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(54) **MINIATURE PNEUMATIC DEVICE**

PNEUMATISCHE MINIATURVORRICHTUNG

DISPOSITIF PNEUMATIQUE MINIATURE

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(73) Proprietor: **Microjet Technology Co., Ltd**
Hsinchu (TW)

(72) Inventors:
- **MOU, Hao-Jan**
  Science-Based Industrial Park, Hsinchu, (TW)
- **HSUEH, Ta-Wei**
  Science-Based Industrial Park, Hsinchu, (TW)
- **HAN, Yung-Lung**
  Science-Based Industrial Park, Hsinchu (TW)
- **HUANG, Chi-Feng**
  Science-based Industrial Park, Hsinchu (TW)

(74) Representative: **2K Patentanwälte Blasberg Kewitz & Reichel Partnerschaft mbB**
Schumannstrasse 27
60325 Frankfurt am Main (DE)

(56) References cited:
US-A1- 2014 377 099
US-A1- 2015 071 797
US-A1- 2016 076 530

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EP 3 321 505 B1

Description

FIELD OF THE INVENTION

[0001] The present invention relates to a miniature pneumatic device, and more particularly to a slim and silent miniature pneumatic device.

BACKGROUND OF THE INVENTION

[0002] With the advancement of science and technology, fluid transportation devices used in many sectors such as pharmaceutical industries, computer techniques, printing industries or energy industries are developed toward elaboration and miniaturization. The fluid transportation devices are important components that are used in for example micro pumps, micro atomizers, printheads or industrial printers. Therefore, it is important to provide an improved structure of the fluid transportation device.

[0003] For example, in the pharmaceutical industries, pneumatic devices or pneumatic machines use motors or pressure valves to transfer gases. However, due to the volume limitations of the motors and the pressure valves, the pneumatic devices or the pneumatic machines are bulky in volume. In other words, the conventional pneumatic device fails to meet the miniaturization requirement, and is not suitable to be installed in or cooperated with a portable equipment. Moreover, during operations of the motor or the pressure valve, annoying noise is readily generated.

[0004] Therefore, there is a need of providing a miniature pneumatic device with small, miniature, silent, portable and comfortable benefits in order to eliminate the above drawbacks.

[0005] In US 2014 / 377099 A1 a micro-gas pressure driving apparatus is disclosed which includes a miniature gas transportation module and a miniature valve module. The miniature gas transportation module includes a gas inlet plate, a fluid channel plate, a resonance membrane and a piezoelectric actuator. A first chamber is defined between the resonance membrane and the piezoelectric actuator. After the piezoelectric actuator is activated to feed a gas through the gas inlet plate, the gas is transferred to the first chamber through the fluid channel plate and the resonance membrane and then transferred downwardly. Consequently, a pressure gradient is generated to continuously push the gas. The miniature valve module includes a gas collecting plate, a valve membrane and a gas outlet plate. After the gas is transferred from the miniature gas transportation module to the gas-collecting chamber, the gas is transferred in one direction, so that a pressure-collecting operation or a pressure-releasing operation is selectively performed.

SUMMARY OF THE INVENTION

[0006] The present invention provides a miniature pneumatic device for use with a portable or wearable equipment or machine. The miniature pneumatic device is a combination of a miniature fluid control device and a miniature valve device. The miniature pneumatic device of the present invention is small, slim, portable and silent. Consequently, the drawbacks of the conventional pneumatic device are overcome.

[0007] In accordance with an aspect of the present invention, a miniature pneumatic device is provided. The miniature pneumatic device includes a miniature fluid control device and a miniature valve device. The miniature fluid control device includes a gas inlet plate, a resonance plate, a piezoelectric actuator and a gas collecting plate. The gas inlet plate includes at least one inlet, at least one convergence channel and a central cavity. A convergence chamber is defined by the central cavity. After a gas is introduced into the at least one convergence channel through the at least one inlet, the gas is guided by the at least one convergence channel and converged to the convergence chamber. The resonance plate has a central aperture corresponding to the convergence chamber of the gas inlet plate. The piezoelectric actuator includes a suspension plate, an outer frame and a piezoelectric ceramic plate. A length of the suspension plate is in a range between 2mm and 4.5mm. A width of the suspension plate is in a range between 2mm and 4.5mm. A thickness of the suspension plate is in a range between 0.1mm and 0.3mm. The outer frame includes at least one bracket by which the suspension plate and the outer frame are connected with each other. The piezoelectric ceramic plate is attached on a first surface of the suspension plate. A length of a side of the piezoelectric ceramic plate is equal to or less than a length of a side of the suspension plate. The length of the piezoelectric ceramic plate is in a range between 2mm and 4.5mm. A width of the piezoelectric ceramic plate is in a range between 2mm and 4.5mm. A thickness of the piezoelectric ceramic plate is in a range between 0.05mm and 0.3mm. A length/width ratio of the piezoelectric ceramic plate is in a range between 0.44 and 2.25. The gas collecting plate includes a first perforation, a second perforation, a first pressure-releasing chamber, a first outlet chamber and a fiducial surface. The gas collecting plate further includes a raised structure disposed in the first outlet chamber and the raised structure is located at a level higher than the fiducial surface of the gas collecting plate. The first perforation is in communication with the first pressure-releasing chamber. The second perforation is in communication with the first outlet chamber. The gas inlet plate, the resonance plate, the piezoelectric actuator and the gas collecting plate are stacked on each other sequentially. A gap is formed between the resonance plate and the piezoelectric actuator to define a first chamber. When the piezoelectric actuator is actuated, the gas is fed into the miniature fluid control device through the at least one inlet of the gas inlet plate, converged to the central cavity through the at least one convergence channel, transferred through the central aperture of the reso-

nance plate, introduced into the first chamber, transferred downwardly to the gas collecting plate through a vacant space between the at least one bracket of the piezoelectric actuator, and exited from the miniature fluid control device. The miniature valve device includes a valve film and a gas outlet plate. The valve film has a valve opening. A thickness of the valve film is in a range between 0.1mm and 0.3mm. The raised structure of the gas collecting plate is aligned with the valve opening of the valve film. The raised structure of the gas collecting plate is contacted with the valve opening to provide a pre-force to tightly close the valve opening. The gas outlet plate includes a pressure-releasing perforation, an outlet perforation, a second pressure-releasing chamber, a second outlet chamber, at least one position-limiting structure and a fiducial surface. The second pressure-releasing chamber and the second outlet chamber are concavely formed in the fiducial surface of the gas outlet plate. The pressure-releasing perforation is located at a center of the second pressure-releasing chamber. A convex structure is located beside an end of the pressure-releasing perforation. The convex structure is located at a level higher than the fiducial surface of the gas outlet plate. The outlet perforation is in communication with the second outlet chamber. The at least one position-limiting structure is disposed within the second pressure-releasing chamber. A thickness of the position-limiting structure is in a range between 0.1mm and 0.5mm. The gas outlet plate further comprises a communication channel between the second pressure-releasing chamber and the second outlet chamber. The gas collecting plate, the valve film and the gas outlet plate are combined together. The pressure-releasing perforation of the gas outlet plate is aligned with the first perforation of the gas collecting plate. The second pressure-releasing chamber of the gas outlet plate is aligned with the first pressure-releasing chamber of the gas collecting plate. The second outlet chamber of the gas outlet plate is aligned with the first outlet chamber of the gas collecting plate. The valve film is arranged between the gas collecting plate and the gas outlet plate for blocking communication between the first pressure-releasing chamber and the second pressure-releasing chamber. The valve opening of the valve film is arranged between the second perforation and the outlet perforation. After the gas is downwardly transferred from the miniature fluid control device to the miniature valve device, the gas is introduced into the first pressure-releasing chamber and the first outlet chamber through the first perforation and the second perforation, and the valve film is quickly contacted with the convex structure of the gas outlet plate to provide a pre-force to tightly close the pressure-releasing perforation, and the gas within the first outlet chamber is further transferred to the outlet perforation of the miniature valve device through the valve opening of the valve film. Consequently, a pressure-collecting operation is performed. While a pressure-releasing operation is performed, the gas is transferred from the outlet perforation to the second outlet chamber to move the valve film, the valve opening of the valve film is contacted with and closed by the gas collecting plate, the at least one position-limiting structure assists in supporting the valve film to avoid collapse of the valve film, the gas is transferred from the second outlet chamber to the second pressure-releasing chamber through the communication channel, the valve film corresponding to the second pressure-releasing chamber is moved, and the gas is exited from the pressure-releasing perforation.

[0008] In accordance with another aspect of the present invention, a miniature pneumatic device is provided. The miniature pneumatic device includes a miniature fluid control device and a miniature valve device. The miniature fluid control device includes a gas inlet plate, a resonance plate, a piezoelectric actuator and a gas collecting plate. The piezoelectric actuator includes a suspension plate. A length of the suspension plate is in a range between 2mm and 4.5mm. A width of the suspension plate is in a range between 2mm and 4.5mm. A thickness of the suspension plate is in a range between 0.1mm and 0.3mm. The gas collecting plate includes a first perforation, a second perforation, a first pressure-releasing chamber and a first outlet chamber. The gas inlet plate, the resonance plate, the piezoelectric actuator and the gas collecting plate are stacked on each other sequentially. A gap is formed between the resonance plate and the piezoelectric actuator to define a first chamber. A gas-collecting chamber is formed between the piezoelectric actuator and the gas collecting plate. When the piezoelectric actuator is actuated, a gas is fed into the miniature fluid control device through the gas inlet plate, transferred through the resonance plate, introduced into the first chamber, and transferred downwardly to the gas-collecting chamber. The miniature valve device includes a valve film and a gas outlet plate. The valve film has a valve opening. The gas outlet plate includes a pressure-releasing perforation, an outlet perforation, a second pressure-releasing chamber and a second outlet chamber. The gas collecting plate, the valve film and the gas outlet plate are combined together. After the gas is downwardly transferred from the gas-collecting chamber to the miniature valve device, the gas is transferred through the first perforation, the second perforation, the first pressure-releasing chamber, the first outlet chamber, the second pressure-releasing chamber, the second outlet chamber, the pressure-releasing perforation and the outlet perforation. The gas is transferred in one direction, and the valve opening of the valve film is correspondingly opened or closed. Consequently, a pressure-collecting operation or a pressure-releasing operation is selectively performed.

[0009] In accordance with a further aspect of the present invention, a miniature pneumatic device is provided. The miniature pneumatic device includes a miniature fluid control device and a miniature valve device. The miniature fluid control device includes a gas inlet plate, a resonance plate, a piezoelectric actuator and a gas collecting plat. The gas inlet plate, the resonance

plate, the piezoelectric actuator and the gas collecting plate are stacked on each other sequentially. A gap is formed between the resonance plate and the piezoelectric actuator to define a first chamber. When the piezoelectric actuator is actuated, a gas is fed into the miniature fluid control device through the gas inlet plate, transferred through the resonance plate, introduced into the first chamber, and exited from the miniature fluid control device. The piezoelectric actuator comprises a suspension plate. A length of the suspension plate is in a range between 2mm and 4.5mm. A width of the suspension plate is in a range between 2mm and 4.5mm. The miniature valve device includes a valve film and a gas outlet plate. The valve film has a valve opening. The gas collecting plate, the valve film and the gas outlet plate are combined together. After the gas is transferred from the miniature fluid control device to the miniature valve device, a pressure-collecting operation or a pressure-releasing operation is selectively performed.

[0010] The above contents of the present invention will become more readily apparent to those ordinarily skilled in the art after reviewing the following detailed description and accompanying drawings, in which:

BRIEF DESCRIPTION OF THE DRAWINGS

[0011]

FIG. 1A is a schematic exploded view illustrating a miniature pneumatic device according to an embodiment of the present invention and taken along a first viewpoint;

FIG. 1B is a schematic assembled view illustrating the miniature pneumatic device of FIG. 1A;

FIG. 2A is a schematic exploded view illustrating the miniature pneumatic device according to the embodiment of the present invention and taken along a second viewpoint;

FIG. 2B is a schematic assembled view illustrating the miniature pneumatic device of FIG. 2A;

FIG. 3A is a schematic perspective view illustrating the piezoelectric actuator of the miniature pneumatic device of FIG. 1A and taken along the front side;

FIG. 3B is a schematic perspective view illustrating the piezoelectric actuator of the miniature pneumatic device of FIG. 1A and taken along the rear side;

FIG. 3C is a schematic cross-sectional view illustrating the piezoelectric actuator of the miniature pneumatic device of FIG. 1A;

FIGS. 4A to 4C schematically illustrate various exemplary piezoelectric actuator used in the miniature pneumatic device of the present invention;

FIGS. 5A to 5E schematically illustrate the actions of the miniature fluid control device of the miniature pneumatic device of FIG. 1A;

FIG. 6A schematically illustrate a gas-collecting operation of the gas collecting plate and the miniature valve device of the miniature pneumatic device of FIG. 1A;

FIG. 6B schematically illustrate a gas-releasing operation of the gas collecting plate and the miniature valve device of the miniature pneumatic device of FIG. 1A;

FIGS. 7A to 7E schematically illustrate a gas-collecting operation of the miniature pneumatic device of FIG. 1A; and

FIG. 8 schematically illustrate the gas-releasing actions or the pressure-reducing actions of the miniature pneumatic device of FIG. 1A.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0012] The present invention will now be described more specifically with reference to the following embodiments. It is to be noted that the following descriptions of preferred embodiments of this invention are presented herein for purpose of illustration and description only. It is not intended to be exhaustive or to be limited to the precise form disclosed.

[0013] The present invention provides a miniature pneumatic device. The miniature pneumatic device may be used in many sectors such as pharmaceutical industries, energy industries, computer techniques or printing industries for transporting gases.

[0014] Please refer to FIGS. 1A, 1B, 2A, 2B and 7A to 7E. FIG. 1A is a schematic exploded view illustrating a miniature pneumatic device according to an embodiment of the present invention and taken along a first viewpoint. FIG. 1B is a schematic assembled view illustrating the miniature pneumatic device of FIG. 1A. FIG. 2A is a schematic exploded view illustrating the miniature pneumatic device according to the embodiment of the present invention and taken along a second viewpoint. FIG. 2B is a schematic assembled view illustrating the miniature pneumatic device of FIG. 2A. FIGS. 7A to 7E schematically illustrate a gas-collecting operation of the miniature pneumatic device of FIG. 1A.

[0015] As shown in FIGS. 1A and 2A, the miniature pneumatic device 1 comprises a miniature fluid control device 1A and a miniature valve device 1B. In this embodiment, the miniature fluid control device 1A comprises a housing 1a, a piezoelectric actuator 13, a first insulation plate 141, a conducting plate 15 and a second insulation

plate 142. The housing 1a comprises a gas collecting plate 16 and a base 10. The base 10 is composed of a gas inlet plate 11 and a resonance plate 12. The piezoelectric actuator 13 is aligned with the resonance plate 12. The gas inlet plate 11, the resonance plate 12, the piezoelectric actuator 13, the first insulation plate 141, the conducting plate 15, the second insulation plate 142 and the gas collecting plate 16 are stacked on each other sequentially to be assembled while an outward surface of the gas inlet plate 11 is towards an input side. Moreover, the piezoelectric actuator 13 comprises a suspension plate 130, an outer frame 131, at least one bracket 132 and a piezoelectric ceramic plate 133. In this embodiment, the miniature valve device 1B comprises a valve film 17 and a gas outlet plate 18.

[0016] As shown in FIG. 1A, the gas collecting plate 16 comprises a bottom plate and a sidewall 168 protruding from the edges of the bottom plate. The gas collecting plate 16 has a length and a width both in the range between 4mm and 10mm. Meanwhile, the length/width ratio of the gas collecting plate 16 is preferably in the range between 0.4 and 2.5. The bottom plate and the sidewall 168 collaboratively define an accommodation space 16a where the piezoelectric actuator 13 is disposed within. The structure of the miniature pneumatic device 1 in assembled state, taken from the front side, is shown in FIG. 1B and FIGS. 7A to 7E. As the miniature fluid control device 1A and the miniature valve device 1B are combined together, the valve film 17 and the gas outlet plate 18 of the miniature valve device 1B are stacked on each other and positioned on the bottom side of the gas collecting plate 16 of the miniature fluid control device 1A. Please refer to FIG. 1A and FIG. 2B, the gas outlet plate 18 has a pressure-releasing perforation 181 and an outlet structure 19. The outlet structure 19 is adapted to be in communication with an inner space inside a target equipment (not shown), and the pressure-releasing perforation 181 is adapted to discharge the gas inside the miniature valve device 1B. As so, the gas pressure of the inner space of the target equipment can be released.

[0017] The miniature pneumatic device 1 in assembled state allows a gas to be fed into the miniature fluid control device 1A through at least one inlet 110 of the gas inlet plate 11 from the input side. The piezoelectric actuator 13 is operable to be activated, and in response of the actions of the piezoelectric actuator 13, the gas is transferred downwardly through plural pressure chambers to the miniature valve device 1B. In the miniature valve device 1B, the gas is transferred in one direction, being discharged from the outlet structure 19 and flows into the inner space of the target equipment (not shown). As a result, the pressure of the gas in the inner space of the target equipment is accumulated.

