

APPARATUS FOR PROCESSING A WAFER-SHAPED ARTICLE AND GRIPPING PIN

Field of the Invention

The present invention relates to an apparatus for processing a wafer-shaped article, such as a
5 semiconductor wafer, and to a gripping pin suitable for use in such an apparatus.

Background

Wafers such as semiconductor wafers may be subjected to various surface treatment processes, such as
etching, cleaning, polishing and material deposition. A wafer is typically held using a chuck while
10 undergoing such surface treatment processes.

At least some of these surface treatment processes involve applying a liquid to a surface of the wafer.
For example, the surface of the wafer may be etched by applying an etching liquid such as hydrofluoric
acid to one or more locations on the surface of the wafer, so as to remove material from the surface of the
wafer. This may be referred to as wet etching of the wafer. Alternatively, the surface of the wafer may be
15 cleaned by applying a cleaning liquid or rinse liquid such as isopropyl alcohol or de-ionised water to the
surface of the wafer, for example so that one or more impurities are thereby carried off the surface of the
wafer. This may be referred to as wet cleaning of the wafer. Etching or cleaning the wafer are both
examples of processing the wafer.

The wafer may be spun while the liquid is applied to the surface of the wafer, for example using a
20 rotatable chuck (a spin chuck), to assist distribution of the liquid over the surface of the wafer and so that
the liquid is subsequently discharged from a peripheral edge of the wafer for recycling or disposal.

Existing apparatuses for processing a wafer are disclosed in US2010200163A1, US2010206481A1,
US2012298149A1, US2014097580A1, and US2017323823A1 for example, which are incorporated
herein by reference.

25 FIGS. 1 to 7 are schematic illustrations of an apparatus for processing a wafer previously used by the
inventors.

As illustrated in FIGS. 1 to 7, the apparatus 1 for processing a wafer comprises a rotary chuck 3 (or spin
chuck) for holding and rotating the wafer. The rotary chuck 3 is configured to hold the wafer in a
substantially horizontal orientation.

30 As illustrated in FIGS. 1 to 7, the rotary chuck 3 comprises a plurality of rotatable gripping pins 5. Eight
rotatable gripping pins 5 are illustrated in FIGS. 2 and 3, but of course the number can be different than
this, for example greater than or equal to three. The rotatable gripping pins 5 are configured to grip a
peripheral edge (circumferential edge) of a wafer W therebetween, for example so as to prevent the wafer
W from sliding laterally off the rotary chuck 3 when the rotary chuck 3 is rotated, and/or so that the wafer
35 W is securely rotated together with the rotary chuck 3 when the rotary chuck 3 is rotated.

In addition, the rotatable gripping pins 5 may also be configured to support a lower surface of the wafer W from beneath so that the lower surface of the wafer W is spaced apart from an upper surface of the rotary chuck 3. Alternatively, or in addition, the wafer W may be held spaced apart from the upper surface of the rotary chuck 3 by gas emitted from a plurality of holes in the upper surface of the rotary chuck 3 according to the Bernoulli principle. Such so called Bernoulli chucks are known in the art.

Supporting the wafer W spaced apart from the upper surface of the rotary chuck 3 may reduce transfer of contaminants from the upper surface of the rotary chuck 3 to the lower surface of the wafer W, for example. It may also enable dispensing of liquid onto the lower surface of the wafer W in some configurations, for example.

10 In more detail, the spin chuck 3 comprises a circular series of the rotatable gripping pins 5 that are provided in the rotary chuck 3 so as to surround a peripheral edge (circumferential edge) of the wafer W received by the rotary chuck 3.

Each of the rotatable gripping pins 5 protrudes from a respective hole in the upper surface of the rotary chuck 3. For example, each of the rotatable gripping pins 5 may protrude through a respective hole 15 formed in a chuck cover of the rotary chuck 3 that is mounted to a base body of the rotary chuck 3.

As illustrated in FIG. 5, each of the rotatable gripping pins 5 comprises a cylindrical body 7 and a projecting gripping portion 9. The projecting gripping portion 9 is formed integrally with the cylindrical body 7. The projecting gripping portion 9 protrudes from a distal end (top end) of the rotatable gripping pin 5.

20 The projecting gripping portion 9 is substantially circularly symmetric and has a substantially cylindrical and/or cone shape.

The projecting gripping portion 9 is off-centre relative to a longitudinal axis of the cylindrical body 7. In other words, the projecting gripping portion 9 is eccentric relative to the longitudinal axis of the cylindrical body 7. Rotation of the rotatable gripping pin 5 around its longitudinal axis therefore causes the 25 projecting gripping portion 9 to move closer to, or further away from, a centre of the top surface of the rotary chuck 3. Therefore, by rotating the plurality of rotatable gripping pins 5 in synchronisation, the rotatable gripping pins 5 can be caused to grip the peripheral edge of the wafer W therebetween by the projecting gripping portions 9 coming into contact with the peripheral edge of the wafer W. In particular, rotation of the rotatable gripping pins 5 causes the projecting gripping portions 9 to move between more 30 radially outer open (non-gripping) positions and more radially inner closed (gripping) positions.

FIG. 3 illustrates the apparatus 1 with the rotatable gripping pins 5 each rotated in synchronisation so that the projecting gripping portions 9 are in the open (non-gripping) positions. In this configuration, each of the projecting gripping portions 9 is at an outermost position in the radial direction. This configuration is also illustrated in FIG. 6A for a single rotatable gripping pin 5 showing the relationship between the 35 projecting gripping portion 9 and the peripheral edge of the wafer W. In particular, in this configuration the projecting gripping portions 9 are spaced apart from a peripheral edge of the wafer W. This configuration is also illustrated in FIG. 1.

