

Description

Field of the Invention

[0001] The present invention relates to a droplet discharging apparatus. More particularly, the present invention relates to a droplet discharging apparatus which has a pressure chamber communicated with a nozzle, a diaphragm which is a member of the pressure chamber, a piezoelectric device for driving the diaphragm, a projection provided on the diaphragm to stay in direct contact with the piezoelectric device for transmitting the oscillating action of the piezoelectric device to the diaphragm, and a flow passage communicated with the pressure chamber, in which droplets of a liquid are discharged from its nozzle.

Background of the Invention

[0002] Some of such conventional droplet discharging apparatuses are known as disclosed in Patent Citations 1 and 2.

Patent Citation 1: JP4-355147.

Patent Citation 2: JP2003-62994.

[0003] As depicted in the citations, an array of projected portions called as islands are provided on the diaphragm of a metallic plate or the like as made from a photosensitive resin material. The projected portion is contemplated particularly in the shape for improving the transmission of the oscillating movement from the piezoelectric device to the diaphragm while inhibiting the diaphragm from being deflected at the center. However, those citations fail to explicitly teach the counter-action against the stress developed on the diaphragm and the solution for overcoming various drawbacks encountered during the manufacturing process.

Disclosure of the Invention

(Problems that the invention is to solve)

[0004] It is an object of the present invention, in view of the above aspects, to provide a droplet discharging apparatus which is improved in the operational durability of activating regions driven by the piezoelectric device and thus increased in the productivity.

(Means for solving the Problems)

[0005] For achievement of the above object, a droplet discharging apparatus according to the present invention is provided having a pressure chamber communicated with a nozzle, a diaphragm which is a member of the pressure chamber, a piezoelectric device for driving the diaphragm, a projection provided on the diaphragm to stay in contact with the piezoelectric device for transmit-

ting the oscillating action of the piezoelectric to the diaphragm, and a flow passage communicated with the pressure chamber for discharging droplets of a liquid from the nozzle, and characterized as a first feature in that a base portion of the projection is arranged to have an enlarged portion at least at its proximal end close to the diaphragm which becomes greater in the cross section towards the diaphragm so that the angle between the side wall of its enlarged portion and the diaphragm is an obtuse angle and/or the boundary between the side wall and the diaphragm is formed to a rounded corner.

[0006] As characterized by the first feature, since "the projection is arranged to have a radially enlarged portion at least at its proximal end close to the diaphragm which becomes greater in the cross section towards the diaphragm", the projection and the diaphragm when having been shaped in a set of forming molds can easily be removed from the molds. Also, they are capable of being patterned by a lithographic technique while the physical removal of waste materials can easily be carried out. Since the joint or boundary where the stress may often be intensified is formed with an obtuse angle or a rounded corner, it can be prevented from being injured. In particular, the oscillating movement of the projection can smoothly be transmitted to the diaphragm. Alternatively, while its enlarged portion at the proximal end is at least provided locally, the projection may entirely be shaped in an enlarged form.

[0007] For achievement of the above object, a droplet discharging apparatus according to the present invention is provided having a pressure chamber communicated with a nozzle, a diaphragm which is a member of the pressure chamber, a piezoelectric device for driving the diaphragm, a projection provided on the diaphragm to stay in direct contact with the piezoelectric device for transmitting the oscillating action of the piezoelectric device to the diaphragm, and a flow passage communicated with the pressure chamber for discharging droplets of a liquid from the nozzle, as characterized as a second feature in that the projection is arranged to have a radially enlarged portion at least at its proximal end close to the diaphragm which becomes greater in the cross section towards the diaphragm while the outer wall of its upper portion and adjacent portion extends at a right angle to the diaphragm.

[0008] As characterized by the second feature, since "the projection is arranged to have a radially enlarged portion at least at its proximal end close to the diaphragm which becomes greater in the cross section towards the diaphragm", its forming process can easily be conducted as described above. Also, since "the outer wall of its uppermost end and adjacent portion extends at a right angle to the diaphragm", the projection can accurately be controlled in the height by adjusting the elevation of a pin when a set of forming molds are used for the shaping. Moreover, the area of contact between the projection and the piezoelectric device can favorably be determined, thus avoiding any unwanted injury at the contact of the

piezoelectric device.

[0009] For achievement of the above object, a droplet discharging apparatus according to the present invention is provided having a pressure chamber communicated with a nozzle, a diaphragm which is a member of the pressure chamber, a piezoelectric device for driving the diaphragm, a projection provided on the diaphragm to stay in direct contact with the piezoelectric device for transmitting the oscillating action of the piezoelectric device to the diaphragm, and a flow passage communicated with the pressure chamber for discharging droplets of a liquid from the nozzle, and characterized as a third feature in that: the diaphragm is arranged to extend continuously to an inner wall which extend proximity at least of the diaphragm faces the side wall of the projection and becomes closer to the projection towards the diaphragm so that the angle between the inner wall and the diaphragm is an obtuse angle and/or the boundary between the inner wall and the diaphragm is formed to a rounded corner.

[0010] As characterized by the third feature, since the inner wall is provided which becomes closer to the projection towards the diaphragm, its forming process can easily be carried out as described previously. Similarly, since the joint or boundary where the stress may often be intensified is formed with an obtuse angle or a rounded corner, it can be prevented from being injured. While the projection and the diaphragm when having been shaped in a set of forming molds can easily be removed from the molds, they are capable for being patterned by a lithographic technique and the physical removal of waste materials can easily be carried out.

[0011] In any of the first to third features, the projection and the diaphragm may be provided on a plate-like member while the uppermost of the projection remains flush with or lower in the height than the upper side of the plate-like member, where a portion of the plate-like member situated circumferentially of the diaphragm and beneath the piezoelectric device is leveled between the uppermost of the projection and the upper side of the diaphragm. This allows the piezoelectric device to be joined at the distal end directly to the uppermost of the projection with no use of any extra process for positioning the distal end of the piezoelectric device within the diameter of the diaphragm.

[0012] In each of the foregoing features, the projection, the diaphragm, and their circumferential portion may be formed integrally by one signal material. This allows those components to be formed together at once with no need of joining steps, hence easing the intensifying of the stress and minimizing the physical injury.

[0013] Moreover in each of the foregoing features, the projection, the diaphragm, and their circumferential portion may be formed integrally by a resin material. This allows those components to be joined together at higher certainty, hence further easing the intensifying of the stress and minimizing the physical injury. Also, when the forming is carried out using a set of molds, the removal

of the components from the molds can easily be made thus improving the productivity. The components may be formed from either one resin material or two or more different resin materials for partial application.

