

COATING METHOD

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a coating method of coating a face side of a wafer with a resin layer.

Description of the Related Art

For grinding a reverse side of a wafer that has a plurality of devices constructed on a face side thereof and a plurality of bumps in contact with the devices, it has been known to coat the face side of the wafer with a resin layer having such a thickness as to embed surface irregularities, for the purposes of preventing the surface irregularities due to the bumps, etc., on the face side from being transferred to the reverse side and reducing in-plane thickness variations of the wafer (see, for example, JP 2017-50536A). Specifically, after the face side of the wafer has been supplied with a liquid ultraviolet (UV)-curable resin, UV rays are applied to the wafer to cure the liquid UV-curable resin into a solid resin layer having a substantially flat outer surface that covers the face side of the wafer.

However, when the face side of the wafer is covered with the liquid resin, air bubbles tend to be trapped in

the liquid resin. If the liquid resin with air bubbles trapped therein is cured, then those bumps, devices, etc., that are positioned in the vicinity of the air bubbles are liable to be left unprotected and damaged due to pressure, impact, etc., exerted on the wafer when the wafer is ground. One known cause of air bubbles trapped in a liquid resin has been suggested to be a mechanism in which, when the supplied liquid resin is spread over the face side of the wafer, the liquid resin flows and separates into upper and lower two regions, producing air bubbles that are trapped in the liquid resin (see, for example, JP 2018-67586A).

According to JP 2018-67586A, it has been proposed to prevent air bubbles from being trapped in a liquid resin when the liquid resin is spread over a face side of the wafer, by keeping the face side of the wafer in contact with a dome of liquid resin placed on a table and bringing the wafer closer to the table while the wafer is repetitively moved toward and away from the table.

SUMMARY OF THE INVENTION

However, at the time at which the liquid resin is applied to the table or the wafer, air bubbles may have already been trapped in the liquid resin.

In view of the above-mentioned problem of the related art, it is an object of the present invention to provide a coating method of coating a face side of a wafer with a resin layer while eliminating air bubbles from a liquid resin after the liquid resin has been applied to the wafer but before the liquid resin is spread over the face side of the wafer.

In accordance with an aspect of the present invention, there is provided a coating method of coating a face side of a wafer with a solid resin layer. The coating method includes a holding step of holding, on a holding table, a reverse side of the wafer, the reverse side being opposite the face side of the wafer, an applying step, after the holding step, of applying a liquid resin to the face side of the wafer or a plate-shaped object, a heating step, after the applying step, of heating the liquid resin, and a pressing step, after the heating step, of pressing at least either the plate-shaped object or the wafer to affix the plate-shaped object and the wafer to each other with the liquid resin interposed therebetween. Air bubbles trapped in the liquid resin are ruptured in the heating step.

Preferably, the heating step includes a step of heating the liquid resin with hot air ejected thereto.

In accordance with another aspect of the present invention, there is provided a coating method of coating a face side of a wafer with a solid resin layer. The coating method includes a holding step of holding, on a holding table, a reverse side of the wafer, the reverse side being opposite the face side of the wafer, an applying step, after the holding step, of applying a liquid resin to the face side of the wafer or a plate-shaped object, an ultrasonic wave applying step, after the applying step, of applying ultrasonic waves to the liquid resin, and a pressing step, after the ultrasonic wave applying step, of pressing at least either the plate-shaped object or the wafer to affix the plate-shaped object and the wafer to each other with the liquid resin interposed therebetween. Air bubbles trapped in the liquid resin are ruptured in the ultrasonic wave applying step.

Preferably, the liquid resin is a UV-curable resin and the plate-shaped object is a transparent substrate that is transmissive of UV rays. The coating method further includes a UV radiating step, after the pressing step, of applying UV rays to the UV-curable resin through the plate-shaped object.

Preferably, the liquid resin is a thermosetting

resin. The coating method further includes a thermosetting step, after the pressing step, of heating the thermosetting resin to cure the thermosetting resin.

The coating methods according to the aspects of the present invention are able to eliminate air bubbles from a liquid resin by rupturing the air bubbles, even if the air bubbles are trapped in the liquid resin when the liquid resin is applied to the wafer.