In contrast, FIG. 4 illustrates the apparatus 1 with the rotatable gripping pins 5 each rotated in synchronisation so that the projecting gripping portions 9 are in the closed (gripping) positions. In this configuration, each of the projecting gripping portions 9 is more radially inwards than in the open (non-gripping) configuration. FIG. 4 further illustrates a wafer W positioned between the rotatable gripping pins 5 with the peripheral edge of the wafer W contacted by each of the projecting gripping portions 9 so that the wafer W is held between the projecting gripping portions 9. This configuration is also illustrated in FIG. 6B for a single rotatable gripping pin 5 showing the relationship between the projecting gripping portion 9 and the peripheral edge of the wafer W. In particular, relative to FIG. 6A, the rotatable gripping pin 5 has been rotated in the anticlockwise (counter-clockwise) direction until the projecting gripping portion 9 is in contact with the peripheral edge of the wafer W. This configuration is also illustrated in FIG. 2.

Typically the rotary chuck 3 and the gripping pins 5 are configured to hold and rotate a wafer with a predetermined diameter, typically 300 mm. Therefore, the gripping pins 5 may be configured to grip a wafer having a diameter of 300 mm in the closed (gripping) positions.

As shown in FIG. 5, the projecting gripping portion 9 comprises a circumferential groove 11 (or lateral recess or cut out) that is designed to accommodate the peripheral edge of the wafer W, so that the peripheral edge of the wafer W is supported from underneath by a lower surface of the groove (or lateral recess or cut-out). Therefore, the wafer W can be supported by the rotatable gripping pins 5 with the lower surface of the wafer W spaced apart from the upper surface of the rotary chuck 3. The groove 11 may be dimensioned to receive and engage a peripheral edge of a wafer having a thickness greater than or equal to 500 μm and less than or equal to 1000 μm , for example.

As shown in FIG. 5, the rotatable gripping pin 5 further comprises a gear 15 at a bottom or lower end (proximal end) of the cylindrical body 7. This gear 15 is positioned inside the rotary chuck 3 when the rotatable gripping pin 5 is mounted in the rotary chuck 3.

As shown in FIGS. 1 and 2, the rotatable gripping pins 5 are rotatable in synchronisation by a ring gear 13 of the rotary chuck 3 housed inside the rotary chuck 3, for example in a space formed between the base body and chuck cover of the rotary chuck 3. The ring gear 13 is simultaneously in meshing engagement with the gears 15 of the rotatable gripping pins 5. The ring gear 13 is rotatably mounted in the rotary chuck 3 via one or more bearings 17 and may be driven to rotate relative to the rotary chuck 3 via an electric motor of the apparatus 1, for example. FIG. 2 shows an arrangement where the rotatable gripping pins 5 have been rotated in synchronisation relative to FIG. 1.

Although not shown in the figures, the rotary chuck 3 may be surrounded by a process chamber, which may be a multi-level process chamber. The spin chuck can be positioned at a selected level by moving the spin chuck axially relative to the stationary surrounding chamber or by moving the surrounding chamber axially relative to the axially-stationary spin chuck.

The rotary chuck 3 is mounted to a rotor 19 of a hollow shaft motor of the apparatus 1. The rotor 19 is illustrated schematically as a block in FIGS. 1 and 2. In practice, the rotor 19 may comprise a rotatable

hollow shaft and the rotary chuck 3 may be mounted on a rotatable support plate that is connected to an end of the rotatable hollow shaft. The rotary chuck 3 is therefore rotatable by the rotor 19 of the hollow-shaft motor.

5 A stator of the hollow-shaft motor is mounted to a mounting plate 21 of the apparatus. The stator and the mounting plate 21 are illustrated schematically as a block in FIGS. 1 and 2. The mounting plate 21 is mounted to a non-rotating (stationary) frame of the apparatus 1. The rotary chuck 3 is therefore rotatable relative to the mounting plate 21 which does not rotate.

10 In addition, the apparatus 1 further comprises a liquid dispenser 23 that is configured to dispense liquid onto an upper surface of the wafer W received by the rotary chuck 3 (a surface of the wafer W that faces away from the rotary chuck 3). The liquid dispenser 23 may comprise one or more dispensing nozzles arranged on a dispensing arm, wherein the dispensing arm is pivotable so as to move the one or more dispensing nozzles over the upper surface of the wafer W, for example.

15 The present inventors have realised that the arrangement illustrated in FIGS. 1 to 7, while appropriate for many circumstances, may lead to splashing of the liquid being dispensed on the upper surface of the wafer onto surrounding surfaces of the apparatus in some circumstances. Such splashing may be undesirable for various reasons, for example because it may cause contamination of subsequent different liquids used in the apparatus, and/or because it may require cleaning before the apparatus can be used again, and/or for safety reasons.

20 In particular, it is a problem if such splashes are splashed back onto the wafer, in particular if the inner part of the wafer is already dry. Such back splashing fine droplets can create defects on the wafer surface that may render the wafer defective and/or unusable.

25 In particular, the present inventors have discovered that such splashing may occur when a liquid flow formed on the upper surface of the wafer W when liquid is dispensed on the upper surface of the wafer W while the wafer W is being rotated impacts the projecting gripping portions 9 of the rotatable gripping pins 5. In particular, when this liquid impacts the cylindrical/cone shaped projecting gripping portions 9, some of the liquid is splashed upwards by the projecting gripping portions 9.

30 FIG. 7 illustrates a direction of travel 25 of a liquid flow formed on the upper surface of the wafer W when liquid is dispensed on the upper surface of the wafer W from the liquid dispenser 23 while the wafer W is rotated in the anti-clockwise (counter-clockwise) direction as indicated by the arrow in FIG. 7. When this liquid flow impacts the projecting gripping portion 9 of the rotatable gripping pin 5, the shape and/or configuration of the projecting gripping portion causes splashing of the liquid. For example, such splashing may occur when a front or edge of the liquid flow impacts the protecting gripping portion 9.

