Device and Method for Bonding of substrates

Specification

This invention relates to a device for especially temporary bonding, especially prebonding of a first substrate to a second substrate ~~as claimed in Claim 1~~ and a corresponding method ~~as claimed in Claim 12~~.

In the semiconductor industry mounting apparatus or sample holders (so called chucks) are used as handling apparatus for supporting and fixing flat semiconductor substrates, especially wafers. The wafers lie flat, are supported thereby, fixed and can be transported to various handling steps and processing stations.

Here it is to some extent necessary to transfer the wafer from one mounting apparatus to another so that not only reliable and flat support/fixing, but also detachment of the wafer as simple and careful as possible play a major part.

The fixing takes place for example by applying a vacuum between the wafer and the mounting apparatus, by electrostatic charging or by other controllable chemical-physical adhesion properties, the detachment of the wafer becoming technically more and more difficult due to the increasingly thinner wafer which is sometimes even polished on both sides, and the optionally existing inherent adhesion of the wafer to the sample holder. The surfaces on which fixing takes place can also be provided with a pattern, grooving or any other topography which further reduces the contact surface in order to obtain a mounting surface as small as possible.

Avoiding contamination is also an important aspect.

The latter plays an important part in methods and devices for bonding of two substrates (wafers), especially in the critical step of contact-making of the aligned contact surfaces of the two opposite substrates since the requirement is for more and more exact alignment accuracy or offset of less than 2 μm, especially less than 250 nm, preferably less than 150 nm, more preferably less than 50 nm. For these alignment accuracies many influencing factors must be considered. But the deposition/contact-making of the substrates is especially critical since faults can occur here, and the faults can add up and thus a reproducible alignment accuracy cannot be maintained. This leads to considerable scrap.

Embodiments~~The object~~ of this invention ~~is therefore to~~ provide a device and a method for bonding of two substrates, mainly for prebonding or temporary bonding, with which alignment accuracy as good as possible is achieved everywhere on the wafer, if possible also contamination of the substrate being avoided.

Hereinafter the words bonding, temporary bonding and prebonding will be used synonymously. It is clear to one skilled in the art that the invention was developed preferably, but not in a limiting manner, in order to join two wafers to one another by a prebond, as much as possible in a blanketing manner, free of distortions and strain.

For prebonding to produce a temporary or reversible bond between the substrates, there are several methods which are known to one skilled in the art. The prebond thicknesses are below the permanent bond thicknesses, at least by the factor of 2 to 3, especially by the factor 5, preferably by the factor 15, still more preferably by the factor 25. Guideline values are prebond thicknesses of

pure, nonactivated, hydrophilized silicon with roughly 100 mJ/m^2 and of pure, plasma-activated, hydrophilized silicon with roughly 200 - 300 mJ/m^2. The prebonds between the molecule-wetted substrates arise mainly due to the van-der-Waals interactions between the molecules of the different sides of the wafers.

Bonding means for bonding and/or prebonding and/or temporary bonding are intended for bonding as per embodiments of the invention.

According to a first aspect, there is provided a device for especially temporary bonding of a first semiconductor substrate with a second semiconductor substrate with the following features: a mounting apparatus for mounting of the first semiconductor substrate on a mounting contour with an active mounting surface of the mounting apparatus with a) an outer ring section for controllable fixing of the first semiconductor substrate and b) an inner ring section which is set back in one at least largely relative to the mounting surface, deformation means for controllable deformation of the first semiconductor substrate, the deformation means being made to act within the outer ring section and bonding means for bonding of the first semiconductor substrate to the second semiconductor substrate by removal of the deformed first semiconductor substrate from the mounting apparatus, wherein the mounting contour in the inner ring section has at least one support surface for supporting the first semiconductor substrate, the support surface being included in the mounting surface, wherein the ring width b_A of the outer ring section is smaller than the ring width b_I of the inner ring section, wherein the ratio of the ring width b_A to b_I is less than 1 to 3, wherein the projection surface of the mounting contour is at least twice,

especially three times, as large as the active mounting surface.