[0018] Please refer to FIGS. 1A and 2A again. The gas inlet plate 11 of the miniature fluid control device 1A comprises a first surface 11b, a second surface 11a and the at least one inlet 110. In this embodiment, the gas inlet plate 11 has four inlets 110. The inlets 110 run through the first surface 11b and the second surface 11a of the gas inlet plate 11, and the second surface 11a is towards exterior of the miniature pneumatic device 1 where is defined as the input side. In response to the action of the atmospheric pressure, the gas is introduced into the miniature fluid control device 1A through the inlets 110. As shown in FIG. 2A, at least one convergence channel 112 is formed on the first surface 11b of the gas inlet plate 11, and is in communication with the at least one inlet 110 of the gas inlet plate 11. The number of the convergence channel 112 is identical to the number of the inlet 110. In this embodiment, the gas inlet plate 11 has four convergence channels 112. It is noted that the number of the at least one convergence channel 112 and the number of the at least one inlet 110 may be varied according to the practical requirements. Moreover, a central cavity 111 is formed on the central of the first surface 11b of the gas inlet plate 11 and located at the intersection of the four convergence channels 112 that forming a convergence chamber for temporarily storing the gas. The central cavity 111 is in communication with all of the convergence channels 112, such that the gas entered by the inlets 110 would be introduced into the at least one convergence channel 112 and is guided to the central cavity 111. In this embodiment, the at least one inlet 110, the at least one convergence channel 112 and the central cavity 111 of the gas inlet plate 11 are integrally formed.

[0019] Preferably but not exclusively, the gas inlet plate 11 is made of stainless steel. The thickness of the gas inlet plate 11 is in the range between 0.3mm and 0.5mm, and preferably 0.4mm. In some embodiments, the depth of the convergence chamber defined by the central cavity 111, is equal to the depth of the at least one convergence channel 112, both of which are preferably in the range between 0.15mm and 0.25mm. The resonance plate 12 is made of a flexible material, which is preferably but not exclusively copper. The resonance plate 12 further has a central aperture 120 corresponding to the central cavity 111 of the gas inlet plate 11 that providing the gas for flowing through. The thickness of the resonance plate 12 is in the range between 0.02mm and 0.07mm, and preferably 0.04mm.

[0020] FIG. 3A is a schematic perspective view illustrating the piezoelectric actuator of the miniature pneumatic device of FIG. 1A and taken along the front side. FIG. 3B is a schematic perspective view illustrating the piezoelectric actuator of the miniature pneumatic device of FIG. 1A and taken along the rear side. FIG. 3C is a schematic cross-sectional view illustrating the piezoelectric actuator of the miniature pneumatic device of FIG. 1A. As shown in FIGS. 3A, 3B and 3C, the piezoelectric actuator 13 comprises the suspension plate 130, the outer frame 131, the at least one bracket 132, and the piezoelectric ceramic plate 133. The piezoelectric ceramic plate 133 is attached on a first surface 130b of the suspension plate 130. In response to an applied voltage, the piezoelectric ceramic plate 133 would be subjected to a curvy vibration. The suspension plate 130 comprises a

middle portion 130d and a periphery portion 130e. When the piezoelectric ceramic plate 133 is subjected to the curvy vibration, the suspension plate 130 is also subjected to the curvy vibration and vibrates from the middle portion 130d to the periphery portion 130e. The at least one bracket 132 is connected between the suspension plate 130 and the outer frame 131, while the two ends of the bracket 132 are connected with the outer frame 131 and the suspension plate 130 respectively that the bracket 131 can elastically support the suspension plate 130. At least one vacant space 135 is formed between the bracket 132, the suspension plate 130 and the outer frame 131 for allowing the gas to go through. The type of the suspension plate 130 and the outer frame 131, and the type and the number of the at least one bracket 132 may be varied according to the practical requirements. Moreover, a conducting pin 134 is protruding outwardly from the outer frame 131 so as to be electrically connected with an external circuit (not shown).

[0021] In this embodiment, the suspension plate 130 has a bulge 130c that makes the suspension plate 130 a stepped structure. The bulge 130c is formed on a second surface 130a of the suspension plate 130, wherein the second surface 130a is opposing to the first surface 130b. The bulge 130c may be a circular convex structure, the thickness of which is in the range between 0.02mm and 0.08mm, and preferably 0.03mm. Preferably but not exclusively, the diameter of the bulge 130c is 0.55 times as large as a length of a shortest side of the suspension plate 130. As shown in FIGS. 3A and 3C, a top surface of the bulge 130c of the suspension plate 130 is coplanar with a second surface 131a of the outer frame 131, while the second surface 130a of the suspension plate 130 is coplanar with a second surface 132a of the bracket 132. Moreover, there is a drop of specified amount from the bulge 130c of the suspension plate 130 (or the second surface 131a of the outer frame 131) to the second surface 130a of the suspension plate 130 (or the second surface 132a of the bracket 132). As shown in FIGS. 3B and 3C, a first surface 130b of the suspension plate 130, a first surface 131b of the outer frame 131 and a first surface 132b of the bracket 132 are coplanar with each other. The piezoelectric ceramic plate 133 is attached on the first surface 130b of the suspension plate 130. The suspension plate 130 may be a square plate structure with two flat surfaces but the type of the suspension plate 130 may be varied according to the practical requirements. In this embodiment, the suspension plate 130, the at least bracket 132 and the outer frame 131 are integrally formed and produced by using a metal plate (e.g., a stainless steel plate). The thickness of the suspension plate 130 is in the range between 0.1mm and 0.3mm, and preferably 0.2mm. The length of the suspension plate 130 is in the range between 2mm and 4.5mm, and preferably in the range between 2.5mm and 3.5mm. The width of the suspension plate 130 is in the range between 2mm and 4.5mm, and preferably in the range between 2.5mm and 3.5mm. The thickness of the outer frame 131 is in the range between 0.1mm and 0.4mm, and preferably 0.3mm.

[0022] The piezoelectric ceramic plate 133 has the same shape with the suspension plate 130 but in smaller size, which means the longest side of the piezoelectric ceramic plate 133 is always equal to or shorter than the longest side of the suspension plate 130. As the suspension plate 130 has a square shape in this embodiment, the piezoelectric ceramic plate 133 also has a square shape. The thickness of the piezoelectric ceramic plate 133 is in the range between 0.05mm and 0.3mm, and preferably 0.10mm. A length of a side of the piezoelectric ceramic plate 133 is equal to or less than a length of a side of the suspension plate 130. Meanwhile, the length of the side of the piezoelectric ceramic plate 133 is in the range between 2mm and 4.5mm, and preferably in the range between 2.5mm and 3.5mm. In some other embodiments, the suspension plate 130 and the piezoelectric ceramic plate 133 may have a rectangular shape, and the width and the length of the rectangular shape is in the range between 2mm and 4.5mm, preferably in the range between 2.5mm and 3.5mm. Moreover, the length/width ratio of the piezoelectric ceramic plate 133 is in the range between 0.44 and 2.25.

[0023] Preferably, the suspension plate 130 of the piezoelectric actuator 13 used in the miniature pneumatic device 1 of the present invention is a square suspension plate. In comparison with the circular suspension plate (e.g., the circular suspension plate j0 with the types (j)~(1) as shown in FIG. 4A), the square suspension plate can make the miniature pneumatic device 1 more power-saving.

[0024] Generally, the consumed power of the capacitive load at the resonance frequency is positively related to the resonance frequency. Since the resonance frequency of the square suspension plate is obviously lower than that of the circular square suspension plate, the consumed power of the square suspension plate is lower. Since the square suspension plate is more power-saving than the circular suspension plate, the piezoelectric actuator 13 with the square suspension plate is suitably used in the portable/wearable devices.

[0025] FIGS. 4A, 4B and 4C schematically illustrate various exemplary piezoelectric actuator used in the miniature pneumatic device of the present invention. As shown in the drawings, the suspension plate 130, the outer frame 131 and the at least one bracket 132 of the piezoelectric actuator 13 have various types.

[0026] FIG. 4A schematically illustrates the types (a)~(1) of the piezoelectric actuator. In the type (a), the outer frame a1 and the suspension plate a0 are square, the outer frame a1 and the suspension plate a0 are connected with each other through eight brackets a2, each two of which are disposed by one side of the square suspension plate a0. Several vacant spaces a3 are formed between the brackets a2, the suspension plate a0 and the outer frame a1 for allowing the gas to go through. In the type (i), the outer frame i1 and the suspension plate

i0 are also square, but the outer frame i1 and the suspension plate i0 are connected with each other through merely two brackets i2. In addition, the outer frame i1 and the suspension plate i0 in each of the types (b)~(h) are also square. In each of the types (j)~(1), the suspension plate is circular, and the outer frame has a square with arc-shaped corners. For example, in the type (j), the suspension plate j0 is circular, and the outer frame has a square with arc-shaped corners.

[0027] FIG. 4B schematically illustrates the types (m)~(r) of the piezoelectric actuator. In these types (m)~(r), the suspension plate 130 and the outer frame 131 are square. In the type (m), the outer frame m1 and the suspension plate m0 are square, the outer frame m1 and the suspension plate m0 are connected with each other through four brackets m2, each of which is disposed by one side of the suspension plate m0. Meanwhile, a vacant space m3 is formed between the brackets m2, the suspension plate m0 and the outer frame m1. The bracket m2 has two ends m2' and m2" respectively connected with the outer frame m1 and the suspension plate m0. The two ends m2' and m2" are opposed to each other and arranged along the same horizontal line.

[0028] In the type (n), the outer frame n1 and the suspension plate n0 are also connected with each other through four brackets n2, and a vacant space n3 is formed between the brackets n2, the suspension plate n0 and the outer frame n1. Nonetheless, the two ends n2' and n2" of the bracket n2, which are respectively connected with the outer frame n1 and the suspension plate n0, are not arranged along the same horizontal line. Instead, the two ends n2' and n2" are inclined at 0~45 degrees with respect to the horizontal line.

[0029] In the type (o), the outer frame o1 and the suspension plate o0 are square, the outer frame o1 and the suspension plate o0 are connected with each other through four brackets o2 in circular profiles, and a vacant space o3 is formed between each two of the brackets o2, the suspension plate o0 and the outer frame o1. The bracket o2 includes a connecting part and two ends o2' and o2". The end o2' of the bracket o2 is connected with the outer frame o1. The end o2" of the bracket o2 is connected with the suspension plate o0. The two ends o2' and o2" are opposed to each other and arranged along the same horizontal line.

[0030] In the type (p), the outer frame p1 and the suspension plate p0 are square, the outer frame p1 and the suspension plate p0 are connected with each other through four brackets p2, and a vacant space p3 is formed between each two of the brackets p2, the suspension plate p0 and the outer frame p1. The bracket p2 includes a first connecting part p20, an intermediate part p21 and a second connecting part p22. The intermediate part p21 is formed in the vacant space p3 and in parallel with the outer frame p1 and the suspension plate p0. The first connecting part p20 is arranged between the intermediate part p21 and the suspension plate p0. The second connecting part p22 is arranged between the intermediate part p21 and the outer frame p1. The first connecting part p20 and the second connecting part p22 are opposed to each other and arranged along the same horizontal line.

[0031] More specifically, the intermediate part p21 is a bar perpendicular to both the first connecting part p20 and the second connecting part p22, which makes the bracket p2 in the shape of a cross. Thus, the whole structure of the bracket p2 is strengthened, which is beneficial for vibration of the suspension plate p0 in a fixed direction. Meanwhile, the bracket p2 can be made of a material with a lesser rigidity, and therefore increases vibration frequency of the suspension plate p0. As a result, the gas pressure output efficiency could be improved.

[0032] In the type (q), the outer frame q1, the suspension plate q0, the bracket q2 and the vacant space q3 are similar to those of the type (m) and the type (o). Each side of the suspension plate q0 is connected with the corresponding side of the outer frame q1 through two connecting parts q2. The two ends q2' and q2" of each connecting part q2 are opposed to each other and arranged along the same horizontal line. In the type (r), the outer frame r1, the suspension plate r0, the bracket r2 and the vacant space r3 are similar to those of the above embodiments. However, the bracket r2 is a V-shaped connecting part. That is, the bracket r2 is connected with the outer frame r1 and the suspension plate r0 at an inclined angle 0~45 degrees. An end r2" of the bracket r2 is connected with the suspension plate r0, and two ends r2' of the bracket r2 are connected with the outer frame r1. That is, the ends b2' and b2" are not arranged along the same horizontal line.

[0033] FIG. 4C schematically illustrates the types (s)~(x) of the piezoelectric actuator. The structures of the types (s)~(x) are similar to those of the types (m)~(r), respectively. However, in the types (s)~(x), the suspension plate 130 of the piezoelectric actuator 13 has a bulge 130c. The bulges 130c in the types (s)~(x) are indicated as s4, t4, u4, v4, w4 and x4, respectively. Regarding the types (m)~(r) and the types (s)~(x) of the piezoelectric actuator, the suspension plate 130 is square for achieving power-saving efficacy, and both the stepped structure with bulge and the flat structure with two flat surfaces are in the scope of the present invention. Meanwhile, the number of the brackets 132 between the outer frame 131 and the suspension plate 130 may be varied according to the practical requirements. The suspension plate 130, the outer frame 131 and the at least one bracket 132 may be integrally formed with each other, and produced by but not limited to a conventional machining process, a photolithography and etching process, a laser machining process, an electroforming process, an electric discharge machining process and so on.

[0034] Please refer to FIGS. 1A and 2A again. The miniature fluid control device 1A further comprises the first insulation plate 141, the conducting plate 15 and the second insulation plate 142. The first insulation plate 141, the conducting plate 15 and the second insulation plate

142 are stacked on each other sequentially and located under the piezoelectric actuator 13. The profiles of the first insulation plate 141, the conducting plate 15 and the second insulation plate 142 substantially match the profile of the outer frame 131 of the piezoelectric actuator 13. The first insulation plate 141 and the second insulation plate 142 are made of an insulating material (e.g. a plastic material) for providing insulating efficacy. The conducting plate 15 is made of an electrically conductive material (e.g. a metallic material) for providing electrically conducting efficacy. Moreover, the conducting plate 15 has a conducting pin 151 so as to be electrically connected with an external circuit (not shown).

[0035] FIGS. 5A to 5E schematically illustrate the actions of the miniature fluid control device of the miniature pneumatic device of FIG. 1A. As shown in FIG. 5A, the gas inlet plate 11, the resonance plate 12, the piezoelectric actuator 13, the first insulation plate 141, the conducting plate 15 and the second insulation plate 142 of the miniature fluid control device 1A are stacked on each other sequentially. Moreover, there is a gap g0 between the resonance plate 12 and the outer frame 131 of the piezoelectric actuator 13, which is formed and maintained by a filler (e.g. a conductive adhesive) inserted therein in this embodiment. The gap g0 ensures the proper distance between the resonance plate 12 and the bulge 130c of the suspension plate 130, so that the contact interference is reduced and the generated noise is largely reduced.

[0036] Please refer to FIGS. 5A to 5E again. A convergence chamber is defined by the resonance plate 12 and the central cavity 111 of the gas inlet plate 11 collaboratively for converging the gas. A first chamber 121 is formed between the resonance plate 12 and the piezoelectric actuator 13, and is in communication with the convergence chamber through the central aperture 120 of the resonance plate 12. Meanwhile, the peripheral regions of the first chamber 121 are in communication with the underlying miniature valve device 1B through the vacant spaces 135 of the piezoelectric actuator 13.

[0037] Please refer to FIG. 5B. When the miniature fluid control device 1A of the miniature pneumatic device 1 is enabled, the piezoelectric actuator 13 is actuated in response to an applied voltage. Consequently, the piezoelectric actuator 13 vibrates along a vertical direction in a reciprocating manner, while the brackets 132 are served as the fulcrums. The resonance plate 12 except for the part of it fixed on the gas inlet plate 11 is hereinafter referred as a movable part 12a, while the rest is referred as a fixed part 12b. Since the resonance plate 12 is light and thin, the movable part 12a vibrates along with the piezoelectric actuator 13 because of the resonance of the piezoelectric actuator 13. In other words, the movable part 12a is reciprocated and subjected to a curvy deformation.

[0038] As shown in FIG. 5C, during the vibration of the movable part 12a of the resonance plate 12, the movable part 12a moves down till being contacted with the bulge 130c of the suspension plate 130. In the meantime, the volume of the first chamber 121 is shrunken and a middle space which was communicating with the convergence chamber is closed. As a result, the pressure gradient occurs to push the gas in the first chamber 121 moving toward peripheral regions of the first chamber 121 and flowing downwardly through the vacant spaces 135 of the piezoelectric actuator 13.

[0039] Please refer to FIG. 5D, which illustrates consecutive action following the action in FIG. 5C. The movable part 12a has returned its original position when the piezoelectric actuator 13 has ascended at a vibration displacement d to an upward position. Consequently, the volume of the first chamber 121 is consecutively shrunken that generating the pressure gradient which makes the gas in the first chamber 121 continuously pushed toward peripheral regions and results in an exterior gas continuously fed into the inlets 110 of the gas inlet plate 11 and transferred to the central cavity 111.

[0040] Then, as shown in FIG. 5E, the resonance plate 12 moves upwardly, which is caused by the resonance of the upward motion of the piezoelectric actuator 13. Under this circumstance, the volume of the first chamber 121 expends, which results in suction applied to the gas in the central cavity 111. The gas in the central cavity 111 is transferred to the first chamber 121 through the central aperture 120 of the resonance plate 12, then transferred downwardly through the vacant spaces 135 of the piezoelectric actuator 13, exiting from the miniature fluid control device 1A.

[0041] From the above description, please notice the gap g0 between the resonance plate 12 and the piezoelectric actuator 13 providing space for vibration of the resonance plate 12. That is, the thickness of the gap g0 affects the amplitude of vibration of the resonance plate 12. A difference x between the gap g0 and the vibration displacement d of the piezoelectric actuator 13 is given by a formula: x=g0 - d. A series of tests about the maximum output pressure of the miniature pneumatic device 1 corresponding to different values of x are performed. In case that $x \leq 0\mu m$, the miniature pneumatic device 1 generates noise. In case that x= 1~5μm, the maximum output pressure of the miniature pneumatic device 1 reaches 350mmHg. In case that x= 5~10μm, the maximum output pressure of the miniature pneumatic device 1 is 250mmHg. In case that x= 10~15 μm, the maximum output pressure of the miniature pneumatic device 1 is 150mmHg. The relationships between the difference x and the maximum output pressure are listed in Table 1 below. The data shown in Table 1 are obtained when the operating voltage is in the range between $\pm$10V and $\pm$20V. A pressure gradient is generated in the fluid channels of the miniature fluid control device 1A to facilitate the gas to flow at a high speed. Moreover, since there is an impedance difference between the feeding direction and the exiting direction, the gas can be transmitted from the input side to the inner space of the target equipment. Even if the inner space of the target equipment has a

certain gas pressure, the miniature fluid control device 1A still has the capability of pushing out the gas as well as achieving the silent efficacy.

