

APPARATUS AND METHOD FOR POLISHING SEMICONDUCTOR
WAFERS USING ONE OR MORE POLISHING SURFACES

CROSS REFERENCE TO RELATED APPLICATION

[0001] This application is entitled to the benefit of U.S. Provisional Patent Application Serial Numbers 60/464,290 filed on April 21, 2003, 60/469,691 filed on May 12, 2003, 60/470,933 filed on May 15, 2003, 60/472,581 filed on May 22, 2003, 60/475,292 filed on June 2, 2003, 60/477,480 filed on June 10, 2003, 60/516,891 filed on November 3, 2003, and 60/541,432 filed on February 3, 2004, which are all incorporated herein by reference.

FIELD OF THE INVENTION

[0002] The invention relates generally to semiconductor processing equipments, and more particularly to an apparatus and method for polishing semiconductor wafers.

BACKGROUND OF THE INVENTION

[0003] Local and global planarization of semiconductor wafers becomes increasingly important as more metal layers and interlayer dielectric layers are stacked on the wafers. A preferred method to planarize semiconductor wafers is the chemical mechanical polishing (CMP) method, where a surface of a semiconductor wafer is polished using a slurry solution supplied between the wafer and a polishing pad. The CMP method is also widely used for damascene process to form copper structures on the semiconductor wafers.

10 [0004] In general, a CMP equipment includes a polishing table where a polishing pad is placed and a wafer carrier that supports a semiconductor wafer and presses the wafer against the polishing pad. One of the most important performances of a CMP equipment is productivity. For higher productivity, a CMP equipment typically requires more polishing tables and more wafer carriers.

15 As the number of polishing tables and wafer carriers included in a CMP equipment is increased, the arrangement of the polishing tables and the wafer carriers becomes important to efficiently polish multiple semiconductor wafers. Furthermore, the manner in which the semiconductor wafers are transferred to and from the wafer carrier becomes important as well. However, the footprint of a

20 CMP equipment must also be considered since a CMP equipment with a large footprint requires a larger clean room to house the equipment, which translates into greater cost of operation.

[0005] In view of these issues, what is needed is an apparatus and method for polishing semiconductor wafer using multiple polishing tables with high

25 productivity that require small footprint.

SUMMARY OF THE INVENTION

[0006] An apparatus and method for polishing objects, such as semiconductor wafers, utilizes one or more polishing surfaces, multiple wafer carriers and at least one load-and-unload cup. The load-and-unload cup may be configured to move to and from the wafer carriers in a pivoting manner. The load-and-unload cup may be configured to move to and from the wafer carriers in

a linear reciprocating manner. The wafer carriers may be configured to move to and from the load-and-unload cup in a pivoting manner. The wafer carriers may be configured to move to and from the load-and-unload cup in a linear reciprocating manner.

5 **[0007]** An apparatus for polishing objects in accordance with an embodiment of the invention comprises a first object carrier positioned over a first polishing surface, a second object carrier positioned over a second polishing surface, a first object relay device positioned between the first and second object carriers, and a second object relay device positioned adjacent to one of the first
10 and second object carriers. The first object relay device includes a first load-and-unload cup and a first pivoting drive mechanism. The first pivoting drive mechanism is configured to pivot the first load-and-unload cup to and from the first and second object carriers about a first pivoting axis to transfer the objects from the first object carrier to the second object carrier. The second object relay
15 device includes a second load-and-unload cup and a second pivoting drive mechanism. The second pivoting mechanism is configured to pivot the second load-and-unload cup to and from one of the first and second object carriers about a second pivoting axis to transfer the objects to the first object carrier or from the second object carrier.

20 **[0008]** A method for polishing objects in accordance with an embodiment of the invention comprises transferring an object to a first object carrier positioned over a first polishing surface, polishing the object on the first polishing surface using the first object carrier, transferring the object from the first object carrier to a second object carrier positioned over a second polishing surface using a first
25 load-and-unload cup, polishing the object on the second polishing surface using the second object carrier, and transferring the object to a second load-and-unload cup positioned adjacent to one of the first and second object carriers to load the object onto the first object carrier or unload the object from the second object carrier. The transferring of the object from the first object carrier to the second
30 object carrier includes pivoting the load-and-unload cup about a pivoting axis.

[0009] An apparatus for polishing objects in accordance with another embodiment of the invention comprises a plurality of object carriers positioned over a plurality of polishing surfaces, and a plurality of object relay devices

positioned between the object carriers such that at least one object relay device is positioned between two adjacent object carriers. Each object relay device includes a load-and-unload cup and a pivoting drive mechanism. The pivoting drive mechanism is configured to pivot the load-and-unload cup to and from the two adjacent object carriers about a pivoting axis to transfer the objects between the two adjacent object carriers.

[0010] A method for polishing objects in accordance with another embodiment of the invention comprises sequentially transferring an object to a plurality of object carriers positioned over a plurality of polishing surfaces using a plurality of load-and-unload cups, and sequentially polishing the object on the polishing surfaces using the object carriers. The sequentially transferring includes pivoting each of the load-and-unload cups about a pivoting axis to transfer the object between two adjacent object carriers of the object carriers.

[0011] An apparatus for polishing objects in accordance with another embodiment of the invention comprises a first object carrier positioned over a first polishing surface, a second object carrier positioned over a second polishing surface, an object relay device positioned between the first and second object carriers, and a linear drive mechanism operatively connected to the object relay device. The object relay device includes a load-and-unload cup. The linear drive mechanism is configured to displace the load-and-unload cup of the object relay device in a substantially linear reciprocating manner to and from the first and second object carriers to transfer the objects from the first object carrier to the second object carrier.

[0012] A method for polishing objects in accordance with another embodiment of the invention comprises transferring an object to a first object carrier positioned over a first polishing surface, polishing the object on the first polishing surface using the first object carrier, transferring the object from the first object carrier to a second object carrier positioned over a second polishing surface using a load-and-unload cup, and polishing the object on the second polishing surface using the second object carrier. The transferring of the object from the first object carrier includes linearly displacing the load-and-unload cup from the first object carrier to the second object carrier.

[0013] An apparatus for polishing objects in accordance with another embodiment of the invention comprises an object polishing station having an input region to receive the objects and an output region to output the objects, and at least one object transport device to transfer the objects to the input region of the object polishing station and to transfer the objects from the output region of the object polishing station. The object polishing station includes a plurality of polishing surfaces, an object transfer station positioned between two adjacent polishing surfaces of the polishing surfaces, a plurality of object carriers, and at least one drive mechanism operatively connected to at least one of the object carriers, wherein each of the objects is transferred from the input region to the output region by way of the polishing surfaces of the object polishing station such that each of the objects is polished on the polishing surfaces. Each object carrier is configured to secure one of the objects. The drive mechanism is configured to displace at least one of the object carriers to and from the object transfer station and one of the two adjacent polishing surfaces.

[0014] A method for polishing objects in accordance with another embodiment of the invention comprises receiving an object at an input region of an object polishing station, sequentially transferring the object to a plurality of polishing surfaces of the object polishing station using a plurality of object carriers of the object polishing station, sequentially polishing the object on the polishing surfaces using the object carriers, transferring the object to an object transfer station of the object polishing station from a first adjacent polishing surface of the polishing surfaces using a first object carrier of the object carriers, transferring the object from the object transfer station to a second adjacent polishing surface of the polishing surfaces using a second object carrier of the object carriers, and outputting the object from an output region of the object polishing station after the object has been polished on the polishing surfaces.

[0015] An apparatus for polishing objects in accordance with another embodiment of the invention comprises a first object transport device, a second object transport device, and an object polishing unit positioned between the first and second object transport devices. The object polishing unit comprises at least one polishing surface, first and second object carriers positioned over the polishing surface to polish the objects on the polishing surface. Each object is

transferred from the first object transport device to the second object transport device by way of one of the first and second object carriers.

[0016] A method for polishing objects in accordance with another embodiment of the invention comprises transferring first and second objects to a first end of an object polishing unit using a first object transport device, polishing the first object on at least one polishing surface of the object polishing unit using a first object carrier of the object polishing unit, polishing the second object on at least one polishing surface using a second object carrier of the object polishing unit, and transferring the first and second object from a second end of the object polishing unit using a second object transport device. The first and second ends are located on opposite ends of the object polishing unit.

[0017] An object relay device for loading and unloading an object in accordance with an embodiment of the invention comprises a load-and-unload cup, an arm operatively connected to the load-and-unload cup to laterally move the load-and-unload cup, and a cup ascending-and-descending mechanism operatively connected to the load-and-unload cup and the arm. The cup ascending-and-descending mechanism is configured to raise and lower the load-and-unload cup with respect to the arm.

[0018] Other aspects and advantages of the present invention will become apparent from the following detailed description, taken in conjunction with the accompanying drawings, illustrated by way of example of the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

25

[0019] Fig. 1 is a top view of a polishing apparatus in accordance with an embodiment of the present invention.

[0020] Fig. 2 is a perspective view of polishing units and a wafer relay device used in the polishing apparatus of Fig. 1.

30 [0021] Figs. 3 (a) and (b) are top and cross-sectional views, respectively, of a wafer relay device used in the polishing apparatus of Fig. 1.

[0022] Figs. 4 (a) and (b) are cross-sectional views of one the wafer relay devices used in the polishing apparatus of Fig. 1, illustrating a wafer transfer process performed by the wafer relay device.

5 [0023] Figs. 5(a)-(n) are sequential top views of a polishing station of Fig. 1, illustrating an exemplary method of wafer processing in the polishing station.

[0024] Figs. 6-8 are top views of polishing stations, which can be used in the polishing apparatus of Fig. 1, in accordance with other embodiments of the invention.

10 [0025] Figs. 9 and 10 are a top view and a side view of a polishing station, respectively, which can be used in the polishing apparatus of Fig. 1, in accordance with another embodiment of the invention.

[0026] Figs. 11-17 are top views of polishing stations, which can be used in the polishing apparatus of Fig. 1, in accordance with other embodiments of the invention.

15 [0027] Figs. 18 and 19 are a top view and a side view of a polishing station, respectively, which can be used in the polishing apparatus of Fig. 1, in accordance with another embodiment of the invention.

[0028] Figs. 20(a) and (b) are top views of the polishing station of Fig. 18, illustrating wafer loading and unloading processes, respectively.

20 [0029] Figs. 21(a)-(c) are top views of polishing stations, which can be used in the polishing apparatus of Fig. 1, in accordance with other embodiments of the invention.

[0030] Fig. 22 is a top view of a polishing station, which can be used in the polishing apparatus of Fig. 1, in accordance with another embodiment of the invention.

[0031] Figs. 23 and 24 are a top view and a side view of a polishing station, which can be used in the polishing apparatus of Fig. 1, in accordance with another embodiment of the invention.

30 [0032] Figs. 25(a)-(c) are top views of polishing stations, which can be used in the polishing apparatus of Fig. 1, in accordance with other embodiments of the invention.

- [0033] Fig. 26 is a top view of a polishing station, which can be used in the polishing apparatus of Fig. 1, in accordance with another embodiment of the invention.
- [0034] Figs. 27 and 28 are a top view and a side view of a polishing station, respectively, which can be used in the polishing apparatus of Fig. 1, in accordance with another embodiment of the invention.
- [0035] Fig. 29 is a top view of a polishing station, which can be used in the polishing apparatus of Fig. 1, in accordance with another embodiment of the invention.
- [0036] Figs. 30(a) and (b) are side views of a polishing unit used in the polishing station of Fig. 29.
- [0037] Figs. 31 and 32 are a top view and a side view of a polishing station, respectively, which can be used in the polishing apparatus of Fig. 1, in accordance with another embodiment of the invention.
- [0038] Fig. 33 is a top view of a polishing station, which can be used in the polishing apparatus of Fig. 1, in accordance with another embodiment of the invention.
- [0039] Figs. 34(a)-(c) are top views of polishing units that can be used in the polishing station of Fig. 33.
- [0040] Figs. 35 is a schematic drawing of a wafer relay device in accordance with an embodiment of the present invention.
- [0041] Fig. 36 is a top view of the wafer relay device of Fig. 35.
- [0042] Figs. 37(a) and (b) are cross-sectional views of a load-and-unload cup used in the wafer relay device of Fig. 35.
- [0043] Figs. 38(a)-(f) are sequential cross-sectional views of the load-and-unload cup of the wafer relay device of Fig. 35, illustrating a process for loading a wafer onto a wafer carrier.
- [0044] Fig. 39 is a flow diagram of a method for polishing objects in accordance with an embodiment of the invention.
- [0045] Fig. 40 is a flow diagram of a method for polishing objects in accordance with another embodiment of the invention.
- [0046] Fig. 41 is a flow diagram of a method for polishing objects in accordance with another embodiment of the invention.

[0047] Fig. 42 is a flow diagram of a method for polishing objects in accordance with another embodiment of the invention.

[0048] Fig. 43 is a flow diagram of a method for polishing objects in accordance with another embodiment of the invention.

5

DETAILED DESCRIPTION

[0049] With reference to Fig. 1, a polishing apparatus 10 in accordance with an embodiment of the present invention is described. Fig. 1 is a top view of the polishing apparatus 10. The polishing apparatus 10 comprises a polishing station 20, a wafer input station 102, a wafer output station 104, a first wafer transport device 150, a second wafer transport device 210, a third wafer transport device 230, and a wafer cleaner 220. The polishing station 20 comprises a first polishing unit 250a, a second polishing unit 250b, a third polishing unit 250c, a first wafer relay device 280a, a second wafer relay device 280b, a third wafer relay device 280c, and a fourth wafer relay device 280d.

[0050] The wafer input station 102 accommodates semiconductor wafers or other comparable objects to be polished by the polishing station 20. The wafer output station 104 accommodates semiconductor wafers or other comparable objects that have been polished and cleaned by the polishing station 20 and the wafer cleaner 220, respectively. The wafer input station 102 and the output station 104 may be configured to comprise multiple slots to accommodate multiple wafers. The polishing apparatus 10 can be configured to comprise the wafer input station 102 without the wafer output station 104. In such a configuration, wafers to be polished and polished wafers are accommodated together in the wafer input station 102.

[0051] The first wafer transport device 150 is configured to transfer wafers from the wafer input station 102 to the polishing station 20. More specifically, the first wafer transport device 150 is configured to transfer wafers from the wafer input station 102 to the first wafer relay device 280a of the polishing station 20, as described in more detail below. The second wafer transport device 210 is configured to transfer wafers from the polishing station 20 to the wafer cleaner 220. More specifically, the second wafer transport device 210 is configured to

transfer wafers from the fourth wafer relay device 280d of the polishing station 20 to the wafer cleaner 220, as described in more detail below. The third wafer transport device 230 is configured to transfer wafers from the wafer cleaner 220 to the wafer output station 104 or to the wafer input station 102, as described in more detail below.

[0052] The first, second and third wafer transport devices 150, 210 and 230 may be situated on respective linear tracks 155, 215 and 235 such that the wafer transport devices can be moved in a linear manner on the linear tracks by respective linear drive mechanisms (not shown). As an example, the first, second and third wafer transport devices 150, 210 and 230 may comprise a robotic arm to handle a wafer for transfer. The first, second and third wafer transport devices 150, 210 and 230 may alternatively be configured to comprise dual robotic arms such that the devices can handle two wafers at a time. The first and second wafer transport devices 150 and 210 may also be configured to turn over wafers before transferring the wafers to the polishing station 20 and to the wafer cleaner 220, respectively.

[0053] The four wafer relay devices 280a-280d and the three polishing units 250a-250c are arranged in such a manner that the first polishing unit 250a is positioned between the first and second wafer relay devices 280a and 280b, the second polishing unit 250b is positioned between the second and third wafer relay devices 280b and 280c, and the third polishing unit 250c is positioned between the third and fourth wafer relay device 280c and 280d.

[0054] Preferably the polishing units 250 are arranged in a linear manner to minimize the width of the polishing station 20, as illustrated in Fig. 1. The polishing units 250 may be arranged so that the distances between two neighboring polishing units 250 are same, as illustrated in Fig. 1. The wafer relay devices 280 are also arranged in a linear manner to minimize the width of the polishing station 20, as illustrated in Fig. 1. More specifically, the wafer relay devices 280 are linearly arranged such that load-and-unload cups 282 of the wafer relay devices 280 are positioned in a linear manner when the load-and-unload cups are parked at their respective parking positions, as illustrated in Fig. 1. The wafer relay devices 280 may be linearly arranged so that the distances between two neighboring load-and-unload 282 are equivalent, as illustrated in Fig. 1.

When the load-and unload cups 282 are parked at their respective parking positions, some portion of the load-and-unload cups 282 may be positioned over their neighboring polishing tables 256, as illustrated in Fig. 1.

[0055] In order to minimize the width of the polishing apparatus 10, the wafer cleaner 220 is preferably positioned such that its longer side 220L is facing the longer side 20L of the polishing station 20, as illustrated in Fig. 1. The area of the polishing station 20 is an area roughly defined by the polishing tables 256a, 256b and 256c of the polishing station 20.

[0056] The wafer relay devices 280 transfer wafers between wafer carriers 262a-262c of the polishing units 250a-250c, respectively, by pivoting motions A, B, C, D, E, and F, as illustrated in Fig. 1, in the following manner. First, a load-and-unload cup 282a of the first wafer relay device 280a receives a wafer from the first wafer transport device 150 and then transfers it to the wafer carrier 262a of the first polishing unit 250a by the pivoting motion A. Next, a load-and-unload cup 282b of the second wafer relay device 280b transfers the wafer from the wafer carrier 262a of the first polishing unit 250a to the wafer carrier 262b of the second polishing unit 250b by the pivoting motions B and C. Next, a load-and-unload cup 282c of the third wafer relay device 280c transfers the wafer from the wafer carrier 262b of the second polishing unit 250b to the wafer carrier 262c of the third polishing unit 250c by the pivoting motions D and E. Next, a load-and-unload cup 282d of the fourth wafer relay device 280d transfers the wafer from the wafer carrier 262c of the third polishing unit 250c by the pivoting motion F. The second wafer transport relay device 210 then removes the wafer from the load-and-unload cup 282d of the fourth wafer relay device 280d, and transfers the wafer to the wafer cleaner 220.

[0057] With reference to Fig. 2, the polishing units 250 and the wafer relay devices 280 of the polishing station 20 are further described using the polishing units 250a and 250b and the wafer relay device 280b as examples. Fig. 2 is a perspective view of the second wafer relay device 280b, the first polishing unit 250a and the second polishing unit 250b of the polishing station 20. Each polishing unit 250 comprises the polishing table 256 and a wafer carrier assembly 260. The polishing table 256 can be rotated or orbited about an axis. The polishing pad 255 may be attached onto the polishing table 256 for chemical and

mechanical polishing process of semiconductor wafers. One or more slurries containing abrasive particles and/or chemicals such as KOH are used with the polishing pad 255 to polish semiconductor wafers. Each polishing unit 250 may further comprises a pad conditioner 258 to condition the surface of the polishing pad 255 during the polishing process to refresh the surface of the polishing pad 255 for proper polishing. Although the polishing of wafers are described herein as being polished on one or more polishing pad surfaces, the wafers may be polished on any polishing surface such as a polishing surface of a polishing table.

[0058] Each wafer carrier assembly 260 comprises a wafer carrier 262, a carrier shaft 264 and a rotating-and-vertical drive mechanism 266. The wafer carrier 262 is designed to hold a semiconductor wafer such that the surface of the wafer to be polished is faced toward the polishing pad 255. The wafer carrier 262 is connected to the rotating-and-vertical drive mechanism 266 through the carrier shaft 264. The rotating-and-vertical drive mechanism 266, as well as the rotating-and-vertical drive mechanisms 266 of other wafer carrier assemblies 260, is mounted to a top housing structure (not shown) of the polishing station 20. The rotating-and-vertical drive mechanism 266 controls the rotational and vertical motions of the wafer carrier 262 through the connected carrier shaft 264. Thus, the rotating-and vertical drive mechanism 266 is configured to rotate the wafer carrier 262 by rotating the connected carrier shaft 264 and to vertically move the wafer carrier 262 by vertically moving the connected carrier shaft 264. The positions of the wafer carriers 262 illustrated in Fig. 2 are their wafer load-and-unload positions over the respective polishing tables 256. In order to polish semiconductor wafers, the wafer carriers 262 are moved down to the polishing positions on the respective polishing pads 255 from their wafer load-and-unload positions by the respective rotating-and-vertical mechanisms 266 to press the wafers held by the wafer carriers 262 onto the respective polishing pads 255.

[0059] Each wafer relay device 280 comprises a load-and-unload cup 282, a pivoting arm 283, a pivoting shaft 284 and a pivoting-and-vertical drive mechanism 286. The load-and-unload cup 282 is connected to the pivoting shaft 284 by the pivoting arm 283. The pivoting shaft 284 is connected to the pivoting-and-vertical drive mechanism 286. The pivoting-and-vertical drive mechanism 286 controls pivoting and vertical motions of the load-and-unload cup 282

through the pivoting shaft 284 and the pivoting arm 283. Thus, the pivoting-and-vertical drive mechanism 286 is configured to pivot the load-and-unload cup 282 through the connected pivoting shaft 284 about a pivoting axis at the pivoting shaft and to vertically move the load-and-unload cup 282 through the connected pivoting shaft.

[0060] The load-and-unload cup 282b of the wafer relay device 280b illustrated in Fig. 2 is positioned at a parking position between the two polishing units 250a and 250b. The load-and-unload cup 282b of the wafer relay device 280b can be pivoted to the wafer load-and-unload positions of the two wafer carriers 262a and 262b by the respective pivoting motions, B and C. The phantom lined wafer relay devices of Fig. 2 show that the load-and-unload cup 282b can be positioned at the respective wafer load-and-unload positions below the respective wafer carriers 262a and 262b.

[0061] With reference to Figs. 3(a) and 3(b), the wafer relay devices 280 of the polishing station 20 is described using a generic wafer relay device, which can be the wafer relay device 280b or the wafer relay device 280a, 280c or 280d. Fig. 3(a) is a top view of the wafer relay device 280. Fig. 3(b) is a cross sectional view of the load-and-unload cup 282 of the wafer relay device 280 of Fig. 3(a) along the line QQ.

[0062] As illustrated in Figs. 3(a) and 3(b), the load-and-unload cup 282 comprises a cup base 290, a cup ring 295, a lifter 300, a wafer tray 310, first multiple nozzles 340, second multiple nozzles 350, a drain channel 360, a first fluid channel 370 and a second fluid channel 372. The fluid channels 370 and 372 may be connected to fluid sources (not shown) through the pivoting arm 283 and the pivoting shaft 284. The drain channel 360 may be connected to a drain pump (not shown) through the pivoting arm 283b and the pivoting shaft 284b, similar to the other fluid channels 370 and 372.

[0063] The cup ring 295 and the wafer tray 310 are mounted on the cup base 290. The wafer tray 310 comprises a hole at the center, which allows the lifter 300 to be positioned at the center of the cup base 290. The lifter 300 is connected to a lifter pneumatic cylinder 304 through a lift piston 302, as illustrated in Fig. 3(b). The lifter 300 is a wafer handling device to raise and lower a wafer to and from a wafer carrier. The lifter 300 is preferably made of soft materials such as

rubber to avoid damaging wafer surface. The lifter 300 has a surface area that is smaller than the surface area of the wafer being handled by the lifter. The lifter cylinder 304 is connected to the first fluid channel 370 and operated by a fluid supplied through the first fluid channel 370. Nitrogen gas is one example of the fluid that can be used. The lifter 300 can be moved up and down by the lifter cylinder 304 using the pressure of the supplied fluid. The lifter 300 can be lifted above the top surface of the cup ring 295 to receive a wafer W from the wafer transport device 150, as illustrated in Fig. 3(b). After the lifter 300 receives the wafer W, the lifter can be moved down below the wafer tray 310 in order to place the wafer W on the wafer tray 310.

[0064] The first multiple nozzles 340 are mounted on the top of the cup base 290 and the second multiple nozzles 350 are mounted on the cup ring 295, as illustrated in Fig. 3(b). The first and second nozzles 340 and 350 are connected to the second fluid channel 372, and thus, can spray a fluid, such as deionized (D.I.) water, which is supplied through the second fluid channel 372. Used fluid, e.g., used D.I. water, is drained through the drain channel 360 by the drain pump (not shown).

[0065] With reference to Figs. 4(a) and 4(b), a wafer transfer process performed by one of the load-and-unload cups 282 is described. Figs. 4(a) and (b) are sequential cross sectional views of the load-and-unload cup 282. After the wafer W is positioned on the wafer tray 310, as previously described with reference to Fig. 3(b), the load-and-unload cup 282 is transferred to a position where the wafer carrier 262 is positioned, as illustrated in Fig. 4(a). The wafer carrier 262 comprises a retainer ring 289 to confine the wafer during a polishing process. Next, the lifter 300 is moved up and the wafer on the lifter is received by the wafer carrier 262 using a vacuum supplied through vacuum channels 285, as illustrated in Fig. 4(b). After the wafer is received by the wafer carrier 262, the lifter 300 is moved down. For unloading the wafer from the wafer carrier 262 onto the load-and-unload cup 282, the vacuum provided through the vacuum channels 285 is removed, which releases the wafer W from the wafer carrier 262 onto the lifter 300 of the load-and-unload cup 282.

[0066] The load-and-unload cup 282 can wash the wafer carrier 262 by spraying D.I. water onto the wafer carrier 262. In the polishing station 20 of Fig.

1, the first wafer carrier 262a can be washed by the first and second load-and-unload cups 282a and 282b. The second wafer carrier 262b can be washed by the second and third load-and-unload cups 282b and 282c. The third wafer carrier 262c can be washed by the third and fourth load-and-unload cups 282c and 282d.

5 [0067] Even though a specific configuration of the load-and-unload cup 282 and its wafer loading and unloading processes have been described, any type of device that can load and unload wafers onto and from the wafer carrier 262 and wash the wafer carrier 262 can be used in the wafer relay device 280.

[0068] With reference to Figs. 5(a)-(n), a method of processing wafers in the
10 polishing station 20 is described. Figs. 5 (a)-(n) are sequential perspective views of the polishing station 20 to show the process sequence.

[0069] In Fig. 5(a), the load-and-unload cups 282a, 282b, 282c and 282d are positioned at their respective parking positions Xa, Xb, Xc and Xd. The wafer carriers 262a, 262b and 262c are positioned at the respective wafer load-and-unload positions over the respective polishing tables 256a, 256b and 256c. A first
15 wafer W1 is supplied to the first load-and-unload cup 282a at the parking position Xa by the first wafer transport device 150 (not shown).

[0070] In Fig. 5(b), the first load-and-unload cup 282a is pivoted to the wafer load-and-unload position of the first wafer carrier 262a over the first
20 polishing table 256a and then loads the first wafer W1 onto the first wafer carrier 262a.

[0071] In Fig. 5(c), the first load-and-unload cup 282a is pivoted back to the parking position Xa and then a second wafer W2 is supplied to the first load-and-unload cup 282a by the first wafer transport device 150 (not shown). The first
25 wafer carrier 262a polishes the first wafer W1 using the polishing pad 255a on the first polishing table 256a. After the polishing process of the first wafer W1 is completed, the first wafer carrier 262a is lifted from the polishing table 256a to its wafer load-and-unload position.

[0072] In Fig. 5(d), the second load-and-unload cup 282b is pivoted to the
30 wafer load-and-unload position of the first wafer carrier 262a and then receives the first wafer W1 from the first wafer carrier 262a.

[0073] In Fig. 5(e), the second load-and-unload cup 282b is pivoted to the wafer load-and-unload position of the second wafer carrier 262b and then loads

the first wafer W1 onto the second carrier 262b. After the first wafer carrier 262a is empty, the first load-and-unload cup 282a is pivoted to the wafer load-and-unload position of the first wafer carrier 262a and then loads the second wafer W2 onto the first wafer carrier 262a.

5 **[0074]** In Fig. 5(f), the first and second load-and-unload cups 282a and 282b are pivoted back to the respective parking positions Xa and Xb. The first and second wafer carriers 262a and 262b polish the second and first wafers W2 and W1 using the polishing pads 255a and 255b on the first and second polishing tables 256a and 256b, respectively. After the polishing processes of the first and
10 second wafers W1 and W2 are completed, the first and second wafer carriers 262a and 262b are lifted from the respective polishing tables 256a and 256b to the respective wafer load-and-unload positions.

[0075] In Fig. 5(g), the second and third load-and-unload cups 282b and 282c are pivoted to the wafer load-and-unload positions of the first and second
15 wafer carriers 262a and 262b, respectively, and then receive the second and first wafers W2 and W1 from the first and second wafer carriers 262a and 262b, respectively.

[0076] In Fig. 5(h), the second and third load-and-unload cups 282b and 282c are pivoted to the wafer load-and-unload positions of the second and third
20 wafer carriers 262b and 262c and then load the second and first wafers W2 and W1 to the second and third wafer carriers 262b and 262c, respectively.

[0077] In Fig. 5(i), the second and third load-and-unload cups 282b and 282c are pivoted back to the respective parking positions Xb and Xc. The second and third wafer carriers 262b and 262c polish the second and first wafers W2 and
25 W1 using the polishing pads 255b and 255c on the second and third polishing tables 256b and 256c, respectively. After the polishing processes of the first and second wafers W1 and W2 are completed, the second and third wafer carriers 262b and 262c are lifted from the respective polishing tables 256b and 256c to the respective wafer load-and-unload positions.

30 **[0078]** In Fig. 5(j), the third and fourth load-and-unload cups 282c and 282d are pivoted to the wafer load-and-unload positions of the second and third wafer carriers 262b and 262c, respectively, and then receive the second and first wafers W2 and W1 from the second and third wafer carriers 262b and 262c, respectively.

[0079] In Fig. 5(k), the fourth load-and-unload cup 282d is pivoted back to its parking positions X_d. The third load-and-unload cup 282c is pivoted to the wafer load-and-unload position of the third wafer carrier 262c and then loads the second wafer W2 onto the third wafer carrier 262c.

5 [0080] In Fig. 5(l), the third wafer carrier 262c is pivoted back to its parking position X_c and then the third wafer carrier 262c polishes the second wafer W2 using the polishing pad 255c on the third polishing table 256c. After the polishing process of the second wafer W2 is completed, the third wafer carrier 262c is lifted from the polishing table 256c to its wafer load-and-unload position. The first
10 wafer W1 is removed from the fourth load-and-unload cup 282d by the second wafer transport device 210 (not shown).

[0081] In Fig. 5(m), the fourth load-and-unload cup 282d is pivoted to the wafer load-and-unload position of the third wafer carrier 262c and then receives the second wafer W2 from the third wafer carrier 262c.

15 [0082] In Fig. 5(n), the fourth load-and-unload cup 282d is pivoted back to its parking position X_d and then the second wafer W2 is removed from the fourth load-and-unload cup 282d by the second wafer transport device 210 (not shown).

[0083] Even though an exemplary sequence of transferring and polishing semiconductor wafers in the polishing station 20 has been described using the two
20 wafers W1 and W2, multiple wafers can be transferred and polished continuously one and after in the polishing station 20 in the same manner as these two wafers W1 and W2 have been transferred and polished.

[0084] Pivoting motions of the load-and-unload cups 282 of the polishing station 20 may be controlled individually. However, it is preferred that the
25 pivoting motions of the load-and-unload cups 282 are synchronized such that the load-and-unload cups 282 cannot be pivoted to the same wafer load-and-unload positions at the same time. Simultaneous loading motions and simultaneous unloading motions of the load-and-unload cups 282, as described with reference to Figs. 5(g) and (h), are also preferred because the simultaneous motions can
30 increase the throughput of the polishing station 20 by making it possible for the wafer carriers 262 to be loaded with next wafers as soon as the wafers on the wafer carriers 262 are removed or unloaded from the wafer carriers 262.

[0085] In the polishing station 20, different polishing parameters, such as polishing pressure, slurry and polishing pad, can be used at different polishing units 250a, 250b and 250c. Wafers polished in the polishing station 20 have uniform polishing result without pad-to-pad variation and wafer carrier-to-wafer carrier variation because the wafers are processed sequentially by all of the wafer carriers 262 and on all of the polishing pads 255 of the polishing station 20.

[0086] Even though the polishing station 20 has been described in Fig. 1 as comprising three polishing units 250 and four wafer relay devices 280, the polishing station 20 can comprise other numbers of polishing units 250 and wafer relay devices 280. In a general form, the polishing station 20 comprises N polishing units 250 and N+1 wafer relay devices 280, where N is an integer equal to or larger than 2. The first wafer relay device 280 receives wafers from the first wafer transport device 150 and then transfers them to the wafer carrier 262 of the first polishing unit 250. The last wafer relay device 280 transfers wafers from the wafer carrier 262 of the last polishing unit 250 to the second wafer transport device 210. Each of the other wafer relay devices 280 of the N+1 wafer relay devices 280 is positioned between two different adjacent polishing units 250 and transfers wafers from the wafer carrier 262 of one of the adjacent polishing units to the wafer carrier 262 of the other adjacent polishing unit 250.

[0087] Turning back to Fig. 1, the wafer cleaner 220 of the polishing apparatus 10 is described. The wafer cleaner 220 comprises a first cleaning station 222, a second cleaning station 224, a drying station 226, a first wafer transport device 232, and a second wafer transport device 234. The first wafer transport device 232 transfers wafers from the first cleaning station 222 to the second cleaning station 224. The second wafer transport device 234 transfers wafers from the second cleaning station 224 to the drying station 226. Dried wafers are removed from the drying station 226 by the third wafer transport device 230 and then transferred to the wafer output station 104. The first and second cleaning stations 222 and 224 remove slurry particles from wafer surfaces using D.I. water and/or chemicals, such as NH_4OH , diluted HF and organic chemicals. After the cleaning process is completed, wafers are rinsed with D.I. water and then dried in the drying station 226. The wafer cleaner 220 may comprise more than two cleaning stations or may comprise a single cleaning

station. In other embodiments, the wafer cleaner 220 may further comprise a buffer station (not shown) and an additional wafer transfer device (not shown) in front of the first cleaning station 222. The buffer station accommodates multiple wafers to be cleaned in the first cleaning station 222 and the additional wafer transfer device transfer the wafers from the buffer station to the first cleaning station 222.

[0088] With reference to Figs. 6-8, polishing stations 25a, 25b and 25c in accordance with other embodiments of the present invention are described. Figs. 6-8 are top views of these polishing stations 25a, 25b and 25c, respectively. Any one of these polishing stations 25a, 25b and 25c can be used in the polishing apparatus 10 of Fig. 1 instead of the polishing station 20. In Figs. 6-8, the wafer carriers 262 are illustrated without the respective carrier shafts 264 and the respective rotating-and-vertical drive mechanisms 266. However, each wafer carrier 262 of the polishing stations 25a, 25b and 25c is a part of a wafer carrier assembly 260 as described above with reference to Figs. 1 and 2.

[0089] The polishing station 25a of Fig. 6 can be derived from the polishing station 20 of Fig. 1 by removing the first wafer relay device 280a from the polishing station 20. Thus, the wafer carrier 262a can be defined as an end wafer carrier of the wafer carriers in the polishing station 25a. In this polishing station 25a, the first wafer transport device 150 loads wafers directly onto the wafer carrier 262a of the first polishing unit 250a. Wafers are processed in the polishing station 250a from the wafer carrier 262a of the first polishing unit 250a through the last wafer relay device 280d in the same manner as wafers are processed in the polishing station 20, which was described above. In the polishing station 25a, the first wafer carrier 262a can be washed by the load-and-unload cup 282b, which can pivot to the first wafer carrier 262a.

[0090] The polishing station 25b of Fig. 7 can be derived from the polishing station 20 of Fig. 1 by removing the fourth wafer relay device 280d from the polishing station 20. Thus, the wafer carrier 262c can be defined as an end wafer carrier of the wafer carriers in the polishing station 25b. In this polishing station 25b, the second wafer transport device 210 removes wafers directly from the wafer carrier 262c of the third polishing unit 250c. Wafers are processed in the polishing station 25b from the first wafer relay device 280a through the wafer

carrier 262c of the third polishing unit 250c in the same manner as wafers are processed in the polishing station 20, which was described above. In the polishing station 25b, the third wafer carrier 262c can be washed by the load-and-unload cup 282c, which can pivot to the third wafer carrier 262c.

5 **[0091]** The polishing station 25c of Fig. 8 can be derived from the polishing station 20 of Fig. 1 by removing the first and fourth wafer relay devices 280a and 280d from the polishing station 20. Thus, the wafer carriers 262a and 262c can be defined end wafer carriers of the wafer carriers in the polishing station 25c. In this polishing station 25c, the first wafer transport device 150 loads wafers
10 directly onto the wafer carrier 262a of the first polishing unit 250a and the second wafer transport device 210 removes wafers directly from the wafer carrier 262c of the third polishing unit 250c. Wafers are processed in the polishing station 25c from the wafer carrier 262a of the first polishing unit 250a through the wafer carrier 262c of the third polishing unit 250c in the same manner as wafers are
15 processed in the polishing station 20, which was described above. In the polishing station 25c, the first wafer carrier 262a can be washed by the load-and-unload cup 282b, which can pivot to the first wafer carrier 262a. Furthermore, the fourth wafer carrier 262d can be washed by the load-and-unload cup 282c, which can pivot to the third wafer carrier 262c.

20 **[0092]** In a general form, the polishing stations 25a and 25b have N polishing **units** 250 and N wafer relay devices 280, where N is an integer equal to or larger than 2. The polishing station 25c has N polishing units 250 and N-1 wafer relay devices 280. In the polishing stations 25a and 25c, the first wafer carrier 262 receives wafers directly from the first wafer transport device 150. In
25 the polishing stations 25b and 25c, the last wafer carrier 262 unloads wafers directly to the second wafer transport device 210.

[0093] With reference to Figs. 9 and 10, a polishing station 30 in accordance with an embodiment of the present invention is described. Fig. 9 shows a top view of the polishing station 30. Fig. 10 shows a side view of the polishing
30 station 30, as viewed in the direction U illustrated in Fig. 9. The polishing station 30 can be used in the polishing apparatus 10 of Fig. 1 instead of the polishing station 20.

[0094] The polishing station 30 comprises a first polishing unit 250a, a second polishing unit 250b, a third polishing unit 250c, a linear reciprocating mechanism 410 and a set of four wafer relay devices 281a, 281b, 281c and 281d. Configuration of the polishing station 30 is similar to the polishing station 20 of Fig. 1 except that the wafer relay devices 281a, 281b, 281c and 281d are connected to the linear reciprocating mechanism 410 such that the wafer relay devices can be moved in a linear reciprocating manner in the directions illustrated by the arrow M in Figs. 9 and 10.

[0095] The linear reciprocating mechanism 410 comprises a reciprocating shaft 412, a linear track 414 and a reciprocating drive mechanism 416. The wafer relay devices 281a, 281b, 281c and 281d are mounted on the reciprocating shaft 412. The reciprocating shaft 412 is connected to the linear track 414. The reciprocating drive mechanism 416 controls the linear reciprocating motions M of the wafer relay devices 281 by reciprocating the reciprocating shaft 412 along the linear track 414.

[0096] The polishing units 250a, 250b and 250c are positioned such that their wafer carriers 262a, 262b and 262c are equally spaced in a linear manner. The wafer relay devices 281a, 281b, 281c and 281d are mounted on the reciprocating shaft 412 such that their load-and-unload cups 282a, 282b, 282c and 282d are equally spaced in a linear manner and the distance between two adjacent load-and-unload cups 282 is equal to the distance between two adjacent wafer carriers 262.

[0097] The wafer relay devices 281 of the polishing station 30 are similar to the wafer relay devices 280 of Fig. 1 except that the load-and-unload cups 282 of the wafer relay devices 281 in the polishing station 30 do not need to pivot. Therefore, the shafts 284 of the wafer relay devices 281 of the polishing station 30 are connected to respective vertical drive mechanisms 287 instead of the pivoting-and-vertical drive mechanisms 286 as in the polishing station 20.

[0098] A method of processing wafers in the polishing station 30 is described with reference to Fig. 9. First, the set of wafer relay devices 281a, 281b, 281c and 281d are positioned at their respective parking positions Xa, Xb, Xc and Xd, as illustrated in Fig. 9. The first wafer relay device 281a receives a first wafer from the first wafer transport device 150 and then transfers the first wafer to the

first wafer carrier 262a by the linear motion M. Next, the first wafer relay device 281a is linearly moved back to its parking position Xa and then the first wafer carrier 262a polishes the wafer using the polishing pad 255a on the first polishing table 256a.

5 **[0099]** After the polishing process is completed, the first wafer carrier 262a is lifted from the polishing table 256a and then the second wafer relay device 281b transfers the first wafer from the first wafer carrier 262a to the second wafer carrier 262b by the linear motion M. Next, the second wafer relay device 281b is linearly moved back to its parking position Xb and then the second wafer carrier
10 262b polishes the wafer using the polishing pad 255b on the second polishing table 256b.

[00100] After the polishing process is completed, the second wafer carrier 262b is lifted from the polishing table 256b and then the third wafer relay device 281c transfers the first wafer from the second wafer carrier 262b to the third wafer
15 carrier 262c by the linear motion M. Next, the third wafer relay device 281c is linearly moved back to its parking position Xc and then the third wafer carrier 262c polishes the wafer using the polishing pad 255c on the third polishing table 256c.

[00101] After the polishing process is completed, the third wafer carrier 262c
20 is lifted from the polishing table 256c and then the fourth wafer relay device 281d transfers the first wafer from the third wafer carrier 262b to the second wafer transport device 210 by the linear motion M.

[00102] In a general form, the polishing station 30 has N polishing units 250 and N+1 wafer relay devices 281, where N is an integer equal to or larger than 2.
25 The first wafer relay device 281 receives wafers from the first wafer transport device 150 and transfers the wafers to the first wafer carrier 262. The last wafer relay device 281 receives wafers from the last wafer carrier 262 and transfers the wafers to the second wafer transport device 210. Each of the other N+1 wafer relay devices 281 transfers wafers between the respective two adjacent wafer
30 carriers 262.

