Retaining System, Device and Method for Handling Substrate Stacks

Specification

This invention relates to a retaining system for handling substrate stacks , a device for handling substrate stacks , as well as a corresponding method for handling substrate stacks.

In the semiconductor industry, substrates are quite often different; product substrates or carrier substrates are connected to one another. Bonding is cited as the connecting process. Two different types of bonds can be distinguished: the temporary bonding and the permanent bonding. In temporary bonding, a first substrate, in most cases a product substrate, is bonded to a second substrate, in particular a carrier substrate, in order to stabilize the product substrate by the carrier substrate.

After additional processes on the product substrate, the latter can be removed from the carrier substrate. In technical terminology, the removal process is called debonding.

In permanent bonding, an irreversible connection between two substrates, in most cases two product substrates, is sought. This type of bonding is used primarily in the building-up of substrate stacks with different functional planes. In the publication of Dragoi, V. and Pabo, E., Wafer Bonding Process Selection, The Electrochemical Society, ECS Transactions 01/2010; 33: 509-517, for example, there is an overview on different bonding methods.

Primarily before the permanent bonding, product substrates have to be aligned to one another with a very high precision via alignment marks, which are located on their surfaces. In this case, to date, the alignment and the bonding of the substrates is done mainly in different modules: an alignment module and a bonding module. The latter is referred to in simplified terms as a bonder. A critical aspect of the separation of the alignment module and the bonding module exists in the transport of the substrates that are aligned to one another from the alignment module to the bonding module. In this way, even though it may be a very short way, the two

substrates can shift toward one another. An attaching of the substrates that are aligned toward one another is therefore necessary.

In the state of the art, the attaching of two substrates is done, for example, with mechanical clamps. In most cases, the mechanical clamps are connected to a substrate holder (English: chuck or fixture). One of the two substrates lies directly on the substrate holder. After the second substrate was aligned relative to the first substrate, the two substrates are brought into contact. Very often, spacers that are inserted from the edge between the two substrates are used in order to prevent the complete contact of the two substrates with one another up until the actual bonding process. Independently of the use of the spacers, mechanical clamps can attach both substrates on the substrate holder. If the substrate holder is used to retain and attach the two substrates, substrate holders and substrates have to be transferred from the alignment module to the bonding module either manually or fully automatically by a robotic arm.

Embodiments of this invention disclose a retaining system and a device as well as a corresponding method with which the handling of substrate stacks is improved and/or simplified.

According to a first aspect of the present invention, there is provided a retaining system for handling a first substrate that is to be bonded with a second substrate with: a retaining surface for retaining a first substrate, and at least one recess, recessed relative to the retaining surface, for retaining magnetically acting attachment means for securing the first substrate relative to a second substrate that is aligned with the first substrate, wherein the magnetically acting attachment means is configured to be placed on a holding side of the second substrate, wherein a substrate stack formed from the first substrate and the second substrate is secured for transportability of the substrate stack when the magnetically acting attachment means is placed on the holding side of the second substrate.

According to a second aspect of the present invention, there is provided a device for handling a substrate stack, the substrate stack comprising a first substrate and a second substrate aligned relative to the first substrate, with magnetically acting attachment means for securing the first substrate relative to the second substrate in an aligned immobilized position, wherein the device comprises a placing system for placing the magnetically acting attachment means on sides of the substrate stack, wherein the sides face away from each other, wherein the substrate stack is secured for transportability of the substrate stack when the magnetically acting attachment means is placed on the holding side of the second substrate.

According to a third aspect of the present invention, there is provided a method for handling a substrate stack that is to be bonded, the substrate stack comprising a first substrate and a second substrate that is aligned relative to the first substrate, whereby the first substrate is secured in an aligned immobilized position by magnetically acting attachment means for handling the substrate stack relative to the second substrate, wherein the magnetically acting attachment means are placed on holding sides of the substrate stack, wherein the holding sides face away from each other, wherein the substrate stack is secured for transportability of the substrate stack when the magnetically acting attachment means is placed on the holding side of the second substrate.

