US 20250262710A1

(19) **United States**

(12) **Patent Application Publication**

(10) **Pub. No.: US 2025/0262710 A1**

(43) **Pub. Date: Aug. 21, 2025**

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(54) **PROCESSING APPARATUS AND POLISHING SURFACE SHAPING METHOD**

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(21) Appl. No.: **19/050,897**

(22) Filed: **Feb. 11, 2025**

(30) **Foreign Application Priority Data**

Feb. 19, 2024 (JP) 2024-022861

Publication Classification

(51) **Int. Cl.**

B24B 37/005 (2012.01)

B24B 37/20 (2012.01)

(52) **U.S. Cl.**

CPC ***B24B 37/005*** (2013.01); ***B24B 37/20*** (2013.01)

(57) **ABSTRACT**

A processing apparatus includes a chuck table having a holding surface for holding a workpiece thereon, a chuck table rotary actuator for rotating the chuck table, a polishing unit on which a polishing pad having a polishing surface for polishing the workpiece is mounted, a polishing pad rotary actuator for rotating the polishing pad, a polishing moving mechanism for moving the chuck table and the polishing pad relatively to each other, a shape measuring instrument for measuring a shape of the holding surface, a shaping mechanism for shaping the polishing surface while in contact therewith, a shaping moving mechanism for moving the polishing pad and the shaping mechanism relatively to each other, and a controller for making the polishing surface complementary in shape to the holding surface.

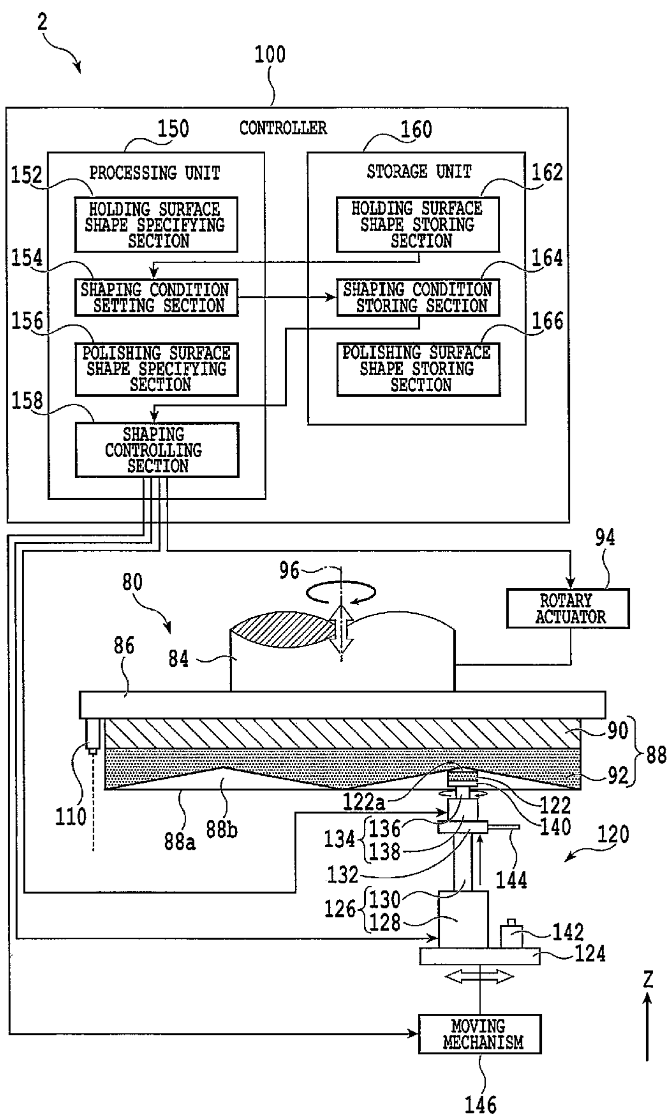
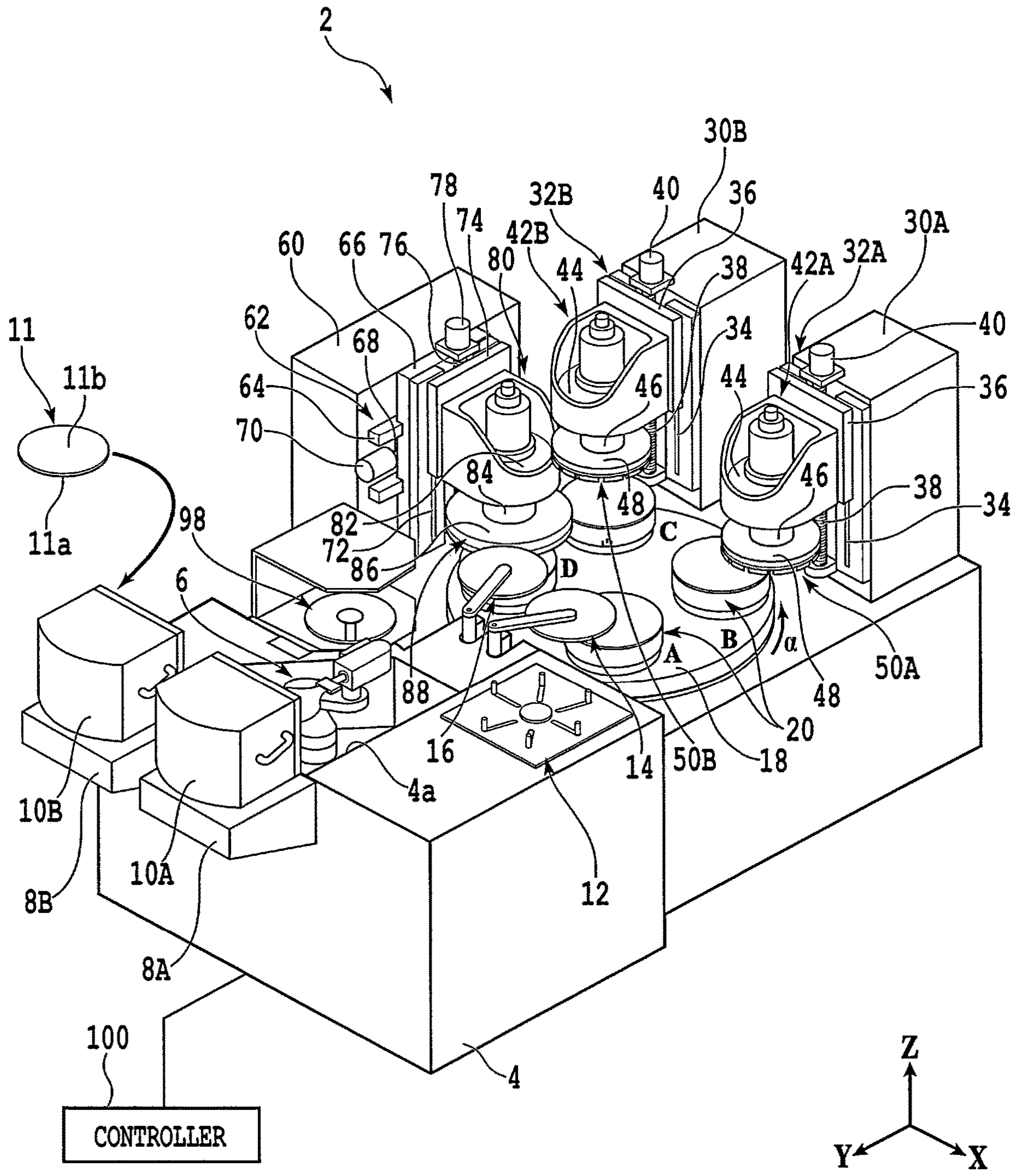


FIG. 1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11b
11a
98
6
10B
8B
10A
8A
100
CONTROLLER
4
4a
12
16
14
50B
18
20
48
50A
88
60
62
64
70
68
66
76
78
74
80
42B
32B
44
40
30B
36
38
34
46
48
84
82
72
86
C
D
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42A
32A
30A
40
36
44
46
38
34
Z
Y
X

FIG.2

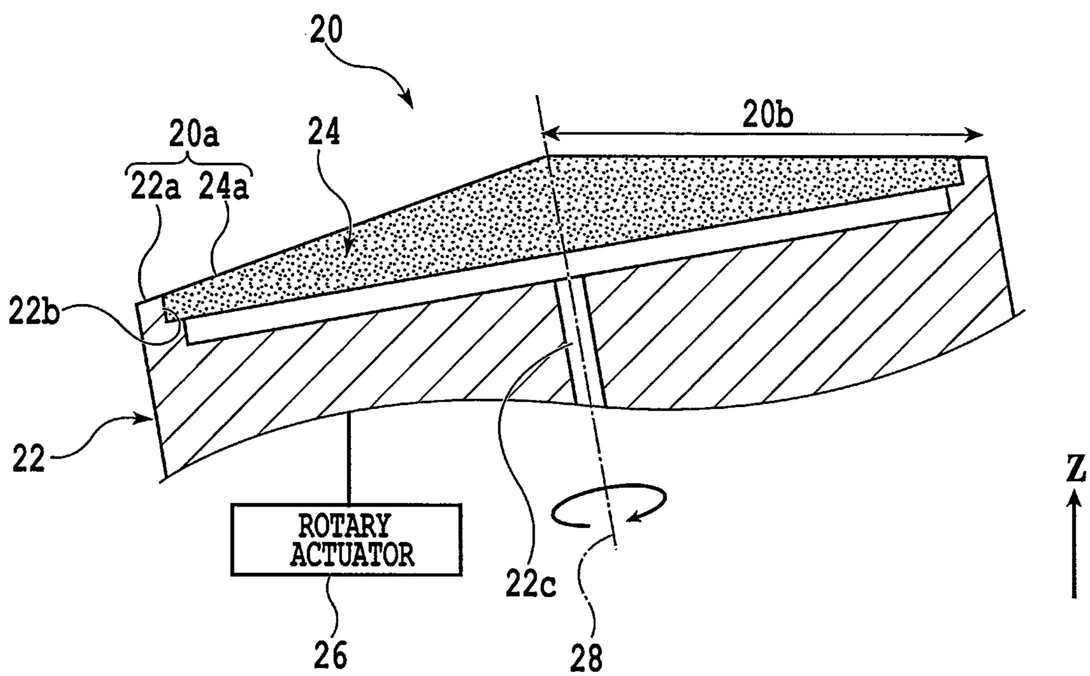
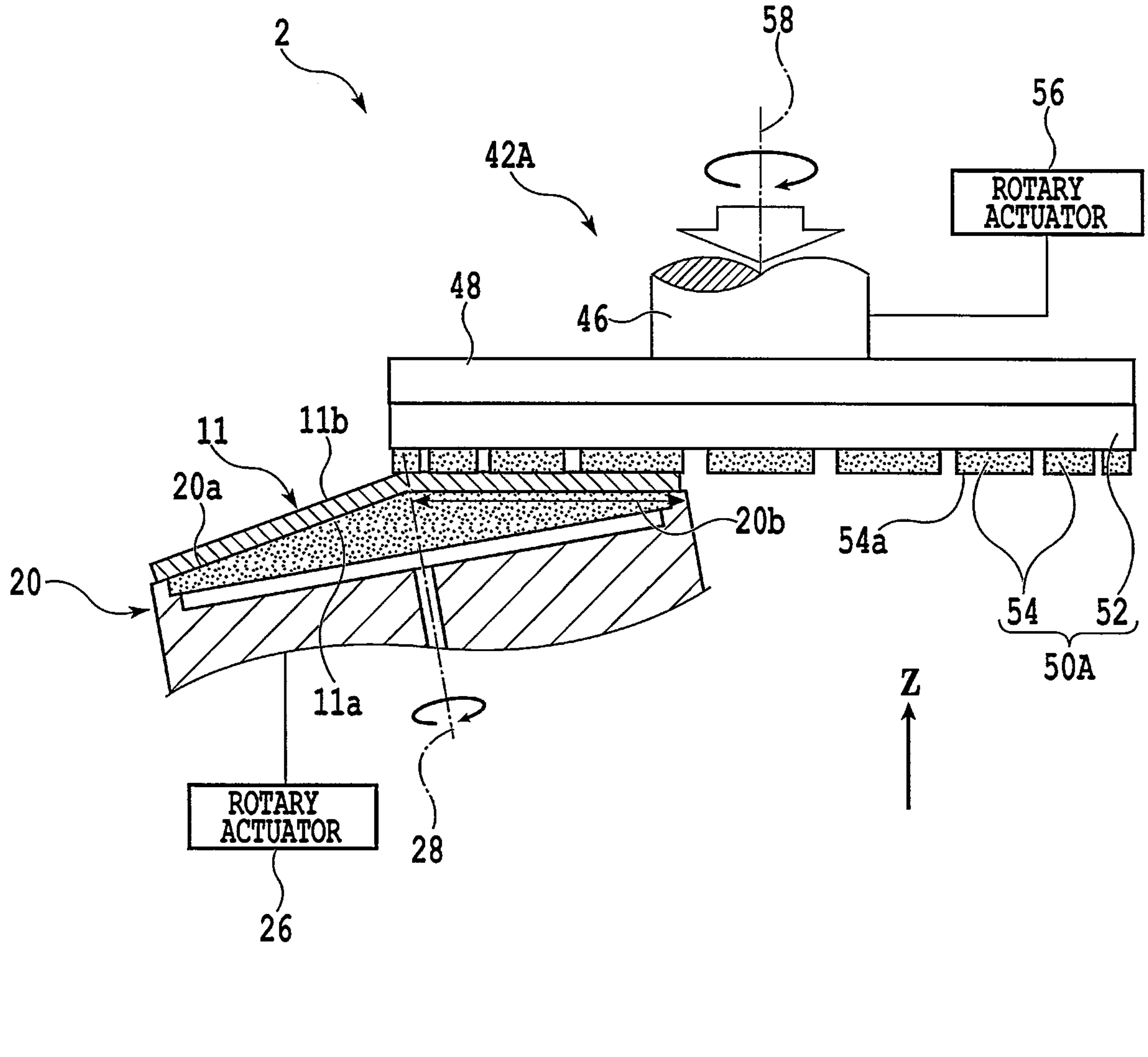


