US 20230356997A1

(19) **United States**

(12) **Patent Application Publication**

TAKAYAMA et al.

(10) **Pub. No.: US 2023/0356997 A1**

(43) **Pub. Date: Nov. 9, 2023**

(54) **PIEZOELECTRIC DRIVE ELEMENT**

(71) Applicant: **Panasonic Intellectual Property Management Co., Ltd.**, Osaka (JP)

(72) Inventors: **Ryouichi TAKAYAMA**, Osaka (JP); **Kazuki Komaki**, Osaka (JP); **Takami Ishida**, Osaka (JP); **Kensuke Mihara**, Osaka (JP)

(21) Appl. No.: **18/223,102**

(22) Filed: **Jul. 18, 2023**

Related U.S. Application Data

(63) Continuation of application No. PCT/JP21/43297, filed on Nov. 25, 2021.

(30) **Foreign Application Priority Data**

Jan. 18, 2021 (JP) 2021-005767

Publication Classification

(51) **Int. Cl.**

B81B 3/00 (2006.01)

G02B 26/08 (2006.01)

G02B 26/10 (2006.01)

(52) **U.S. Cl.**

CPC ***B81B 3/0021*** (2013.01); ***G02B 26/0858*** (2013.01); ***G02B 26/105*** (2013.01); *B81B 2201/042* (2013.01); *B81B 2203/058* (2013.01); *B81B 2203/019* (2013.01)

(57) **ABSTRACT**

A piezoelectric drive element includes: a movable part; a pair of piezoelectric drive parts each connected at one end portion thereof to the movable part and configured to rotate the movable part about at least a rotation axis; and a fixing part to which end portions of the piezoelectric drive parts are connected. The pair of piezoelectric drive parts are aligned in a direction along the rotation axis with the movable part located therebetween, a width of the movable part is narrower than a width of each of the pair of piezoelectric drive parts in a plan view, and the fixing part is placed in a gap region that is outside the movable part and that is located between the pair of piezoelectric drive parts in a plan view.

EMBODIMENT 1

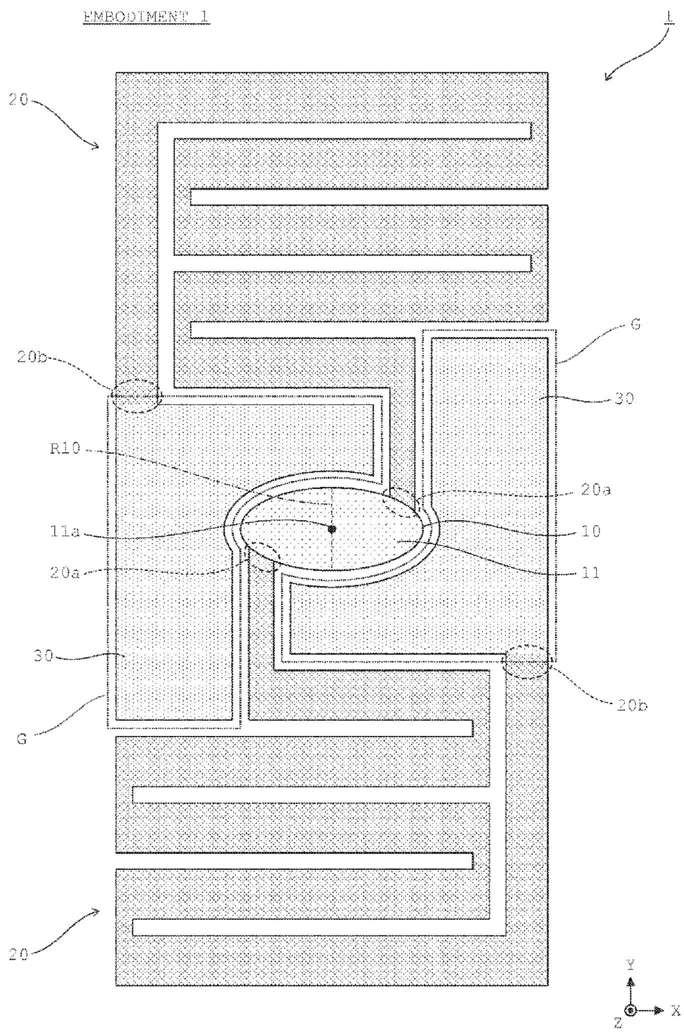


FIG. 1 EMBODIMENT 1

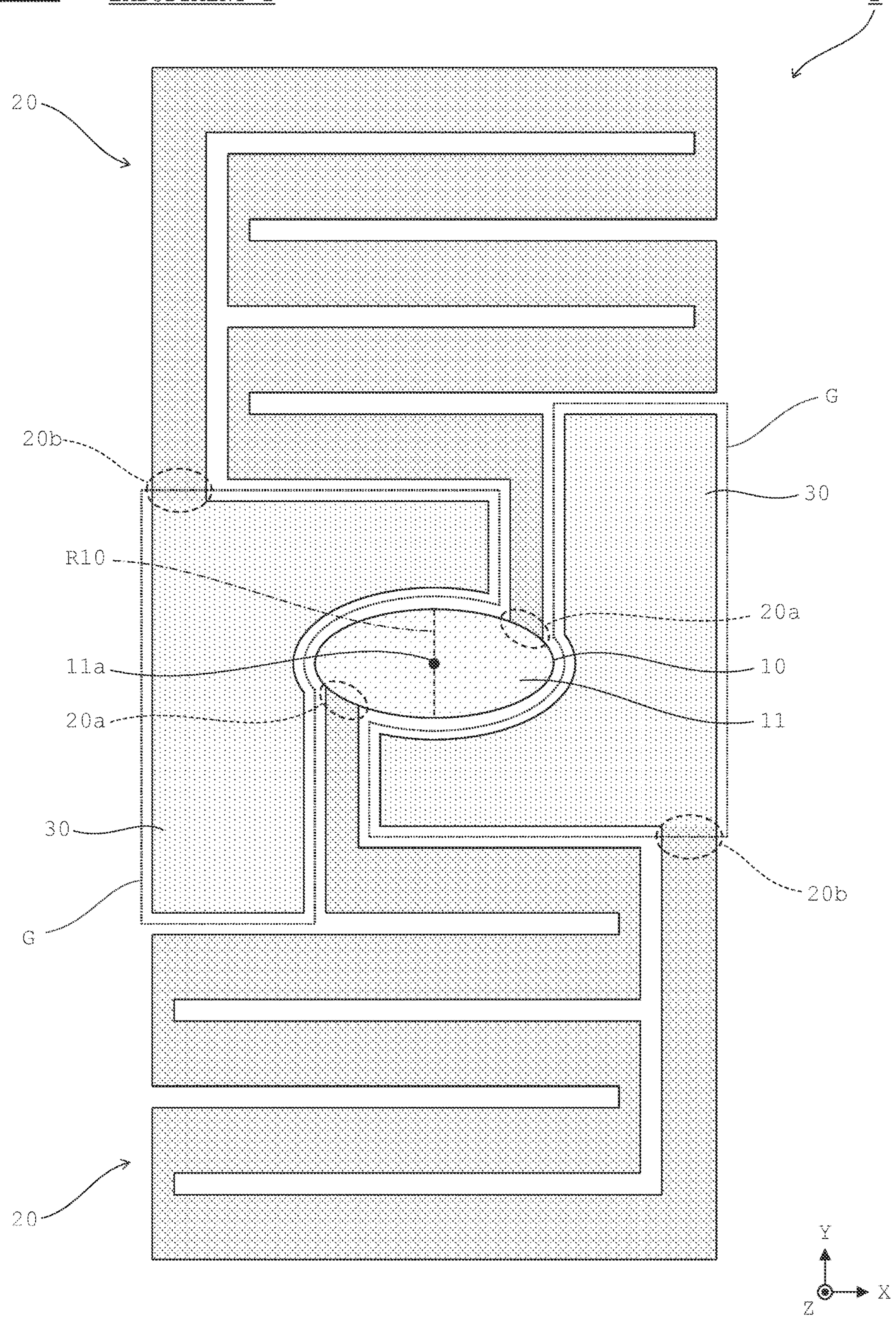
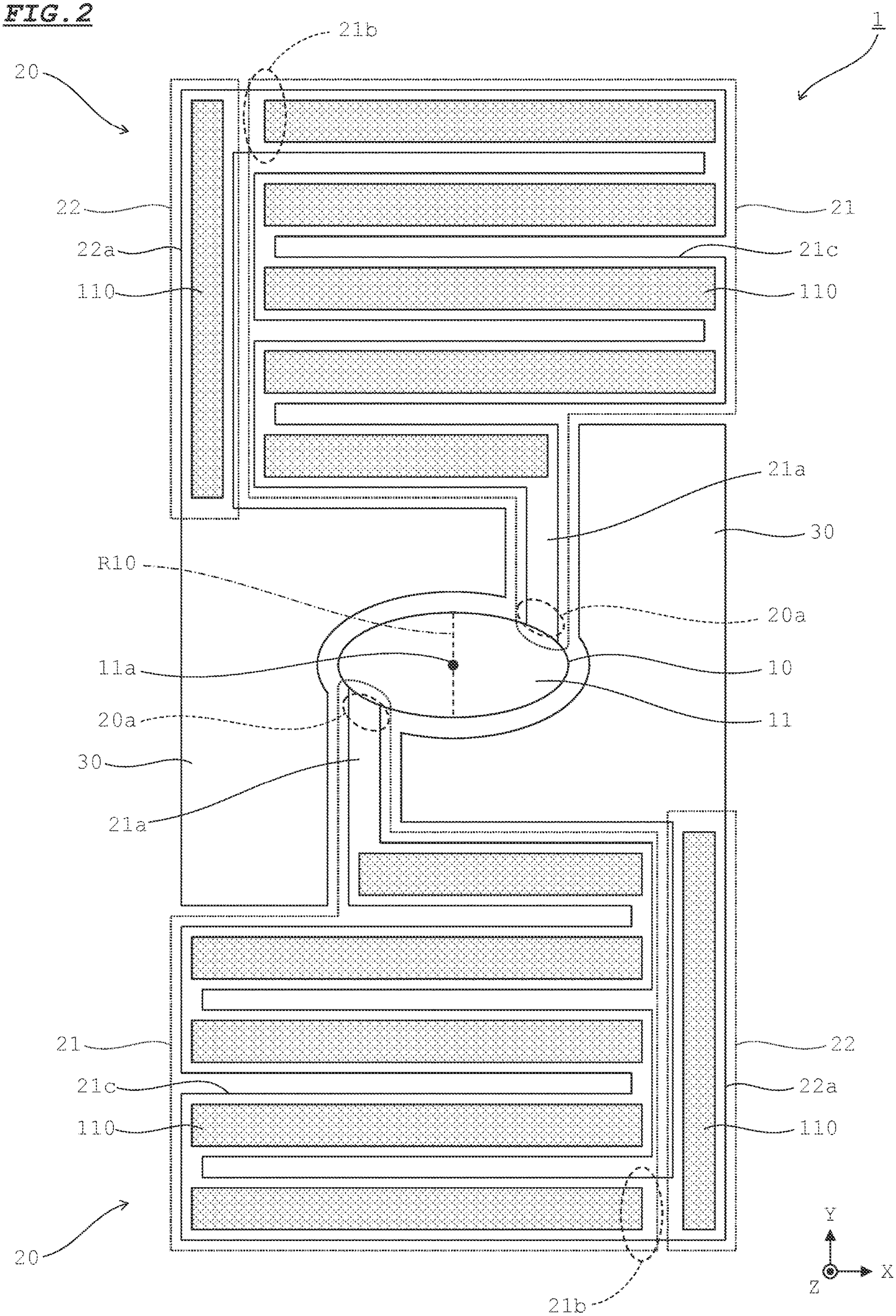


FIG. 2



21b
1
20
22
22a
110
21
21c
110
21a
30
R10
20a
11a
10
20a
11
30
21a
21
22
21c
22a
110
110
20
21b
Y
X
Z