[0014] In addition to the foregoing features, the diaphragm may be arranged greater in dimension in the region covered with the projection than in the other remaining region when viewed from a direction which extends at a right angle to the diaphragm. This increases the area of the diaphragm which is covered with the projection and improved in the rigidity, whereby the diaphragm can oscillate without deflection throughout its open surface, thus improving the efficiency of applying a pressure in the pressure chamber.

[0015] Furthermore, both the projection and the diaphragm may be arranged of a circular shape when viewed from a direction which extends at a right angle to the diaphragm. The circular shape permits the displacement and biasing to be dissipated uniformly in all directions, thus allowing the diaphragm to be smoothly oscillated and avoided from any local fatigue injury.

Advantages of the Invention

[0016] The droplet discharging apparatus according to the present invention is advantageous in that its moving parts including the boundary of the diaphragm and the joining with the piezoelectric device can be increased in the operational durability while the structural arrangement is improved in the removal from the forming molds as well as the processing action, hence increasing the productivity.

[0017] Other objects, arrangements, and advantages of the present invention will be apparent from the following description of embodiments of the present invention.

Brief Description of the Drawings

[0018]

Fig. 1A is an exploded perspective view of a head and Fig. 1B is a perspective view of an arrangement in the proximity of a projection;

Fig. 2 is a longitudinally cross sectional view of the head;

Fig. 3 is a lower longitudinally cross sectional view of the head;

Fig. 4 is a plan view of an arrangement in the proximity of the projection and a communication aperture;

Fig. 5 is a perspective view seen from the bottom side of Fig. 4;

Fig. 6 is a longitudinally cross sectional view of an arrangement in the proximity of the projection;

Fig. 7 illustrates a modification of the arrangement shown in Fig. 6;

Fig. 8 is a longitudinally cross sectional view of molds for forming the projection and the diaphragm;

Fig. 9 is a plan view showing another modification

of the arrangement in the proximity of the projection;
and

Fig. 10 is a plan view showing a further modification
of the arrangement in the proximity of the projection.

(Description of Numerals)

[0019] 1: droplet discharging apparatus, 2: head, 6: upper cover, 7: cable, 7a, 7b: leads, 8: retainer, 9: tooling, 9a: inclined side, 9b: contact side, 10: piezoelectric device, 10a: holding portion, 10b: activating portion, 10c: connecting portion, 10d: lower end, 10f1, 10f2: external electrodes, 20: bracket, 21: groove, 21a: inclined surface, 22: upper open region, 23: mounting region, 23a: side surface, 23b: bottom surface, 24: cavity region, 25: second groove, 25a: projected surface, 25b: opposite surface, 26: third groove, 26a: partition, 27: communication inlet, 27c: flow passage, 29: projection, 30: oscillator inlet, 31: projection, 31a: upper portion, 31b: sidewall, 32: diaphragm (oscillating diaphragm), 32a: circumferential portion, 32b: center portion, 32d: inner boundary, 32e: outer boundary, 33: recessed portion, 33a: inner wall, 34: upper side, 35: flow passage, 35a: downstream end, 35x: groove, 36: communication aperture, 39a: round slot, 39b: long slot, 40: nozzle plate, 41: nozzle, 42: pressure chamber, 42a: downstream side wall, 42b: upstream side wall, 42x: recess, 43: downward passage, 49a: round slot, 49b: long slot, 50: contactor, 50a: first contactor, 50b: second contactor, 51: base portion, 52: bent portion, 54: intermediate portion, 55: connector strip, 100: molds, 101: upper mold, 102: lower mold, 103: base, 103a: cylinder portion, 103b: tapered surface, 103c: projected portion, 104: pin, 105: cavity, C1, C2: joint angles, CS: corner, CL: cross corner, R1: rounded corner.

Best Modes for embodying the Invention

[0020] One embodiment of the present invention will be described referring to the relevant drawings.

As shown in Figs. 1 to 6, a droplet discharging apparatus 1 according to the present invention includes a head 2 for discharging from a nozzle 41 droplets of a liquid which has been supplied from a cartridge not shown. The head 2 comprises a piezoelectric device 10, an oscillator plate 30, a nozzle plate 40, contactors 50, an upper cover 6, and a cable 7 which all are fixedly mounted to a bracket 20. More specifically, the bracket 20, the oscillator plate 30, the nozzle plate 40, and the upper cover 6 are fabricated respectively by injection molding of resin materials. The components may be fabricated using glass, metals, and other appropriate materials while the molding may be replaced with etching or electro-forming technique.

[0021] The bracket 20 has a groove 21 provided there-through from the upper end to the lower end for guiding the piezoelectric device 10. The guiding groove 21 comprises from an upper open region 22 to the lower end, a mounting region 23, and a cavity region 24. Also, the bracket 20 has a second groove 25 provided in the prox-

imity of the upper open region 22 and a third groove 26 provided in the upper side thereof to extend from the upper open region 22 to the back side of the bracket 20 where the cable 7 is fitted in. The bracket 20 furthermore has a communication inlet 27 provided in the back side thereof for communication with a cartridge. The bracket 20 has projections 29 provided on the lower side thereof and arranged to fit and engage with the oscillator plate 30 and the nozzle plate 40. A pressure-chamber and a nozzle are provided in the lower front of the head 2 for being driven with the oscillator plate 30, the nozzle plate 40, and the piezoelectric device 10. The contactors 50 are fitted into the second groove 25 for electrically connecting between the piezoelectric device 10 and the cable 7.

[0022] The piezoelectric device 10 may be implemented by a PZT (leadzirconatetitanate) material so that its activating portion 10b at the lower end can be expanded and contracted when being energized. As the piezoelectric device 10 is fixedly mounted at its center holding portion 10a to the bracket 20, its lower end 10d oscillates up and down for driving the diaphragm 32 through a projection 31 which will be explained later. A pair of external electrodes are provided on the upper connecting portion 10c of the piezoelectric device 10 for connection to bent portions 52 of the contactors 50 which extend from base portions 51. The piezoelectric device 10 is arranged of a square in the cross section and secured to the mounting region 23 with its distal end positioned in the cavity region 24 when having been inserted from the upper open region 22. More particularly, the piezoelectric device 10 is fixedly mounted by an adhesive to the mounting region 23 of the bracket 20. As shown in Fig. 2, the guiding groove 21 where the piezoelectric device 10 is installed extends from the upper end to the lower end of the bracket 20, thus allowing the projection 31 to be viewed from the upper opening region 22. The other side of the guiding groove 21 opposite to the piezoelectric device 10 mounted side has an inclined surface 21a which becomes closer to the piezoelectric device 10 from the upper open region 22 towards the lower end of the groove 21. The inclined surface 21a is configured to come into direct contact with the inclined surface 9a of a tooling 9 for ensuring the precise fitness between the piezoelectric device 10 and the mounting region 23 when the tooling 9 has been inserted.