The present invention has been devised in light of the above considerations.

Summary of the Invention

According to a first aspect of the present invention there is provided an apparatus for processing a wafer-shaped article, comprising: a rotary chuck having a plurality of gripping pins adapted to hold a wafer-shaped article on the rotary chuck, wherein each of the plurality of gripping pins comprises a cylindrical
5 body and a projecting gripping portion, wherein the projecting gripping portion comprises a first face configured to contact the wafer-shaped article and a second face, and wherein an angle of greater than or equal to 10 degrees and less than or equal to 70 degrees is formed between the first face and the second face at an edge of the projecting gripping portion.

Therefore, in the present invention an angle of greater than or equal to 10 degrees and less than or equal
10 to 70 degrees is formed between the first face of the projecting gripping portion that contacts the wafer-shaped article and the second face at an edge of the projecting gripping portion. This means that the edge is shaped so as to cut through a liquid flow, formed when liquid is dispensed on an upper surface of the wafer-shaped article, when the projecting gripping portion is in contact with the wafer-shaped article and the wafer-shaped article is rotated, with reduced or minimal splashing of the liquid.

15 The present invention may therefore reduce splashing of the liquid dispensed on the upper surface of the wafer.

The apparatus according to the present invention may have any one, or, where compatible, any combination of the following optional features.

The angle of greater than or equal to 10 degrees and less than or equal to 70 degrees may be measured
20 in a plane that goes through the contact point or contact line where the wafer-shaped article contacts the projecting gripping portion and that is parallel to the upper and lower surfaces of the wafer-shaped article. For example, the plane may be the plane of symmetry of the wafer-shaped article between the upper and lower surfaces of the wafer-shaped article.

The angle may be measured in a plane that is parallel to the upper and lower surfaces of the wafer-
25 shaped article and that passes through the wafer-shaped article, for example midway between the upper and lower surfaces of the wafer-shaped article.

The angle may only be formed at the edge where the plane intersects the edge, or only over a portion of the edge that includes the point where the plane intersects the edge. In other words, it is not necessary for the angle to be formed over the whole edge, or even most of the edge. Alternatively, the angle may
30 be formed over most or all of the edge.

The angle may be measured between tangents of the first surface and the second surface in the plane at the edge.

The wafer-shaped article may be a wafer such as a semiconductor wafer. The wafer-shaped article may comprise or be a semiconductor substrate.

35 Processing the wafer-shaped article may comprise etching and/or cleaning the wafer-shaped article, for example.

Processing the wafer-shaped article may comprise dispensing a liquid onto a surface of the wafer-shaped article, such as an etching liquid or a cleaning liquid.

For example, processing the wafer-shaped article may comprise dispensing an etching liquid onto a surface of the wafer-shaped article to etch the surface of the wafer-shaped article, or dispensing a
5 cleaning liquid such as water onto a surface of the wafer-shaped article to clean the surface of the wafer-shaped article.

Cleaning the surface of the wafer-shaped article may comprise removing one or more impurities from the surface of the wafer-shaped article.

Processing the wafer-shaped article may comprise treatment of the wafer-shaped article, for example wet
10 treatment of the wafer shaped article.

Processing the wafer-shaped article may comprise processing of a surface of the wafer-shaped article.

The chuck being a rotary chuck may mean that the chuck can be rotated or spun around a central axis of the spin chuck.

The spin chuck may alternatively be referred to as a spin chuck, or rotatable chuck, or a rotatable
15 support.

The rotary chuck may be configured to receive the wafer-shaped article from below or beneath the wafer-shaped article. Therefore, the rotary chuck may be positioned below or beneath the wafer-shaped article when the wafer-shaped article is received by the rotary chuck.

Holding the wafer-shaped article may comprise supporting and/or gripping and/or clamping and/or
20 restraining the wafer-shaped article.

The plurality of gripping pins may comprise three or more gripping pins.

The rotary chuck may have a circular series of the gripping pins.

The gripping pins may be provided in the rotary chuck so as to surround a peripheral edge (circumferential edge) of the wafer-shaped article received by the rotary chuck.

25 Each of the gripping pins may protrude from a respective hole in an upper surface of the rotary chuck.

The gripping pins may be adapted to hold the wafer shaped article by contacting or gripping a peripheral edge (circumferential edge) of the wafer-shaped article.

The gripping pins may be rotatable gripping pins.

The gripping pins may be configured to grip the wafer therebetween.

30 The projecting gripping portion may project from a distal, or top, or uppermost, end of the gripping pin.

The projecting portion may project or protrude upwards, or in a longitudinal direction of the cylindrical body, from the cylindrical body.

The projecting gripping portion may be configured to contact or grip a peripheral edge (circumferential edge) of the wafer-shaped article.

The projecting gripping portions may be configured to grip the wafer therebetween.

The projecting gripping portion may be formed integrally with the cylindrical body.

- 5 The first face may be front face, or proximal face, of the projecting gripping portion.

The first face may be a contact face or a gripping face of the projecting gripping portion that is configured to contact or grip the peripheral edge of the wafer-shaped article.

The first face may comprise a first surface, or front surface, or contact surface or gripping surface.

- 10 The first face being configured to contact the wafer-shaped article may mean that at least part of the first face, for example at least part of the horizontal extent of the first face, may be configured to contact the wafer-shaped article.

The second face may be opposite to the first face, for example on an opposite side of the projecting gripping portion to the first face.

The second face may not be configured to contact the peripheral edge of the wafer-shaped article.

- 15 The second face may be a rear face, or distal face, or back face, or second surface or rear surface of the projecting gripping portion.

The front face and/or the second face may extend, at least partly, in a vertical direction (for example perpendicular to the upper surface of the wafer-shaped article).