According to a fourth aspect of the present invention, there is provided a substrate stack secured by magnetically acting attachment means, which are placed on holding sides of the substrate stack, the substrate stack comprising a first substrate and a second substrate that is aligned relative to the first substrate, wherein the holding sides face away from each other, wherein the substrate stack is secured for transportability of the substrate stack when the magnetically acting attachment means is placed on the holding side of the second substrate.

Also, all combinations that consist of at least two of the features indicated in the specification, the claims and/or the figures fall within the scope of the invention. In the indicated ranges of values, values that lie within the above-mentioned limits are also to be disclosed as boundary values and can be claimed in any combination.

In particular, embodiments of the invention relate to a method and a device for aligning, clamping and bonding two (semiconductor) substrates or a substrate stack formed from the two (or more) substrates. The method according to embodiments of the invention is advantageously used in an ultrahigh-vacuum environment.

Embodiments of the invention are based on the idea of securing two (or more) aligned substrates on one another by magnetic attachment means, in particular with omission of a retaining system (chuck or fixture) on at least one of the two holding sides of the substrate stack facing away from the contact sides of the substrates, so that the substrates can be handled as substrate stacks that are aligned in an immobilized position with respect to one another.

In particular, embodiments of the invention proceed from a method of attaching two or more substrates, which form a substrate stack, via at least two magnets that are located on the opposite sides of the substrate stack in each case. The holding force generated by the magnets in this case is higher than 0.01N, preferably greater than 0.1N, more preferably greater than 1N, even more preferably greater than 10N, and most preferably greater than 100N. The force values indicated here are determined most simply by having at least one of the two magnets be fastened on a spring balance and be brought into the vicinity of the second magnet so that the force action developing between the two magnets results in an expansion of the spring balance and thus in a simple determination of the force caused by the magnetic force of attraction of the two magnets. In the case where the two magnets are in the vertical position and have different masses, the

calculated force values can be corrected against the force of gravity. The measurement of the magnetic force, however, can also be determined by any other known and tried and true method.

In general, in the case of bar magnets, a magnetic force law equivalent to Coulomb's Law can be found. The magnetic force in this case is directly proportional to the product of the pole strengths of the two magnets, but conversely proportional to the square of the distance. The magnetic force decreases as with increasing distance r with $1/r^2$. This law is also known under the name "magnetostatic force law."

Since a minimum holding force is necessary in order to ensure an attachment of the two substrates to one another according to an embodiment of the invention, and the thickness of any substrate in most cases can be very readily determined, a way arises, through the application of the "magnetostatic force law," of determining the minimum magnetic force that is necessary in order to attach the two substrates to one another. As a result, the possibility of selecting a magnetic material specifically is achieved, which material is able to apply the corresponding minimum force for a given substrate stack thickness.

The substrates according to embodiments of the invention are preferably substrates, in particular semiconductor substrates, preferably wafers. The latter have in particular a thickness of less than 1500 μm, and even more preferably less than 1000 μm.

For handling (in particular the transport from an alignment module to a bonding module or other processing modules), it is no longer necessary to carry along a retaining system (substrate holder) on one of the two - or on both - holding sides of the substrate stack. The substrate holders are in most cases very expensive, heavy tools optimized in particular for a module. The transport of the substrate holders between the modules is therefore connected to energy and costs, which can be saved with embodiments of the invention. Primarily with application in alignment modules, in which preferably other substrate holders than in bonding

modules are used, embodiments of this invention are of great technical advantage since the substrate stack can be moved solely with the attachment means or is transportable, without the alignment of the substrates of the substrate stack being adversely affected.

The use of a substrate holder for transport of the aligned substrate stack between the modules can thus be completely eliminated. As a result, not only are the above-mentioned energy and cost savings produced, but rather also the required substrate holders are freed up for the actually intended purposes for which they were designed. The misappropriation of the substrate holders for transport is thus avoided by the embodiments of the invention.

