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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates generally to a small pump used in a sphygmomanometer, for example, and, in particular but not exclusively, to the structure of a piezoelectric pump that operates with the action of a piezoelectric actuator.

2. Description of the Related Art

[0002] A pump of this type is taught in Japanese Laid-Open Patent Publication (unexamined) No. 59-200081, USP No. 6,033,191 and the like.

[0003] As shown in Fig. 46, the pump taught in USP No. 6,033,191 is of a lamellar construction having a valve membrane 52 disposed between an upper housing 50 and a lower housing 51 with inlet and outlet flow channels 53 formed on the upper surface of the lower housing 51. A diaphragm 54 vibrated by a piezoelectric actuator is disposed on the upper housing 50, forming a pump chamber between the diaphragm 54 and top of the upper housing 50. The pump chamber and inlet and outlet side flow channels 53 communicate through respective holes 55 in the upper housing 50, and inlet and outlet check valves are formed by the valve membrane 52 at portions where holes 55 and flow channels 53 communicate. When the diaphragm 54 vibrates, air is sucked to the pump chamber from the suction side flow channel 53 and air is discharged from the pump chamber to the discharge side flow channel 53.

[0004] A problem with a compact pump thus comprised is that in order to assure airtightness it is necessary to assure sufficient flatness and parallelism on the mating surfaces of the upper and lower housings 50, 51. It is also difficult to simultaneously position the three layers, upper housing 50, lower housing 51, and valve membrane 52.

[0005] In addition, if positioning precision drops when the check valve is formed by disposing the valve membrane 52 between the upper housing 50 and lower housing 51, production yield of the pump body also drops.

[0006] Furthermore, the mating faces of the upper and lower housings 50, 51 are laser welded along the flow channels 53 as indicated by the welding beads 56 shown in Fig. 47 for airtightness, but air leaks between the valve membrane 52 and upper housing 50 are unavoidable in the flow channels 53. This creates a problem of degraded compression efficiency. Forming .the flow channels 53 is not simple, in addition.

[0007] Other piezoelectric pumps are described in EP 0 424 087 A1 which is considered to be the closest priort art EP 0 789 146 A1, DE 197 11 270 A1 and US 5,759,014.

[0008] A problem with the pump taught in Japanese Laid-Open Patent Publication No. 59-200081 is that because it uses a check valve the upper housing must be thick enough to dispose the check valve therein, and the upper housing cannot be made extremely thin.

SUMMARY OF THE INVENTION

[0009] The present invention is therefore directed to solving the problems described above by providing a compact pump that is easy to manufacture and offers high efficiency and reliability, and by providing a manufacturing method for this pump.

[0010] In accomplishing the above and other objectives, a pump according to the present Invention is a piezoelectric pump for sucking fluid to a pump chamber and discharging fluid from the pump chamber by changing a volume of the pump chamber by action of a piezoelectric actuator. The piezoelectric pump includes a casing having inlet and outlet flow channels both communicating with the pump chamber, and first and second check valve units each having a thin-film check valve membrane and a check valve body having a channel opened and closed by the check valve membrane. The first and second check valve units are disposed between the pump chamber and the inlet and outlet flow channels, respectively.

[0011] This configuration makes it possible to easily manufacture a compact pump and improve the pump efficiency.

[0012] The check valve function of the check valve units can also be confirmed before installation to the casing, thereby improving pump reliability and improving pump manufacturing yield. Furthermore, if a check valve becomes damaged from extended use, this configuration enables replacing only the damaged check valve unit.

[0013] The diaphragm is preferably made up of a piezoelectric actuator and a thin metal plate joined together and is mounted to the casing, forming a pump chamber between the diaphragm and casing. This makes it possible to reduce the volume of fluid from the pump chamber to the check valve membrane, and increases the pressure inside the pump chamber during discharge, as compared with conventional pumps. High pressure fluid discharge is thus possible, and pump efficiency improves.

[0014] Further preferably, the first and second check valve units are identically configured and installed to the casing in inverse positions. Identical check valve units can therefore be used on both suction and discharge sides, and production cost can therefore be reduced.

[0015] Further preferably, the check valve units are installed to the casing from the side opposite the diaphragm side, making it possible to replace the check valve unit without removing the diaphragm.

[0016] The diaphragm is easily damaged by external force. However, if the casing part to which the diaphragm is disposed and the casing part to which the check valve units are installed are separate parts, the part to which the diaphragm is joined and the part to which the check

valve units are fit can be separated, making it easier to replace the diaphragm and easier to replace the check valve units. Furthermore, because the same check valve unit can be used with different diaphragms, it is easy to determine how pump characteristics change when the diaphragm is changed.

[0017] Further preferably, a fitting structure is used at least between the casing and check valve units or between the discrete casing parts, and this fitting structure is preferably an interference fitting assembled by press fitting. This makes it simple to separate the casing and check valve unit (or the casing parts) when replacing a check valve unit (or a diaphragm). An interference fitting also makes it easy to secure the check valve unit (or casing part) in the casing (or other casing part), airtightness is assured by interference fitting, and pump reliability can be improved.

[0018] The same benefits can be achieved using a transition fitting or clearance fitting completed with adhesion or welding.

[0019] It is also possible to form screw threads on the fitting surfaces so that the casing and check valve units, or the casing parts, are screwed together. The parts can thus be easily fastened together or separated.

[0020] If the check valve membrane is disposed covering the channel in the check valve body and the check valve membrane is joined to the check valve body, a check valve membrane of the smallest necessary size can be used and the yield of the thin film material used for the check valve membrane can be improved.

[0021] If the check valve membrane having one or more vents formed therein is disposed covering the channel in the check valve body, and the check valve membrane around the vent containing the channel is joined to the check valve body, the size of the thin film can be freely set, handling is easier during assembly, and welding is also easier.

[0022] If the vents are formed at positions on opposite sides of the channel, a check valve that operates reliably and has an extremely simple configuration can be provided, and high precision positioning is not needed for the check valve membrane.

[0023] If a single vent parallel to a tangent to the outside circumference of the channel is formed at a position removed from the channel, leaks cannot easily occur. If a plurality of vents each parallel to a tangent to the outside circumference of the channel are formed circumferentially to the channel at positions removed therefrom, the check valve membrane is prevented from wrinkling.

[0024] Furthermore, if the shape of a vent formed in the check valve membrane is a continuous curve, damage to the check valve membrane due to tension is prevented.

[0025] Yet further, if the check valve membrane is disposed covering the channel and two sides on opposite sides of the channel are joined to the check valve body, a check valve can be formed with a simple configuration and high precision positioning is not needed for the check valve membrane.

[0026] If a check valve membrane having one openable side is disposed covering the channel and is joined to the check valve body surrounding the channel except on the one openable side, a check valve function can be achieved with a simple configuration and leaks cannot occur easily.

[0027] If the check valve membrane is disposed covering the channel, the check valve membrane is joined in spots around the circumference of the channel to the check valve body, and intervals between the joined spots function as vents, and therefore the spots where the check valve membrane is joined to the check valve body will be concentric to the channel and wrinkles will not easily occur in the check valve membrane.

[0028] If a polygonally shaped check valve membrane is placed covering the channel and each corner of the polygon is joined to the check valve body, the spots where the check valve membrane is joined to the check valve body will be concentric to the channel. Wrinkles will therefore not easily occur in the check valve membrane, and the edges of the check valve membrane will not curl because the sides that open are straight.

[0029] Furthermore, if the check valve membrane has a flap formed by removing a part of a thin film, and the check valve membrane is joined to the check valve body around the flap, a check valve unit with a simple configuration not requiring high precision positioning of the check valve membrane can be provided. Furthermore, because the channel is opened and closed by the flexural modulus of the thin film, pressure loss due to the tension of the thin film can be reduced.

[0030] Furthermore, if the channel opened and closed by the flap is formed from a plurality of openings separated a specific interval and a support part for supporting the flap is formed in a center of the plurality of openings, fluid leaks resulting from the thin film being pulled into the channel can be prevented, and the pressure inside the pump can be further increased.

[0031] If the check valve membrane is formed into a rectangular strip and is joined on only one side perpendicular to a long side to the check valve body, a check valve unit with a simple configuration not requiring high precision positioning of the check valve membrane can be provided. In addition, the channel can be opened and closed by the flexural modulus of the thin film, and pressure loss due to the tension of the thin film can be reduced.

[0032] If the check valve body is formed with first and second spacers, the first and second spacers have a fitting structure, and the check valve membrane is inserted between and joined to the first and second spacers when they are fit together, the check valve membrane can be easily fixed in place by an interference fitting, for example.

[0033] If the first and second spacers are adhesively bonded, air leaks can be eliminated.

[0034] Furthermore, if the check valve membrane and

check valve body are welded together, the check valve membrane can be reliably joined to the check valve body by welding.

[0035] If the check valve body is formed with first and second spacers, the check valve membrane is disposed between the first and second spacers, and the first and second spacers and check valve membrane are welded together, welding damage to the check valve membrane is prevented because three layers are welded.

[0036] A manufacturing method for a pump according to another aspect of the invention includes: forming a vent in a check valve membrane made of a thin film; forming a channel in a check valve body; placing the check valve membrane so as to cover the channel; joining the check valve membrane around the vent to the check valve body to form a check valve unit in which the channel is opened and closed by the check valve membrane due to a pressure differential; and installing the check valve unit in a casing.

[0037] Vents can thus be easily formed in the thin film, and high precision positioning is not needed when welding.

[0038] The vents can be formed in the check valve membrane after check valve unit is assembled. This completely eliminates any need for positioning the check valve membrane for joining to the check valve body. The vents can also be formed at appropriate positions after the check valve membrane is fixed.

[0039] If the vents in the thin film are formed with an excimer laser, wrinkles are not formed by process heat, the thin film can be precision processed, and there is little likelihood of damage (laser marks) being left on the check valve body from post-processing.

[0040] Another manufacturing method for a pump according to the present invention includes: forming a channel in a check valve body; placing a check valve membrane so as to cover the channel; joining the check valve membrane to the check valve body around the channel; forming a vent in the check valve membrane at a position between a joint and the channel to form a check valve unit in which the channel is opened and closed by the check valve membrane due to a pressure differential; and installing the check valve unit in a casing.

[0041] This method holds the check valve membrane and the check valve body tight together while welding them together, and thus improves airtightness.

[0042] Furthermore, if an iris having an aperture is used for laser welding to simultaneously weld specific parts of the check valve membrane to the check valve body, the effects of welding heat can be further lessened.

BRIEF DESCRIPTION OF THE DRAWINGS

[0043] The above and other objectives and features of the present invention will become more apparent from the following description of preferred embodiments thereof with reference to the accompanying drawings, throughout which like parts are designated by like reference numerals, and wherein:

Fig. 1 is a perspective view of a diaphragm pump according to a first embodiment of the present invention;
Fig. 2 is an exploded perspective view of the pump shown in Fig. 1;
Fig. 3 is an exploded perspective view of a check valve unit disposed in the pump shown in Fig. 1;
Fig. 4A is a sectional view showing the suction operation of the check valve unit shown in Fig. 3;
Fig. 4B is a sectional view showing the discharge operation of the check valve unit shown in Fig. 3;
Fig. 5A is a perspective view of a check valve unit in a diaphragm pump according to a second preferred embodiment of the present invention;
Fig. 5B is a sectional view of the diaphragm pump having the check valve unit shown in Fig. 5A;
Fig. 6A is a perspective view of a check valve unit in a diaphragm pump according to a third preferred embodiment of the present invention;
Fig. 6B is a sectional view of the diaphragm pump having the check valve unit shown in Fig. 6A;
Fig. 7A is an exploded perspective view of a diaphragm pump according to a fourth preferred embodiment of the present invention;
Fig. 7B is a sectional view of the diaphragm pump shown in Fig. 7A;
Fig. 8 is a perspective view as viewed from the back of an assembled diaphragm pump according to a modification of the pump shown in Fig. 7A;
Fig. 9 is a perspective view of a check valve membrane disposed in a check valve unit according to the present invention;
Fig. 10A is a perspective view of the check valve membrane shown in Fig. 9 when open;
Fig. 10B is a sectional view of the check valve membrane shown in Fig. 9 when open;
Fig. 11A is a perspective view of the check valve membrane shown in Fig. 9 when closed;
Fig. 11B is a sectional view of the check valve membrane shown in Fig. 9 when closed;
Fig. 12 is a perspective view of an alternative check valve membrane;
Fig. 13A is a perspective view of the check valve membrane shown in Fig. 12 when open;
Fig. 13B is a sectional view of the check valve membrane shown in Fig. 12 when open;
Fig. 14A is a perspective view of the check valve membrane shown in Fig. 12 when closed;
Fig. 14B is a sectional view of the check valve membrane shown in Fig. 12 when closed;
Fig. 15A is a perspective view of another alternative check valve membrane;
Fig. 15B is a perspective view of the check valve membrane shown in Fig. 15A when open;
Fig. 16A is a perspective view of another alternative check valve membrane;

