided with feed means for a reduction material connecting to the mould cavity. The feed means for the reduction material can comprise a heating element for bringing the reduction material to a desired condition for the purpose of feeding, and the feed means for the reduction material can for instance be
20 formed by one or more nozzles connecting to the mould cavity. Using such a device the advantages can be achieved as already described above with reference to the method according to the present invention, and are deemed also included herein by way of reference in respect of the device according to the invention. The feed of the reduction material can thus be incorporated with only very limited structural changes to existing
25 encapsulating equipment.

An embodiment variant of the device according to the present invention is also provided with feed means for feeding a film material between the mould parts. The feed means for a reduction material and the feed means for encapsulating material can be located
30 here on opposite sides of the film fed by the feed means for film material. With such a device, in which the feed of a reduction material is combined with a film feed, the advantages can be realized as already described above in relation to the method according to the present invention, wherein the feed of reduction material and the presence of a film material are also combined during the encapsulation. These above

stated advantages are also included herein by way of reference in respect of the device in which these two feed facilities are combined. Not only is it possible to suffice with a simpler construction of the mould part provided with the mould cavity, the reduction material is also prevented from making contact with the electronic component for encapsulating. Because the reduction material in this embodiment variant does not come into contact with the electronic component for encapsulating and the carrier, the reduction material cannot therefore have any undesirable effect thereon. This increases the possibilities for the choice of a suitable reduction material. It should also be noted here that the encapsulating material also remains physically separated from the reduction material, which also prevents reduction material and encapsulating material influencing each other undesirably.

A simplified feed of the reduction material can be realized if the feed means for a reduction material are adapted to arrange the reduction material on a film material. The reduction material then need no longer be introduced into a mould cavity by the feed means. It suffices for the reduction material to be arranged on the film material, which film material with adhering encapsulating material is then anyway placed between the mould parts. The feed of the film material is thus also used to introduce the reduction material between the mould parts.

The invention will be further elucidated on the basis of the following non-limitative exemplary embodiments. Herein:

figure 1 shows a schematic perspective view of a part of a prior art device for encapsulating electronic components mounted on a carrier,
figures 2A and 2B show two different top views of a carrier with electronic components during successive phases of the prior art encapsulating process,
figure 3 shows a schematic side view of a device for encapsulating electronic components mounted on a carrier according to the present invention,
figures 4A and 4B show schematic side views of a device for encapsulating electronic components mounted on a carrier according to the present invention, wherein the device is also provided with a feed for film material, and
figure 5 shows a cross-section through a part of an embodiment variant of an encapsulating device according to the invention with a so-called “top edge” feed for the encapsulating material.

Figure 1 shows a cut-away cross-section through two mould parts 1, 2. Arranged in the lower mould part 2 is a recess 3 for receiving a carrier 4 (for instance a lead frame or a board) on which electronic components 5 are arranged. Via a channel 6 connecting to the mould cavity encapsulating material 7 is fed to the mould cavity as according to arrow P_1 . In the shown situation mould cavity 3 is only partially filled with encapsulating material 7; the encapsulating material flows with a flow front 8 into the mould cavity and thereby encapsulates electronic components 5.

The prior art method of encapsulation shown schematically with reference to figure 1 is also applied in figure 2A. Shown here in top view is a carrier 10 to which encapsulating material 12 is fed by means of feed channels 11. From feed channels 11 the encapsulating material 12 flows to a distributing chamber 13, from which the encapsulating material 12 flows with a flow front 14 over a great width over the carrier (film gating) as according to arrows P_2 . Situated on carrier 10 are electronic components 15 which, because they protrude above the surface of carrier 10, produce a determined resistance to the flow of encapsulating material 12 over carrier 10. The result hereof is that the flow front does not flow in a straight line over carrier 10 but has a more complex shape which, as shown, can lag behind at the position of electronic components 15. The encapsulating material flows between the electronic components with less resistance, which causes the risk of gas inclusions 16 at the position of (adjacently of) electronic components 15. This is undesirable because gas inclusions 16 can form openings in the final encapsulation of electronic components 15. Further also included in this figure 2A are two discharge channels 17 for gases from the mould cavity through which gases present in the mould cavity will escape passively or actively as according to arrows P_3 .