The first face and the second face may meet at the edge.

- 20 The first face and the second face may be joined at the edge.

The edge may be an edge of the first face and an edge of the second face.

The edge may extend, at least partly, in a vertical direction (for example perpendicular to the upper surface of the wafer-shaped article).

The edge may extend substantially in the vertical direction.

- 25 The edge may be a side edge of the projecting gripping portion.

The edge may be a vertical or substantially vertical side edge of the projecting gripping portion.

The projecting gripping portion may further comprise a top face or top surface at a distal end (top end) of the projecting gripping portion.

- 30 The edge may be arranged and/or configured to cut through a liquid flow formed when liquid is dispensed on an upper surface of the wafer-shaped article when the projecting gripping portion is in contact with the wafer-shaped article and the wafer-shaped article is rotated.

The angle may be an angle between the first face at or adjacent to the edge and the second face at or adjacent to the edge in a plan view of the projecting gripping portion (when viewed from above).

As mentioned above, the angle is measured in a plane that passes through a contact point or contact line where the wafer-shaped article contacts the projecting gripping portion and that is parallel to the upper and lower surfaces of the wafer-shaped article.

The angle may be greater than or equal to 25 degrees and less than or equal to 60 degrees, for example.

- 5 The angle may be greater than or equal to 35 degrees and less than or equal to 55 degrees, for example.

The edge may be a substantially sharp edge of the projecting gripping portion.

The edge may be a substantially wedge-shaped edge of the projecting gripping portion.

- The first face may be configured to contact the wafer-shaped article at and/or adjacent to the edge. The edge may therefore be at or adjacent to the peripheral edge of the wafer-shaped article when the projecting gripping portion is in contact with the peripheral edge of the wafer-shaped article.
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The edge may be arranged and/or positioned and/or configured to be impacted by a liquid flow formed when liquid is dispensed on an upper surface of the wafer-shaped article when the projecting gripping portion is in contact with the wafer-shaped article and the wafer-shaped article is rotated.

- The edge may be arranged and/or positioned and/or configured to be a first part of the projecting gripping portion to be impacted by the liquid flow.
- 15

The edge may be positioned downstream on the projecting gripping portion relative to a rotation direction of the wafer-shaped article when the projecting gripping portion is in contact with the wafer-shaped article.

The edge may be a downstream edge of the first surface relative to a rotation direction of the wafer-shaped article when the first surface is in contact with the wafer-shaped article.

- 20 At least part of the first face may be concave in a vertical direction.

Each of the gripping pins may comprise a groove formed in at least part of the first face of the projecting gripping portion for receiving an edge of the wafer-shaped article. The groove may be configured to accommodate the peripheral edge of the wafer-shaped article.

- The groove may support the peripheral edge of the wafer-shaped article from underneath by a lower surface of the groove contacting a lower surface of the wafer-shaped article. The wafer-shaped article may therefore be supported by the gripping pins with the lower surface of the wafer-shaped article spaced apart from the upper surface of the rotary chuck.
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The groove may be dimensioned to receive and engage a peripheral edge of a wafer having a thickness greater than or equal to 500 μm and less than or equal to 1000 μm , for example.

- 30 The groove may extend in a horizontal direction along the front face.

At least part of the first face may be curved in a horizontal direction of the first face. In other words, at least part of the first face may be curved when viewed in a plan view (from above), or in a plane of the wafer-shaped article.

At least part of the first face may be curved in the horizontal direction of the first face with a first radius of curvature.

At least part of the second face may be curved in a horizontal direction of the second face. In other words, at least part of the second face may be curved when viewed in a plan view (from above), or in a
5 plane of the wafer-shaped article.

At least part of the second face may be curved in the horizontal direction of the second face with a second radius of curvature.

The projecting gripping portion may be offset from a longitudinal axis of the cylindrical body.

The projecting gripping portion may be at least partly offset from the longitudinal axis of the cylindrical
10 body.

A centre or mid-point of the projecting gripping portion may be offset from the longitudinal axis of the cylindrical body.

Each of the gripping pins may be mounted in the rotary chuck for rotation about a central axis of the respective cylindrical body.

15 The gripping pins may be configured to be rotated in synchronisation between a gripping (closed) configuration in which the protruding gripping portions are arranged to contact a peripheral edge of the wafer-shaped article and a non-gripping (open) configuration in which the protruding gripping portions are arranged not to contact the peripheral edge of the wafer-shaped article.

The rotary chuck and the rotatable gripping pins may be configured to hold a wafer-shaped article having
20 a predetermined diameter, for example 300 mm.

The rotatable gripping pins may therefore be configured to grip the edge of a wafer-shaped article with a diameter of 300 mm in the closed (gripping) positions.

Each of the plurality of gripping pins may comprise a respective gear, and the apparatus may comprise a ring gear in meshing engagement with each of the gears.

25 The gear may be positioned at or around a bottom or lower end of the cylindrical body.

The gear may be positioned inside the rotary chuck when the gripping pin is mounted in the rotary chuck.

The rotatable gripping pins may be rotatable in synchronisation by the ring gear.

The ring gear may be rotatably mounted in the rotary chuck, for example via one or more bearings.

The apparatus may comprise a liquid dispenser configured to dispense liquid on an upper surface of a
30 wafer-shaped article held on the rotary chuck.

The liquid dispenser may comprise an arm that is rotatable above the surface of the rotary chuck so as to change a position at which the liquid is dispensed on the upper surface of the wafer-shaped article.

The liquid dispenser may comprise one or more nozzles for dispensing the liquid.

The one or more nozzles may be positioned on the rotatable arm described above. For example, the arm may be mounted for rotation at or adjacent to a first end of the arm and the one or more nozzles may be positioned at or adjacent to an opposite second end of the arm.

