US 20040076531A1

(19) **United States**

(12) **Patent Application Publication** (10) **Pub. No.: US 2004/0076531 A1**

Takeuchi et al. (43) **Pub. Date: Apr. 22, 2004**

(54) **CIRCUIT CHANGEOVER SWITCH**

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(21) Appl. No.: **10/299,023**

(22) Filed: **Nov. 18, 2002**

(30) **Foreign Application Priority Data**

Nov. 19, 2001 (JP) 2001-353749

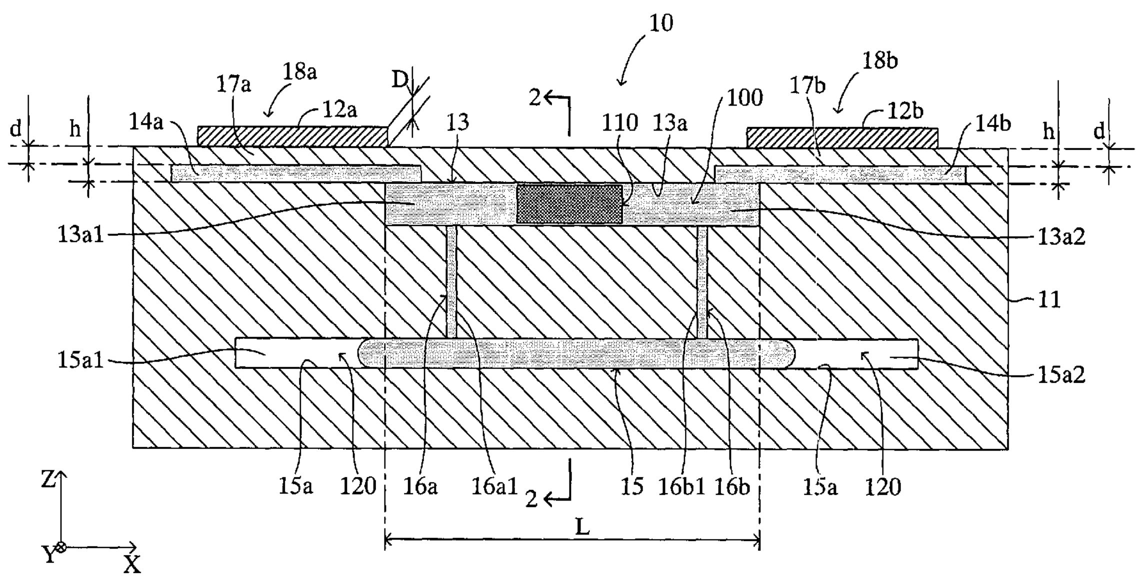
Publication Classification

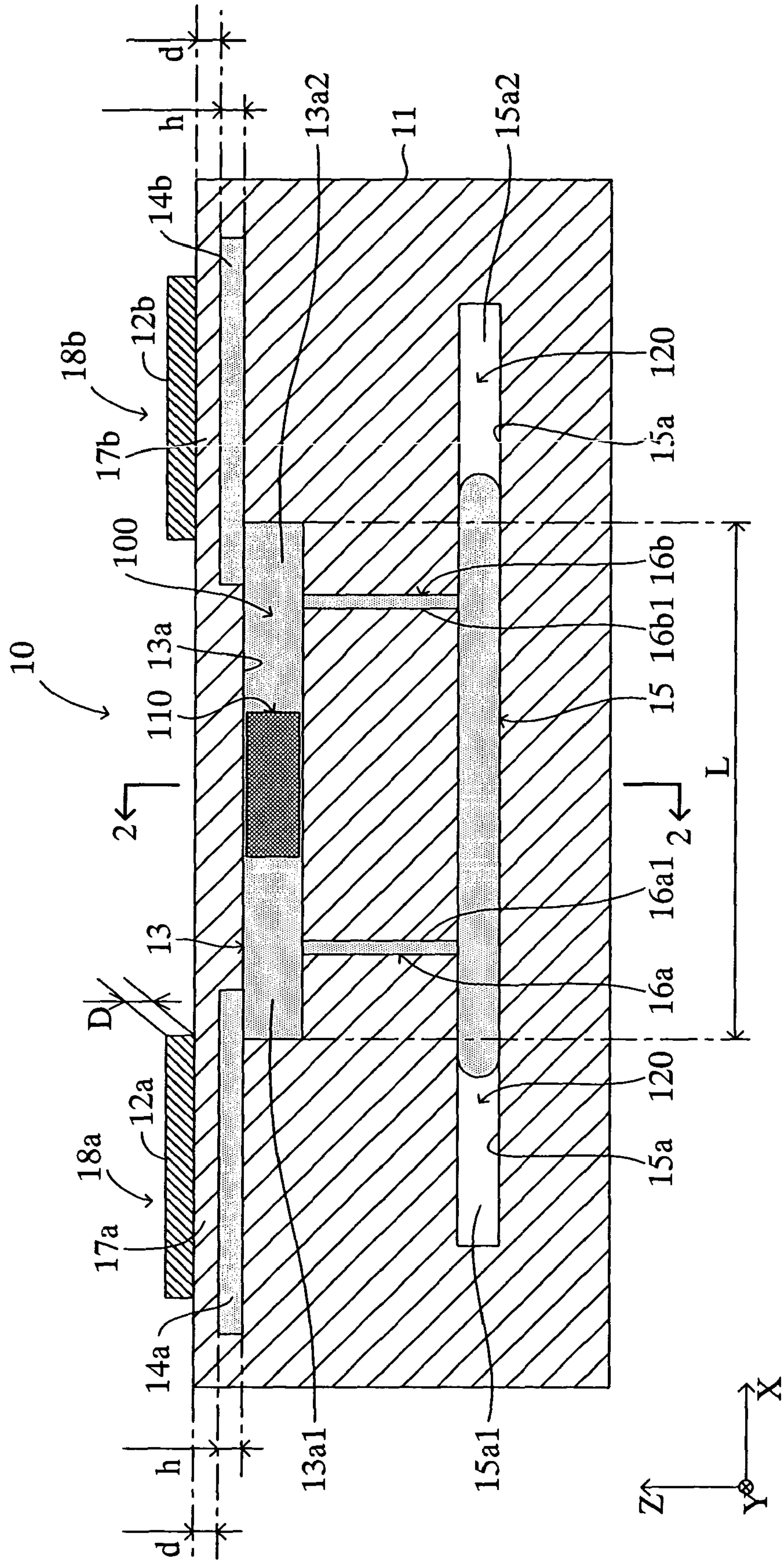
(51) **Int. Cl.**[7] **F04B 17/00**

(52) **U.S. Cl.** **417/322**

(57) **ABSTRACT**

A circuit changeover switch **60**, which includes a drive device **10**, includes ceramic pumps **18***a* and **18***b*, which alternately pressurize and depressurize operation fluid **100** within a fluid chamber **13***a* on opposite sides of an electrically conductive movable body **110**, to thereby move the movable body **110** within the flow chamber **13***a*, whereby one of changeover electrodes **62***a* and **62***b* is electrically connected to a common electrode **61**. When the pressure of the operation fluid is increased and decreased at high speed by the ceramic pumps, micro channels **16***a* and **16***b* exhibit a high passage resistance, so that the pressure within the channel does not escape to an internal-pressure buffering chamber **15***a*, and the movable body moves without fail. When the pressure of the operation fluid increases slowly due to expansion of the operation fluid, the micro channels exhibit a low passage resistance, so that an expanded portion of the operation fluid is led to the internal-pressure buffering chamber, and the pressure increase of the operation fluid is suppressed. A drive device which does not cause breakage of a pump chamber or a seal due to thermal expansion of operation fluid is provided.





d
h
11
13a2
15a2
14b
12b
18b
17b
120
15a
100
16b
16b1
10
13a
110
15
2
L
16a1
13
16a
D
12a
18a
17a
14a
13a1
15a1
X
Y
Z

FIG.1

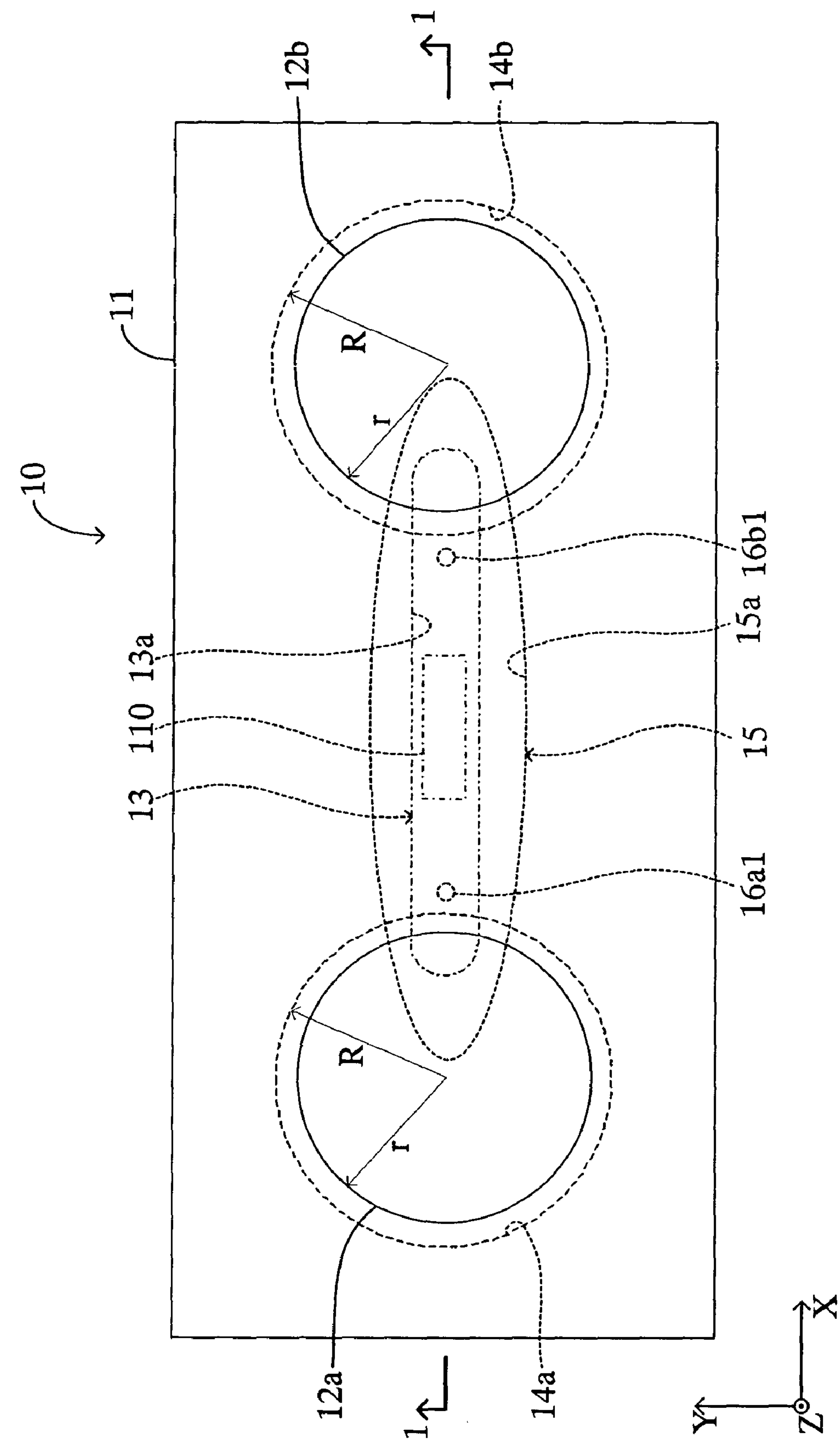


FIG.2

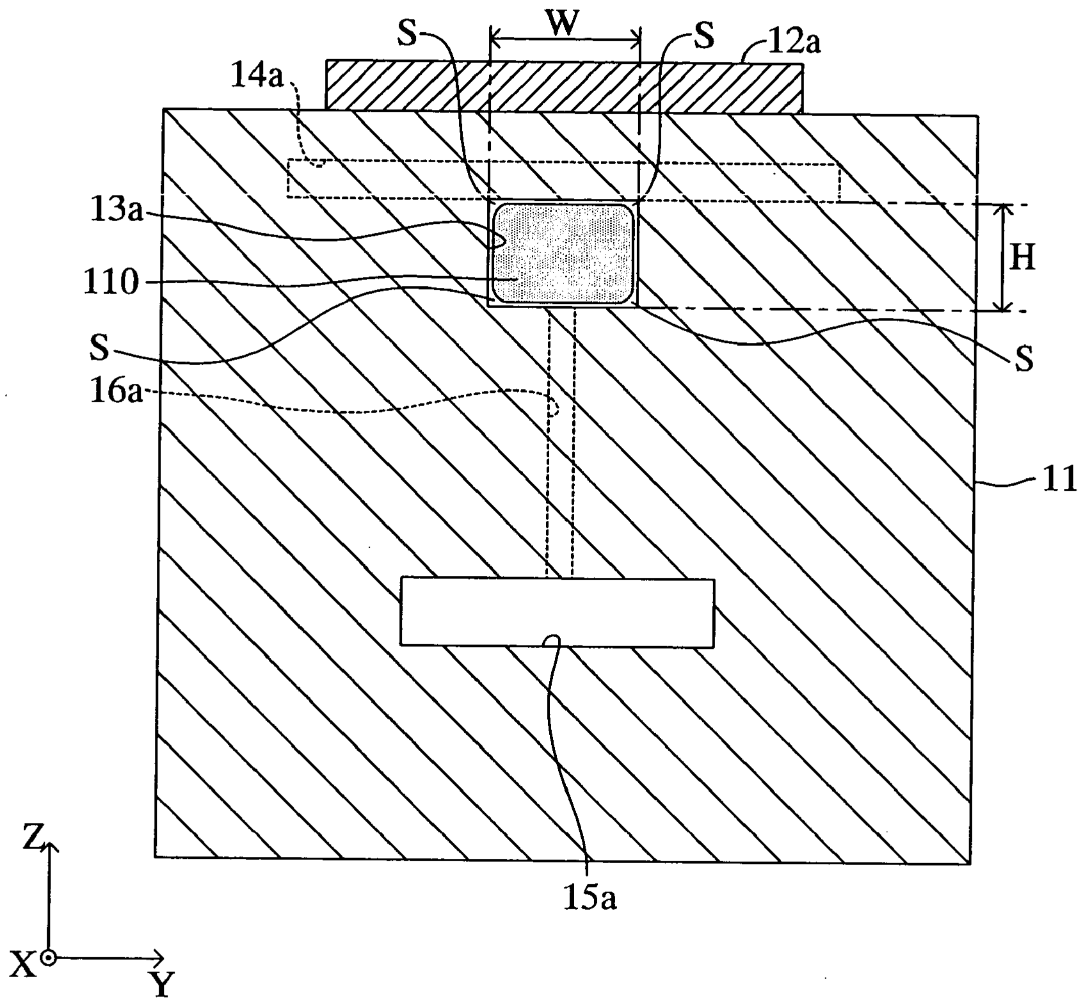


FIG.3

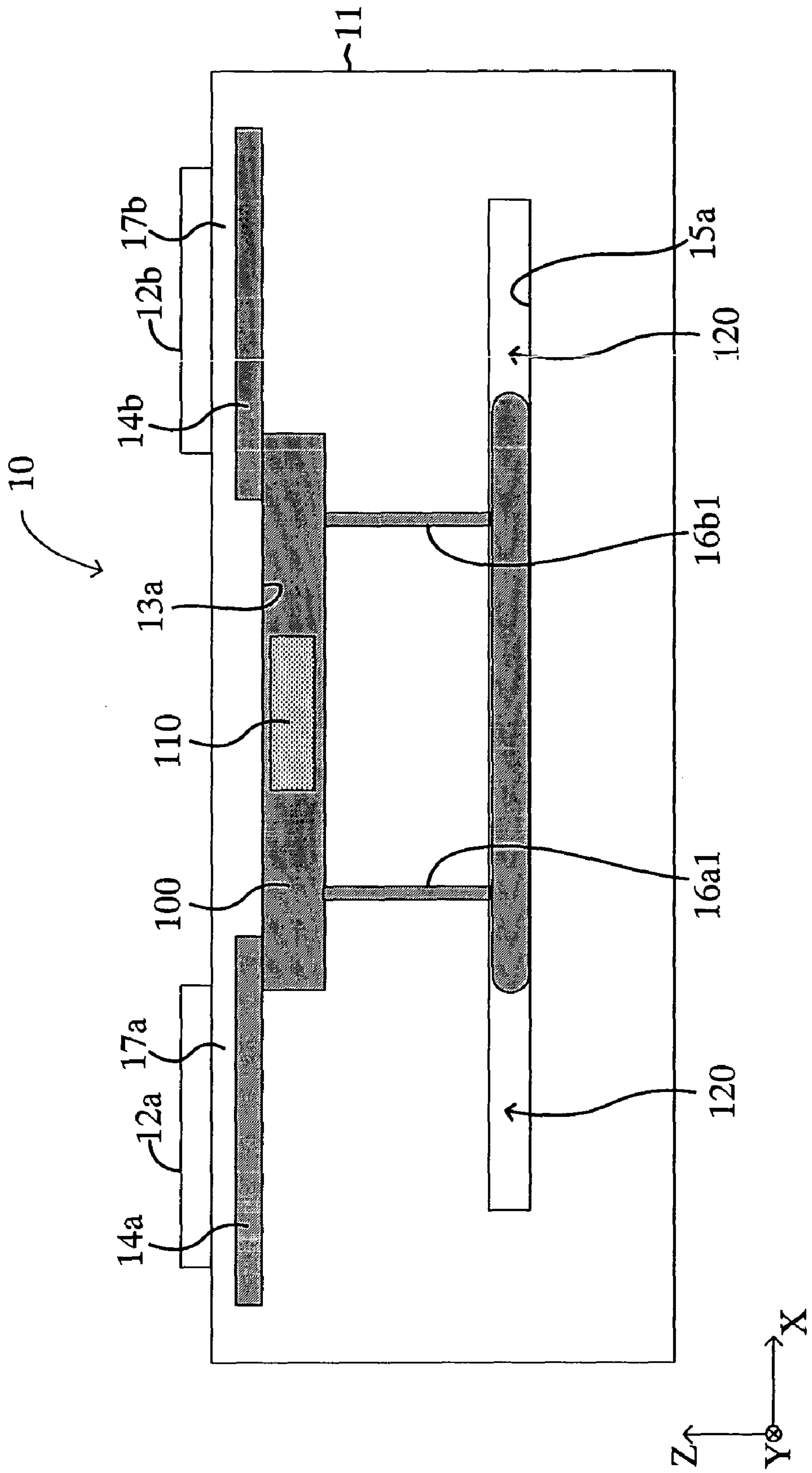

11
10
17b
12b
14b
13a
110
100
17a
12a
14a
15a
120
16b1
16a1
120
X
Z
Y

FIG.4

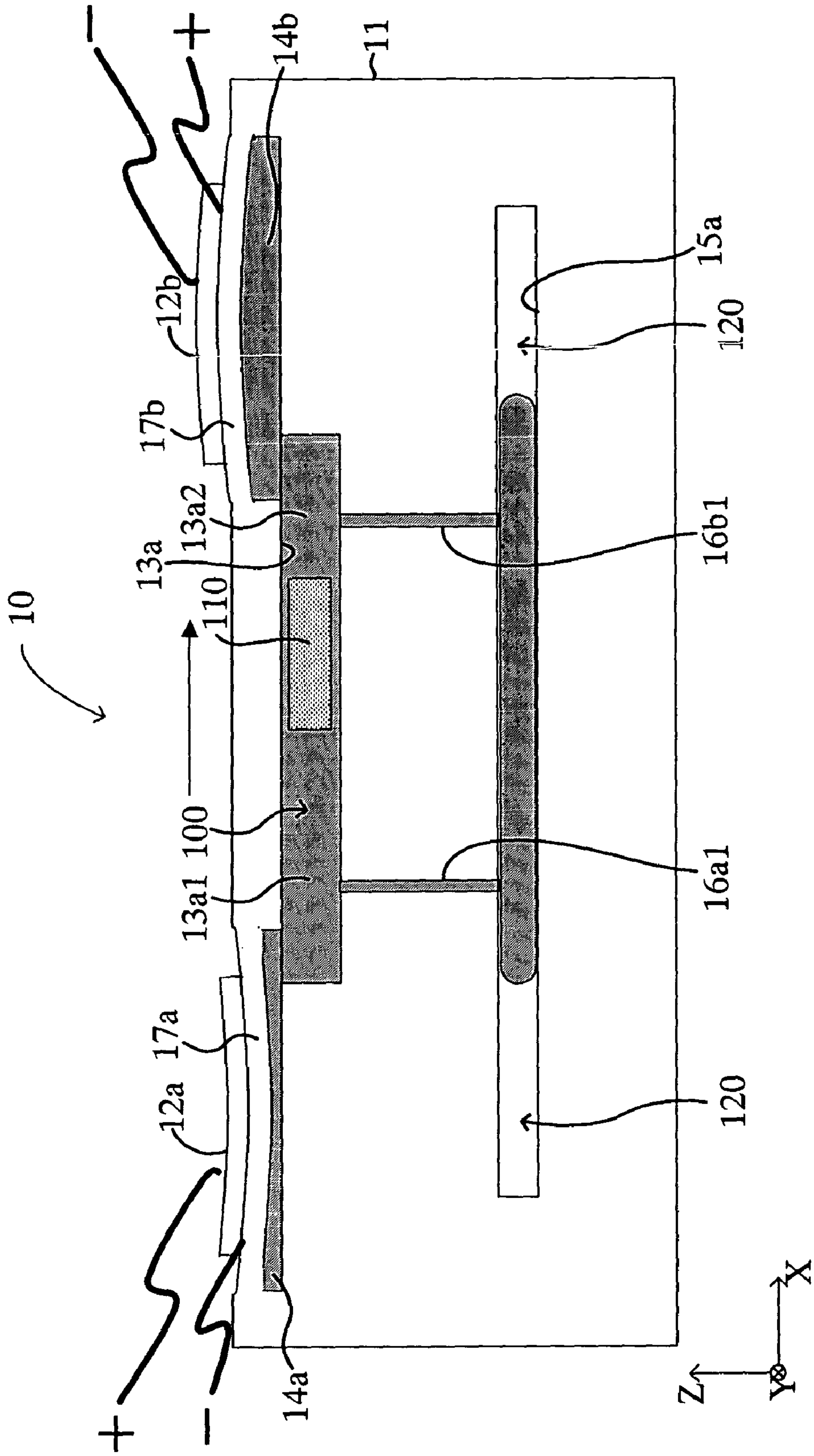

10
11
12a
12b
13a
13a1
13a2
14a
14b
15a
16a1
16b1
17a
17b
100
110
120
120
+
-
+
-
X
Y
Z

FIG.5

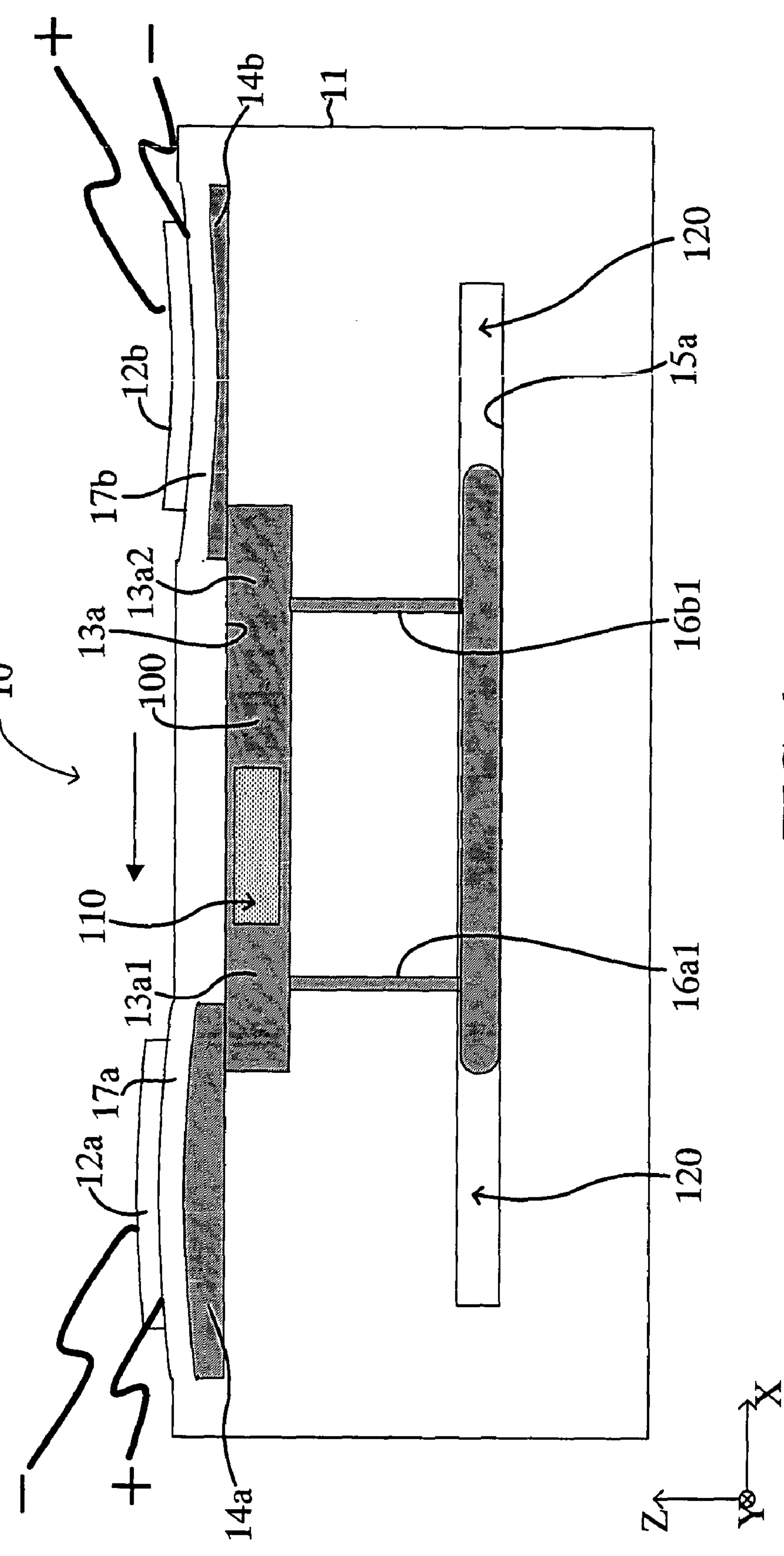
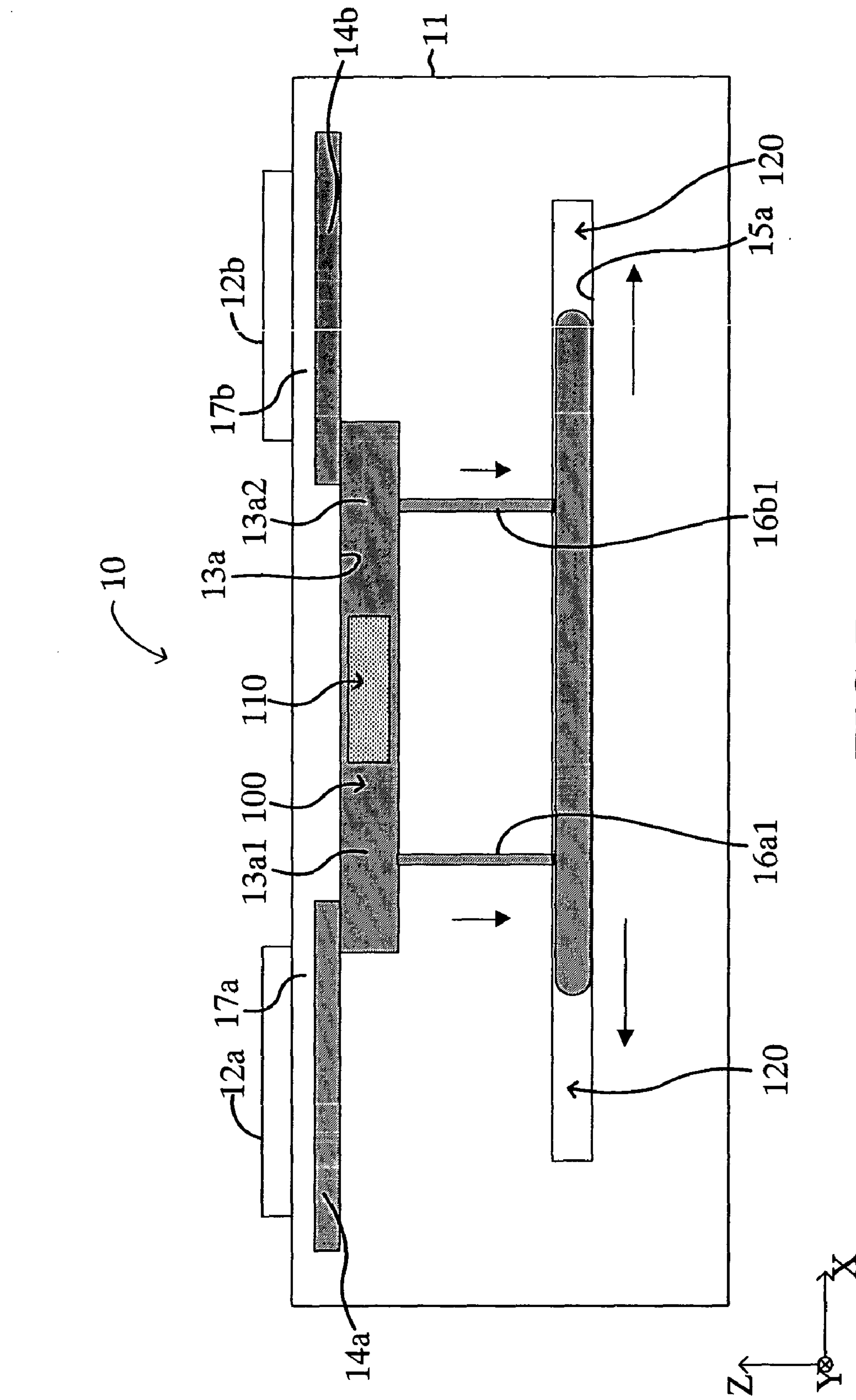

10
11
12a
12b
13a
13a1
13a2
14a
14b
15a
16a1
16b1
17a
17b
100
110
120
120
+
−
+
−
X
Y
Z

FIG.6



10
11
12a
12b
13a
13a1
13a2
14a
14b
15a
16a1
16b1
17a
17b
100
110
120
120
X
Y
Z

FIG.7

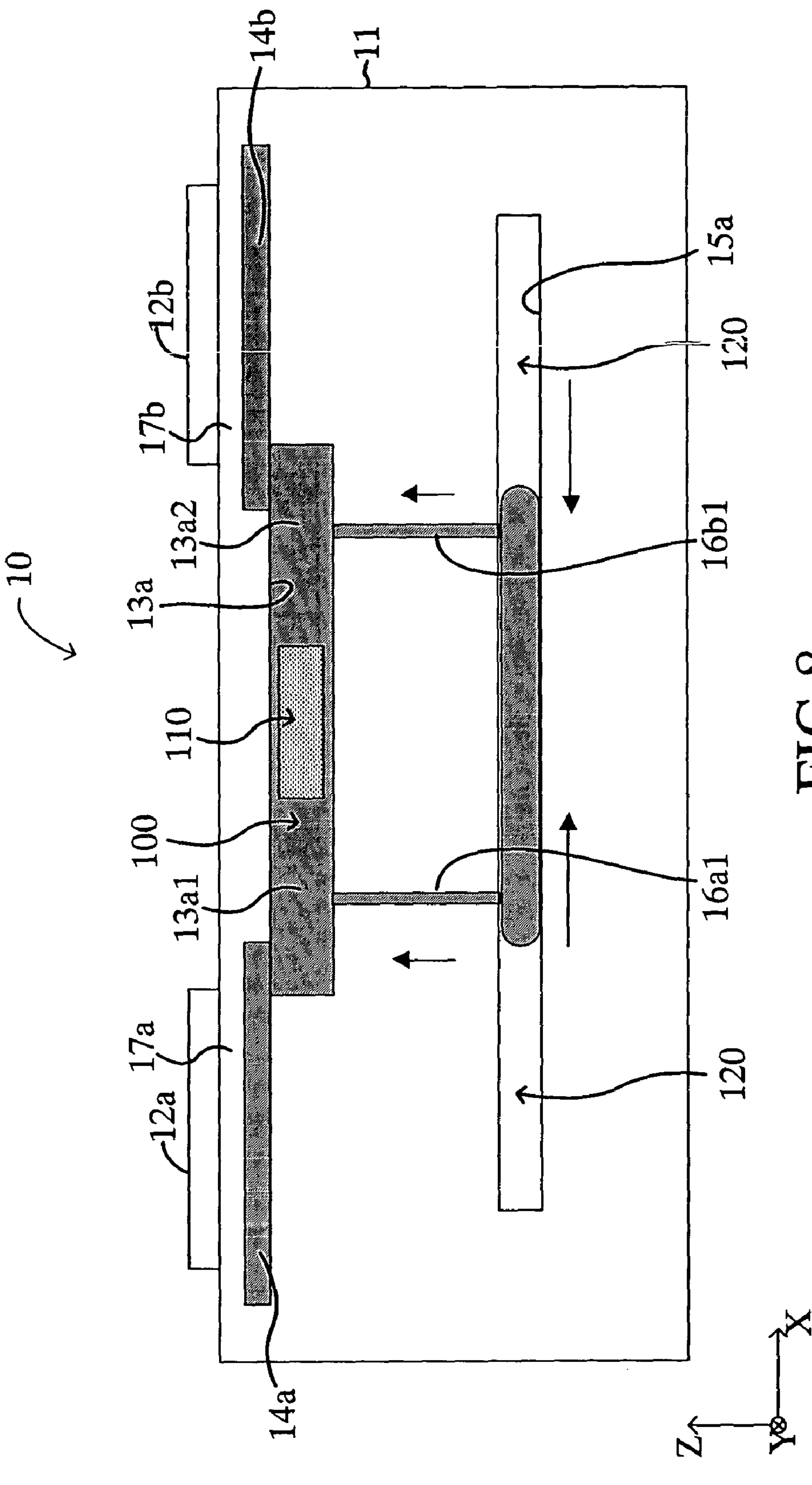
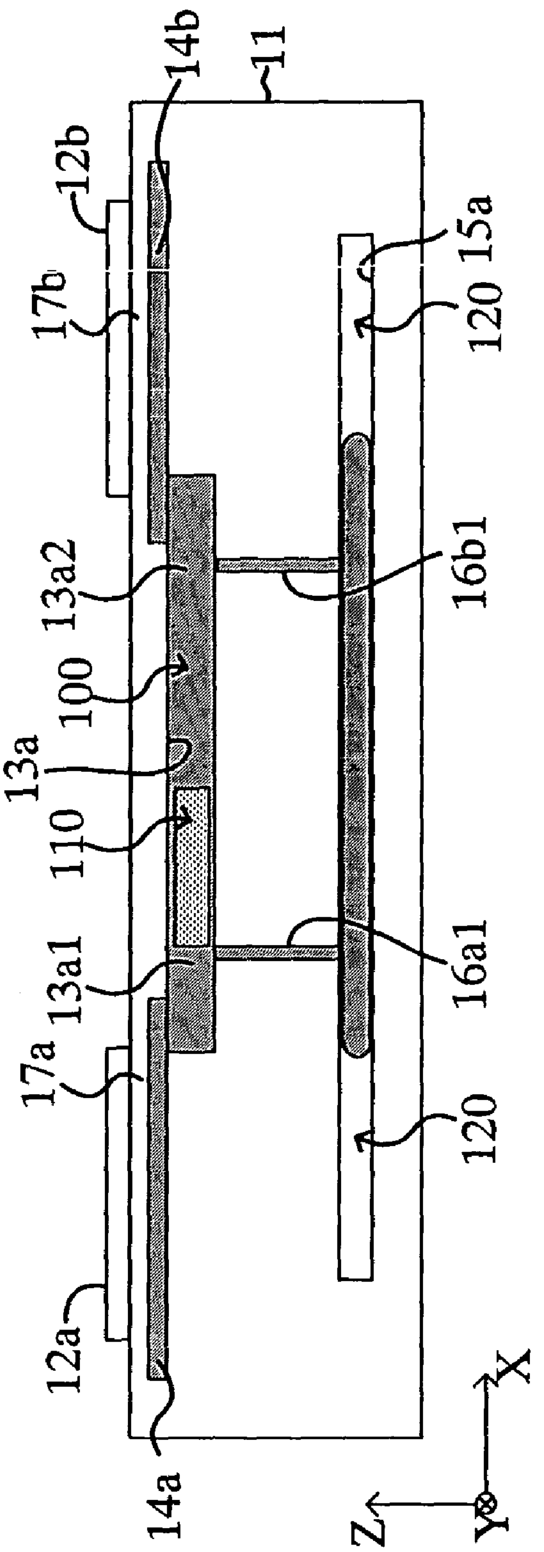

