Device and method for at least partially encapsulating a closed flat carrier with electronic components

The present invention relates to a device for at least partially encapsulating a closed flat carrier with electronic components, comprising a first mould part with a first cavity, which first cavity is adapted to connect to a first side of the carrier and to arrange a layer of encapsulating material on this first side of the carrier.

A carrier is understood to mean a substantially flat material part carrying electronic circuits. The electronic components, more particularly integrated electrically conductive connections, can be arranged here on the carrier as well as at least partially in the carrier. Such a carrier will usually be manufactured from at least partially electrically insulating material such as silicon or a ceramic material, although a material which good electrical conduction, such as for instance copper, is not precluded, with the proviso that the carrier must then also be provided with at least one insulating material layer in order to bring about electrical separation of the diverse circuits. Such carriers may be formed particularly, though not exclusively, by semiconductor material.

It is known to provide such carriers on one side with segments of encapsulating material or a layer of encapsulating material with which the electronic circuits connected to the carrier are protected. Such carriers usually have considerable dimensions, up to several tens of centimetres. Experience has shown that the carriers can warp as a result of the encapsulating material being arranged. This can result in considerable problems in the further processing of the carriers because of the connections being placed extremely close to each other.

The present invention has for its object to provide a method and a device wherein such problems are avoided.

This object is achieved with a device of the type stated in the preamble, wherein the encapsulating device is provided with a second mould cavity which is adapted to connect to the carrier on the second side of the carrier and to arrange a layer of encapsulating material on this second side of the carrier.

This object is likewise achieved by a method for at least partially encapsulating a closed flat carrier with electronic components, comprising of placing the closed flat carrier on a first mould part, enclosing the closed flat carrier with electronic components in the mould on opposite sides between the first and a second mould part and arranging a layer of encapsulating material on both sides of the carrier.

As a result of these measures a layer of encapsulating material is arranged on both sides of the carrier, so that the stresses caused in the carrier by arranging the layers compensate each other and warping is avoided. It is pointed out here that the thickness of the layers on either side of the carrier can differ, to enable compensation for asymmetric configurations of the carrier itself, but also that the layers of the carrier do not have to be fully closed.

The use of such a device or application of such a method results in a substantially flat, closed carrier with electronic components which is provided on at least one side with a layer of encapsulating material, this carrier also being provided on its second side with a layer of encapsulating material. Warping of the carrier is hereby prevented in efficient manner.

According to a first preferred embodiment, the device is adapted to arrange a layer of encapsulating material on both sides of a semiconductor wafer. Semiconductor wafers represent an extremely important field of application of the invention; electronic circuits initially formed in semiconductor wafers are recently already being encapsulated on one side at the stage where the semiconductor wafer still forms one whole. The individual circuits are then separated from each other by sawing or cutting of the semiconductor wafer, after which further processing follows. Problems with warping also occur in one-sided covering of these semiconductor wafers, which makes further processing thereof more difficult or even impossible. These problems are avoided by applying the measures according to the present invention. Depending partly on the further production process, the further treatment of the semiconductor wafers and the resulting products is also simplified because they have already been encapsulated on both sides.

This preferred embodiment likewise relates to such a method, wherein the carrier is formed by a semiconductor wafer. For the advantages of this method reference is made to the above described advantages of the device according to the invention.

The first and the second mould cavity are preferably adapted to arrange on both sides of the carrier a layer of encapsulating material distributed over the whole surface. Warping of the carrier is here prevented over the whole surface of the carrier. It is pointed out that the phrase "over the whole surface" does not preclude openings being present in the layers, for instance for passage of contact parts, but that the arranged layers each consist of a single part so that they can be reached from a single runner connecting to the relevant mould cavity; the layers do not therefore need to be closed. When the invention is applied to a semiconductor wafer, the circuits formed therein will later be separated; each of the parts of the semiconductor wafer formed by the separation will normally then be provided with a substantially equal part of the encapsulation, which can only be achieved by arranging the layer of encapsulating material distributed over the whole surface.

This embodiment likewise relates to such a method, wherein the encapsulating material is arranged distributed over the whole surface on both sides of the carrier, and to a thus obtained carrier.