The above and other objects, features and advantages of the present invention and the manner of realizing them will become more apparent, and the invention itself will best be understood from a study of the following description and appended claims with reference to the attached drawings showing some preferred embodiments of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a flowchart of the sequence of a coating method according to a first embodiment of the present invention;

FIG. 2 is a side elevational view, partly in cross section, illustrating a holding step of the coating method according to the first embodiment;

FIG. 3 is a side elevational view, partly in cross

section, illustrating an applying step of the coating method according to the first embodiment;

FIG. 4 is a side elevational view, partly in cross section, illustrating a heating step of the coating method according to the first embodiment;

FIG. 5 is a side elevational view, partly in cross section, illustrating a liquid resin, etc., having undergone the heating step;

FIG. 6 is a side elevational view, partly in cross section, illustrating a pressing step of the coating method according to the first embodiment;

FIG. 7 is a side elevational view, partly in cross section, illustrating a UV radiating step of the coating method according to the first embodiment;

FIG. 8A is a photographic representation of an image captured from above of the liquid resin that has not yet undergone the heating step;

FIG. 8B is a photographic representation of an image captured from above of the liquid resin that has undergone the heating step;

FIG. 9 is a side elevational view, partly in cross section, illustrating a holding step of a coating method according to a second embodiment of the present invention;

FIG. 10 is a side elevational view, partly in cross section, illustrating an applying step of the coating method according to the second embodiment;

FIG. 11 is a side elevational view, partly in cross section, illustrating a heating step of the coating method according to the second embodiment;

FIG. 12 is a side elevational view, partly in cross section, illustrating a liquid resin, etc., having undergone the heating step of the coating method according to the second embodiment;

FIG. 13 is a side elevational view, partly in cross section, illustrating a pressing step of the coating method according to the second embodiment;

FIG. 14 is a side elevational view, partly in cross section, illustrating a UV radiating step of the coating method according to the second embodiment;

FIG. 15 is a flowchart of the sequence of a coating method according to a third embodiment of the present invention;

FIG. 16 is a side elevational view, partly in cross section, illustrating a thermosetting step of the coating method according to the third embodiment;

FIG. 17 is a flowchart of the sequence of a coating method according to a fourth embodiment of the present

invention;

FIG. 18 is a side elevational view, partly in cross section, illustrating an ultrasonic wave applying step of the coating method according to the fourth embodiment of the present invention;

FIG. 19 is a side elevational view, partly in cross section, illustrating an ultrasonic wave applying step of a coating method according to a fifth embodiment of the present invention; and

FIG. 20 is a flowchart of the sequence of a coating method according to a sixth embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Preferred embodiments of the present invention will be described hereinbelow with reference to the accompanying drawings.

FIRST EMBODIMENT:

First, a coating method according to a first embodiment of the present invention will be described below with reference to FIGS. 1 through 8B. FIG. 1 is a flowchart of the sequence of the coating method according to the first embodiment. As illustrated in FIG. 1, the coating method according to the first embodiment includes

a holding step S10, an applying step S20, a heating step S30, a pressing step S40, and a UV radiating step S50. These steps are successively carried out in the order mentioned to cover a face side 11a (see FIG. 2) of a wafer 11 with a cured solid resin layer, i.e., a solid resin, 25 (see FIG. 7).

A processing apparatus 2 that is used to cover the face side 11a of the wafer 11 with the resin layer 25 will first be described below with reference to FIGS. 2 through 7. As illustrated in FIG. 2, the processing apparatus 2 has a disk-shaped chuck table, i.e., a disk-shaped holding table, 4. The chuck table 4 has a metal frame that is larger in diameter than the wafer 11. The frame has an unillustrated disk-shaped recess defined in an upper surface thereof. The chuck table 4 also has an unillustrated disk-shaped porous plate made of porous ceramic that is fixedly disposed in the recess in the frame. The frame also has a plurality of unillustrated radial slots defined in the bottom of the recess.

The slots are joined to an unillustrated through hole defined in the frame in such a manner as to extend vertically through the frame at a diametrically central position thereof. The through hole is fluidly connected to an unillustrated suction source such as an ejector.

When actuated, the suction source generates a vacuum or negative pressure that is transmitted through the through hole and the slots to the porous plate and also through the porous plate to the upper surface of the porous plate. The frame has an upper surface lying substantially flush with the upper surface of the porous plate. The upper surfaces of the frame and the porous plate jointly function as a holding surface 4a for holding the wafer 11 under suction thereon by the negative pressure transmitted to the upper surface of the porous plate. The holding surface 4a holds under suction thereon a reverse side 11b of the wafer 11, the reverse side 11b being positioned opposite the face side 11a of the wafer 11.

The wafer 11 includes a disk-shaped monocrystalline substrate 13 having a predetermined diameter of 12 inches or approximately 300 mm, for example. The monocrystalline substrate 13 is made of silicon, for example, though it may be made of other materials including silicon carbide (SiC), gallium nitride (GaN), etc. The monocrystalline substrate 13 has a face side corresponding to the face side 11a of the wafer 11 and a reverse side corresponding to the reverse side 11b of the wafer 11. A plurality of unillustrated projected dicing lines or streets are established in a grid pattern on the face side of the

monocrystalline substrate 13.

