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(54) PIEZOELECTRIC CERAMIC AIR PUMP AND CONSTRUCTION METHOD THEREOF

(57) A piezoelectric ceramic air pump comprises: a pump body, a piezoelectric ceramic crystal diaphragm, and air inlet and output valves, the piezoelectric ceramic crystal diaphragm being co-central-axially mounted on the pump body to construct a working pump chamber for the piezoelectric ceramic air pump; wherein the pump body is approximately tubular, with the diameter being much greater than the axial length, and air inlet and outlet ports configured to communicate the working pump chamber with an external air passage are arranged at a position of a peripheral wall of the pump body; an air inlet and outlet component respectively laminates the air inlet and outlet valves onto the air inlet and outlet ports, such that the air inlet and outlet holes are in communication with the air inlet and outlet valves and the air inlet and outlet ports to form air inlet and outlet passages in communication with the external air passage. The air inlet and outlet ports on the side wall of the pump body help to simplify the air inlet and outlet passages for communication between the working pump chamber and the external fluid, shorten the pipeline in which the fluid flows, reduce the resistance of the pipeline, decrease the volume of the dead cavity, and improve the efficiency of fluid pumping. The number of piezoelectric ceramic crystal diaphragms may be flexibly set to one or two according to the flow rate in practice, and a lot of components are shared in the piezoelectric ceramic air pump, thereby lowering the cost of manufacturing air pumps with different powers.

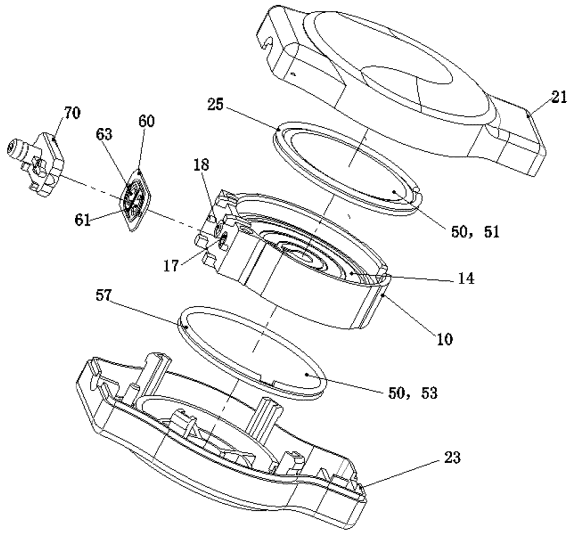

FIG. 2

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Description

TECHNICAL FIELD

[0001] The present invention relates to variable displacement hydraulic pumps, and in particular, relates to an air pump in which an alternating current power drives a piezoelectric ceramic sheet to vibrate.

BACKGROUND

[0002] In the prior art, in a piezoelectric ceramic air pump, the volume of a pump chamber changes due to extension, bending and deformation of a piezoelectric ceramic sheet, and a fluid is taken in or discharged from the chamber under an extrusion effect caused to the fluid in the chamber. In the operating process of the piezoelectric ceramic air pump, an air inlet valve and an air outlet valve are constantly turned on or turned off, thereby implementing constant negative-pressure-caused suction and positive-pressure-caused extrusion.

[0003] In the air passage design of the piezoelectric ceramic air pump in the prior art, generally an air suction chamber and an air discharge chamber are needed to serve as buffer spaces for air suction and air discharge, generally independent air inlet and output pipes and components are arranged, and thus the loop structure for air flows is complicated. As a result, the resistance of air flows inside the chamber is great, and thus the operating efficiency of the air pump is reduced and the flow rate of the air pump is small.

SUMMARY

[0004] To solve the technical problem that the air passage design is complicated, the resistance is great and thus the operating efficiency of the air pump is low and the flow rate is small in the prior art, the present invention provides a design solution of a highly efficient and small-sized piezoelectric ceramic air pump. The piezoelectric ceramic air pump comprises: a pump body , a piezoelectric ceramic crystal diaphragm, and air inlet and output valves; wherein the piezoelectric ceramic crystal diaphragm is co-central-axially mounted on the pump body to construct a working pump chamber for the piezoelectric ceramic air pump; the pump body is approximately tubular, with the diameter being much greater than the axial length, and air inlet and outlet ports configured to communicate the working pump chamber with an external air passage are arranged at a position of a peripheral wall of the pump body; and the air inlet and output valves are mounted at the position of the air inlet and outlet ports.

[0005] In the piezoelectric ceramic air pump, only one piezoelectric ceramic crystal diaphragm is mounted, and the piezoelectric ceramic crystal diaphragm is fitted and fixed onto the pump body via a lower pump cover, and seals and encloses the pump body to construct the working pump chamber.

[0006] In the piezoelectric ceramic air pump, two piezoelectric ceramic crystal diaphragms, including upper and lower piezoelectric ceramic crystal diaphragms are mounted; wherein the upper and lower piezoelectric ceramic crystal diaphragms are respectively fitted and fixed onto inner sides of upper and lower parts of the pump body via upper and lower pump cover; and the upper and lower piezoelectric ceramic crystal diaphragms are coaxially oppositely arranged on an outer surface of a metal substrate thereof, and seal and enclose the pump body to construct the shared working pump chamber.

[0007] In the piezoelectric ceramic air pump, the air inlet and outlet ports are adjacently or non-adjacently arranged on the peripheral wall on one side of the pump body, or the air inlet and outlet ports are oppositely arranged on peripheral walls at two ends of a diameter line of the pump body.

[0008] In the piezoelectric ceramic air pump, the piezoelectric ceramic air pump further comprises an air inlet and outlet component configured to respectively laminate the air inlet and outlet valves onto the air inlet and outlet ports, such that the air inlet and outlet holes on the air inlet and outlet component are in communication with the air inlet and outlet valves and the air inlet and outlet ports to form air inlet and outlet passages in communication with the external air passage; and the air inlet and outlet valves are independently molded or manufactured into an integral valve sheet which is provided with a positioning hole configured to perform fitting-based positioning on the peripheral wall of the pump body.

[0009] In the piezoelectric ceramic air pump, the piezoelectric ceramic crystal diaphragm seals and encloses the pump body via a first sealing ring arranged on one side of the piezoelectric ceramic crystal diaphragm to construct the working pump chamber; and the lower pump cover is fitted and fixed onto the pump body via a second sealing ring.

[0010] In the piezoelectric ceramic air pump, a spacer that is configured to support and isolate the upper and lower piezoelectric ceramic crystal diaphragms and parallel thereto is provided in the pump body, wherein an opening is provided on the spacer in the vicinity of the air inlet and outlet valves, such that the working pump chamber is shared by the upper and lower piezoelectric ceramic crystal diaphragms; and the upper and lower piezoelectric ceramic crystal diaphragms are laminated on the spacer respectively via third and fourth sealing rings, and seal and enclose the pump

body via the opening to construct the working pump chamber with a cross section in the shape of a horizontal U.

[0011] In the piezoelectric ceramic air pump, an annular boss that supports the upper and lower piezoelectric ceramic crystal diaphragms and inwardly protrudes is coaxially arranged on an inner wall of the pump body, and the upper and lower piezoelectric ceramic crystal diaphragms are laminated on the annular boss via third and fourth sealing rings, and seal and enclose the pump body to construct the working pump chamber in the shape of an oval; and the upper and lower pump cover are respectively laminated and fixedly connected onto the pump body via fifth and sixth sealing rings.

[0012] In the piezoelectric ceramic air pump, an end portion of the air outlet port on the pump body is an annular-surfaced arc shape, such that the pump body is in line contact with the end portion of the air outlet port when the air outlet valve is turned off; and an end portion of the air outlet component is also an annular-surfaced arc shape, such that the pump body is in line contact with an end portion of the air inlet hole when the air inlet valve is turned off.

[0013] In the piezoelectric ceramic air pump, the piezoelectric ceramic crystal diaphragm further comprises an insulating layer and a silver plating layer arranged on the metal substrate, wherein a piezoelectric ceramic layer is arranged between the insulating layer and the silver plating layer, and electrodes of the piezoelectric ceramic crystal diaphragm are respectively led out from the metal substrate and the silver plating layer.

[0014] A technical solution employed by the present invention to solve the technical problem in the prior art may also be a construction method of a piezoelectric ceramic air pump, based on a main structure comprising a pump body, a piezoelectric ceramic crystal diaphragm, and air inlet and output valves, the piezoelectric ceramic crystal diaphragm being co-central-axially mounted on the pump body to construct a working pump chamber for the piezoelectric ceramic air pump; wherein the method comprises step A: adjacently arranging air inlet and output ports configured to communicate the working pump chamber and an external air passage on a peripheral wall on one side of the pump body, wherein the air inlet and outlet valves are mounted at the position of the air inlet and outlet ports.