Table 1:

Test	X	Maximum output pressure
1	x=1~5μm	350mmHg
2	x=5~10μm	250mmHg
3	x=10~15μm	150mmHg

[0042] In some embodiments, the vibration frequency of the resonance plate 12 along the vertical direction in the reciprocating manner is identical to the vibration frequency of the piezoelectric actuator 13. That is, the resonance plate 12 and the piezoelectric actuator 13 are synchronously vibrated along the upward direction or the downward direction. It is noted that numerous modifications and alterations of the actions of the miniature fluid control device 1A may be made while retaining the teachings of the invention.

[0043] Please refer to FIGS. 1A, 2A, 6A and 6B. FIG. 6A schematically illustrate a gas-collecting operation of the gas collecting plate and the miniature valve device of the miniature pneumatic device of FIG. 1A. FIG. 6B schematically illustrate a gas-releasing operation of the gas collecting plate and the miniature valve device of the miniature pneumatic device of FIG. 1A. As shown in FIGS. 1A and 6A, the valve film 17 and the gas outlet plate 18 of the miniature valve device 1B are stacked on each other sequentially. Moreover, the miniature valve device 1B cooperates with the gas collecting plate 16 of the miniature fluid control device 1A.

[0044] In this embodiment, the gas collecting plate 16 comprises a first surface 160 and a second surface 161 (also referred as a fiducial surface). The first surface 160 of the gas collecting plate 16 is concaved to define a gas-collecting chamber 162 which accommodates the piezoelectric actuator 13. The gas that is transferred downwardly by the miniature fluid control device 1A is temporarily accumulated in the gas-collecting chamber 162. The gas collecting plate 16 has a first perforation 163 and a second perforation 164. A first end of the first perforation 163 and a first end of the second perforation 164 are in communication with the gas-collecting chamber 162. A second end of the first perforation 163 and a second end of the second perforation 164 are respectively in communication with a first pressure-releasing chamber 165 and a first outlet chamber 166, which are formed on the second surface 161 of the gas collecting plate 16. Moreover, the gas collecting plate 16 has a raised structure 167 corresponding to the first outlet chamber 166. For example, the raised structure 167 includes but is not limited to a cylindrical post. The raised structure 167 is located at a level higher than the second surface 161 of the gas collecting plate 16. Moreover, a thickness of the raised structure 167 is in a range between 0.1mm and 0.55mm, and preferably 0.2mm.

[0045] The gas outlet plate 18 comprises a pressure-releasing perforation 181, an outlet perforation 182, a first surface 180 (also referred as a fiducial surface) and a second surface 187. The pressure-releasing perforation 181 and the outlet perforation 182 run through the first surface 180 and the second surface 187. The first surface 180 of the gas outlet plate 18 is concaved to define a second pressure-releasing chamber 183 and a second outlet chamber 184. The pressure-releasing perforation 181 is located at a center of the second pressure-releasing chamber 183. Moreover, the gas outlet plate 18 further comprises a communication channel 185 between the second pressure-releasing chamber 183 and the second outlet chamber 184 for allowing the gas to go through. A first end of the outlet perforation 182 is in communication with the second outlet chamber 184. A second end of the outlet perforation 182 is in communication with an outlet structure 19 to gain access to the inner space of the target equipment. The outlet structure 19 is in connected with the target equipment (not shown). The equipment is for example but not limited to a gas-pressure driving equipment.

[0046] The valve film 17 comprises a valve opening 170 and plural positioning openings 171 (see FIG. 1A). The thickness of the valve film 17 is in the range between 0.1mm and 0.3mm, and preferably 0.2mm.

[0047] After the gas collecting plate 16, the valve film 17 and the gas outlet plate 18 are combined together, the pressure-releasing perforation 181 of the gas outlet plate 18 is aligned with the first perforation 163 of the gas collecting plate 16, the second pressure-releasing chamber 183 of the gas outlet plate 18 is aligned with the first pressure-releasing chamber 165 of the gas collecting plate 16, and the second outlet chamber 184 of the gas outlet plate 18 is aligned with the first outlet chamber 166 of the gas collecting plate 16. The valve film 17 is arranged between the gas collecting plate 16 and the gas outlet plate 18 for blocking the communication between the first pressure-releasing chamber 165 and the second pressure-releasing chamber 183. The valve opening 170 of the valve film 17 is arranged between the second perforation 164 and the outlet perforation 182. Moreover, the valve opening 170 of the valve film 17 is aligned with the raised structure 167 corresponding to the first outlet chamber 166 of the gas collecting plate 16. Due to such arrangement of the single valve opening 170, the gas can be transferred through the miniature valve device 1B in one direction in response to the pressure difference.

[0048] In this embodiment, the gas outlet plate 18 has the convex structure 181a beside a first end of the pressure-releasing perforation 181. Preferably but not exclusively, the convex structure 181a is a cylindrical post. The thickness of the convex structure 181a is in the range between 0.1mm and 0.55mm, and preferably 0.2mm. The top surface of the convex structure 181a is located at a level higher than the first surface 180 of the gas outlet

plate 18. Consequently, the pressure-releasing perforation 181 can be quickly contacted with and closed by the valve film 17. Moreover, the convex structure 181a can provide a pre-force against the valve film 17 to achieve a good sealing effect.

[0049] In this embodiment, the gas outlet plate 18 further comprises a position-limiting structure 188. The thickness of the position-limiting structure 188 is 0.2mm. The position-limiting structure 188 is disposed within the second pressure-releasing chamber 183. Preferably but not exclusively, the position-limiting structure 188 is a ring-shaped structure. While the gas-collecting operation of the miniature valve device 1B is performed, the position-limiting structure 188 can assist in supporting the valve film 17 and avoid collapse of the valve film 17. Consequently, the valve film 17 can be opened or closed more quickly.

[0050] Hereinafter, the gas-collecting operation of the miniature valve device 1B will be illustrated with reference to FIG. 6A. In case that the gas from the miniature fluid control device 1A is being transferred downwardly to the miniature valve device 1B, or the ambient air pressure is higher than the gas pressure of the inner space of the target equipment which is in communication with the outlet structure 19, the gas will be transferred from the miniature fluid control device 1A to the gas-collecting chamber 162 of the gas collecting plate 16. Then, the gas is transferred downwardly to the first pressure-releasing chamber 165 and the first outlet chamber 166 through the first perforation 163 and the second perforation 164. In response to the downward gas, the flexible valve film 17 is subjected to a downward curvy deformation. Consequently, the volume of the first pressure-releasing chamber 165 is expanded, and the valve film 17 is in close contact with the first end of the pressure-releasing perforation 181 corresponding to the first perforation 163. Under this circumstance, the pressure-releasing perforation 181 of the gas outlet plate 18 is closed, and thus the gas within the second pressure-releasing chamber 183 is not leaked out from the pressure-releasing perforation 181. In this embodiment, the gas outlet plate 18 has the convex structure 181a beside of the first end of the pressure-releasing perforation 181. Due to the arrangement of the convex structure 181a, the pressure-releasing perforation 181 can be quickly closed by the valve film 17. Moreover, the convex structure 181a can provide a pre-force to achieve a good sealing effect. The position-limiting structure 188 is arranged around the pressure-releasing perforation 181 to assist in supporting the valve film 17 and avoid collapse of the valve film 17. On the other hand, the gas is transferred downwardly to the first outlet chamber 166 through the second perforation 164. In response to the downward gas, the valve film 17 corresponding to the first outlet chamber 166 is also subjected to the downward curvy deformation. Consequently, the valve opening 170 of the valve membrane 17 is correspondingly opened to the downward side. Under this circumstance, the gas is transferred from the first outlet chamber 166 to the second outlet chamber 184 through the valve opening 170. Then, the gas is transferred to the outlet structure 19 through the outlet perforation 182 and then transferred to the inner space of the target equipment which is in communication with the outlet structure 19. Consequently, the purpose of collecting the gas pressure is achieved.

[0051] Hereinafter, the gas-releasing operation of the miniature valve device 1B will be illustrated with reference to FIG. 6B. For performing the gas-releasing operation, the user may adjust the amount of the gas to be fed into the miniature fluid control device 1A, so that the gas is no longer transferred to the gas-collecting chamber 162. Alternatively, in case that the inner pressure of the target equipment which is in communication with the outlet structure 19 is higher than the ambient air pressure, which means the gas pressure of the inner space of the target equipment is greater than the gas pressure of the input side, the gas-releasing operation may be performed. Under this circumstance, the gas is transferred from the outlet structure 19 to the second outlet chamber 184 through the outlet perforation 182. Consequently, the volume of the second outlet chamber 184 is expanded, and the flexible valve film 17 corresponding to the second outlet chamber 184 is subjected to the upward curvy deformation. In addition, the valve film 17 is in close contact with the gas collecting plate 16. Consequently, the valve opening 170 of the valve film 17 is closed by the gas collecting plate 16. Moreover, the gas collecting plate 16 has the raised structure 167 corresponding to the first outlet chamber 166. Due to the arrangement of the raised structure 167, the flexible valve film 17 can be bent upwardly more quickly. Moreover, the raised structure 167 can provide a pre-force to achieve a good sealing effect of the valve opening 170. Since the valve opening 170 of the valve film 17 is contacted with and closed by the raised structure 167, the gas in the second outlet chamber 184 will not be reversely returned to the first outlet chamber 166. Consequently, the efficacy of avoiding gas leakage is enhanced. Moreover, since the gas in the second outlet chamber 184 is transferred to the second pressure-releasing chamber 183 through the communication channel 185, the volume of the second pressure-releasing chamber 183 is expanded. Consequently, the valve film 17 corresponding to the second pressure-releasing chamber 183 is also subjected to the upward curvy deformation. Since the valve film 17 is no longer in contact with the first end of the pressure-releasing perforation 181, the pressure-releasing perforation 181 is opened. Under this circumstance, the gas in the second pressure-releasing chamber 183 is outputted through the pressure-releasing perforation 181. Consequently, the pressure of the gas is released. Similarly, due to the convex structure 181a beside the pressure-releasing perforation 181 or the position-limiting structure 188 within the second pressure-releasing chamber 183, the flexible valve film 17 can be subjected to the upward curvy deformation more quickly. Consequently, the pressure-re-

leasing perforation 181 can be quickly opened. After the gas-releasing operation in one direction is performed, the gas within the inner space of the target equipment is partially or completely exited to the surrounding. Under this circumstance, the gas pressure of the target equipment is reduced.

[0052] FIGS. 7A to 7E schematically illustrate the gas-collecting actions of the miniature pneumatic device of FIG. 2A. Please refer to FIGS. 1A, 2A and 7A to 7E. As shown in FIG. 7A, the miniature pneumatic device 1 comprises the miniature fluid control device 1A and the miniature valve device 1B. As mentioned above, the gas inlet plate 11, the resonance plate 12, the piezoelectric actuator 13, the first insulation plate 141, the conducting plate 15, the second insulation plate 142 and the gas collecting plate 16 of the miniature fluid control device 1A are stacked on each other sequentially. There is a gap g0 between the resonance plate 12 and the piezoelectric actuator 13. Moreover, the first chamber 121 is formed between the resonance plate 12 and the piezoelectric actuator 13. The valve film 17 and the gas outlet plate 18 of the miniature valve device 1B are stacked on each other and disposed under the gas collecting plate 16 of the miniature fluid control device 1A. The gas-collecting chamber 162 is arranged between the gas collecting plate 16 and the piezoelectric actuator 13. The first pressure-releasing chamber 165 and the first outlet chamber 166 are formed in the second surface 161 of the gas collecting plate 16. The second pressure-releasing chamber 183 and the second outlet chamber 184 are concavely formed in the first surface 180 of the gas outlet plate 18. In an embodiment, the operating voltage of the miniature pneumatic device 1 is in the range between ±10V and ±16V. Moreover, due to the arrangements of the plural pressure chambers, the actuation of the piezoelectric actuator 13 and the vibration of the plate 12 and the valve film 17, the gas can be transferred downwardly.

[0053] As shown in FIG. 7B, the piezoelectric actuator 13 of the miniature fluid control device 1A is vibrated downwardly in response to the applied voltage. Consequently, the gas is fed into the miniature fluid control device 1A through the at least one inlet 110 of the gas inlet plate 11 from the input side. The gas is sequentially converged to the central cavity 111 through the at least one convergence channel 112 of the gas inlet plate 11, transferred through the central aperture 120 of the resonance plate 12, and introduced downwardly into the first chamber 121.

[0054] As the piezoelectric actuator 13 is actuated, the resonance of the resonance plate 12 occurs. Consequently, the resonance plate 12 is also vibrated along the vertical direction in the reciprocating manner. As shown in FIG. 7C, the resonance plate 12 is vibrated downwardly and contacted with the bulge 130c of the suspension plate 130 of the piezoelectric actuator 13. Due to the deformation of the resonance plate 12, the volume of the chamber corresponding to the central cavity 111 of the gas inlet plate 11 is expanded but the volume of the first chamber 121 is shrunken. Under this circumstance, the gas is pushed toward peripheral regions of the first chamber 121. Consequently, the gas is transferred downwardly through the vacant spaces 135 of the piezoelectric actuator 13. Then, the gas is transferred to the gas-collecting chamber 162 between the miniature fluid control device 1A and the miniature valve device 1B. After that, the gas is transferred downwardly to the first pressure-releasing chamber 165 and the first outlet chamber 166 through the first perforation 163 and the second perforation 164, which are in communication with the gas-collecting chamber 162. Consequently, when the resonance plate 12 is vibrated along the vertical direction in the reciprocating manner, the gap g0 between the resonance plate 12 and the piezoelectric actuator 13 is helpful to increase the amplitude of the resonance plate 12. That is, due to the gap g0 between the resonance plate 12 and the piezoelectric actuator 13, the amplitude of the resonance plate 12 is increased when the resonance occurs.

[0055] As shown in FIG. 7D, the resonance plate 12 of the miniature fluid control device 1A is returned to its original position, and the piezoelectric actuator 13 is vibrated upwardly in response to the applied voltage. The difference x between the gap g0 and the vibration displacement d of the piezoelectric actuator 13 is given by a formula: x=g0 - d. A series of tests about the maximum output pressure of the miniature pneumatic device 1 corresponding to different values of x are performed. The operating voltage of the miniature pneumatic device 1 is in the range between ±10V and ±16V. In case that x= 1~5μm, the maximum output pressure of the miniature pneumatic device 1 is at least 300mmHg. Consequently, the volume of the first chamber 121 is also shrunken, and the gas is continuously pushed toward peripheral regions of the first chamber 121. Moreover, the gas is continuously transferred to the gas-collecting chamber 162, the first pressure-releasing chamber 165 and the first outlet chamber 166 through the vacant spaces 135 of the piezoelectric actuator 13. Consequently, the pressure in the first pressure-releasing chamber 165 and the first outlet chamber 166 will be gradually increased. In response to the increased gas pressure, the flexible valve film 17 is subjected to the downward curvy deformation. Consequently, the valve film 17 corresponding to the second pressure-releasing chamber 183 is moved downwardly and contacted with the convex structure 181a corresponding to the first end of the pressure-releasing perforation 181. Under this circumstance, the pressure-releasing perforation 181 of the gas outlet plate 18 is closed. In the second outlet chamber 184, the valve opening 170 of the valve film 17 corresponding to the outlet perforation 182 is opened downwardly. Then, the gas within the second outlet chamber 184 is transferred downwardly to the outlet structure 19 through the outlet perforation 182 and then transferred to the inner space of the target equipment which is in communication with

the outlet structure 19. Consequently, the inner space of the target equipment is pressurized, and the purpose of collecting the gas pressure is achieved.

[0056] Then, as shown in FIG. 7E, the resonance plate 12 of the miniature fluid control device 1A is vibrated upwardly. Under this circumstance, the gas in the central cavity 111 of the gas inlet plate 11 is transferred to the first chamber 121 through the central aperture 120 of the resonance plate 12, and then the gas is transferred downwardly to the gas collecting plate 16 through the vacant space 135 of the piezoelectric actuator 13. As the gas pressure is continuously increased along the downward direction, the gas is continuously transferred to the gas-collecting chamber 162, the second perforation 164, the first outlet chamber 166, the second outlet chamber 184 and the outlet perforation 182 and then transferred to the target equipment which is in communication with the outlet structure 19. Such pressure-collecting operation may be but not limited to be triggered by the pressure difference between the ambient pressure of the input side and the gas pressure of the inner space of the target equipment.