[00103] With reference to Figs. 11-13, polishing stations 35a, 35b and 35c in accordance with other embodiments of the present invention are described. Figs. 11-13 are top views of these polishing stations 35a, 35b and 35c. Any one of

these polishing station 35a, 35b and 35c can be used in the polishing apparatus 10 of Fig. 1 instead of the polishing station 20.

[00104] The polishing station 35a of Fig. 11 can be derived from the polishing station 30 of Fig. 9 by removing the first wafer relay device 281a from the polishing station 30. In this polishing station 35a, the first wafer transport device 150 loads wafers directly onto the wafer carrier 262a of the first polishing unit 250a. Wafers are processed in the polishing station 35a from the wafer carrier 262a of the first polishing unit 250a through the last wafer relay device 281d in the same manner as wafers are processed in the polishing station 30, which was described above with reference to Fig. 9. In the polishing station 35a, the first wafer carrier 262a can be washed by the load-and-unload cup 282b, which can be moved to the first wafer carrier 262a.

[00105] The polishing station 35b of Fig. 12 can be derived from the polishing station 30 of Fig. 9 by removing the fourth wafer relay device 281d from the polishing station 30. In this polishing station 35b, the second wafer transport device 210 removes wafers directly from the wafer carrier 262c of the third polishing unit 250c. Wafers are processed in the polishing station 35b from the first wafer relay device 281a through the wafer carrier 262c of the third polishing unit 250c in the same manner as wafers are processed in the polishing station 30, which was described above with reference to Fig. 9. In the polishing station 35b, the third wafer carrier 262c can be washed by the load-and-unload cup 282c, which can be moved to the third wafer carrier 262c.

[00106] The polishing station 35c of Fig. 13 can be derived from the polishing station 30 of Fig. 9 by removing the first and fourth wafer relay devices 281a and 281d from the polishing station 30. In this polishing station 35c, the first wafer transport device 150 loads wafers directly onto the wafer carrier 262a of the first polishing unit 250a and the second wafer transport device 210 removes wafers directly from the wafer carrier 262c of the third polishing unit 250c. Wafers are processed in the polishing station 35c from the wafer carrier 262a of the first polishing unit 250a through the wafer carrier 262c of the third polishing unit 250c in the same manner as wafers are processed in the polishing station 30, which was described above with reference to Fig. 9. In the polishing station 35c, the first wafer carrier 262a can be washed by the load-and-unload cup 282b,

which can be moved to the first wafer carrier 262a. Furthermore, the third wafer carrier 262c can be washed by the load-and-unload cup 282c, which can be moved to the third wafer carrier 262c.

[00107] In a general form, the polishing stations 35a and 35b can have N
5 polishing stations 250 and N wafer relay devices 281, where N is an integer equal to or larger than 2. The polishing station 35c can have N polishing stations 250 and N-1 wafer relay devices 281. In the polishing stations 35a and 35c, the first wafer carrier 262 receives wafers directly from the first wafer transport device 150. In the polishing stations 35b and 35c, the last wafer carrier 262 unloads wafers
10 directly to the second wafer transport device 210.

[00108] With reference to Fig. 14, a polishing station 40 in accordance with another embodiment of the present invention is described. Fig. 14 is a top view of the polishing station 40. A side view of the polishing station 40, as viewed in the direction U illustrated in Fig. 14, is similar to the side view of the polishing station
15 30 illustrated in Fig. 10. The polishing station 40 can be used in the polishing apparatus 10 of Fig. 1 instead of the polishing station 20.

[00109] The polishing station 40 comprises a first polishing unit 251a, a second polishing unit 251b, a third polishing unit 251c, first and second linear reciprocating mechanisms 410 and 410' and first and second sets of four wafer relay devices 281a-281d and 281a'-281d'.
20

[00110] Configuration of the polishing station 40 is similar to the polishing station 30 illustrated in Fig. 9 except that the polishing station 40 further comprises the second set of four wafer relay devices 281a'-281d' and the second linear reciprocating mechanism 410'. Another difference is that the polishing
25 station 40 comprises the polishing units 251a, 251b and 251c instead of the polishing units 250a, 250b and 250c. Each polishing unit 251 comprises a polishing table 256 and first and second wafer carriers 262 and 262'. Each polishing unit 251 may further comprise a pad conditioner 258.

[00111] The polishing units 251a, 251b and 251c are positioned in the
30 polishing station 40 such that the first wafer carriers 262a, 262b and 262c are equally spaced in a linear manner, the second wafer carriers 262a', 262b' and 262c' are also equally spaced in a linear manner, and the first and second wafer carriers 262a-262c and 262a'-262c' are arranged in parallel.

[00112] The second set of wafer relay devices 281a', 281b', 281c' and 281d' are connected to the second linear reciprocating mechanism 410' in the same manner as the first set of wafer relay devices 281a, 281b, 281c and 281d are connected to the first linear reciprocating mechanism 410, as described above with reference to the polishing station 30 of Fig. 9. The second linear reciprocating mechanism 410' controls reciprocating motion M' of the second set of wafer relay devices 281a'-281d' in the same manner as the first linear reciprocating mechanism 410 controls the reciprocating motion M of the first set of wafer relay devices 281a-281d, as described above with reference to the polishing station 30 of Fig. 9.

[00113] The second wafer carriers 262a'-262c' of the polishing units 251a-251c, the second set of wafer relay devices 281a'-281d' and the polishing tables 256a-256c transfer and polish wafers in the same manner as the wafer carriers 262a-262c, the first set of wafer relay devices 281a-281d and the polishing tables 256a-256c of the polishing station 30 transfer and polish wafers, as described above.

[00114] A method of processing wafers in the polishing station 40 can be described with reference to Fig. 14 in the following manner. 1'st, 3'rd, ... and (2N-1)'th wafers are supplied to the first wafer relay device 281a of the first set of wafer relay devices 281a-281d by the first wafer transport device 150 and then transferred from the first wafer relay device 281a through the fourth wafer relay device 281d via the first wafer carriers 262a-262c of the polishing units 251a-251c. During the transferring, the wafers are polished on the polishing tables 256a-256c by the first wafer carriers 262a-262c of the polishing units 251a-251c in a sequential manner. 2'nd, 4'th, ... and 2N'th wafers are supplied to the first wafer relay device 281a' of the second set of wafer relay devices 281a'-281d' by the first wafer transport device 150 and then transferred from the first wafer relay device 281a' through the fourth wafer relay device 281d' via the second wafer carriers 262a'-262c' of the polishing units 251a-251c. During the transferring, the wafers are polished on the polishing tables 256a-256c by the second wafer carriers 262a'-262c' of the polishing units 251a-251c in a sequential manner. Thus, two wafers can be simultaneously polished on each of the polishing tables 256a-256c.

[00115] In a general form, the polishing station 40 can have N polishing units 251 and two sets of N+1 wafer relay devices 281, where N is an integer equal to or larger than 2. The first wafer transport device 150 transfers wafers to the first two wafer relay devices 281 and the second wafer transport device 210 removes the wafers from the last two wafer relay devices 281.

[00116] The polishing station 40 can be modified such that the first wafer transport device 150 transfer wafers directly to the wafer carriers 262a and 262a' of the first polishing unit 251a by removing the first wafer relay devices 281a and 281a' from the polishing station 40 of Fig. 14. Wafers are processed in this modified polishing station from the wafer carriers 262a and 262a' of the first polishing unit 251a through the last wafer relay devices 281d and 281d' in the same manner as wafers are processed in the polishing station 40, which was described above with reference to Fig. 14. In this modified polishing station, the wafer carriers 262a and 262a' of the first polishing unit 251a can be washed by the load-and-unload cups 282b and 282b', respectively, which can be moved to the wafer carriers 262a and 262a'.

[00117] In a general form, this modified polishing station has N polishing units 251 and two sets of N wafer relay devices 281, where N is an integer equal to or larger than 2. The first wafer transport device 150 transfers wafers to the wafer carriers 262 of the first polishing unit 251 and the second wafer transport device 210 removes the wafers from the last two wafer relay devices 281.

[00118] The polishing station 40 can be also modified such that the second wafer transport device 210 transfer wafers directly from the wafer carriers 262c and 262c' of the last polishing unit 251c by removing the last wafer relay devices 281d and 281d' from the polishing station 40 of Fig. 14. Wafers are processed in this modified polishing station from the first wafer relay devices 281a and 281' through the wafer carriers 262c and 262c' of the third polishing unit 251c in the same manner as wafers are processed in the polishing station 40, which was described above with reference to Fig. 14. In this modified polishing station, the wafer carriers 262c and 262c' of the third polishing unit 251c can be washed by the load-and-unload cups 282c and 282c', respectively, which can be moved to the wafer carriers 262c and 262c'.

[00119] In a general form, this modified polishing station has N polishing units 251 and two sets of N wafer relay devices 281, where N is an integer equal to or larger than 2. The first wafer transport device 150 transfers wafers to the first wafer relay devices 281 and the second wafer transport device 210 removes the wafers from the wafer carriers 262 of the last wafer relay devices 281.

[00120] The polishing station 40 can be further modified such that the first and second wafer transport devices 150 and 210 transfer wafers directly to and from the wafer carriers 262 of the first and last polishing units 251a and 251c, respectively, by removing the first wafer relay devices 281a and 281a' and the last wafer relay devices 281d and 281d' from the polishing station 40 of Fig. 14.

Wafers are processed in this modified polishing station from the wafer carriers 262a and 262a' of the first polishing unit 251a to the wafer carriers 262c and 262c' of the third polishing unit 251c in the same manner as wafers are processed in the polishing station 40, which was described above with reference to Fig. 14.

In this modified polishing station 40, the wafer carriers 262a and 262a' of the first polishing unit 251a can be washed by the load-and-unload cups 282b and 282b', respectively, which can be moved to the wafer carriers 262a and 262a'.

Furthermore, the wafer carriers 262c and 262c' of the third polishing unit 251c can be washed by the load-and-unload cups 282c and 282c', respectively, which can be moved to the wafer carriers 262c and 262c'.

[00121] In a general form, this modified polishing station has N polishing units 251 and N-1 wafer relay devices 281, where N is an integer equal to or larger than 2. The first wafer transport device 150 transfers wafers to the wafer carriers 262 of the first polishing unit 251a and the second wafer transport device 210 removes the wafers from the wafer carriers 262 of the last polishing unit 251.

[00122] With reference to Fig. 15, a polishing station 45 in accordance with an embodiment of the present invention is described. Fig. 15 shows a top view of the polishing station 45. A side view of the polishing station 45, as viewed in the direction U illustrated in Fig. 15, is similar to the side view of the polishing station 30 illustrated in Fig. 10. The polishing station 45 can be used in the polishing apparatus 10 of Fig. 1 instead of the polishing station 20.

[00123] The polishing station 45 can be derived from the polishing station 40 of Fig. 14 by removing the second linear reciprocating mechanism 410' from the

- polishing station 40 and connecting the load-and-unload cups 282a', 282b', 282c' and 282d' to the load-and-unload cups 282a, 282b, 282c and 282d, respectively, forming dual wafer relay devices 680a-680d. Each dual wafer relay device 680 of the polishing station 45 comprises first and second load-and-unload cups 282 and 282', an arm 283, a shaft 284 and a vertical drive mechanism 287. The first and second load-and-unload cups 282 and 282' are connected to the arm 283, which is connected to the shaft 284. The shaft 284 is connected to the vertical drive mechanism 287. The vertical drive mechanisms 287a-287d of the four dual wafer relay devices 680a-680d are connected to the linear reciprocating mechanism 410.
- Vertical motions of the load-and-unload cups 282a and 282a', 282b and 282b', 282c and 282c', and 282d and 282d' are controlled by the respective vertical drive mechanisms 287a, 287b, 287c and 287d. Linear reciprocating motions of the four dual wafer relay devices 680a-680d, which is illustrated with the arrow M in Fig 15, are controlled by the linear reciprocating mechanism 410.
- [00124]** A method of processing wafers in the polishing station 45 is described with reference to Fig. 15. First, the first dual wafer relay device 680a receives wafers from the first wafer transport device 150 and then transfers them to the wafer carriers 262a and 262a' of the first polishing unit 251a by the linear motion M. After the first dual wafer relay device 680a is backed to its parking position, which is located between the first wafer transport device 150 and the first polishing unit 251a, the wafer carriers 262a and 262a' polish the wafers using the polishing pad 255a on the polishing table 256a.
- [00125]** After the polishing process is completed, the wafer carriers 262a and 262a' are lifted from the polishing table 256a and then the second dual wafer relay device 680b transfers the wafers from the wafer carrier 262a and 262a' to the wafer carrier 262b and 262b' of the second polishing unit 251b by the linear motion M. Next, the second dual wafer relay device 680b is moved back to its parking position, which is located between the first and second polishing units 251a and 251b. Next, the wafer carrier 262b and 262b' polish the wafers using the polishing pad 255b on the second polishing table 256b.
- [00126]** After the polishing process is completed, the wafer carrier 262b and 262b' are lifted from the polishing table 256b and then the third dual wafer relay device 680c transfers the wafers from the wafer carriers 262b and 262b' to the

wafer carriers 262c and 262c' by the linear motion M. Next, the third dual wafer relay device 680c is moved back to its parking position, which is located between the second and third polishing units 251b and 251c. Next, the wafer carriers 262c and 262c' polish the wafers using the polishing pad 255c on the third polishing table 256c.

[00127] After the polishing process is completed, the wafer carriers 262c and 262c' are lifted from the polishing table 256c and then the fourth dual wafer relay device 680d transfers the wafers from the wafer carriers 262c and 262c' to the second wafer transport device 210 by the linear motion M.

10 [00128] In a general form, the polishing station 45 can have N polishing units 251 and N+1 dual wafer relay devices 680, where N is an integer equal to or larger than 2. The first wafer transport device 150 transfers wafers to the first dual wafer relay device 680 and the second wafer transport device 210 removes the wafers from the last dual wafer relay device 680.

15 [00129] The polishing station 45 can be modified such that the first wafer transport device 150 transfer wafers directly to the wafer carriers 262a and 262a' of the first polishing unit 251a by removing the first dual wafer relay device 680a from the polishing station 45. Wafers are processed in this modified polishing station from the wafer carriers 262a and 262a' of the first polishing unit 251a through the last dual wafer relay device 680d in the same manner as wafers are processed in the polishing station 45, which was described above with reference to Fig. 15. In this modified polishing station, the wafer carriers 262a and 262a' of the first polishing unit 251a can be washed by the dual wafer relay device 680b, which can be moved to the wafer carriers 262a and 262a'.

25 [00130] In a general form, this modified polishing station has N polishing units 251 and N dual wafer relay devices 680, where N is an integer equal to or larger than 2. The first wafer transport device 150 transfers wafers to the wafer carriers 262 of the first polishing unit 251 and the second wafer transport device 210 removes the wafers from the last dual wafer relay device 680.

30 [00131] The polishing station 45 can be also modified such that the second wafer transport device 210 transfer wafers directly from the wafer carriers 262c and 262c' of the last polishing unit 251c by removing the last dual wafer relay device 680d from the polishing station 45. Wafers are processed in this modified

polishing station from the first dual wafer relay device 680a through the wafer carriers 262c and 262c' of the third polishing unit 251c in the same manner as wafers are processed in the polishing station 45, which was described above with reference to Fig. 15. In this modified polishing station, the wafer carriers 262c and 262c' of the third polishing unit 251c can be washed by the dual wafer relay device 680c, which can be moved to the wafer carriers 262c and 262c'.

[00132] In a general form, this modified polishing station has N polishing units 251 and N dual wafer relay devices 680, where N is an integer equal to or larger than 2. The first wafer transport device 150 transfers wafers to the first dual wafer relay device 680 and the second wafer transport device 210 removes the wafers from the wafer carriers 262 of the last polishing unit 251.

[00133] The polishing station 45 can be further modified such that the first and second wafer transport devices 150 and 210 transfer wafers directly to and from the wafer carriers 262 of the first and last polishing units 251, respectively, by removing the first and last dual wafer relay devices 680a and 680c from the polishing station 45. Wafers are processed in this modified polishing station from the wafer carriers 262a and 262a' of the first polishing unit 251a to the wafer carriers 262c and 262c' of the third polishing unit 251c in the same manner as wafers are processed in the polishing station 45, which was described above with reference to Fig. 15. In this modified polishing station, the wafer carriers 262a and 262a' of the first polishing unit 251a can be washed by the dual wafer relay device 680b, which can be moved to the wafer carriers 262a and 262a'.

Furthermore, the wafer carriers 262c and 262c' of the third polishing unit 251c can be washed by the dual wafer relay device 680c, which can be moved to the wafer carriers 262c and 262c'.

[00134] In a general form, this modified polishing station has N polishing units 251 and N-1 dual wafer relay devices 680, where N is an integer equal to or larger than 2. The first wafer transport device 150 transfers wafers to the wafer carriers 262 of the first polishing unit 251 and the second wafer transport device 210 removes the wafers from the wafer carriers 262 of the last polishing unit 251.

[00135] With reference to Fig. 16, a polishing station 50 in accordance with an embodiment of the present invention is described. Fig. 16 is a top view of the

polishing station 50. The polishing station 50 can be used in the polishing apparatus 10 of Fig. 1 instead of the polishing station 20.

[00136] The polishing station 50 can be derived from the polishing station 30 of Fig. 9 by connecting the first wafer relay device 281a of the polishing station
5 30 to a first linear reciprocating mechanism 410a, connecting the second and third wafer relay devices 281b and 281c of the polishing station 30 to a second linear reciprocating mechanism 410b and connecting the fourth wafer relay device 281d of the polishing station 30 to a third linear reciprocating mechanism 410c.

[00137] The first linear reciprocating mechanism 410a controls reciprocating
10 motion of the first wafer relay device 281a as illustrated with the arrow Ma in Fig. 16. The second linear reciprocating mechanism 410b controls reciprocating motions of the second and third wafer relay devices 281b and 281c, as illustrated with the arrow Mb in Fig. 16. The third linear reciprocating mechanism 410c controls reciprocating motion of the fourth wafer relay device 281d, as illustrated
15 with the arrow Mc in Fig. 16.

[00138] A method of processing wafers in the polishing station 50 is similar to the method of processing wafers in the polishing station 30 of Fig. 9 except that linear reciprocating motions of the first wafer relay device 281a, the second and third wafer relay devices 281b and 281c, and the fourth wafer relay device 281d
20 are controlled individually in the polishing station 50.

[00139] In a general form, the polishing station 50 can have N polishing units 250 and N+1 wafer relay devices 281, where N is an integer equal to or larger than 2. The first wafer transport device 150 transfers wafers to the first wafer relay device 281 and the second wafer transport device 210 removes the wafers
25 from the last wafer relay device 281.

[00140] The polishing station 50 can be modified such that the first wafer transport device 150 transfers wafers directly to the wafer carrier 262a of the first polishing unit 250a by removing the first wafer relay device 281a and the first linear reciprocating mechanism 410a. Wafers are processed in this modified
30 polishing station from the wafer carrier 262a of the first polishing unit 250a through the last wafer relay device 281d in the same manner as wafers are processed in the polishing station 50, which was described above with reference to Fig. 16. In this modified polishing station, the wafer carrier 262a of the first

polishing unit 250a can be washed by the wafer relay device 281b, which can be moved to the wafer carrier 262a.

[00141] In a general form, the polishing station 50 can be modified to have N polishing units 250 and N wafer relay devices 281, where N is an integer equal to or larger than 2, such that the first wafer transport device 150 transfers wafers to the wafer carrier of the first polishing unit 250 and the second wafer transport device 210 removes the wafers from the last wafer relay device 281.

[00142] The polishing station 50 can be also modified such that the second wafer transport device 210 transfers wafers directly from the wafer carrier 262c of the last polishing unit 250c by removing the last wafer relay devices 281c and the third linear reciprocating mechanism 410c. Wafers are processed in this modified polishing station from the first wafer relay device 281a through the wafer carrier 262c of the third polishing unit 250c in the same manner as wafers are processed in the polishing station 50, which was described above with reference to Fig. 16. In this modified polishing station 50, the wafer carrier 262c of the third polishing unit 250c can be washed by the wafer relay device 281c, which can be moved to the wafer carrier 262c.

[00143] In a general form, the polishing station 50 can be modified to have N polishing unit 250 and N wafer relay devices 281, where N is an integer equal to or larger than 2, such that the first wafer transport device 150 transfers wafers to the first wafer relay device 281 and the second wafer transport device 210 removes the wafers from the wafer carrier 262 of the last polishing unit 250.

[00144] The polishing station 50 can be further modified such that the first and second wafer transport devices 150 and 210 transfer wafers directly to and from the wafer carriers 262 of the first and last polishing units 250a and 250c, respectively, by removing the first and last wafer relay devices 281a and 281c and the first and third linear reciprocating mechanisms 410a and 410c. Wafers are processed in this modified polishing station from the wafer carrier 262a of the first polishing unit 250a to the wafer carrier 262c of the third polishing unit 250c in the same manner as wafers are processed in the polishing station 50, which was described above with reference to Fig. 16. In this modified polishing station, the wafer carrier 262a of the first polishing unit 250a can be washed by the wafer relay device 281b, which can be moved to the wafer carrier 262a. Furthermore,

the wafer carrier 262c of the third polishing unit 250c can be washed by the wafer relay device 281c, which can be moved to the wafer carrier 262c.

[00145] In a general form, the polishing station 50 can be modified to have N polishing unit 250 and N-1 wafer relay device 281, where N is an integer equal to
5 or larger than 2. The first wafer transport device 150 transfers wafers to the wafer carrier 262 of the first polishing unit 250 and the second wafer transport device 210 removes the wafers from the wafer carrier 262 of the last polishing unit 250.

[00146] The polishing station 50 of Fig. 16 and its modified embodiments described above can be modified such that each wafer relay device 281 is
10 connected to its own linear reciprocating mechanism 410. In this modified polishing station, each wafer relay device 281 is driven individually by the respective linear reciprocating mechanism 410. This modified polishing station, therefore, comprises the same number of linear reciprocating mechanisms 410 as the number of wafer relay devices 281.

[00147] Methods of processing wafers in these modified polishing stations
15 are similar to the methods of processing wafers in the polishing station 30, 35(a), 35(b) and 35(c) of Figs. 9, 11, 12 and 13 except that linear reciprocating motions of each wafer relay device 281 are controlled individually.

[00148] With reference to Fig. 17, a polishing station 55 in accordance with
20 another embodiment of the present invention is described. Fig. 17 is a top view of the polishing station 55. The polishing station 55 can be used in the polishing apparatus 10 of Fig. 1 instead of the polishing station 20.

[00149] Configuration of the polishing station 55 is similar to the polishing station 50 of Fig. 16 except that the polishing station 50 further comprises the
25 second set of four wafer relay devices 281a'-281d' and the second set of three linear reciprocating mechanisms 410a'-410c' over the first set of four wafer relay devices 281a-281d and the first set of three linear reciprocating mechanisms 410a-410c of the polishing station 50 of Fig. 16. Another difference is that the polishing station 55 comprises the polishing units 251a, 251b and 251c instead of
30 the polishing units 250a, 250b and 250c. Each polishing unit 251 comprises a polishing table 256, and first and second wafer carriers 262 and 262'. Although not shown, each polishing unit 251 may also include a pad conditioner 258.

[00150] The second set of wafer relay devices 281a'-281d' are connected to the second set of three linear reciprocating mechanisms 410a'-410c' in the same manner as the first set of wafer relay devices 281a-281d are connected to the first set of three linear reciprocating mechanisms 410a-410c in the polishing station 55 of Fig. 16. The second set of three linear reciprocating mechanisms 410a'-410c' control reciprocating motions Ma', Mb' and Mc' of the second set of wafer relay devices 281a'-281d' in the same manner as the first set of three linear reciprocating mechanisms 410a-410c control the reciprocating motions Ma, Mb and Mc of the first set of wafer relay devices 281a-281d, as described above with reference to Fig. 16.

[00151] The second set of wafer relay devices 281a'-281d' and the second wafer carriers 262a'-262c' of the polishing units 251a-251c transfer and polish wafers in the same manner as the first set of wafer relay devices 281a-281d and the first wafer carriers 262a-262c of the polishing units 251a-251c, as described above with reference to Fig. 16.

[00152] A method of processing wafers in the polishing station 55 is similar to the method of processing wafers in the polishing station 40 of Fig. 14 except that linear reciprocating motions of the first wafer relay device 281a, the second and third wafer relay devices 281b and 281c, the fourth wafer relay device 281d, the first wafer relay device 281a', the second and third wafer relay devices 281b' and 281c', and the fourth wafer relay device 281d' are controlled individually in the polishing station 55.

[00153] In a general form, the polishing station 55 can have N polishing units 251 and $2*(N+1)$ wafer relay devices 281, where N is an integer equal to or larger than 2. The first wafer transport device 150 transfers wafers to the first two wafer relay devices 281 and the second wafer transport device 210 removes the wafers from the last two wafer relay devices 281.

[00154] The polishing station 55 can be modified such that the first wafer transport device 150 transfer wafers directly to the wafer carriers 262a and 262a' of the first polishing unit 251a by removing the first wafer relay devices 281a and 281a' and the first linear reciprocating mechanisms 410a and 410a'. Wafers are processed in this modified polishing station from the wafer carriers 262a and 262a' of the first polishing unit 251a through the last wafer relay devices 281d and

281d' in the same manner as wafers are processed in the polishing station 55. In this modified polishing station, the wafer carriers 262a and 262a' of the first polishing unit 251a can be washed by the load-and-unload cups 282b and 282b', respectively, which can be moved to the wafer carriers 262a and 262a'.

5 [00155] In a general form, the polishing station 55 can be modified to have N polishing unit 251 and $2*N$ wafer relay devices 281, where N is an integer equal to or larger than 2, such that the first wafer transport device 150 transfers wafers to the two wafer carriers 262 of the first polishing unit 251 and the second wafer transport device 210 removes the wafers from the last two wafer relay devices 281.

10 [00156] The polishing station 55 can be also modified such that the second wafer transport device 210 removes wafers directly from the wafer carriers 262c and 262c' of the last polishing unit 251c by removing the last wafer relay devices 281d and 281d' and the third linear reciprocating mechanisms 410c and 410c', respectively. Wafers are processed in this modified polishing station from the
15 first wafer relay devices 281a and 281' through the wafer carriers 262c and 262c' of the third polishing unit 251c in the same manner as wafers are processed in the polishing station 55, which was described above with reference to Fig. 17. In this modified polishing station, the wafer carriers 262c and 262c' of the third polishing unit 251c can be washed by the load-and-unload cups 282c and 282c',
20 respectively, which can be moved to the wafer carriers 262c and 262c'.

[00157] In a general form, the polishing station 55 can be modified to have N polishing units 251 and $2*N$ wafer relay devices 281, where N is an integer equal to or larger than 2, such that the first wafer transport device 150 transfers wafers to the first wafer relay devices 281a and 281a' and the second wafer transport
25 device 210 removes the wafers from the wafer carriers 262 of the last polishing unit 251.

[00158] The polishing station 55 can be further modified such that the first and second wafer transport devices 150 and 210 transfer wafers directly to and from the wafer carriers 262 of the first polishing unit 251a and the last polishing
30 units 251c, respectively, by removing the first wafer relay devices 281a and 281a', the last wafer relay devices 281d and 281d', and the first and last linear reciprocating mechanisms 410a, 410a', 410c and 410c'.

[00159] In a general form, the polishing station 55 can be modified to have N polishing units 251 and $2*(N-1)$ wafer relay devices 281, where N is an integer equal to or larger than 2. The first wafer transport device 150 transfers wafers to the wafer carriers 262 of the first polishing unit 251 and the second wafer
5 transport device 210 removes the wafers from the wafer carriers 262 of the last polishing unit 251. In this modified polishing station, the wafer carriers 262a and 262a' of the first polishing unit 251a can be washed by the load-and-unload cups 282b and 282b', respectively, which can be moved to the wafer carriers 262a and 262a'. Furthermore, the wafer carriers 262c and 262c' of the third polishing unit
10 251c can be washed by the load-and-unload cups 282c and 282c', respectively, which can be moved to the wafer carriers 262c and 262c'.

[00160] The polishing station 55 of Fig. 17 and its modified embodiments described above can be modified such that each wafer relay device 281 is connected to its own linear reciprocating mechanism 410. In these modified
15 polishing stations, each wafer relay device 281 is driven individually by the respective linear reciprocating mechanism 410. This modified polishing station, therefore, comprises the same number of the linear reciprocating mechanisms 410 as the number of the wafer relay devices 281.

[00161] Methods of processing wafers in these modified polishing stations
20 are similar to the method of processing wafers in the polishing station 55 of Fig. 17 except that linear reciprocating motions of each wafer relay device 281 are controlled individually.

[00162] With reference to Figs. 18 and 19, a polishing station 60 in accordance with another embodiment of the present invention is described. The
25 polishing station 60 can be used in the polishing apparatus 10 instead of the polishing station 20. Fig. 18 shows a top view of the polishing station 60. Fig. 19 is a side view of the polishing station 60, as viewed in the U direction illustrated in Fig. 18.

[00163] The polishing station 60 comprises a set of four wafer transfer
30 stations 285a- 285d, three polishing tables 256a-256c, three wafer carrier assemblies 260a-260c and a wafer conveying device 480. The region of the polishing station 60 adjacent to the first wafer transport device 150 is an input region of the polishing station to receive wafers into the polishing station. The

region of the polishing station 60 adjacent to the second wafer transport device 210 is an output region of the polishing station to output polished wafers from the polishing station. Preferably, the input region and the output region of the polishing station 60 are at opposite ends of the polishing station. The wafer transfer stations 285a-285d are equally spaced in a linear manner such that one polishing table 256 is situated between two adjacent wafer transfer stations 285. Each wafer transfer station 285 comprises a load-and-unload cup 282, a shaft 284 and a vertical drive mechanism 287, as illustrated in Fig. 19. The load-and-unload cup 282 is mounted on the shaft 284, which is connected to the vertical drive mechanism 287. Therefore, the load-and-unload cup 282 can move vertically by the vertical drive mechanism 287. The load-and-unload cups 282 can wash the wafer carriers 262 by spraying D.I. water when the wafer carriers 262 are positioned on the load-and-unload cups 282.

[00164] The polishing tables 256a-256c are also arranged in a linear manner such that one polishing table 256 is situated between two adjacent wafer transfer stations 285. The first, second and third wafer carriers 262a, 262b and 262c polish wafers using polishing pads 255a-255c on the first, second and third polishing tables 256a-256c, respectively.

[00165] The wafer conveying device 480 comprises a conveyer 482, a conveying track 484 and a reciprocating drive mechanism 486. The three wafer carrier assemblies 260a-260c are mounted to the conveyer 482 such that the wafer carriers 262 are equally spaced. The distance between the neighboring two wafer carriers 262 is set to be same as the distance between the neighboring two wafer transfer stations 285 such that the wafer carriers 262a-262c can be positioned simultaneously on the wafer transfer stations 285a-285c or 285b-285d. The conveyer 482 is mounted on the conveying track 484, which is connected to the reciprocating drive mechanism 486. The reciprocating drive mechanism 486 moves the wafer carrier assemblies 260a-260c back and forth in a linear manner by reciprocating the conveyer 482 along the conveying track 484. The forward and backward linear motions are designated as X and Y, respectively, as illustrated in Figs. 20 and 21. The conveying track 484 is mounted to a top housing 488 of the polishing station 60.

- [00166] A method of processing wafers in the polishing station 60 is described with reference to Figs. 18, 20(a) and 20(b). Figs. 20(a) and 20(b) are top views of the polishing station 60 where wafer carriers 262 are positioned in wafer loading positions and wafer unloading positions, respectively. Fig. 20(a) illustrates a wafer loading process. Fig. 20(b) illustrates a wafer unloading process. First, the wafer carriers 262a-262c are temporarily positioned over the polishing tables 256a, 256b and 256c, respectively, as illustrated in Fig. 18. The first wafer is supplied to the first wafer transfer station 285a by the first wafer transport device 150.
- 10 [00167] Next, the wafer carriers 262a, 262b and 262c are transferred to respective wafer loading positions that are located over the wafer transfer stations 285a-285c, respectively, by the forward linear motion X of the conveyer 482, as illustrated in Fig. 20(a). The first wafer is loaded from the first wafer transfer station 285a onto the first wafer carrier 262a.
- 15 [00168] Next, the wafer carriers 262a-262c are transferred to the respective wafer polishing positions over the polishing tables 256a-256c, respectively, by the backward linear motion Y of the conveyer 482, as illustrated in Fig. 18. The first wafer carrier 262a polishes the first wafer using the polishing pad 255a on the first polishing table 256a. After the polishing process of the first wafer is completed, the first wafer carrier 262a is lifted from the polishing table 256a.
- 20 [00169] Next, the wafer carriers 262a-262c are transferred to the respective wafer unloading positions that are located over the wafer transfer stations 285b-285d, respectively, by the backward linear motion Y of the conveyer 482, as illustrated in Fig. 20(b). The first wafer is unloaded from the first wafer carrier 262a to the second wafer transfer station 285b.
- 25 [00170] Next, the wafer carriers 262a-262c are transferred again to the respective wafer loading positions by the forward linear motion X of the conveyer 482, as illustrated in Fig. 20(a). The first wafer is loaded from the second wafer transfer station 285b onto the second wafer carrier 262b.
- 30 [00171] Next, the wafer carriers 262a-262c are transferred to the respective wafer polishing positions again by the backward linear motion Y of the conveyer 482, as illustrated in Fig. 18. The second wafer carrier 262b polishes the first wafer using the polishing pad 255b on the second polishing table 256b. After the

polishing process of the first wafer is completed, the second wafer carrier 262b is lifted from the polishing tables 256b.

[00172] Next, the wafer carriers 262a-262c are transferred to the respective wafer unloading positions again by the backward linear motion Y of the conveyer 482, as illustrated in Fig. 20(b). The first wafer is unloaded from the second wafer carrier 262b to the third wafer transfer station 285c.

[00173] Next, the wafer carriers 262a-262c are transferred to the respective wafer loading positions again by the forward linear motion X of the conveyer 482, as illustrated in Fig. 20(a). The first wafer is loaded from the third wafer transfer station 285c onto the third wafer carrier 262c.

[00174] Next, the wafer carriers 262a-262c are transferred to the respective wafer polishing positions by the backward linear motion Y of the conveyer 482, as illustrated in Fig. 18. The third wafer carrier 262c polishes the first wafer by using the polishing pad 255c on the third polishing table 256c. After the polishing process of the first wafer is completed, the third wafer carrier 262c is lifted from the polishing table 256c.

[00175] Next, the wafer carriers 262a-262c are transferred to the respective wafer unloading positions again by the backward linear motion Y of the conveyer 482, as illustrated in Fig. 20(b). The first wafer is unloaded from the third wafer carrier 262c to the fourth wafer transfer stations 285d.

[00176] Next, the wafer carriers 262a-262c are transferred to the respective wafer loading positions again by the forward linear motion X of the conveyer 482, as illustrated in Fig. 20(a). The first wafer is removed from the fourth wafer transfer station 285d by the second wafer transport device 210. In this fashion, wafers can be sequentially polished on the polishing tables 256a-256c one after another.

[00177] In a general form, the polishing station 60 comprises N polishing tables 256, N+1 wafer transfer stations 285, a wafer conveying device 480 and N wafer carriers 262, where N is an integer equal to or larger than 2. The first wafer transport device 150 transfers wafers to be polished to the first wafer transfer station 285 of the N+1 wafer transfer stations 285 and the second wafer transport device 210 transfers polished wafers from the last wafer transfer station 285 of the N+1 wafer transfer stations 285.

[00178] With reference to Figs. 21(a), 21(b) and 21(c), polishing stations 65a, 65b and 65c in accordance with other embodiments of the present invention are described. Any of these polishing stations can be used in the polishing apparatus 10 of Fig. 1 instead of the polishing station 20. Fig. 21(a), 21(b) and 21(c) are top
5 views of the polishing stations 65a, 65b and 65c, respectively.

[00179] The polishing station 65a of Fig. 21(a) can be derived from the polishing station 60 by removing the first wafer transfer station 285a. In this polishing station 65a, the first wafer transport device 150 transfers wafers directly to the first wafer carrier 262a. Wafers are processed in the polishing station 65a
10 from the first wafer carrier 262a through the last wafer transfer station 285d in the same manner as wafers are processed in the polishing station 60, which was described above. In the polishing station 65a, the first wafer carrier 262a can be washed at the wafer transfer station 285b that is located between the first and second polishing tables 256a and 256b.

[00180] The polishing station 65b of Fig. 21(b) can be derived from the polishing station 60 by removing the last wafer transfer station 285d. Therefore, the second wafer transport device 210 transfers wafers directly from the wafer carrier 262c. Wafers are processed in the polishing station 65b from the first
15 wafer transfer station 285a through the last wafer carrier 262c in the same manner as wafers are processed in the polishing station 60, which was described above. In the polishing station 65b, the third wafer carrier 262c can be washed at the wafer transfer station 285c that is located between the second and third polishing tables 256b and 256c.

[00181] The polishing station 65c of Fig. 21(c) can be derived from the polishing station 60 by removing the first and last wafer transfer stations 285a and 285d. In this polishing station 65c, the first wafer transport device 150 loads
25 wafers directly onto the first wafer carrier 262a and the second wafer transport device 210 removes wafers directly from the last wafer carrier 262c. Wafers are processed in the polishing station 65c from the first wafer carrier 262a through the last wafer carrier 262c in the same manner as wafers are in the polishing station
30 60, which was described above. In the polishing station 65c, the first wafer carrier 262a can be washed at the wafer transfer station 285b that is located between the first polishing table 256a and the second polishing table 256b. Furthermore, the

third wafer carrier 262c can be washed at the wafer transfer station 285c that is located between the second polishing table 256b and the third polishing table 256c.

[00182] In a general form, the polishing stations 65a and 65b can have N polishing tables 256, N wafer carriers 262 and N wafer transfer stations 285, where N is an integer equal to or larger than 2. The polishing station 65c has N polishing tables 256, N wafer carriers 262 and N-1 wafer transfer stations 285. In the polishing stations 65a and 65c, the first wafer carrier 262 receives wafers directly from the first wafer transport device 150. In the polishing stations 65b and 65c, the last wafer carrier 262 unloads wafers directly to the second wafer transport device 210.

[00183] With reference to Fig. 22, a polishing station 70 in accordance with another embodiment of the present invention is described. Fig. 22 is a top view of the polishing station 70. A side view of the polishing station 70, as viewed in the direction U illustrated in Fig. 22, is similar to the side view of the polishing station 60 illustrated in Fig. 19. The polishing station 70 can be used in the polishing apparatus 10 of Fig. 1 instead of the polishing station 20. The polishing station 70 is modified from the polishing station 60 illustrated in Fig. 18 by adding a second wafer conveying device 480', a second set of four wafer transfer stations 285a'-285d', and a second set of three wafer carrier assemblies 260a'-260c' to the polishing station 60.

[00184] The second set of wafer transfer stations 285a'-285d' are arranged in the same manner as the first set of wafer transfer stations 285a-285d are arranged relatively to the polishing tables 256a, 256b and 256c. The second set of three wafer carriers 262a'-262c' can move in a reciprocating manner by the second wafer conveying device 480' similar to the way the first set of three wafer carriers 262a-262c can move in a reciprocating manner by the first wafer conveying device 480. The second wafer conveying device 480' is arranged in a parallel manner to the first wafer conveying device 480 such that the second set of three wafer carriers 262a'-262c' can polish wafers on the first, second and third polishing tables 256a-256c, respectively. The second wafer conveying device 480' transfers wafers in the same manner as the first wafer conveying device 480. The first and second conveying devices 480 and 480' can be operated individually or collectively.

- [00185] In the individual manner, first and second wafers W1 and W2 to be polished are supplied to the first two wafer transfer stations 285a and 285a' of the first and second sets of wafer transfer stations 285, respectively, by the first wafer transport device 150, as illustrated in Fig. 22. Next, the first wafer W1 is transferred from the first wafer transfer station 285a to the first wafer carrier 262a and then polished on the polishing tables 256 according to the sequence described above with reference to Figs. 18, 20(a) and 20(b). After the first wafer W1 is transferred from the first wafer transfer station 285a, the second wafer W2 is transferred from the first wafer transfer station 285a' to the first wafer carrier 262a' and then polished on the polishing tables 256 according to the same sequence described above with reference to Figs. 18, 20(a) and 20(b). 3rd, 5th, ... and (2N-1)th wafers are processed in the same manner as the first wafer W1. 4th, 6th, ... and 2Nth wafers are processed in the same manner as the second wafer W2.
- [00186] In the collective manner, the first and second wafers W1 and W2 are simultaneously transferred from the first two wafer transfer stations 285a and 285a' to the first wafer carriers 262a and 262a', respectively, and then simultaneously polished on the polishing tables 256 according to the sequence described above with reference to Figs. 18, 20(a) and 20(b).
- [00187] In the polishing station 70 of Fig. 22, the conveyers 482 and 482' of the first and second wafer conveying devices 480 and 480' can be connected using a connector (not shown) such that their reciprocating motions are controlled collectively by a single reciprocating drive mechanism.
- [00188] In a general form, the polishing station 70 comprises N polishing tables 256, two sets of N wafer carriers 262, two sets of N + 1 wafer transfer stations 285 and at least one wafer conveying device 480, where N is an integer equal to or larger than 2. The first wafer transport device 150 transfers wafers to the first two wafer transfer stations 285 and the second wafer transport device 210 removes the wafers from the last two wafer transfer stations 285.
- [00189] The polishing station 70 of Fig. 22 can be modified such that the first wafer transport device 150 transfer wafers directly to the first wafer carriers 262a and 262a' by removing the first two wafer transfer stations 285a and 285a' from the polishing station 70. Wafers are processed in this modified polishing station

from the first two wafer carriers 262a and 262a' through the last two wafer transfer stations 285d and 285d' in the same manner as wafers are processed in the polishing station 70, which was described above with reference to Fig. 22. In this modified polishing station, the first two wafer carriers 262a and 262a' can be
5 washed at the wafer transfer stations 285b and 285b' that are located between the first polishing table 256a and the second polishing table 256b.

