Device and Method for Bonding

Specification

The invention relates to a device for bonding as claimed in Claim 1 and a corresponding method as claimed in Claim 10.

In the semiconductor industry product wafers are more and more often temporarily cemented to carrier wafers. The cement, the so-called bonding adhesive, is applied to the product wafer and/or the carrier wafer in the form of a layer with a thickness which is as uniform as possible. After the coating process the two wafers must however be pressed onto one another with high forces. This process is known under the term bonding. The pressure discs used which apply pressure to the two wafers should be flat according to the prior art, in order to apply a bond force which is as uniform as possible overall. Accordingly the pressure discs are also exactly produced. The lower disc is produced as a resting part of a bond chuck, therefore a sample carrier. The upper disc is called the pressure disc and is accordingly mounted on the top of the bond chamber.

After a product and/or a carrier wafer has been lacquered with a spin lacquering method, generally a so-called "edge bead" is established on the layer edge based on rheological and fluid-dynamic properties. This "edge bead" is an accumulation of material which can be found on a round substrate, a wafer, along the entire edge. The difference between the material thickness in the center and the material thickness on the edge is only a few microns, often even only a few nanometers. In bonding, therefore in the application of the bond force, very often the problem of a nonuniform bond force and/or of the forcing-out of the protruding or excess cement arises therefrom.

In the ideal case one layer has a homogeneous thickness for the bonding process as claimed in the invention. In this connection homogenous thickness means that the thickness of the bonding layer is the same at any position or is within an acceptable tolerance. But experience shows that even under ideal bonding conditions, therefore in the case of a homogeneous layer thickness, a perfectly evenly machined pressure disc, a perfectly evenly machined bond chuck, and uniform, homogenous pressure application, after the bonding process there can be a layer with an inhomogeneous thickness. The reason for this is the rheological and fluid-dynamic properties of the layer and the prevailing initial and boundary conditions of the physical problem. Since the material cannot spread equally quickly in the plane in the center, like the material on the edge of the substrate, an increased flow velocity occurs in the vicinity of the edge. It could be said that the material in the center itself is obstructed, conversely the edge material can drain freely to the outside. For a layer with a corresponding "edge bead" the situation would deteriorate accordingly, since in this case even more material is present on the edge than in the center per unit of area.

The object of this invention is therefore to develop the generic devices and methods for bonding such that the indicated problems of the inhomogeneous layer thickness can be prevented or at least reduced.

This object is achieved with the features of Claims 1 and 10. Advantageous developments of the invention are given in the dependent claims. All combinations of at least two of the features given in the specification, the claims and/or the drawings also fall within the scope of the invention. For value ranges, values within the indicated limits will also be considered to be disclosed as boundary values and will be claimed in any combination.

Hereinafter it is distinguished between a product substrate and a substrate to illustrate the

version as claimed in the invention. The product substrate and substrate can be optionally interchanged and/or combined so that for example also substrate-substrate, product substrate-product substrate, substrate-product substrate or product substrate-substrate combinations are conceivable. Furthermore lacquering of the carrier substrate is also conceivable. A first substrate can be the substrate, for example a carrier substrate. A second substrate can be the product substrate.

The basic idea of this invention is to apply a bond force to the product substrate on one action side of the product substrate facing away from the bond layer proceeding from an initial zone A which lies within an edge zone R of the action side. In other words: first of all the product substrate, especially dictated by the shape of one pressure transfer side of the action apparatus, is pressed within the initial zone onto the bond layer (the product substrate in the region of the edge zone can rest at least partially on a bead which has formed by applying the bond layer - the so-called "edge bead" - of the bond layer to the extent this bead is present).

One inventive idea is to initiate the pressure application in the center of the bond layer where the material of the bond layer toward the side is completely surrounded by the further material of the bond layer so that the material in the center is subject to flow obstruction due to the prevailing edge conditions. As claimed in the invention this yields one optimum possibility for joining the two wafers to one another since a so-called "squeeze out", therefore (uncontrolled and excess) forcing-out of the bond material is hindered or is at least reduced. For an existing "edge bead" the product wafer which has been deposited on the bond layer is bent as claimed in the invention by the action apparatus toward the center of the bond layer and thus due to its elastic deformation prevents the premature transfer of force from the action apparatus to the "edge bead".

One aspect of this invention is to provide an engineering design for a pressure disk with which it is possible as claimed in the invention to concentrate and initiate the application of force in the center in which the material is located which flows poorly due to edge conditions.