[0057] FIG. 8 schematically illustrate the gas-releasing actions or the pressure-reducing actions of the miniature pneumatic device of FIG. 1A. In case that the inner pressure of the target equipment is greater than the ambient air pressure of the input side, the gas-releasing operation (or a pressure-reducing operation) may be performed. As mentioned above, the user may adjust the amount of the gas to be fed into the miniature fluid control device 1A, so that the gas is no longer transferred to the gas-collecting chamber 162. Under this circumstance, the gas is transferred from the outlet structure 19 to the second outlet chamber 184 through the outlet perforation 182. Consequently, the volume of the second outlet chamber 184 is expanded, and the flexible valve film 17 corresponding to the second outlet chamber 184 is bent upwardly. In addition, the valve film 17 is in close contact with the raised structure 167 corresponding to the first outlet chamber 166. Since the valve opening 170 of the valve film 17 is closed by the raised structure 167, the gas in the second outlet chamber 184 will not be reversely returned to the first outlet chamber 166. Moreover, the gas in the second outlet chamber 184 is transferred to the second pressure-releasing chamber 183 through the communication channel 185, and then the gas in the second pressure-releasing chamber 183 is transferred to the pressure-releasing perforation 181. Under this circumstance, the gas-releasing operation is performed. After the gas-releasing operation of the miniature valve device 1B in one direction is performed, the gas within the inner space of the target equipment is partially or completely exited to the surrounding. Under this circumstance, the inner pressure of the equipment is reduced.

[0058] As mentioned above, the suspension plate 130 used in the present invention is a square suspension plate. As the length of the suspension plate 130 is reduced, the area of the suspension plate 130 is correspondingly reduced. Since the size of the suspension plate 130 is reduced, the rigidity of the suspension plate 130 is increased. Moreover, since the volume of the internal gas channel is reduced, the efficacy of pushing or compressing the gas is increased and the output pressure value is increased. Moreover, since the deformation of the suspension plate 130 in the horizontal direction is reduced while the suspension plate 130 is operating the vertical vibration, the piezoelectric actuator 13 is not readily inclined in the same vertical direction during operation. Moreover, since the collision interference between the suspension plate 13 and the resonance plate 12 or other components can be reduced, the noise is reduced and the defect rate is reduced. All in all, as the size of the suspension plate 130 is reduced, the size of the piezoelectric actuator 13 can be correspondingly reduced. Under this circumstance, the output pressure is increased, the noise is reduced, and the product yield is enhanced. On the contrary, as the size of the suspension plate 130 is increased, the output pressure value becomes low, and the defect rate of the miniature pneumatic device is increased.

[0059] The suspension plate 130 and the piezoelectric ceramic plate 133 are the core components of the miniature pneumatic device 1. As the areas of the two components are reduced, the area and the weight of the miniature pneumatic device 1 are correspondingly reduced. Consequently, the miniature pneumatic device 1 can be easily installed in a portable/wearable device. Since the volume is reduced, the applications of the miniature pneumatic device 1 are expanded.

[0060] After the miniature fluid control device 1A and the miniature valve device 1B are combined together, the total thickness of the miniature pneumatic device 1 is in the range between 1.5mm and 4mm. Since the miniature pneumatic device is slim and portable, the miniature pneumatic device is suitably applied to medical equipment or any other appropriate equipment.

[0061] From the above descriptions, the present invention provides the miniature pneumatic device. The miniature pneumatic device comprises the miniature fluid control device and the miniature valve device. After the gas is fed into the miniature fluid control device through the inlet, the piezoelectric actuator is actuated. Consequently, a pressure gradient is generated in the fluid channels of the miniature fluid control device and the gas-collecting chamber to facilitate the gas to flow to the miniature valve device at a high speed. Moreover, due to the one-way valve film of the miniature valve device, the gas is transferred in one direction. Consequently, the pressure of the gas is accumulated to any equipment that is connected with the outlet structure, which is referred as the target equipment above. For performing a gas-releasing operation (or a pressure-reducing operation), the user may adjust the amount of the gas to be fed into the miniature fluid control device, so that the gas is no longer transferred to the gas-collecting chamber. Under this circumstance, the gas is transferred from the outlet

structure to the second outlet chamber of the miniature valve device, then transferred to the second pressure-releasing chamber through the communication channel, and finally exited from the pressure-releasing perforation. By the miniature pneumatic device of the present invention, the gas can be quickly transferred while achieving silent efficacy. Moreover, due to the special configurations, the miniature pneumatic device of the present invention has small volume and small thickness. Consequently, the miniature pneumatic device is portable and suitable to be applied to medical equipment or any other appropriate equipment. In other words, the miniature pneumatic device of the present invention has significant advantages that creating industrial values.

Claims

1. A miniature pneumatic device (1), comprising:

a miniature fluid control device (1A) comprising:

a gas inlet plate (11) comprising at least one inlet (110), at least one convergence channel (112) and a central cavity (111), wherein a convergence chamber is defined by the central cavity (111), wherein after a gas is introduced into the at least one convergence channel (112) through the at least one inlet (110), the gas is guided by the at least one convergence channel (112) and converged to the convergence chamber;
a resonance plate (12) having a central aperture (120) corresponding to the convergence chamber of the gas inlet plate (11);
a piezoelectric actuator (13) comprising a suspension plate (130), an outer frame (131) and a piezoelectric ceramic plate (133), wherein the outer frame (131) comprises at least one bracket (132), and the suspension plate (130) and the outer frame (131) are connected with each other through the at least one bracket (132), wherein the piezoelectric ceramic plate (133) is attached on a first surface (130b) of the suspension plate (130);
a gas collecting plate (16) comprising a first perforation (163), a second perforation (164), a first pressure-releasing chamber (165), a first outlet chamber (166) and a fiducial surface (161), wherein the gas collecting plate (16) further comprises a raised structure (167) disposed in the first outlet chamber (166) and located at a level higher than the fiducial surface (161) of the gas collecting plate (16), the first perforation (163) is in communication with the first pressure-releasing chamber (165), and the second perforation (164) is in communication with the first outlet chamber (166),
wherein the gas inlet plate (11), the resonance plate (12), the piezoelectric actuator (13) and the gas collecting plate (16) are stacked on each other sequentially, and a gap (g0) is formed between the resonance plate (12) and the piezoelectric actuator (13) to define a first chamber (121), wherein when the piezoelectric actuator (13) is actuated, the gas is fed into the miniature fluid control device (1A) through the at least one inlet (110) of the gas inlet plate (11), converged to the central cavity (111) through the at least one convergence channel (112), transferred through the central aperture (120) of the resonance plate (12), introduced into the first chamber (121), transferred downwardly to the gas collecting plate (16) through a vacant space (135) between the at least one bracket (132) of the piezoelectric actuator (13), and exited from the miniature fluid control device (1A); and

a miniature valve device (1B) comprising:

a valve film (17) having a valve opening (170), the raised structure (167) of the gas collecting plate (16) is aligned with the valve opening (170) of the valve film (17) and is contacted with the valve film (17) that providing a pre-force against the valve film (17) to tightly close the valve opening (170); and
a gas outlet plate (18) comprising a pressure-releasing perforation (181), an outlet perforation (182), a second pressure-releasing chamber (183), a second outlet chamber (184) and a fiducial surface (180), wherein the second pressure-releasing chamber (183) and the second outlet chamber (184) are concavely formed in the fiducial surface (180) of the gas outlet plate (18), the pressure-releasing perforation (181) is located at a center of the second pressure-releasing chamber (183), a convex structure (181a) is located beside an end of the pressure-releasing perforation (181), the convex structure (181a) is located at a level higher than the fiducial surface (180) of the gas outlet plate (18), the outlet perforation (182) is in communication with the second outlet chamber (184) and the gas outlet plate (18) further comprises a communication channel (185) between the second pressure-releasing chamber (183) and the second outlet chamber (184),
wherein the valve film (17) and the gas outlet plate (18) are sequentially disposed on

the gas collecting plate (16), the pressure-releasing perforation (181) of the gas outlet plate (18) is aligned with the first perforation (163) of the gas collecting plate (16), the second pressure-releasing chamber (183) of the gas outlet plate (18) is aligned with the first pressure-releasing chamber (165) of the gas collecting plate (16), and the second outlet chamber (184) of the gas outlet plate (18) is aligned with the first outlet chamber (166) of the gas collecting plate (16), wherein the valve film (17) is arranged between the gas collecting plate (16) and the gas outlet plate (18) for blocking communication between the first pressure-releasing chamber (165) and the second pressure-releasing chamber (183), and the valve opening (170) of the valve film (17) is arranged between the second perforation (164) and the outlet perforation (182), wherein after the gas is downwardly transferred from the miniature fluid control device (1A) to the miniature valve device (1B), the gas is introduced into the first pressure-releasing chamber (165) through the first perforation (163) and is introduced into the first outlet chamber (166) through the second perforation (164), while the valve film (17) is quickly contacted with the convex structure (181a) of the gas outlet plate (18) to provide a pre-force to tightly close the pressure-releasing perforation (181), and the gas within the first outlet chamber (166) is further transferred to the outlet perforation (182) of the miniature valve device (1B) through the valve opening (170) of the valve film (17) and is discharged to an inner space of a target equipment, so that a pressure-collecting operation is performed, wherein while a pressure-releasing operation is performed, the gas in the inner space of the target equipment is transferred from the outlet perforation (182) to the second outlet chamber (184) to move the valve film (17) so that the valve opening (170) thereof is contacted with and closed by the gas collecting plate (16), the gas is transferred from the second outlet chamber (184) to the second pressure-releasing chamber (183) through the communication channel (185), a part of the valve film (17) corresponding to the second pressure-releasing chamber (183) is moved such that the gas is exited from the pressure-releasing perforation (181) to release the pressure of the inner space of the target equipment,

wherein the miniature pneumatic device (1) is **characterized in that**:

a length of the suspension plate (130) of the piezoelectric actuator (13) of the miniature fluid control device (1A) is in a range between 2mm and 4.5mm, a width of the suspension plate (130) is in a range between 2mm and 4.5mm, and a thickness of the suspension plate (130) is in a range between 0.1mm and 0.3mm;

a length of the piezoelectric ceramic plate (133) of the piezoelectric actuator (13) of the miniature fluid control device (1A) is equal to or less than a length of the suspension plate (130), the length of the piezoelectric ceramic plate (133) is in a range between 2mm and 4.5mm, a width of the piezoelectric ceramic plate (133) is in a range between 2mm and 4.5mm, a thickness of the piezoelectric ceramic plate (133) is in a range between 0.05mm and 0.3mm, and a length/width ratio of the piezoelectric ceramic plate (133) is in a range between 0.44 and 2.25;

a thickness of the valve film (17) of the miniature valve device (1B) is in a range between 0.1mm and 0.3mm; and

the gas outlet plate (18) of the miniature valve device (1B) further comprises at least one position-limiting structure (188), wherein the at least one position-limiting structure (188) is disposed within the second pressure-releasing chamber (183) and spaced apart from the convex structure (181a), so as to assist in supporting the valve film (17) to avoid collapse, and a thickness of the position-limiting structure (188) is in a range between 0.1mm and 0.5mm.

2. The miniature pneumatic device (1) according to claim 1, wherein an operating voltage of the miniature pneumatic device (1) is $\pm$15V, and when the miniature pneumatic device (1) is operated at the operating voltage, an output pressure of the miniature pneumatic device (1) is at least 300mmHg.

3. The miniature pneumatic device (1) according to claim 1 or 2, wherein the length of the piezoelectric ceramic plate (133) is in a range between 2.5mm and 3.5mm, the width of the piezoelectric ceramic plate (133) is in a range between 2.5mm and 3.5mm, and the thickness of the piezoelectric ceramic plate (133) is 0.1mm.

4. The miniature pneumatic device (1) according to one of the preceding claims, wherein the length of the suspension plate (130) is in a range between 2.5mm and 3.5mm, the width of the suspension plate (130)

is in a range between 2.5mm and 3.5mm, and the thickness of the suspension plate (130) is 0.2mm.

5. The miniature pneumatic device (1) according to one of the preceding claims, wherein the thickness of the position-limiting structure (188) of the miniature valve device (1B) is 0.2mm.

6. The miniature pneumatic device (1) according to claim 1, wherein
the gas collecting plate (16) further comprises a gas-collecting chamber (162) formed between the piezoelectric actuator (13) and the gas collecting plate (16), when the piezoelectric actuator (13) is actuated, a gas is fed into the miniature fluid control device (1A) through the gas inlet plate (11), transferred through the resonance plate (12), introduced into the first chamber (121), and transferred downwardly to the gas-collecting chamber (162).

Patentansprüche

1. Pneumatische Miniaturvorrichtung (1), umfassend eine Miniatur-Fluidsteuerungsvorrichtung (1A), umfassend:

eine Gaseinlassplatte (11) mit mindestens einem Einlass (110), mindestens einem Konvergenzkanal (112) und einem zentralen Hohlraum (111), wobei durch den zentralen Hohlraum (111) eine Konvergenzkammer definiert ist, wobei nach dem Einleiten eines Gases in den mindestens einen Konvergenzkanal (112) durch den mindestens einen Einlass (110) das Gas durch den mindestens einen Konvergenzkanal (112) geführt und zu der Konvergenzkammer konvergiert wird;
eine Resonanzplatte (12) mit einer zentralen Öffnung (120), die zu der Konvergenzkammer der Gaseinlassplatte (11) passt;
einen piezoelektrischen Aktuator (13), der eine Aufhängungsplatte (130), einen äußeren Rahmen (131) und eine piezoelektrische Keramikplatte (133) umfasst, wobei der äußere Rahmen (131) mindestens eine Klammer (132) umfasst und die Aufhängungsplatte (130) und der äußere Rahmen (131) durch die mindestens eine Klammer (132) miteinander verbunden sind, wobei die piezoelektrische Keramikplatte (133) an einer ersten Oberfläche (130b) der Aufhängungsplatte (130) angebracht ist;
eine Gassammelplatte (16), die eine erste Perforation (163), eine zweite Perforation (164), eine erste Druckentlastungskammer (165), eine erste Auslasskammer (166) und eine Bezugsfläche (161) umfasst, wobei die Gassammelplatte (16) ferner eine erhabene Struktur (167) umfasst, die in der ersten Auslasskammer (166) angeordnet ist und sich auf einem höheren Niveau als die Bezugsfläche (161) der Gassammelplatte (16) befindet, wobei die erste Perforation (163) in Verbindung mit der ersten Druckentlastungskammer (165) steht und die zweite Perforation (164) in Verbindung mit der ersten Auslasskammer (166) steht,
wobei die Gaseinlassplatte (11), die Resonanzplatte (12), der piezoelektrische Aktuator (13) und die Gassammelplatte (16) sequentiell aufeinander gestapelt sind und ein Spalt (g0) zwischen der Resonanzplatte (12) und dem piezoelektrischen Aktuator (13) ausgebildet ist, um eine erste Kammer (121) zu definieren, wobei, wenn der piezoelektrische Aktuator (13) betätigt wird, das Gas in die Miniatur-Fluidsteuerungsvorrichtung (1A) durch den mindestens einen Einlass (110) der Gaseinlassplatte (11) eingeführt wird, durch den mindestens einen Konvergenzkanal (112) zu dem zentralen Hohlraum (111) konvergiert, durch die zentrale Öffnung (120) der Resonanzplatte (12) übergeleitet, in die erste Kammer (121) eingeleitet wird, durch einen Freiraum (135) zwischen der mindestens einen Klammer (132) des piezoelektrischen Aktors (13) nach unten zur Gassammelplatte (16) übergeleitet und aus der Miniatur-Fluidsteuerungsvorrichtung (1A) ausgeleitet wird; und
eine Miniatur-Ventilvorrichtung (1B), die umfasst:

eine Ventilfolie (17) mit einer Ventilöffnung (170), wobei die erhabene Struktur (167) der Gassammelplatte (16) mit der Ventilöffnung (170) der Ventilfolie (17) ausgerichtet ist und mit der Ventilfolie (17) in Kontakt steht, die eine Vorkraft gegen die Ventilfolie (17) bereitstellt, um die Ventilöffnung (170) dicht zu schließen; und
eine Gasauslassplatte (18), die eine Druckentlastungsperforation (181), eine Auslassperforation (182), eine zweite Druckentlastungskammer (183), eine zweite Auslasskammer (184) und eine Bezugsfläche (180) umfasst, wobei die zweite Druckentlastungskammer (183) und die zweite Auslasskammer (184) konkav in der Bezugsfläche (180) der Gasauslassplatte (18) ausgebildet sind, die Druckentlastungsperforation (181) in einer Mitte der zweiten Druckentlastungskammer (183) angeordnet ist, eine konvexe Struktur (181a) neben einem Ende der druckentlastenden Perforation (181) angeordnet ist, die konvexe Struktur (181a) auf einem höheren Niveau als die Bezugsfläche (180) der Gasauslassplatte (18) angeordnet ist, die Auslassperforation (182)