[0015] The method further comprises step B: mounting two piezoelectric ceramic crystal diaphragms, including upper and lower piezoelectric ceramic crystal diaphragms; wherein the upper and lower piezoelectric ceramic crystal diaphragms are coaxially oppositely arranged on an outer surface of a metal substrate thereof, and seal and enclose the pump body to construct the shared working pump chamber.

[0016] The method further comprises step C: arranging a spacer that is configured to support and isolate the upper and lower piezoelectric ceramic crystal diaphragms and parallel thereto in the pump body, wherein an opening is provided on the spacer in the vicinity of the air inlet and outlet valves, such that the dead cavity of the shared working pump chamber is reduced and the pumping efficiency is improved.

[0017] The method further comprises step D: simultaneously compressing towards each other or expansion-wise axially moves away from each other by the upper and lower piezoelectric ceramic crystal diaphragms within each power source semi-cycle when an alternating current excitation voltage is applied to the upper and lower piezoelectric ceramic crystal diaphragms.

[0018] The method further comprises step E: respectively laminating the air inlet and outlet valves onto the air inlet and outlet ports, such that the air inlet and outlet holes on the air inlet and outlet component are in communication with the air inlet and outlet valves and the air inlet and outlet ports to form air inlet and outlet passages in communication with the external air passage; and the air inlet and outlet valves are manufactured into an integral valve sheet which is provided with a positioning hole configured to perform fitting-based positioning on the peripheral wall of the pump body.

[0019] Compared with the prior art, the present invention achieves the following beneficial effects:

[0020] 1. The air inlet and outlet ports for communication between the working pump chamber and the external air passage are arranged on the peripheral wall of the pump body, and the inlet and outlet valves are arranged thereon, such that the air inlet and outlet passages for communication between the working pump chamber and the external fluid are simplified, the pipeline in which the fluid flows is shortened, the resistance of the pipeline is reduced, the volume of the dead cavity is decreased, and the efficiency of fluid pumping is improved.

[0021] 2. The number of piezoelectric ceramic crystal diaphragms may be flexibly set to one or two according to the flow rate in practice, and a lot of components are shared in the piezoelectric ceramic air pump, thereby lowering the cost of manufacturing air pumps with different powers.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022]

FIG. 1 is a schematic top view of front projection of a piezoelectric ceramic crystal air pump according to first to third preferred embodiments of the present invention, wherein an upper pump cover 21 is partially removed, and a partial cross section is exhibited at the position the removed part;

FIG. 2 is a schematic axonometric projection view in an exploded state according to the first preferred embodiment of the present invention;

FIG. 3 is a schematic axonometric projection view in an exploded state when an upper pump cover 21 and a lower

pump cover 23 are removed according to the first preferred embodiment of the present invention;

FIG. 4 is a schematic front projection view of a D-D cross section in FIG. 1 according to the first preferred embodiment of the present invention;

FIG. 5 is a schematic front projection view of a D-D cross section in FIG. 1 according to the third preferred embodiment of the present invention;

FIG. 6 is a schematic front projection of an E-E cross section in FIG. 4 or FIG. 5;

FIG. 7 is a schematic enlarged view of part A in FIG. 1 or part J in FIG. 13;

FIG. 8 is a schematic view of an air inlet state of the piezoelectric ceramic air pump in FIG. 7, wherein the arrow direction represents an air inlet direction;

FIG. 9 is a schematic view of an air output state of the piezoelectric ceramic air pump in FIG. 7, wherein the arrow direction represents an air inlet direction;

FIG. 10 is a schematic front view of front projection of an integral valve sheet 60 according to the present invention;

FIG. 11 is a schematic front view of front projection of an air inlet valve 61 and an air outlet valve that are independently molded according to the present invention;

FIG. 12 is a schematic axonometric projection view in an exploded state when an upper pump cover 21 and a lower pump cover 23 are removed according to the second preferred embodiment of the present invention;

FIG. 13 is a schematic top view of the front projection in FIG. 3, wherein an upper piezoelectric ceramic crystal diaphragm 51 is partially removed, and a partial cross section is exhibited at the position the removed part;

FIG. 14 is a schematic front projection view of an H-H cross section in FIG. 13 according to the second preferred embodiment of the present invention;

FIG. 15 is a schematic enlarged view of the front projection when the upper pump cover 21 and the lower pump cover 23 are removed from a D-D cross section in FIG. 1 according to a preferred embodiment of the present invention, wherein FIG. 15 further schematically illustrates circuit connection of the two piezoelectric ceramic crystal diaphragms; and

FIG. 16 is a schematic enlarged front projection view of a cross section of a piezoelectric ceramic crystal diaphragm 50 according to the present invention.

DETAILED DESCRIPTION

[0023] Embodiments of the present invention are further described in detail with reference to the accompanying drawings.

[0024] In a piezoelectric ceramic air pump and a construction method thereof according to a first preferred embodiment as illustrated in FIG. 1 to FIG. 4, two piezoelectric ceramic crystal diaphragms 50 are mounted; wherein an upper piezoelectric ceramic crystal diaphragm 51 and a lower piezoelectric ceramic crystal diaphragm 53 are respectively fitted and fixed onto inner sides of upper and lower parts of a pump body 10 via an upper pump cover 21 and a lower pump cover 23; and the upper and lower piezoelectric ceramic crystal diaphragms are coaxially oppositely arranged on an outer surface of a metal substrate 91 thereof, and seal and enclose the pump body 10 to construct a shared working pump chamber 15.

[0025] In the piezoelectric ceramic air pump and the construction method thereof according to the first preferred embodiment as illustrated in FIG. 3 and FIG. 4, a spacer 14 that is configured to support and isolate the upper and lower piezoelectric ceramic crystal diaphragms and parallel thereto is provided in the pump body 10, wherein an opening 16 is provided on the spacer 14 in the vicinity of the air inlet and outlet valves, such that the working pump chamber 15 is shared by the upper and lower piezoelectric ceramic crystal diaphragms; and the upper and lower piezoelectric ceramic crystal diaphragms are laminated on the spacer 14 respectively via a third sealing ring 55 and a fourth sealing ring 57, and seal and enclose the pump body 10 via the opening 16 to construct the working pump chamber 15 with a cross section in the shape of a horizontal U. The opening 16 is provided on the spacer 14 in the vicinity of the air inlet and outlet valves, such that the dead cavity of the shared working pump chamber 15 is reduced and the pumping efficiency is improved.

[0026] In a piezoelectric ceramic air pump and a construction method thereof according to a second preferred embodiment as illustrated in FIG. 12 to FIG. 14, an annular boss 12 that supports the upper and lower piezoelectric ceramic crystal diaphragms and inwardly protrudes is coaxially arranged on an inner wall of the pump body 10, and the upper and lower piezoelectric ceramic crystal diaphragms are laminated on the annular boss 12 via a third sealing ring 55 and a fourth sealing ring 57, and seal and enclose the pump body 10 to construct the working pump chamber 15 in the shape of an oval.

[0027] In the first and second preferred embodiments, the upper pump cover 21 and the lower pump cover 23 are respectively laminated and fixedly connected onto the pump body 10 via a fifth sealing ring 25 and a sixth sealing ring 27.

[0028] In a third preferred embodiment of the piezoelectric ceramic air pump as illustrated in FIG. 1 to FIG. 5, only one piezoelectric ceramic crystal diaphragm 50 is mounted, and the piezoelectric ceramic crystal diaphragm 50 is fitted

and fixed onto the pump body 10 via the lower pump cover 23, and seals and encloses the pump body 10 to construct the working pump chamber 15. The piezoelectric ceramic crystal diaphragm 50 seals and encloses the pump body 10 via a first sealing ring 59 arranged on one side of the piezoelectric ceramic crystal diaphragm 50 to construct the working pump chamber 15; and the lower pump cover 23 is fitted and fixed onto the pump body 10 via a second sealing ring 29.

[0029] In some other embodiments as illustrated in FIG. 1 to FIG. 9, the air inlet port 17 and the air outlet port 18 are adjacently or non-adjacently arranged on the peripheral wall on one side of the pump body 10; an air inlet and outlet component 70 respectively laminates the air inlet valve 61 and the air outlet valve 63 onto the air inlet and outlet ports, such that an air inlet hole 71 and an air outlet hole 73 on the air inlet and outlet component 70 are in communication with the air inlet and outlet valves and the air inlet and outlet ports to form an air inlet passage 81 and an air outlet passage 83 in communication with an external air passage. Nevertheless, the air inlet and outlet ports may also be oppositely arranged on peripheral walls at two ends of a diameter line of the pump body 10.

[0030] As illustrated in FIG. 7, the air inlet passage 81 has an air inlet valve space 82 on the side on which the air inlet valve 61 is turned on or off; and the air outlet passage 83 has an air outlet valve space 84 on the side on which the air outlet valve 63 is turned on or off.