[00190] In a general form, this modified polishing station comprises N polishing tables 256, two sets of N wafer carriers 262, two sets of N wafer transfer stations 285 and at least one wafer conveying device 480, where N is an integer
10 equal to or larger than 2. The first wafer transport device 150 transfers wafers to the first two wafer carriers 262 and the second wafer transport device 210 removes the wafers from the last two wafer transfer stations 285.

[00191] The polishing station 70 of Fig. 22 can be also modified such that the second wafer transport device 210 transfers wafers directly from the last wafer
15 carriers 262c and 262c' by removing the last wafer transfer stations 285d and 285d'. Wafers are processed in this modified polishing station from the first two wafer transfer stations 285a and 285a' through the third two wafer carriers 262c and 262c' in the same manner as wafers are processed in the polishing station 70, which was described above with reference to Fig. 22. In this modified polishing
20 station, the third wafer carriers 262c and 262c' can be washed at the wafer transfer stations 285c and 285c' that are located between the second and third polishing tables 256b and 256c.

[00192] In a general form, this modified polishing station comprises N polishing tables 256, two sets of N wafer carriers 262, two sets of N wafer transfer
25 stations 285 and at least one wafer conveying device 480, where N is an integer equal to or larger than 2. The first wafer transport device 150 transfers wafers to the first two wafer transfer stations 285 and the second wafer transport device 210 removes the wafers from the last two wafer carriers 262.

[00193] The polishing station 70 of Fig. 22 can be further modified such that
30 the first wafer transport device 150 transfers wafers directly to the first two wafer carriers 262a and 262a' and the second wafer transport device 210 removes the wafers directly from the last two wafer carriers 262c and 262c' by removing the first two and the last two wafer transfer stations 285a, 285a', 285d and 285d'.

- Wafers are processed in this modified polishing station from the first two wafer carriers 262a and 262a' through the third two wafer carriers 262c and 262c' in the same manner as wafers are processed in the polishing station 70, which was described above with reference to Fig. 22. In this modified polishing station, the
- 5 first wafer carriers 262a and 262a' can be washed at the wafer transfer stations 285b and 285b' that are located between the first and second polishing tables 256a and 256b. Furthermore, the third wafer carriers 262c and 262c' can be washed at the wafer transfer stations 285c and 285c' that are located between the second and third polishing tables 256b and 256c.
- 10 **[00194]** In a general form, this modified polishing station comprises N polishing tables 256, two sets of N wafer carriers 262, two sets of (N-1) wafer transfer stations 285 and at least one wafer conveying device 480, where N is an integer equal to or larger than 2. The first wafer transport device 150 transfers wafers to the first two wafer carriers 262 and the second wafer transport device
- 15 210 removes the wafers from the last two wafer carriers 262.
- [00195]** With reference to Figs. 23 and 24, a polishing station 80 in accordance with another embodiment of the present invention is described. The polishing station 80 can be used in the polishing apparatus 10 of Fig. 1 instead of the polishing station 20. Fig. 23 is a top view of the polishing station 80. Fig. 24
- 20 is a side view of the polishing station 80, as viewed in the direction U illustrated in Fig. 23. The polishing station 80 is similar to the polishing station 60 described with reference to Figs. 18 and 19 except that each wafer carrier assembly 260 can move between adjacent two wafer transfer stations 285 individually by a wafer conveying device 481.
- 25 **[00196]** The wafer conveying device 481 comprises a conveying track 484 and a reciprocating drive mechanism 486, as illustrated in Fig. 24. The three wafer carrier assemblies 260 are mounted on the conveying track 484, which is connected to the reciprocating drive mechanism 486. The reciprocating drive mechanism 486 moves the wafer carrier assemblies 260 back and forth in a linear
- 30 manner along the conveying track 484. The forward and backward linear motions are designated as X and Y, respectively, as illustrated in Figs. 23 and 24. The conveying track 484 is mounted to a top housing 488 of the polishing station 80.

- [00197] A method of processing wafers in the polishing station 80 is described with reference to Fig. 23. First, a first wafer is supplied to the first wafer transfer station 285a by the first wafer transport device 150 and then the first wafer carrier 262a is transferred to the first wafer transfer station 285a by its forward linear motion X along the conveying track 484. Next, the first wafer is loaded from the first wafer transfer station 285a onto the first wafer carrier 262a and then the first wafer carrier 262a is transferred to the first polishing table 256a by its backward linear motion Y. Next, the first wafer carrier 262a polishes the first wafer using the polishing pad 255a on the first polishing table 256a.
- 10 [00198] Next, after the polishing process of the first wafer is completed, the first wafer carrier 262a is lifted from the polishing table 256a and then the first wafer carrier 262a is transferred to the second wafer transfer station 285b by the backward linear motion Y along the conveying track 484. Next, the first wafer W1 is unloaded from the first wafer carrier 262a to the second wafer transfer station 285b. Next, the first wafer carrier 262a is transferred to the first wafer transfer station 285a to pick the next wafer to be polished and then the second wafer carrier 262b is transferred to the second wafer transfer station 285b by its forward linear motions X along the conveying track 484.
- 15 [00199] Next, the first wafer is loaded from the second wafer transfer station 285b onto the second wafer carrier 262b and then the second wafer carrier 262b is transferred to the second polishing table 256b by its backward linear motions Y along the conveying track 484. Next, the second wafer carrier 262b polishes the first wafer using the polishing pad 255 on the second polishing table 256b.
- 20 [00200] Next, after the polishing process of the first wafer is completed, the second wafer carrier 262b is lifted from the second polishing table 256b and then transferred to the third wafer transfer station 285c by its backward linear motion Y along the conveying track 484. Next, the first wafer is unloaded from the second wafer carrier 262b to the third wafer transfer station 285c.
- 25 [00201] Next, the second wafer carrier 262b is transferred to the second wafer transfer station 285b to pick the next wafer and then the third wafer carrier 262c is transferred to the third wafer transfer station 285c by their forward linear motions X along the conveying track 484. Next, the first wafer is loaded from the third wafer transfer station 285c onto the third wafer carrier 262c and then the
- 30

third wafer carrier 262c is transferred to the third polishing table 256c by its backward linear motion Y along the conveying track 484. Next, the third wafer carrier 262c polishes the first wafer using the polishing pad 255c on the third polishing table 256c.

5 **[00202]** Next, after the polishing process is completed, the third wafer carrier 262c is lifted from the polishing table 256c and then the third wafer carrier 262c is transferred to the fourth wafer transfer station 285d by its backward linear motion Y along the conveying track 484. Next, the first wafer is unloaded from the third wafer carrier 262c to the fourth wafer transfer station 285d and then the third
10 wafer carrier is transferred to the third wafer transfer station 285c to pick the next wafer. Next, the first wafer is removed from the fourth wafer transfer station 285d by the second wafer transfer device 210. In this fashion, wafers can be sequentially polished on the polishing tables 256a-256c one after another.

15 **[00203]** In a general form, the polishing station 80 comprises N polishing tables 256, N wafer carriers 262, N+1 wafer transfer stations 285 and a wafer conveying device 481, where N is an integer equal to or larger than 2. The first wafer transport device 150 transfers wafers to the first wafer transfer station 285 and the second wafer transport device 210 removes the wafers from the last wafer transfer station 285.

20 **[00204]** With reference to Figs. 25(a)-25(c), polishing stations 85a-85c in accordance with other embodiments of the present invention are described. Any of these polishing stations can be used in the polishing apparatus 10 of Fig. 1 instead of the polishing station 20. Figs. 25(a)-25(c) are top views of the polishing stations 85a-85c, respectively.

25 **[00205]** The polishing station 85a of Fig. 25(a) can be derived from the polishing station 80 of Fig. 23 by removing the first wafer transfer station 285a. In the polishing station 85a, the first wafer transport device 150 transfers wafers directly to the first wafer carrier 262a. Wafers are processed in the polishing station 85a from the first wafer carrier 262a through the last wafer transfer station
30 285d in the same manner as wafers are processed in the polishing station 80, which was described above with reference to Fig. 23. In the polishing station 85a, the first wafer carrier 262a can be washed at the wafer transfer station 285b that is located between the first polishing table 256a and the second polishing table 256b.

[00206] In a general form, the polishing station 85a can comprise N polishing tables 256, N wafer carriers 262, N wafer transfer stations 285 and a wafer conveying device 481, where N is an integer equal to or larger than 2. The first wafer transport device 150 transfers wafers to the first wafer carrier 262 and the second wafer transport device 210 removes the wafers from the last wafer transfer station 285.

[00207] The polishing station 85b of Fig. 25(b) can be derived from the polishing station 80 of Fig. 23 by removing the last wafer transfer station 285d. In the polishing station 85b, the second wafer transport device 210 removes wafers directly from the third wafer carrier 262c. Wafers are processed in the polishing station 85b from the first wafer transfer station 285a through the third wafer carrier 262c in the same manner as wafers are processed in the polishing station 80, which was described above with reference to Fig. 23. In the polishing station 85b, the third wafer carrier 262c can be washed at the wafer transfer station 285c that is located between the second and third polishing tables 256b and 256c.

[00208] In a general form, the polishing station 85b can comprise N polishing tables 256, N wafer carriers 262, N wafer transfer stations 285 and a wafer conveying device 481, where N is an integer equal to or larger than 2. The first wafer transport device 150 transfers wafers to the first wafer transfer station 285 and the second wafer transport device 210 removes the wafers from the last wafer carrier 262.

[00209] The polishing station 85c of Fig. 25(c) can be derived from the polishing station 80 of Fig. 23 by removing the first and last wafer transfer stations 285a and 285d. In the polishing station 85c, the first wafer transport device 150 transfers wafers directly to the first wafer carrier 262a and the second wafer transport device 210 removes the wafers directly from the third wafer carrier 262c. Wafers are processed in the polishing station 85c from the first wafer carrier 262a through the third wafer carrier 262c in the same manner as wafers are processed in the polishing station 80, which was described above with reference to Fig. 23. In the polishing station 85c, the first wafer carrier 262a can be washed at the wafer transfer station 285b that is located between the first and second polishing tables 256a and 256b. Furthermore, the third wafer carrier 262c

can be washed at the wafer transfer station 285c that is located between the second and third polishing tables 256b and 256c.

[00210] In a general form, the modified polishing station 85c can comprise N polishing tables 256, N wafer carriers 262, N-1 wafer transfer stations 285 and a
5 wafer conveying device 481, where N is an integer equal to or larger than 2. The first wafer transport device 150 transfers wafers to the first wafer carrier 262 and the second wafer transport device 210 removes the wafers from the last wafer carrier 262.

[00211] With reference to Fig. 26, a polishing station 90 in accordance with
10 another embodiment of the present invention is described. The polishing station 90 can be used in the polishing apparatus 10 of Fig. 1 instead of the polishing station 20. Fig. 26 is a top view of the polishing station 90. The polishing station 90 is similar to the polishing station 70 described with reference to Fig. 22 except that each wafer carrier assembly 260 can move between two adjacent wafer
15 transfer stations 285 individually by wafer conveying devices 481 and 481'.

[00212] The first and second sets of three wafer carrier assemblies 260a-260c and 260'a-260'c are mounted on the conveying tracks 484 and 484' of the first and second wafer conveying devices 481 and 481', respectively. The reciprocating drive mechanism 486 (not shown) of the first wafer conveying
20 device 481 moves each of the three wafer carrier assemblies 260a-260c individually back and forth in a linear manner. Similarly, the reciprocating drive mechanism 486' (not shown) of the second wafer conveying device 481' moves each of the three wafer carrier assemblies 260a'-260c' individually back and forth in a linear manner.

[00213] A method of processing wafers in the polishing station 90 is similar
25 to the method of processing wafers in the polishing stations 80, which was described above with reference to Fig. 23. Wafers can be processed using the four wafer transfer station 285a'-285d', the three wafer carriers 262a'-262c' and the three polishing tables 256a-256c in the same manner as wafers are processed in
30 the polishing station 80 using the four wafer transfer station 285a-285d, the three wafer carriers 262a-262c and the three polishing tables 256a-256c, as described above.

[00214] In a general form, this polishing station 90 comprises N polishing tables 256, two sets of N wafer carriers 262, two sets of (N+1) wafer transfer stations 285 and two wafer conveying devices 481, where N is an integer equal to or larger than 2. The first wafer transport device 150 transfers wafers to the first two wafer transfer stations 285 and the second wafer transport device 210 removes the wafers from the last two wafer transfer stations 285.

[00215] The polishing station 90 of Fig. 26 can be modified such that the first wafer transport device 150 transfer wafers directly to the first two wafer carriers 262a and 262a' by removing the first two wafer transfer stations 285a and 285a' from the polishing station 90. Wafers are processed in this modified polishing station from the first two wafer carriers 262a and 262a' through the last two wafer transfer stations 285d and 285d' in the same manner as wafers are processed in the polishing station 90. In this modified polishing station, the first two wafer carriers 262a and 262a' can be washed at the wafer transfer stations 285b and 285b', respectively, that are located between the first polishing table 256a and the second polishing table 256b.

[00216] In a general form, this modified polishing station comprises N polishing tables 256, two sets of N wafer carriers 262, two sets of N wafer transfer stations 285 and two wafer conveying devices 481, where N is an integer equal to or larger than 2. The first wafer transport device 150 transfers wafers to the first two wafer carriers 262 and the second wafer transport device 210 removes the wafers from the last two wafer transfer stations 285.

[00217] The polishing station 90 of Fig. 26 can be also modified such that the second wafer transport device 210 transfers wafers directly from the last wafer carriers 262c and 262c' by removing the last wafer transfer stations 285d and 285b'. Wafers are processed in this modified polishing station from the first two wafer transfer stations 285a and 285a' through the last two wafer carriers 262c and 262c' in the same manner as wafers are processed in the polishing station 90. In this modified polishing station, the third wafer carriers 262c and 262c' can be washed at the wafer transfer stations 285c and 285c' that are located between the second and third polishing tables 256b and 256c.

[00218] In a general form, this modified polishing station comprises N polishing tables 256, two sets of N wafer carriers 262, two sets of N wafer transfer

stations 285 and two wafer conveying devices 481, where N is an integer equal to or larger than 2. The first wafer transport device 150 transfers wafers to the first two wafer transfer stations 285 and the second wafer transport device 210 removes the wafers from the last two wafer carriers 262.

- 5 [00219] The polishing station 90 of Fig. 26 can be further modified such that the first wafer transport device 150 transfers wafers to directly to the first two wafer carriers 262a and 262a' and the second wafer transport device 210 removes the wafers directly from the last two wafer carriers 262c and 262c' by removing the first two and the last two wafer transfer stations 285a, 285a', 285d and 285d'.
- 10 Wafers are processed in this modified polishing station from the first two wafer carriers 262a and 262a' through the last two wafer carriers 262c and 262c' in the same manner as wafers are processed in the polishing station 90. In this modified polishing station, the first wafer carriers 262a and 262a' can be washed at the wafer transfer stations 285b and 285b' that are located between the first and
- 15 second polishing tables 256a and 256b. Furthermore, the third wafer carriers 262c and 262c' can be washed at the wafer transfer stations 285c and 285c' that are located between the second and third polishing tables 256b and 256c.

- [00220] In a general form, this modified polishing station comprises N polishing tables 256, two sets of N wafer carriers 262, two sets of (N-1) wafer transfer stations 285 and two wafer conveying devices 481, where N is an integer equal to or larger than 2. The first wafer transport device 150 transfers wafers to the first two wafer carriers 262 and the second wafer transport device 210 removes the wafers from the last two wafer carriers 262.
- 20

- [00221] With reference to Figs. 27 and 28, a polishing station 100 in accordance with another embodiment of the present invention is described. The polishing station 100 can be used in the polishing apparatus 10 of Fig. 1 instead of the polishing station 20. Fig. 27 is a top view of the polishing station 100. Fig. 28 is a side view of the polishing station 100, as viewed in the direction V illustrated in Fig. 27. The polishing station 100 is similar to the polishing station 90 described with reference to Fig. 26 except that first, second and third two wafer carrier assemblies 260a and 260a', 260b and 260b', and 260c and 260c' are connected to each other by respective connectors 487. The connectors 487 are mounted on the conveying track 484 of the wafer conveying device 481 of the
- 25
- 30

polishing station 100, as illustrated in Fig. 28. Reciprocating linear motions X and Y of the connectors 487 are controlled by the reciprocating drive mechanism 486.

[00222] The first wafer carriers 262a and 262a' are transferred together between the first wafer transfer stations 285a and 285a', the first polishing table 256a and the second wafer transfer stations 285b and 285b' by reciprocating the first connector 487a connected to the wafer carrier assemblies 260a and 260a' along the conveying track 484. Similarly, the second wafer carriers 262b and 262b' are transferred together between the second wafer transfer stations 285b and 285b', the second polishing table 256b and the third wafer transfer stations 285c and 285c' by reciprocating the second connector 487b connected to the wafer carrier assemblies 260b and 260b' along the conveying track 484. The third wafer carriers 262c and 262c' are also transferred together between the third wafer transfer stations 285c and 285c', the third polishing table 256c and the fourth wafer transfer stations 285d and 285d' by reciprocating the third connector 487c connected to the wafer carrier assemblies 260c and 260c' along the conveying track 484.

[00223] A method of processing wafers in the polishing station 100 is similar to the method of processing wafers in the polishing station 80, which was described above with reference to Fig. 23 except that each pair of wafer carriers connected to each other by the respective connector 487 is moved together by the reciprocating linear motions X and Y. Another difference is that two wafers can be polished on one polishing table 256 in the polishing station 100.

[00224] In a general form, the polishing station 100 comprises N polishing tables 256, two sets of N wafer carriers 262, two sets of N+1 wafer transfer stations 285 and one wafer conveying device 481, where N is an integer equal to or larger than 2. The first wafer transport device 150 transfers wafers to the first two wafer transfer stations 285 and the second wafer transport device 210 removes the wafers from the last two wafer transfer stations 285.

[00225] The polishing station 100 of Fig. 27 can be modified such that the first wafer transport device 150 transfers wafers directly to the wafer carriers 262a and 262a' by removing the first two wafer transfer stations 285a and 285a' from the polishing station 100. Wafers are processed in this modified polishing station from the first two wafer carriers 262a and 262a' through the last two wafer

transfer stations 285d and 285d' in the same manner as wafers are processed in the polishing station 100. In this modified polishing station, the wafer carriers 262a and 262a' can be washed at the wafer transfer stations 285b and 285b' that are located between the first polishing table 256a and the second polishing table 256b.

5 **[00226]** In a general form, this modified polishing station comprises N polishing tables 256, two sets of N wafer carriers 262, two sets of N wafer transfer stations 285 and one wafer conveying device 481, where N is an integer equal to or larger than 2. The first wafer transport device 150 transfers wafers to the first two wafer carriers 262 and the second wafer transport device 210 removes the
10 wafers from the last two wafer transfer stations 285.

[00227] The polishing station 100 of Fig. 27 can be also modified such that the second wafer transport device 210 transfers wafers directly from the last wafer carriers 262c and 262c' by removing the last wafer transfer stations 285d and 285d'. Wafers are processed in this modified polishing station from the first two
15 wafer transfer stations 285a and 285a' through the last two wafer carriers 262c and 262c' in the same manner as wafers are processed in the polishing station 100. In this polishing station, the third wafer carriers 262c and 262c' can be washed at the wafer transfer stations 285c and 285c' that are located between the second and third polishing tables 256b and 256c.

20 **[00228]** In a general form, this modified polishing station comprises N polishing tables 256, two sets of N wafer carriers 262, two sets of N wafer transfer stations 285 and one wafer conveying device 481, where N is an integer equal to or larger than 2. The first wafer transport device 150 transfers wafers to the first two wafer transfer stations 285 and the second wafer transport device 210
25 removes the wafers from the last two wafer carriers 262.

[00229] The polishing station 100 of Fig. 27 can be further modified such that the first wafer transport device 150 transfers wafers directly to the first two wafer carriers 262a and 262a' and the second wafer transport device 210 removes the wafers directly from the last two wafer carriers 262c and 262c' by removing the
30 first two and the last two wafer transfer stations 285a, 285a', 285d and 285d'. Wafers are processed in this modified polishing station from the first two wafer carriers 262a and 262a' through the last two wafer carriers 262c and 262c' in the same manner as wafers are processed in the polishing station 100. In this

modified polishing station, the first wafer carriers 262a and 262a' can be washed at the wafer transfer stations 285b and 285b' that are located between the first and second polishing tables 256a and 256b. Furthermore, the third wafer carriers 262c and 262c' can be washed at the wafer transfer stations 285c and 285c' that are
5 located between the second and third polishing tables 256b and 256c.

[00230] In a general form, this modified polishing station comprises N polishing table 256, two sets of N wafer carriers 262, two sets of (N-1) wafer transfer stations 285 and one wafer conveying device 481, where N is an integer equal to or larger than 2. The first wafer transport device 150 transfers wafers to
10 the first two wafer carriers 262 and the second wafer transport device 210 removes the wafers from the last two wafer carriers 262.

[00231] With reference to Figs. 29, 30(a) and 30(b), a polishing station 110 in accordance with another embodiment of the present invention is described. The polishing station 110 can be used in the polishing apparatus 10 of Fig. 1 instead of
15 the polishing station 20. Fig. 29 is a top view of the polishing station 110. Fig. 30(a) is a side view of a polishing unit 252 of the polishing station 110, as viewed in the direction U illustrated in Fig. 29. Fig. 30(b) is a side view of the polishing unit 252, as viewed in the direction V illustrated in Fig. 29.

[00232] The polishing station 110 comprises a first polishing unit 252a, a
20 second polishing unit 252b, a third polishing unit 252c, a first wafer transfer station 285a, a second wafer transfer station 285b, a third wafer transfer station 285c, and a fourth wafer transfer station 285d.

[00233] Each polishing unit 252 comprises a polishing table 256, a wafer carrier assembly 260. Each polishing unit 252 may further comprise a pad
25 conditioner 258. Each polishing unit 252 further comprises a pivoting arm 267, a pivoting shaft 268 and a pivoting-and-vertical drive mechanism 269. The pivoting arm 267 connects the wafer carrier assembly 260 to the pivoting shaft 268, which is connected to the pivoting-and-vertical drive mechanism 269. Therefore, a wafer carrier 262 of the wafer carrier assembly 260 can be moved in pivoting and
30 vertical manners by the pivoting-and-vertical drive mechanism 269.

[00234] The four wafer transfer stations 285a-285d and the wafer carriers 262a-262c are arranged such that wafers can be transferred from the first wafer transfer station 285a through the last wafer transfer station 285d by the wafer

carriers 262a-262c in the following manner. First, the wafer carrier 262a of the first polishing unit 252a transfers a first wafer from the first wafer transfer station 285a to the second wafer transfer station 285b by its pivoting motions a and b, as illustrated in Fig. 30. Next, the wafer carrier 262b of the second polishing unit 252b similarly transfers the first wafer from the second wafer transfer station 285b to the third wafer transfer station 285c by its pivoting motions c and d. Next, the wafer carrier 262c of the third polishing unit 252c similarly transfers the first wafer from the third wafer transfer station 285c to the fourth wafer transfer station 285d by its pivoting motions e and f. The first wafer transport device 150 supplies wafers to the first wafer transfer station 285a and the second wafer transport device 210 removes wafers from the fourth wafer transfer station 285d.

[00235] Pivoting motions of the wafer carriers 262 may be controlled individually. It is preferred, however, that the pivoting motions of the wafer carriers 262 are synchronized such that the wafer carriers 262 cannot be pivoted to the same wafer transfer station 285 at the same time.

[00236] A method of processing wafers in the polishing station 110 is similar to the method of processing wafers in the polishing stations 80, as described above with reference to Fig. 23 except that each wafer carrier 262 in the polishing station 110 transfers wafers between two adjacent wafer transfer stations 285 by its respective pivoting motion while each wafer carrier 262 in polishing station 80 transfers wafers between two adjacent wafer transfer stations 285 by its respective linear motions. Simultaneous pivoting motion of the wafer carriers 262a toward a same direction is also preferred because the simultaneous motion can increase the throughput of the polishing station 110 by making it possible for the wafer carriers 262 to be loaded with next wafers as soon as the wafers on the wafer carriers 262 are unloaded from the wafer carriers 262.

[00237] In a general form, the polishing station 110 comprises N polishing units 252 and N+1 wafer transfer stations 285, where N is an integer equal to or larger than 2. The first wafer transport device 150 transfers wafers to the first wafer transfer station 285 and the second wafer transport device 210 removes the wafers from the last wafer transfer station 285.

[00238] The polishing station 110 of Fig. 29 can be modified such that the first wafer transport device 150 transfer wafers directly to the wafer carrier 262a

of the first polishing unit 252a by removing the first wafer transfer station 285a from the polishing station 110. Wafers are processed in this modified polishing station from the wafer carrier 262a of the first polishing unit 252a through the last wafer transfer station 285d in the same manner as wafers are processed in the polishing station 110. In this modified polishing station, the wafer carrier 262a of the first polishing unit 252a can be washed at the wafer transfers station 285b that is located between the first polishing unit 252a and the second polishing unit 252b.

[00239] In a general form, this modified polishing station comprises N polishing units 252 and N wafer transfer stations 285, where N is an integer equal to or larger than 2. The first wafer transport device 150 transfers wafers to the wafer carrier 262 of the first polishing unit 252 and the second wafer transport device 210 removes the wafers from the last wafer transfer station 285.

[00240] The polishing station 110 of Fig. 29 can be also modified such that the second wafer transport device 210 transfers wafers directly from the wafer carrier 262c of the third polishing unit 252c by removing the last wafer transfer station 285d. Wafers are processed in this modified polishing station from the first wafer transfer station 285a through the wafer carrier 262c of the third polishing unit 252c in the same manner as wafers are processed in the polishing station 110. In this modified polishing station, the third wafer carrier 262c can be washed at the wafer transfer station 285c that is located between the second and third polishing tables 256b and 256c.

[00241] In a general form, this modified polishing station comprises N polishing units 252 and N wafer transfer stations 285, where N is an integer equal to or larger than 2. The first wafer transport device 150 transfers wafers to the first wafer transfer station 285 and the second wafer transport device 210 removes the wafers from the wafer carrier 262 of the last polishing unit 252.

[00242] The polishing station 110 of Fig. 29 can be further modified such that the first wafer transport device 150 transfers wafers directly to the wafer carrier 262 of the first polishing unit 252a and the second wafer transport device 210 removes the wafers directly from the wafer carrier 262c of the third polishing unit 252c by removing the first and last wafer transfer stations 285a and 285d. Wafers are processed in this modified polishing station from the wafer carrier 262a of the first polishing unit 252a through the wafer carrier 262c of the third polishing unit

252c in the same manner as wafers are processed in the polishing station 110. In this modified polishing station, the first wafer carrier 262a can be washed at the wafer transfer station 285b that is located between the first and second polishing tables 256a and 256b. Furthermore, the third wafer carrier 262c can be washed at
5 the wafer transfer station 285c that is located between the second and third polishing tables 256b and 256c.

[00243] In a general form, this modified polishing station comprises N polishing units 252 and N-1 wafer transfer stations 285, where N is an integer equal to or larger than 2. The first wafer transport device 150 transfers wafers to
10 the wafer carrier 262 of the first polishing unit 252 and the second wafer transport device 210 removes the wafers from the wafer carrier 262 of the last polishing unit 252.

[00244] With reference to Fig. 31, a polishing station 120 in accordance with another embodiment of the present invention is described. The polishing station
15 120 can be used in the polishing apparatus 10 of Fig. 1 instead of the polishing station 20. Fig. 31 is a top view of the polishing station 120.

[00245] The polishing station 120 comprises a first polishing unit 251a, a second polishing unit 251b and a wafer transport device 160. The wafer transport device 160 is positioned between the first and second polishing units 251a and
20 251b and transfers wafers from the wafer carriers 262a and 262b' of the first polishing unit 251a to the wafer carriers 262b and 262b' of the second polishing unit 251b. The side of the polishing station 120 adjacent to the first wafer transport device 150 is an input end of the polishing station to receive wafers into the polishing station. The side of the polishing station 120 adjacent to the second
25 wafer transport device 210 is an output end of the polishing station to output polished wafers from the polishing station. Preferably, the input end and the output end of the polishing station 120 are at opposite sides of the polishing station.

[00246] The wafer transport device 160 may be mounted on a linear track
30 165 such that the wafer transport device 160 can move in a linear manner on the linear track 165. As an example, the wafer transport device 160 may comprise a robotic arm to handle a wafer for transfer. The wafer transport device 160 may be

further configured to comprise dual robotic arms such that the wafer transport device can handle two wafers at a time.

[00247] The polishing station 120 may further comprise washing stations 157a-157c, as illustrated in Fig. 31. When wafer holding portions 156, 166 and 176 of the wafer transport devices 150, 160 and 210 need to be cleaned, the wafer holding portions 156, 166 and 176 are sent to the washing stations 157a-157c, respectively, to be cleaned.

[00248] Each washing station 157 comprises first multiple nozzles to spray or jet D.I. water or cleaning chemicals such as KOH to wash the wafer holding portion of one of the wafer transport devices 150, 160 and 210. Each washing station 157 may further comprise second multiple nozzles to jet gases such as nitrogen to remove slurry particles adhered to the wafer holding portion of one of the wafer transport device 150, 160 and 210.

[00249] Each polishing unit 251 used in the polishing station 120 may comprise a central fluid assembly 275 to provide fluid channels for slurry and D.I. wafer. With reference to Fig. 32, which is a schematic drawing of the polishing unit 251a, the central fluid assembly is described in detail. The central fluid assembly 275 comprises a first fluid nozzle 276, a second fluid nozzle 277 to supply slurry and D.I. water, respectively, to the associated polishing table 256. The central fluid assembly 275 may further comprise a first nozzle 278 and a second nozzle 279 to jet D.I. water to the wafer carriers 262a and 262b, respectively. Each central fluid assembly 275 is preferably installed over the center of the polishing table 256 of the respective polishing unit 251.

[00250] A method of processing wafers in the polishing station 120 is described with reference to Fig. 31. First, a first wafer is transferred to the first wafer carrier 262a of the first polishing unit 251a by the first wafer transport device 150 and then the first wafer carrier 262a polishes the first wafer using the polishing pad 255a on the polishing table 256a. Next, a second wafer is transferred to the second wafer carrier 262a' of the first polishing unit 251a by the first wafer transport device 150 and the second wafer carrier 262b polishes the second wafer using the polishing pad 255a on the polishing table 256a.

[00251] Next, after the polishing process of the first wafer is completed, the first wafer carrier 262a is lifted from the polishing table 256a to its wafer load-

and-unload position and then the wafer transport device 160 transfers the first wafer to the first wafer carrier 262b of the second polishing unit 251b. The first wafer carrier 262b of the second polishing unit 251b then polishes the first wafer using the polishing pad 255b on the polishing table 256b.

5 **[00252]** Next, after the polishing process of the second wafer in the first polishing unit 251a is completed, the second wafer carrier 262a' of the first polishing unit 251a is lifted from the polishing table 256a to its wafer load-and-unload position and then the wafer transport device 160 transfers the second wafer from the second wafer carrier 262a' of the first polishing unit 251a to the second
10 wafer carrier 262b' of the second polishing unit 251b. The second wafer carrier 262b' of the second polishing unit 251b polishes the second wafer using the polishing pad 255b on the polishing table 256b of the second polishing unit 251b.

[00253] Next, after the polishing processes of the first and second wafers in the second polishing unit 251b are completed, the first and second wafer carriers
15 262b and 262b' of the second polishing unit 251b are lifted from the polishing table 256b to their respective wafer load-and-unload positions and then the second wafer transport device 210 removes the first and second wafers from the first and second wafer carriers 262b and 262b' and then send the wafers to the next destination in the polishing apparatus 10.

20 **[00254]** In a general form, the polishing station 120 can comprise N polishing units 251 and N-1 wafer transport devices 160, where N is an integer equal to or larger than 1. Each wafer transport device 160 is positioned between two neighboring polishing units 251 and transfers wafers from two wafer carriers 262 of one polishing unit 251 to two wafer carriers 262 of the other polishing unit 251.
25 The first wafer transport device 150 transfers wafers to be polished to the wafer carriers 262 of the first polishing unit and the second wafer transport device 210 transfers polished wafers from the wafer carriers 262 of the last polishing unit 251.

[00255] With reference to Fig. 33, a polishing station 130 in accordance with an embodiment of the present invention is described. The polishing station 130
30 can be used in the polishing apparatus 10 of Fig. 1 instead of the polishing station 20. Fig. 34 is a top view of the polishing station 130.

[00256] The polishing station 130 comprises a first polishing unit 135a, a second polishing unit 135b and the wafer transport device 160. The wafer

transport device 160 is positioned between the first and second polishing units 135a and 135b and transfers wafers from first polishing unit 135a to the second polishing unit 135b.

5 [00257] Each polishing unit 135 comprises a polishing table 256, two wafer carriers 262 and two wafer relay devices 280x and 280y. The two wafer carriers 262 are positioned over the polishing table 256. The first wafer relay device 280x is positioned on the right side of the wafer carriers and 280y and the second wafer relay device 280y is positioned on the left side of the wafer carriers.

10 [00258] The pivoting shafts 284, and therefore pivoting axes, of the load-and-unload cups 282 are preferably positioned over the polishing table 256. To position the pivoting shafts 284 over the polishing table 256, the pivoting-and-vertical drive mechanisms 286 are preferably mounted to the same top housing (not shown) to which the wafer carrier assemblies 260 are mounted.

15 [00259] The load-and-unload cups 282x and 282y of each polishing station illustrated in Fig. 33 are positioned at their respective parking positions X and Y. The load-and-unload cup 282x of the first wafer relay device 280x can be pivoted to wafer load-and-unload positions of the two wafer carriers 262a and 262a' or 262b and 262' by the respective pivoting motions A and B. The load-and-unload cup 282y of the second wafer relay device 280y can be pivoted to the wafer load-and-unload positions of the two wafer carriers 262a and 262a' or 262b and 262b' by the respective pivoting motions C and D.

20 [00260] A method of processing wafers in the polishing station 130 is described with reference to Fig. 33. First, a first wafer is supplied to the first load-and-unload cup 282x of the first polishing unit 135a at the parking position X by the first wafer transport device 150. Next, the first load-and-unload cup 282x transfers the wafer to the first wafer carrier 262a of the first polishing unit 135a by its pivoting motion A. Next, the first load-and-unload cup 282x is pivoted back to the parking position X and then the first wafer carrier 262a polishes the first wafer W1 using the polishing pad 255a on the polishing table 256a.

30 [00261] Next, a second wafer is supplied to the first load-and-unload cup 282x by the first wafer transport device 150 and the first load-and-unload cup 282x transfers the second wafer to the second wafer carrier 262a' by its pivoting motion B. Next, the first load-and-unload cup 282x is pivoted back to the parking

position X and then the second wafer carrier 262a' polishes the second wafer W2 on the polishing pad 255a on the polishing table 256a.

[00262] Next, after the polishing process of the first wafer is completed, the first wafer carrier 262a is lifted from the polishing table 256a and then the second
5 load-and-unload cup 282y removes the first wafer from the first wafer carrier 262a by its pivoting motion C. Next, the second load-and-unload cup 282y of the first polishing unit 135a is pivoted back to its parking position Y and then the first wafer is transferred from the second load-and-unload cup 282y of the first polishing unit 135a to the first load-and-unload cup 282x' of the second polishing
10 unit 135b by the wafer transport device 160.

[00263] Next, the first load-and-unload cup 282x' transfers the wafer to the first wafer carrier 262b of the second polishing unit 135b by its pivoting motion A. Next, the first load-and-unload cup 282x' is pivoted back to the parking position
15 X and then the first wafer carrier 262b polishes the first wafer using the polishing pad 255b on the polishing table 256b.

[00264] Next, after the polishing process of the second wafer is completed, the second wafer carrier 262a' is lifted from the polishing table 256a and then the second load-and-unload cup 282y removes the second wafer from the second
20 wafer carrier 262a' by its pivoting motion D. Next, the second load-and-unload cup 282y of the first polishing unit 135a is pivoted back to its parking position Y and then the second wafer is transferred from the second load-and-unload cup 282y of the first polishing unit 135a to the first load-and-unload cup 282x' of the second polishing unit 135b by the wafer transport device 160.

[00265] Next, the first load-and-unload cup 282x' transfers the second wafer
25 to the second wafer carrier 262b' of the second polishing unit 135b by its pivoting motion B. Next, the first load-and-unload cup 282x' is pivoted back to the parking position X and then the second wafer carrier 262b' polishes the first wafer using the polishing pad 255b on the polishing table 256b.

[00266] Next, after the polishing process of the first wafer is completed, the
30 first wafer carrier 262b is lifted from the polishing table 256b and then the second load-and-unload cup 282y' removes the first wafer from the first wafer carrier 262b by its pivoting motion C. Next, the second load-and-unload cup 282y of the second polishing unit 135b is pivoted back to its parking position Y and then the

first wafer is removed from the second load-and-unload cup 282y of the second polishing unit 135b by the wafer transport device 210.

[00267] Next, after the polishing process of the second wafer is completed, the second wafer carrier 262b' is lifted from the polishing table 256b and then the second load-and-unload cup 282y' removes the second wafer from the second wafer carrier 262b' by its pivoting motion D. Next, the second load-and-unload cup 282y of the second polishing unit 135b is pivoted back to its parking position Y and then the second wafer is removed from the second load-and-unload cup 282y of the second polishing unit 135b by the wafer transport device 210.

10 [00268] In a general form, the polishing station 130 can comprise N polishing units 135 and N-1 wafer transport devices 160, where N is an integer equal to or larger than 1. Each wafer transport device 160 is positioned between two neighboring polishing units 135 and transfers wafers from the wafer relay device 280y of one polishing unit 135 to the wafer relay device 280x of the other
15 polishing unit 135. The first wafer transport device 150 transfers wafers to be polished to the wafer relay device 280x of the first polishing unit 135 and the second wafer transport device 210 removes polished wafers from the wafer relay device 280y of the last polishing unit 135.

[00269] With reference to Figs. 34(a)-34(c), polishing units 140a-140c in
20 accordance with other embodiments of the present invention are described. These polishing units 140a-140c can be used in the polishing station 130 of Fig. 33 instead of the polishing unit 135. Figs. 34(a)-34(c) are top views of the polishing units 140a-140c, respectively.

[00270] The polishing unit 140a of Fig. 34(a) is similar to the polishing unit
25 135 of Fig. 33 except that it comprises two polishing tables 256a and 256b such that each of two wafer carriers 262 and 262' can polish wafers using the polishing pad 255 on the respective polishing table 256. A method of processing wafers in the polishing station 130 having the polishing units 140a is similar to the method of processing wafers in the polishing station 130 having the polishing units 135
30 described with reference to Fig. 33 except that each wafer carrier 262 polishes a wafer using the polishing pad 255 on the respective polishing table 256 in the polishing station 140a.

[00271] The polishing unit 140b of Fig. 34(b) can be derived from the polishing unit 135 of Fig. 33(a) by removing the wafer relay device 280y from the polishing unit 140a. The polishing unit 140b can be positioned in the polishing station 130 such that the wafer relay device 280 is positioned next to the first
5 wafer transport device 150. In this configuration, wafers are supplied to the wafer relay device 280 by the first wafer transport device 150 and then loaded onto the two wafer carriers 262 and 262' by the wafer relay device 280. Polished wafers are removed from the wafer carriers 262 and 262' by the wafer transport device 160 and then transferred to the second polishing unit 140b included in the
10 polishing station 130.

[00272] In an alternative configuration, the polishing unit 140b may include just the wafer relay device 280y, rather than just the wafer relay device 280x. In this alternative configuration, wafers are supplied directly to the two wafer carriers 262 and 262' by the first wafer transport device 150. Polished wafers are
15 individually removed from the wafer carriers 262 and 262' by the wafer relay device 280y. Since the wafer relay device 280y is located between the wafer carriers 262 and 262' and the wafer transport device 160, the polished wafers are then transferred from the wafer relay device 280y to the second polishing unit 140b included in the polishing station 130 by the wafer transport device 160.

[00273] The polishing unit 140c of Fig. 34(c) can be derived from the polishing unit 135 by positioning the two wafer relay devices 280x and 280y on the same side of the two wafer carriers 262 and 262'. In the illustrated configuration, the two wafer relay devices 280x and 280y are both positioned on the right side of the two wafer carriers 262 and 262'. The polishing unit 140c can
25 be positioned in the polishing station 130 such that the wafer relay devices 280x and 280y are positioned next to the first wafer transport device 150. In this configuration, wafers are supplied to the wafer relay devices 280x and 280y by the first wafer transport device 150 and then loaded onto the two wafer carriers 262 and 262' by the wafer relay devices 280x and 280y, respectively. Polished wafers
30 are removed from the wafer carriers 262 and 262' by the wafer transport device 160 and then transferred to the second polishing unit 140c included in the polishing station 130.

[00274] In an alternative configuration, the two wafer relay devices 280x and 280y are both positioned on the left side of the two wafer carriers 262 and 262'.

In this alternative configuration, wafers are supplied directly to the two wafer carriers 262 and 262' by the first wafer transport device 150. Polished wafers are removed from the wafer carriers 262 and 262' by the wafer relay devices 280x and 280y, respectively. Since the wafer relay devices 280x and 280y are located between the wafer carriers 262 and 262' and the wafer transport device 160, the polished wafers are then transferred from the wafer relay devices 280x and 280y to the second polishing unit 140c included in the polishing station 130 by the wafer transport device 160.

[00275] The polishing units 140b and 140c can be modified to have two polishing tables 256 such that the two wafer carriers 262 and 262' polish wafers on the respective polishing tables 256.

[00276] With reference to Fig. 35, a wafer relay device 500 in accordance with an embodiment of the present invention is described. Figs. 35 is a schematic drawing of the wafer relay devices 500. The wafer relay device 500 comprises the load-and-unload cup 282 described with reference to Figs. 3(a) and 3(b), an ascending and descending device 520 such as a shaft, a cup ascending and descending mechanism 530, a pivoting arm 283, a pivoting shaft 284 and a cup drive mechanism 286. The cup ascending and descending mechanism 530 is connected to a fluid channel 550 and operated by a fluid supplied through the fluid channel 550. Nitrogen gas is one example of the fluid that can be used. Any type of load-and-unload cup that can accommodate a semiconductor wafer to be loaded onto a wafer carrier 262 can be used in the wafer relay device 500.