[0023] The cable 7 with its leads 7a, 7b stripped at the distal end is fitted into the third groove 26 and securely held with the retainer 8. The leads 7a, 7b are separated to left and right by a partition 26a projected at the center in the upper open region 22 and connected to the first and second contactors 50a, 50b respectively by the connecting strips 55 folded down. Then, the upper cover 6 is mounted for protection at the upper end.

[0024] The oscillator plate 30 and the nozzle plate 40 are placed one over the other and bonded together before joined to the lower side of the bracket 20. The oscillator plate 30 has a round slot 39a and a long slot 39b provided

therein through which a pair of projections 29 projected outwardly on the lower side of the bracket 20 extend respectively for determining the position. The nozzle plate 40 also has a round slot 49a and a long slot 49b provided therein at the locations corresponding to the round slot 39a and the long slot 39b respectively of the oscillator plate 30. The pair of projections 29 are fitted into the round slots 39a, 49a and the long slots 39b, 49b for accurately determining the position of the bracket 20, the oscillator plate 30 and the nozzle plate 40. In particular, the round slot 49a and the long slot 49b are provided not through but shut up at the bottom, hence allowing the projections 29 not to extend through the nozzle plate 40 and permitting the nozzle plate 40 to be easily cleaned down even if having been fouled with a leakage of the liquid while avoiding the mixture with unwanted types of liquid.

[0025] The oscillator plate 30 includes the projection 31, the diaphragm 32, and a recessed portion 33 which are located beneath the lower end of the guiding groove 21 of the bracket 20. The nozzle plate 40 has a recess 42x provided in the upper side thereof for forming the pressure chamber 42 while the oscillator plate 30 has a groove 35x provided in the lower side thereof for forming the flow passage 35 which is communicated with the pressure chamber 42. When the two plates have been bonded to each other, the pressure chamber 42 and the flow passage 35 are produced. The flow passage 35 is further communicated across a communication aperture 36 to a flow passage 27c in the bracket 20. The projection 31, the diaphragm 32, and the recessed portion 33 are arranged concentrically at their boundaries and become greater in the diameter towards the outer edge, as shown in Figs. 4 and 6. The pressure chamber 42 is communicated across a communication passage 43 to the nozzle 41. The piezoelectric device 10 remains at the lower end 10d partially in direct contact with the projection 31 as the piezoelectric device 10 and the projection 31 are securely joined by the adhesive to each other. The recessed portion 33 is greater in the outer edge than the lower end 10d of the piezoelectric device 10, whereby the lower end 10d can be avoided from coming into direct contact with the upper side 34 of the oscillator plate 30.

[0026] As shown in Figs. 4 to 6, the base portion of the projection 31 close to the diaphragm 32 is enlarged in the cross section as coming close to the diaphragm 32. As the enlarged portion becomes greater in the diameter towards the diaphragm 32, its side wall at the enlarged portion is denoted by 31b. The joint angle C1 between the side wall 31b and the diaphragm 32 along the inner boundary 32d where the projection 31 meets the diaphragm 32 is set as an obtuse angle so that the inner boundary 32d with its neighbor area is increased in the rigidity while the removal from the molds after the molding process can easily be carried out. The inclined side wall 31b may be provided partially close to the inner boundary 32d.

[0027] The side wall 31b of the projection 31 is ar-

ranged at its upper portion 31a to extend at a right angle to the diaphragm 32, whereby the overall form will be a circular cylinder in this embodiment. As the upper portion 31a of the projection 31 is arranged of a circular cylinder form, its rigidity can be maintained. This allows the molds for producing the form to be simply constructed with a combination of a cylindrical hole and a cylindrical pin. With the pin adjusted carefully in the elevation, the height of the upper portion 31a can be improved in the accuracy. In practice, the molds is constructed preferably as shown in Fig. 8. The molds 100 include an upper mold 101 and a lower mold 102. While the upper mold 101 has a pin 104 fitted into a cylindrical hole 103a provided in a base portion 103 thereof, the molding is carried out by filling a cavity 105 between the molds with a resin material. The insert position of the pin 104 in relation to the cylindrical hole 103a can easily be controlled so that the distance H between the lower end of the cylindrical hole 103a and the lower end of the pin 104 is equal to the height of the upper portion 31a of the projection 31. While its tapered surface 103b determines the shape of the side wall 31b, the upper mold 101 forms apart of the diaphragm 32 with its projected portion 103c.

[0028] The diaphragm 32 comprises a center portion 32b of a disk-like shape directly beneath the projection 31 and a circumferential portion 32a of an annular shape provided about the center portion 32b. In this embodiment, the center portion 32b is arranged greater in the area size than the circumferential portion 32a, as shown in the plan view of Fig. 4, whereby the oscillating movement of the piezoelectric device 10 can be transmitted uniformly to the projection 31 by the diaphragm 32.

[0029] Alternatively, instead of the joint angle C1 set as an obtuse angle, the lower end of the projection 31 along the inner boundary 32d may be formed to a rounded corner R1 as shown in Fig. 7. In this case, the projection 31 has a so-called beveled bottom along the inner boundary 32d. Meanwhile, an inner wall 33a of a cylindrical shape is provided between the recessed portion 33 and the diaphragm 32. The joint angle C2 between the inner wall 33a and the diaphragm 32 along the outer boundary 32e may be set as an obtuse angle so that the diaphragm 32 can be increased in the rigidity and improved in the removal from the molds. Similar to the inner boundary 32d and the side wall 31b, the outer boundary 32e may be modified with a rounded corner and the inner wall 33a may be inclined as becoming close to the projection 31 towards the diaphragm 32.

[0030] Since the pressure chamber 42 is greater in the outer diameter than the diaphragm 32, it is overlapped just beneath as eccentric with the diaphragm 32 so that its downstream side wall 42a of the pressure chamber 42 coincides substantially with the outer boundary 32e of the diaphragm 32 at the communication passage 43 side. This eccentricity allows a clearance to be developed between the upstream side wall 42b of the pressure chamber 42 and the outer boundary 32e of the diaphragm 32 at the flow passage 35 side. Accordingly, the clear-

ance is thus communicated with the downstream end 35a of the flow passage 35.

[0031] Before the oscillator plate 30 and the nozzle plate 40 are bonded to each other, they are coated with an adhesive. The adhesive may be a liquid type thermoset adhesive agent or the like. Preferably, a type of varnish in which the same resin material as of the two plates 30, 40 is dispersed is used as the adhesive. For the application, some drops of the adhesive are spotted on the joining side of one of the two plates 30, 40 and spread uniformly by the spinning action of a spin coater. The other plate is then placed and bonded to the joining side of the adhesive coated plate. Then, the two joined plates 30, 40 are placed between dies, overlap with each other and, if the adhesive is of thermo-set type, heated in a furnace for curing the adhesive.

