AN APPARATUS AND METHOD FOR WAFER STACKING

FIELD OF THE INVENTION

This invention relates to an apparatus and method for wafer stacking.

BACKGROUND OF THE INVENTION

With electronic devices, particularly portable devices such as smart phones, tablets, etc. becoming smaller and yet at the same time offering a wider range of functions and capabilities, there is a need to integrate multifunctional chips. However, this must be achieved without increasing the size of the devices, and keeping a small form factor. Increasing the number of electronic components in a 2D structure is not compatible with these objectives. Therefore, 3D packages are increasingly being adopted in order to provide greater functionality and higher component density with a small form factor. To that end, accurate stacking and bonding of wafer onto wafer, also referred to as wafer stacking, is a critical and key enabling technology for the high-growth Smart Phones and Tablets industry.

SUMMARY OF INVENTION

According to a first aspect, there is provided an apparatus for wafer stacking, the apparatus comprising: a wafer stacker configured to bond a top wafer with a bottom wafer; a top chuck configured to releasably and invertibly retain the top wafer such that when the top wafer is placed on the top chuck and the top chuck is inverted, the top wafer is inverted and under the top chuck; a transfer stage configured to releasably support and invert the top chuck and to move the top chuck between a top wafer loading position and the wafer stacker; and a bottom chuck configured to releasably support the bottom wafer and to move between a bottom wafer loading position and the wafer stacker; wherein the wafer stacker is configured to engage the inverted top chuck when the transfer stage is at the wafer stacker and to bond the inverted top wafer with the bottom wafer when the bottom chuck is at the wafer stacker and the transfer stage is at the top wafer loading position.

The transfer stage may be configured to invert the top chuck at the top wafer loading position before moving the inverted top chuck to the wafer stacker.

The transfer stage may be configured to release the inverted top chuck at the wafer stacker.

The transfer stage may be configured to rotatably engage the top chuck such that the top chuck is inverted by rotation of the top chuck 180° relative to the transfer stage.

The transfer stage may comprise a rotary cylinder configured to releasably engage the top chuck and

to rotate the top chuck relative to the transfer stage.

The top chuck may be provided with vacuum suction to retain the top wafer against the top chuck when the top chuck is inverted.

The apparatus may further comprise a top wafer pre-position vision system at the top wafer loading position for assisting a user to position the top wafer on the top chuck.

The wafer stacker may further comprise an alignment imaging sensor configured to accurately align the inverted top wafer with the bottom wafer before bonding of the inverted top wafer with the bottom wafer.

According to a second aspect, there is provided a method of wafer stacking, the method comprising the steps of: positioning and retaining a top wafer on a top chuck at a top wafer loading position, the top chuck supported by a transfer stage; the transfer stage inverting the top chuck such that the top wafer is inverted and under the top chuck; the transfer stage moving the inverted top chuck and top wafer from the top wafer loading position to a wafer stacker; the wafer stacker engaging the inverted top chuck and the transfer stage releasing the inverted top chuck; a bottom chuck moving from the wafer stacker to a bottom wafer loading position; positioning a bottom wafer on the bottom chuck; the bottom chuck moving the bottom wafer from the bottom wafer loading position to the wafer stacker; the transfer stage moving from the wafer stacker to the top wafer loading position; and bonding the inverted top wafer with the bottom wafer.

Steps (c) and (e) may occur concurrently.

Steps (g) and (h) occur concurrently.

The method may further comprise an alignment imaging sensor accurately aligning the inverted top wafer with the bottom wafer before step (i).

Step (b) may comprise rotating the top chuck relative to the transfer stage.

Step (a) may comprise a top wafer pre-position vision system at the top wafer loading position assisting a user to accurately position the top wafer on the top chuck.

Step (a) may comprise using vacuum suction to retain the top wafer on the top chuck.

BRIEF DESCRIPTION OF FIGURES

In order that the invention may be fully understood and readily put into practical effect there shall now be described by way of non-limitative example only exemplary embodiments of the present invention, the description being with reference to the accompanying illustrative drawings.