in Verbindung mit der zweiten Auslasskammer (184) steht und die Gasauslassplatte (18) ferner einen Verbindungskanal (185) zwischen der zweiten Druckentlastungskammer (183) und der zweiten Auslasskammer (184) umfasst,
wobei die Ventilfolie (17) und die Gasauslassplatte (18) sequentiell aufeinanderfolgend auf der Gassammelplatte (16) angeordnet sind, die Druckentlastungsperforation (181) der Gasauslassplatte (18) mit der ersten Perforation (163) der Gassammelplatte (16) ausgerichtet ist, die zweite Druckentlastungskammer (183) der Gasauslassplatte (18) mit der ersten Druckentlastungskammer (165) der Gassammelplatte (16) ausgerichtet ist, und die zweite Auslasskammer (184) der Gasauslassplatte (18) mit der ersten Auslasskammer (166) der Gassammelplatte (16) ausgerichtet ist, wobei die Ventilfolie (17) zwischen der Gassammelplatte (16) und der Gasauslassplatte (18) angeordnet ist, um die Verbindung zwischen der ersten Druckentlastungskammer (165) und der zweiten Druckentlastungskammer (183) zu sperren, und die Ventilöffnung (170) der Ventilfolie (17) zwischen der zweiten Perforation (164) und der Auslassperforation (182) angeordnet ist, wobei, nachdem das Gas nach unter von der Miniatur-Fluidsteuereinrichtung (1A) zur Miniatur-Ventileinrichtung (1B) übergeleitet worden ist, das Gas durch die erste Perforation (163) in die erste Druckentlastungskammer (165) eingeleitet wird und durch die zweite Perforation (164) in die erste Auslasskammer (166) eingeleitet wird, während die Ventilfolie (17) schnell mit der konvexen Struktur (181a) der Gasauslassplatte (18) in Kontakt gebracht wird, um eine Vorkraft zum dichten Schließen der Druckentlastungsperforation (181) bereitzustellen, und das Gas innerhalb der ersten Auslasskammer (166) weiter zu der Auslassperforation (182) der Miniatur-Ventileinrichtung (1B) durch die Ventilöffnung (170) der Ventilfolie (17) übergeleitet wird und zu einem Innenraum einer Zieleinrichtung abgelassen wird, so dass ein Drucksammelvorgang durchgeführt wird, wobei, während ein Druckentlastungsvorgang durchgeführt wird, das Gas in dem Innenraum der Zieleinrichtung von der Auslassperforation (182) zu der zweiten Auslasskammer (184) übergeleitet wird, um die Ventilfolie (17) zu bewegen, so dass deren Ventilöffnung (170) mit der Gassammelplatte (16) in Kontakt kommt und von dieser geschlossen wird, wobei das Gas von der zweiten Auslasskammer (184) zur zweiten Druckentlastungskammer (183) durch den Verbindungskanal (185) übergeleitet wird, wobei ein Teil der Ventilfolie (17), die zu der zweiten Druckentlastungskammer (183) passt, so bewegt wird, dass das Gas aus der Druckentlastungsperforation (181) austritt, um den Druck des Innenraums der Zielvorrichtung freizulassen,

wobei die pneumatische Miniaturvorrichtung (1) **dadurch gekennzeichnet ist, dass**:

eine Länge der Aufhängungsplatte (130) des piezoelektrischen Aktors (13) der Miniatur-Fluidsteuerungsvorrichtung (1A) in einem Bereich zwischen 2 mm und 4,5 mm liegt, eine Breite der Aufhängungsplatte (130) in einem Bereich zwischen 2 mm und 4,5 mm liegt, und eine Dicke der Aufhängungsplatte (130) in einem Bereich zwischen 0,1 mm und 0,3 mm liegt;
eine Länge der piezoelektrischen Keramikplatte (133) des piezoelektrischen Aktors (13) der Miniatur-Fluidsteuerungsvorrichtung (1A) gleich oder kleiner als eine Länge der Aufhängungsplatte (130) ist, die Länge der piezoelektrischen Keramikplatte (133) in einem Bereich zwischen 2mm und 4. 5mm liegt, eine Breite der piezoelektrischen Keramikplatte (133) in einem Bereich zwischen 2mm und 4,5mm liegt, eine Dicke der piezoelektrischen Keramikplatte (133) in einem Bereich zwischen 0,05mm und 0,3mm liegt und ein Längen/Breiten-Verhältnis der piezoelektrischen Keramikplatte (133) in einem Bereich zwischen 0,44 und 2,25 liegt;
eine Dicke der Ventilfolie (17) der Miniatur-Ventilvorrichtung (1B) in einem Bereich zwischen 0,1 mm und 0,3 mm liegt; und
die Gasauslassplatte (18) der Miniatur-Ventilvorrichtung (1B) ferner mindestens eine positionsbegrenzende Struktur (188) umfasst, wobei die mindestens eine positionsbegrenzende Struktur (188) innerhalb der zweiten Druckentlastungskammer (183) und beabstandet von der konvexen Struktur (181a) angeordnet ist, um das Abstützen der Ventilfolie (17) zu unterstützen, um ein Kollabieren zu vermeiden, und eine Dicke der positionsbegrenzenden Struktur (188) in einem Bereich zwischen 0,1mm und 0,5mm liegt.

2. Pneumatische Miniaturvorrichtung (1) nach Anspruch 1, wobei eine Betriebsspannung der pneumatischen Miniaturvorrichtung (1) $\pm$15 V beträgt,

und wenn die pneumatische Miniaturvorrichtung (1) mit der Betriebsspannung betrieben wird, ein Ausgangsdruck der pneumatische Miniaturvorrichtung (1) mindestens 300 mmHg beträgt.

3. Pneumatische Miniaturvorrichtung (1) nach Anspruch 1 oder 2, wobei die Länge der piezoelektrischen Keramikplatte (133) in einem Bereich zwischen 2,5 mm und 3,5 mm liegt, die Breite der piezoelektrischen Keramikplatte (133) in einem Bereich zwischen 2,5 mm und 3,5 mm liegt und die Dicke der piezoelektrischen Keramikplatte (133) 0,1 mm beträgt.

4. Pneumatische Miniaturvorrichtung (1) nach einem der vorhergehenden Ansprüche, wobei die Länge der Aufhängeplatte (130) in einem Bereich zwischen 2,5 mm und 3,5 mm liegt, die Breite der Aufhängeplatte (130) in einem Bereich zwischen 2,5 mm und 3,5 mm liegt und die Dicke der Aufhängeplatte (130) 0,2 mm beträgt.

5. Pneumatische Miniaturvorrichtung (1) nach einem der vorhergehenden Ansprüche, wobei die Dicke der positionsbegrenzenden Struktur (188) der Miniatur-Ventilvorrichtung (1B) 0,2mm beträgt.

6. Pneumatische Miniaturvorrichtung (1) nach Anspruch 1, wobei die Gassammelplatte (16) ferner eine zwischen dem piezoelektrischen Aktor (13) und der Gassammelplatte (16) gebildete Gassammelkammer (162) aufweist, wobei bei Betätigung des piezoelektrischen Aktors (13) ein Gas durch die Gaseinlassplatte (11) in die Miniatur-Fluidsteuerungsvorrichtung (1A) eingespeist, durch die Resonanzplatte (12) geleitet, in die erste Kammer (121) eingeleitet und nach unten in die Gassammelkammer (162) geleitet wird.

Revendications

1. Un dispositif pneumatique miniature (1) comprenant un dispositif miniature de contrôle des fluides (1A) comprenant :

une plaque d'entrée de gaz (11) ayant au moins une entrée (110), au moins un canal de convergence (112), et une cavité centrale (111), dans laquelle une chambre de convergence est définie par la cavité centrale (111), dans laquelle lors de l'introduction d'un gaz dans le au moins un canal de convergence (112) à travers la au moins une entrée (110), le gaz est passé à travers le au moins un canal de convergence (112) et converge vers la chambre de convergence ;
une plaque résonante (12) ayant une ouverture centrale (120) qui correspond à la chambre de convergence de la plaque d'entrée de gaz (11) ;
un actionneur piézoélectrique (13) comprenant une plaque de suspension (130), un cadre extérieur (131) et une plaque piézoélectrique en céramique (133), dans lequel le cadre extérieur (131) comprend au moins un support (132) et la plaque de suspension (130) et le cadre extérieur (131) sont reliés entre eux par le au moins un support (132), dans lequel la plaque piézoélectrique en céramique (133) est fixée à une première surface (130b) de la plaque de suspension (130) ;
une plaque de collecte de gaz (16) comprenant une première perforation (163), une deuxième perforation (164), une première chambre de décharge de pression (165), une première chambre de sortie (166) et une surface de référence (161), dans laquelle la plaque de collecte de gaz (16) comprend en outre une structure surélevée (167) disposée dans ladite première chambre de sortie (166) et située à un niveau plus élevé que ladite surface de référence (161) de ladite plaque de collecte de gaz (16), ladite première perforation (163) étant en communication avec ladite première chambre de décharge de pression (165) et ladite seconde perforation (164) étant en communication avec ladite première chambre de sortie (166)
dans lequel la plaque d'entrée de gaz (11), la plaque de résonance (12), l'actionneur piézoélectrique (13) et la plaque de collecte de gaz (16) sont empilées séquentiellement les unes sur les autres, et un espace (g0) est formé entre la plaque de résonance (12) et l'actionneur piézoélectrique (13) pour définir une première chambre (121), dans laquelle, lorsque l'actionneur piézoélectrique (13) est actionné, le gaz est introduit dans le dispositif miniature de commande de fluide (1A) par l'intermédiaire de la au moins une entrée (110) de la plaque d'entrée de gaz (11) converge à travers le au moins un canal de convergence (112) vers la cavité centrale (111), est transféré à travers l'ouverture centrale (120) de la plaque de résonance (12), est introduit dans la première chambre (121), est transféré vers le bas vers la plaque de collecte de gaz (16) à travers un espace (135) entre la au moins une pince (132) de l'actionneur piézoélectrique (13), et est déchargé du dispositif miniature de contrôle de fluide (1A) ; et
un dispositif de valve miniature (1B) comprenant :

une plaque de vanne (17) ayant une ouverture de vanne (170), la structure en relief (167) de la plaque de collecte de gaz (16) étant alignée avec l'ouverture de vanne (170) de la plaque de vanne (17) et étant

en contact avec la plaque de vanne (17) fournissant une force de sollicitation contre la plaque de vanne (17) pour sceller l'ouverture de vanne (170) ; et

une plaque de sortie de gaz (18) comprenant une perforation de décharge de pression (181), une perforation de sortie (182), une deuxième chambre de décharge de pression (183), une deuxième chambre de sortie (184) et une surface de référence (180), ladite deuxième chambre de décharge de pression (183) et ladite deuxième chambre de sortie (184) étant formées de manière concave dans ladite surface de référence (180) de ladite plaque de sortie de gaz (18), ladite perforation de décharge de pression (181) étant située au centre de ladite deuxième chambre de décharge de pression (183), **caractérisé par** une structure convexe (181a) est disposée à côté d'une extrémité de la perforation de détente (181), la structure convexe (181a) est disposée à un niveau plus élevé que la surface de référence (180) de la plaque de sortie de gaz (18), la perforation de sortie (182) est en communication avec la deuxième chambre de sortie (184), et la plaque de sortie de gaz (18) comprend en outre un canal de communication (185) entre la deuxième chambre de détente (183) et la deuxième chambre de sortie (184)

ladite tôle de soupape (17) et ladite plaque de sortie de gaz (18) étant disposées séquentiellement sur ladite plaque de collecte de gaz (16), ladite perforation de décharge de pression (181) de ladite plaque de sortie de gaz (18) étant alignée avec ladite première perforation (163) de ladite plaque de collecte de gaz (16) la deuxième chambre de décharge de pression (183) de la plaque de sortie de gaz (18) est alignée avec la première chambre de décharge de pression (165) de la plaque de collecte de gaz (16), et la deuxième chambre de sortie (184) de la plaque de sortie de gaz (18) est alignée avec la première chambre de sortie (166) de la plaque de collecte de gaz (16), dans lequel la feuille de soupape (17) est disposée entre la plaque de collecte de gaz (16) et la plaque de sortie de gaz (18) pour bloquer la communication entre la première chambre de surpression (165) et la deuxième chambre de surpression (183), et l'ouverture de soupape (170) de la feuille de soupape (17) est disposée entre la deuxième perforation (164) et la perforation de sortie (182), dans laquelle, après que le gaz a été transféré en aval du dispositif miniature de contrôle des fluides (1A) vers le dispositif miniature de soupape (1B), le gaz est introduit par la première perforation (163) dans la première chambre de détente (165) et est introduit par la deuxième perforation (164) dans la première chambre de sortie (166) tandis que le film de la soupape (17) est rapidement mis en contact avec la structure convexe (181a) de la plaque de sortie du gaz (18) pour fournir une pré-force permettant de fermer hermétiquement la perforation de décharge de pression (181) et le gaz à l'intérieur de la première chambre de sortie (166) est ensuite transféré vers la perforation de sortie (182) du dispositif de soupape miniature (1B) à travers l'ouverture de soupape (170) de la feuille de soupape (17) et est évacué vers un espace intérieur d'un dispositif cible de sorte qu'une opération de collecte de pression est effectuée, dans laquelle pendant qu'une opération de décharge de pression est effectuée le gaz dans l'espace intérieur du dispositif cible est transféré de la perforation de sortie (182) à la deuxième chambre de sortie (184) pour déplacer la feuille de soupape (17) de sorte que l'ouverture de soupape (170) de celle-ci entre en contact et soit fermée par la plaque collectrice de gaz (16), dans lequel le gaz est transféré de la deuxième chambre de sortie (184) à la deuxième chambre de surpression (183) par le canal de liaison (185), dans lequel une partie de la feuille de soupape (17) s'accouplant avec la deuxième chambre de surpression (183) est déplacée de telle sorte que le gaz sort de la perforation de surpression (181) pour libérer la pression de l'intérieur du dispositif cible,

le dispositif pneumatique miniature (1) étant **caractérisé en ce que:**

une longueur de la plaque de suspension (130) de l'actionneur piézoélectrique (13) du dispositif miniature de contrôle des fluides (1A) est comprise entre 2 mm et 4,5 mm, une largeur de la plaque de suspension (130) est comprise entre 2 mm et 4,5 mm, et une épaisseur de la plaque de suspension (130) est comprise entre 0,1 mm et 0,3 mm ;

une longueur de la plaque céramique piézoélectrique (133) de l'actionneur piézoélectrique (13) du dispositif miniature de commande de fluide (1A) est égale ou inférieure à une longueur de la plaque de suspension (130), la longueur de la plaque cé-

ramique piézoélectrique (133) est comprise entre 2 mm et 4. 5 mm, une largeur de la plaque céramique piézoélectrique (133) est comprise entre 2 mm et 4,5 mm, une épaisseur de la plaque céramique piézoélectrique (133) est comprise entre 0,05 mm et 0,3 mm, et un rapport longueur/largeur de la plaque céramique piézoélectrique (133) est compris entre 0,44 et 2,25 ;

l'épaisseur du film de la valve (17) du dispositif de valve miniature (1B) est comprise entre 0,1 mm et 0,3 mm

ladite plaque de sortie de gaz (18) dudit dispositif de soupape miniature (1B) comprend en outre au moins une structure de limitation de position (188), ladite au moins une structure de limitation de position (188) étant disposée à l'intérieur de ladite seconde chambre de décharge de pression (183) et espacée de ladite structure convexe (181a) pour aider à supporter ledit film de soupape (17) afin d'empêcher l'effondrement, et une épaisseur de ladite structure de limitation de position (188) étant dans une plage comprise entre 0,1 mm et 0,5 mm.

2. Le dispositif pneumatique miniature (1) selon la revendication 1, dans lequel une tension de fonctionnement du dispositif pneumatique miniature (1) est de ± 15 V, et lorsque le dispositif pneumatique miniature (1) fonctionne avec la tension de fonctionnement, une pression de sortie du dispositif pneumatique miniature (1) est d'au moins 300 mmHg.

3. Le dispositif pneumatique miniature (1) selon la revendication 1 ou 2, dans lequel la longueur de la plaque céramique piézoélectrique (133) est comprise entre 2,5 mm et 3,5 mm, la largeur de la plaque céramique piézoélectrique (133) est comprise entre 2,5 mm et 3,5 mm, et l'épaisseur de la plaque céramique piézoélectrique (133) est de 0,1 mm.

4. Le dispositif pneumatique miniature (1) selon l'une quelconque des revendications précédentes, dans lequel la longueur de la plaque de suspension (130) est comprise entre 2,5 mm et 3,5 mm, la largeur de la plaque de suspension (130) est comprise entre 2,5 mm et 3,5 mm, et l'épaisseur de la plaque de suspension (130) est de 0,2 mm.

5. Le dispositif pneumatique miniature (1) selon l'une quelconque des revendications précédentes, dans lequel l'épaisseur de la structure de limitation de position (188) du dispositif de soupape miniature (1B) est de 0,2 mm.

6. Le dispositif pneumatique miniature (1) selon la revendication 1, dans lequel la plaque de collecte de gaz (16) comprend en outre une chambre de collecte de gaz (162) formée entre l'actionneur piézoélectrique (13) et la plaque de collecte de gaz (16), dans lequel, lors de l'actionnement de l'actionneur piézoélectrique (13), un gaz est injecté dans le dispositif miniature de contrôle des fluides (1A) par la plaque d'entrée de gaz (11), passe à travers la plaque de résonance (12), est introduit dans la première chambre (121) et est dirigé vers le bas dans la chambre de collecte de gaz (162).