FIG. 3A

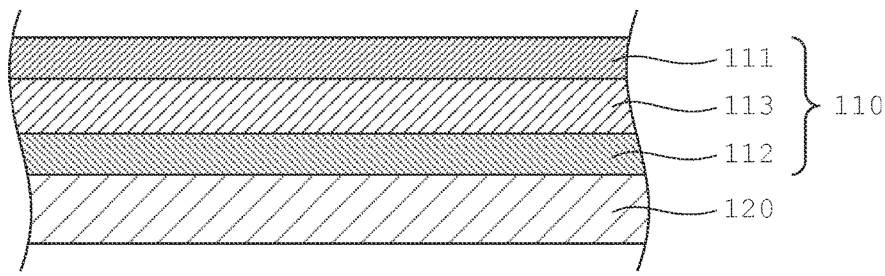


FIG. 3B

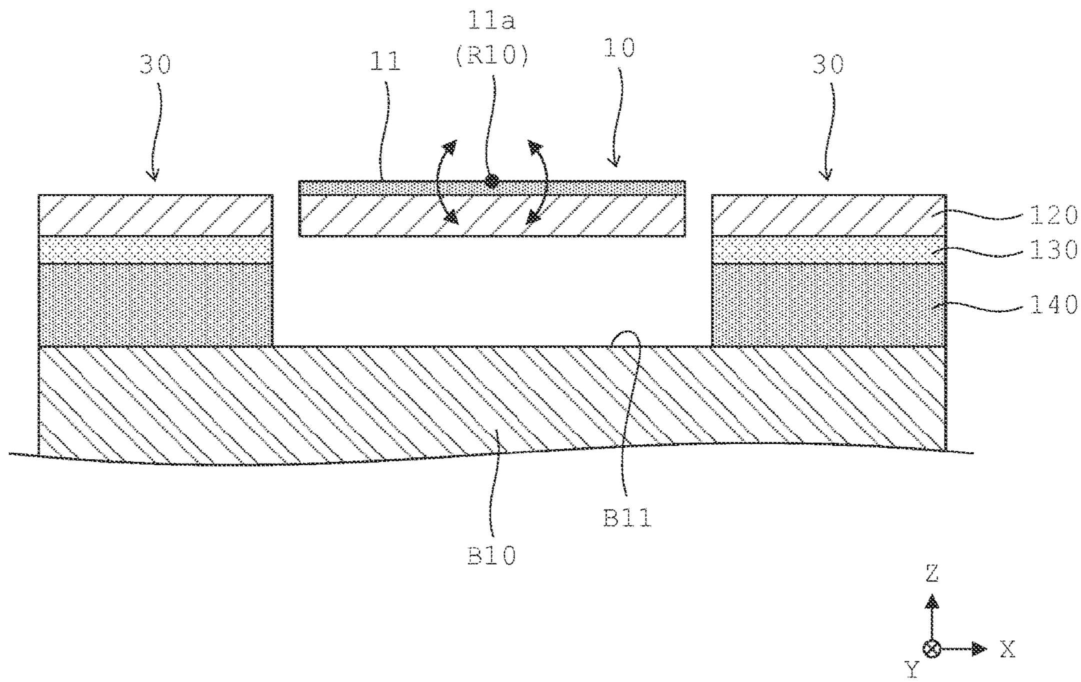


FIG. 4A

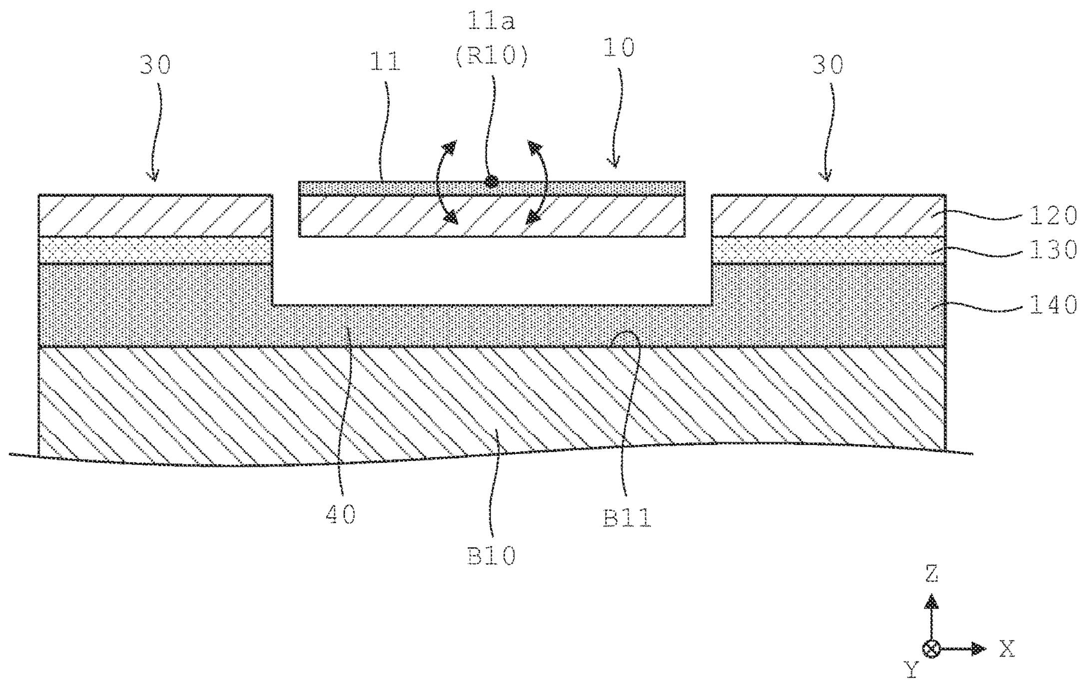

11a
(R10)
30
11
10
30
120
130
140
40
B10
B11
Z
X
Y

FIG. 4B

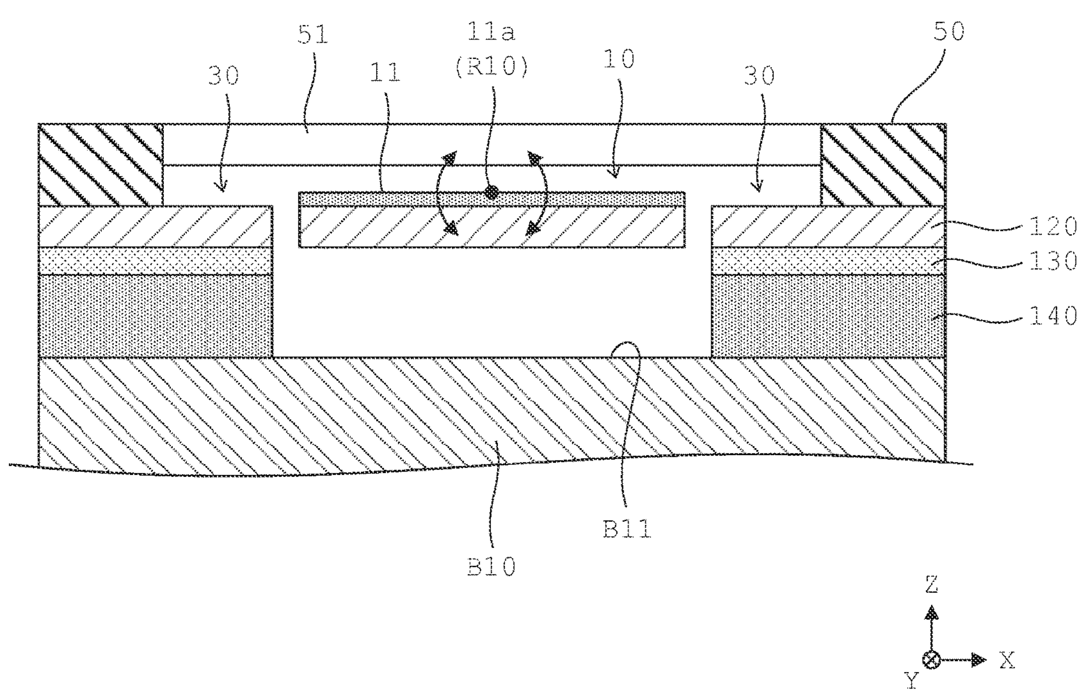

51
11a
(R10)
50
30
11
10
30
120
130
140
B11
B10
Z
X
Y

FIG. 5 EMBODIMENT 2

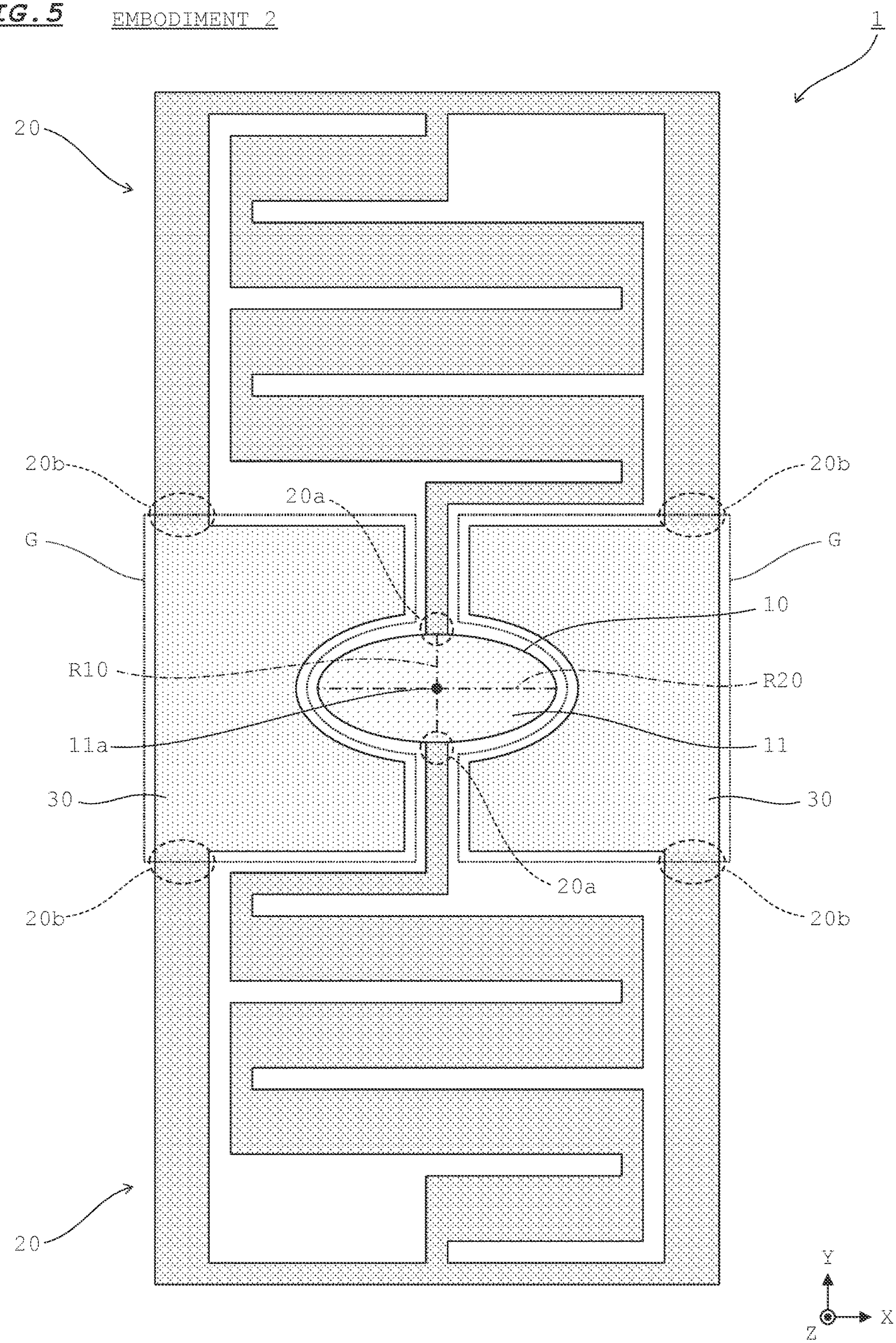


FIG. 6

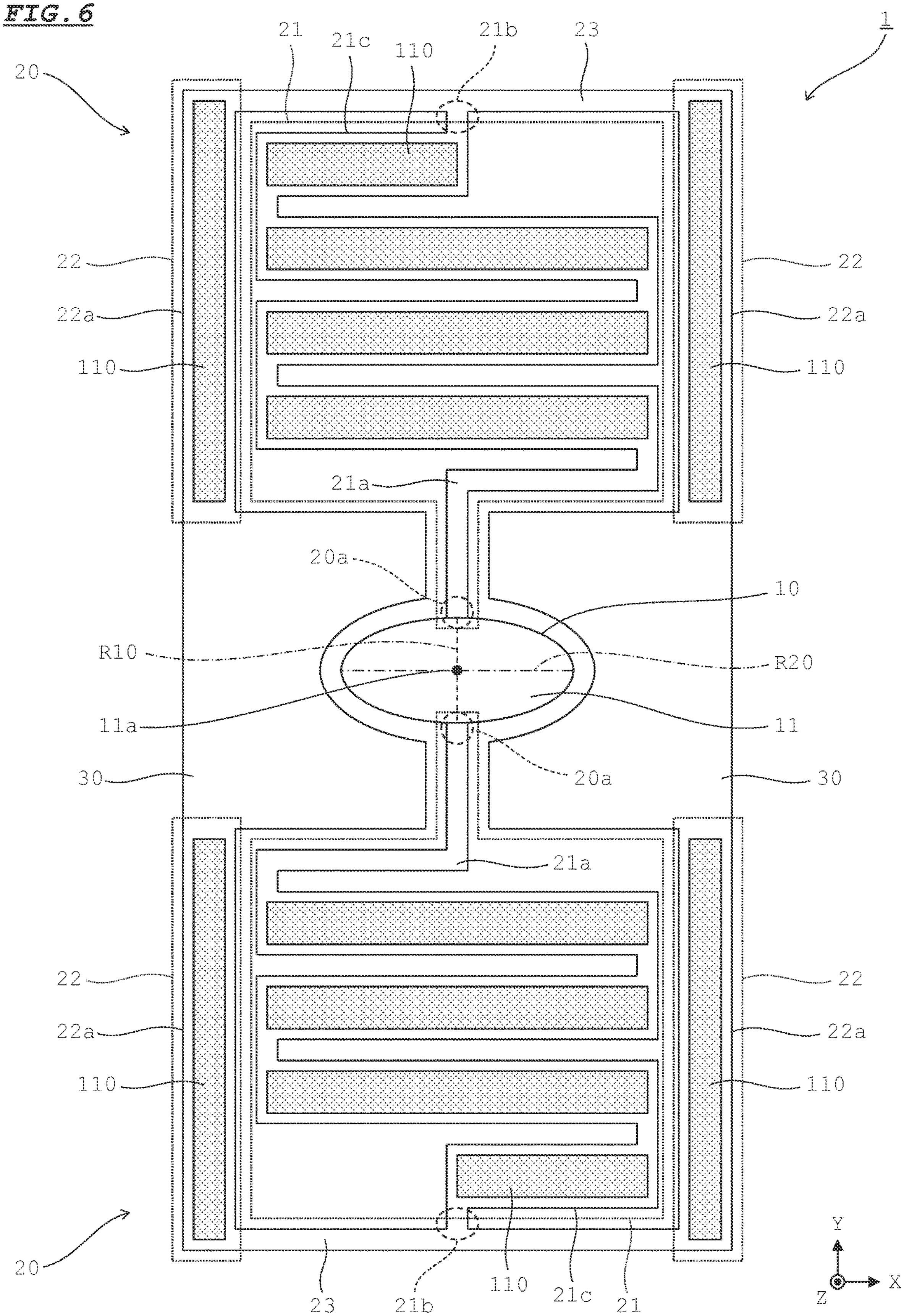


FIG. 7 MODIFICATION 1 OF EMBODIMENT 2

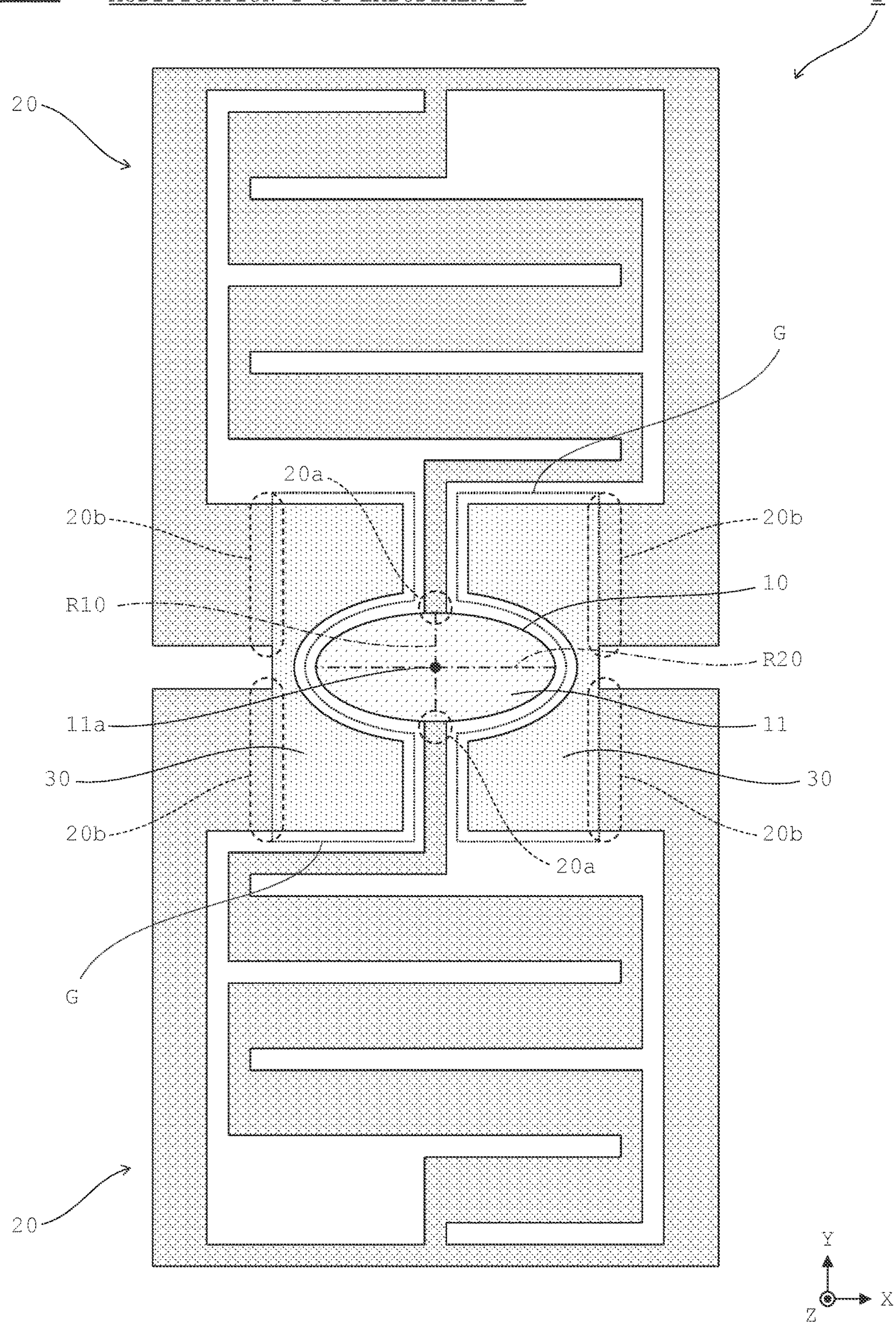


FIG. 8