According to a second aspect, there is provided a method for especially temporary bonding of a first semiconductor substrate to a second semiconductor substrate with the following steps, especially the following sequence: mounting the first semiconductor substrate on a mounting contour with an active mounting surface of the mounting apparatus with a) an outer ring section for controllable fixing of the first semiconductor substrate, b) an inner ring section which is set back in one at least largely relative to the mounting surface, wherein the mounting contour in the inner ring section has at least one support surface for supporting the first semiconductor substrate, the support surface being included in the mounting surface, deforming the first semiconductor substrate within the outer ring section by deformation means for controllable deformation of the first semiconductor substrate bonding the first semiconductor substrate to the second semiconductor substrate by bonding means by removal of the deformed first semiconductor substrate from the mounting apparatus.

According to a third aspect, there is provided a device for especially temporary bonding of a first semiconductor substrate with a second semiconductor substrate with the following features: a mounting apparatus for mounting of the first semiconductor substrate on a mounting contour with an active mounting surface of the mounting apparatus with a) an outer ring section for controllable fixing of the first semiconductor substrate and b) an inner ring section which is set back at least largely relative to the mounting surface, deformation means for controllable deformation and herewith pretensioning of the first semiconductor substrate, wherein the deformation means are designed to act within the outer ring section and bonding means for automatic bonding of the first semiconductor substrate with the second semiconductor substrate due to the pretensioning, wherein the mounting contour in the inner ring section has at least one support surface for supporting the semiconductor semiconductor substrate, the support surface being included in the mounting surface, wherein the ring width b_A of the outer ring section is smaller than the ring width b_I of the inner ring section, wherein

the ratio of the ring width b_A to b_I is less than 1 to 3, wherein the projection surface of the mounting contour is at least twice, especially three times, as large as the active mounting surface.

Embodiments of invention are based on the idea of making contact between the two substrates in a manner as coordinated and at the same time as quasi-independently as possible by at least one of the substrates being exposed to pretensioning which runs radially to the outside, especially concentrically to the middle M of one contact surface of the substrates, before contact-making and then only the beginning of contact-making being influenced, while after contact-making of one section, especially of the middle M of the substrates, the substrate being exposed and bonded in a controlled manner to the opposite substrate automatically based on its pretensioning. The pretensioning is achieved by a deformation of the first substrate by deformation means, the deformation means especially based on their shape acting on the side facing away from the bond side and the deformation being controllable accordingly by using different (especially

interchangeable) deformation means. The control also takes place by the pressure or the force with which the deformation means act on the substrate. It is advantageous here to reduce the active mounting surface of the mounting apparatus with the semiconductor substrate so that the semiconductor substrate is only partially supported by the mounting apparatus. In this way the smaller contact surface yields a lower adhesion between the wafer and the sample holder or the mounting apparatus. Fixing is applied as per embodiments of~~claimed in~~ the invention, especially solely, in the region of the periphery of the semiconductor substrate (first substrate) so that there is effective fixing for a mounting surface which is at the same time active as little as possible between the mounting contour of the mounting apparatus and the semiconductor substrate. Thus, at the same time careful and reliable detachment of the semiconductor substrate is possible since the detachment forces necessary for detaching the wafer are as small as possible.

The mounting contour is the region of the mounting apparatus on which the semiconductor substrate comes to rest so that the outer periphery for circular semiconductor substrates is accordingly circular with analogous dimensions. Conventional outside dimensions are diameters of 200 mm, 300 mm, or 450 mm.

At the same time, in the region of the mounting contour outside the active mounting surface elevated structures of the wafer can be accommodated so that the mounting apparatus is made at the same time CMOS-compatible.

Detachment is mainly controllable, especially by reducing the negative pressure on the mounting surface. Controllable means that after the contact of the wafer with a second wafer the wafer on the sample holder remains fixed and only by dedicated (controlled) reduction of the

negative pressure is removal of the substrate (wafer) from the sample holder (mounting apparatus) effected, especially from the inside to the outside. The embodiment of~~as claimed in~~ the invention leads mainly to the detachment being able to be effected by very small forces.

