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(54) **PUMP FOR SUPPLYING CHEMICAL LIQUIDS**

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(57) **ABSTRACT**

An opening **22***d* of a supply/withdrawal passage **22***b* is positioned at the center part of the internal wall surface **22***c* of the operating chamber **26** (concave area **22***a*), and a cross-shaped venting groove **22***e* extending from the opening **22***d* of the passage **22***b* to the periphery of the wall surface **22***c* is formed in the wall surface **22***c*. Thus, an operating air in the chamber **26** is discharged (sucked) through the passage **22***b* during drawing in the chemical liquid. Since the opening **22***d* communicates with the venting groove **22***e* extending to the periphery of the chamber **26**, if the center of the diaphragm **23** covers the opening **22***d* first, the operating air in the chamber **26** can be continuously evacuated (drew out) from the venting groove **22***e* positioned on the outside of the center part which first comes into contact with the opening **22***d*

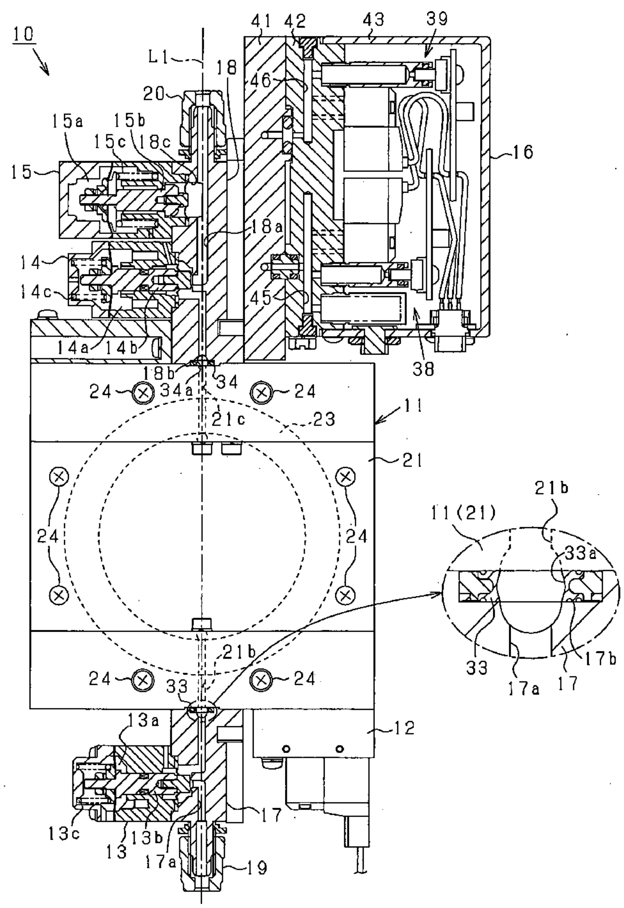


FIG. 1

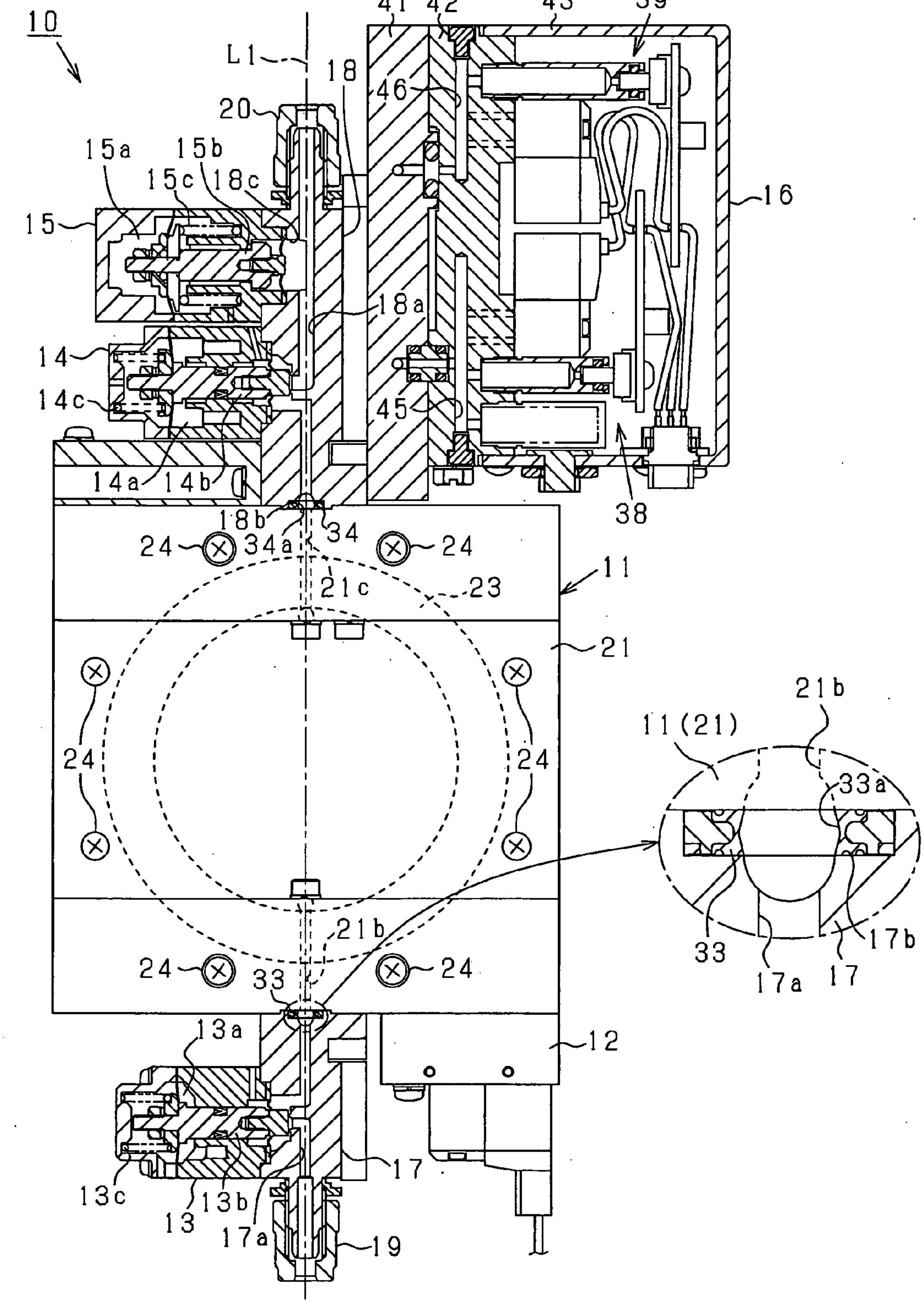

10
L1
18
20
15a
15b
15c
18c
15
18a
14
14c
14a
14b
18b
34a
34
41
42
43
39
46
16
45
38
24
11
21c
23
21
21b
11(21)
33a
33
17a
17
17b
13a
12
13c
13b
13
19