In order to achieve a uniform and rapid filling of the mould cavities it is important that the device is provided with at least a first and second runner, the first runner connecting to the first mould cavity and the second runner connecting to the second mould cavity. This avoids encapsulating material from the one mould cavity having to be moved through or along the carrier to the other mould cavity. The same effects are achieved when the encapsulating material is fed independently to both sides of the carrier.

It is attractive in some cases for both runners to be connected to the same source of encapsulating material and for an adjustable or controllable restriction to be arranged in at least one of the runners. A measure of independent control is hereby achieved with a single source. The feed of encapsulating material usually takes place by means of a plunger with which encapsulating material, which has become liquid as a result of

heating, is pressed into the mould cavities (also referred to as transfer moulding). Within the context of this invention other methods of feeding encapsulating material are however possible, such as for instance by means of injection moulding. In respect of the encapsulating material there are also other alternatives within the context of the invention, such as for instance the feed of encapsulating material supplied in liquid form (liquid epoxy) or for instance a thermocuring encapsulating material consisting of at least two separately supplied components which cure as a result of mixing.

Alternatively, it is possible for the runner connecting to a first mould cavity to be connected to a first source of encapsulating material and the runner connecting to a second mould cavity to be connected to a second source of encapsulating material, and for both sources of encapsulating material to be controllable independently of each other. Flow rate and pressure of the feed of encapsulating material can hereby be adjusted independently of each other on either side of the carrier, this being important in the case of carriers having a different configuration on either side. The encapsulating material will after all then exhibit differing flow behaviour on either side of the carrier, wherein the behaviour of the encapsulating material can be controlled independently.

The same advantages are obtained when the encapsulating material is fed from a different source to the two sides of the carrier placed in the mould cavity.

According to another preferred embodiment, the encapsulating material is therefore fed at a different flow rate to each of the sides of the carrier placed in the mould cavity.

In order to obtain a difference in the properties of the encapsulation on either side of the carrier, for instance to obtain a greater thermal conduction on the first side of the carrier than on the other side of the carrier, it is recommended that the first and the second source of encapsulating material are adapted to feed mutually differing types of encapsulating material. A different encapsulating material with differing properties can hereby be obtained on either side of the carrier.

An attractive embodiment, particularly for carriers provided with protruding parts such as protruding contact elements, provides the measure that at least one of the mould cavities is at least partially shielded by a layer of resilient material. This resilient layer

can be formed by a fixed layer arranged in the mould cavity, but also by a tape or film of resilient material renewed after one or more process cycles by means of a feed mechanism. The advantage of the presence of a resilient material is that the protruding contact elements or other protruding parts can penetrate into the resilient layer when the mould cavity is closed, thereby preventing the encapsulating material covering the protruding parts. The parts of the contact elements thus remaining free of encapsulating material can thus be connected without cleaning. The chance of damage to the protruding parts is also considerably reduced.

The same embodiment relates to a method wherein a carrier provided on at least one side with parts protruding outside its surface is placed in the mould cavity, and the protruding parts, such as more particularly the contact elements, penetrate into a layer of resilient material at least partially shielding the mould cavity when the mould cavity is closed. A carrier is hereby obtained which is provided on at least one of its sides with parts protruding outside the surface of the encapsulating material.

Carriers, in particular semiconductor wafers, are usually provided on at least one side with semiconductor circuits connected to the carriers. It can also be advantageous to apply the invention in such situations. The encapsulating device is preferably adapted for this purpose to at least partially encapsulate carriers provided on at least one side with semiconductor circuits connected to the carriers.

When there is space between the carrier and the semiconductor circuits in such a situation, it is also attractive for the encapsulating device to be adapted to arrange encapsulating material in the space between the carrier and these components.

The same embodiment provides the measure that a carrier provided on at least one of its sides with electronic circuits is placed in the encapsulating device, and that during encapsulation encapsulating material is arranged in spaces between the electronic circuits and the carrier. It is further also possible for the electronic components to be provided with openings of a limited (1-20 μm) dimension (also referred to as "vias"). An improved adhesion between the electronic component and the encapsulating material is obtained by filling the openings with encapsulating material.