Devices such as integrated circuits (ICs) are constructed in respective rectangular areas demarcated on the face side of the monocrystalline substrate 13 by the streets. The devices are digital ICs such as logic ICs or memory ICs or analog ICs. According to the present invention, however, the devices are not limited to any particular types, and may be light emitting devices such as light emitting diodes (LEDs) or microelectromechanical systems (MEMS). One or a plurality of bumps 15 of gold (Au), solder, or the like are electrically connected to the devices. The bumps 15 and the devices provide surface irregularities of the face side 11a of the wafer 11.

A protective film 17 is provided on the face side 11a in conformity and intimate contact with the surface irregularities of the face side 11a. The protective film 17 serves to protect the bumps 15 and the devices against physical and/or chemical damage. The protective film 17 is made of resin and has a thickness ranging from 5 μm to 200 μm . However, the protective film 17 is not thick enough to embed the surface irregularities of the face side 11a therein. Therefore, the protective film 17 on the face side 11a is not effective to completely conceal the surface irregularities of the face side 11a.

The protective film 17 is of a layered structure having an adhesive layer and a base layer, for example. The adhesive layer of the protective film 17 is affixed to the face side 11a. The adhesive layer is made of acrylic resin or epoxy resin, for example, whereas the base layer is made of polyolefin, polyvinyl chloride, or the like. Alternatively, the protective film 17 may be devoid of an adhesive layer and include only a base layer. According to the alternative, the base layer is affixed to the face side 11a in intimate contact therewith. The protective film 17 is affixed to the face side 11a in intimate contact therewith by way of vacuum bonding, thermocompression bonding, pressure bonding, or the like.

The chuck table 4 is movable in horizontal directions perpendicular to Z-axis directions, e.g., vertical directions or upward and downward directions, by unillustrated X-axis and Y-axis moving mechanisms. When the chuck table 4 is positioned in a loading/unloading area A1, the wafer 11 is loaded onto or from the holding surface 4a. When the chuck table 4 is positioned in a coating/deaerating area A2 (see FIG. 3) different from the loading/unloading area A1, a coating/heating unit 6 is disposed directly above the holding surface 4a. The

coating/heating unit 6 has a dispenser, i.e., a constant liquid delivery device, 8 for applying a liquid resin 21 at a constant rate to the wafer 11 on the holding surface 4a.

The dispenser 8 is an air-pulse dispenser, for example. The dispenser 8 includes a syringe 10 containing the liquid resin 21 therein. The syringe 10 is connected to a controller 12 that controls the timing, rate, etc., of delivery of the liquid resin 21 from the syringe 10. The syringe 10 has a needle or a nozzle on a lower end portion thereof that is surrounded by an annular nozzle 14 disposed therearound. The annular nozzle 14 has an opening 14a defined therein that is directed downwardly as a ring-shaped slit extending through 360° in circumferential directions of the annular nozzle 14. Alternatively, the annular nozzle 14 may have a plurality of openings 14a angularly spaced at substantially equal intervals over 360° in circumferential directions of the annular nozzle 14.

The annular nozzle 14 is also connected to a hot air supply mechanism 16 including a heater, an electric motor, a fan, etc. When the hot air supply mechanism 16 is energized, it supplies hot air 14b (see FIG. 4) to the annular nozzle 14, which ejects the hot air 14b

downwardly through the opening 14a toward the wafer 11 on the chuck table 4. The annular nozzle 14 is combined with an unillustrated position adjusting mechanism that adjusts the position along the Z-axis directions of the annular nozzle 14. When the hot air 14b is to be ejected from the annular nozzle 14, the position adjusting mechanism adjusts the position along the Z-axis directions of the annular nozzle 14, i.e., the vertical position of the annular nozzle 14, in order to keep the opening 14a spaced from the face side 11a of the wafer 11 by a predetermined distance. The annular nozzle 14 and the hot air supply mechanism 16 jointly make up a heating unit 18 for heating the liquid resin 21 with the hot air 14b. The heating unit 18 heats the liquid resin 21 at a temperature low enough to keep the liquid resin 21 uncured.

When the chuck table 4 is positioned in an affixing area A3 (see FIG. 6) different from the loading/unloading area A1 and the coating/deaerating area A2, a pressing unit 20 is disposed above the chuck table 4 in the affixing area A3. The pressing unit 20 has a vertical arm 22 movable in the Z-axis directions. The arm 22 is combined with an unillustrated ball-screw-type Z-axis moving mechanism, for example, that adjusts the position

along the Z-axis directions of the arm 22. A disk-shaped suction disk 24 is fixed to the lower end of the arm 22.

The suction disk 24 is of a structure that is substantially identical to that of the chuck table 4, and includes a frame and a porous plate. A vacuum or negative pressure can be transmitted from an unillustrated suction source to the porous plate. The suction disk 24 has a lower surface 24a functioning as a holding surface for holding under suction a disk-shaped carrier substrate 23 as a plate-shaped object. The carrier substrate 23 is substantially equal in diameter to the wafer 11, for example, though it may be larger in diameter than the wafer 11. The carrier substrate 23 has a thickness in the range of 500 μm to 1000 μm , for example.