[0031] FIG. 8 is a schematic view of an air inlet state of the piezoelectric ceramic air pump. As illustrated in FIG. 8, the arrow direction represents an air inlet direction; in case where the air is taken in, i.e., when the piezoelectric ceramic diaphragm 50 vibrates and causes deformation outwardly, the volume of the working pump chamber 15 increases and a negative pressure is formed in the working pump chamber 15, the air inlet valve 61 is pushed open by the negative pressure, and the air outlet valve 63 is suctioned closed by the negative pressure. In this case, an external fluid enters the working pump chamber 15 through the air inlet valve 61 and the air inlet hole 71 sequentially.

[0032] FIG. 9 is a schematic view of an air outlet state of the piezoelectric ceramic air pump. As illustrated in FIG. 9, the arrow direction represents an air outlet direction; in case where the air is taken in, i.e., when the piezoelectric ceramic diaphragm 50 vibrates and causes deformation in the working pump chamber 15, the volume of the working pump chamber 15 decreases, a positive pressure is formed in the working pump chamber 15, the air inlet valve 61 is suctioned closed by the positive pressure, and the air outlet valve 63 is pushed open by the positive pressure. In this case, an fluid in the working pump chamber 15 flows through the air outlet hole 73 and the air outlet valve 63 sequentially.

[0033] In an embodiment as illustrated in FIG. 10, the air inlet valve 61 and the air outlet valve 63 are manufactured into an integral valve sheet 60. In an embodiment as illustrated in FIG. 11, the air inlet valve 61 and the air outlet valve 63 are independently arranged, or may be shared, that is, the air inlet valve 61 and the air outlet valve 63 are the same component. As illustrated in FIG. 10 and FIG. 11, the air inlet valve 61 and the air outlet valve 63 or the integral valve sheet 60 is provided with a positioning hole 66 configured to perform fitting-based positioning on the peripheral wall of the pump body 10, such that the air inlet valve 61 is accurately aligned with the air inlet port 17 on the peripheral wall of the pump body 10, and such that the air outlet valve 63 is accurately aligned with the air outlet port 18 on the peripheral wall of the pump body 10.

[0034] In a piezoelectric ceramic air pump and a construction method thereof according to a preferred embodiment as illustrated in FIG. 15 and FIG. 16, the piezoelectric ceramic crystal diaphragm 50 further comprises an insulating layer 92 and a silver plating layer 94 arranged on the metal substrate 91, wherein a piezoelectric ceramic layer 93 is arranged between the insulating layer and the silver plating layer, and electrodes of the piezoelectric ceramic crystal diaphragm are respectively led out from the metal substrate 91 and the silver plating layer 94. The method further comprises: simultaneously compressing towards each other or expansion-wise axially moves away from each other by the upper and lower piezoelectric ceramic crystal diaphragms within each power source semi-cycle when an alternating current excitation voltage is applied to the upper and lower piezoelectric ceramic crystal diaphragms. The arrangement of the piezoelectric ceramic crystal diaphragm and the manner of applying the alternating current excitation voltage greatly increase the extrusion efficiency of the fluid in the working pump chamber under extrusion by the diaphragm.

[0035] In the prior art, the piezoelectric ceramic air pump has a small flow rate which is generally between 0.3 L/min and 0.5 L/min. The piezoelectric ceramic air pump in the technical solution of the present invention has a reasonable deployment of air passages, and thus the operating efficiency of the air pump is improved. Therefore, the piezoelectric ceramic air pump according to the present invention is a highly efficient miniature air pump. A sample designed according to the solution of a preferred embodiment of the present invention is compared with a conventional piezoelectric ceramic air pump in the prior art under the same conditions. The comparison test, as listed in Table 1, reveals that although the desired sample has two piezoelectric ceramic diaphragms, the actual power consumption is two-fold lower than that of a single piezoelectric ceramic diaphragm, and the output flow rate is two-fold greater than that of the single piezoelectric ceramic crystal diaphragm. Apparently, the technical solution according to the present invention is superior over the prior art, with the flow rate output capability and the energy efficiency being both better over the prior art.

[0036] Described above are exemplary embodiments of the present invention, but are not intended to limit the scope of the present invention. Any equivalent structure or equivalent process variation made based on the specification and drawings of the present invention, which is directly or indirectly applied in other related technical fields, fall within the scope of the present invention.

Table 1

Test sample	Voltage/Frequ ency	Current (mA)	Power (W)	Flow rate (L/min)
Piezoelectric ceramic air pump in the prior art	120/60	39.5	0.48	0.36
Sample designed according to the solution of a preferred embodiment	120/60	46.15	0.76	0.90

Claims

1. A piezoelectric ceramic air pump, comprising: a pump body (10), a piezoelectric ceramic crystal diaphragm (50), and air inlet and output valves (61, 63), the piezoelectric ceramic crystal diaphragm (50) being co-central-axially mounted on the pump body (10) to construct a working pump chamber (15) for the piezoelectric ceramic air pump; wherein
the pump body (10) is approximately tubular, with the diameter being much greater than the axial length, and air inlet and outlet ports (17, 18) configured to communicate the working pump chamber (15) with an external air passage are arranged at a position of a peripheral wall of the pump body (10); and
the air inlet and output valves (61, 63) are mounted at the position of the air inlet and outlet ports (17, 18).

2. The piezoelectric ceramic air pump according to claim 1, wherein
only one piezoelectric ceramic crystal diaphragm (50) is mounted, and the piezoelectric ceramic crystal diaphragm (50) is fitted and fixed onto the pump body (10) via a lower pump cover (23), and seals and encloses the pump body (10) to construct the working pump chamber (15).

3. The piezoelectric ceramic air pump according to claim 1, wherein
two piezoelectric ceramic crystal diaphragms (50), including upper and lower piezoelectric ceramic crystal diaphragms (51, 53), are mounted; wherein the upper and lower piezoelectric ceramic crystal diaphragms (51, 53) are respectively fitted and fixed onto inner sides of upper and lower parts of the pump body (10) via upper and lower pump cover (21, 23); and
the upper and lower piezoelectric ceramic crystal diaphragms (51, 53) are coaxially oppositely arranged on an outer surface of a metal substrate (91) thereof, and seal and enclose the pump body (10) to construct the shared working pump chamber (15).

4. The piezoelectric ceramic air pump according to claim 1, wherein
the air inlet and outlet ports (17, 18) are adjacently or non-adjacently arranged on the peripheral wall on one side of the pump body (10), or the air inlet and outlet ports (17, 18) are oppositely arranged on peripheral walls at two ends of a diameter line of the pump body (10).

5. The piezoelectric ceramic air pump according to claim 1, wherein
the piezoelectric ceramic air pump further comprises an air inlet and outlet component (70) configured to respectively laminate the air inlet and outlet valves (61, 63) onto the air inlet and outlet ports (17, 18), such that the air inlet and outlet holes (71, 73) on the air inlet and outlet component (70) are in communication with the air inlet and outlet valves (61, 63) and the air inlet and outlet ports (17, 18) to form air inlet and outlet passages (81, 83) in communication with the external air passage; and the air inlet and outlet valves (61, 63) are independently molded or manufactured into an integral valve sheet (60) which is provided with a positioning hole (66) configured to perform fitting-based positioning on the peripheral wall of the pump body (10).

6. The piezoelectric ceramic air pump according to claim 2, wherein
the piezoelectric ceramic crystal diaphragm (50) seals and encloses the pump body (10) via a first sealing ring (59) arranged on one side of the piezoelectric ceramic crystal diaphragm (50) to construct the working pump chamber (15); and the lower pump cover (23) is fitted and fixed onto the pump body (10) via a second sealing ring (29).

7. The piezoelectric ceramic air pump according to claim 3, wherein
a spacer (14) that is configured to support and isolate the upper and lower piezoelectric ceramic crystal diaphragms (51, 53) and parallel thereto is provided in the pump body (10), wherein an opening (16) is provided on the spacer

(14) in the vicinity of the air inlet and outlet valves (61, 63), such that the working pump chamber (15) is shared by the upper and lower piezoelectric ceramic crystal diaphragms (51, 53); and
the upper and lower piezoelectric ceramic crystal diaphragms (51, 53) are laminated on the spacer (14) respectively via third and fourth sealing rings (55, 57), and seal and enclose the pump body (10) via the opening (16) to construct the working pump chamber (15) with a cross section in the shape of a horizontal U.

8. The piezoelectric ceramic air pump according to claim 3, wherein
an annular boss (12) that supports the upper and lower piezoelectric ceramic crystal diaphragms (51, 53) and inwardly protrudes is coaxially arranged on an inner wall of the pump body (10), and the upper and lower piezoelectric ceramic crystal diaphragms (51, 53) are laminated on the annular boss (12) via third and fourth sealing rings (55, 57), and seal and enclose the pump body (10) to construct the working pump chamber (15) in the shape of an oval; and
the upper and lower pump cover (21, 23) are respectively laminated and fixedly connected onto the pump body (10) via fifth and sixth sealing rings (25, 27).