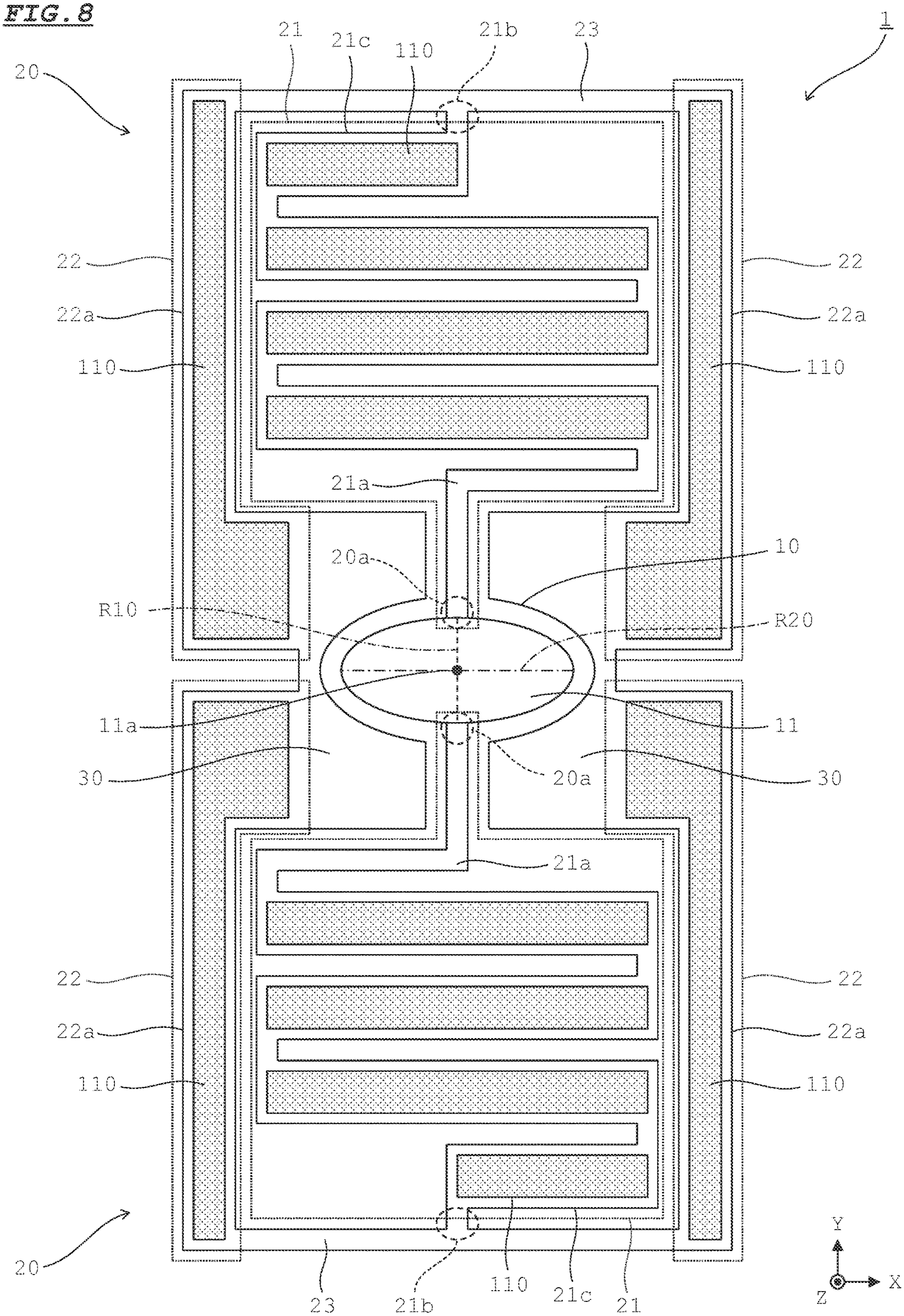


FIG. 9 MODIFICATION 2 OF EMBODIMENT 2

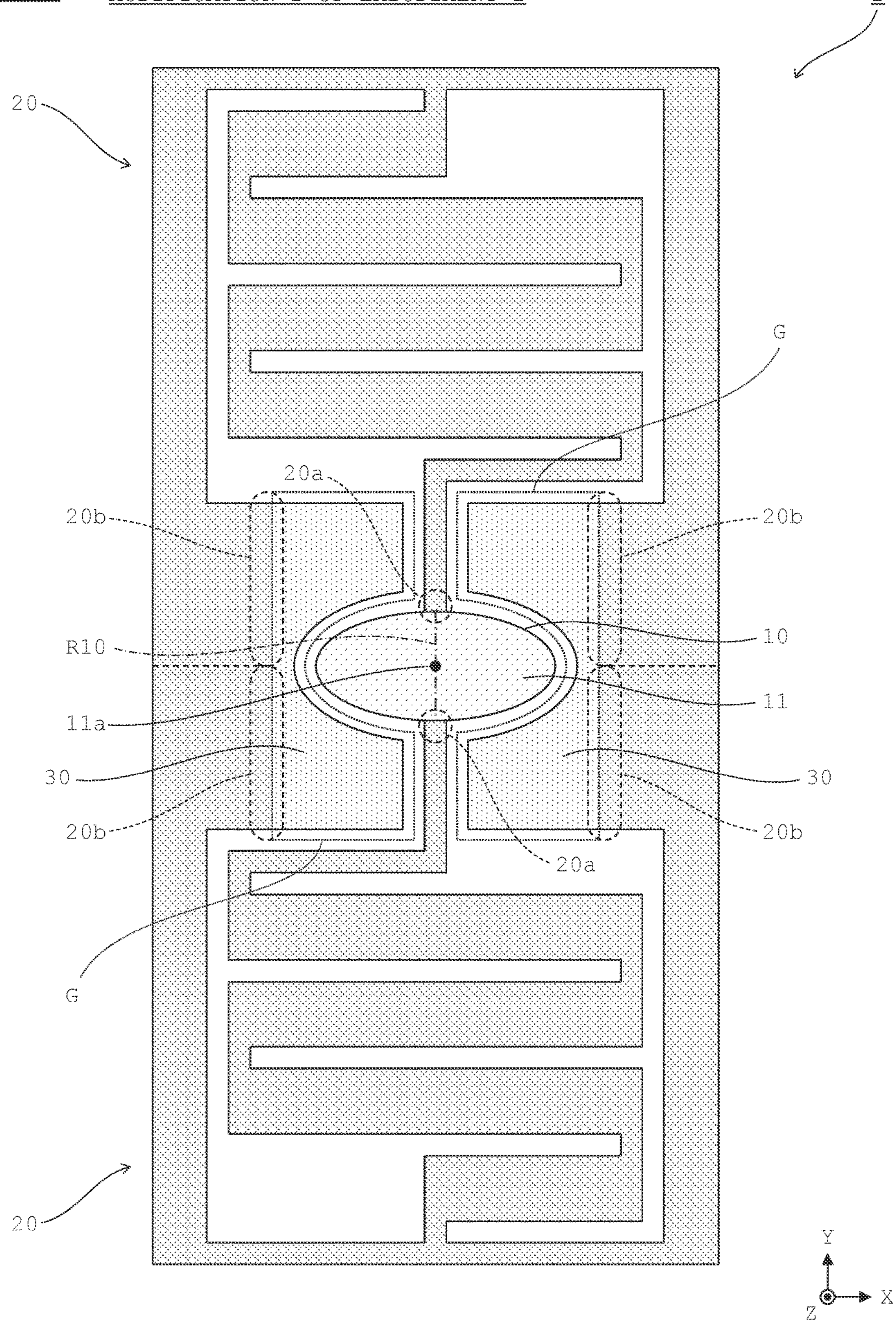


FIG. 10

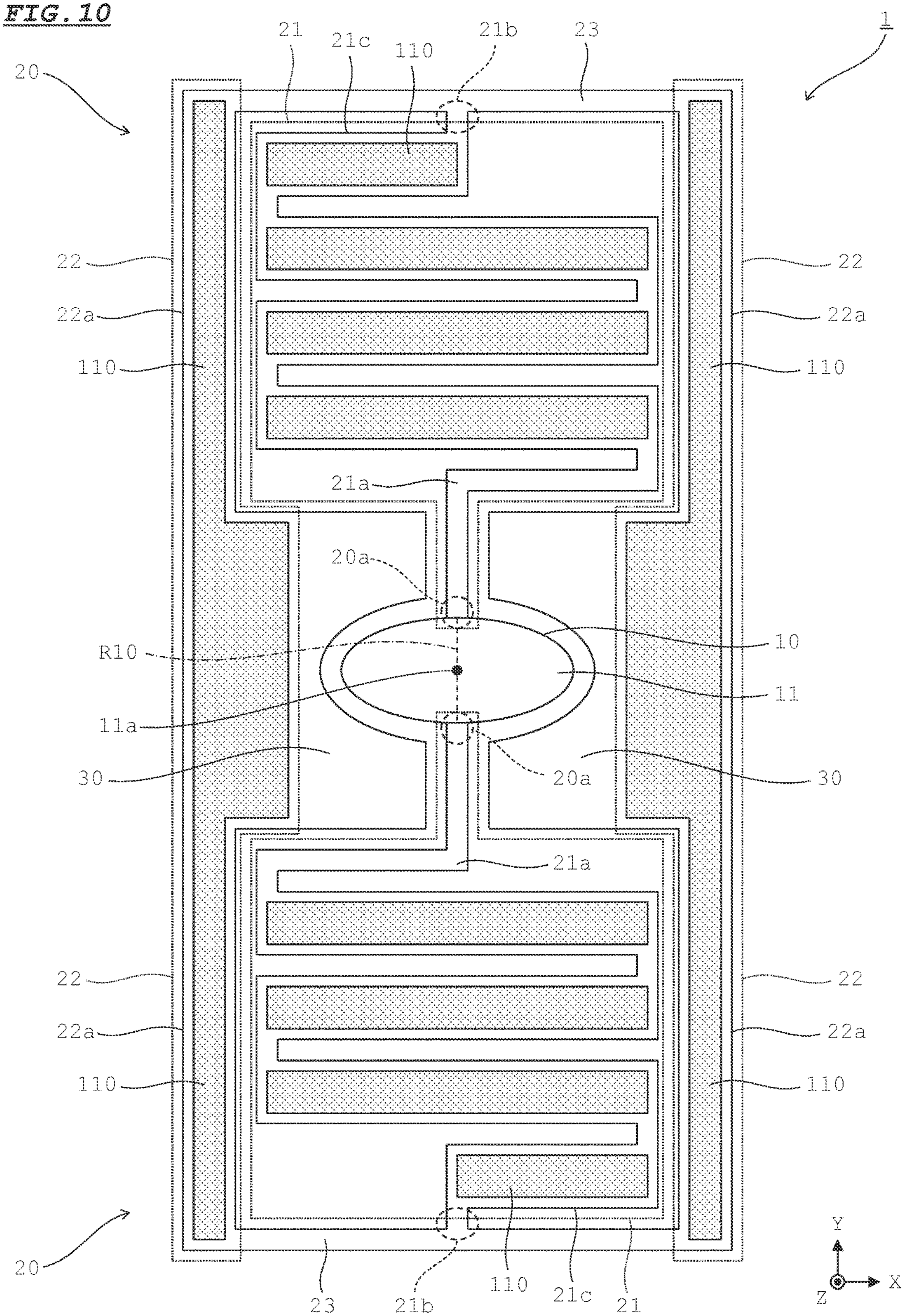


FIG. 11 EMBODIMENT 3

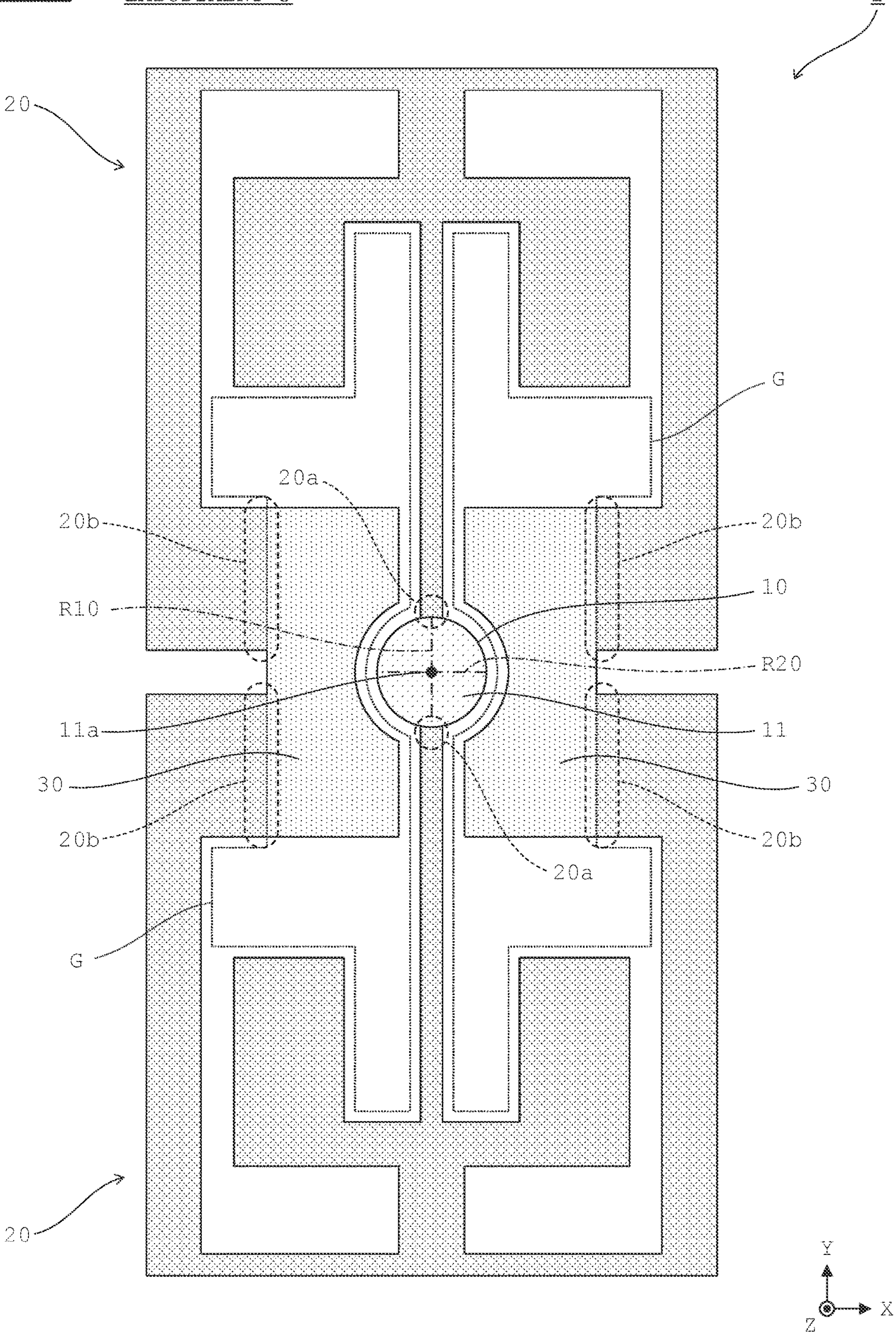


FIG. 12

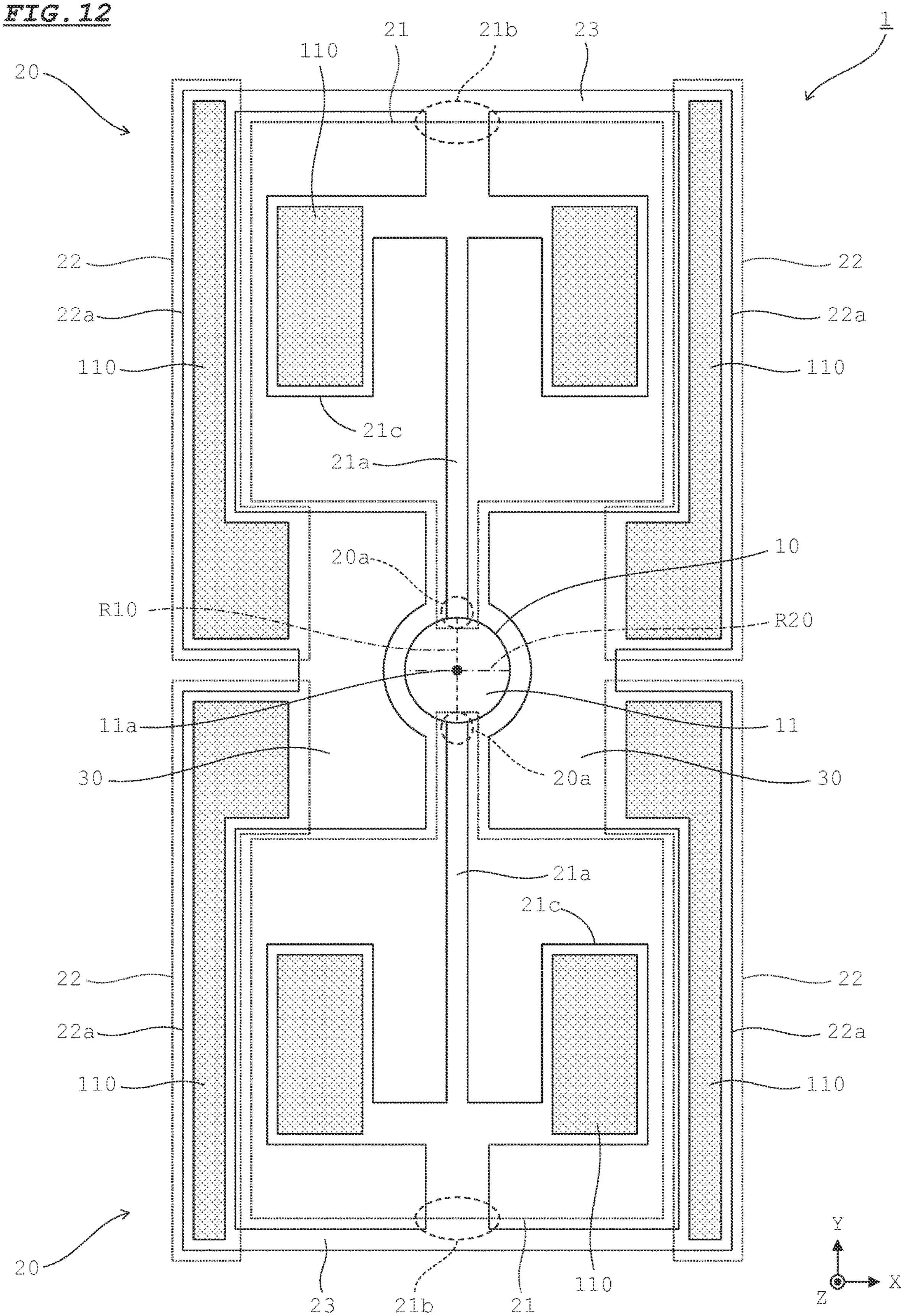


FIG. 13 MODIFICATION OF EMBODIMENT 3

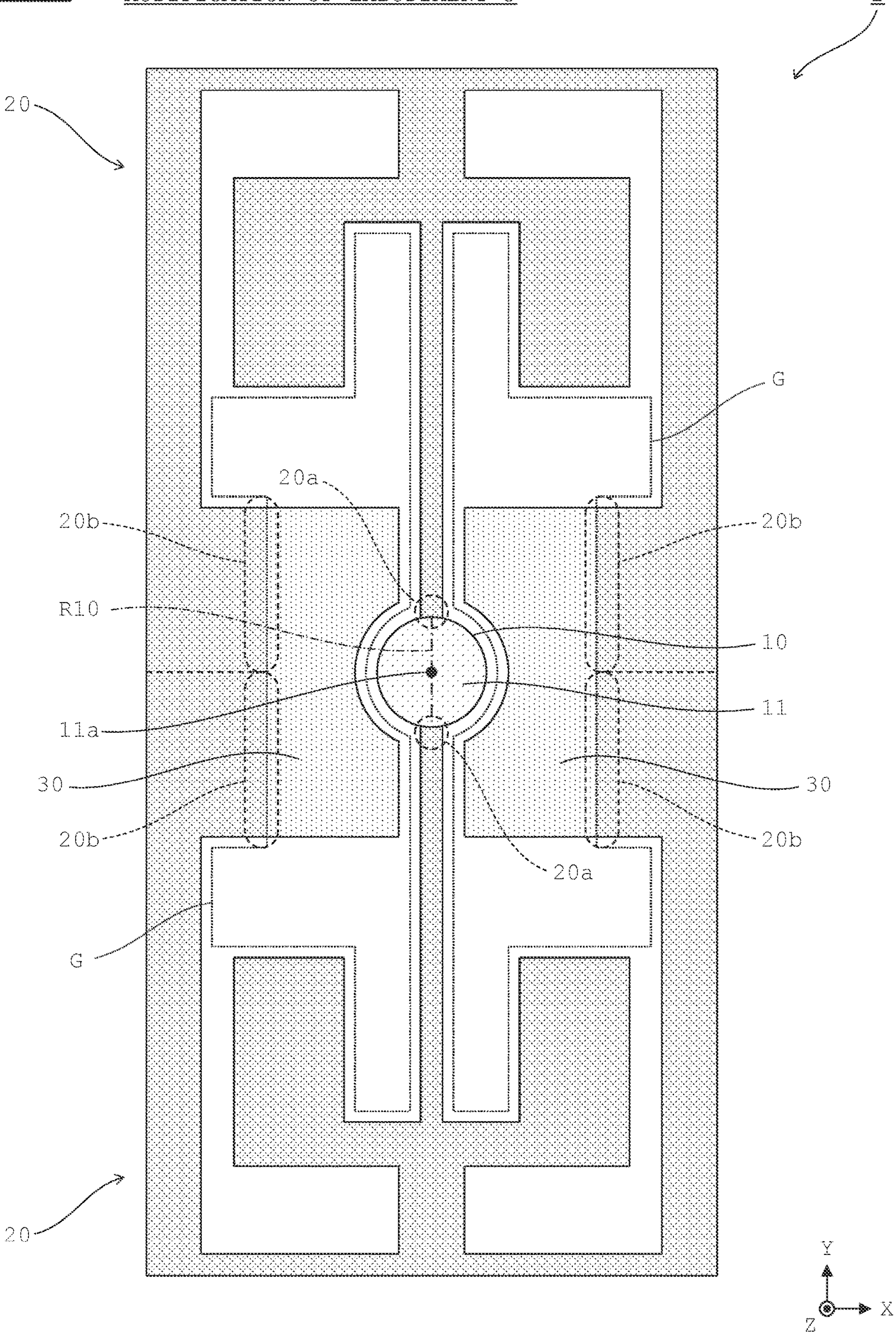


FIG. 14

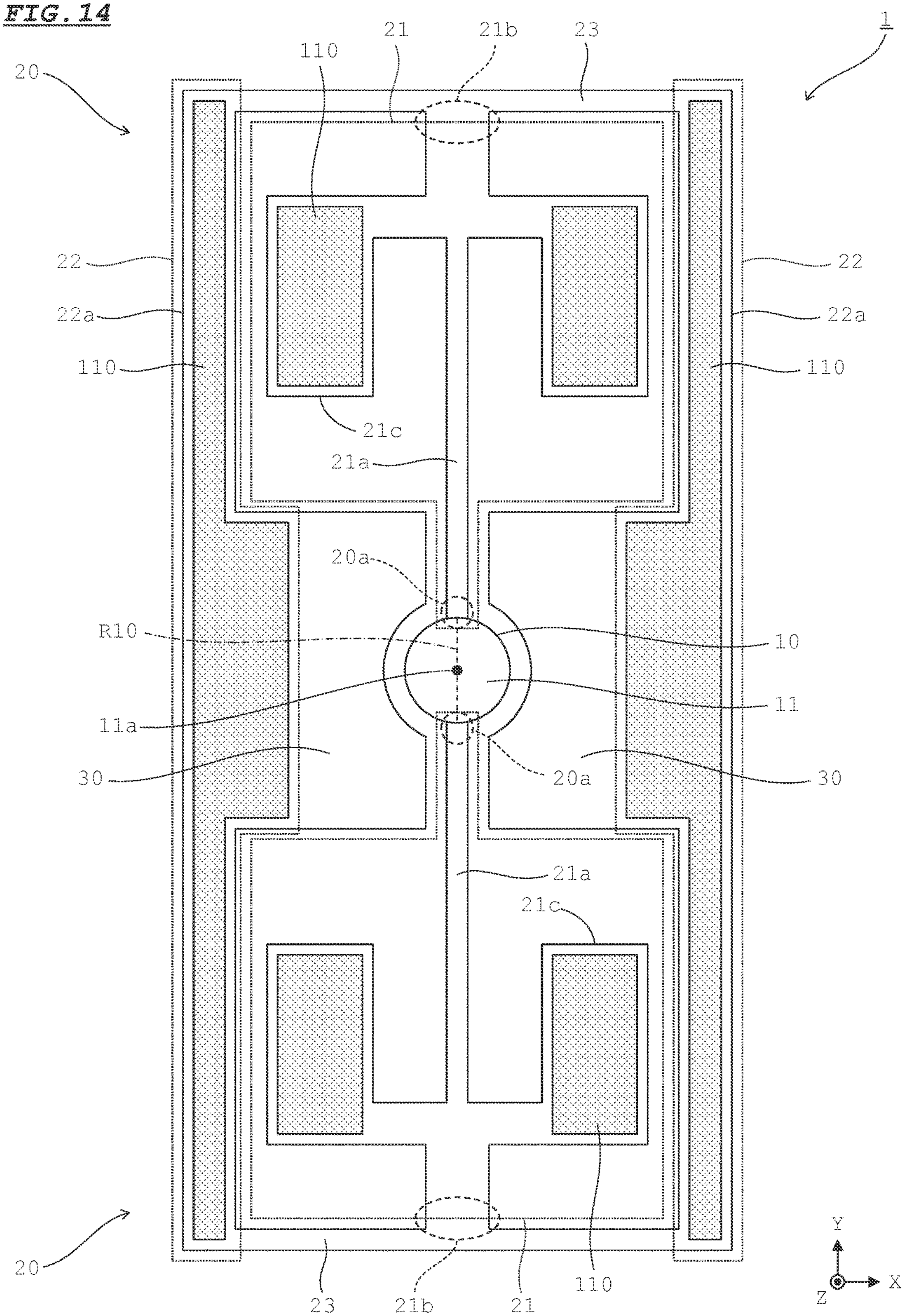


FIG. 15 EMBODIMENT 4

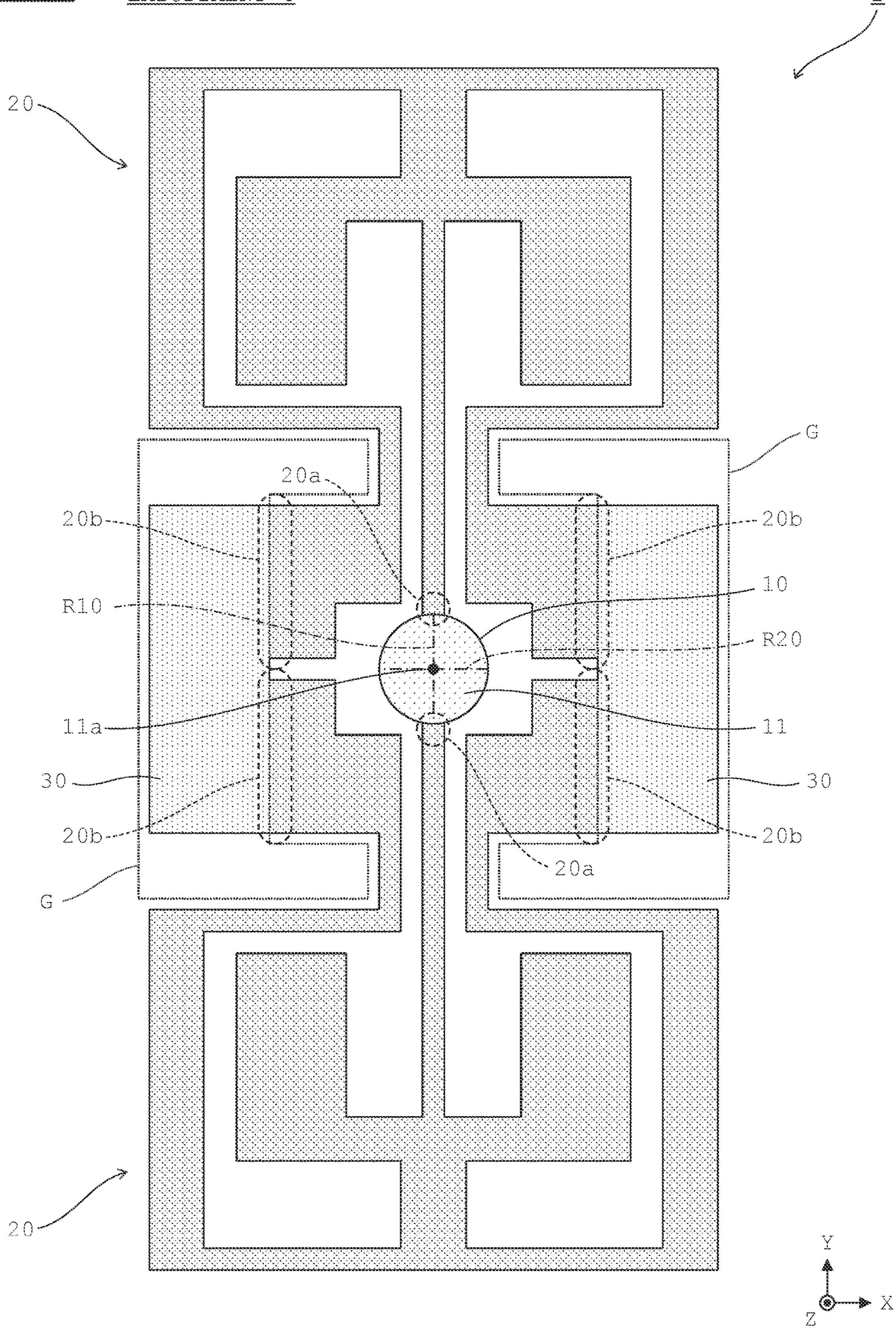
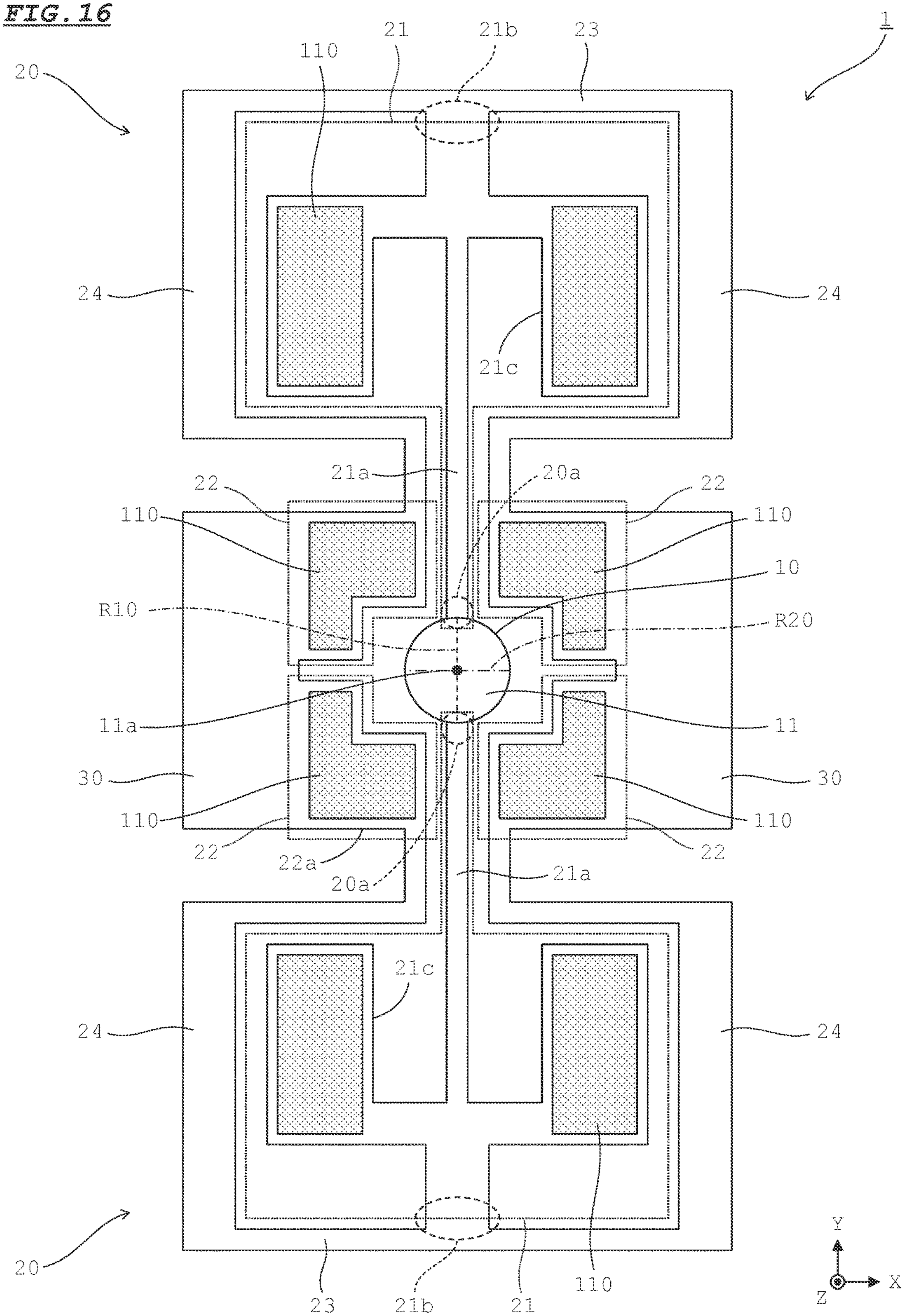