The carrier substrate 23 is a transparent substrate that is transmissive of light in the UV band and the visible light band. Specifically, the carrier substrate 23 may be a glass substrate made of alkali-free glass, quartz glass, or the like, a transparent resin substrate made of acrylic resin or the like, a monocrystalline sapphire substrate, or the like. The carrier substrate 23 held under suction on the lower surface 24a of the suction disk 24 is transferred to the wafer 11 held on the holding surface 4a under suction. Thereafter, the

chuck table 4 is moved horizontally to a UV applying area A4 (see FIG. 7) different from the loading/unloading area A1, the coating/deaerating area A2, and the affixing area A3. A lamp unit 26 is disposed above the chuck table 4 in the UV applying area A4. The lamp unit 26 includes a plurality of UV lamps 26a for radiating UV rays. The UV lamps 26a are mercury discharge lamps, metal halide lamps, or the like.

The coating method according to the first embodiment by which the face side 11a of the wafer 11 is covered with the resin layer 25 with use of the processing apparatus 2 will be described below. FIG. 2 illustrates the holding step S10 in side elevation, partly in cross section. In the holding step S10, the reverse side 11b of the wafer 11 is held under suction on the holding surface 4a of the chuck table 4 positioned in the loading/unloading area A1. After the holding step S10, the chuck table 4 is moved to the coating/deaerating area A2. At this time, the chuck table 4 is positionally adjusted to position the center of the face side 11a of the wafer 11 directly below the syringe 10 (see FIG. 3).

Then, the controller 12 is energized to control the syringe 10 to discharge a predetermined amount of liquid resin 21 onto the face side 11a of the wafer 11. For

example, if the wafer 11 is to be thinned down to a thickness of 165 μm by way of grinding, then the face side 11a is coated with 15 ml of liquid resin 21, depending on the thickness of the resin layer 25 to coat the face side 11a. FIG. 3 illustrates in side elevation, partly in cross section, the applying step S20 of applying the liquid resin 21 to a central region of the face side 11a. According to the first embodiment, the liquid resin 21 is a UV-curable resin that can be cured upon exposure to UV rays. The UV-curable resin may be ResiFlat (registered trademark) manufactured and sold by DISCO Corporation, TEMPLOC (registered trademark) manufactured and sold by Denka Company Limited, or other commercially available UV-curable resins.

The applied liquid resin 21 is deposited as a dome in the central region of the face side 11a. The applied liquid resin 21 contains air bubbles 21a of air or the like as an atmospheric gas trapped by sucking back, etc., of the dispenser 8. According to the first embodiment, after the applying step S20, the heating unit 18 is energized to heat the liquid resin 21 to rupture the air bubbles 21a, thereby removing the air bubbles 21a from the liquid resin 21 (heating step S30).

FIG. 4 illustrates the heating step S30 in side

elevation, partly in cross section. In the heating step S30, the liquid resin 21 is heated to a temperature ranging from 80°C to 200°C, preferably from 90°C to 150°C, or more preferably from 100°C to 120°C. The lower limit of temperatures at which to heat the liquid resin 21 is determined on the basis of the ratings of the heater of the hot air supply mechanism 16, the degree of expansion of the air bubbles 21a, etc., for example. The upper limit of temperatures at which to heat the liquid resin 21 is determined in view of reduction of damage to the devices on the wafer 11, for example.

According to the first embodiment, the distance from the annular nozzle 14 to the liquid resin 21 is adjusted to approximately 50 mm, and the hot air 14b at a temperature of approximately 100°C is ejected to the liquid resin 21 at a speed of 1.5m/s for approximately five seconds, thereby heating the liquid resin 21 to approximately 100°C. The speed at which the hot air 14b is ejected is not limited to 1.5m/s, and may be of a predetermined value in the range of 1.0 m/s to 2.0 m/s. The air bubbles 21a in the heated liquid resin 21 are expanded and finally ruptured and eliminated when they reach a gas-liquid interface between the liquid resin 21 and the atmospheric gas. According to the first

embodiment, in particular, the hot air 14b is uniformly ejected downwardly from the ring-shaped opening 14a. The ejected hot air 14b is able to impart impact, vibrations, etc., to the liquid resin 21.

By contrast, if the liquid resin 21 is supplied with heat by electromagnetic waves, i.e., by way of heat radiation, or if the liquid resin 21 is supplied with heat from a heater in the chuck table 4 through the wafer 11 by way of heat conduction, then it is difficult to impart as much impact, vibrations, etc., to the liquid resin 21 as with the hot air 14b. According to the first embodiment, the hot air 14b is used to impart impact, vibrations, etc., in addition to heat, to the liquid resin 21 for thereby efficiently moving the air bubbles 21a to the gas-liquid interface and rupturing the air bubbles 21a, compared with heating the liquid resin 21 by way of heat radiation or heat conduction. FIG. 5 illustrates the liquid resin 21, etc., having undergone the heating step S30, in side elevation, partly in cross section.