[0032] In this embodiment, the diaphragm 32 and the flowpassage are provided in the same oscillator plate 30 as described above, so that the pair of corners CS at the downstream end 35a of the flowpassage 35 where the adhesive tends to stagnate are gently projected towards the space in the pressure chamber 42 and thus avoid the flow passage 35 from being choked up.

[0033] The action of assembling the above-described head 2 starts with the piezoelectric device 10 being coated with an adhesive, inserted into the guiding groove 21 from its upper open region 22, and secured at the mounting region 23 in the groove 21. Then, the tooling 9 is inserted into the guiding groove 21 and its inclined side 9a and contact side 9b come into direct contact with the wall of the groove 21 and the piezoelectric device 10 respectively, whereby the piezoelectric device 10 can be secured at the mounting region 23. The adhesive is then cured.

[0034] At a separate step, the oscillator plate 30 and the nozzle plate 40 are bonded to each other. Then, their round slots 39a, 49a and the long slots 39b, 49b are engaged with the pair of projections 29 on the lower side of the bracket 20 and bonded together. Before the two plates 30, 40 are joined to the bracket 20, the lower end 10d of the piezoelectric device 10 is coated with an adhesive and bonded directly to the projection 31 of the oscillator plate 30.

[0035] Then, while the contactors 50 are inserted into the second grooves 25, the cable 7 is inserted into the third groove 26 and its leads 7a, 7b are secured with the connecting strips 55 being folded down, thus completing the electrical connection between the external electrodes 10f1, 10f2, the two, first and second, contactors 50a, 50b, and the leads 7a, 7b respectively. With the cable 7 being supplied with an actuating current, the projection 31 can be observed through the guiding groove 21. This allows the bonding state between the lower end 10d of the piezoelectric device 10 and the projection 31 to be examined from the oscillating movement of the projection 31.

[0036] Other embodiments of the present invention will then be described in the respect to provability. Like components are denoted by like numerals as those of the

previous embodiment.

[0037] In the above described embodiment, the flow passage 35 is arranged to extend across the center of the pressure chamber 42. However, as shown in Fig. 9, the flow passage 35 may be biased to one side of the pressure chamber 42 so that it overlaps partially with the pressure chamber 42. While the downstream end 35a of the flowpassage 35 is located just over the pressure chamber 42 as shown in the previous embodiment, it may be extended further to the out side of the pressure chamber 42. In any case, the flow passage can be avoided from being choked up with the adhesive even when the adhesive tends to stagnate on the pair of corners CS. Also, the projection 31 and the pressure chamber 42 are not limited to a circular shape but may be arranged of such a particular shape as shown in Fig. 10. The droplet discharging apparatus according to the present invention may be modified in various forms without departing from the scope of the present invention.

Industrial Applicability

[0038] The present invention is applicable to chemical experiments, biotechnology experiments, medical diagnosis, electronics production, and so on. The liquid may be selected from various types. For example, the liquid may contain biological materials such as DNA, protein, or fungus, fluorescent particles, electrically conductive particles, resin particles, ceramic particles, pigments, or dyes. It is suitable for discharging droplets of high surface-tension liquid such as distilled water or expensive liquid. It is also suitable for drawing lines through printing as well as fabricating electrodes and micro-lenses. Moreover, the present invention is favorable for applying an array of droplets at desired locations such as forming biological chips, producing flavors through dispensing or spraying, providing a mixture through controlling the amount to be discharged, or forming films.

Claims

1. A droplet discharging apparatus having a pressure chamber communicated with a nozzle, a diaphragm which is a member of the pressure chamber, a piezoelectric device for driving the diaphragm, a projection provided on the diaphragm to stay in contact with the piezoelectric device for transmitting the oscillating action of the piezoelectric device to the diaphragm, and a flow passage communicated with the pressure chamber for discharging droplets of a liquid from the nozzle, **characterized in that:**

a base portion of the projection is arranged to have an enlarged portion at least at its proximal end close to the diaphragm which becomes greater in the cross section towards the diaphragm so that the angle between the side wall

of its enlarged portion and the diaphragm is an obtuse angle and/or the boundary between the side wall and the diaphragm is formed to a rounded corner.

- 2. A droplet discharging apparatus having a pressure chamber communicated with a nozzle, a diaphragm which is a member of the pressure chamber, a piezoelectric device for driving the diaphragm, a projection provided on the diaphragm to stay in direct contact with the piezoelectric device for transmitting the oscillating action of the piezoelectric device to the diaphragm, and a flow passage communicated with the pressure chamber for discharging droplets of a liquid from the nozzle, **characterized in that:**

the projection is arranged to have a radially enlarged portion at least at its proximal end close to the diaphragm which becomes greater in the cross section towards the diaphragm while the outer wall of its upper portion and adjacent portion extends at a right angle to the diaphragm.

- 3. A droplet discharging apparatus having a pressure chamber communicated with a nozzle, a diaphragm which is a member of the pressure chamber, a piezoelectric device for driving the diaphragm, a projection provided on the diaphragm to stay in direct contact with the piezoelectric device for transmitting the oscillating action of the piezoelectric device to the diaphragm, and a flow passage communicated with the pressure chamber for discharging droplets of a liquid from the nozzle, **characterized in that:**

the diaphragm is arranged to extend continuously to an inner wall which extend proximity at least of the diaphragm faces the side wall of the projection and becomes closer to the projection towards the diaphragm so that the angle between the inner wall and the diaphragm is an obtuse angle and/or the boundary between the inner wall and the diaphragm is formed to a rounded corner.

- 4. The droplet discharging apparatus according to any of claims 1 to 3, wherein the projection and the diaphragm are provided on a plate-like member while the uppermost of the projection remains flush with or lower in the height than the upper side of the plate-like member, and a portion of the plate-like member situated circumferentially of the diaphragm and beneath the piezoelectric device is leveled between the uppermost of the projection and the upper side of the diaphragm.
- 5. The droplet discharging apparatus according to any of claims 1 to 3, wherein the projection, the diaphragm, and their circumfer-

ential portion are formed integrally by one signal material.

- 6. The droplet discharging apparatus according to any of claims 1 to 3, wherein the projection, the diaphragm, and their circumferential portion are formed integrally by a resin material.
- 7. The droplet discharging apparatus according to any of claims 1 to 3, wherein the diaphragm is arranged greater in dimension in the region covered with the projection than in the other remaining region when viewed from a direction which extends at a right angle to the diaphragm.
- 8. The droplet discharging apparatus according to any of claims 1 to 3, wherein both the projection and the diaphragm are arranged of a circular shape when viewed from a direction which extends at a right angle to the diaphragm.