10
11
12a
12b
13a
13a1
13a2
14a
14b
15a
16a1
16b1
17a
17b
100
110
120
120
X
Y
Z

FIG.8



10
11
12a
12b
13a
13a1
13a2
14a
14b
15a
16a1
16b1
17a
17b
100
110
120
120
X
Y
Z

FIG.9

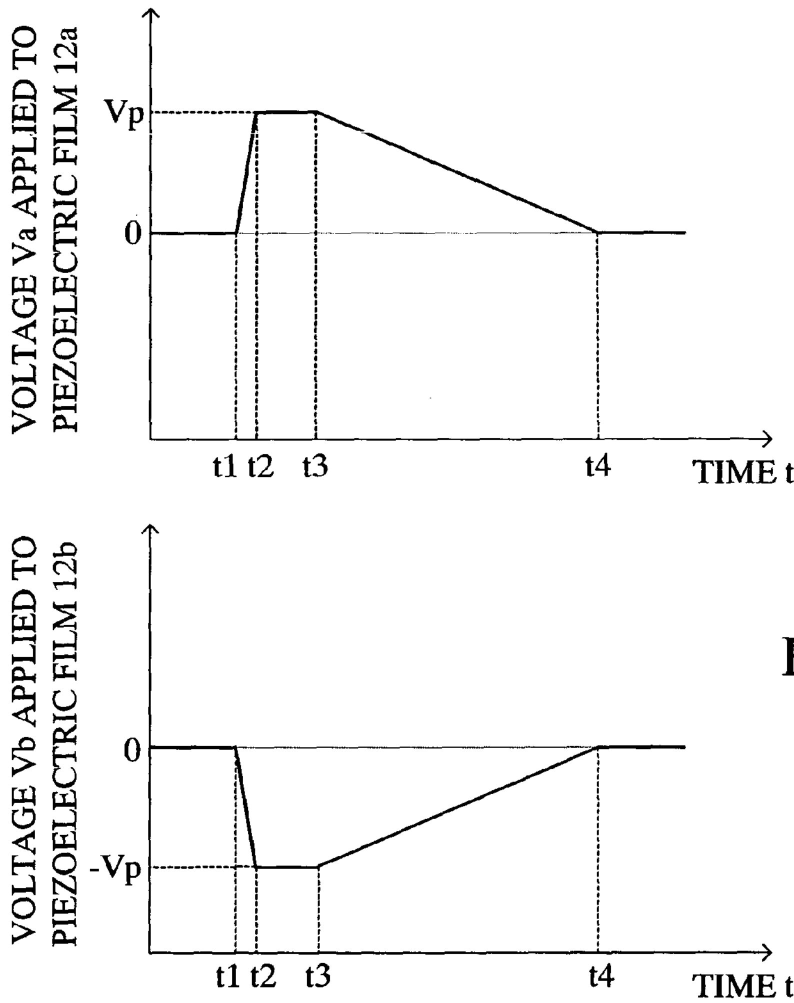

VOLTAGE Va APPLIED TO PIEZOELECTRIC FILM 12a
Vp
0
t1 t2 t3 t4 TIME t
VOLTAGE Vb APPLIED TO PIEZOELECTRIC FILM 12b
0
-Vp
t1 t2 t3 t4 TIME t

FIG.10

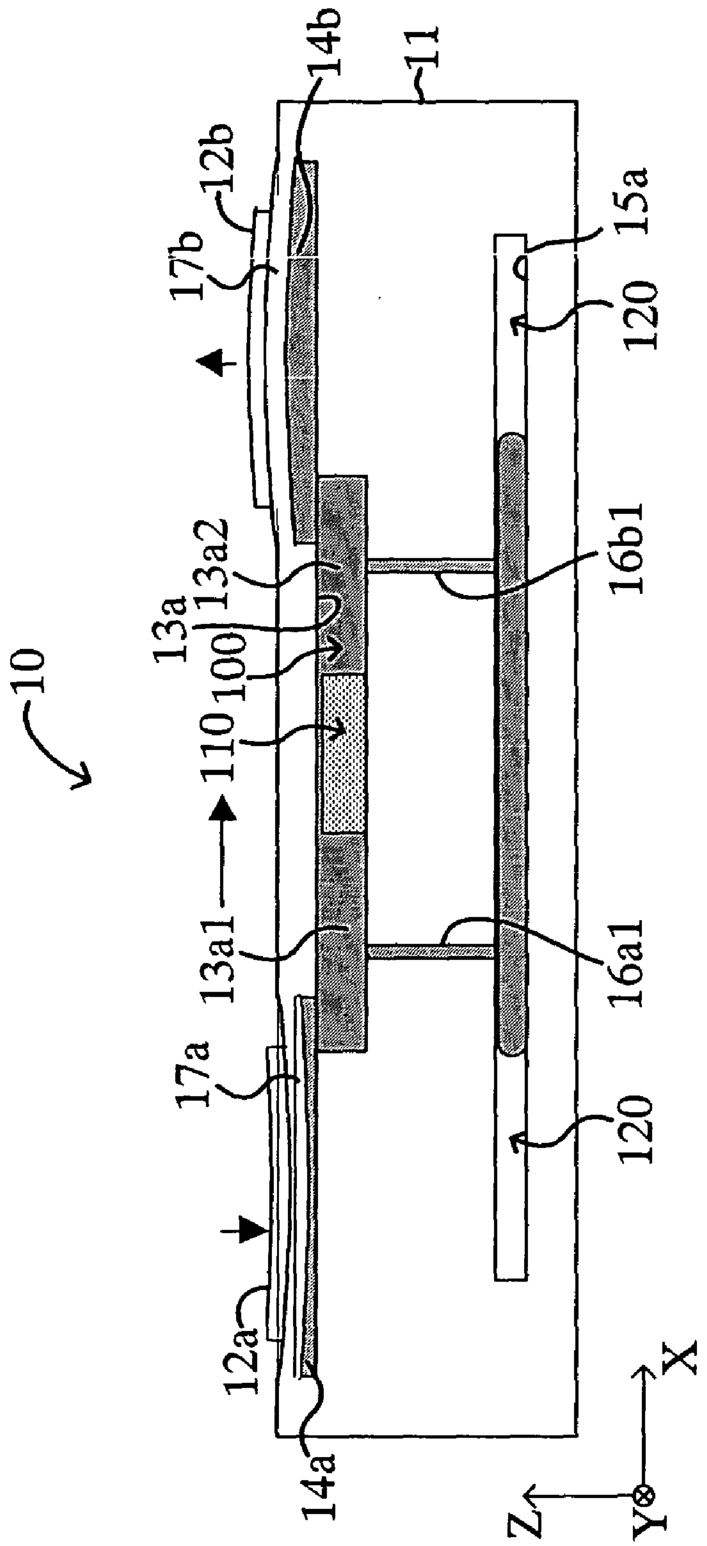

10
11
12a
12b
13a
13a1
13a2
14a
14b
15a
16a1
16b1
17a
17b
100
110
120
120
X
Y
Z

FIG.11

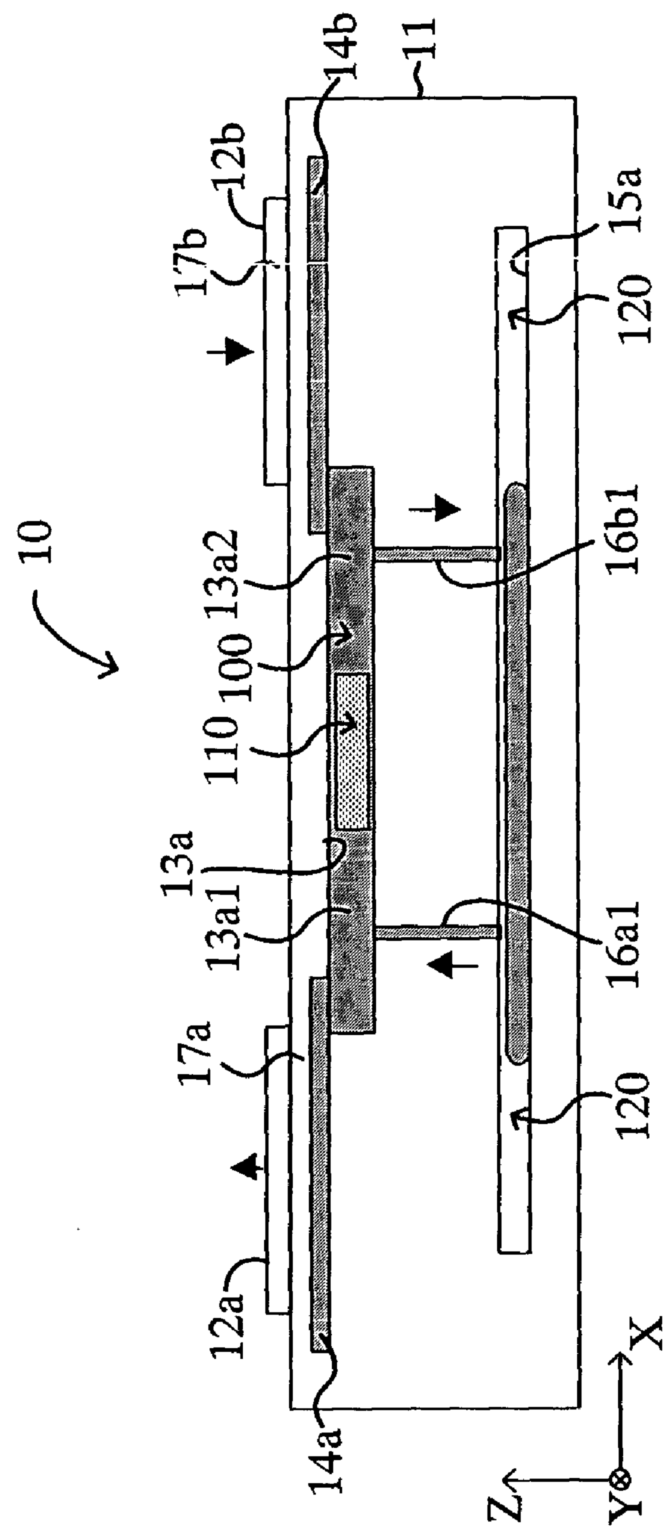

10
11
14b
12b
17b
15a
120
16b1
13a2
100
110
13a
13a1
16a1
17a
120
12a
14a
Z
Y
X

FIG.12

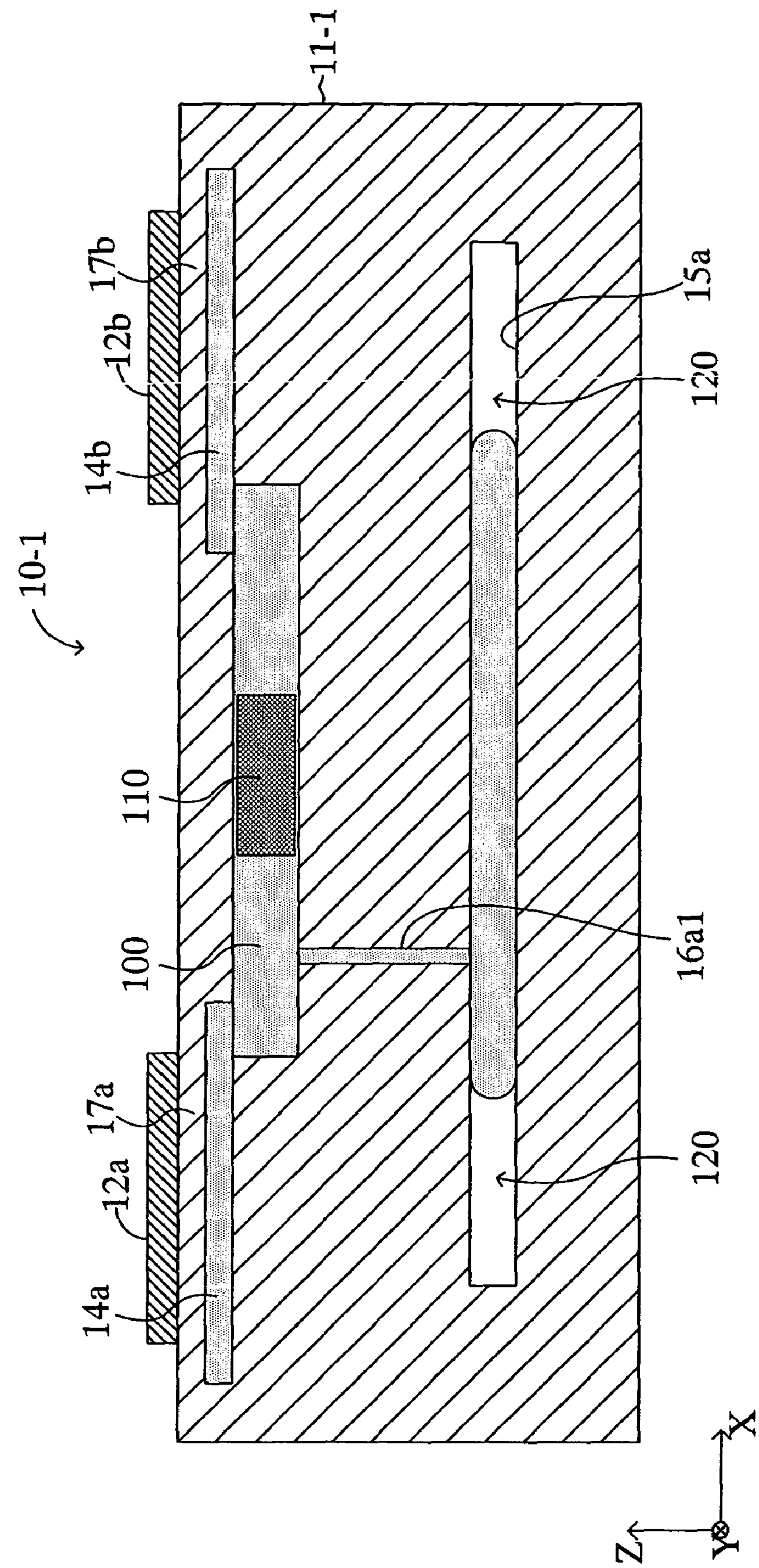


FIG.13

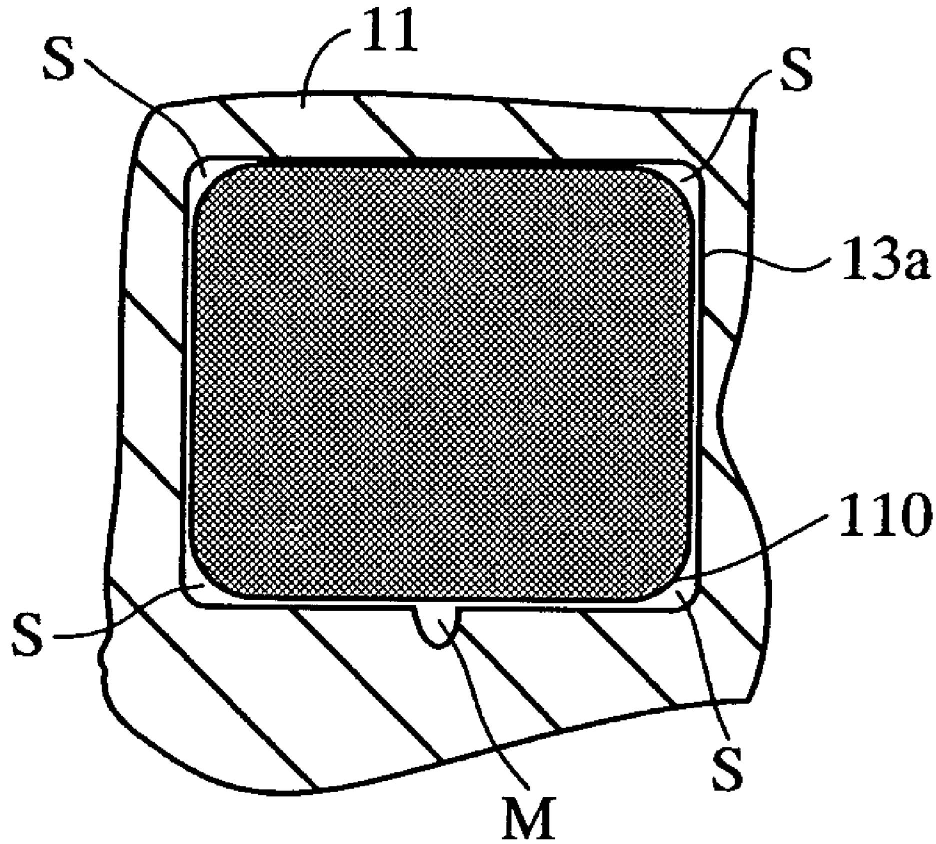


FIG.14

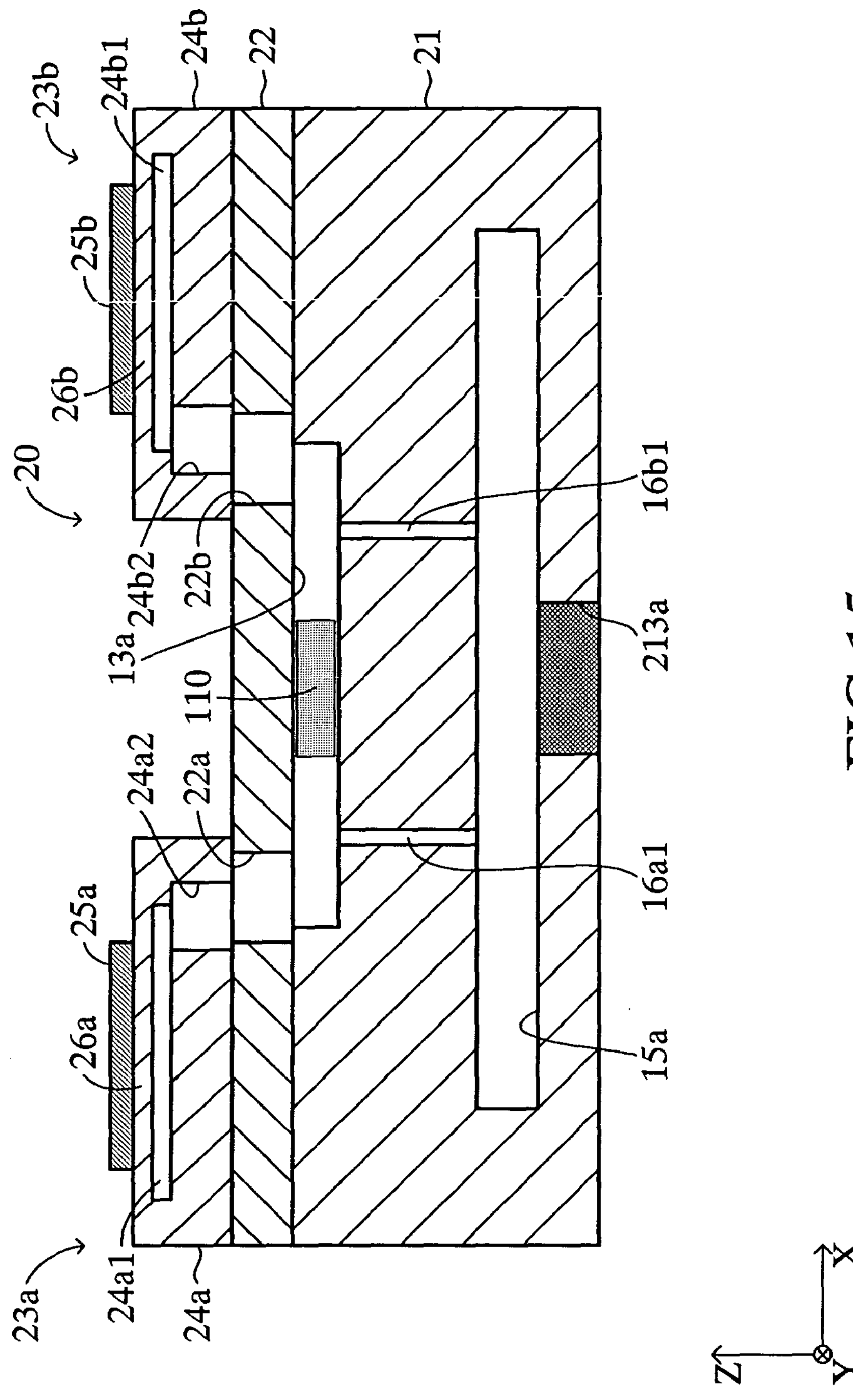
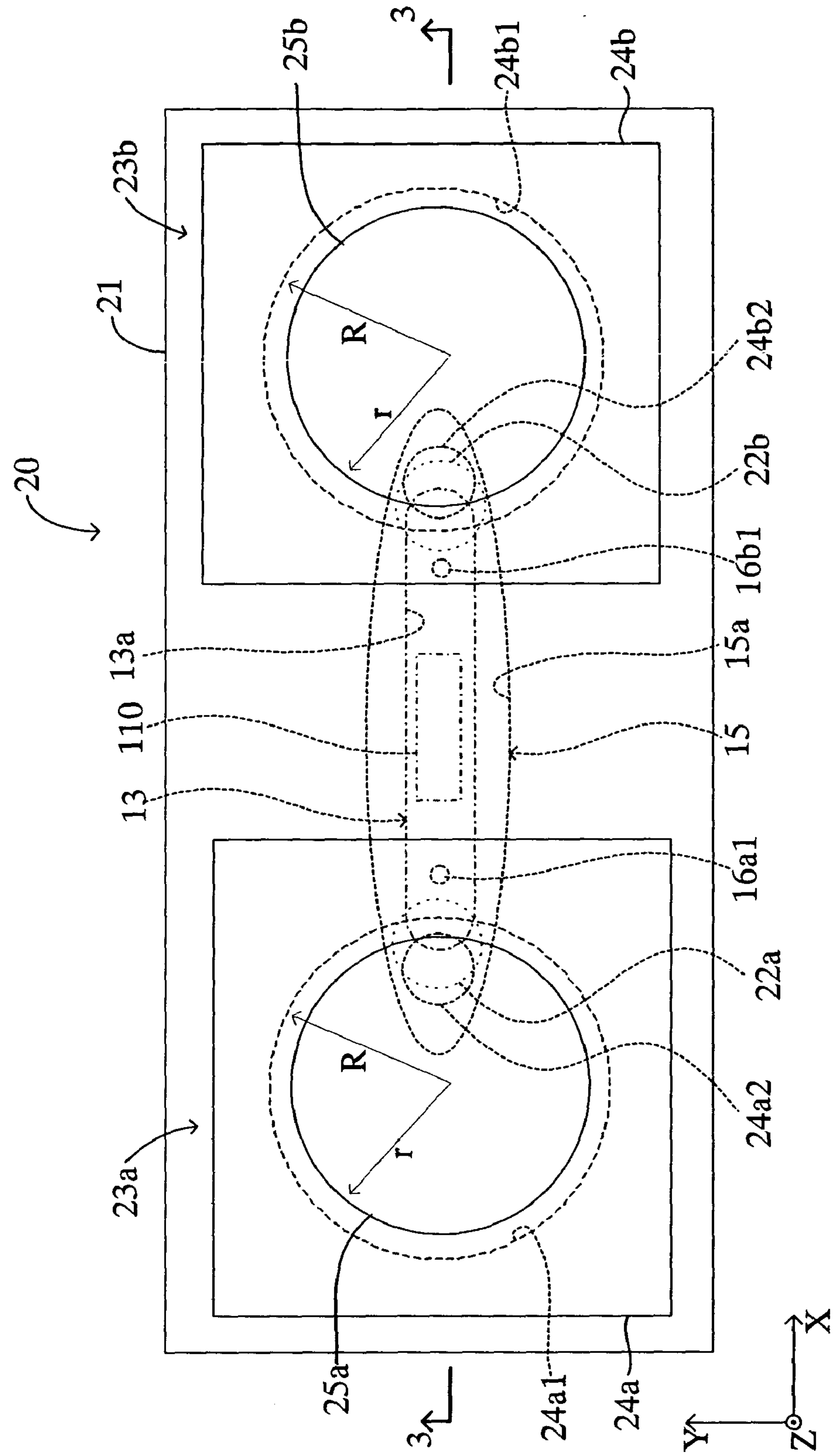

23b
24b1
24b
22
21
25b
26b
20
24b2
22b
13a
110
24a2
22a
16b1
213a
16a1
25a
26a
15a
23a
24a1
24a
X
Z
Y

FIG.15



3
25b
24b1
24b
23b
21
R
r
24b2
20
22b
16b1
13a
15a
110
15
13
16a1
22a
R
24a2
23a
r
25a
3
24a1
24a
X
Y
Z

FIG.16

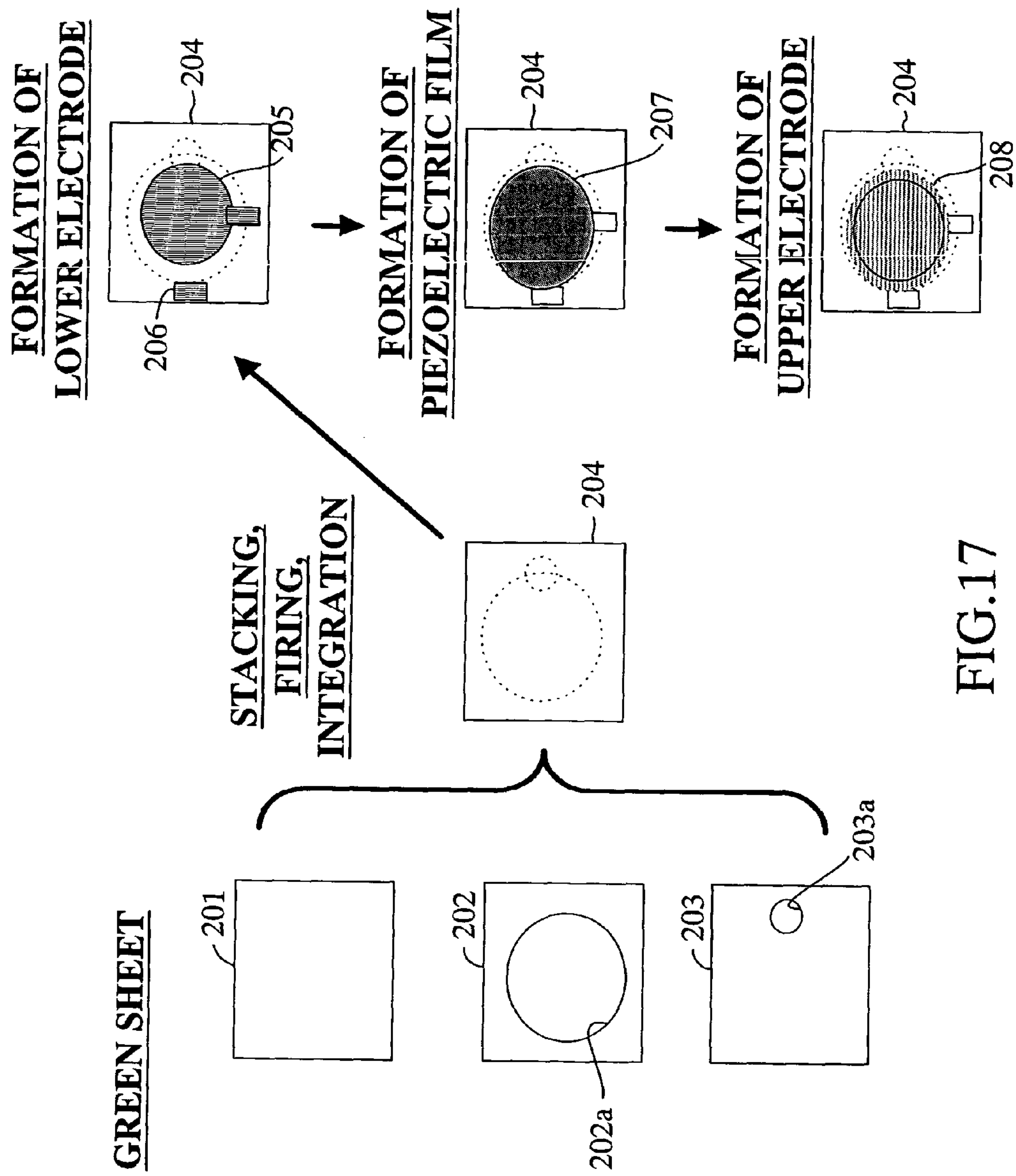

GREEN SHEET
201
202
202a
203
203a
STACKING, FIRING, INTEGRATION
204
FORMATION OF LOWER ELECTRODE
204
205
206
FORMATION OF PIEZOELECTRIC FILM
204
207
FORMATION OF UPPER ELECTRODE
204
208

FIG.17

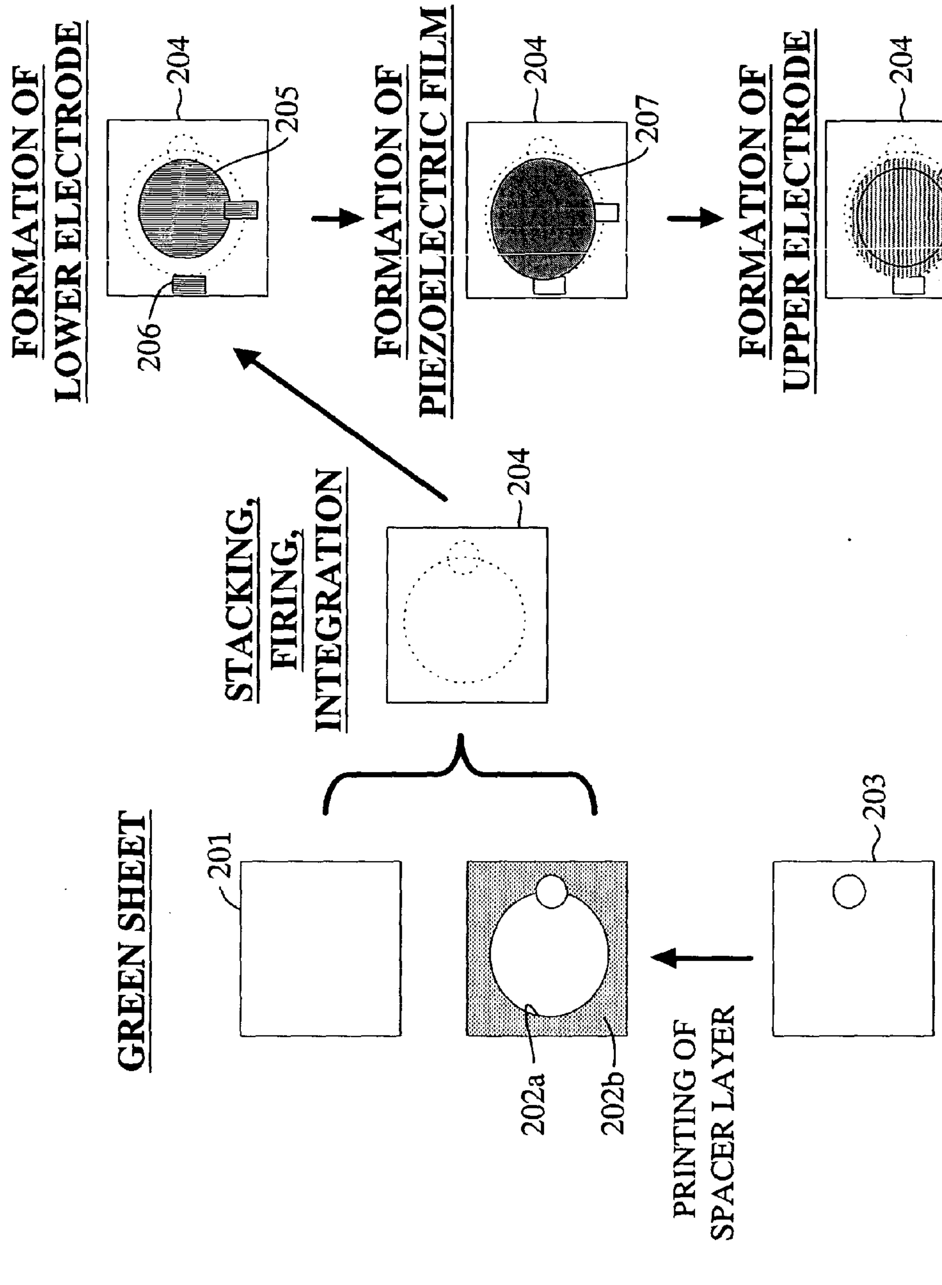

GREEN SHEET
201
202a
202b
PRINTING OF SPACER LAYER
203
STACKING, FIRING, INTEGRATION
204
FORMATION OF LOWER ELECTRODE
205
206
FORMATION OF PIEZOELECTRIC FILM
207
FORMATION OF UPPER ELECTRODE
208