FIG.3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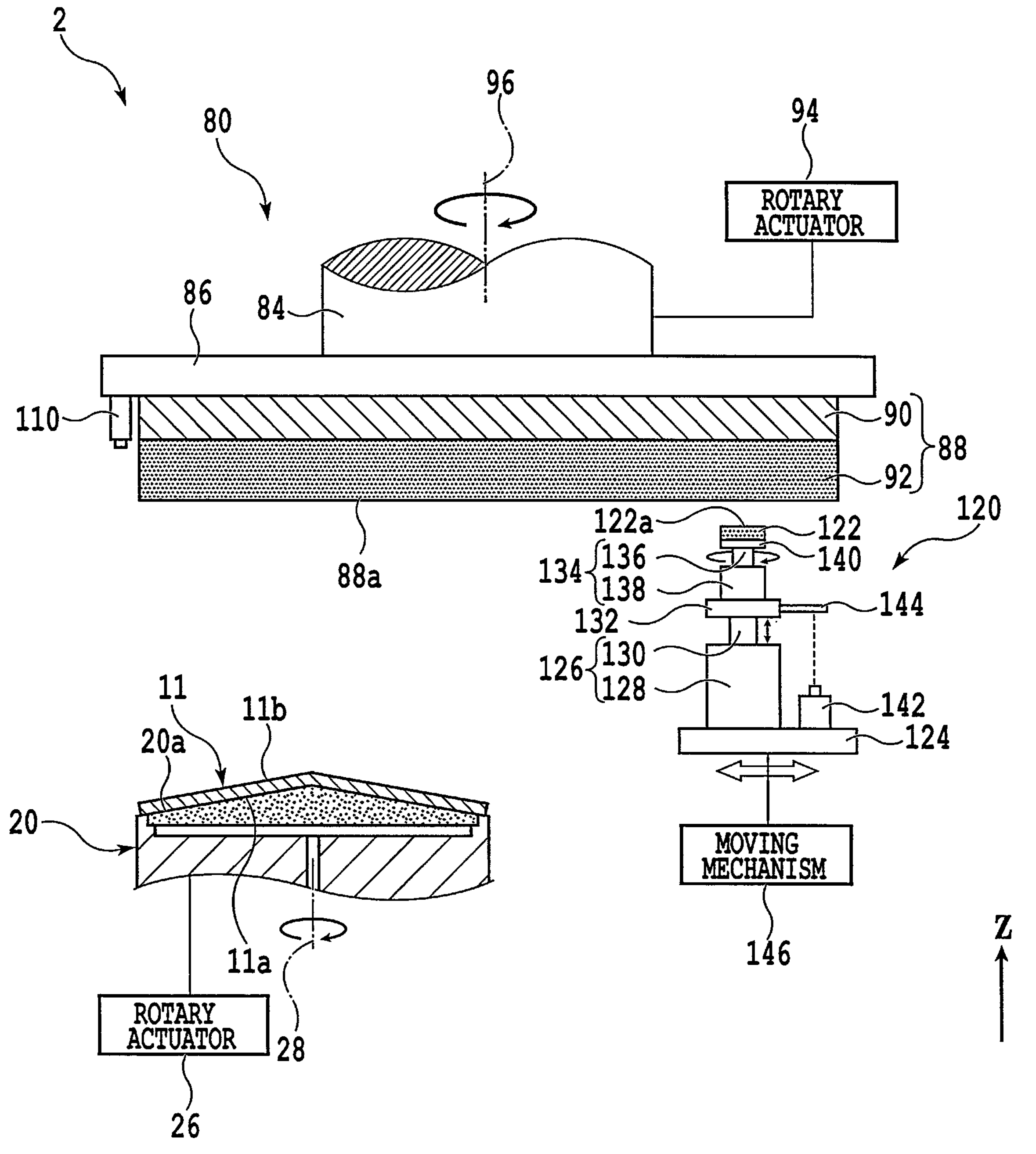
58
56
ROTARY ACTUATOR
42A
48
46
11
11b
20a
20b
20
54a
54
52
50A
11a
Z
ROTARY ACTUATOR
28
26

FIG.4



2
80
96
94
ROTARY ACTUATOR
86
84
110
90
88
92
88a
122a
122
120
134
136
140
138
144
132
126
130
128
142
124
11
11b
20a
20
11a
MOVING MECHANISM
146
Z
ROTARY ACTUATOR
28
26

FIG.5

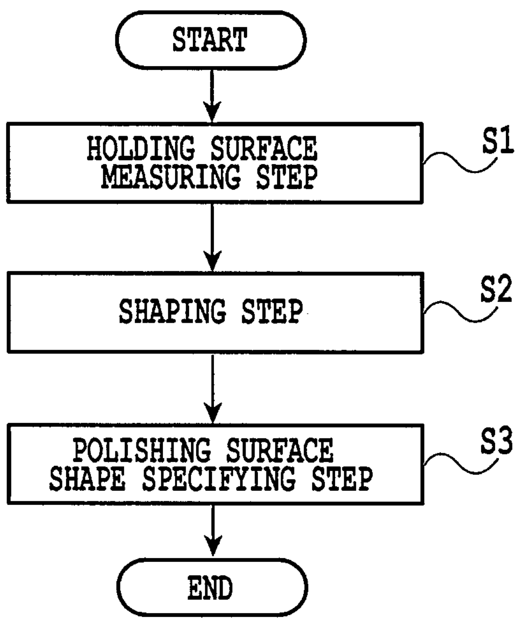
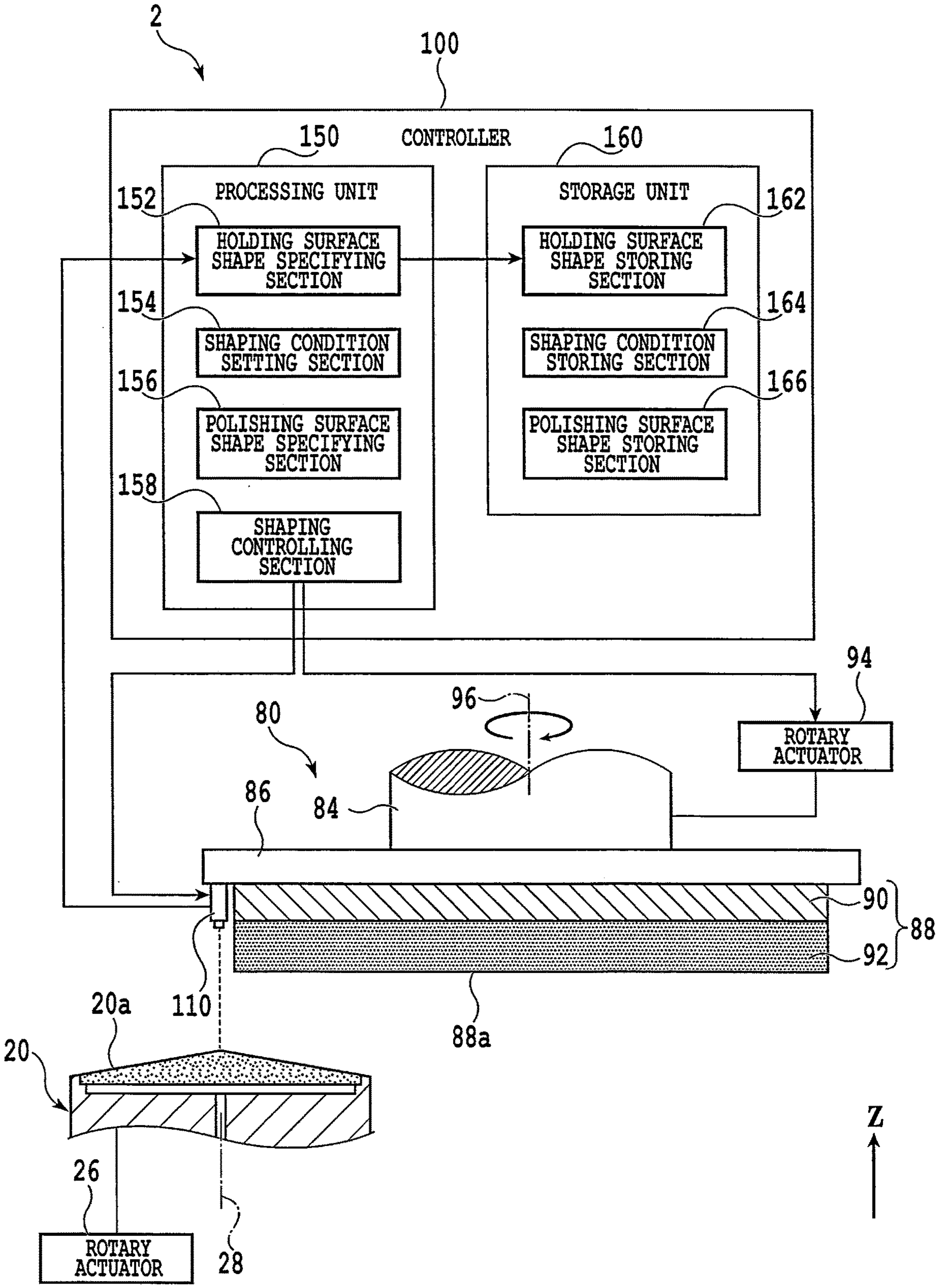

START
HOLDING SURFACE MEASURING STEP
S1
SHAPING STEP
S2
POLISHING SURFACE SHAPE SPECIFYING STEP
S3
END

FIG.6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PROCESSING UNIT
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HOLDING SURFACE SHAPE SPECIFYING SECTION
154
SHAPING CONDITION SETTING SECTION
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POLISHING SURFACE SHAPE SPECIFYING SECTION
158
SHAPING CONTROLLING SECTION
160
STORAGE UNIT
162
HOLDING SURFACE SHAPE STORING SECTION
164
SHAPING CONDITION STORING SECTION
166
POLISHING SURFACE SHAPE STORING SECTION
94
ROTARY ACTUATOR
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88a
20a
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26
ROTARY ACTUATOR
28
Z

FIG.7

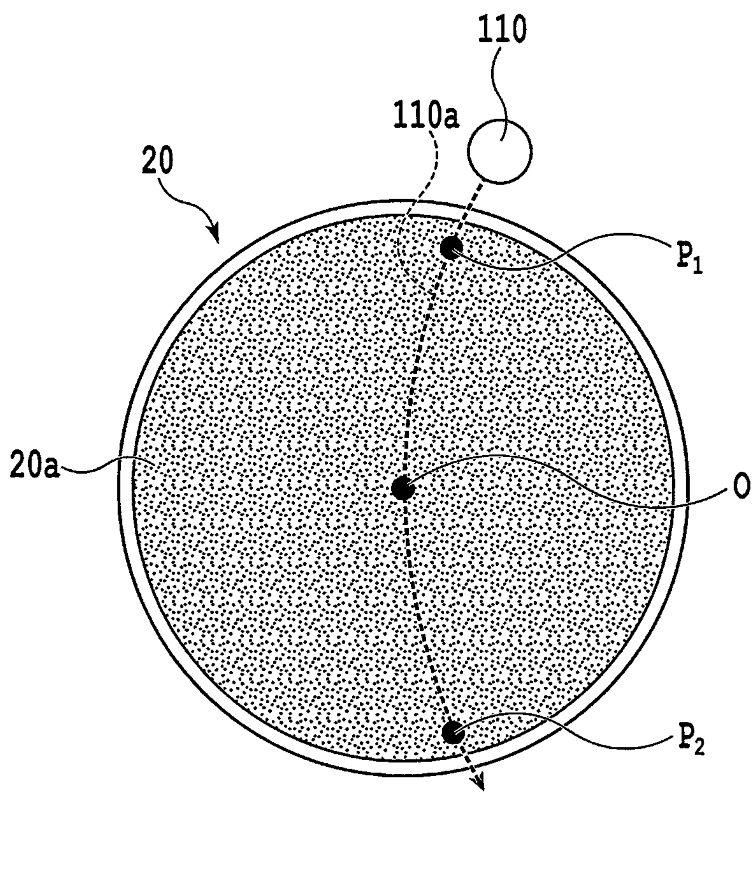
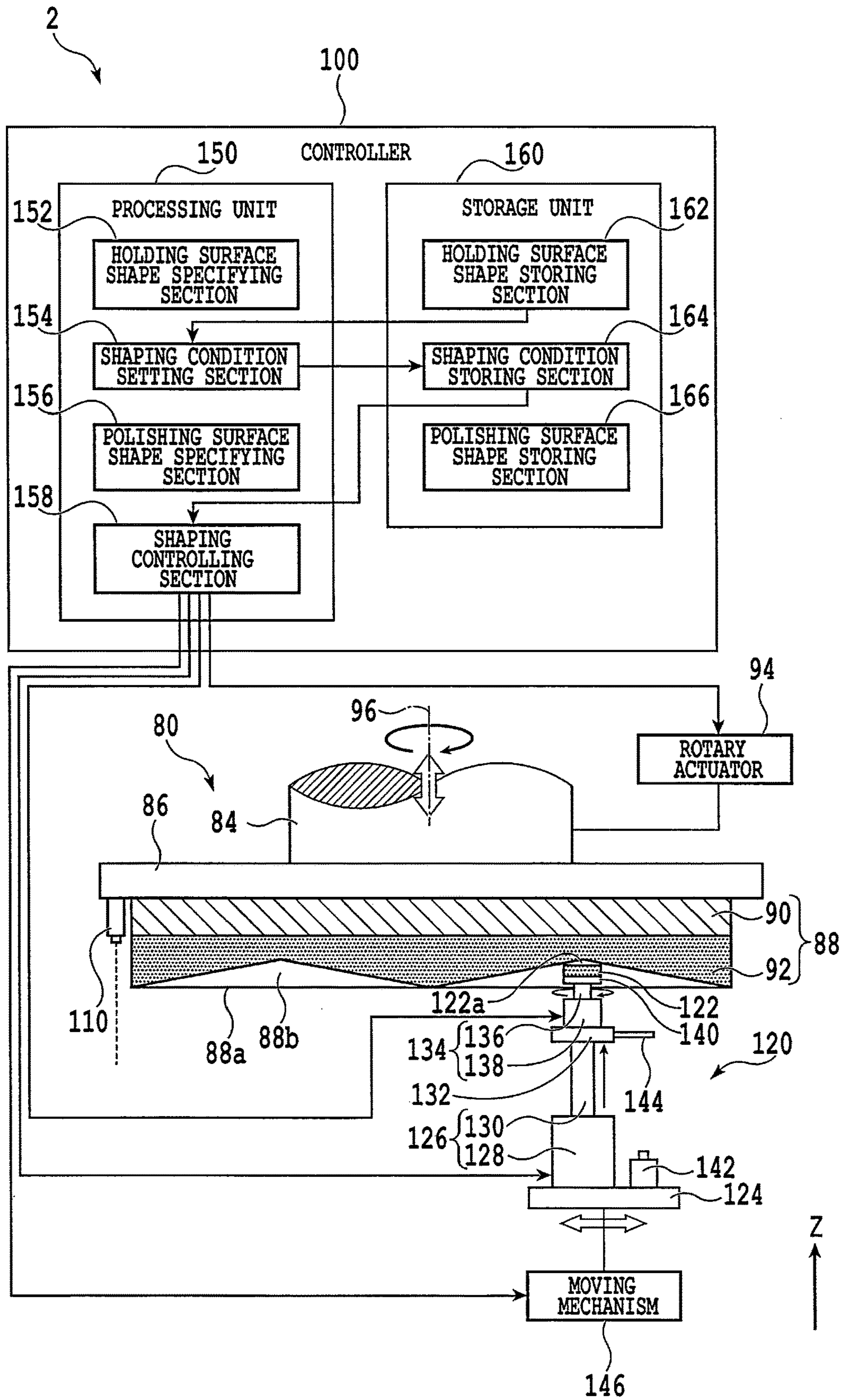