Fig. 1

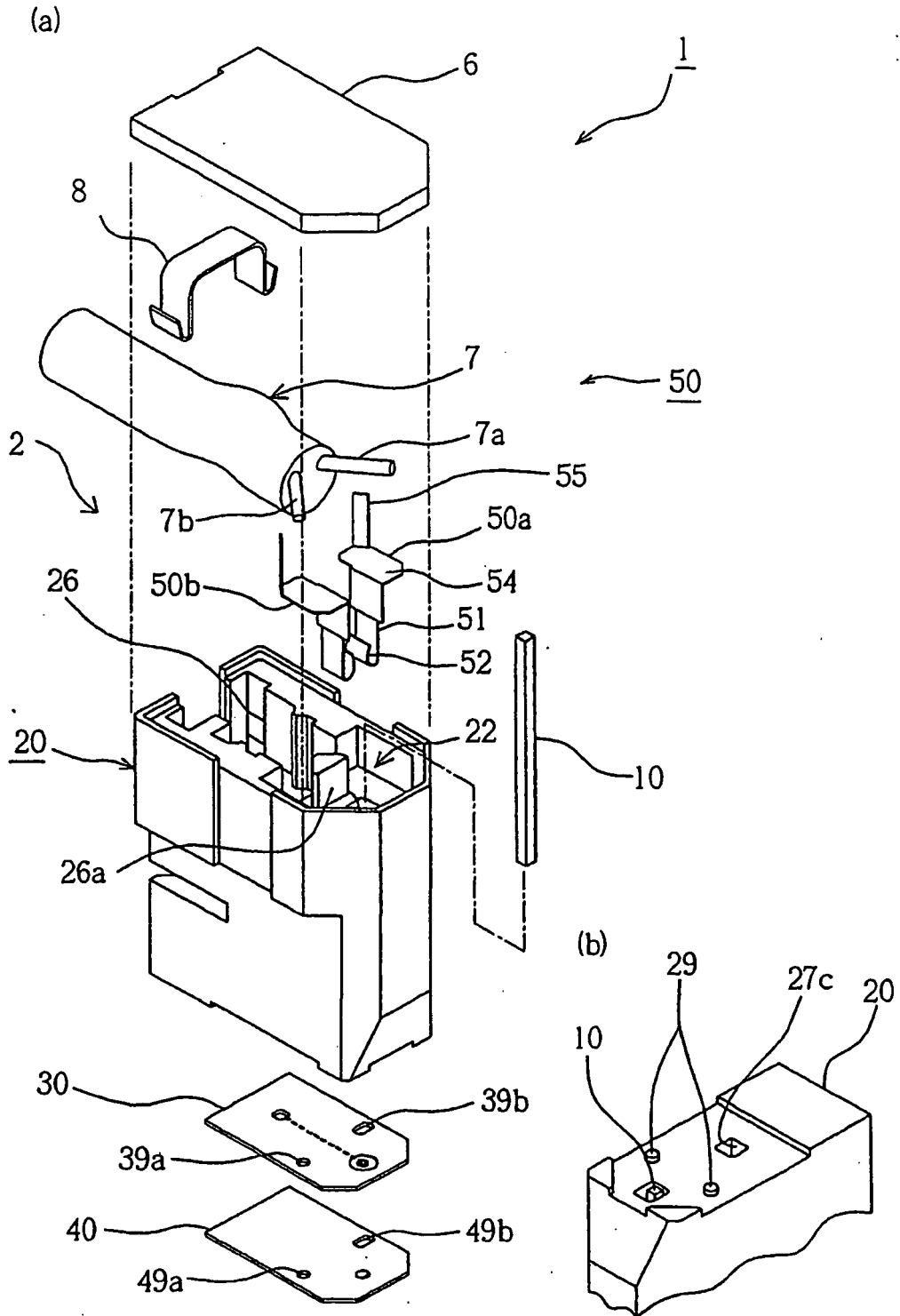


Fig. 2

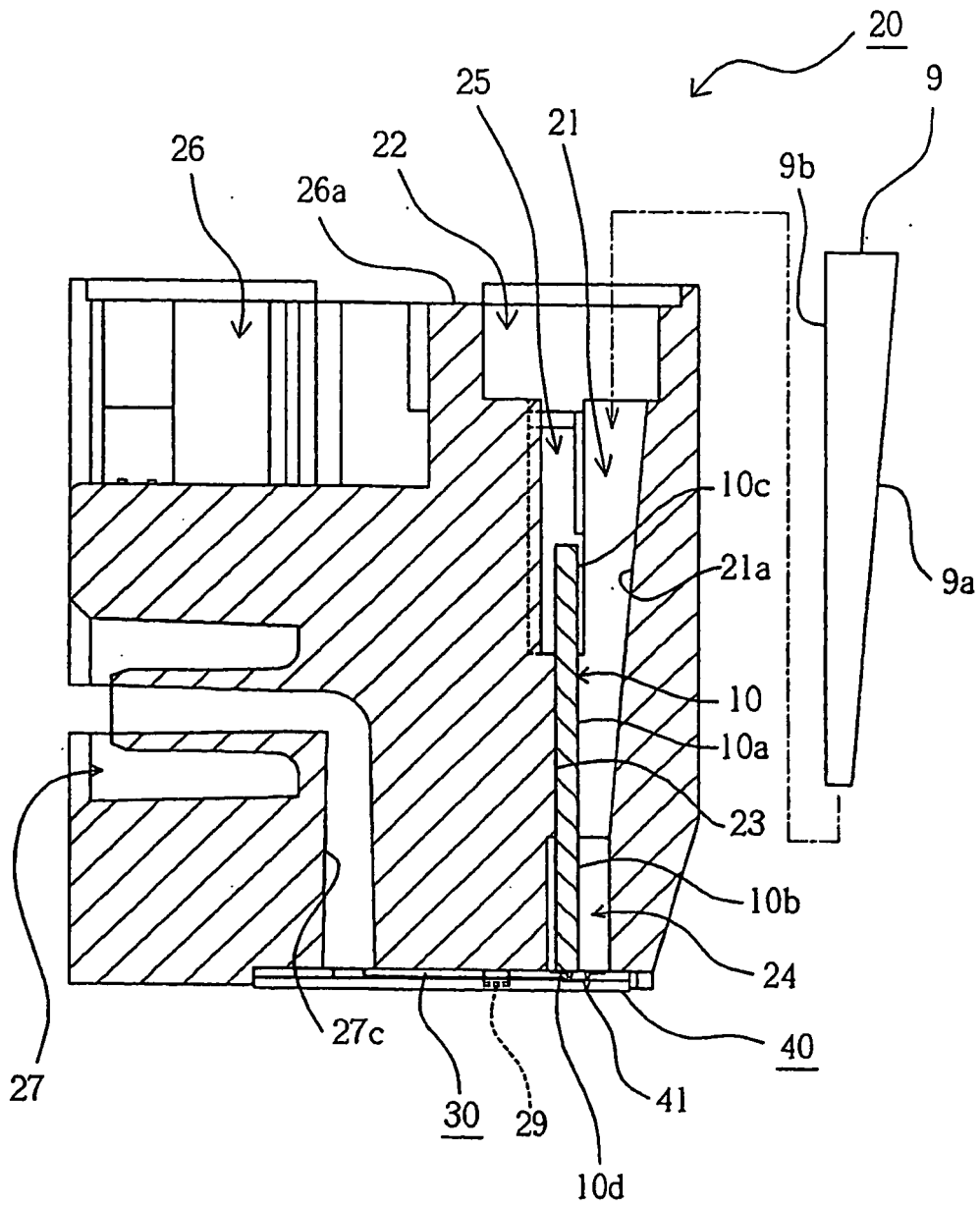


Fig. 3

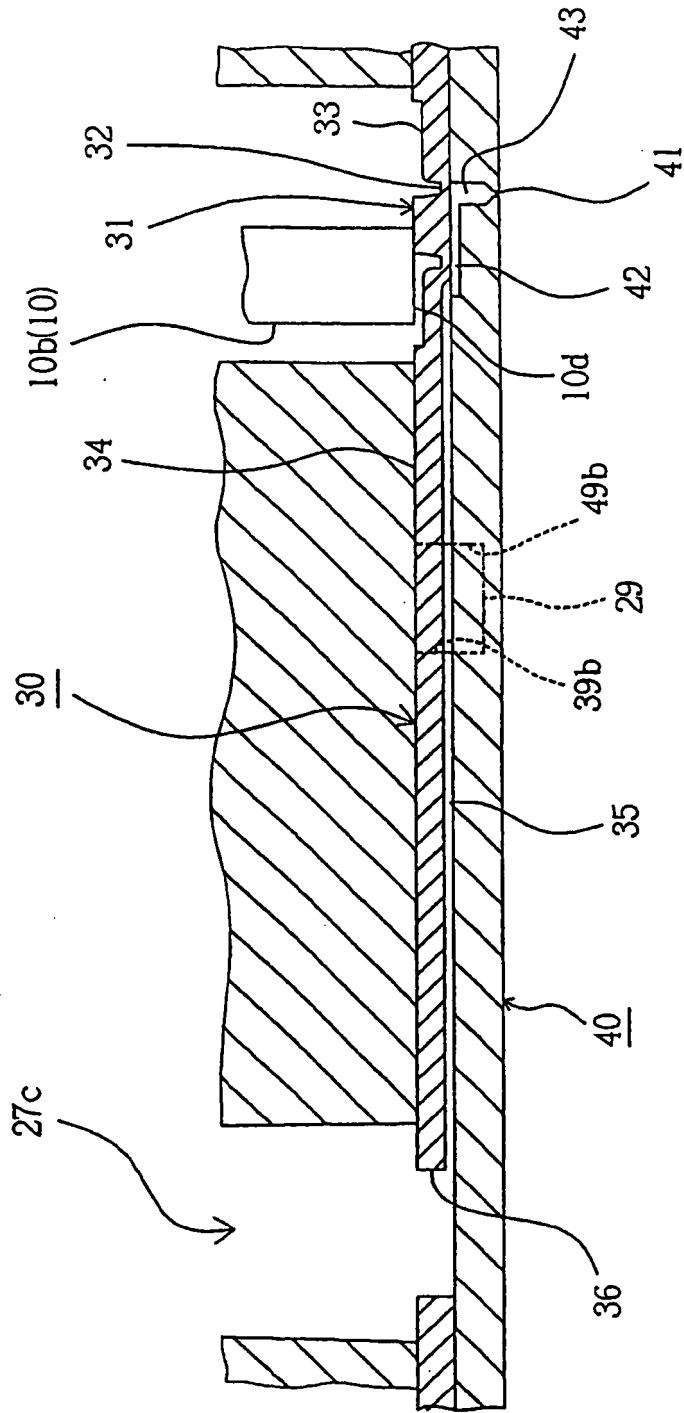


Fig. 4

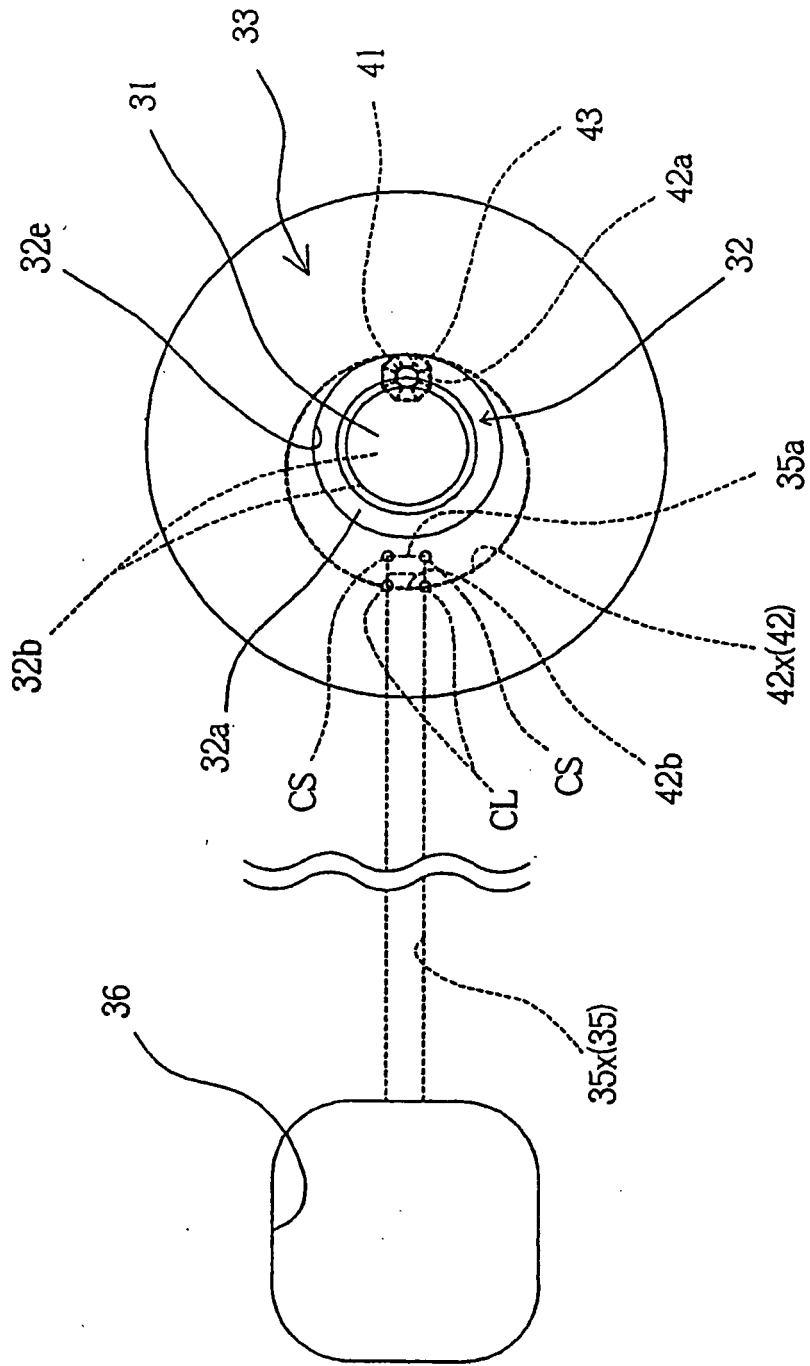


Fig. 5

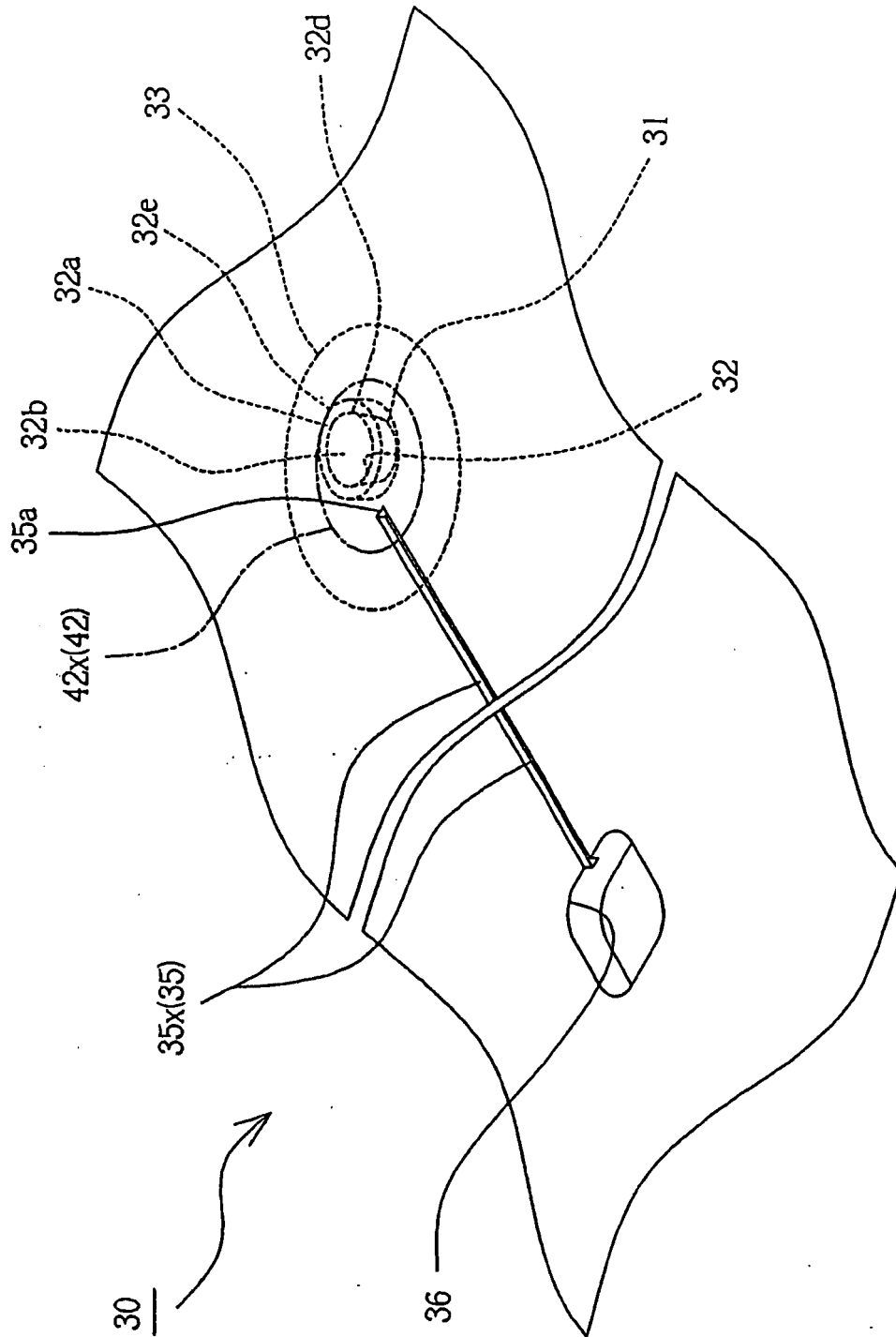


Fig. 8

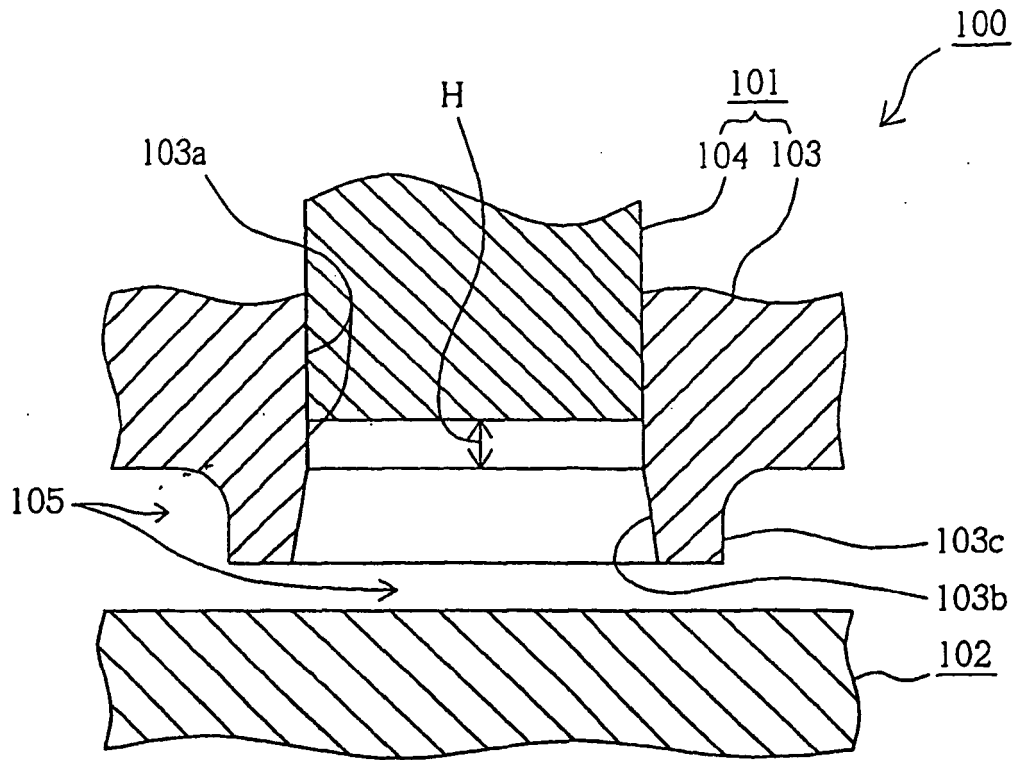


Fig. 9

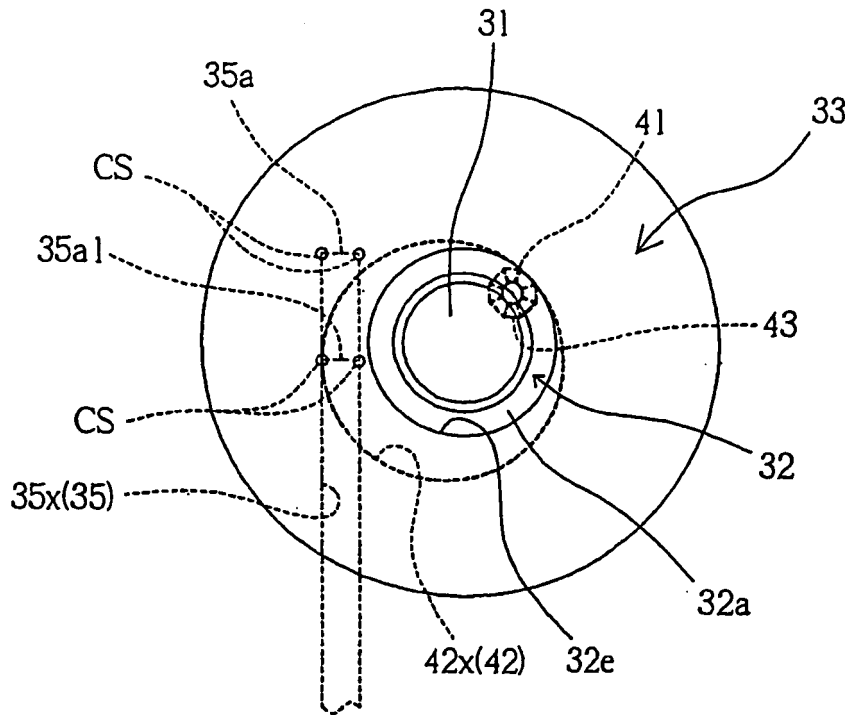
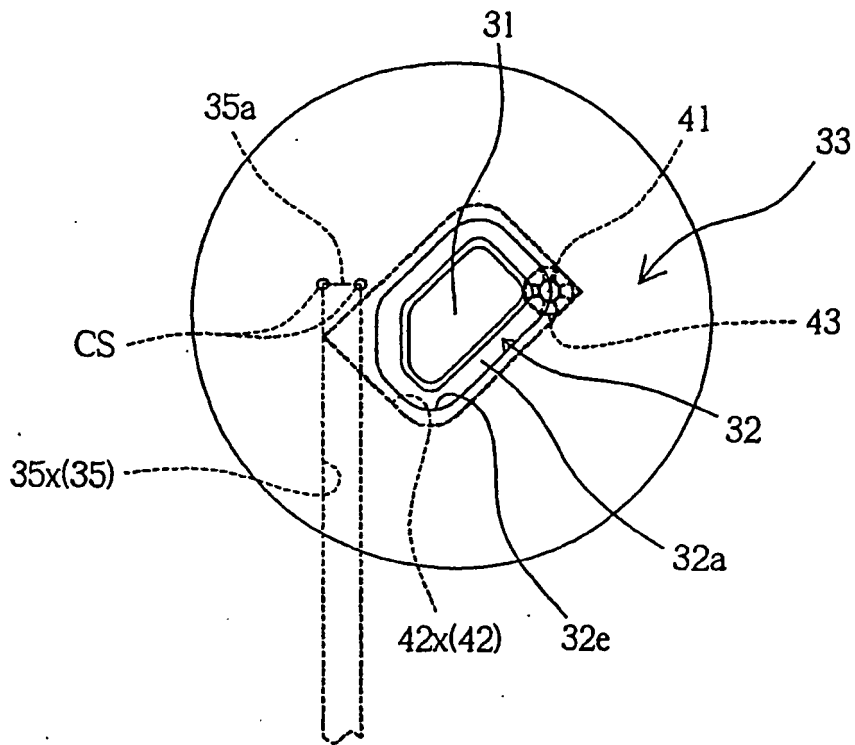


Fig. 10



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2006/321399

| A. CLASSIFICATION OF SUBJECT MATTER F04B43/04(2006.01) i | | |
|---|---|--|
| According to International Patent Classification (IPC) or to both national classification and IPC | | |