5 According to a second aspect of the present invention there is provided a gripping pin for use in an apparatus for processing a wafer-shaped article, the gripping pin comprising: a cylindrical body; and a projecting gripping portion, wherein the projecting gripping portion comprises a first face configured to contact a wafer-shaped article and a second face, and wherein an angle of greater than or equal to 10 degrees and less than or equal to 70 degrees is formed between the first face and the second face at an edge of the projecting gripping portion.

10 The gripping pin according to the second aspect of the present invention may have any of the features of the gripping pin in the first aspect of the present invention described above. Those features are not described again here for conciseness.

The invention includes the combination of the aspects and preferred features described except where such a combination is clearly impermissible or expressly avoided.

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Summary of the Figures

Embodiments and experiments illustrating the principles of the invention will now be discussed with reference to the accompanying figures in which:

20 **Figure 1** is a schematic illustration of an apparatus for processing a wafer-shaped article in a first configuration.

Figure 2 is a schematic illustration of the apparatus for processing a wafer-shaped article of FIG. 1 in a second configuration.

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Figure 3 is a schematic plan view of the apparatus illustrated in FIG. 1.

Figure 4 is a schematic plan view of the apparatus illustrated in FIG. 2.

30 **Figure 5** is a schematic illustration of a gripping pin previously used by the inventors.

Figures 6A and 6B are schematic plan views of the gripping pin illustrated in FIG. 5 and a peripheral edge of a wafer.

Figure 7 is a schematic illustration of the gripping pin illustrated in FIG. 5 contacting the peripheral edge of a wafer.

- 5 **Figure 8** is a schematic illustration of an apparatus for processing a wafer-shaped article according to an embodiment of the present invention.

Figure 9 is a schematic illustration of a gripping pin according to an embodiment of the present invention.

- 10 **Figure 10** is a partial enlarged view of FIG. 9.

Figures 11A and 11B are schematic illustrations of different shapes of the projecting gripping portion of the gripping pin according to embodiments of the present invention.

- 15 **Figures 12A and 12B** are schematic plan views of the gripping pin illustrated in FIG. 9 and an edge of a wafer.

Figure 13 is a schematic illustration of the gripping pin illustrated in FIG. 7 contacting the peripheral edge of a wafer.

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Detailed Description of the Invention

Aspects and embodiments of the present invention will now be discussed with reference to the accompanying figures. Further aspects and embodiments will be apparent to those skilled in the art. All documents mentioned in this text are incorporated herein by reference.

- 25 An apparatus for processing a wafer according to an embodiment of the present invention is illustrated in FIGS. 8 to 13.

- The apparatus according to the embodiment of the present invention may be a modified version of the apparatus 1 illustrated in FIGS. 1 to 7 or described above, for example. The apparatus according to the embodiment of the present invention may therefore include any of the features illustrated in FIGS. 1 to 7 or described above unless those features are incompatible with the features of the embodiment of the present invention described below. In other words, any of the features illustrated in FIGS. 1 to 7 or described above may also form part of the apparatus according to the embodiment of the present invention, unless incompatible.
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For example, the apparatus according to the embodiment of the present invention may be a modified version of the apparatus 1 illustrated in FIGS. 1 to 7 or described above in which the rotatable gripping pins 5 are replaced with a new rotatable gripping pin according to the embodiment of the present invention. In that case, the apparatus according to the embodiment of the present invention may include
5 any of the features of the apparatus 1 illustrated in FIGS. 1 to 7 or described above apart from those features of the rotatable gripping pins 5 which are replaced with the features of the new rotatable gripping pin according to the embodiment of the present invention described below.

Of course, the apparatus according to the embodiment of the present invention may include other changes from the apparatus 1 illustrated in FIGS. 1 to 7 or described above.

10 FIG. 8 to 13 are schematic illustrations of an apparatus 27 for processing a wafer according to an embodiment of the present invention. Features that are the same as the features of the apparatus 1 illustrated in FIGS. 1 to 7 or described above are indicated with the same reference signs in FIGS. 8 to 13 and a detailed description thereof is omitted for conciseness.

As illustrated in FIG. 8, the apparatus 27 is the same as the apparatus 1 illustrated in FIGS. 1 to 7 or
15 described above except that each of the rotatable gripping pins 5 is replaced with a rotatable gripping pin 29 according to the embodiment.

Of course, it is not necessary for the apparatus 27 to include 8 gripping pins. Instead, in other embodiments, the apparatus 27 may comprise three or more gripping pins, for example.

Furthermore, the apparatus 27 may comprise a different electric motor to the hollow-shaft electric motor
20 described above. For example, in an alternative embodiment the rotary chuck 3 could instead be driven to rotate without physical contact through a magnetic bearing.

The rotatable gripping pin 29 in this embodiment is illustrated in more detail in FIG. 9.

As illustrated in FIG. 9, each of the rotatable gripping pins 29 comprises a cylindrical body 31 and a
25 projecting gripping portion 33. The projecting gripping portion 33 is formed integrally with the cylindrical body 31. The projecting gripping portion 33 protrudes from a distal end (top end) of the cylindrical body 31. In particular, the projecting gripping portion protrudes longitudinally from the cylindrical body (in a longitudinal direction of the cylindrical body 31).

The projecting gripping portion 33 is off-centre relative to a longitudinal axis of the cylindrical body 31. In other words, the projecting gripping portion 33 is eccentric relative to the longitudinal axis of the cylindrical
30 body 31. Rotation of the rotatable gripping pin 29 around its longitudinal axis therefore causes the projecting gripping portion 33 to move closer to, or further away from, a centre of the top surface of the rotary chuck 3. Therefore, by rotating the plurality of rotatable gripping pins 29 in synchronisation, the rotatable gripping pins 29 can be caused to grip the peripheral edge of the wafer W therebetween by the projecting gripping portions 33 coming into contact with the peripheral edge of the wafer W. In particular,
35 rotation of the rotatable gripping pins 29 causes the projecting gripping portions 33 to move between more radially outer open (non-gripping) positions and more radially inner closed (gripping) positions.