FIG.8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HOLDING SURFACE SHAPE SPECIFYING SECTION
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154
SHAPING CONDITION SETTING SECTION
164
SHAPING CONDITION STORING SECTION
156
POLISHING SURFACE SHAPE SPECIFYING SECTION
166
POLISHING SURFACE SHAPE STORING SECTION
158
SHAPING CONTROLLING SECTION
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ROTARY ACTUATOR
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88b
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144
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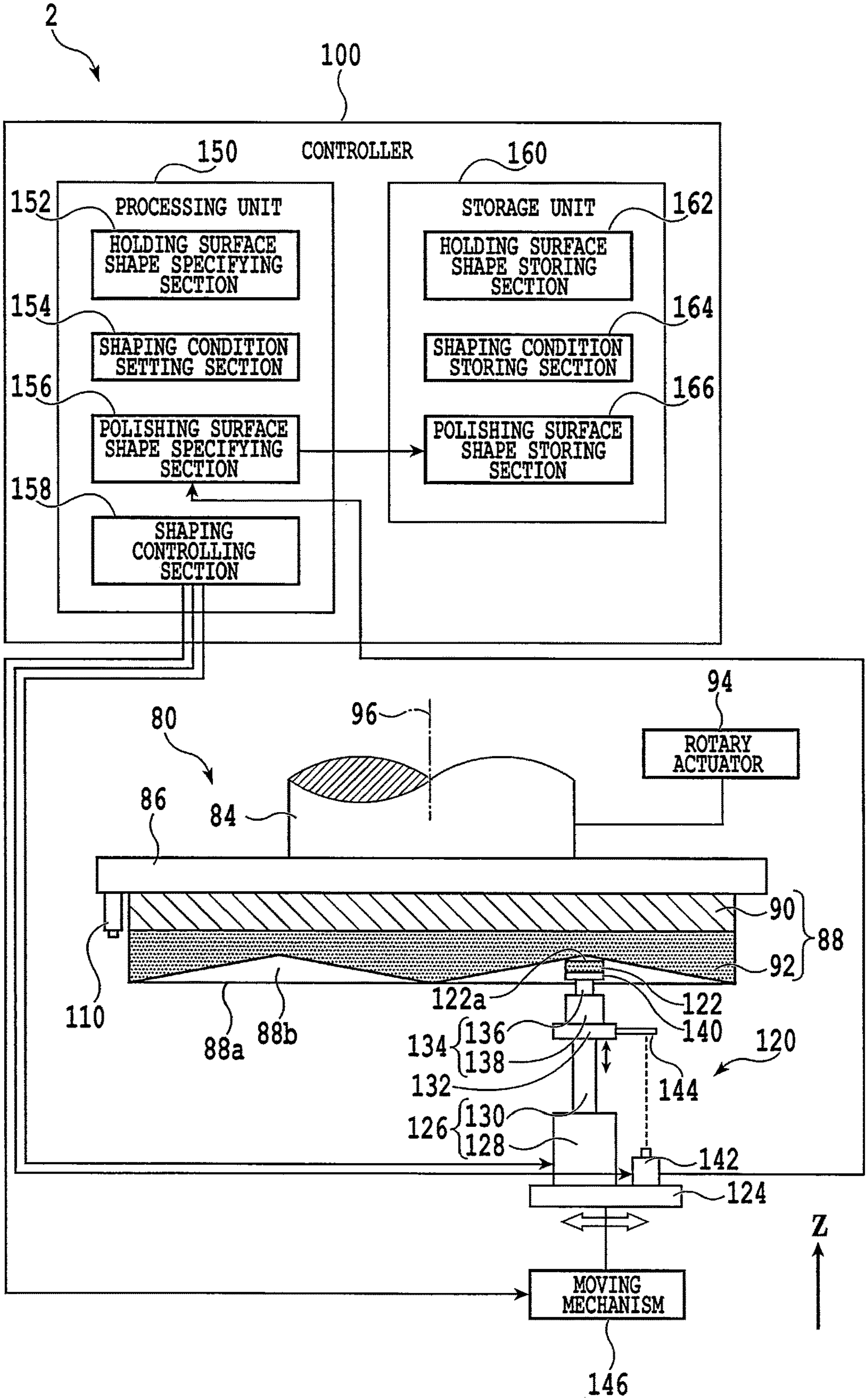
142
124
Z
MOVING MECHANISM
146

FIG.9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PROCESSING UNIT
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HOLDING SURFACE SHAPE SPECIFYING SECTION
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SHAPING CONDITION SETTING SECTION
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POLISHING SURFACE SHAPE SPECIFYING SECTION
158
SHAPING CONTROLLING SECTION
160
STORAGE UNIT
162
HOLDING SURFACE SHAPE STORING SECTION
164
SHAPING CONDITION STORING SECTION
166
POLISHING SURFACE SHAPE STORING SECTION
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ROTARY ACTUATOR
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88b
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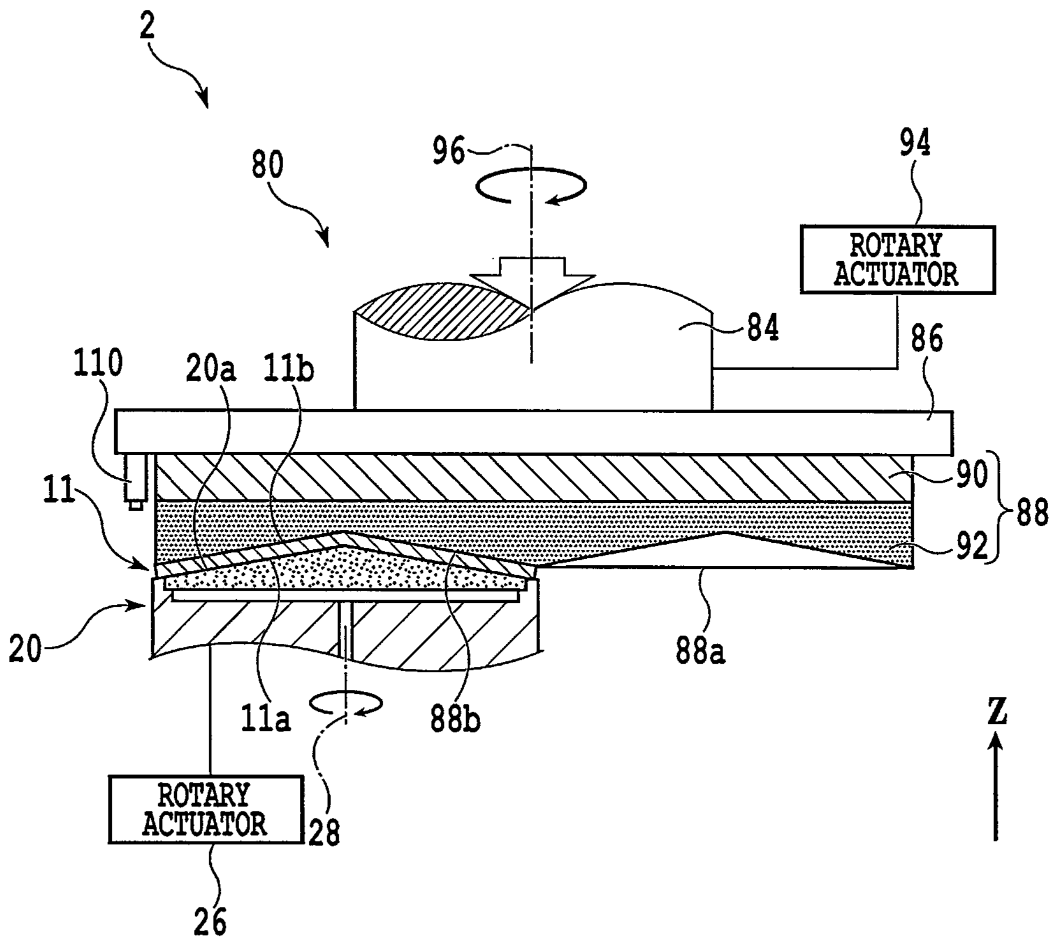
Z
MOVING MECHANISM
146

FIG.10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ROTARY ACTUATOR
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11b
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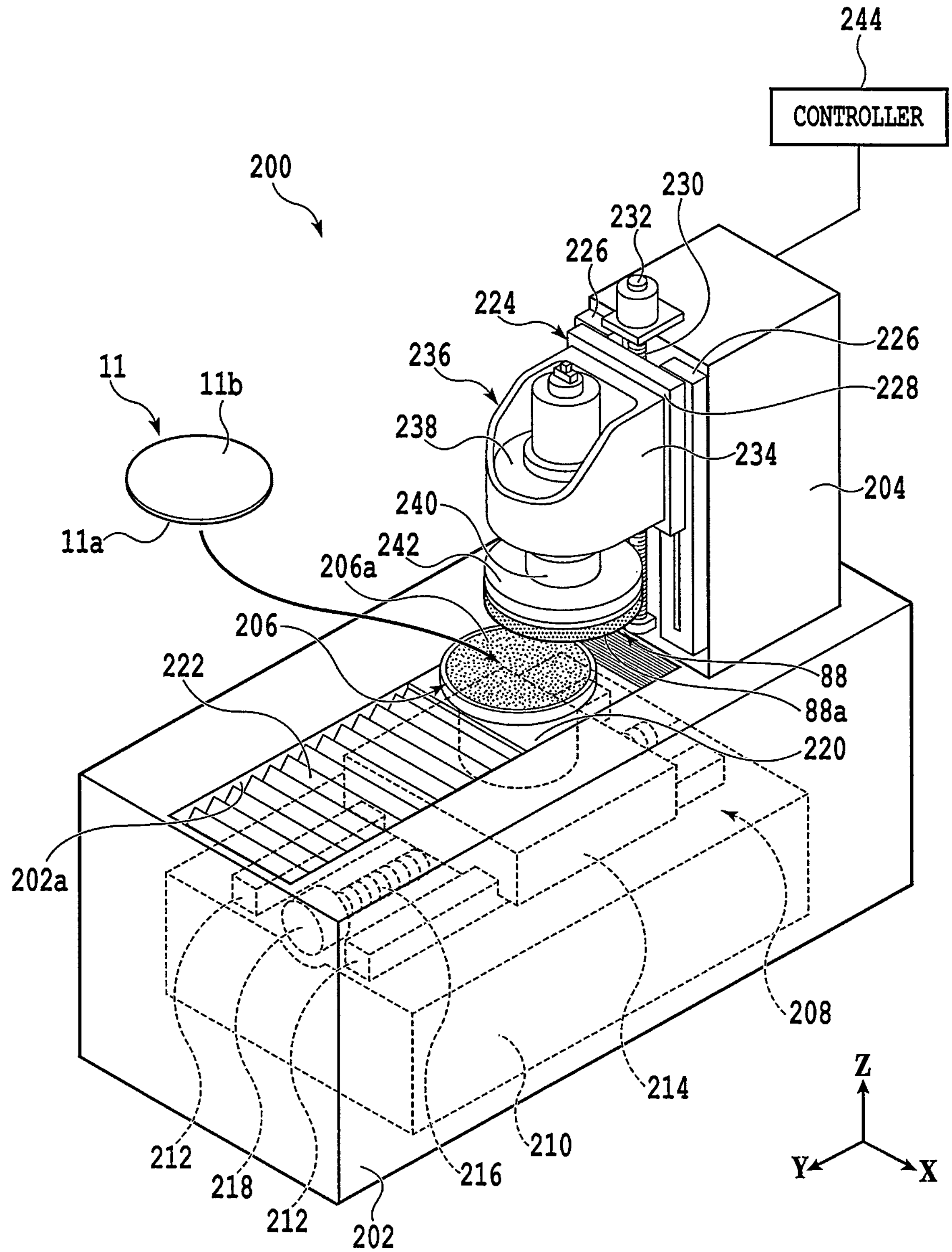
92
20
88a
11a
88b
Z
ROTARY ACTUATOR
28
26

FIG. 11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11b
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234
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240
11a
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206a
206
88
222
88a
220
202a
208
214
Z
212
210
Y
X
218
216
212
202

PROCESSING APPARATUS AND POLISHING SURFACE SHAPING METHOD

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to a processing apparatus for shaping, i.e., dressing, a polishing surface of a polishing pad that polishes a workpiece, and a polishing surface shaping method.

Description of the Related Art

[0002] According to a process of manufacturing device chips, wafers each having devices constructed in respective areas demarcated on face sides thereof by a grid of streets or projected dicing lines are processed, e.g., ground and polished, by a processing apparatus. Each of the processed wafers is then divided into device chips that include the respective devices along the streets. The device chips thus fabricated will be incorporated into various types of electronic equipment such as cellular phones and personal computers.

[0003] If wafers from which to manufacture device chips have face sides that are not flat but contain minute surface irregularities such as faults or scratches, they tend to give rise to bending strength reductions and dimensional errors, for example, of the device chips, possibly resulting in a poor device chip quality. To avoid these deficiencies, it has been customary in the art to polish wafers with use of a polishing apparatus before the wafers are divided into device chips.

[0004] The polishing apparatus includes a chuck table for holding a workpiece, e.g., a wafer, thereon and a polishing unit for polishing the workpiece on the chuck table. The polishing unit houses a spindle therein, and a disk-shaped polishing pad is mounted on the distal end of the spindle that faces the chuck table. In operation, the workpiece is held on the chuck table, and while the chuck table and the polishing pad are being rotated about their own axes independently of each other, the polishing pad is moved toward the workpiece, bringing its polishing surface into abrasive contact with a surface to be polished, i.e., a face side, of the workpiece, thereby polishing the workpiece. By polishing the workpiece, the polishing pad removes minute surface irregularities from the face side of the workpiece, planarizing the face side of the workpiece.

[0005] If a workpiece to be polished has in-plane thickness variations, then the workpiece cannot be polished uniformly by the polishing pad and is liable to leave the thickness variations unremoved even when the workpiece is polished. In view of this drawback, there has been proposed a processing apparatus that measures a thickness distribution of a workpiece and shapes the polishing surface of a polishing pad on the basis of the measured thickness distribution of the workpiece (see JP 2015-223636A). The proposed processing apparatus makes it possible to press the polishing pad uniformly against a workpiece that contains thickness variations, so that the thickness variations of the workpiece can be reduced after it has been polished.

SUMMARY OF THE INVENTION

[0006] When a workpiece is polished on a processing apparatus, the workpiece is held on a holding surface of a chuck table. However, the holding surface of the chuck table may not have been formed flatwise because of the specifications of the processing apparatus. In this case, even though the workpiece itself has a uniform thickness, the workpiece held on the chuck table is deformed to match the shape of the holding surface and fails to keep its face side at a constant height. As a result, the force, i.e., the polishing pressure, applied to the workpiece when the polishing pad is pressed against the face side of the workpiece tends to become irregular, with the result that the polished workpiece is likely to have thickness variations.

[0007] The present invention has been made in view of the above problems. It is an object of the present invention to provide a processing apparatus and a polishing surface shaping method that are capable of reducing thickness variations of a processed workpiece.

[0008] In accordance with an aspect of the present invention, there is provided a processing apparatus including a chuck table having a holding surface for holding a workpiece thereon, a chuck table rotary actuator for rotating the chuck table about an axis extending across the holding surface, a polishing unit on which a polishing pad having a polishing surface for polishing the workpiece is mounted, a polishing pad rotary actuator for rotating the polishing pad about an axis extending across the polishing surface, a polishing moving mechanism for moving the chuck table and the polishing pad relatively to each other along a first direction across the holding surface and the polishing surface, a shape measuring instrument for measuring a shape of the holding surface, a shaping mechanism for shaping the polishing surface while in contact therewith, a shaping moving mechanism for moving the polishing pad and the shaping mechanism relatively to each other along a second direction across the first direction, and a controller for controlling shaping of the polishing surface with the shaping mechanism depending on the shape of the holding surface that has been measured by the shape measuring instrument, thereby to make the polishing surface complementary in shape to the holding surface.

[0009] Preferably, a diameter of the polishing pad is at least twice a diameter of the workpiece. Preferably, the shaping mechanism has a shaping member for shaping the polishing surface while in contact therewith and a displacement measuring instrument for measuring an amount of displacement of the shaping member in the first direction, and the controller specifies a shape of the polishing surface on the basis of the amount of displacement of the shaping member that has been measured by the displacement measuring instrument when the shaping member has contacted the polishing surface at a plurality of positions.

[0010] In accordance with another aspect of the present invention, there is provided a polishing surface shaping method including measuring a shape of a holding surface of a chuck table for holding a workpiece thereon, and shaping a polishing surface of a polishing pad for polishing the workpiece by bringing a shaping member for shaping the polishing surface into contact with the polishing surface depending on the shape of the holding surface that has been measured in the measuring of the holding surface, thereby to make the polishing surface complementary in shape to the holding surface.

[0011] Preferably, the polishing surface shaping method further includes specifying a shape of the polishing surface on the basis of an amount of displacement of the shaping member when the shaping member has contacted the polishing surface shaped in the shaping at a plurality of positions. Preferably, the holding surface of the chuck table is of a conical shape, and in the shaping, the polishing surface of the polishing pad is shaped to form in the polishing surface an annular recess that is complementary in shape to the holding surface.