FIG. 16



1
20
110
21
21b
23
24
24
21c
21a
20a
22
22
110
110
10
R10
R20
11a
11
30
30
110
110
22
22a
20a
22
21a
21c
24
24
20
23
21b
21
110
Y
X
Z

FIG. 17 MODIFICATION OF EMBODIMENT 4

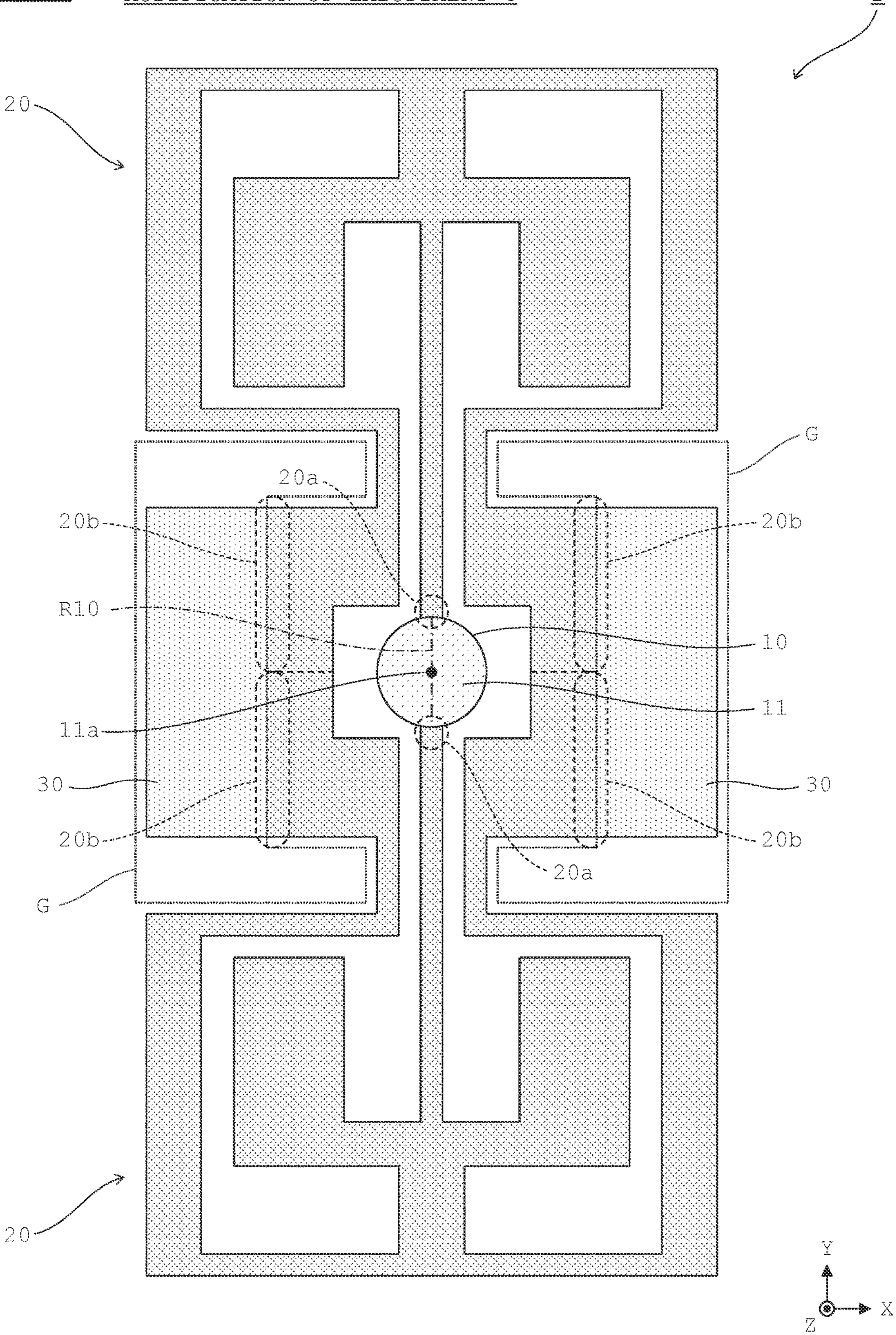
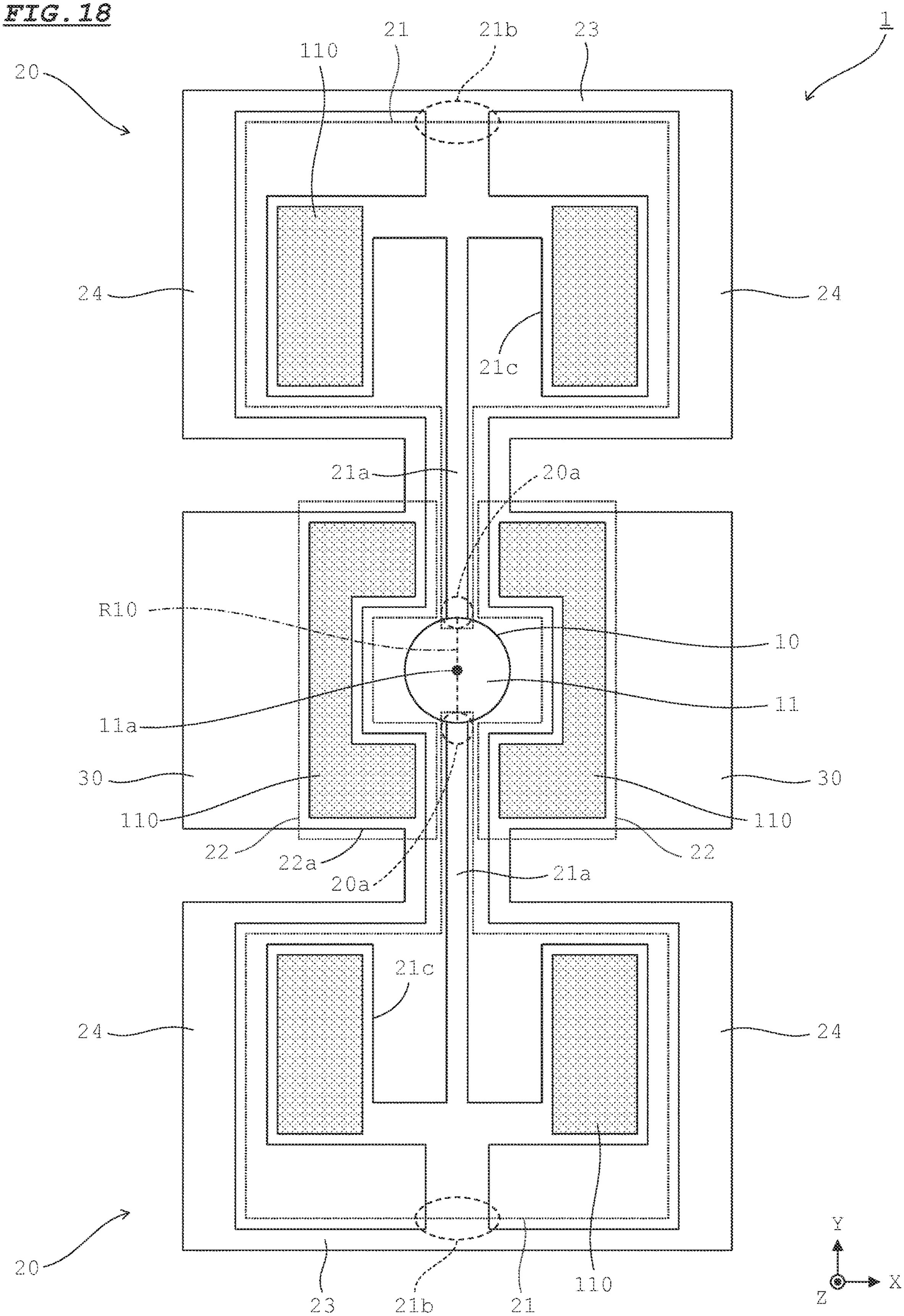


FIG. 18



1
20
110
21
21b
23
24
24
21c
21a
20a
R10
10
11a
11
30
30
110
110
22
22a
20a
21a
22
21c
24
24
20
23
21b
21
110
Y
X
Z