FIG. 2

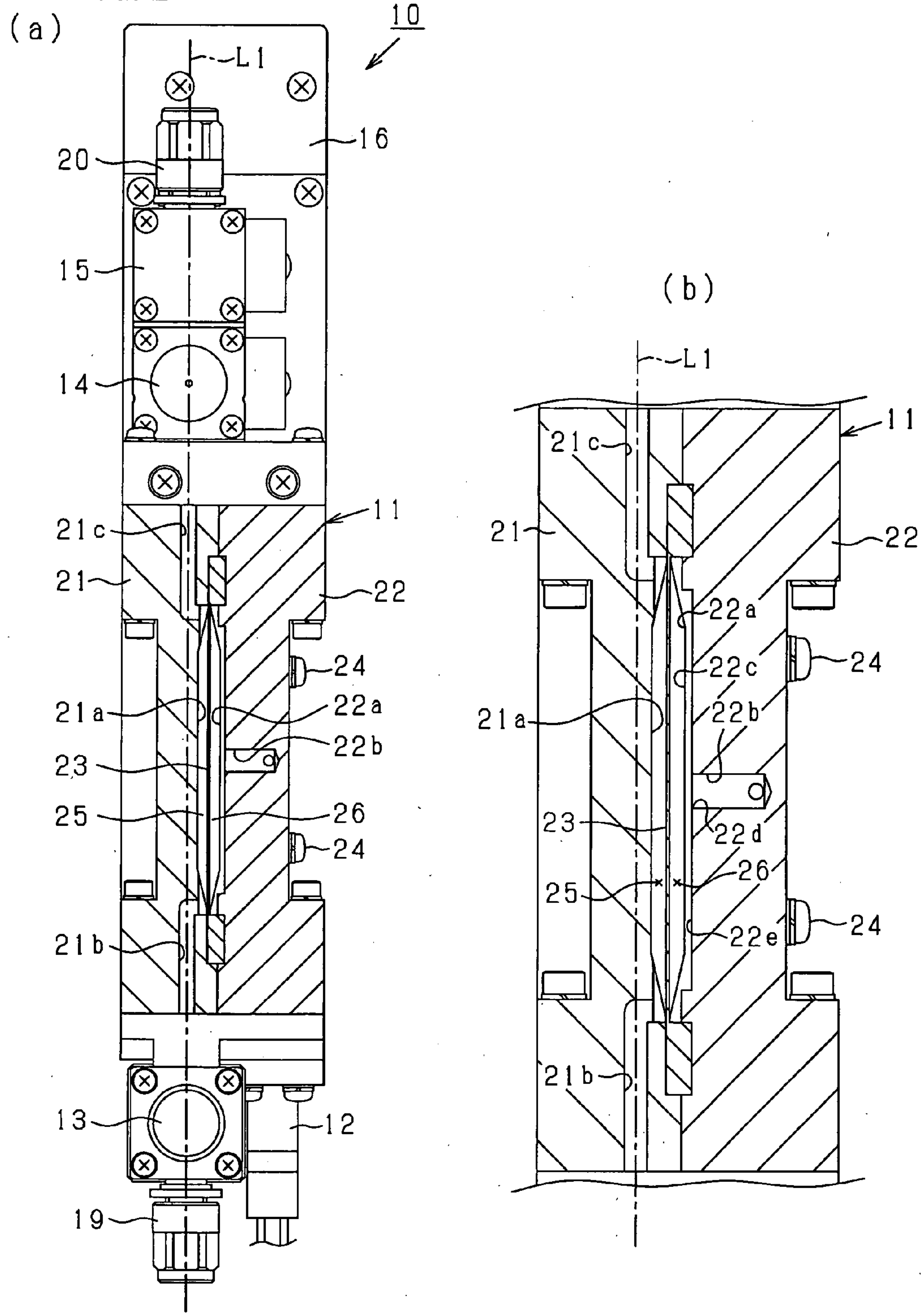

(a)
10
L1
16
20
15
14
11
21c
21
22
24
21a
22a
22b
23
25
26
24
21b
13
12
19
(b)
L1
11
21c
21
22
22a
22c
24
21a
22b
23
22d
25
26
22e
24
21b

FIG. 3

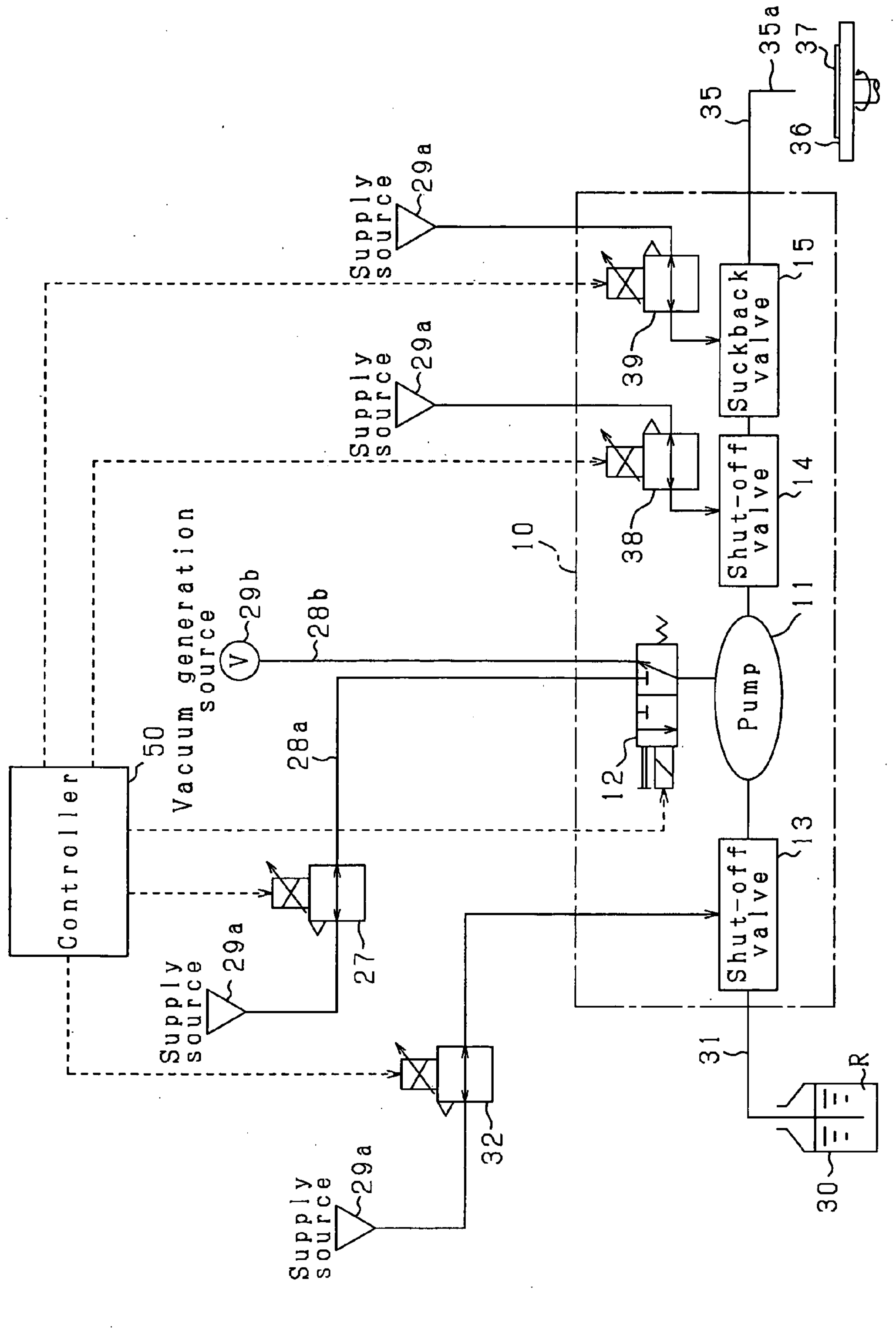

Controller
50
Vacuum generation source
V
29b
28b
28a
27
Supply source
29a
Supply source
29a
Supply source
29a
Supply source
29a
32
Shut-off valve
13
Pump
11
12
10
Shut-off valve
14
38
Suckback valve
15
39
35
35a
37
36
31
30
R