[0012] The processing apparatus and the polishing surface shaping method according to the aspects of the present invention measure the shape of the holding surface of the chuck table and shape the polishing surface of the polishing pad depending on the measured shape of the holding surface. It is thus possible to make the shape of the polishing surface of the polishing pad complementary in shape to the holding surface of the chuck table. Therefore, at the time the workpiece is held on the chuck table and polished by the polishing pad, thickness variations of the workpiece are reduced.

[0013] 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 preferred embodiments of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] FIG. **1** is a perspective view of a processing apparatus according to a first embodiment of the present invention;

[0015] FIG. **2** is an enlarged cross-sectional view of a chuck table of the processing apparatus;

[0016] FIG. **3** is a side elevational view, partly in cross-section of a grinding unit of the processing apparatus;

[0017] FIG. **4** is a side elevational view, partly in cross-section, of a polishing unit of the processing apparatus;

[0018] FIG. **5** is a flowchart of a sequence of a polishing surface shaping method;

[0019] FIG. **6** is a side elevational view, partly in cross-section and partly in block form, of the processing apparatus in a holding surface measuring step of the polishing surface shaping method;

[0020] FIG. **7** is a plan view of the chuck table and a shape measuring instrument;

[0021] FIG. **8** is a side elevational view, partly in cross-section and partly in block form, of the processing apparatus in a shaping step of the polishing surface shaping method;

[0022] FIG. **9** is a side elevational view, partly in cross-section and partly in block form, of the processing apparatus in a polishing surface shape specifying step of the polishing surface shaping method;

[0023] FIG. **10** is a side elevational view, partly in cross-section, illustrating the manner in which the processing apparatus polishes a workpiece; and

[0024] FIG. **11** is a perspective view of a processing apparatus according to a second embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

First Embodiment

[0025] A first embodiment of the present invention will be described below with reference to the accompanying drawings. First, a structural example of a processing apparatus according to the first embodiment will be described below. FIG. **1** illustrates in perspective the processing apparatus, i.e., a grinding and polishing apparatus, denoted by **2**, that is capable of grinding and polishing a workpiece **11**. In FIG. **1**, the processing apparatus **2** is illustrated in reference to a three-dimensional coordinate system having an X-axis, a Y-axis, and a Z-axis. The X-axis and the Y-axis extend perpendicularly to each other, and the Z-axis extends perpendicularly to the X-axis and the Y-axis. The X-axis refers to an axis along which first horizontal directions or leftward and rightward directions are defined, and the Y-axis refers to an axis along which second horizontal directions or forward and rearward directions are defined. The Z-axis refers to an axis along which vertical directions, heightwise directions, or upward and downward directions are defined.

[0026] The workpiece **11** includes, for example, a disk-shaped wafer made of a semiconductor material such as monocrystalline silicon, for example, and has a face side, i.e., a first surface, **11***a* and a reverse side, i.e., a second surface, **11***b* that lie opposite each other and that extend generally parallel to each other. The workpiece **11** has a plurality of rectangular areas demarcated by a grid of streets or projected dicing lines established thereon. Devices, not depicted, such as integrated circuits (ICs), large-scale-integration (LSI) circuits, light-emitting diodes (LEDs), or microelectromechanical-systems (MEMS) devices, for example, are constructed respectively in the demarcated rectangular areas on the face side **11***a*.

[0027] When the workpiece **11** is divided along the streets, a plurality of device chips including the respective devices are fabricated from the workpiece **11**. The workpiece **11** is divided by a processing apparatus such as a cutting apparatus for cutting the workpiece **11** with an annular cutting blade or a laser processing apparatus for processing the workpiece **11** with a laser beam applied thereto, for example. The processing apparatus **2** grinds and polishes the reverse side **11***b* of the workpiece **11** before the workpiece **11** is divided. When the reverse side **11***b* of the workpiece **11** is ground and polished, the workpiece **11** is thinned down, and the reverse side **11***b* of the workpiece **11** is planarized.

[0028] The workpiece **11** is not limited to any particular kinds, materials, sizes, shapes, and structures. For example, the workpiece **11** may include a substrate or wafer made of a semiconductor other than silicon, e.g., GaAs, InP, GaN, SiC, or sapphire, glass, ceramic, resin, or metal, for example. The devices are not limited to any particular kinds, numbers, shapes, structures, sizes, and layouts, for example. The workpiece **11** may even be free of the devices.

[0029] According to the present embodiment, the reverse side **11***b* of the workpiece **11** will be described by way of example as a processed surface, i.e., a ground surface and polished surface, that is ground and polished by the processing apparatus **2**. While the reverse side **11***b* of the workpiece **11** is being processed, a protective member may be attached to the face side **11***a* of the workpiece **11**. For example, a film-shaped protective sheet made of resin is affixed as the protective member to the face side **11***a* of the workpiece **11**, thereby protecting the face side **11***a* of the workpiece **11**.

[0030] The processing apparatus **2** includes a foundation base **4** supporting and/or housing various components of the processing apparatus **2**. The foundation base **4** has an opening **4***a* defined in an upper surface of a front end portion thereof. The opening **4***a* houses therein a delivery unit, i.e., a delivery mechanism, **6** for delivering the workpiece **11**. For example, the delivery unit **6** includes a delivery robot having a robot hand, i.e., an end effector, for capable of holding the workpiece **11**.

[0031] A pair of cassette support tables **8**A and **8**B are mounted on a front end of the foundation base **4** forwardly of the opening **4***a*. The cassette support tables **8**A and **8**B support box-shaped cassettes **10**A and **10**B respectively thereon. Each of the cassettes **10**A and **10**B includes a receptacle capable of storing a plurality of workpieces **11** to be processed by the processing apparatus **2**. For processing workpieces **11** on the processing apparatus **2**, the cassettes **10**A and **10**B with the workpieces **11** stored therein are set on the respective cassette support tables **8**A and **8**B.

[0032] An alignment mechanism, i.e., a positioning mechanism, **12** for positioning a workpiece **11** supplied thereto is disposed on the foundation base **4** obliquely rearwardly of the opening **4***a*. The alignment mechanism **12** includes, for example, a temporary rest table for supporting the workpiece **11** temporarily placed thereon and a circular array of radially movable pins for contacting the outer circumferential edge of the workpiece **11** placed on the temporary rest table and gripping the workpiece **11**. The workpieces **11** stored in the cassettes **10**A and **10**B are delivered one at a time to the alignment mechanism **12** by the delivery unit **6**. The alignment mechanism **12** holds the delivered workpiece **11** on the temporary rest table and grips the workpiece **11** with the plurality of movable pins, thereby bringing the workpiece **11** into a predetermined position on the temporary rest table.

[0033] In the vicinity of the alignment mechanism **12**, there are disposed a delivery unit, i.e., a delivery mechanism or a loading arm, **14** and a delivery unit, i.e., a delivery mechanism or an unloading arm, **16**, each for holding and turning a workpiece **11** supplied thereto. The delivery units **14** and **16** are positioned behind the opening **4***a*. Each of the delivery units **14** and **16** includes one or more suction pads for attracting the upper surface of the workpiece **11** under suction and delivering the attracted workpiece **11**.

[0034] A moving mechanism **18** is disposed on the foundation base **4** behind the alignment mechanism **12** and the delivery units **14** and **16**. The moving mechanism **18** includes a disk-shaped turntable, for example, and a rotary actuator, not depicted, such as an electric motor, coupled to the turntable for rotating the turntable about a vertical axis extending generally parallel to the Z-axis.

[0035] A plurality of chuck tables, i.e., holding tables, **20** each for holding a workpiece **11** are mounted on the moving mechanism **18**. Each of the chuck tables **20** has an upper surface acting as a holding surface for holding a workpiece **11** thereon. The chuck tables **20** include four chuck tables **20**, for example, angularly spaced at substantially equal intervals, i.e., 90° intervals, along circumferential directions of the moving mechanism **18**. While the moving mechanism **18** is in operation, the rotary actuator intermittently rotates the turntable about the vertical axis counterclockwise as viewed in plan in the direction indicated by the arrow x, positioning each of the chuck tables **20** successively in a delivery zone A, a grinding zone B, i.e., a first grinding zone or a coarsely grinding zone, a grinding zone C, i.e., a second grinding zone or a finishingly grinding zone, a polishing zone D, and back in the delivery zone A.

[0036] The delivery unit **14** holds a workpiece **11** that has been positioned by the alignment mechanism **12** and moves the workpiece **11** rearwardly, thereby delivering the workpiece **11** from the alignment mechanism **12** to a chuck table **20** positioned in the delivery zone A. The delivery unit **16** holds a workpiece **11** held on a chuck table **20** that has been positioned in the delivery zone A and moves the workpiece **11** forwardly, thereby delivering the workpiece **11** from the chuck table **20** in the delivery zone A to a cleaning unit **98** to be described later.

[0037] FIG. **2** illustrates one of the chuck tables **20** in cross section. All the chuck tables **20** are structurally identical to each other. The chuck table **20** includes a cylindrical frame body or main body **22** made of a metal material such as stainless steel (SUS), glass, ceramic, or resin, for example. The frame body **22** has an annular upper surface **22***a* extending circumferentially therealong and an upwardly open, hollow cylindrical recess **22***b* defined therein that is concentrically encircled by the annular upper surface **22***a*. A disk-shaped holding member **24** made of a porous material such as porous ceramic is fitted in the recess **22***b*. The holding member **24** contains a multiplicity of pores defined therein that are interconnected from upper to lower surfaces of the holding member **24**. When the chuck table **20** holds a workpiece **11** on the holding member **24**, the upper surface of the holding member **24** acts as a circular suction surface **24***a* that attracts the workpiece **11** under suction.

[0038] The upper surface **22***a* of the frame body **22** and the suction surface **24***a* of the holding member **24** jointly make up a holding surface **20***a* of the chuck table **20**. The holding surface **20***a* is fluidly connected to a suction source, not depicted, such as an ejector, via the pores contained in the holding member **24**, a fluid channel **22***c* defined in the frame body **22**, and a valve, not depicted. With the workpiece **11** placed on the holding surface **20***a* of the chuck table **20**, the suction source is actuated to generate and apply a suction force, i.e., a negative pressure via the valve, the fluid channel **22***c*, and the pores in the holding member **24** to the holding surface **20***a*, whereupon the workpiece **11** is held under suction on the chuck table **20**.

[0039] The holding surface **20***a* of the chuck table **20** is of an upwardly protruding conical shape whose apex is aligned with the center of the holding surface **20***a*. Therefore, the holding surface **20***a* is slightly inclined to a diametrical plane that lies perpendicularly to the central axis of the chuck table **20**. In FIG. **2** and some other figures, the inclination of the holding surface **20***a* is illustrated as exaggerated for a better understanding of the present embodiment. Actually, however, the holding surface **20***a* is inclined to a much smaller extent. For example, in case the holding surface **20***a* has a diameter ranging approximately from 290 mm to 310 mm, the difference between the heights of the center of the holding surface **20***a* and its outer circumferential edge, i.e., the height of the conical shape, is approximately in the range from 20 to 40 μm.

[0040] A rotary actuator, i.e., a chuck table rotary actuator, **26** for rotating the chuck table **20** is coupled to the chuck table **20**. The rotary actuator **26** includes an electric motor, for example, for rotating the chuck table **20** about a rotation axis, i.e., a chuck table axis, **28** that is aligned with the central axis of the chuck table **20** and extends across the holding surface **20***a*. For example, the rotation axis **28**

extends perpendicularly to the diametrical plane, referred to above, and extends across the holding surface **20***a* through the center thereof.

[0041] A tilt adjusting mechanism, not depicted, for adjusting tilt of the chuck table **20** is operatively coupled to the chuck table **20**. The tilt adjusting mechanism is actuated to adjust the tilt of the chuck table **20** to switch between a vertical position in which the rotation axis **28** extends along the Z-axis and a tilted position in which the rotation axis **28** is tilted from the Z-axis.

[0042] For grinding a workpiece **11** held on the chuck table **20**, the tilt adjusting mechanism is actuated to adjust the tilt of the chuck table **20** such that the rotation axis **28** is slightly tilted from the Z-axis (see FIG. **3**). At this time, a grinding holding region **20***b* that is part of the holding surface **20***a* and extends from the center of the holding surface **20***a* radially outwardly to an outer circumferential edge thereof lies generally parallel to a horizontal plane, i.e., an XY plane, along the X-axis and the Y-axis. Then, the workpiece **11** is placed and held on the holding surface **20***a* of the chuck table **20**, and a region of the reverse side **11***b* of the workpiece **11** that is held on the grinding holding region **20***b* and close regions thereto is ground by grinding units **42**A and **42**B to be described later. In FIG. **3**, the region of the reverse side **11***b* of the workpiece **11** is illustrated as being ground by the grinding unit **42**A. For polishing a workpiece **11** held on the chuck table **20**, the tilt adjusting mechanism is actuated to adjust the tilt of the chuck table **20** such that the rotation axis **28** extends generally parallel to the Z-axis (see FIG. **4**). The workpiece **11** is placed and held on the holding surface **20***a* of the chuck table **20**, and the reverse side **11***b* of the workpiece **11** is polished in its entirety by a polishing unit **80** to be described later.

[0043] As illustrated in FIG. **1**, the processing apparatus **2** includes a pair of support structures **30**A and **30**B mounted on a rear end portion of the foundation base **4** behind the moving mechanism **18** and the chuck tables **20** thereon. The support structures **30**A and **30**B, each in the shape of a rectangular parallelepiped, protrude upwardly from the upper surface of the foundation base **4**. Also, the support structures **30**A and **30**B have respective face sides, i.e., front surfaces, lying generally parallel to a vertical plane, i.e., an XZ plane along the X-axis and the Z-axis. The support structures **30**A and **30**B are disposed adjacent to each other, i.e., spaced from each other, along the X-axis.

[0044] A moving mechanism, i.e., a grinding moving mechanism, **32**A for moving the grinding unit **42**A along the Z-axis is mounted on the face side of the support structure **30**A. A moving mechanism, i.e., a grinding moving mechanism, **32**B for moving the grinding unit **42**B along the Z-axis is mounted on the face side of the support structure **30**B.

[0045] The moving mechanisms **32**A and **32**B have respective pairs of guide rails **34** extending along the Z-axis and mounted respectively on the face sides of the support structures **30**A and **30**B. A movable plate **36** shaped as a flat plate is slidably mounted on the guide rails **34** in each pair for sliding movement along the guide rails **34**. A nut, not depicted, is fixedly disposed on a reverse side, i.e., a rear surface, of the movable plate **36** and operatively threaded over a ball screw **38** that is disposed between the guide rails **34** and extends along the Z-axis. The ball screw **38** has an upper end to which a stepping motor **40** is coupled for rotating the ball screw **38** about its central axis. When the stepping motor **40** is energized, it rotates the ball screw **38** about its central axis, causing the nut to move the movable plate **36** along the Z-axis along the guide rails **34**.

[0046] The grinding unit **42**A for coarsely grinding a workpiece **11** on the chuck table **20** in the grinding zone B is fixedly mounted on a face side, i.e., a front surface, of the movable plate **36** of the moving mechanism **32**A. The grinding unit **42**B for finishingly grinding a workpiece **11** on the chuck table **20** in the grinding zone C is fixedly mounted on a face side, i.e., a front surface, of the movable plate **36** of the moving mechanism **32**B. The grinding unit **42**A is positioned above the grinding zone B, whereas the grinding unit **42**B is positioned above the grinding zone C.

[0047] Each of the grinding units **42**A and **42**B includes a tubular housing **44** and a cylindrical spindle **46** extending along the Z-axis and rotatably disposed in the housing **44** for rotation around the Z-axis. The spindle **46** has a lower distal end portion protruding downwardly from the lower end of the housing **44**. A disk-shaped mount **48** made of metal, for example, is fixed to a lower distal end of the spindle **46**.