After the heating step S30, the chuck table 4 is moved to the affixing area A3, as illustrated in FIG. 6, where the center of the face side 11a of the wafer 11 on the chuck table 4 and the center of a surface 23a of the

carrier substrate 23 are substantially aligned with each other. Another surface 23b, opposite the surface 23a, of the carrier substrate 23, is held under suction on the suction disk 24. The arm 22 is moved downwardly while the surface 23a of the carrier substrate 23 is facing downwardly. According to the first embodiment, the chuck table 4 is held at rest against movement along the Z-axis directions, and the suction disk 24 is lowered to press the carrier substrate 23 against the wafer 11 (pressing step S40). FIG. 6 illustrates the pressing step S40 in side elevation, partly in cross section.

In the pressing step S40, the liquid resin 21 is pressed by the carrier substrate 23 and spread fully over the face side 11a of the wafer 11. The distance that the carrier substrate 23 is pressed downwardly is adjusted to flatten the liquid resin 21 to a predetermined thickness 21b. In this manner, the wafer 11 and the carrier substrate 23 are affixed to each other with the protective film 17 and the liquid resin 21 interposed therebetween. Providing the chuck table 4 is combined with an unillustrated lifting/lowering mechanism, the suction disk 24 may be held at rest, and the chuck table 4 may be lifted to press the wafer 11 against the carrier substrate 23. Alternatively, the suction disk 24 may be

lowered and the chuck table 4 may be lifted to press the wafer 11 and the carrier substrate 23 against each other. In other words, at least either the carrier substrate 23 or the wafer 11 may be pressed against the other.

After the pressing step S40, the chuck table 4 is moved to the UV applying area A4, as illustrated in FIG. 7, where the carrier substrate 23 is positioned below the lamp unit 26 in facing relation thereto. Then, the lamp unit 26 applies UV rays to the liquid resin 21 through the carrier substrate 23 (UV radiating step S50). FIG. 7 illustrates the UV radiating step S50 in side elevation, partly in cross section. In the UV radiating step S50, the lamp unit 26 applies UV rays to the liquid resin 21 at an intensity level of 50 mW/cm^2 for 12 seconds, for example. The liquid resin 21 thus irradiated with the UV rays is cured into a solid resin layer 25.

According to the first embodiment, even though the air bubbles 21a are trapped in the liquid resin 21 when the liquid resin 21 is applied to the wafer 11, the air bubbles 21a are ruptured and eliminated in the heating step S30. Therefore, the possibility that the bumps 15, the devices, etc., on the wafer 11 will be damaged when the reverse side 11b of the wafer 11 is ground is smaller than if the heating step S30 is not carried out.

An experimental example in which the air bubbles 21a are eliminated by ejection of the hot air 14b to the liquid resin 21 will be described below with reference to FIGS. 8A and 8B. FIG. 8A is a photographic representation of an image captured from above of the liquid resin 21 that has not yet undergone the heating step S30, and FIG. 8B is a photographic representation of an image captured from above of the liquid resin 21 that has undergone the heating step S30.

In the experimental example, the protective film 17 on the face side 11a of the wafer 11 was coated with 15 ml of liquid resin 21 by the dispenser 8. The applied liquid resin 21 contained many air bubbles 21a, as illustrated in FIG. 8A. Then, the annular nozzle 14 was positioned at a distance of approximately 50 mm from the liquid resin 21 that contained the air bubbles 21a, and ejected the hot air 14b at the temperature of approximately 100°C to the liquid resin 21 for approximately five seconds. As a result, the air bubbles 21a in the liquid resin 21 were eliminated, as illustrated in FIG. 8B.

SECOND EMBODIMENT:

A coating method according to a second embodiment of the present invention will be described below with

reference to FIGS. 9 through 14. According to the second embodiment, steps of the coating method are successively carried out in the sequence illustrated in FIG. 1. However, the second embodiment is different from the first embodiment in that the wafer 11 and the carrier substrate 23 are inverted vertically, i.e., turned upside down. According to the second embodiment, as illustrated in FIG. 9, the reverse side 11b of the wafer 11 is held under suction on the lower surface, i.e., the holding surface, 24a of the suction disk, i.e., a holding table, 24 disposed in the affixing area A3 (holding step S10). FIG. 9 illustrates the holding step S10 according to the second embodiment in side elevation, partly in cross section.

After the holding step S10, as illustrated in FIG. 10, a transparent table 28 disposed in the coating/deaerating area A2 supports, on an upper surface 28a thereof, the other surface 23b of the carrier substrate 23. As with the chuck table 4 according to the first embodiment, the transparent table 28 is movable in horizontal directions perpendicular to the Z-axis directions by unillustrated X-axis and Y-axis moving mechanisms. The transparent table 28 has a plurality of unillustrated protrusions on its upper surface 28a, the

protrusions preventing the carrier substrate 23 placed thereon from being shifted in position.