9. The piezoelectric ceramic air pump according to claim 5, wherein
an end portion of the air outlet port (18) on the pump body (10) is an annular-surfaced arc shape, such that the pump body (10) is in line contact with the end portion of the air outlet port (18) when the air outlet valve (63) is turned off; and an end portion of the air outlet component (70) is also an annular-surfaced arc shape, such that the pump body (10) is in line contact with an end portion of the air inlet hole (71) when the air inlet valve (61) is turned off.

10. The piezoelectric ceramic air pump according to claim 1, wherein
the piezoelectric ceramic crystal diaphragm (50) further comprises an insulating layer (92) and a silver plating layer (94) arranged on the metal substrate (91), wherein a piezoelectric ceramic layer (93) is arranged between the insulating layer and the silver plating layer, and electrodes of the piezoelectric ceramic crystal diaphragm are respectively led out from the metal substrate (91) and the silver plating layer (94).

11. A construction method of a piezoelectric ceramic air pump, based on a main structure comprising a pump body (10), a piezoelectric ceramic crystal diaphragm (50), and air inlet and output valves (61, 63), the piezoelectric ceramic crystal diaphragm (50) being co-central-axially mounted on the pump body (10) to construct a working pump chamber (15) for the piezoelectric ceramic air pump; wherein the method comprises step A:

adjacently arranging air inlet and output ports (17, 18) configured to communicate the working pump chamber (15) and an external air passage on a peripheral wall on one side of the pump body (10), wherein the air inlet and outlet valves (61, 63) are mounted at the position of the air inlet and outlet ports (17, 18).

12. The construction method of a piezoelectric ceramic air pump according to claim 11, further comprising step B:

mounting two piezoelectric ceramic crystal diaphragms (50), including upper and lower piezoelectric ceramic crystal diaphragms (51, 53); wherein the upper and lower piezoelectric ceramic crystal diaphragms (51, 53) are coaxially oppositely arranged on an outer surface of a metal substrate (91) thereof, and seal and enclose the pump body (10) to construct the shared working pump chamber (15).

13. The construction method of a piezoelectric ceramic air pump according to claim 12, further comprising step C:

arranging a spacer (14) that is configured to support and isolate the upper and lower piezoelectric ceramic crystal diaphragms (51, 53) and parallel thereto in the pump body (10), wherein an opening (16) is provided on the spacer (14) in the vicinity of the air inlet and outlet valves (61, 63), such that the dead cavity of the shared working pump chamber (15) is reduced and the pumping efficiency is improved.

14. The construction method of a piezoelectric ceramic air pump according to claim 12 or 13, further comprising step D:

simultaneously compressing towards each other or expansion-wise axially moves away from each other by the upper and lower piezoelectric ceramic crystal diaphragms (51, 53) within each power source semi-cycle when an alternating current excitation voltage is applied to the upper and lower piezoelectric ceramic crystal diaphragms (51, 53).

15. The construction method of a piezoelectric ceramic air pump according to claim 11, wherein the method further comprises step E:

respectively laminating the air inlet and outlet valves (61, 63) onto the air inlet and outlet ports (17, 18), such that the air inlet and outlet holes (71, 73) on the air inlet and outlet component (70) are in communication with the air inlet and outlet valves (61, 63) and the air inlet and outlet ports (17, 18) to form air inlet and outlet passages (81, 83) in communication with the external air passage; and the air inlet and outlet valves (61, 63) are manufactured into an integral valve sheet (60) which is provided with a positioning hole (66) configured to perform fitting-based positioning on the peripheral wall of the pump body (10).

Amended claims under Art. 19.1 PCT

1. A piezoelectric ceramic air pump, comprising: a pump body (10), a piezoelectric ceramic crystal diaphragm (50), and air inlet and output valves (61, 63), the piezoelectric ceramic crystal diaphragm (50) being co-central-axially mounted on the pump body (10) to construct a working pump chamber (15) for the piezoelectric ceramic air pump; wherein
the pump body (10) is approximately tubular, with the diameter being much greater than the axial length, and air inlet and outlet ports (17, 18) configured to communicate the working pump chamber (15) with an external air passage are arranged at a position of a peripheral wall of the pump body (10);
the air inlet and output valves (61, 63) are mounted at the position of the air inlet and outlet ports (17, 18); and
the piezoelectric ceramic air pump further comprises an air inlet and outlet component (70) configured to respectively laminate the air inlet and outlet valves (61, 63) onto the air inlet and outlet ports (17, 18), such that the air inlet and outlet holes (71, 73) on the air inlet and outlet component (70) are in communication with the air inlet and outlet valves (61, 63) and the air inlet and outlet ports (17, 18) to form air inlet and outlet passages (81, 83) in communication with the external air passage; and the air inlet and outlet valves (61, 63) are independently molded or manufactured into an integral valve sheet (60) which is provided with a positioning hole (66) configured to perform fitting-based positioning on the peripheral wall of the pump body (10).

2. The piezoelectric ceramic air pump according to claim 1, wherein
only one piezoelectric ceramic crystal diaphragm (50) is mounted, and the piezoelectric ceramic crystal diaphragm (50) is fitted and fixed onto the pump body (10) via a lower pump cover (23), and seals and encloses the pump body (10) to construct the working pump chamber (15).

3. The piezoelectric ceramic air pump according to claim 1, wherein
two piezoelectric ceramic crystal diaphragms (50), including upper and lower piezoelectric ceramic crystal diaphragms (51, 53), are mounted; wherein the upper and lower piezoelectric ceramic crystal diaphragms (51, 53) are respectively fitted and fixed onto inner sides of upper and lower parts of the pump body (10) via upper and lower pump cover (21, 23); and
the upper and lower piezoelectric ceramic crystal diaphragms (51, 53) are coaxially oppositely arranged on an outer surface of a metal substrate (91) thereof, and seal and enclose the pump body (10) to construct the shared working pump chamber (15).

4. The piezoelectric ceramic air pump according to claim 1, wherein
the air inlet and outlet ports (17, 18) are adjacently or non-adjacently arranged on the peripheral wall on one side of the pump body (10), or the air inlet and outlet ports (17, 18) are oppositely arranged on peripheral walls at two ends of a diameter line of the pump body (10).

5. The piezoelectric ceramic air pump according to claim 2, wherein
the piezoelectric ceramic crystal diaphragm (50) seals and encloses the pump body (10) via a first sealing ring (59) arranged on one side of the piezoelectric ceramic crystal diaphragm (50) to construct the working pump chamber (15); and the lower pump cover (23) is fitted and fixed onto the pump body (10) via a second sealing ring (29).

6. The piezoelectric ceramic air pump according to claim 3, wherein
a spacer (14) that is configured to support and isolate the upper and lower piezoelectric ceramic crystal diaphragms (51, 53) and parallel thereto is provided in the pump body (10), wherein an opening (16) is provided on the spacer (14) in the vicinity of the air inlet and outlet valves (61, 63), such that the working pump chamber (15) is shared by the upper and lower piezoelectric ceramic crystal diaphragms (51, 53); and
the upper and lower piezoelectric ceramic crystal diaphragms (51, 53) are laminated on the spacer (14) respectively via third and fourth sealing rings (55, 57), and seal and enclose the pump body (10) via the opening (16) to construct the working pump chamber (15) with a cross section in the shape of a horizontal U.

7. The piezoelectric ceramic air pump according to claim 3, wherein
an annular boss (12) that supports the upper and lower piezoelectric ceramic crystal diaphragms (51, 53) and inwardly protrudes is coaxially arranged on an inner wall of the pump body (10), and the upper and lower piezoelectric ceramic crystal diaphragms (51, 53) are laminated on the annular boss (12) via third and fourth sealing rings (55, 57), and seal and enclose the pump body (10) to construct the working pump chamber (15) in the shape of an oval; and the upper and lower pump cover (21, 23) are respectively laminated and fixedly connected onto the pump body (10) via fifth and sixth sealing rings (25, 27).

8. The piezoelectric ceramic air pump according to claim 1, wherein
an end portion of the air outlet port (18) on the pump body (10) is an annular-surfaced arc shape, such that the pump body (10) is in line contact with the end portion of the air outlet port (18) when the air outlet valve (63) is turned off; and an end portion of the air outlet component (70) is also an annular-surfaced arc shape, such that the pump body (10) is in line contact with an end portion of the air inlet hole (71) when the air inlet valve (61) is turned off.