FIG. 1 is a perspective view of a top wafer being loaded on an exemplary top chuck of the apparatus of the present invention;

FIG. 2 is a flowchart of an exemplary method of the present invention;

FIG. 3 is a perspective view of the top chuck of FIG. 1 supported by a transfer stage of the apparatus;

FIG. 4 is a perspective view of the transfer stage of FIG. 3 inverting the top chuck;

FIG. 5 is an illustration of rotational means provided on the transfer stage and the top chuck;

FIG. 6 is an illustration of the top chuck after rotation by the transfer stage;

FIG. 7 is a perspective view of the transfer stage and the top chuck at a top wafer loading position;

FIG. 8 is a perspective view of the transfer stage and the top chuck at a wafer stacker;

FIG. 9 is a front elevation view of the top chuck engaged by a top chuck clamper of the wafer stacker;

FIG. 10 is a perspective view of L-brackets provided on an underside of the top chuck;

FIG. 11 is a front elevation view of a rotational cylinder at an extended position;

FIG. 12 is a front elevation view of the rotational cylinder of FIG. 11 at a retracted position;

FIG. 13 is a front elevation view of the top chuck clamped by the top chuck clamper of the wafer stacker; and

FIG. 14 is a front elevation view of the top chuck and the bottom chuck at the wafer stacker before bonding.

DETAILED DESCRIPTION

Exemplary embodiments of the invention will be described with reference to FIGS. 1 to 14.

The apparatus 100 comprises a top chuck 110 configured for supporting a top wafer 10 thereon, as shown in FIG. 1. The top wafer 10 generally has a substrate supporting a device layer, thereby having a substrate side and a device side. The top chuck 110 is configured to releasably and invertibly retain the top wafer 10 such that when the top wafer 10 is placed on the top chuck 110 and the top chuck 110 is inverted, the top wafer 10 is inverted and retained under the top chuck 110. To do so, the top chuck 110 is preferably provided with vacuum suction to retain the top wafer 10 against the top chuck 110. The vacuum suction should be activated prior to inverting the top chuck 110 to avoid the top wafer 10 falling off the top chuck 110 during inversion of the top chuck 110.

By configuring the top chuck to be invertible, a user is better able to align the top wafer 10 on the top chuck 110 as the top wafer 10 is loaded and positioned with its device side facing up on the top chuck 110. This allows the device side to be visible to the user for checking alignment of the top wafer 10 on

the top chuck 110. After positioning the top wafer 10 on the top chuck 110, the top chuck 110 can then be inverted so that device side of the top wafer 10 faces downwards in order to be bonded with an upward facing bonding surface of a bottom wafer 20, as shown in FIG. 14.

The apparatus 100 further comprises a transfer stage 111 configured to releasably support and invert the top chuck 110, as shown in FIG. 3. To invert the top chuck 110, the transfer stage 111 rotatably engages the top chuck 110 such that the top chuck 110 is inverted by rotation of the top chuck 180° relative to the transfer stage 111 as shown in FIG. 4. Rotation of the top chuck 110 may be achieved by a rotary cylinder 113 provided on the transfer stage 111.

As shown in FIG. 5, the top chuck 110 rotatably engages the transfer stage 111 at two pivot points 114a, 114b on the transfer stage 111. Accordingly, rotation of the top chuck 110 relative to the transfer stage 111 would take place about an axis R that passes through the two pivot points 114a, 114b. The two pivot points 114a, 114b are preferably located diametrically opposite each other relative to the top wafer 10 when the top wafer 10 is on the top chuck 110. In this way, the diametric centre of the top wafer 10 may be used as a position referencing point for accurate positioning of the top wafer 10 on the top chuck 110 and also subsequently for accurate positioning before bonding with the bottom wafer 20.

In order for the rotary cylinder 113 to rotate the top chuck 110, an attaching point 115 is provided on the top chuck 110 to engage with an attaching pin 116 provided on the rotary cylinder 113, as shown in FIG. 6. The rotary cylinder 113 is positioned with its axis of rotation collinear with the axis R. In one embodiment, the attaching point 115 and attaching pin 116 are each positioned on the top chuck 110 and the rotary cylinder 113 respectively at a same off-set displacement from the axis R. A greater off-set displacement lowers the torque that is needed from the rotary cylinder 113 to rotate the top chuck 110.

The transfer stage 111 is configured to move the top chuck 110 between a top wafer loading position (as shown in FIG. 7) and a wafer stacker 130 (as shown in FIGS. 7 and 8), as indicated by the arrow P in FIG. 8. The transfer stage 111 is configured to invert the top chuck 110 before moving the inverted top chuck 110 to the wafer stacker 130. Loading and positioning of the top wafer 10 on the top chuck 110 take place at the top wafer loading position. Preferably, inversion of the top chuck 110 also takes place at the top wafer loading position. In addition, there is preferably provided a top wafer pre-position vision system (not shown) at the top wafer loading position for assisting the user to accurately position the top wafer 10 on the top chuck 110 before inverting the top chuck 110 and the top wafer 10.