FIG. 4

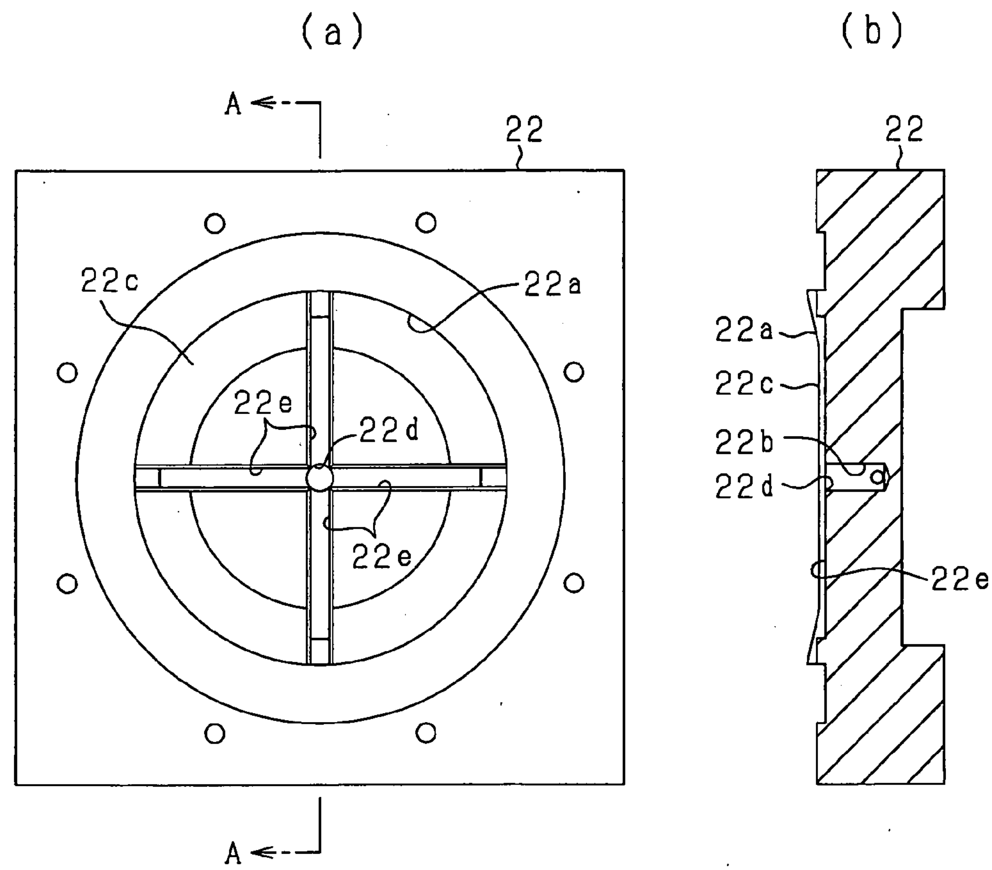


FIG. 5

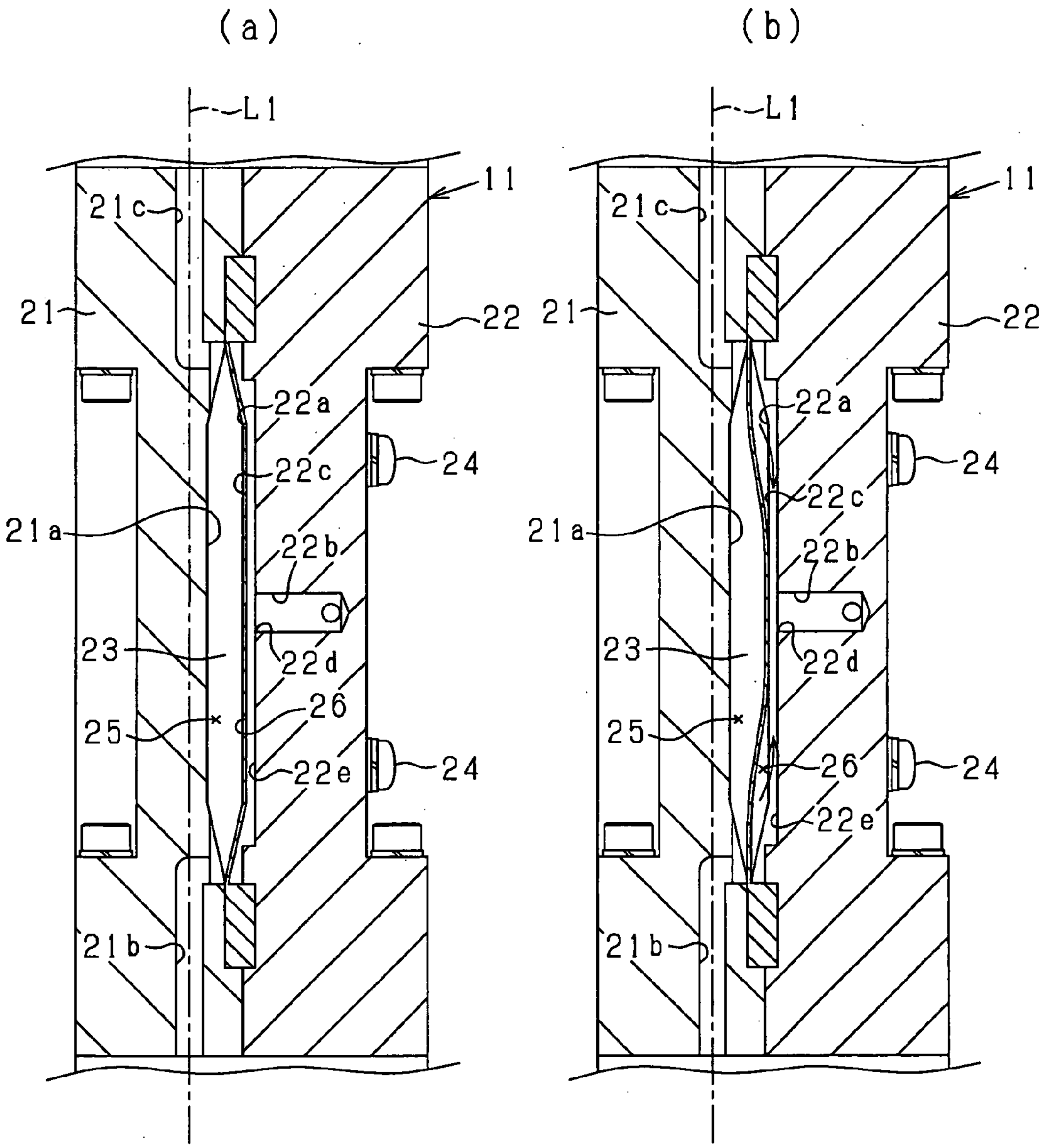


FIG. 6

(a) (b)