The open (non-gripping) positions correspond to the configuration illustrated in FIG. 3 with the rotatable gripping pins 5 and protruding gripping portions 9 replaced with the rotatable gripping pins 29 and protruding gripping portions 33.

5 The closed (gripping) positions corresponds to the configuration in FIG. 4 with the rotatable gripping pins 5 and protruding gripping portions 9 replaced with the rotatable gripping pins 29 and protruding gripping portions 33.

FIG. 12A illustrates one of the rotatable gripping pins 29 in the open (non-gripping) configuration. In particular, in this configuration the rotatable gripping pins 29 have each been rotated in synchronisation so that the projecting gripping portions 33 are at a more outer (or outermost) position in the radial
10 direction. FIG. 12A shows the relationship between the projecting gripping portion 33 and the peripheral edge of the wafer W. In particular, in this configuration the projecting gripping portions 33 are spaced apart from a peripheral edge of the wafer W. This corresponds to the configuration illustrated in FIG. 3.

In contrast, FIG. 12B illustrates one of the rotatable gripping pins 29 in the closed (gripping) configuration. In particular, in this configuration the rotatable gripping pins 29 have each been rotated in synchronisation
15 so that the projecting gripping portions 33 are more radially inwards than in the open (non-gripping) configuration. FIG. 12B shows the relationship between the projecting gripping portion 33 and the peripheral edge of the wafer W. In particular, relative to FIG. 12A, the rotatable gripping pin 29 has been rotated in the anti-clockwise (counter-clockwise) direction until the projecting gripping portion 33 is in contact with the peripheral edge of the wafer W. This corresponds to the configuration illustrated in FIG.
20 4.

The rotary chuck 3 and the rotatable gripping pins 29 may be configured to hold a wafer having a predetermined diameter, for example 300 mm. The rotatable gripping pins 29 may therefore be configured to grip the edge of a wafer with a diameter of 300 mm in the closed (gripping) positions.

As shown in FIG. 9, the rotatable gripping pin 29 further comprises a gear 15 at a bottom or lower end
25 (proximal end) of the cylindrical body 31. This gear 15 is positioned inside the rotary chuck 3 when the rotatable gripping pin 29 is mounted in the rotary chuck 3.

As shown in FIG. 8, the rotatable gripping pins 29 are rotatable in synchronisation by a ring gear 13 housed in the rotary chuck 3, for example in a space formed between the base body and chuck cover of the rotary chuck 3. The ring gear 13 is simultaneously in meshing engagement with the gears 15 of the
30 rotatable gripping pins 29. The ring gear 13 is rotatably mounted in the rotary chuck 3 via one or more bearings 17 and may be driven to rotate relative to the rotary chuck 3 via an electric motor of the apparatus 1, for example.

The rotary chuck 3 is mounted to a rotor 19 of a hollow shaft motor of the apparatus 1. The rotor 19 is illustrated schematically as a block in FIG. 8. In practice, the rotor 19 may comprise a rotatable hollow
35 shaft and the rotary chuck 3 may be mounted on a rotatable support plate that is connected to an end of the rotatable hollow shaft. The rotary chuck 3 is therefore rotatable by the rotor 19 of the hollow-shaft motor.

A stator of the hollow-shaft motor is mounted to a mounting plate 21 of the apparatus. The stator and the mounting plate 21 are illustrated schematically as a block in FIG. 8. The mounting plate 21 is mounted to a non-rotating (stationary) frame of the apparatus 1. The rotary chuck 3 is therefore rotatable relative to the mounting plate 21 which does not rotate.

- 5 In addition, the apparatus 27 further comprises a liquid dispenser 23 that is configured to dispense liquid onto an upper surface of the wafer W received by the rotary chuck 3 (a surface of the wafer W that faces away from the rotary chuck 3). The liquid dispenser 23 may comprise one or more dispensing nozzles arranged on a dispensing arm, wherein the dispensing arm is pivotable so as to move the one or more dispensing nozzles over the upper surface of the wafer W, for example. For example, the dispensing arm
10 may be mounted for rotation at or adjacent to a first end of the dispensing arm and the one or more nozzles may be positioned at or adjacent to an opposite second end of the dispensing arm.

The projecting gripping portion 33 has a shape that is configured to reduce an amount of splashing caused when a liquid flow formed in the liquid dispensed on the upper surface of the wafer while the wafer is being rotated impacts the projecting gripping portion 33.

- 15 In particular, the projecting gripping portion 33 has a wing-shaped appearance, and/or is shaped similarly to a bow of a ship, and/or has a sharp edge, and/or has a tapered or wedge-shaped appearance, where the projecting gripping portion 33 will be impacted by the liquid flow formed in the liquid dispensed on the upper surface of the wafer, so that the projecting gripping portion 33 can cut through the liquid flow with minimal splashing.
- 20 More specifically, as illustrated in FIGS. 9 and 10, the projecting gripping portion 33 comprises a front face 35 (a first face) that is adapted to contact a peripheral edge of the wafer. The front face 35 may instead be referred to as a contact face or a gripping face or a front surface or contact surface or gripping surface of the projecting gripping portion 33. In addition, the projecting gripping portion 33 further comprises a rear face 37 (a second face) on an opposite side of the projecting gripping portion 33 to the
25 front face 35. The rear face 37 is not configured to contact the peripheral edge of the wafer. The rear face 37 may instead be referred to as a rear surface or back surface or face.

The front face and the second face both extend at least partly, or substantially, in a vertical direction (perpendicular to the upper surface of the wafer W).