The retaining system according to embodiments of the invention is further developed by the recess(es) being designed as at least one shelf arranged on the periphery with a seating section for seating the attachment means and a seating section pointing toward the center of the seating surface for installation of the attachment means. According to embodiments of the invention, the attachment means, in particular in the form of magnetic bodies, are at least predominantly, preferably completely, held by their own weight in the recesses until the substrates are secured in an immobilized position by the attachment means. In this case, it is advantageous when the recesses are arranged uniformly distributed on the periphery, in particular rotating throughout and/or facing each other in each case.

According to another advantageous embodiment of the retaining system, the seating section is tilted relative to the retaining surface by an angle a that is less than 60°, in particular a less than 45°, preferably a less than 30°, and even more preferably a less than 15°. In this connection, an automatic movement of the attachment means, in particular of the magnetic body, preferably spherical magnetic body, is made possible as long as the attachment means are not still in the immobilized position or the magnetic action of the attachment means is eliminated.

According to an advantageous embodiment of the device of the invention, the attachment means have at least two pairs of magnetic elements. By the arrangement of the magnetic bodies

of the pairs of magnetic elements on the holding sides of the substrate stack, the substrates in the aligned immobilized position are at least predominantly, preferably completely, attached by the magnetic force of the pairs of magnetic elements.

By each pair of magnetic elements being formed from a first magnetically active magnetic body and a second, in particular magnetically active, magnetic body magnetically attracted by the first magnetic body, the substrates can be secured in the aligned immobilized position at low cost. The first magnetic bodies are advantageously physically separated from the second magnetic bodies.

In further development of the device, it is provided to make the first and/or the second magnetic body(ies) spherical. By spherical configuration, the seating surface on the holding side of the substrates is minimized, and the spherical magnetic bodies can be mechanically scraped in a simple way from the respective holding side during or after the bonding process. By the mutually induced polar alignment of two magnetic balls on respectively one of the surfaces of the substrate to be attached to one another, the magnetic bodies are secured in their opposing positions.

The magnetic bodies can be removed by one of the following methods:

- Active, mechanical scraping or rolling off with a mechanical device,
- Passive mechanical dropping due to loss of magnetic force of at least one of the magnetic bodies, caused by demagnetization by means of temperature and/or magnetic alternating fields,
- Mechanical grabbing of the magnetic bodies by means of a claw, and/or
- Magnetic attraction of the magnetic bodies with one or more magnets.

According to another advantageous embodiment of the invention, it is provided that the device has an alignment system for aligning the first substrate relative to the second substrate as well as a contacting system for bringing the substrates into contact. It is further advantageously

provided that the device has a placing system for placing the attachment means, in particular the magnetic bodies, on sides of the substrate stack that are facing away from one another.

The features described for the retaining system are also to apply as disclosed as features of the method described below and vice versa.

In an embodiment, a method for handling a substrate stack that is to be bonded and that consists of a first substrate and a second substrate aligned relative to the first substrate is also disclosed, whereby the first substrate for handling the substrate stack relative to the second substrate is secured by magnetically acting attachment means in an aligned immobilized position.

In this case, it is provided according to an advantageous embodiment of the method that the attachment means are also placed on holding sides of the substrate stack that are facing away from one another.

Other advantages, features and details of the invention follow from the subsequent description of preferred embodiments as well as based on the drawings; the latter in each case show in diagrammatic view:

Fig. 1 A first embodiment of a substrate stack that is secured according to the invention with attachment means,

Fig. 2 A second embodiment of a substrate stack that is secured according to the invention with attachment means,

Fig. 3 A third embodiment of a substrate stack that is secured according to the invention with attachment means,

Fig. 4a A first process step of an embodiment of the method according to the invention,

Fig. 4b A second process step of the embodiment according to Fig. 4a,

Fig. 4c A third process step of the embodiment according to Fig. 4a,