In figure 2B the encapsulating material has reached the outer end 18 of the mould cavity located opposite feed channels 11, and discharge channels 17 are closed as shown schematically with closures 19. This can for instance take place in practice using V-pins as already developed previously by the present applicant. By closing discharge channels 17 the filling pressure on the encapsulating material can be increased, with the result that the gas inclusions 16 present will become smaller or even disappear. Resulting gas

inclusions 16 in encapsulating material 12 nevertheless remain a problem which results in rejection of encapsulated products.

Figure 3 shows a cut-away cross-section through two mould parts 20, 21 of an encapsulating device 22 according to the present invention. Likewise arranged here in lower mould part 21 is a recess 23 for receiving a carrier 24 on which stacked electronic components 25 (flip chips) are arranged. Encapsulating material 27 can be fed to mould cavity 28 via a runner 26 connecting to the mould cavity. The feed of encapsulating material 27 takes place here by means of a plunger 29 with which pressure can be exerted on encapsulating material 27. Plunger 29 is displaceable for this purpose in a housing 30 into which the encapsulating material 27 is also carried. A reduction material 31, for instance in the form of water vapour 32, can be introduced into mould cavity 26. Before introducing encapsulating material 27 into the mould cavity it is for instance possible to “flush” mould cavity 28 with reduction material 31, 32. An option here is to apply an underpressure in mould cavity 28 by a suction opening 33. Since a reservoir 34 with reduction material 31, 32 is in open connection with mould cavity 28, the vapour pressure will also decrease in reservoir 34, whereby the reduction material 31, 32 (for instance water) begins to boil. The temperature of the reduction material in reservoir 34 is chosen for this purpose such that the desired boiling state of reduction material 31, 32 occurs precisely as a result of the reduced pressure. The water vapour will flush through mould cavity 28 through a conduit 35 with the then opened valve 36 and (partly) disappear again through the suction opening. It is of course also possible to envisage numerous other methods of flushing mould cavity 28 (for instance by arranging an additional flushing conduit in upper mould part 21). Once mould cavity 27 has been filled with reduction material 32 in vapour form (or at least substantially all air has completely disappeared from the mould cavity), the flushing can be stopped by closing the valve 36. Encapsulating material 27 can subsequently be pressed into the mould cavity by the plunger. It is again noted here, perhaps unnecessarily, that there are also numerous other ways in which encapsulating material can be introduced into a mould cavity. These alternative methods of feeding encapsulating material, in combination with the filling of the mould cavity with reduction material, also form part of the present invention.

Figure 4A shows a cross-section through an encapsulating device 37 according to an embodiment variant of the present invention provided with two mould parts 20, 21 connecting on opposite sides to a carrier 24 with electronic components 25. In this encapsulating device 37 the lower mould part 21 is likewise provided with a flat contact side 23 which supports carrier 24. Mould part 20 is provided with a mould cavity 40
 5 which encloses a plurality of electronic components.

Fed between mould parts 20, 21 by a feed roller 45 is a film material 38 which, following one or more process runs, is discharged again to a discharge roller 46. The
 10 film material forms a separating layer, on one side of which encapsulating material can be fed between carrier 24 and film material 38 (see figure 4B herefor) by feed means for encapsulating material 42 which connect to an intermediate space 39 to be created between carrier 24 and film material 38. Feed means 41 for reduction material are placed such that the reduction material can be fed onto film material 38 as according to
 15 arrow P₅ before this latter is carried between mould parts 20, 21. During feed of film material 38 the reduction material is thus also fed at a location where mould cavity 40 is situated. Liquid encapsulating material is then guided as according to arrow P₄ between film material 38 and carrier 24 by means of feed means 42. Under the pressure of the encapsulating material and as a result of the phase change of the reduction material in
 20 mould cavity 40 film 38 will be displaced toward the walls of mould cavity 40 (see figure 4B). For the discharge of gases and possible surplus fed encapsulating material (arrow P₆) a venting 43 is left clear by the mould parts.