The wafer stacker 130 is configured to engage the inverted top chuck 110 when the transfer stage 111 is at the wafer stacker 130, as shown in FIG. 8. As can be seen in the front elevation view of FIG. 9, the wafer stacker 130 has a top chuck clamper 131 that is provided with guide rails 132 that project below a clamper platform 133 to engage corresponding L-shaped brackets 117 provided on the underside of the top chuck 110. It should be noted that when the top chuck 110 has been inverted as shown in FIG. 10, the L-shaped brackets 117 face up. As the transfer stage 111 moves the top chuck 110 to the wafer stacker 130, the L-shaped brackets 117 slide into engagement with the guide rails 132 as shown in FIG. 9.

The transfer stage 111 is configured to release the inverted top chuck 110 when the top chuck 110 is engaged with the wafer stacker 130. This may be achieved by configuring the rotary cylinder 113 to releasably engage the top chuck 110, for example, by configuring the rotary cylinder 113 to be retractable. In this way, retracting the rotary cylinder 113 disengages the attaching pin 116 of the rotary cylinder 113 from the attaching point 115 on the top chuck 110, thereby releasing the inverted top chuck 110 from the transfer stage 111. FIGS. 11 and 12 show the rotary cylinder 113 in an extended and a retracted position respectively.

When the top chuck 110 has been engaged by the wafer stacker 130 and has also been released from the transfer stage 111, the top chuck clamper 131 is configured to lift and clamp the top chuck 110 by lifting the guide rails 132 to clamp the L-shaped brackets 117 on the top chuck 110 against the clamper platform 133, as shown in FIG. 13. Hydraulic or pneumatic cylinders (not shown) may be provided on the top chuck clamper 131 to actuate the lifting and clamping. Lifting the top chuck 110 clears it away from the transfer stage 111, thereby allowing the transfer stage to move away from the wafer stacker 130 and leave the top chuck 110 at the wafer stacker 130.

The wafer stacker 130 is configured to bond the top wafer 10 with the bottom wafer 20. Accordingly, the apparatus 100 further comprises a bottom chuck 120 that is configured to releasably support the bottom wafer 20 and to move between a bottom wafer loading position and the wafer stacker 130.

The wafer stacker 130 is configured to bond the inverted top wafer 10 with the bottom wafer 20 when the bottom chuck 120 is at the wafer stacker 130 and the transfer stage 111 is at the top wafer loading position. At the wafer stacker 130, the bottom chuck 120 is configured to move upwards, as shown by arrows Q in FIG. 14, in order to contact the bottom wafer 20 with the inverted top wafer 10 for bonding to take place.

The wafer stacker 130 preferably comprises an alignment imaging sensor (not shown) configured to accurately align the inverted top wafer 10 with the bottom wafer 20 before bonding occurs. In one

embodiment, an alignment accuracy of +/- 3 microns may be achieved.

In use, as shown in the flowchart of the exemplary method 200 in FIG. 2, the top wafer 10 is positioned by a user and retained on the top chuck 110 at the top wafer loading position. Positioning is preferably assisted by the top wafer pre-position vision system at the top wafer loading position. The top wafer 10 is retained by the top chuck 110 after positioning, by using the vacuum suction provided on the top chuck 110 (202). The top chuck 110, which is supported by the transfer stage 111, is then inverted by the transfer stage 111 such that the top wafer 10 is inverted and under the top chuck 110 (204).

The transfer stage 111 moves the inverted top chuck 110 and top wafer 10 from the top wafer loading position to the wafer stacker 130 (206). At the same time, the bottom chuck 120 moves from the wafer stacker 130 to the bottom wafer loading position (208). The user then positions the bottom wafer 20 on the bottom chuck 120 (210) at the bottom wafer loading position. The bottom chuck 120 is preferably at the wafer stacker 130 during loading of the top chuck 110 in order to be out of the way. It is then moved away from the wafer stacker 130 in order to make way for the loaded top chuck 110 to be brought to the wafer stacker 130.

As the top wafer 20 is moved to the wafer stacker 130, the wafer stacker 130 engages the inverted top chuck 110. The transfer stage then releases the inverted top chuck 110 (212). After releasing the top chuck 110, the transfer stage 111 moves from the wafer stacker 130 back to the top wafer loading position (214) while the bottom chuck 120 moves the bottom wafer 20 from the bottom wafer loading position to the wafer stacker 130 (216). Simultaneously moving the transfer stage 111 and the bottom chuck 120 thereby shortens the time taken to load the top and bottom wafers onto their respective chucks and to transfer them to the wafer stacker 130.

Preferably, the alignment imaging sensor at the wafer stacker 130 accurately aligns the inverted top wafer with the bottom wafer before bonding takes place. Bonding finally takes place when the bottom chuck 120 moves upwards at the wafer stacker 130 so that the bottom wafer 20 is put in contact with the inverted top wafer 10 (218) at the wafer stacker 130.