In yet another embodiment variant a plurality of electronic components are stacked. The thus stacked electronic components can likewise be coupled, optionally conductively, to each other by means of through-channels, also referred to as TSVs (through silicon vias) of limited (1-20 μm) dimensions.

Carriers of the type to which the invention relates, usually in the form of semiconductor wafers, often have considerable dimensions. The pressures which occur on the walls of the mould cavities due to the encapsulating mass flowing into the mould cavity are considerable. This creates the danger of opening or deformation of the mould parts and resulting variations of the encapsulated carrier and disruption of the encapsulating process. In order to avoid these problems, a preferred embodiment proposes that the encapsulating device be provided with control means for controlling the closing pressure with which the mould parts close onto the carrier. A controllable compensation pressure, which can be controlled subject to the situation, can hereby be applied to the outer side of the walls of the mould parts. This controllability is important in preventing this pressure damaging the carrier by exerting an excessive pressure when there is still no encapsulating material present in the interior of the mould.

The same advantages are obtained when the closing pressure on the mould parts is controlled during encapsulation of the carrier placed in the mould cavity.

In order to enable compensating of the pressure exerted by the encapsulating material in the cavities of the mould, another embodiment proposes that the control means for the closing pressure of the mould parts are connected to sensors for detecting the pressures prevailing in the mould cavities.

The same embodiment results in the measure that the closing pressure exerted on the carrier by the mould parts is controlled subject to the pressure exerted by the at least one source of encapsulating material.

It is attractive when the runners connect to the mould cavities such that the direction of movement of the flow of encapsulating material extends substantially diagonally relative to a grid in accordance with which the electronic circuits are placed on the carrier. The encapsulating material can hereby advance without strong, sudden changes

in direction, so that the flow of encapsulating material encounters fewer obstacles and travels more uniformly. It is noted here that this measure can be applied not only in combination with the present invention; it can also be applied in situations wherein only a single side of a carrier for electronic circuits is being encapsulated, or when other types of component ordered substantially in a rectangular structure are being encapsulated.

The present invention is particularly applicable to carriers for electronic components of quite large dimensions which, before they are further processed, must be separated into smaller segments by for instance sawing, laser cutting or water cutting.

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

figure 1A is a cross-sectional view of a first embodiment of the device according to the invention;

figures 1B and 1C show two successive cross-sectional views of the first embodiment of the device according to the invention;

figure 2 is a cross-sectional view of a second embodiment of the invention;

figure 3 is a schematic cross-sectional view of a third embodiment of the invention in an opened position of the mould;

figure 4 is a schematic cross-sectional view of the embodiment shown in figure 3 in closed position of the mould;

figure 5 is a schematic cross-section of the embodiment shown in figure 3 during encapsulation;

figure 6 is a schematic cross-sectional view of the product obtained with the method shown in figures 3-5;

figure 7 is a cross-sectional view of a carrier according to the invention provided with encapsulating material on two sides; and

figure 8 is a cross-sectional view of an alternative embodiment variant of a carrier according to the invention provided with encapsulating material on two sides.

Figure 1A shows schematically a cross-section through a device for encapsulating carriers for electronic components, designated in its entirety with 1. The device comprises a lower mould part 2a and an upper mould part 2b. Recessed into each of the

mould parts 2a, 2b is a respective mould cavity 3a, 3b. When a carrier 4 is placed between mould parts 2a, 2b, the respective mould cavities 3a, 3b close onto carrier 4. A runner 5 is arranged leading to the mould cavities for the purpose of feeding encapsulating material to cavity 3. The encapsulating material is supplied by a plunger 6 which is movable in a cylinder casing 10. A venting channel 7 is connected to the side of the cavity 3 lying opposite runner 5. Both mould halves 2a, 2b can be moved apart for the purpose of placing carriers 4 for encapsulating or removing encapsulated carriers 4.