Fig. 16B is a perspective view of the check valve membrane shown in Fig. 16A when open;
Fig. 17A is a perspective view of another alternative check valve membrane;
Fig. 17B is a perspective view of the check valve membrane shown in Fig. 17A when open;
Fig. 18 is a perspective view of another alternative check valve membrane;
Fig. 19A is a perspective view of the check valve membrane shown in Fig. 18 when open;
Fig. 19B is a sectional view of the check valve membrane shown in Fig. 18 when open;
Fig. 20A is a perspective view of the check valve membrane shown in Fig. 18 when closed;
Fig. 20B is a sectional view of the check valve membrane shown in Fig. 18 when closed;
Fig. 21 is a perspective view of another alternative check valve membrane;
Fig. 22A is a perspective view of the check valve membrane shown in Fig. 21 when open;
Fig. 22B is a sectional view of the check valve membrane shown in Fig. 21 when open;
Fig: 23A is a perspective view of the check valve membrane shown in Fig. 21 when closed;
Fig. 23B is a sectional view of the check valve membrane shown in Fig. 21 when closed;
Fig. 24 is a perspective view of another alternative check valve membrane;
Fig. 25A is a perspective view of the check valve membrane shown in Fig. 24 when open;
Fig. 25B is a sectional view of the check valve membrane shown in Fig. 24 when open;
Fig. 26A is a perspective view of the check valve membrane shown in Fig. 24 when closed;
Fig. 26B is a sectional view of the check valve membrane shown in Fig. 24 when closed;
Fig. 27A is a perspective view of another alternative check valve membrane;
Fig. 27B is a perspective view of the check valve membrane shown in Fig. 27A when open;
Fig. 28A is a perspective view of a channel with a configuration different from that shown in Fig. 27A;
Fig. 28B is a perspective view of the check valve membrane shown in Fig. 28A when open;
Fig. 29A is a perspective view of another alternative check valve membrane;
Fig. 29B is a perspective view of the check valve membrane shown in Fig. 29A when open;
Fig. 30 is an exploded perspective view of a check valve unit;
Fig. 31 is a perspective view of the check valve unit shown in Fig. 30;
Fig. 32 is a sectional view of the check valve unit shown in Fig. 30;
Fig. 33 is an exploded perspective view of another check valve unit;
Fig. 34 is a perspective view of the check valve unit shown in Fig. 33;
Fig. 35 is a sectional view of the check valve unit shown in Fig. 33;
Fig. 36 is an exploded perspective view of another check valve unit;
Fig. 37 is a perspective view of the check valve unit shown in Fig. 36;
Fig. 38 is a sectional view of the check valve unit shown in Fig. 36;
Fig. 39 is a perspective view showing the formation of vents in the check valve membrane after the check valve unit is assembled;
Fig. 40 is a perspective view of the check valve unit before the check valve membrane is welded;
Fig. 41 is a perspective view of the check valve unit when the check valve membrane is welded;
Fig. 42 is a perspective view showing welding of the check valve membrane using a laser device;
Fig. 43A is a perspective view showing a preferred embodiment of a diaphragm pump according to the present invention;
Fig. 43B is an exploded perspective view of the diaphragm pump shown in Fig. 42A;
Fig. 43C is an exploded perspective view of a check valve unit disposed in the diaphragm pump shown in Fig. 43A;
Fig. 44A is a perspective view showing an example of the check valve unit shown in Fig. 43C;
Fig. 44B is a partial perspective view of the check valve unit shown in Fig. 44A;
Fig. 44C is a perspective view showing the check valve membrane in the check valve unit shown in Fig. 43C when open;
Fig. 45A is a perspective view showing welding of the check valve membrane to the check valve unit using a YAG laser;
Fig. 45B is a perspective view showing the formation of vents in the check valve membrane using an excimer laser;
Fig. 46 is an exploded perspective view of a prior art diaphragm pump; and
Fig. 47 is a partial sectional view of the prior art diaphragm pump shown in Fig. 46.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0044] This application is based on an application No. 2001-125904 filed April 24, 2001 in Japan, the content of which is herein expressly incorporated by reference in its entirety.

[0045] Preferred embodiments of the present invention are described below with reference to the accompanying drawings.

Embodiment 1

[0046] Figs. 1 to 3 and Figs. 4A and 4B show a diaphragm pump having a disc-shaped diaphragm 12, a

disc-shaped casing 9, and a pair of check valve units 8. The diaphragm 12 is disposed on top of the casing 9 with the edges of the diaphragm 12 welded or adhesively bonded to the top of the casing 9, thereby forming a pump chamber 1 between the diaphragm 12 and casing 9.

[0047] The outside diameter A of the diaphragm 12 in this exemplary pump is 20 mm, the outside diameter B of the casing 9 is 22 mm, and the height C is 3 mm.

[0048] An inlet channel 2 for suction into the pump chamber 1 and an outlet channel 3 for discharge from the pump chamber 1 are formed in the casing 9 through the thickness direction of the casing 9. Check valve housings 18 are formed between the pump chamber 1 and the inlet and outlet channels 2, 3. The check valve units 8 are housed in these check valve housings 18. Each check valve unit 8 has a check valve membrane 5, which is a thin film with elasticity, and a check valve body 7, which has a channel 6 opened and closed by the check valve membrane 5 according to the pressure differential between respective sides thereof. Channel 6 passes completely through the check valve body 7, and channels 2, 3 communicate with the pump chamber 1 through channels 6.

[0049] The check valve body 7 has a first spacer 7a and a second spacer 7b. The check valve membrane 5 is located between the first spacer 7a and second spacer 7b so as to block the channel 6, and the check valve membrane 5 is disposed in the check valve body 7 by integrating the check valve membrane 5 with the first spacer 7a and second spacer 7b.

[0050] The check valve unit 8 on the inlet channel 2 side displaces upward and opens when pressure is applied from the inlet channel 2 to the pump chamber 1, and a space 19 large enough for the check valve membrane 5 to so displace is disposed in the first.spacer 7a on the pump chamber 1 side.

[0051] The check valve unit 8 on the outlet channel 3 side displaces downward and opens when pressure is applied from the pump chamber 1 to the outlet channel 3 side, and a space 19 large enough for the check valve membrane 5 to so displace is disposed in the second spacer 7b on the side away from the pump chamber 1.

[0052] When the diaphragm 12 is vibrated by the piezoelectric actuator or other drive means, vibration of diaphragm 12 causes suction of fluid from the inlet channel 2 to the pump chamber 1, and causes the fluid compressed inside the pump chamber 1 to then be discharged from the outlet channel 3. During suction phase the diaphragm 12 is driven to separate from the casing 9 as shown in Fig. 4A and fluid can be suctioned from the inlet channel 2 into the pump chamber 1 because the check valve membrane 5 communicating with the inlet channel 2 opens while the check valve membrane 5 communicating with the outlet channel 3 closes. Similarly during the discharge phase, the diaphragm 12 is driven in the direction closing to the casing 9 as shown in Fig. 4B, but this time the check valve membrane 5 communicating with the inlet channel 2 closes and the check valve membrane 5 communicating with the outlet channel 3 opens so that fluid can be discharged from the pump chamber 1 to the outlet channel 3.

[0053] By constructing the check valve unit 8 separately from the casing 9 as described above, the check valve unit 8 can be installed to the casing 9 after first confirming that the check valve unit 8 functions properly, and pump production yield can therefore be improved. Furthermore, if a check valve becomes damaged with extended use, for example, it is possible to replace just the damaged check valve unit 8.

[0054] The diaphragm 12 is made up of a piezoelectric actuator 10 and a brass or other thin metal plate 11. The piezoelectric actuator 10 is a PZT element or other piezoelectric element with silver or other metallic conductor electrodes. When a voltage such as a commercial AC voltage is applied to the piezoelectric actuator 10, the diaphragm 12 is reciprocally driven by the piezoelectric actuator 10 and a pumping action is achieved.

[0055] The first and second spacers 7a, 7b and the check valve membrane 5 of the check valve body 7 are made, for example, from polycarbonate (PC) resin, and the casing 9 is made of polyphthalamide (PPA), for example.

[0056] The distance from the top of the casing 9, which is the bottom of the pump chamber 1, to the check valve membrane 5 is shorter, and the volume of the channels from the pump chamber 1 to both check valve membranes 5 when fluid is ingested to the pump chamber 1 is less in this embodiment than in the related art described above. If V is the volume of the channels from the pump chamber 1 to both check valve membranes 5 when fluid is ingested to the pump chamber 1, ΔV is the discharge volume, that is, the volume discharged for this V, and ΔP is the internal pressure rise from the initial pressure P, $\Delta P = \Delta V/(V-\Delta V) \times P$, and ΔP is increased by reducing V.

Embodiment 2

[0057] Fig. 5A and Fig. 5B show a different embodiment in which the fluid suction side check valve unit 8 and fluid discharge side check valve unit 8 are identically constructed, and are simply installed to the casing 9 in different directions on the suction and discharge sides.

[0058] As in the first embodiment the check valve body 7 has a first spacer 7a and second spacer 7b, but in this embodiment the first spacer 7a and second spacer 7b have the same thickness and outside diameter. A check valve membrane 5 is disposed between the first spacer 7a and second spacer 7b, and a space 19 of a diameter large enough for the check valve membrane 5 to displace is disposed in the first spacer 7a. The suction-side check valve unit 8 is installed so that the first spacer 7a is on the pump chamber 1 side, and the discharge-side check valve unit 8 is installed so that the second spacer 7b is on the pump chamber 1 side.

[0059] Production cost is reduced with this embodiment because the same check valve unit 8 can be used

on both the suction and discharge sides.

Embodiment 3

[0060] Fig. 6A and Fig. 6B show a different embodiment in which the check valve units 8 are housed to the casing 9 from the side opposite the diaphragm 12 side.

[0061] As shown in Fig. 6A and Fig. 6B, the check valve body 7 has a first spacer 7a, second spacer 7b, and third spacer 7c. Similarly to the first spacer 7a and second spacer 7b, this third spacer 7c is made of polycarbonate resin.

[0062] A check valve membrane 5 is again disposed between the first spacer 7a and second spacer 7b, but the space 19 for check valve membrane 5 displacement is disposed to the first spacer 7a in the suction-side check valve unit 8 and is disposed to the second spacer 7b in the discharge-side check valve unit 8.

[0063] By thus inserting the check valve units 8 to the check valve housings 18 in the casing 9 from the side of the casing 9 opposite the diaphragm 12, this embodiment enables the check valve units 8 to be replaced without removing the diaphragm 12.

Embodiment 4

[0064] Fig. 7A and Fig. 7B show an embodiment in which the casing part 9a to which the diaphragm 12 is disposed and the casing part 9b to which the check valve units 8 are disposed are separate components.

[0065] As shown in Fig. 7A and Fig. 7B, the disc-shaped casing 9 is formed from a casing part 9a and a separate casing part 9b. The one casing part 9a is annularly shaped with a hole 20 in the center. The other casing part 9b is disc-shaped with a protrusion 21 on top. The protrusion 21 of this casing part 9b is fit to the hole 20 in casing part 9a to integrate casing part 9a and casing part 9b. The diaphragm 12 is disposed on top of casing part 9a and integrated with the casing part 9a by bonding the edge of the diaphragm 12 to the top of the casing part 9a. The check valve units 8 are installed to casing part 9b.

[0066] While the diaphragm 12 is susceptible to damage from external forces with this configuration, the part to which the diaphragm 12 is disposed can be separated from the part to which the check valve units 8 are disposed, and the diaphragm 12 and check valve units 8 can therefore be easily replaced. Furthermore, because the same set of check valve units 8 can be used when the diaphragm 12 is replaced, pump characteristics can be easily evaluated after the diaphragm 12 is exchanged.

[0067] Installing the check valve units 8 to the casing 9, and assembling the two casing parts 9a, 9b, are described next.

[0068] An integrated casing 9 is assembled by interference fitting the protrusion 21 of casing part 9b into the hole 20 in casing part 9a. The check valve units 8 can also be installed by interference fitting them into the check valve housings 18 in the casing part 9b. If the inside diameter of the hole 20 and the outside diameter of the protrusion 21 are both nominally 16 mm, the protrusion 21 can be interference fit in the hole 20 by forming the hole 20 with a tolerance of +0.018 mm to 0 mm and the protrusion 21 with a tolerance of +0.029 mm to +0.018 mm.

[0069] By interference fitting components together as described above, the check valve unit 8 and casing 9 (or casing part 9a and casing part 9b) can be easily separated in order to replace a check valve unit 8 (or diaphragm 12). Furthermore, the tolerances of the interference fitting makes it easy to secure the check valve units 8 (or casing part 9b) in the casing 9 (or casing part 9a), and airtightness can be assured by press fitting.

[0070] The process tolerances between the casing 9 and check valve units 8, or between the separate casing parts 9a and 9b can be set for transition fitting or clearance fitting with the fitting then secured by adhesive bonding or welding.

[0071] For example, if the inside diameter of the hole 20 and the outside diameter of the protrusion 21 are both nominally 16 mm and the tolerance of the hole 20 is +0.018 mm to 0 mm and the tolerance of protrusion 21 is 0 mm to -0.018 mm, the casing part 9a and casing part 9b can be fastened by bonding or welding after they are fit together. Fig. 8 shows an example in which the casing part 9a and casing part 9b are bonded together with adhesive. Reference numeral 22 in Fig. 8 shows where the adhesive is applied.

[0072] It is therefore possible as described above to reliably assure airtightness between the casing 9 and check valve units 8 (or between casing part 9a and casing part 9b) by thus adhesively bonding or welding them.

[0073] It is also possible to form female threads and male threads on the inside circumference of the hole 20 in casing part 9a and the outside circumference of the protrusion 21 on casing part 9b so that one can be screwed into the other for fastening. Female threads and male threads can likewise be formed on the inside circumference of the check valve housings 18 in casing part 9b and the outside circumference of the check valve units 8 so that these can be similarly screwed together and fastened.

[0074] It will also be noted that by threading the check valve units 8 to the casing 9 or casing part 9b to casing part 9a, the parts can be easily connected and disconnected.

(Various embodiments of the check valve membrane)

[0075] A check valve membrane 5 is used as the member achieving the check valve function in the first to fourth embodiments described above, and various embodiments of the check valve membrane 5 are described next below.

[0076] Fig. 9 shows the part where the check valve membrane 5 is installed to the check valve unit 8 shown

in Fig. 5A. The thin-film check valve membrane 5 is formed as a rectangular band and is disposed across so as to cover the channel 6. With the check valve membrane 5 thus covering the channel 6, the check valve membrane 5 is bonded with adhesive 14 on opposite sides of the channel 6 perpendicular to the longitudinal direction of the check valve membrane 5.

[0077] When the check valve unit 8 is open, the long sides of the check valve membrane 5 are lifted as shown in Fig. 10A and Fig. 10B. When the check valve unit 8 is closed, the channel 6 is closed by the check valve membrane 5 as shown in Fig. 11A and Fig. 11B.

[0078] By thus using a band-shaped check valve membrane 5 the check valve membrane 5 can be made of the smallest piece of thin film necessary as a check valve, and less thin film material is therefore required.

[0079] Fig. 12 shows a variation in which two parallel slitted vents 13 are formed in the check valve membrane 5 disposed so as to cover the channel 6. The check valve membrane 5 is then bonded with adhesive 14 around the vents 13 containing channel 6.