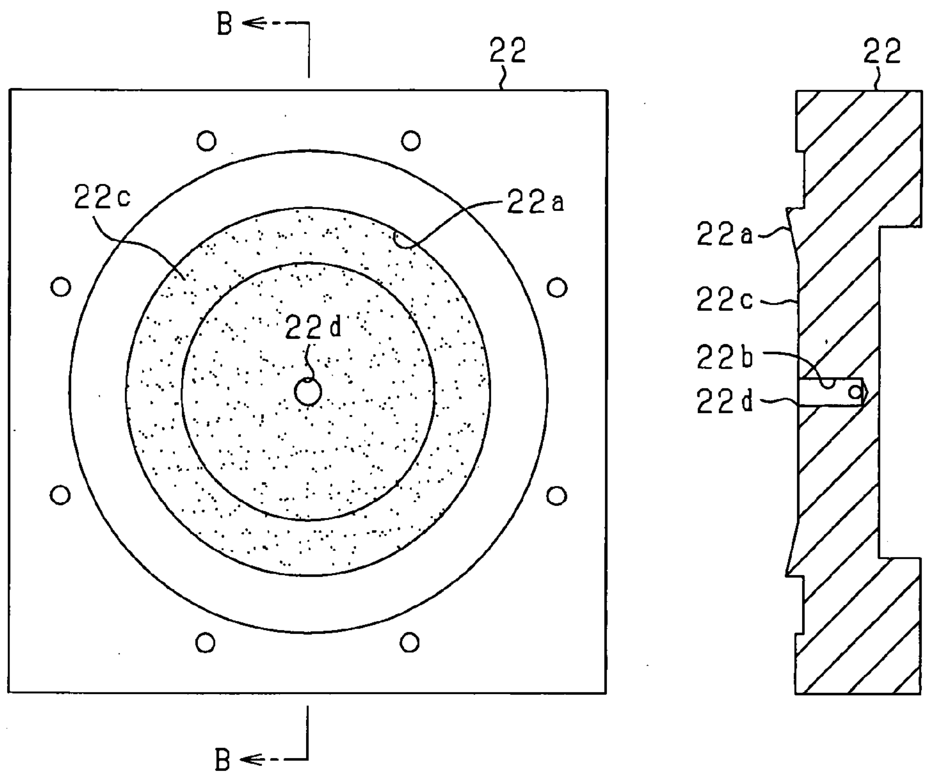
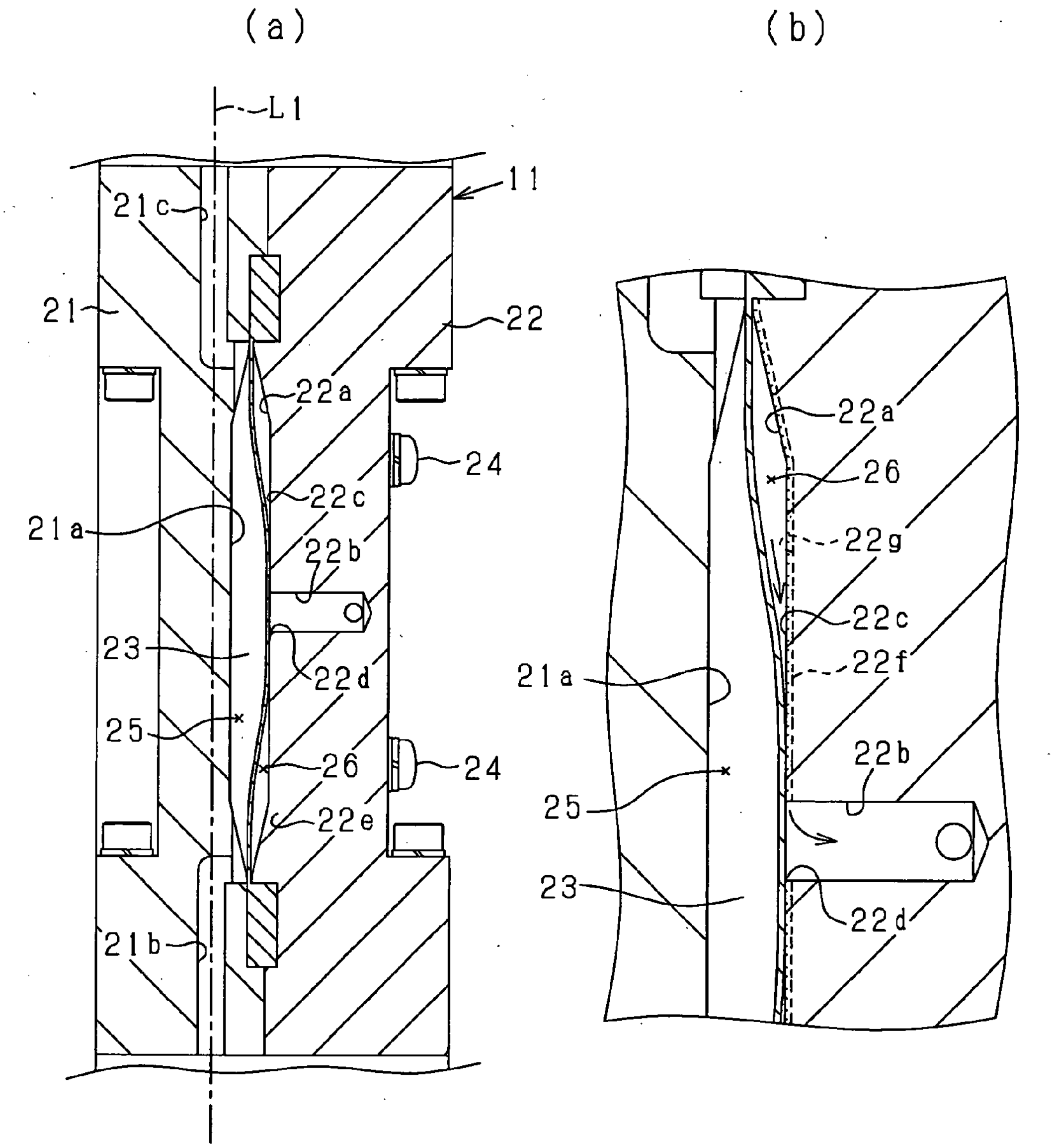


FIG. 7


(a)
L1
11
21c
21
22
22a
24
22c
21a
22b
23
22d
25
26
24
22e
21b
(b)
22a
26
22g
22c
22f
21a
22b
25
23
22d

PUMP FOR SUPPLYING CHEMICAL LIQUIDS

TECHNICAL FIELD

[0001] The present invention relates to a pump for supplying chemical liquids that is suitable for applying a predetermined volume of a chemical liquid, such as a photoresist liquid, to individual semiconductor wafers in the chemical-using process of, for example, a semiconductor manufacturing device.

BACKGROUND ART

[0002] In order to pump a chemical liquid such as a photoresist out of a bottle and apply a predetermined volume of this liquid to individual semiconductor wafers, a pump for supplying chemical liquids such as that disclosed in Patent Document 1, for example, is currently in use. This pump is divided by a diaphragm into a pump chamber and an operating chamber (a pressurization chamber in Patent Document 1), and driving the diaphragm by supplying air to or withdrawing air from the operating chamber, via a supply/withdrawal passage connected to the operating chamber, changes the volume inside the pump chamber, thereby causing the pump chamber to suction or discharge a chemical liquid.

[0003] When the pump chamber and the operating chamber are formed to be thin and the pump is made thin through the use of a diaphragm comprised of a flexible film, the diaphragm is secured at its perimeter, and consequently tends to deform more at its center. At the same time, to ensure efficient deformation of the entire diaphragm, it has been preferable to position the opening of the supply/withdrawal passage in the operating chamber in its center.

[0004] When the interior of the operating chamber is evacuated in order to draw the chemical liquid into the pump chamber or when the interior of the operating chamber is opened to the surrounding atmosphere in order to supply the pressurized chemical liquid, the diaphragm begins to deform at its center toward the operating chamber, with the result that the center tends to come into contact with the internal wall of the operating chamber first. In such a case, the center of the diaphragm blocks the opening of the supply/withdrawal passage while the area surrounding the center of the diaphragm does not contact the internal wall of the operating chamber. This slows down the deformation of the diaphragm toward the operating chamber, and moreover, may prevent the diaphragm from deforming fully. As a result, it may take a long time for the chemical liquid to fill the pump chamber or it may not be possible to supply the pump chamber with the specified volume of chemical liquid.

Patent document 1: Japanese patent application publication No. 2003-49778

DISCLOSURE OF THE INVENTION

[0005] A primary object of the present invention is to provide a pump for supplying chemical liquids that can ensure quick and reliable deformation of the diaphragm toward the operating chamber, and that can shorten the time needed for filling the pump chamber with a chemical liquid and ensure that the pump chamber is filled with a sufficient volume of chemical liquid.

[0006] A pump for supplying chemical liquids according to the present teaching is configured as described below. That is, in a pump for supplying chemical liquids in which the pump chamber and operating chamber are divided by means of a diaphragm comprised of a flexible film, the diaphragm deforms toward the pump chamber when the interior of the pump chamber is pressurized using an operating gas, thereby discharging the chemical liquid that has been supplied into the pump chamber; and when the interior of the operating chamber reaches a negative pressure because of the withdrawal of the operating gas or when the interior of the operating chamber is opened to the surrounding atmosphere, the diaphragm deforms toward the operating chamber, thereby drawing a chemical liquid into the pump chamber, and

[0007] a supply/withdrawal passage for supplying the operating gas to or withdrawing same from the operating chamber is formed in the pump housing, and the opening of the supply/withdrawal passage is provided in part of the internal wall surface of the operating chamber, and

a venting groove that extends from the opening of the supply/withdrawal passage to the periphery of the internal wall surface is formed on the internal wall surface of the operating chamber.

[0008] In this pump for supplying chemical liquids, the opening of the supply/withdrawal passage is provided in part of the internal wall surface of the operating chamber, and a venting groove is formed, which extends from the opening of the supply/withdrawal passage to the periphery of the interior wall surface. Here, when the chemical liquid is to be drawn in, the operating gas inside the operating chamber is evacuated (sucked out) through the supply/withdrawal passage. In this case, the diaphragm tends to deform from its center, which may cover the opening of the supply/withdrawal passage first. However, the opening of the supply/withdrawal passage is connected to the vent groove, which opens toward the periphery of the operating chamber as described above. Therefore, even when the diaphragm deforms from the center, thus covering the opening of the supply/withdrawal passage first, because the venting groove positioned on the outside of the contacted center is open, it is possible to continue to evacuate (draw out) the operating gas inside the operating chamber through the open venting groove. In this way, even when such uneven deformation occurs in the diaphragm, the diaphragm still quickly and reliably deforms toward the operating chamber, shortening the time needed for filling the pump chamber with the chemical liquid, and filling the pump chamber with a sufficient volume of chemical liquid.