As shown in figure 1A, the device is dimensioned for the purpose of encapsulating on both sides a carrier 4 placed between mould parts 3a, 3b. This finds particular application in the encapsulation of semiconductor wafers on both sides. In recent times the encapsulating step is usually being performed earlier in the production process, after which the electronic circuits arranged already encapsulated in the semiconductor wafers are separated together with the meanwhile arranged encapsulation, for instance by sawing or laser cutting. In order to prevent warping of the semiconductor wafers thus encapsulated on a single side as according to the prior art, the semiconductor wafer is encapsulated on both sides. As is the case in the situation shown in figure 1A, this can take place by feeding from a single runner 5.

It is noted here that the encapsulation can take place on a bare carrier, wherein openings are arranged later in the encapsulation in order to acquire access to the circuit and electrical connections arranged in the carrier, but also on carriers on which contact elements have already been placed in the form of for instance solder beads 8 or electronic circuits 9, such as memory chips, placed on the carrier. It will be apparent that, although figure 1 shows that chips 9 are placed on the side opposite the side of solder beads 8, it is likewise possible for chips 9 or beads 8 to be placed on only a single side. Beads 8 and chips 9 can also be placed on the same side of the carrier, possibly in combination with chips 9 or beads 8 on the other side. In addition, it is possible for the contact elements to have a form other than beads, such as for instance rods, blocks or any other random form.

Figures 1B and 1C show two successive views of the device as shown in figure 1A for the purpose of illustrating that the device can be provided with two plungers 6, 6' which

are movable in two separate cylinder casings 10, 10'. Plunger 6 shown in figure 1B controls the feed of encapsulating material to mould cavity 3b in mould part 2b and plunger 6' shown in figure 1C controls the feed of encapsulating material to mould cavity 3a in mould part 2a. The feed of encapsulating material to the opposite sides of carrier 4 is thus controlled by separate plungers 6, 6', and the flow rate of the feed to mould cavities 3a, 3b can be regulated independently of each other, ideally such that the flow fronts of the encapsulating material move more or less at the same speed on both sides of carrier 4.

According to a second embodiment as shown in figure 2, use is made of two runners 5a, 5b, each connected to a separate source 6a, 6b respectively of encapsulating material. These sources 6a, 6b are individually controllable to allow the feed of encapsulating material to lower mould cavity 3a to take place independently of feed to upper mould cavity 3b. This is particularly important when the spaces inside the two mould cavities differ from each other as a result of a differing thickness of the cavity or a differing configuration of components placed on or under the carrier. It is likewise possible for use to be made of a single source, and for a controllable restriction to be arranged in one or both runners in order to be able to achieve independent feed using only a single source.

Both sources 6a, 6b can also comprise a differing encapsulating material for the purpose of encapsulation with a different material on either side of the carrier.

Figure 3 shows an embodiment wherein the inner side of upper mould cavity 3b opposite carrier 4 is provided with a layer of flexible material 12. This layer can be formed by a layer which is arranged fixedly in mould cavity 3b and which will still have to be replaced from time to time, but also by a piece of for instance self-adhesive tape which is replaced after each encapsulation. Figure 3 shows an embodiment wherein a tape 12 is used.

This embodiment is particularly applicable on carriers 4 which are provided on their upper side with contact elements in the form of contact beads 8. It is important that these contact beads 8 can be reached for the purpose of forming electrical connections

after the encapsulation has been arranged. Figure 3 shows here the situation wherein carrier 4 is placed in mould 1, but wherein mould 1 is not yet closed.

Figure 4 shows the situation in which mould 1 is closed, wherein it can be seen that contact beads 8 have penetrated into the layer of flexible material 12, while figure 5 shows the situation wherein mould halves 3a, 3b have been filled with encapsulating material. It is noted that contact beads 8 protrude outside the layer of encapsulating material so that they are readily accessible for the purpose of forming contacts. This is likewise shown in figure 6, which shows an encapsulated carrier 4 as it is removed after completion of the encapsulating process between mould parts 2a, 2b. This protruding can otherwise be minimal, and can even be level with the plane of the encapsulation itself.

Attention is finally drawn to the fact that the carrier is provided on its underside with a number of components 9 which are attached to carrier 4. These will generally be components 9 formed by semiconductor circuits or chips, such as for instance memory circuits, which are adapted for co-action with circuits integrated into carrier 4. Carrier 4 here usually comprises a large number of identical circuits which are separated after the encapsulating process. Each of the thus created parts then comprises such a memory circuit, which in the present embodiment is provided with a memory circuit 9 on one side and a number of contact beads 8 or contact elements in other than bead-like form on the other.