According to one advantageous embodiment of this invention it is provided that the action apparatus be equipped with a pressure disc with a convexly curved pressure transfer side. Uniform application of pressure is possible with one pressure transfer side which is especially closed over the entire surface. The pressure disc is made especially nonadhering on its pressure transfer side.

Here it is especially advantageous if the tangential plane of the pressure transfer side which is curved as claimed in the invention is spaced in the direction of the normal to an imaginary plane of an ideally planar pressure transfer side at least by 5 nm and/or a maximum 500 μm, especially at least by 20 nm and/or a maximum 200 μm, preferably at least by 50 nm and/or at maximum 50 μm, more preferably at least 100 nm and/or a maximum 5 μm. Here it is especially advantageous if the curvature is made concentric. This is because in this way the pressure disc can be made on the one hand rigid and unyielding for the bond force used, due to the very small curvature with a very large radius of curvature there being only a minimum bulge by which on the one hand a leveling or planarization of the bond layer takes place from the inside to the outside and on the other hand a corresponding concave, slight curvature also arises in the bond layer.

A bond result as uniform as possible can be achieved by the initial zone A being arranged concentrically to the product substrate side.

An embodiment is especially preferred in which the action apparatus has a punch which applies the bond force controlled by a control apparatus. The punch is connected preferably interchangeably to the pressure disc, so that different pressure discs can be used for the respective

requirements. Advantageously it can be provided as claimed in the invention that the formation of the bond layer is measured especially on the edge zone R in order to choose a suitable pressure disc.

According to another advantageous embodiment of the invention it is provided that the pressure disc is formed from a lower disk which encompasses the pressure transfer side and from a retaining disc which fixes the pressure disc, especially in the region of one periphery P via fixing means. In this way the pressure disc can be produced with the above described properties, especially an only slight curvature, in an especially simple and exact manner.

It is especially advantageous here if the lower disc in the region of the initial zone A is made thicker than on the periphery P.

Alternatively, between the lower disc and the retaining disc in the region of the initial zone A there is a spacer element so that in this case the lower disc can also have two parallel flat sides and thus can be more easily produced. The lower disc is more elastic than the upper retaining disc which is made especially rigid.

In another alternative configuration, for setting the curvature of the pressure transfer side there is a curvature element which acts on the lower disk opposite the retaining disc in the region of the initial zone A and which is especially controlled by the control apparatus. In this way not only can the curvature be set one time, but even active control of the curvature can take place during the approach and during the bonding.

Here it is provided as claimed in the invention in particular that the radius of curvature of the pressure disc be set or a pressure disc with a certain radius of curvature which is suitable for the wafer be selected.

The described features apply analogously to the device as claimed in the invention and the

method as claimed in the invention as well as the use as claimed in the invention.

The pressure disc as claimed in the invention can be produced from any material. But it has been shown that materials with high E moduli and high hardness values show especially good bond results. The following materials are preferably used for the pressure disc

- ceramics, especially silicon nitride (Si_3N_4), silicon carbide (SiC) and/or boron nitride (BN) and/or
- metals and their alloys in general, refractory materials, especially steels and/or iron-based materials and/or
- graphite and/or
- glass and/or
- polymers and/or
- composite materials.

Other advantages, features and details of the invention will become apparent from the description of preferred exemplary embodiments and using the drawings.

Figure 1 shows a cross sectional view of a first step of one embodiment of the method as claimed in the invention,

Figure 2 shows a cross sectional view of a second step of one embodiment of the method as claimed in the invention,

Figure 3 shows a cross sectional view of a third step of one embodiment of the method as claimed in the invention,

Figure 4 shows a cross sectional view of one embodiment of the method as claimed in the invention at the start of bonding,

Figure 5 shows a cross sectional view of one embodiment of the method as claimed in the invention during bonding,

Figure 6 shows a cross sectional view of one embodiment of the method as claimed in the invention at the end of bonding,

Figure 7 shows a cross sectional view of a first embodiment of a pressure disc as claimed in the invention,

Figure 8 shows a cross sectional view of a second embodiment of a pressure disc as claimed in the invention,

Figure 9 shows a cross sectional view of a third embodiment of a pressure disc as claimed in the invention.

The same components or components with the same action are identified with the same reference numbers in the figures.

A process as claimed in the invention is described below; it uses a pressure disc as claimed in the invention in order to carry out a controlled bond process. The process as claimed in the invention is shown on a bond layer with an "edge bead". The process as claimed in the invention can also be carried out on a bond layer with a homogeneous layer thickness, therefore without an "edge bead". The control takes place via an especially software-supported control apparatus which is not shown.