9. The piezoelectric ceramic air pump according to claim 1, wherein
the piezoelectric ceramic crystal diaphragm (50) further comprises an insulating layer (92) and a silver plating layer (94) arranged on the metal substrate (91), wherein a piezoelectric ceramic layer (93) is arranged between the insulating layer and the silver plating layer, and electrodes of the piezoelectric ceramic crystal diaphragm are respectively led out from the metal substrate (91) and the silver plating layer (94).

10. A construction method of a piezoelectric ceramic air pump, based on a main structure comprising a pump body (10), a piezoelectric ceramic crystal diaphragm (50), and air inlet and output valves (61, 63), the piezoelectric ceramic crystal diaphragm (50) being co-central-axially mounted on the pump body (10) to construct a working pump chamber (15) for the piezoelectric ceramic air pump; wherein the method comprises step A:

adjacently arranging air inlet and output ports (17, 18) configured to communicate the working pump chamber (15) and an external air passage on a peripheral wall on one side of the pump body (10), wherein the air inlet and outlet valves (61, 63) are mounted at the position of the air inlet and outlet ports (17, 18); and
wherein the method further comprises step E:

respectively laminating the air inlet and outlet valves (61, 63) onto the air inlet and outlet ports (17, 18), such that the air inlet and outlet holes (71, 73) on the air inlet and outlet component (70) are in communication with the air inlet and outlet valves (61, 63) and the air inlet and outlet ports (17, 18) to form air inlet and outlet passages (81, 83) in communication with the external air passage; and the air inlet and outlet valves (61, 63) are manufactured into an integral valve sheet (60) which is provided with a positioning hole (66) configured to perform fitting-based positioning on the peripheral wall of the pump body (10).

11. The construction method of a piezoelectric ceramic air pump according to claim 10, further comprising step B:

mounting two piezoelectric ceramic crystal diaphragms (50), including upper and lower piezoelectric ceramic crystal diaphragms (51, 53); wherein the upper and lower piezoelectric ceramic crystal diaphragms (51, 53) are coaxially oppositely arranged on an outer surface of a metal substrate (91) thereof, and seal and enclose the pump body (10) to construct the shared working pump chamber (15).

12. The construction method of a piezoelectric ceramic air pump according to claim 11, further comprising step C:

arranging a spacer (14) that is configured to support and isolate the upper and lower piezoelectric ceramic crystal diaphragms (51, 53) and parallel thereto in the pump body (10), wherein an opening (16) is provided on the spacer (14) in the vicinity of the air inlet and outlet valves (61, 63), such that the dead cavity of the shared working pump chamber (15) is reduced and the pumping efficiency is improved.

13. The construction method of a piezoelectric ceramic air pump according to claim 11 or 12, further comprising step D:

simultaneously compressing towards each other or expansion-wise axially moves away from each other by the upper and lower piezoelectric ceramic crystal diaphragms (51, 53) within each power source semi-cycle when an alternating current excitation voltage is applied to the upper and lower piezoelectric ceramic crystal diaphragms (51, 53).