It will be apparent that it is likewise possible to also place a layer of flexible material on the underside of carrier 4 in order to optionally leave the active or non-active side of an electronic component clear for cooling purposes or for optical, chemical and/or mechanical interaction. It is also possible to opt to leave contact elements 8 placed on the underside clear during encapsulation. These contact elements 8 can otherwise also be situated on components 9.

Figure 7 shows a carrier 20 on which a special electronic component 21 (a so-called MEMS) is placed. Electronic component 21 connects with contacts 22 to carrier 20 and is also provided with a seal 23, thereby creating a closed space below electronic component 21. Electronic component 21 is encapsulated with encapsulating material 24.

Also arranged in the carrier are passages 25 with which electronic component 21 is connected to contact positions 26 on the opposite side of carrier 20. Arranged at these contact positions 26 are solder beads 27 which are shielded by means of a flexible material layer (not shown in this figure) during feed of encapsulating material 28 on the opposite side of carrier 20 such that the solder beads 27 remain partially free of encapsulating material 28. The encapsulating material 24 around electronic component 21 can, if desired, be identical to or, conversely, differ from the encapsulating material 28 arranged between solder beads 27.

Figure 8 shows a carrier 30 provided with encapsulating material 31, 32 on two sides. Situated on the contact side are solder beads 33 which are partially enclosed with encapsulating material 32 such that solder beads 33 can be electrically coupled in simple manner without performing further operations. On the side of carrier 30 opposite solder beads 33 four stacked electronic components 34 are placed on carrier 30. Electronic components 34 are provided with through-channels 35, 36 (TSVs) which, in the case of so-called hollow TSVs 35, can also be filled with encapsulating material 32 during feed of encapsulating material 31. This is shown in the two left-hand TSVs 35. These through-channels 35 usually have a very small diameter (1-20 μm), and are thus clearly not drawn to scale. The four right-hand TSVs have a construction other than the hollow TSVs 35; TSVs 36 are not hollow but consist of a solid construction of for instance copper. The stacked electronic components 34 are coupled functionally to each other using for instance an adhesive layer. The TSVs 35 filled with encapsulating material 31 impart more mechanical strength to the stacked electronic components 34. The broken lines form possible saw lines along which carrier 30 can be subdivided.

It will be apparent that the measures discussed in the different embodiments can be combined with each other.

Claims

1. Device for at least partially encapsulating a closed flat carrier with electronic components, comprising a first mould part with a first mould cavity, which first mould cavity is adapted to connect to a first side of the carrier and to arrange a layer of encapsulating material on this first side of the carrier, **characterized in that** the encapsulating device is also provided with a second mould part with a second mould cavity which is adapted to connect to the second side of the carrier and to arrange a layer of encapsulating material on this second side of the carrier.

2. Device as claimed in claim 1, **characterized in that** the device is adapted to arrange a layer of encapsulating material on both sides of a semiconductor wafer.

3. Device as claimed in claim 1 or 2, **characterized in that** the first and the second mould cavity are adapted to arrange on both sides of the carrier a layer of encapsulating material distributed over the whole surface of the carrier.

4. Device as claimed in claim 1, 2 or 3, **characterized in that** the encapsulating device is provided with at least a first and a second runner, a first of which connects to the first mould cavity and a second connects to the second mould cavity.

5. Device as claimed in claim 4, **characterized in that** both runners are connected to the same source of encapsulating material and that a controllable restriction is arranged in at least one of the runners.

6. Device as claimed in claim 4, **characterized in that** the runner connecting to the first mould cavity is connected to a first source of encapsulating material, that the runner debouching in the second mould cavity is connected to a second source of encapsulating material, and that both sources of encapsulating material are controllable independently of each other.

7. Device as claimed in claim 6, **characterized in that** the first and the second source of encapsulating material are adapted to feed mutually differing types of encapsulating material.