[0048] The mount **48** of the grinding unit **42**A has a lower surface on which a grinding wheel **50**A for coarsely grinding a workpiece **11** is mounted. The mount **48** of the grinding unit **42**B has a lower surface on which a grinding wheel **50**B for finishingly grinding a workpiece **11** is mounted. The grinding wheels **50**A and **50**B are detachably fastened to the respective mounts **48** by fasteners such as bolts.

[0049] FIG. **3** illustrates the grinding unit **42**A in side elevation, partly in cross-section. As illustrated in FIG. **3**, the grinding wheel **50**A includes an annular wheel base **52** made of a metal material such as aluminum alloy, for example, and a plurality of grindstones **54** fixed to a lower surface of the wheel base **52**. The grindstones **54** have respective lower surfaces collectively acting as a grinding surface **54***a* for grinding the workpiece **11** in abrasive contact therewith. Each of the grindstones **54** is made of abrasive grains of diamond and cubic boron nitride (cBN), for example, fixedly bound together by a binder or a bonding material such as a metal bond, a resin bond, or a vitrified bond. The grindstones **54**, each shaped as a rectangular parallelepiped, for example, are arranged in an annular array at substantially equal spaced intervals along the outer circumferential edge of the wheel base **52**.

[0050] The spindle **46** has an upper proximal end that is coupled to a rotary actuator, i.e., a grinding wheel rotary actuator, **56** for rotating the grinding wheel **50**A. The rotary actuator **56** includes an electric motor, for example, that rotates the spindle **46** about a rotation axis, i.e., a grinding wheel axis, **58** that extends perpendicularly to the grinding surface **54***a*. For example, the rotation axis **58** extends generally parallel to the Z-axis. When the rotary actuator **56** is energized, it rotates the spindle **46**, the mount **48**, and the grinding wheel **50**A about the rotation axis **58**, turning the grindstones **54** along an annular turn path generally parallel to the horizontal plane, i.e., the XY plane.

[0051] The grinding unit **42**B and the grinding wheel **50**B (see FIG. **1**) are similar in structure and function to the grinding unit **42**A and the grinding wheel **50**A, respectively. However, the abrasive grains contained in the grindstones **54** of the grinding wheel **50**B are smaller in average grain size than the abrasive grains contained in the grindstones **54** of the grinding wheel **50**A.

[0052] A workpiece **11** is ground successively by the grinding units **42**A and **42**B as follows. The workpiece **11** is delivered to the chuck table **20** positioned in the delivery zone A (see FIG. **1**) and held on the chuck table **20**. Specifically, the workpiece **11** is placed on the chuck table **20** such that the reverse side **11***b*, i.e., the processed surface, is exposed upwardly and the face side **11***a* faces the holding surface **20***a*. When the suction force from the suction source is then applied to act on the holding surface **20***a*, the workpiece **11** is held under suction on the chuck table **20**. In case the protective member is attached to the face side **11***a* of the workpiece **11**, the workpiece **11** is held under suction on the chuck table **20** through the protective member interposed therebetween.

[0053] As described above, the holding surface **20***a* of the chuck table **20** is of an upwardly protruding conical shape. When the workpiece **11** is held under suction on the chuck table **20**, the workpiece **11** is slightly flexibly deformed along the conical holding surface **20***a*. The region of the reverse side **11***b* of the workpiece **11** that is held on the grinding holding region **20***b* and close regions thereto are disposed generally parallel to the horizontal plane, i.e., the XY plane.

[0054] Then, the moving mechanism **18** (see FIG. **1**) is actuated to move and position the chuck table **20** that is holding the workpiece **11** in the grinding zone B. The workpiece **11** that is held on the chuck table **20** is positioned beneath the grinding wheel **50**A. At this time, the chuck table **20** is positioned such that the center of the workpiece **11** and the annular turn path along which the grindstones **54** will turn overlap each other along the Z-axis.

[0055] The chuck table rotary actuator **26** rotates the chuck table **20** about the rotation axis **28**, and the grinding wheel rotary actuator **56** rotates the grinding wheel **50**A about the rotation axis **58**. At the same time, the moving mechanism **32**A (see FIG. **1**) lowers the grinding wheel **50**A to bring the grinding surface **54***a* of the grindstones **54** into abrasive contact with the reverse side **11***b* of the workpiece **11**. The grinding surface **54***a* of the grindstones **54** now grinds the reverse side **11***b* of the workpiece **11** in its entirety, thereby coarsely grinding and hence thinning down the workpiece **11**. When the workpiece **11** has been thinned down to a predetermined thickness, the moving mechanism **32**A stops lowering the grinding wheel **50**A. The process of coarsely grinding the workpiece **11** on the grinding unit **42**A is now completed.

[0056] Then, the moving mechanism **18** (see FIG. **1**) is actuated to move and position the chuck table **20** that is holding the workpiece **11** in the grinding zone C. The workpiece **11** that is held on the chuck table **20** is positioned beneath the grinding wheel **50**B. The grinding wheel **50**B now finishingly grinds the reverse side **11***b* of the workpiece **11** in its entirety. The grinding wheel **50**B grinds the workpiece **11** in essentially the same manner as the grinding wheel **50**A grinds the workpiece **11**.

[0057] A nozzle, not depicted, for supplying a grinding liquid such as pure water, for example, is provided in or near each of the grinding units **42**A and **42**B. While each of the grinding units **42**A and **42**B is grinding the workpiece **11**, the nozzle continuously supplies the workpiece **11** and the grindstones **54** with the grinding liquid. The grinding liquid thus supplied cools the workpiece **11** and the grindstones **54** and washes away debris or swarf produced while the grindstones **54** grind the workpiece **11**.

[0058] The workpiece **11** has now been coarsely and finishingly ground by the grinding wheels **50**A and **50**B. When the grindstones **54** grind the reverse side **11***b* of the workpiece **11**, they tend to leave arcuate saw marks on the reverse side **11***b* along the turn path followed by the grindstones **54**.

[0059] As illustrated in FIG. **1**, the processing apparatus **2** further includes a support structure **60** mounted on a side wall of the foundation base **4** alongside of the polishing zone D, i.e., the moving mechanism **18**. The support structure **60** is in the shape of a rectangular parallelepiped and has a face side facing the moving mechanism **18** and lying generally parallel to a vertical plane, i.e., a YZ plane along the Y-axis and the Z-axis. A moving mechanism, i.e., a polishing moving mechanism, **62** for moving the polishing unit **80** along the Y-axis and the Z-axis is mounted on the face side of the support structure **60**.

[0060] The moving mechanism **62** has a pair of Y-axis guide rails **64** extending along the Y-axis and mounted on the face side of the support structure **60**. A Y-axis movable plate **66** shaped as a flat plate is slidably mounted on the Y-axis guide rails **64** for sliding movement along the Y-axis guide rails **64**. A nut, not depicted, is fixedly disposed on a reverse side, i.e., a rear surface, of the Y-axis movable plate **66** and operatively threaded over a Y-axis ball screw **68** that is disposed between the Y-axis guide rails **64** and extends along the Y-axis. The Y-axis ball screw **68** has an end to which a Y-axis stepping motor **70** is coupled for rotating the Y-axis ball screw **68** about its central axis. When the Y-axis stepping motor **70** is energized, it rotates the Y-axis ball screw **68** about its central axis, causing the nut to move the Y-axis movable plate **66** along the Y-axis along the Y-axis guide rails **64**.

[0061] A pair of Z-axis guide rails **72** extending along the Z-axis are mounted on a face side of the Y-axis movable plate **66** that faces the moving mechanism **18**. A Z-axis movable plate **74** shaped as a flat plate is slidably mounted on the Z-axis guide rails **72** for sliding movement along the Z-axis guide rails **72**. A nut, not depicted, is fixedly disposed on a reverse side, i.e., a rear surface, of the Z-axis movable plate **74** and operatively threaded over a Z-axis ball screw **76** that is disposed between the Z-axis guide rails **72** and extends along the Z-axis. The Z-axis ball screw **76** has an upper end to which a Z-axis stepping motor **78** is coupled for rotating the Z-axis ball screw **76** about its central axis. When the Z-axis stepping motor **78** is energized, it rotates the Z-axis ball screw **76** about its central axis, causing the nut to move the Z-axis movable plate **74** along the Z-axis along the Z-axis guide rails **72**.

[0062] The polishing unit **80** for polishing a workpiece **11** on the chuck table **20** in the polishing zone D is fixedly mounted on a face side of the Z-axis movable plate **74** that faces the moving mechanism **18**. The polishing unit **80** is positioned above the polishing zone D. The moving mechanism **62** controls the movement of the polishing unit **80** along the Y-axis and the Z-axis. However, in case it is possible for the moving mechanism **18** to adjust the positional relation of the chuck table **20** and the polishing unit **80** along the Y-axis, the moving mechanism **62** may be free of the mechanism for moving the polishing unit **80** along the Y-axis, i.e., the Y-axis guide rails **64**, the Y-axis movable plate **66**, the Y-axis ball screw **68**, and the Y-axis stepping motor **70**.

[0063] The polishing unit **80** includes a tubular housing **82** and a cylindrical spindle **84** extending along the Z-axis and rotatably disposed in the housing **82** for rotation around the Z-axis. The spindle **84** has a lower distal end portion protruding downwardly from the lower end of the housing **82**. A disk-shaped mount **86** made of metal, for example, is fixed to a lower distal end of the spindle **84**. The mount **86** has a lower surface on which a polishing pad **88** for polishing the workpiece **11** is mounted. The polishing pad **88** is detachably fastened to the mount **86** by fasteners such as bolts.

[0064] FIG. **4** illustrates the polishing unit **80** in side elevation, partly in cross-section. As illustrated in FIG. **4**, the polishing pad **88** includes a disk-shaped base **90** and a polishing layer **92** fixed to the base **90**. The base **90** is made of a metal material such as aluminum alloy, for example, and is substantially equal in diameter to the mount **86**. The polishing layer **92** is of a disk shape that is substantially equal in diameter to the base **90**, and is secured to the lower surface of the base **90** by way of adhesive bonding, for example.

[0065] The polishing layer **92** is made of a non-woven fabric such as felt or resin such as polyurethane, for example, and contains abrasive grains, i.e., bound abrasive grains. For example, particles of silica or alumina having an average gain size ranging from 0.2 to 0.5 μm are retained in the polishing layer **92**. The abrasive grains may be made of a material and may have a grain size that are appropriately selected depending on the material of the workpiece **11**, and the like. The polishing layer **92** has a lower surface acting as a polishing surface **88***a* for polishing the workpiece **11** in abrasive contact therewith.

[0066] The spindle **84** has an upper proximal end that is coupled to a rotary actuator, i.e., a polishing pad rotary actuator, **94** for rotating the polishing pad **88**. The rotary actuator **94** includes an electric motor, for example, that rotates the spindle **84** about a rotation axis, i.e., a polishing pad axis, **96** that extends across the polishing surface **88***a*. For example, the rotation axis **96** extends generally parallel to the Z-axis. When the rotary actuator **94** is energized, it rotates the spindle **84**, the mount **86**, and the polishing pad **88** about the rotation axis **96**.

[0067] When the moving mechanism **62** (see FIG. **1**) moves the polishing unit **80** along the Z-axis, the chuck table **20** and the polishing pad **88** move relatively to each other in a first direction along the Z-axis across the holding surface **20***a* and the polishing surface **88***a*. When the moving mechanism **18** (see FIG. **1**) moves the chuck table **20** or the moving mechanism **62** (see FIG. **1**) moves the polishing unit **80** along the Y-axis, the chuck table **20** and the polishing pad **88** move relatively to each other in a second direction along the XY plane across the first direction along the Z-axis. A lifting and lowering mechanism, not depicted, for lifting and lowering the chuck table **20** along the Z-axis may be coupled to the chuck table **20**. The lifting and lowering mechanism functions as a polishing moving mechanism for moving the chuck table **20** and the polishing pad **88** relatively to each other in the first direction along the Z-axis.

[0068] When the grinding of the workpiece **11** (see FIG. **3**) is completed, the moving mechanism **18** (see FIG. **1**) is actuated to bring the chuck table **20** that is holding the ground workpiece **11** to the polishing zone D where the workpiece **11** is positioned beneath the polishing pad **88**. The moving mechanism **62** (see FIG. **1**) then adjusts the position of the polishing pad **88** along the Y-axis to position the polishing layer **92** of the polishing pad **88** over the entire reverse side **11***b*, i.e., the processed surface, of the workpiece **11**.

[0069] The tilt of the chuck table **20** is adjusted to make the rotation axis **28** generally parallel to the Z-axis. The rotation axis **28** of the chuck table **20** and the rotation axis **96** of the polishing pad **88** now lie generally parallel to each other. Then, the chuck table **20** is rotated about the rotation axis **28**, whereas the polishing pad **88** is rotated about the rotation axis **96**. The moving mechanism **62** (see FIG. **1**) lowers the polishing pad **88** to move the workpiece **11** and the polishing pad **88** relatively to each other, bringing the workpiece **11** and the polishing pad **88** toward each other along the Z-axis. The process of moving the workpiece **11** and the polishing pad **88** toward each other along the Z-axis is also referred to as a processing feed process. The polishing surface **88***a* of the polishing pad **88** now abrasively contacts the reverse side **11***b* of the workpiece **11**, starting to polish the reverse side **11***b*.

[0070] While the workpiece **11** is being polished by the polishing pad **88**, the workpiece **11** and the polishing pad **88** are supplied with a polishing liquid. The polishing liquid includes, for example, a liquid or chemical solution for performing a chemical surface treatment on the workpiece **11**. The polishing liquid may be made of a material appropriately selected depending on the material of the workpiece **11**, the purpose for which the workpiece **11** is polished, and processing conditions in which the workpiece **11** is polished, for example. Examples of the polishing liquid include an acidic solution in which permanganate is dissolved and an alkaline solution in which sodium hydroxide or potassium hydroxide is dissolved. In case the polishing layer **92** of the polishing pad **88** contains bound abrasive grains, the polishing solution contains no abrasive grains.

[0071] When the polishing liquid is supplied to an area of contact between the reverse side **11***b* of the workpiece **11** and the polishing surface **88***a* of the polishing pad **88**, the polishing liquid acts on the reverse side **11***b* of the workpiece **11**, thereby performing chemical mechanical polishing (CMP) on the reverse side **11***b* of the workpiece **11**. The polishing layer **92** of the polishing pad **88** may not contain abrasive grains. In case the polishing layer **92** is free of abrasive grains, the polishing liquid contains free abrasive grains that are supplied together with the polishing liquid to the area of contact between the workpiece **11** and the polishing pad **88**.

[0072] When the reverse side **11***b* of the workpiece **11** is thus polished by the polishing unit **80**, minute surface irregularities remaining on the reverse side **11***b* are removed, with the result that the reverse side **11***b* is planarized. For example, if saw marks remain unremoved on the reverse side **11***b* after the workpiece **11** has been ground, the saw marks are polished off when the reverse side **11***b* is polished. After the workpiece **11** has been continuously polished until its thickness reaches a predetermined thickness, the processing feed process is brought to a stop, and the polishing of the workpiece **11** is completed.

[0073] As illustrated in FIG. **1**, the processing apparatus **2** further includes a cleaning unit **98** for cleaning the polished workpiece **11**. The cleaning unit **98** is positioned on the foundation base **4** forwardly of the moving mechanism **18** and the chuck tables **20** thereon. The cleaning unit **98** includes a spinner table that rotates about its vertical axis while holding the workpiece **11** thereon and a nozzle for supplying a cleaning liquid such as pure water to the workpiece **11**. In operation, the workpiece **11** is held on the spinner table, and then the spinner table is rotated about its vertical axis while the cleaning liquid is being supplied from the nozzle to the workpiece **11**. The workpiece **11** is thus cleaned with remaining debris or swarf washed away therefrom by the cleaning liquid and under centrifugal forces generated by the rotating spinner table.