Using the above described apparatus 100 and method 200 allows high bonding accuracies (for example +/- 3 microns) in the wafer stacking process to be achieved, while minimizing time delays associated with positioning and transferring of the top and bottom wafers, thereby reducing costs and improving productivity.

Whilst there has been described in the foregoing description exemplary embodiments of the present

invention, it will be understood by those skilled in the technology concerned that many variations in details of design, construction and/or operation may be made without departing from the present invention. For example, while guide rails 132 and L-shape brackets 117 have been described above for engaging the wafer stacker 130 with the top chuck 110, other appropriate means such as clamps may be used. Instead of an attaching pin 115 provided on the rotary cylinder 113 for engaging the top chuck 110, other appropriate means such as jaws may be provided. Instead of using a rotary cylinder 113 to effect rotation of the top chuck 110, other appropriate means such as a piston-and-crank or gears and a motor may be used. Instead of inverting the top chuck 110 at the top wafer loading position, the top chuck 110 may be inverted while it is being moved by the transfer stage 111 to the wafer stacker 130.

CLAIMS

1. An apparatus for wafer stacking, the apparatus comprising:

a wafer stacker configured to bond a top wafer with a bottom wafer;

a top chuck configured to releasably and invertibly retain the top wafer such that when the top wafer is placed on the top chuck and the top chuck is inverted, the top wafer is inverted and under the top chuck;

a transfer stage configured to releasably support and invert the top chuck and to move the top chuck between a top wafer loading position and the wafer stacker; and

a bottom chuck configured to releasably support the bottom wafer and to move between a bottom wafer loading position and the wafer stacker;

wherein the wafer stacker is configured to engage the inverted top chuck when the transfer stage is at the wafer stacker and to bond the inverted top wafer with the bottom wafer when the bottom chuck is at the wafer stacker and the transfer stage is at the top wafer loading position.

2. The apparatus of claim 1, wherein the transfer stage is configured to invert the top chuck at the top wafer loading position before moving the inverted top chuck to the wafer stacker.

3. The apparatus of claim 1 or claim 2, wherein the transfer stage is configured to release the inverted top chuck at the wafer stacker.

4. The apparatus of any preceding claim, wherein the transfer stage is configured to rotatably engage the top chuck such that the top chuck is inverted by rotation of the top chuck 180° relative to the transfer stage.

5. The apparatus of claim 4, wherein the transfer stage comprises a rotary cylinder configured to releasably engage the top chuck and to rotate the top chuck relative to the transfer stage.

6. The apparatus of any preceding claim, wherein the top chuck is provided with vacuum suction to retain the top wafer against the top chuck when the top chuck is inverted.

7. The apparatus of any preceding claim, further comprising a top wafer pre-position vision system at the top wafer loading position for assisting a user to position the top wafer on the top chuck.

8. The apparatus of any preceding claim, wherein the wafer stacker further comprises an alignment imaging sensor configured to accurately align the inverted top wafer with the bottom wafer before bonding of the inverted top wafer with the bottom wafer.

9. A method of wafer stacking, the method comprising the steps of:
   (a) positioning and retaining a top wafer on a top chuck at a top wafer loading position, the top chuck supported by a transfer stage;
   (b) the transfer stage inverting the top chuck such that the top wafer is inverted and under the top chuck;
   (c) the transfer stage moving the inverted top chuck and top wafer from the top wafer loading position to a wafer stacker;
   (d) the wafer stacker engaging the inverted top chuck and the transfer stage releasing the inverted top chuck;
   (e) a bottom chuck moving from the wafer stacker to a bottom wafer loading position;
   (f) positioning a bottom wafer on the bottom chuck;
   (g) the bottom chuck moving the bottom wafer from the bottom wafer loading position to the wafer stacker;
   (h) the transfer stage moving from the wafer stacker to the top wafer loading position; and
   (i) bonding the inverted top wafer with the bottom wafer.

10. The method of claim 9, wherein steps (c) and (e) occur concurrently.

11. The method of claim 9 or claim 10, wherein steps (g) and (h) occur concurrently.

12. The method of any one of claims 9 to 11, further comprising an alignment imaging sensor accurately aligning the inverted top wafer with the bottom wafer before step (i).

13. The method of any one of claims 9 to 12, wherein step (b) comprises rotating the top chuck relative to the transfer stage.

14. The method of any one of claims 9 to 13, wherein step (a) comprises a top wafer pre-position vision system at the top wafer loading position assisting a user to accurately position the top wafer on the top chuck.

15. The method of any one of claims 9 to 14, wherein step (a) comprises using vacuum suction to retain the top wafer on the top chuck.