[00277] The load-and-unload cup 282 is connected to the ascending and descending device 520, which is connected to the cup ascending and descending mechanism 530. The cup ascending and descending mechanism 530 is mounted to the pivoting arm 283. The pivoting arm 283 is connected to the pivoting shaft 284 and the pivoting shaft 284 is connected to the cup drive mechanism 286. The cup drive mechanism 286 controls pivoting motion of the load-and-unload cup 282 through the pivoting shaft 284, the pivoting arm 283, the cup ascending and descending mechanism 530 and the ascending and descending device 520.

[00278] In order to load and unload a wafer W onto and from the wafer carrier 262, the load-and-unload cup 282 is pivoted toward the wafer carrier 262. The load-and-unload cup 282 is then moved upward toward the wafer carrier 262 by the vertical motion of the ascending and descending device 520. The wafer carrier 262 then receives the wafer from the load-and-unload cup 282. During this loading process, the load-and-unload cup 282 receives a vertical action force from the wafer carrier 262. In order to absorb this action force, the cup ascending and descending mechanism 530 can be designed to have an action force sensing mechanism (not shown) and an action force absorbing mechanism (not shown) such as an air cushioning mechanism. The action force absorbing mechanism can absorb the action force acting on the load-and-unload cup 282.

[00279] The wafer relay device 500 can use an air bladder as the ascending and descending device 520. The air bladder can ascend and descend the load-and-unload cup 282 by inflating and deflating the air bladder using the fluid supplied through the fluid channel 550.

[00280] With reference to Figs. 36, 37(a) and 37(b), a load-and-unload cup 380 in accordance with another embodiment of the present invention is described. The load-and-unload cup 380 can be used in the wafer relay device 280 of Fig. 1, the wafer relay device 281 of Fig. 9, the dual cup wafer relay device 680 of Fig. 19 and the wafer transfer station 285 of Fig. 18 instead of the load-and-unload cup 282. Fig. 36 is a top view of the load-and-unload cup 380. Figs. 39(a) and 39(b) are cross sectional views of the load-and-unload cup 380 illustrated in Fig. 36 along the lines PP and QQ, respectively.

[00281] The load-and-unload cup 380 is connected to the pivoting shaft 284 by the pivoting arm 283. It is also possible to connect the load-and-unload cup 380 directly to the pivoting shaft 284 without the pivoting arm 283. The pivoting shaft 284 is connected to the cup drive mechanism 286. The cup drive mechanism 286 controls pivoting and vertical motions of the load-and-unload cup 380 through the pivoting shaft 284 and the pivoting arm 283.

[00282] The load-and-unload cup 380 comprises a cup base 290, a cup ring 295, a wafer bladder 400, a wafer bladder holder 405, multiple aligners 420, multiple radial bladders 422, multiple vertical bladders 423, multiple vertical bladder holders 424, first multiple nozzles 340, second multiple nozzles 350,

multiple drains 360, a first fluid channel 370, a second fluid channel 371, a third fluid channel 372, a fourth fluid channel 373 and a fifth fluid channel 374. The fluid channels 370, 371, 372 and 273 can be connected to fluid sources (not shown) through the pivoting arm 283 and the pivoting shaft 284, as illustrated in Fig. 36. The cup base 290 and the cup ring 295 can be viewed together as a wafer supporting structure.

[00283] The wafer bladder 400 is mounted to the wafer bladder holder 405, which is mounted on a top surface of the cup base 290, as illustrated in Figs. 37(a) and 37(b). The wafer bladder 400 is inflated and deflated by supplying a fluid into the bladder 400 and removing the fluid from the bladder through the first fluid channel 370. Nitrogen gas can be used as the fluid to inflate and deflate the wafer bladder 400.

[00284] Each radial bladder 422 connects one of the aligners 420 to the cup ring 295, which is mounted on the cup base 290. Each radial bladder 422 is inflated and deflated by supplying a fluid into the radial bladder 422 and removing the fluid from the radial bladder 422 through the second fluid channel 371.

Nitrogen gas can be used as the fluid to inflate and deflate the radial bladders 422.

[00285] Each vertical bladder 423 connects one of the aligners 420 to the vertical bladder holder 424. Each vertical bladder 423 is inflated and deflated by supplying a fluid into the vertical bladder 423 and removing the fluid from the vertical bladder 423 through the fourth fluid channel 373. Nitrogen gas can be used as the fluid to inflate and deflate the vertical bladders 423

[00286] Each aligner 420 comprises a first vertical surface 425a, a second vertical surface 425b, a first horizontal surface 426a and a second horizontal surface 426b, as illustrated in Fig. 37(a). A wafer is positioned on the first horizontal surfaces 426a of the aligners 420. The horizontal surfaces 426a and 426b can be moved upward and downward by inflating and deflating the vertical bladders 423, respectively. The vertical surfaces 425a and 425b can be moved inward and outward by inflating and deflating the radial bladders 422, respectively.

[00287] The first multiple nozzles 340 and the drains 360 are mounted on the top surface of the cup base 290 and the second multiple nozzles 350 are mounted to the cup ring 295, as illustrated in Figs. 37(a) and 37(b). The first and the second multiple nozzles 340 and 350 are connected to the third fluid channel 372

and spray DI water supplied through the third fluid channel 372. Used DI wafer is drained through the fifth fluid channel 374, which is connected to the drain 360.

[00288] With reference to Figs. 38(a)-38(f), a method of loading a wafer W onto the wafer carrier 262 from the load-and-unload cup 380 and unloading the wafer W from the wafer carrier 262 onto the load-and-unload cup 380 is described. Fig. 38(a)-38(f) are sequential cross sectional views of the load-and-unload cup 380. In Fig. 38(a), the aligners 420 are positioned at outward and downward positions by deflating the vertical and radial bladders 422 and 423. The wafer W is then transferred to the load-and-unload cup 380 and placed on the first horizontal surfaces 426a of the aligners 420 by the wafer transport device 150.

[00289] Next, as shown in Fig. 38(b), the load-and-unload cup 380 is transferred to the wafer load-and-unload position below the wafer carrier 262. The wafer carrier 262 comprises a retainer ring 289 to confine the wafer during a polishing process. Next, as shown in Fig. 38(c), the aligners 420 are moved upward by inflating the vertical bladders 423 until the second horizontal surfaces 426b of the aligners 420 touch the bottom surface 483 of the retainer ring 289. Preferably, the height of the second vertical surface 425b of the aligner 420 is designed to be larger than the thickness of the wafer W.

[00290] Next, as shown in Fig. 38(d), the aligners 420 are moved inward by inflating the radial bladders 422 until the first vertical surfaces 425a of the aligners 420 touch the outer surface of the retainer ring 289 of the wafer carrier 262. While the aligners 420 are moved inward, the second vertical surfaces 425b of some of the aligners 420 touch the wafer and move the wafer inward. When the inward movements of the aligners 420 are stopped by the output surface of the retainer ring 289, the wafer is automatically aligned horizontally such that the wafer can be safely loaded onto the wafer carrier 262 within the retainer ring 289. To achieve this automatic alignment of the wafer, the width of the second horizontal surface 426b of the aligner 420 should be larger than the width of the bottom surface 483 of the retainer ring 289.

[00291] Rather than moving the aligners 420 upward and then inward, the aligners can be moved first inward and then upward. It is also possible to move the aligners 420 inward and upward at the same time.

[00292] Next, as shown in Fig. 38(e), the wafer is transferred (raised) to the wafer carrier 262 by inflating the wafer bladder 400. The wafer carrier 262 receives the wafer using a vacuum supplied through vacuum channels 285. Next, as shown in Fig. 38(f), after the wafer is received by the wafer carrier 262, the
5 wafer bladder 400 is deflated and the aligners 420 are moved outward and downward by deflating the radial and vertical bladders 422 and 423.

[00293] To unload the wafer from the wafer carrier 262 onto the load-and-unload cup 380, the load-and-unload cup 380 is positioned below the wafer carrier 262 and the aligners 420 are moved upward and inward, as described with
10 reference to Fig. 38(b)-38(d) such that the load-and-unload cup 380 is aligned to the wafer carrier 262. Then the wafer is unloaded from the wafer carrier 262 to the first horizontal surfaces 426a of the aligners 420. It is also possible to unload the wafer to the wafer bladder 400 after the wafer bladder 400 is inflated, as illustrated in Fig. 38(e). Before or after unloading the wafer to the load-and-
15 unload cup 380, the wafer carrier 262 and the wafer can be washed by D.I. water sprayed from the first and second multiple nozzles 340 and 350 of the load-and-unload cup 380.

[00294] A method for polishing objects, such as semiconductor wafers, in accordance with an embodiment of the invention is described with reference to a
20 flow diagram of Fig. 39. At block 3902, an object is transferred to a first object carrier positioned over a first polishing surface. Next, at block 3904, the object is polished on the first polishing surface using the first object carrier. Next, at block 3906, the object is transferred from the first object carrier to a second object carrier positioned over a second polishing surface using a first load-and-unload
25 cup. The transferring of the object from the first object carrier to the second object carrier includes pivoting the load-and-unload cup about a pivoting axis. Next, at block 3908, the object is polished on the second polishing surface using the second object carrier. Next, at block 3910, the object is transferred to a second load-and-unload cup positioned adjacent to one of the first and second object
30 carriers to load the object onto the first object carrier or unload the object from the second object carrier.

[00295] A method for polishing objects in accordance with another embodiment of the invention is described with reference to a flow diagram of Fig.

40. At block 4002, an object is sequentially transferred to a plurality of object carriers positioned over a plurality of polishing surfaces using a plurality of load-and-unload cups. The sequentially transferring the object between object carriers includes pivoting each of the load-and-unload cups about a pivoting axis to
5 transfer the object between two adjacent object carriers of the object carriers. Next, at block 4004, the object is sequentially polished on the polishing surfaces using the object carriers.

[00296] A method for polishing objects in accordance with another embodiment of the invention is described with reference to a flow diagram of Fig.
10 41. At block 4102, an object is transferred to a first object carrier positioned over a first polishing surface. Next, at block 4104, the object is polished on the first polishing surface using the first object carrier. Next, at block 4106, the object is transferred from the first object carrier to a second object carrier positioned over a second polishing surface using a load-and-unload cup. The transferring of the
15 object from the first object carrier includes linearly displacing the load-and-unload cup from the first object carrier to the second object carrier. Next, at block 4108, the object is polished on the second polishing surface using the second object carrier.

[00297] A method for polishing objects in accordance with another embodiment of the invention is described with reference to a flow diagram of Fig.
20 42. At block 4202, an object is received at an input region of an object polishing station. Next, at block 4204, the object is sequentially transferred to a plurality of polishing surfaces of the object polishing station using a plurality of object carriers of the object polishing station. Next, at block 4206, the object is
25 sequentially polished on the polishing surfaces using the object carriers. Next, at block 4208, the object is transferred to an object transfer station of the object polishing station from a first adjacent polishing surface of the polishing surfaces using a first object carrier of the object carriers. Next, at block 4210, the object is transferred from the object transfer station to a second adjacent polishing surface
30 of the polishing surfaces using a second object carrier of the object carriers. Next, at block 4212, the object is output from an output region of the object polishing station after the object has been polished on the polishing surfaces.

[00298] A method for polishing objects in accordance with another embodiment of the invention is described with reference to a flow diagram of Fig. 43. At block 4302, first and second object are transferred to a first end of an object polishing unit using a first object transport device. Next, at block 4304, the first object is polished on at least one polishing surface of the object polishing unit using a first object carrier of the object polishing unit. Next, at block 4306, the second object is polished on at least one polishing surface using a second object carrier of the object polishing unit. Next, at block 4308, the first and second objects are transferred from a second end of the object polishing unit using a second object transport device. The first and second ends are located on opposite ends of the object polishing unit.

[00299] Although specific embodiments and examples of the invention have been illustrated and described, the invention is not to be limited to the specific forms or methods described and illustrated.

WHAT IS CLAIMED IS:

- 1 1. An apparatus for polishing objects, said apparatus comprising:
2 a first object carrier positioned over a first polishing surface;
3 a second object carrier positioned over a second polishing surface;
4 a first object relay device positioned between said first and second
5 object carriers, said first object relay device including a first load-and-unload cup
6 and a first pivoting drive mechanism, said first pivoting drive mechanism being
7 configured to pivot said first load-and-unload cup to and from said first and
8 second object carriers about a first pivoting axis to transfer said objects from said
9 first object carrier to said second object carrier; and
10 a second object relay device positioned adjacent to one of said first
11 and second object carriers, said second object relay device including a second
12 load-and-unload cup and a second pivoting drive mechanism, said second pivoting
13 mechanism being configured to pivot said second load-and-unload cup to and
14 from one of said first and second object carriers about a second pivoting axis to
15 transfer said objects to said first object carrier or from said second object carrier.
- 1 2. The apparatus of claim 1 wherein said first and second object carriers are
2 arranged in a first linear manner, and parking positions of said first and second
3 load-and-unload cups of said first and second object relay devices are arranged in
4 a second linear manner such that said first and second object carriers are
5 positioned to be substantially parallel to said first and second load-and-unload
6 cups positioned at said parking positions.
- 1 3. The apparatus of claim 2 wherein the distance between said first and
2 second object carriers is substantially equivalent to the distance between said
3 parking positions.
- 1 4. The apparatus of claim 1 further comprising an object cleaner configured
2 to clean said objects, said object cleaner being positioned such that a longer side
3 of said object cleaner is adjacent to a longer side of an area defined by said first
4 and second polishing surfaces.

1 5. The apparatus of claim 1 further comprising a first object transport device
2 to transfer said objects to said first object carrier or said second load-and-unload
3 cup of said second object relay device, and a second object transport device to
4 transfer said objects from said second object carrier or from said second load-and-
5 unload cup.

1 6. The apparatus of claim 1 wherein said second object relay device is
2 positioned adjacent to said first object carrier such that said first object carrier is
3 positioned between said first and second object relay devices, and further
4 comprising a third object relay device positioned adjacent to said second object
5 carrier such that said second object carrier is positioned between said first object
6 relay device and said third object relay device, said third object relay device
7 including a third load-and-unload cup and a third pivoting drive mechanism, said
8 third pivoting mechanism being configured to pivot said third load-and-unload
9 cup to and from said second object carrier about a third pivoting axis to transfer
10 said objects from said second object carrier.

1 7. A method for polishing objects, said method comprising:
2 transferring an object to a first object carrier positioned over a first
3 polishing surface;
4 polishing said object on said first polishing surface using said first
5 object carrier;
6 transferring said object from said first object carrier to a second
7 object carrier positioned over a second polishing surface using a first load-and-
8 unload cup, including pivoting said load-and-unload cup about a pivoting axis;
9 polishing said object on said second polishing surface using said
10 second object carrier; and
11 transferring said object to a second load-and-unload cup positioned
12 adjacent to one of said first and second object carriers to load said object onto said
13 first object carrier or unload said object from said second object carrier.

1 8. The method of claim 7 further comprising transferring said object to said
2 first object carrier or said second load-and-unload cup, and transferring said object
3 from said second load-and-unload cup or from said second object carrier.

1 9. The method of claim 7 further comprising transferring said object from
2 said second object carrier to a third load-and-unload cup positioned adjacent to
3 said second object carrier.

1 10. An apparatus for polishing objects, said apparatus comprising:
2 a plurality of object carriers positioned over a plurality of polishing
3 surfaces; and
4 a plurality of object relay devices positioned between said object
5 carriers such that at least one object relay device is positioned between two
6 adjacent object carriers, each object relay device including a load-and-unload cup
7 and a pivoting drive mechanism, said pivoting drive mechanism being configured
8 to pivot said load-and-unload cup to and from said two adjacent object carriers
9 about a pivoting axis to transfer said objects between said two adjacent object
10 carriers.

1 11. The apparatus of claim 10 wherein said object carriers are arranged in a
2 linear manner.

1 12. The apparatus of claim 11 wherein parking positions of load-and-unload
2 cups of said object relay devices are further arranged in a linear manner such that
3 said object carriers are positioned to be substantially parallel to said load-and-
4 unload cups positioned at said parking positions.

1 13. The apparatus of claim 12 wherein the distance between adjacent object
2 carriers of said object carriers is substantially equivalent to the distance between
3 adjacent parking positions of said parking positions.

1 14. The apparatus of claim 10 wherein parking positions of load-and-unload
2 cups of said object relay devices are arranged in a linear manner.

1 15. The apparatus of claim 10 further comprising a first object transport device
2 to transfer said objects to a first end object carrier of said object carriers, and a
3 second object transport device to transfer said objects from a second end object
4 carrier of said object carriers.

1 16. The apparatus of claim 10 further comprising an additional object relay
2 device positioned to transfer said objects to or from a first end object carrier of
3 said object carriers, said additional object relay device including a load-and-
4 unload cup and a pivoting drive mechanism.

1 17. The apparatus of claim 16 further comprising a first object transport device
2 to transfer said objects to said load-and-unload cup of said additional object relay
3 device, and a second object transport device to transfer said objects from a second
4 end object carrier of said object carriers.

1 18. The apparatus of claim 16 further comprising a first object transport device
2 to transfer said objects to a second end object carrier of said object carriers, and a
3 second object transport device to transfer said objects from said load-and-unload
4 cup of said additional object relay device.

1 19. The apparatus of claim 16 further comprising a second additional object
2 relay device positioned to transfer said objects to a second end object carrier of
3 said object carriers, said second additional object relay device including a load-
4 and-unload cup and a pivoting drive mechanism.

1 20. The apparatus of claim 19 further comprising a first object transport device
2 to transfer said objects to said load-and-unload cup of said additional object relay
3 device, and a second object transport device to transfer said objects from said
4 load-and-unload cup of said second additional object relay device.

1 21. The apparatus of claim 10 wherein said object carriers are arranged such
2 that distances between adjacent object carriers are substantially equivalent.

1 22. The apparatus of claim 10 wherein parking positions of load-and-unload
2 cups of said object relay devices are arranged such that distances between adjacent
3 load-and-unload cups are substantially equivalent when said load-and-unload cups
4 are positioned at said parking positions.

1 23. The apparatus of claim 10 further comprising an object cleaner configured
2 to clean said objects, said object cleaner being positioned such that a longer side
3 of said object cleaner is adjacent to a longer side of an area defined by said
4 polishing surfaces.

1 24. A method for polishing objects, said method comprising:
2 sequentially transferring an object to a plurality of object carriers
3 positioned over a plurality of polishing surfaces using a plurality of load-and-
4 unload cups, including pivoting each of said load-and-unload cups about a
5 pivoting axis to transfer said object between two adjacent object carriers of said
6 object carriers; and
7 sequentially polishing said object on said polishing surfaces using
8 said object carriers.

1 25. The method of claim 24 further comprising transferring said object to a
2 first end object carrier of said object carriers, and transferring said object from a
3 second end object carrier of said object carriers.

1 26. The method of claim 24 further comprising transferring said object to an
2 additional load-and-unload cup positioned adjacent to an end object carrier of said
3 object carriers, and pivoting said additional load-and-unload cup about a second
4 pivoting axis to transfer said object to or from said end object carrier.

1 27. The method of claim 26 further comprising transferring said object to said
2 additional load-and-unload cup, and transferring said object from a second end
3 object carrier of said object carriers.

1 28. The method of claim 26 further comprising transferring said object to a
2 second end object carrier of said object carriers, and transferring said object from
3 said additional load-and-unload cup.

1 29. The method of claim 26 further comprising transferring said object to a
2 second additional load-and-unload cup positioned adjacent to a second end object
3 carrier of said object carriers, and pivoting said second additional load-and-unload
4 cup about a third pivoting axis to transfer said object from said second end object
5 carrier.

1 30. The method of claim 29 further comprising transferring said object to said
2 additional load-and-unload cup, and transferring said object from said second
3 additional load-and-unload cup.

1 31. An apparatus for polishing objects, said apparatus comprising:
2 a first object carrier positioned over a first polishing surface;
3 a second object carrier positioned over a second polishing surface;
4 an object relay device positioned between said first and second
5 object carriers, said object relay device including a load-and-unload cup; and
6 a linear drive mechanism operatively connected to said object relay
7 device, said linear drive mechanism being configured to displace said load-and-
8 unload cup of said object relay device in a substantially linear reciprocating
9 manner to and from said first and second object carriers to transfer said objects
10 from said first object carrier to said second object carrier.

1 32. The apparatus of claim 31 further comprising a first object transport device
2 to transfer said objects to said first object carrier, and a second object transport
3 device to transfer said objects from said second object carrier.

1 33. The apparatus of claim 31 further comprising:
2 a first additional object carrier positioned over said first polishing
3 surface;
4 a second additional object carrier positioned over said second
5 polishing surface; and
6 an additional object relay device positioned between said first and
7 second additional object carriers, said additional object relay device including an
8 additional load-and-unload cup, said additional load-and-unload cup being
9 displaced in a substantially linear reciprocating manner to and from said first and
10 second additional object carriers to transfer said objects from said first additional
11 object carrier to said second additional object carrier.

1 34. The apparatus of claim 33 wherein said additional object relay device is
2 coupled to said object relay device such that said additional load-and-unload cup
3 and said load-and-unload cup are linearly displaced together.

1 35. The apparatus of claim 31 further comprising:
2 a plurality of object carriers positioned over a plurality of polishing
3 surfaces, said plurality of object carriers including said first and second object
4 carriers; and
5 a plurality of object relay devices positioned between said object
6 carriers such that at least one object relay device is positioned between two
7 adjacent object carriers, said object relay devices being operatively connected to
8 said linear drive mechanism to be linearly displaced, each object relay device
9 including a load-and-unload cup, said plurality of object relay devices including
10 said object relay device.

1 36. The apparatus of claim 35 wherein said linear drive mechanism is
2 configured to collectively displace some of said object relay devices in a
3 substantially linear motion.

1 37. The apparatus of claim 35 wherein said linear drive mechanism is
2 configured to individually displace each of said object relay devices in a
3 substantially linear motion.

1 38. The apparatus of claim 35 wherein said object carriers are arranged in a
2 linear manner.

1 39. The apparatus of claim 38 wherein said load-and-unload cups of said
2 object relay devices are further arranged in a linear manner such that said object
3 carriers are positioned to be substantially parallel to said load-and-unload cups.

1 40. The apparatus of claim 39 wherein the distance between adjacent object
2 carriers of said object carriers is substantially equivalent to the distance between
3 load-and-unload cups of adjacent object relay devices.

1 41. The apparatus of claim 35 wherein said load-and-unload cups of said
2 object relay devices are arranged in a linear manner.

1 42. The apparatus of claim 35 further comprising a first object transport device
2 to transfer said objects to a first end object carrier of said object carriers, and a
3 second object transport device to transfer said objects from a second end object
4 carrier of said object carriers.

1 43. The apparatus of claim 35 further comprising an additional object relay
2 device positioned to transfer said objects to or from an end object carrier of said
3 object carriers, said additional object relay device including a load-and-unload
4 cup.

1 44. The apparatus of claim 43 further comprising a first object transport device
2 to transfer said objects to said load-and-unload cup of said additional object relay
3 device, and a second object transport device to transfer said objects from a second
4 end object carrier of said object carriers.

1 45. The apparatus of claim 43 further comprising a first object transport device
2 to transfer said objects to a second end object carrier of said object carriers, and a
3 second object transport device to transfer said objects from said load-and-unload
4 cup of said additional object relay device.

1 46. The apparatus of claim 43 further comprising a second additional object
2 relay device positioned to transfer said objects to a second end object carrier of
3 said object carriers, said second additional object relay device including a load-
4 and-unload cup.

1 47. The apparatus of claim 46 further comprising a first object transport device
2 to transfer said objects to said load-and-unload cup of said additional object relay
3 device, and a second object transport device to transfer said objects from said
4 load-and-unload cup of said second additional object relay device.

1 48. The apparatus of claim 35 wherein said object carriers are arranged such
2 that distances between adjacent object carriers are substantially equivalent.

1 49. The apparatus of claim 35 wherein said load-and-unload cups of said
2 object relay devices are arranged such that distances between adjacent load-and-
3 unload cups are substantially equivalent when said load-and-unload cups are
4 positioned at respective parking positions.

1 50. The apparatus of claim 35 further comprising:
2 a plurality of additional object carriers positioned over said
3 plurality of polishing surfaces such that at least one of said object carriers and at
4 least one of said additional object carriers are positioned over each of said
5 polishing surfaces; and
6 a plurality of additional object relay devices positioned between
7 said additional object carriers such that at least one additional object relay device
8 is positioned between two adjacent additional object carriers, each of said
9 additional object relay devices including an additional load-and-unload cup, each
10 additional load-and-unload cup of said additional object relay devices being
11 displaced in a substantially linear reciprocating manner to transfer said objects
12 between two adjacent additional object carriers.

1 51. The apparatus of claim 50 wherein at least one of said additional object
2 relay devices is coupled to at least one of said object relay devices such that said
3 additional load-and-unload cup of said at least one of said additional object relay
4 devices and said load-and-unload cup of said at least one of said object relay
5 devices are linearly displaced together.

1 52. The apparatus of claim 31 further comprising an object cleaner configured
2 to clean said objects, said object cleaner being positioned such that a longer side
3 of said object cleaner is adjacent to a longer side of an area defined by said first
4 and second polishing surfaces.

1 53. A method for polishing objects, said method comprising:
2 transferring an object to a first object carrier positioned over a first
3 polishing surface;
4 polishing said object on said first polishing surface using said first
5 object carrier;
6 transferring said object from said first object carrier to a second
7 object carrier positioned over a second polishing surface using a load-and-unload
8 cup, including linearly displacing said load-and-unload cup from said first object
9 carrier to said second object carrier; and
10 polishing said object on said second polishing surface using said
11 second object carrier.

1 54. The method of claim 53 further comprising transferring said object to said
2 first object carrier using a first object transport device, and transferring said object
3 from said second object carrier using a second object transport device.

1 55. The method of claim 53 further comprising:
2 transferring a second object to a first additional object carrier
3 positioned over said first polishing surface;
4 polishing said second object on said first polishing surface using
5 said first additional object carrier;
6 transferring said second object from said first additional object
7 carrier to a second additional object carrier positioned over said second polishing
8 surface using an additional load-and-unload cup, including linearly displacing said
9 additional load-and-unload cup from said first additional object carrier to said
10 second additional object carrier; and
11 polishing said second object on said second polishing surface using
12 said second additional object carrier.

1 56. The method of claim 55 wherein said transferring said object from said
2 first object carrier to said second object carrier and said transferring said second
3 object from said first additional object carrier to said second additional object
4 carrier include linearly displacing said load-and-unload cup and said additional
5 load-and-unload cup together.

1 57. The method of claim 53 wherein said first and second object carriers are
2 part of a plurality of object carriers positioned over a plurality of polishing
3 surfaces, and wherein said load-and-unload cup is part of a plurality of load-and-
4 unload cups that can be positioned between said object carriers such that at least
5 one load-and-unload cup is positioned between two adjacent object carriers.

1 58. The method of claim 57 wherein said linearly displacing said load-and-
2 unload cup includes collectively displacing some of said load-and-unload cups in
3 a substantially linear motion.

1 59. The method of claim 57 wherein said linearly displacing said load-and-
2 unload cup includes individually displacing said load-and-unload cups in a
3 substantially linear motion.

1 60. The method of claim 57 further comprising transferring said object to a
2 first object transport device positioned adjacent to a first end object carrier of said
3 object carriers, and transferring said object to a second object transport device
4 positioned adjacent to a second end object carrier of said object carriers.

1 61. The method of claim 57 further comprising transferring said object to an
2 additional load-and-unload cup positioned to adjacent to an end object carrier of
3 said object carriers, and transferring said object to or from said end object carrier
4 using said additional load-and-unload cup.

1 62. The method of claim 61 further comprising transferring said object to said
2 additional load-and-unload cup using a first object transport device, and
3 transferring said object from a second end object carrier of said object carriers
4 using a second object transport device.

1 63. The method of claim 61 further comprising transferring said object to a
2 second end object carrier of said object carriers using a first object transport
3 device, and transferring said object from said additional load-and-unload cup
4 using a second object transport device.

1 64. The method of claim 61 further comprising transferring said object to a
2 second additional load-and-unload cup positioned adjacent to a second end object
3 carrier of said object carriers, and transferring said object from said second end
4 object carrier using said second additional load-and-unload cup.

1 65. The method of claim 64 further comprising transferring said object to said
2 additional load-and-unload cup using a first object transport device, and
3 transferring said object from said second additional load-and-unload cup using a
4 second object transport device.

1 66. The method of claim 57 further comprising:
2 sequentially transferring a second object to a plurality of additional
3 object carriers, said additional object carriers being positioned over said plurality
4 of polishing surfaces such that at least one of said object carriers and at least one
5 of said additional object carriers are positioned over each of said polishing
6 surfaces;
7 sequentially polishing said second object on said polishing surfaces
8 using said additional object carriers;
9 transferring said second object between said additional object
10 carriers using a plurality of additional load-and-unload cups, including linearly
11 displacing said additional load-and-unload cups between said additional object
12 carriers.

1 67. The method of claim 66 wherein said transferring said second object
2 between said additional object carriers includes linearly displacing at least one of
3 said additional load-and-unload cups and at least one of said load-and-unload cups
4 together.

1 68. An apparatus for polishing objects, said apparatus comprising:
2 an object polishing station having an input region to receive said
3 objects and an output region to output said objects, said object polishing station
4 including:
5 a plurality of polishing surfaces;
6 an object transfer station positioned between two adjacent
7 polishing surfaces of said polishing surfaces;
8 a plurality of object carriers, each of said object carriers
9 being configured to secure one of said objects; and
10 at least one drive mechanism operatively connected to at
11 least one of said object carriers, said drive mechanism being configured to
12 displace at least one of said object carriers to and from said object transfer station
13 and one of said two adjacent polishing surfaces; and
14 at least one object transport device to transfer said objects to said
15 input region of said object polishing station and to transfer said objects from said
16 output region of said object polishing station,
17 wherein each of said objects is transferred from said input region to
18 said output region by way of said polishing surfaces of said object polishing
19 station such that each of said objects is polished on said polishing surfaces.

1 69. The apparatus of claim 68 wherein said at least one object transport device
2 is configured to transfer said objects directly to a first end object carrier of said
3 object carriers of said object polishing station, said at least one object transport
4 device being further configured to transfer said objects directly from a second end
5 object carrier of said object carriers.

1 70. The apparatus of claim 68 wherein said drive mechanism of said object
2 polishing station is configured to collectively displace some of said object carriers
3 in a substantially linear motion.

1 71. The apparatus of claim 68 wherein said drive mechanism of said object
2 polishing station is configured to individually displace each of said object carriers
3 in a substantially linear motion.

1 72. The apparatus of claim 68 wherein said object polishing station further
2 comprises a plurality of drive mechanisms, said drive mechanisms including said
3 drive mechanism, each of said drive mechanisms being configured to individually
4 displace each of said object carriers in a pivoting motion.

1 73. The apparatus of claim 68 wherein said object carriers of said object
2 polishing station are arranged in a linear manner.

1 74. The apparatus of claim 73 wherein said object polishing station further
2 comprises a plurality of object transfer stations positioned between said polishing
3 surfaces such that at least one object transfer station is positioned between two
4 adjacent polishing surfaces, said plurality of object transfer stations including said
5 object transfer station, said object transfer stations being arranged in a linear
6 manner such that said object transfer stations are positioned substantially parallel
7 to said object carriers.

1 75. The apparatus of claim 74 wherein the distance between adjacent object
2 carriers of said object polishing station is substantially equivalent to the distance
3 between adjacent object transfer stations of said object polishing station.

1 76. The apparatus of claim 68 wherein said object polishing station further
2 comprises a plurality of object transfer stations positioned between said polishing
3 surfaces such that at least one object transfer station is positioned between two
4 adjacent polishing surfaces, said plurality of object transfer stations including said
5 object transfer station, said object transfer stations being arranged in a linear
6 manner.

1 77. The apparatus of claim 68 wherein said object polishing station comprises
2 an additional object transfer station positioned to transfer said objects to or from
3 an end object carrier of said object carriers.

1 78. The apparatus of claim 77 wherein said at least one transport device is
2 configured to transfer said objects to said additional object transfer station of said
3 object polishing station, said at least one object transport device being further
4 configured to transfer said objects from a second end object carrier of said object
5 carriers.

1 79. The apparatus of claim 78 said at least one object transport device is
2 configured to transfer said objects to a second end object carrier of said object
3 carriers, said at least one object transport device being further configured to
4 transfer said objects from said additional object transfer station.

1 80. The apparatus of claim 77 wherein said object polishing station further
2 comprising a second additional object transfer station positioned to transfer said
3 objects to a second end object carrier of said object carriers.

1 81. The apparatus of claim 80 wherein said at least one object transport device
2 is configured to transfer said objects to said additional object transfer station, said
3 at least one object transport device being further configured to transfer said
4 objects from said second additional object transfer station.

1 82. The apparatus of claim 68 wherein said object carriers of said object
2 polishing station are arranged such that distances between adjacent object carriers
3 are substantially equivalent.

1 83. The apparatus of claim 68 wherein said object polishing station further
2 comprises:
3 a plurality of additional object transfer stations positioned between
4 said polishing surfaces such that at least one of said additional object transfer
5 stations is positioned between two adjacent polishing surfaces; and
6 a plurality of additional object carriers, each of said additional
7 object carriers being displaced in a substantially linear reciprocating manner to
8 transfer said objects between one of said additional object transfer stations and
9 one of said polishing surfaces.

1 84. The apparatus of claim 83 wherein at least one of said additional object
2 carriers is coupled to at least one of said object carriers such that said at least one
3 of said additional object carriers and said at least one of said object carriers are
4 displaced together.

1 85. The apparatus of claim 68 further comprising an object cleaner configured
2 to clean said objects, said object cleaner being positioned such that a longer side
3 of said object cleaner is adjacent to a longer side of an area defined by said
4 polishing surfaces.

1 86. A method for polishing objects, said method comprising:
2 receiving an object at an input region of an object polishing station;
3 sequentially transferring said object to a plurality of polishing
4 surfaces of said object polishing station using a plurality of object carriers of said
5 object polishing station;
6 sequentially polishing said object on said polishing surfaces using
7 said object carriers;
8 transferring said object to an object transfer station of said object
9 polishing station from a first adjacent polishing surface of said polishing surfaces
10 using a first object carrier of said object carriers;
11 transferring said object from said object transfer station to a second
12 adjacent polishing surface of said polishing surfaces using a second object carrier
13 of said object carriers; and
14 outputting said object from an output region of said object
15 polishing station after said object has been polished on said polishing surfaces.

1 87. The method of claim 86 wherein said receiving includes transferring said
2 object directly to a first end object carrier of said object carriers, and wherein said
3 outputting includes transferring said object directly from a second end object
4 carrier of said object carriers.

1 88. The method of claim 86 wherein said transferring said object to said object
2 transfer station and said transferring said object from said object transfer station
3 include collectively displacing said first and second object carriers in a
4 substantially linear motion.

1 89. The method of claim 86 wherein said transferring said object to said object
2 transfer station and said transferring said object from said object transfer station
3 include individually displacing said first and second object carriers in a
4 substantially linear motion.

1 90. The method of claim 86 wherein said transferring said object to said object
2 transfer station and said transferring said object from said object transfer station
3 include individually displacing each of said first and second object carriers in a
4 pivoting motion.

1 91. The method of claim 86 further comprising transferring said object to an
2 additional object transfer station of said object polishing station positioned
3 adjacent to an end object carrier of said object carriers such that said end object
4 carrier can transfer said object to or from said additional object transfer station.

1 92. The method of claim 91 wherein said receiving includes transferring said
2 object directly to said additional object transfer station, and wherein said
3 outputting includes transferring said object directly from a second end object
4 carrier of said object carriers.

1 93. The method of claim 91 wherein said receiving includes transferring said
2 object directly to a second end object carrier of said object carriers, and wherein
3 said outputting includes transferring said object directly from said additional
4 object transfer station.

1 94. The method of claim 91 further comprising transferring said object to a
2 second additional object transfer station of said object polishing station positioned
3 adjacent to a second end object carrier of said object carriers such that said second
4 object carrier can transfer said object to said second additional object transfer
5 station.

1 95. The method of claim 94 wherein said receiving includes transferring said
2 object directly to said additional object transfer station, and wherein said
3 outputting includes transferring said object directly from said second additional
4 object transfer station.

1 96. The method of claim 86 further comprising:
2 sequentially transferring a second object to said polishing surfaces
3 using a plurality of additional object carriers of said object polishing station;
4 sequentially polishing said second object on said polishing surfaces
5 using said additional object carriers;
6 transferring said second object to an additional object transfer
7 station of said object polishing station from said first adjacent polishing surface
8 using a first additional object carrier of said additional object carriers;
9 transferring said second object from said additional object transfer
10 station to said second adjacent polishing surface using a second additional object
11 carrier of said additional object carriers.

1 97. The method of claim 96 wherein said sequentially transferring said second
2 object includes displacing at least one of said additional object carriers and at least
3 one of said object carriers together.

1 98. An apparatus for polishing objects, said apparatus comprising:
2 a first object transport device;
3 a second object transport device; and
4 an object polishing unit positioned between said first and second
5 object transport devices, said object polishing unit comprising:
6 at least one polishing surface; and
7 first and second object carriers positioned over said
8 polishing surface to polish said objects on said polishing surface,
9 wherein each of said objects is transferred from said first object
10 transport device to said second object transport device by way of one of said first
11 and second object carriers.

1 99. The apparatus of claim 98 wherein said object polishing unit further
2 comprises first and second polishing surfaces such that said first object carrier can
3 polish some of said objects on said first polishing surface and said second object
4 carrier can polish some of said object on said second polishing surface.

1 100. The apparatus of claim 98 wherein said object polishing unit further
2 comprises an object relay device positioned between said first and second object
3 transport devices, said object relay device including a load-and-unload cup and a
4 pivoting drive mechanism, said pivoting drive mechanism being configured to
5 pivot said load-and-unload cup about a pivoting axis to transfer said objects to or
6 from said first and second object carriers.

1 101. The apparatus of claim 100 wherein said object polishing unit further
2 comprises an additional object relay device positioned between said object relay
3 device and said second object transport device, said additional object relay device
4 including an additional load-and-unload cup and an additional pivoting drive
5 mechanism, said additional pivoting drive mechanism being configured to pivot
6 said additional load-and-unload cup about a second pivoting axis to transfer said
7 objects from said first and second object carriers.

1 102. The apparatus of claim 98 wherein said object polishing unit further
2 comprises first and second object relay devices positioned between said first and
3 second object transport devices, each of said first and second object relay devices
4 including a load-and-unload cup and a pivoting drive mechanism, said pivoting
5 drive mechanism of said first object relay device being configured to pivot said
6 load-and-unload cup of said first object relay device about a first pivoting axis to
7 transfer some of said objects to or from said first object carrier, said pivoting drive
8 mechanism of said second object relay device being configured to pivot said load-
9 and-unload cup of said second object relay device about a second pivoting axis to
10 transfer some of said objects to or from said second object carrier.

1 103. A method for polishing objects, said method comprising:
2 transferring first and second objects to a first end of an object
3 polishing unit using a first object transport device;
4 polishing said first object on at least one polishing surface of said
5 object polishing unit using a first object carrier of said object polishing unit;
6 polishing said second object on said at least one polishing surface
7 using a second object carrier of said object polishing unit; and
8 transferring said first and second object from a second end of said
9 object polishing unit using a second object transport device, said first and second
10 ends being located on opposite ends of said object polishing unit.

1 104. The method of claim 103 wherein said polishing said first object includes
2 polishing said first object on a first polishing surface of said object polishing unit,
3 and wherein said polishing said second object includes polishing said second
4 object on a second polishing surface of said object polishing unit.

1 105. The method of claim 103 further comprising transferring said first and
2 second objects between said first and second object carriers and one of said first
3 and second object transport devices using a load-and-unload cup of said object
4 polishing unit, including pivoting said load-and-unload cup about a pivoting axis.

1 106. The method of claim 105 further comprising transferring said first and
2 second objects between said first and second object carriers and said second object
3 transport device using an additional load-and-unload cup of said object polishing
4 unit, including pivoting said additional load-and-unload cup about a second
5 pivoting axis.

1 107. The method of claim 103 further comprising transferring said first object
2 between said first object carrier and one of said first and second object transport
3 devices using a first load-and-unload cup of said object polishing unit, including
4 pivoting said first load-and-unload cup about a first pivoting axis, and transferring
5 said second object between said second object carrier and one of said first and
6 second object transport devices using a second load-and-unload cup of said object
7 polishing unit, including pivoting said second load-and-unload cup about a second
8 pivoting axis.

1 108. An object relay device for loading and unloading an object, said wafer
2 relay device cup device comprising:
3 a load-and-unload cup;
4 an arm operatively connected to said load-and-unload cup to
5 laterally move said load-and-unload cup; and
6 a cup ascending-and-descending mechanism operatively connected
7 to said load-and-unload cup and said arm, said cup ascending-and-descending
8 mechanism being configured to raise and lower said load-and-unload cup with
9 respect to said arm.

1 109. The object relay device of claim 108 wherein said load-and-unload cup
2 comprises a central bladder connected to a surface of said load-and-unload cup,
3 said central bladder being configured to be inflated and deflated pneumatically in
4 a vertical direction with respect said surface, said central bladder being configured
5 to support said object to raise said object when said central bladder is inflated.

1 110. The object relay device of claim 108 further comprising an air cushioning
2 mechanism operatively coupled to said load-and-unload cup to absorb a vertical
3 action force.

1 111. The object relay device of claim 108 wherein said load-and-unload cup
2 comprises:
3 an object supporting structure;
4 a plurality of bladders coupled to said object supporting structure,
5 each of said bladders being configured to be inflated and deflated pneumatically in
6 a vertical direction with respect to a surface of said object supporting structure;
7 and
8 a plurality of aligners coupled to said plurality of bladders such that
9 at least one bladder is coupled to each aligner, each of said aligners comprising a
10 first horizontal portion to support said object and a second horizontal portion to
11 contact a bottom portion of an object carrier when said bladders are inflated.