[0080] Fig. 13A and Fig. 13B show the vents 13 in the check valve membrane 5 shown in Fig. 12 when open, and Fig. 14A and Fig. 14B show the channel 6 closed by the check valve membrane 5.

[0081] The size of the check valve membrane 5 can be freely determined with this embodiment so that handling during assembly is easier and welding is also easier.

[0082] Fig. 15A and Fig. 15B show a rectangular thin film check valve membrane 5 placed covering the channel 6. A pair of parallel slitted vents 13 is formed in the check valve membrane 5 on opposite sides of the channel 6, and the check valve membrane 5 is bonded with adhesive 14 completely encircling the vents 13.

[0083] As shown in Fig. 15B, the check valve membrane 5 lifts up so that a horizontal semi-cylinder is formed between the two vents 13 when the vents 13 of the check valve membrane 5 open.

[0084] This embodiment assures that the check valve operates reliably with a simple configuration, and does not require high precision positioning of the check valve membrane 5.

[0085] It is also possible as shown in Fig. 16A to form a single slitted vent 13 in the check valve membrane 5 at a point separated from the channel 6. This vent 13 extends parallel to a tangent to the outside circumference of the channel 6, and the check valve membrane 5 is fixed to the check valve body 7 with adhesive 14 completely encircling the vent 13.

[0086] When the vent 13 of this check valve membrane 5 opens, the check valve membrane 5 is displaced upward from the vent 13 in the check valve membrane 5 across the channel 6 as shown in Fig. 16B.

[0087] This configuration is resistant to leaks even when the distance from the channel 6 to the opening of the vent 13 is short.

[0088] Multiple vents 13 can also be formed in the check valve membrane 5 as shown in Fig. 17A. More specifically, the rectangular thin film check valve membrane 5 is placed so as to cover the channel 6, and multiple (three in this example) slitted vents 13 parallel to tangents to the outside circumference of the channel 6 are formed at positions apart from the outside circumference of the channel 6 and circumferentially to the channel 6. The check valve membrane 5 is fixed with adhesive 14 completely encircling the vents 13.

[0089] Fig. 17B shows the vents 13 of this check valve membrane 5 when open.

[0090] Wrinkles do not easily form in the check valve membrane 5 because the vents 13 are formed equidistantly in the circumferential direction to the channel 6 and the adhesive 14 is located on a circle centered on the channel 6.

[0091] The corners of the vents 13 in the check valve membrane 5 must be curved. If the vents 13 have sharp corners such as in a square, the corners can tear easily when tension is applied to the check valve membrane 5. If the corners of the vents 13 are round or nearly round, however, tension tears in the check valve membrane 5 can be prevented. More specifically, the vents formed in the check valve membrane are preferably continuous curves.

[0092] Fig. 18 shows an embodiment in which the rectangular thin film check valve membrane 5 is placed so as to cover the channel 6 with an openable side of the check valve membrane 5 proximal to the channel 6. The check valve membrane 5 is then fixed with a U-shaped adhesive bead 14 encircling the channel 6 except on this one openable side.

[0093] This check valve membrane 5 opens on only one side as shown in Fig. 19A and Fig. 19B, and the channel 6 is closed by the check valve membrane 5 as shown in Fig. 20A and Fig. 20B.

[0094] This embodiment provides a check valve with a very simple configuration, and leaks cannot occur easily.

[0095] As shown in Fig. 21 it is also possible to place the check valve membrane 5 covering the channel 6 and spot bond the check valve membrane 5 around the channel 6 with adhesive bead 14 so that the spaces between the adhesive beads 14 function as vents. In the example shown in Fig. 21 note that the three adhesive spots are spaced at equal intervals in the circumferential direction around the check valve membrane 5.

[0096] This check valve membrane 5 opens on three sides except the adhesive spots as shown in Fig. 22A and Fig. 22B, and the channel 6 is closed by the check valve membrane 5 as shown in Fig. 23A and Fig. 23B.

[0097] Wrinkles do not occur easily with this check valve membrane 5 because the adhesive bead 14 is in a circumference around the channel 6.

[0098] As shown in Fig. 24, the check valve membrane 5 could yet further alternatively be substantially polygonal in shape, covering the channel 6 with adhesive bead 14 placed at each corner of the membrane. The spaces between the adhesive beads 14 become vents in this case.

[0099] In the example shown in Fig. 24 the thin film check valve membrane 5 is shaped as a triangle as an example of one polygon. As shown in Fig. 25A and Fig. 25B, the check valve opens when the three straight sides of the check valve membrane 5 balloon up, and the channel 6 is closed when the check valve membrane 5 settles down as shown in Fig. 26A and Fig. 26B.

[0100] The adhesive beads 14 of this check valve membrane 5 are also located concentrically to the channel 6, thus preventing wrinkles in the check valve membrane 5. Because they are straight, the opening edges of the check valve membrane 5 also do not curl up.

[0101] As shown in Fig. 27A, a flap 5b can be formed in the check valve membrane 5 by arcuatedly cutting the thin film. The check valve membrane 5 is then placed with the flap 5b covering the channel 6, and is bonded with adhesive 14 encircling the channel 6 and the cut-out part 5a. The substantially semicircular flap 5b inside the cut-out part 5a thus functions as a valve membrane.

[0102] With this check valve membrane 5 the flap 5b functions as the valving element and flaps up and down to open and close the channel 6 as shown in Fig. 27B.

[0103] This variation of the check valve membrane 5 is extremely simple, does not require high precision positioning, and reduces pressure loss due to the tension of the valve membrane because it opens and closes the channel 6 using the flexural modulus of the valve membrane.

[0104] As shown in Fig. 28A and Fig. 28B, the channel 6 in this case preferably has plural (three in this example) equidistantly spaced arc-shaped openings 6a with a support 6b for supporting the flap 5b in the center of the plural openings 6a.

[0105] When the channel 6 is shaped as shown in Fig. 27 and the flap 5b (valving element) closes, the center of the flap 5b occluding the channel 6 is pulled down into the channel 6. When a support 6b positioned at the center of the flap 5b is provided as shown in Fig. 28A and Fig. 28B, however, the center of the flap 5b is not pulled into the channel 6 when the flap 5b closes. This check valve membrane 5 configuration is therefore more resistant to fluid leaks and enables an even higher pressure to be used.

[0106] It will also be obvious that the shape of the openings 6a shall not be limited to an arc, and could be circular, elliptical, or other shape.

[0107] It will also be noted that the configuration of the channel 6 shown in Fig. 28A and Fig. 28B can also be applied to the other check valve membranes 5 described above.

[0108] As shown in Fig. 29A, the thin film check valve membrane 5 could also have a band (rectangular) shape placed covering the channel 6 and then bonded with adhesive 14 perpendicular to the long side at only one end of the check valve membrane 5.

[0109] The rectangular flap 5b thus disposed over the channel 6 operates as the valving element in this configuration, and the channel 6 opens and closes as the flap 5b moves up and down as shown in Fig. 29B.

[0110] This variation of the check valve membrane 5 is also extremely simple, does not require high precision positioning, and reduces pressure loss due to valve membrane tension because it opens and closes the channel 6 using the flexural modulus of the valve membrane.

(Various embodiments of the check valve unit)

[0111] The check valve body 7 shown in Fig. 30 to Fig. 32 is formed by first and second spacers 7a, 7b. The check valve membrane 5 is inserted between the first and second spacers 7a, 7b, which are fit together to fix the check valve membrane 5. The vents of the check valve membrane 5 can be as in any of the variations described above, and further description thereof is thus omitted here.

[0112] If the nominal inside diameter of the fitting recess in the first spacer 7a and the outside diameter of the fitting protrusion of the second spacer 7b is 4 mm and the thickness of the check valve membrane 5 is 0.002 mm, the inside diameter tolerance of the recess in the first spacer 7a is +0.02 mm to +0.01 mm, and the outside diameter tolerance of the second spacer 7b protrusion is -0.01 mm to -0.02 mm, the first and second spacers 7a, 7b can be easily joined by interference fitting.

[0113] It will also be obvious that instead of interference fitting the check valve membrane 5 could be disposed between the first spacer 7a and second spacer 7b and the entire perimeters of the first spacer 7a and second spacer 7b are then bonded.

[0114] As shown in Fig. 33 to Fig. 35, the check valve membrane 5 can alternatively be reliably joined to the check valve body 7 by placing the thin film check valve membrane 5 on top of the check valve body 7 and then welding the check valve membrane 5 around the outside edge of the check valve body 7 with a welding bead 25 as shown in Fig. 34 and Fig. 35.

[0115] It is yet further possible, as shown in Fig. 36 to Fig. 38, to form the check valve body 7 with a first spacer 7a and second spacer 7b, dispose the thin film check valve membrane 5 between the first spacer 7a and second spacer 7b, and weld the first spacer 7a, second spacer 7b, and check valve membrane 5 around the entire outside perimeter. Welding damage to the check valve membrane 5 is less likely with this method because the three layers are welded at a time.

(Manufacture of piezoelectric pump)

[0116] A piezoelectric pump according to the present invention can be easily manufactured as follows. One or more vents 13 are first formed in the thin film, or the check valve membrane 5 is formed by processing a thin film to the desired configuration. The channel 6 that will be opened and closed by the check valve membrane 5 is also formed in the check valve body 7. The check valve

membrane 5 is then placed covering the channel 6 and joined to the check valve body 7 by various methods such as described above to form the check valve unit 8. The check valve unit 8 is then installed to the casing 9 between the pump chamber 1 and inlet and outlet channels 2, 3. The one or more vents 13 can thus be easily formed in a thin film.

[0117] The vents 13 can also be formed in the check valve membrane 5 after joining the check valve membrane 5 and check valve body 7 to form the check valve unit 8. This method completely eliminates the need to position the check valve membrane 5 for installation, and enables the vents 13 to be formed appropriately to the desired locations.

[0118] The vents 13 can be formed in a thin film 4 (blank of the check valve membrane 5) using an excimer laser as shown in Fig. 39.

[0119] When the check valve body 7 is formed with a first spacer 7a and second spacer 7b as shown in Fig. 39 and an excimer laser or other laser is used, the first spacer 7a is preferably made of a transparent polycarbonate resin and the second spacer 7b is made of a black polycarbonate resin, for example. Before the vent 13 is formed in this example the thin film 4 is disposed between the first spacer 7a and second spacer 7b, joined with adhesive 14, and the check valve unit 8 is assembled. A laser beam 27 is then emitted from the laser device 28 to form a vent 13.

[0120] Wrinkles caused by process heat do not occur and the thin film 4 can be precision processed by thus using an excimer laser or other type of laser to form the vents 13. Damage (laser marks) from post-processing to the check valve body 7 is also less likely to occur.

[0121] Alternatively, a check valve membrane made of a flexible thin film 4 is placed on the check valve body 7 covering the channel 6 as shown in Fig. 40. A glass plate 16 is then placed over the thin film 4 as shown in Fig. 41 to press the thin film 4 to the check valve body 7 while emitting a laser to form a weld 25.

[0122] By thus holding the thin film 4 tight to the check valve body 7 while welding the thin film 4 to the check valve body 7, the thin film 4 can be reliably welded without producing any wrinkles, and airtightness can be improved.

[0123] When welding with a laser, an iris 17 with a specific aperture or other opening can be used as shown in Fig. 42 to simultaneously emit the laser beam 27 to a specific place and thereby integrally bond the first spacer 7a, thin film 4, and second spacer 7b. In the example shown in Fig. 42 two irises 17 each with a specific aperture are installed stacked together in the laser device 28, and the laser beam 27 is emitted simultaneously to a specific circle around the first spacer 7a, thin film 4, and second spacer 7b, thus a weld 25 is formed. A YAG laser is used for the laser device 28 in this example, and sample laser emission conditions are shown in Table 1.

Table 1

	Acrylic	Polycarbonate
Power	0.56 J/shot	0.24 J/shot
Number of shots	5	5

[0124] When the entire perimeter is welded simultaneously, the effects of the welding heat can be lessened.

(Example)

[0125] A diaphragm pump according to the present invention can be manufactured as described below. Fig. 43A shows the assembled diaphragm pump, and Fig. 43B is an exploded perspective view of the diaphragm pump.

[0126] The drive voltage, drive frequency, maximum pressure, and flow of this diaphragm pump are as follow.

- Drive voltage: -100, 400 V
- Drive frequency: 100 Hz (square wave)
- Maximum pressure: 450 hPa
- Flow: 85 ml/min

[0127] This diaphragm pump is made up of a disc-shaped diaphragm 12, disc-shaped casing 9, and check valve units 8. The diaphragm 12 is placed on top of the casing 9 and the edge of the diaphragm 12 is bonded to the top of the casing 9 to form a pump chamber.

[0128] The casing 9 is formed from a casing part 9a and a separate casing part 9b. The one casing part 9a is annularly shaped with a hole 20 in the center. The other casing part 9b is disc-shaped with a protrusion 21 on top. The protrusion 21 of this casing part 9b is fit to the hole 20 in casing part 9a to integrate casing part 9a and casing part 9b. The diaphragm 12 is disposed on top of casing part 9a and integrated with the casing part 9a by bonding the edge of the diaphragm 12 to the top of the casing part 9a. Check valve housings 18 are formed in casing part 9b, and the check valve units 8 are installed to these check valve housings 18.

[0129] The check valve body 7 is made up of a first spacer 7a and second spacer 7b, which are disc shaped members identical in thickness and outside diameter. The first spacer 7a is made of a transparent polycarbonate resin, the second spacer 7b is made of a black polycarbonate resin, and the check valve membrane 5 is made of a transparent polycarbonate resin. The check valve unit 8 is assembled by placing the check valve membrane 5 between the first spacer 7a and second spacer 7b and then joining the first spacer 7a and second spacer 7b.

[0130] The diaphragm 12 is made of a thin metal plate 11 and piezoelectric actuator 10. The piezoelectric actuator 10 is a PZT element 20 mm in diameter and 0.25 mm thick. The thin metal plate 11 is preferably brass,

20.2 mm in diameter and 0.05 mm thick. Electrodes of the PZT element are silver and 18 mm in diameter.