FIG.18

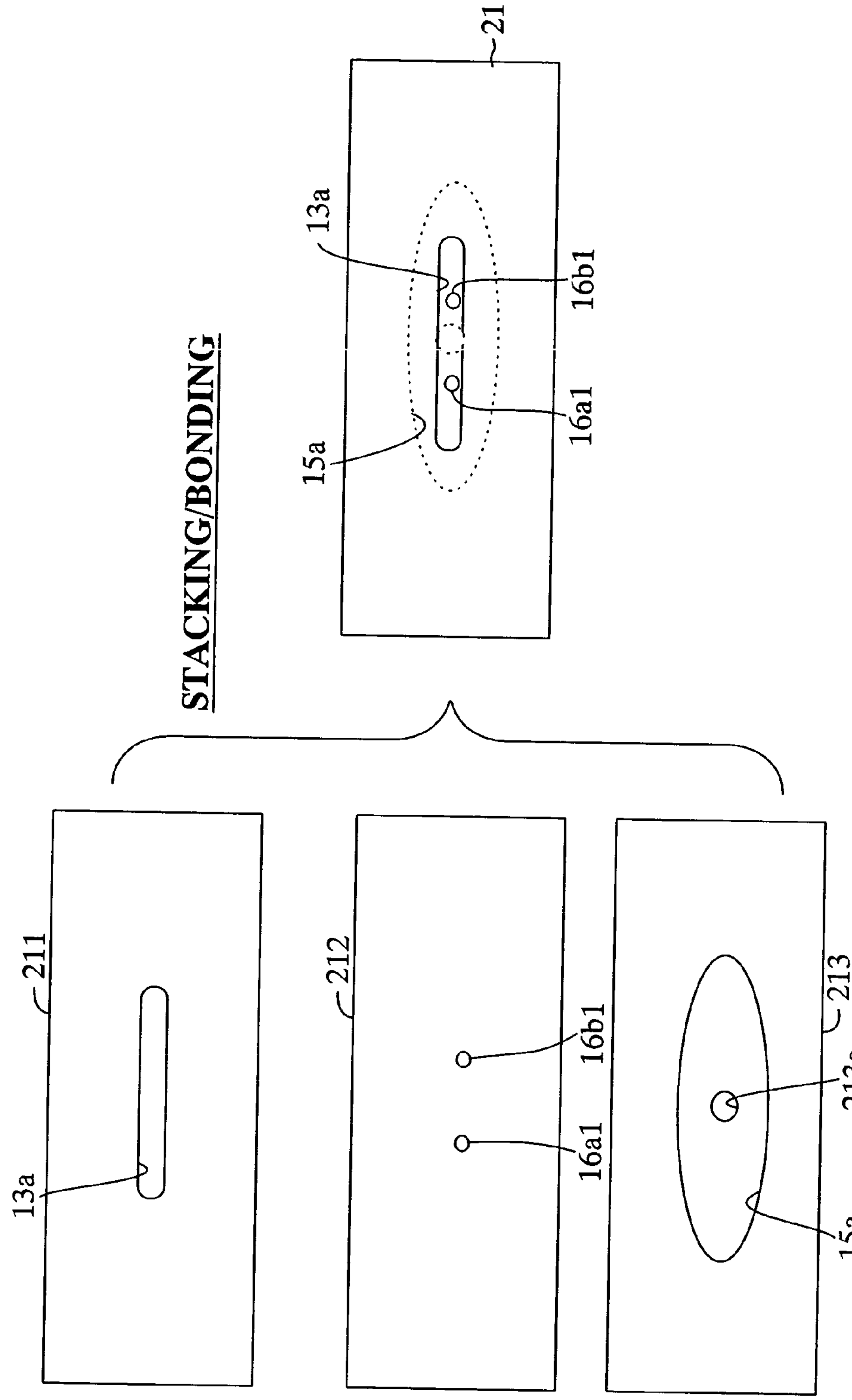

STACKING/BONDING
21
13a
16b1
16a1
15a
211
13a
212
16b1
16a1
213
213a
15a

FIG.19

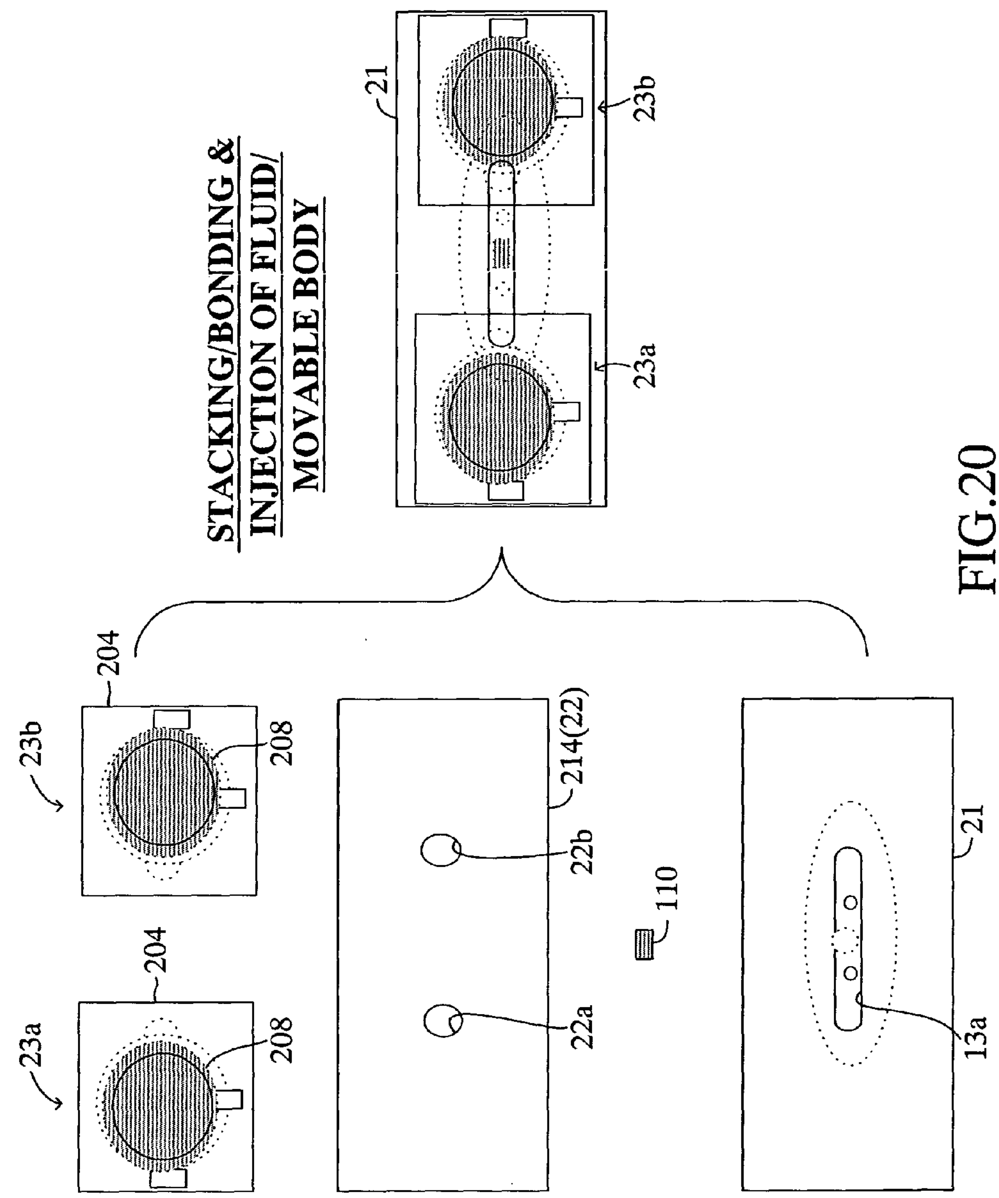

STACKING/BONDING & INJECTION OF FLUID/ MOVABLE BODY
21
23a
23b
204
208
214(22)
22a
22b
110
13a

FIG.20

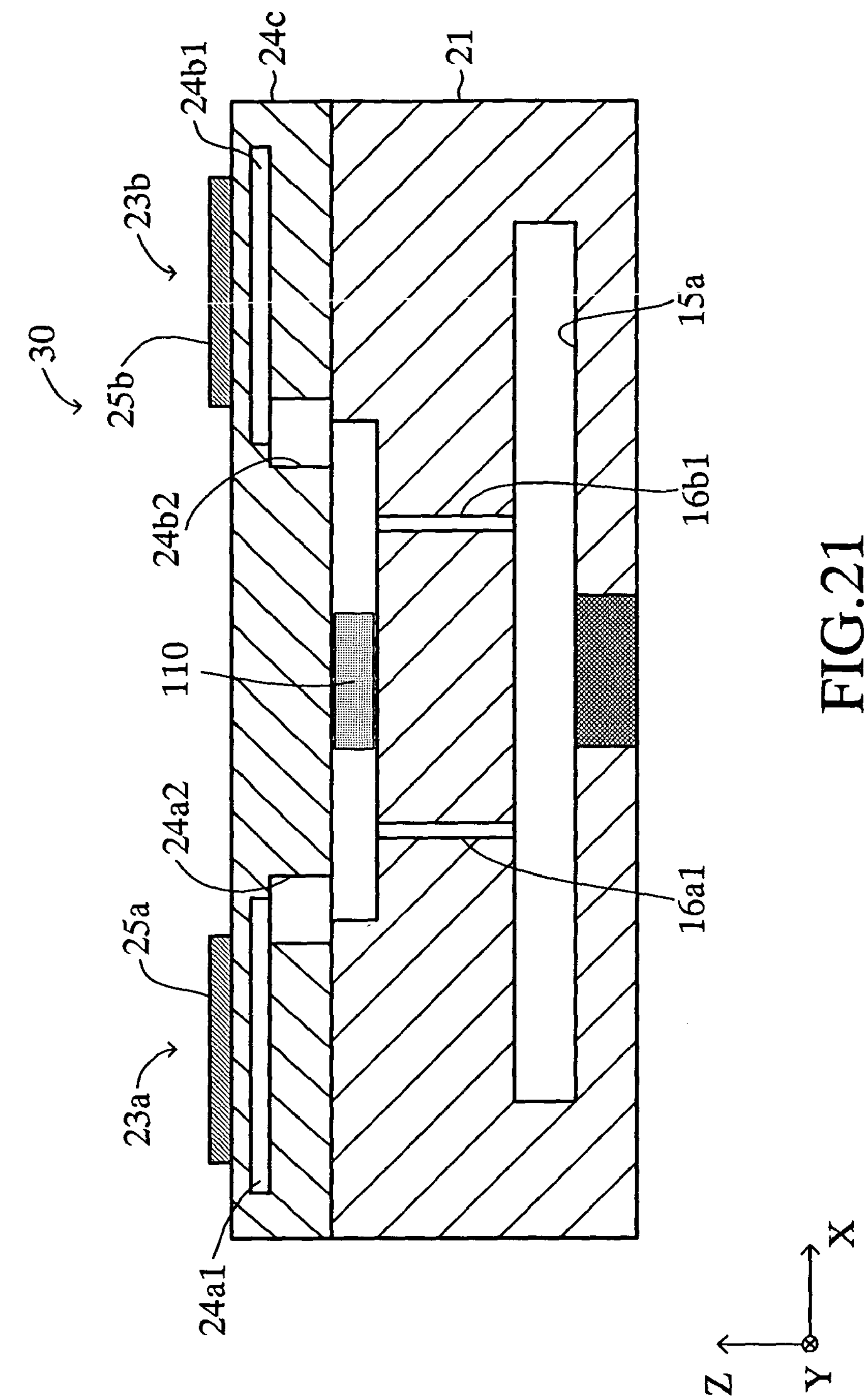

24b1
24c
21
23b
15a
30
25b
24b2
16b1
110
24a2
25a
16a1
23a
24a1
X
Z
Y

FIG.21

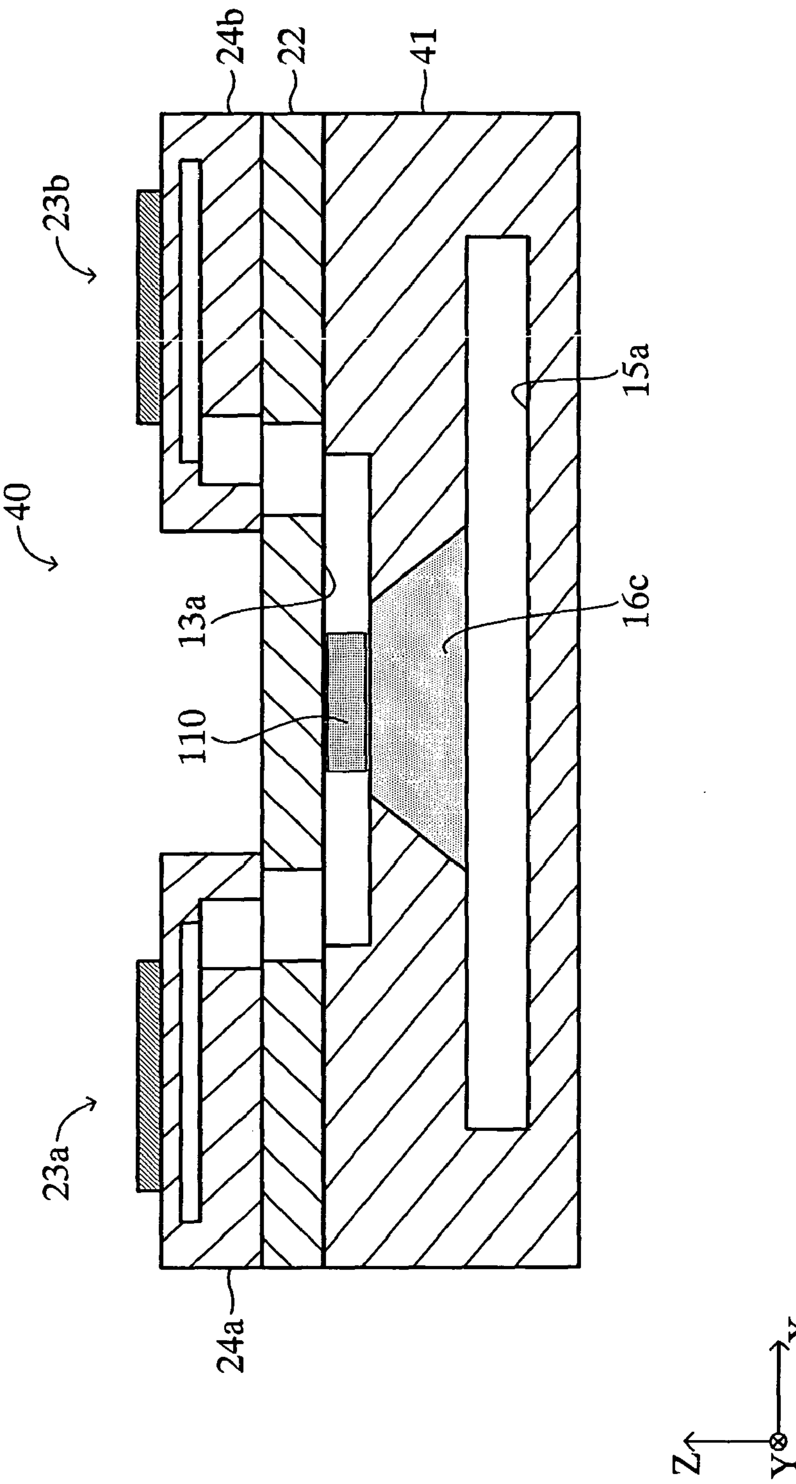


FIG.22

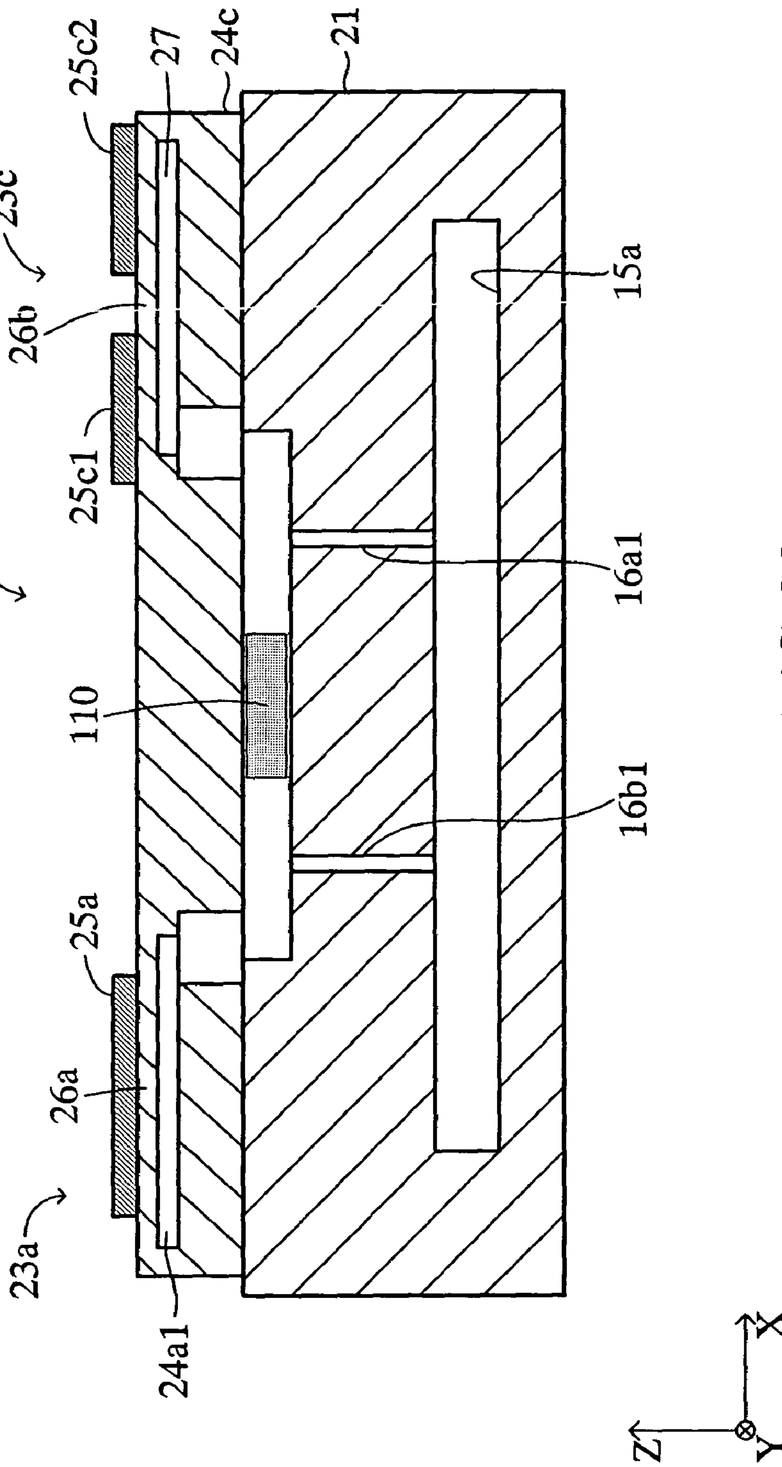

25c2
27
24c
21
23c
15a
26b
25c1
50
16a1
110
16b1
25a
26a
23a
24a1
X
Z
Y

FIG.23

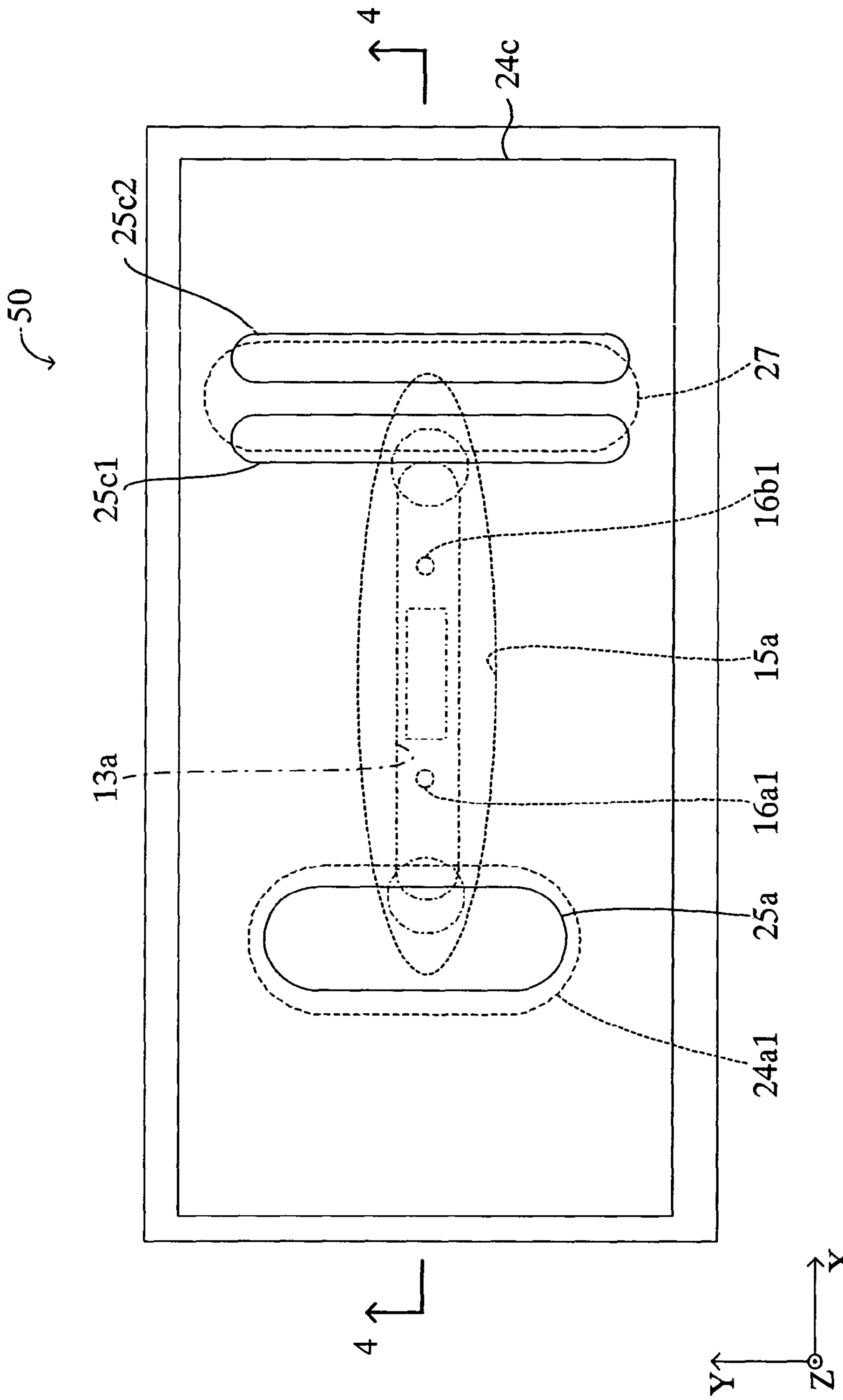
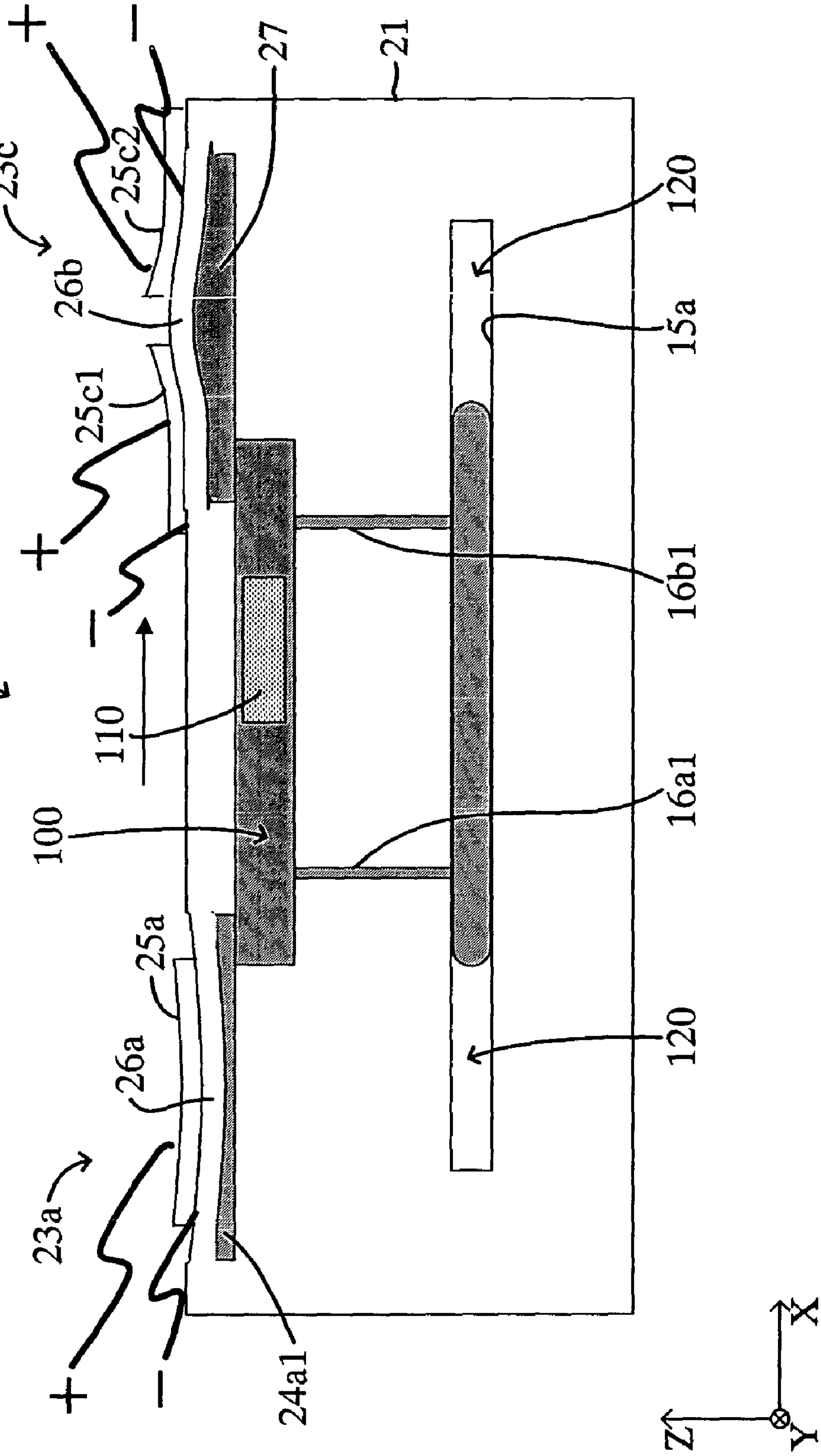


FIG.24



23c
27
21
25c2
26b
120
15a
25c1
16b1
50
110
100
16a1
25a
26a
120
23a
24a1
X
Y
Z

FIG.25

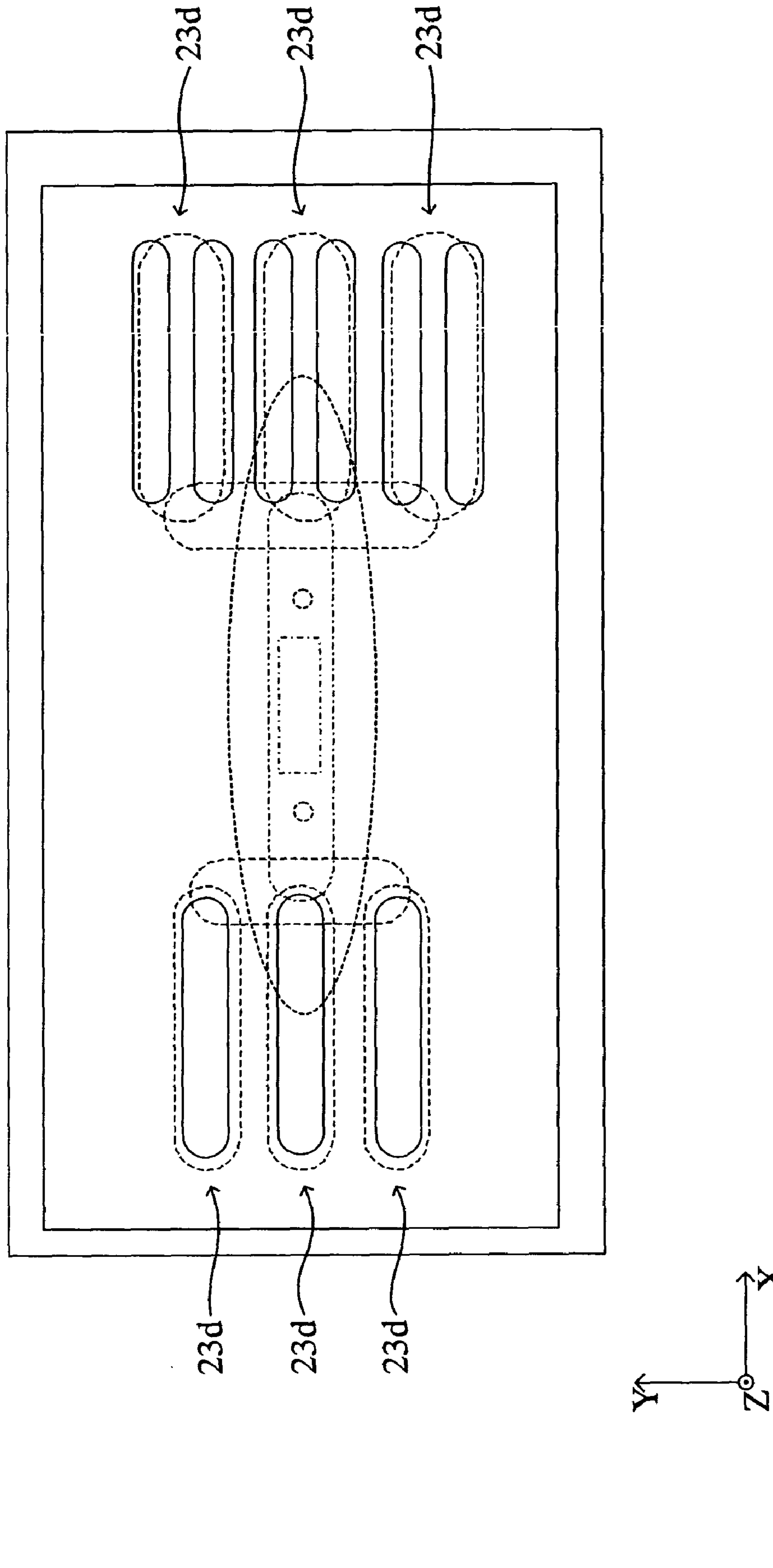


FIG.26

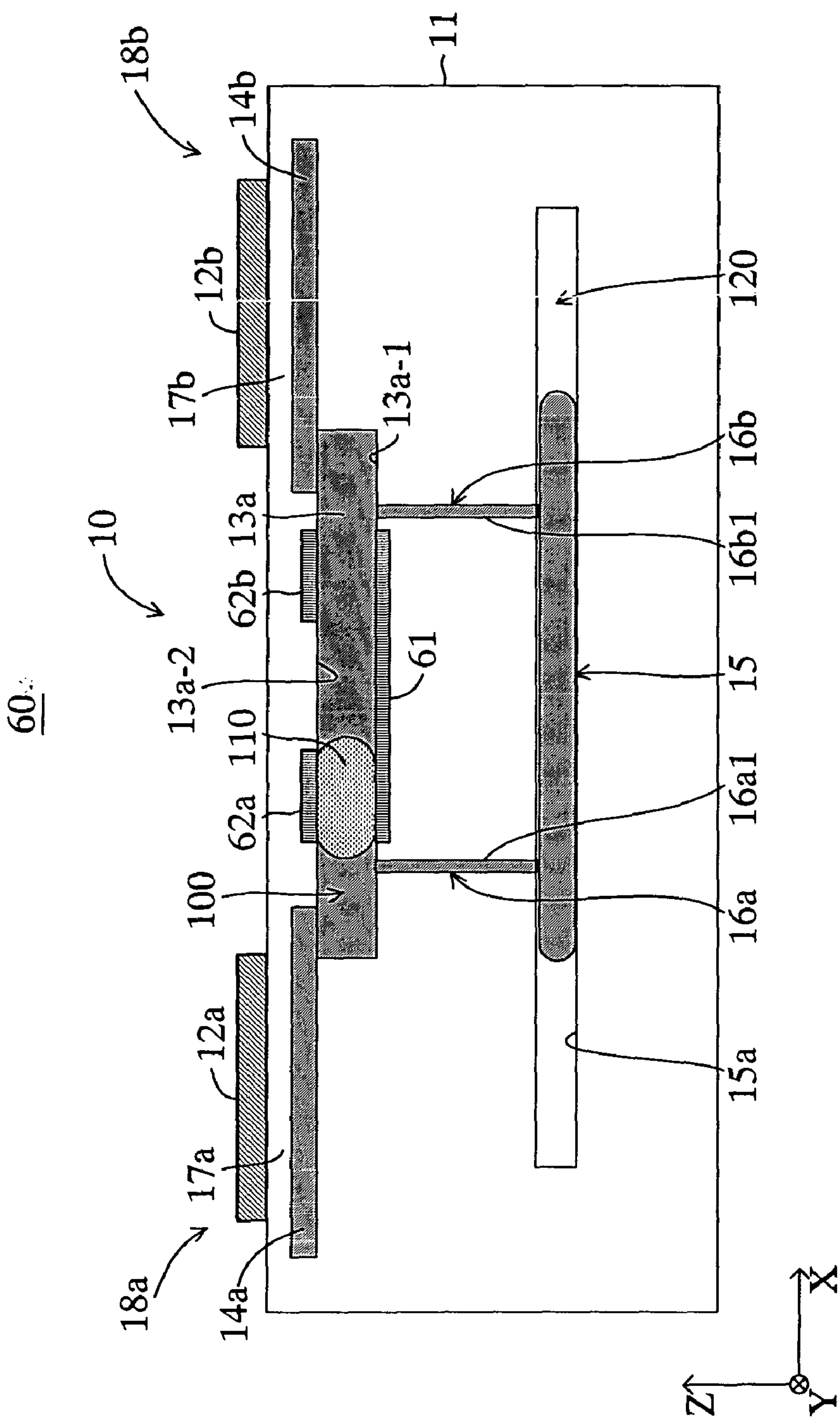

60
10
11
18a
18b
14a
14b
12a
12b
17a
17b
13a
13a-1
13a-2
62a
62b
61
110
100
16a
16a1
16b
16b1
15
15a
120
X
Y
Z

FIG.27

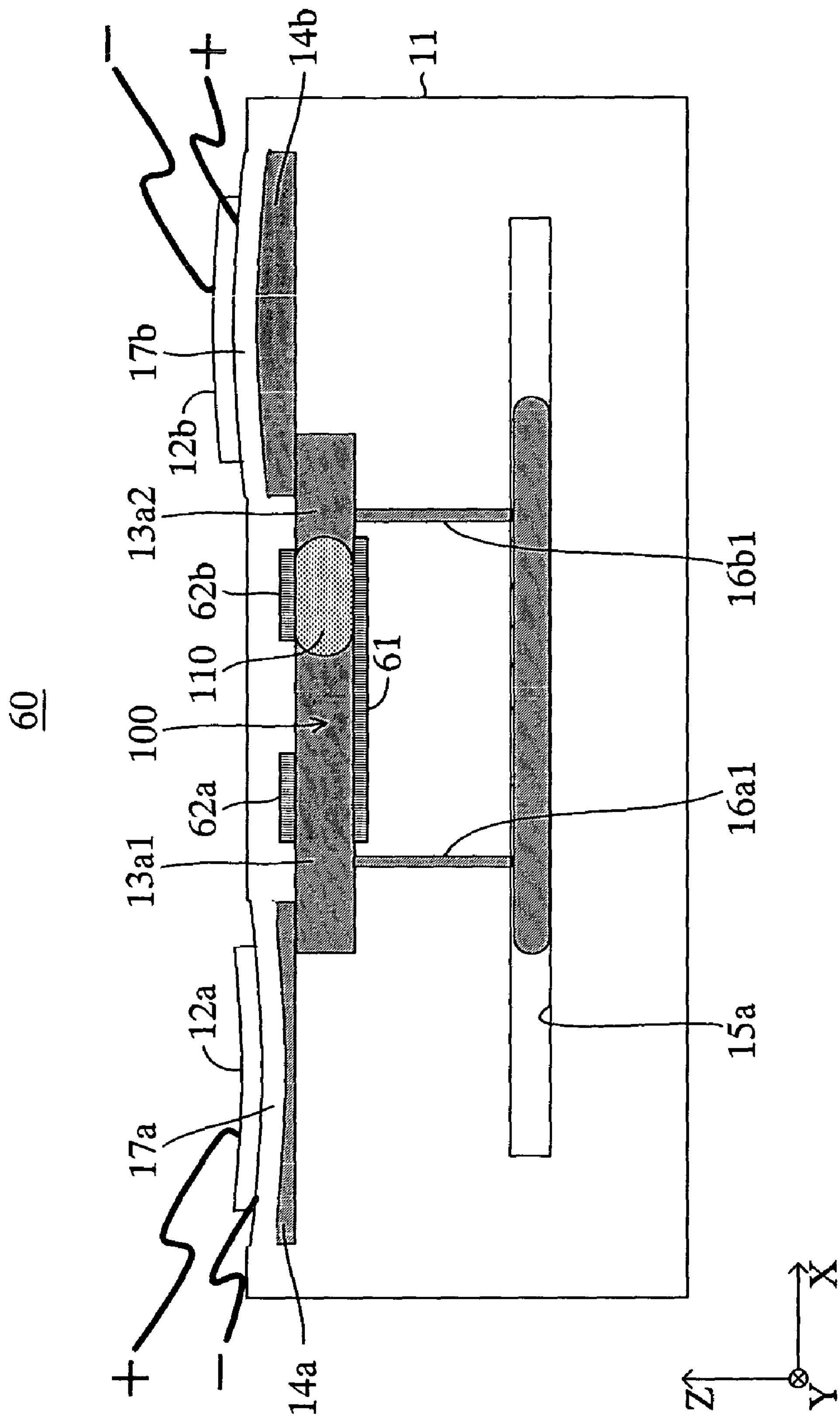
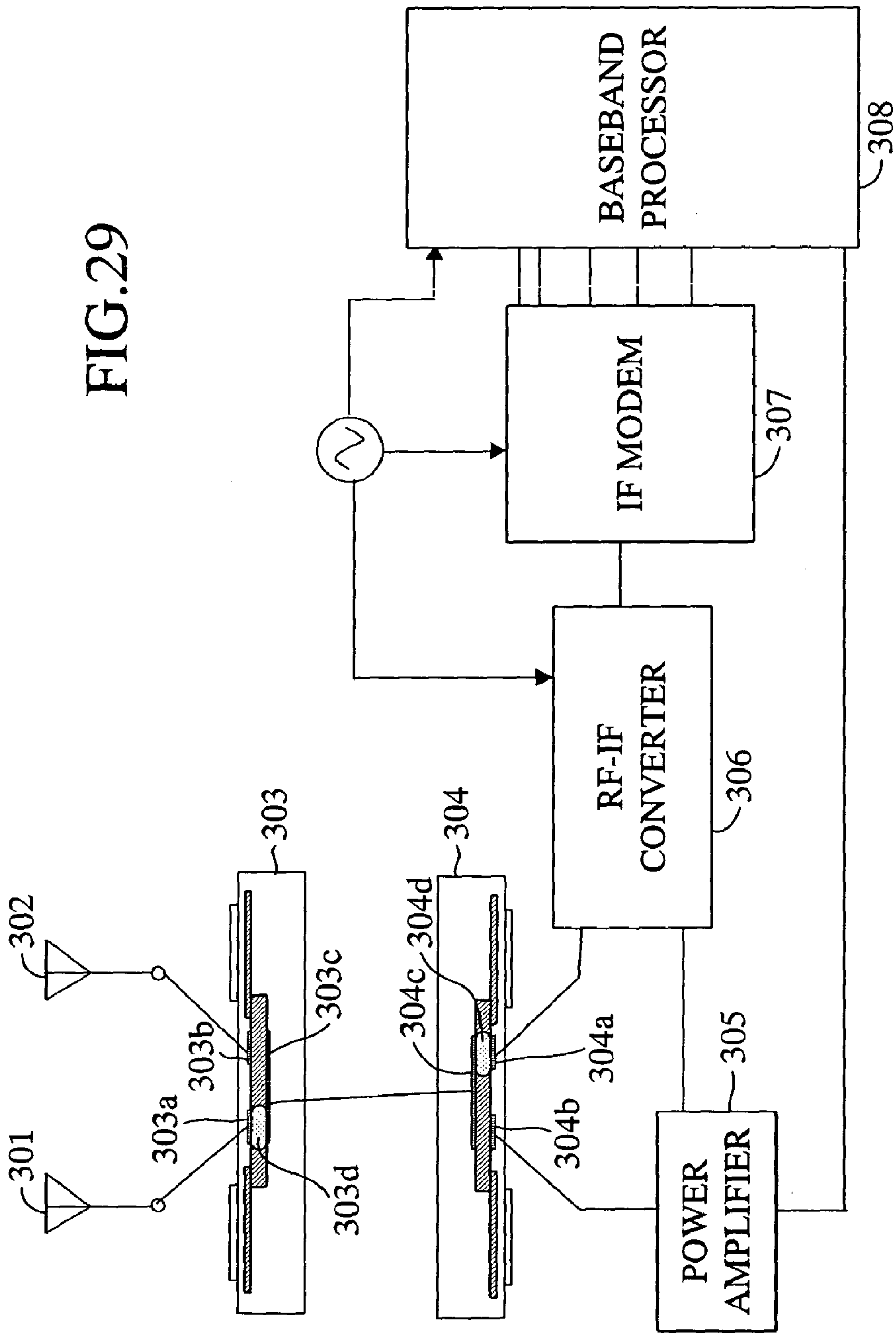

60
11
14b
14a
17b
12b
17a
12a
13a2
13a1
62b
62a
110
100
61
16b1
16a1
15a
+
−
X
Y
Z

FIG.28

FIG.29


BASEBAND PROCESSOR
308
IF MODEM
307
RF-IF CONVERTER
306
POWER AMPLIFIER
305
301
302
303
303a
303b
303c
303d
304
304a
304b
304c
304d