1 112. The object relay device of claim 111 wherein said load-and-unload cup
2 further comprises a plurality of second bladders coupled to said object supporting
3 structure and said aligners, each of said second bladders being configured to be
4 inflated and deflated pneumatically in a horizontal direction with respect to said
5 surface of said object supporting structure.

1 113. The load-and-unload cup device of claim 112 wherein each of said
2 aligners further comprises a first vertical portion to move an edge of said object
3 inward when said second bladders are inflated and a second vertical portion to
4 contact an outer surface of said object carrier when said second bladders are
5 inflated.

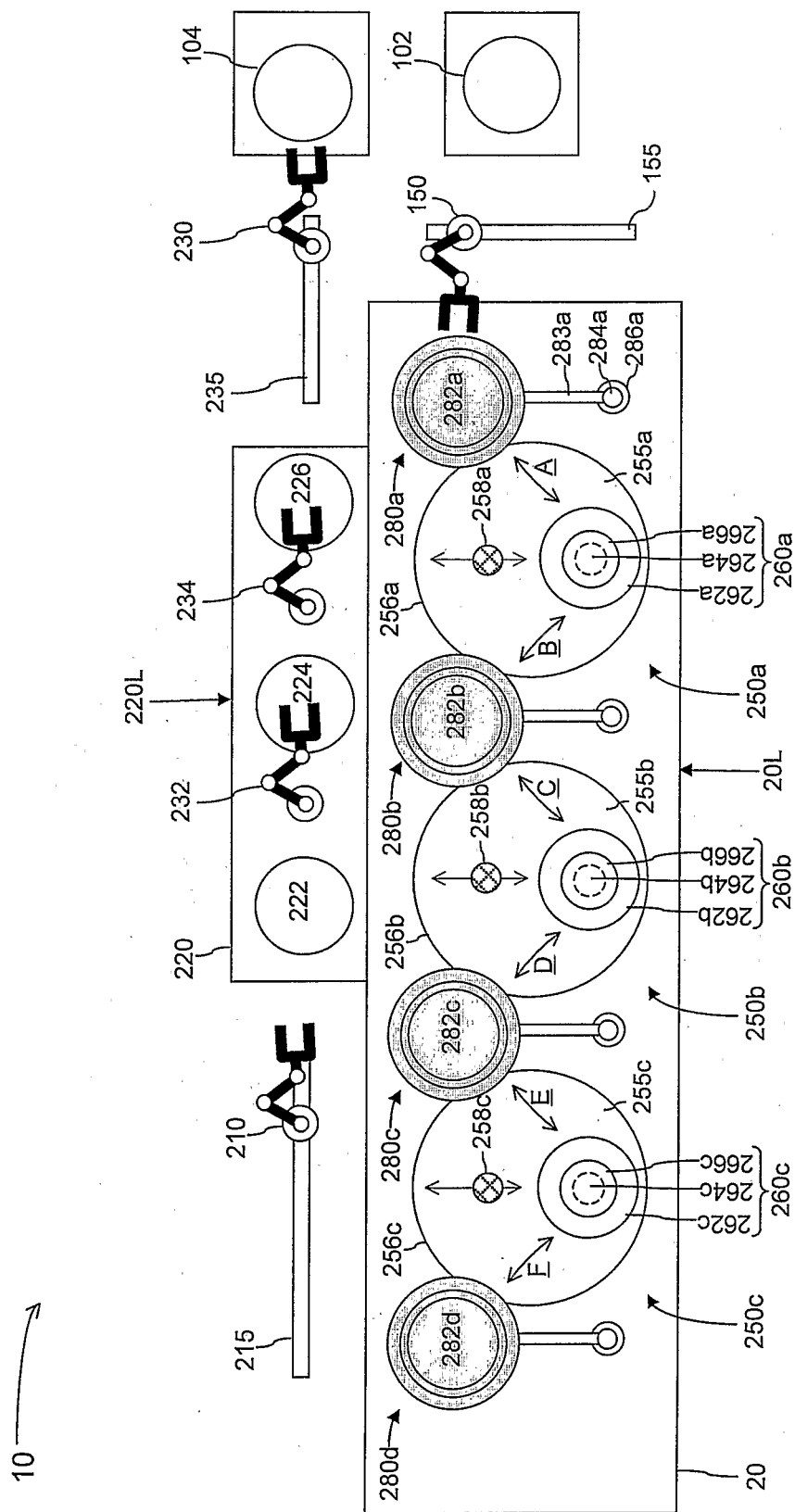


Fig. 1

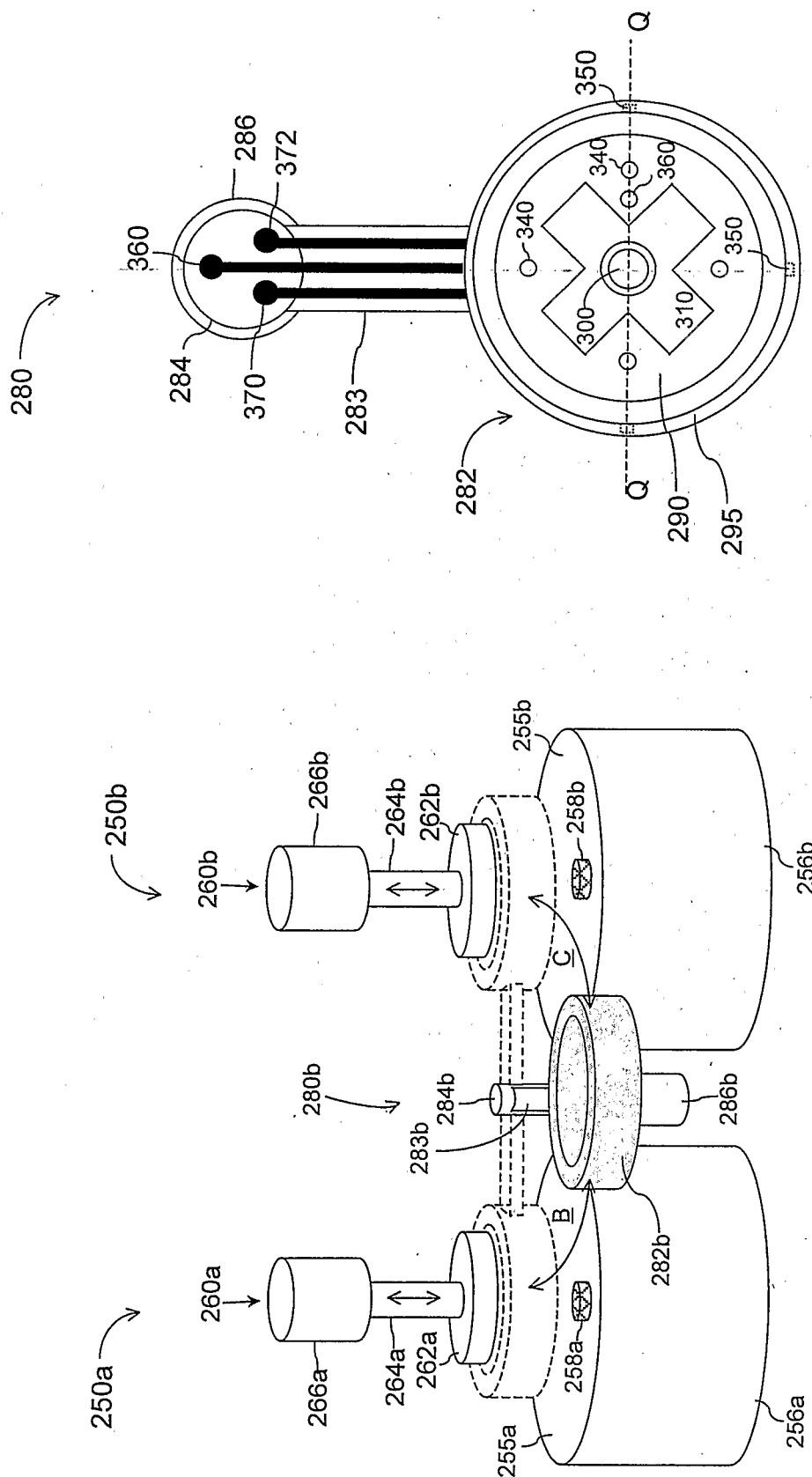


Fig. 2

FIG. 3(a)

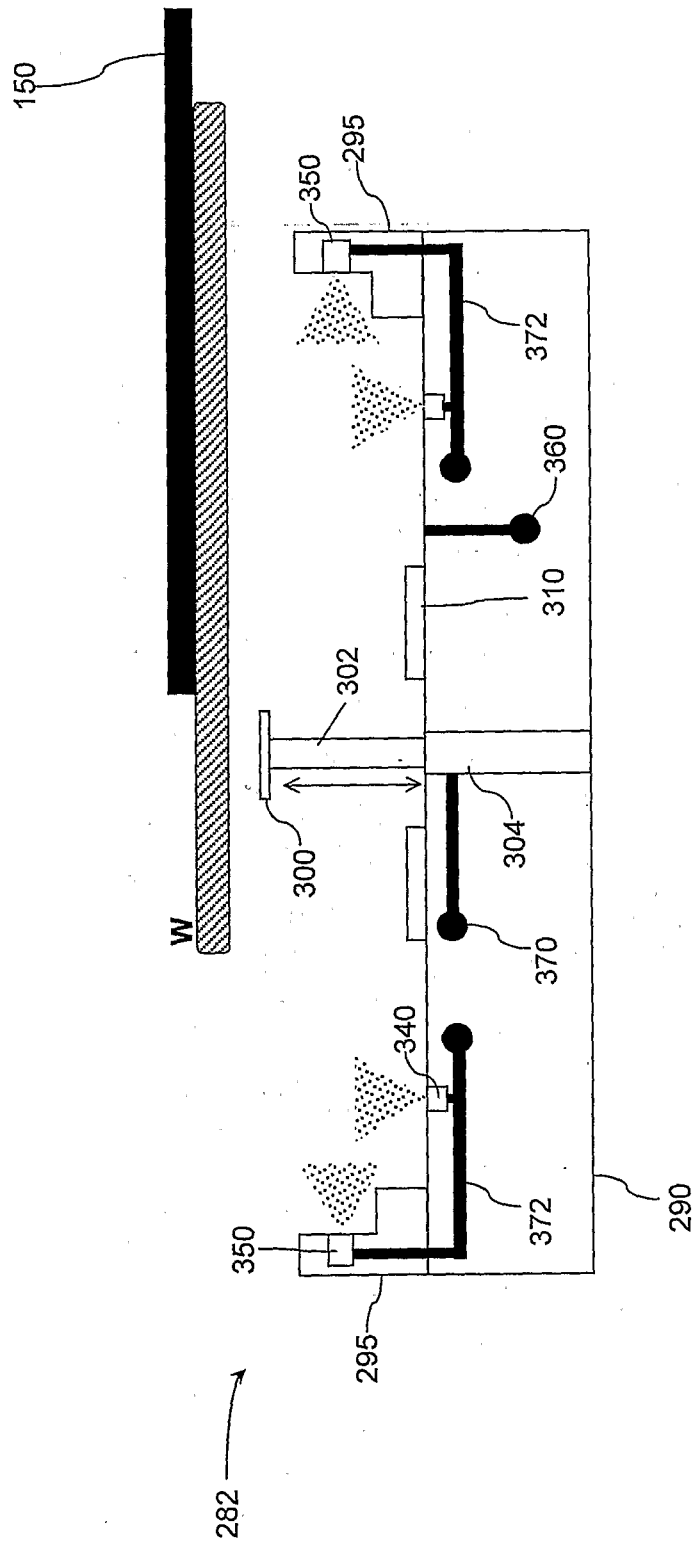


FIG. 3(b)

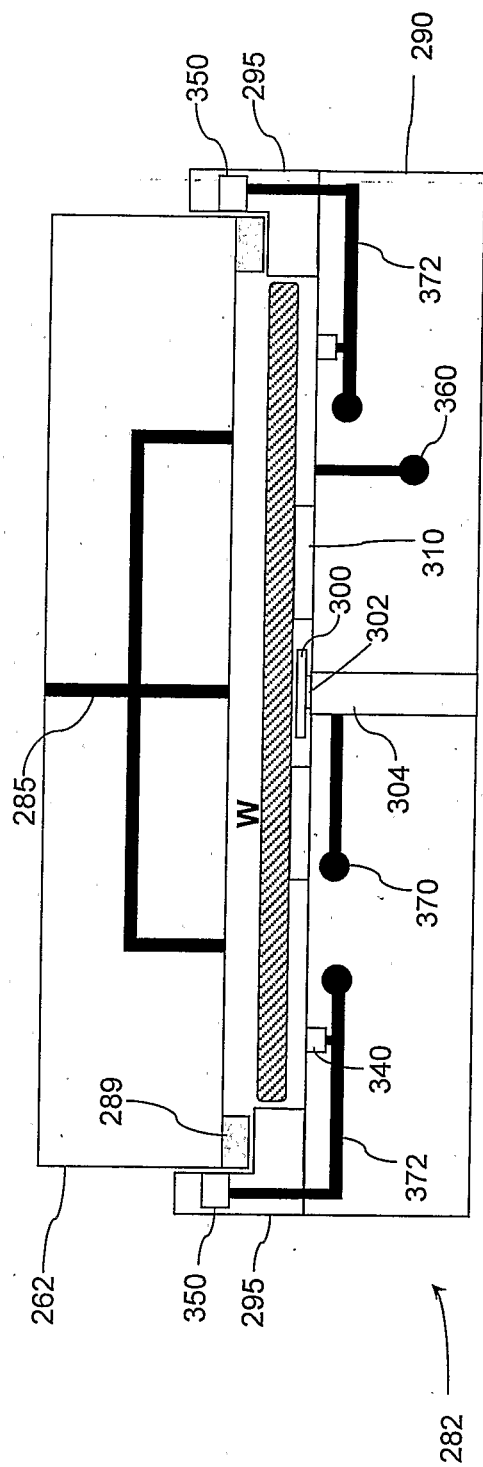


FIG. 4(a)

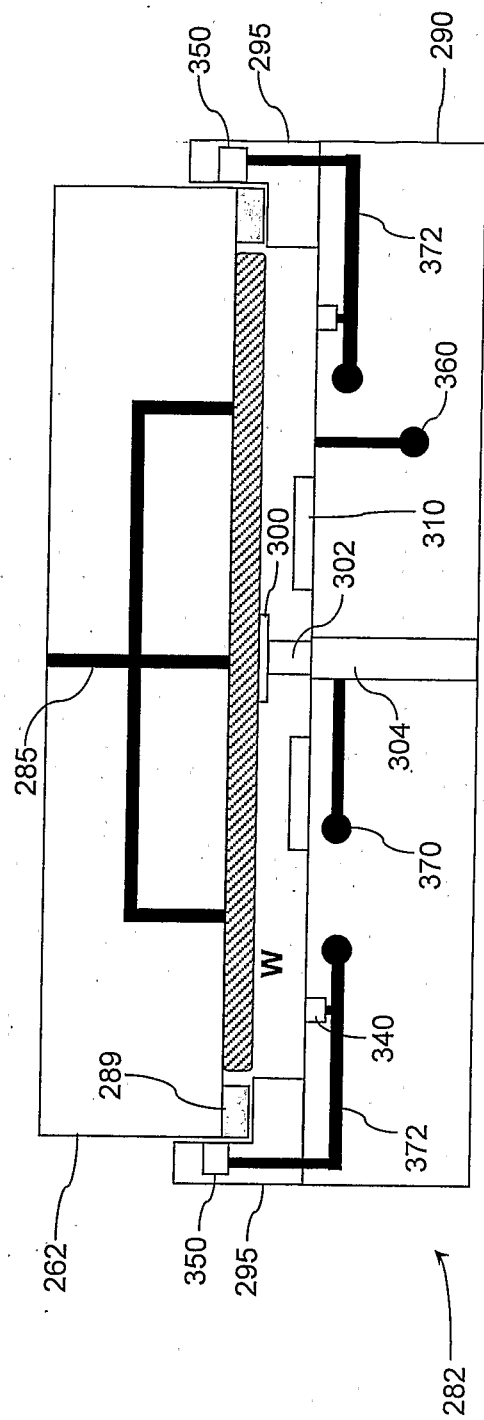


FIG. 4(b)

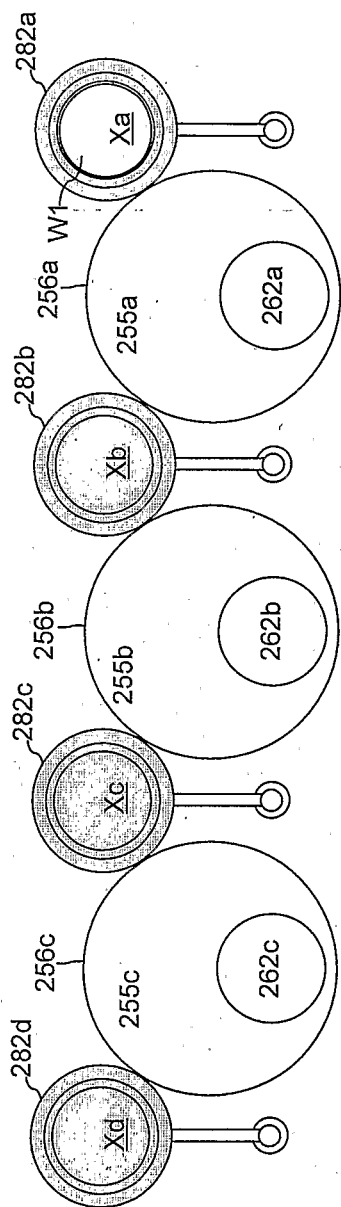


Fig. 5(a)

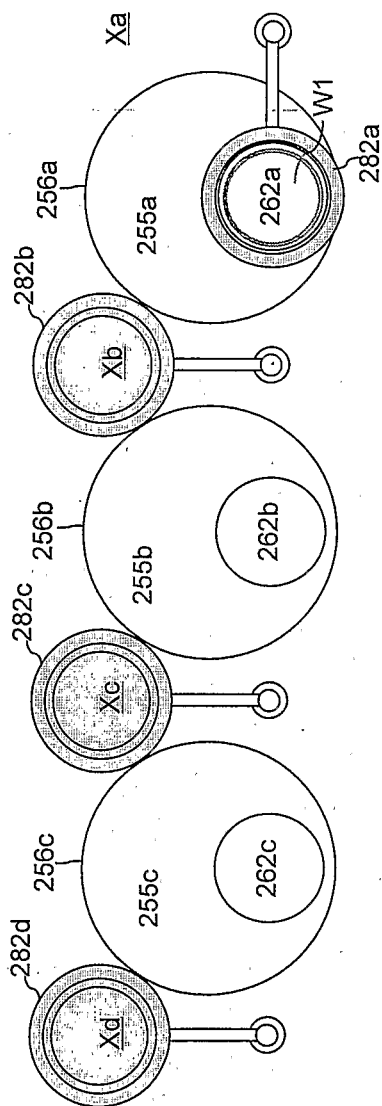


Fig. 5(b)

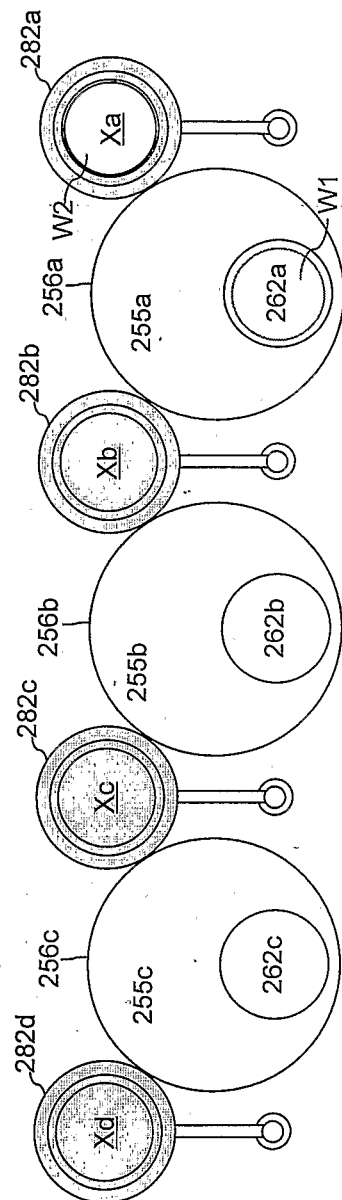


Fig. 5(c)

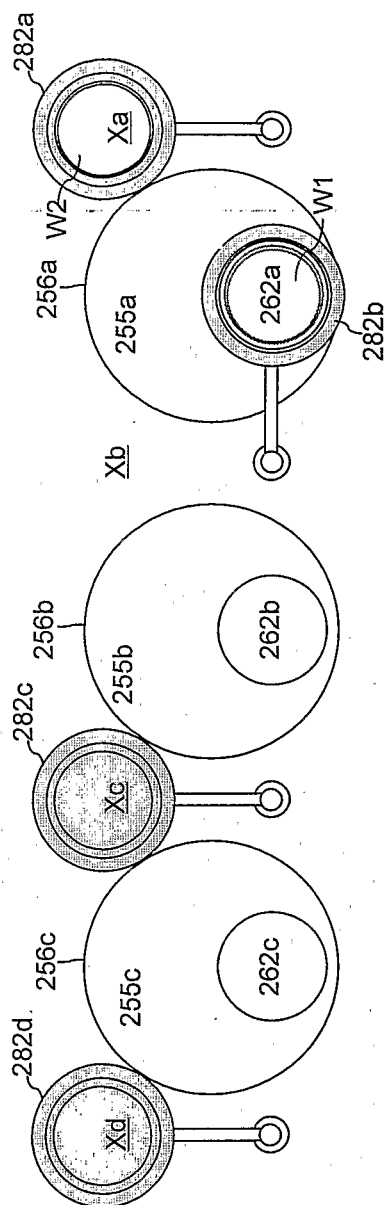


Fig. 5(d)

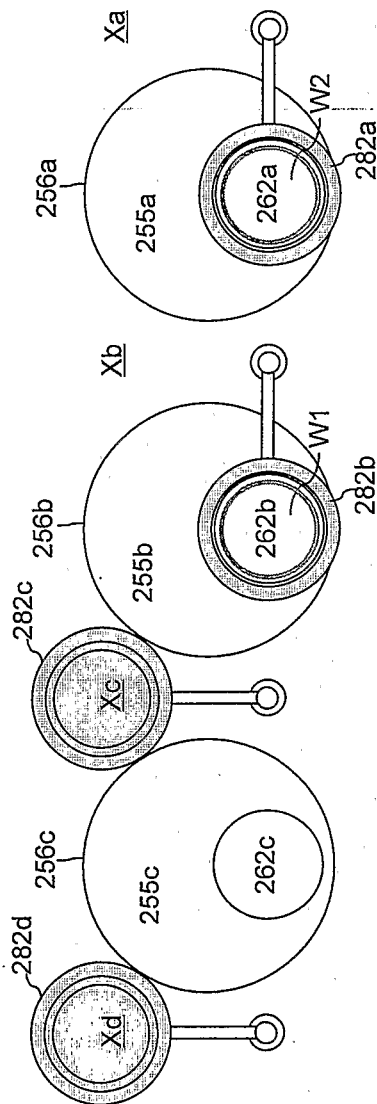


Fig. 5(e)

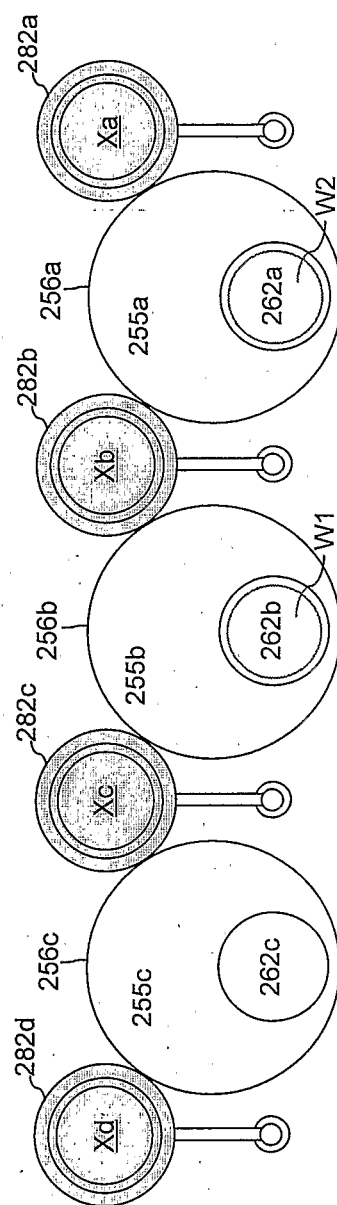


Fig. 5(f)

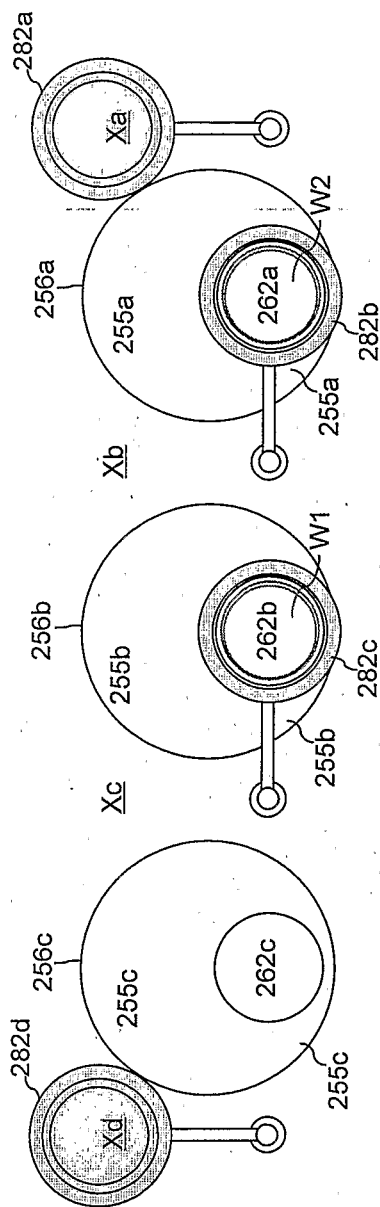


Fig. 5(g)

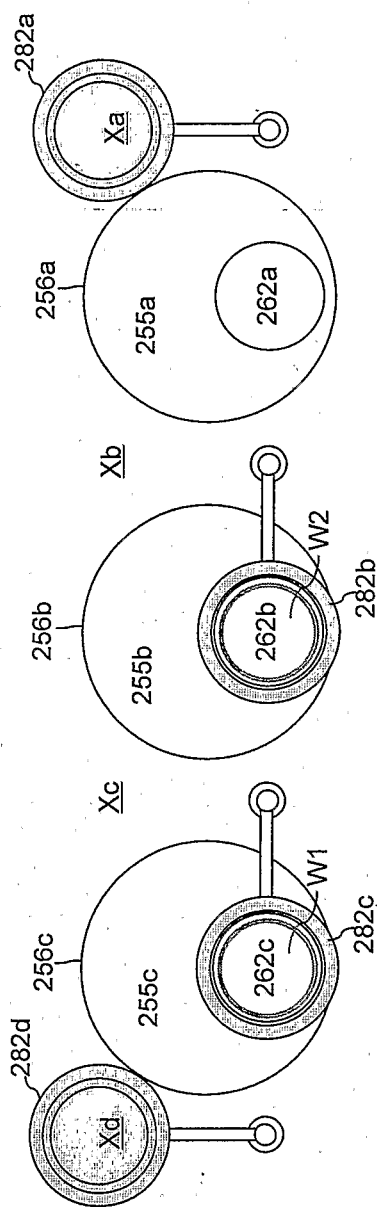


Fig. 5(h)

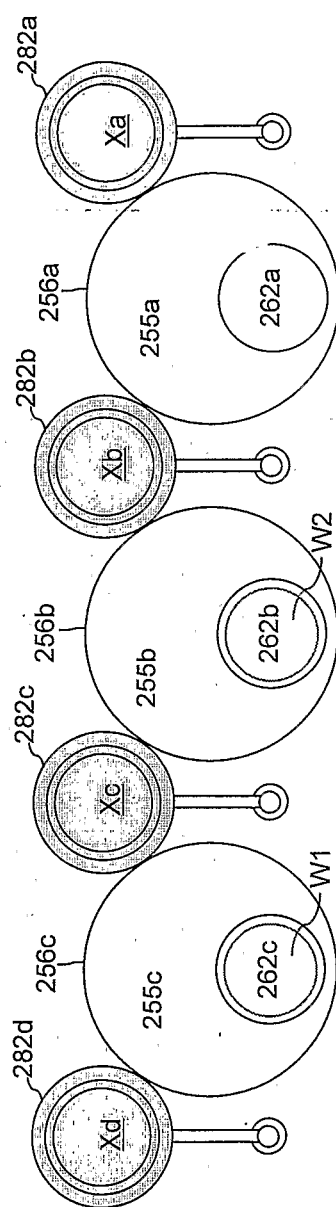


Fig. 5(i)

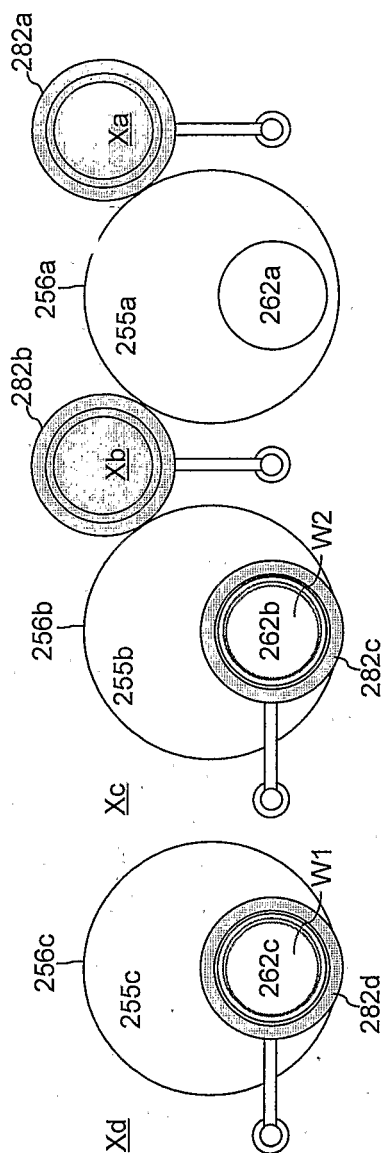


Fig. 5(j)

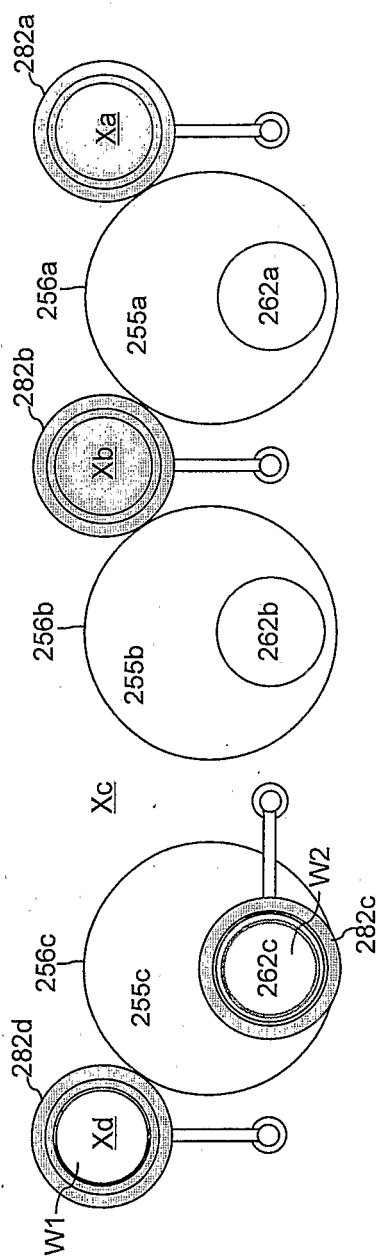


Fig. 5(k)

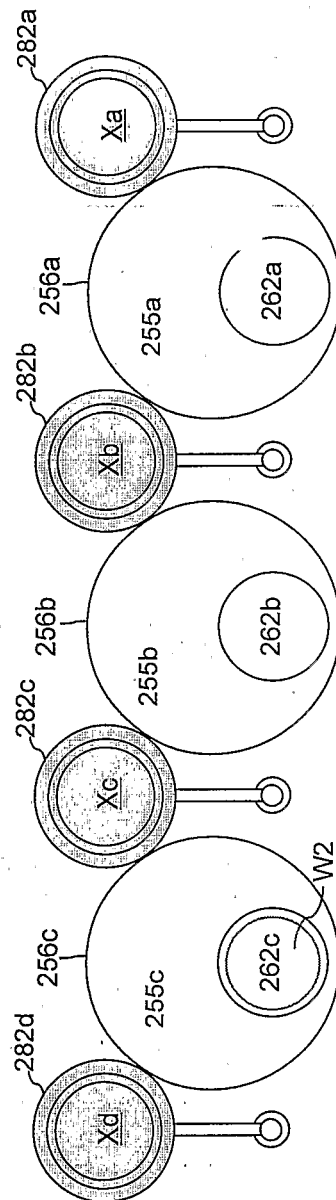


Fig. 5(l)

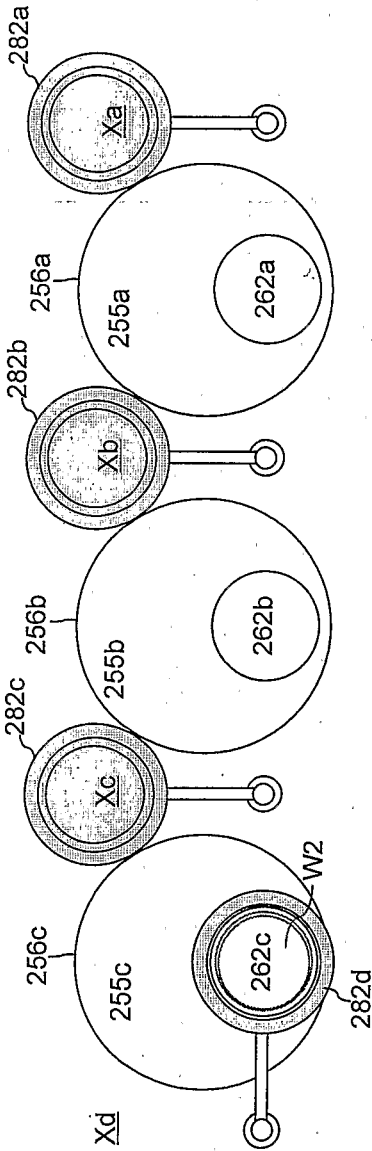


Fig. 5(m)

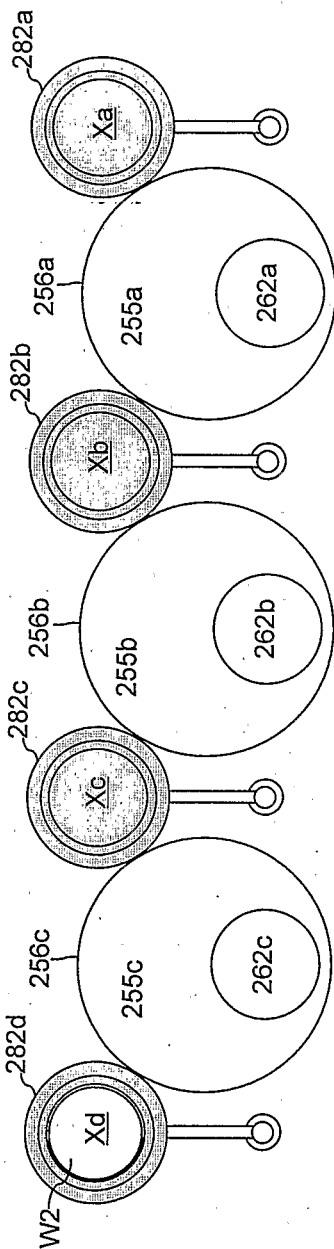


Fig. 5(n)