[0131] The check valve membrane 5 is made of a polycarbonate film 0.002 mm thick. This check valve membrane 5 is disposed between the first spacer 7a and second spacer 7b of the check valve body 7, and the check valve unit 8 is assembled by integrally welding the check valve membrane 5, first spacer 7a, and second spacer 7b with a weld 25.

[0132] As shown in Fig. 44A, the height of the check valve unit 8 is 1.6 mm, the outside diameter of the check valve unit 8 is 5.5 mm, and the fitting tolerance is -0.004 mm to -0.012 mm, for example.

[0133] The diameter of the space 19 into which the check valve membrane 5 displaces is 2.8 mm as shown in Fig. 448, and the diameter of the channel 6 is 1 mm. The suction side and discharge side of this check valve unit 8 are identically configured, and the orientation of the check valve unit 8 is simply inverted on the suction and discharge sides.

[0134] Fig. 44C shows the operation of this check valve. The vents 13 are 1 mm long, the gap between the pair of vents 13 is 2 mm, and the vents 13 are 0.3 mm wide.

[0135] Casing part 9a of this casing 9 is made of PPA resin, and casing part 9b is made of transparent acrylic resin. The outside diameter of casing part 9a of casing 9 is 22 mm, the inside diameter is 13 mm, the fitting tolerance is +0.018 mm to 0 mm, for example, and the thickness is 1 mm. The outside diameter of casing part 9b of casing 9 is 15 mm and the thickness is 2 mm. The outside diameter of the protrusion 21 of casing part 9b is 13 mm, and the fitting tolerance is -0.006 mm to -0.017 mm, for example. The inside diameter of the check valve housing 18 is 5.5 mm, the fitting tolerance is +0.012 mm to 0 mm, for example, and the depth is 1.6 mm.

[0136] A YAG laser is used to integrally weld the first spacer 7a, second spacer 7b, and check valve membrane 5 with a weld 25, which as shown in Fig. 45A completely encircles the space 19. The vents 13 are formed using an excimer laser as shown In Fig. 45B.

Claims

1. A piezoelectric pump for sucking fluid to a pump chamber (1) and discharging fluid from the pump chamber (1) by changing a volume of the pump chamber (1) by action of a piezoelectric actuator (10), said piezoelectric pump comprising:

   a casing (9) having inlet and outlet flow channels (2, 3) both communicating with the pump chamber (1);
   first and second check valve units (8) each having a thin-film check valve membrane (5) and a check valve body (7) having a channel (6) opened and dosed by the check valve membrane (5);
   the casing (9) having first and second check valve housings (18) formed between the pump chamber (1) and the inlet and outlet flow channels (2, 3), respectively; **characterised in that** the first and second check valve units (8) are removably housed in the first and second check valve housing (18) respectively, so that each check valve unit (8) can be removed as one unit from the respective check valve housing (18).

2. The piezoelectric pump according to claim 1, further comprising a diaphragm (12) comprising a piezoelectric actuator (10) and a thin metal plate (11) joined together, wherein the diaphragm (12) is mounted to the casing (9) to form the pump chamber (1) between the diaphragm (12) and the casing (9).

3. The piezoelectric pump according to claim 1 or 2, wherein the first and second check valve units (8) are identically configured and installed to the casing (9) in inverse positions.

4. The piezoelectric pump according to one of the claims 1 to 3, wherein the first and second check valve units (8) are Installed to the casing (9) from a side opposite the diaphragm (12) side.

5. The piezoelectric pump according to one of the claims 1 to 4, wherein the casing (9) comprises a first casing part (9a) to which the diaphragm (12) is disposed and a second casing part (9b) that is separate from the first casing part (9a) and to which the first and second check valve units (8) are installed.

6. The piezoelectric pump according to claim 5, wherein a fitting structure is used at least between the casing (9) and the first and second check valve units (8) or between the first and second casing parts (9a, 9b), and the fitting structure is an interference fitting assembled by press fitting.

7. The piezoelectric pump according to claim 5, wherein a fitting structure is used at least between the casing (9) and the first and second check valve units (8) or between the first and second casing parts (9a, 9b), and the fitting structure is a transition fitting or clearance fitting completed with adhesion or welding.

8. The piezoelectric pump according to claim 5, wherein a fitting structure is used at least between the casing (9) and the first and second check valve units (8) or between the first and second casing parts (9a, 9b), and the fitting structure has screw threads formed therein for screw fitting.

9. The piezoelectric pump according to one of the

claims 1 to 8, wherein the check valve membrane (5) is positioned to cover the channel (6) in the check valve body, and the check valve membrane is joined to the check valve body (7).

10. The piezoelectric pump according to claim 9, wherein the check valve membrane (5) has at least one vent (13) formed therein and is disposed so as to cover the channel (6) in the check valve body (7), and the check valve membrane (5) around the vent (13) is joined to the check valve body (7).

11. The piezoelectric pump according to claim 10, wherein the check valve membrane (5) has two vents (13) formed at positions on opposite sides of the channel (6).

12. The piezoelectric pump according to claim 10, wherein the check valve membrane (5) has a single vent (13) parallel to a tangent to the outside circumference of the channel (6), the single vent (13) being formed at a position removed from the channel (6).

13. The piezoelectric pump according to claim 10, wherein the check valve membrane (5) has a plurality of vents (13) each parallel to a tangent to an outside circumference of the channel (6), the plurality of vents (13) being formed circumferentially to the channel (6) at positions removed therefrom.

14. The piezoelectric pump according to claim 10, wherein the vent (13) in the check valve membrane (5) is shaped Into a continuous curve.

15. The piezoelectric pump according to one of the claims 9 to 14, wherein the check valve membrane (5) is disposed so as to cover the channel (6), and two sides thereof on opposite sides of the channel (6) are joined to the check valve body (7).

16. The piezoelectric pump according to one of the claims 9 to 14, wherein the check valve membrane (5) has one openable side and is disposed so as to cover the channel (6), the check valve membrane (5) being joined to the check valve body (7) surrounding the channel (6) except on the one openable side.

17. The piezoelectric pump according to one of the claims 9 to 14, wherein the check valve membrane (5) is disposed so as to cover the channel (6) and joined in spots around the circumference of the channel (6) to the check valve body (7), and intervals between the joined spots are vents (13),

18. The piezoelectric pump according to claim 17, wherein the check valve membrane (5) is shaped into a polygon and placed so as to cover the channel (6), and each corner of the polygon is joined to the check valve body (7).

19. The piezoelectric pump according to one of the claims 9 to 18, wherein the check valve membrane (5) has a flap (5b) formed by removing a part of a thin film, and the check valve membrane (5) is joined to the check valve body (7) around the perimeter of the flap (5b).

20. The piezoelectric pump according to claim 19, wherein the channel (6) opened and closed by the flap (5b) is formed from a plurality of openings (6a) separated a specific interval, and a support part (6b) for supporting the flap (5b) is formed in a center of the plurality of openings (6a).

21. The piezoelectric pump according to claim 9, wherein the check valve membrane (5) is formed into a rectangular strip and is joined on only one side thereof perpendicular to a long side thereof to the check valve body (7).

22. The piezoelectric pump according to one of the claims 9 to 21, wherein the check valve body (7) is formed with first and second spacers (7a, 7b) having a fitting structure, and the check valve membrane (7) is inserted between and joined to the first and second spacers (7a, 7b).

23. The piezoelectric pump according to claim 22, wherein the first and second spacers (7a, 7b) are bonded.

24. The piezoelectric pump according to one of the claims 9 to 23, wherein the check valve membrane (5) and the check valve body (7) are welded together.

25. The piezoelectric pump according to one of the claims 9 to 21, wherein the check valve body (7) is formed with first and second spacers (7a, 7b), the check valve membrane (5) is disposed between the first and second spacers (7a, 7b), and the first and second spacers (7a, 7b) and the check valve membrane (5) are welded together.

26. A method of manufacturing a pump, comprising:

forming a channel (6) in a check valve body (7);
placing a check valve membrane (5) so as to cover the channel (6); joining the check valve membrane (5) to the check valve body (7) around the channel (6);
forming a vent (13) in the check valve membrane (5) at a position between a joint and the channel (6) to form a check valve unit (8) in which the channel (6) is opened and closed by the check valve membrane (5) due to a pressure differential;

installing the check valve unit (8) in a casing (9) and disposing a diaphragm (12) on the top of the casing (9) so as to cover the check valve unit (8).

27. The method according to claim 26, wherein the vent (13) in the thin film is formed with an excimer laser.

Revendications

1. Pompe piézoélectrique pour introduire par aspiration un fluide dans une chambre (1) de pompe et pour refouler du fluide depuis la chambre (1) de pompe en modifiant un volume de la chambre (1) de pompe sous l'action d'un actionneur piézoélectrique (10), ladite pompe piézoélectrique comprenant :

un carter (9) ayant des conduits d'écoulement d'entrée et de sortie (2, 3) communiquant tous deux avec la chambre (1) de pompe ;
un premier et un deuxième systèmes de clapets anti-retour (8) comportant chacun une membrane (5) de clapet anti-retour sous la forme d'un film mince et un corps (7) de clapet anti-retour possédant un conduit (6) ouvert et fermé par la membrane (5) du clapet anti-retour ;
le carter (9) ayant un premier et un deuxième logements (18) de clapet anti-retour formés entre la chambre (1) de pompe et respectivement les conduits d'écoulement d'entrée et de sortie (2, 3) ; **caractérisée en ce que**
le premier et le deuxième systèmes de clapets anti-retour (8) sont logés de manière amovible respectivement dans le premier et le deuxième logements (18) de clapets anti-retour de façon que chaque système de clapet anti-retour (8) puisse être retiré d'un seul bloc du logement respectif (18) de clapet anti-retour.

2. Pompe piézoélectrique selon la revendication 1, comprenant en outre un diaphragme (12) comportant un actionneur piézoélectrique (10) et une mince plaque métallique (11) réunis l'un avec l'autre, le diaphragme (12) étant monté dans le carter (9) pour former la chambre (1) de pompe entre le diaphragme (12) et le carter (9).

3. Pompe piézoélectrique selon la revendication 1 ou 2, dans laquelle les premier et deuxième systèmes de clapets anti-retour (8) ont la même configuration et sont installés dans des positions inverses dans le carter (9).

4. Pompe piézoélectrique selon l'une des revendications 1 à 3, dans laquelle les premier et deuxième systèmes de clapets anti-retour (8) sont installés dans le carter (9) depuis un côté opposé au côté du diaphragme (12).

5. Pompe piézoélectrique selon l'une des revendications 1 à 4, dans laquelle le carter (9) comprend une première partie (9a) de carter dans laquelle est disposé le diaphragme (12), et une deuxième partie (9b) de carter qui est séparée de la première partie (9a) de carter et dans laquelle sont installés les premier et deuxième systèmes de clapets anti-retour (8).

6. Pompe piézoélectrique selon la revendication 5, dans laquelle une structure de montage est utilisée au moins entre le carter (9) et les premier et deuxième systèmes de clapets anti-retour (8) ou entre les première et deuxième parties (9a, 9b) de carter, et la structure de montage est un moyen d'ajustement avec serrage monté par assemblage à la presse.

7. Pompe piézoélectrique selon la revendication 5, dans laquelle une structure de montage est utilisée au moins entre le carter (9) et les premier et deuxième systèmes de clapets anti-retour (8) ou entre la première et la deuxième parties (9a, 9b) de carter, et la structure de montage est un moyen de montage à transition ou un moyen de montage à jeu complété par un collage ou un soudage.

8. Pompe piézoélectrique selon la revendication 5, dans laquelle une structure de montage est utilisée au moins entre le carter (9) et les premier et deuxième systèmes de clapets anti-retour (8) ou entre les première et deuxième parties (9a, 9b) de carter, et la structure de montage comporte des filets formés dans celle-ci pour permettre un vissage.

9. Pompe piézoélectrique selon l'une des revendications 1 à 8, dans laquelle la membrane (5) du clapet anti-retour est placée de manière à couvrir le conduit (6) présent dans le corps de clapet anti-retour, et la membrane du clapet anti-retour est réunie au corps (7) de clapet anti-retour.

10. Pompe piézoélectrique selon la revendication 9, dans laquelle la membrane (5) du clapet anti-retour comporte au moins un orifice (13) ménagé dans celle-ci et est disposée de façon à couvrir le conduit (6) présent dans le corps (7) du clapet anti-retour, et la membrane (5) du clapet anti-retour autour de l'orifice (13) est réunie au corps (7) de clapet anti-retour.

11. Pompe piézoélectrique selon la revendication 10, dans laquelle la membrane (5) du clapet anti-retour comporte deux orifices (13) ménagés à des emplacements situés de part et d'autre du conduit (6).

12. Pompe piézoélectrique selon la revendication 10, dans laquelle la membrane (5) du clapet anti-retour a un seul orifice (13) parallèle à une tangente au

pourtour extérieur du conduit (6), l'orifice unique (13) étant formé à un emplacement distant du conduit (6).

13. Pompe piézoélectrique selon la revendication 10, dans laquelle la membrane (5) du clapet anti-retour comporte plusieurs orifices (13), chacun étant parallèle à une tangente à un pourtour extérieur du conduit (6), les différents orifices (13) étant formés sur le pourtour du conduit (6), à des emplacements distants de celui-ci.

14. Pompe piézoélectrique selon la revendication 10, dans laquelle l'orifice (13) de la membrane (5) de clapet anti-retour présente une forme à courbure continue.

15. Pompe piézoélectrique selon l'une des revendications 9 à 14, dans laquelle la membrane (5) du clapet anti-retour est disposée de manière à couvrir le conduit (6), et deux côtés de celle-ci de part et d'autre du conduit (6) sont réunis au corps (7) du clapet anti-retour.

16. Pompe piézoélectrique selon l'une des revendications 9 à 14, dans laquelle la membrane (5) du clapet anti-retour a un premier côté pouvant s'ouvrir et est disposée de manière à couvrir le conduit (6), la membrane (5) du clapet anti-retour étant réunie au corps (7) du clapet anti-retour en entourant le conduit (6) sauf sur le côté pouvant s'ouvrir.

17. Pompe piézoélectrique selon l'une des revendications 9 à 14, dans laquelle la membrane (5) du clapet anti-retour est disposée de manière à couvrir le conduit (6) et est réunie par points, sur le pourtour du conduit (6), au corps (7) du clapet anti-retour, et les intervalles entre les points de jonction sont des orifices (13).