[0074] When the polishing of the workpiece **11** by the polishing unit **80** is completed, the moving mechanism **18** rotates the turntable to move the chuck table **20** that is holding the polished workpiece **11** from the polishing zone D back to the delivery zone A. The workpiece **11** is then delivered by the delivery unit **16** from the chuck table **20** to the cleaning unit **98**, and cleaned by the cleaning unit **98**. The workpiece **11** that has been cleaned is stored back into the cassette **10**A or the cassette **10**B by the delivery unit **6**.

[0075] The processing apparatus **2** includes a controller, also referred to as a control unit, a control section, or a control device, **100** for controlling the processing apparatus **2**. The controller **100** is electrically connected to various components of the processing apparatus **2** that include the delivery unit **6**, the alignment mechanism **12**, the delivery units **14** and **16**, the moving mechanism **18**, the chuck tables **20**, the rotary actuator **26**, the moving mechanisms **32**A and **32**B, the grinding units **42**A and **42**B, the rotary actuator **56**, the moving mechanism **62**, the polishing unit **80**, the rotary actuator **94**, and the cleaning unit **98** among others. The controller **100** controls the processing apparatus **2** in its operation by outputting control signals to the components of the processing apparatus **2**. For example, the controller **100** is constituted by a computer and includes a processing unit for performing processing operations such as arithmetic operations required to operate the processing apparatus **2** and a storage unit for storing various pieces of information, i.e., data and programs, used to operate the processing apparatus **2**. The processing unit includes a processor such as a central processing unit (CPU). The storage unit also includes memories such as a read only memory (ROM) and a random access memory (RAM).

[0076] For processing a workpiece **11** on the processing apparatus **2**, the holding surface **20***a* of each of the chuck tables **20** is of an upwardly protruding conical shape (see FIG. **3**). When the workpiece **11** is held on each chuck table **20**, the workpiece **11** is deformed to match the conical shape of the holding surface **20***a*. At a time at which the workpiece **11** that is held on the chuck table **20** is polished (see FIG. **4**) as described above, the processed surface of the workpiece **11** is conical in shape and does not have a constant height, and as a result, lies out of parallel with the polishing surface **88***a* of the polishing pad **88** that lies flatwise along the XY plane. If the polishing pad **88** were pressed against the conical workpiece **11** in this state, then the polishing pad **88** would be pressed strongly against the center of the workpiece **11** in particular, and the force, i.e., the polishing pressure, applied from the polishing pad **88** to the workpiece **11** would tend to become irregular within the plane of the workpiece **11**, with the result that the polished workpiece **11** would be likely to have thickness variations.

[0077] According to the present embodiment, the processing apparatus **2** shapes the polishing surface **88***a* of the polishing pad **88** to a shape matching the shape of the holding surface **20***a* of the chuck table **20**, thereby making the polishing surface **88***a* complementary in shape to the holding surface **20***a*. With the polishing surface **88***a* being thus shaped, even though the holding surface **20***a* of the chuck table **20** is not flat, it is possible for the polishing surface **88***a* to apply a uniform polishing pressure to the workpiece **11** held on the chuck table **20**, thereby reducing thickness variations of the polished workpiece **11**.

[0078] Specifically, as illustrated in FIG. **4**, the processing apparatus **2** includes a shape measuring instrument **110** for measuring the shape of the holding surface **20***a* of the chuck table **20** and a shaping mechanism (dressing mechanism) **120** for contacting and shaping, i.e., dressing, the polishing surface **88***a* of the polishing pad **88**.

[0079] The shape measuring instrument **110** includes, for example, a laser displacement meter for measuring the heightwise position, i.e., the position along the Z-axis, of the holding surface **20***a* of the chuck table **20** in a contactless manner. The laser displacement meter as the shape measuring instrument **110** operates as follows: The laser displacement meter applies a laser beam to the holding surface **20***a* and detects a laser beam reflected from the holding surface **20***a*. Then, the laser displacement meter specifies the heightwise position of the holding surface **20***a* on the basis of an amount of displacement of the detected spot of the laser beam. The shape measuring instrument **110** is not limited to the laser displacement meter, but may be of any of other types as long as it is capable of measuring the heightwise position of the holding surface **20***a*.

[0080] The shape measuring instrument **110** is coupled to a moving mechanism that moves the shape measuring instrument **110** along the horizontal plane, i.e., the XY plane. For example, as illustrated in FIG. **4**, the shape measuring instrument **110** is mounted on the lower surface of an outer circumferential edge of the mount **86** of the polishing unit **80**. The positions of the shape measuring instrument **110** along the Y-axis and the Z-axis can be adjusted by the moving mechanism **62** (see FIG. **1**). When the rotary actuator **94** is energized, the shape measuring instrument **110** turns along an annular turn path generally parallel to the horizontal plane, i.e., the XY plane, about the rotation axis **96**. When the shape measuring instrument **110** has reached a desired position on the annular turn path, the rotary actuator **94** is de-energized.

[0081] The shape measuring instrument **110** may be installed in any of other positions. For example, the shape measuring instrument **110** may be mounted on the mount **48** (see FIG. **1**) of one of the grinding units **42**A and **42**B. The shape measuring instrument **110** mounted on the mount **48** may have its position adjusted along the Z-axis by the corresponding one of the moving mechanisms **32**A and **32**B (FIG. **1**). In addition, when the rotary actuator **56** (see FIG. **3**) is energized, it turns the shape measuring instrument **110** along an annular turn path generally parallel to the horizontal plane, i.e., the XY plane, about the rotation axis **58**. Alternatively, the shape measuring instrument **110** may be coupled to a moving mechanism such as a swing arm provided separately from the grinding units **42**A and **42**B and the polishing unit **80**.

[0082] For measuring the shape of the holding surface **20***a* of the chuck table **20**, the shape measuring instrument **110** is positioned in overlapping relation to the holding surface **20***a* along the Z-axis. Then, while the chuck table **20** and the shape measuring instrument **110** are being horizontally moved relatively to each other, the shape measuring instrument **110** continuously or intermittently measures the heightwise position of the holding surface **20***a*. In this manner, the shape of the holding surface **20***a* is measured. The positional relation between the chuck table **20** and the shape measuring instrument **110** may be adjusted by moving the chuck table **20** with the moving mechanism **18** (see FIG. **1**). In this case, the shape measuring instrument **110** may not necessarily be coupled to the mounts **48** and **86** or a dedicated moving mechanism. Details of a process of measuring the shape of the holding surface **20***a* with the shape measuring instrument **110** will be described later.

[0083] As illustrated in FIG. **4**, the shaping mechanism **120** includes a shaping member (dressing member) **122** for contacting and shaping the polishing surface **88***a* of the polishing pad **88**. The shaping member **122** includes, for example, a plate-shaped or columnar grindstone including a base of metal and abrasive grains of diamond, for example, electrodeposited on the base. The shaping member **122** has an upper surface acting as a shaping surface **122***a* for contacting the polishing surface **88***a* of the polishing pad **88**, with abrasive grains exposed to an appropriate extent from the shaping surface **122***a*. The shaping mechanism **120** shapes the polishing surface **88***a* of the polishing pad **88** with the shaping surface **122***a* by moving and rotating the shaping member **122**.

[0084] The shaping mechanism **120** includes a support base **124** that supports thereon various components of the shaping mechanism **120**. The components of the shaping mechanism **120** will be described in detail below. The support base **124** supports directly thereon a lifting and lowering mechanism **126** for moving the shaping member **122** in first directions along the Z-axis, i.e., lifting and lowering the shaping member **122** along the Z-axis, across the holding surface **20***a* and the polishing surface **88***a*. The lifting and lowering mechanism **126** includes, for example, an air cylinder including a tubular cylinder **128** and a rod **130** telescopically housed in the cylinder **128**. The rod **130** has an upper distal end portion protruding upwardly from the upper end of the cylinder **128** and fixed to a support member **132**. The rod **130** has a lower end fixed to a piston, not depicted, that is movably fitted in the cylinder **128** and divides the inner space of the cylinder **128** into a first compartment and a second compartment. A pressure regulator, not depicted, and the like, controls the pressure of air supplied to the first compartment and the second compartment to move the rod **130** upwardly in a direction to protrude out of the cylinder **128** or downwardly in a direction to retract into the cylinder **128**, thereby lifting or lowering the rod **130** and the support member **132** along the Z-axis.

[0085] A rotating mechanism **134** for rotating the shaping member **122** is mounted on the support member **132**. The rotating mechanism **134** includes, for example, a cylindrical spindle **136** and a rotary actuator **138** such as an electric motor, for example, connected to the lower proximal end of the spindle **136**. The shaping member **122** is supported on a base **140** fixed to the upper distal end of the spindle **136**. The shaping member **122** supported on the base **140** has its shaping surface **122***a* exposed upwardly. When the rotary actuator **138** is energized, it rotates the shaping member **122**, the spindle **136**, and the base **140** about an axis generally parallel to the Z-axis.

[0086] The shaping mechanism **120** includes a displacement measuring instrument **142** for measuring an amount of displacement of the shaping member **122**. The displacement measuring instrument **142** directly or indirectly measures an amount of displacement, i.e., an amount of positional change, of the shaping member **122** in the first directions along the Z-axis across the holding surface **20***a* and the polishing surface **88***a*. For example, the displacement measuring instrument **142** includes a laser displacement meter mounted on the support base **124**. The shaping mechanism **120** also includes a reference element **144** that functions as a reference with respect to displacement of the shaping member **122**. The reference element **144** is made of a material that reflects light, i.e., a laser beam, emitted from the displacement measuring instrument **142**. The reference element **144** is fixed to one of the components of the shaping mechanism **120** that is lifted or lowered in unison with the shaping member **122** and positioned in overlapping relation to the displacement measuring instrument **142** along the Z-axis. In FIG. **4**, the reference element **144** is illustrated as being fixed to the support member **132**.

[0087] When the shaping member **122** is lifted or lowered along the Z-axis by the lifting and lowering mechanism **126** or an external force applied thereto, the reference element **144** is also lifted or lowered in unison with the shaping member **122**. In other words, an amount of displacement of the shaping member **122** and an amount of displacement of the reference element **144** are equal to each other. The displacement measuring instrument **142** detects light reflected by a lower surface of the reference element **144** and measures the amount of displacement of the reference element **144** along the Z-axis on the basis of the detected light. In this fashion, the displacement of the shaping member **122** is indirectly measured by the displacement measuring instrument **142**.

[0088] To the shaping mechanism **120**, there is connected a moving mechanism, i.e., a shaping moving mechanism **146**, for moving the shaping mechanism **120** in second directions, i.e., horizontal directions or along the XY plane, across the first directions along the Z-axis. The moving mechanism **146** includes, for example, a ball-screw-type moving mechanism including a ball screw, not depicted, extending along the X-axis or the Y-axis and a stepping motor, not depicted, for rotating the ball screw about its central axis. Specific structural details of the ball-screw-type moving mechanism are similar to those of the moving mechanisms **32**A and **32**B and the moving mechanism **62** (see FIG. **1**). The moving mechanism **146** is coupled to the support base **124** of the shaping mechanism **120**. When the moving mechanism **146** is actuated, it moves the support base **124** and the components supported thereon in the second or horizontal directions. The moving mechanism **146** is thus able to control the relative positional relation in the horizontal directions between the polishing pad **88** and the shaping member **122**.

[0089] The shaping mechanism **120** and the moving mechanism **146** may be structurally modified as long as they remain capable of moving and rotating the shaping member **122**. For example, the shaping mechanism **120** may further include a tilt adjusting mechanism for adjusting a tilt angle of the shaping member **122**, and the like.

[0090] A specific example of a polishing surface shaping method for shaping the polishing surface **88***a* of the polishing pad **88** on the processing apparatus **2** will be described below. FIG. **5** is a flowchart of a sequence of a polishing surface shaping method according to the present embodiment. The polishing surface shaping method according to the present embodiment includes a holding surface measuring step **S1** that measures the shape of the holding surface **20***a* of the chuck table **20** and a shaping step **S2** that shapes the polishing surface **88***a* of the polishing pad **88** to a shape matching the holding surface **20***a* of the chuck table **20**, thereby making the polishing surface **88***a* complementary in shape to the holding surface **20***a*. The polishing surface shaping method according to the present embodiment may additionally include a polishing surface shape specifying step S**3** that specifies the shape of the shaped polishing surface **88***a* on the basis of the amount of displacement of the shaping member **122**.

[0091] FIG. **6** illustrates, in side elevation, partly in cross-section and partly in block form, the processing apparatus **2** in the holding surface measuring step S**1**. FIG. **6** illustrates in functional block form the controller **100** including its functions, as well as the chuck table **20**, the polishing unit **80**, the polishing pad **88**, the rotary actuator **94**, and the shape measuring instrument **110**. As illustrated in FIG. **6**, the controller **100** includes a processing unit **150** for performing processing operations required to shape the polishing surface **88***a* of the polishing pad **88** and a storage unit, i.e., memories, **160** for storing various pieces of information, i.e., data and programs, used to shape the polishing surface **88***a* of the polishing pad **88**.

[0092] The processing unit **150** includes a holding surface shape specifying section **152**, a shaping condition setting section **154**, and a polishing surface shape specifying section **156**. The holding surface shape specifying section **152** specifies the shape of the holding surface **20***a* of the chuck table **20** and stores information regarding the shape of the holding surface **20***a*, i.e., holding surface shape information, in a holding surface shape storing section **162** included in the storage unit **160**. The shaping condition setting section **154** sets shaping conditions for shaping the polishing surface **88***a* of the polishing pad **88** to a predetermined shape and stores information regarding the shaping conditions, i.e., shaping condition information, in a shaping condition storing section **164** included in the storage unit **160**. The polishing surface shape specifying section **156** specifies the shape of the shaped polishing surface **88***a* and stores information regarding the shape of the shaped polishing surface **88***a*, i.e., polishing surface shape information, in a polishing surface shape storing section **166** included in the storage unit **160**.

[0093] The processing unit **150** further includes a shaping controlling section **158** for controlling the shaping of the polishing surface **88***a* of the polishing pad **88**. The shaping controlling section **158** is connected to those components of the processing apparatus **2** that are involved in shaping the polishing surface **88***a*. The shaping controlling section **158** outputs control signals to the components to control operation thereof for thereby enabling the processing apparatus **2** to shape the polishing surface **88***a* of the polishing pad **88**.

[0094] In the holding surface measuring step S**1**, in a state in which no workpiece **11** is placed on the holding surface **20***a* of the chuck table **20**, the angle of the chuck table **20** is adjusted to make the rotation axis **28** of the chuck table **20** generally parallel to the Z-axis. In addition, the positional relation between the chuck table **20** and the shape measuring instrument **110** is adjusted. For example, the shaping controlling section **158** outputs a control signal to the moving mechanism **18** and/or the moving mechanism **62** (see FIG. **1**) to position the chuck table **20** and the polishing unit **80** such that the center, i.e., the rotation axis **28**, of the holding surface **20***a* of the chuck table **20** and the turn path of the shape measuring instrument **110** overlap each other along the Z-axis.

[0095] Then, the shaping controlling section **158** outputs a control signal to the rotary actuator **94** and the shape measuring instrument **110**. The shape measuring instrument **110** starts to operate to measure the heightwise position of the holding surface **20***a*. Moreover, the rotary actuator **94** is energized to rotate the spindle **84** about the rotation axis **96**, causing the shape measuring instrument **110** to turn along its turn path while measuring the heightwise position of the holding surface **20***a*.