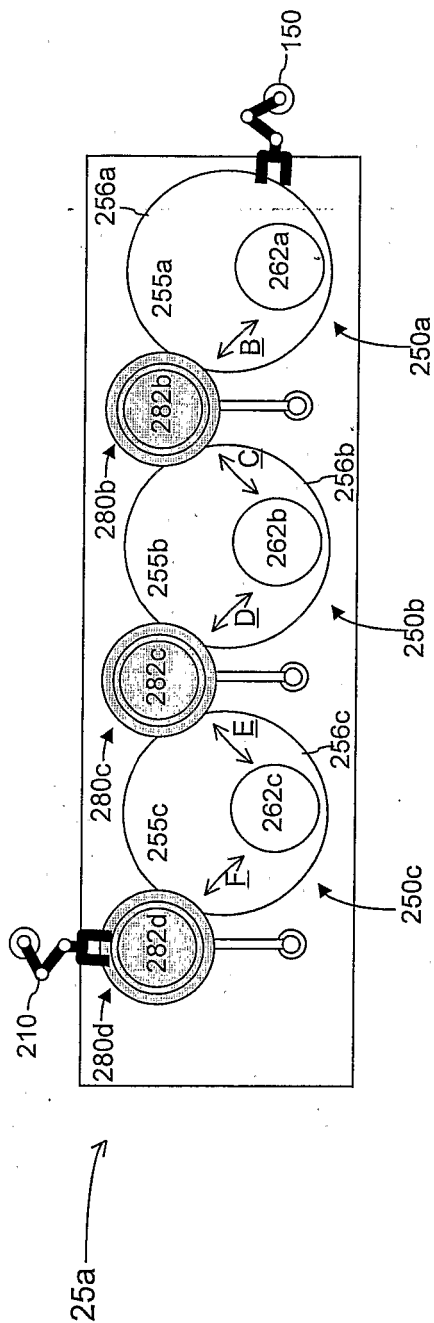


Fig. 6

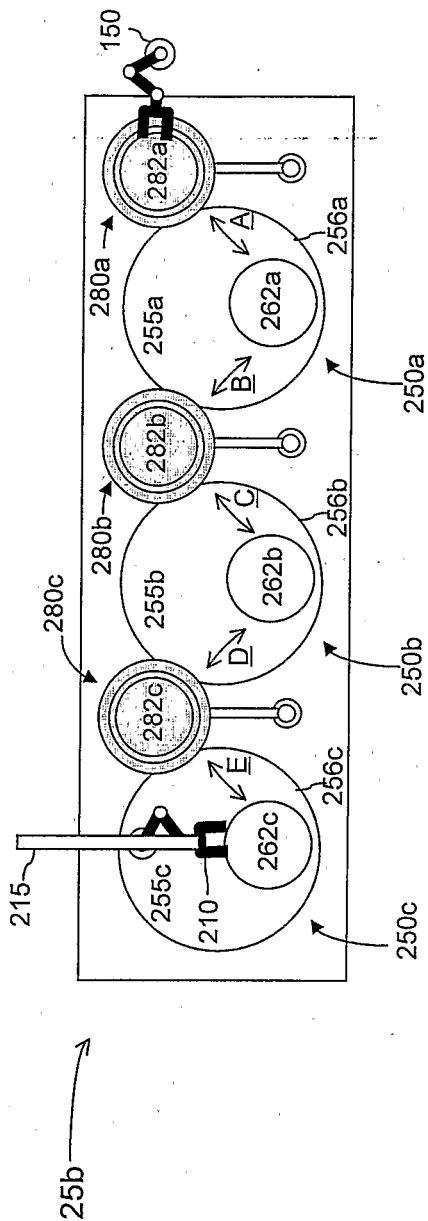


Fig. 7

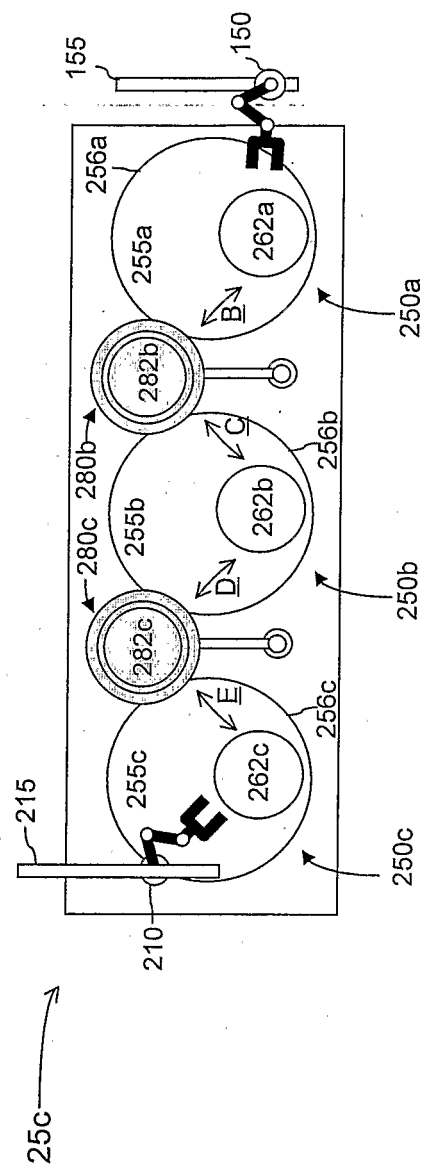


Fig. 8

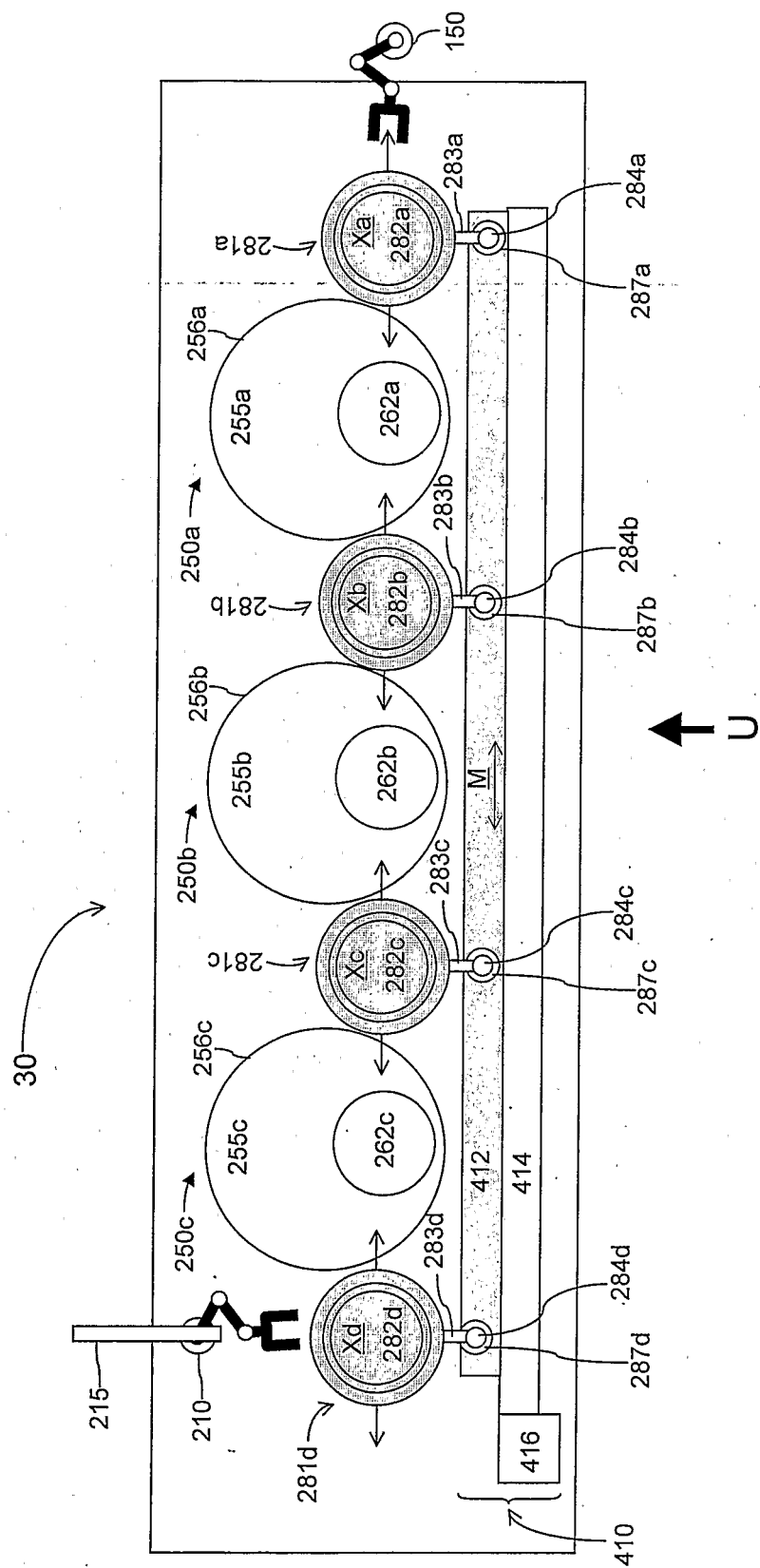


Fig. 9

30 →

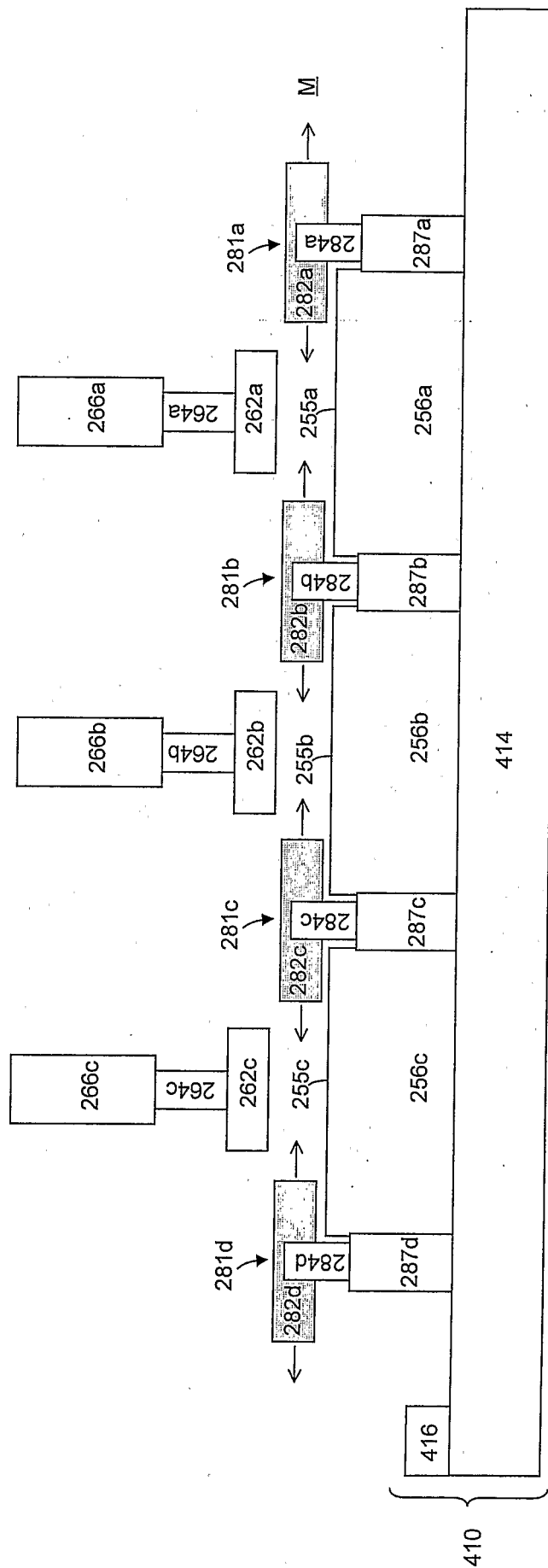
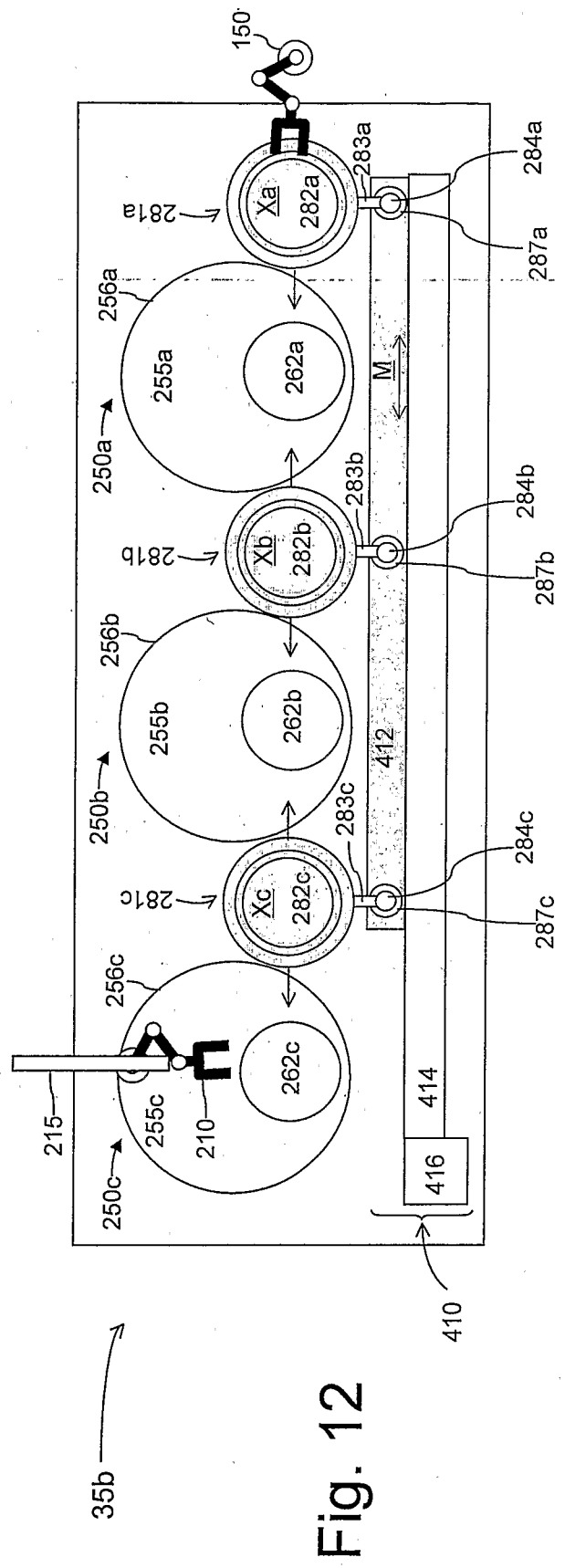
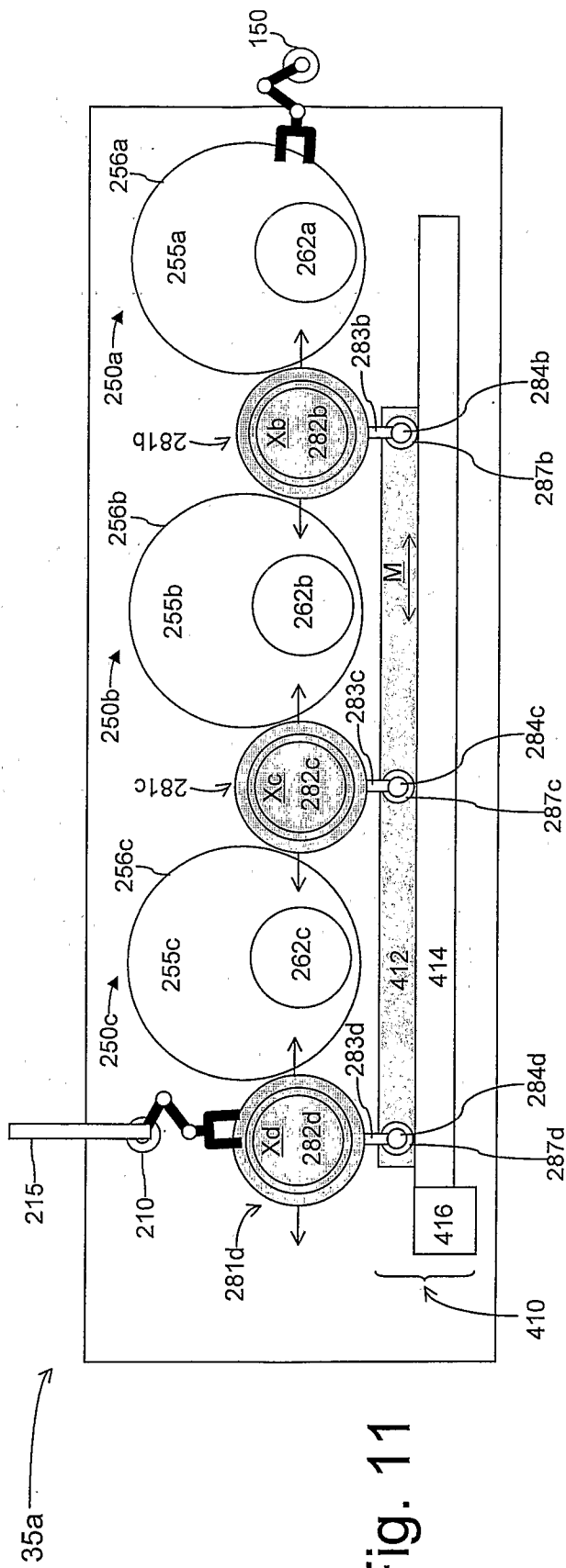


Fig. 10



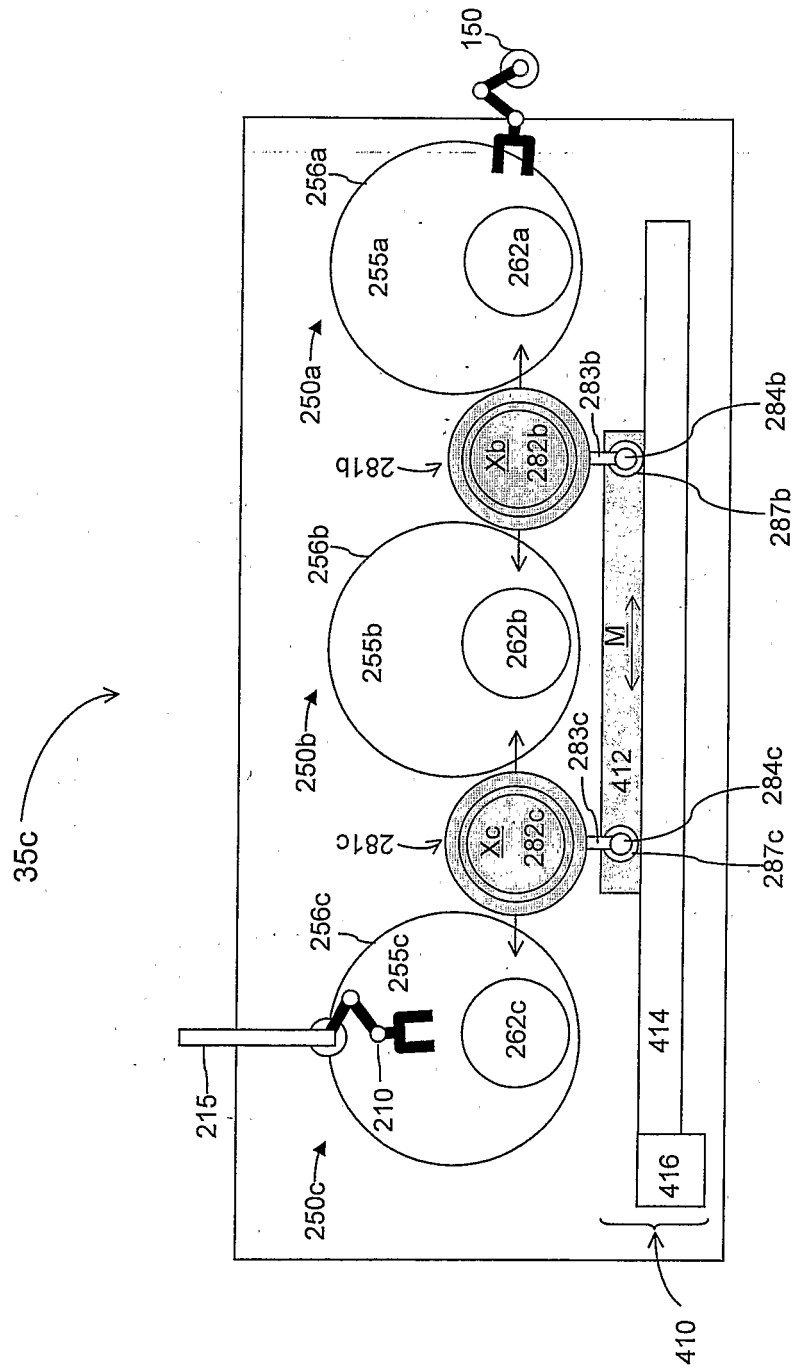


Fig. 13

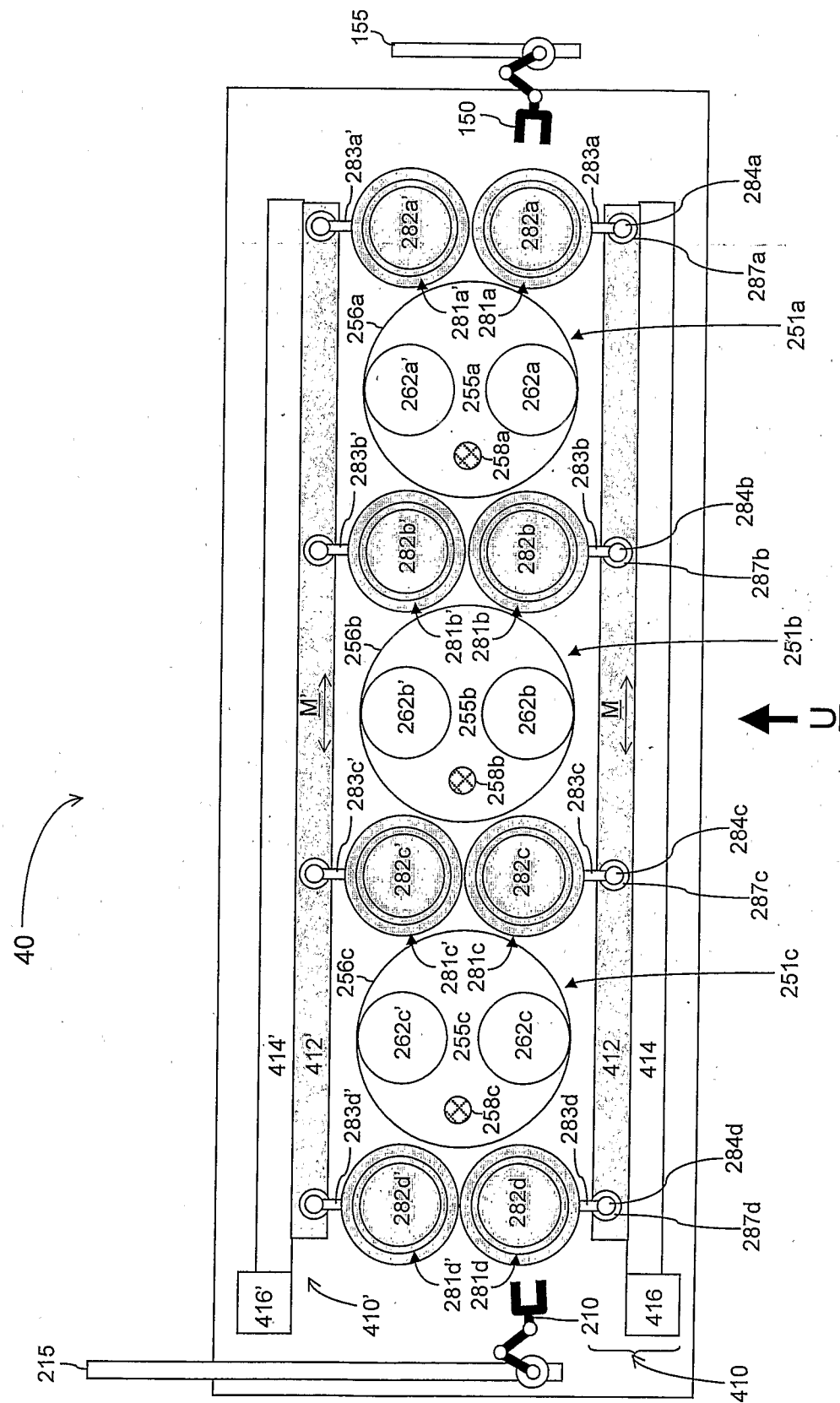


Fig. 14

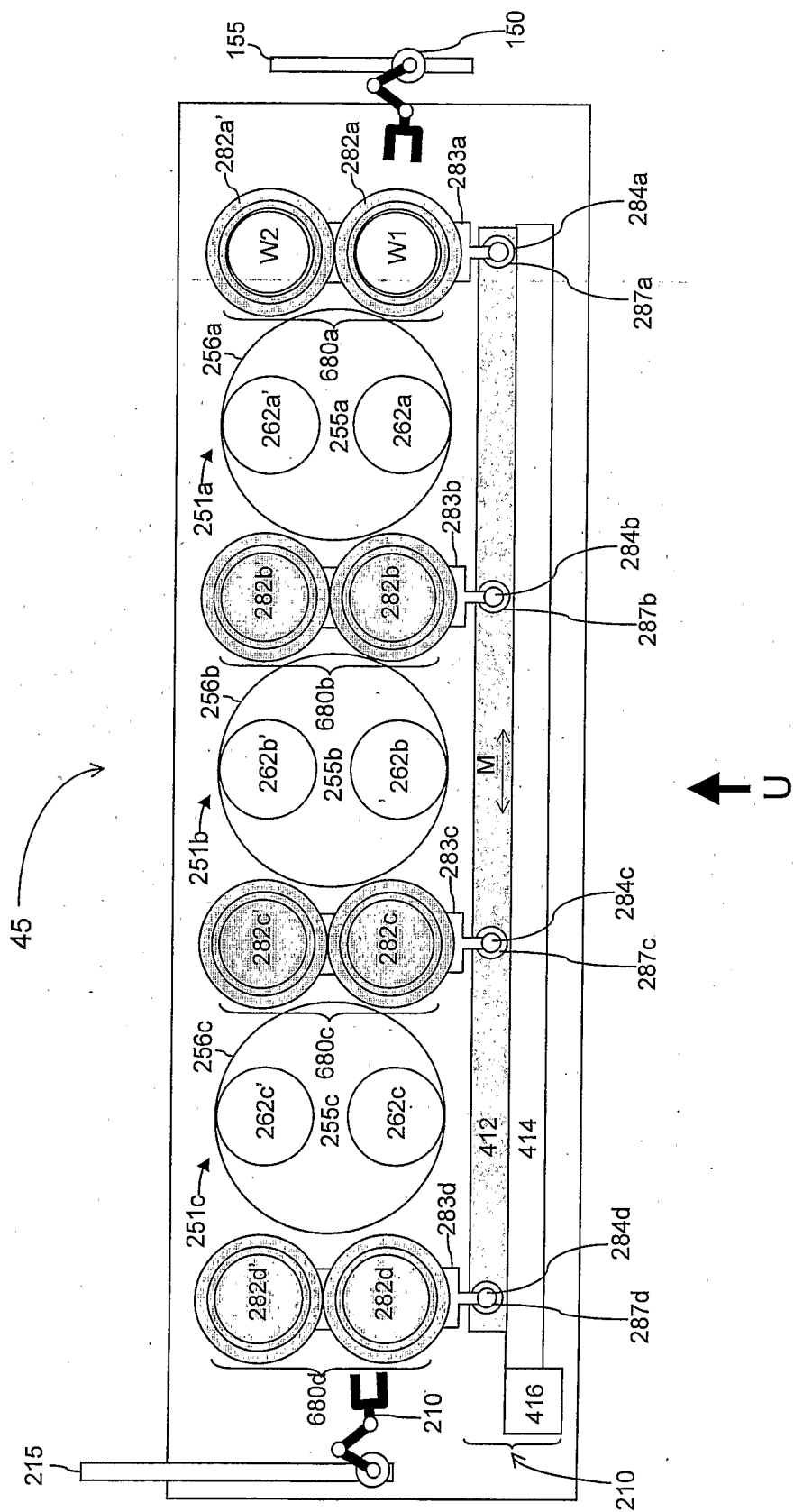


Fig. 15

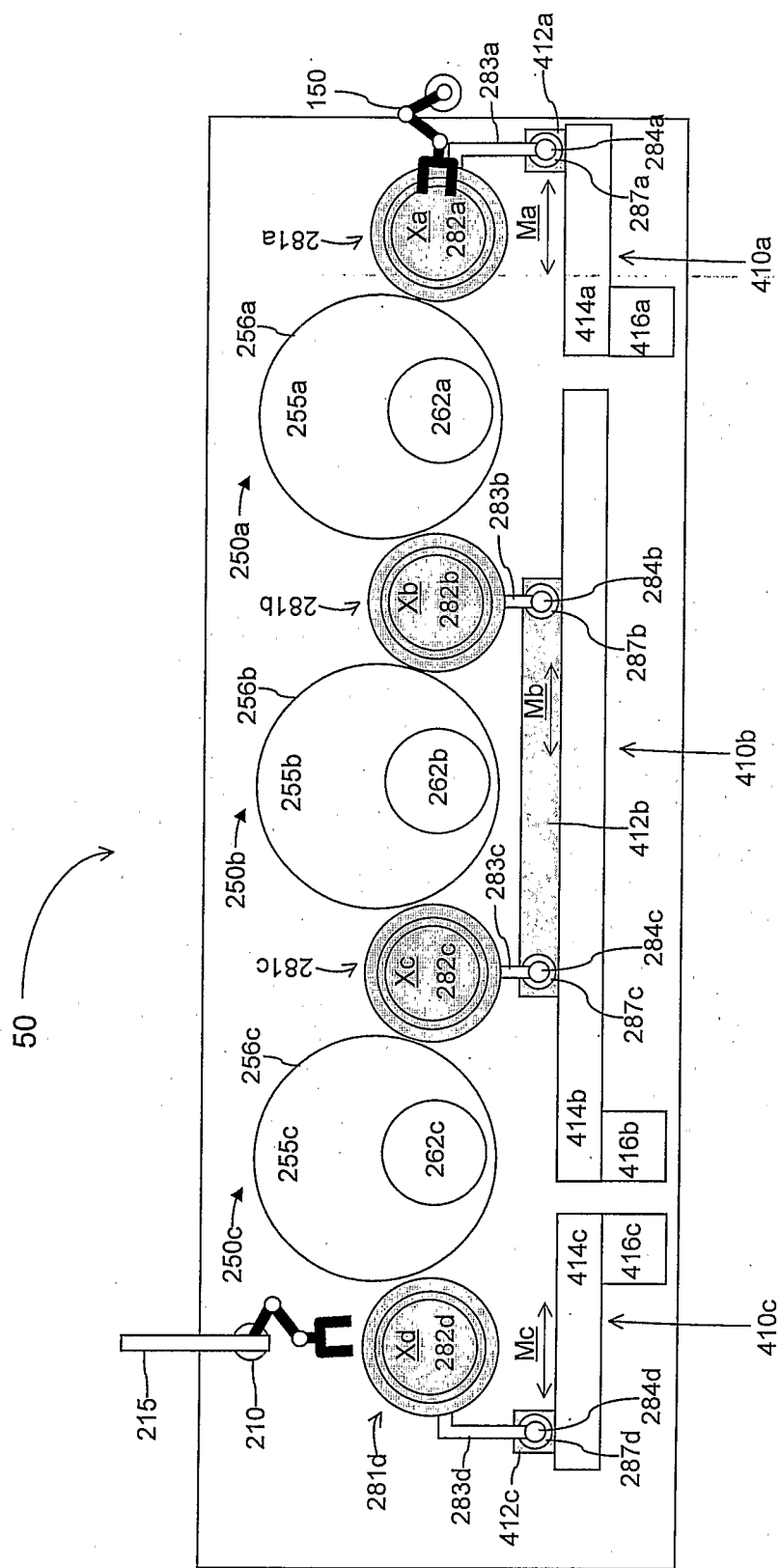


Fig. 16

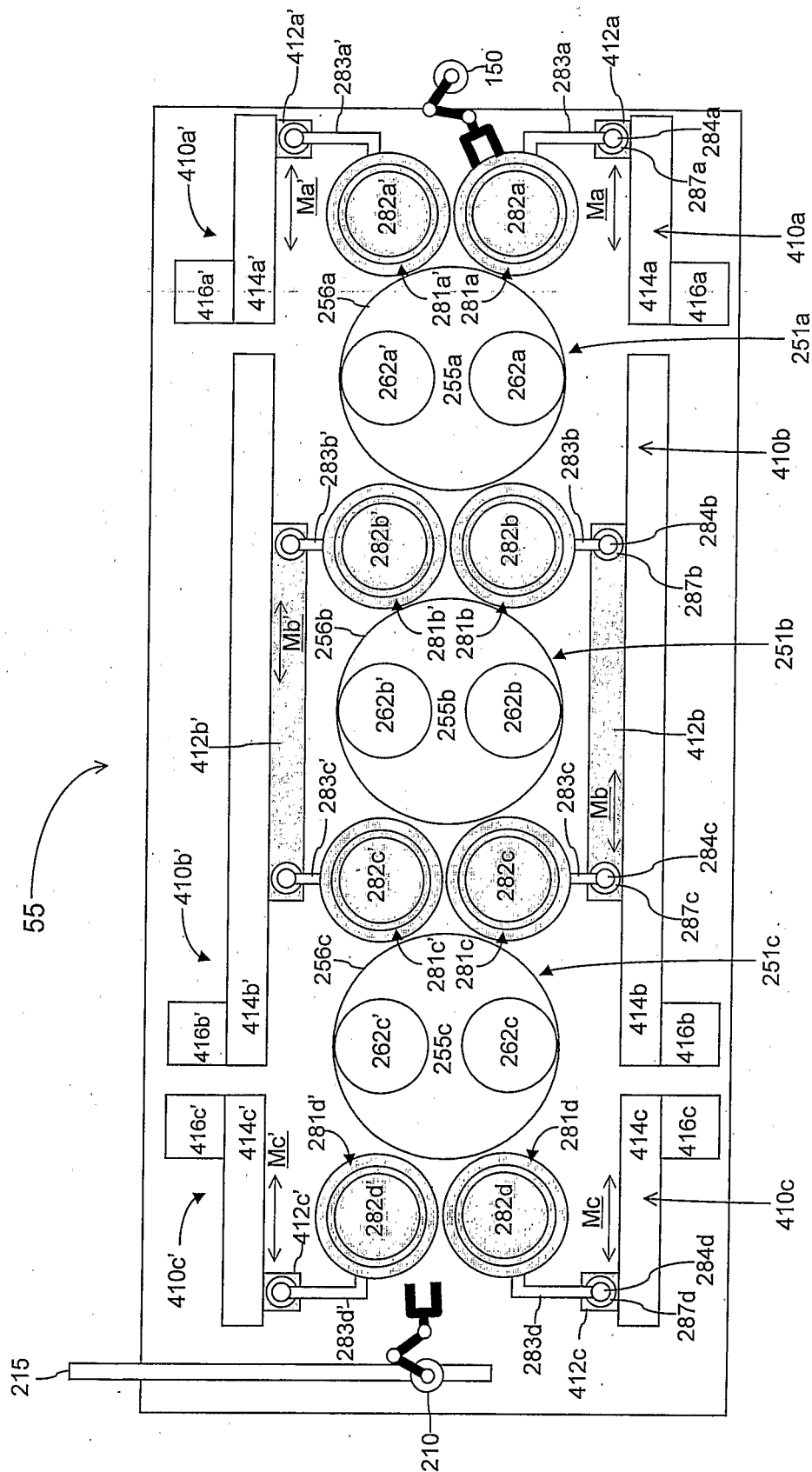
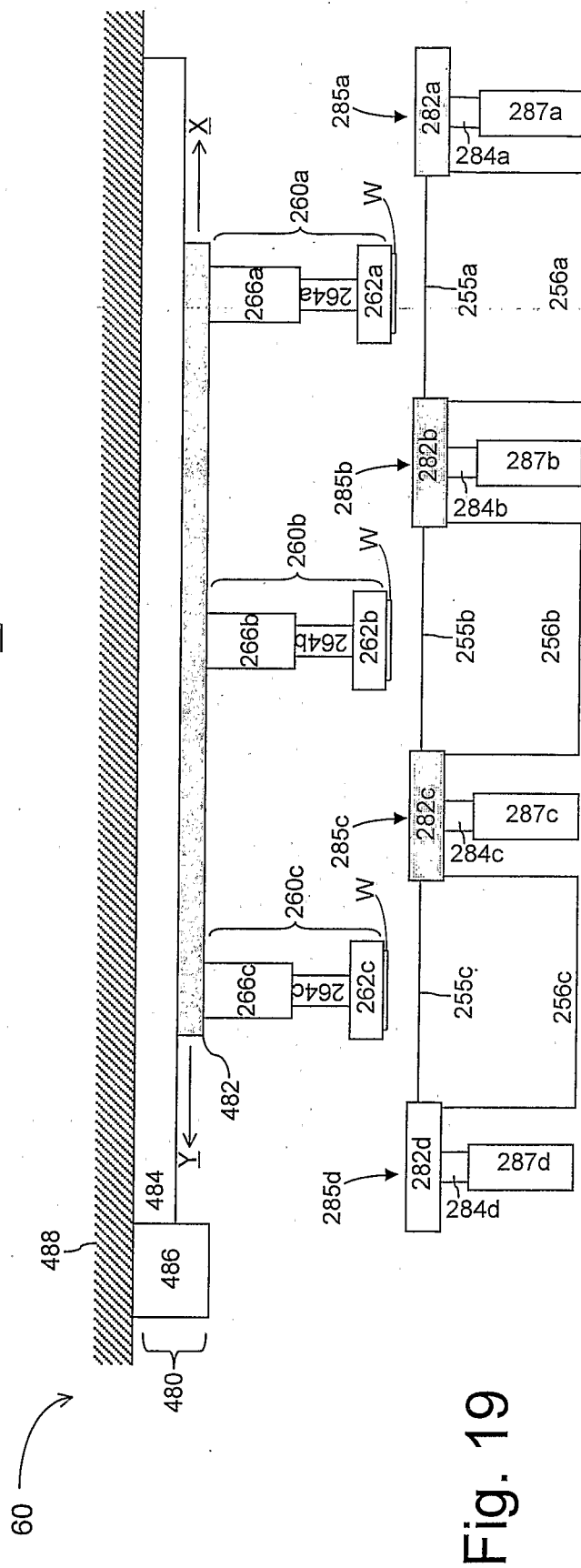
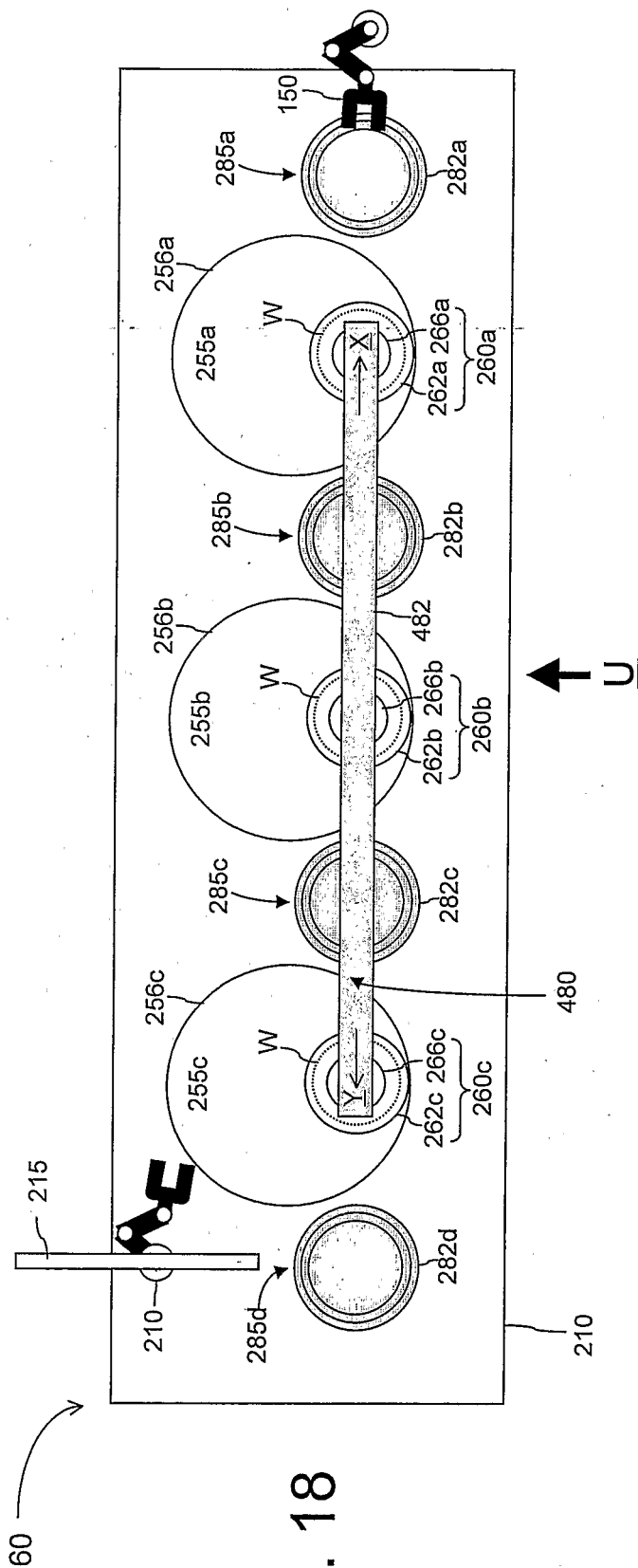


Fig. 17



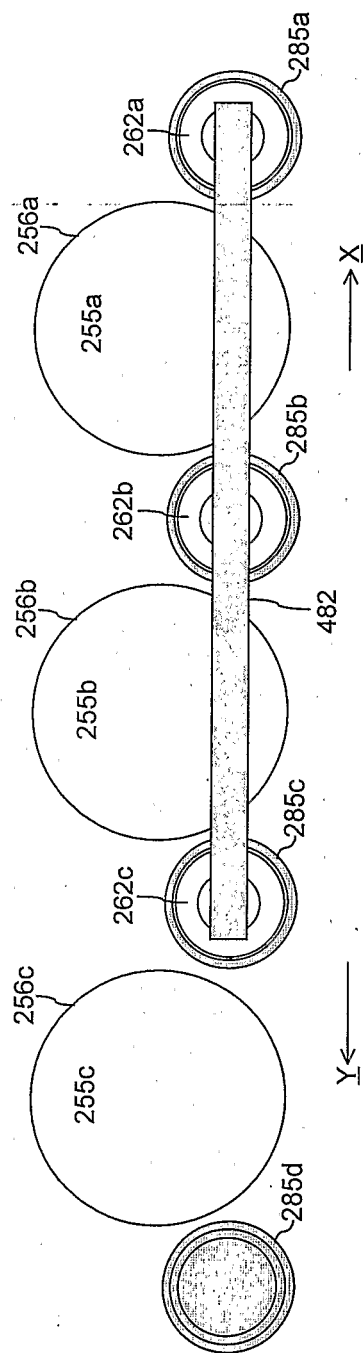


Fig. 20(a)

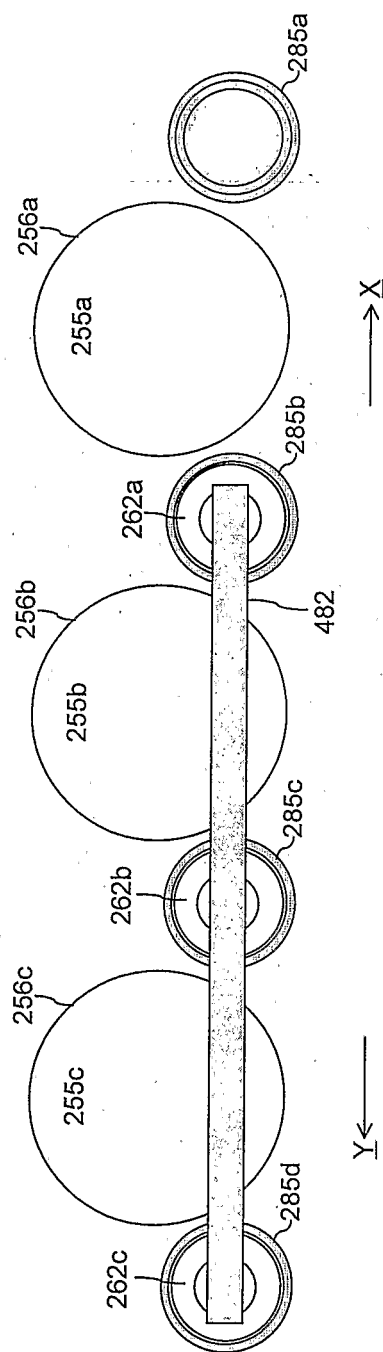


Fig. 20(b)

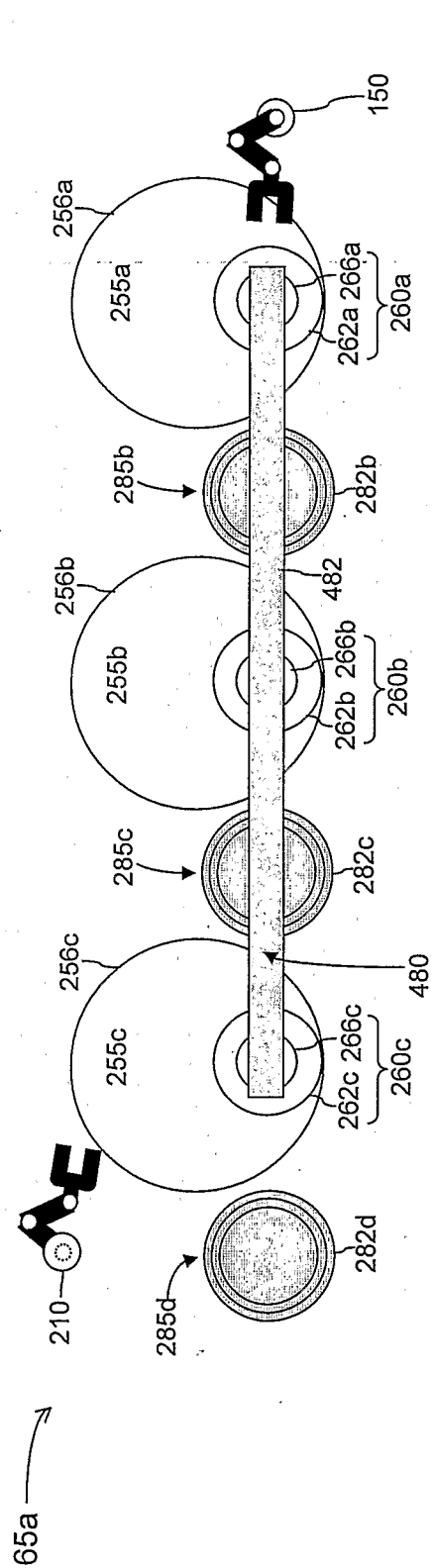


Fig. 21(a)