The protrusions on the upper surface 28a of the transparent table 28 abut against an outer circumferential edge of the carrier substrate 23, securing the carrier substrate 23 in position on the upper surface 28a. Alternatively, the transparent table 28 may be free of the protrusions, and the carrier substrate 23 may be held under suction on the transparent table 28 by a negative pressure, or may be combined with clamps for gripping an outer circumferential edge portion of the carrier substrate 23 to keep the carrier substrate 23 securely positioned on the transparent table 28. The transparent table 28 includes a transparent base plate that is transmissive of light in the UV band and the visible light band, as with the carrier substrate 23. The surface 23a of the carrier substrate 23 securely positioned on the upper surface 28a of the transparent table 28 is coated with the liquid resin 21 (applying step S20).

FIG. 10 illustrates the applying step S20 according to the second embodiment in side elevation, partly in cross section. The amount of applied liquid resin 21 according to the second embodiment is the same as the

amount of applied liquid resin 21 according to the first embodiment. After the applying step S20, the annular nozzle 14 ejects the hot air 14b to the liquid resin 21, heating the liquid resin 21 (heating step S30). FIG. 11 illustrates the heating step S30 according to the second embodiment in side elevation, partly in cross section. In the heating step S30, the liquid resin 21 is heated to rupture and eliminate the air bubbles 21a, as described above. FIG. 12 illustrates in cross section the liquid resin 21, etc., having undergone the heating step S30 according to the second embodiment.

After the heating step S30, the transparent table 28 is moved to the affixing area A3. Then, the suction disk 24 is lowered to press the wafer 11 against the carrier substrate 23 (pressing step S40). FIG. 13 illustrates the pressing step S40 according to the second embodiment in side elevation, partly in cross section.

Providing the transparent table 28 is combined with an unillustrated lifting/lowering mechanism, the suction disk 24 may be held at rest, and the transparent table 28 may be lifted to press the carrier substrate 23 against the wafer 11. Alternatively, the suction disk 24 may be lowered and the transparent table 28 may be lifted to press the wafer 11 and the carrier substrate 23 against

each other. In other words, at least either the wafer 11 or the carrier substrate 23 may be pressed against the other.

After the pressing step S40, the transparent table 28 is moved to the UV applying area A4. Then, the lamp unit 26 applies UV rays to the liquid resin 21 through the transparent table 28 and the carrier substrate 23 (UV radiating step S50). In the UV radiating step S50, the liquid resin 21 thus irradiated with the UV rays is cured into a solid resin layer 25. FIG. 14 illustrates the UV radiating step S50 according to the second embodiment in side elevation, partly in cross section. According to the second embodiment, the air bubbles 21a are also ruptured and eliminated in the heating step S30.

THIRD EMBODIMENT:

A coating method according to a third embodiment of the present invention will be described below with reference to FIGS. 15 and 16. FIG. 15 is a flowchart of the sequence of the coating method according to the third embodiment. The third embodiment is different from the first and second embodiments in that a thermosetting resin is used instead of the UV-curable resin as the liquid resin 21. The third embodiment will be described below with reference to FIGS. 2 through 6. After the

holding step S10 (see FIG. 2), the face side 11a of the wafer 11 is coated with the liquid resin 21 in the form of a thermosetting resin in the applying step S20 (see FIG. 3).

In the heating step S30 (see FIG. 4), the liquid resin 21 is heated to a predetermined temperature low enough to keep the liquid resin 21 uncured. For example, the thermosetting resin contains an epoxy resin and a curing agent, and is cured at a predetermined temperature of 200°C, for example, in a temperature range of 150°C or higher. In the heating step S30 according to the third embodiment, the liquid resin 21 is heated to a temperature ranging from 80°C to lower than 150°C, preferably from 90°C to 130°C, or more preferably from 100°C to 110°C such that the liquid resin 21 will not be cured.

The lower limit of temperatures at which to heat the liquid resin 21 is determined in the same manner as with the first embodiment. The upper limit of temperatures at which to heat the liquid resin 21 is determined in view of not curing the thermosetting resin, in addition to reduction of damage to the devices on the wafer 11. In the heating step S30 according to the third embodiment, the distance from the annular nozzle 14 to

the liquid resin 21 is adjusted to approximately 50 mm, and the hot air 14b at a temperature of approximately 100°C is ejected to the liquid resin 21 for approximately five seconds, thereby heating the liquid resin 21 to approximately 100°C. The air bubbles 21a in the heated liquid resin 21 are expanded and finally ruptured and eliminated (see FIGS. 4 and 5). In the pressing step S40 (see FIG. 6), the chuck table 4 is held at rest against movement along the Z-axis directions, and the suction disk 24 is lowered to press the carrier substrate 23 against the wafer 11. Alternatively, at least either the carrier substrate 23 or the wafer 11 may be pressed.