FIG. 19 EMBODIMENT 5

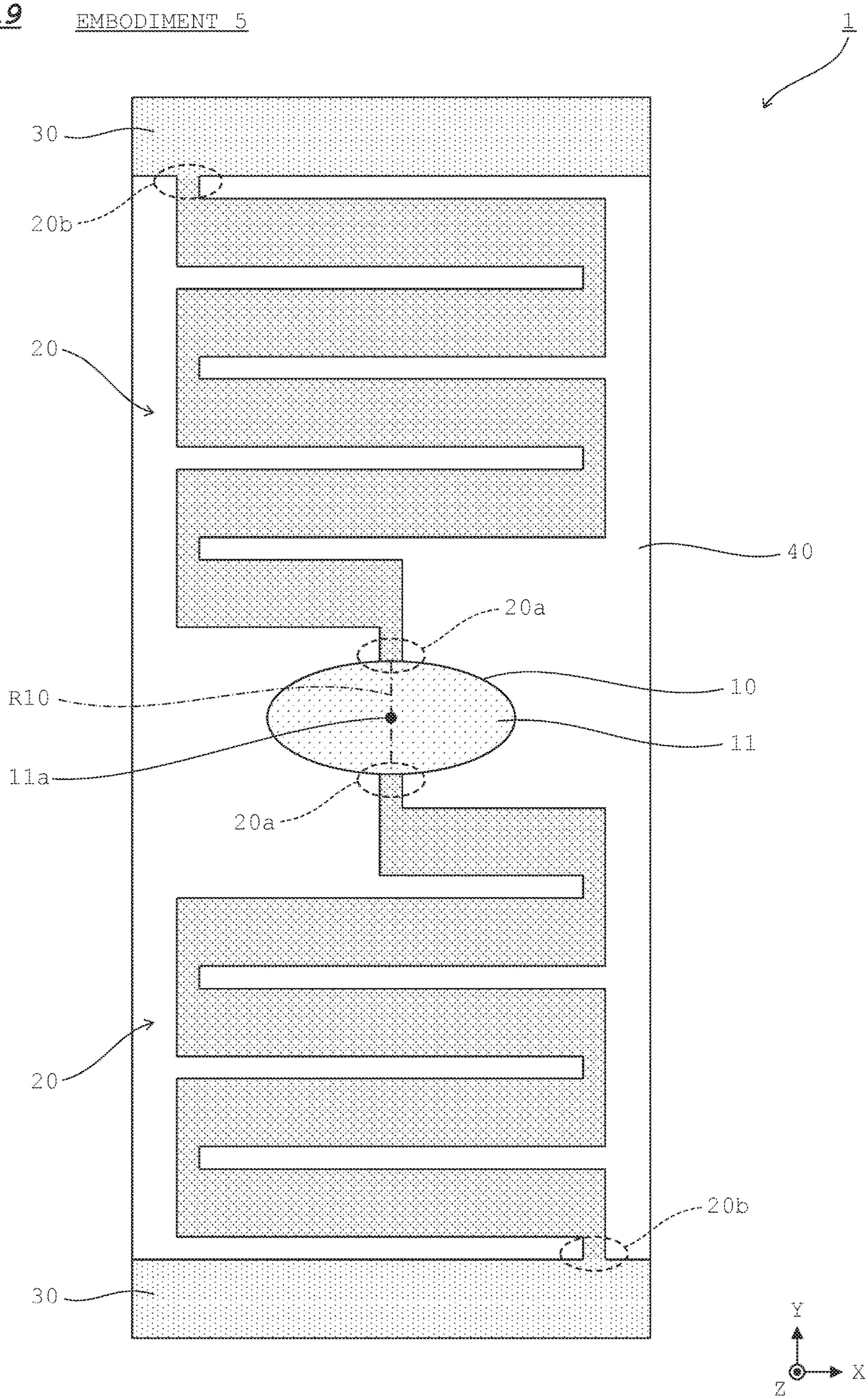


FIG. 20

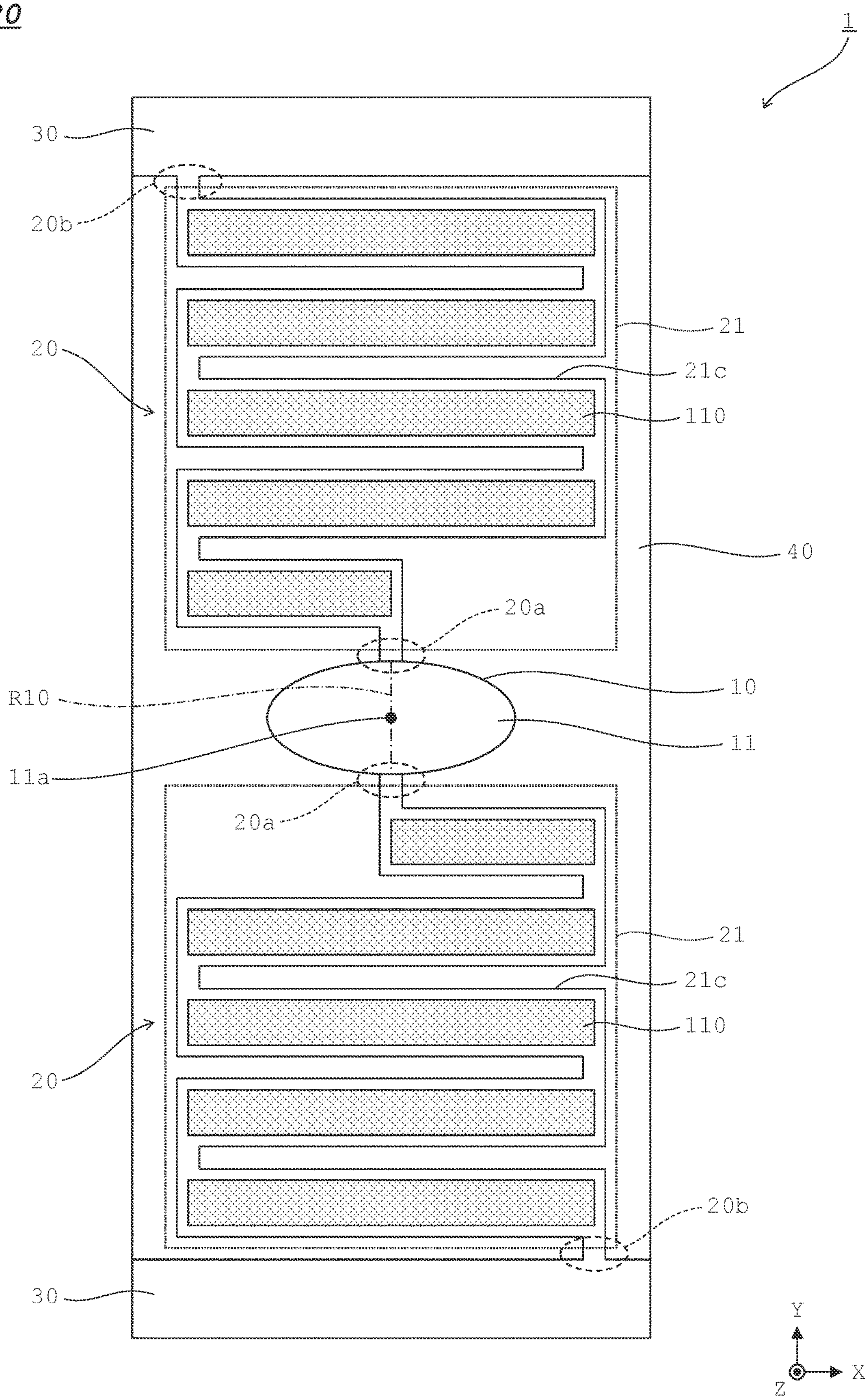

1
30
20b
20
21
21c
110
40
20a
10
R10
11
11a
20a
21
21c
110
20
20b
30
Y
X
Z

FIG.21

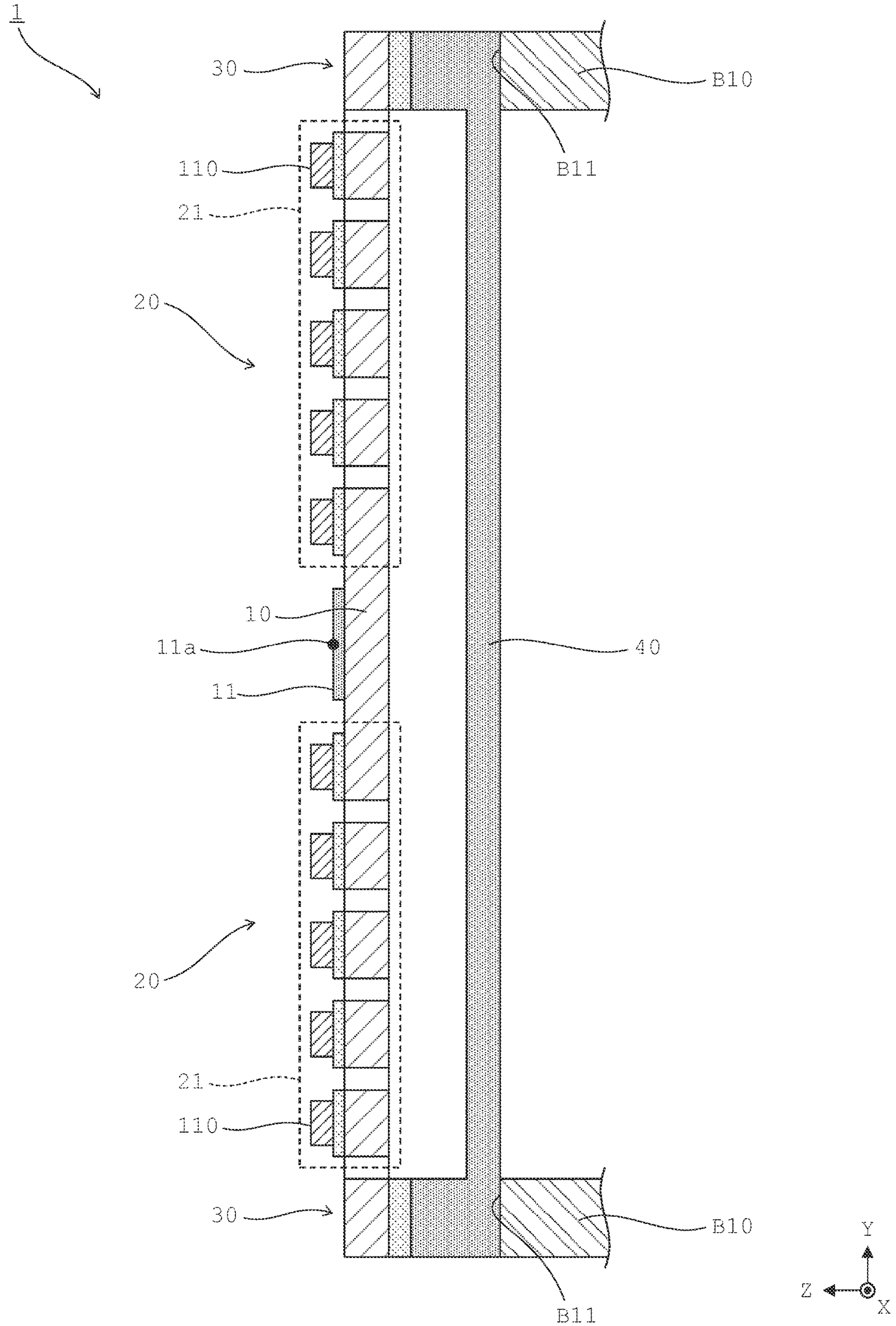


FIG.22 MODIFICATION 1 OF EMBODIMENT 5

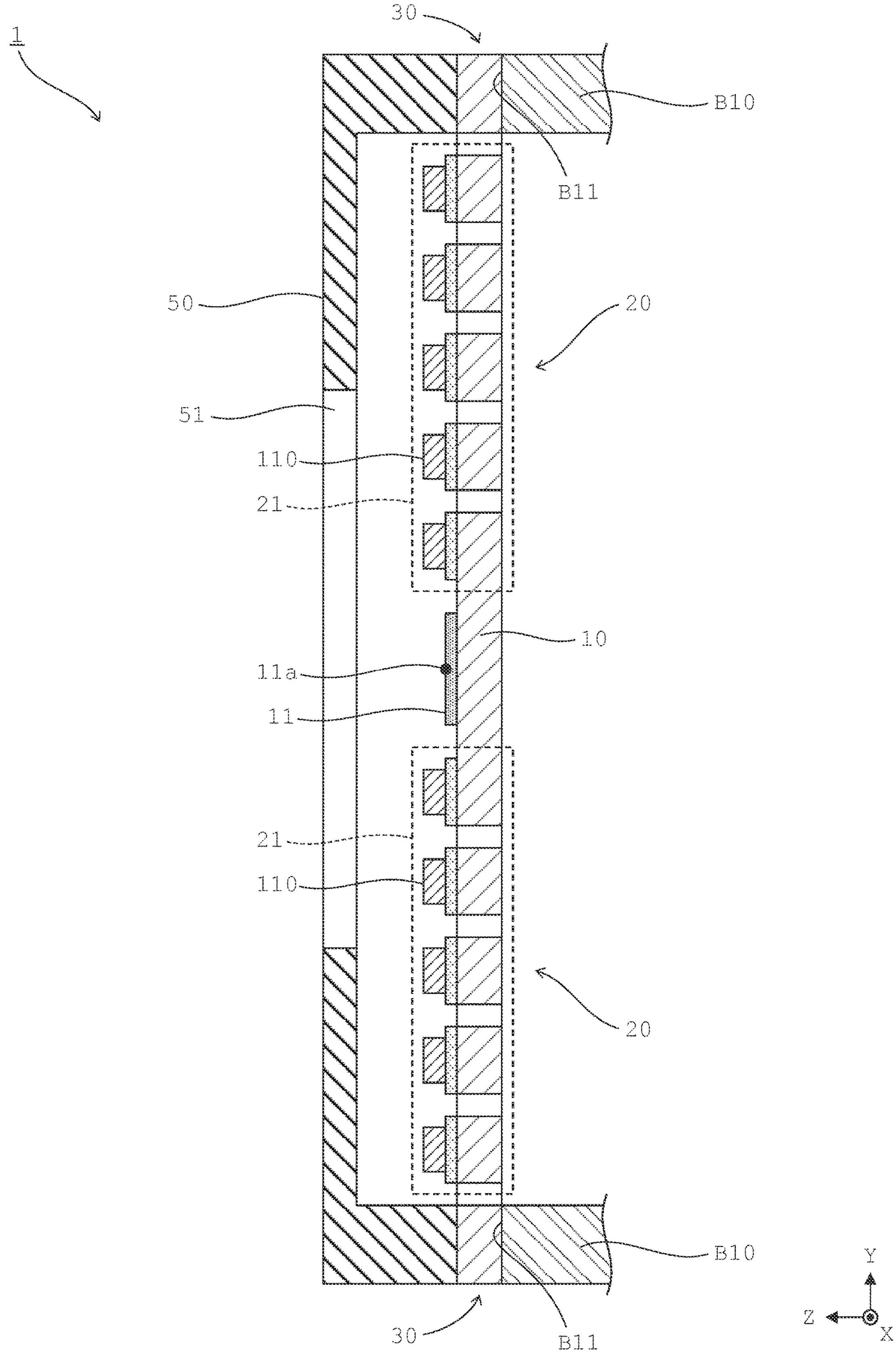


FIG.23 MODIFICATION 2 OF EMBODIMENT 5

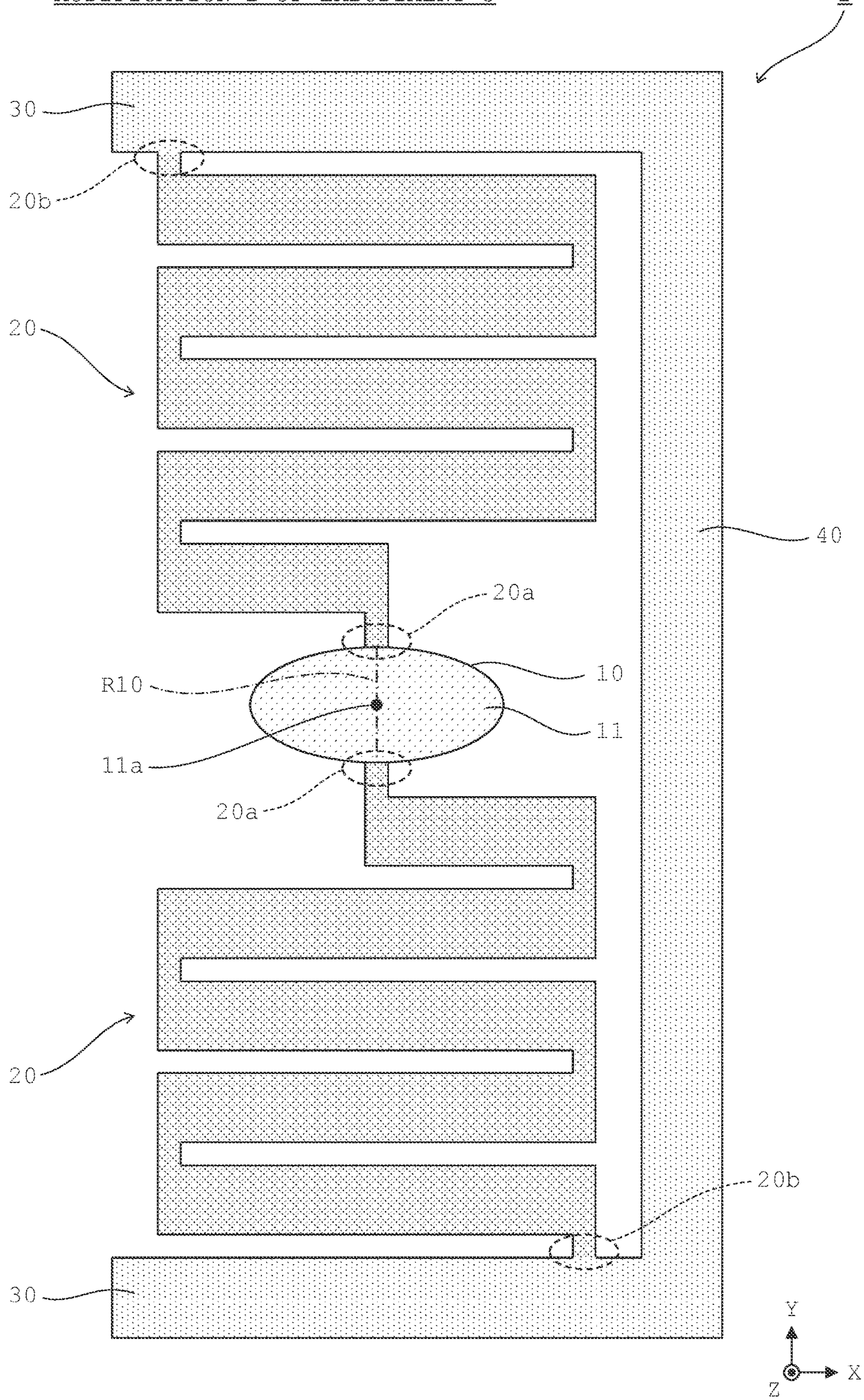


FIG. 24 EMBODIMENT 6

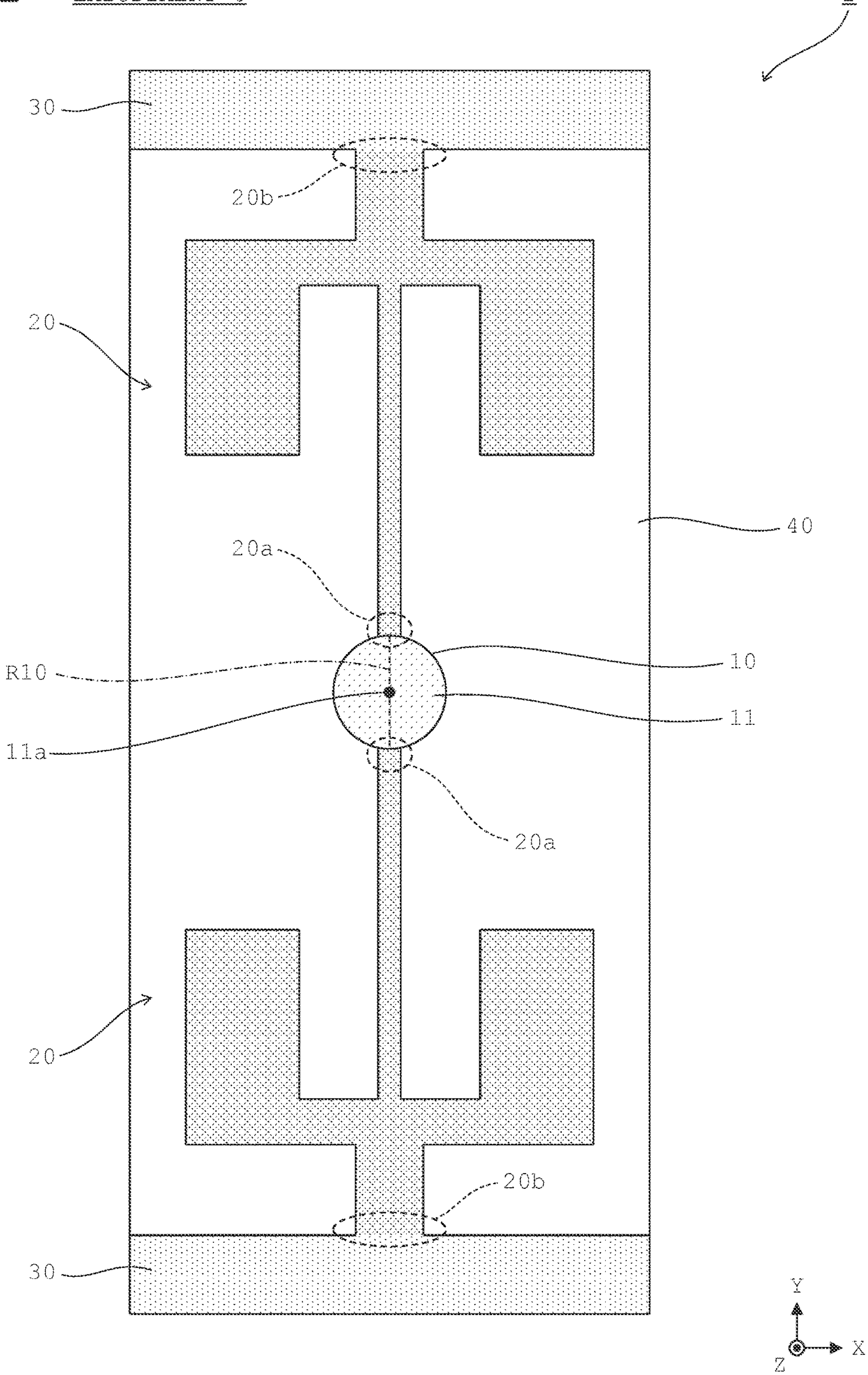


FIG. 25

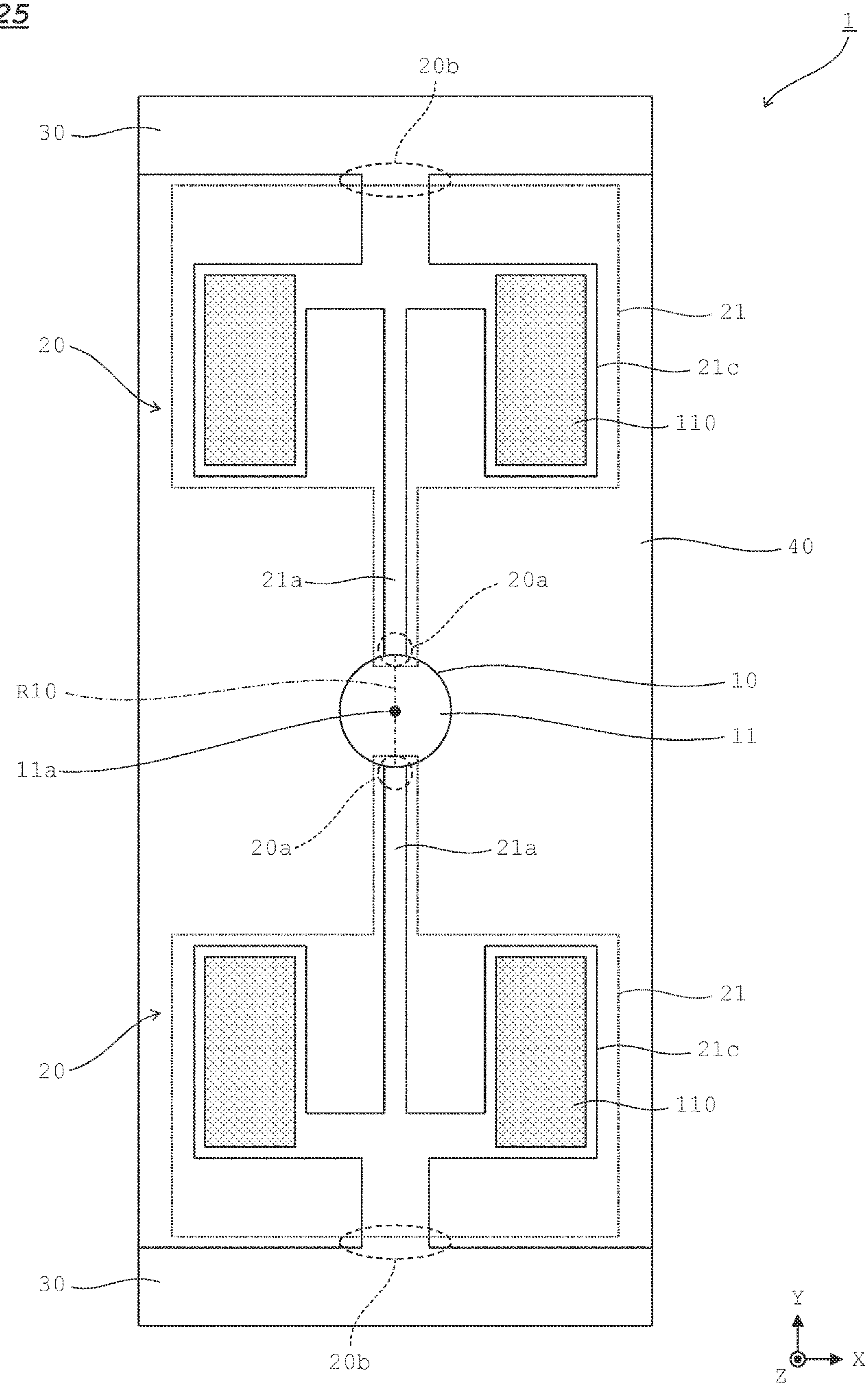

1
20b
30
20
21
21c
110
40
21a
20a
R10
10
11
11a
20a
21a
21
20
21c
110
30
20b
Y
X
Z