[0009] Note that it is desirable to position the extension destination of the venting groove as close as possible to the periphery of the operating chamber, and it is best to extend it to the periphery. With such a configuration, the diaphragm will not block the venting groove until the diaphragm has sufficiently deformed toward the operating chamber, ensuring reliable evacuation (drawing out) of the operating gas from the operating chamber.

[0010] In a preferred embodiment of the pump for supplying chemical liquids, the internal wall surface of the operating chamber is circular in shape and the opening of the supply/withdrawal passage is positioned in the center of the internal wall surface of the operating chamber.

[0011] In this configuration, the fact that the opening of the supply/withdrawal passage is positioned in the center of the circular internal wall surface of the operating chamber allows the operating gas to be efficiently supplied to or withdrawn from the operating chamber.

[0012] In another preferred embodiment of the pump for supplying chemical liquids, the opening of the supply/withdrawal passage is positioned in the center of the internal wall surface of the operating chamber, with the internal wall formed symmetrically from its center; and the venting groove is formed to be symmetrical, with the center of the opening of the supply/withdrawal passage at its center, in correspondence with the internal wall surface of the operating chamber.

[0013] In this configuration, the venting groove is formed to be symmetrical from its center positioned at the center of the internal wall surface of the operating chamber, where the opening of the supply/withdrawal passage is positioned. Therefore, if, while a chemical liquid is being drawn in, the center of the diaphragm covers the opening of the supply/withdrawal passage first, this venting groove maintains the interior of the operating chamber at a stable negative pressure, enabling the diaphragm to stably deform.

[0014] In either of the above configurations, the venting groove should preferably have a linear shape.

[0015] Such a linear shape allows the venting groove to be easily formed.

[0016] The venting groove can also be configured from continuous concave areas obtained by forming a rough internal wall surface in the operating chamber.

[0017] Configuring the venting groove from continuous concave areas obtained by forming a rough internal wall surface in the operating chamber allows the venting groove to be easily formed by simply roughening the internal wall surface.

[0018] Note that the internal wall surface can be easily roughened by means of shot blasting, that is, by blasting the surface with abrasive grains.

[0019] Preferably, the entire internal wall surface of the operating chamber should be roughened.

[0020] According to this configuration, the roughening of the internal wall surface of the operating chamber is applied to the entire internal wall surface, which corresponds to the deformation region of the diaphragm. Thus, there is no need to separate the internal wall surface of the operating chamber into an area that should be roughened and an area that should not be roughened, thereby simplifying the operation of roughening the internal wall surface. Furthermore, the fact that the entire internal wall surface of the operating chamber is roughened prevents the diaphragm from blocking the venting groove until the diaphragm deforms sufficiently toward the operating chamber, thus ensuring reliable evacuation (drawing out) of the operating gas from the operating chamber.

[0021] In either of the above configurations, the pump housing should preferably be formed to be thin in the deformation direction of the diaphragm.

[0022] When the pump housing is formed to be thin in the deformation direction of the diaphragm, the operating chamber must also be formed to be thin in the same direction. Since the resulting structure tends to cause the center of the diaphragm to contact the internal wall surface of the operating chamber first during suctioning of a chemical liquid, the significance of providing the venting groove is great.

BRIEF EXPLANATION OF DRAWINGS

[0023] [FIG. **1**] is a frontal cross-sectional diagram illustrating the pump unit inside the chemical liquid supply system.

[0024] [FIG. **2**] (a) is a side cross-sectional diagram of the pump unit, and (b) is an enlarged cross-sectional diagram of (a).

[0025] [FIG. **3**] is a circuit diagram illustrating the entire circuitry of the chemical liquid supply system.

[0026] [FIG. **4**] (a) is the front view of the pump housing on the operating chamber side, and (b) is a cross-sectional diagram along line A-A in (a).

[0027] [FIG. **5**] (a) and (b) are diagrams explaining the operation of the diaphragm.

[0028] [FIG. **6**] (a) is the front view of the pump housing on the operating chamber side in another example, and (b) is a cross-sectional diagram along line B-B in (a).

[0029] [FIG. **7**] (a) and (b) are diagrams explaining the operation of the diaphragm in another example.

EXPLANATION OF SYMBOLS

[0030] **22** . . . pump housing; **22***b* . . . supply/withdrawal passage; **22***c* . . . internal wall surface; **22***d* . . . opening; **22***e* . . . venting groove; **22***f* . . . venting groove; **22***g* . . . concave area; **23** . . . diaphragm; **25** . . . pump chamber; **26** . . . operating chamber; R . . . resist liquid (chemical liquid).

DESCRIPTION OF THE PREFERRED EMBODIMENT

[0031] An embodiment in which the present invention is implemented into a pump unit of a chemical liquid supply system used in a manufacturing line of a semiconductor device, etc. is explained below, referencing the drawings. Note that FIG. **1** and FIG. **2** illustrate a pump unit **10**, which is a primary component of the system, while FIG. **3** illustrates the entire chemical liquid supply system.

[0032] As shown in FIGS. **1** and **2**, the pump unit **10** is formed by assembling together a pump **11**, a solenoid switching valve **12**, a suction-side shut-off valve **13**, a discharge-side shut-off valve **14**, a suckback valve **15**, a regulator **16**, a suction-side passage member **17** and a discharge-side passage member **18**.

[0033] The pump **11** has a thin flat prism form having a nearly square shape when viewed from the front, and a pair of pump housings **21** and **22**. Concave areas **21***a* and **22***a*, opened in almost circular dome shapes, are formed in the center of the opposing faces of pump housings **21** and **22**, respectively. In the pump housings **21** and **22**, the peripheries of the concave areas **21***a* and **22***a* hold and support a diaphragm **23** comprised of a circular flexible film made of a fluorine resin or the like, and the pump housings **21** and **22** are secured to each other using eight screws **24**.

[0034] A diaphragm **23** partitions the space formed by the concave areas **21***a* and **22***a* of the pump housings **21** and **22**, with the space on the side of pump housing **21** (the left side of the diaphragm **23** in FIG. **2**) used as a pump chamber **25** and the space on the side of pump housing **22** (the right side of the diaphragm **23** in FIG. **2**) used as an operating chamber **26**. The pump chamber **25** is a space for supplying/withdrawing the resist liquid R (see FIG. **3**) used as a chemical liquid, and the operating chamber **26** is a space for supplying/withdrawing the operation air for driving the diaphragm **23**. Note that in order to reduce the thickness of the pump **11**, the pump housings **21** and **22** are made thin (in this case in the deformation direction of the diaphragm **23**), with the result that both the pump chamber **25** and the operating chamber **26** form thin spaces in the same direction.

[**0035**] A suction passage **21***b*, which is connected to the pump chamber **25** and extends linearly downward, is formed in pump housing **21** on the pump chamber **25** side. The Suction passage **21***b* is connected to suction passage **17***a* of the suction-side passage member **17**. A discharge passage **21***c*, which is connected to the pump chamber **25** and extends linearly upward, is also formed in the pump housing **21**. Furthermore, this discharge passage **21***c* is provided on the same line L**1** as the suction passage **21***b*. Since the pump chamber **25** in this embodiment is formed as a thin space in the deformation direction of the diaphragm **23**, the suction passage **21***b* and discharge passage **21***c* connected to this pump chamber **25** are bent perpendicularly near the pump chamber **25** to the degree necessary for connection (roughly equaling the width of the passage) (see FIG. **2**). However, these bends do not significantly impact (create resistance to) the flow of the resist liquid R inside the pump **11**, but allow the resist liquid R to flow smoothly in these areas.

[**0036**] A supply/withdrawal passage **22***b*, which supplies operating air to the operating chamber **26**, is formed in the pump housing **22** on the operating chamber **26** side. An opening **22***d* of the supply/withdrawal passage **22***b* on the internal wall surface **22***c* of the operating chamber **26** (concave area **22***a*) is positioned in the center of the circular concave area **22***a*. Furthermore, as shown in FIG. **4**, a cross-shaped venting groove **22***e*, whose end extends to the periphery of the operating chamber **26**, is formed on the internal wall surface **22***c* of the operating chamber **26**, and the opening **22***d* of the supply/withdrawal passage **22***b* is positioned in the intersection of the cross-shaped venting groove **22***e*. This supply/withdrawal passage **22***b* is then connected to a solenoid switching valve **12** secured to the pump housing **22**.