According to the third embodiment, since the liquid resin 21 is cured by heat instead of UV rays, the carrier substrate 23 may not essentially be transmissive to light such as UV rays. For example, the carrier substrate 23 is made of a material whose coefficient of linear expansion is substantially the same as that of the wafer 11. Specifically, if the wafer 11 includes a monocrystalline silicon substrate, then the carrier substrate 23 is made of alumina (Al_2O_3), aluminum nitride (AlN), silicon nitride (Si_3N_4), SiC, or the like.

As the coefficients of linear thermal expansion of the wafer 11 and the carrier substrate 23 are

substantially equal to each other, the amount of warpage that may occur, in a stacked assembly including the carrier substrate 23, the wafer 11, etc., due to the heat applied to cure the liquid resin 21 is reduced. After the pressing step S40, the liquid resin 21, i.e., the thermosetting resin, is cured by being heated (thermosetting step S55). In the thermosetting step S55, the liquid resin 21 is cured by being heated to a predetermined temperature equal to or higher than 150°C.

FIG. 16 illustrates the thermosetting step S55 according to the third embodiment in side elevation, partly in cross section. In the thermosetting step S55, the chuck table 4 is moved to a thermosetting area A5 different from the loading/unloading area A1, the coating/deaerating area A2, and the affixing area A3. A disk-shaped heater unit 30 is disposed above the chuck table 4 positioned in the thermosetting area A5. The heater unit 30 is combined with an unillustrated ball-screw-type Z-axis moving mechanism that is similar to the ball-screw-type Z-axis moving mechanism incorporated in the pressing unit 20 according to the first embodiment.

The heater unit 30 includes a plurality of ring-shaped resistive heating bodies 32 disposed concentrically with each other. The resistive heating

bodies 32 are covered with an insulating casing 34, making up a disk-shaped heating device. The heater unit 30 also includes a disk-shaped frame 36 made of metal. The frame 36 has a disk-shaped cavity defined in its bottom, and the disk-shaped heating device is housed in the disk-shaped cavity. The heater unit 30 may have a temperature measuring mechanism, a cooling mechanism, etc. When the heater device is heated to 200°C, for example, with the heater unit 30 having a lower surface held in contact with the carrier substrate 23, the heat, denoted by 32a, is transferred from the heater device through the carrier substrate 23 to the liquid resin 21, heating the liquid resin 21 to 200°C to cure the liquid resin 21.

According to the third embodiment, since the heat 32a is transferred from the heater device through the carrier substrate 23 to the liquid resin 21, any thermal damage to the bumps 15, the devices, etc., on the wafer 11 is smaller than if a heater in the chuck table 4 heats the liquid resin 21 through the wafer 11. According to the third embodiment, as with the second embodiment, the surface 23a of the carrier substrate 23 may be coated with the liquid resin 21, i.e., the thermosetting resin. However, inasmuch as no UV rays are applied in such a

modification, the carrier substrate 23 is held under suction on the holding surface 4a of the chuck table 4 instead of the transparent table 28.

FOURTH EMBODIMENT:

A coating method according to a fourth embodiment of the present invention will be described below with reference to FIGS. 17 and 18. FIG. 17 is a flowchart of the sequence of the coating method according to the fourth embodiment. The fourth embodiment is different from the above embodiments in that, after an applying step S20, ultrasonic waves, instead of the hot air 14b, are applied to the liquid resin 21 in an ultrasonic wave applying step S35. A holding step S10 and the applying step S20 according to the fourth embodiment are identical to those according to the first embodiment, and hence will be omitted from description and illustration. The ultrasonic wave applying step S35 according to the fourth embodiment is carried out by an ultrasonic wave applying unit 40 illustrated in FIG. 18. The ultrasonic wave applying unit 40 is disposed in a position out of physical interference with the dispenser 8 in the coating/deaerating area A2, for example.

The ultrasonic wave applying unit 40 is movable along the Z-axis directions by an unillustrated ball-

screw-type Z-axis moving mechanism. The ultrasonic wave applying unit 40 has an unillustrated ultrasonic vibrator that converts electric power applied thereto into ultrasonic vibrations. The ultrasonic vibrator is made of a material containing lead zirconate titanate, for example. A horn 42 functioning as a resonator is mounted on the ultrasonic vibrator. The ultrasonic wave applying unit 40 also includes a nozzle 46 disposed near the horn 42, the nozzle 46 supplying liquid 44 such as pure water that functions as an acoustic matching layer between the liquid resin 21 and the horn 42.