FIG. 26

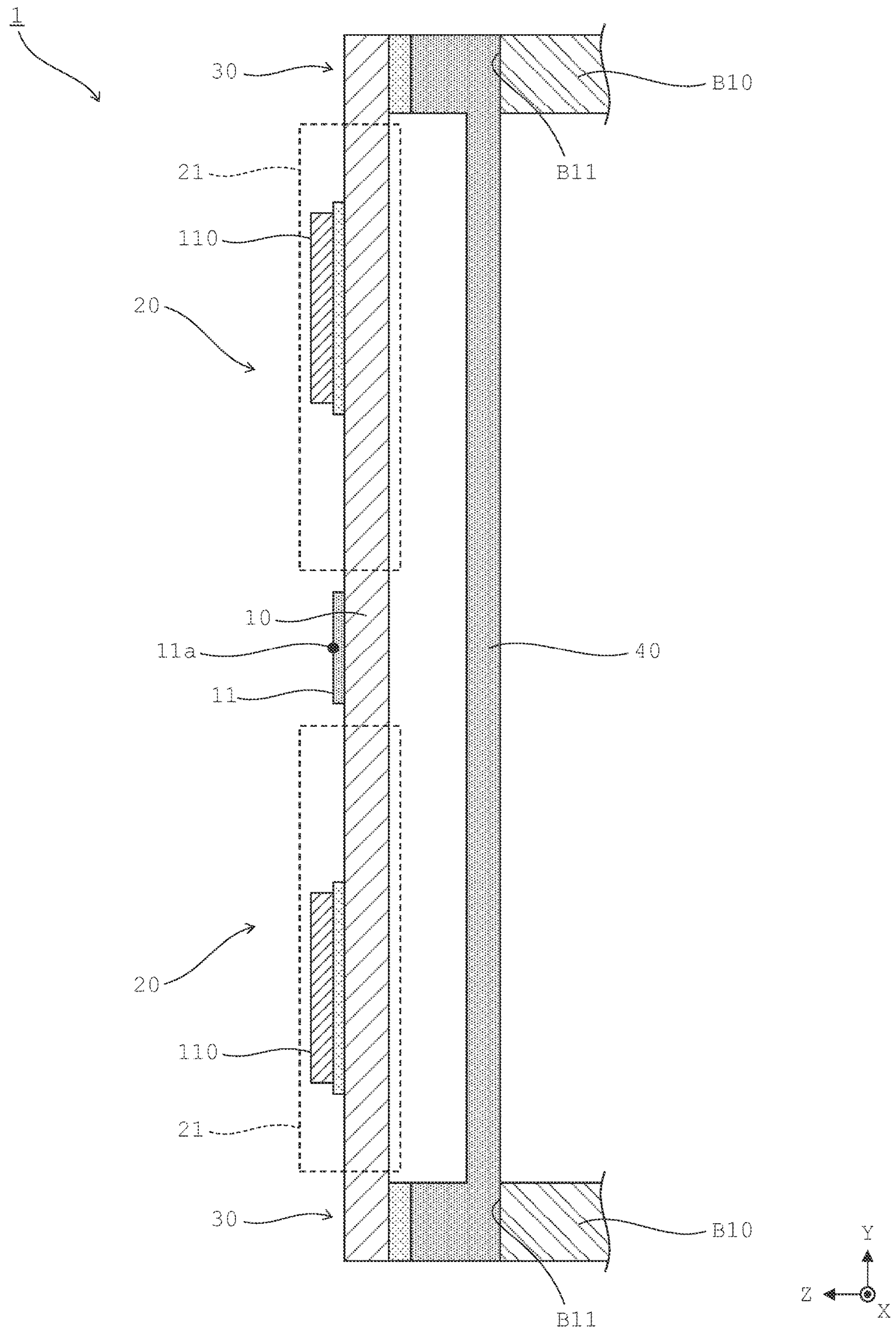


FIG. 27 MODIFICATION 1 OF EMBODIMENT 6

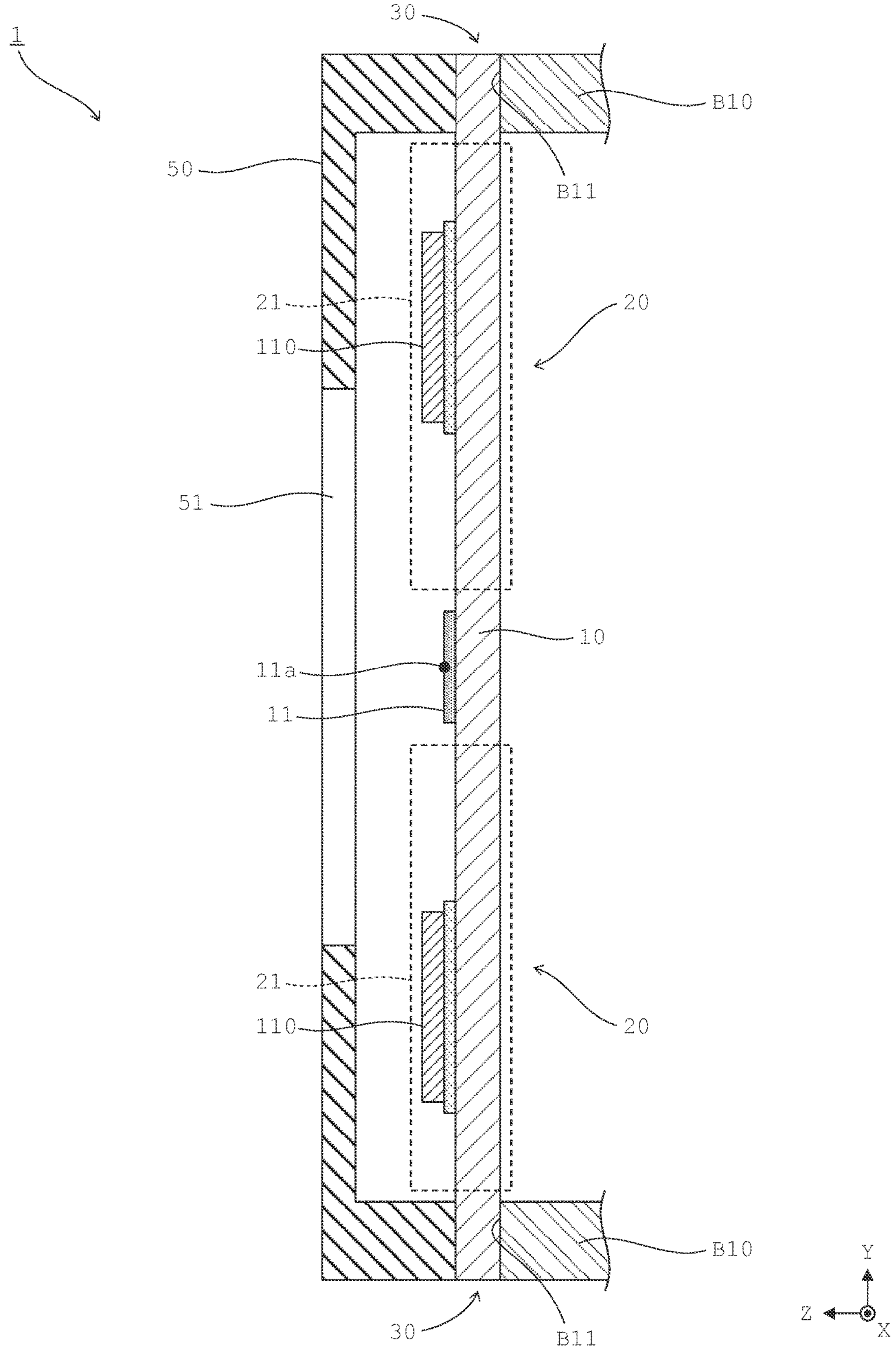


FIG. 28 MODIFICATION 2 OF EMBODIMENT 6

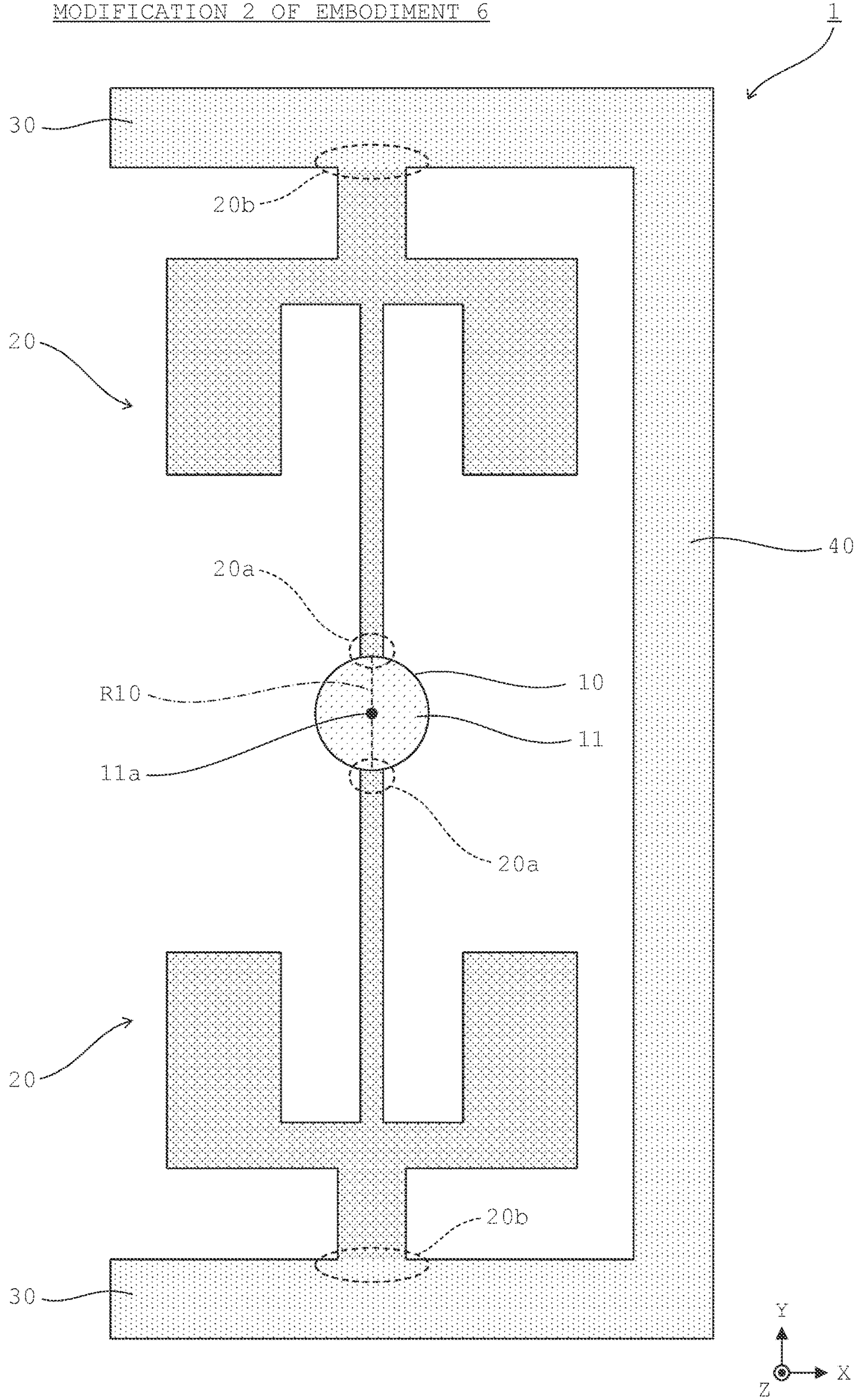


FIG.29 ANOTHER MODIFICATION

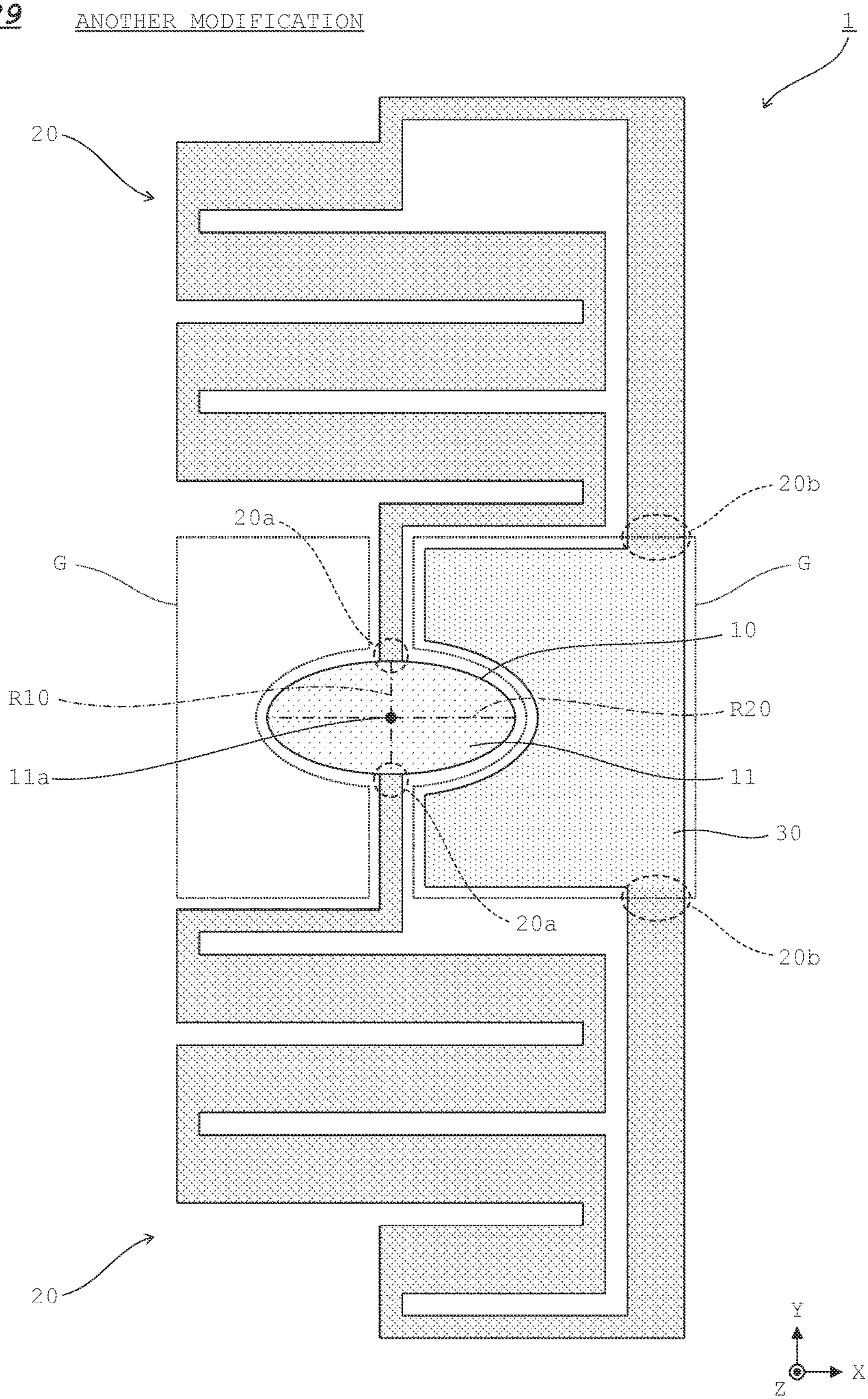
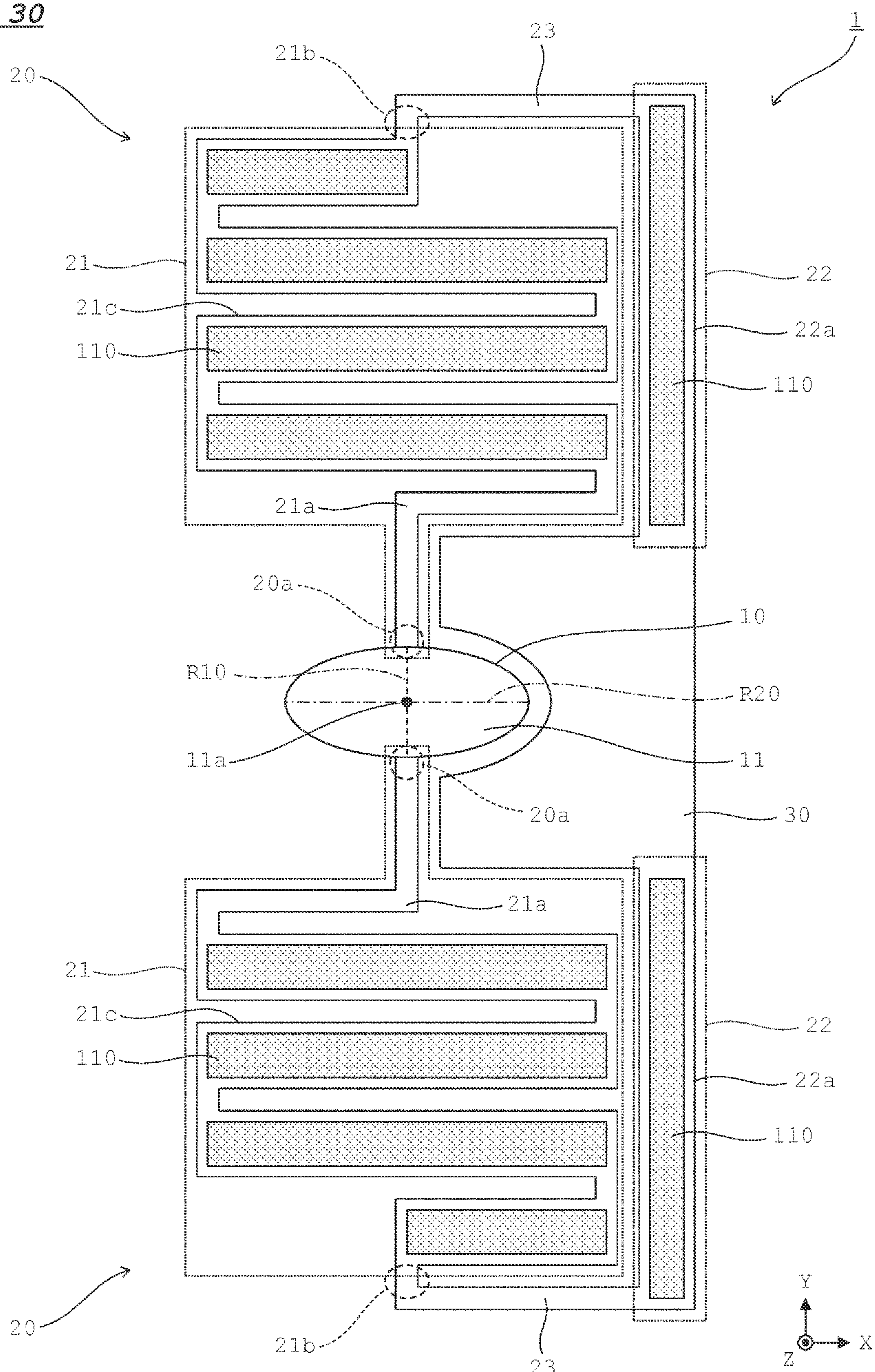


FIG. 30



1
20
21b
23
21
21c
110
22
22a
110
21a
20a
10
R10
R20
11a
11
20a
30
21a
21
21c
110
22
22a
110
20
21b
23
Y
X
Z

PIEZOELECTRIC DRIVE ELEMENT

CROSS REFERENCE TO RELATED APPLICATION

[0001] This application is a continuation of International Application No. PCT/JP2021/043297 filed on Nov. 25, 2021, entitled "PIEZOELECTRIC DRIVE ELEMENT", which claims priority under 35 U.S.C. Section 119 of Japanese Patent Application No. 2021-005767 filed on Jan. 18, 2021, entitled "PIEZOELECTRIC DRIVE ELEMENT". The disclosures of the above applications are incorporated herein by reference.

BACKGROUND OF THE INVENTION

Field of the Invention

[0002] The present invention relates to a piezoelectric drive element that drives a movable part by a piezoelectric actuator and that is suitable for use, for example, for the case of performing scanning with light by a mirror placed on the movable part.

Description of Related Art

[0003] In recent years, by using micro electro mechanical system (MEMS) technology, piezoelectric drive elements that rotate a movable part have been developed. In this type of piezoelectric drive element, a mirror is placed on the movable part, thereby allowing scanning to be performed at a predetermined deflection angle with light incident on the mirror.

[0004] For example, Japanese Patent No. 6310786 describes a light deflector including: a mirror part that reflects light; a frame part that surrounds and supports the mirror part; and a pair of piezoelectric actuators that are interposed between the mirror part and the frame part and that rotate the mirror part in a reciprocating manner. The frame part is placed so as to surround both the pair of piezoelectric actuators and the mirror part which is a movable part.

[0005] When the frame part is provided so as to surround both the movable part and the pair of piezoelectric actuators as described above, a problem that the installation area of a piezoelectric drive element is increased, arises.

SUMMARY OF THE INVENTION

[0006] A main aspect of the present invention is directed to a piezoelectric drive element. The piezoelectric drive element according to this aspect includes: a movable part; a pair of piezoelectric drive parts each connected at one end thereof to the movable part and configured to rotate the movable part about at least a rotation axis; and a fixing part to which other ends of the piezoelectric drive parts are connected. The pair of piezoelectric drive parts are aligned in a direction along the rotation axis with the movable part located therebetween, a width of the movable part is narrower than a width of each of the pair of piezoelectric drive parts in a plan view, and the fixing part is placed in a gap region that is outside the movable part and that is located between the pair of piezoelectric drive parts in a plan view.

[0007] In the piezoelectric drive element according to this aspect, the fixing part is placed in the gap region between the movable part and the pair of piezoelectric drive parts. Accordingly, the installation area of the piezoelectric drive element can be reduced.

[0008] The effects and the significance of the present invention will be further clarified by the description of the embodiments below. However, the embodiments below are merely examples for implementing the present invention. The present invention is not limited to the description of the embodiments below in any way.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. **1** is a plan view schematically showing a configuration of a piezoelectric drive element according to Embodiment 1;

[0010] FIG. **2** is a plan view schematically showing a configuration of a pair of piezoelectric drive parts according to Embodiment 1;

[0011] FIG. **3**A is a cross-sectional view schematically showing a cross-section of a vibration portion according to Embodiment 1;

[0012] FIG. **3**B is a cross-sectional view schematically showing a cross-section of the piezoelectric drive element according to Embodiment 1;

[0013] FIG. **4**A and FIG. **4**B are cross-sectional views schematically showing configurations when a pair of fixing parts according to a modification of Embodiment 1 are connected to each other on the lower side and the upper side of a rotation axis, respectively;

[0014] FIG. **5** is a plan view schematically showing a configuration of a piezoelectric drive element according to Embodiment 2;

[0015] FIG. **6** is a plan view schematically showing a configuration of a pair of piezoelectric drive parts according to Embodiment 2;

[0016] FIG. **7** is a plan view schematically showing a configuration of a piezoelectric drive element according to Modification 1 of Embodiment 2;

[0017] FIG. **8** is a plan view schematically showing a configuration of a pair of piezoelectric drive parts according to Modification 1 of Embodiment 2;

[0018] FIG. **9** is a plan view schematically showing a configuration of a piezoelectric drive element according to Modification 2 of Embodiment 2;

[0019] FIG. **10** is a plan view schematically showing a configuration of a pair of piezoelectric drive parts according to Modification 2 of Embodiment 2;

[0020] FIG. **11** is a plan view schematically showing a configuration of a piezoelectric drive element according to Embodiment 3;

[0021] FIG. **12** is a plan view schematically showing a configuration of a pair of piezoelectric drive parts according to Embodiment 3;

[0022] FIG. **13** is a plan view schematically showing a configuration of a piezoelectric drive element according to a modification of Embodiment 3;

[0023] FIG. **14** is a plan view schematically showing a configuration of a pair of piezoelectric drive parts according to the modification of Embodiment 3;

[0024] FIG. **15** is a plan view schematically showing a configuration of a piezoelectric drive element according to Embodiment 4;

[0025] FIG. **16** is a plan view schematically showing a configuration of a pair of piezoelectric drive parts according to Embodiment 4;

[0026] FIG. **17** is a plan view schematically showing a configuration of a piezoelectric drive element according to a modification of Embodiment 4;

[0027] FIG. **18** is a plan view schematically showing a configuration of a pair of piezoelectric drive parts according to the modification of Embodiment 4;

[0028] FIG. **19** is a plan view schematically showing a configuration of a piezoelectric drive element according to Embodiment 5;

[0029] FIG. **20** is a plan view schematically showing a configuration of a pair of piezoelectric drive parts according to Embodiment 5;

[0030] FIG. **21** is a cross-sectional view schematically showing a cross-section of the piezoelectric drive element according to Embodiment 5;

[0031] FIG. **22** is a cross-sectional view schematically showing a cross-section of a piezoelectric drive element according to Modification 1 of Embodiment 5;

[0032] FIG. **23** is a plan view schematically showing a configuration of a piezoelectric drive element according to Modification 2 of Embodiment 5;

[0033] FIG. **24** is a plan view schematically showing a configuration of a piezoelectric drive element according to Embodiment 6;

[0034] FIG. **25** is a plan view schematically showing a configuration of a pair of piezoelectric drive parts according to Embodiment 6;

[0035] FIG. **26** is a cross-sectional view schematically showing a cross-section of the piezoelectric drive element according to Embodiment 6;

[0036] FIG. **27** is a cross-sectional view schematically showing a cross-section of a piezoelectric drive element according to Modification 1 of Embodiment 6;

[0037] FIG. **28** is a plan view schematically showing a configuration of a piezoelectric drive element according to Modification 2 of Embodiment 6;

[0038] FIG. **29** is a plan view schematically showing a configuration of a piezoelectric drive element according to another modification; and

[0039] FIG. **30** is a plan view schematically showing a configuration of a pair of piezoelectric drive parts according to the other modification.

[0040] It should be noted that the drawings are solely for description and do not limit the scope of the present invention by any degree.

DETAILED DESCRIPTION

[0041] In the following embodiments, each piezoelectric drive element **1** is an element for rotating a mirror around a rotation axis R**10**, reflecting light incident on the mirror, and scanning a target region. This type of piezoelectric drive element is sometimes also referred to as light deflector or mirror actuator. The piezoelectric drive element is not limited to one for rotating the mirror, but may rotate a member or a film other than the mirror. The following embodiments are each one embodiment of the present invention, and the present invention is not limited to the following embodiments in any way.

[0042] Hereinafter, embodiments of the present invention will be described with reference to the drawings. For convenience, in each drawing, X, Y, and Z axes that are orthogonal to each other are additionally shown, and the Z-axis positive direction is the vertical upward direction with respect to the surface of the drawing sheet.

Embodiment 1

[0043] FIG. **1** is a plan view schematically showing a configuration of the piezoelectric drive element **1**.

[0044] The piezoelectric drive element **1** includes a movable part **10**, a pair of piezoelectric drive parts **20**, and a pair of fixing parts **30**. In FIG. **1**, for convenience, three configurations of the movable part **10**, the pair of piezoelectric drive parts **20**, and the pair of fixing parts **30** are hatched differently such that the regions thereof are recognized. In the following embodiments and modifications, the same hatching is also applied in a plan view of the piezoelectric drive element **1**.

[0045] The movable part **10** has a plate shape and an elliptical shape. In a plan view, the width in the X-axis direction of the movable part **10** is narrower than the width in the X-axis direction of each of the pair of piezoelectric drive parts **20**. A mirror **11** is placed on the upper surface of the movable part **10**. The mirror **11** is an optical reflection film formed on the upper surface of the movable part **10**. The mirror **11** is composed of, for example, a dielectric multilayer film, a metal film, or the like. Light incident on the mirror **11** is reflected by the mirror **11**.

[0046] The pair of piezoelectric drive parts **20** are placed and configured so as to be point-symmetrical with respect to a center **11***a* of the mirror **11** in a plan view. The pair of piezoelectric drive parts **20** rotate the movable part **10** about the rotation axis R**10**. The rotation axis R**10** is an axis that passes through the center **11***a* and that is parallel to the Y-axis direction.

[0047] The pair of piezoelectric drive parts **20** are aligned in a direction along the rotation axis R**10** with the movable part **10** located therebetween. One piezoelectric drive part **20** is placed on the Y-axis positive side of the movable part **10**, and the other piezoelectric drive part **20** is placed on the Y-axis negative side of the movable part **10**. End portions **20***a* of the pair of piezoelectric drive parts **20** are connected to the movable part **10**, and other end portions **20***b* thereof are connected to the pair of fixing parts **30**, respectively.