The substrates (wafers) are aligned to one another prior to the bonding process in order to ensure uniform congruence (exact alignment, especially with an accuracy of less than 2 μm, preferably less than 250 nm, still more preferably less than 150 nm, most preferably less than 100 nm) of corresponding structures on their surfaces. In the bonding method as per embodiments of~~claimed in~~ the invention the wafers are not placed flat on one another, but are brought into contact with one another first in the middle M by one of the two wafers being pressed lightly against the second wafer or being deformed according in the direction of the opposite wafer. After removing the deformed wafer which is bowed (in the direction of the opposite wafer) by the advance of a bond wave, a continuous and more uniformed bonding along the bond front takes place which is especially at least largely automatic and which is associated with minimal force and thus with minimal, preferably horizontal distortions.

According to one advantageous embodiment of the invention it is provided that the mounting contour and/or the mounting surface and/or the mounting apparatus is/are made rotationally symmetrical, especially concentric to a center Z of the mounting apparatus. This results in uniform holding and simple production of the mounting apparatus. To the extent the mounting apparatus is made rigid at least on the mounting surface, reliable fixing of the wafer which is accurate in alignment is possible.

By at least one negative pressure channel which interrupts the mounting surface being

provided in the outer ring section of the mounting contour and the mounting contour being set back in one inner ring section at least largely relative to the mounting surface, there is a geometrical arrangement which is advantageous for the implementation of embodiments of this invention and with which on the one hand deformation is perfectly executed and on the other the contact-making can be carried out in a controlled manner as described above with little effort.

Advantageously the negative pressure channel runs concentrically, especially in the shape of a circular ring, to a center Z of the mounting apparatus, especially around the entire periphery. This ensures uniform fixing.

In another advantageous embodiment of the invention it is provided that the ring width b_A of the outer, especially circular ring-shaped ring section is smaller than the ring width b_1 of the inner ring section. The ratio of the ring width b_A to b_1 is especially less than 1 to 3, preferably less than 1 to 5, even more preferably less than 1 to 7. The smaller the ring width b_A relative to the ring width b_1, the more easily the semiconductor substrate can be detached from the mounting apparatus.

Here it is especially advantageous if the projection surface of the mounting contour is at least twice, especially three times, as large as the active mounting surface.

According to another advantageous embodiment of the invention it is provided that the mounting contour in the inner ring section has at least one, especially circular ring-shaped support surface which is located preferably concentrically to the center Z for supporting, especially without active fixing, of the semiconductor substrates, the support surface being included in the mounting surface and being flush with it. This measure results in further planarization of the mounting apparatus during handling so that the semiconductor substrate does not bow toward the mounting

apparatus, or in general, arch.

In another embodiment ofas claimed in the invention it is provided that the deformation means are made to act on the semiconductor substrate on the side of the mounting surface, especially outside, preferably solely outside the mounting surface. It has been surprisingly shown that by acting on the semiconductor substrate on the side of the mounting surface (generally back of the semiconductor substrate) especially careful detachment is possible. Moreover contamination of the other (generally more important because they are for example processed) surfaces of the semiconductor substrate is avoided.

To the extent the deformation means is at least one pressure element which penetrates the mounting contour, the pressure can be applied uniformly, especially from the center Z. In this connection a mechanical design, especially by a pin, but also application of a fluid, especially a gas, is possible. For this purpose there is especially an opening, especially a bore, which penetrates the mounting body.

Bonding takes place especially effectively and with high alignment accuracy due to the smallest possible distortion when the deformation means are made such that the deformation takes place concentrically to the first substrate.

According to another advantageous embodiment it is provided that in the inner ring section there are especially individually triggerable fixing elements for fixing of the corresponding fixing sections along the first substrate. In this way, in addition distortions and/or strains in the x, y and/or z direction of the first and/or second substrate can be influenced. The distortions and/or strains (which run primarily along the contact surface of the substrates, therefore in the surface) are recorded

especially in a prior method step, preferably in the form of stress and/or strain maps of the substrate/substrates and by switching the fixing element when contact is made between the substrates an additional sectional deformation is produced which is made such that especially local distortion/strains are compensated. This is because these distortions/strains more and more strongly influence the alignment accuracy, especially for alignment accuracies less than 250 nm. Fundamentally therefore it is possible to distinguish between horizontal and vertical distortions. The vertical distortions arise due to the evacuation process in the vertical direction, therefore in the z-direction. These distortions however necessarily also result in the horizontal, therefore the x and y distortions, which with respect to the alignment accuracy which is to be achieved constitute the actual problem.