FIG. 18 illustrates the ultrasonic wave applying step S35 according to the fourth embodiment in side elevation, partly in cross section. In the ultrasonic wave applying step S35, the liquid 44 is supplied at a predetermined rate onto the liquid resin 21, covering the liquid resin 21 with the liquid 44. The ultrasonic vibrator applies ultrasonic waves having a predetermined frequency equal to or higher than 20 kHz from the horn 42 through the liquid 44 to the liquid resin 21.

When the ultrasonic waves are applied to the liquid resin 21, the air bubbles 21a in the liquid resin 21 are vibrated, and adjacent ones of the air bubbles 21a are joined together, producing air bubbles 21a having larger

volumes. The larger-volume air bubbles 21a move toward and reach the interface between the liquid resin 21 and the liquid 44, and are ruptured. The gas released from the ruptured air bubbles 21a is carried and removed by the liquid 44 that flows off the wafer 11. A pressing step S40 and a UV radiating step S50 according to the fourth embodiment are identical to those according to the first embodiment, and hence will be omitted from description and illustration. The ultrasonic wave applying step S35 may be included in the coating method according to the second embodiment (see FIG. 19).

FIFTH EMBODIMENT:

FIG. 19 illustrates an ultrasonic wave applying step S35 according to a fifth embodiment of the present invention. According to the fifth embodiment, ultrasonic waves are applied from the horn 42 through the liquid 44 to the liquid resin 21 on the carrier substrate 23, rupturing and eliminating the air bubbles 21a trapped in the liquid resin 21.

SIXTH EMBODIMENT:

The ultrasonic wave applying step S35 may be included in the coating method according to the third embodiment (see FIGS. 15 and 16) that uses the liquid resin 21, i.e., the thermosetting resin, as illustrated

in FIG. 20. FIG. 20 is a flowchart of the sequence of a coating method according to a sixth embodiment of the present invention. According to the sixth embodiment, even though the air bubbles 21a are trapped in the liquid resin 21 when the liquid resin 21 is applied to the wafer 11, the air bubbles 21a are ruptured and eliminated in the ultrasonic wave applying step S35. Similarly, the ultrasonic wave applying step S35 may be carried out when the surface 23a of the carrier substrate 23 is coated with the liquid resin 21, i.e., the thermosetting resin.

The structures, methods, etc., according to the above embodiments may be changed or modified without departing from the scope of the present invention. In the pressing step S40, the face side 11a of the wafer 11 may be kept in contact with the liquid resin 21, and the carrier substrate 23 and the wafer 11 may be repetitively moved toward and away from each other in a plurality of cycles in a process of being brought closer to each other until the liquid resin 21 is flattened to the predetermined thickness 21b.

The present invention is not limited to the details of the above described preferred embodiments. The scope of the invention is defined by the appended claims and all changes and modifications as fall within the

equivalence of the scope of the claims are therefore to be embraced by the invention.

WHAT IS CLAIMED IS:

1. A coating method of coating a face side of a wafer with a solid resin layer, the coating method comprising:

a holding step of holding, on a holding table, a reverse side of the wafer, the reverse side being opposite the face side of the wafer;

an applying step, after the holding step, of applying a liquid resin to the face side of the wafer or a plate-shaped object;

a heating step, after the applying step, of heating the liquid resin; and

a pressing step, after the heating step, of pressing at least either the plate-shaped object or the wafer to affix the plate-shaped object and the wafer to each other with the liquid resin interposed therebetween,

wherein air bubbles trapped in the liquid resin are ruptured in the heating step.

2. The coating method according to claim 1, wherein the heating step includes a step of heating the liquid resin with hot air ejected thereto.

3. A coating method of coating a face side of a wafer with a solid resin layer, the coating method comprising:

a holding step of holding, on a holding table, a reverse side of the wafer, the reverse side being opposite the face side of the wafer;

an applying step, after the holding step, of applying a liquid resin to the face side of the wafer or a plate-shaped object;

an ultrasonic wave applying step, after the applying step, of applying ultrasonic waves to the liquid resin; and

a pressing step, after the ultrasonic wave applying step, of pressing at least either the plate-shaped object or the wafer to affix the plate-shaped object and the wafer to each other with the liquid resin interposed therebetween,

wherein air bubbles trapped in the liquid resin are ruptured in the ultrasonic wave applying step.

4. The coating method according to any one of claims 1 through 3,

wherein the liquid resin is an ultraviolet-curable resin,

the plate-shaped object is a transparent substrate that is transmissive of ultraviolet rays, and

the coating method further includes an ultraviolet radiating step, after the pressing step, of applying

ultraviolet rays to the ultraviolet-curable resin through the plate-shaped object.

5. The coating method according to any one of claims 1 through 3,

wherein the liquid resin is a thermosetting resin,
and

the coating method further includes a thermosetting step, after the pressing step, of heating the thermosetting resin to cure the thermosetting resin.