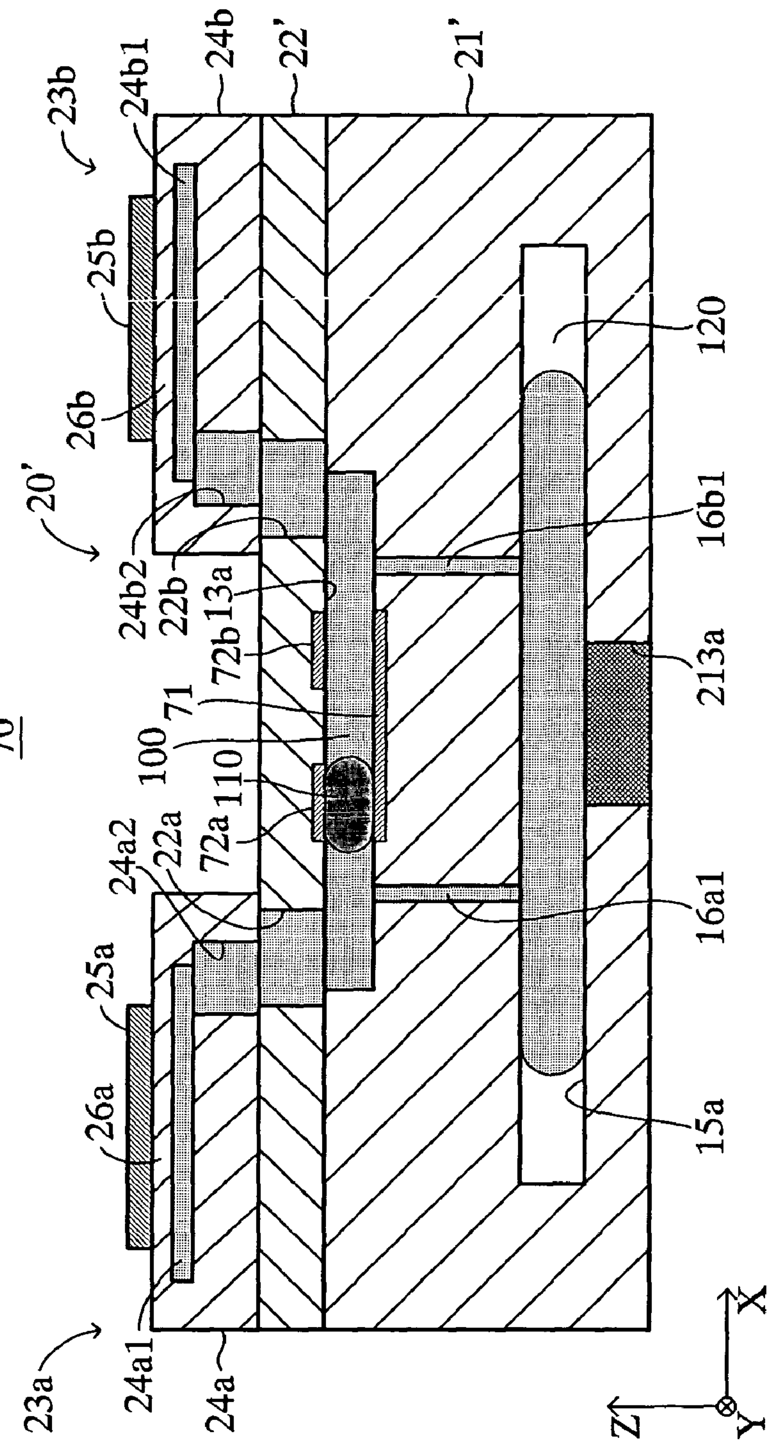
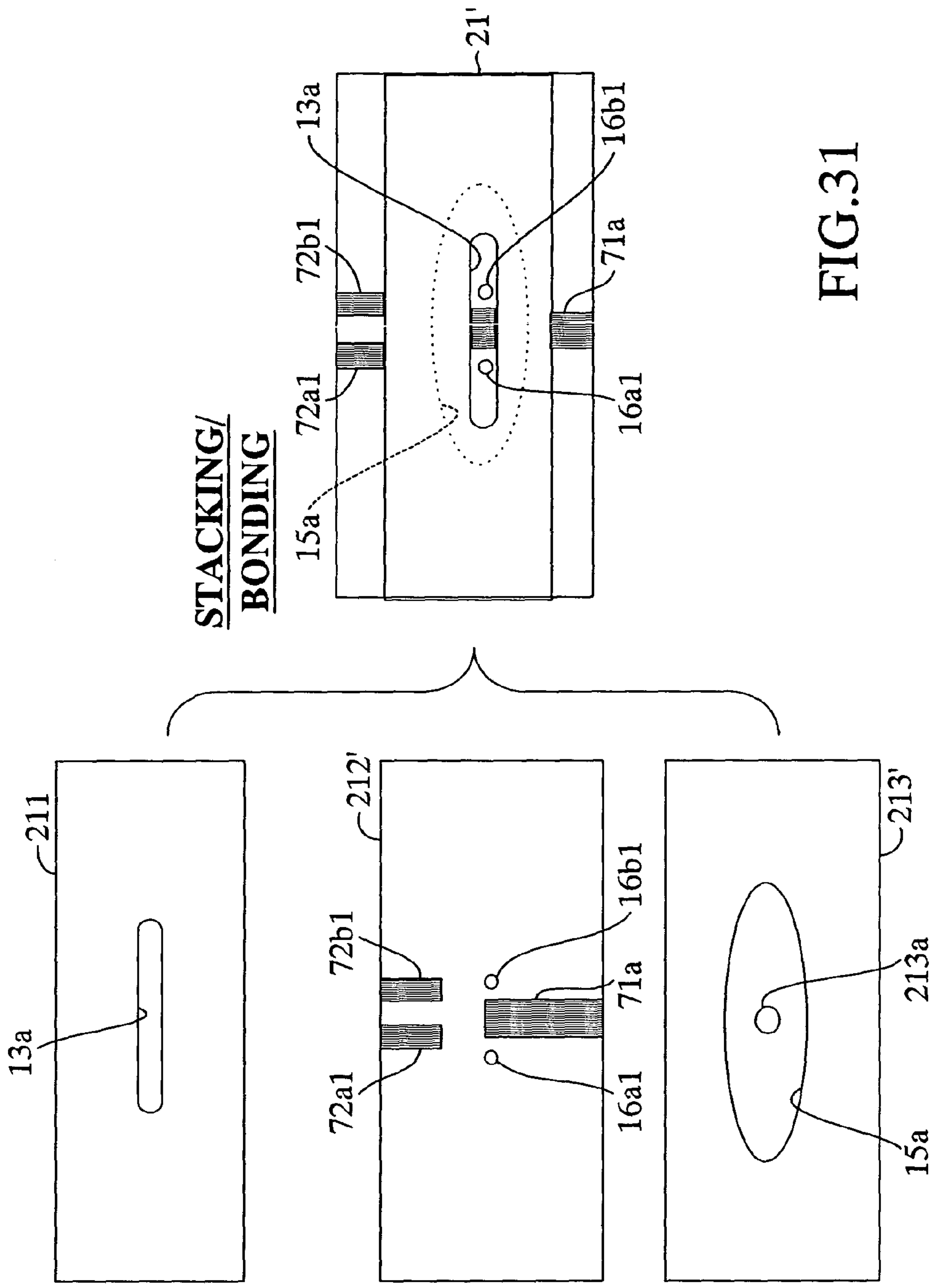

70
23b
24b1
24b
22'
21'
25b
26b
120
20'
24b2
22b
13a
16b1
72b
71
100
110
213a
72a
24a2
22a
25a
16a1
26a
15a
23a
24a1
24a
Z
Y
X

FIG.30



STACKING/
BONDING
21'
13a
16b1
72b1
71a
72a1
16a1
15a
211
13a
212'
72b1
16b1
71a
72a1
16a1
213'
213a
15a

FIG.31

STACKING/BONDING & INJECTION OF MERCURY DROPLET

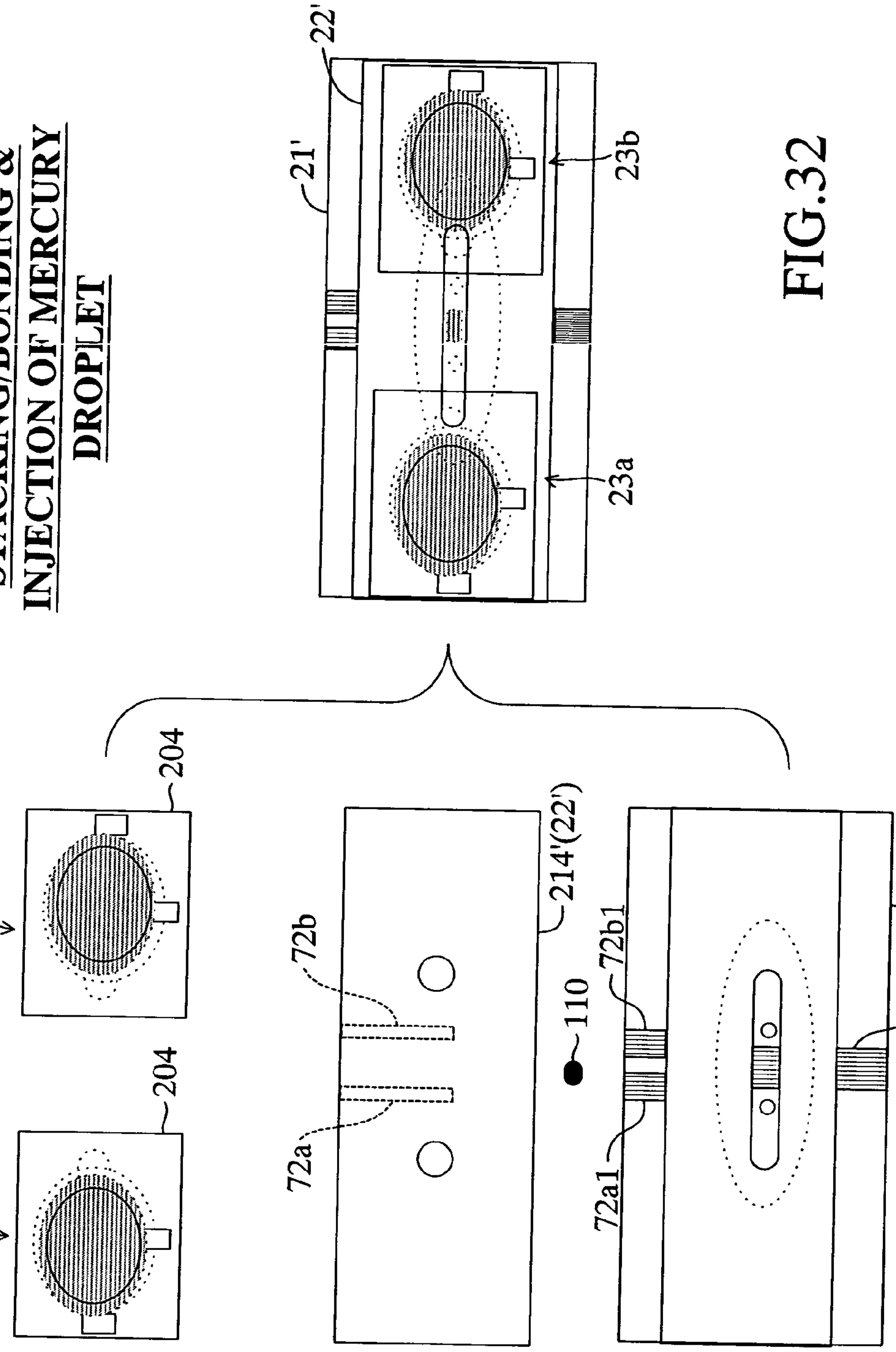
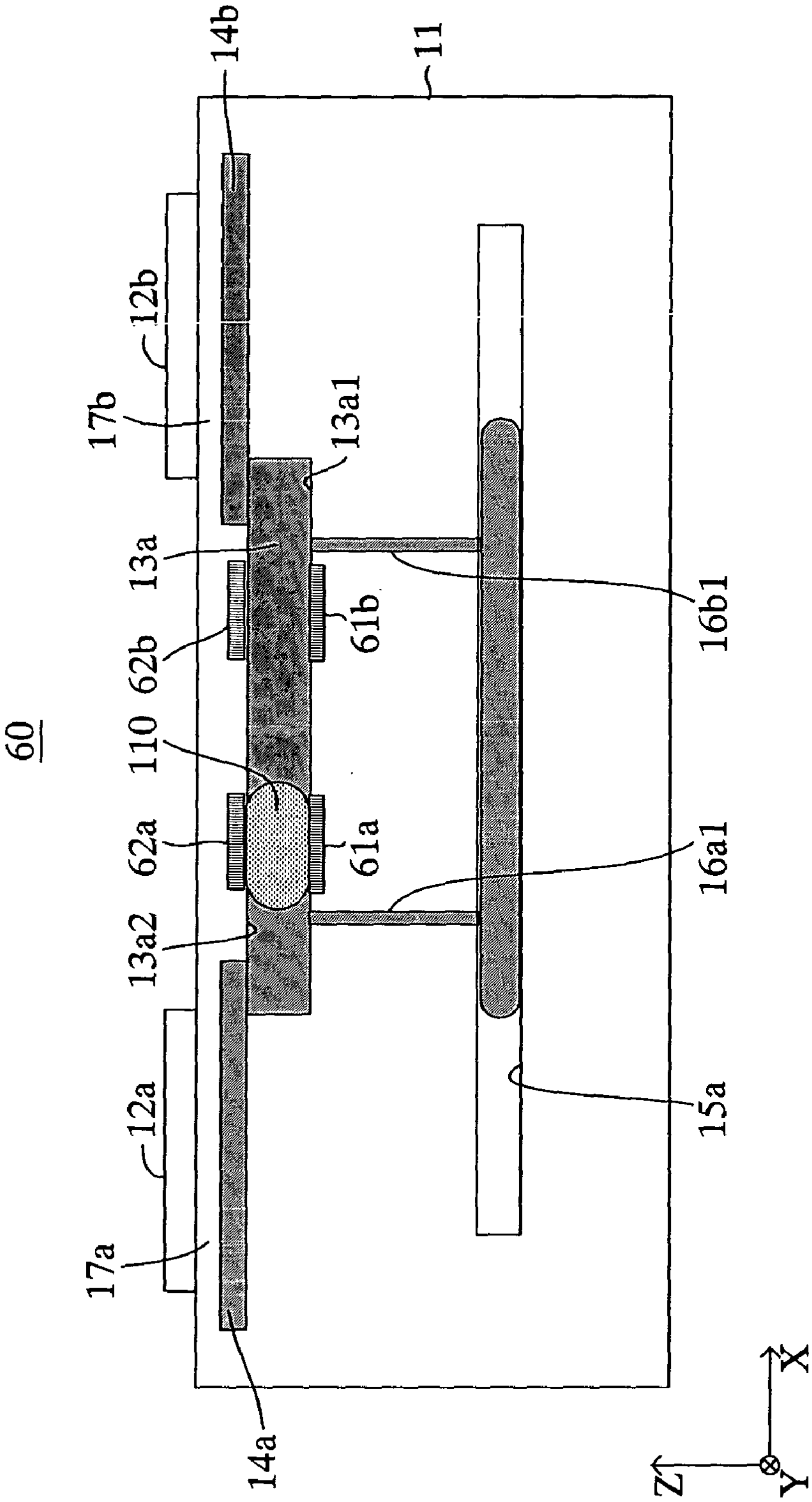


FIG.32



60
11
14b
12b
17b
13a1
13a
62b
61b
16b1
110
62a
61a
16a1
13a2
12a
17a
15a
14a
X
Y
Z

FIG.33

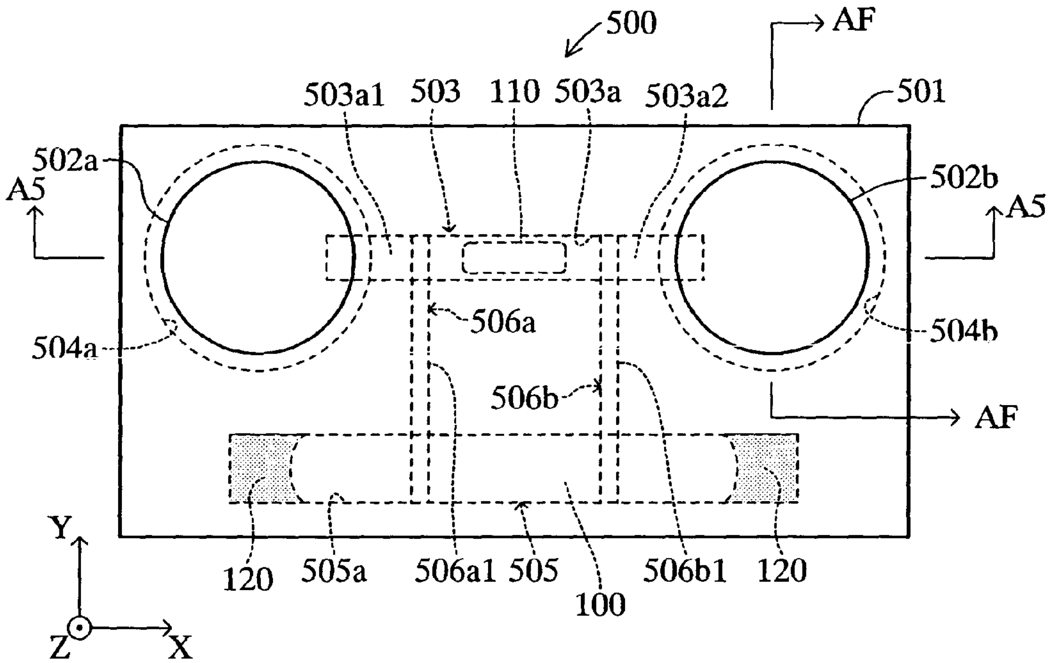

500
AF
503a1
503
110
503a
503a2
501
502a
A5
502b
A5
506a
504a
504b
506b
AF
Y
120
505a
506a1
505
100
506b1
120
Z
X

FIG.34

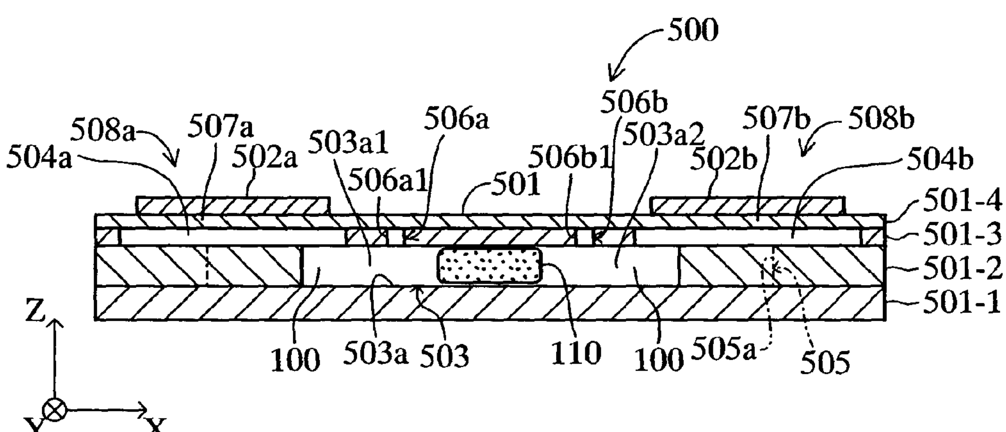

500
506b
508a
507a
506a
503a2
507b
508b
504a
502a
503a1
506b1
502b
504b
506a1
501
501-4
501-3
501-2
501-1
Z
100
503a
503
110
100
505a
505
Y
X

FIG.35

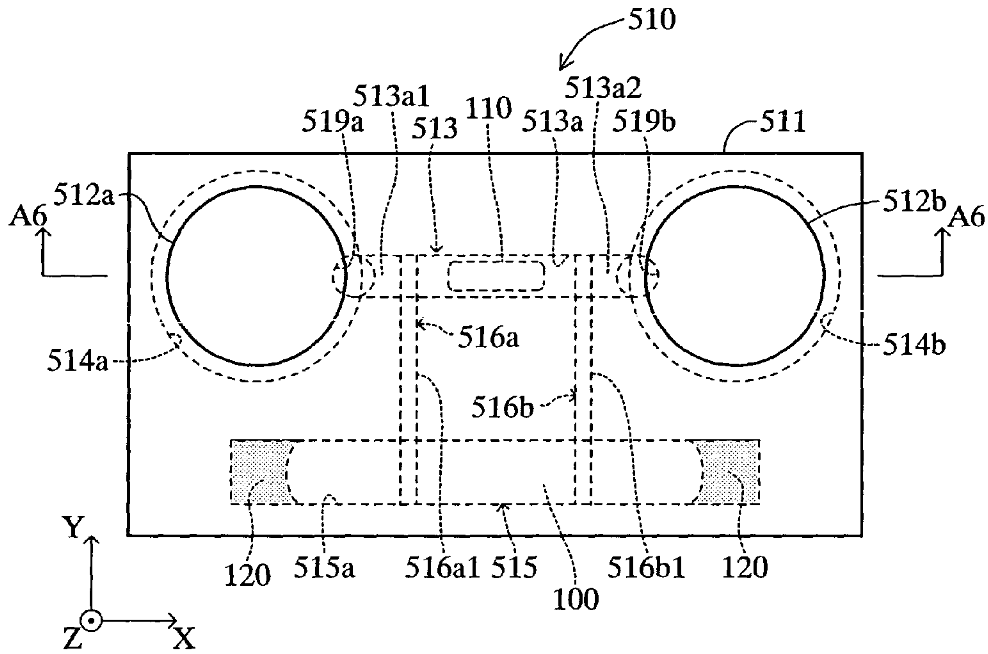

510
513a1
513a2
519a
513
110
513a
519b
511
512a
512b
A6
A6
516a
514a
514b
516b
Y
120
515a
516a1
515
516b1
120
100
Z
X

FIG.36

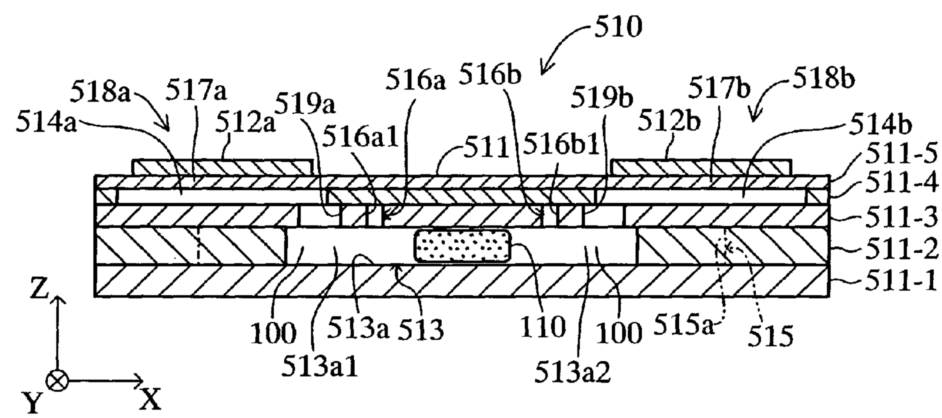

510
516a
516b
518a
517a
519a
519b
517b
518b
514a
512a
516a1
512b
514b
511
516b1
511-5
511-4
511-3
511-2
511-1
Z
100
513a
513
110
100
515a
515
513a1
513a2
Y
X

FIG.37

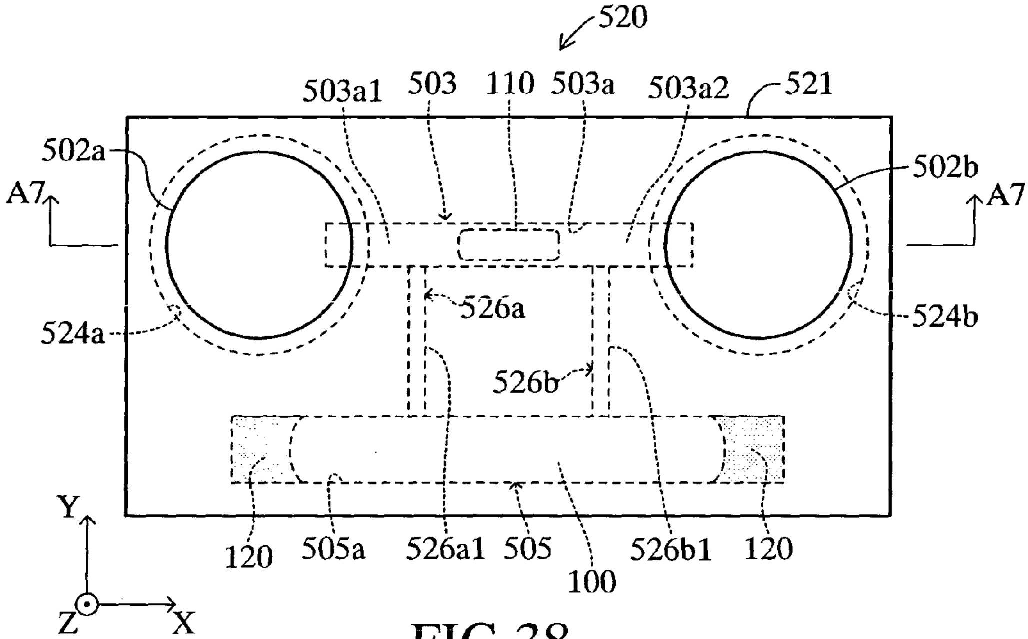

520
503a1
503
110
503a
503a2
521
502a
502b
A7
A7
526a
524a
524b
526b
Y
120
505a
526a1
505
526b1
120
100
Z
X

FIG.38

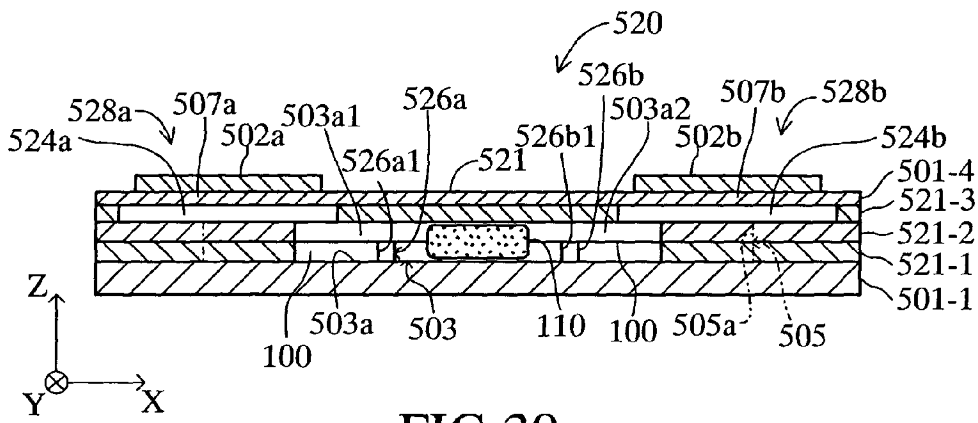

520
526b
528a
507a
503a1
526a
503a2
507b
528b
524a
502a
526b1
502b
524b
526a1
521
501-4
521-3
521-2
521-1
501-1
Z
503a
503
110
100
505a
505
100
Y
X

FIG.39

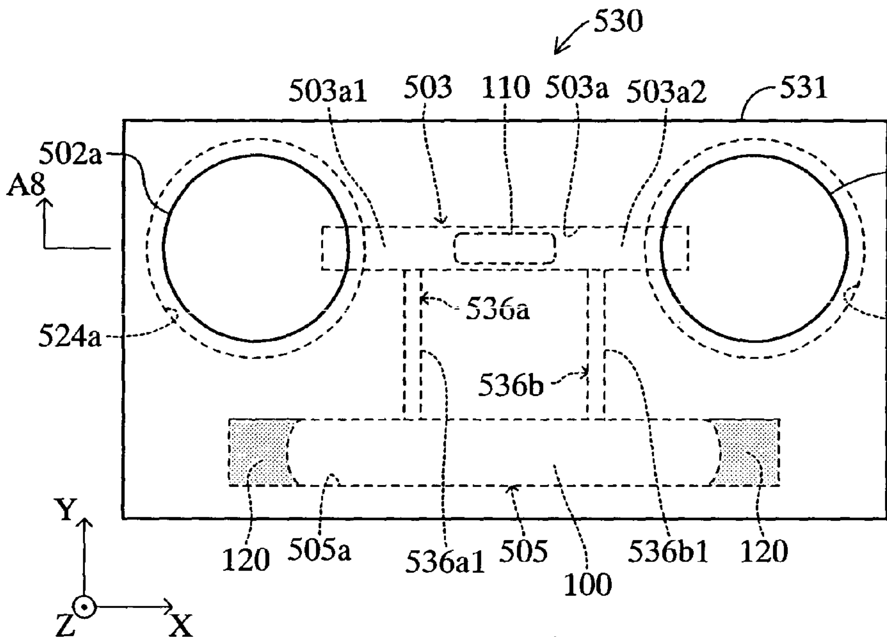

530
503a1
503
110
503a
503a2
531
502a
A8
502b
A8
536a
524a
524b
536b
Y
120
505a
536a1
505
100
536b1
120
Z
X

FIG.40

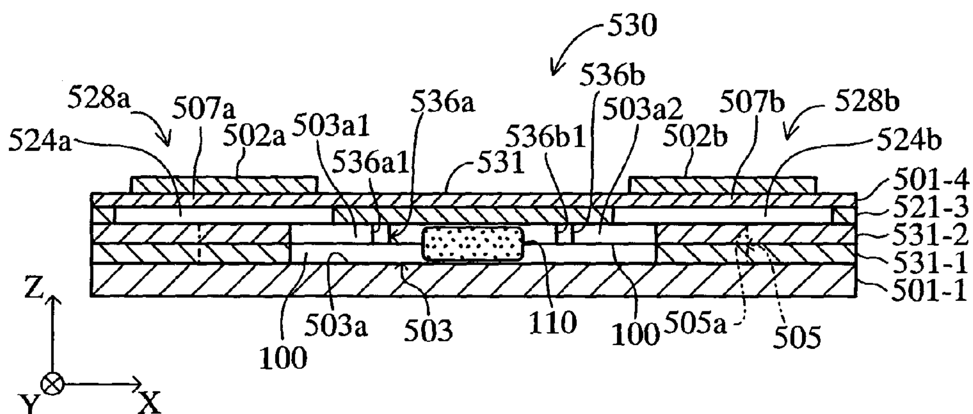
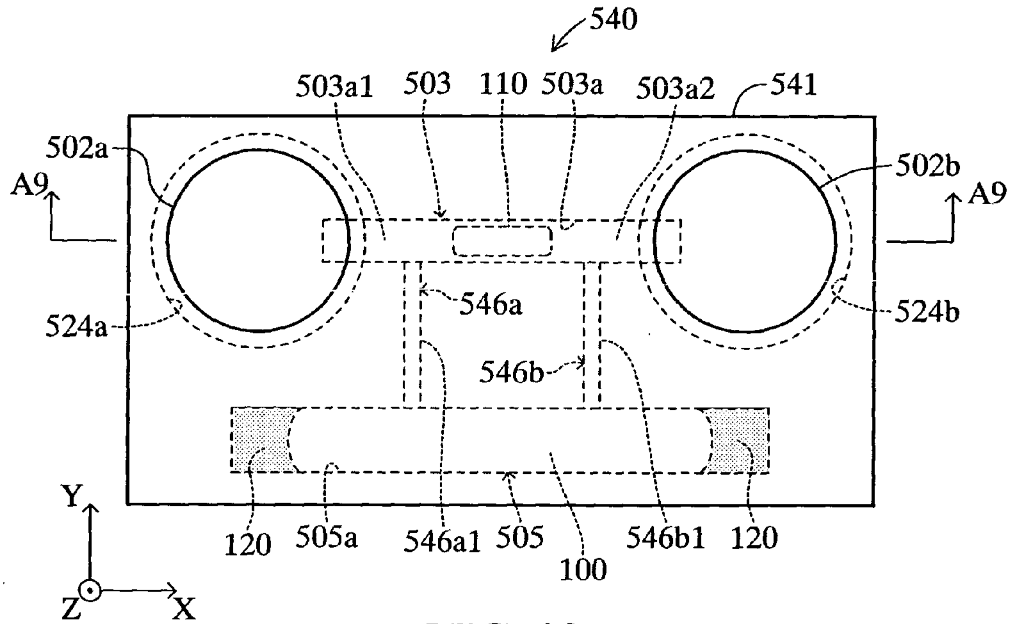
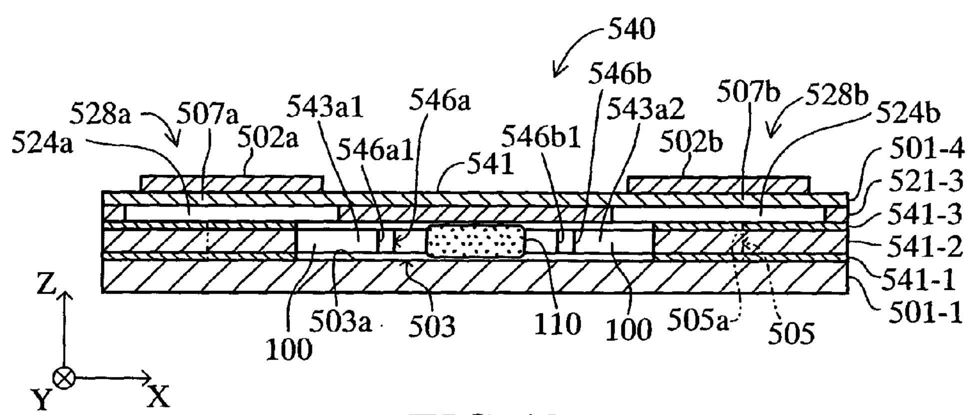

530
536b
528a
507a
536a
503a2
507b
528b
524a
502a
503a1
536b1
502b
524b
536a1
531
501-4
521-3
531-2
531-1
501-1
Z
503a
503
110
100
505a
505
100
Y
X

FIG.41



540
503a1
503
110
503a
503a2
541
502a
502b
A9
A9
546a
524a
524b
546b
Y
120
505a
546a1
505
546b1
120
100
Z
X

FIG.42



540
546b
528a
507a
543a1
546a
543a2
507b
528b
524b
524a
502a
546a1
546b1
502b
501-4
541
521-3
541-3
541-2
Z
541-1
501-1
503a
503
110
100
505a
505
100
Y
X

FIG.43

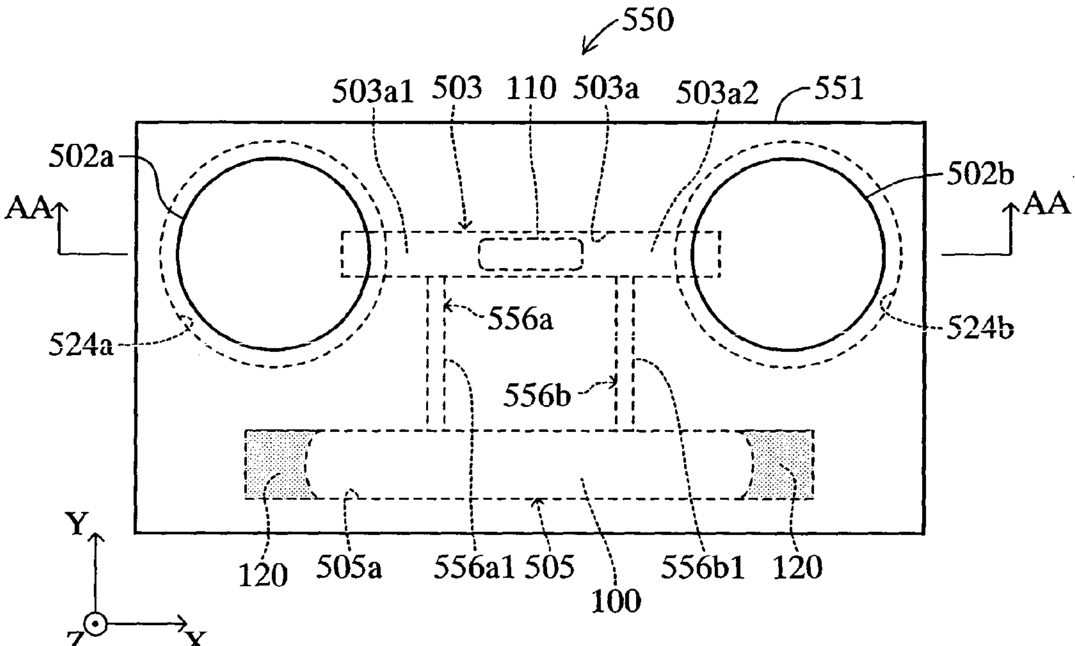

550
503a1
503
110
503a
503a2
551
502a
502b
AA
AA
556a
524a
524b
556b
Y
120
505a
556a1
505
556b1
120
100
Z
X

FIG.44

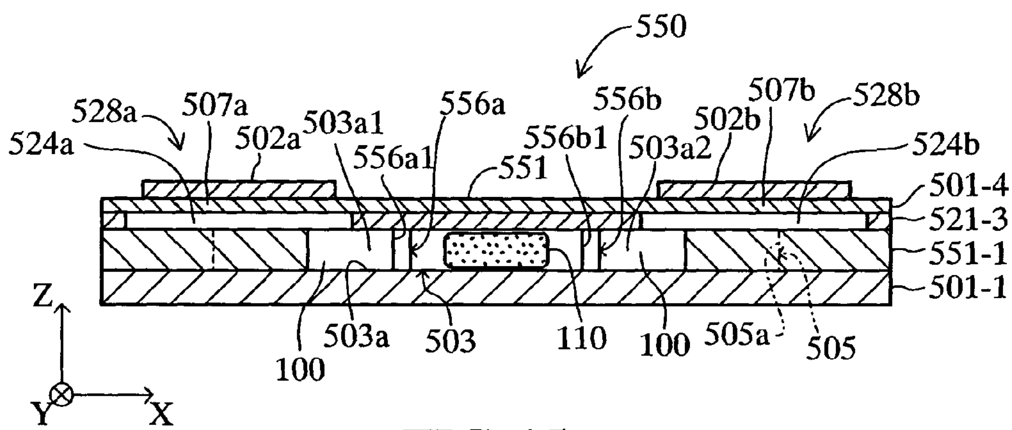

550
528a
507a
503a1
556a
556b
507b
528b
524a
502a
556a1
551
556b1
502b
503a2
524b
501-4
521-3
551-1
501-1
Z
503a
503
110
100
505a
505
100
Y
X