[**0037**] Here, the intake port of the solenoid switching valve **12** is connected to one end of a supply tube **28** as shown in FIG. **3**. The supply tube **28** has an electro-pneumatic regulator **27** in the middle, and the other end of the supply tube **28** is connected to a supply source **29***a*. The electro-pneumatic regulator **27** is adjusted by a controller **50**, such that the pressure of the operating air supplied from the supply source **29***a* to the pump **11** remains constant at a preset value. The exhaust port of the solenoid switching valve **12** is connected to a vacuum generation source **29***b* via an exhaust pipe **28***b*. The solenoid switching valve **12** is controlled and switched by the controller **50** to connect the operating chamber **26** to either the supply source **29***a* or the vacuum generation source **29***b*. This switching action either supplies operating air to or withdraws it from the operating chamber **26**, thereby switching the pump **11** between suctioning and discharging actions.

[**0038**] That is, when the action of the solenoid switching valve **12** supplies operating air to the operating chamber **26**, the interior of the operating chamber **26** is pressurized, pushing the diaphragm **23** to the pump chamber **25** side and discharging the resist liquid R contained inside the pump chamber **25** to the downstream side via the discharge passage **21***c*. In contrast, when the action of the solenoid switching valve **12** evacuates the operating air out of the operating chamber **26** and the pressure inside the operating chamber **26** becomes negative, the diaphragm **23**, which has been pushed to the pump chamber **25** side, moves toward the operating chamber **26**, introducing the resist liquid R from the upstream side into the pump chamber **25** via the suction passage **21***b*.

[**0039**] Here, during suctioning of the resist liquid R, the diaphragm **23** deforms to its maximum deformation position to contact the internal wall surface **22***c* of the operating chamber **26**, as shown in FIG. **5** (*a*). During this deformation, the diaphragm **23** tends to deform at its center, as shown in FIG. **5** (*b*), such that its center may cover the opening **22***d* of the supply/withdrawal passage **22***b* before the diaphragm **23** deforms to its maximum deformation position. In this case, the opening **22***d* is connected to the venting groove **22***e*, which extends to the periphery of the operating chamber **26**. Consequently, even when the diaphragm **23** deforms from the center, thus the center covers the opening **22***d* of the supply/withdrawal passage **22***b* first, the venting groove **22***e* positioned on the outside of the contacted center is open. Therefore, it is possible to continue to evacuate the interior of the operating chamber **26** through the open venting groove **22***e* (the arrow in FIG. **5** (*b*) indicates the flow of the operating air). As a result, even when such uneven deformation occurs in the diaphragm **23**, the diaphragm **23** still reliably deforms to its maximum deformation position within a short period, thus shortening the time needed for filling the pump chamber **25** with the resist liquid R and ensuring a sufficient charging volume.

[**0040**] A rod-shaped, suction-side passage member **17** is secured to the center of the bottom of the pump housings **21** and **22**. The suction-side passage member **17** is disposed along the flat direction of the pump **11**. A suction passage **17***a*, which extends nearly linearly downward, is formed in the suction-side passage member **17**. This suction passage **17***a* is disposed on the same line L**1** as the suction passage **21***b* of the pump **11**. On the surface of the suction-side passage member **17** where it faces the pump housing **21**, a concave housing section **17***b* is formed around the suction passage **17***a*, and the seal ring **33** is housed inside the concave housing section **17***b*. The seal ring **33** is disposed between the suction-side passage member **17** and the pump housing **21**, preventing the resist liquid R inside the suction passages **17***a* and **21***b* from leaking out of the gap between the suction-side passage member **17** and the pump housing **21**.

[**0041**] The inner peripheral surface **33***a* of the seal ring **33** is smoothly continuous with the inner peripheral surfaces of the suction passages **17***a* and **21***b*. Specifically, the seal ring **33** has a shape in which the inner peripheral surface **33***a* is continuous with the inner peripheral surfaces of the suction passages **17***a* and **21***b*, and in which the concave area gradually deepens toward the outside in the radial direction as the distance from the internal passages **17***a* or **21***b* toward the center of the seal ring **33** in its thickness direction increases. In other words, this shape allows the resist liquid R to flow smoothly in the seal ring **33** area, preventing the resist liquid R and air bubbles from becoming trapped. Note that using an ordinary seal ring (O-ring) having a circular cross section creates an acute-angled dip between the seal ring and suction passages **17***a* and **21***b*. This results in a shape that is not smoothly continuous with the inner peripheral surfaces of the passages **17***a* and **21***b*, and causes the resist liquid R and air bubbles to problematically become trapped in this area. Additionally, as shown in FIG. **3**, the suction-side passage member **17**, using a coupling **19** provided at its tip, is connected to one end of a suction tube **31**, while the other end of the suction tube **31** is guided into the resist liquid R contained inside a resist bottle **30**.

[**0042**] The suction-side shut-off valve **13** consisting of an air-operated valve is assembled together with the suction-side passage member **17**. The suction-side shut-off valve **13** has a nearly square prism shape, and is disposed in the direction perpendicular to the suction-side passage member **17** and along the flat direction of the pump **11** (pump housings **21** and **22**). Here, as shown in FIG. **3**, the suction-side shut-off valve **13** switches between opening and closing the suction passage **17***a* based on the switching action of an electro-pneumatic regulator **32** that is controlled by the controller **50**. That is, the suction-side shut-off valve **13** has the structure shown in FIG. **1**. When its supply/withdrawal chamber **13***a* is opened to the atmosphere by the switching action of the electro-pneumatic regulator **32**, the valve body **13***b* of the suction-side shut-off valve **13** receives a spring force from a spring **13***c* and shuts off the suction passage **17***a*; when operating air is supplied to the supply/withdrawal chamber **13***a* from the supply source **29***a*, the valve body **13***b* sinks by working against the spring force of the spring **13***c* to open the suction passage **17***a*. Note that the part of the suction passage **17***a* near the valve body **13***b* is bent perpendicularly to the degree necessary for ensuring the reliable opening and closing action of the valve body **13***b* (roughly equaling the width of the passage). However, this bend does not significantly impact (create resistance to) the flow of the resist liquid R inside the passage member **17**, but allows the resist liquid R to flow smoothly in this area as well.

[**0043**] The rod-shaped, discharge-side passage member **18** is secured to the center of the top of the pump housings **21** and **22**. The discharge-side passage member **18** is disposed along the flat direction of the pump **11**. The discharge passage **18***a*, which extends nearly linearly upward, is formed in the discharge-side passage member **18**. This discharge passage **18***a* is disposed on the same line L**1** as the discharge passage **21***c* of the pump **11**. On the surface of the discharge-side passage member **18** where it faces the pump housing **21**, a concave housing section **18***b* is formed around the discharge passage **18***a*, and a seal ring **34** is housed inside the concave housing section **18***b*. The seal ring **34** is disposed between the discharge-side passage member **18** and the pump housing **21**, preventing the resist liquid R inside the discharge passages **18***a* and **21***c* from leaking out of the gap between the discharge-side passage member **18** and the pump housing **21**.

[**0044**] Like the aforementioned seal ring **33**, the inner peripheral surface **34***a* of the seal ring **34** is smoothly continuous with the inner peripheral surfaces of the discharge passages **18***a* and **21***c*, resulting in a structure that prevents the resist liquid R and air bubbles from becoming trapped. Additionally, as shown in FIG. **3**, the discharge-side passage member **18**, using a coupling **20** provided at its tip, is connected to one end of a discharge tube **35** having a nozzle **35***a* on its other end. The nozzle **35***a* is orientated downward and disposed in a position that allows it to drip the resist liquid R onto the center of a semiconductor wafer **37** that is placed on and spins with a spinning platform **36**.