In a first step (Figure 1) a coating material (especially temporary cement) is applied as a bond layer 3 to one substrate 2 (especially a wafer). The coating takes place in a coating unit which is conventional in the industry. In the production of the bond layer 3 by a spin-coating process a peripheral bead 3w often arises in an edge zone R and is characterized by a thickness D_2 which is

increased in contrast to the average layer thickness D_1.

In a second process step the wafer 2 which has been lacquered with the bond layer 3 is transported into a bonding unit and is deposited on a receiving apparatus 1, especially a sample holder (bond chuck). The product substrate 5 (second wafer) which is to be bonded to the substrate 2 is brought into contact with the bond layer 3 (Figure 2). In a bond chamber which is not shown for example spacers (not shown), so-called "flags", are used in order to keep the product substrate 5 first separate from the surface 3o of the layer 3 until a complete evacuation of the bond space has taken place by a vacuum unit which is connected to the bond chamber and which is not shown.

In another step as claimed in the invention the closing of the bond chamber takes place. In this way a pressure disc 6 which is attached especially to the cover of the bond chamber is positioned over the product substrate 5. The pressure disc 6 as claimed in the invention has a convex curvature which faces the product substrate 5, with a radius of curvature r. Several embodiments as claimed in the invention for the pressure disc 6 are shown in Figures 7 to 9.

In a fourth process step as claimed in the invention according to Figure 4 the product substrate 5 is touched by the convex pressure disc 6 as claimed in the invention first in an especially point-like initial zone A, preferably exactly in the center of the product substrate 5, and accordingly a bond force is applied to it. Due to the convex shape of the pressure disc 6 as claimed in the invention, in this process step the edge zone R of the layer 3 is not exposed to any noteworthy pressure (in any case above a negligible stress and weight of the product substrate 5). The application of pressure to the center of the wafer 5, in the presence of an edge bead, leads first only to a bowing of the product substrate 5 in the direction of the bond layer 3.

By a continuous relative movement of the pressure disc 6, especially normally, toward the

receiving apparatus 1 the center of the product substrate 5 is guided nearer and nearer to the surface 3o of the bond layer 3, without a noteworthy increase of the pressure stress on the edge zone R. Only with the contact of the convexly curved pressure disc 6 with a periphery P of the product substrate 5 does a transfer of pressure with a bond force to the edge zone R of the bond layer 3 take place.

This is especially the case when the tangential plane of the pressure transfer side 6u is spaced in the direction of the normal to the tangential plane at least by 5 nm and/or a maximum 500 μm, especially at least by 20 nm and/or a maximum 200 μm, preferably at least 50 nm and/or at maximum by 50 μm, more preferably at least 100 nm and/or a maximum 5 μm. Preferably the pressure disc 6, especially after determining the height of the bead 3w, is set or selected such that the distance of the tangential plane to the pressure transfer side 6u on one peripheral edge of the pressure disc 6 corresponds to the (especially) average height ($H = D_2 - D_1$) of the bead.

In the case of the absence of an "edge bead" the product wafer 5 rests flat on the bond layer 3 and the initiation and transfer of the force from the pressure disc 6 to the product wafer 5 take place without prior bowing of the product wafer 5.

By further raising the pressure a larger and larger part of the pressure disc 6 makes contact with the product substrate 5 and thus with advancing approach distributes the force over the entire action side 5o.

In both cases the material in the center is more strongly hindered from flowing than the material on the edge. The reduced flow capacity of the material in the center is explained by its flow capacity in the radial direction being hindered by material lying farther outside and in the perpendicular direction by the pressure disc. In other words: Since the action side 5o is exposed to

corresponding force first in the center, a force is transferred which however leads to an inconsiderable flow of the material in the center. The edge at this instant is not at all included in the flow since the corresponding force has not yet been distributed over the entire action side 5o.

Due to the process flow as claimed in the invention an almost completely leveled surface 3o' is formed which no longer has a bead 3w, but at the same time does not have any prematurely and uncontrollably displaced material on the edge. The concave negative of the layer 3' which has been produced by the convex pressure disc 6 has a deviation of planarity which is small, if not even negligibly small, compared to the untreated bond layer 3. This deviation from planarity is negligible due to the very large radius of curvature r of the pressure disc 6 as claimed in the invention and for further processing it is essentially irrelevant, especially since the advantage of the leveling of the bond layer 3 as claimed in the invention predominates.