According to the method this is achieved by distortions and/or strains of the first and/or second substrate which have been determined by an upstream measurement method being reduced by action, especially by controlled distortion and/or strain of sections of the first and/or second substrate, on the first and/or second substrate, especially by means of fixing elements for fixing of corresponding fixing sections. The distortions and/or strains can be determined by an external measurement apparatus. The external measurement apparatus is then connected accordingly ~~to the embodiment~~ as per embodiments of~~claimed in~~ the invention via a data link. Advantageously a measurement apparatus for determining the distortion and/or strain maps would be located in the same module as the embodiment of~~as claimed in~~ the invention. Furthermore the possibility of using the same interface for triggering the apparatus for determining the distortion and/or strain maps and of the embodiment of~~as claimed in~~ the invention will be disclosed.

CLAIMS

1. A device for especially temporary bonding of a first semiconductor substrate (15) with a second semiconductor substrate (15') with the following features:

- a mounting apparatus for mounting of the first semiconductor substrate (15) on a mounting contour (8, 8', 8", 8"', 8^{IV}) with an active mounting surface (7, 7', 7", 7"', 7^{IV}) of the mounting apparatus with

a) an outer ring section (10) for controllable fixing of the first semiconductor substrate (15) and

b) an inner ring section (11) which is set back in one at least largely relative to the mounting surface (7, 7', 7", 7"', 7^{IV}),

- deformation means for controllable deformation of the first semiconductor substrate (15), the deformation means being made to act within the outer ring section and

- bonding means for bonding of the first semiconductor substrate (15) to the second semiconductor substrate (15') by removal of the deformed first semiconductor substrate (15) from the mounting apparatus, wherein the mounting contour (8, 8', 8", 8"', 8^{IV}) in the inner ring section (11) has at least one support surface (12, 12', 12") for supporting the first semiconductor substrate (15), the support surface (12, 12', 12") being included in the mounting surface (7, 7', 7", 7"', 7^{IV}),

wherein the ring width b_A of the outer ring section (10) is smaller than the ring width b_1 of the inner ring section (11), wherein the ratio of the ring width b_A to b_1 is less than 1 to 3,

wherein the projection surface of the mounting contour (8, 8', 8", 8"') is at least twice, especially three times, as large as the active mounting surface (7, 7', 7", 7"', 7^{IV}).

2. The device as claimed in Claim 1, wherein the mounting contour (8, 8', 8", 8"', 8^{IV}) and/or the mounting surface (7, 7', 7", 7"', 7^{IV}) and/or the mounting apparatus is/are made rotationally symmetrical, especially concentric to a center Z of the mounting apparatus.

3. The device as claimed in claim 1 or 2, wherein at least one negative pressure channel (3) which interrupts the mounting surface (7, 7', 7", 7"', 7^{IV}) is provided in the outer ring section (10) of the mounting contour (8, 8', 8", 8"', 8^{IV}).

4. The device as claimed in claim 3, wherein the negative pressure channel (3) runs concentrically, especially in the shape of a circular ring, to a center Z of the mounting apparatus, especially around the entire periphery.

~~5. The device as claimed in one of the preceding claims, wherein the projection surface of the mounting contour (8, 8', 8", 8"') is at least twice, especially three times, as large as the active mounting surface (7, 7', 7", 7"', 7^{IV}).~~

~~6~~5. The device as claimed in one of the preceding claims, wherein the support surface (12, 12', 12'') is circular ring shaped, preferably concentrically to the center Z.