FIG.45

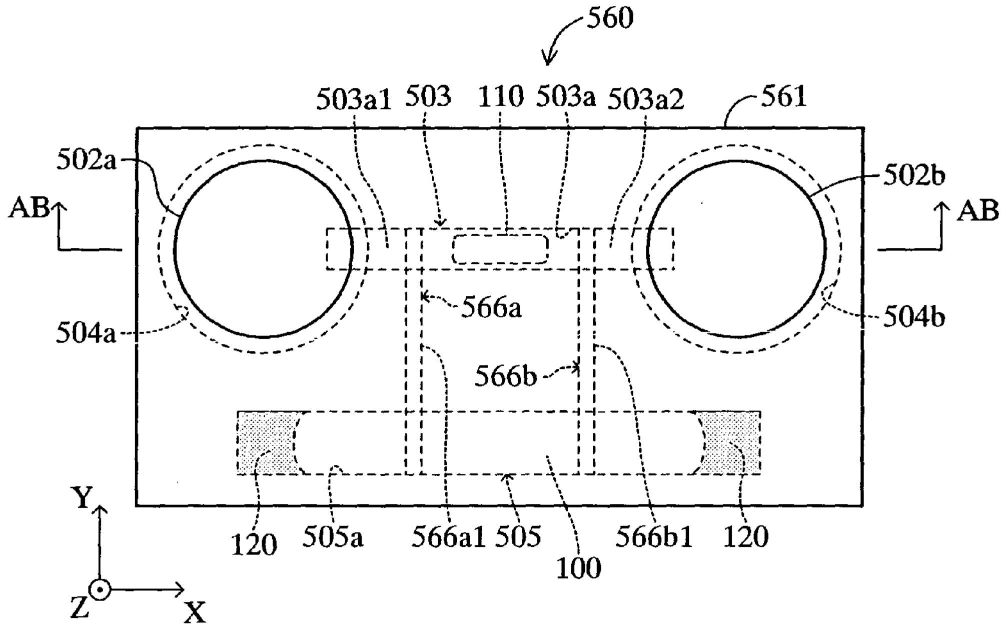

560
503a1 503 110 503a 503a2
561
502a
502b
AB
AB
566a
504a
504b
566b
120 505a 566a1 505 566b1 120
100
Y
Z
X

FIG.46

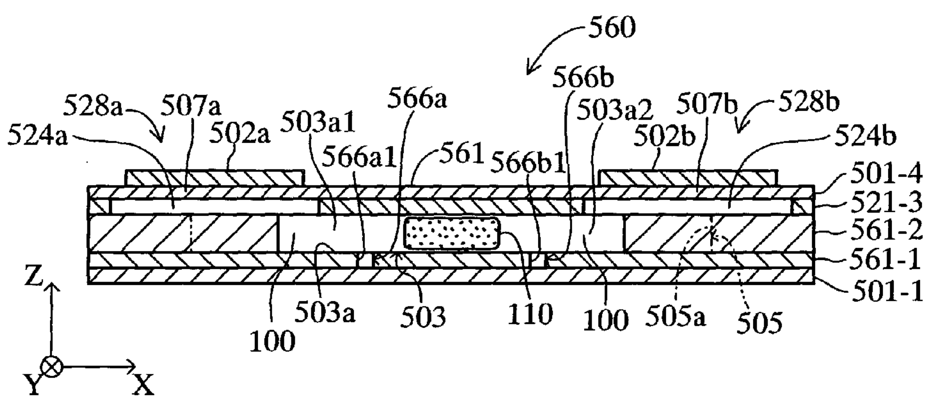

560
566b
528a 507a
566a
503a2 507b 528b
524a
502a 503a1
524b
566a1 561 566b1
502b
501-4
521-3
561-2
561-1
501-1
Z
503a 503 110 100 505a 505
100
Y
X

FIG.47

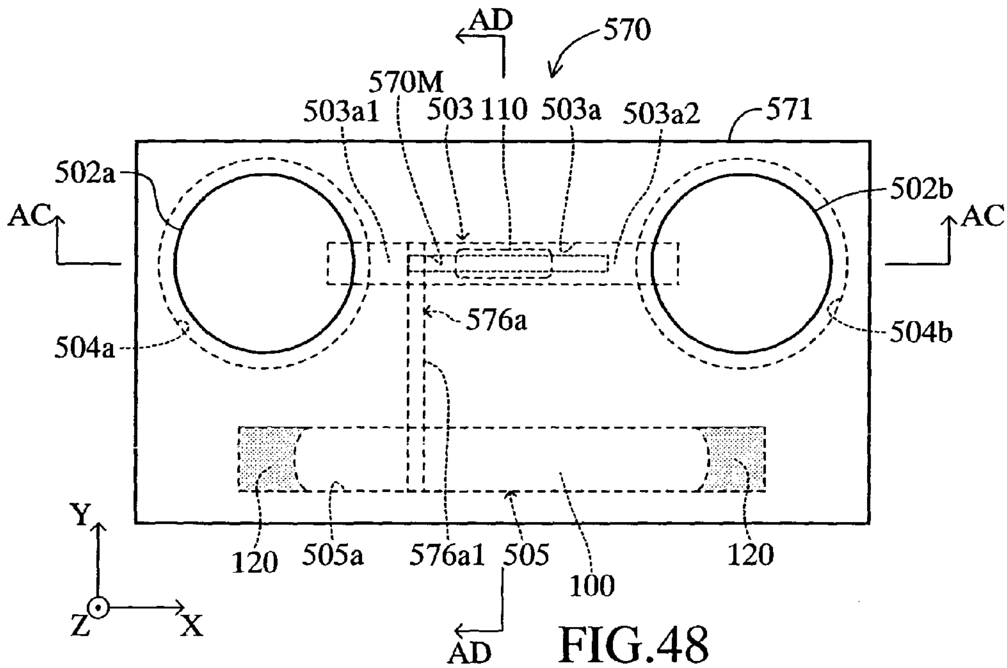


FIG.48

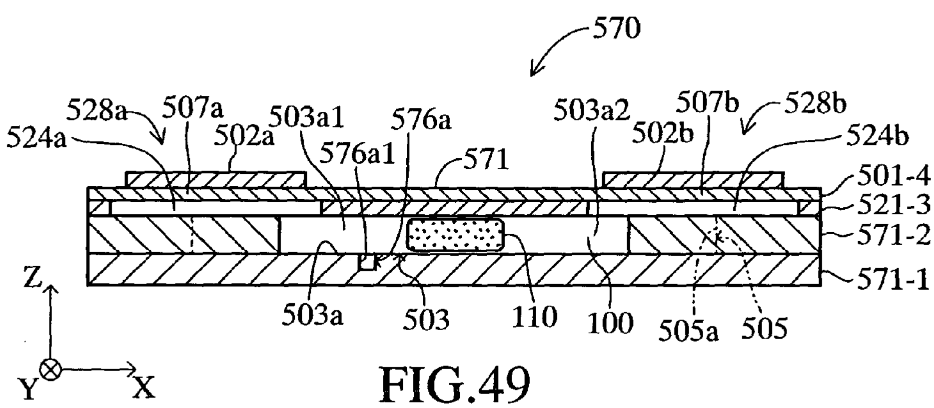


FIG.49

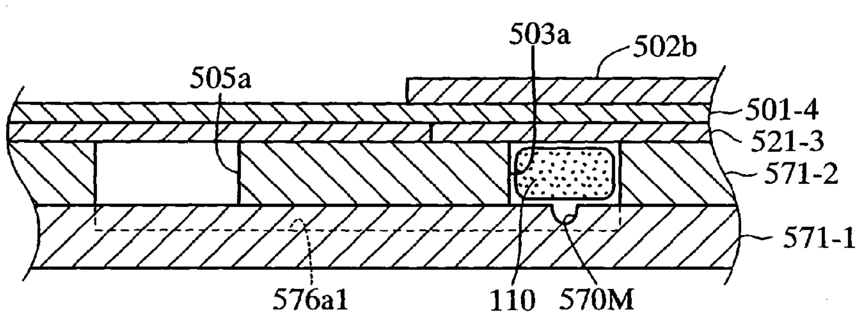


FIG.50

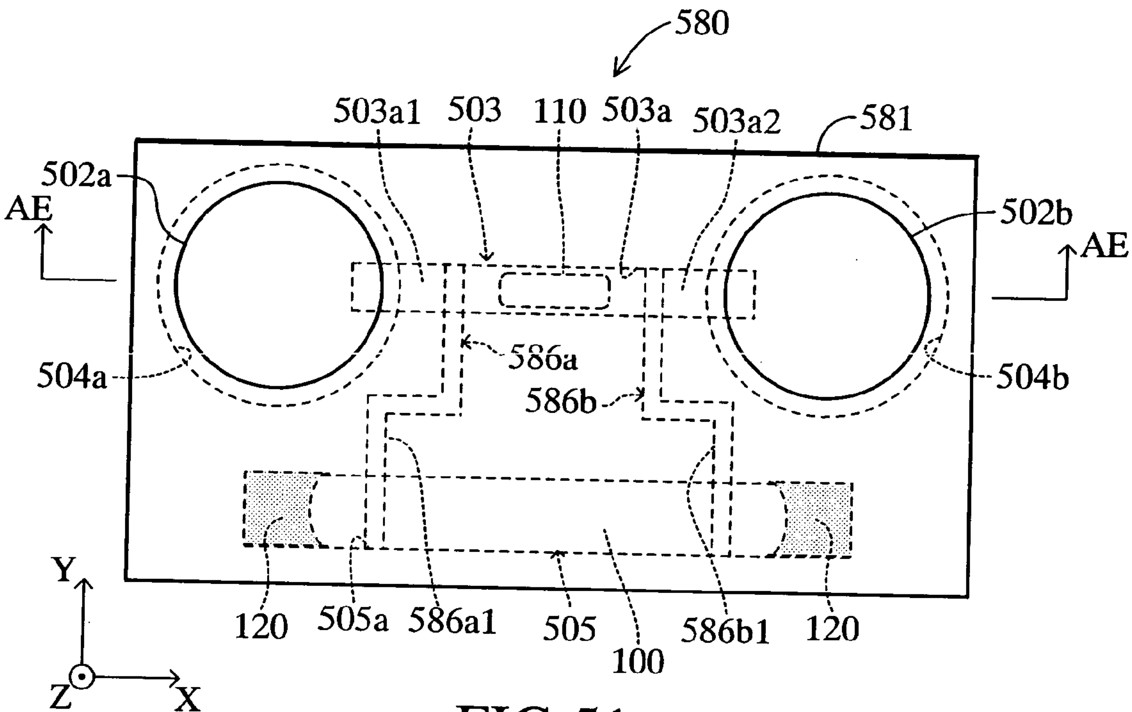

580
503a1
503
110
503a
503a2
581
502a
AE
502b
AE
504a
586a
586b
504b
Y
Z
X
120
505a
586a1
505
100
586b1
120

FIG.51

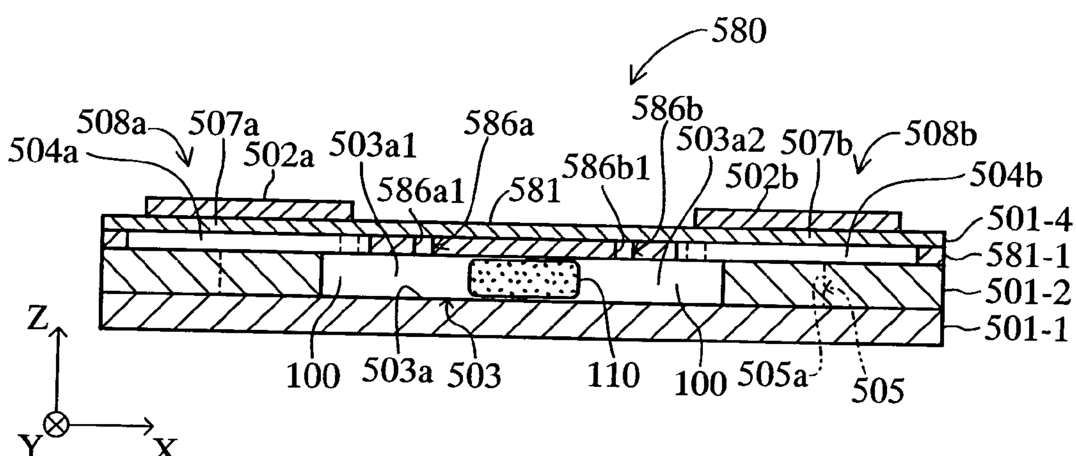

580
508a
507a
504a
502a
503a1
586a
586b
503a2
507b
508b
586b1
502b
504b
586a1
581
501-4
581-1
501-2
501-1
Z
Y
X
100
503a
503
110
100
505a
505

FIG.52

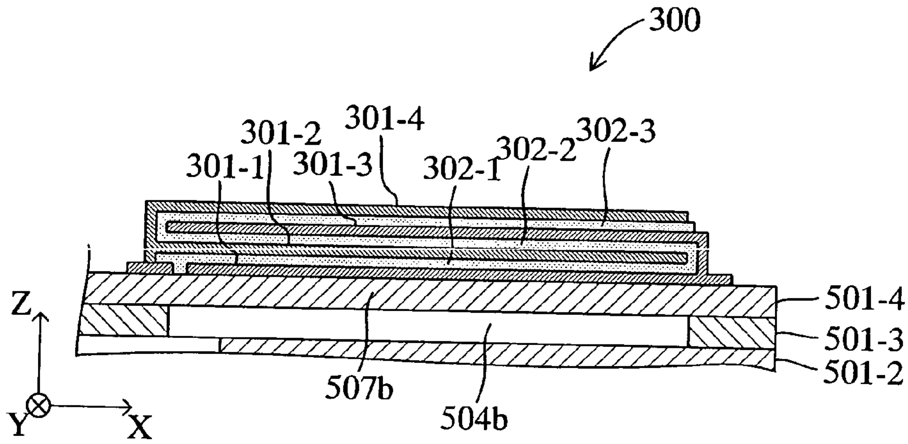

300
301-4
301-2
302-2
302-3
301-1
301-3
302-1
Z
501-4
501-3
501-2
507b
504b
Y
X

FIG.53

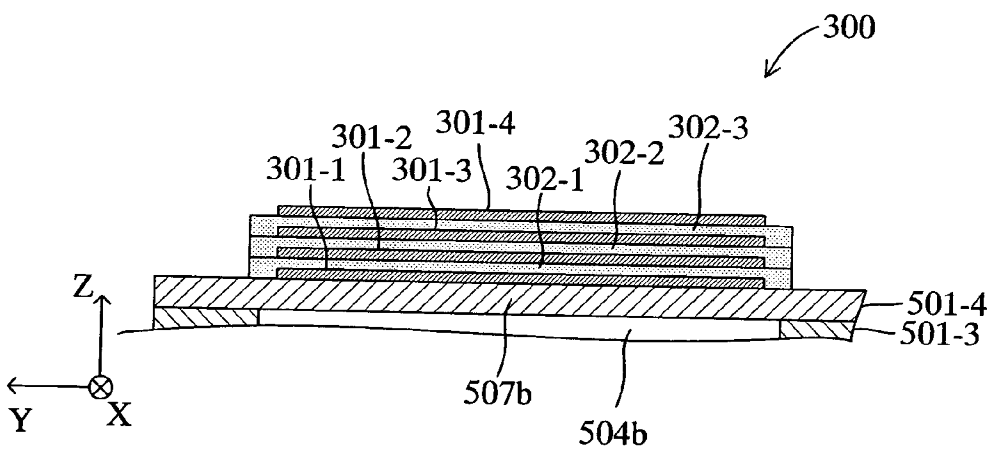

300
301-4
302-3
301-2
302-2
301-1
301-3
302-1
Z
501-4
501-3
507b
504b
Y
X

FIG.54

CIRCUIT CHANGEOVER SWITCH

TECHNICAL FIELD

[0001] The present invention relates to a circuit changeover switch which switches an electrical path by use of a drive device for moving a movable body through utilization of operation fluid.

BACKGROUND ART

[0002] In recent years, there have been developed micro motors, micro sensors, micro switches, etc. which have sizes of several millimeters to several tens of microns and which are fabricated through utilization of a technique for micro-machining of materials, such as a semiconductor fabrication technique, or by making use of piezoelectric material or a like material which can effect mutual conversion between electrical energy and mechanical energy. These elementary devices can be widely applied to, for example, ink-jet printer heads, micro valves, flow sensors, pressure sensors, recording heads, actuators for tracking servos, on-chip biochemical analyzers, micro reactors, high-frequency components, micro magnetic devices, micro relays, acceleration sensors, gyroscopes, drive devices, displays, and optical scanners (Nikkei Micro Device, July 2000, pp 164-165).

[0003] In these micro machines, electrostatic force is often used as drive force. Further, various types of drive sources have been studied, such as a type which utilizes distortion deformation of a piezoelectric material caused through application of voltage thereto, a type which utilizes changes in shape of a shape memory alloy, and a type which utilizes changes in volume of liquid caused by phase change thereof induced by heating. However, in micro mechanisms, force generated by a drive source and drive stroke become extremely small, and therefore, in some applications a mechanical amplification mechanism such as a lever must be combined with a drive source.

[0004] However, when the size of such a mechanical amplification mechanism is reduced to that of a micro machine, wear or sticking, which does not raise any problem in the case of a machine of ordinary size, raises a big problem. Further, since a micro machine having an amplification mechanism (drive function) such as a lever inevitably requires formation of a three-dimensional structure having a depth (height), micro machining of such a micro machine requires a longer time, and assembly of micro components requires a greater number of steps. For this reasons, some micro machines involve the problem of not being suitable for mass production.

[0005] Meanwhile, in order to be used as a circuit changeover switch that functions as an electrical switch (or a relay), among the above-described devices, there has been developed a mercury micro relay of a type which realizes switching operation through movement of a mercury droplet and which utilizes, as a drive force for moving the mercury droplet, pressure created upon instantaneous generation of a bubble by means of heating by a micro heater (see, for example, J. Kim et al., Proc. 46th Annual Int. Relay Conf., Oak Brook, Ill., April 1998, pp. 19-1-19-8). This switch is reported to have various features, such as a wide frequency range of DC to 10 GHz, high insulating resistance and low insertion loss in the GHz band, and no signal bounce.

[0006] However, the above-described mercury micro relay of a bubble generation type has drawbacks, in that heat accumulates through heating operation and that a large amount of electrical power is consumed.

[0007] Accordingly, an object of the present invention is to provide a circuit changeover switch which is a device using operation fluid, which maintains the features of micro machines such as small size and low power consumption, which does not include a mechanical amplification mechanism having intrinsic problems of wear and sticking, which facilitates mass production, and which hardly causes leakage of operation fluid under variation in atmospheric temperature. Another object of the present invention is to provide a circuit changeover switch which is free from the problem of heat accumulation and which enables high-speed changeover operation.

DISCLOSURE OF THE INVENTION

[0008] In order to achieve the above-described object, the present invention provides a circuit changeover switch comprising: a channel forming portion for forming a channel (i.e. a flow-passage forming portion for forming a flow passage), the channel accommodating an incompressible operation fluid and a movable body made of a substance different from that of the operation fluid, and being substantially divided into two operation chambers by means of the movable body; a pair of pumps each including a pump chamber communicating with the corresponding operation chamber and being filled with the operation fluid, an actuator provided for the pump chamber, and a diaphragm deformed by the actuator, the operation fluid within the pump chamber being pressurized or depressurized through deformation of the diaphragm; an internal-pressure-buffering-chamber-forming portion for forming an internal-pressure buffering chamber which accommodates the operation fluid and a compressible fluid for pressure buffering; and a micro channel portion for forming a micro channel which connects the channel of the channel forming portion and the internal-pressure buffering chamber of the internal-pressure-buffering-chamber-forming portion, the micro channel exhibiting a high passage resistance against abrupt pressure change of the operation fluid within the channel, to thereby substantially prohibit passage of the operation fluid through the micro channel and exhibiting a low passage resistance against slow pressure change of the operation fluid within the channel, to thereby substantially permit passage of the operation fluid through the micro channel. The micro channel may connect the channel of the channel-forming portion and the internal-pressure buffering chamber of the internal-pressure-buffering-chamber-forming portion directly, or via another portion (e.g., a connection passage for connecting the channel and the pump chamber, or a pump chamber). Further, three or more pumps may be provided.

[0009] By virtue of the above-described configuration, when the diaphragm is deformed by the actuator, the operation fluid within the channel is pressurized or depressurized. At this time, when the pressure of the operation fluid changes abruptly, the micro channel exhibits a high passage resistance in order to substantially prohibit passage of the operation fluid through the micro channel. Therefore, the pressure change of the operation fluid is transmitted to the movable body within the channel, so that the movable body moves. In contrast, when the pressure of the operation fluid changes slowly due to thermal expansion of the operation fluid caused by variation in the ambient temperature or due to slow operation of the actuator, the micro channel exhibits a low passage resistance in order to substantially permit passage of the operation fluid through the micro channel. Therefore, the operation fluid moves via the micro channel to the internal-pressure buffering chamber, which accommodates a compressible fluid for pressure buffering. As a result, pressure increase of the operation fluid within the channel is suppressed, and it becomes possible to avoid breakage of the device (switch) due to excessive pressure of the operation fluid and to prevent leakage of the operation fluid due to breakage of the device.

[**0010**] Preferably, the actuator includes a film-type piezoelectric element comprising a piezoelectric/electrostrictive film or an antiferroelectric film and electrodes; and the diaphragm is formed of ceramic.

[**0011**] In this case, micro machining can be performed more easily, and circuit changeover switches which are well suited for mass production and which have excellent durability can be provided.

[**0012**] Preferably, the circuit changeover switch according to the present invention includes a first changeover electrode exposed to a portion of the channel of the channel forming portion; a second changeover electrode exposed to another portion of the channel of the channel forming portion and electrically isolated from the first changeover electrode; and an electrode (common electrode) exposed to the channel of the channel forming portion to face the first changeover electrode and the second changeover electrode via the channel (to be connected with the first changeover electrode and the second changeover electrode through the movable body within the channel), wherein at least a surface portion of the movable body is formed of an electrically conductive material. In this case, the operation fluid must be electrically non-conductive.

[**0013**] Preferably, the circuit changeover switch according to the present invention includes a first changeover electrode exposed to a portion of the channel of the channel forming portion; a second changeover electrode exposed to another portion of the channel of the channel forming portion and electrically isolated from the first changeover electrode; an electrode exposed to the channel of the channel forming portion to face the first changeover electrode via the channel (to be connected with the first changeover electrode through the movable body within the channel); and another electrode exposed to the channel of the channel forming portion to face the second changeover electrode via the channel (to be connected with the second changeover electrode through the movable body within the channel), wherein at least a surface portion of the movable body is formed of an electrically conductive material.

[**0014**] Notably, in such a switch, no limitation is imposed on the number of the changeover electrodes, so long as the number is not less than two.

[**0015**] By virtue of the above-described structure, the movable body is moved between the first changeover electrode and the second changeover electrode by pumps each comprising a film-type piezoelectric element and a ceramic diaphragm, whereby an electric circuit (electric path) is switched. Thus is provided a circuit changeover switch which exhibits reduced electrical power consumption and which does not involve a problem of heat accumulation, which would otherwise be caused by heating by a micro heater. Further, since such a pump can be operated at high speed and has excellent durability, a circuit changeover switch suitable for portable information terminals, etc. can be provided.

[**0016**] In the above-described circuit changeover switch, preferably, each of the diaphragms of the pumps constitutes a portion of the walls of the corresponding pump chamber and has a film surface in a common plane; the channel of the channel forming portion forms a space whose longitudinal axis lies in a plane parallel to the film surfaces of the diaphragms; the micro channel of the micro channel portion extends along a direction parallel to the film surfaces of the diaphragms; and the internal-pressure buffering chamber of the internal-pressure-buffering-chamber-forming portion forms a space whose longitudinal axis lies in a plane parallel to the film surfaces of the diaphragms and is connected with the channel of the channel forming portion via the micro channel of the micro channel portion.

[**0017**] When each of the pumps is configured in such a manner that a diaphragm formed of a single deformable plate member such as a ceramic sheet forms a portion of the walls of the pump chambers, the volume of each pump chamber is changed directly upon operation of the corresponding actuator, whereby the operation fluid can be pressurized or depressurized efficiently. Accordingly, it is preferable that each of the diaphragms of the pumps form a portion of the walls of the corresponding pump chamber and have a film surface in the common plane.

[**0018**] Meanwhile, in order to produce a passage resistance having the above-described characteristics, the micro channel must have a small cross section. However, when the cross section of the micro channel is extremely small, high machining accuracy is required, thereby increasing the production cost of the circuit changeover switch. By contrast, the micro channel can produce a passage resistance having the above-described characteristics when the micro channel has an increased length. However, when the micro channel is extended only along a direction intersecting the film surface of the diaphragm (e.g., a direction perpendicularly intersecting the film surface of the diaphragm), the thickness of the circuit changeover switch increases.

[**0019**] In order to solve the above problem, the circuit changeover switch of the present invention employs the above-described structure in which the micro channel of the micro channel portion extends along a direction parallel to the film surface of the diaphragm; and the micro channel connects the channel of the channel forming portion and the internal-pressure buffering chamber of the internal-pressure-buffering-chamber-forming portion, each being a space whose longitudinal axis lies in a plane parallel to the film surface of the diaphragm. Since the above arrangement and configuration enable formation of the channel, the internal-pressure buffering chamber, and the micro channel within a certain thickness, a circuit changeover switch (drive device) of small thickness (a thin type) can be provided. Further, since such a thin-type circuit changeover switch increases the surface area of the circuit changeover switch relative to the overall volume of the circuit changeover switch, heat generated upon operation can be dissipated to the outside with ease, and the circuit changeover switch can operate stably.

BRIEF DESCRIPTION OF DRAWINGS

[0020] **FIG. 1** is a sectional view of a drive device which serves as a portion of a circuit changeover switch according to a first embodiment of the present invention.

[0021] **FIG. 2** is a plan view of the drive device shown in **FIG. 1**.

[0022] **FIG. 3** is a sectional view of the drive device taken along line **2-2** in **FIG. 1**.

[0023] **FIG. 4** is a sectional view of the drive device shown in **FIG. 1**, showing an initial state thereof.

[0024] **FIG. 5** is a sectional view of the drive device shown in **FIG. 1**, showing an operated state thereof.

[0025] **FIG. 6** is a sectional view of the drive device shown in **FIG. 1**, showing another operated state thereof.

[0026] **FIG. 7** is a sectional view of the drive device shown in **FIG. 1**, showing flow of operation fluid when the ambient temperature increases.

[0027] **FIG. 8** is a sectional view of the drive device shown in **FIG. 1**, showing flow of the operation fluid when the ambient temperature decreases.

[0028] **FIG. 9** is a view used for explaining an operation for finely adjusting the position of a movable body of the drive device shown in **FIG. 1**.

[0029] **FIG. 10** is a pair of time charts showing waveforms of voltages which are applied to piezoelectric films of the drive device shown in **FIG. 1** for the purpose of fine adjustment of the position of the movable body of the drive device.

[0030] **FIG. 11** is a view used for explaining an operation for finely adjusting the position of the movable body of the drive device shown in **FIG. 1**.

[0031] **FIG. 12** is a view used for explaining an operation for finely adjusting the position of the movable body of the drive device shown in **FIG. 1**.

[0032] **FIG. 13** is a sectional view of a modification of the drive device shown in **FIG. 1**.

[0033] **FIG. 14** is a sectional view showing a modification of a channel of the drive device shown in **FIG. 1**.

[0034] **FIG. 15** is a sectional view of a drive device which serves as a portion of a circuit changeover switch according to a second embodiment of the present invention. **FIG. 16** is a plan view of the drive device shown in **FIG. 15**.

[0035] **FIG. 17** is a conceptional diagram showing a process of fabricating a piezoelectric/electrostrictive actuator of the drive device shown in **FIG. 15**.

[0036] **FIG. 18** is a conceptional diagram showing a different process of fabricating a piezoelectric/electrostrictive actuator of the drive device shown in **FIG. 15**.

[0037] **FIG. 19** is a conceptional diagram showing a process of fabricating the drive device shown in **FIG. 15**.

[0038] **FIG. 20** is a conceptional diagram showing a process of fabricating the drive device shown in **FIG. 15**.

[0039] **FIG. 21** is a sectional view of a drive device which serves as a portion of a circuit changeover switch according to a third embodiment of the present invention.

[0040] **FIG. 22** is a sectional view of a drive device which serves as a portion of a circuit changeover switch according to a fourth embodiment of the present invention.

[0041] **FIG. 23** is a sectional view of a drive device which serves as a portion of a circuit changeover switch according to a fifth embodiment of the present invention.

[0042] **FIG. 24** is a plan view of the drive device shown in **FIG. 23**.

[0043] **FIG. 25** is a sectional view of the drive device shown in **FIG. 23**, showing an operated state thereof.

[0044] **FIG. 26** is a plan view of a modification of the drive device which serves as a portion of the circuit changeover switch according to the fifth embodiment of the present invention.

[0045] **FIG. 27** is a sectional view of one embodiment of the circuit changeover switch of the present invention, showing an initial state thereof.

[0046] **FIG. 28** is a sectional view of the circuit changeover switch shown in **FIG. 27**, showing a driven state thereof.

[0047] **FIG. 29** is a system block diagram of a portable information terminal to which the circuit changeover switch shown in **FIG. 27** is applied.

[0048] **FIG. 30** is a sectional view of another embodiment of the circuit changeover switch of the present invention, showing an initial state thereof.

[0049] **FIG. 31** is a conceptional diagram showing a process of fabricating the circuit changeover switch shown in **FIG. 30**.

[0050] **FIG. 32** is a conceptional diagram showing a different process of fabricating the circuit changeover switch shown in **FIG. 30**.

[0051] **FIG. 33** is a sectional view of still another embodiment of the circuit changeover switch of the present invention, showing an initial state thereof.

[0052] **FIG. 34** is a plan view of a drive device which serves as a portion of a circuit changeover switch according to a sixth embodiment of the present invention.

[0053] **FIG. 35** is a sectional view of the drive device taken along line A5-A5 in **FIG. 34**.

[0054] **FIG. 36** is a plan view of a drive device which serves as a portion of a circuit changeover switch according to a seventh embodiment of the present invention.

[0055] **FIG. 37** is a sectional view of the drive device taken along line A6-A6 in **FIG. 36**.

[0056] **FIG. 38** is a plan view of a drive device which serves as a portion of a circuit changeover switch according to an eighth embodiment of the present invention.

[0057] **FIG. 39** is a sectional view of the drive device taken along line A7-A7 in **FIG. 38**.

[0058] **FIG. 40** is a plan view of a drive device which serves as a portion of a circuit changeover switch according to a ninth embodiment of the present invention.

[0059] **FIG. 41** is a sectional view of the drive device taken along line **A8-A8** in **FIG. 40**.

[0060] **FIG. 42** is a plan view of a drive device which serves as a portion of a circuit changeover switch according to a tenth embodiment of the present invention.

[0061] **FIG. 43** is a sectional view of the drive device taken along line A9-A9 in **FIG. 42**.

[0062] **FIG. 44** is a plan view of a drive device which serves as a portion of a circuit changeover switch according to an eleventh embodiment of the present invention.

[0063] **FIG. 45** is a sectional view of the drive device taken along line AA-AA in **FIG. 44**.

[0064] **FIG. 46** is a plan view of a drive device which serves as a portion of a circuit changeover switch according to a twelfth embodiment of the present invention.

[0065] **FIG. 47** is a sectional view of the drive device taken along line AB-AB in **FIG. 46**.

[0066] **FIG. 48** is a plan view of a drive device which serves as a portion of a circuit changeover switch according to a thirteenth embodiment of the present invention.

[0067] **FIG. 49** is a sectional view of the drive device taken along line AC-AC in **FIG. 48**.

[0068] **FIG. 50** is a sectional view of the drive device taken along line AD-AD in **FIG. 48**.

[0069] **FIG. 51** is a plan view of a drive device which serves as a portion of a circuit changeover switch according to a fourteenth embodiment of the present invention.

[0070] **FIG. 52** is a sectional view of the drive device taken along line AE-AE in **FIG. 51**.

[0071] **FIG. 53** is an enlarged sectional view of a modification of the piezoelectric/electrostrictive film actuator applied to the drive device shown in **FIG. 34**, taken along line A5-A5 in **FIG. 34**.

[0072] **FIG. 54** is an enlarged sectional view of the modification of the piezoelectric/electrostrictive film actuator applied to the drive device shown in **FIG. 34**, taken along line AF-AF in **FIG. 34**.

BEST MODE FOR CARRYING OUT THE INVENTION

[0073] Embodiments of the circuit changeover switch containing the drive device according to the present invention will now be described with reference to the drawings. However, the present invention is not limited to these embodiments, and on the basis of knowledge of persons with ordinary skill in the art, various changes, modifications, and improvements can be made without departing from the scope of the present invention. Notably, when the drive device is described, descriptions of electrodes are omitted.

[0074] **FIG. 1** is a vertical sectional view of a drive device **10**, which serves as a portion of a circuit changeover switch according to a first embodiment of the present invention; and **FIG. 2** is a plan view of the drive device **10**. Notably, **FIG. 1** is a sectional view of the drive device **10** taken along line **1-1** in **FIG. 2**.

[0075] The drive device **10** comprises a ceramic base body **11** of a substantially rectangular parallelepiped shape having sides which respectively extend along the X-axis, Y-axis, and Z-axis directions, which are mutually perpendicular; and a pair of piezoelectric films (piezoelectric/electrostrictive elements) **12*a*** and **12*b***. The base body **11** includes a channel forming portion **13**, a pair of pump chambers **14*a*** and **14*b***, an internal-pressure-buffering-chamber-forming portion **15**, and a pair of micro channel portions **16*a*** and **16*b***.

[0076] The channel forming portion **13** has a long axis along the X-axis direction. As shown in **FIG. 3**, which is a sectional view of the base body **11** taken along line **2-2** in **FIG. 1** (along a plane parallel to the Y-Z plane), the channel forming portion **13** forms a channel **13*a*** having a substantially rectangular cross section. For example, the channel **13*a*** has dimensions such that the width (along the Y-axis direction) W of the substantially rectangular cross section is 100 μm, the depth (along the Z-axis direction; i.e., height) H is 50 μm, and the longitudinal length (in the X-axis direction) L is 1 mm. Incompressible operation fluid (e.g., liquid such as water or oil) **100** and a movable body **110** are accommodated within the channel **13*a***. The movable body **110** is formed from a material ,such as magnetic material or liquid metal (e.g., gallium alloy), differing from the operation fluid **100** and having electric conductivity at least at its surface portion. The channel **13*a*** is divided substantially into two operation chambers **13*a*1** and **13*a*2** by means of the movable body **110**. Within the channel **13*a***, the movable body **110** is present in the form of a single mass (liquid mass (vacuole), bubble, or micro solid) and, as shown in **FIG. 3**, forms very small clearances S at the four corners of the rectangular cross section of the channel **13*a*** in order to permit passage of the operation fluid **100** therethrough.

[0077] The pump chamber **14*a*** is a space in the form of a cylinder which has a center axis extending along the Z-axis direction and is filled with the operation fluid **100**, the space being formed above the channel **13*a*** in such a manner that a lower portion of the space communicates with one end portion of the passage **13*a***, located at the negative side in the direction of the X-axis. For example, the pump chamber **14*a*** has dimensions such that the bottom and top surfaces of the cylinder have a radius R of 0.5 mm, and the depth (height) h is 10 μm. A ceramic diaphragm (diaphragm portion) **17*a*** having a thickness (height) d of 10 μm is formed above the pump chamber **14*a***.

[0078] The pump chamber **14*b*** has the same shape as the pump chamber **14*a*** and is formed above the channel **13*a*** in such a manner that a lower portion of the space communicates with the other end portion of the passage **13*a***, located at the positive side in the direction of the X-axis. The pump chamber **14*b*** is filled with the operation fluid **100**. A ceramic diaphragm **17*b*** having the same shape as that of the diaphragm **17*a*** is formed above the pump chamber **14*b***.

[0079] The piezoelectric film **12*a*** constitutes a ceramic pump **18*a*** together with the pump chamber **14*a*** and the diaphragm **17*a***. The piezoelectric film **12*a*** has a thickness D of 20 microns and assumes the shape of a circular thin plate which has a radius r slightly smaller than the radius R of the pump chambers as viewed from above. The piezoelectric film **12***a* is fixed to the upper surface of the diaphragm **17***a* in such a manner that the piezoelectric film **12***a* is located above the pump chamber **14***a* and that the center of the circular bottom surface of the piezoelectric film **12***a* coincides with the center of the pump chamber **14***a* as viewed from above. When a voltage is applied to unillustrated paired electrodes formed to sandwich the piezoelectric film **12***a*, the piezoelectric film **12***a* increases and decreases the volume of the pump chamber **14***a* by deforming the diaphragm **17***a*, to thereby pressurize or depressurize the operation fluid **100** within the pump chamber **14***a*. Notably, the piezoelectric film **12***a* is polarized in the positive direction of the Z-axis.