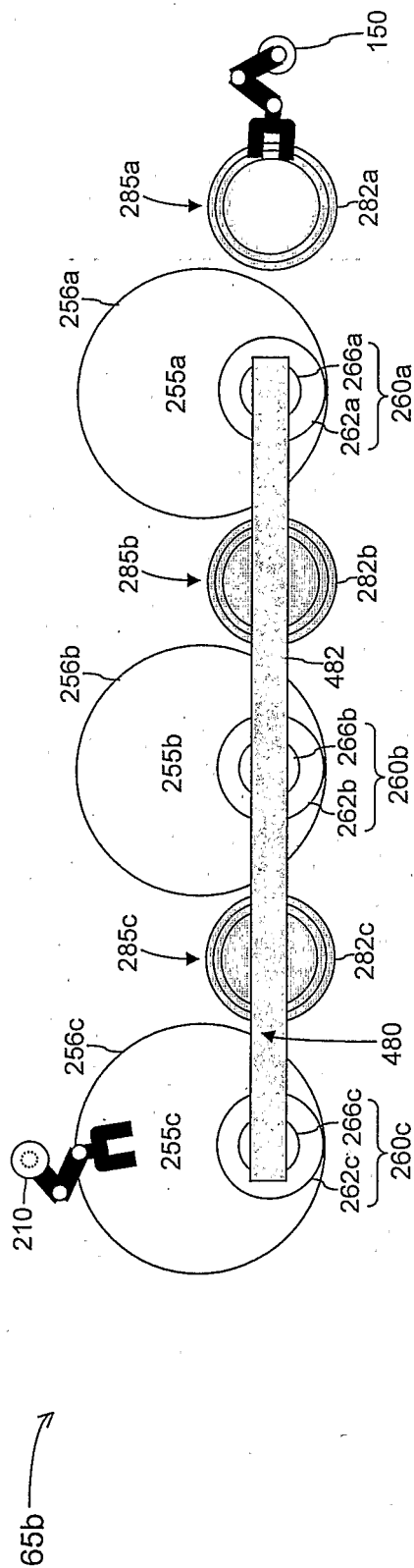


Fig. 21(b)

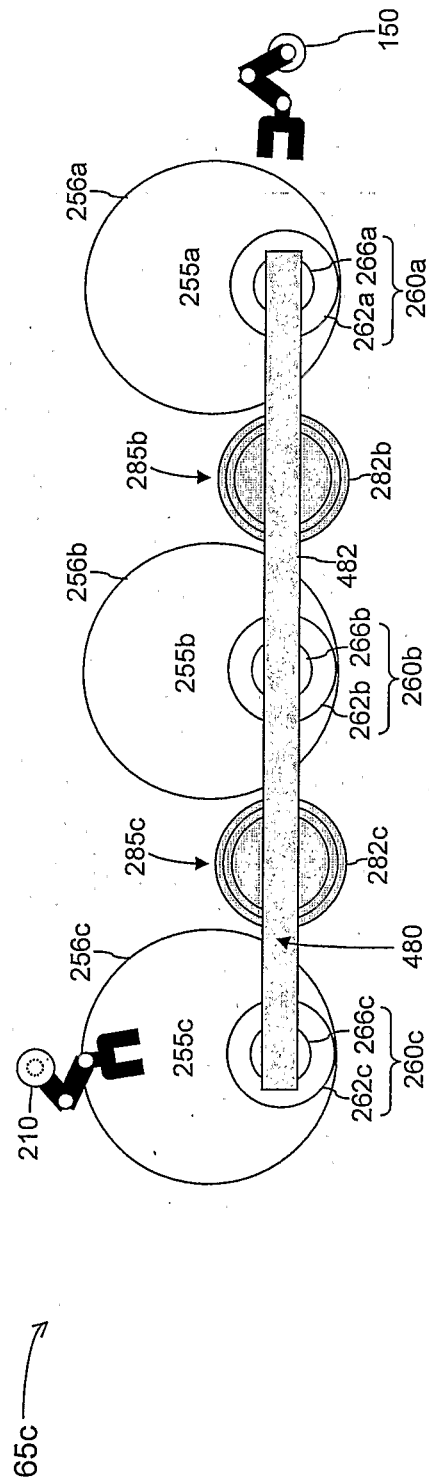


Fig. 21(c)

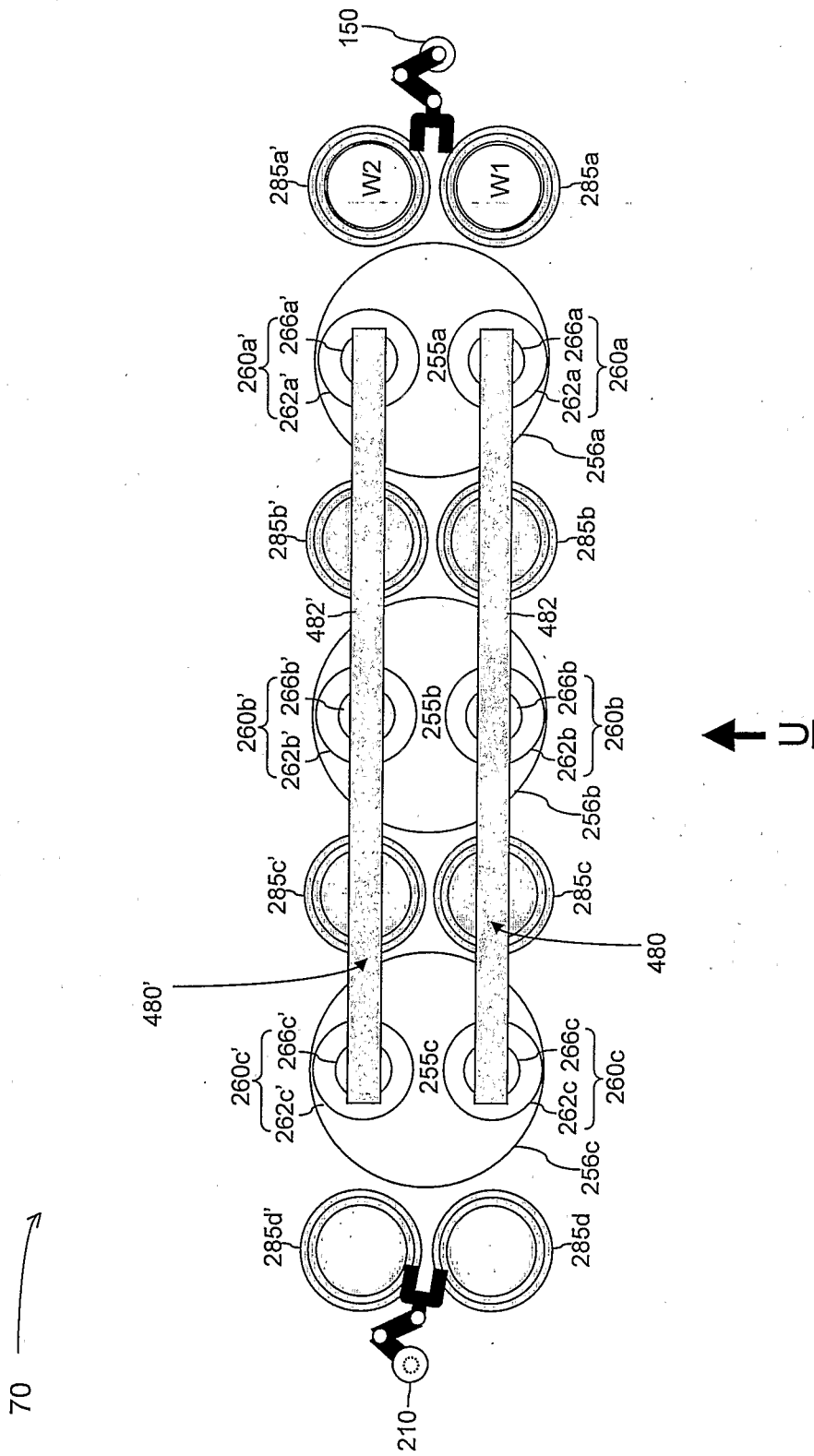


Fig. 22

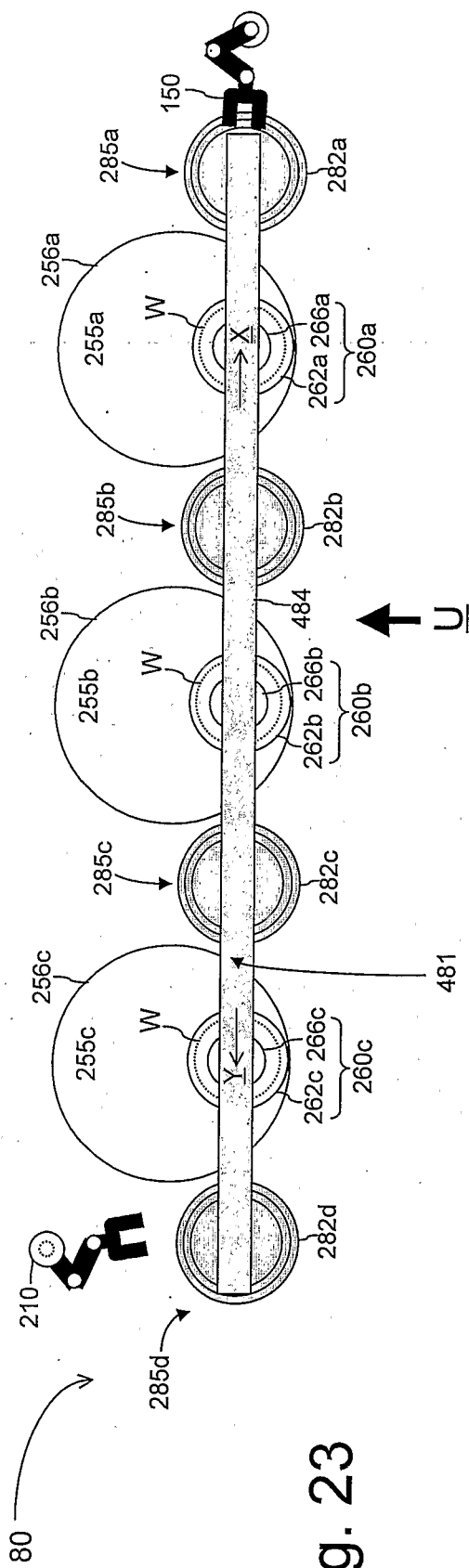


Fig. 23

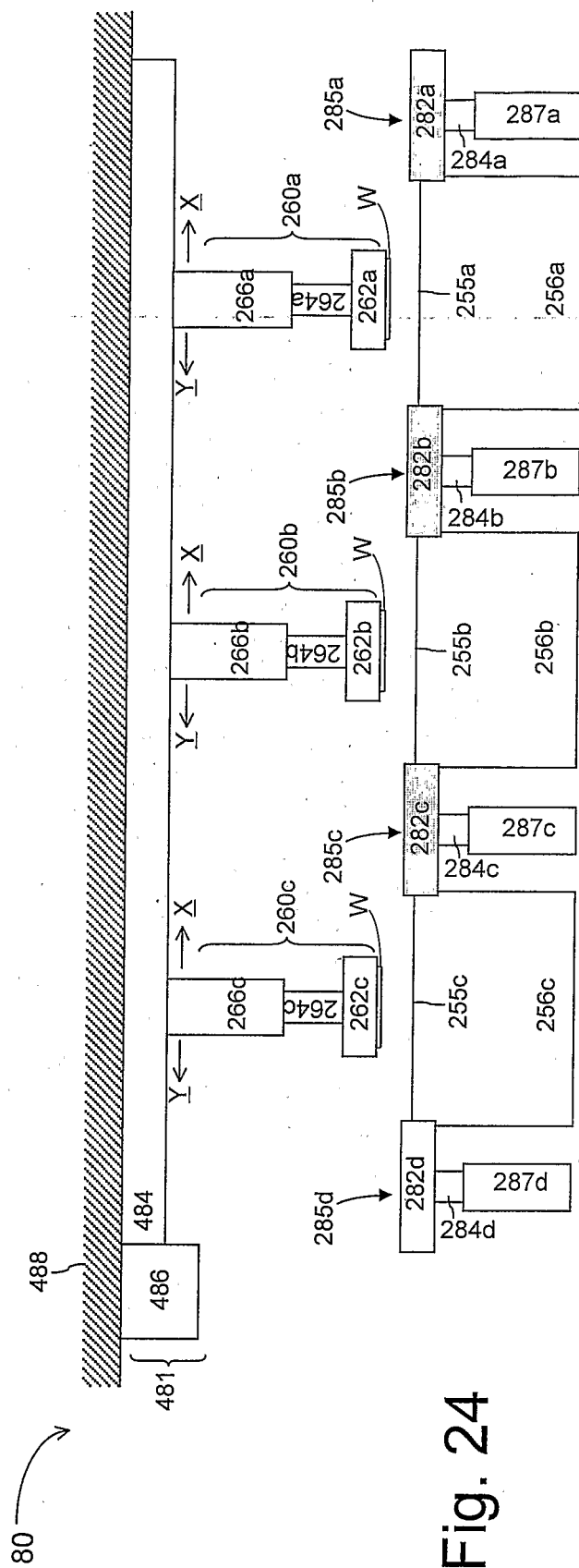


Fig. 24

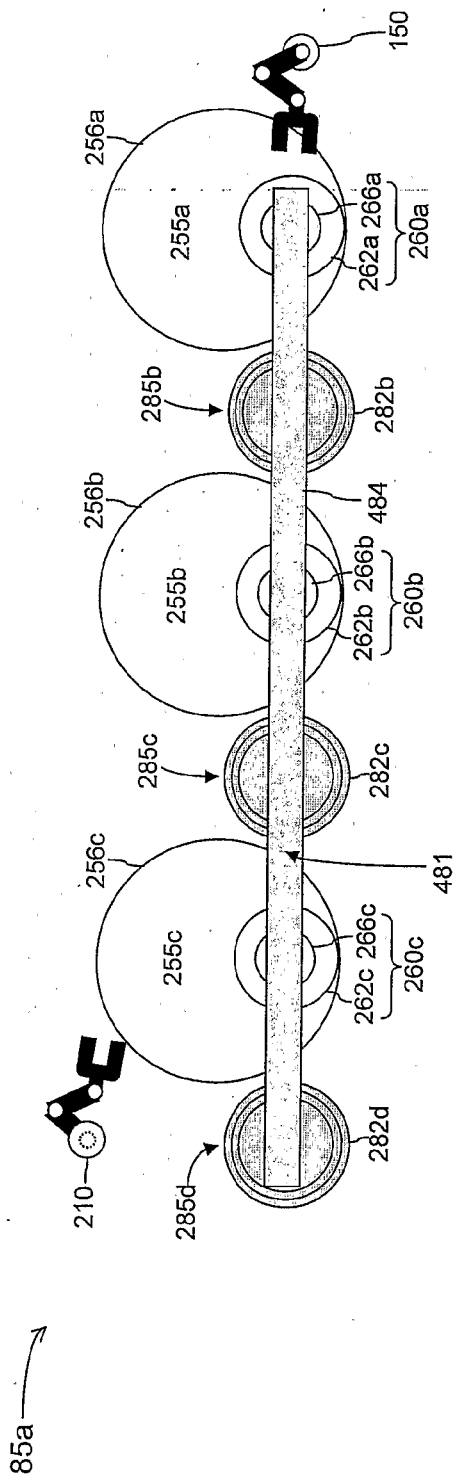


Fig. 25(a)

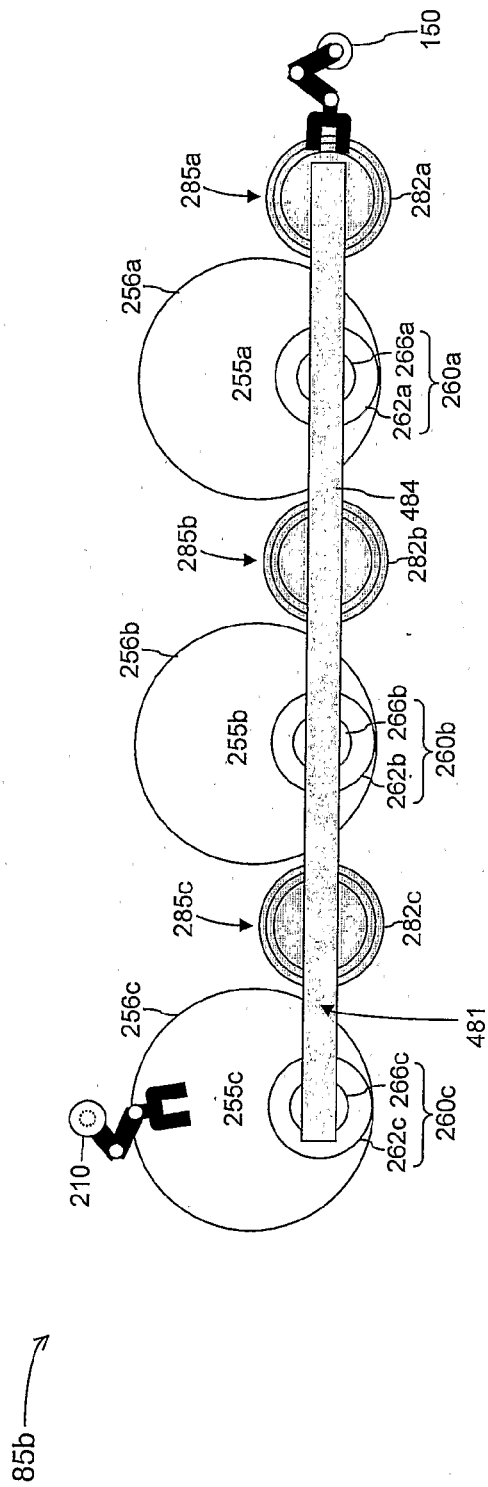


Fig. 25(b)

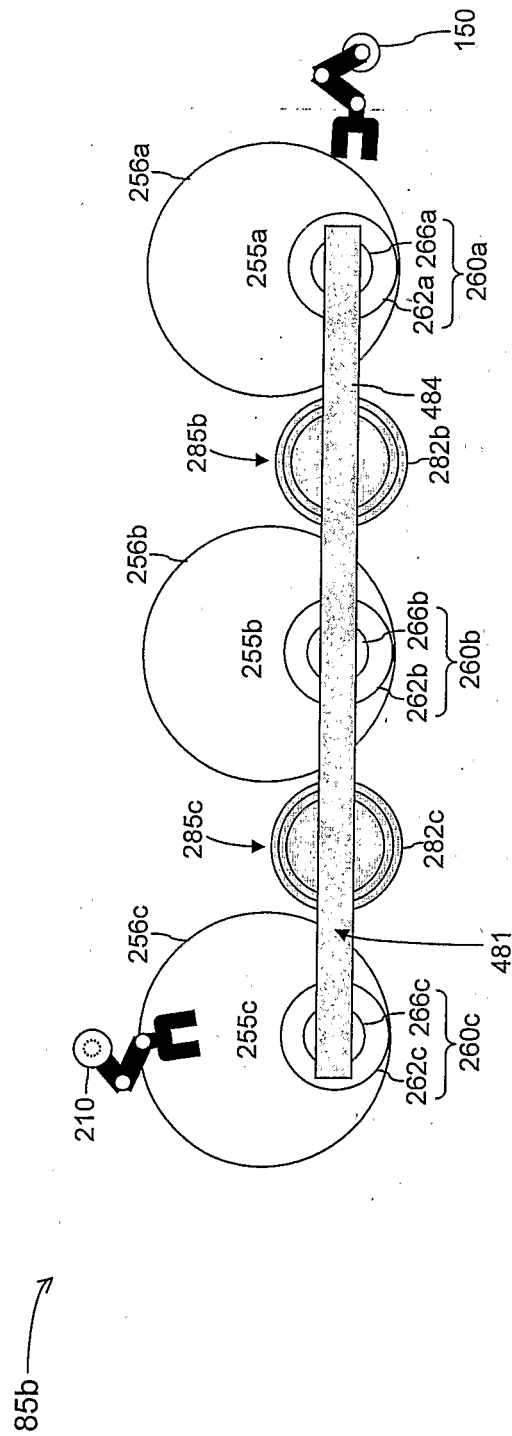


Fig. 25(c)

90 →

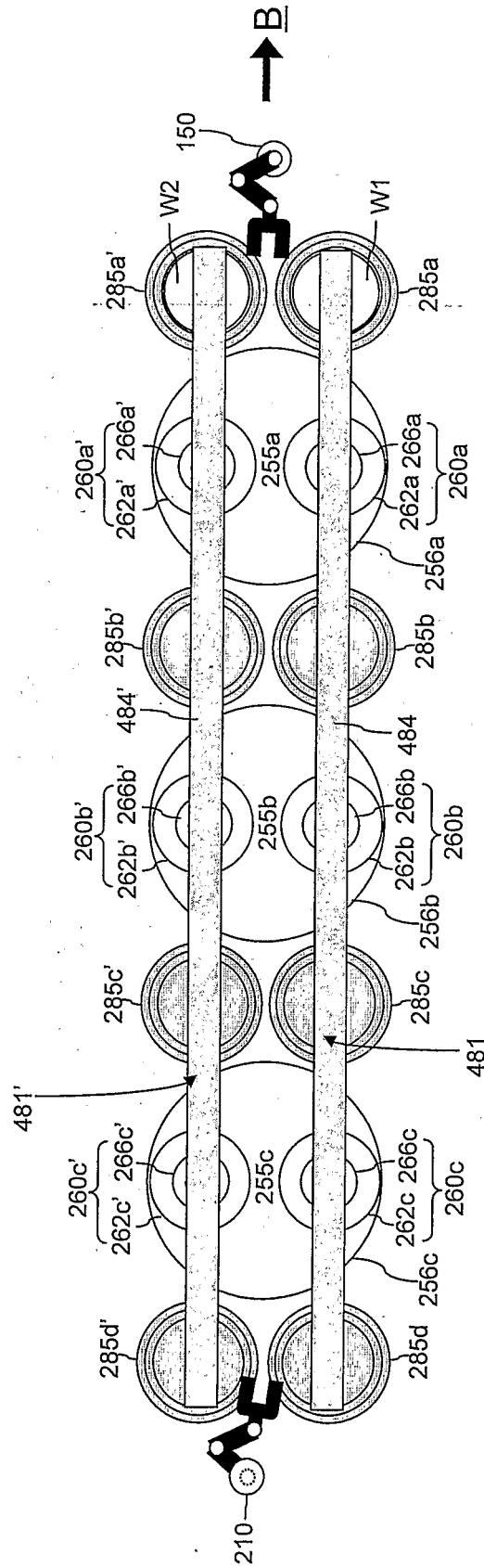


Fig. 26

100 —————>

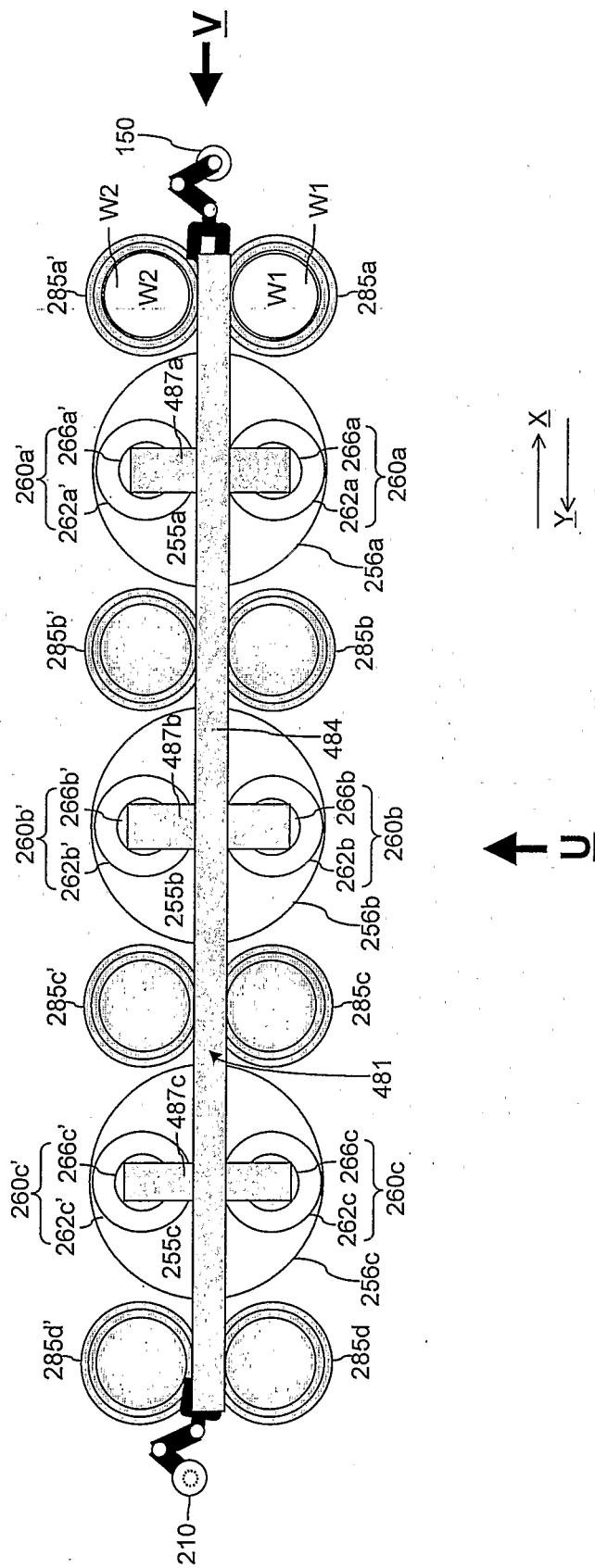


Fig. 27

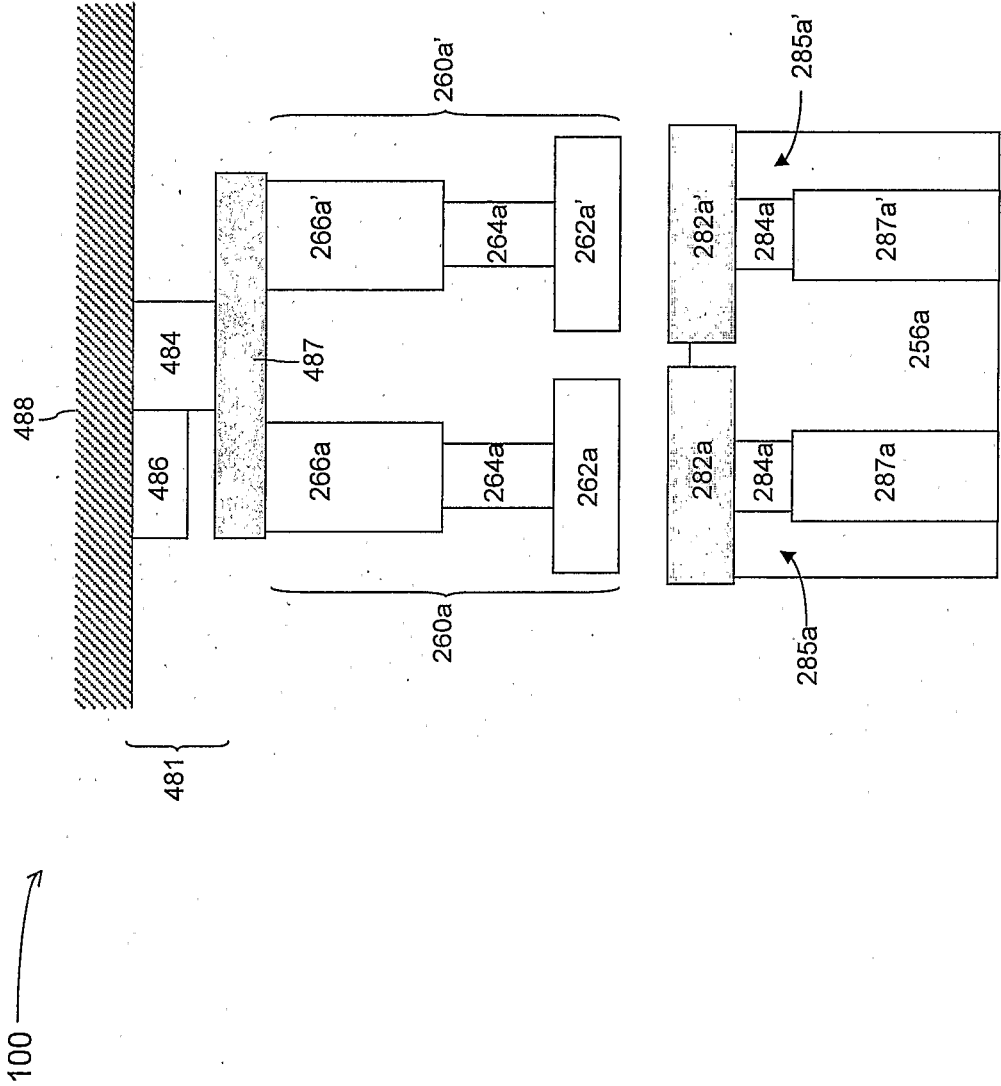


Fig. 28

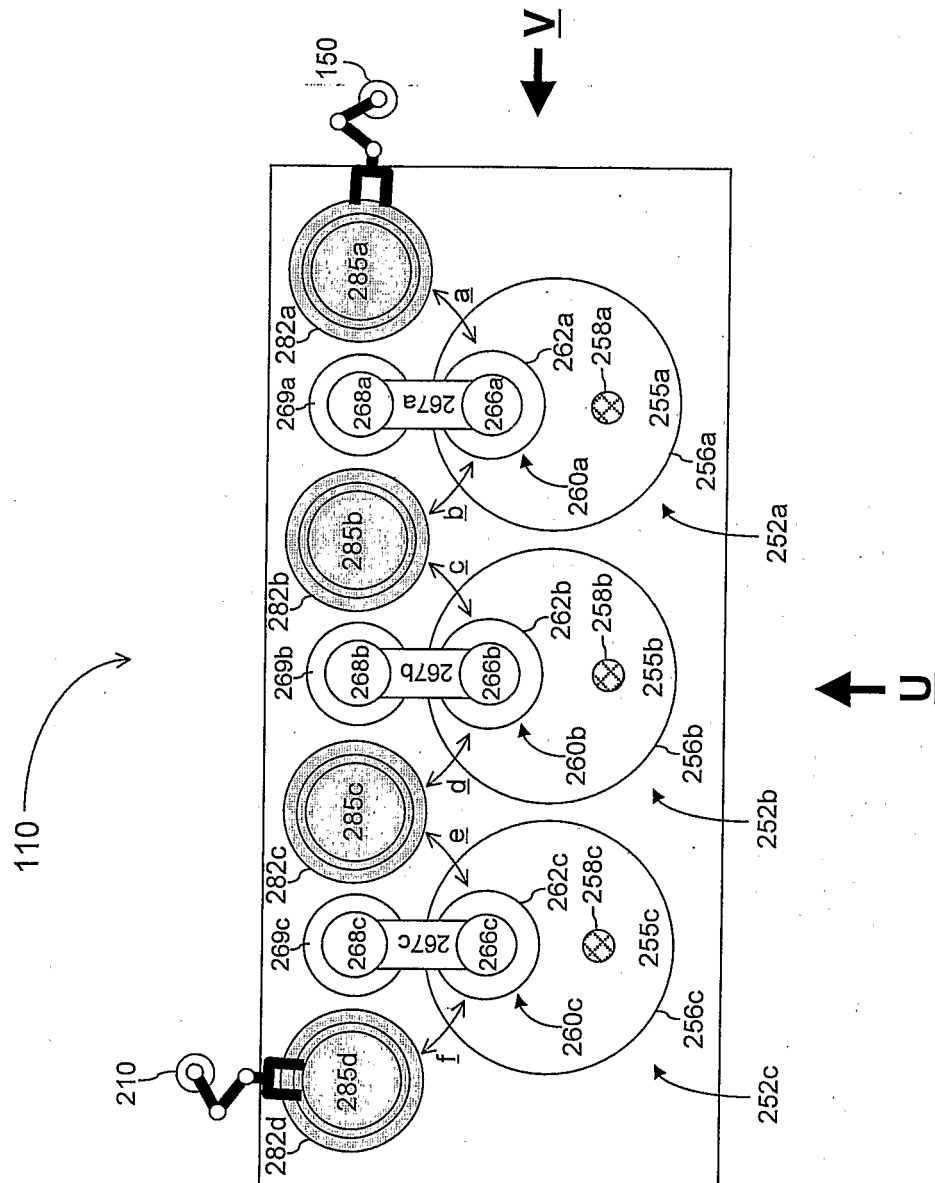


FIG. 29

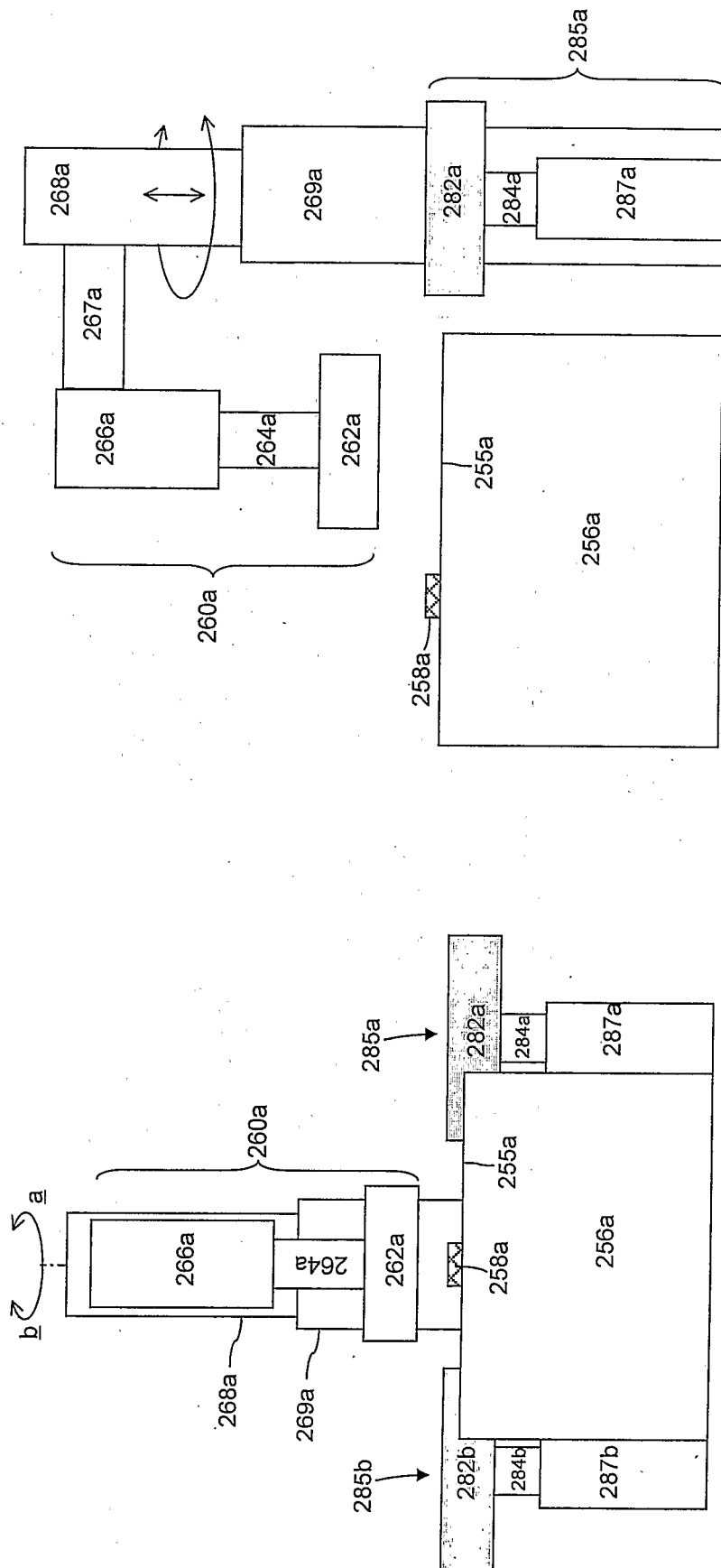


Fig. 30(a)

Fig. 30(b)