[0096] FIG. **7** illustrates in plan the chuck table **20** and the shape measuring instrument **110**. For example, the shape measuring instrument **110** turns along an arcuate turn path **110***a*, which is part of the annular turn path thereof, while passing directly over the center, denoted by O, of the holding surface **20***a* of the chuck table **20**. The shape measuring instrument **110** turns along the arcuate turn path **110***a* while being in operation, thereby measuring heightwise positions of the holding surface **20***a* at a plurality of points on the arcuate turn path **110***a*.

[0097] In case the holding surface **20***a* of the chuck table **20** is of an upwardly protruding conical shape, heightwise positions of the holding surface **20***a* are measured at two or more points that are spaced different distances from the center O of the holding surface **20***a*, and the gradient of the holding surface **20***a* may be calculated on the basis of the heightwise positions thus measured, so that the shape of the holding surface **20***a* can be specified. In the holding surface measuring step S**1**, therefore, the arcuate turn path **110***a* of the shape measuring instrument **110** is established to overlap the center O of the holding surface **20***a* and measuring points P_1 and P_2 that are positioned between the center O and the outer circumferential edge of the holding surface **20***a*. Then, heightwise positions of the holding surface **20***a* are measured at three points, i.e., the center O and the measuring points P_1 and P_2. Conditions for measuring the holding surface **20***a* with the shape measuring instrument **110** may be set appropriately depending on the specifications of the chuck table **20**. For example, the shape measuring instrument **110** may measure heightwise positions of the holding surface **20***a* continuously along the arcuate turn path **110***a*. The positions of measuring points may also be adjusted by rotating the chuck table **20** with the rotary actuator **26** (see FIG. **6**).

[0098] As illustrated in FIG. **6**, information regarding the heightwise positions of the holding surface **20***a* as measured by the shape measuring instrument **110** is input to the holding surface shape specifying section **152** of the processing unit **150**. On the basis of the information regarding the measured heightwise positions of the holding surface **20***a* with the shape measuring instrument **110**, the holding surface shape specifying section **152** specifies the shape of the holding surface **20***a* and generates information regarding the shape of the holding surface **20***a*, i.e., the holding surface shape information. The holding surface shape information generated and acquired by the holding surface shape specifying section **152** is stored in the holding surface shape storing section **162**.

[0099] The holding surface shape information is not limited to any particular types and kinds. For example, the holding surface shape specifying section **152** calculates an approximate surface that approximates the shape of the holding surface **20***a* from the heightwise positions of the holding surface **20***a* that have been measured by the shape measuring instrument **110**, and stores the calculated approximate surface as holding surface shape information in the holding surface shape storing section **162**. Specifically, in case heightwise positions of the holding surface **20***a* are measured at three points, i.e., the center O and the measuring points P_1 and P_2, as illustrated in FIG. **7**, providing the holding surface **20***a* of the chuck table **20** is of an upwardly protruding conical shape, the holding surface shape specifying section **152** calculates a cone having an apex at the center O and including the measuring points P_1 and P_2 on its lateral area. The lateral area of the calculated cone corresponds to the approximate surface that approximates the holding surface **20***a* and is used as holding surface shape information.

[0100] However, the holding surface shape specifying section **152** may store the heightwise positions of the holding surface **20***a* that have been measured by the shape measuring instrument **110** directly as holding surface shape information in the holding surface shape storing section **162**. For example, in case heightwise positions are continuously measured along a path from the center of the holding surface **20***a* to the outer circumferential edge thereof, the heightwise positions of the holding surface **20***a* that have been measured by the shape measuring instrument **110** directly correspond to the shape of the holding surface **20***a*. In this case, the set of the heightwise positions of the holding surface **20***a* that have been measured by the shape measuring instrument **110** may also be used as holding surface shape information.

[0101] Then, in the shaping step S2, the polishing surface **88***a* of the polishing pad **88** is shaped according to the shape of the holding surface **20***a* of the chuck table **20** that has been measured in the holding surface measuring step S1. FIG. **8** illustrates, in side elevation, partly in cross-section and partly in block form, the processing apparatus **2** in the shaping step S2.

[0102] In the shaping step S2, the shaping mechanism **120** shapes the polishing surface **88***a* of the polishing pad **88**. Specifically, the shaping controlling section **158** outputs a control signal to the moving mechanism **62** (see FIG. **1**) and/or the shaping moving mechanism **146** to adjust the positional relation between the polishing pad **88** and the shaping mechanism **120** such that the shaping mechanism **120** is positioned beneath the polishing pad **88**.

[0103] Further, the shaping condition setting section **154** sets shaping conditions, i.e., processing conditions, for shaping the polishing surface **88***a* of the polishing pad **88** with the shaping mechanism **120**. Specifically, the shaping condition setting section **154** selects shaping conditions for shaping the polishing surface **88***a* of the polishing pad **88** into a shape complementary in shape to the holding surface **20***a* of the chuck table **20**, on the basis of the holding surface shape information stored in the holding surface shape storing section **162**. More specifically, the shaping condition setting section **154** selects shaping conditions for forming a recess or slot **88***b* complementary in shape to the holding surface **20***a* of the chuck table **20** in the polishing surface **88***a* side of the polishing pad **88**. Examples of the shaping conditions selected by the shaping condition setting section **154** include the speed at which the polishing pad **88** is to move, the distance that the polishing pad **88** is to move, the speed at which the polishing pad **88** is to rotate, the speed at which the shaping member **122** is to move, the distance that the shaping member **122** is to move, and the speed at which the shaping member **122** is to rotate. The shaping conditions set by the shaping condition setting section **154** is stored in the shaping condition storing section **164**.

[0104] Then, the shaping controlling section **158** reads the shaping conditions stored in the shaping condition storing section **164** and controls the components of the processing apparatus **2** for shaping the polishing surface **88***a* of the polishing pad **88** according to the read shaping conditions. Specifically, the shaping controlling section **158** outputs a control signal to the lifting and lowering mechanism **126** of the shaping mechanism **120** to lift the shaping member **122** and secure the shaping member **122** in the lifted position. For example, in case the lifting and lowering mechanism **126** includes the air cylinder as described above, air is supplied under high pressure to the cylinder **128** to cause the rod **130** to protrude from the cylinder **128** and keep the rod **130** in the protruding position.

[0105] The shaping controlling section **158** then outputs a control signal to at least one of the components including the moving mechanism **62** (see FIG. **1**), the rotary actuator **94**, the rotary actuator **138**, and the shaping moving mechanism **146** to enable the shaping mechanism **120** to shape the polishing surface **88***a* of the polishing pad **88** according to the shaping conditions set by the shaping condition setting section **154**. Now, while the polishing pad **88** and the shaping member **122** are being rotated, the polishing surface **88***a* of the polishing pad **88** and the shaping surface **122***a* of the shaping member **122** are brought into contact with each other. As a result, the recess **88***b* complementary in shape to the holding surface **20***a* is formed in the polishing surface **88***a* side of the polishing pad **88**.

[0106] The speed at which the polishing pad **88** and the shaping member **122** are moved relatively to each other and the distance that they are moved in horizontal directions along the XY plane are adjusted by controlling the moving mechanism **62** (see FIG. **1**) and/or the shaping moving mechanism **146**, for example. The shaping surface **122***a* can thus be brought into contact with the polishing surface **88***a* at a desired position thereon to form the recess **88***b* at a desired position and in a desired range in the polishing pad **88**.

[0107] Moreover, the speed at which the polishing pad **88** and the shaping member **122** are moved relatively to each other and the distance that they are moved along the Z-axis are adjusted by controlling the moving mechanism **62** (see FIG. **1**). Furthermore, the speed at which the polishing pad **88** is rotated and the speed at which the shaping member **122** is rotated are adjusted by controlling the rotary actuator **94** and the rotary actuator **138**, respectively. The depth of the recess **88***b* is thus adjusted in the area of contact where the polishing surface **88***a* and the shaping surface **122***a* are held in contact with each other, so that the recess **88***b* can be formed to a desired depth in the polishing pad **88**. While the polishing surface **88***a* is being shaped, the angle of the shaping member **122** may appropriately be adjusted depending on the shape of the recess **88***b*.

[0108] For shaping the polishing surface **88***a* of the polishing pad **88**, the speed at which the polishing pad **88** and the shaping member **122** are moved relatively to each other along the Z-axis is adjusted to keep the pressure, i.e., a pressing force, that the shaping member **122** applies to the polishing surface **88***a* in a range from 100 N to 200 N, for example. However, the pressing force may be set to an appropriate level depending on the material of the polishing pad **88**, for example.

[0109] As described above, the polishing surface **88***a* of the polishing pad **88** is shaped under predetermined shaping conditions to form the recess **88***b* that has a desired shape in the polishing surface **88***a*, by the shaping mechanism **120**. For example, the diameter of the polishing pad **88**, i.e., the diameter of the polishing layer **92**, is set to at least twice the diameter of the workpiece **11**. While the polishing pad **88** and the shaping member **122** are being rotated, the polishing surface **88***a* and the shaping surface **122***a* are held in contact with each other and the polishing pad **88** and the shaping member **122** are moved relatively to each other. The speeds at which the polishing pad **88** and the shaping member **122** are rotated, the distances that the polishing pad **88** and the shaping member **122** are moved, the speeds at which the polishing pad **88** and the shaping member **122** are moved, and the like, at this time, are set on the basis of the shaping conditions selected by the shaping condition setting section **154**. The recess **88***b*, which is of an annular shape, complementary in shape to the holding surface **20***a* of the chuck table **20** is now formed in the polishing surface **88***a* side of the polishing pad **88**.

[0110] The annular recess **88***b* is concentric with the polishing surface **88***a* along circumferential directions of the polishing surface **88***a*. The recess **88***b* is of a triangular cross-sectional shape that is complementary in shape to the holding surface **20***a* of the chuck table **20**. Consequently, the region of the polishing pad **88** between the center and the outer circumferential edge thereof is smaller in thickness than the center and the outer circumferential edge of the polishing pad **88**. The shaping conditions are set such that the gradient of the side surface, i.e., the inner wall surface, of the recess **88***b* is equal to the gradient of the holding surface **20***a* of the chuck table **20**. This makes the holding surface **20***a* and the recess **88***b* equal to each other in cross-sectional shape.

[0111] However, the cross-sectional shape of the holding surface **20***a* of the chuck table **20** and the cross-sectional shape of the shaped polishing surface **88***a* of the polishing pad **88**, i.e., the cross-sectional shape of the recess **88***b*, may not necessarily be in full agreement with each other. For example, the bottom of the recess **88***b* that corresponds to the apex of the holding surface **20***a* may be of a round shape. Moreover, the side surface, i.e., the inner wall surface, of the recess **88***b* that is complementary in shape to the slanted holding surface **20***a* may be of a slightly curved shape. In this case, the side surface of the recess **88***b* may be in an upwardly protruding curved shape or a downwardly protruding curved shape.

[0112] As described above, when the shaping step S**2** is carried out, the polishing surface **88***a* of the polishing pad **88** is shaped under the shaping conditions that correspond to the shape of the holding surface **20***a* of the chuck table **20**, thereby forming the recess **88***b* that is complementary in shape to the holding surface **20***a* in the polishing surface **88***a* side. The recess **88***b* represents a slot capable of receiving the holding surface **20***a* fitted therein.

[0113] After the shaping step S**2** has been carried out, the polishing surface shape specifying step S**3** that specifies the shape of the shaped polishing surface **88***a* may be carried out. FIG. **9** illustrates in side elevation, partly in cross-section and partly in block form, the processing apparatus **2** in the polishing surface shape specifying step S**3**.

[0114] In the polishing surface shape specifying step S**3**, the shaping controlling section **158** outputs a control signal to the lifting and lowering mechanism **126** to cause the shaping member **122** to be lifted or lowered under an external force applied thereto. Specifically, the air supplied to the cylinder **128** is depressurized to the extent that the rod **130** is kept protruding from the cylinder **128**. Then, when a downward external force is applied to the rod **130**, the rod **130** is lowered in a direction to retract into the cylinder **128**, and when the downward external force is removed, the rod **130** is lifted in a direction to protrude out of the cylinder **128**. In other words, the rod **130** operates like a spring contracting under the external force applied thereto and expanding upon removal of the external force.

[0115] The shaping controlling section **158** outputs a control signal to the displacement measuring instrument **142** to energize the displacement measuring instrument **142**. Now, the displacement measuring instrument **142** starts to monitor the amount of displacement of the shaping member **122** along the Z-axis. The displacement measuring instrument **142** indirectly monitors the amount of displacement of the shaping member **122** by continuously measuring the amount of displacement of the reference element **144** that is lifted and lowered in unison with the shaping member **122**.

[0116] In a state in which the polishing pad **88** and the shaping member **122** are being kept rotating, the shaping controlling section **158** outputs control signals to the moving mechanism **62** (see FIG. **1**) and the shaping moving mechanism **146** to adjust the positional relationship between the polishing pad **88** and the shaping mechanism **120** such that the shaping surface **122***a* of the shaping member **122** contacts the shaped polishing surface **88***a*. With the polishing surface **88***a* and the shaping surface **122***a* being held in contact with each other, the polishing pad **88** and the shaping member **122** are moved relatively to each other in horizontal directions.

[0117] For example, the moving mechanism **146** moves the shaping member **122** along a straight path interconnecting the center of the polishing surface **88***a* and the outer circumferential edge thereof. At this time, the rod **130** is lifted and lowered, i.e., contracted and expanded, depending on the depth of the recess **88***b* so as to keep the shaping member **122** and the polishing surface **88***a* in contact with each other. The shaping member **122** thus moves as it is lifted and lowered in tracing the polishing surface **88***a*, successively contacting a plurality of positions on the polishing surface **88***a*. The pressure, i.e., the pressing force, applied from the shaping member **122** to the polishing surface **88***a* is set to a level equal to or smaller than $1/5$, preferably $1/10$, or more preferably $1/20$, of the pressing force applied when the polishing surface **88***a* is shaped in the shaping step S**2**. Typically, the pressure of the air supplied to the cylinder **128** is regulated to enable the shaping member **122** to apply a pressing force of approximately 10 N to the polishing surface **88***a*. However, the pressing force may be appropriately set depending on the material of the polishing pad **88**, and the like. The rotation of the polishing pad **88** and the shaping member **122** may be decelerated or stopped to the extent that the shaping member **122** can be moved smoothly while being held in contact with the polishing surface **88***a*.

[0118] While the shaping member **122** is moving along the polishing surface **88***a*, the displacement measuring instrument **142** measures the amount of displacement of the shaping member **122**, i.e., the reference element **144**, along the Z-axis. The amount of displacement of the shaping member **122** at this time corresponds to the shape of the shaped polishing surface **88***a*. The amount of displacement of the shaping member **122** that has been measured by the displacement measuring instrument **142** is input to the polishing surface shape specifying section **156** of the controller **100**.

[0119] The polishing surface shape specifying section **156** specifies the shape of the polishing surface **88***a* on the basis of the amount of displacement of the shaping member **122** that has been measured by the displacement measuring instrument **142** and generates information regarding the shape of the polishing surface **88***a*, i.e., polishing surface shape information. The polishing surface shape information generated and acquired by the polishing surface shape specifying section **156** is stored in the polishing surface shape storing section **166**. The holding surface shape specifying section **152** may use the amount of displacement of the shaping member **122** that has been measured by the displacement measuring instrument **142** directly as the polishing surface shape information or may use information obtained by performing predetermined data processing on the amount of displacement of the shaping member **122** as the polishing surface shape information.

[0120] The amount of displacement of the reference element **144** has been described as being measured by the displacement measuring instrument **142**. However, the displacement measuring instrument **142** may directly measure the heightwise position of the polishing surface **88***a* depending on the material of the polishing pad **88**. In this case, the displacement measuring instrument **142** may directly measure the heightwise position of the polishing surface **88***a* and input the heightwise position of the polishing surface **88***a* to the polishing surface shape specifying section **156**.