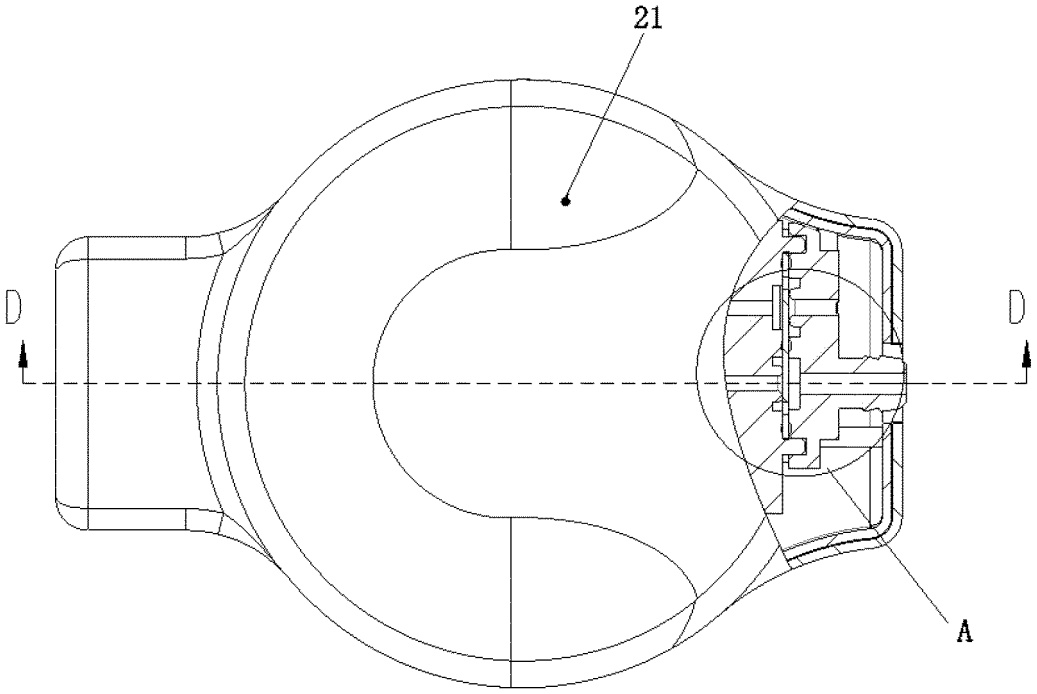

FIG. 1

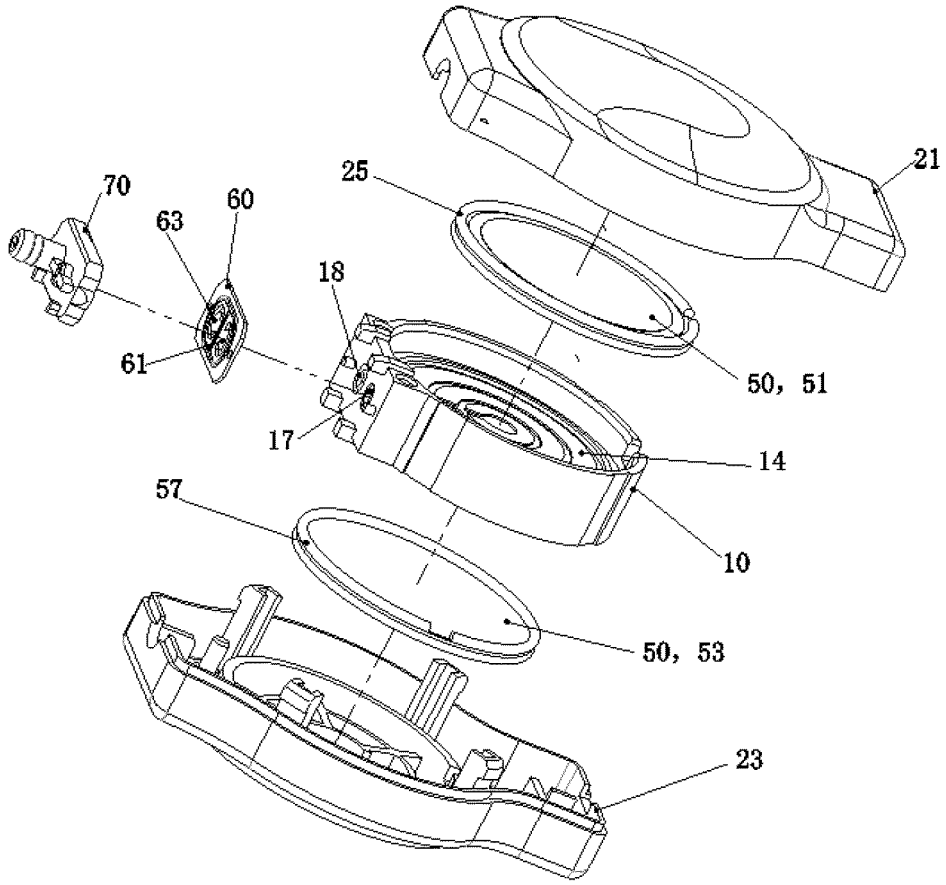

FIG. 2

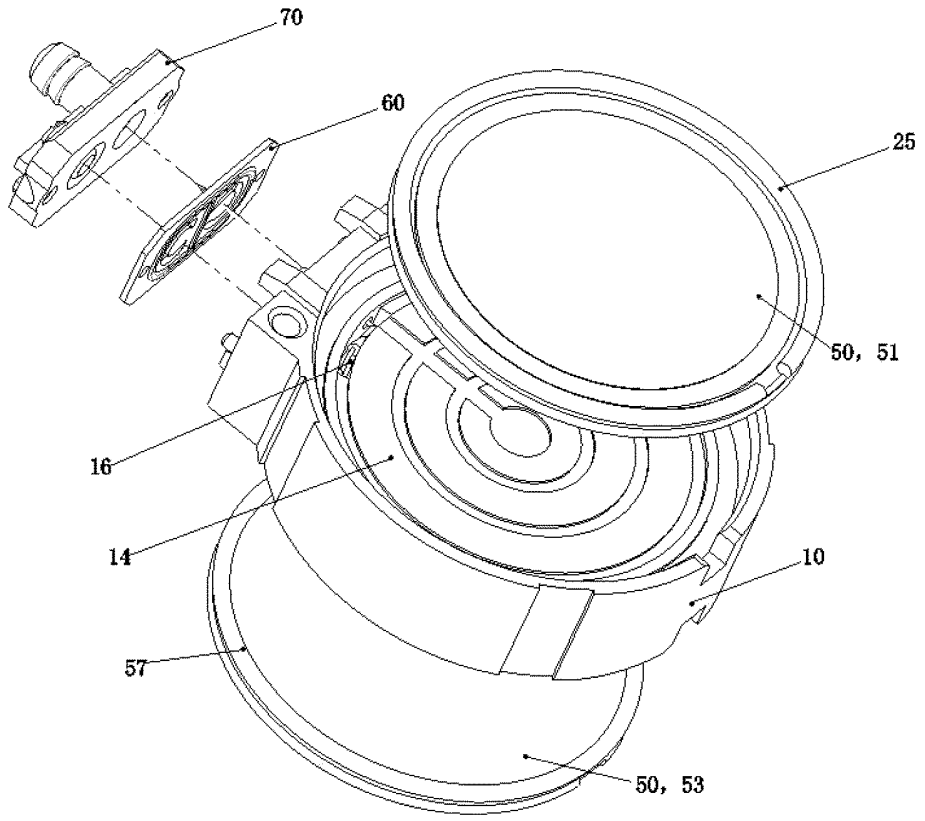
70
60
25
50, 51
16
14
10
57
50, 53

FIG. 3

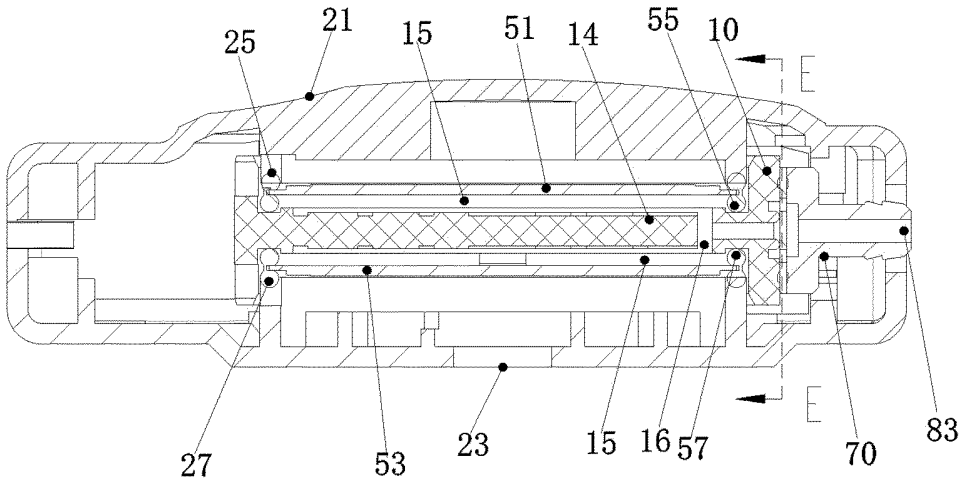
25
21
15
51
14
55
10
E
E
27
53
23
15
16
57
70
83