[0048] In the configuration in FIG. **1**, in a plan view, the end portions **20***a* of the pair of piezoelectric drive parts **20** are connected to the movable part **10** at positions displaced relative to the rotation axis R**10** in opposite directions by the same distance. However, the connection positions of the end portions **20***a* of the pair of piezoelectric drive parts **20** are not limited thereto, and each end portion **20***a* may be connected to the movable part **10**, for example, at a position on the rotation axis R**10**.

[0049] The lower surfaces of the pair of fixing parts **30** are each a flat surface, and are installed on an installation surface B**11** of a base member B**10** (see FIG. **3**B). In a plan view, a gap region G is formed on each of the X-axis positive side and the X-axis negative side of the rotation axis R**10**. The gap region G is a region that is outside the movable part **10** and that is located between the pair of piezoelectric drive parts **20** in a plan view. The pair of fixing parts **30** are placed in these gap regions G, respectively, in a plan view.

[0050] FIG. **2** is a plan view schematically showing the configuration of the pair of piezoelectric drive parts **20**.

[0051] Each piezoelectric drive part **20** includes a first drive portion **21** and a second drive portion **22**. The first drive portion **21** includes a coupling portion **21***a*, and is connected to the movable part **10** via the coupling portion **21***a*. An end portion of the coupling portion **21***a* connected to the movable part **10** forms the end portion **20***a* shown also in FIG. **1**. The second drive portion **22** is interposed between the first drive portion **21** and the fixing part **30**, and connects an end portion **21***b*, opposite to the end portion **20***a*, of the first drive portion **21** and the fixing part **30**. The first drive portion **21** on the Y-axis positive side and the first drive portion **21** on the Y-axis negative side are placed at positions that are point-symmetrical with respect to the movable part **10**, and the second drive portion **22** on the Y-axis positive side and the second drive portion **22** on the Y-axis negative side are placed at positions that are point-symmetrical with respect to the movable part **10**.

[0052] In a plan view, one second drive portion **22** extends in one direction parallel to the rotation axis R**10** from one fixing part **30** at one edge in the width direction (X-axis direction) of the piezoelectric drive element **1**, and the other second drive portion **22** extends in another direction parallel to the rotation axis R**10** from the other fixing part **30** at the other edge in the width direction (X-axis direction) of the piezoelectric drive element **1**. In addition, in a plan view, one first drive portion **21** is placed in a range from the one second drive portion **22** to the edge on the opposite side in the width direction (X-axis direction) of the piezoelectric drive element **1**, and the other first drive portion **21** is placed in a range from the other second drive portion **22** to the edge on the opposite side in the width direction (X-axis direction) of the piezoelectric drive element **1**.

[0053] In a plan view, the pair of fixing parts **30** are placed in the left and right gap regions G such that the contour of the piezoelectric drive element **1** has a quadrangular shape (here, a rectangular shape). Here, the pair of fixing parts **30** are placed so as to extend over the entire gap regions G with at least an acceptable minimum gap with respect to the pair of piezoelectric drive parts **20** and the movable part **10**, that is, with a minimum gap that allows the pair of piezoelectric drive parts **20** and the movable part **10** to be stably moved.

[0054] Each first drive portion **21** rotates the movable part **10** about the rotation axis R**10**. The first drive portion **21** includes a so-called meander-type piezoelectric actuator. That is, the first drive portion **21** includes a plurality of vibration portions **21***c* coupled to each other so as to form a meander shape. Each vibration portion **21***c* has a piezoelectric actuator **110** on an upper surface (surface on the Z-axis positive side) thereof. A wire which is not shown is connected to the piezoelectric actuator **110**. When a voltage is applied to each piezoelectric actuator **110** of the first drive portion **21**, a piezoelectric body **113** (see FIG. **3**A) in the piezoelectric actuator **110** expands and contracts, and the first drive portion **21** bends in the Z-axis direction.

[0055] A voltage is applied to each of the piezoelectric actuators **110** of the pair of first drive portions **21** such that the pair of first drive portions **21** repeatedly oscillate in a direction parallel to the X-Z plane in the same cycle. Accordingly, the movable part **10** and the mirror **11** repeatedly rotate about the rotation axis R**10**.

[0056] Each second drive portion **22** extends parallel to the Y axis. The second drive portion **22** is connected at one end portion thereof to the fixing part **30**, and is connected at another end portion thereof to the end portion **21***b* of the first drive portion **21**. The second drive portion **22** includes one vibration portion **22***a*. As in the first drive portion **21**, the vibration portion **22***a* of the second drive portion **22** also has a piezoelectric actuator **110** on an upper surface (surface on the Z-axis positive side) thereof. When a voltage is applied to the piezoelectric actuator **110** of the second drive portion **22**, a piezoelectric body **113** (see FIG. **3**A) in the piezoelectric actuator **110** expands and contracts, and the second drive portion **22** bends in the Z-axis direction.

[0057] A voltage is applied to each of the piezoelectric actuators **110** of the pair of second drive portions **22** such that the pair of second drive portions **22** repeatedly drive the end portions **21***b* of the pair of first drive portions **21** in the Z-axis direction in opposite phases. At this time, the drive of each second drive portion **22** is controlled such that the drive of the end portions **21***b* by the pair of second drive portions **22** and the drive of the end portions **21***b* by the pair of first drive portions **21** are synchronized in opposite phases. Accordingly, the driving force by each first drive portion **21** is increased, so that the rotational width of the movable part **10** and the mirror **11** can be widened.

[0058] FIG. **3**A is a cross-sectional view schematically showing a cross-section of the vibration portion **21***c* or **22***a* obtained by cutting the vibration portion **21***c* or **22***a* along a plane perpendicular to the X-Y plane.

[0059] The vibration portions **21***c* and **22***a* each have a configuration in which the piezoelectric actuator **110** and a device layer **120** are stacked. The device layer **120** is formed from a material that is the same as that of a part of the fixing parts **30**, and the piezoelectric actuator **110** is formed on the upper surface of the device layer **120**. The device layer **120** is composed of Si. The piezoelectric actuator **110** is configured by stacking an upper electrode **111**, a lower electrode **112**, and the piezoelectric body **113**. The piezoelectric body **113** is interposed between the upper electrode **111** and the lower electrode **112**. The upper electrode **111** and the lower electrode **112** are each composed of a conductive film such as metal. The piezoelectric body **113** is composed of lead zirconate titanate (PZT), for example.

[0060] Each part of the vibration portion shown in FIG. **3**A is placed by a semiconductor formation process, whereby the first drive portion **21** and the second drive portion **22** shown in FIG. **2** are formed, and the pair of piezoelectric drive parts **20** shown in FIG. **1** are formed.

[0061] FIG. **3**B is a cross-sectional view schematically showing a configuration when a cross-section of the piezoelectric drive element **1** obtained by cutting the piezoelectric drive element **1** along a plane that passes through the center **11***a* of the mirror **11** and that is parallel to the X-Z plane is viewed in the Y-axis positive direction.

[0062] The rotation axis R**10** extends in the Y-axis direction through the center **11***a* of the mirror **11**, and the movable part **10** and the mirror **11** rotate about the rotation axis R**10**. The pair of fixing parts **30** are placed on the X-axis positive side and the X-axis negative side of the movable part **10**, respectively, with gaps between the movable part **10** and the fixing parts **30**. Each fixing part **30** has a configuration in which a device layer **120**, a thermal oxide film **130**, and a base layer **140** are stacked. The thickness of the movable part **10** is substantially equal to the thickness of the device layer **120** in FIG. **3**A, and the thickness of the fixing part **30** is larger than the thickness of the movable part **10**. In addition, the lower surfaces of the pair of fixing parts **30** are installed on the installation surface B**11** of the base member B**10** placed below the pair of fixing parts **30**. The base member B**10** is, for example, a member in an apparatus in which the piezoelectric drive element **1** is installed.

[0063] The piezoelectric drive element **1** is fixed to the base member B**10** by installing the pair of fixing parts **30** on the installation surface B**11** of the base member B**10**.

[0064] The pair of fixing parts **30** may be connected to each other on the lower side or the upper side of the rotation axis R**10**.

[0065] FIG. **4**A and FIG. **4**B are cross-sectional views schematically showing configurations when the pair of fixing parts **30** are connected to each other on the lower side and the upper side of the rotation axis R**10**, respectively.

[0066] In the configuration shown in FIG. **4**A, a connection part **40** is formed from a material that is the same as the material forming a part of the pair of fixing parts **30**, and is integrally formed with the pair of fixing parts **30**. The pair of fixing parts **30** are connected to each other below the rotation axis R**10** by the connection part **40**. In this case as well, the lower surfaces of the fixing parts **30** are installed on the installation surface B**11** of the base member B**10**. The connection part **40** may be made of another material different from that of the fixing parts **30**.

[0067] In the configuration shown in FIG. **4**B, a connection member **50** is installed on the upper surfaces of the pair of fixing parts **30**. The connection member **50** is shaped to cover the upper side (Z-axis positive side) of the mirror **11**, and two end portions in the X-axis direction of the connection member **50** are installed on the upper surfaces of the pair of fixing parts **30**. In this case, a portion of the connection member **50** that covers the mirror **11** has a hole **51** formed so as to penetrate the connection member **50** in the Z-axis direction. Accordingly, light incident from the outside through the hole **51** is reflected by the mirror **11**, and the light reflected by the mirror **11** is guided to the outside through the hole **51**. As in FIG. 3B, the pair of fixing parts **30** are installed on the installation surface B**11** of the base member B**10**. The connection member **50** is not limited to being made of a material different from that of the fixing parts **30**, may be formed from a material that is the same as the material forming a part of the pair of fixing parts **30**, and may be integrally formed with the pair of fixing parts **30**.

Effects of Embodiment 1

[0068] According to Embodiment 1, the following effects are achieved.

[0069] As shown in FIG. **1**, the pair of piezoelectric drive parts **20** are aligned in the direction along the rotation axis R**10** with the movable part **10** located therebetween. In a plan view, the width (width in the X-axis direction) of the movable part **10** is narrower than the width (width in the X-axis direction) of each of the pair of piezoelectric drive parts **20**, and each fixing part **30** is placed in the gap region G, which is outside the movable part **10** and which is located between the pair of piezoelectric drive parts **20**, in a plan view. Since each fixing part **30** is placed in the gap region G as described above, the installation area on the X-Y plane of the piezoelectric drive element **1** can be reduced.

[0070] As shown in FIG. **1**, the fixing parts **30** are placed in the gap regions G on both sides (the X-axis positive side and the X-axis negative side) of the rotation axis R**10**, respectively, in a plan view. According to this configuration, the pair of piezoelectric drive parts **20** and the movable part **10** can be more stably supported by the fixing parts **30**.

[0071] As shown in FIG. **2**, the pair of piezoelectric drive parts **20** each include the first drive portion **21** which rotates the movable part **10** about the rotation axis R**10** and the second drive portion **22** which drives the end portion **21***b* of the first drive portion **21** up and down (in the Z-axis direction). According to this configuration, the rotational width of the movable part **10** can be widened by controlling the drive of the second drive portion **22** as described above.

[0072] One second drive portion **22** of one piezoelectric drive part **20** and one second drive portion **22** of the other piezoelectric drive part **20** are respectively placed at positions that are point-symmetrical with respect to the movable part **10**. With this placement, the rotational width of the movable part **10** can be widened in accordance with the drive control of the two second drive portions **22**. In addition, the rotational width of the movable part **10** can be widened with fewer components than in the case where two second drive portions **22** are placed in one piezoelectric drive part **20** as in Embodiment 2 described later.

[0073] In the configurations shown in FIG. **4**A and FIG. **4**B, the fixing parts **30**, which are placed in the gap regions G on both sides (the X-axis positive side and the X-axis negative side) of the rotation axis R**10**, are connected to each other. Accordingly, since the two fixing parts **30** are integrated with each other, it is easier to handle the pair of fixing parts **30** when installing the pair of fixing parts **30** on the installation surface B**11**. Therefore, the pair of fixing parts **30** can be easily and stably fixed to the installation surface B**11**.

Embodiment 2

[0074] FIG. **5** is a plan view schematically showing a configuration of the piezoelectric drive element **1** according to Embodiment 2.

[0075] In the configuration in FIG. **5**, the placement and the configuration of the pair of piezoelectric drive parts **20** are different from those in Embodiment 1 described above, and the shape of each fixing part **30** in a plan view is further different from that in Embodiment 1 described above. That is, two end portions **20***b* are provided on the opposite sides of the end portion **20***a* of each piezoelectric drive part **20**, and the two end portions **20***b* are connected to the pair of fixing parts **30**, respectively. In the present embodiment as well, in a plan view, the gap region G is formed on each of the X-axis positive side and the X-axis negative side of the rotation axis R**10**, and a region that is outside the movable part **10** and that is located between the pair of piezoelectric drive parts **20** is the gap region G. The fixing parts **30** are placed in the gap regions G on both sides, respectively.

[0076] FIG. **6** is a plan view schematically showing a configuration of the pair of piezoelectric drive parts **20**.

[0077] Each piezoelectric drive part **20** includes a first drive portion **21**, two second drive portions **22**, and a coupling portion **23**. The two second drive portions **22** in one piezoelectric drive part **20** are respectively provided on the X-axis positive side and the X-axis negative side of the first drive portion **21** and placed at positions that are line-symmetrical with respect to the rotation axis R**10**. Each of the two second drive portions **22** in one piezoelectric drive part **20** is connected to the end portion **21***b* of the first drive portion **21** in the piezoelectric drive part **20** via the coupling portion **23**. That is, in the present embodiment as well, each second drive portion **22** is interposed between the first drive portion **21** and the fixing part **30** and connects the end portion **21***b* of the first drive portion **21** and the fixing part **30**. The end portion **21***b* is located on the rotation axis R**10**.

[0078] In a plan view, the two second drive portions **22** in one piezoelectric drive part **20** extend in one direction parallel to the rotation axis R**10** from the pair of fixing parts **30** at the edges on both sides in the width direction (X-axis direction) of the piezoelectric drive element **1**, and the two second drive portions **22** in the other piezoelectric drive part **20** extend in another direction parallel to the rotation axis R**10** from the pair of fixing parts **30** at the edges on both sides in the width direction (X-axis direction) of the piezoelectric drive element **1**. In addition, in a plan view, the first drive portion **21** in one piezoelectric drive part **20** is placed in a range located between the two second drive portions **22**, and the first drive portion **21** in the other piezoelectric drive part **20** is placed in a range located between the two second drive portions **22**.

[0079] In a plan view, the pair of fixing parts **30** are placed in the left and right gap regions G such that the contour of the piezoelectric drive element **1** has a quadrangular shape (here, a rectangular shape). Here, the pair of fixing parts **30** are placed so as to extend over the entire gap regions G with at least an acceptable minimum gap with respect to the pair of piezoelectric drive parts **20** and the movable part **10**, that is, with a minimum gap that allows the pair of piezoelectric drive parts **20** and the movable part **10** to be stably moved.

[0080] Here, in the present embodiment, each second drive portion **22** is driven in accordance with first drive control or second drive control.

[0081] In the first drive control, the two second drive portions **22** are driven such that the pair of coupling portions **23** repeatedly rotate about the rotation axis R**10** in the same cycle in synchronization with the pair of first drive portions **21**. Since the pair of coupling portions **23**, which respectively support the end portions **21***b* of the pair of first drive portions **21**, repeatedly rotate in the same cycle in synchronization with the pair of first drive portions **21** as described above, the rotation of the pair of first drive portions **21** is enhanced. Accordingly, as in Embodiment 1, the rotational width of the movable part **10** and the mirror **11** is increased. Therefore, the range of scanning with the light reflected by the mirror **11** can be expanded.

[0082] In the second drive control, the two second drive portions **22** are driven such that the pair of coupling portions **23** are displaced in directions opposite to each other in the Z-axis direction. Accordingly, the movable part **10** and the mirror **11** rotate about a rotation axis R**20**. The rotation axis R**20** is an axis that passes through the center **11***a* and that is parallel to the X axis. By controlling the second drive portions **22** as described above, in combination with the drive by the first drive portion **21**, the movable part **10** and the mirror **11** can be biaxially driven about the two rotation axes R**10** and R**20**. Therefore, scanning can be performed two-dimensionally with the light reflected by the mirror **11**.

[0083] In the configuration in FIG. **5** and FIG. **6**, the end portions **20***a* of the pair of piezoelectric drive parts **20** are placed on the rotation axis R**10** in a plan view, but as in Embodiment 1 described above, the end portions **20***a* of the pair of piezoelectric drive parts **20** may be connected to the movable part **10** at positions displaced from the rotation axis R**10** in opposite directions by the same distance.

Effects of Embodiment 2

[0084] According to the present embodiment, the following effects are achieved in addition to the same effects as those of Embodiment 1.

[0085] The pair of piezoelectric drive parts **20** each include the first drive portion **21** which rotates the movable part **10** about the rotation axis R**10** and the second drive portions **22** which drive the end portion **21***b* of the first drive portion **21** up and down (in the Z-axis direction). According to this configuration, in accordance with the drive control of the second drive portion **22**, the rotational width of the movable part **10** can be widened, or the movable part **10** can be rotated in a direction perpendicular to the rotation axis R**10** (in the direction of the rotation axis R**20**).

[0086] More specifically, in each piezoelectric drive part **20**, the second drive portions **22** are respectively placed at the positions that are line-symmetrical with respect to the rotation axis R**10**. According to this configuration, the rotational width of the movable part **10** can be widened in accordance with the first drive control of the second drive portions **22**, or the movable part **10** can be rotated in the direction perpendicular to the rotation axis R**10** (the direction of the rotation axis R**20**) as a rotation axis in accordance with the second drive control of the second drive portions **22**.

Modification 1 of Embodiment 2

[0087] In Embodiment 2 described above, as shown in FIG. **5**, the position of the outer side in the X-axis direction of each fixing part **30** coincides with the position of the outer edge in the X-axis direction of the piezoelectric drive part **20**. However, in the present modification, the position of the outer side in the X-axis direction of each fixing part **30** is displaced inward. Hereinafter, the configuration different from that of Embodiment 2 described above will be described.

[0088] FIG. **7** is a plan view schematically showing a configuration of the piezoelectric drive element **1** according to Modification 1 of Embodiment 2.

[0089] In the present modification, as compared to Embodiment 2 in FIG. **5**, the end portion **20***b* on the X-axis positive side of each piezoelectric drive part **20** and the end portion **20***b* on the X-axis negative side of each piezoelectric drive part **20** are both displaced to the center **11***a* side. Accordingly, the outer side in the X-axis direction of each gap region G is displaced inward as compared to Embodiment 2 in FIG. **5**. In the present modification as well, in a plan view, the gap region G is formed on each of the X-axis positive side and the X-axis negative side of the rotation axis R**10**, and a region that is outside the movable part **10** and that is located between the pair of piezoelectric drive parts **20** is the gap region G. The fixing parts **30** are placed in the gap regions G on both sides, respectively.

[0090] FIG. **8** is a plan view schematically showing a configuration of the pair of piezoelectric drive parts **20**.

[0091] An end portion on the center **11***a* side of each second drive portion **22** is displaced to the center **11***a* side as compared to Embodiment 2 described above. An end portion on the center **11***a* side of the piezoelectric actuator **110** of each second drive portion **22** is also displaced to the center **11***a* side as compared to Embodiment 2 described above. In the present modification as well, the two second drive portions **22** in one piezoelectric drive part **20** are placed at positions that are line-symmetrical with respect to the rotation axis R**10**.

[0092] In a plan view, the two second drive portions **22** in one piezoelectric drive part **20** extend in one direction parallel to the rotation axis R**10** from the pair of fixing parts **30** at the edges on both sides in the width direction (X-axis direction) of the piezoelectric drive element **1**, and the two second drive portions **22** in the other piezoelectric drive part **20** extend in another direction parallel to the rotation axis

R**10** from the pair of fixing parts **30** at the edges on both sides in the width direction (X-axis direction) of the piezoelectric drive element **1**. Each second drive portion **22** has an L-shape in a plan view. In addition, in a plan view, the first drive portion **21** in one piezoelectric drive part **20** is placed in a range located between the two second drive portions **22**, and the first drive portion **21** in the other piezoelectric drive part **20** is placed in a range located between the two second drive portions **22**.

[0093] In a plan view, the pair of fixing parts **30** are placed in the left and right gap regions G such that the contour of the piezoelectric drive element **1** has a quadrangular shape (here, a rectangular shape). Here, the pair of fixing parts **30** are placed so as to extend over the entire gap regions G with at least an acceptable minimum gap with respect to the pair of piezoelectric drive parts **20** and the movable part **10**, that is, with a minimum gap that allows the pair of piezoelectric drive parts **20** and the movable part **10** to be stably moved.

[0094] In the present modification as well, the second drive portions **22** are driven in accordance with the first drive control or the second drive control. Accordingly, the rotational width of the movable part **10** can be widened in accordance with the first drive control of the second drive portions **22**, or the movable part **10** can be rotated in the direction perpendicular to the rotation axis R**10** (the direction of the rotation axis R**20**) as a rotation axis in accordance with the second drive control of the second drive portions **22**.