Figure 5 shows a part of an encapsulating device 50 with an upper mould part 52 and a
 25 lower mould part 51 assembled from a plurality of relatively displaceable components. A carrier 54 is clamped between a relatively displaceable support 55 and edge part 53 such that encapsulating material 60 can be fed through a feed channel 61 over the upper side of edge part 53 by means of a plunger 59. One of the advantages of using edge part 53 is that an edge area of carrier 54 can thus be kept free of encapsulating material. In a
 30 situation where mould parts 51, 52 have been moved apart and before the encapsulating material is fed, a second feed channel 56 for feeding a reduction material is opened, with the result that reduction material can be fed as according to arrow P₇. This reduction material penetrates here between a film 62 placed on carrier 54 with electronic components and the mould cavity 58 in upper mould part 52.

Claims

1. Method for encapsulating electronic components mounted on a carrier, comprising the processing steps of:
 - 5 A) placing an electronic component for encapsulating into a mould cavity connecting to the carrier;
 - B) filling the mould cavity with liquid encapsulating material; and
 - C) at least partially curing the encapsulating material in the mould cavity,
 wherein:
 - 10 - a reduction material is introduced into the mould cavity before filling the mould cavity with encapsulating material during processing step B), which reduction material undergoes a phase change during processing step B) whereby the volume of the reduction material decreases; and
 - before introducing the reduction material into the mould cavity, a film
 - 15 material is arranged between the carrier with the electronic component and the mould cavity connecting to the carrier,**characterized in that** the liquid encapsulating material is fed between the carrier and the film material and the reduction material is carried between the film material and the mould cavity.
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2. Method as claimed in claim 1, **characterized in that** the reduction material at least condenses from the gas phase during filling of the mould cavity with encapsulating material as according to processing step B).
- 25 3. Method as claimed in claim 1 or 2, **characterized in that** the reduction material is carried actively into the mould cavity in gas phase.
4. Method as claimed in any of the foregoing claims, **characterized in that** the reduction material is carried actively into the mould cavity as mist.
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5. Method as claimed in any of the foregoing claims, **characterized in that** the reduction material is in liquid phase when it is actively carried into the mould cavity.
6. Method as claimed in any of the foregoing claims, **characterized in that** the
 - 35 reduction material is in solid phase when it is actively carried into the mould cavity.

7. Method as claimed in any of the foregoing claims, **characterized in that** the reduction material is chosen from the group of: H₂O (water) and C₂H₅OH (ethanol).
- 5 8. Method as claimed in any of the foregoing claims, **characterized in that** an underpressure is applied in the mould cavity before or during:
- filling of the mould cavity with encapsulating material as according to processing step B); and/or
 - introduction of the reduction material into the mould cavity.
- 10 9. Method as claimed in any of the foregoing claims, **characterized in that** the reduction material is fed into the mould cavity through a suction opening for gases before the mould cavity is closed.
- 15 10. 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; and
- 20 - feed means for encapsulating material connecting to the mould cavity, wherein the device is also provided with:
- feed means for a reduction material connecting to the mould cavity; and
 - feed means for feeding a film material between the mould parts,
- 25 **characterized in that** the feed means for a reduction material and the feed means for encapsulating material are located on opposite sides of the film material fed by the feed means for film material.
- 30 11. Encapsulating device as claimed in claim 10, **characterized in that** the feed means for a reduction material are adapted to arrange the reduction material on the film material fed by the feed means for film material.