[**0080**] The piezoelectric film **12***b* has the same shape as the piezoelectric film **12***a*. The piezoelectric film **12***b* constitutes a ceramic pump **18***b* together with the pump chamber **14***b* and the diaphragm **17***b*. That is, the piezoelectric film **12***b* is fixed to the upper surface of the diaphragm **17***b* in such a manner that the piezoelectric film **12***b* is located above the pump chamber **14***b*. When a voltage is applied to unillustrated paired electrodes, the piezoelectric film **12***b* increases and decreases the volume of the pump chamber **14***b* by deforming the diaphragm **17***b*, to thereby pressurize or depressurize the operation fluid **100** within the pump chamber **14***b*. Notably, the piezoelectric film **12***b* is also polarized in the positive direction of the Z-axis.

[**0081**] The internal-pressure-buffering-chamber-forming portion **15** forms an internal-pressure buffering chamber **15***a* which assumes a substantially elliptical shape having a major axis along the X-axis direction as viewed from above. The internal-pressure buffering chamber **15***a* has a length along the X-axis greater than the length L of the channel **13***a* and a length along the Y-axis (minor axis) direction greater than the width W of the channel **13***a*, and has a substantially rectangular cross section, as shown in **FIG. 3**. The internal-pressure buffering chamber **15***a* is formed within the base body **11** to be located below the channel **13***a* (on the Z-axis negative direction side of the channel **13***a*) in such a manner that the major axis of the chamber **15***a* coincides with the center axis of the channel **13***a* as viewed from above. The above-described operation fluid **100** fills a substantially central portion of the chamber **15***a* with respect to the X-axis direction. A compressible fluid for pressure buffering (hereinafter may be referred to as a "compressible fluid") **120** (having a compressibility considerably lower than that of the operation fluid **100**) fills the peripheral portions of the chamber **15***a*. In the present embodiment, the compressible fluid **120** is vapor of the operation fluid **100**. However, a predetermined amount of an inert gas may be mixed into the vapor, or the vapor may be replaced with a gas not containing the vapor.

[**0082**] The micro channel portion **16***a* forms a micro channel **16***a***1** which extends along the Z-axis direction and assumes the shape of a hollow cylinder. The micro channel **16***a***1** connects the left-hand operation chamber **13***a***1** of the channel **13***a* with the internal-pressure buffering chamber **15***a*. The micro channel **16***a***1** is also filled with the operation fluid **100**. For example, the micro channel **16***a***1** has dimensions such that the cylinder has a radius of 15 μm, and the length along the Z-axis direction (height of the cylinder) is 100 μm. The shape of the micro channel **16***a***1** is selected to produce a fluid resistance greater than that produced by the channel **13***a*. Specifically, the micro channel **16***a***1** has a so-called throttle function which produces a high passage resistance against abrupt pressure change of the operation fluid **100** within the channel **13***a*, to thereby substantially prohibit passage (movement) of the operation fluid **100** toward the internal-pressure buffering chamber **15***a*, and which produces only a small passage resistance against slow pressure change of the operation fluid **100** within the channel **13***a*, to thereby substantially permit passage (movement) of the operation fluid **100** toward the internal-pressure buffering chamber **15***a*.

[**0083**] The micro channel portion **16***b* forms a micro channel **16***b***1**, which has the same shape as the micro channel **16***a***1**. The micro channel **16***b***1** connects the right-hand operation chamber **13***a***2** of the channel **13***a* with the internal-pressure buffering chamber **15***a*. The micro channel **16***b***1** is also filled with the operation fluid **100**. The micro channel **16***b***1** also has a throttle function identical to that of the micro channel **16***a***1**.

[**0084**] As described above, the operation fluid **100** continuously fills the channel **13***a*, the pair of pump chambers **14***a* and **14***b*, the pair of micro channels **16***a***1** and **16***b***1**, and a portion of the internal-pressure buffering chamber **15***a*, which communicates with the channel **13***a* via the pair of micro channels **16***a***1** and **16***b***1**. Further, the vapor **120** of the operation fluid **100** fills the spaces of the internal-pressure buffering chamber **15***a* that are not filled with the operation fluid **100**.

[**0085**] Next, operation of the drive device **10** configured as described above will be described with reference to FIGS. **4** to **7**, which show different operation states. **FIG. 4** shows an initial state of the drive device **10** in which drive voltage is applied to none of the electrodes of the piezoelectric films **12***a* and **12***b*. In this case, since both the pump chambers **14***a* and **14***b* maintain their initial volumes, the operation fluid **100** charged into the pump chambers **14***a* and **14***b* and the channel **13***a* is neither pressurized or depressurized. Consequently, the movable body **110** accommodated within the channel **13***a* remains at the initial position (at the substantially central portion of the channel **13***a* with respect to the X-axis direction).

[**0086**] During drive, as shown in **FIG. 5, a** voltage is applied to the upper and lower electrodes of the piezoelectric film **12***a* disposed on the diaphragm **17***a* of the pump chamber **14***a* in such a manner that the upper electrode assumes a positive polarity and the lower electrode assumes a negative polarity. Simultaneously, a voltage is applied to the upper and lower electrodes of the piezoelectric film **12***b* disposed on the diaphragm **17***b* of the pump chamber **14***b* in such a manner that the upper electrode assumes a negative polarity and the lower electrode assumes a positive polarity.

[**0087**] As a result, the piezoelectric film **12***a* contracts along the transverse direction (i.e., in a plane substantially parallel to the X-Y plane, or in the direction perpendicular to the direction of the thickness D of the piezoelectric film **12***a*), so that the diaphragm **17***a* above the pump chamber **14***a* bends and deforms downward to thereby reduce the volume of the pump chamber **14***a*. As a result, the operation fluid **100** within the pump chamber **14***a* is pressurized, so that the operation fluid **100** flows from the pump chamber **14***a* to the operation chamber **13***a***1** of the channel **13***a*. Simultaneously, the piezoelectric film **12***b* expands along the transverse direction (i.e., in a plane substantially parallel to the X-Y plane), so that the diaphragm **17***b* bends and deforms upward to thereby increase the volume of the pump chamber **14***b*. As a result, the operation fluid **100** within the pump chamber **14***b* is depressurized, so that the operation fluid **100** flows from the operation chamber **13***a***2** of the channel **13***a* to the pump chamber **14***b*. Accordingly, due to the pressure difference between the pump chambers **14***a* and **14***b*, the movable body **110** accommodated within the channel **13***a* moves from the operation chamber **13***a***1** (pump chamber **14***a*) toward the operation chamber **13***a***2** (pump chamber **14***b*) (i.e., in the positive direction of the X-axis).

[**0088**] Further, when, as shown in **FIG. 6, a** voltage is applied to the upper and lower electrodes of the piezoelectric film **12***a* in such a manner that the upper electrode assumes a negative polarity and the lower electrode assumes a positive polarity, and simultaneously, a voltage is applied to the upper and lower electrodes of the piezoelectric film **12***b* in such a manner that the upper electrode assumes a positive polarity and the lower electrode assumes a negative polarity, the operation fluid **100** within the pump chamber **14***b* is pressurized, and the operation fluid **100** within the pump chamber **14***a* is depressurized. Due to the pressure difference, the movable body **110** moves from the operation chamber **13***a***2** (pump chamber **14***b*) toward the operation chamber **13***a***1** (pump chamber **14***a*) (i.e., in the negative direction of the X-axis).

[**0089**] During such ordinary driving, pressurization and depressurization of the pump chambers **14***a* and **14***b* are performed at high speed by varying the voltages applied to the piezoelectric films **12***a* and **12***b* at high speed (i.e., by having larger speed at which the applied voltages are increased and decreased). As a result, the passage resistances of the micro channels **16***a***1** and **16***b***1** become sufficiently large, and the operation fluid **100** within the channel **13***a* does not move to (go through), or return from, the micro channels **16***a***1** and **16***b***1**. Therefore, the pressure difference generated between the operation chambers **13***a***1** and **13***a***2** of the channel **13***a* acts on the movable body **110** without decreasing (without generation of so-called pressure escaping). Accordingly, the movable body **110** moves without fail.

[**0090**] Incidentally, in the case of a drive device which does not include the micro channels **16***a***1** and **16***b***1** and the internal-pressure buffering chamber **15***a*, when the operation fluid **100** thermally expands due to an increase in the environment temperature of the drive device, the pressure of the operation fluid **100** becomes excessive, possibly raising a problem such that the pump chambers **14***a* and **14***b* increase in volume, and the diaphragms **17***a* and **17***b* are pushed up and broken. Further, in the case in which the base body **11** is formed of an assembly of bonded ceramic sheets, there may arise the problem such that a bonded portion (the seal of the bonded portion) is broken, and the operation fluid **100** leaks.

[**0091**] By contrast, the drive device **10** according to the present invention is provided with the micro channels **16***a***1** and **16***b***1** and the internal-pressure buffering chamber **15***a*. In addition, since the temperature increase of the operation fluid **100** occurs slowly, the pressure of the operation fluid **100** increases slowly. Accordingly, as indicated by arrows in **FIG. 7**, an amount of the operation fluid **100** corresponding to expansion due to temperature elevation flows into the internal-pressure buffering chamber **15***a* via the micro channels **16***a***1** and **16***b***1**, which produce an extremely low passage resistance against such slow increase in pressure of the operation fluid **100**. Within the internal-pressure buffering chamber **15***a*, the vapor **120** of the operation fluid **100** is compressed, and pressure increase occurs. However, the pressure increase of the operation fluid **100** is slight, because the compressibility of gas is lower than that of liquid. Accordingly, there can be avoided the situation in which the diaphragms **17***a* and **17***b* above the pump chambers **14***a* and **14***b* are pushed up and broken and the situation in which a seal of the bond-assembled portion is broken, with resultant leakage of the operation fluid **100**. Further, when the operation fluid **100** thermally contracts due to a decrease in the environmental temperature of the drive device **10**, as indicated by arrows in **FIG. 8**, the operation fluid **100** returns from the internal-pressure buffering chamber **15***a* to the channel **13***a* via the micro channels **16***a***1** and **16***b***1**, because the temperature decrease of the operation fluid **100** occurs slowly.

[**0092**] As described above, by virtue of provision of the micro channels **16***a***1** and **16***b***1** and the internal-pressure buffering chamber **15***a*, the drive device **10** can be used within a wide temperature range, and can have enhanced reliability and durability.

[**0093**] Next, an operation which the drive device **10** performs in the initial state in order to finely adjust the position of the movable body **110** will be described by reference to FIGS. **9** to **12**. Here, it is assumed that, as shown in **FIG. 9**, in the initial state the movable body **110** remains at a position deviated to the side toward the piezoelectric film **12***a*. Such a state may result from variation, or erroneous work, involved in a fabrication process which will be described later; specifically, in a step of placing the movable body **110** in the channel **13***a*.

[**0094**] First, during a period of time from t1 to t2 shown in **FIG. 10**, voltages Va and Vb, which change at high speed, are applied to (the electrodes of) the piezoelectric films **12***a* and **12***b*, respectively. For example, the applied voltage Va is a drive voltage whose absolute value increases from 0 V to 50 V during a period of 1 to 20 μsec and which has a polarity such that the upper electrode becomes the positive side and the lower electrode becomes the negative side. Similarly, the applied voltage Vb is a drive voltage whose absolute value increases from 0 V to 50 V during a period of 1 to 20 μsec and which has a polarity such that the upper electrode becomes the negative side and the lower electrode becomes positive side. As a result, as shown in **FIG. 11**, the operation fluid **100** is pressurized in the pump chamber **14***a* and is depressurized in the pump chamber **14***b*, so that the movable body **110** moves toward the center (toward the pump chamber **14***b*). In this case, since the applied voltages Va and Vb change at high speed, the passage resistances of the micro channels **16***a***1** and **16***b***1** become sufficiently large, and thus the operation fluid **100** within the channel **13***a* does not move to, or return from, the micro channels **16***a***1** and **16***b***1**.

[**0095**] Subsequently, during a short period of time from t2 to t3 shown in **FIG. 10**, the applied voltages Va and Vb are maintained constant; and during a subsequent period of time from t3 to t4, the absolutes values of the applied voltages Va and Vb are decreased slowly to 0 V over a period of, for example, about 0.1 to 1 sec. In this case, since the passage resistances of the micro channels **16*a*1** and **16*b*1** become small, as shown in **FIG. 12**, the operation fluid **100** within the right-hand operation chamber **13*a*2** of the channel **13*a*** flows into the internal-pressure buffering chamber **15*a*** via the micro channel **16*b*1**, and the operation fluid **100** within the internal-pressure buffering chamber **15*a*** flows into the left-hand operation chamber **13*a*1** of the channel **13*a*** via the micro channel **16*a*1**. That is, the pressure change of the operation fluid **100** becomes sufficiently slow such that pressure escapes via the micro channels **16*a*1** and **16*b*1**, and the internal pressure of the pump chamber **14*a*** and **14*b*** and the channel **13*a*** hardly changes. Thus, the movable body **110** can be maintained stationary. Alternatively, as compared with the moving distance L0 of the movable body **110** upon application of voltages during the period of t1 to t2, the return distance L1 of the movable body **110** during the period of t3 to t4 can be reduced to about one-tenth (L1=L0/10).

[**0096**] Through performing the above-described operation once or a plurality of times, the movable body **110** can be positioned at a desired initial position. Further, the movable body **110** can be moved to stop at a desired position through appropriate selection of the peak values Vp and −Vp of the applied voltages Va and Vb shown in **FIG. 10**, the voltage change speed at which the applied voltages Va and Vb are changed to the peak values Vp and −Vp, and the voltage change speed at which the applied voltages Va and Vb are changed from the peak values Vp and −Vp to 0 V.

[**0097**] In the above-described embodiment, through application of voltages to the piezoelectric films **12*a*** and **12*b***, electric fields are applied to the piezoelectric films **12*a*** and **12*b*** in the positive direction (in the present embodiment, Z-axis positive direction) and the negative direction (Z-axis negative direction), respectively. However, in some cases, application of such electric fields is not desirable, because an electric field of a direction opposite the polarization direction of the piezoelectric films **12*a*** and **12*b*** cancels the polarization if the intensity of the electric field exceeds that of a coercive field. In view of this, a bias voltage may be applied so as to establish the initial state of the drive device **10**. In this case, the drive device **10** can be driven through use of electric fields of the same direction as that of the polarization. Specifically, for example, the potential of the lower electrode is maintained at 0 V, which is a reference potential, and a bias voltage of 25 V is applied to the upper electrode to establish an initial state. When the potential of the upper electrode of either one of piezoelectric film **12*a*** or **12*b*** is increased to 50 V, an electric field is applied to that piezoelectric film in the same direction as the polarization direction, so that the piezoelectric film contracts. As a result, the diaphragm **17*a*** or **17*b*** located under the piezoelectric film bends and deforms downward, and the corresponding pump chamber **14*a*** or **14*b*** pressurizes the operation fluid **100**. Simultaneously, when the potential of the upper electrode of the other of the piezoelectric films **12*a*** and **12*b*** is decreased to 0 V, the contraction of that piezoelectric film is cancelled. Accordingly, the diaphragm **17*a*** or **17*b*** located under the piezoelectric film bends and deforms upward with respect to the initial state, and the corresponding pump chamber **14*a*** or **14*b*** depressurizes the operation fluid **100**.

[**0098**] Next, a modification of the drive device according to the first embodiment will be described with reference to **FIG. 13**. The drive device **10-1** according to this modification differs from the drive device **10** shown in **FIG. 1** only in that a base body **11-1** of the drive device **10-1** includes a single micro channel **16*a*1**, whereas the base body **11** of the drive device **10** has the pair of micro channels **16*a*1** and **16*b*1**. This configuration can be employed only in the case in which the gap (clearance S shown in **FIG. 3**) between the movable body **110** and the channel **13*a*** can have a cross section equal to or greater than a predetermined value. Since this configuration can halve labor and time required to machine the micro channels, the drive device **10-1** can be fabricated at lower cost. However, in this modification, the stationary position of the movable body **110** in the initial state in which no voltage is applied to the drive device **10-1** is difficult to control. In relation to this point, the drive device **10** of the first embodiment is considered superior.

[**0099**] Note that in addition to the above-described gap (clearance S), a micro groove M may be formed in the wall surface of the channel **13*a***, as shown in, for example, **FIG. 14**, which shows a cross section of the channel **13*a***. The micro groove M may be configured in such a manner that the operation fluid **100** can enter the groove M insofar as the pressure change of the operation fluid **100** is slow and the surface of the movable body **110** cannot enter the micro groove M. Notably, the micro groove M can be applied to other embodiments of the present invention, and the number and shape of the micro grooves may be selected appropriately.

[**0100**] Further, the piezoelectric/electrostrictive film type actuator for a display device disclosed in, for example, Japanese Patent Application Laid-Open (kokai) No. 10-78549 can be applied to the piezoelectric films **12*a*** and **12*b***, the diaphragms **17*a*** and **17*b***, and the pump chambers **14*a*** and **14*b*** of the above-described drive devices **10** and **10-1** (and drive devices of other embodiments which will be described later). Since this actuator is small and can produce a large pressurizing force, it is suitable for the drive device of the present invention. Further, when the drive operation which has been described with reference to FIGS. **4** to **6** is performed, an important consideration is that the piezoelectric films **12*a*** and **12*b*** be formed of a piezoelectric material which has a large coercive electric field, because of occurrence of a state in which voltage is applied to the piezoelectric films **12*a*** and **12*b*** in the direction opposite the polarization direction of the piezoelectric films **12*a*** and **12*b***. When the intensity of a coercive electric field is low, the polarization may be disturbed through application of voltage in the direction opposite the polarization direction.

[**0101**] In order to reduce the amount of thermal expansion and contraction of the operation fluid **100** stemming from variation in the environmental temperature, it is desirable that the volumes of the pump chambers **14*a*** and **14*b*** be close to a minimum required value. In order to achieve this, the method disclosed in Japanese Patent Application Laid-Open (kokai) No. 9-229013 is preferably used to fabricate a diaphragm substrate used in the process of fabricating the above-described piezoelectric/electrostrictive film type actuator, because the disclosed method can reduce the depths of the pump chambers **14*a*** and **14*b*** to about 5 (minimum) to 10 μm.

[**0102**] Next, a drive device **20**, which serves as a portion of a circuit changeover switch according to a second embodiment of the present invention, will be specifically described, together with a method of fabricating the device. **FIG. 15** is a vertical sectional view of the drive device **20**, and **FIG. 16** is a plan view of the drive device **20**. Notably, **FIG. 15** is a sectional view of the drive device **20** taken along line **3-3** in **FIG. 16**. In the following description, the same structural portions in respective embodiments are denoted by the same reference numerals, and their detailed descriptions are not repeated.

[**0103**] The drive device **20** includes a base body **21** having a channel **13***a* which is formed to be exposed at the upper surface thereof; a connection plate (connection substrate) **22** disposed on the base body **21** and formed of a ceramic thin plate; and a pair of ceramic pumps **23***a* and **23***b* disposed on the connection plate **22**.

[**0104**] The connection plate **22** includes left-hand and right-hand channel connection holes **22***a* and **22***b*, which are formed at positions separated from each other along the X-axis direction and each assume the shape of a hollow cylinder. The bottom ends of the channel connection holes **22***a* and **22***b* are connected to the opposite end portions of the channel **13***a* with respect to the X-axis direction.

[**0105**] The ceramic pumps **23***a* and **23***b* are each formed of a ceramic thin plate(s). The ceramic pumps **23***a* and **23***b* include pump-chamber forming portions **24***a* and **24***b* having a substantially square shape as viewed from above; and piezoelectric films **25***a* and **25***b* fixed to the upper surfaces of the pump-chamber forming portions **24***a* and **24***b*, respectively. The pump-chamber forming portions **24***a* and **24***b* include pump chambers **24***a***1** and **24***b***1** having a shape similar to that of the pump chambers **14***a* and **14***b* of the drive device **10** according to the first embodiment; thin-plate-shaped diaphragms **26***a* and **26***b* formed on the pump chambers **24***a***1** and **24***b***1**, respectively; and pump-chamber connection holes **24***a***2** and **24***b***2** which each assume the shape of a hollow cylinder and which connect bottom portions of the pump chambers **24***a***1** and **24***b***1** with the upper portions of the channel connection holes **22***a* and **22***b*. The pump chambers **24***a***1** and **24***b***1** and the pump-chamber connection holes **24***a***2** and **24***b***2** are filled with the operation fluid **100** as in the case of the channel connection holes **22***a* and **22***b* and the channel **13***a*.

[**0106**] The ceramic pumps **23***a* and **23***b* are piezoelectric/electrostrictive film type actuators which are fabricated by utilization of the method and structure disclosed in Japanese Patent Application Laid-Open Nos. 10-78549 and 7-214779, etc. The ceramic pumps **23***a* and **23***b* are formed on the base body **21** serving as a channel substrate and the connection plate **22**, in a stacked configuration.

[**0107**] The operation of the drive device **20** for driving (moving) the movable body **110** is the same as that of the drive device **10**. Further, the operation of the drive device **20** for absorbing changes in the internal pressure due to thermal expansion and contraction of the operation fluid **100** charged into the pump chambers **24***a***1** and **24***b***1**, the pump-chamber connection holes **24***a***2** and **24***b***2**, the channel connection holes **22***a* and **22***b*, and the channel **13***a* is also the same as that of the drive device **10**.

[**0108**] Next, a method of fabricating the drive device **20** will be described. First, a fabrication process of the ceramic pumps **23***a* and **23***b*, which are piezoelectric/electrostrictive film type actuators, will be described. As shown in **FIG. 17**, ceramic green sheets **201**, **202**, and **203** are prepared. Subsequently, by means of mechanical machining such as punching, a window portion **202***a* for forming the pump chamber **24***a***1** (**24***b***1**) is formed in the green sheet **202**, and a hole portion **203***a* is formed in the green sheet **203**. The hole portion **203***a* is to serve as the pump-chamber connection hole **24***a***2** (**24***b***2**) for connecting the pump chamber **24***a***1** (**24***b***1**) with the channel **13***a* via the channel connection hole **22***a* (**22***b*).

[**0109**] Subsequently, the green sheets **201**, **202**, and **203** are stacked and heated under pressure to thereby be fired. Thus, the green sheets **201**, **202**, and **203** are integrated together to thereby form a diaphragm substrate **204**. Subsequently, a lower electrode **205** and an auxiliary electrode **206** as disclosed in Japanese Patent Application Laid-Open (kokai) No. 5-267742 are formed on the substrate **204** The electrode **205** and the electrode **206** are formed from a high-melting-point metal and in accordance with a thick-film forming process, such as screen printing. If necessary, the substrate is subjected to heat treatment such as firing. A piezoelectric film **207** is formed on the electrodes in accordance with a thick-film forming process, and finally an upper electrode **208** is formed. In forming the upper electrode **208**, a thin-film forming process such as sputtering may be used instead of the thick-film forming process. In the above-described manner, portions corresponding to the ceramic pumps **23***a* and **23***b* are fabricated.

[**0110**] **FIG. 18** shows a different method for fabricating the portions corresponding to the above-described ceramic pumps **23***a* and **23***b*. In this method, during the process of fabricating the diaphragm substrate, in place of using the above-described green sheet **202**, a spacer layer **202***b* is formed on the green sheet **203** by means of screen printing in such a manner that the spacer layer **202***b* has a window portion **202***a* for forming the pump chamber **24***a***1** (**24***b***1**) . The remaining portion is the same as that of the fabrication method having been described with reference to **FIG. 17**. The details of this fabrication method are disclosed in Japanese Patent Application Laid-Open No. 9-229013. The technique disclosed in the patent publication enables the depth of the pump chamber **24***a***1** (**24***b***1**) (the height of the hollow cylinder along the Z-axis direction in the assembled state) to be reduced to about 10 μm. Therefore, the diaphragm substrate (i.e., the ceramic pumps **23***a* and **23***b*) can have a pump chamber **24***a***1** (**24***b***1**) of small volume.

[**0111**] Next, a method of fabricating the base body (channel substrate) **21** will be described with reference to **FIG. 19**. First, an appropriate material is selected from plastic, glass, metal, and ceramics, and then substrates **211**, **212**, and **213** are made using the selected material. Subsequently, the channel **13***a*, the micro channels **16***a***1** and **16***b***1**, and the internal-pressure buffering chamber **15***a* are formed in the substrates **211**, **212**, and **213**, respectively. Further, an operation fluid injection hole **213***a* is formed in the substrate **213** in such a manner that the operation fluid injection hole **213***a* penetrates from the bottom wall surface of the internal-pressure buffering chamber **15***a* to the lower surface of the substrate **213**. A machining method suitable for forming channels, etc. in the substrates **211**, **212**, and **213** is selected from among punching, etching, laser machining, coining, sandblasting, etc. Subsequently, the substrates **211**, **212**, and

213 are stacked and bonded by use of epoxy resin or the like to thereby complete the base body 21.

[0112] Notably, in order to make the thermal expansion coefficient of the base body 21 equal, to the extent possible, to that of the ceramic pumps 23a and 23b, which are piezoelectric/electrostrictive film type actuators, the substrates 211, 212, and 213 are preferably formed of ceramic or glass whose expansion coefficient is close to that of the ceramic pumps. Further, etching or coining is preferably used for depression machining; i.e., forming the channel 13a and the internal-pressure buffering chamber 15a having a depth of 200 μm. Alternatively, the substrate 211 having the channel 13a may be obtained through bonding plates each having a punched window portion corresponding to the channel 13a, and a closure plate. Similarly, the substrate 213 having the internal-pressure buffering chamber 15a may be obtained through bonding plates each having a punched window portion corresponding to the internal-pressure buffering chamber 15a, and a closure plate. Meanwhile, the micro channels 16a1 and 16b1, which must have a high aspect ratio, are preferably formed by means of laser machining or by means of a process of punching a ceramic green sheet in order to form holes having a high aspect ratio therein, and then firing the green sheet.

[0113] Meanwhile, as shown in FIG. 20, as in the case of the substrate 211, the pair of channel connection holes 22a and 22b are formed in a connection substrate 214, which is to serve as the connection plate 22; and finally, the ceramic pumps 23a and 23b (piezoelectric/electrostrictive film type actuators), the connection substrate 214, and the base body 21 are stacked and united by use of joining means such as adhesion-bonding, press-bonding, or diffusion joining.

[0114] During this process, the movable body 110 is placed at a predetermined position within the channel 13a. When the movable body 110 is a vacuole (liquid mass), a material that is insoluble against the vacuole is selected for the operation fluid 100, and the movable body 110 is placed at the predetermined position within the channel 13a by use of a dispenser or the like. When the movable body is a bubble, an injection hole for injecting a gas is branched from the channel 13a, and the bubble and the operation fluid 100 are injected into the channel 13a via the injection hole. There after, the injection hole is sealed.

[0115] Subsequently, the thus-obtained stacked product is placed under vacuum by use of, for example, a vacuum chamber, and a predetermined amount of the operation fluid 100 is injected from the injection hole 213a into the internal-pressure buffering chamber 15a by use of metering means such as a dispenser. Notably, before injection, the operation fluid 100 is preferably subjected to vacuum degassing in order to remove dissolved gases. In order to charge the injected operation fluid 100 into the channel 13a, the pump chambers 24a1 and 24b1, etc., via the micro channels 16a1 and 16b1, the pressure within the channel is increased to a predetermined level by means of a seal gas 120, which is a compressible fluid such as an inert gas, vapor of the operation fluid 100, or a mixture thereof. Finally, the injection hole 213a is sealed by use of adhesive or the like to thereby obtain the drive device 20 of the present invention.

[0116] Notably, the depth (height along the Z-axis direction) of the internal-pressure buffering chamber 15a is desirably rendered greater than the depth of the pump chambers 24a1 and 24b1, as well as greater than the depth of the channel 13a, so as to enable smooth charging. With this configuration, when the operation fluid 100 is liquid, the radius of curvature of the gas-liquid interface within the internal-pressure buffering chamber 15a becomes greater than those of the gas-liquid interfaces formed within the pump chambers 24a1 and 24b1 and the channel 13a under charging, whereby charging can be performed more smoothly.

[0117] Next, a drive device 30, which serves as a portion of a circuit changeover switch according to a third embodiment of the present invention, will be described. As shown in FIG. 21, which shows a vertical cross section of the drive device 30, the drive device 30 differs from the drive device 20 of the second embodiment shown in FIG. 15 only in that the two pump-chamber forming portions 24a and 24b of the two ceramic pumps 23a and 23b (piezoelectric/electrostrictive film type actuators) are replaced with a single pump-chamber forming portion 24c and in that the connection plate 22 provided in the drive device 20 is omitted. The drive device 30 can achieve the effect of lowering fabrication cost, by virtue of employing fewer bonded portions and components. In the drive device 20 shown in FIG. 15, the connection plate 22 can be formed of a transparent glass or a metal plate which also serves as an electrode. However, in the drive device 30 shown in FIG. 21, since the connection plate 22 does not exist, the material of the pump-chamber forming portion 24c is restricted to the material of the ceramic substrate of the piezoelectric/electrostrictive film type actuators.

[0118] Next, a drive device 40, which serves as a portion of a circuit changeover switch according to a fourth embodiment of the present invention, will be described. In the drive device 40, whose vertical cross section is shown in FIG. 22, a base body 41 includes a porous member 16c in place of the micro channels 16a1 and 16b1 of the drive device 20 of the second embodiment shown in FIG. 15; and the channel 13a and the internal-pressure buffering chamber 15a are connected together via the porous member 16c. Provision of the porous member 16c achieves the same effect as that obtained through formation of a large number of extremely fine (thin) micro channels 16a1 and 16b1. In order to facilitate assembly and improve seal performance, the porous member 16c preferably has a tapered or stepped side surface, as shown in FIG. 22.

[0119] Next, a drive device 50, which serves as a portion of a circuit changeover switch according to a fifth embodiment of the present invention, will be described. FIG. 23 is a vertical sectional view of the drive device 50, and FIG. 24 is a plan view of the drive device 50. Notably, FIG. 23 is a sectional view of the drive device 50 taken along line 4-4 in FIG. 24. In the drive device 50, in place of the piezoelectric film 25b of the ceramic pump 23b provided in the drive device 30 shown in FIG. 21, a ceramic pump 23c having a pair of piezoelectric films 25c1 and 25c2 is provided. Like the piezoelectric film 25a, the piezoelectric films 25c1 and 25c2 are polarized in the positive direction of the Z-axis.

[0120] The piezoelectric films 25c1 and 25c2 each assume an elliptical shape having a long axis along the Y-axis direction as viewed from above. The piezoelectric films 25c1 and 25c2 are fixed onto the diaphragm 26b, which is a ceramic thin plate, in such a manner that their long axes become parallel to each other while being separated by a predetermined distance along the direction of the X-axis. A pump chamber **27**, which is formed under the diaphragm **26***b*, assumes an elliptical shape having its long axis along the Y-axis direction as viewed from above, as in the case of the piezoelectric films **25***c***1** and **25***c***2**. The piezoelectric films **25***c***1** and **25***c***2** are disposed in such a manner that they sandwich the pump chamber **27** as viewed from above, and that about one-half of the piezoelectric film **25***c***1** and one-half of the piezoelectric film **25***c***2** overlap the pump chamber **27** as viewed from above. The pump chamber **25***a* is also formed such that it assumes an elliptical shape having a long axis along the Y-axis direction as viewed from above.

[**0121**] Next, operation of the drive device **50** configured as described above will be described. As shown in **FIG. 25**, voltages of the same polarity are applied to the piezoelectric films **25***c***1** and **25***c***2** and the piezoelectric film **25***a*. That is, a drive voltage which changes at high speed is applied to each of the piezoelectric films **25***a*, **25***c***1**, and **25***c***2** in such a manner that a positive voltage is applied to the upper electrode and a negative voltage is applied to the lower electrode. Thus, the diaphragm **26***a* bends and deforms downward due to contraction of the piezoelectric film **25***a*. In contrast, the diaphragm **26***b* displaces upward at the central portion due to contraction of the piezoelectric films **25***c***1** and **25***c***2**. As a result, the operation fluid **100** is pressurized in the pump chamber **24***a***1** and is depressurized in the pump chamber **27**, so that the movable body **110** moves from the pump chamber **24***a***1** toward the pump chamber **27** (in the positive direction of the X-axis)

[**0122**] Piezoelectric/electrostrictive film type actuators (ceramic pumps) which operate in the above-described manner are disclosed in Japanese Patent Application Laid-Open (kokai) No. 7-202284. Unlike the case of first through fourth embodiments, in the fifth embodiment (drive device **50**), voltages of constant polarity are applied to the piezoelectric films **25***c***1**, **25***c***2**, and **25***a*, and the piezoelectric films **25***c***1**, **25***c***2**, and **25***a* can be driven at all times in the same polarity as that of the polarization electric field thereof. Therefore, the piezoelectric films **25***c***1**, **25***c***2**, and **25***a* can be formed of a material of weak coercive field. Further, it should be understood that even in the case in which the drive device is configured in such a manner that one of the pair of pumps can provide only pressurization or both pressurization and depressurization and the other pump can provide depressurization only, and the pumps are operated in such a manner, the drive device may sufficiently provide required functions and performance. By contrast, when the pump structure of the drive devices **10**, **20**, **30**, and **40** of the first through fourth embodiments is employed, film of an electrostrictive material cannot be used as a piezoelectric film of a pump which provides depressurization only, unless a special drive scheme, such as application of bias voltage, is employed. This is because an electrostrictive material does not expand, irrespective of the direction of an applied electric field, although it contracts along a direction perpendicular to the applied electric field, and therefore, the electrostrictive material cannot bend or deform a diaphragm upward. By contrast, in the case of the piezoelectric films **25***c***1** and **25***c***2** of the pump **23***c* of the drive device **50** according to the fifth embodiment, since the piezoelectric films **25***c***1** and **25***c***2** can bend and deform the diaphragm **26***b* upward through their contracting actions to thereby reduce the internal pressure of the pump chamber **27**, film of an electrostrictive material can be used as the piezoelectric films **25***c***1** and **25***c***2**.

[**0123**] Notably, as shown in **FIG. 26**, there may be provided a necessary number of pumps **23***d* which are similar to the pump **23***c* and which have pump chambers of an appropriate shape, depending on the performance of each device. In such a case, if a configuration for driving the pumps individually is employed, the differential pressure acting on the movable body **110** can be adjusted by, for example, properly changing the number of driven pumps, to thereby control the amount of movement and/or moving speed of the movable body **110**.

[**0124**] Next, an example application of the above-described circuit changeover switches (drive devices) of the first to fifth embodiments will be described. A circuit changeover switch **60** shown in **FIG. 27** includes the above-described drive device **10**, and is provided with a common electrode **61** formed of platinum, gold, nickel, or any other suitable material, and a pair of changeover electrodes **62***a* and **62***b* formed of platinum, gold, nickel, or any other suitable material.

[**0125**] The common electrode **61** is formed on a lower wall surface (wall surface on the negative side with respect to the Z-axis direction) **13***a***-1**, which is one of the wall surfaces constituting the channel **13***a*, in such a manner that the common electrode **61** is exposed to the channel **13***a* at a position between the micro channels **16***a***1** and **16***b***1**. The common electrode **61** is electrically connected to an external electric component via an unillustrated connection line (terminal electrode) so that the electrical potential of the common electrode **61** is transmitted to the electric component.

[**0126**] The changeover electrodes **62***a* and **62***b* have the same shape and are formed on an upper wall surface (wall surface on the positive side with respect to the Z-axis direction) **13***a***-2**, which is another one of the wall surfaces constituting the channel **13***a*, in such a manner that the changeover electrodes **62***a* and **62***b* are exposed to the channel **13***a* so as to face the common electrode **61**. The changeover electrodes **62***a* and **62***b* are mutually separated along the X-axis direction. The changeover electrodes **62***a* and **62***b* are electrically isolated from each other, and electrically connected to the external electric component via unillustrated connection lines (terminal electrodes) so that their electrical potentials are transmitted to the electric component. Notably, in the following description, the changeover electrode **62***a* will be called the first changeover electrode **62***a*, and the changeover electrode **62***b* will be called the second changeover electrode **62***b*.

[**0127**] The movable body **110** is formed of an electrically conductive liquid metal such as mercury or Ga-base alloy and has a size substantially the same as that of the first changeover electrode **62***a* (or the second changeover electrode **62***b*) when viewed from the side. The movable body **110** moves within the channel **13***a* while maintaining contact with the common electrode **61**, and selectively comes into contact with the first changeover electrode **62***a* or the second changeover electrode **62***b*. In other words, the first changeover electrode **62***a* and the second changeover electrode **62***b* are electrically connected to the common electrode **61** via the movable body **110**.

[0128] Next, operation of the circuit changeover switch **60** will be described. **FIG. 27** shows an initial state of the drive device **10** in which drive voltage is applied to none of the electrodes of the piezoelectric films **12***a* and **12***b*. In this state, the movable body **110** comes into contact with the first changeover electrode **62***a* and the common electrode **61** and does not come into contact with the second changeover electrode **62***b*. Thus, the first changeover electrode **62***a* and the common electrode **61** are electrically connected to each other. Notably, the position of the movable body **110** in such an initial state is adjusted by the method having been described with reference to FIGS. **9** to **12**.