18. Pompe piézoélectrique selon la revendication 17, dans laquelle la membrane (5) du clapet anti-retour a la forme d'un polygone et est placée de manière à couvrir le conduit (6), et chaque angle du polygone est réuni au corps (7) du clapet anti-retour.

19. Pompe piézoélectrique selon l'une des revendications 9 à 18, dans laquelle la membrane (5) du clapet anti-retour comporte un rabat (5b) formé en retirant une partie d'un film mince, et la membrane (5) du clapet anti-retour est réunie au corps (7) du clapet anti-retour sur le pourtour du rabat (5b).

20. Pompe piézoélectrique selon la revendication 19, dans laquelle le conduit (6) ouvert et fermé par le rabat (5b) est formé à partir d'une pluralité d'ouvertures (6a) séparées par un intervalle spécifique, et une partie de support (6b) destinée à supporter le rabat (5b) est formée au centre de la pluralité d'ouvertures (6a).

21. Pompe piézoélectrique selon la revendication 9, dans la quelle la membrane (5) du clapet anti-retour se présente sous la forme d'une bande rectangulaire et est réunie, sur un seul côté de celle-ci perpendiculaire à un grand côté de celle-ci, au corps (7) du clapet anti-retour.

22. Pompe piézoélectrique selon l'une des revendications 9 à 21, dans laquelle le corps (7) de clapet anti-retour est pourvu d'une première et d'une deuxième entretoises (7a, 7b) ayant une structure de montage, et la membrane (5) du clapet anti-retour est insérée entre et réunie aux première et deuxième entretoises (7a, 7b).

23. Pompe piézoélectrique selon la revendication 22, dans laquelle les première et deuxième entretoises (7a, 7b) sont fixées.

24. Pompe piézoélectrique selon l'une des revendications 9 à 23, dans laquelle la membrane (5) du clapet anti-retour et le corps (7) du clapet anti-retour sont soudés l'un à l'autre.

25. Pompe piézoélectrique selon l'une des revendications 9 à 21, dans laquelle le corps (7) du clapet anti-retour est pourvu d'une première et d'une deuxième entretoises (7a, 7b), la membrane (5) du clapet anti-retour étant disposée entre la première et la deuxième entretoises (7a, 7b), et la première et la deuxième entretoises (7a, 7b) et la membrane (5) du clapet anti-retour étant soudées les unes aux autres.

26. Procédé de fabrication d'une pompe, comprenant les étapes consistant à :

former un conduit (6) dans un corps (7) de clapet anti-retour ;
mettre en place une membrane (5) de clapet anti-retour de manière à couvrir le conduit (6) ;
réunir la membrane (5) du clapet anti-retour avec le corps (7) de clapet anti-retour autour du conduit (6);
former un orifice (13) dans la membrane (5) de clapet anti-retour à un emplacement situé entre une jonction et le conduit (6) afin de former un système de clapet anti-retour (8) dans lequel le conduit (6) est ouvert et fermé par la membrane (5) de clapet anti-retour sous l'effet d'une différence de pression ;
installer le système de clapet anti-retour (8) dans un carter (9)
et disposer un diaphragme (12) par-dessus le carter (9) de manière à couvrir le système de clapet anti-retour (8) .

27. Procédé selon la revendication 26, dans lequel l'orifice (13) présent dans le film mince est formé à l'aide d'un laser à excimère.

Patentansprüche

1. Piezoelektrische Pumpe zum Ansaugen von Fluid in eine Pumpenkammer (1) und Ausstoßen von Fluid aus der Pumpenkammer (1) durch Verändern des Volumens der Pumpenkammer (1) durch die Wirkung eines piezoelektrischen Stellglieds (10), wobei die piezoelektrische Pumpe aufweist:

ein Gehäuse (9) mit Ein- und Auslaßströmungskanälen (2,3), die beide mit der Pumpenkammer (1) in Verbindung stehen;
eine erste und zweite Absperrventileinheit (8), die jeweils eine Dünnfilmabsperrventilmembran (5) und einen Absperrventilkörper (7) mit einem Kanal (6) aufweisen, der von der Absperrventilmembran (5) geöffnet und geschlossen wird;
wobei das Gehäuse (9) ein erstes und ein zweites Absperrventilgehäuse (18) aufweist, die zwischen der Pumpenkammer (1) und dem Ein- bzw. Auslaßströmungskanal (2,3) ausgebildet sind; **dadurch gekennzeichnet, daß**
die erste und zweite Absperrventileinheit (8) demontierbar in dem ersten bzw. zweiten Absperrventilgehäuse (18) untergebracht sind, so daß jede Absperrventileinheit (8) als eine Einheit von dem entsprechenden Absperrventilgehäuse (18) demontiert werden kann.

2. Piezoelektrische Pumpe nach Anspruch 1,ferner mit einer Federplatte (12) mit einem piezoelektrischen Stellglied (10) und einer dünnen Metallplatte (11), die miteinander verbunden sind, wobei die Federplatte (12) an dem Gehäuse (9) befestigt ist, um die Pumpenkammer (1) zwischen der Federplatte (12) und dem Gehäuse (9) zu bilden.

3. Piezoelektrische Pumpe nach Anspruch 1 oder 2, bei der die erste und die zweite Absperrventileinheit (8) identisch ausgestaltet und in entgegengesetzten Positionen an dem Gehäuse (9) installiert sind.

4. Piezoelektrische Pumpe nach einem der Ansprüche 1 bis 3, bei der die erste und die zweite Absperrventileinheit (8) von einer der Seite der Federplatte (12) gegenüberliegenden Seite aus an dem Gehäuse (9) installiert sind.

5. Piezoelektrische Pumpe nach einem der Ansprüche 1 bis 4, bei der das Gehäuse (9) einen ersten Gehäuseteil (9a), an dem die Federplatte (12) angeordnet ist, und einen zweiten Gehäuseteil (9b) aufweist, der von dem ersten Gehäuseteil (9a) getrennt ist und an dem die erste und die zweite Absperrventileinheit (8) installiert sind.

6. Piezoelektrische Pumpe nach Anspruch 5, bei der wenigstens zwischen dem Gehäuse (9) und der ersten und zweiten Absperrventileinheit (8) oder zwischen dem ersten und dem zweiten Gehäuseteil (9a,9b) eine Paßkonstruktion verwendet wird, und die Paßkonstruktion ein durch Preßpassung zusammengefügter Preßsitz ist.

7. Piezoelektrische Pumpe nach Anspruch 5, bei der wenigstens zwischen dem Gehäuse (9) und der ersten und zweiten Absperrventileinheit (8) oder zwischen dem ersten und dem zweiten Gehäuseteil (9a,9b) eine Paßkonstruktion verwendet wird, und die Paßkonstruktion eine durch haftendes Anbringen oder Schweißen vollendete Übergangs- oder Spielpassung ist.

8. Piezoelektrische Pumpe nach Anspruch 5, bei der wenigstens zwischen dem Gehäuse (9) und der ersten und zweiten Absperrventileinheit (8) oder zwischen dem ersten und zweiten Gehäuseteil (9a,9b) eine Paßkonstruktion verwendet wird, und die Paßkonstruktion ein darin ausgebildetes Schraubgewinde für eine Schraubpassung aufweist.

9. Piezoelektrische Pumpe nach einem der Ansprüche 1 bis 8, bei der die Absperrventilmembran (5) so positioniert ist, daß sie den Kanal (6) in dem Absperrventilkörper abdeckt, und die Absperrventilmembran mit dem Absperrventilkörper (7) verbunden ist.

10. Piezoelektrische Pumpe nach Anspruch 9, bei der in der Absperrventilmembran (5) mindestens ein Luftloch (13) ausgebildet ist und diese so angeordnet ist, daß sie den Kanal (6) in dem Absperrventilkörper (7) abdeckt, und die Absperrventilmembran (5) um das Luftloch (13) mit dem Absperrventilkörper (7) verbunden ist.

11. Piezoelektrische Pumpe nach Anspruch 10, bei der die Absperrventilmembran (5) zwei Luftlöcher (13) aufweist, die an Positionen auf gegenüberliegenden Seiten des Kanals (6) ausgebildet sind.

12. Piezoelektrische Pumpe nach Anspruch 10, bei der die Absperrventilmembran (5) ein einzelnes Luftloch (13) aufweist, das parallel zu einer Tangente zum Außenumfang des Kanals (6) ist, wobei das einzelne Luftloch (13) an einer von dem Kanal (6) entfernten Position ausgebildet ist.

13. Piezoelektrische Pumpe nach Anspruch 10, bei der die Absperrventilmembran (5) mehrere Luftlöcher (13) aufweist, die jeweils parallel zu einer Tangente zu einem Außenumfang des Kanals (6) sind, wobei

die mehreren Luftlöcher (13) an von dem Kanal (6) entfernten Positionen umfangsmäßig in bezug auf diesen ausgebildet sind.

14. Piezoelektrische Pumpe nach Anspruch 10, bei der das Luftloch (13) in der Absperrventilmembran (5) die Form eines durchgehenden Bogens hat.

15. Piezoelektrische Pumpe nach einem der Ansprüche 9 bis 14, bei der die Absperrventilmembran (5) so angeordnet ist, daß sie den Kanal (6) abdeckt, und zwei ihrer Seiten auf gegenüberliegenden Seiten des Kanals (6) mit dem Absperrventilkörper (7) verbunden sind.

16. Piezoelektrische Pumpe nach einem der Ansprüche 9 bis 14, bei der die Absperrventilmembran (5) eine zu öffnende Seite aufweist und so angeordnet ist, daß sie den Kanal (6) abdeckt, wobei die Absperrventilmembran (5) abgesehen von der einen zu öffnenden Seite den Kanal (6) umgebend mit dem Absperrventilkörper (7) verbunden ist.

17. Piezoelektrische Pumpe nach einem der Ansprüche 9 bis 14, bei der die Absperrventilmembran (5) so angeordnet ist, daß sie den Kanal (6) abdeckt, und an Stellen um den Umfang des Kanals (6) mit dem Absperrventilkörper (7) verbunden ist, und Zwischenräume zwischen den Verbindungsstellen Luftlöcher (13) sind.

18. Piezoelektrische Pumpe nach Anspruch 17, bei der die Absperrventilmembran (5) die Form eines Polygons hat und so angeordnet ist, daß sie den Kanal (6) abdeckt, und jede Ecke des Polygons mit dem Absperrventilkörper (7) verbunden ist.

19. Piezoelektrische Pumpe nach einem der Ansprüche 9 bis 18, bei der die Absperrventilmembran (5) eine Klappe (5b) aufweist, die durch Entfernen eines Teils eines Dünnfilms gebildet ist, und die Absperrventilmembran (5) um den Umfang der Klappe (5b) mit dem Absperrventilkörper (7) verbunden ist.

20. Piezoelektrische Pumpe nach Anspruch 19, bei der der mittels der Klappe (5b) geöffnete und geschlossene Kanal (6) aus einer Vielzahl von Öffnungen (6a) gebildet ist, die durch einen spezifischen Abstand voneinander getrennt sind, und in einem Mittelpunkt der Vielzahl von Öffnungen (6a) ein Stützteil (6b) zum Abstützen der Klappe (5b) ausgebildet ist.

21. Piezoelektrische Pumpe nach Anspruch 9, bei der die Absperrventilmembran (5) zu einem rechteckigen Streifen geformt und nur an einer Seite, die senkrecht zu einer ihrer Längsseiten ist, mit dem Absperrventilkörper (7) verbunden ist.

22. Piezoelektrische Pumpe nach einem der Ansprüche 9 bis 21, bei der der Absperrventilkörper (7) mit einem ersten und einem zweiten Abstandhalter (7a,7b) mit einer Paßkonstruktion ausgebildet ist, und die Absperrventilmembran (7) zwischen den ersten und zweiten Abstandhalter (7a,7b) eingefügt und mit diesen verbunden ist.

23. Piezoelektrische Pumpe nach Anspruch 22, bei der der erste und der zweite Abstandhalter (7a,7b) verbondet sind.

24. Piezoelektrische Pumpe nach einem der Ansprüche 9 bis 23, bei der die Absperrventilmembran (5) und der Absperrventilkörper (7) zusammengeschweißt sind.

25. Piezoelektrische Pumpe nach einem der Ansprüche 9 bis 21, bei der der Absperrventilkörper (7) mit einem ersten und einem zweiten Abstandhalter (7a,7b) ausgebildet ist, die Absperrventilmembran (5) zwischen dem ersten und dem zweiten Abstandhalter (7a,7b) angeordnet ist, und der erste und der zweite Abstandhalter (7a,7b) und die Absperrventilmembran (5) miteinander verschweißt sind.

26. Verfahren zur Herstellung einer Pumpe, mit den folgenden Schritten:

Ausbilden eines Kanals (6) in einem Absperrventilkörper (7); Anordnen einer Absperrventilmembran (5) so, daß sie den Kanal (6) bedeckt; Verbinden der Absperrventilmembran (5) um den Kanal (6) mit dem Absperrventilkörper (7); Ausbilden eines Luftlochs (13) in der Absperrventilmembran (5) an einer Position zwischen einer Verbindungsstelle und dem Kanal (6) zur Bildung einer Absperrventileinheit (8), in der der Kanal (6) aufgrund einer Druckdifferenz von der Absperrventilmembran (5) geöffnet und geschlossen wird;
Einbauen der Absperrventileinheit (8) in ein Gehäuse (9)
und Anordnen einer Federplatte (12) oben auf dem Gehäuse (9) so, daß sie die Absperrventileinheit (8) abdeckt.