| B. FIELDS SEARCHED | | |
| Minimum documentation searched (classification system followed by classification symbols) F04B43/04, B41J2/015-2/065 | | |
| Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2007 Kokai Jitsuyo Shinan Koho 1971-2007 Toroku Jitsuyo Shinan Koho 1994-2007 | | |
| Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) | | |
| C. DOCUMENTS CONSIDERED TO BE RELEVANT | | |
| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
| X Y A | JP 2001-347674 A (Seiko Epson Corp.), 18 December, 2001 (18.12.01), Par. Nos. [0059] to [0060]; Fig. 1 (Family: none) | 1, 3, 7 4-6, 8 2 |
| X Y A | JP 2001-284669 A (Hitachi Koki Co., Ltd.), 12 October, 2001 (12.10.01), Par. No. [0022]; Fig. 1 (Family: none) | 1, 7 4-6, 8 2 |
| Y | JP 2003-94644 A (Ricoh Co., Ltd.), 03 April, 2003 (03.04.03), Fig. 2 (Family: none) | 4 |
| <input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/> See patent family annex. | | |
| * Special categories of cited documents: | | |
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| "P" | document published prior to the international filing date but later than the priority date claimed | |
| Date of the actual completion of the international search 22 January, 2007 (22.01.07) | | Date of mailing of the international search report 30 January, 2007 (30.01.07) |
| Name and mailing address of the ISA/ Japanese Patent Office | | Authorized officer |
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INTERNATIONAL SEARCH REPORT

International application No.
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| C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT | | |
|---|---|-----------------------|
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REFERENCES CITED IN THE DESCRIPTION

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