[0129] Meanwhile, during drive, as shown in **FIG. 28, a** voltage is applied to the upper and lower electrodes of the piezoelectric film **12***a* by means of an unillustrated control circuit in such a manner that the upper electrode assumes a positive polarity and the lower electrode assumes a negative polarity. Simultaneously, a voltage is applied to the upper and lower electrodes of the piezoelectric film **12***b* in such a manner that the upper electrode assumes a negative polarity and the lower electrode assumes a positive polarity. As a result of application of the drive voltage, the pump chambers **14***a* and **14***b* operate; and by virtue of a pressure difference of the operation fluid **100** generated upon operation of the pump chambers **14***a* and **14***b*, the movable body **110** moves from the operation chamber **13***a***1** (pump chamber **14***a*) toward the operation chamber **13***a***2** (pump chamber **14***b*) (i.e., in the positive direction of the X-axis) up to a position where the movable body **110** comes into contact with the second changeover electrode **62***b*, to thereby electrically connect the second changeover electrode **62***b* and the common electrode **61**.

[0130] Subsequently, the control circuit removes the drive voltage applied to the respective electrodes of the piezoelectric films **12***a* and **12***b*. As a result, the pump chambers **14***a* and **14***b* return to their original states; and, by virtue of a pressure difference of the operation fluid **100** generated while the pump chambers **14***a* and **14***b* return to their original states, the movable body **110** moves from the operation chamber **13***a***2** toward the operation chamber **13***a***1** (i.e., in the negative direction of the X-axis) up to a position where the movable body **110** comes into contact with the first changeover electrode **62***a*, to thereby electrically connect the first changeover electrode **62***a* and the common electrode **61**.

[0131] As described above, the circuit changeover switch **61** selectively connects the first changeover electrode **62***a* or the second changeover electrode **62***b* to the common electrode **61** in order to establish electrical continuity therebetween, by moving the movable body **110**. The movable body **110** exhibits a higher degree of wettability for each of the first and second changeover electrodes **62***a* and **62***b* and a lower degree of wettability for the wall surface of the channel **13***a* at portions where the first and second changeover electrodes **62***a* and **62***b* are not provided. Therefore, the movable body **110** reliably maintains contact with the first changeover electrodes **62***a* in the initial state and contact with the second changeover electrodes **62***b* in the driven state.

[0132] Next, a specific application of the above-described circuit changeover switch **60** will be described with reference to **FIG. 29**. The system shown in **FIG. 29** includes two circuit changeover switches each having the same structure as that of the circuit changeover switch **60**. These switches are used as a diversity antenna changeover switch and a transmission/reception changeover switch of a portable information terminal called PDA (Personal Digital Assistant) that is configured to enable radio communications.

[0133] More specifically, the system includes a main antenna **301**, a diversity antenna **302**, a diversity antenna changeover switch **303** having the same structure as that of the circuit changeover switch **60**, d transmission/reception changeover switch **304** having the same structure as that of the circuit changeover switch **60**, a power amplifier **305**, an RF-IF converter **306**, an IF modem **307**, and a baseband processor **308**.

[0134] The main antenna **301** and the diversity antenna **302** are electrically connected to a first changeover electrode **303***a* and a second changeover electrode **303***b*, respectively, of the diversity antenna changeover switch **303**. A common electrode **303***c* of the diversity antenna changeover switch **303** is electrically connected to a common electrode **304***c* of the transmission/reception changeover switch **304**. A first changeover electrode **304***a* of the transmission/reception changeover switch **304** is electrically connected to the RF-IF converter (radio frequency—intermediate frequency converter) **306**; and a second changeover electrode **304***b* of the transmission/reception changeover switch **304** is electrically connected to the power amplifier **305**. The baseband processor **308** is electrically connected to the RF-IF converter **306** via the IF modem **307** and is electrically connected to the power amplifier **305**. The power amplifier **305** is further connected to the RF-IF converter **306**. The upper and lower electrodes of the respective piezoelectric films of the diversity antenna changeover switch **303** and the transmission/reception changeover switch **304** are connected to an unillustrated control circuit.

[0135] Next, operation of the system will be described. When the system is in a "reception wait state" in which the system awaits arrival of radio waves from the outside, the control circuit does not apply any drive voltage to the upper and lower electrodes of the respective piezoelectric films of the diversity antenna changeover switch **303**. As a result, the diversity antenna changeover switch **303** maintains its initial state, and a movable body **303***d* of the switch **303** stays at the position shown in **FIG. 29** in order to maintain connection between the first changeover electrode **303***a* and the common electrode **303***c*.

[0136] When the system is in the reception wait state, the control circuit does not apply any drive voltage to the upper and lower electrodes of the respective piezoelectric films of the transmission/reception changeover switch **304**. As a result, the transmission/reception changeover switch **304** maintains its initial state, and a movable body **304***d* of the switch **304** stays at the position shown in **FIG. 29** in order to maintain connection between the first changeover electrode **304***a* and the common electrode **304***c*.

[0137] As described above, the present system operates in such a manner that when the system in the reception wait state, the diversity antenna changeover switch **303** and the transmission/reception changeover switch **304** electrically connect the main antenna **301** to the RF-IF converter **306** without consuming electrical power.

[0138] In a reception mode, the control circuit selects from the main antenna **301** and the diversity antenna **302** an antenna suitable for reception (e.g., an antenna which provides high received-radio-wave intensity) . When the main antenna **301** is selected, the control circuit does not apply any drive voltage to the upper and lower electrodes of the respective piezoelectric films of the diversity antenna changeover switch **303**. As a result, the diversity antenna changeover switch **303** maintains its initial state, and the movable body **303**_d_ of the switch **303** stays at the position shown in **FIG. 29** in order to maintain connection between the first changeover electrode **303**_a_ and the common electrode **303**_c_.

[**0139**] In contrast, when the diversity antenna **302** is selected, the control circuit applies drive voltages to the upper and lower electrodes of the respective piezoelectric films of the diversity antenna changeover switch **303**. As a result, the movable body **303**_d_ of the diversity antenna changeover switch **303** moves rightward in **FIG. 29** in order to electrically connect the second changeover electrode **303**_b_ and the common electrode **303**_c_. Thus, there is established a state in which the diversity antenna **302** can be electrically connected to the RF-IF converter **306** or the power amplifier **305**. Further, in accordance with needs, the control circuit applies drive voltages to the upper and lower electrodes of the respective piezoelectric films of the transmission/reception changeover switch **304** in order to move the movable body **304**_d_ of the transmission/reception changeover switch **304** leftward in **FIG. 29**, to thereby connect the common electrode **304**_c_ to the power amplifier **305** via the movable body **304**_d_ and the second changeover electrode **304**_b_. As a result, the received signal is amplified to an appropriate level. Notably, the control circuit may be configured in such a manner that no drive voltage is applied to the upper and lower electrodes of the respective piezoelectric films of the transmission/reception changeover switch **304** throughout the entire reception period, in order to maintain the switch **304** in the initial state.

[**0140**] Further, the control circuit may be configured in such a manner that in the above-described reception wait state as well, the control circuit selects an appropriate antenna as in the reception mode. Even in the case where the control circuit is configured in the above-described manner, the diversity antenna changeover switch **303** can maintain the reception wait state without consuming electrical power, at least when the main antenna **301** is determined (selected) to be an appropriate antenna.

[**0141**] In a transmission mode, the control circuit does not apply any drive voltage to the upper and lower electrodes of the respective piezoelectric films of the diversity antenna changeover switch **303**, whereby the diversity antenna changeover switch **303** selects the main antenna **301** as a transmission antenna. Further, the control circuit applies drive voltages to the upper and lower electrodes of the respective piezoelectric films of the transmission/reception changeover switch **304** in order to connect the common electrode **304**_c_ to the power amplifier **305** via the movable body **304**_d_ and the second changeover electrode **304**_b_. As a result, a transmission signal amplified by the power amplifier **305** is transmitted from the main antenna **301**. Of course, in the transmission mode as well, drive voltages may be applied to the upper and lower electrodes of the respective piezoelectric films of the diversity antenna changeover switch **303** so as to select the diversity antenna **302** through the diversity antenna changeover switch **303**.

[**0142**] Next, a circuit changeover switch **70** according to the present invention which includes a drive device **20'** similar to the drive device **20** will be described with reference to **FIG. 30**. In the circuit changeover switch **70**, a common electrode **71**, a first changeover electrode **72**_a_, and a second changeover electrode **72**_b_, which are similar to those of the circuit changeover switch **60**, are provided on the drive device **20'**. The circuit changeover switch **70** operates in the same manner as the circuit changeover switch **60**.

[**0143**] A method of fabricating the circuit changeover switch **70** will be described. The ceramic pumps **23**_a_ and **23**_b_, which are piezoelectric/electrostrictive film-type actuators, are fabricated by the method illustrated in **FIG. 17** or **FIG. 18**. A substrate **21'** is fabricated by the fabrication method illustrated in **FIG. 31**. The fabrication method illustrated in **FIG. 31** is identical with the fabrication method illustrated in **FIG. 19**, except that before lamination and bonding of the substrate **211**, a substrate **212'** corresponding to the substrate **212**, and a substrate **213'** corresponding to the substrate **213**, a terminal electrode **71**_a_ for leading out (providing) electrical potential of the common electrode **71**, a terminal electrode **72**_a_**1** for leading out (providing) electrical potential of the first changeover electrode **72**_a_, and a terminal electrode **72**_b_**1** for leading out (providing) electrical potential of the second changeover electrode **72**_b_ are formed on the upper surface of the substrate **212'** by means of a thick-film forming technique such as screen printing.

[**0144**] Subsequently, the circuit changeover switch **70** is fabricated by the fabrication method illustrated in **FIG. 32**. The fabrication method illustrated in **FIG. 32** is identical with the fabrication method illustrated in **FIG. 20**, except that the first changeover electrode **72**_a_ and the second changeover electrode **72**_b_ are formed on the lower surface of a substrate **214'** corresponding to the substrate **214**, by means of a thick-film forming technique such as screen printing, and that the first changeover electrode **72**_a_ and the second changeover electrode **72**_b_ are electrically connected to the terminal electrodes **72**_a_**1** and the terminal electrode **72**_b_**1**, respectively, by use of, for example, electrically conductive adhesive, when the ceramic pumps **23**_a_ and **23**_b_, the connection substrate **214'**, and the substrate **21'** are laminated and unified by coupling means such as bonding, compression bonding, or diffusion joining. In this manner, the circuit changeover switch **70** is fabricated.

[**0145**] As described above, a small switch or small relay can be fabricated through modification of the drive device of the present invention in such a manner that the movable body **110** is formed of a liquid droplet of liquid metal; and a plurality of electrodes **62**_a_, **62**_b_, etc., which are connected to an external circuit by means of lead wires, are provided on the wall surfaces of the channel **13**_a_.

[**0146**] An example of such a switch is a mercury micro relay of a type which realizes switching operation through movement of a mercury droplet and which utilizes, as a drive force for moving the mercury droplet, pressure created upon instantaneous generation of a bubble by means of heating by a micro heater (see, for example, J. Kim et al., Proc. 46th Annual Int. Relay Conf., Oak Brook, Ill., April 1998, pp. 19-1-19-8). This switch is reported to have various features such as a wide frequency range of DC to 10 GHz, high insulating resistance and low insertion loss in the GHz band, and no signal bounce.

[0147] In contrast with such a conventional switch, the above-described circuit changeover switch of the present invention utilizes piezoelectric/electrostrictive actuators for generating drive force for moving the movable body **110**, which is a droplet of mercury. As a result, as compared with the above-described mercury micro relay of the type which utilizes pressure at the time of generation of a bubble, the above-described circuit changeover switch of the present invention has advantages of no heat accumulation and reduced consumption of electrical power. Therefore, as having been described with reference to **FIG. 29**, the circuit changeover switch of the present invention can be suitably used in, for example, PDAs, which have recently been developed to improve functions and capability of radio communications, in order to serve as an antenna changeover switch for switching antennas used for both reception and sending (transmission), a circuit changeover switch for selectively connecting one of a sending (transmission) circuit and a reception circuit to an antenna, or any other switch.

[0148] When the circuit changeover switch of the present invention is used in the above-described application, unlike conventional semiconductor switches, the circuit changeover switch of the present invention provides the following advantages. (a) Since standby or idle electrical power is not consumed unless reception or transmission is performed, the overall electrical power consumption of the system can be reduced, and battery life can be extended. (b) Transmission and reception signals hardly deteriorate even in a high frequency band of 1 GHz or higher or even 5 GHz or higher. Further, as compared with a wet-type mercury lead switch, the circuit changeover switch of the present invention has advantages in that no restriction is imposed on inclination angle during use, and a greatly extended life is attained, because the drive sections (movable sections such as pump chambers) are integrally formed of ceramic.

[0149] Additionally, the circuit changeover switch of the present invention is suitable for use as a DC changeover switch. In other words, application of the circuit changeover switch of the present invention is not limited to switches for high frequency bands.

[0150] Although the common electrode **61** (**71**) of the above-described circuit changeover switch **60** (**70**) has been described as being a single electrode, the common electrode **61** (**71**) is preferably divided into two pieces corresponding to the first changeover electrode **62***a* (**72***a*) and the second changeover electrode **62***b* (**72***b*) (i.e., an electrode **61***a* facing the first changeover electrode **62***a* and an electrode **61***b* facing the second changeover electrode **62***b* are provided), as shown in **FIG. 33**; and the electrodes **61***a* and **61***b* are electrically connected together outside the circuit changeover switch **60** (**70**). This configuration is preferable, because the movable body **110**, which is formed of, for example, mercury having a high degree of wettability for the electrode surfaces, can move within the channel **13***a* with reduced resistance. Further, the first and second changeover electrodes and the common electrodes may be exposed to any wall surface (upper surface, lower surface, side wall surface) of the channel, so long as the insulation among the electrodes is secured.

[0151] Next, a drive device **500**, which serves as a portion of a circuit changeover switch according to a sixth embodiment of the present invention, will be described. **FIG. 34** is a plan view of the drive device **500**; and **FIG. 35** is a sectional view of the drive device **500** taken along line A5-A5 in **FIG. 34**. The drive device **500** differs from the drive device **10** of the first embodiment mainly in that an internal-pressure buffering chamber is provided at the same vertical position as that of the channel and that micro channels extend along the Y-axis (maintaining the same vertical position) so as to connect the channel and the internal-pressure buffering chamber.

[0152] Specifically, the drive device **500** comprises a ceramic base body **501** of a substantially rectangular parallelepiped shape having sides which respectively extend along the X-axis, Y-axis, and Z-axis directions, which are mutually perpendicular; and a pair of piezoelectric films (piezoelectric/electrostrictive elements) **502***a* and **502***b*. As shown in **FIG. 35**, the base body **501** is formed through a process of successively laminating thin plates of ceramic (hereinafter referred to as "ceramic sheets") **501-1** to **501-4** and firing the resultant laminate in such a manner that the base body **501** contains therein a channel forming portion **503**, a pair of pump chambers **504***a* and **504***b*, an internal-pressure-buffering-chamber-forming portion **505**, and a pair of micro channel portions **506***a* and **506***b*.

[0153] The channel forming portion **503** forms a channel **503***a* similar to the channel **13***a* of the drive device **10** according to the first embodiment. The channel **503***a* is a hollow space which is defined by side wall surfaces of a substantially rectangular parallelepiped through hole formed in the ceramic sheet **501-2**, the upper surface of the ceramic sheet **501-1**, and the lower surface of the ceramic sheet **501-3**. The space has a substantially rectangular parallelepiped shape having sides extending along the X-axis, Y-axis, and Z-axis directions, respectively, and has a long axis along the X-axis direction (a rectangular columnar space whose longitudinal axis lies in a plane parallel to the X-Y plane). As in the case of the channel **13***a*, an operation fluid **100** and a movable body **110** are accommodated within the channel **503***a*, whereby the channel **503***a* is divided substantially into two operation chambers **503***a***1** and **503***a***2** by means of the movable body **110**. Within the channel **503***a*, the movable body **110** is present in the form of a single mass and forms very small clearances S at the four corners of the rectangular cross section of the channel **503***a* in order to permit passage of the operation fluid **100** therethrough (see **FIG. 3**). Notably, a groove similar to the groove M shown in **FIG. 14** may be formed on the wall of the channel **503***a*.

[0154] The pump chambers **504***a* and **504***b* are similar to the pump chambers **14***a* and **14***b*, respectively, of the drive device **10**. The pump chambers **504***a* and **504***b* are cylindrical spaces defined by side wall surfaces of through holes formed in the ceramic sheet **501-3**, the upper surface of the ceramic sheet **501-2**, and the lower surface of the ceramic sheet **501-4**. Thin-plate shaped ceramic diaphragms **507***a* and **507***b* formed of the ceramic sheet **501-4** are provided above the pump chambers **504***a* and **504***b*, respectively. In other words, the diaphragms **507***a* and **507***b* are disposed to constitute respective walls (upper walls) of the pump chambers **504***a* and **504***b* (the diaphragms **507***a* and **507***b* constitute portions of the walls of the pump chambers **504***a* and **508***b* and to have respective film surfaces in a common X-Y plane. The ceramic diaphragms **507**_a_ and **507**_b_ are identical in configuration with the diaphragms **17**_a_ and **17**_b_ of the above-described drive device **10**.

[0155] The piezoelectric film **502**_a_ is formed on the upper surface of the diaphragm **507**_a_, and constitutes a ceramic pump **508**_a_ together with the pump chamber **504**_a_ and the diaphragm **507**_a_. The piezoelectric film **502**_b_ is formed on the upper surface of the diaphragm **507**_b_, and constitutes a ceramic pump **508**_b_ together with the pump chamber **504**_b_ and the diaphragm **507**_b_. The ceramic pumps **508**_a_ and **508**_b_ are identical in configuration with the ceramic pumps **18**_a_ and **18**_b_ of the drive device **10**. When a voltage is applied to unillustrated paired electrodes for the piezoelectric film **502**_a_ (**502**_b_), the piezoelectric film **502**_a_ (**502**_b_) deforms the diaphragm **507**_a_ (**507**_b_) in order to increase or decrease the volume of the pump chamber **504**_a_ (**504**_b_), to thereby pressurize or depressurize the operation fluid **100** within the pump chamber **504**_a_ (**504**_b_). Notably, the piezoelectric films **502**_a_ and **502**_b_ are each polarized in the positive direction of the Z-axis.

[0156] The internal-pressure-buffering-chamber-forming portion **505** forms an internal-pressure buffering chamber **505**_a_. As in the case of the channel **503**_a_, the internal-pressure buffering chamber **505**_a_ is a hollow space which is defined by side wall surfaces of a through hole of the ceramic sheet **501-2**, the upper surface of the ceramic sheet **501-1**, and the lower surface of the ceramic sheet **501-3**. The space has a substantially rectangular parallelepiped shape having sides extending along the X-axis, Y-axis, and Z-axis directions, respectively, and has a long axis along the X-axis direction (a rectangular columnar space whose longitudinal axis lies in a plane parallel to the X-Y plane in which the film surfaces of the diaphragms **507**_a_ and **507**_b_ are present; i.e., a rectangular columnar space having a long axis which is parallel to the long axis of the channel **503**_a_ and is located at the same vertical position as the long axis of the channel **503**_a_). The internal-pressure buffering chamber **505**_a_ is formed at a position separated from the channel **503**_a_ in the Y-axis negative direction. The length of the internal-pressure buffering chamber **505**_a_ as measured along the X-axis direction is greater than that of the channel **503**_a_; the length (width) of the internal-pressure buffering chamber **505**_a_ as measured along the Y-axis direction is greater than that of the channel **503**_a_; and the length (height) of the internal-pressure buffering chamber **505**_a_ as measured along the Z-axis direction is equal to that of the channel **503**_a_. A substantially central portion of the chamber **505**_a_ with respect to the X-axis direction is filled with the above-described operation fluid **100**; and the peripheral portions thereof are filled with the above-described compressible fluid for pressure buffering **120**.

[0157] The micro channel portion **506**_a_ forms a micro channel **506**_a_**1**. As in the case of the pump chambers **504**_a_ and **504**_b_, the micro channel **506**_a_**1** is a substantially rectangular parallelepiped space which is defined by side wall surfaces of a slit-like through hole formed in the ceramic sheet **501-3**, the upper surface of the ceramic sheet **501-2**, and the lower surface of the ceramic sheet **501-4** and which has a long axis along the Y-axis direction. The micro channel **506**_a_**1** connects a left-hand operation chamber **503**_a_**1** (an upper portion of the operation chamber **503**_a_**1**) of the channel **503**_a_ with the internal-pressure buffering chamber **505**_a_ (an upper portion of the internal-pressure buffering chamber **505**_a_). In other words, the micro channel **506**_a_**1** extends only along a direction (Y-axis direction) parallel to the X-Y plane in which the film surfaces of the diaphragms **507**_a_ and **507**_b_ are present, to thereby connect the flow chamber **503**_a_ with the internal-pressure buffering chamber **505**_a_. The micro channel **506**_a_**1** is also filled with the operation fluid **100**.

[0158] For example, the micro channel **506**_a_**1** has specific dimensions such that when the micro channel **506**_a_**1** is sectioned along a plane (i.e., an X-Z plane) perpendicular to the long axis, the height (length as measured along the Z-axis direction) of the rectangular cross section is 10 μm, and the width (length as measured along the X-axis direction) of the rectangular cross section is 10 μm, and that the length as measured along the Y-axis direction (excluding a portion above the channel **503**_a_ and a portion above the internal-pressure buffering chamber **505**_a_) is 500 μm. As in the case of the micro channel **16**_a_**1**, the shape and the dimensions of the micro channel **506**_a_**1** are selected in such a manner that a high passage resistance is produced against abrupt pressure change of the operation fluid **100** within the channel **503**_a_ in order to substantially prohibit passage (movement) of the operation fluid **100** toward the internal-pressure buffering chamber **505**_a_, and only a small passage resistance is produced against slow pressure change of the operation fluid **100** within the channel **503**_a_, in order to substantially permit passage (movement) of the operation fluid **100** toward the internal-pressure buffering chamber **505**_a_ (that is, the shape and the dimensions of the micro channel **506**_a_**1** are selected so as to provide a throttle function).

[0159] The micro channel portion **506**_b_ forms a micro channel **506**_b_**1** having the same shape as that of the micro channel **506**_a_**1** at a position separated from the micro channel **506**_a_**1** by a predetermined distance along the X-axis direction. The micro channel **506**_b_**1** extends only along a direction (Y-axis direction) parallel to the X-Y plane in which the film surfaces of the diaphragms **507**_a_ and **507**_b_ are present, to thereby connect a right-hand operation chamber **503**_a_**2** (an upper portion of the operation chamber **503**_a_**2**) of the channel **503**_a_ with the internal-pressure buffering chamber **505**_a_ (an upper portion of the internal-pressure buffering chamber **505**_a_). The micro channel **506**_b_**1** is also filled with the operation fluid **100**. That is, the micro channel **506**_b_**1** also extends only along the direction (Y-axis direction) parallel to the X-Y plane in which the film surfaces of the diaphragms **507**_a_ and **507**_b_ are present, connects the flow chamber **503**_a_ with the internal-pressure buffering chamber **505**_a_, and has the throttle function described in connection with the micro channel **506**_a_**1**.

[0160] As described above, the operation fluid **100** continuously fills the channel **503**_a_, the pair of pump chambers **504**_a_ and **504**_b_, the pair of micro channels **506**_a_**1** and **506**_b_**1**, and a portion of the internal-pressure buffering chamber **505**_a_, which communicates with the channel **503**_a_ via the pair of micro channels **506**_a_**1** and **506**_b_**1**. Further, the compressible fluid for pressure buffering **120** fills the spaces of the internal-pressure buffering chamber **505**_a_ that are not filled with the operation fluid **100**.

[0161] The operation of the drive device **500** for driving (moving) the movable body **110** is the same as that of the drive device **10**. Further, the operation of the drive device

500 for absorbing changes in the internal pressure of the channel **503***a* resulting from thermal expansion and contraction of the operation fluid **100** is also the same as that of the drive device **10**.

[**0162**] The thickness (height or length as measured along the Z-axis direction) of the drive device **500** of the sixth embodiment can be very small (reduced), because the drive device **500** is configured to have the micro channels **506***a***1** and **506***b***1** each having a long axis along the Y-axis direction, to have the channel **503***a* and the internal-pressure buffering chamber **505***a* formed at the same vertical position (in the common plane or within the common ceramic sheet **501-2**), and to establish communication between an upper portion of the channel **503***a* and an upper portion of the internal-pressure buffering chamber **505***a* by means of the micro channels **506***a***1** and **506***b***1**. Further, the drive device **500** can be made compact, because of a large volume of the space (the total sum of the volume of the channel **503***a*, those of the pump chambers **504***a* and **504***b*, that of the internal-pressure buffering chamber **505***a*, and those of the micro channels **506***a***1** and **506***b***1**), as compared with the volume of the base body **501**. Further, since the drive device **500** can have a small thickness and/or an increased surface area relative to the volume thereof, heat generated upon operation can be dissipated to the outside with ease. Accordingly, since the entirety of the drive device **500** heats uniformly (that is, temperature differences among different portions of the device are small), the drive device **500** operates stably by virtue of uniform heating, and has enhanced durability against heat. Next, a drive device **510**, which serves as a portion of a circuit changeover switch according to a seventh embodiment of the present invention, will be described. **FIG. 36** is a plan view of the drive device **510**; and **FIG. 37** is a sectional view of the drive device **510** taken along line A6-A6 in **FIG. 36**. The drive device **510** differs from the drive device **500** mainly in that a pair of micro channels **516***a***1** and **516***b***1** and a pair of pump-chamber communication holes **519***a* and **519***b* are formed in a ceramic sheet **511-3**, which is disposed between a ceramic sheet **511-2** in which a channel **513***a* is formed and a ceramic sheet **511-4** in which pump chambers **514***a* and **514***b* are formed.

[**0163**] Specifically, the drive device **510** comprises a ceramic base body **511** of a substantially rectangular parallelepiped shape having sides which respectively extend along the X-axis, Y-axis, and Z-axis directions, which are mutually perpendicular; and a pair of piezoelectric films (piezoelectric/electrostrictive elements) **512***a* and **512***b*. As shown in **FIG. 37**, the base body **511** is formed through a process of successively laminating ceramic sheets **511-1** to **511-5** and firing the resultant laminate in such a manner that the base body **511** contains therein a channel forming portion **513**, an internal-pressure-buffering-chamber-forming portion **515**, the pair of pump chambers **514***a* and **514***b*, and the pair of micro channel portions **516***a* and **516***b*.

[**0164**] The channel forming portion **513** forms a channel **513***a* similar to the channel **503***a* of the drive device **500**. The channel **513***a* is a space which is defined by side wall surfaces of a through hole formed in the ceramic sheet **511-2**, the upper surface of the ceramic sheet **511-1**, and the lower surface of the ceramic sheet **511-3** and whose longitudinal axis coincides with the X-axis direction (which has a long axis extending along the X-axis direction). As in the case of the channel **503***a*, an operation fluid **100** and a movable body **110** are accommodated within the channel **513***a*, whereby the channel **513***a* is divided substantially into two operation chambers **513***a***1** and **513***a***2** by means of the movable body **110**.

[**0165**] The pump chambers **514***a* and **514***b* are identical in configuration with the pump chambers **504***a* and **504***b*. The pump chambers **514***a* and **514***b* are cylindrical spaces defined by side wall surfaces of through holes formed in the ceramic sheet **511-4**, the upper surface of the ceramic sheet **511-3**, and the lower surface of the ceramic sheet **511-5**. Ceramic diaphragms **517***a* and **517***b* formed of the ceramic sheet **511-5** are provided above the pump chambers **514***a* and **514***b*, respectively. The diaphragms **517***a* and **517***b* are identical in configuration with the diaphragms **507***a* and **507***b*, and are disposed to constitute portions of the walls (upper walls) of the pump chambers **514***a* and **514***b* and to have respective film surfaces in a common X-Y plane. Piezoelectric films **512***a* and **512***b* are formed on the upper surfaces of the diaphragms **517***a* and **517***b*, respectively. The piezoelectric films **512***a* and **512***b* are identical in configuration with the piezoelectric films **502***a* and **502***b*. As a result, the pump chamber **514***a*, the diaphragm **517***a*, and the piezoelectric film **512***a* constitute a ceramic pump **518***a*; and the pump chamber **514***b*, the diaphragm **517***b*, and the piezoelectric film **512***b* constitute a ceramic pump **518***b*. The ceramic pumps **518***a* and **518***b* are identical in configuration with the ceramic pumps **508***a* and **508***b*.

[**0166**] The internal-pressure-buffering-chamber-forming portion **515** forms an internal-pressure buffering chamber **515***a*. The internal-pressure buffering chamber **515***a* is a hollow space which is defined by side wall surfaces of a through hole of the ceramic sheet **511-2**, the upper surface of the ceramic sheet **511-1**, and the lower surface of the ceramic sheet **511-3**, which is identical in configuration with the internal-pressure buffering chamber **505***a*, and whose longitudinal axis coincides with the X-axis direction (which has a long axis extending along the X-axis direction). The internal-pressure buffering chamber **515***a* is also formed at a position separated from the channel **513***a* in the Y-axis negative direction. As in the case of the size of the internal-pressure buffering chamber **505***a* relative to the channel **503***a*, the internal-pressure buffering chamber **515***a* is greater in size than the channel **513***a*. A substantially central portion of the chamber **515***a* with respect to the X-axis direction is filled with the above-described operation fluid **100**; and the peripheral portions thereof are filled with the above-described compressible fluid for pressure buffering **120**.

[**0167**] The micro channel portions **516***a* and **516***b* respectively form micro channels **516***a***1** and **516***b***1**, which are of the same shape and parallel with each other. Each of the micro channels **516***a***1** and **516***b***1** is a substantially rectangular parallelepiped space which is defined by side wall surfaces of a slit-like through hole formed in the ceramic sheet **511-3**, the upper surface of the ceramic sheet **511-2**, and the lower surface of the ceramic sheet **511-4** and which has a long axis along the Y-axis direction. The micro channel **516***a***1** extends from an upper portion of a left-hand operation chamber **513***a***1** of the channel **513***a* to an upper portion of the internal-pressure buffering chamber **515***a* to thereby connect the left-hand operation chamber **513***a***1** with the internal-pressure buffering chamber **515***a*. The micro channel **516***b***1** extends from an upper portion of a right-hand operation chamber **513**a**2** of the channel **513**a to an upper portion of the internal-pressure buffering chamber **515**a to thereby connect the right-hand operation chamber **513**a**2** with the internal-pressure buffering chamber **515**a. The micro channels **516**a**1** and **516**b**1** are also filled with the operation fluid **100**.

[**0168**] For example, the micro channel **516**a**1** (**516**b**1**) has specific dimensions such that when the micro channel **516**a**1** is sectioned along a plane (i.e., an X-Z plane) perpendicular to the long axis, the height (length along the Z-axis direction) and width (length along the X-axis direction) of the rectangular cross section are each 15 μm, and the length as measured along the Y-axis direction (excluding a portion above the channel **513**a and a portion above the internal-pressure buffering chamber **515**a) is 500 μm. As in the case of the channel **506**a**1**, the shape and the dimensions of the micro channel **516**a**1** (**516**b**1**) are selected so as to provide a throttle function such that a high passage resistance is produced against abrupt pressure change of the operation fluid **100** within the channel **513**a in order to substantially prohibit passage (movement) of the operation fluid **100** toward the internal-pressure buffering chamber **515**a, and only a low passage resistance is produced against slow pressure change of the operation fluid **100** within the channel **513**a, in order to substantially permit passage (movement) of the operation fluid **100** toward the internal-pressure buffering chamber **515**a.

[**0169**] The pump chamber communication holes **519**a and **519**b are cylindrical spaces formed of through holes, which are formed in the ceramic sheet **511-3**, as in the case of the micro channels **516**a**1** and **5161**b. The pump chamber communication hole **519**a connects an upper portion of the left-hand operation chamber **513**a**1** of the channel **513**a with the pump chamber **514**a. The pump chamber communication hole **519**b connects an upper portion of the right-hand operation chamber **513**a**2** of the channel **513**a with the pump chamber **514**b. The pump chamber communication holes **519**a and **519**b are also filled with the operation fluid **100**.

[**0170**] As described above, the operation fluid **100** continuously fills the channel **513**a, the pair of pump chambers **514**a and **514**b, the pair of micro channels **516**a**1** and **516**b**1**, the pump chamber communication holes **519**a and **519**b, and a portion of the internal-pressure buffering chamber **515**a, which communicates with the channel **513**a via the pair of micro channels **516**a**1** and **516**b**1**. Further, the compressible fluid for pressure buffering **120** fills the spaces of the internal-pressure buffering chamber **515**a that are not filled with the operation fluid **100**.

[**0171**] The operation of the drive device **510** for driving (moving) the movable body **110** is the same as that of the drive device **10**. Further, the operation of the drive device **510** for absorbing changes in the internal pressure of the channel **513**a resulting from thermal expansion and contraction of the operation fluid **100** is also the same as that of the drive device **10**.

[**0172**] The thickness (height or length as measured along the Z-axis direction) of the drive device **510** of the seventh embodiment can be very small (reduced), because the drive device **510** is configured to have the micro channels **516**a**1** and **516**b**1** each having a long axis along the Y-axis direction, to have the channel **513**a and the internal-pressure buffering chamber **515**a formed at the same vertical position (in the common plane or within the common ceramic sheet **511-2**), and to establish communication between an upper portion of the channel **513**a and an upper portion of the internal-pressure buffering chamber **515**a by means of the micro channels **516**a**1** and **516**b**1**. Further, the drive device **510** can be made compact, because of a large volume of the space (the total sum of the volume of the channel **513**a, those of the pump chambers **514**a and **514**b, that of the internal-pressure buffering chamber **515**a, those of the micro channels **516**a**1** and **516**b**1**, and those of the pump chamber communication holes **519**a and **519**b), as compared with the volume of the base body **511**. Further, since the drive device **510** can have a small thickness and/or an increased surface area relative to the volume thereof, heat generated upon operation can be dissipated to the outside with ease. Accordingly, the entirety of the drive device **510** heats uniformly (that is, temperature differences among different portions of the device are small), the drive device **510** operates stably by virtue of uniform heating, and has enhanced durability against heat.

[**0173**] Next, a drive device **520**, which serves as a portion of a circuit changeover switch according to an eighth embodiment of the present invention, will be described. **FIG. 38** is a plan view of the drive device **520**; and **FIG. 39** is a sectional view of the drive device **520** taken along line A7-A7 in **FIG. 38**. The drive device **520** differs from the drive device **500** mainly in that a pair of micro channels are formed in a ceramic sheet **521-1**, which forms a channel and an internal-pressure buffering chamber in cooperation with a ceramic sheet **521-2**. Therefore, in the following description, structural portions identical with those of the drive device **500** are denoted by the same reference numerals, their detailed descriptions are not repeated, and the above-described difference will be mainly described.

[**0174**] The drive device **520** can be obtained through replacement of the ceramic sheets **501-2** and **501-3** of the drive device **500** with ceramic sheets **521-1** to **521-3**, which are successively laminated on the ceramic sheet **501-1** and fired integrally. The drive device **520** comprises a base body **521** and a pair of piezoelectric films (piezoelectric/electrostrictive elements) **502**a and **502**b. The base body **521** contains therein a channel forming portion **503**, an internal-pressure-buffering-chamber-forming portion **505**, a pair of pump chambers **524**a and **524**b, and a pair of micro channel portions **526**a and **526**b.

[**0175**] The channel forming portion **503** forms a channel **503**a, which is defined by side wall surfaces of substantially rectangular parallelepiped through holes formed in the ceramic sheets **521-1** and **521-2**, the upper surface of the ceramic sheet **501-1**, and the lower surface of the ceramic sheet **521-3**.

[**0176**] The pump chambers **524**a and **524**b are identical in configuration with the pump chambers **504**a and **504**b. The pump chambers **524**a and **524**b are cylindrical spaces defined by side wall surfaces of through holes formed in the ceramic sheet **521-3**, the upper surface of the ceramic sheet **521-2**, and the lower surface of a ceramic sheet **501-4**. Ceramic diaphragms **507**a and **507**b formed of the ceramic sheet **501-4** are provided above the pump chambers **524**a and **524**b, respectively, in such a manner that the ceramic diaphragms **507**a and **507**b constitute portions of the walls (upper walls) of the pump chambers **524**a and **524**b, respectively. Piezoelectric films **502***a* and **502***b* are formed on the upper surfaces of the diaphragms **507***a* and **507***b*, respectively. As a result, the pump chamber **524***a*, the diaphragm **507***a*, and the piezoelectric film **502***a* constitute a ceramic pump **528***a*; and the pump chamber **524***b*, the diaphragm **507***b*, and the piezoelectric film **502***b* constitute a ceramic pump **528***b*. The ceramic pumps **528***a* and **528***b* are identical in configuration with the ceramic pumps **508***a* and **508***b*.

[**0177**] The internal-pressure-buffering-chamber-forming portion **505** forms an internal-pressure buffering chamber **505***a*, which is defined by side wall surfaces of substantially rectangular parallelepiped through holes formed in the ceramic sheets **521-1** and **521-2**, the upper surface of the ceramic sheet **501-1**, and the lower surface of the ceramic sheet **521-3**, as in the case of the channel **503***a*.

[**0178**] The micro channel portion **526***a* forms a micro channel **526***a***1**. The micro channel **526***a***1** is a substantially rectangular parallelepiped space which is defined by side wall surfaces of a slit-like through hole formed in the ceramic sheet **521-1** the upper surface of the ceramic sheet **501-1**, and the lower surface of the ceramic sheet **521-2** and which has a long axis along the Y-axis direction. The micro channel **526***a***1** connects a left-hand operation chamber **503***a***1** (a side wall portion of the operation chamber **503***a***1** formed in the ceramic sheet **521-1**) of the channel **503***a* with the internal-pressure buffering chamber **505***a* (a side wall portion of the internal-pressure buffering chamber **505***a* formed in the ceramic sheet **521-1**). Notably, the micro channel **526***a***1** has the same dimensions as the micro channel **506***a***1**.