[0121] By carrying out the polishing surface shape specifying step S**3** to specify the shape of the shaped polishing surface **88***a* as described above, it can be subsequently confirmed whether the polishing surface **88***a* has been shaped into a desired shape in the shaping step S**2**. After the polishing surface shape specifying step S**3** has been carried out, the holding surface shape information, the shaping condition information, and the polishing surface shape information that have been stored respectively in the holding surface shape storing section **162**, the shaping condition storing section **164**, and the polishing surface shape storing section **166** are read and referred to for subsequently verifying the degree to which the shape of the holding surface **20***a* and the shape of the shaped polishing surface **88***a* have been in agreement with each other, the relation between the shape of the holding surface **20***a* and the shaping conditions, the relation between the shaping conditions and the shape of the shaped polishing surface **88***a*, and the like. This allows the shaping of the polishing surface **88***a* to be assessed and also allows the shaping conditions to be reviewed for an increase in the level of shaping accuracy.

[0122] There are no limitations on the timing of the holding surface measuring step S**1**, the shaping step S**2**, and the polishing surface shape specifying step S**3**. For example, the holding surface measuring step S**1**, the shaping step S**2**, and the polishing surface shape specifying step S**3** may be carried out when the workpiece **11** is not ground and polished while the processing apparatus **2** is in operation, e.g., while the processing apparatus **2** is being set up, workpieces **11** are being delivered, and workpieces **11** are being cleaned. Moreover, the holding surface measuring step S**1**, the shaping step S**2**, and the polishing surface shape specifying step S**3** may be carried out immediately after a chuck table **20** has been replaced or during maintenance of the processing apparatus **2**.

[0123] After the shaping of the polishing surface **88***a* of the polishing pad **88** has been completed, a workpiece **11** is polished as described above. Specifically, the workpiece **11** is held on a chuck table **20** and then coarsely ground and finishingly ground in the respective grinding zones B and C (see FIG. **1**). Thereafter, the chuck table **20** is positioned in the polishing zone D and then polished by the polishing pad **88** that has been shaped.

[0124] FIG. **10** illustrates in side elevation, partly in cross-section, the manner in which the processing apparatus **2** polishes a workpiece **11** held on a chuck table **20**. For polishing the workpiece **11**, the positional relation between the chuck table **20** and the polishing pad **88** is adjusted such that the reverse side **11***b*, i.e., the processed surface, of the workpiece **11** and the recess **88***b* in the polishing pad **88** overlap each other along the Z-axis. In a state in which the chuck table **20** is being rotated about the rotation axis **28** and the polishing pad **88** is being rotated about the rotation axis **96**, the polishing pad **88** is lowered toward the workpiece **11** in the processing feed process such that the polishing pad **88** and the workpiece **11** become close to each other. The polishing pad **88** is continuously lowered to bring the polishing surface **88***a* into abrasive contact with the reverse side **11***b* of the workpiece **11**, polishing the reverse side **11***b*.

[0125] As described above, the polishing surface **88***a* of the polishing pad **88** has been shaped in a manner to be complementary in shape to the holding surface **20***a* of the chuck table **20**. Consequently, the reverse side **11***b* of the workpiece **11** held on the holding surface **20***a* of the chuck table **20** and the polishing surface **88***a* are complementary in shape to each other. When the polishing pad **88** is pressed against the workpiece **11**, the reverse side **11***b* of the workpiece **11** enters the recess **88***b* and is entirely brought into contact with the side surface, i.e., the inner wall surface, of the recess **88***b*. The polishing pad **88** is thus uniformly pressed against the reverse side **11***b* of the workpiece **11**. As a result, the workpiece **11** is less liable to be polished in local areas thereof, so that any thickness variations of the workpiece **11** after it has been polished are reduced.

[0126] When the polishing pad **88** is pressed against the reverse side **11***b* of the workpiece **11**, the polishing layer **92** that is pliable is elastically deformed along the reverse side **11***b* of the workpiece **11**. Therefore, even if the cross-sectional shape of the reverse side **11***b* and the cross-sectional shape of the recess **88***b* are not in full agreement with each other, the polishing layer **92** is elastically deformed to cause the polishing surface **88***a* to contact the reverse side **11***b* of the workpiece **11** in its entirety.

[0127] As described above, the processing apparatus **2** and the polishing surface shaping method according to the present embodiment measure the shape of the holding surface **20***a* of the chuck table **20** and shape the polishing surface **88***a* of the polishing pad **88** depending on the measured shape of the holding surface **20***a*. It is thus possible to make the polishing surface **88***a* complementary in shape to the holding surface **20***a* of the chuck table **20**. At the time at which the workpiece **11** is held on the chuck table **20** and polished by the polishing pad **88**, therefore, in-plane variations of the polishing rate, i.e., the amount of material polished off the workpiece **11** per unit time, are reduced, resulting in a reduction in thickness variations of the workpiece **11** that has been polished.

[0128] The polishing surface shaping method according to the present embodiment is performed by the controller **100** (see FIG. **6** and other drawings) when it executes programs. Specifically, the storage unit **160** of the controller **100** stores programs for operating the processing apparatus **2** to carry out the holding surface measuring step **S1**, the shaping step **S2**, and the polishing surface shape specifying step **S3**. The programs contain commands for enabling the controller **100** to generate control signals to be output to the components of the processing apparatus **2** for carrying out the holding surface measuring step **S1**, the shaping step **S2**, and the polishing surface shape specifying step **S3**. For shaping the polishing surface **88***a* of the polishing pad **88**, the controller **100** reads the programs from the storage unit **160** and executes the read programs. In this manner, the controller **100** performs a sequence of processing operations representing the holding surface measuring step **S1**, the shaping step **S2**, and the polishing surface shape specifying step **S3** and successively output control signals to the components of the processing apparatus **2**. The polishing surface shaping method according to the present embodiment is thus carried out automatically.

[0129] Structural and methodical details according to the first embodiment may be changed or modified without departing from the scope of the invention.

Second Embodiment

[0130] The processing apparatus **2** (see FIG. **1**) that is capable of grinding and polishing the workpiece **11** has been described according to the first embodiment. According to the present invention, a processing apparatus may be a dedicated processing apparatus for polishing the workpiece **11**, i.e., a polishing apparatus. A structural example of the polishing apparatus to which the principles of the present invention are applicable will be described below as a processing apparatus according to a second embodiment.

[0131] FIG. **11** illustrates in perspective a processing apparatus, i.e., a polishing apparatus, **200** for polishing a workpiece **11**. In FIG. **11**, the processing apparatus **200** is illustrated in reference to a three-dimensional coordinate system having an X-axis, a Y-axis, and a Z-axis. The X-axis and the Y-axis extend perpendicularly to each other, and the Z-axis extends perpendicularly to the X-axis and the Y-axis. The X-axis refers to an axis along which first horizontal directions or leftward and rightward directions are defined, and the Y-axis refers to an axis along which second horizontal directions or forward and rearward directions are defined. The Z-axis refers to an axis along which vertical directions, heightwise directions or upward and downward directions are defined.

[0132] The processing apparatus **200** includes a foundation base **202** supporting and/or housing various components of the processing apparatus **200**. The foundation base **202** has a rectangular opening **202***a* defined in the upper surface thereof and having a longitudinal axis extending along the Y-axis. A columnar support structure **204** is mounted on the upper surface of a rear end portion of the foundation base **202** and extends vertically along the Z-axis.

[0133] The opening **202***a* houses therein a chuck table, i.e., a holding table, **206** for holding the workpiece **11** thereon. The chuck table **206** has an upper surface lying generally parallel to a horizontal plane, i.e., an XY plane, along the X-axis and the Y-axis, and acting as a holding surface **206***a* for holding the workpiece **11** thereon. The holding surface **206***a* is porous in nature and fluidly connected to a suction source, not depicted, such as an ejector, for example, via a fluid channel, not depicted, defined in the chuck table **206** and a valve, not depicted.

[0134] The opening **202***a* also houses a moving mechanism **208** therein. The moving mechanism **208** is coupled to the chuck table **206** for moving the chuck table **206** along the Y-axis. The moving mechanism **208** includes a ball-screw-type moving mechanism, for example.

[0135] Specifically, the moving mechanism **208** includes a support base **210** that supports thereon various components of the moving mechanism **208**. The moving mechanism **208** includes a pair of guide rails **212** mounted on the support base **210** and extending along the Y-axis and a movable table **214** slidably mounted on the guide rails **212** for movement along the guide rails **212**. A nut, not depicted, is fixedly disposed on a lower surface, i.e., a reverse side, of the movable table **214**. The nut is operatively threaded over a ball screw **216** disposed between the guide rails **212** and extending along the Y-axis. The ball screw **216** has an end coupled to a stepping motor **218** for rotating the ball screw **216** about its central axis. When the stepping motor **218** is energized, it rotates the ball screw **216** about its central axis, causing the nut to move the movable table **214** along the guide rails **212** along the Y-axis.

[0136] The chuck table **206** is mounted on the movable table **214**. The chuck table **206** is surrounded by a table cover **220** shaped as a flat plate disposed in the opening **202***a* around the chuck table **206**. Bellows-like dust-proof, drip-proof covers **222** that are expandable and contractible along the Y-axis are disposed in the opening **202***a* forwardly and rearwardly of the table cover **220**. The table cover **220** and the dust-proof, drip-proof covers **222** close off the opening **202***a* in covering relation to the components of the moving mechanism **208**.

[0137] When the moving mechanism **208** is actuated, it moves the chuck table **206** together with the table cover **220** along the Y-axis until the chuck table **206** is positioned at a front end portion of the opening **202***a* where a delivery position is defined or a rear end portion of the opening **202***a* where a processing position is defined. The chuck table **206** is coupled to a rotary actuator, not depicted, such as an electric motor for rotating the chuck table **206** about a vertical axis generally parallel to the Z-axis.

[0138] The support structure **204** has a face side, i.e., a front surface, lying along an XZ plane defined along the X-axis and the Z-axis. A moving mechanism **224** for moving a polishing unit **236**, to be described later, along the Z-axis is mounted on the face side of the support structure **204**. The moving mechanism **224** includes a ball-screw-type moving mechanism, for example.

[0139] Specifically, the moving mechanism **224** includes a pair of guide rails **226** mounted on face side of the support structure **204** and extending along the Z-axis and a movable table **228** shaped as a flat plate slidably mounted on the guide rails **226** for movement along the guide rails **226**. A nut, not depicted, is fixedly disposed on a reverse side, i.e., a rear surface, of the movable table **228**. The nut is operatively threaded over a ball screw **230** disposed between the guide rails **226** and extending along the Z-axis. The ball screw **230** has an upper end coupled to a stepping motor **232** for rotating the ball screw **230** about its central axis. When the stepping motor **232** is energized, it rotates the ball screw **230** about its central axis, causing the nut to move the movable table **228** along the guide rails **226** along the Z-axis, i.e., to lift and lower the movable table **228**.

[0140] A support member **234** is fixedly mounted on a face side, i.e., a front surface, of the movable table **228**. The support member **234** supports thereon the polishing unit **236** that polishes the workpiece **11**. The polishing unit **236** is similar in structure and function to the polishing unit **80** (see FIG. **1** and other drawings) of the processing apparatus **2**. Specifically, the polishing unit **236** includes a housing **238**, a spindle **240**, and a mount **242**. The polishing pad **88** is detachably mounted on the lower surface of the mount **242**.

[0141] The processing apparatus **200** includes a controller, also referred to as a control unit, a control section, or a control device, **244** for controlling the processing apparatus **200**. The controller **244** is connected to various components of the processing apparatus **200** that include the chuck table **206**, the moving mechanism **208**, the moving mechanism **224**, the polishing unit **236**, and the like. The controller **244** is similar in structure and function to the controller **100** (see FIG. **1** and other drawings) of the processing apparatus **2**.

[0142] The holding surface **206***a* of the chuck table **206** of the processing apparatus **200** may not be flat for various reasons. For example, the holding surface **206***a* may be inclined or curved or have surface irregularities depending on the kind of the workpiece **11**, the specifications of the chuck table **206**, and the like. Moreover, the planarity of the holding surface **206***a* may be low due to manufacturing errors of the chuck table **206**. Therefore, as with the processing apparatus **2**, the processing apparatus **200** incorporates the shape measuring instrument **110** and the shaping mechanism **120** (see FIG. **4**). The controller **244** controls the moving mechanism **208**, the moving mechanism **224**, the undepicted rotary actuator for rotating the chuck table **206**, the undepicted rotary actuator for rotating the polishing pad **88**, the shape measuring instrument **110**, and the shaping mechanism **120** to measure the holding surface **206***a* of the chuck table **206** with the shape measuring instrument **110** and shape the polishing surface **88***a* of the polishing pad **88** with the shaping mechanism **120**. The polishing surface **88***a* is thus shaped into a shape complementary in shape to the holding surface **206***a* of the chuck table **206**. Specific process details for shaping the polishing surface **88***a* of the polishing pad **88** are similar to those for shaping the polishing surface **88***a* with the processing apparatus **2** (see FIGS. **5** through **9**).

[0143] The structural and methodical details according to the second embodiment may appropriately be changed or modified without departing from the scope of the invention. The description of the details of the first embodiment may appropriately be incorporated herein by way of reference with respect to the details of the second embodiment that have not been described above.

[0144] The present invention is not limited to the details of the above described preferred embodiment. 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 processing apparatus comprising:

a chuck table having a holding surface for holding a workpiece thereon;

a chuck table rotary actuator for rotating the chuck table about an axis extending across the holding surface;

a polishing unit on which a polishing pad having a polishing surface for polishing the workpiece is mounted;

a polishing pad rotary actuator for rotating the polishing pad about an axis extending across the polishing surface;

a polishing moving mechanism for moving the chuck table and the polishing pad relatively to each other along a first direction across the holding surface and the polishing surface;

a shape measuring instrument for measuring a shape of the holding surface;

a shaping mechanism for shaping the polishing surface while in contact therewith;

a shaping moving mechanism for moving the polishing pad and the shaping mechanism relatively to each other along a second direction across the first direction; and

a controller for controlling shaping of the polishing surface with the shaping mechanism depending on the shape of the holding surface that has been measured by the shape measuring instrument, thereby to make the polishing surface complementary in shape to the holding surface.

2. The processing apparatus according to claim **1**, wherein

a diameter of the polishing pad is at least twice a diameter of the workpiece.

3. The processing apparatus according to claim **1**, wherein

the shaping mechanism has a shaping member for shaping the polishing surface while in contact therewith and a displacement measuring instrument for measuring an amount of displacement of the shaping member in the first direction, and

the controller specifies a shape of the polishing surface on a basis of the amount of displacement of the shaping member that has been measured by the displacement measuring instrument when the shaping member has contacted the polishing surface at a plurality of positions.

4. A polishing surface shaping method comprising:

measuring a shape of a holding surface of a chuck table for holding a workpiece thereon; and

shaping a polishing surface of a polishing pad for polishing the workpiece by bringing a shaping member for shaping the polishing surface into contact with the polishing surface depending on the shape of the holding surface that has been measured in the measuring of the holding surface, thereby to make the polishing surface complementary in shape to the holding surface.

5. The polishing surface shaping method according to claim **4**, further comprising:

specifying a shape of the polishing surface on a basis of an amount of displacement of the shaping member when the shaping member has contacted the polishing surface shaped in the shaping at a plurality of positions.

6. The polishing surface shaping method according to claim **4**, wherein

the holding surface of the chuck table is of a conical shape, and in the shaping, the polishing surface of the polishing pad is shaped to form in the polishing surface an annular recess that is complementary in shape to the holding surface.

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