[**0045**] A discharge-side shut-off valve **14** consisting of an air-operated valve is assembled together with the discharge-side passage member **18**. The discharge-side shut-off valve **14** has a nearly square prism shape, and is disposed in the direction perpendicular to the discharge-side passage member **18** and along the flat direction of the pump **11** (pump housings **21** and **22**). Here, as shown in FIG. **3**, the discharge-side shut-off valve **14** is constructed in the same way as the aforementioned suction-side shut-off valve **13** and switches between opening and closing the discharge passage **18***a* based on the switching action of an electro-pneumatic regulator **38** that is controlled by the controller **50**. That is, the discharge-side shut-off valve **14** has the structure shown in FIG. **1**. When its supply/withdrawal chamber **14***a* is opened to the atmosphere by the switching action of the electro-pneumatic regulator **38**, a valve body **14***b* of the discharge-side shut-off valve **14** receives a spring force from a spring **14***c* and shuts off the discharge passage **18***a*; when operating air is supplied to the supply/withdrawal chamber **14***a* from the supply source **29***a*, the valve body **14***b* sinks by working against the spring force of the spring **14***c* to open the discharge passage **18***a*. Note that the part of the discharge passage **18***a* near the valve body **14***b* is bent perpendicularly to the degree necessary for ensuring the reliable opening and closing action of the valve body **14***b* (roughly equaling the width of the passage). However, this bend does not significantly impact (create resistance to) the flow of the resist liquid R inside the passage member **18**, but allows the resist liquid R to flow smoothly in this area as well.

[**0046**] The suckback valve **15** consisting of an air-operated valve is assembled together with the discharge-side passage member **18**, next to and on the downstream side of the discharge-side shut-off valve **14**. The suckback valve **15** also has a nearly square prism shape, and is disposed in the direction perpendicular to the discharge-side passage member **18** and along the flat direction of the pump **11** (pump housings **21** and **22**). Here, as shown in FIG. **3**, the suckback valve **15** is designed to suck back a predetermined amount of the resist liquid R located downstream of the valve **15** to the upstream side to prevent unintended dripping of the resist liquid R from the nozzle **35***a*, based on the switching actions of an electro-pneumatic regulator **39**. That is, the suckback valve **15** has the structure shown in FIG. **1**. When its supply/withdrawal chamber **15***a* is opened to the atmosphere by the switching action of the electro-pneumatic regulator **39**, a valve body **15***b* of the suckback valve **15** sinks by receiving a spring force from a spring **15***c* and enlarges the volume of the volume-expansion chamber **18***c* connected in communication with the discharge passage **18***a*, sucking in the predetermined amount of the resist liquid R into the volume-expansion chamber **18***c*. In contrast, when operating air is supplied to the supply/withdrawal chamber **15***a* from the supply source **29**, the valve body **15***b* protrudes by working against the spring force of the spring **15***c*, reducing the volume of the volume-expansion chamber **18***c* provided in the discharge passage **18***a*.

[0047] Furthermore, the regulator **16** having the shape of an approximate rectangular parallelepiped is secured to the discharge-side passage member **18** on the side opposite from the discharge-side shut-off valve **14** and the suckback valve **15**. That is, the regulator **16** is installed on the discharge-side passage member **18** along the flat direction of the pump **11**. A base **41** of the regulator **16** is secured to the discharge-side passage member **18**. A securing platform **42** is secured to the base **41**, and the electro-pneumatic regulators **38** and **39**, which switch the discharge-side shut-off valve **14** and the suckback valve **15**, are secured to the securing platform **42**. A cover **43** that covers the electro-pneumatic regulators **38** and **39** is installed on this securing platform **42**. Furthermore, communication passages **45** and **46**, which are connected to the electro-pneumatic regulators **38** and **39**, are respectively formed on the securing platform **42** and the base **41**, and are respectively connected to the supply/withdrawal chambers **14***a* of the discharge-side shut-off valve **14** and the supply/withdrawal chambers **15***a* of the suckback valve **15**, though not shown in the figure. Based on the control by the controller **50**, the electro-pneumatic regulators **38** and **39** either supply operating air to or withdraw it from the supply/withdrawal chambers **14***a* of the discharge-side shut-off valve **14** and the supply/withdrawal chambers **15***a* of the suckback valve **15**, thereby operating the discharge-side shut-off valve **14** and the suckback valve **15**.

[0048] In the pump unit **10** thus configured, the suction passage **17***a* inside the suction-side passage member **17**, the suction passage **21***b* and the discharge passage **21***c* inside the pump **11**, and the discharge passage **18***a* of the discharge-side passage member **18**, through all of which the resist liquid R passes, are all linear in shape and disposed on the same line L**1**. That is, the structure of this pump unit **10** allows the length of the resist liquid R passage to be short as much as possible, while nearly eliminating areas inside the resist liquid R passage where the resist liquid R or air bubbles could become trapped. The structure of the seal rings **33** and **34** also nearly eliminates areas where the resist liquid R or air bubbles could become trapped.

[0049] As shown in FIG. **3**, the controller **50** controls a series of actions of the chemical liquid supply system, by controlling the electro-pneumatic regulator **27** to set the operating air supplied to the pump **11** at the predetermined pressure level, and also by controlling the solenoid switching valve **12**, which switches and operates the pump **11**; the electro-pneumatic regulator **32**, which switches and operates the suction-side shut-off valve **13**; and the electro-pneumatic regulators **38** and **39**, which operate the discharge-side shut-off valve **14** and the suckback valve **15**.

[0050] That is, when a command to begin the operation of the chemical liquid supply system is generated, the controller **50** first controls the electro-pneumatic regulator **32** to switch the suction-side shut-off valve **13**, shutting off the suction passage **17***a*. This action cuts the pump **11** off from the resist bottle **30**. The controller **50** also switches the solenoid switching valve **12** to supply operating air adjusted to the predetermined pressure to the operating chamber **26** inside the pump **11**. This action causes the diaphragm **23** to, move toward the pump chamber **25**, pressurizing the resist liquid R contained inside the pump chamber **25**. During this process, the discharge passage **18***a* is shut off by the discharge-side shut-off valve **14** on the downstream side of the pump **11**, preventing discharge of the resist liquid R.

[0051] Next, the controller **50** controls the electro-pneumatic regulator **38** to switch the discharge-side shut-off valve **14**, opening the discharge passage **18***a*, and also controls the electro-pneumatic regulator **39** to cancel the sucking-in of the resist liquid R by the suckback valve **15**. During this process, the resist liquid R inside the pump chamber **25**, pressurized by the diaphragm **23**, is discharged from the pump **11**, and a predetermined amount of this resist liquid R is dripped onto a semiconductor wafer from the nozzle **35***a* at the tip of the discharge pipe **35** via the discharge passage **18***a*.

[0052] Next, the controller **50** controls the electro-pneumatic regulator **38** to switch the discharge-side shut-off valve **14**, shutting off the discharge passage **18***a*. This action stops the discharge of the resist liquid R from the nozzle **35***a*. The controller **50** also controls the electro-pneumatic regulator **39** to cause the suckback valve **15** to draw in a predetermined amount of the resist liquid R, preventing unintended dripping of the resist liquid R from the nozzle **35***a*.

[0053] Next, the controller **50** controls the electro-pneumatic regulator **32** to switch the suction-side shut-off valve **13**, opening the suction passage **17***a*. This action connects the pump **11** to the resist bottle **30**. The controller **50** also switches the solenoid switching valve **12**, causing the operating air to be suctioned from the operating chamber **26** by means of the vacuum generation source **29***b*. Then, the pressure inside the operating chamber **26** becomes negative, with the result that the diaphragm **23** deforms to its maximum deformation position to contact the internal wall surface **22***c* of the operating chamber **26** and the resist liquid R is suctioned into and fills the pump chamber **25**.

[0054] During this suctioning, if the center of the diaphragm **23** first covers the opening **22***d* of the supply/withdrawal passage **22***b*, the opening **22***d* is connected to the venting groove **22***e*, which extends to the periphery of the operating chamber **26**, causing the evacuation of the interior of the operating chamber **26** to continue through the venting groove **22***e* positioned on the outside of the center that is contacted first. Therefore, even when such uneven deformation occurs in the diaphragm **23**, the diaphragm **23** can reliably deform to its maximum deformation position within a short period, thus shortening the time needed for filling the pump chamber **25** with the resist liquid R and ensuring a sufficient charging volume. From this point on, the controller **50** repeats the aforementioned actions such that a predetermined amount of resist liquid R is dripped onto each semiconductor wafer **37**, as they are carried in one after another.

[0055] Next, the characteristic effects of such an embodiment are described.