~~7~~6. The device as claimed in one of the preceding claims, wherein the deformation means are made to act on the first semiconductor substrate (15) on the side of the mounting surface (7, 7', 7", 7"', 7^{IV}) especially outside, preferably solely outside the mounting surface (7, 7', 7", 7"', 7^{IV}).

~~8~~7. The device as claimed in one of the preceding claims, wherein the deformation means is at least one pressure element (6, 6', 6", 6"') which penetrates the mounting contour (8, 8', 8", 8"', 8^{IV}).

~~9~~8. The device as claimed in one of the preceding claims, wherein the deformation means are made such that the deformation takes place concentrically to the first semiconductor substrate (15).

~~10~~9. The device as claimed in Claim 2, wherein in the inner ring section (11) there are especially individually triggerable fixing elements (16) for fixing of the corresponding fixing sections along the first semiconductor substrate (15).

~~11~~10. A method for especially temporary bonding of a first semiconductor substrate (15) to a second semiconductor substrate (15') with the following steps, especially the following sequence:

- mounting the first semiconductor substrate (15) on a mounting contour (8, 8', 8", 8"', 8^{IV}) with an active mounting surface (7, 7', 7", 7"', 7^{IV}) of the mounting apparatus (1) with

a) an outer ring section (10) for controllable fixing of the first semiconductor substrate (15),

b) an inner ring section (11) which is set back in one at least largely relative to the mounting surface (7, 7', 7", 7"', 7^{IV}), wherein the mounting contour (8, 8', 8", 8"', 8^{IV}) in the inner ring section (11) has at least one support surface (12, 12', 12") for supporting the first semiconductor substrate (15), the support surface (12, 12', 12") being included in the mounting surface (7, 7', 7", 7"', 7^{IV}),

- deforming the first semiconductor substrate (15) within the outer ring section by deformation means for controllable deformation of the first semiconductor substrate (15)

- bonding the first semiconductor substrate (15) to the second semiconductor substrate by bonding means by removal of the deformed first semiconductor substrate (15) from the mounting apparatus.

~~12~~11. The method as claimed in Claim ~~11~~10, wherein bonding takes place essentially concentrically proceeding from the middle M of the contact surface of the first and second semiconductor substrate by deformation of the first semiconductor substrate (15).

~~13~~12. The method as claimed in one of claims ~~11~~10 or ~~12~~11, wherein distortions and/or strains of the first and/or second semiconductor substrate which have been determined by an upstream measurement method are reduced by action, especially by controlled distortion and/or strain of sections of the first and/or second semiconductor substrate, on the first and/or second semiconductor substrate, especially by means of fixing elements (16) for fixing of corresponding fixing sections.

~~14~~13. A device for especially temporary bonding of a first semiconductor substrate (15) with a second semiconductor substrate (15') with the following features:

- a mounting apparatus for mounting of the first semiconductor substrate (15) on a mounting contour (8, 8', 8", 8"', 8^{IV}) with an active mounting surface (7, 7', 7", 7"', 7^{IV}) of the mounting apparatus with

a) an outer ring section (10) for controllable fixing of the first semiconductor substrate (15) and

b) an inner ring section (11) which is set back at least largely relative to the mounting surface (7, 7', 7", 7"', 7^{IV}),

- deformation means for controllable deformation and herewith pretensioning of the first semiconductor substrate (15), wherein the deformation means are designed to act within the outer ring section and

- bonding means for automatic bonding of the first semiconductor substrate (15) with the second semiconductor substrate (15') due to the pretensioning, wherein the mounting contour (8, 8', 8", 8"', 8^{IV}) in the inner ring section (11) has at least one support surface (12, 12', 12") for supporting the semiconductor semiconductor substrate (15), the support surface (12, 12', 12") being included in the mounting surface (7, 7', 7", 7"', 7^{IV}),

wherein the ring width b_A of the outer ring section (10) is smaller than the ring width b_1 of the inner ring section (11), wherein the ratio of the ring width b_A to b_1 is less than 1 to 3,

wherein the projection surface of the mounting contour (8, 8', 8", 8"') is at least twice, especially three times, as large as the active mounting surface (7, 7', 7", 7"', 7^{IV}).