- 30 The front face 35 and the rear face 37 meet at an edge 39 of the projecting gripping portion 33 with an angle of greater than or equal to 10 degrees and less than or equal to 70 degrees between the front face 35 and the rear face 37. The edge 39 is at a side of the projecting gripping portion 33 and may therefore be referred to as a side edge of the projecting gripping portion.

The edge 39 extends at least partly, or substantially, in a vertical direction (perpendicular to the surface of the wafer W).

- 35 The angle of between 10 degrees and 70 degrees is measured in a plane that passes through the contact point or line where the wafer contacts the projecting gripping portion and that is parallel to the upper and lower surfaces of the wafer. The angle may be formed only at the point where the plane intersects the

edge, or over a portion or region of the edge that includes the point where the plane intersects the edge, or over most or all of the edge. The angle may be measured between tangents of the first surface and the second surface in the plane at the edge.

5 The projecting gripping portion 33 is therefore shaped similarly to a bow of a ship at the edge 39, such that when the edge 39 is impacted by a liquid flow formed when liquid is dispensed on the upper surface of the wafer while the wafer is being rotated, the edge 39 will cut through the liquid flow with minimal splashing.

FIG. 13 illustrates the gripping pin 29 rotated in the anti-clockwise (counter-clockwise) direction so that the projecting gripping portion 33 is in contact with the peripheral edge of the wafer W. In particular, the front face 35 of the projecting gripping portion 33 is in contact with the peripheral edge of the wafer W.

10 The front face 35 is in contact with the peripheral edge of the wafer W at and/or adjacent to the edge 39.

FIG. 13 further illustrates the direction of travel 41 of a liquid flow formed on the upper surface of the wafer W when liquid is dispensed on the upper surface of the wafer W from the liquid dispenser 23 while the wafer W is rotated in the anti-clockwise (counter-clockwise) direction as shown by the arrow in FIG. 13.

15 As shown in FIG. 13, the liquid flow does not travel directly radially outwards towards the projecting gripping portion 33 and instead impacts the projecting gripping portion in a direction that is partly in the radially outward direction and partly in a direction opposite to the rotation direction of the wafer W. When the liquid flow impacts the projecting gripping portion 33 from this direction, the specific shape of the projecting gripping portion 33 means that the projecting gripping portion 33 cuts through the liquid flow with minimal splashing.

In particular, the edge 39 is positioned and/or configured to be impacted by a liquid flow formed in liquid dispensed on an upper surface of the wafer-shaped article when the projecting gripping portion 33 is in contact with the wafer W and the wafer W is rotated.

25 More specifically, the edge 39 is arranged to be a first part of the projecting gripping portion 33 to be impacted by the liquid flow.

As shown in FIGS. 12B and 13, when the front face 35 is in contact with the peripheral edge of the wafer W, the edge 39 is positioned downstream on the projecting gripping portion 33 relative to the rotation direction of the wafer W. In particular, the edge 39 is a downstream edge of the front face 35 relative to the rotation direction of the wafer W. This means that the edge 39 is the first part of the projecting gripping portion 33 to be impacted by the liquid flow formed on the upper surface of the wafer W when the liquid is dispensed on the upper surface of the wafer W and the wafer W is rotated. This is particularly true when the liquid is dispensed on the upper surface of the wafer close to the peripheral edge of the wafer, for example with an impact point of the liquid on the upper surface of the wafer less than or equal to 20 mm from the peripheral edge of the wafer. When the liquid is dispensed close to the peripheral edge of the wafer the liquid may not be fully accelerated to the rotational speed of the wafer when the liquid reaches the edge of the wafer. This means that there will be a relative rotational velocity between

the gripping pins and the flow of liquid at the edge of the wafer. Consequently, the gripping pin will travel through the not yet fully accelerated/more slowly moving liquid, such that the liquid does not impact the gripping pin in a purely radially outward direction. The projecting gripping portion of the gripping pin in the present embodiment is configured to pass through the liquid with minimal splashing when the liquid
5 impacts the projecting gripping portion in this manner.

FIGS. 11A and 11B illustrate two different angles between the front face 35 and the rear face 37 in different embodiments of the present invention.

In FIG. 11A an angle "a" of 60 degrees is formed between the front face 35 and the rear face 37 of the projecting gripping portion 33. Furthermore, the front face 35 has a radius of curvature Rx of 10mm and
10 the rear face 37 has a radius of curvature Ry of 10mm. The angle is measured between tangents to the front face 35 and rear face 37 at the edge.

In FIG. 11B and angle "a" of 20 degrees is formed between the front face 35 and the rear face 37 of the projecting gripping portion 33. Furthermore, the front face 35 has a radius of curvature Rx of 100mm and
15 the rear face 37 has a radius of curvature Ry of 100mm. The angle is measured between tangents to the front face 35 and rear face 37 at the edge.

As mentioned above, these angles are measured in a plane that passes through the contact point or contact line where the wafer contacts the gripping pin and in a plane that is parallel to the upper and lower surfaces of the wafer and that passes through the wafer, for example mid-way between the upper and lower surfaces of the wafer.

As illustrated in FIGS. 9 and 10, the projecting gripping portion 33 comprises a groove 43 formed in the front face 35 that is configured to accommodate the peripheral edge of the wafer W, so that the peripheral edge of the wafer W is supported from underneath by a lower surface of the groove 43. Therefore, the wafer W can be supported by the rotatable gripping pins 29 with the lower surface of the wafer W spaced apart from the upper surface of the rotary chuck 3. The groove 43 may be dimensioned to receive and
25 engage a peripheral edge of a wafer having a thickness greater than or equal to 500 μm and less than or equal to 1000 μm . The groove may extend in a horizontal direction along the front face 35.