FIG. 4

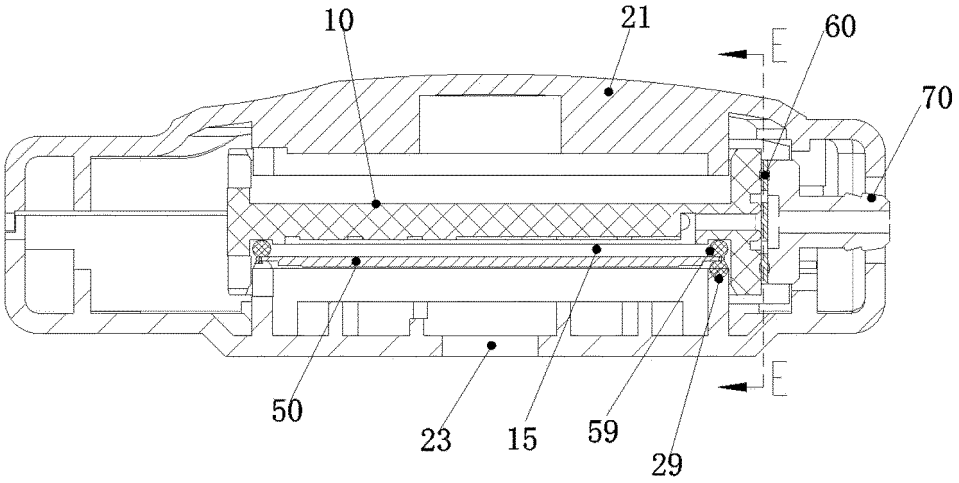

FIG. 5

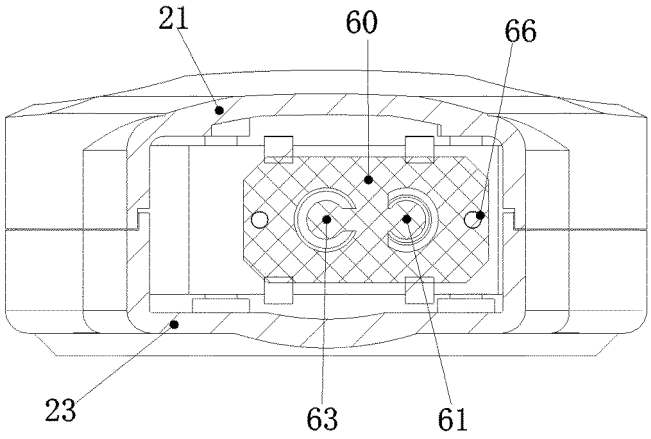

FIG. 6

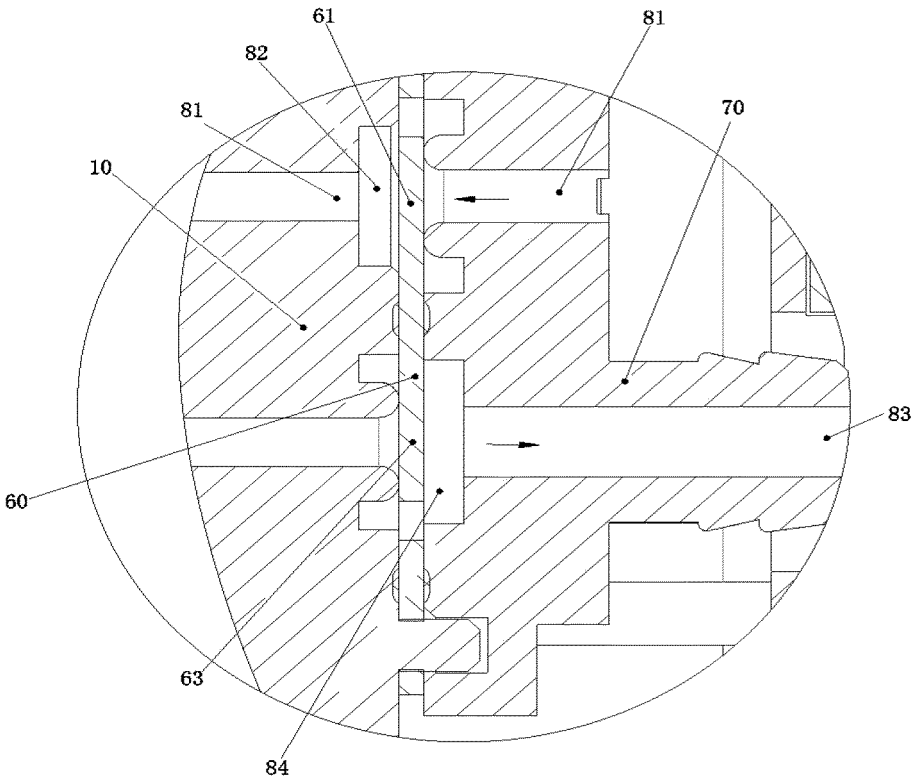

FIG. 7

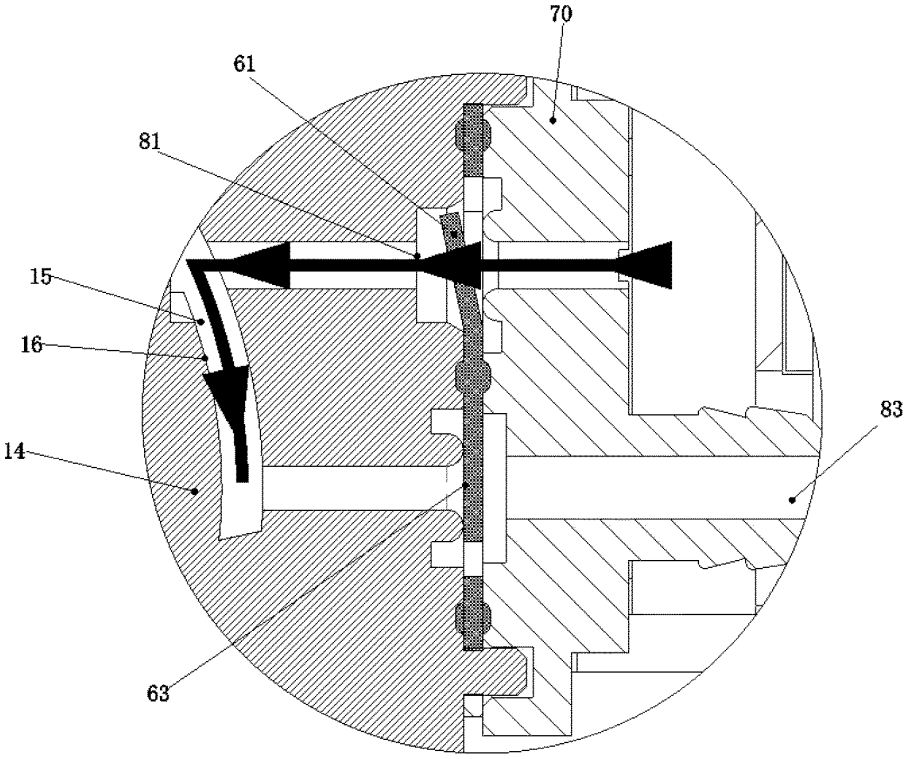

FIG. 8

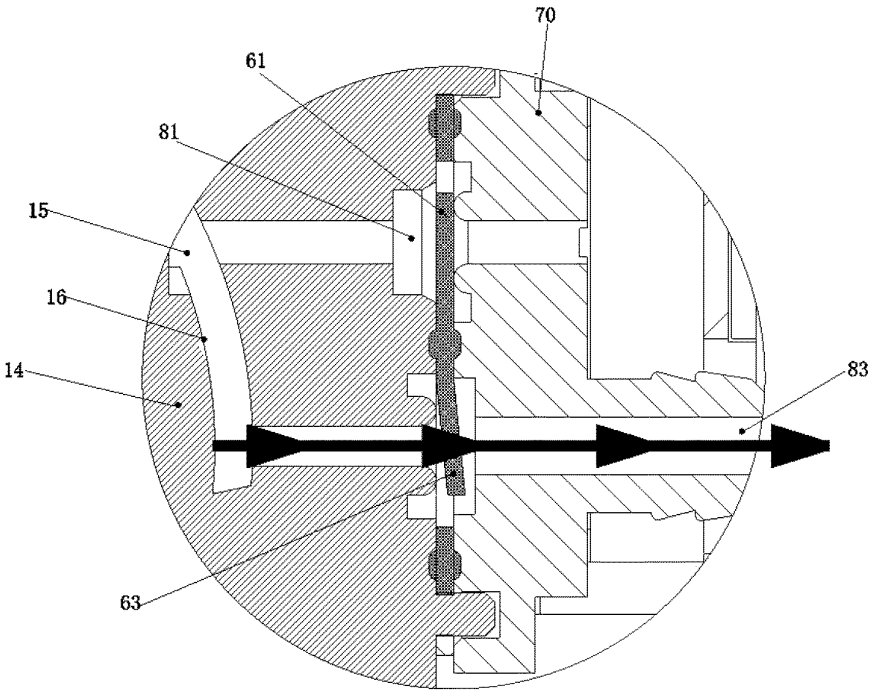

FIG. 9

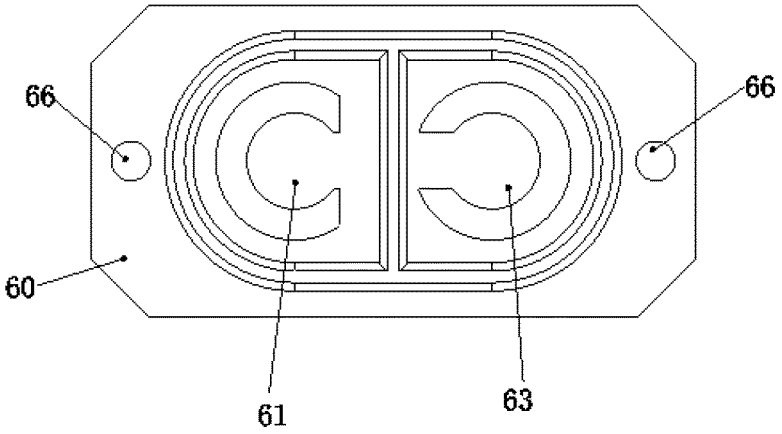

FIG. 10

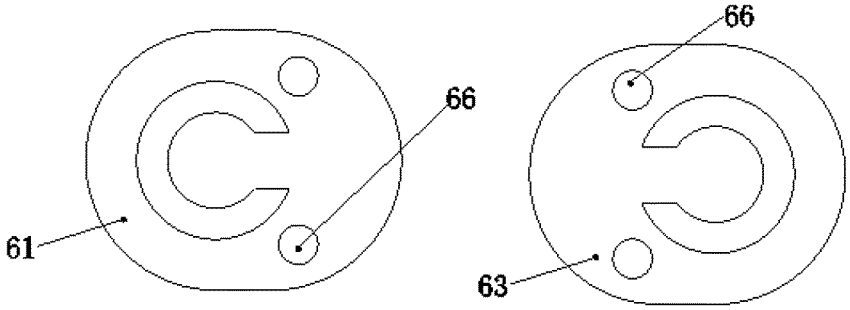

FIG. 11

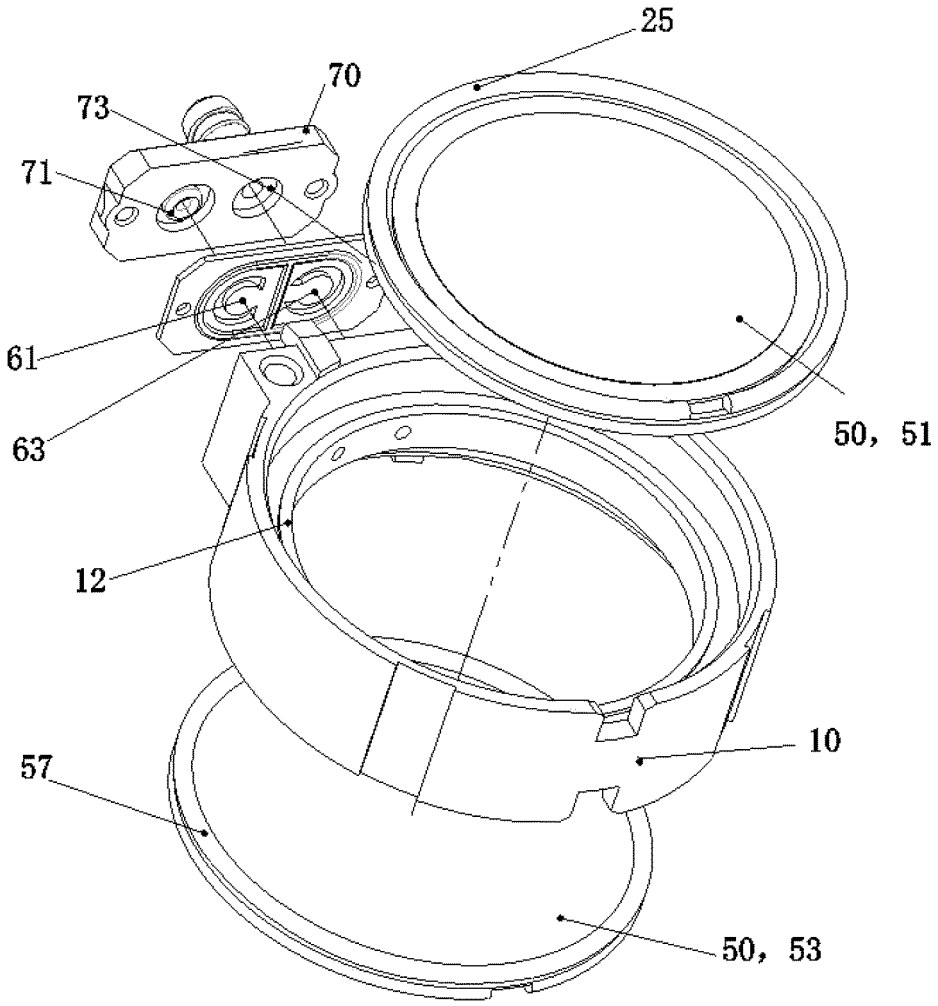

FIG. 12

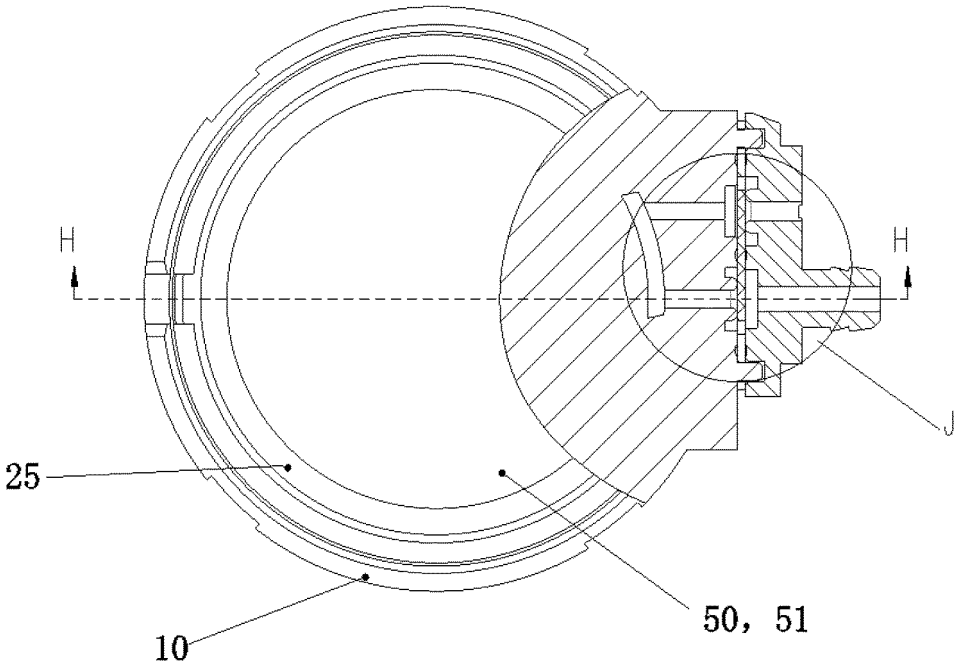

FIG. 13

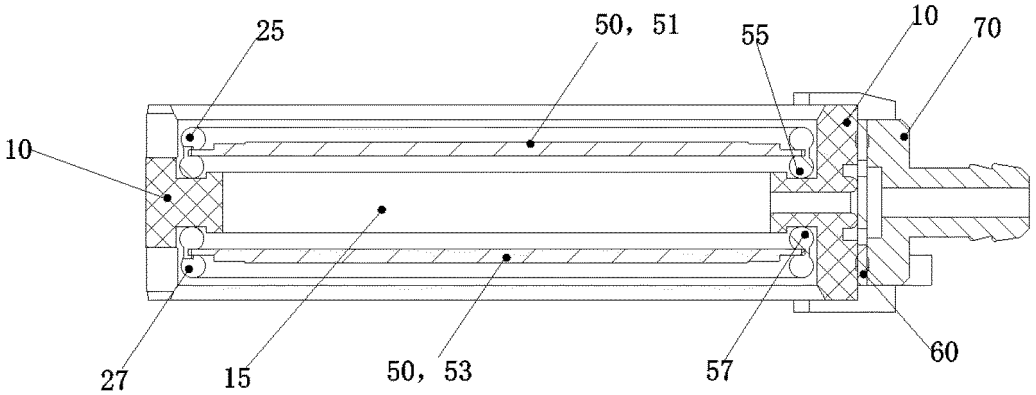

FIG. 14

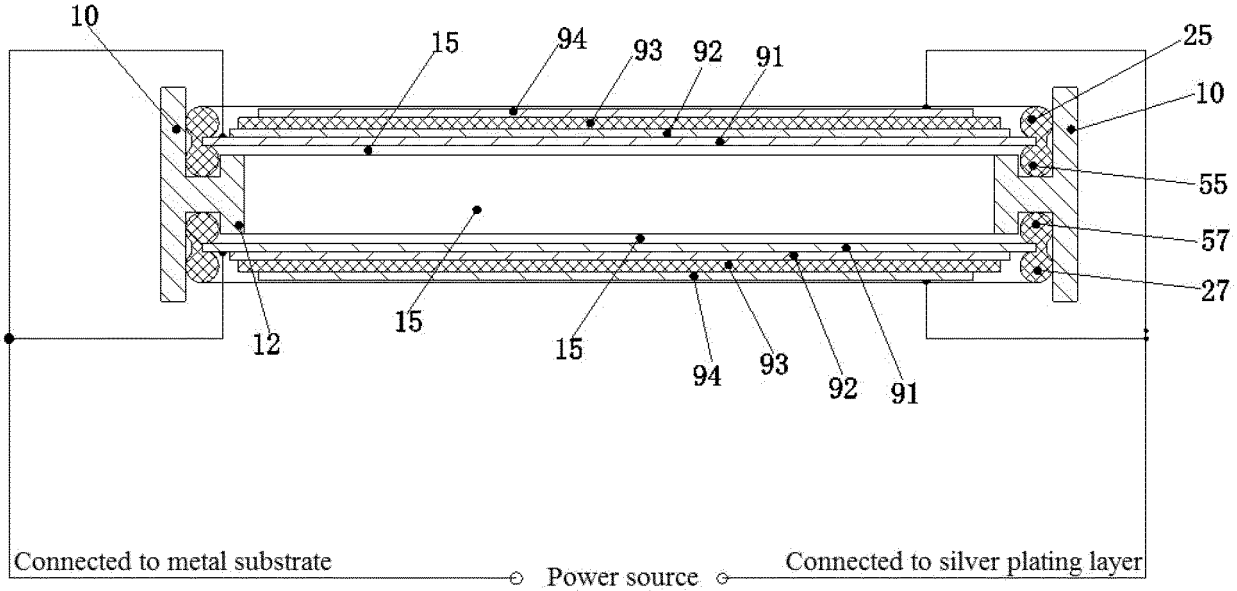
10
15
94
93
92
91
25
10
55
57
27
12
15
15
94
93
92
91
Connected to metal substrate
Power source
Connected to silver plating layer

FIG. 15

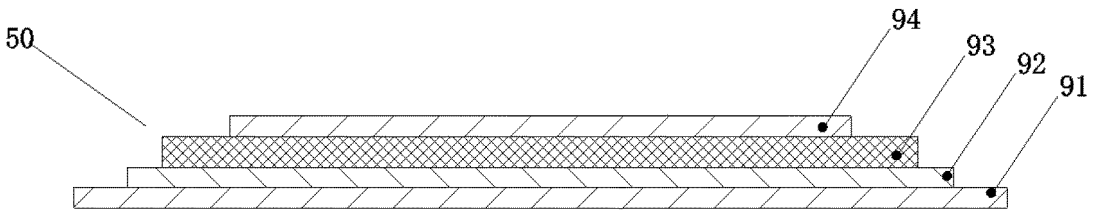
50
94
93
92
91

FIG. 16

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2016/072799

A. CLASSIFICATION OF SUBJECT MATTER

F04B 43/04 (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)

F04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

VEN, CNABS, CNKI: piezoelectric, ceramic, pump, valve, isolate, sheet, seal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
E	CN 205478232 U (SHENZHEN HINGRISHENG INDUSTRIAL CO., LTD.) 17 August 2016 (17.08.2016) description, paragraphs [0031]-[0043], and figures 1-16	1-10