27. Verfahren nach Anspruch 26, bei dem das Luftloch (13) in dem Dünnfilm mit einem Excimerlaser ausgebildet wird.

Fig. 1

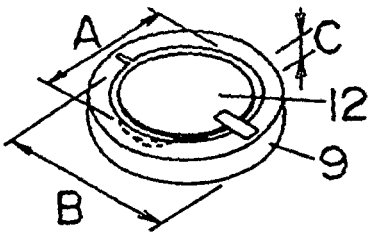


Fig. 2

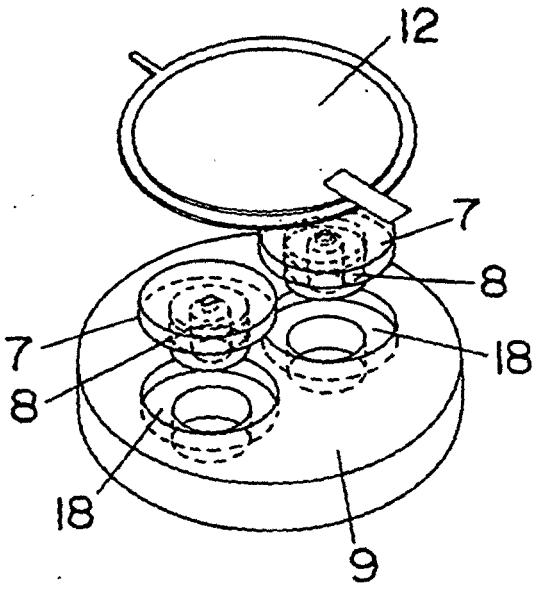


Fig. 3

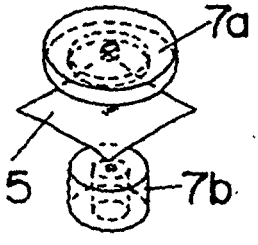


Fig. 4A

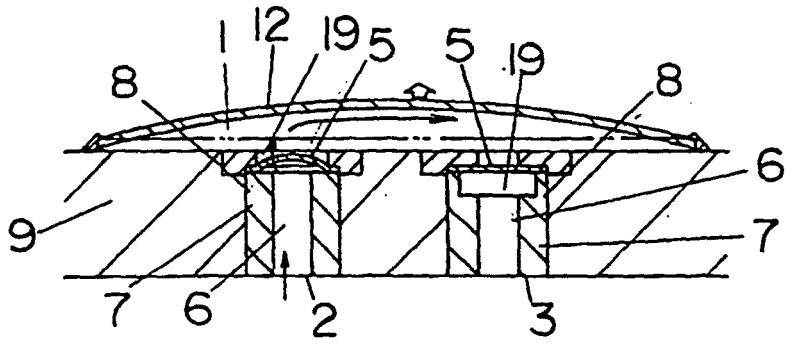


Fig. 4B

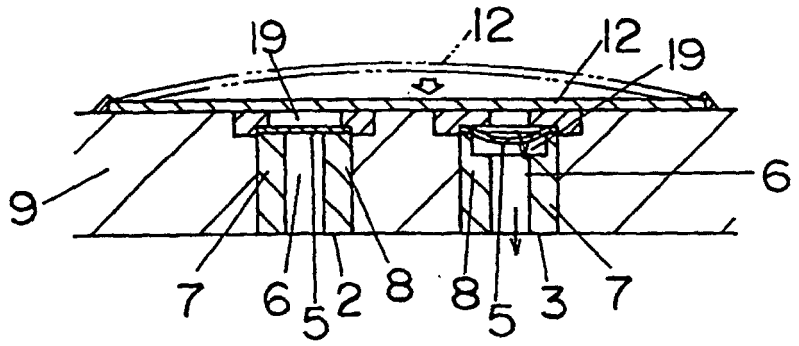


Fig. 5A

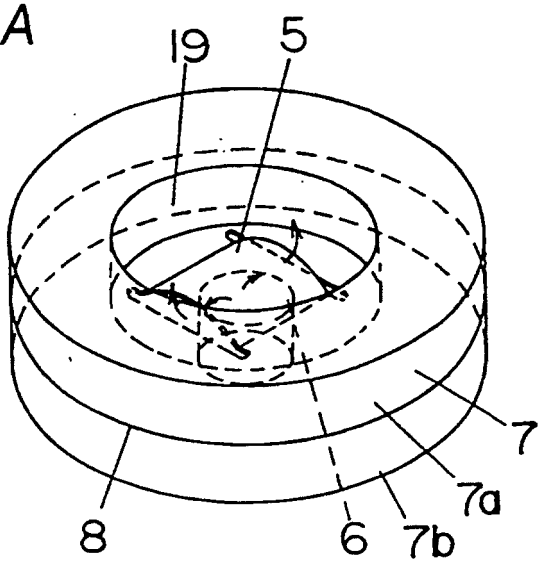


Fig. 5B

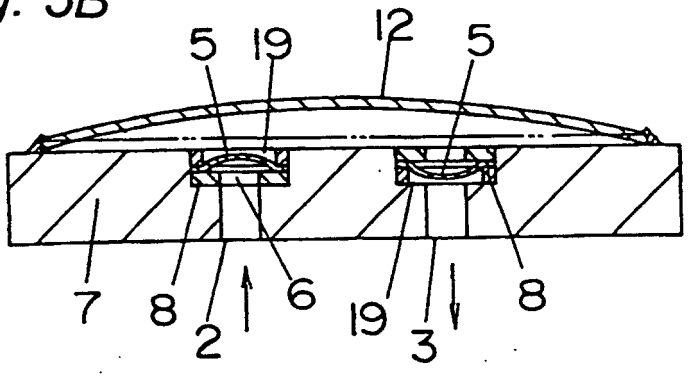


Fig. 6A

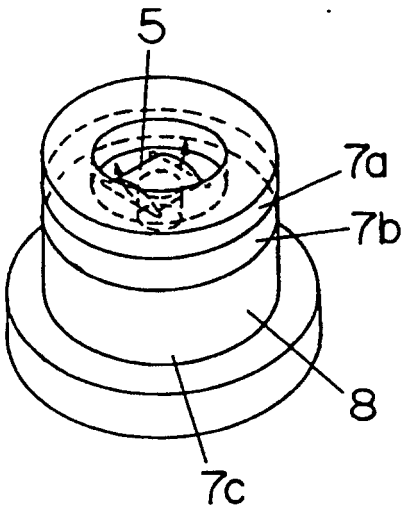


Fig. 6B

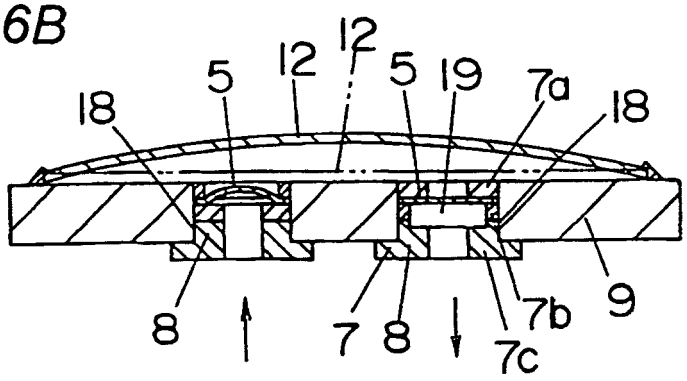


Fig. 7A

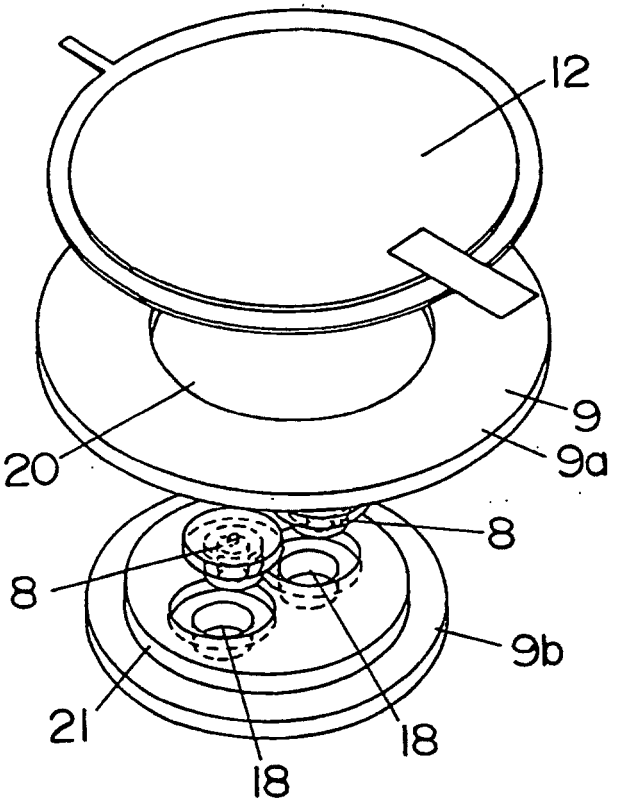


Fig. 7B

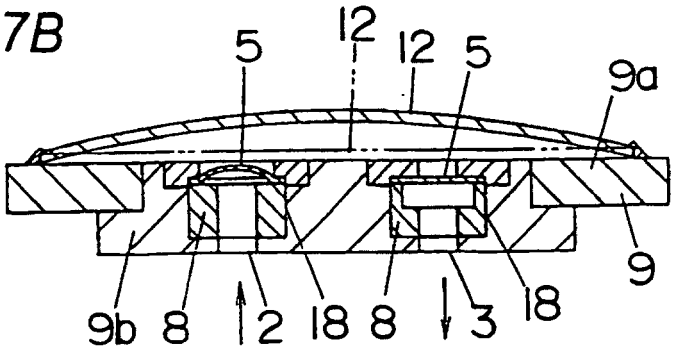


Fig. 8

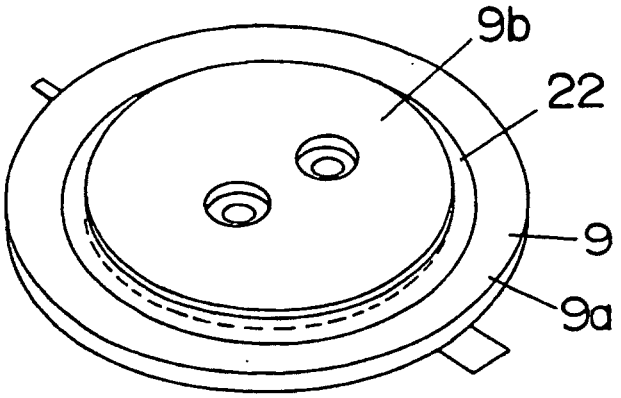


Fig. 9

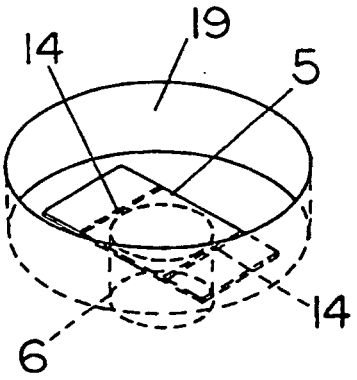


Fig. 10A

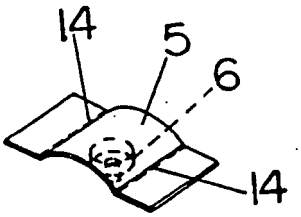


Fig. 10B

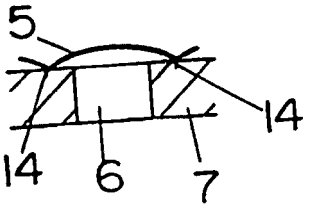


Fig. 11A

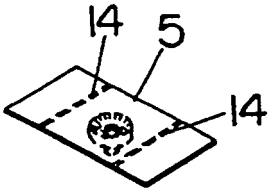


Fig. 11B

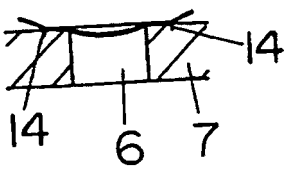


Fig. 12

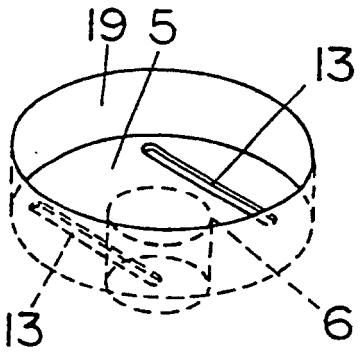


Fig. 13A

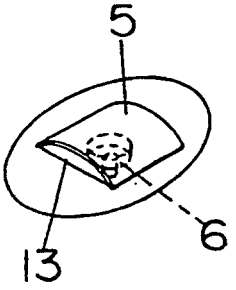


Fig. 13B

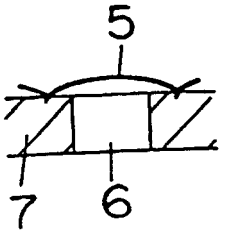


Fig. 14A

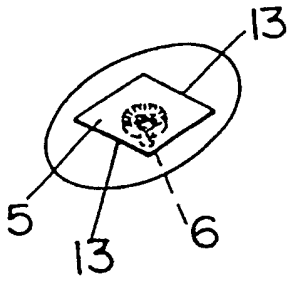


Fig. 14B

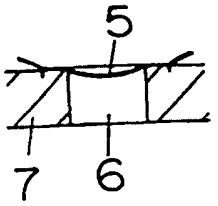


Fig. 15A