[0056] In the present embodiment, the opening **22***d* of the supply/withdrawal passage **22***b* is positioned in the center of the internal wall surface **22***c* of the operating chamber **26** (concave area **22***a*), and the cross-shaped venting groove **22***e*, which extends from the opening **22***d* of the supply/withdrawal passage **22***b* toward the periphery of the internal wall surface **22***c*, is formed on the internal wall surface **22***c*. During suctioning of the resist liquid R, the operating air the operating chamber **26** is evacuated through the supply/withdrawal passage **22***b*. In this case, the diaphragm **23** tends to deform in its center, which may cover the opening **22***d* of the supply/withdrawal passage **22***b* first. However, in the present embodiment, the opening **22***d* of the supply/withdrawal passage **22***b* is connected to the venting groove **22***e*, which opens toward the periphery of the operating chamber **26**. Therefore, even when the diaphragm **23** deforms in this manner, the venting groove **22***e* positioned on the outside of the contacted center is open, making it possible to continue to evacuate the operating air inside the operating chamber **26** through the open venting groove. As a result, even when such uneven deformation occurs in the diaphragm **23**, the diaphragm **23** can reliably deform to its maximum deformation position toward the operating chamber **26** within a short period, thus shortening the time needed for filling the pump chamber **25** with the resist liquid R and ensuring a sufficient charging volume.

[0057] In the present embodiment, the fact that the opening **22***d* of the supply/withdrawal passage **22***b* is positioned in the center of the circular internal wall surface **22***c* of the operating chamber **26** allows the operating air to be efficiently supplied to or withdrawn from the operating chamber **26**.

[0058] In the present embodiment, since the venting groove **22***e* extends to the periphery of the operating chamber **26**, the diaphragm **23** can be prevented from blocking the venting groove **22***e* until the diaphragm **23** deforms sufficiently toward the operating chamber **26**, thus ensuring reliable evacuation of the operating air inside the operating chamber **26**.

[0059] In the present embodiment, the venting groove **22***e* is formed in a symmetric cross shape, with its center positioned at the center of the internal wall surface **22***c* of the circular operating chamber **26** (concave area **22***a*), which has a symmetric shape. Therefore, during suctioning of the resist liquid R, even if the center of the diaphragm **23** covers the opening **22***d* of the supply/withdrawal passage **22***b* first, the venting groove **22***e* maintains the pressure inside the operating chamber **26** at a stable negative pressure, enabling the diaphragm **23** to stably deform.

[0060] In the present embodiment, the venting groove **22***e* is designed to have a linear shape, which allows it to be easily formed.

[0061] In the present embodiment, since the pump housing **22** is formed to be thin in the deformation direction of the diaphragm **23** in order to make the pump **11** thin, the operating chamber **26** is also formed to be thin in the same direction. Because the resulting structure tends to cause the center of the diaphragm **23** to contact the internal wall surface **22***c* of the operating chamber **26** first during suctioning of the resist liquid R, the significance of providing the venting groove **22***e* is great.

[0062] Note that the present invention is not limited to the described contents of the aforementioned embodiment and may be implemented in other ways, as in the following examples.

[0063] In the aforementioned embodiment, the cross-shaped venting groove **22***e* is formed on the internal wall surface **22***c* of the operating chamber **26** (concave area **22***a*). However, the shape of the venting groove is not limited to such a shape. Although the venting groove **22***e* has a cross shape that extends in all four directions from the opening **22***d*, it can also have a Y shape that extends in three directions, for example. The venting groove may also have a shape that extends in any other odd or even number of directions. Note that when changing the shape of the venting groove, it is desirable to position the venting groove as close as possible to the periphery of the operating chamber, and it is best to extend the venting groove to the periphery of the operating chamber **26** (concave area **22***a*) as in the aforementioned embodiment.

[0064] Furthermore, as indicated by the dots in FIG. **6**, it is also possible to form the entire internal wall surface **22***c* of the operating chamber **26** as a rough surface, and configure a venting groove **22***f* with continuous individual concave areas **22***g* obtained by roughening the surface, as indicated by the dash line in FIG. **7** (*b*). With such a configuration, even when the center of the diaphragm **23** covers the opening **22***d* of the supply/withdrawal passage **22***b* first during suctioning of the resist liquid R as shown in FIG. **7** (*a*), the opening **22***d* is connected to the venting groove **22***f*, which extends to the periphery of the operating chamber **26** as the continuation of the concave areas **22***g*. This allows the evacuation of the interior of the operating chamber **26** to continue through the venting groove **22***f*, which is positioned on the outside of the contacted center. (In FIG. **7** (*b*), the arrow indicates the flow of the operating air.) Such a configuration also provides similar effects to those provided by the embodiment described above.

[0065] Note that the internal wall surface **22***c* can be easily roughened by means of shot blasting, that is, by blasting the surface with abrasive grains. Moreover, since the entire internal wall surface **22***c* is roughened, there is no need to mask an area of the internal wall surface **22***c* that should not be roughened, thus simplifying the operation of roughening the internal wall surface **22***c*.

[0066] In the aforementioned embodiment, the opening **22***d* of the supply/withdrawal passage **22***b* is positioned at the center of the operating chamber **26** (concave area **22***a*), but it can also be offset from the center.

[0067] In the aforementioned embodiment, the pressure inside the operating chamber **26** is set to be negative during suctioning of the resist liquid R. However, the operating chamber **26** can also be opened to the surrounding atmosphere. In this case, the interior of the resist bottle **30**, for example, must be pressurized.

[0068] In the aforementioned embodiment, the pump unit **10** is comprised of the pump **11**, which acts as a pump for supplying chemical liquids and into which shut-off valves **13** and **14**, the suckback valve **15**, or the like are integrated. However, other configurations that have at least the pump **11** body can also be used.

[0069] In the aforementioned embodiment, an explanation is provided using operating air as an example. However, it is also possible to use another gas such as nitrogen in place of air.

[0070] In the aforementioned embodiment, an example using the resist liquid R is described. This is because the target onto which the chemical liquid is to be dripped is assumed to be a semiconductor wafer **37**. However, other chemical liquids and other chemical liquid dripping targets may also be used.

1. In a pump for supplying chemical liquids in which a pump chamber and an operating chamber are divided by means of a diaphragm comprised of a flexible film, the diaphragm deforms toward the pump chamber when the interior of the pump chamber is pressurized using an operating gas, thereby discharging the chemical liquid that has been supplied into the pump chamber; and when the interior of the operating chamber reaches a negative pressure because of the withdrawal of the operating gas or when the interior of the operating chamber is opened to the surrounding atmosphere, the diaphragm deforms toward the operating chamber, thereby drawing a chemical liquid into the pump chamber, and a supply/withdrawal passage for supplying the operating gas to or withdrawing same from the operating chamber is formed in the pump housing, and an opening of the supply/withdrawal passage is provided in part of the internal wall surface of the operating chamber, and a venting groove that extends from the opening of the supply/withdrawal passage to the periphery of the internal wall surface is formed on the internal wall surface of the operating chamber.

2. The pump for supplying chemical liquids according to claim 1, wherein the internal wall surface of the operating chamber is circular in shape, and the opening of the supply/withdrawal passage is positioned in the center of the internal wall surface of the operating chamber.

3. The pump for supplying chemical liquids according to claim 1, wherein the opening of the supply/withdrawal passage is positioned in the center of the internal wall surface of the operating chamber with the internal wall formed symmetrically from its center; and

the venting groove is formed to be symmetrical, with the center of the opening of the supply/withdrawal passage at its center, in correspondence with the internal wall surface of the operating chamber.

4. The pump for supplying chemical liquids according to claim 1, wherein the venting groove is linear in shape.

5. The pump for supplying chemical liquids according to claim 1, wherein the venting groove is configured from continuous concave areas obtained by forming a rough internal wall surface in the operating chamber.

6. The pump for supplying chemical liquids according to any of claim 5, wherein roughening of the internal wall surface of the operating chamber is applied to the entire internal wall surface.

7. The pump for supplying chemical liquids according to claim 1, wherein the pump housing is formed to be thin in the deformation direction of the diaphragm.

8. The pump for supplying chemical liquids according to claim 2, wherein the venting groove is linear in shape.

9. The pump for supplying chemical liquids according to claim 2, wherein the venting groove is configured from continuous concave areas obtained by forming a rough internal wall surface in the operating chamber.

10. The pump for supplying chemical liquids according to claim 9, wherein roughening of the internal wall surface of the operating chamber is applied to the entire internal wall surface.

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