X	CN 1840903 A (CENTER FOR SPACE SCIENCE AND APPLIED RESEARCH, CHINESE ACADEMY OF SCIENCES) 04 October 2006 (04.10.2006) description, page 4, the first line to the last line and figure 1	1-4, 6, 8, 10-12, 14
A	WO 2014105898 A1 (APPLIED CAVITATION INC.) 03 July 2014 (03.07.2014) the whole document	1-15
A	CN 1280250 A (ZHANG, Jianhui) 17 January 2001 (17.01.2001) the whole document	1-15

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&"document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
13 October 2016	02 November 2016
Name and mailing address of the ISA State Intellectual Property Office of the P. R. China No. 6, Xitucheng Road, Jimenqiao Haidian District, Beijing 100088, China Facsimile No. (86-10) 62019451	Authorized officer SUN, Li Telephone No. (86-10) 62085456

Form PCT/ISA /210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2016/072799

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
CN 205478232 U	17 August 2016	None	
CN 1840903 A	04 October 2006	None	
WO 2014105898 A1	03 July 2014	EP 2939281 A1	04 November 2015
		EP 2939281 A4	20 April 2016
		US 2016218272 A1	28 July 2016
CN 1280250 A	17 January 2001	CN 1082625 C	10 April 2002

Form PCT/ISA /210 (patent family annex) (July 2009)