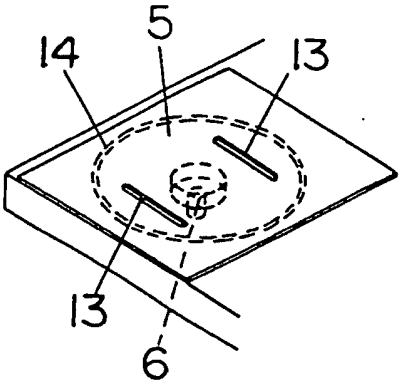


Fig. 15B

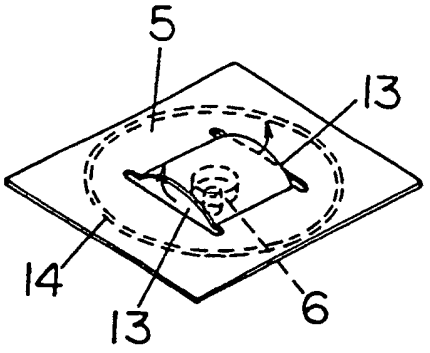


Fig. 16A

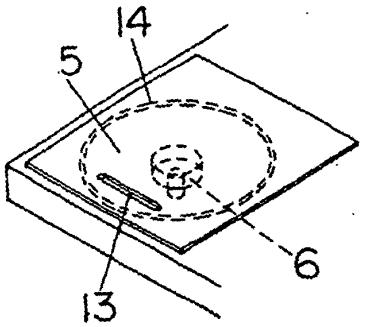


Fig. 16B

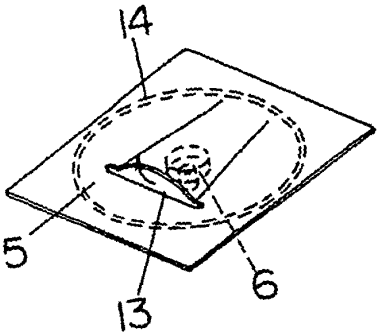


Fig. 17A

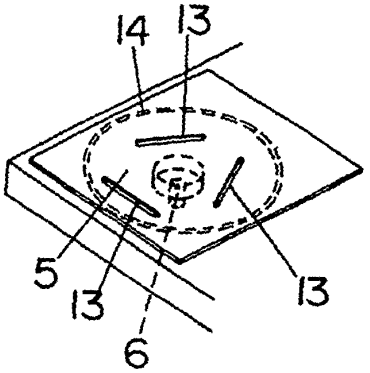


Fig. 17B

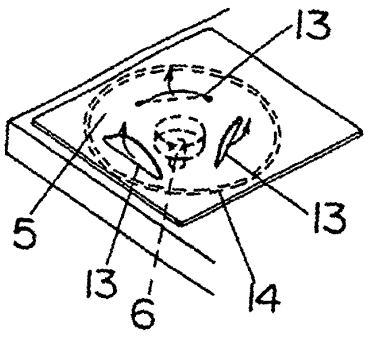


Fig. 18

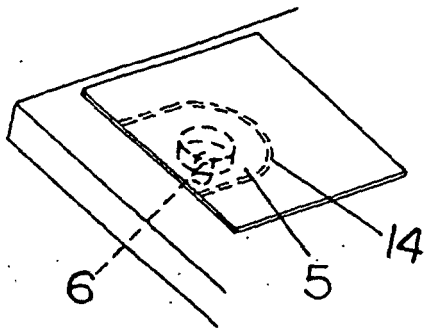


Fig. 19A

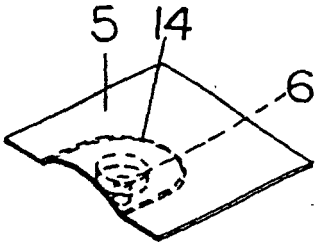


Fig. 19B

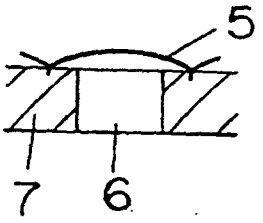


Fig. 20A

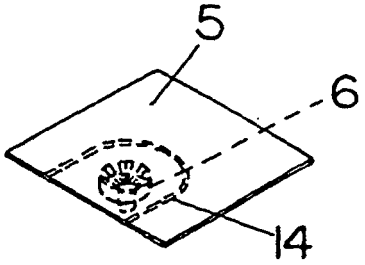


Fig. 20B

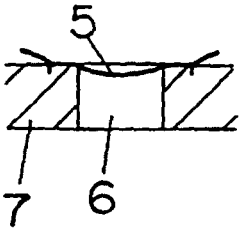


Fig. 21

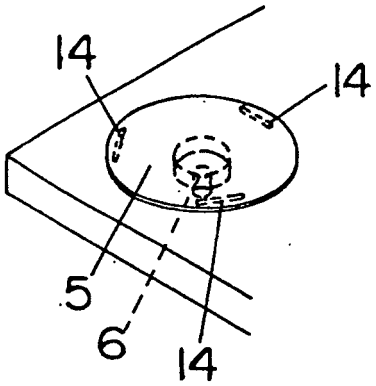


Fig. 22A

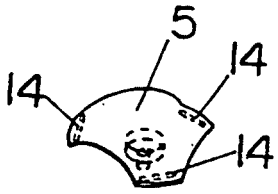


Fig. 22B

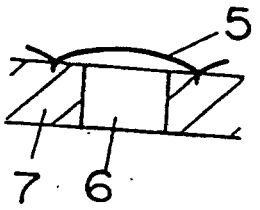


Fig. 23A

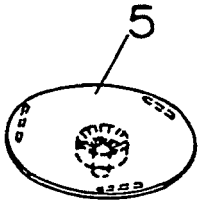


Fig. 23B

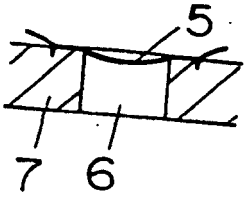


Fig. 24

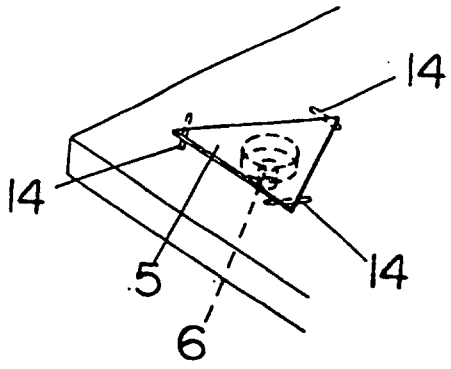


Fig. 25A

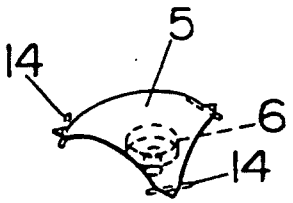


Fig. 25B

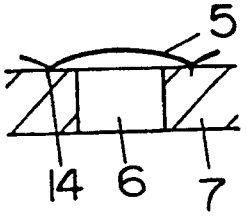


Fig. 26A

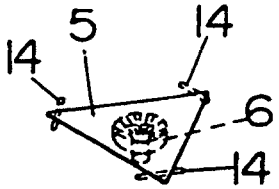


Fig. 26B

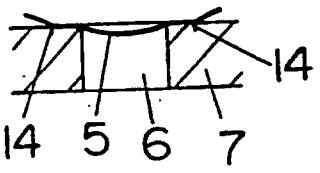


Fig. 27A

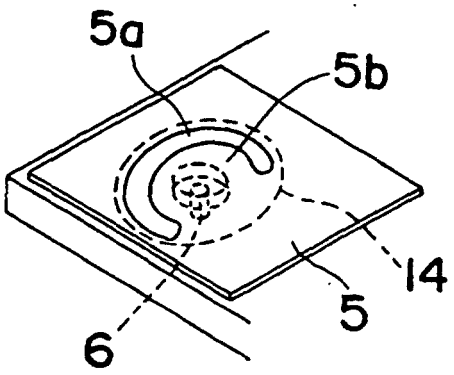


Fig. 27B

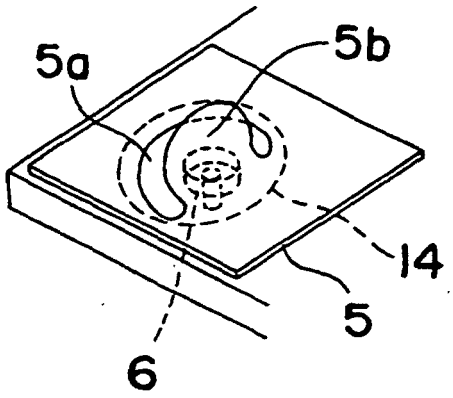


Fig. 28A

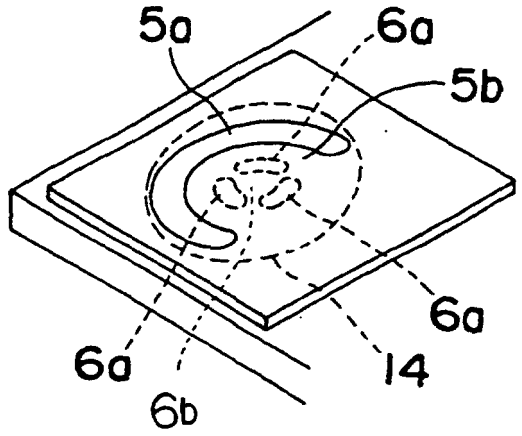


Fig. 28B

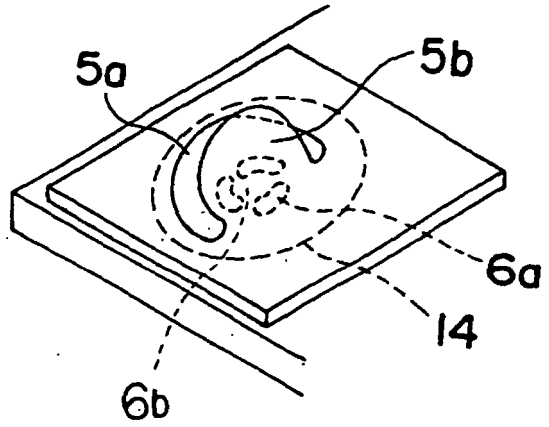