The features disclosed in the foregoing description, or in the following claims, or in the accompanying drawings, expressed in their specific forms or in terms of a means for performing the disclosed function, or a method or process for obtaining the disclosed results, as appropriate, may, separately, or in any
30 combination of such features, be utilised for realising the invention in diverse forms thereof.

While the invention has been described in conjunction with the exemplary embodiments described above, many equivalent modifications and variations will be apparent to those skilled in the art when given this disclosure. Accordingly, the exemplary embodiments of the invention set forth above are considered to be illustrative and not limiting. Various changes to the described embodiments may be made without
35 departing from the spirit and scope of the invention.

For the avoidance of any doubt, any theoretical explanations provided herein are provided for the purposes of improving the understanding of a reader. The inventors do not wish to be bound by any of these theoretical explanations.

Any section headings used herein are for organizational purposes only and are not to be construed as
5 limiting the subject matter described.

Throughout this specification, including the claims which follow, unless the context requires otherwise, the word “comprise” and “include”, and variations such as “comprises”, “comprising”, and “including” will be understood to imply the inclusion of a stated integer or step or group of integers or steps but not the exclusion of any other integer or step or group of integers or steps.

10 It must be noted that, as used in the specification and the appended claims, the singular forms “a,” “an,” and “the” include plural referents unless the context clearly dictates otherwise. Ranges may be expressed herein as from “about” one particular value, and/or to “about” another particular value. When such a range is expressed, another embodiment includes from the one particular value and/or to the other particular value. Similarly, when values are expressed as approximations, by the use of the antecedent “about,” it
15 will be understood that the particular value forms another embodiment. The term “about” in relation to a numerical value is optional and means for example +/- 10%.

Claims:

1. An apparatus for processing a wafer-shaped article, comprising:
a rotary chuck having a plurality of gripping pins adapted to hold a wafer-shaped article on the
5 rotary chuck,
wherein each of the plurality of gripping pins comprises a cylindrical body and a projecting
gripping portion,
wherein the projecting gripping portion comprises a first face configured to contact the wafer-
shaped article and a second face, and wherein an angle of greater than or equal to 10 degrees and less
10 than or equal to 70 degrees is formed between the first face and the second face at an edge of the
projecting gripping portion.
2. The apparatus according to claim 1, wherein:
an angle of greater than or equal to 25 degrees and less than or equal to 60 degrees is formed
15 between the first face and the second face at an edge of the projecting gripping portion; or
an angle of greater than or equal to 35 degrees and less than or equal to 55 degrees is formed
between the first face and the second face at an edge of the projecting gripping portion.
3. The apparatus according to claim 1 or claim 2, wherein the first face is configured to contact the
20 wafer-shaped article at and/or adjacent to the edge.
4. The apparatus according to any one of the preceding claims, wherein the edge is arranged to be
impacted by a liquid flow formed when liquid is dispensed on an upper surface of the wafer-shaped article
when the projecting gripping portion is in contact with the wafer-shaped article and the wafer-shaped
25 article is rotated.
5. The apparatus according to claim 4, wherein the edge is arranged to be a first part of the
projecting gripping portion to be impacted by the liquid flow.
- 30 6. The apparatus according to any one of the preceding claims, wherein the edge is positioned
downstream on the projecting gripping portion relative to a rotation direction of the wafer-shaped article
when the projecting gripping portion is in contact with the wafer-shaped article.
7. The apparatus according to claim 6, wherein the edge is configured to be a downstream edge of
35 the first surface relative to a rotation direction of the wafer-shaped article when the first surface is in
contact with the wafer-shaped article.
8. The apparatus according to any one of the preceding claims, wherein at least part of the first face
is concave in a vertical direction.

9. The apparatus according to any one of the preceding claims, wherein each of the gripping pins comprises a groove formed in at least part of the first face of the projecting gripping portion for receiving an edge of the wafer-shaped article.
- 5 10. The apparatus according to any one of the preceding claims, wherein at least part of the first face is curved in a horizontal direction of the first face.
11. The apparatus according to claim 10, wherein at least part of the first face is curved in the horizontal direction of the first face with a first radius of curvature.
- 10 12. The apparatus according to any one of the preceding claims, wherein at least part of the second face is curved in a horizontal direction of the second face.
13. The apparatus according to claim 12, wherein at least part of the second face is curved in the horizontal direction of the second face with a second radius of curvature.
- 15 14. The apparatus according to any one of the preceding claims, wherein the projecting gripping portion is at least partly offset from a longitudinal axis of the cylindrical body.
- 20 15. The apparatus according to any one of the preceding claims, wherein each of the gripping pins is mounted in the rotary chuck for rotation about a central axis of the respective cylindrical body.
16. The apparatus according to any one of the preceding claims, wherein the gripping pins are configured to be rotated in synchronisation between a gripping configuration in which the protruding gripping portions are arranged to contact a peripheral edge of the wafer-shaped article and a non-gripping configuration in which the protruding gripping portions are arranged not to contact the peripheral edge of the wafer-shaped article.
- 25 17. The apparatus according to any one of the preceding claims, wherein each of the plurality of gripping pins comprises a respective gear, and wherein the apparatus comprises a ring gear in meshing engagement with each of the gears.
- 30 18. The apparatus according to any one of the preceding claims, wherein the projecting gripping portion is formed integrally with the cylindrical body.
- 35 19. The apparatus according to any one of the preceding claims, wherein the apparatus comprises a liquid dispenser configured to dispense liquid on an upper surface of a wafer-shaped article held on the rotary chuck.
- 40 20. A gripping pin for use in an apparatus for processing a wafer-shaped article, the gripping pin comprising:

a cylindrical body; and

a projecting gripping portion,

wherein the projecting gripping portion comprises a first face configured to contact a wafer-shaped article and a second face, and wherein an angle of greater than or equal to 10 degrees and less than or equal to 70 degrees is formed between the first face and the second face at an edge of the projecting gripping portion.