[**0179**] The micro channel portion **526***b* forms a micro channel **526***b***1**. The micro channel **526***b***1** is identical in shape with the micro channel **526***a***1**, and is a substantially rectangular parallelepiped space which is defined by side wall surfaces of a slit-like through hole formed in the ceramic sheet **521-1**, the upper surface of the ceramic sheet **501-1**, and the lower surface of the ceramic sheet **521-2**, which is located at a position separated from the micro channel **526***a***1** by a predetermined distance along the X-axis positive direction, and which has a long axis along the Y-axis direction. The micro channel **526***b***1** connects a right-hand operation chamber **503***a***2** (a side wall portion of the operation chamber **503***a***2** formed in the ceramic sheet **521-1**) of the channel **503***a* with the internal-pressure buffering chamber **505***a* (a side wall portion of the internal-pressure buffering chamber **505***a* formed in the ceramic sheet **521-1**).

[**0180**] As in the case of the micro channels **506***a***1**, **506***b***1**, etc., the shape and the dimensions of the micro channels **526***a***1** and **526***b***1** are selected so as to provide a throttle function such that a high passage resistance is produced against abrupt pressure change of the operation fluid **100** within the channel **503***a* in order to substantially prohibit passage (movement) of the operation fluid **100** toward the internal-pressure buffering chamber **505***a*, and only a low passage resistance is produced against slow pressure change of the operation fluid **100** within the channel **503***a* in order to substantially permit passage (movement) of the operation fluid **100** toward the internal-pressure buffering chamber **505***a*.

[**0181**] In the drive device **520** as well, the operation fluid **100** continuously fills the channel **503***a*, the pair of pump chambers **524***a* and **524***b*, the pair of micro channels **526***a***1** and **526***b***1**, and a portion of the internal-pressure buffering chamber **505***a*, which communicates with the channel **503***a* via the pair of micro channels **526***a***1** and **526***b***1**. Further, the compressible fluid for pressure buffering **120** fills the spaces of the internal-pressure buffering chamber **505***a* that are not filled with the operation fluid **100**.

[**0182**] The operation of the drive device **520** for driving (moving) the movable body **110** is the same as that of the drive device **10**. Further, the operation of the drive device **520** for absorbing changes in the internal pressure of the channel **503***a* resulting from thermal expansion and contraction of the operation fluid **100** is also the same as that of the drive device **10**. As a result, the drive device **520** have the same advantages as does the drive device **500**. Further, since the drive device **520** is small (thin), as is the drive device **500**, the drive device **520** provides the same effects as does the drive device **500**.

[**0183**] Next, a drive device **530**, which serves as a portion of a circuit changeover switch according to a ninth embodiment of the present invention, will be described. **FIG. 40** is a plan view of the drive device **530**; and **FIG. 41** is a sectional view of the drive device **530** taken along line A8-A8 in **FIG. 40**. The drive device **530** differs from the drive device **520** only in that the ceramic sheets **521-1** and **521-2** of the drive device **520** have been replaced with ceramic sheets **531-1** and **531-2** successively laminated on a ceramic sheet **501-1** and fired integrally. Therefore, in the following description, structural portions identical with those of the drive device **520** are denoted by the same reference numerals, their detailed descriptions are not repeated, and the above-described difference will be mainly described.

[**0184**] In the drive device **530**, a channel **503***a* and an internal-pressure buffering chamber **505***a* are formed by means of side wall surfaces of through holes formed in the ceramic sheets **531-1** and **531-2**, the upper surface of the ceramic sheet **501-1**, and the lower surface of a ceramic sheet **521-3**.

[**0185**] Meanwhile, a micro channel **536***a***1** is a substantially rectangular parallelepiped space which is defined by side wall surfaces of a slit-like through hole formed in the ceramic sheet **531-2**, the upper surface of the ceramic sheet **531-1**, and the lower surface of the ceramic sheet **521-3** and which has a long axis along the Y-axis direction. The micro channel **536***a***1** connects a left-hand operation chamber **503***a***1** (a side wall portion of the operation chamber **503***a***1** formed in the ceramic sheet **531-2**) of the channel **503***a* with the internal-pressure buffering chamber **505***a* (a side wall portion of the internal-pressure buffering chamber **505***a* formed in the ceramic sheet **531-2**). Notably, the micro channel **536***a***1** has the same dimensions as the micro channel **506***a***1**.

[**0186**] A micro channel **536***b***1** is identical in shape with the micro channel **536***a***1**. The micro channel **536***b***1** is a substantially rectangular parallelepiped space which is defined by side wall surfaces of a slit-like through hole formed in the ceramic sheet **531-2**, the upper surface of the ceramic sheet **531-1**, and the lower surface of the ceramic sheet **521-3**, which is located at a position separated from the micro channel **536***a***1** by a predetermined distance along the X-axis positive direction, and which has a long axis along the Y-axis direction. The micro channel **536***b***1** connects a right-hand operation chamber **503**a**2** (a side wall portion of the operation chamber **503**a**2** formed in the ceramic sheet **531-2**) of the channel **503**a with the internal-pressure buffering chamber **505**a (a side wall portion of the internal-pressure buffering chamber **505**a formed in the ceramic sheet **531-2**). The functions of the micro channels **536**a**1** and **536**b**1** are the same as those of the micro channels **526**a**1** and **526**b**1**.

[0187] The drive device **530** accommodates a movable body **110**, an operation fluid **100**, and a compressible fluid for pressure buffering **120** in the same manner as the drive device **520**. The drive device **530** provides the same operation and advantages as those provided by the drive device **520**, and is a small, reliable device.

[0188] Next, a drive device **540**, which serves as a portion of a circuit changeover switch according to a tenth embodiment of the present invention, will be described. **FIG. 42** is a plan view of the drive device **540**; and **FIG. 43** is a sectional view of the drive device **540** taken along line A9-A9 in **FIG. 42**. The drive device **540** differs from the drive device **520** only in that the ceramic sheets **521-1** and **521-2** of the drive device **520** have been replaced with ceramic sheets **541-1**, **5412**, and **541-3** successively laminated on a ceramic sheet **501-1** and fired integrally. Therefore, in the following description, structural portions identical with those of the drive device **520** are denoted by the same reference numerals, their detailed descriptions are not repeated, and the above-described difference will be mainly described.

[0189] In the drive device **540**, a channel **503**a and an internal -pressure buffering chamber **505**a are formed by means of side wall surfaces of through holes formed in the ceramic sheets **541-1**, **541-2**, and **541-3**, the upper surface of the ceramic sheet **501-1**, and the lower surface of the ceramic sheet **521-3**.

[0190] Meanwhile, the micro channel **546**a**1** is a substantially rectangular parallelepiped space which is defined by side wall surfaces of a slit-like through hole formed in the ceramic sheet **541-2**, the upper surface of the ceramic sheet **541-1**, and the lower surface of the ceramic sheet **541-3** and which has a long axis along the Y-axis direction. The micro channel **546**a**1** connects a left-hand operation chamber **503**a**1** (a side wall portion of the operation chamber **503**a**1** formed in the ceramic sheet **541-2**) of the channel **503**a with the internal-pressure buffering chamber **505**a (a side wall portion of the internal-pressure buffering chamber **505**a formed in the ceramic sheet **541-2**).

[0191] For example, the micro channel **546**a**1** has specific dimensions such that when the micro channel **546**a**1** is sectioned along a plane (i.e., an X-Z plane) perpendicular to the long axis, the height (length along the Z-axis direction) of the rectangular cross section is 30 μm, and the width (length along the X-axis direction) of the rectangular cross section is 15 μm, and that the length as measured along the Y-axis direction (the length of a portion not including the channel **503**a and the internal-pressure buffering chamber **505**a) is 500 μm.

[0192] A micro channel **546**b**1** is identical in shape with the micro channel **546**a**1**. The micro channel **546**b**1** is a substantially rectangular parallelepiped space which is defined by side wall surfaces of a slit-like through hole formed in the ceramic sheet **541-2**, the upper surface of the ceramic sheet **541-1**, and the lower surface of the ceramic sheet **541-3**, which is located at a position separated from the micro channel **546**a**1** by a predetermined distance along the X-axis positive direction, and which has a long axis along the Y-axis direction. The micro channel **546**b**1** connects a right-hand operation chamber **503**a**2** (a side wall portion of the operation chamber **503**a**2** formed in the ceramic sheet **541-2**) of the channel **503**a with the internal-pressure buffering chamber **505**a (a side wall portion of the internal-pressure buffering chamber **505**a formed in the ceramic sheet **541-2**). The functions of the micro channels **546**a**1** and **546**b**1** are the same as those of the micro channels **526**a**1** and **526**b**1**.

[0193] The drive device **540** accommodates a movable body **110**, an operation fluid **100**, and a compressible fluid for pressure buffering **120** in the same manner as the drive device **520**. The drive device **540** provides the same operation and advantages as those provided by the drive device **520**, and is a small, reliable device.

[0194] Next, a drive device **550**, which serves as a portion of a circuit changeover switch according to an eleventh embodiment of the present invention, will be described. **FIG. 44** is a plan view of the drive device **550**; and **FIG. 45** is a sectional view of the drive device **550** taken along line AA-AA in **FIG. 44**. The drive device **550** differs from the drive device **520** only in that the ceramic sheets **521-1** and **521-2** of the drive device **520** have been replaced with a ceramic sheet **551-1** laminated on a ceramic sheet **501-1**. Therefore, in the following description, structural portions identical with those of the drive device **520** are denoted by the same reference numerals, their detailed descriptions are not repeated, and the above-described difference will be mainly described.

[0195] In the drive device **550**, a channel **503**a and an internal-pressure buffering chamber **505**a are formed by means of side wall surfaces of through holes formed in the ceramic sheet **551-1**, the upper surface of the ceramic sheet **501-1**, and the lower surface of a ceramic sheet **521-3**.

[0196] Meanwhile, a micro channel **556**a**1** is a substantially rectangular parallelepiped space which is defined by side wall surfaces of a slit-like through hole formed in the ceramic sheet **551-1**, the upper surface of the ceramic sheet **501-1**, and the lower surface of the ceramic sheet **521-3** and which has a long axis along the Y-axis direction. The micro channel **556**a**1** connects a left-hand operation chamber **503**a**1** (a side wall portion of the operation chamber **503**a**1** formed in the ceramic sheet **551-1**) of the channel **503**a with the internal-pressure buffering chamber **505**a (a side wall portion of the internal-pressure buffering chamber **505**a formed in the ceramic sheet **551-1**).

[0197] For example, the micro channel **556**a**1** has specific dimensions such that when the micro channel **556**a**1** is sectioned along a plane (i.e., an X-Z plane) perpendicular to the long axis, the height (length along the Z-axis direction) of the rectangular cross section is 50 μm, and the width (length along the X-axis direction) of the rectangular cross section is 15 μm, and that the length as measured along the Y-axis direction (the length of a portion not including the channel **503**a and the internal-pressure buffering chamber **505**a) is 500 μm.

[0198] A micro channel **556**b**1** is identical in shape with the micro channel **556**a**1**. The micro channel **556**b**1** is a substantially rectangular parallelepiped space which is defined by side wall surfaces of a slit-like through hole formed in the ceramic sheet **551-1**, the upper surface of the ceramic sheet **501-1**, and the lower surface of the ceramic sheet **521-3**, which is located at a position separated from the micro channel **556*a*1** by a predetermined distance along the X-axis positive direction, and which has a long axis along the Y-axis direction. The micro channel **556*b*1** connects a right-hand operation chamber **503*a*2** (a side wall portion of the operation chamber **503*a*2** formed in the ceramic sheet **551-1**) of the channel **503*a*** with the internal-pressure buffering chamber **505*a*** (a side wall portion of the internal-pressure buffering chamber **505*a*** formed in the ceramic sheet **551-1**). The functions of the micro channels **556*a*1** and **556*b*1** are the same as those of the micro channels **526*a*1** and **526*b*1**.

[**0199**] The drive device **550** accommodates a movable body **110**, an operation fluid **100**, and a compressible fluid for pressure buffering **120** in the same manner as the drive device **520**. The drive device **550** provides the same operation and advantages as those provided by the drive device **520**, and is a small, reliable device. Further, by contrast with the drive devices **520**, **530**, and **540**, the side wall surfaces of the channel **503*a*** and the internal-pressure buffering chamber **505*a*** can be formed by use of the single ceramic sheet **551-1**, so that the drive device **550** can be fabricated with ease and at low cost.

[**0200**] Next, a drive device **560**, which serves as a portion of a circuit changeover switch according to a twelfth embodiment of the present invention, will be described. **FIG. 46** is a plan view of the drive device **560**; and **FIG. 47** is a sectional view of the drive device **560** taken along line AB-AB in **FIG. 46**. The drive device **560** differs from the drive device **520** only in that the ceramic sheets **521-1** and **521-2** of the drive device **520** have been replaced with ceramic sheets **561-1** and **561-2** laminated on a ceramic sheet **501-1** and then fired integrally. Therefore, in the following description, structural portions identical with those of the drive device **520** are denoted by the same reference numerals, their detailed descriptions are not repeated, and the above-described difference will be mainly described.

[**0201**] In the drive device **560**, a channel **503*a*** and an internal-pressure buffering chamber **505*a*** are formed by means of side wall surfaces of through holes formed in the ceramic sheet **561-2**, the upper surface of the ceramic sheet **561-1**, and the lower surface of the ceramic sheet **521-3**.

[**0202**] Meanwhile, a micro channel **566*a*1** is a substantially rectangular parallelepiped space which is defined by side wall surfaces of a slit-like through hole formed in the ceramic sheet **561-1**, the upper surface of the ceramic sheet **501-1**, and the lower surface of the ceramic sheet **561-2** and which has a long axis along the Y-axis direction. The micro channel **566*a*1** connects a left-hand operation chamber **503*a*1** (a lower portion of the operation chamber **503*a*1**) of the channel **503*a*** with the internal-pressure buffering chamber **505*a*** (a lower portion of the internal-pressure buffering chamber **505*a***). The micro channel **566*a*1** has the same dimensions as does the micro channel **506*a*1** shown in **FIG. 35**.

[**0203**] A micro channel **566*b*1** is identical in shape with the micro channel **566*a*1**. The micro channel **566*b*1** is a substantially rectangular parallelepiped space which is defined by side wall surfaces of a slit-like through hole formed in the ceramic sheet **561-1**, the upper surface of the ceramic sheet **501-1**, and the lower surface of the ceramic sheet **561-2**, which is located at a position separated from the micro channel **566*a*1** by a predetermined distance along the X-axis positive direction, and which has a long axis along the Y-axis direction. The micro channel **566*b*1** connects a right-hand operation chamber **503*a*2** (a lower portion of the operation chamber **503*a*2**) of the channel **503*a*** with the internal-pressure buffering chamber **505*a*** (a lower portion of the internal-pressure buffering chamber **505*a***). The functions of the micro channels **566*a*1** and **566*b*1** are the same as those of the micro channels **526*a*1** and **526*b*1**.

[**0204**] The drive device **560** accommodates a movable body **110**, an operation fluid **100**, and a compressible fluid for pressure buffering **120** in the same manner as the drive device **520**. The drive device **560** provides the same operation and advantages as those provided by the drive device **520**, and is a small, reliable device.

[**0205**] Next, a drive device **570**, which serves as a portion of a circuit changeover switch according to a thirteenth embodiment of the present invention, will be described. **FIG. 48** is a plan view of the drive device **570**; **FIG. 49** is a sectional view of the drive device **570** taken along line AC-AC in **FIG. 48**; and **FIG. 50** is a sectional view of the drive device **570** taken along line AD-AD in **FIG. 48**.

[**0206**] The drive device **570** differs from the drive device **560** in that the ceramic sheets **501-1** and **561-1** of the drive device **560** have been replaced with a ceramic sheet **571-1**; the ceramic sheet **561-2** of the drive device **560** have been replaced with a ceramic sheet **571-2**; and a single micro channel is provided. Therefore, in the following description, structural portions identical with those of the drive device **560** are denoted by the same reference numerals, their detailed descriptions are not repeated, and the above-described difference will be mainly described.

[**0207**] In the drive device **570**, a channel **503*a*** and an internal-pressure buffering chamber **505*a*** are formed by means of side wall surfaces of through holes formed in the ceramic sheet **571-2**, the upper surface of the ceramic sheet **571-1**, and the lower surface of the ceramic sheet **521-3**. Further, as shown in **FIGS. 48 and 50**, a groove **570M** is formed on the upper surface of the ceramic sheet **571-1**. The groove **570M** having a long axis extending along the X-axis direction is disposed at a substantially central portion of a lower wall surface of the channel **503*a*** with respect to the X-axis direction, and provides the same function as that provided by the groove M shown in **FIG. 14**.

[**0208**] Meanwhile, the micro channel **576*a*1** is a substantially rectangular parallelepiped space which is defined by side wall surfaces of a rectangular groove formed, through laser machining, on the upper surface of the ceramic sheet **571-1** and the lower surface of the ceramic sheet **571-2** and which has a long axis along the Y-axis direction. The micro channel **576*a*1** connects a lower portion of a left-hand operation chamber **503*a*1** of the channel **503*a*** and the groove **570M** with the internal-pressure buffering chamber **505*a*** (a lower portion of the internal-pressure buffering chamber **505*a***). The micro channel **576*a*1** has the same dimensions as the micro channel **506*a*1** shown in **FIG. 35**, and provides the same function as that provided by the micro channel **506*a*1**.

[0209] The drive device **570** accommodates a movable body **110**, an operation fluid **100**, and a compressible fluid for pressure buffering **120** in the same manner as the drive device **520**. The drive device **570** provides the same operation as that provided by the drive device **10-1**, which is a modification of the first embodiment and is shown in **FIG. 13**. As a result, the drive device **570** can serve as a small, reliable device as in the case of the drive device **520**. Further, since the drive device **570** has the single micro channel **576***a***1**, labor and time needed for machining of the micro channel can be halved, and the drive device can be provided inexpensively.

[0210] Next, a drive device **580**, which serves as a portion of a circuit changeover switch according to a fourteenth embodiment of the present invention, will be described. **FIG. 51** is a plan view of the drive device **580**; and **FIG. 52** is a sectional view of the drive device **580** taken along line AE-AE in **FIG. 51**.

[0211] The drive device **580** differs from the drive device **500** of the sixth embodiment shown in **FIGS. 34 and 35** in that the ceramic sheet **501-3** of the drive device **500** has been replaced with a ceramic sheet **581-1** in order to provide bent micro channels. Therefore, in the following description, structural portions identical with those of the drive device **500** are denoted by the same reference numerals, their detailed descriptions are not repeated, and the above-described difference will be mainly described.

[0212] In the drive device **580**, micro channels **586***a***1** and **586***b***1** are defined by side wall surfaces of slit-like through holes formed in the ceramic sheet **581-1**, the upper surface of a ceramic sheet **501-2**, and the lower surface of a ceramic sheet **501-4**.

[0213] The micro channel **586***a***1** communicates with an upper portion of a left-hand operation chamber **503***a***1** of the channel **503***a*, extends in the Y-axis negative direction from the upper portion of the operation chamber **503***a***1**, bends at a substantially central portion of the base body **581** with respect to the Y-axis direction toward the X-axis negative direction, then extends again in the Y-axis negative direction in order to communicate with an upper portion of the internal-pressure buffering chamber **505***a*. Similarly, the micro channel **586***b***1** communicates with an upper portion of a right-hand operation chamber **503***a***2** of the channel **503***a*, extends in the Y-axis negative direction from the upper portion of the operation chamber **503***a***2**, bends at a substantially central portion of the base body **581** with respect to the Y-axis direction toward the X-axis positive direction, then extends again in the Y-axis negative direction in order to communicate with an upper portion of the internal-pressure buffering chamber **505***a*.

[0214] The micro channels **586***a***1** and **586***b***1** each have a substantially rectangular cross section when taken along a plane (i.e., an X-Z plane) perpendicular to the axial direction. Example dimensions at a portion extending in the Y-axis negative direction are such that the height (length along the Z-axis direction) of the rectangular cross section is 10 μm, and the width (length along the X-axis direction) of the rectangular cross section is 10 μm. Further, the overall axial length (the overall length of a channel excluding a portion above the channel **503***a* and a portion above the internal-pressure buffering chamber **505***a*) is 700 μm.

[0215] The drive device **580** accommodates a movable body **110**, an operation fluid **100**, and a compressible fluid for pressure buffering **120** in the same manner as the drive device **500**. The drive device **580** provides the same operation and advantages as those provided by the drive device **500**, and is a small, reliable device. Further, in the drive device **580**, the axial length (channel length) of each micro channel is increased and/or the micro channel is bent in order to attain an effect of increasing passage resistance which is similar to that obtained through reduction of the cross sectional area of the micro channel. As a result, in the drive device **580**, even when a higher passage resistance must be produced against abrupt pressure change of the operation fluid **100**, drastic reduction in the cross sectional areas of the micro channels **586***a***1** and **586***b***1** is not required. Therefore, machining accuracy involved in formation of micro slits in the ceramic sheet **581-1** is not required to increase very much, whereby the drive device can be fabricated at low cost.

[0216] Next, a modification of the piezoelectric/electrostrictive actuators employed in the above-described embodiments will be described with reference to an example in which a modified piezoelectric/electrostrictive actuator is used for the drive device **500** of the sixth embodiment shown in **FIGS. 34 and 35** in order to replace the ceramic pump **508***b* (**508***a*). The modified piezoelectric/electrostrictive actuator includes a plurality of layered piezoelectric films to serve as a pump, and, needless to say, can be used not only as the ceramic pumps **508***a* and **508***b*, but also as actuators (pumps) of other embodiments.

[0217] **FIGS. 53 and 54** are enlarged sectional views of a piezoelectric/electrostrictive film actuator **300** of the modification applied to the drive device **500** shown in **FIGS. 34 and 35**, taken along lines A5-A5 and AF-AF, respectively, in **FIG. 34**.

[0218] As shown in these drawings, the piezoelectric/electrostrictive film actuator **300** includes a first electrode film **301-1**, a first piezoelectric/electrostrictive film **302-1**, a second electrode film **301-2**, a second piezoelectric/electrostrictive film **3022**, a third electrode film **301-3**, a third piezoelectric/electrostrictive film **302-3**, and a fourth electrode film **301-4**, which are successively stacked on the upper surface of the ceramic diaphragm **507***b* formed of the ceramic sheet **501-4**.

[0219] The first electrode film **301-1** and the third electrode film **301-3** are connected together to assume the same potential to thereby constitute a first electrode section. The second electrode film **301-2** and the fourth electrode film **301-4** are connected together to assume the same potential to thereby constitute a second electrode section. The first electrode section and the second electrode section are mutually isolated by means of the piezoelectric/electrostrictive films; and as in the case of the above-described upper and lower electrodes, a drive voltage is applied to the first and second electrode sections in such a manner that the first and second electrode sections assume different polarities.

[0220] The first to fourth electrode films **301-1** to **301-4** are preferably formed of a metallic material which is solid at room temperature, which can endure an oxidizing atmosphere at high temperature of about firing temperature employed during fabrication of the piezoelectric/electrostrictive film actuator **300**, and which has excellent electrical conductivity. Examples of such a metallic material include pure metals such as aluminum, titanium, chromium, iron, cobalt, nickel, copper, zinc, niobium, molybdenum, ruthenium, palladium, rhodium, silver, tin, tantalum, tungsten, iridium, platinum, gold, and lead; and alloys of these metals. The first to fourth electrode films **301-1** to **301-4** may be formed of a cermet material which contains any of the above-described materials and into which the same material as that of the piezoelectric/electrostrictive films or the base body **501** is dispersed. Alternatively, the first to fourth electrode films **301-1** to **301-4** may be formed of gold resinated paste, platinum resinated paste, silver resinated paste, or a like material which enables formation of dense, thin electrode Further, in the above-described multilayer-type piezoelectric/electrostrictive film actuator, the lowermost electrode (first electrode film **301-1**) and intermediate electrodes (second and third electrode films **301-2** and **301-3**) provided between the piezoelectric/electrostrictive films are preferably formed of an electrode material that contains platinum, etc., as a main component, and an additive such as zirconia oxide, cerium oxide, or titanium oxide. Although the reasons are unknown, when the lowermost and intermediate electrodes are formed of these materials, separation between the electrodes and the piezoelectric/electrostrictive films can be prevented. Notably, the above-mentioned additive is preferably added in an amount of 0.01 to 20% by mass with respect to the entirety of the electrode material in order to obtain a desired separation prevention effect.

[**0221**] Since, in some cases, an increase in thickness of the electrode films results in a reduced amount of displacement of the piezoelectric/electrostrictive film actuator, the electrode films are preferably thin, in order to maintain a large amount of displacement. Therefore, in general, each of the electrode films preferably has a thickness of 15 μm or less, more preferably, 5 μm or less.

[**0222**] The first to third piezoelectric/electrostrictive films **302-1** to **302-3** must be formed of a material which generates electric-field induced distortion such as that due to the piezoelectric effect or that due to the electrostrictive effect, but no restriction is imposed in terms of whether the material is crystalline or amorphous. Also, a semiconductor, ferroelectric ceramic, or antiferroelectric ceramic may be used.

[**0223**] Examples of materials for producing piezoelectric/electrostrictive film include ceramic materials formed from lead zirconate, lead titanate, lead magnesium niobate, lead nickel niobate, lead zinc niobate, lead manganese niobate, lead antimony stannate, lead manganese tungustate, lead cobalt niobate, barium titanate, sodium bismuth titanate, potassium sodium niobate, strontium bismuth tantalate, and mixtures thereof.

[**0224**] Each of the first to third piezoelectric/electrostrictive films **302-1** to **302-3** preferably has a small thickness, in order to obtain large displacement at low voltage. For example, each piezoelectric/electrostrictive film is designed to have a thickness of 100 μm or less, more preferably a thickness of about 3 to 30 μm. Further, when a plurality of piezoelectric/electrostrictive films are layered on a diaphragm, the thicknesses of the piezoelectric/electrostrictive films are preferably determined in such a manner that the film thickness decreases gradually toward the uppermost layer (i.e., with increasing distance from the diaphragm). More specifically, the piezoelectric/electrostrictive films are preferably formed so as to satisfy the following relation:

$$t_n \leqq t_{n-1} \times 0.95$$

[**0225**] where t_n represents the thickness of the n-th piezoelectric/electrostrictive film as counted from the lowermost piezoelectric/electrostrictive film (the piezoelectric/electrostrictive film formed immediately on the diaphragm via an electrode film).

[**0226**] The reason why the thicknesses of the piezoelectric/electrostrictive films are determined in such a manner that the film thickness decreases toward the uppermost layer is as follows. The amount of distortion of a piezoelectric/electrostrictive film increases with the strength of an applied electric field (in other words, when a constant drive voltage is applied to the piezoelectric/electrostrictive film, the amount of distortion increases with decreasing thickness of the piezoelectric/electrostrictive film) . Accordingly, when the thicknesses of the piezoelectric/electrostrictive films are determined as described above; i.e., in such a manner that film thickness decreases toward the uppermost layer, a piezoelectric/electrostrictive film formed on an upper portion distorts to a greater extent than does a piezoelectric/electrostrictive film formed on a lower portion. As a result, the efficiency in bending the diaphragm increases, whereby the amount of bending displacement of the diaphragm can be increased.

[**0227**] The piezoelectric/electrostrictive film actuator **300** can be fabricated by a method similar to the fabrication method having been described with reference to **FIG. 17** or **18**.

[**0228**] Specifically, the first electrode film **301-1** is first formed on the upper surface of the ceramic member **501-4** serving as a diaphragm **507*b***, by means of a method similar to that used to form the above-described lower electrode **205**; and the first piezoelectric/electrostrictive film **302-1** is formed on the upper surface of the electrode film **301-1** by means of a method similar to that used to form the piezoelectric film **207**. Subsequently, the second electrode film **301-2** is formed on the upper surface of the first piezoelectric/electrostrictive film **302-1** by means of a method similar to that used to form the above-described lower electrode **205** or the above-described upper electrode **208**; and the second piezoelectric/electrostrictive film **302-2** is formed on the upper surface of the electrode film **301-2** by means of a method similar to that used to form the piezoelectric film **207**. Subsequently, the third electrode film **301-3** is formed on the upper surface of the second piezoelectric/electrostrictive film **302-2** by means of a method similar to that used to form the above-described lower electrode **205** or the above-described upper electrode **208**; and the third piezoelectric/electrostrictive film **302-3** is formed on the upper surface of the electrode film **301-3** by means of a method similar to that used to form the piezoelectric film **207**. Finally, the fourth electrode film **301-4** is formed by means of a method similar to that used to form the above-described upper electrode **208**.

[**0229**] As described above, a modification of the piezoelectric/electrostrictive film actuator, which is applicable to the respective drive devices of the present invention, is the piezoelectric/electrostrictive film actuator **300**, which includes a piezoelectric/electrostrictive element provided on the diaphragm **507***b* and consisting of piezoelectric/electrostrictive films and electrode films, which deforms the diaphragm **507***b* by means of displacement (deformation) of the piezoelectric/electrostrictive element, and in which the piezoelectric/electrostrictive element is formed in such a manner that the electrode films and the piezoelectric/electrostrictive films are laminated alternately, and the uppermost layer and the lowermost layers are formed of electrode films (the first electrode film.**301-1** and the fourth electrode film **301-4**).

[**0230**] Since the actuator **300** includes a plurality of piezoelectric/electrostrictive films, each of which generates force, a greater drive force (a force for deforming the diaphragm) can be generated upon application of an electrical potential difference between the electrodes (i.e., between the first and second electrode sections), as compared with the case where the same electrical potential difference is applied between the electrodes (i.e., between the upper and lower electrodes) of a piezoelectric/electrostrictive film actuator which includes only a single piezoelectric/electrostrictive film between the electrodes.

[**0231**] Further, in the piezoelectric/electrostrictive film actuator **300**, a plurality of piezoelectric/electrostrictive films are stacked. This configuration enables easy fabrication of a piezoelectric/electrostrictive element having a high aspect ratio, in which the ratio of the dimension in the vertical direction (as measured along the Z-axis direction) to the dimensions in the horizontal direction (as measured along an X-Y plane) is high. Since a piezoelectric/electrostrictive element having a high aspect ratio has high rigidity at a portion which causes bending displacement, the element exhibits an increased response speed. Therefore, through employment of the actuator **300**, a drive device of enhanced responsiveness can be obtained.

[**0232**] Notably, although the piezoelectric/electrostrictive film actuator **300** includes three piezoelectric/electrostrictive films (and four electrode films), no limitation is imposed on the number of the piezoelectric/electrostrictive films, so long as the number is not less than two.

[**0233**] As described above, according to the embodiments of the present invention and their modifications, there can be provided drive devices and circuit changeover switches using the same, which can maintain the features of micro machines such as small size and low power consumption; do not include a mechanical amplification mechanism involving intrinsic problems of wear and sticking; and can facilitate mass production. In addition, since the drive devices (switches) hardly break even when the atmospheric temperature increases, the drive devices (circuit changeover switches) have enhanced reliability and durability.

[**0234**] Notably, the present invention is not limited to the above-described embodiments, and various modifications may be employed within the scope of the present invention. For example, although the above-described circuit changeover switches each have two changeover electrodes, each of the circuit changeover switches may have three or more changeover electrodes. Further, the changeover electrodes and the common electrode may be provided on any wall surface of the channel **13***a* so long as these electrodes are exposed to the channel **13***a* and are isolated from one another. For example, the changeover electrodes and the common electrode may be provided on the opposite side wall surfaces. Alternatively, the changeover electrodes may be provided on a side wall surface, and the common electrode may be provided on the lower wall surface or the upper wall surface.

[**0235**] Moreover, while the basic configurations of the respective drive devices of the present invention are maintained, the films of a piezoelectric/electrostrictive material for deforming diaphragms may be replaced with films of an antiferroelectric material (antiferroelectric film). Further, electrostatic force which is generated between electrodes opposed via a gap and deforming force which is generated in a shape memory alloy heated through application of voltage thereto—which have been actively studied in the field of micro machines—may be used in place of deforming force of piezoelectric film, in order to deform a diaphragm. Even in such a configuration, the combined use of the micro channels **16***a***1**, **16***b***1**, **16***c* and the internal-pressure buffering chamber **15***a* as in the above-described embodiments prevents breakage of the drive devices due to variation in atmospheric temperature. In addition, the position of the movable body in the initial state can be controlled through control of the drive voltage (applied voltage).

[**0236**] Notably, the drive device of the present invention can be used as a device for constructing a so-called rod-less cylinder in the form of a micro machine. As disclosed in, for example, U.S. Pat. No. 3,779,401, a rod-less cylinder is configured as follows. A cylinder working section is sealed completely; an operation member, which is magnetically coupled with the working member (the movable body of the present invention) moving within the sealed space, reciprocates outside the sealed space; and movement of the operation member is transmitted to the outside of the rod-less cylinder system.

[**0237**] Accordingly, when the movable body **110** of the present invention is formed of a magnetic material, and an operation member magnetically coupled with the movable body **110** is provided outside, there can be obtained a micro rod-less cylinder to which the drive device according to the present invention is applied. Further, the drive device of the present invention may be configured in such a manner that very small electrodes (detection electrodes) are provided within the channel **13***a* at numerous locations, and the movable body **110** is formed of an electrically conductive magnetic material. This configuration enables detection of the position of the movable body **110** on the basis of an "ON (close)" or "Off (open)" state of each electrode, to thereby enable control of the stroke position of the micro rod-less cylinder.

[**0238**] The drive device of the present invention can be applied not only to micro machines, such as a micro motor, which are adapted for simple mechanical movement of an object, but also to a wide range of uses of various types of micro machines. For example, a portion or the entirety of the wall surface of the channel **13***a* may be formed of a transparent material, and the movable body **110** may be formed of a bubble, a colored liquid, a vacuole of a fluorescent liquid, or a very small metal piece capable of reflecting light. In this case, the drive device can be used as an optical display element. Moreover, when magnetic, optical, or electrical means for detecting the position of the movable body **110** from the outside is provided, the drive device of the present invention can be used as a memory element. Further, the movable body **110** may be forced to undergo oscillation motion, and the influence of an external force, such as Coriolis force, exerted on the oscillation motion may be sensed by electrical or optical means. Thus, the drive device can be used as a sensor such as a gyroscope.

[**0239**] The above-described drive device (circuit changeover switch) of the present invention can be said to have the following features. Ceramic pumps (**23***a*, **23***b*, **23***c*) each including a ceramic diaphragm and a film-type piezoelectric element comprising (consisting of) a piezoelectric/electrostrictive film or an antiferroelectric film and electrodes are provided on a substrate (**11**, **21**, **41**) having a channel (**13***a*). This channel is formed to have a shape for connecting the ceramic pumps, and accommodates a liquid (**100**) and a movable body (**110**), such as a bubble, a vacuole, or a micro solid, to be moved. The channel is connected to a buffering space (**15***a*) via micro channels (**16***a***1**, **16***b***1**, **16***c*). When pressurization or depressurization is effected at high speed by the ceramic pump, the speed at which the liquid enters and returns from the micro channels is low, so that the micro channels exhibit an effect for reducing the pressurization or depressurization with a time delay. When pressurization or depressurization is effected at low speed, the liquid freely enters and returns from the micro channels, so that the micro channels exhibit a buffering effect for suppressing pressure variation within the channel to substantially zero.

1. A circuit changeover switch comprising:

a channel forming portion for forming a channel, the channel accommodating an incompressible operation fluid and a movable body made of a substance different from that of the operation fluid, and being substantially divided into two operation chambers by means of the movable body;

a pair of pumps each including a pump chamber communicating with the corresponding operation chamber and being filled with the operation fluid, an actuator provided for the pump chamber, and a diaphragm deformed by the actuator, the operation fluid within the pump chamber being pressurized or depressurized through deformation of the diaphragm;

an internal-pressure-buffering-chamber-forming portion for forming an internal-pressure buffering chamber which accommodates the operation fluid and a compressible fluid for pressure buffering; and

a micro channel portion for forming a micro channel which connects the channel of the channel forming portion and the internal-pressure buffering chamber of the internal-pressure-buffering-chamber-forming portion, the micro channel exhibiting a high passage resistance against abrupt pressure change of the operation fluid within the channel, to thereby substantially prohibit passage of the operation fluid through the micro channel and exhibiting a low passage resistance against slow pressure change of the operation fluid within the channel, to thereby substantially permit passage of the operation fluid through the micro channel.

2. A circuit changeover switch according to claim 1, wherein the actuator includes a film-type piezoelectric element comprising a piezoelectric/electrostrictive film or an antiferroelectric film and electrodes; and the diaphragm is formed of ceramic.

3. A circuit changeover switch according to claim 1 or **2**, wherein

each of the diaphragms of the pumps constitutes a portion of the walls of the corresponding pump chamber and has a film surface in a common plane;

the channel of the channel forming portion forms a space whose longitudinal axis lies in a plane parallel to the film surfaces of the diaphragms;

the micro channel of the micro channel portion extends along a direction parallel to the film surfaces of the diaphragms; and

the internal-pressure buffering chamber of the internal-pressure-buffering-chamber-forming portion forms a space whose longitudinal axis lies in a plane parallel to the film surfaces of the diaphragms and is connected with the channel of the channel forming portion via the micro channel of the micro channel portion.

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