Fig.29A

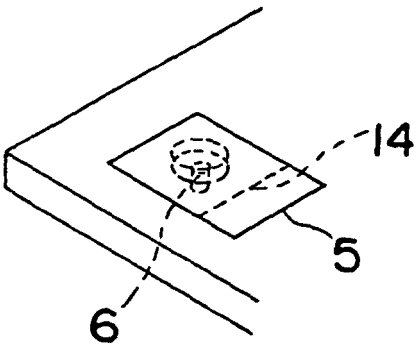


Fig.29B

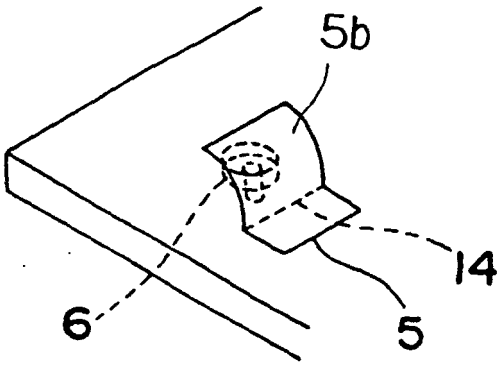


Fig. 30

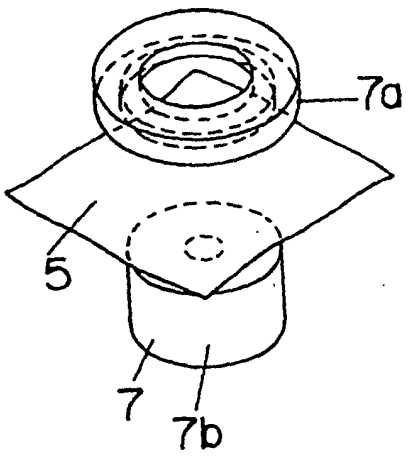


Fig. 31

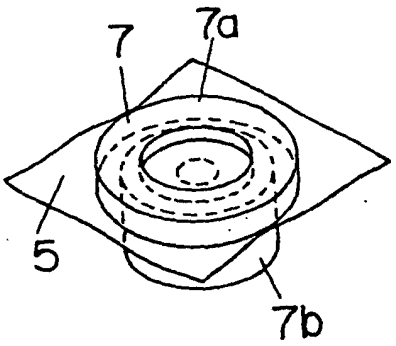


Fig. 32

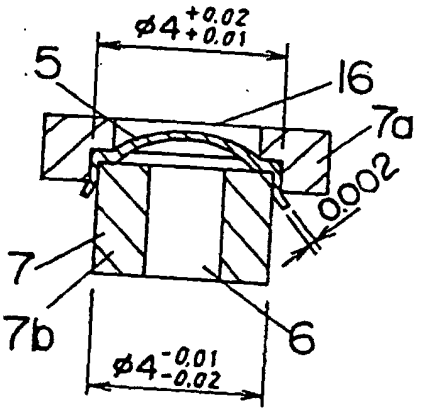


Fig. 33

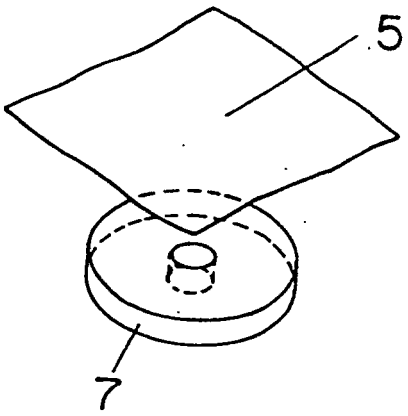


Fig. 34

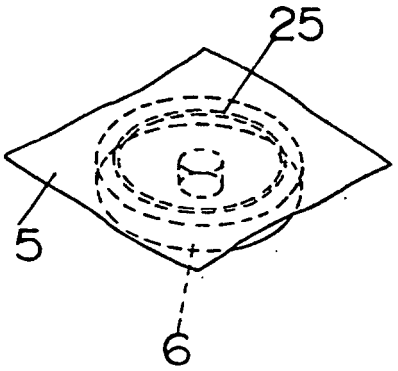


Fig. 35

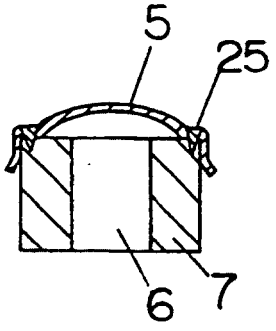


Fig. 36

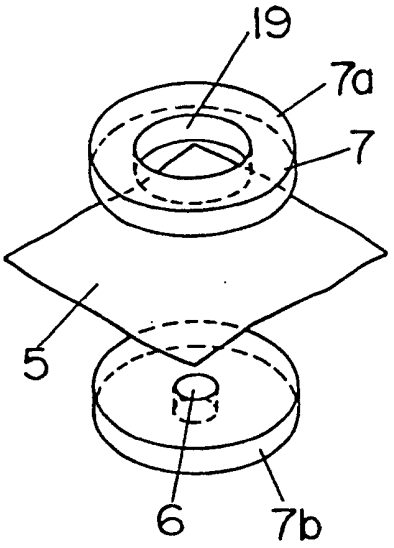


Fig. 37

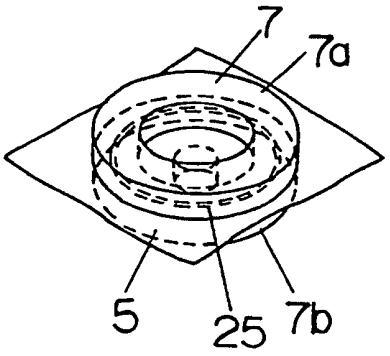


Fig. 38

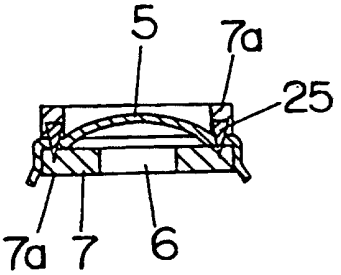


Fig. 39

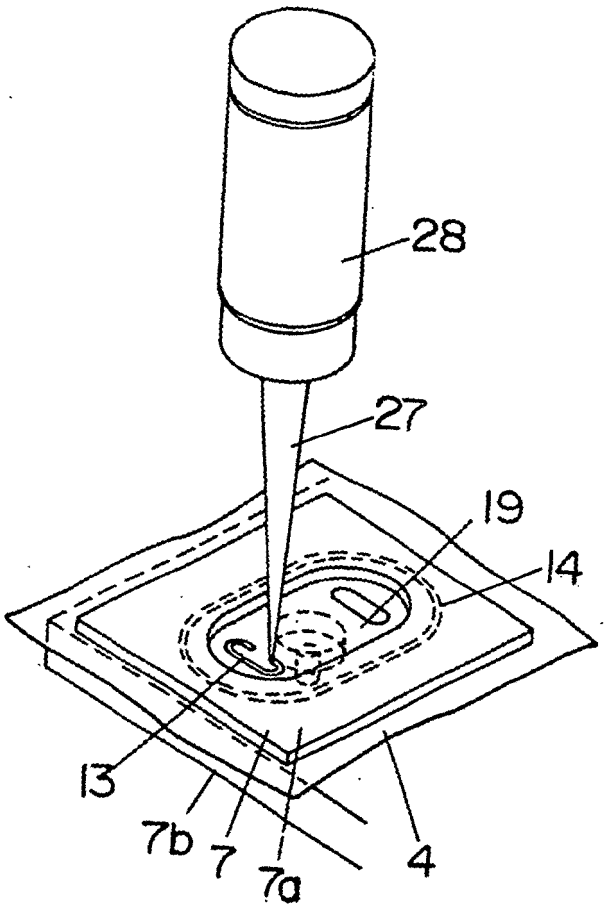


Fig. 40

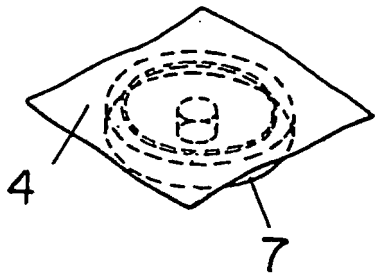


Fig. 41

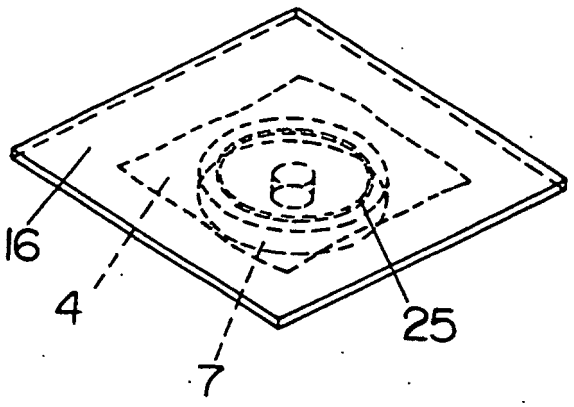


Fig. 42

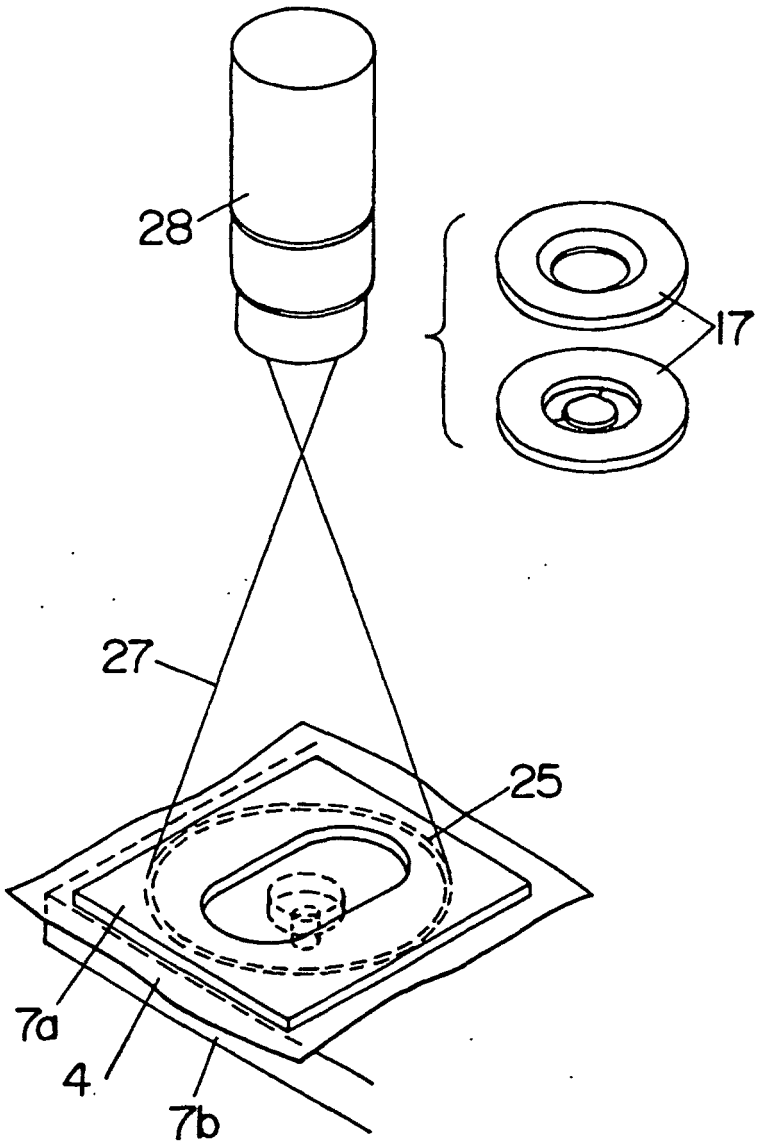


Fig. 43A

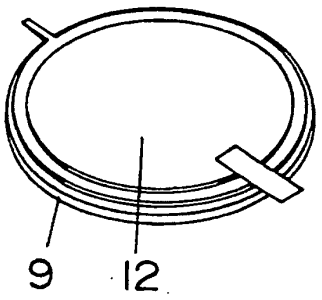


Fig. 43B

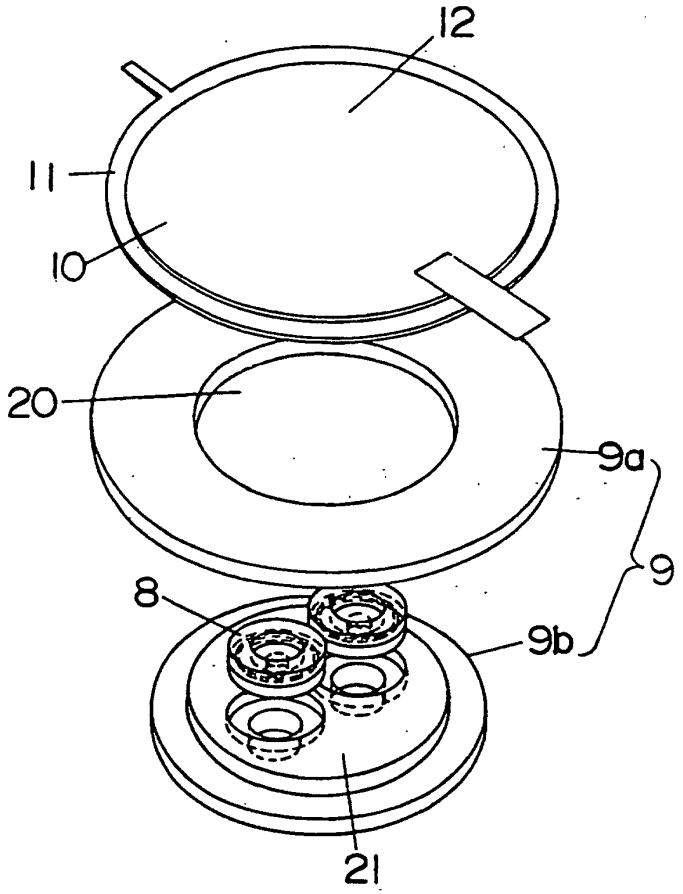


Fig. 43C

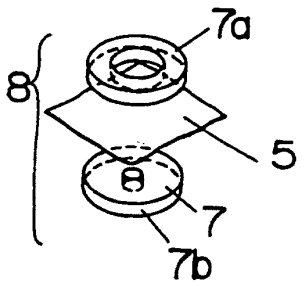


Fig. 44A

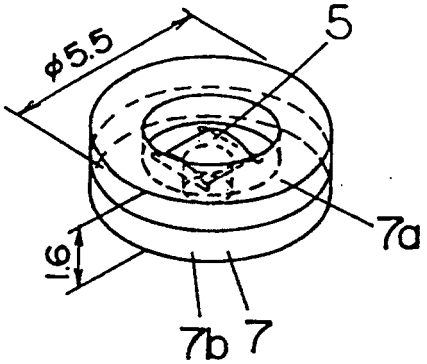


Fig. 44B

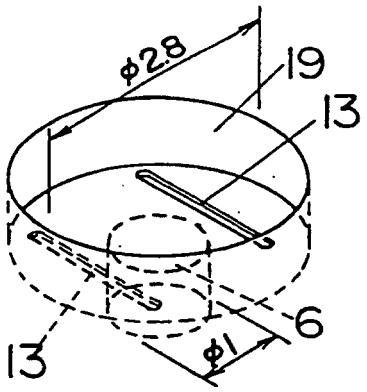


Fig. 44C

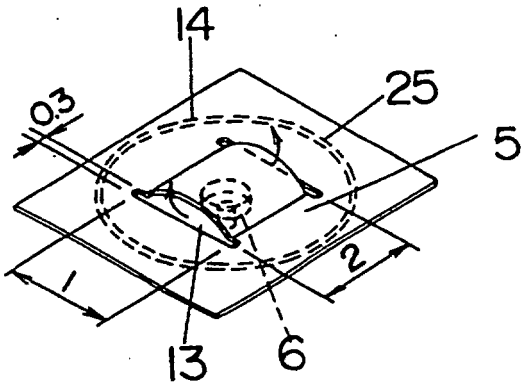


Fig. 45A

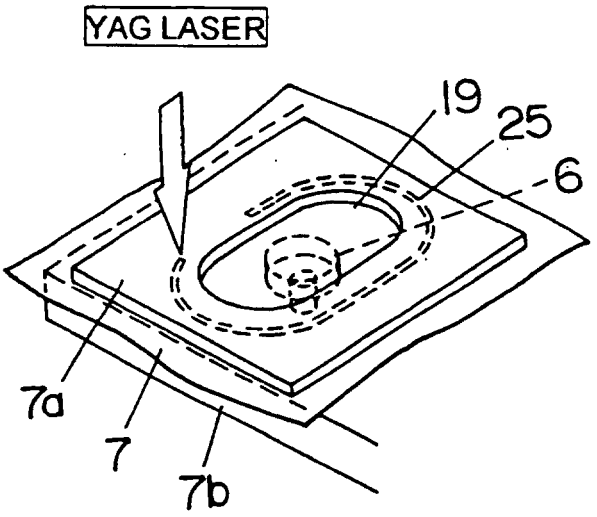


Fig. 45B

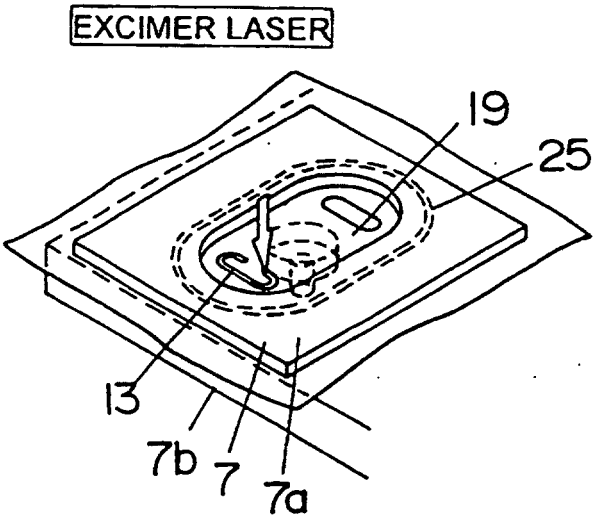


Fig. 46
PRIOR ART

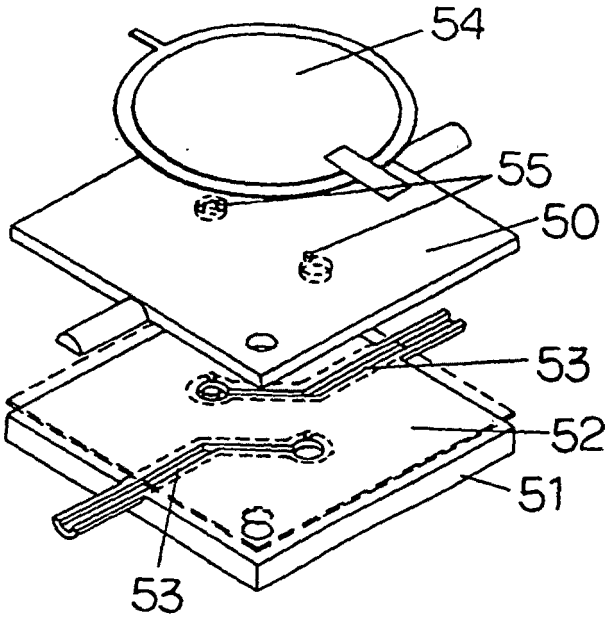


Fig. 47
PRIOR ART