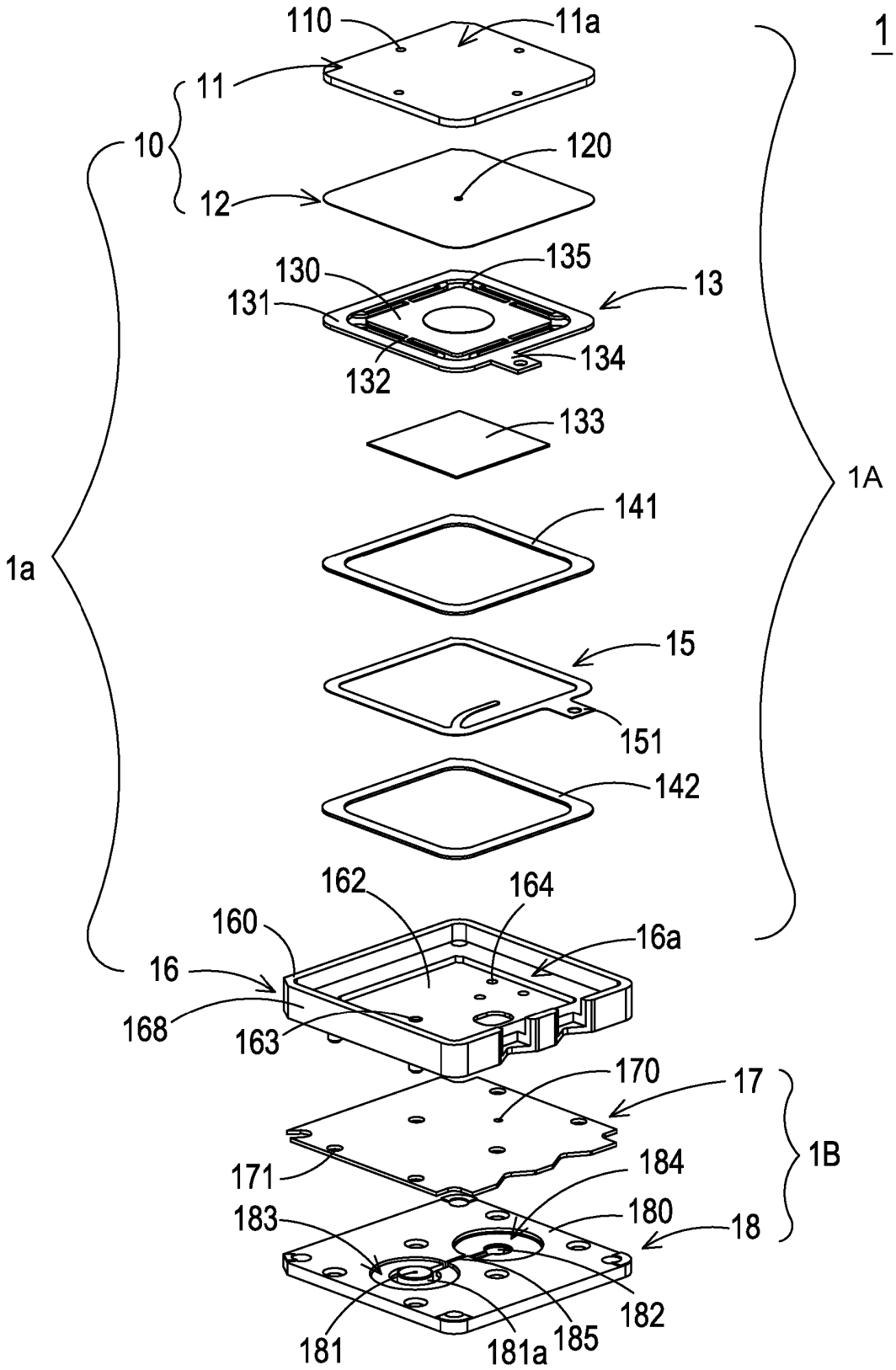

1
110
11a
11
10
120
12
130
135
131
13
132
134
133
1A
141
1a
15
151
142
162
164
160
16a
16
168
163
170
17
1B
171
184
183
180
18
182
181
181a
185

FIG.1A

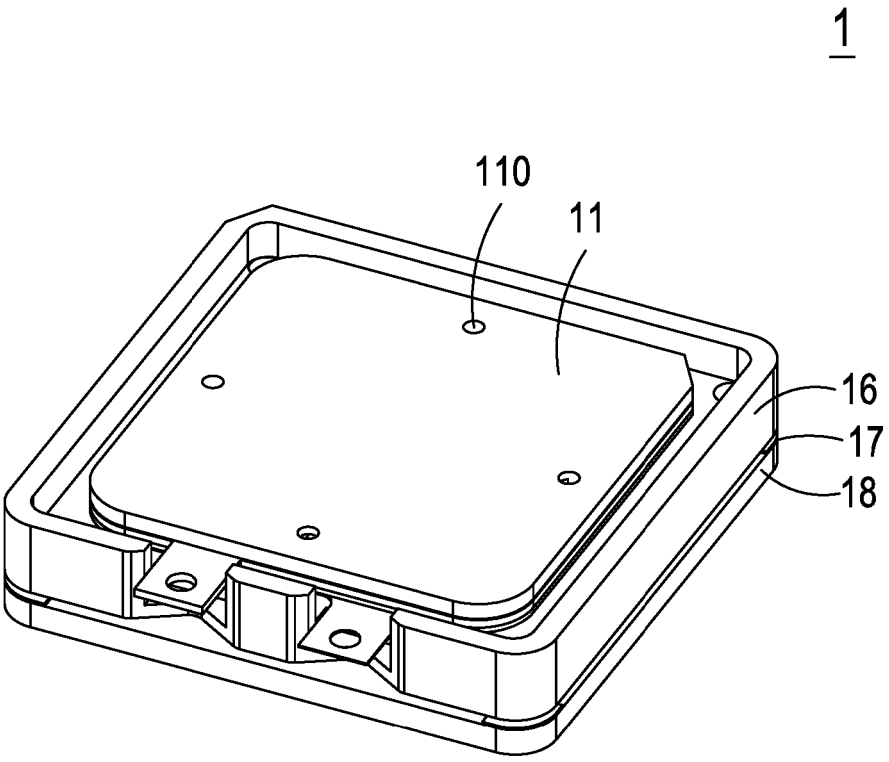


FIG.1B

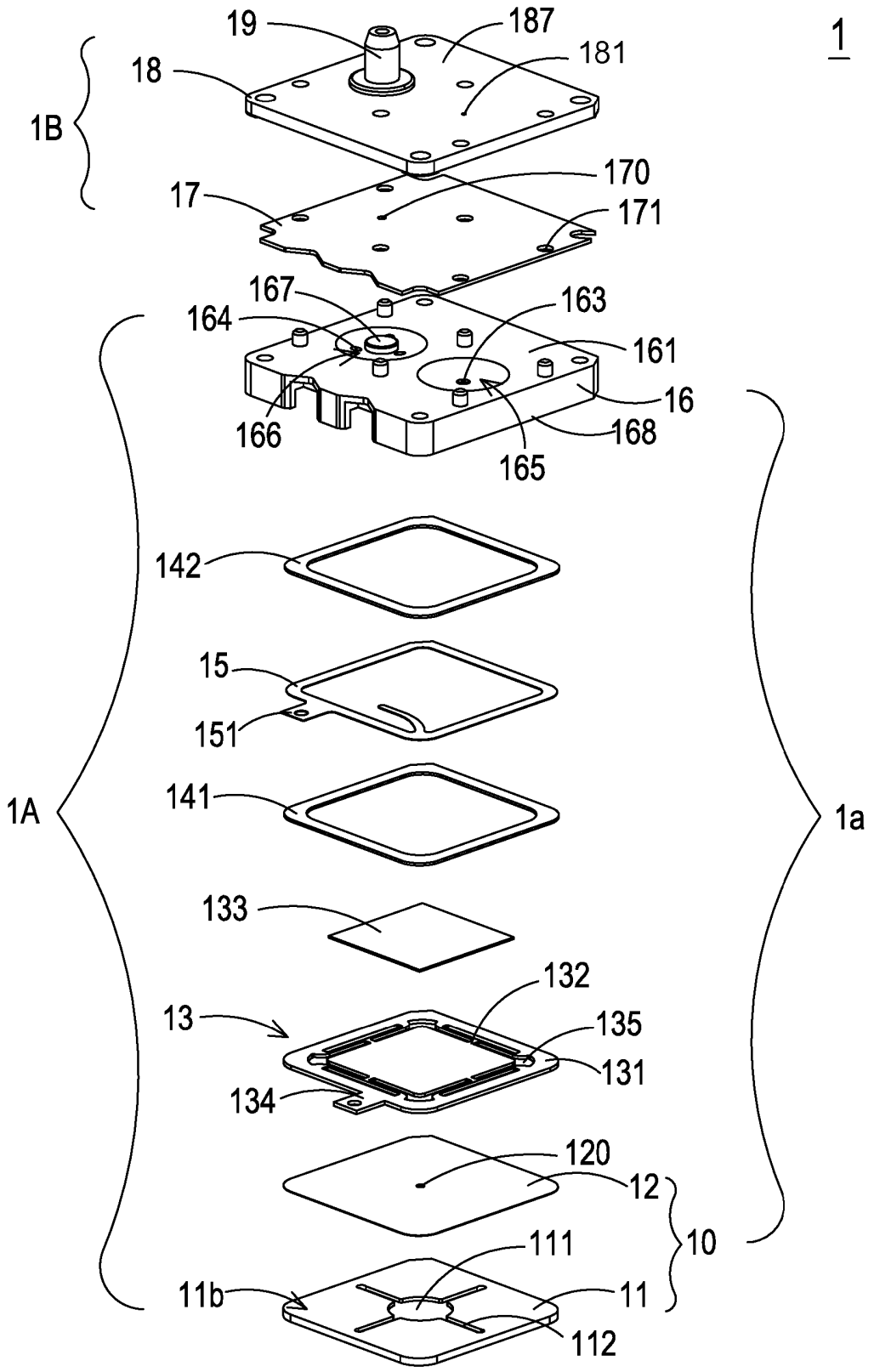

1
19
187
181
18
1B
170
17
171
167
163
164
161
16
166
168
165
142
15
151
141
1A
1a
133
132
13
135
131
134
120
12
10
111
11b
11
112