Furthermore the following embodiments of the pressure disc 6 according to Figures 7 to 9 are disclosed.

The configuration of the pressure disc 6 of several components is common to all three embodiments, specifically:

- a lower disc 9 which has the pressure transfer side 6u and
- a retaining disc 4 for holding/fixing of the lower disc 9 via fixing means 8 which have been localized in the region of the periphery P.

In a first embodiment the pressure disc 6 is already convexly shaped and is connected to a retaining element 4 via the fixing means 8 on its top 9o.

In a second embodiment a planar lower disc 9 which is connected by the fixing means 8 on its top 9o to the retaining disc 4 is brought by a spacer element 7 into a correspondingly convex

shape by the lower disc 9 being made more flexible than the especially rigid retaining disc 4. The spacer element 7 is preferably round. It has a thickness of less than 5 mm, preferably less than 1 mm, more preferably less than 100 μm, still more preferably less than 1 μm, most preferably less than 100 nm.

In a third embodiment a curvature element 10 is used to apply pressure to the center of the lower disc 9 which is connected via fixing means 8 on its top 9o to the retaining element 4. By applying pressure to the center of the pressure disc 6 with a curvature pressure the convex curvature of the pressure disc 6 can be continuously changed or set one time. Preferably the elasticity of the pressure disc 6 is so great that when the center of the pressure disc 6 is relieved by removing the curvature element 10, the pressure disc 6 is automatically deformed back into a planar initial position. As claimed in the invention a corresponding embodiment is conceivable in which the curvature element 10 is connected to the lower disc 9 and allows a corresponding active control of the radius of curvature of the pressure disc 6.

Reference number list

1	receiving apparatus
2	substrate
3	bond layer
3o, 3o'	surface
3w	bead
4	retaining disc
5	product substrate
5o	action side
6	pressure disc
6u	pressure transfer side
6o	top
7	spacer element
8	fixing means
9	lower disc
10	curvature element
A	initial zone
D_1, D_2	thickness
R	edge zone
P	periphery
r	radius of curvature
H	height

Z	center

Claims

1. A device for bonding of a second substrate (5) onto a first substrate (2) with the following features:

- a receiving apparatus (1) for receiving the first substrate (2) which has been coated with a bond layer (3) and the second substrate (5) which is held on the bond layer (3),
- an action apparatus for applying a bond force to the second substrate (5) on one action side (5o) of the second substrate (5), which side faces away from the bond layer (3) proceeding from an initial zone A which lies within an edge zone R of the action side (5o) as far as action on the entire action side (5o).

2. The device as claimed in Claim 1, wherein the action apparatus has a pressure disc (6) with a convexly curved pressure transfer side (6u).

3. The device as claimed in Claim 2, wherein the tangential plane of the pressure transfer side (6u) is spaced in the direction of the normal to the tangential plane at least by 5 nm and/or a maximum 500 μm, especially at least by 20 nm and/or a maximum 200 μm, preferably at least by 50 nm and/or at maximum 50 μm, more preferably at least 100 nm and/or a maximum 5 μm.

4. The device as claimed in at least one of the preceding claims, wherein the initial zone A is arranged concentrically to the action side (5o).

5. The device as claimed in at least one of the preceding claims, wherein the action apparatus has a punch which applies the bond force controlled by a control apparatus.

6. The device as claimed in Claim 2, wherein the pressure disc is formed from a lower disk (9) which encompasses the pressure transfer side (6u) and of a retaining disc (4) which fixes the

pressure disc (6), especially in the region of one periphery P via fixing means (8).

7. The device as claimed in Claim 6, wherein the lower disc (9) in the region of the initial zone A is made thicker than on the periphery P.

8. The device as claimed in Claim 6, wherein between the lower disc (9) and the retaining disc (4) in the region of the initial zone A there is a spacer element (7).

9. The device as claimed in Claim 6, wherein for setting the curvature of the pressure transfer side (6u) there is a curvature element (10) which acts on the lower disk (9) opposite the retaining disc (4) in the region of the initial zone A, especially controlled by the control apparatus.

10. A method for bonding of a second substrate (5) onto a first substrate (2) with the following steps, especially the following sequence:

- a receiving apparatus (1) for receiving the first substrate (2) which has been coated with a bond layer (3) and the second substrate (5) which is held on the bond layer (3),
- an action apparatus for applying a bond force to the second substrate (5) on one action side (5o) of the second substrate (5), which side faces away from the bond layer (3) proceeding from an initial zone A which lies within an edge zone R of the action side (5o) as far as action on the entire action side (5o).