8. Device as claimed in any of the foregoing claims, **characterized in that** at least one of the mould cavities is at least partially shielded by a layer of resilient material.

9. Device as claimed in any of the foregoing claims, **characterized in that** the encapsulating device is adapted to at least partially encapsulate carriers provided on at least one side with semiconductor circuits connected to the carriers.

10. Device as claimed in claim 9, **characterized in that** the encapsulating device is adapted to arrange encapsulating material in space between the carrier and the semiconductor circuits.

11. Device as claimed in any of the foregoing claims, **characterized in that** the encapsulating device is provided with control means for controlling the closing pressure with which the mould parts connect to the carrier.

12. Device as claimed in claim 11, **characterized in that** the control means for the closing pressure of the mould parts are connected to sensors for detecting the pressure prevailing in the mould cavities.

13. Device as claimed in any of the claims 9-12, **characterized in that** the runners connect to the mould cavities such that the direction of movement of the flow of encapsulating material extends substantially diagonally relative to a grid in accordance with which the electronic components are placed on the carrier.

14. Method for at least partially encapsulating a closed flat carrier with electronic components, comprising of:

- placing a closed flat carrier with electronic components on a first mould part,
- enclosing the closed flat carrier with electronic components on opposite sides between the first and a second mould part, and
- arranging a layer of encapsulating material on at least a first side of the carrier,

characterized in that a layer of encapsulating material is also arranged on the second side of the carrier.

15. Method as claimed in claim 14, **characterized in that** a layer of encapsulating material is arranged on both sides of a semiconductor wafer.

16. Method as claimed in claim 14 or 15, **characterized in that** the encapsulating material is arranged distributed over the whole surface on both sides of the carrier.

17. Method as claimed in claim 14, 15 or 16, **characterized in that** the encapsulating material is fed independently to both sides of the carrier.

18. Method as claimed in claim 17, **characterized in that** the encapsulating material is fed from different sources to each of the sides of the carrier.

19. Method as claimed in claim 18, **characterized in that** the encapsulating material is fed at a different flow rate to each of the sides of the carrier.

20. Method as claimed in any of the claims 14-19, **characterized in that** a carrier provided on at least one side with parts protruding outside its surface, such as contact elements, is placed between the mould parts, and that the protruding parts penetrate into a layer of resilient material at least partially shielding at least one of the mould cavities of a mould part when the mould parts are closed.

21. Method as claimed in any of the claims 14-20, **characterized in that** a carrier provided on at least one of its sides with electronic components is enclosed between the mould parts and that during encapsulation encapsulating material is arranged in spaces between the electronic components and the carrier.

22. Method as claimed in any of the claims 14-21, **characterized in that** a plurality of electronic components are placed stacked on a carrier and during encapsulation of the stacked electronic components through-channels (TSVs) arranged in the electronic components are filled with encapsulating material.

23. Method as claimed in any of the claims 14-22, **characterized in that** the closing pressure exerted on the carrier by the mould parts is controlled during feed of the encapsulating material.

24. Method as claimed in claim 23, **characterized in that** the closing pressure exerted on the carrier by the mould parts is controlled subject to the pressure exerted on the carrier by the encapsulating material.

25. Method as claimed in any of the claims 14-24, **characterized in that** the carrier, after arranging of encapsulating material on both sides, is subdivided into smaller segments.

26. Method as claimed in any of the claims 14-25, **characterized in that** the flat carrier with electronic components is at least partially shielded from encapsulating material on at least one side by a layer of flexible material during feed of the encapsulating material.

27. Flat closed carrier with electronic components, which is provided on one side with encapsulating material, **characterized in that** the carrier is also provided with encapsulating material on its second side.

28. Carrier as claimed in claim 27, **characterized in that** the carrier is formed by a semiconductor wafer.

29. Carrier as claimed in claim 27 or 28, **characterized in that** the carrier is provided with a layer of encapsulating material distributed over the whole surface.

30. Carrier as claimed in claim 27, 28 or 29, **characterized in that** the carrier is provided on either side with different types of encapsulating material.

31. Carrier as claimed in any of the claims 27-30, **characterized in that** the carrier is provided on at least one side with accessible parts protruding outside the encapsulating material.