FIG.2A

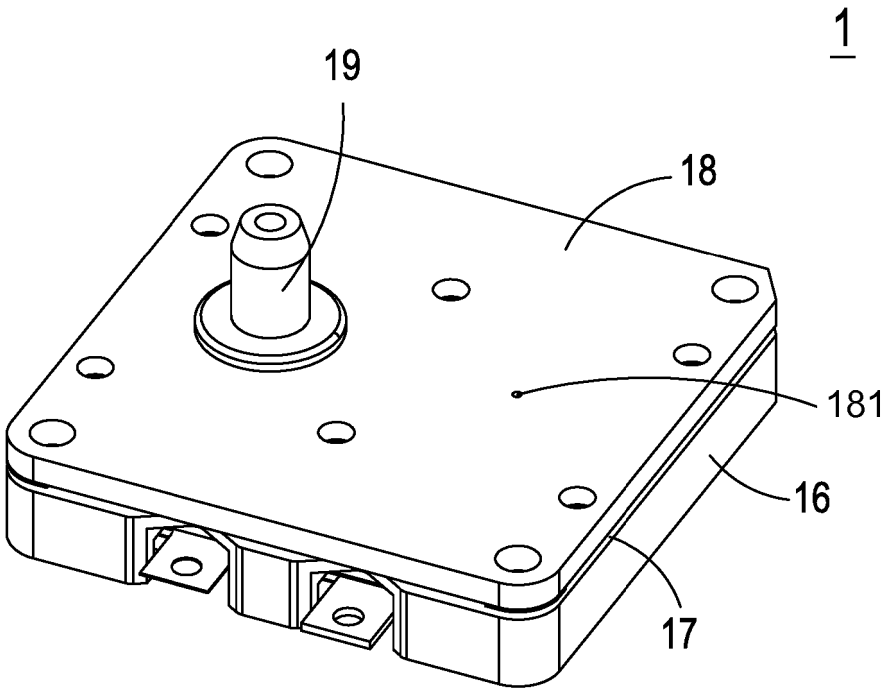


FIG.2B

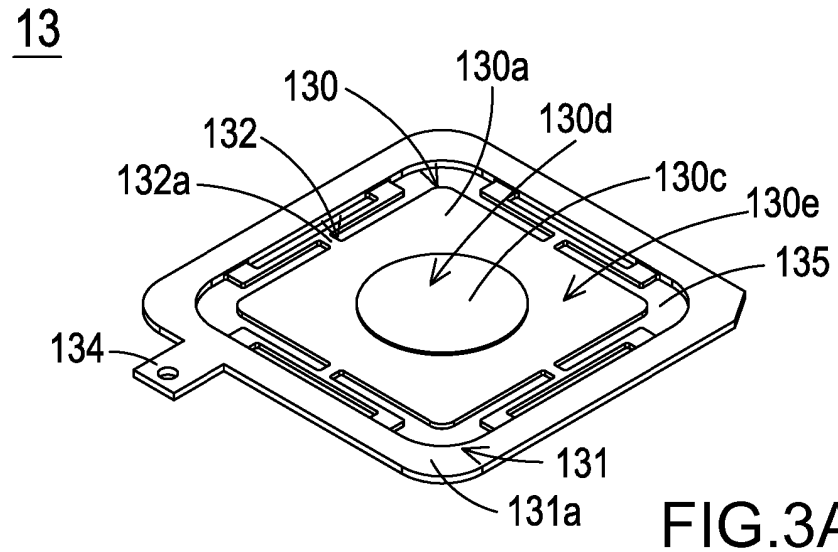


FIG.3A

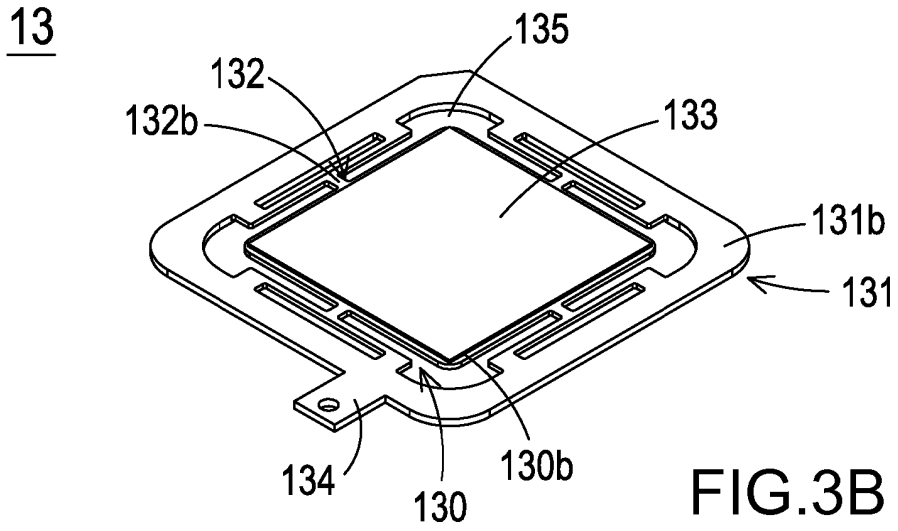


FIG.3B

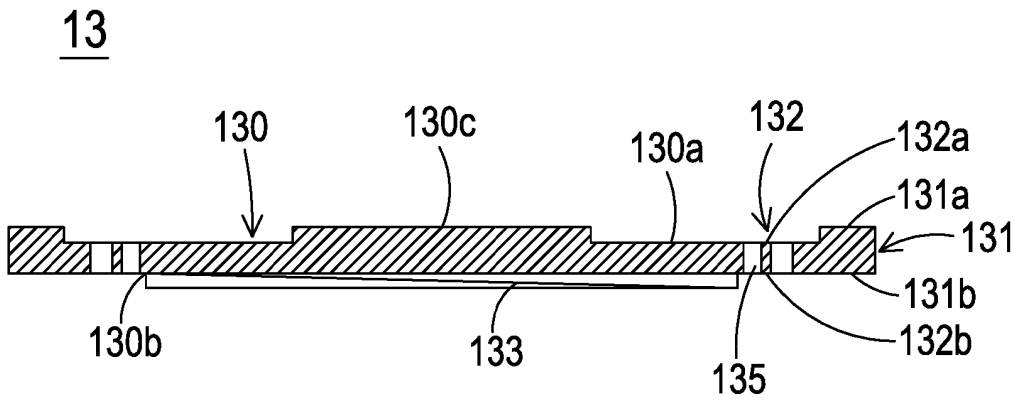


FIG.3C

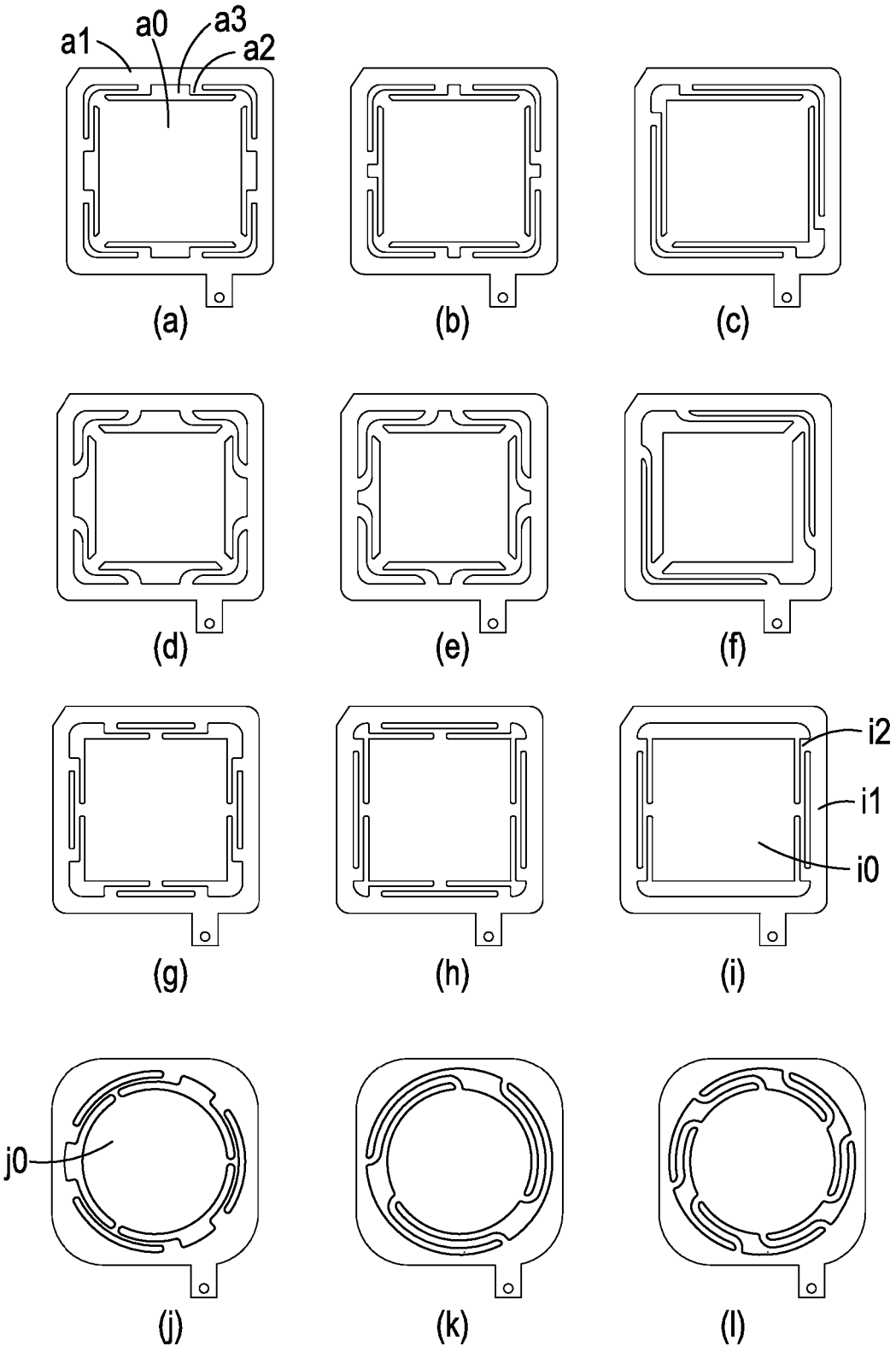


FIG.4A

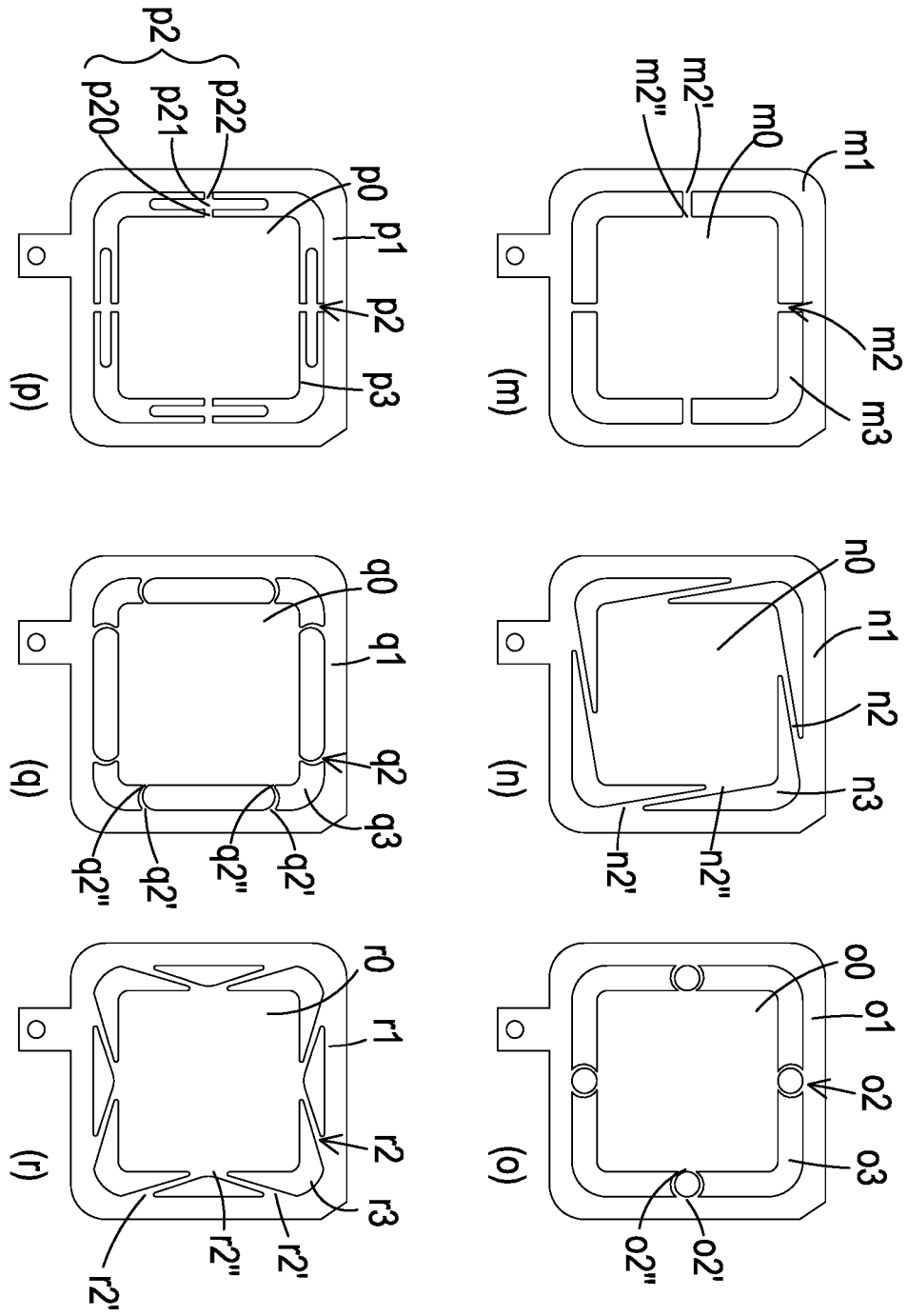

(m)
m0
m1
m2
m2'
m2"
m3
(n)
n0
n1
n2
n2'
n2"
n3
(o)
o0
o1
o2
o2'
o2"
o3
(p)
p0
p1
p2
p20
p21
p22
p3
(q)
q0
q1
q2
q2'
q2"
q3
(r)
r0
r1
r2
r2'
r2"
r3

FIG.4B

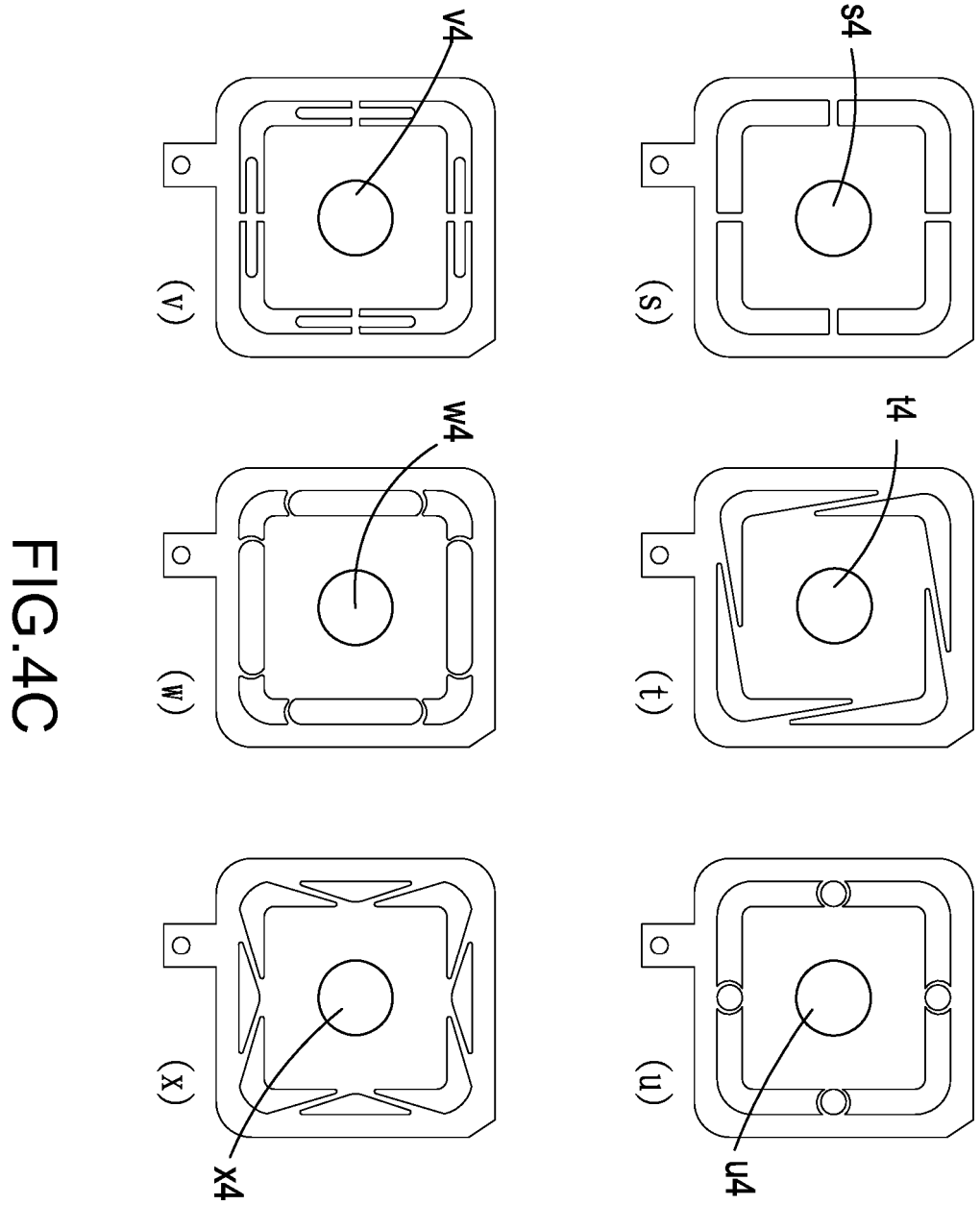


FIG.4C

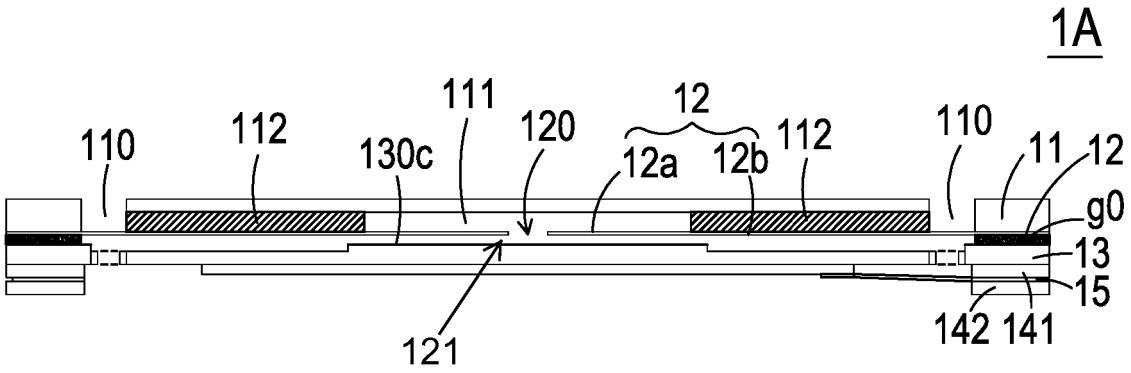


FIG.5A

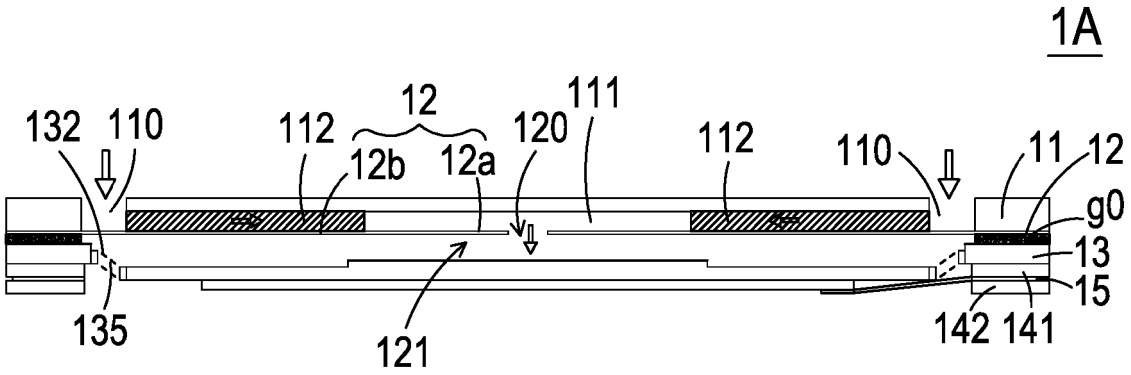


FIG.5B

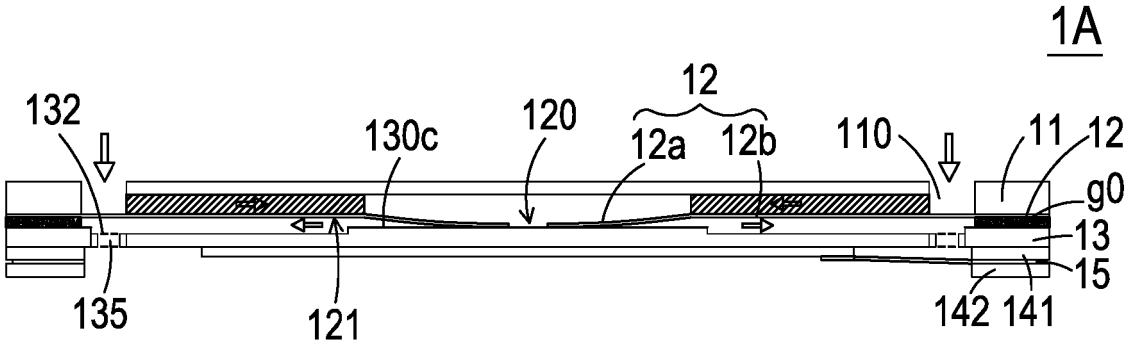
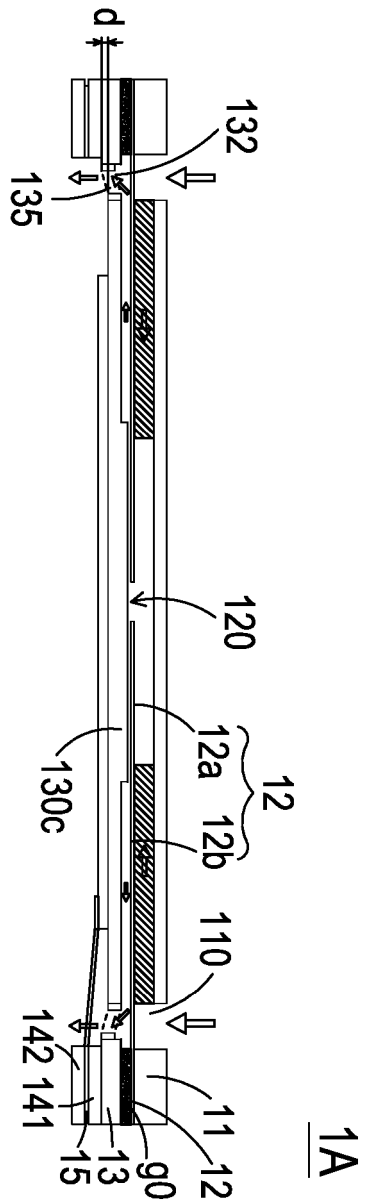


FIG.5C


d
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135
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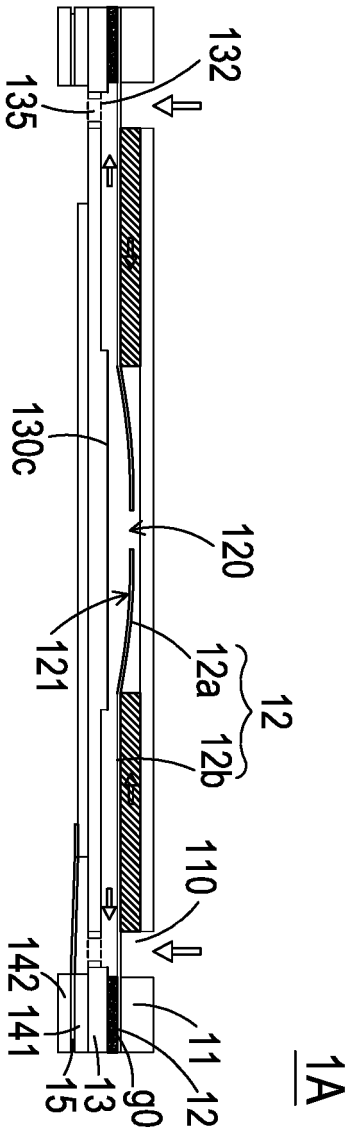
12a
12
130c
12b
110
142
141
11
12
1A
15
13
g0

FIG.5D


132
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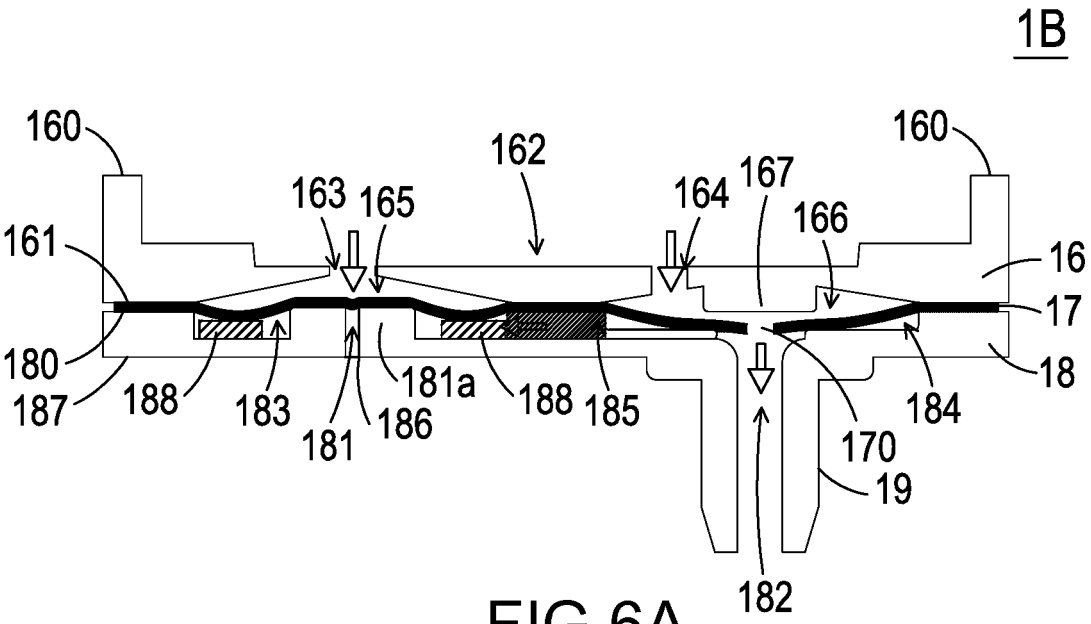
12a
12
12b
110
142
141
11
12
1A
15
13
g0