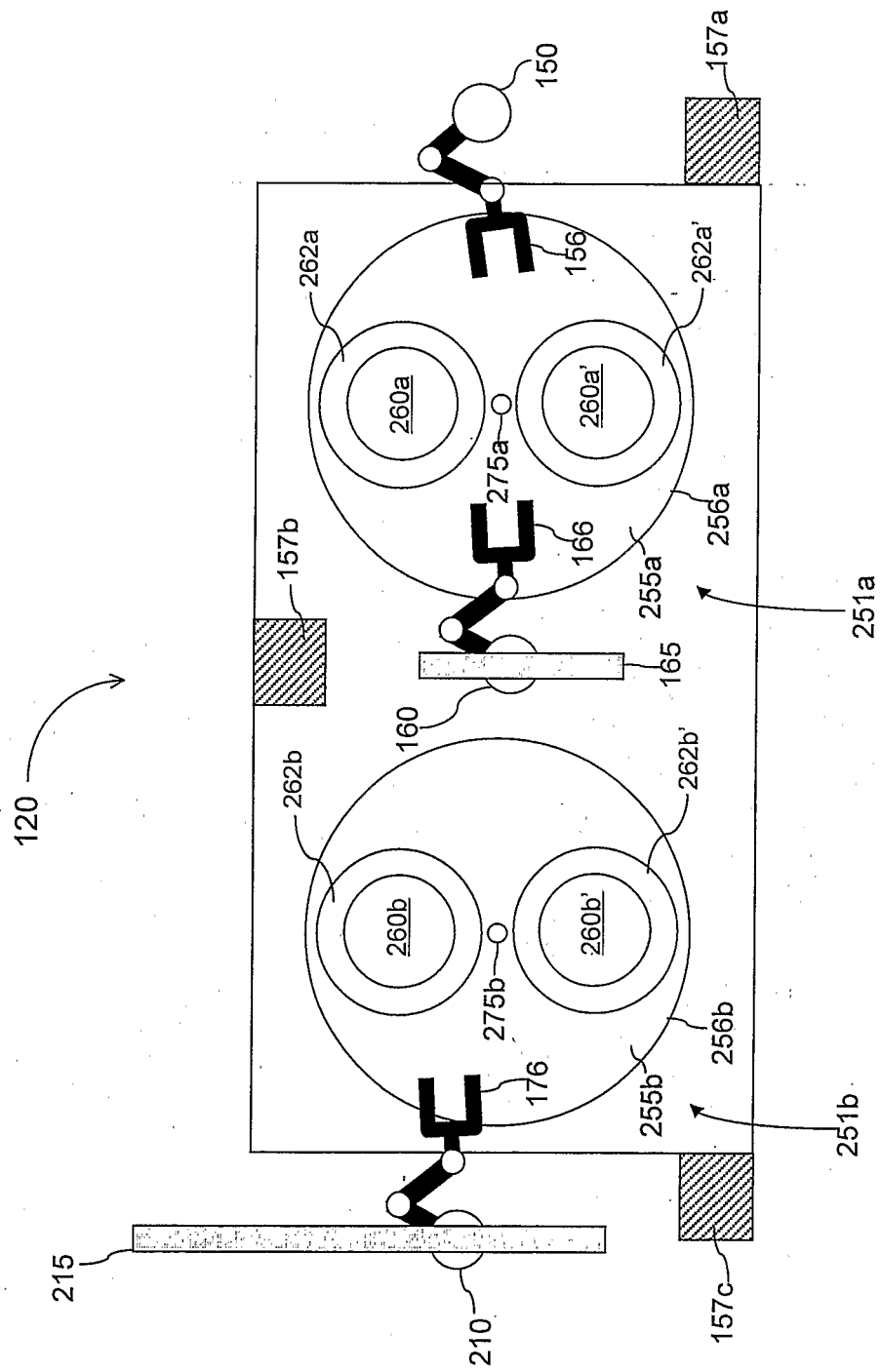


Fig. 31

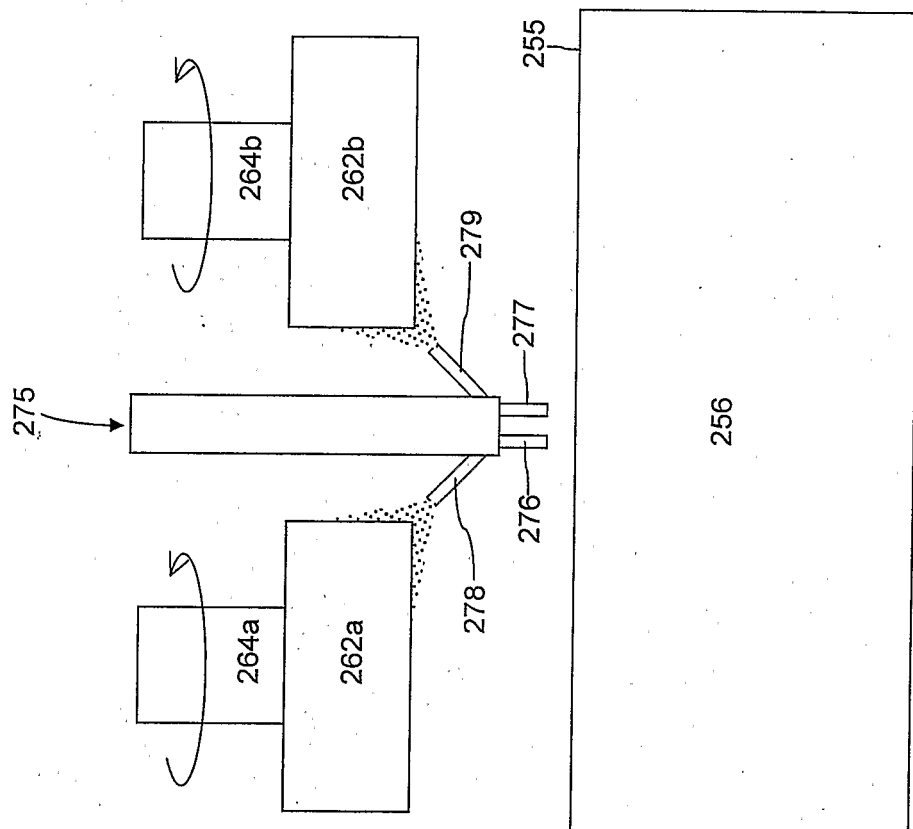


Fig. 32

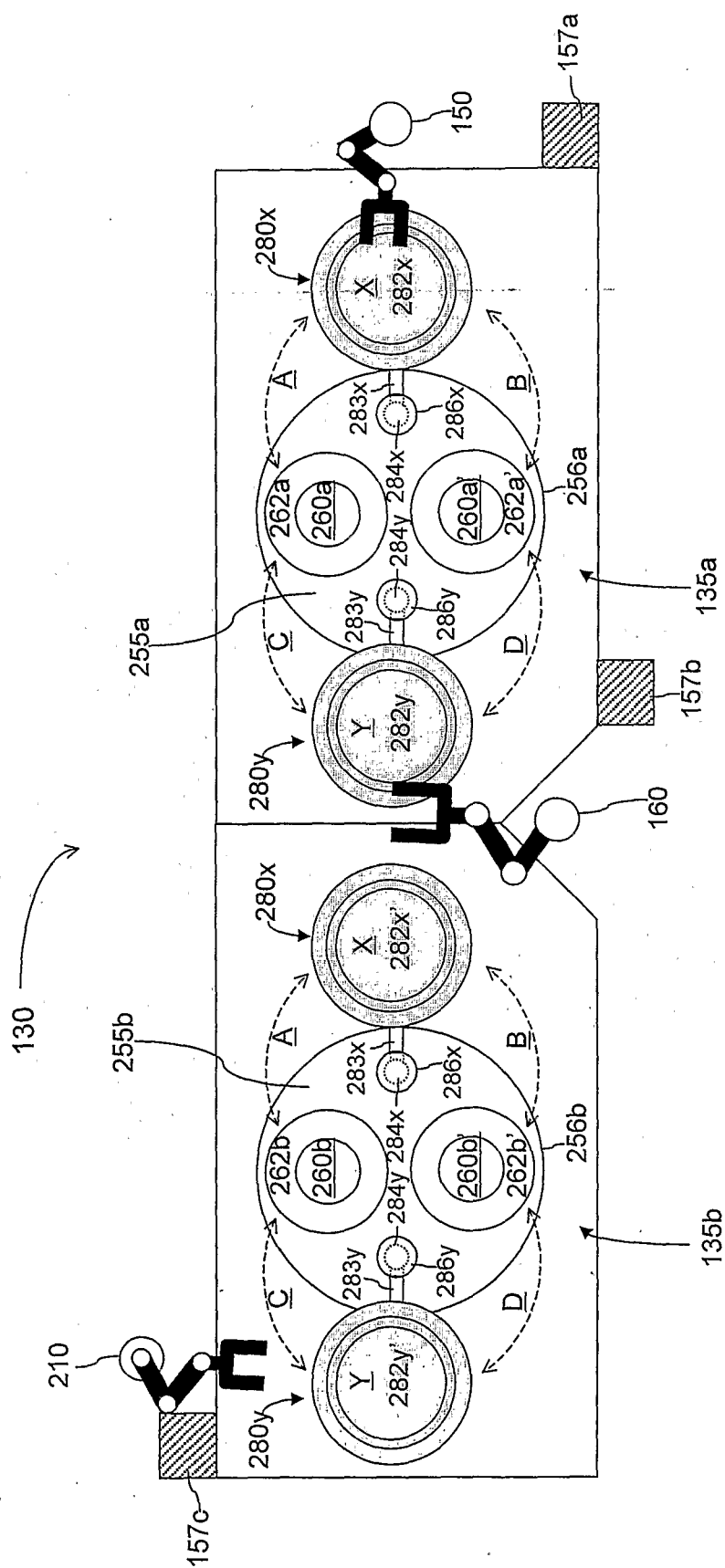
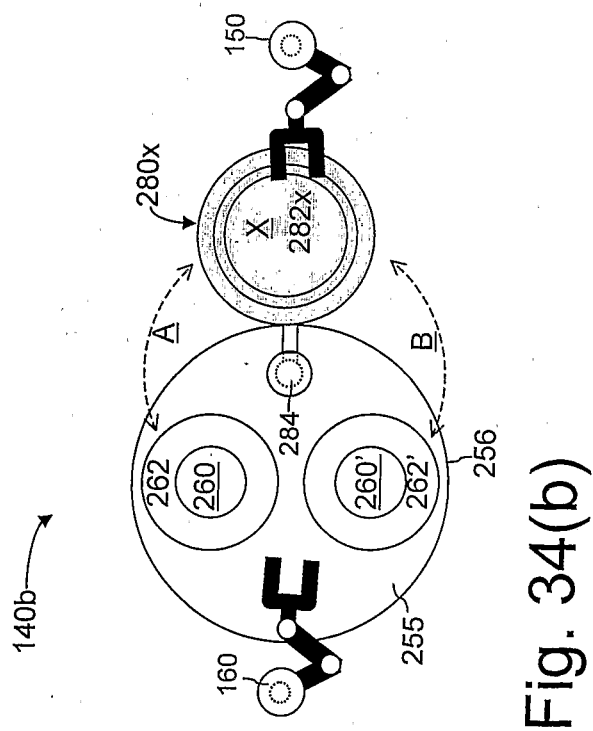
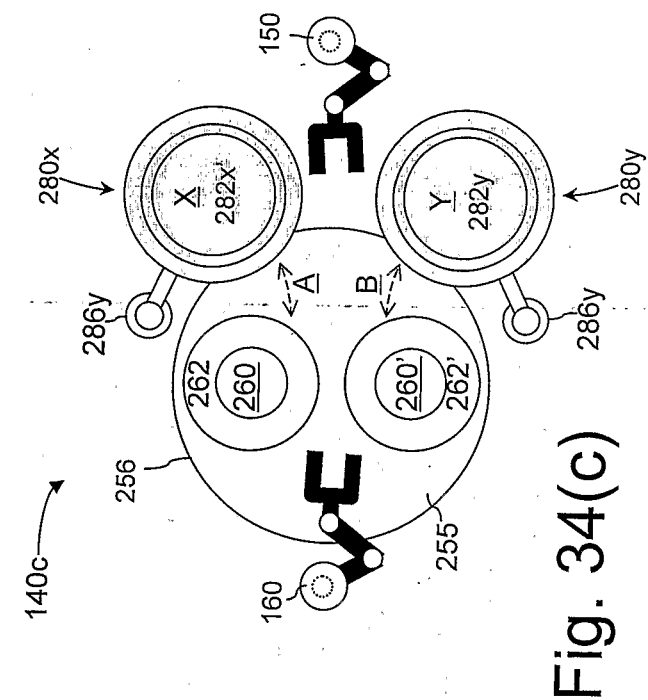
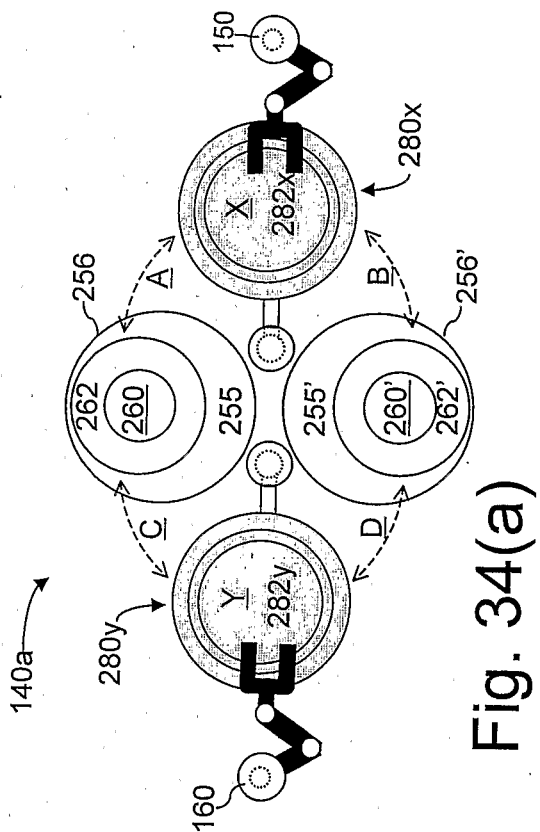


Fig. 33



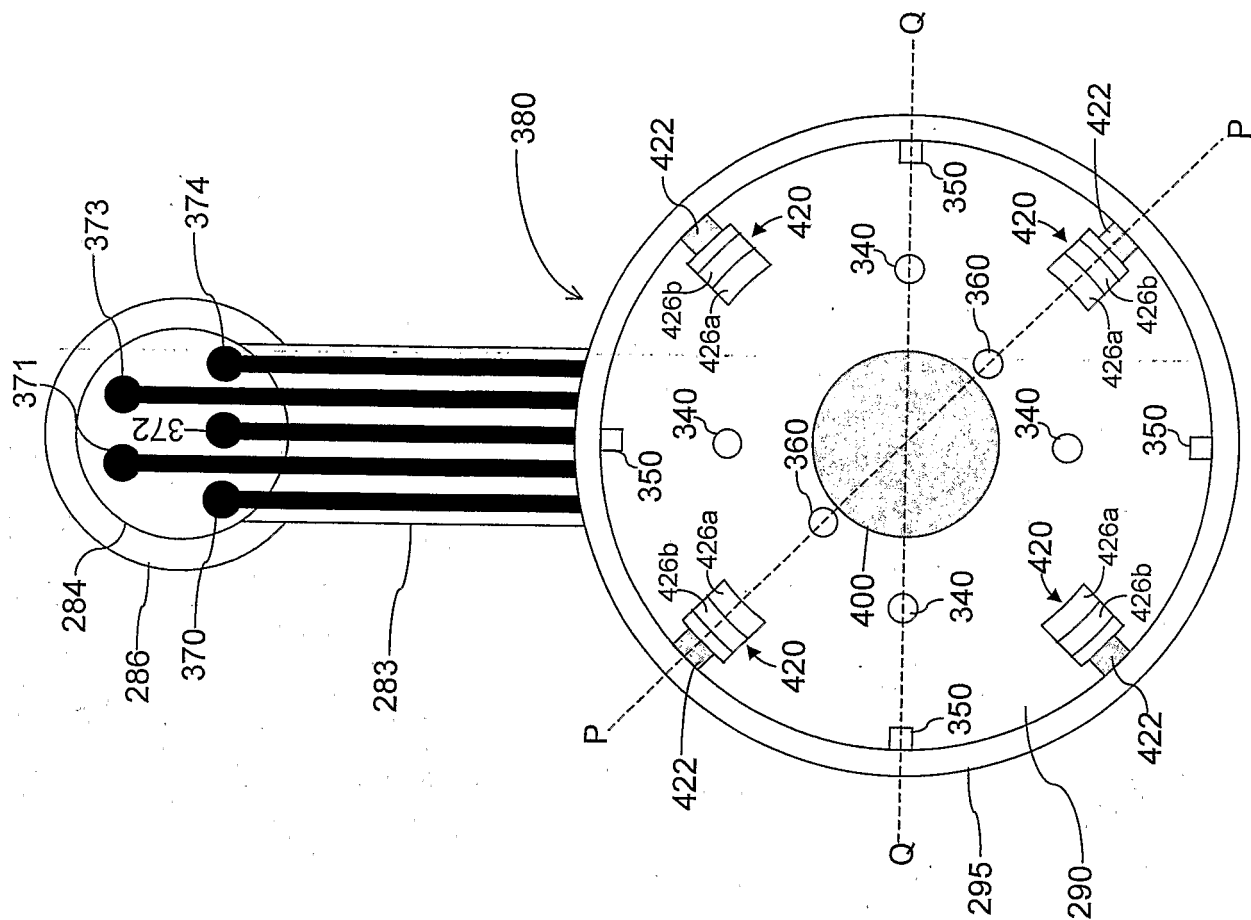


FIG. 36

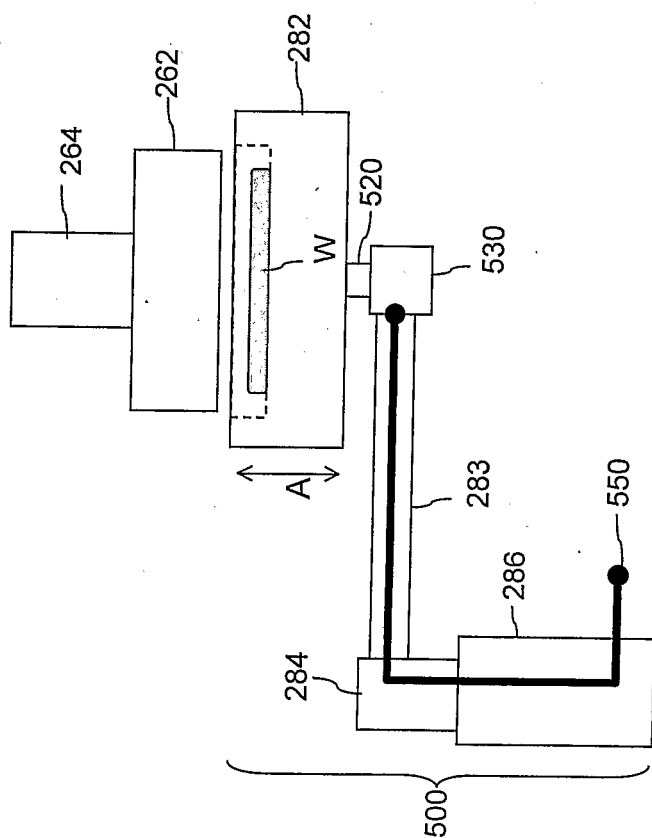


FIG. 35

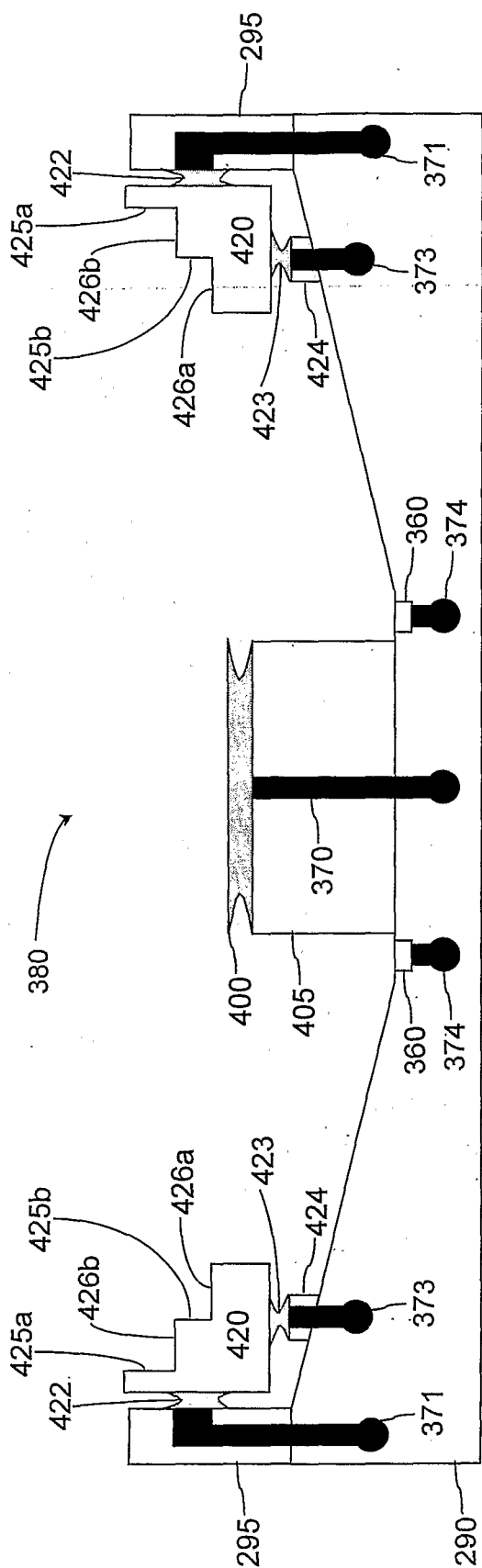


Fig. 37(a)

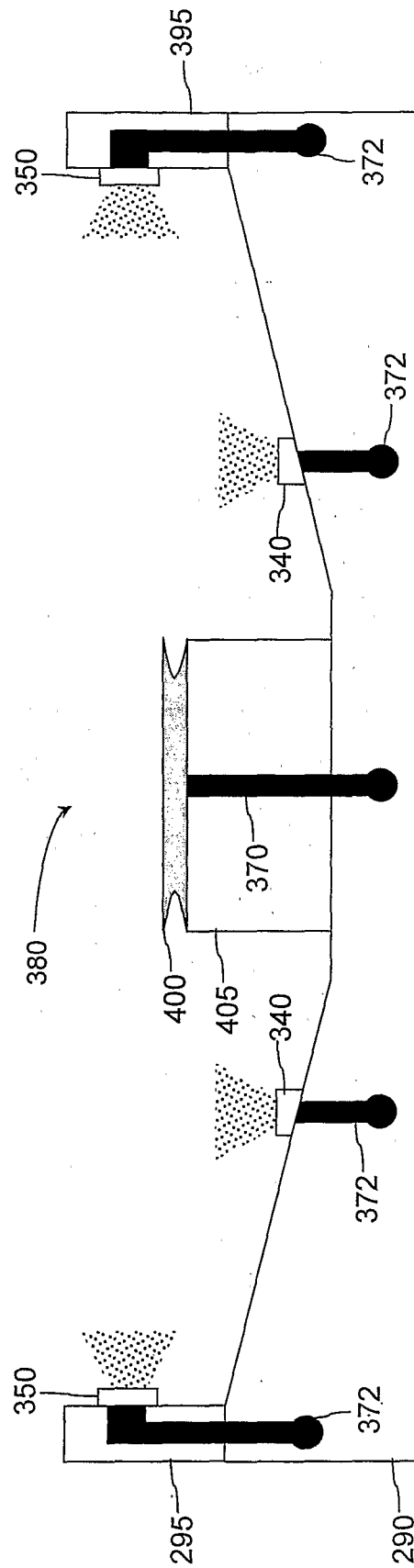


Fig. 37(b)

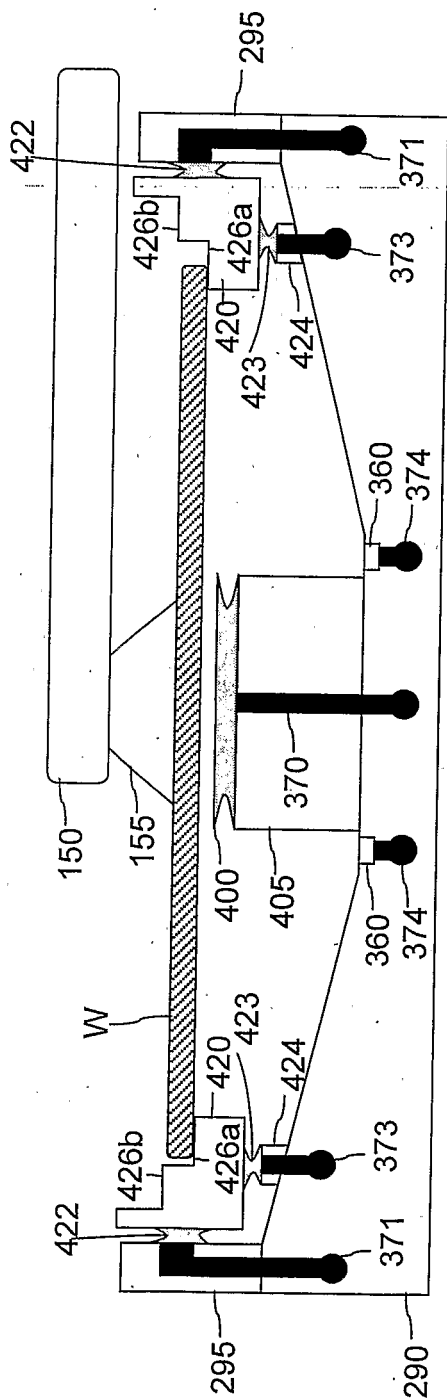


Fig. 38(a)

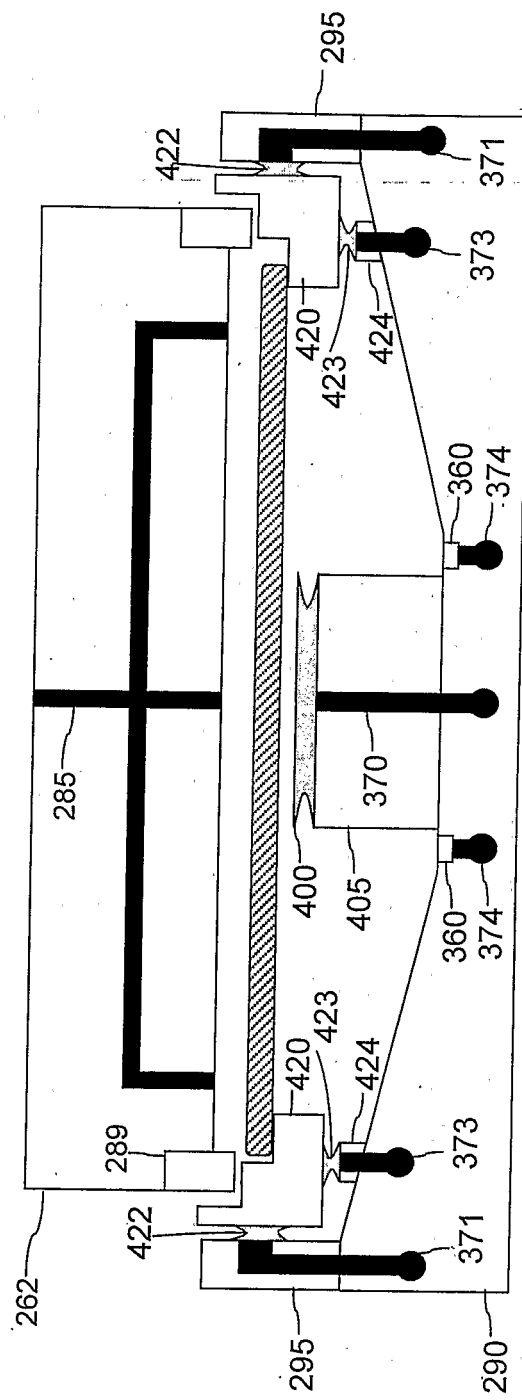


Fig. 38(b)

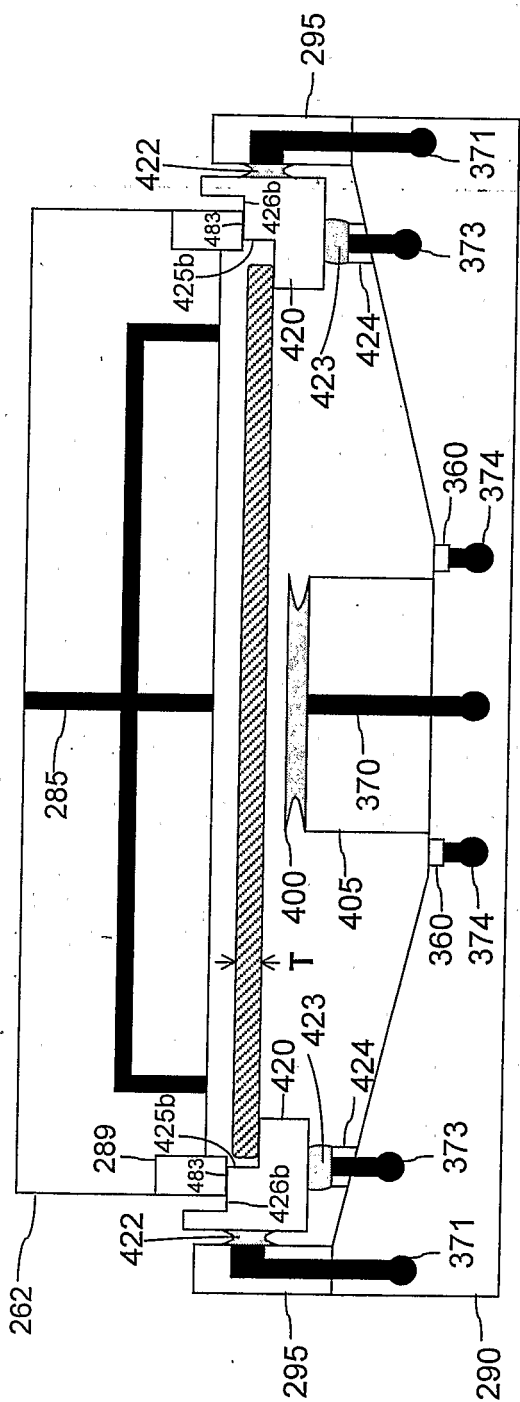


Fig. 38(c)

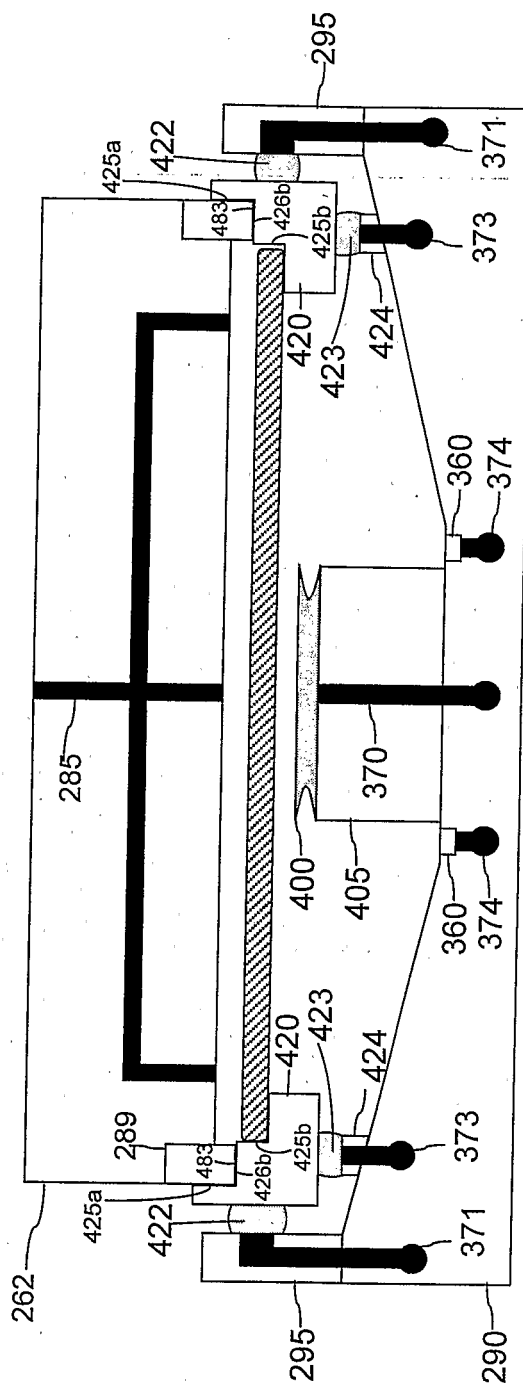


Fig. 38(d)

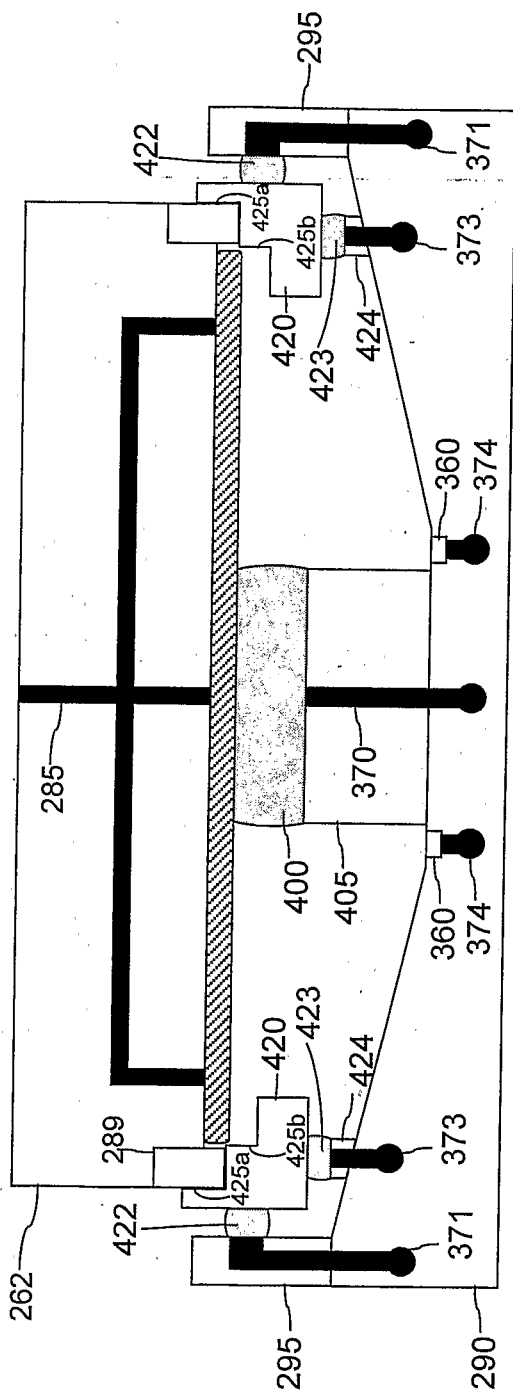


Fig. 38(e)

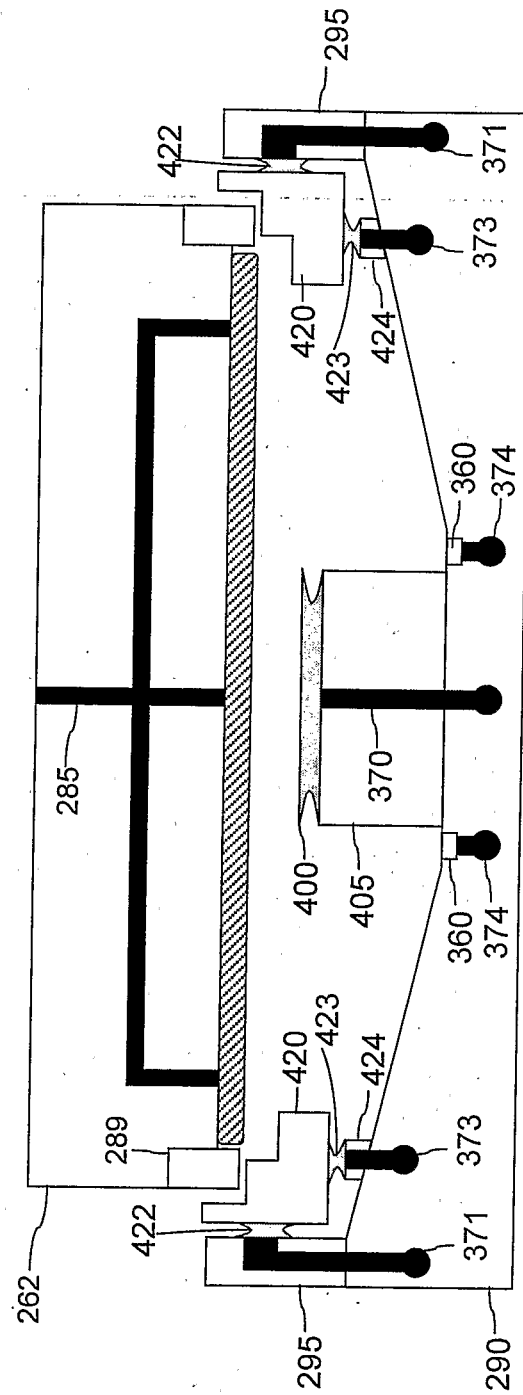


Fig. 38(f)

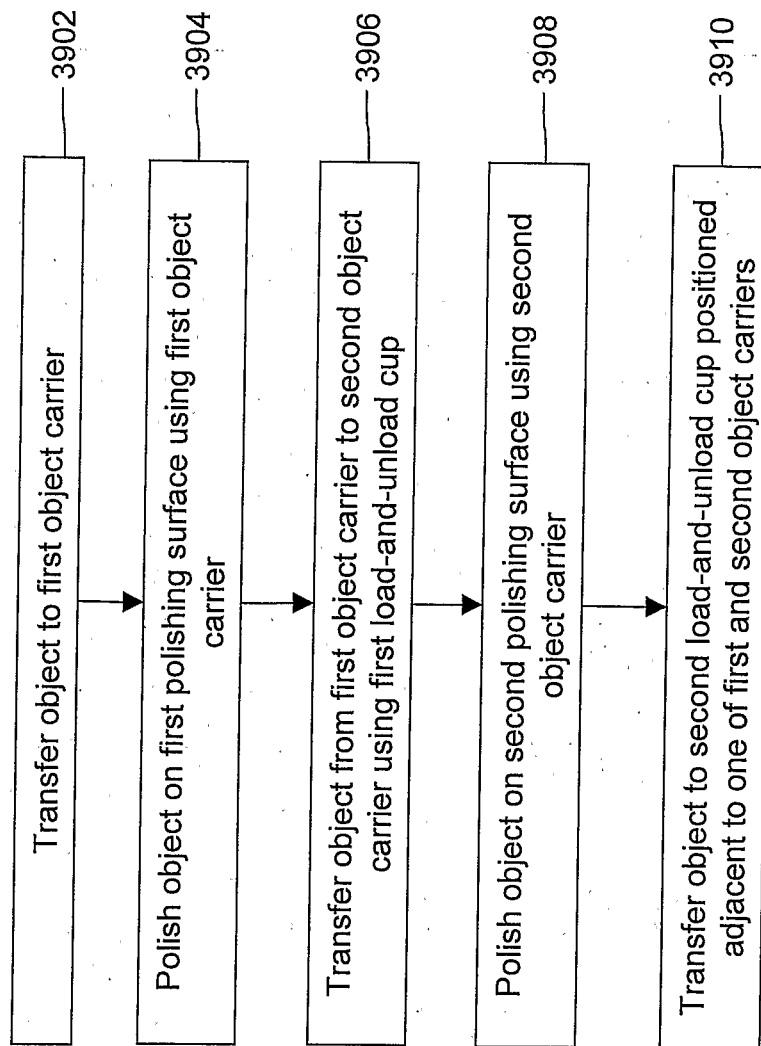


Fig. 39

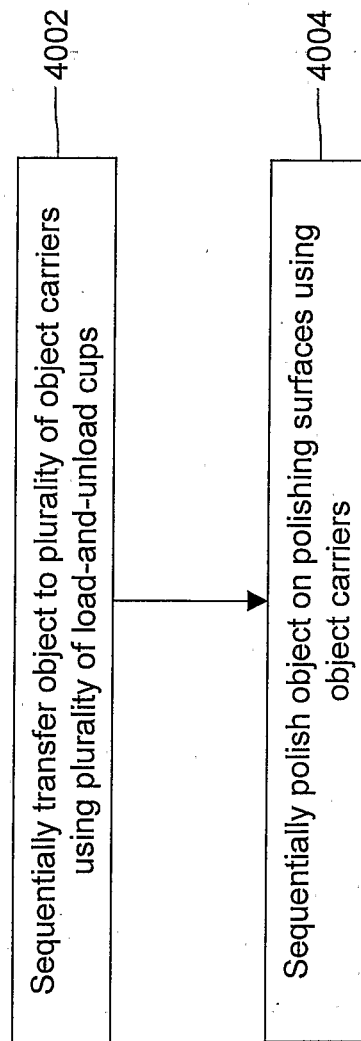


Fig. 40

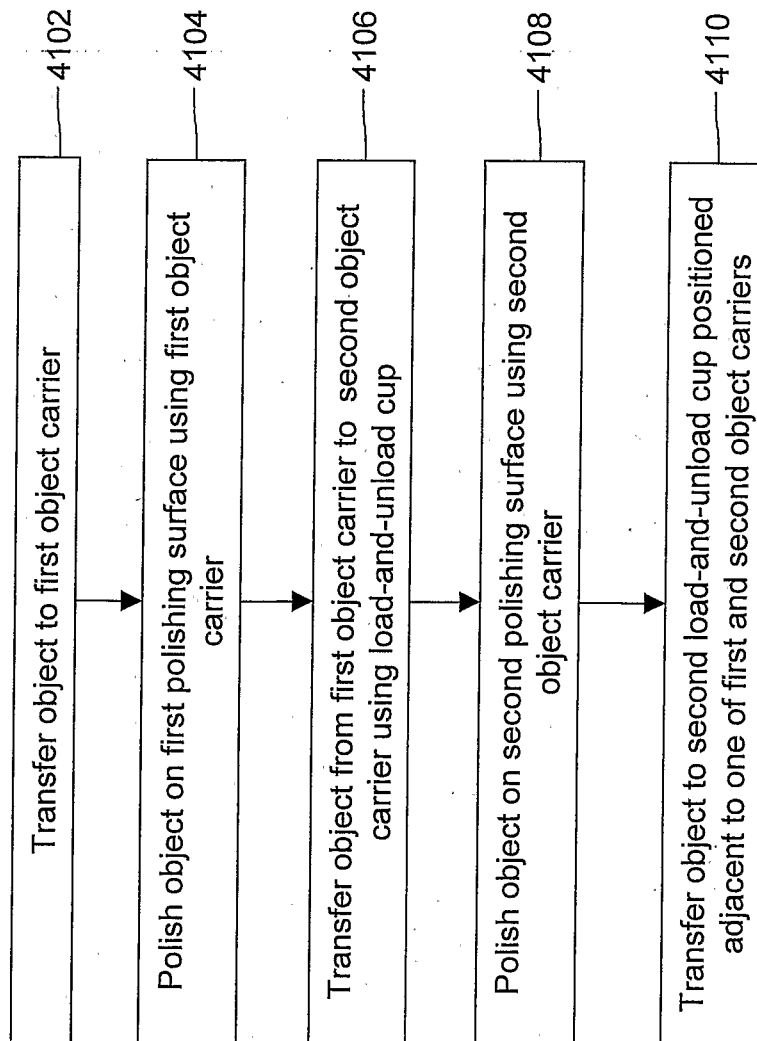


Fig. 41

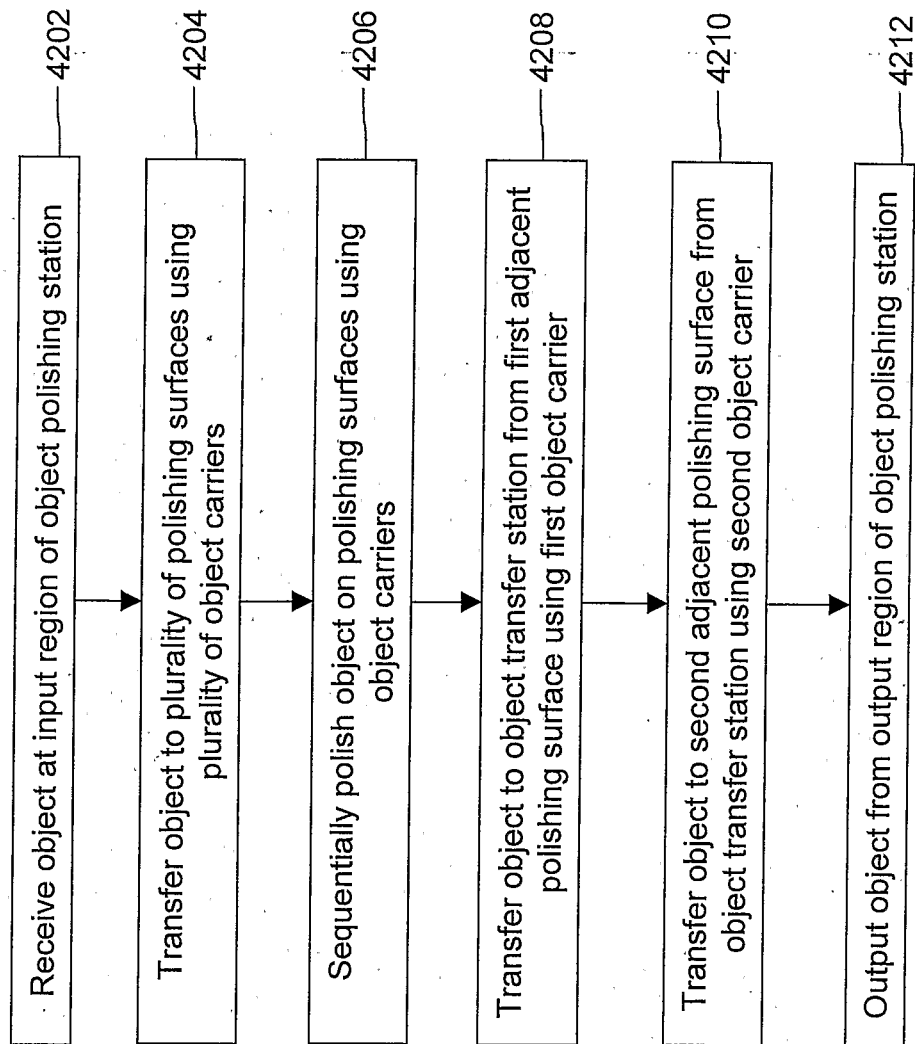


Fig. 42

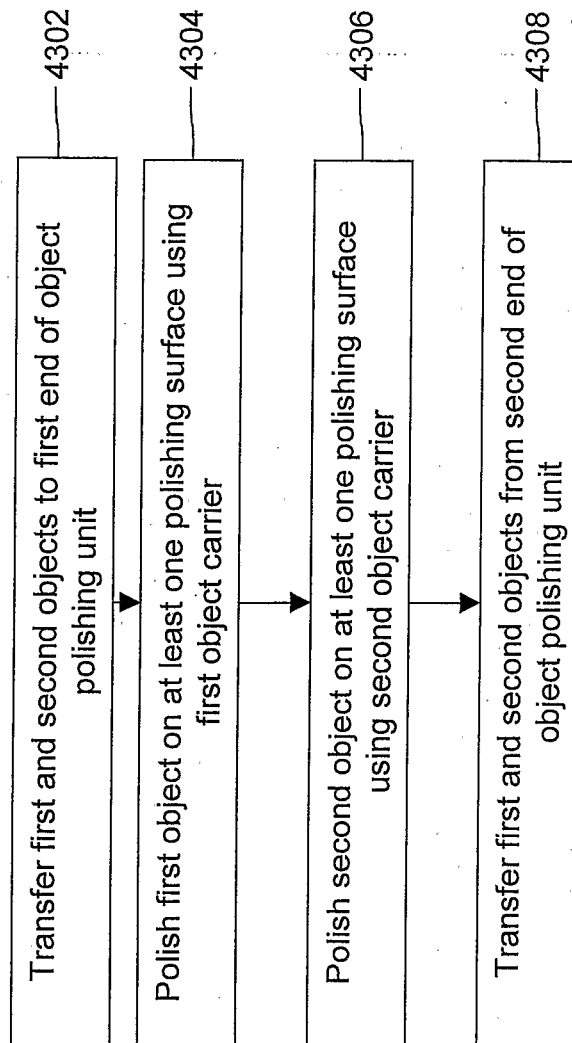


Fig. 43