FIG.5E


1B
160
162
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163
165
164
167
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161
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17
180
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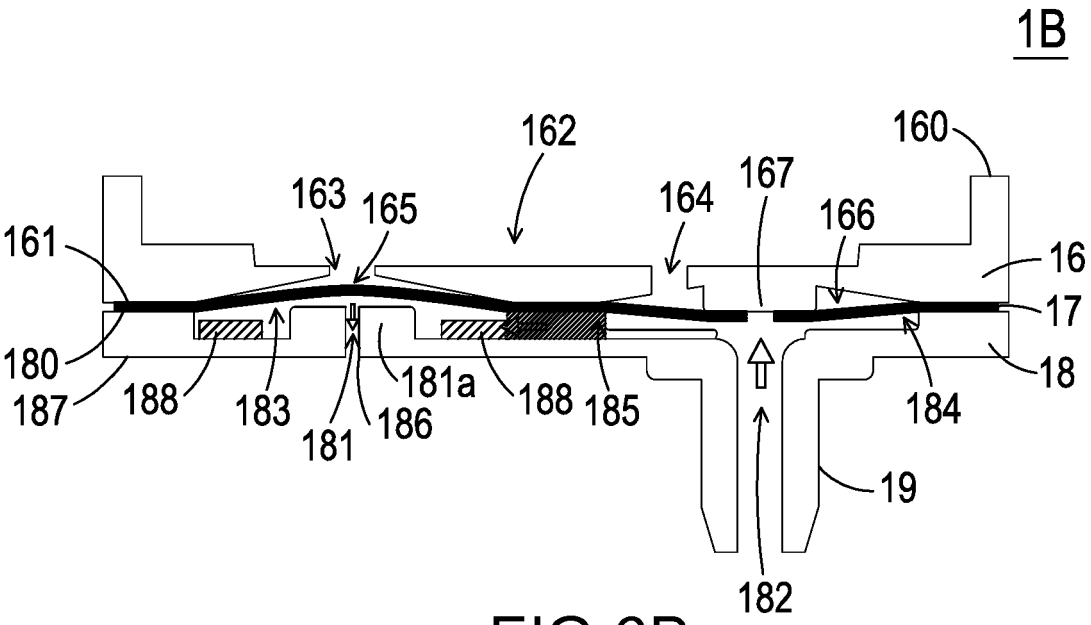
187
188
183
181a
188
185
184
181
186
170
19
182

FIG.6A


1B
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181a
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186
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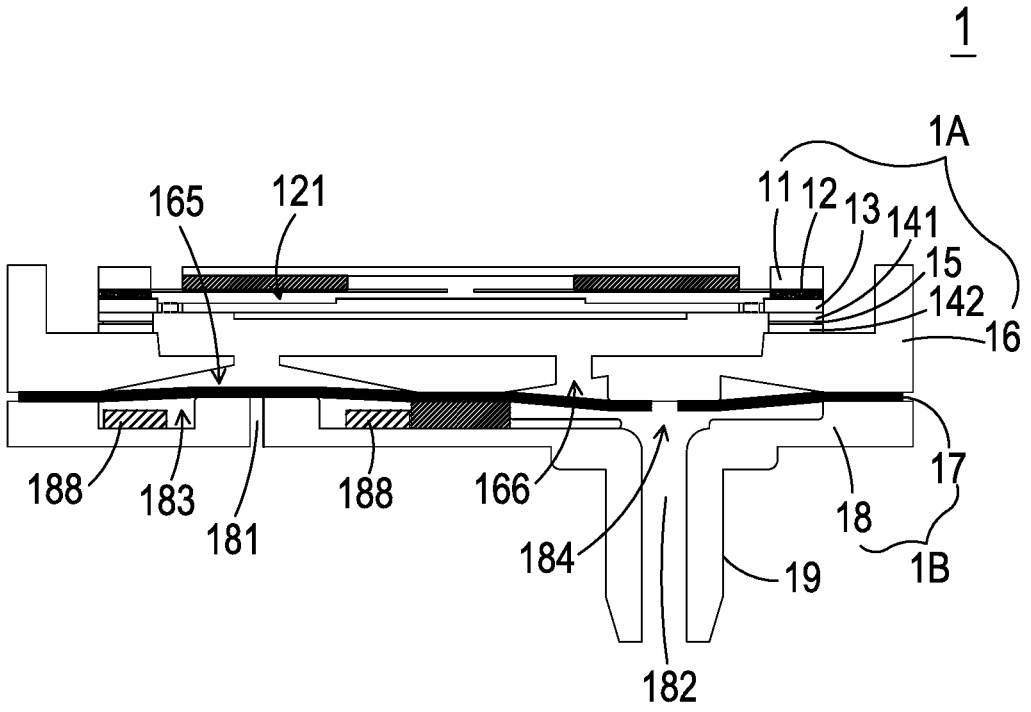
182

FIG.6B


1
1A
165
121
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13
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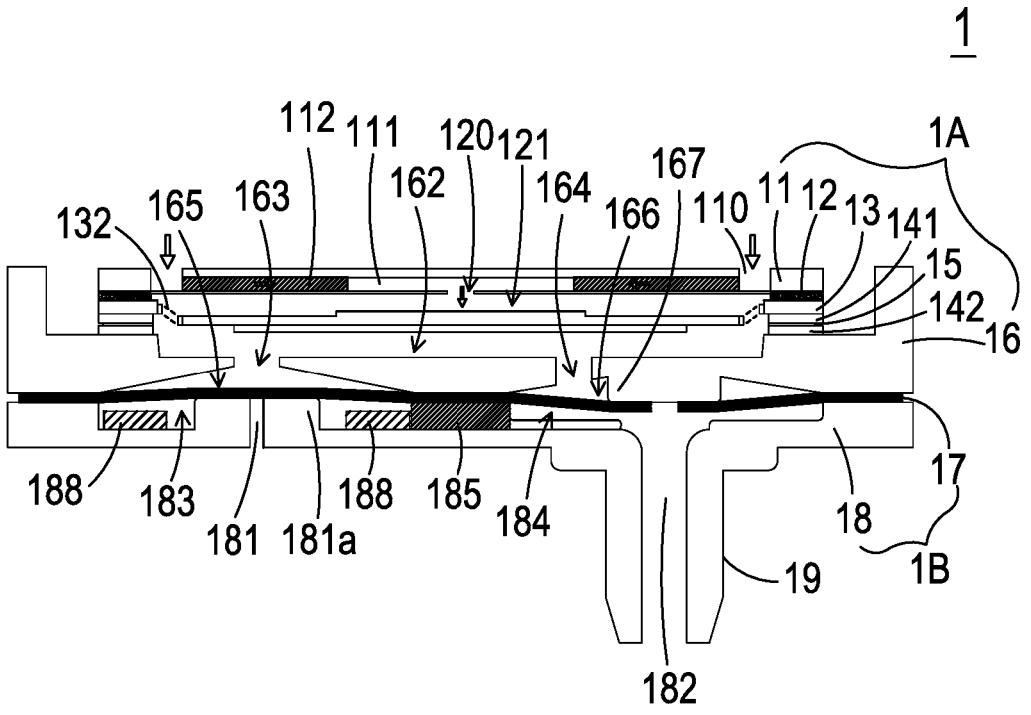
142
16
188
183
181
188
166
184
17
18
19
1B
182

FIG.7A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1A
112
111
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167
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163
162
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16
188
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181
181a
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184
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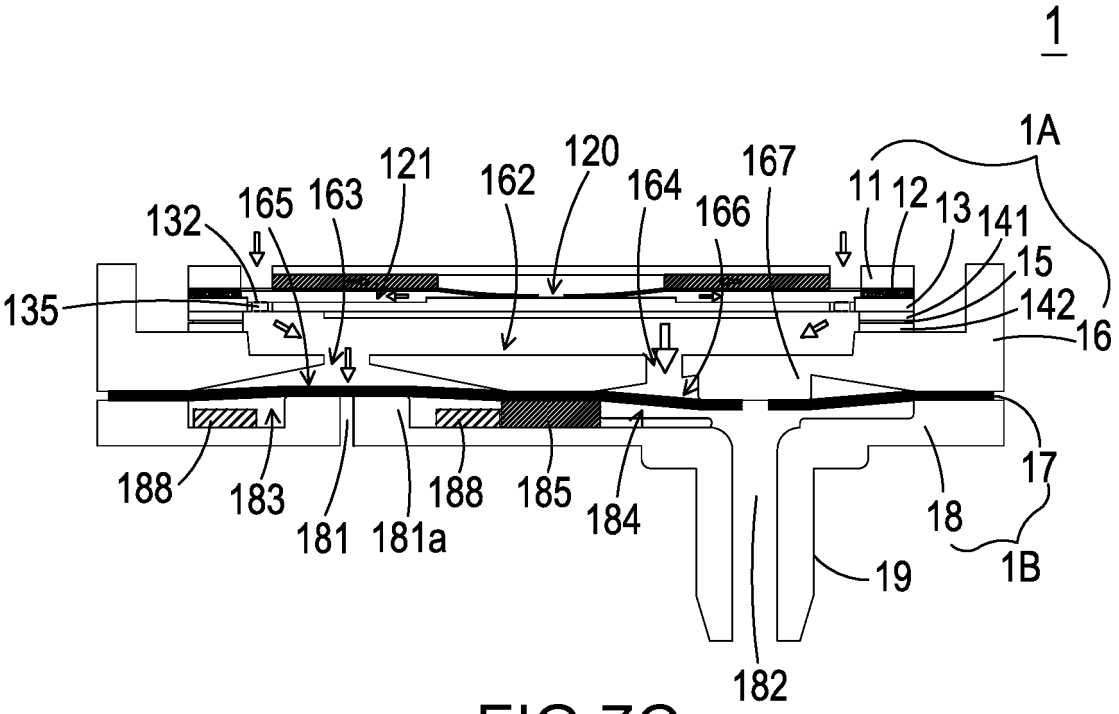
19
1B
182

FIG.7B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181a
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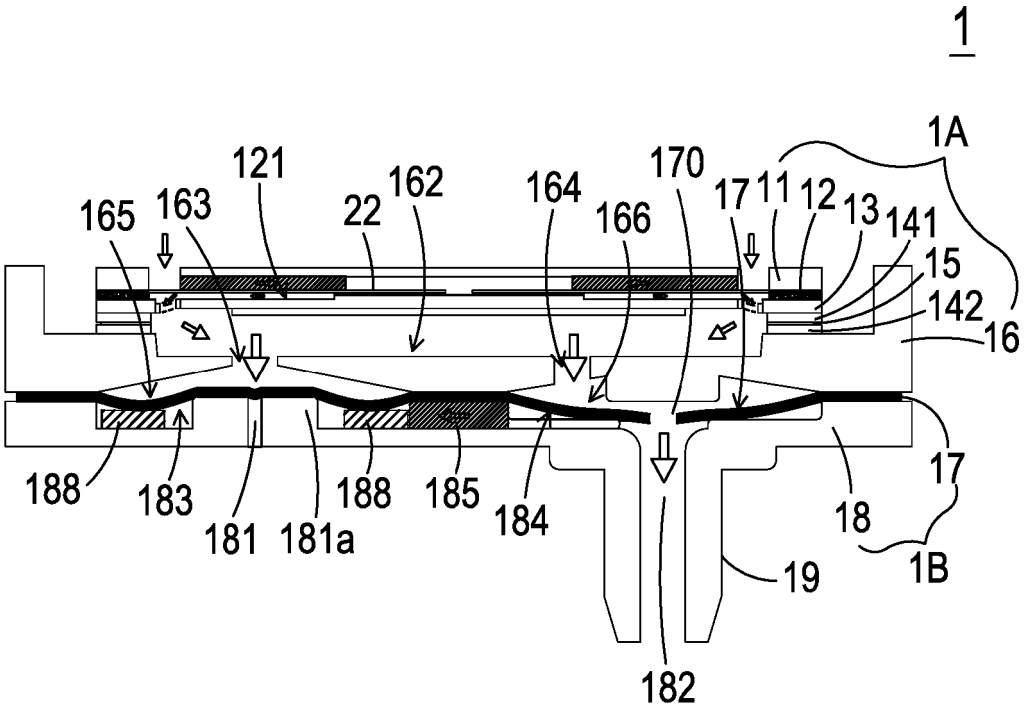
1B
182

FIG.7C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182

FIG.7D

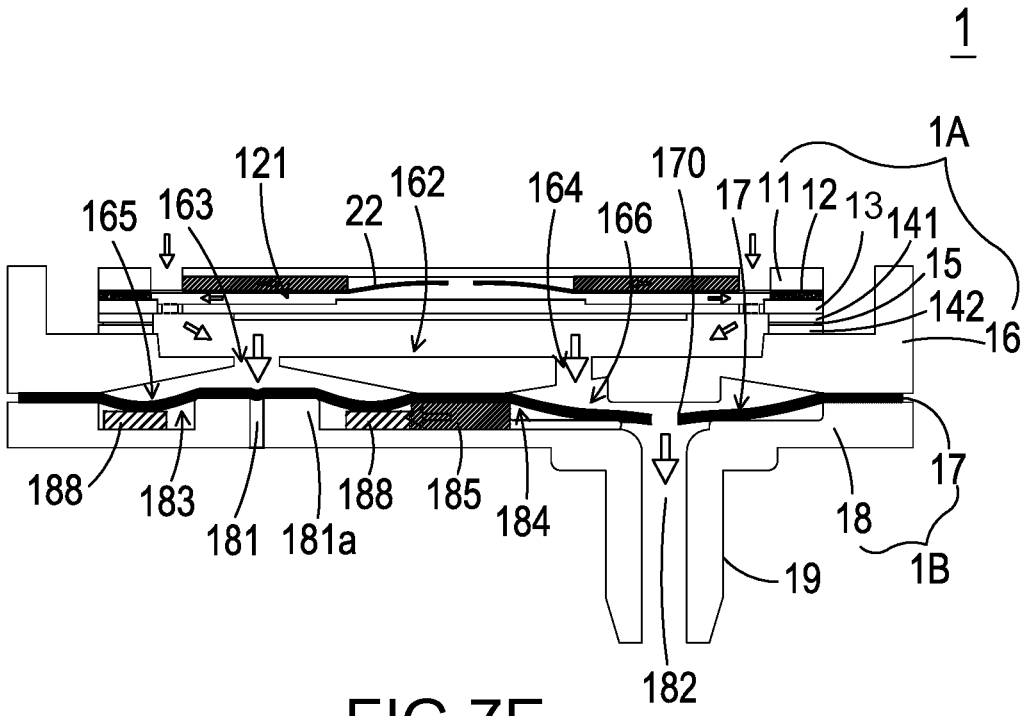
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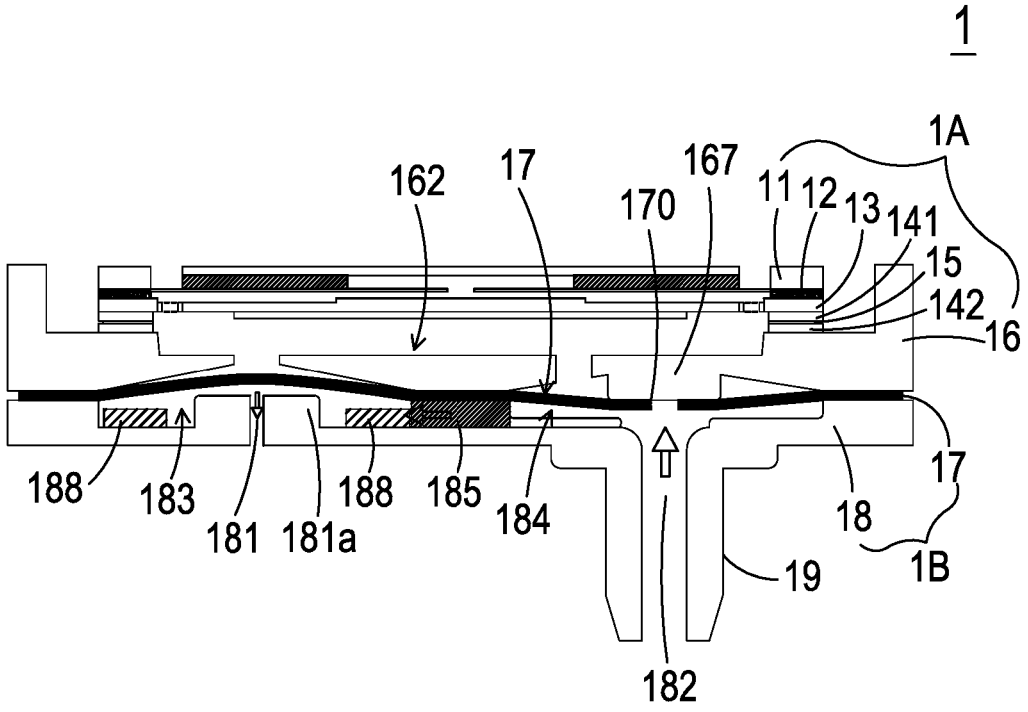
FIG.7E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181a
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1B
19

FIG.8

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 2014377099 A1 **[0005]**