Modification 2 of Embodiment 2

[0095] In Modification 1 of Embodiment 2, as shown in FIG. **7**, the two piezoelectric drive parts **20** opposing each other in the Y-axis direction are placed on the X-axis positive side and the X-axis negative side of the movable part **10** with a gap therebetween. On the other hand, in the present modification, the two piezoelectric drive parts **20** opposing each other in the Y-axis direction are connected to each other. Hereinafter, the configuration different from that of Modification 1 of Embodiment 2 will be described.

[0096] FIG. **9** is a plan view schematically showing a configuration of the piezoelectric drive element **1** according to Modification 2 of Embodiment 2.

[0097] In the present modification, the two piezoelectric drive parts **20** opposing each other in the Y-axis direction are connected to each other on the X-axis positive side and the X-axis negative side of the movable part **10** without any gap therebetween. Accordingly, the end portions **20***b* of the piezoelectric drive part **20** on the Y-axis positive side and the end portions **20***b* of the piezoelectric drive part **20** on the Y-axis negative side are connected to each other without any gap therebetween.

[0098] FIG. **10** is a plan view schematically showing a configuration of the pair of piezoelectric drive parts **20**.

[0099] In the present modification, one second drive portion **22** is placed on each of the X-axis positive side and the X-axis negative side of the pair of piezoelectric drive parts **20**. The second drive portions **22** of the present modification extend from an end portion on the Y-axis positive side to an end portion on the Y-axis negative side of the piezoelectric drive element **1**. That is, in the present modification, the second drive portions **22** of the two piezoelectric drive parts **20** on one side (X-axis positive side) with respect to the rotation axis R**10** are shared by the pair of piezoelectric drive parts **20**, and the second drive portions **22** of the two piezoelectric drive parts **20** on the other side (X-axis negative side) with respect to the rotation axis R**10** are shared by the pair of piezoelectric drive parts **20**.

[0100] In the present modification, the entirety of each second drive portion **22** bends in one direction when a voltage is applied thereto, so that the pair of coupling portions **23** cannot be displaced in directions opposite to each other. Therefore, in the present modification, the above-described second drive control cannot be performed.

[0101] On the other hand, in the present modification as well, the pair of coupling portions **23** can be rotated about the rotation axis R**10** in the same direction by driving the two second drive portions **22** in phases opposite to each other. Therefore, in the present modification as well, the above-described first drive control can be performed. That is, in the present modification, in the first drive control, the two second drive portions **22** are repeatedly driven in opposite phases such that the pair of coupling portions **23** rotate about the rotation axis R**10** in the same phase in synchronization with the pair of first drive portions **21**. Accordingly, as in the configuration of Embodiment 2 shown in FIG. **5** and FIG. **6**, the rotational width of the movable part **10** can be widened.

Embodiment 3

[0102] As shown in FIG. **11**, in the piezoelectric drive element **1** of Embodiment 3, as compared to Modification 1 of Embodiment 2 shown in FIG. **7** and FIG. **8**, the meander-type drive portions of the piezoelectric drive parts **20** are changed to tuning fork-type drive portions. In addition, the range of each gap region G becomes larger due to the change of each piezoelectric drive part **20**. The other configuration is the same as in Modification 1 of Embodiment 2.

[0103] As shown in FIG. **12**, each piezoelectric drive part **20** includes a first drive portion **21**, a pair of second drive portions **22**, and a coupling portion **23**. The first drive portion **21** includes a coupling portion **21***a* extending along the rotation axis R**10**, and is connected to the movable part **10** via the coupling portion **21***a*. The end portion **21***b* of the first drive portion **21** is located on the rotation axis R**10**, and is connected to the coupling portion **23**. The first drive portion **21** includes a so-called tuning fork-type actuator. That is, the first drive portion **21** includes a pair of vibration portions **21***c* coupled to each other so as to form a tuning fork shape. Each vibration portion **21***c* is configured in the same manner as in Embodiment 1 described above. As shown in FIG. **11** and FIG. **12**, the gap regions G of the present modification are regions surrounded by the pair of vibration portions **21***c* of the first drive portion **21**, the second drive portions **22**, and the movable part **10**.

[0104] In a plan view, the two second drive portions **22** in one piezoelectric drive part **20** extend in one direction parallel to the rotation axis R**10** from the pair of fixing parts **30** at the edges on both sides in the width direction (X-axis direction) of the piezoelectric drive element **1**, and the two second drive portions **22** in the other piezoelectric drive part **20** extend in another direction parallel to the rotation axis R**10** from the pair of fixing parts **30** at the edges on both sides in the width direction (X-axis direction) of the piezoelectric drive element **1**. Each second drive portion **22** has an L-shape in a plan view. In addition, in a plan view, the first drive portion **21** in one piezoelectric drive part **20** is placed in a range located between the two second drive portions **22**, and the first drive portion **21** in the other piezoelectric drive part **20** is placed in a range located between the two second drive portions **22**.

[0105] In a plan view, the pair of fixing parts **30** are placed in the left and right gap regions G such that the contour of the piezoelectric drive element **1** has a quadrangular shape (here, a rectangular shape). Here, the pair of fixing parts **30** are placed so as to extend over partial regions in the gap regions G (regions obtained by cutting the region of the movable part **10** from the regions of quadrangular shapes sandwiching the movable part **10**) with at least an acceptable minimum gap with respect to the pair of piezoelectric drive parts **20** and the movable part **10**, that is, with a minimum gap that allows the pair of piezoelectric drive parts **20** and the movable part **10** to be stably moved.

[0106] However, the present invention is not limited thereto, and each fixing part **30** may be placed so as to extend over the entire gap region G. In addition, as in Embodiment 2 shown in FIG. **5** and FIG. **6**, in a plan view, the pair of fixing parts **30** may be placed so as to extend to the edge in the width direction of the piezoelectric drive element **1**, and each second drive portion **22** may be provided so as to extend parallel to the rotation axis R**10** in a straight manner from the fixing part **30**.

[0107] A voltage is applied to each piezoelectric actuator **110** of each first drive portion **21** such that a state where one vibration portion **21***c* is displaced in the Z-axis positive direction and the other vibration portion **21***c* is displaced in the Z-axis negative direction and a state where the one vibration portion **21***c* is displaced in the Z-axis negative direction and the other vibration portion **21***c* is displaced in the Z-axis positive direction are repeated. Accordingly, the movable part **10**, which is connected via the coupling portion **21***a*, and the mirror **11** repeatedly rotate about the rotation axis R**10**.

[0108] In the present embodiment as well, the second drive portions **22** are driven in accordance with the first drive control or the second drive control. Accordingly, as in Modification 1 of Embodiment 2, the rotational width of the movable part **10** can be widened in accordance with the first drive control of the second drive portions **22**, or the movable part **10** can be rotated in the direction perpendicular to the rotation axis R**10** (the direction of the rotation axis R**20**) as a rotation axis in accordance with the second drive control of the second drive portions **22**.

Modification of Embodiment 3

[0109] As shown in FIG. **13**, in the piezoelectric drive element **1** of the present modification, as compared to Modification 2 of Embodiment 2 shown in FIG. **9**, the meander-type drive portions of the piezoelectric drive parts **20** are changed to tuning fork-type drive portions. The other configuration is the same as in Modification 2 of Embodiment 2.

[0110] As shown in FIG. **14**, the first drive portions **21** are configured in the same manner as the first drive portions **21** of Embodiment 3 shown in FIG. **12**. In the present modification, the second drive portions **22** are driven in accordance with the first drive control as in Modification 2 of Embodiment 2. Accordingly, the rotational width of the movable part **10** can be widened.

Embodiment 4

[0111] As shown in FIG. **11**, in Embodiment 3, each fixing part **30** is placed on the inner side of the end portion **20***b* of each piezoelectric drive part **20** with respect to the center **11***a*. On the other hand, in the present embodiment, as shown in FIG. **15**, each fixing part **30** is placed on the outer side of the end portion **20***b* of each piezoelectric drive part **20** with respect to the center **11***a*. Hereinafter, the configuration different from that of Embodiment 3 will be described.

[0112] As shown in FIG. **16**, each piezoelectric drive part **20** includes a first drive portion **21**, a pair of second drive portions **22**, a coupling portion **23**, and a pair of coupling portions **24**. Each second drive portion **22** is placed between the movable part **10** and the fixing part **30**. Each second drive portion **22** is connected to the coupling portion **23** via the coupling portion **24**. One second drive portion **22** includes one vibration portion **22***a*. The second drive portion **22** is placed adjacent to the coupling portion **21***a* and the movable part **10**, and each fixing part **30** is placed on the outer side of the second drive portion **22** with respect to the center **11***a*. As shown in FIG. **15** and FIG. **16**, each gap region G of the present embodiment is a region that is located between the coupling portions **24** in the Y-axis direction and that is located on the outer side of the coupling portions **24** and the second drive portions **22** with respect to the center **11***a* in the X-axis direction.

[0113] In a plan view, the two second drive portions **22** in one piezoelectric drive part **20** are placed on a side in one direction parallel to the rotation axis R**10** at a position adjacent to the movable part **10** and the coupling portions **24** placed along the rotation axis R**10**, and the two second drive portions **22** in the other piezoelectric drive part **20** are placed on a side in another direction parallel to the rotation axis R**10** at a position adjacent to the movable part **10** and coupling portions **24** placed along the rotation axis R**10**. In addition, in a plan view, in the one piezoelectric drive part **20**, the first drive portion **21** is placed on the side in the one direction parallel to the rotation axis R**10**, with respect to the two second drive portions **22**, and in the other piezoelectric drive part **20**, the first drive portion **21** is placed on the side in the other direction parallel to the rotation axis R**10**, with respect to the two second drive portions **22**.

[0114] In a plan view, the pair of fixing parts **30** are placed in the left and right gap regions G such that the contour of the piezoelectric drive element **1** has a quadrangular shape (here, a rectangular shape). Here, the pair of fixing parts **30** are placed so as to extend over partial regions in the gap regions G (regions obtained by cutting the region of the movable part **10** and the second drive portions **22** from the regions of quadrangular shapes sandwiching the movable part **10**) with at least an acceptable minimum gap with respect to the pair of piezoelectric drive parts **20** and the movable part **10**, that is, with a minimum gap that allows the pair of piezoelectric drive parts **20** and the movable part **10** to be stably moved. However, the present invention is not limited thereto, and each fixing part **30** may be placed so as to extend over the entire gap region G.

[0115] In the present embodiment as well, the second drive portions **22** are driven in accordance with the first drive control or the second drive control. Accordingly, as in Embodiment 3 described above, the rotational width of the movable part **10** can be widened in accordance with the first drive control of the second drive portions **22**, or the movable part **10** can be rotated in the direction perpendicular to the rotation axis R**10** (the direction of the rotation axis R**20**) as a rotation axis in accordance with the second drive control of the second drive portions **22**.

Modification of Embodiment 4

[0116] As shown in FIG. **17**, in the piezoelectric drive element **1** of the present modification, as compared to Embodiment 4 shown in FIG. **15**, the two piezoelectric drive parts **20** opposing each other in the Y-axis direction are connected to each other as in the modification of Embodiment 3 shown in FIG. **13**. Hereinafter, the configuration different from that of Embodiment 4 will be described.

[0117] As shown in FIG. **18**, in the present modification, the two second drive portions **22** placed on one side (X-axis positive side) with respect to the rotation axis R**10** in Embodiment 4 are shared by the pair of piezoelectric drive parts **20**, and the two second drive portions **22** placed on the other side (X-axis negative side) with respect to the rotation axis R**10** in Embodiment 4 are shared by the pair of piezoelectric drive parts **20**.

[0118] In the present modification, the entirety of each second drive portion **22** bends in one direction when a voltage is applied thereto, so that the pair of coupling portions **23** cannot be displaced in directions opposite to each other. Therefore, in the present modification, the above-described second drive control cannot be performed.

[0119] On the other hand, in the present modification as well, the pair of coupling portions **23** can be rotated about the rotation axis R**10** in the same direction by driving the two second drive portions **22** in phases opposite to each other. Therefore, in the present modification as well, the above-described first drive control can be performed. Accordingly, the rotational width of the movable part **10** can be widened.

Embodiment 5

[0120] In Embodiments 1 to 4 and the modifications thereof, each fixing part **30** is placed in the gap region G which is outside the movable part **10** and which is located between the pair of piezoelectric drive parts **20** in a plan view. On the other hand, in the present embodiment, the end portions in the Y-axis direction of the fixing parts **30** are placed on the outer side of the pair of piezoelectric drive parts **20** with respect to the center **11***a*. Hereinafter, the configuration different from that of Embodiment 1 will be described.

[0121] FIG. **19** is a plan view schematically showing a configuration of the piezoelectric drive element **1** according to Embodiment 5.

[0122] In the present embodiment, one fixing part **30** is placed on the outer side (Y-axis positive side) of the piezoelectric drive part **20** on the Y-axis positive side, with respect to the center **11***a*, and the other fixing part **30** is placed on the outer side (Y-axis negative side) of the piezoelectric drive part **20** on the Y-axis negative side, with respect to the center **11***a*. The end portions **20***a* and **20***b* of each piezoelectric drive part **20** are connected to the movable part **10** and the fixing part **30**, respectively. The end portions **20***a* of the pair of piezoelectric drive parts **20** are placed on the rotation axis R**10**. The end portions **20***a* of the pair of piezoelectric drive parts **20** may be connected to the movable part **10** at positions displaced from the rotation axis R**10** in opposite directions by the same distance.

[0123] The pair of fixing parts **30** are connected to each other by the connection part **40** on the Z-axis negative side of the rotation axis R**10**. The connection part **40** is integrally formed with the fixing parts **30** from a material that is the same as at least one of the materials forming the fixing parts **30**. The connection part **40** may be made of another material different from that of the fixing part **30**.

[0124] FIG. **20** is a plan view schematically showing a configuration of the pair of piezoelectric drive parts **20**.

[0125] In the present embodiment, as compared to Embodiment 1, the second drive portions **22** are omitted. In addition, each first drive portion **21** of the present modification is configured in the same manner as each first drive portion **21** of Embodiment 1, and is driven in the same manner as each first drive portion **21** of Embodiment 1. Accordingly, the movable part **10** and the mirror **11** rotate about the rotation axis R**10**.

[0126] FIG. **21** is a cross-sectional view schematically showing a configuration when a cross-section of the piezoelectric drive element **1** obtained by cutting the piezoelectric drive element **1** along a plane that passes through the center **11***a* of the mirror **11** and that is parallel to the Y-Z plane is viewed in the X-axis negative direction.

[0127] In the Y-axis direction, the pair of fixing parts **30** define the length in the Y-axis direction of the piezoelectric drive element **1**. The connection part **40** connects a lower portion of the fixing part **30** on the Y-axis positive side and a lower portion of the fixing part **30** on the Y-axis negative side. The pair of fixing parts **30** are installed on the installation surfaces B**11** of a pair of base members B**10**.

Effects of Embodiment 5

[0128] According to the present embodiment, the following effects are achieved.

[0129] The other ends (end portions **20***b*) of the pair of piezoelectric drive parts **20** are connected to the pair of fixing parts **30**, respectively, and the pair of fixing parts **30** are connected to each other at a position displaced relative to the rotation axis R**10** only in one direction (Z-axis negative direction). According to this configuration, since the pair of fixing parts **30** are integrated with each other, each fixing part **30** can be easily and stably fixed to the installation surface B**11**. In addition, the installation area of the piezoelectric drive element **1** can be reduced as compared to the case where a fixing part is placed so as to surround both the movable part **10** and the pair of piezoelectric drive parts **20** over the entire periphery.

Modification 1 of Embodiment 5

[0130] In Embodiment 5 described above, the pair of fixing parts **30** are connected to each other at the position displaced relative to the rotation axis R**10** only in the Z-axis negative direction. On the other hand, in the present modification, the pair of fixing parts **30** are connected to each other by the connection member **50** at a position displaced relative to the rotation axis R**10** only in the Z-axis positive direction.

[0131] FIG. **22** is a cross-sectional view schematically showing a configuration when a cross-section of the piezoelectric drive element **1** according to Modification 1 of Embodiment 5 obtained by cutting the piezoelectric drive element **1** along a plane that passes through the center **11***a* of the mirror **11** and that is parallel to the Y-Z plane is viewed in the X-axis negative direction.

[0132] The connection member **50** is shaped to cover the Z-axis positive side of the mirror **11**, and two end portions in the Y-axis direction of the connection member **50** are installed on the surfaces on the Z-axis positive side of the pair of fixing parts **30**. In this case, a portion of the connection member **50** that covers the mirror **11** has a hole **51** formed so as to penetrate the connection member **50** in the Z-axis direction. Accordingly, light incident from the outside through the hole **51** is reflected by the mirror **11**, and the light reflected by the mirror **11** is guided to the outside through the hole **51**. The pair of fixing parts **30** are installed on the installation surfaces B**11** of the pair of base members B**10**. The connection member **50** is not limited to being made of a material different from that of the fixing parts **30**, and may be integrally formed with the fixing parts **30** from a material that is the same as at least one of the materials forming the fixing parts **30**.

[0133] In the present modification as well, since the pair of fixing parts **30** are integrated with each other, each fixing part **30** can be easily and stably fixed to the installation surface B**11**. In addition, the installation area of the piezoelectric drive element **1** can be reduced as compared to the case where a fixing part is placed so as to surround both the movable part **10** and the pair of piezoelectric drive parts **20** over the entire periphery.

Modification 2 of Embodiment 5

[0134] In Embodiment 5 and Modification 1 of Embodiment 5 described above, the pair of fixing parts **30** are connected to each other at the position displaced relative to the rotation axis R**10** only in the Z-axis direction. On the other hand, in the present modification, the pair of fixing parts **30** are connected to each other by the connection part **40** at a position displaced relative to the rotation axis R**10** only in the X-axis direction.

[0135] FIG. **23** is a plan view schematically showing a configuration of the piezoelectric drive element **1** according to Modification 2 of Embodiment 5.

[0136] In the present modification, an end portion on the X-axis positive side of one fixing part **30** and an end portion on the X-axis positive side of the other fixing part **30** are connected to each other by the connection part **40** on the X-axis positive side of the rotation axis R**10**. In the present modification, each fixing part **30** or the connection part **40** is installed on the installation surface B**11** of the base member B**10**.

[0137] In the present modification as well, since the pair of fixing parts **30** are integrated with each other, each fixing part **30** can be easily and stably fixed to the installation surface B**11**. In addition, the installation area of the piezoelectric drive element **1** can be reduced as compared to the case where a fixing part is placed so as to surround both the movable part **10** and the pair of piezoelectric drive parts **20** over the entire periphery.

Embodiment 6

[0138] As shown in FIG. **24** and FIG. **25**, in the piezoelectric drive element **1** of the present embodiment, as compared to Embodiment 5 shown in FIG. **19** and FIG. **20**, the first drive portions **21** of the piezoelectric drive parts **20** are changed from a meander type to a tuning fork type. The other configuration of the present embodiment is the same as in Embodiment 5.

[0139] As shown in FIG. **25**, similar to each first drive portion **21** of Embodiment 3 shown in FIG. **12**, each first drive portion **21** is configured as a tuning fork type. In the present embodiment, each first drive portion **21** is driven in the same manner as in Embodiment 3 shown in FIG. **12**.

[0140] As shown in FIG. **26**, the pair of fixing parts **30** are connected to each other by the connection part **40** at a position displaced relative to the rotation axis R**10** only in the Z-axis negative direction. The pair of fixing parts **30** are installed on the installation surfaces B**11** of the pair of base members B**10**.

[0141] In the present embodiment as well, since the pair of fixing parts **30** are integrated with each other, each fixing part **30** can be easily and stably fixed to the installation surface B**11**. In addition, the installation area of the piezoelectric drive element **1** can be reduced as compared to the case where a fixing part is placed so as to surround both the movable part **10** and the pair of piezoelectric drive parts **20** over the entire periphery.

Modification 1 of Embodiment 6

[0142] In Embodiment 6 described above, the pair of fixing parts **30** are connected to each other at the position displaced relative to the rotation axis R**10** only in the Z-axis negative direction. On the other hand, in the present modification, the pair of fixing parts **30** are connected to each other by the connection member **50** at a position displaced relative to the rotation axis R**10** only in the Z-axis positive direction.

[0143] As shown in FIG. **27**, the pair of fixing parts **30** are connected to each other by the connection member **50** at a position displaced relative to the rotation axis R**10** only in the Z-axis positive direction. The connection member **50** has a hole **51** formed so as to penetrate the connection member **50** in the Z-axis direction. The pair of fixing parts **30** are installed on the installation surfaces B**11** of the pair of base members B**10**. In the present modification as well, the same effects as those of Embodiment 6 are achieved.

Modification 2 of Embodiment 6

[0144] In Embodiment 6 and Modification 1 of Embodiment 6 described above, the pair of fixing parts **30** are connected to each other at the position displaced relative to the rotation axis R**10** only in the Z-axis direction. On the other hand, in the present modification, the pair of fixing parts **30** are connected to each other by the connection part **40** at a position displaced relative to the rotation axis R**10** only in the X-axis direction.

[0145] As shown in FIG. **28**, the pair of fixing parts **30** are connected to each other by the connection part **40** at a position displaced relative to the rotation axis R**10** only in the X-axis positive direction. In the present modification, each fixing part **30** or the connection part **40** is installed on the installation surface B**11** of the base member B**10**. In the present modification as well, the same effects as those of Embodiment 6 are achieved.

OTHER MODIFICATIONS

[0146] In Embodiments 1, 2, and 4 and the modification of Embodiment 4 described above, each fixing part **30** is configured such that the end portion in the Y-axis direction thereof coincides with the outer edge of the piezoelectric drive element **1** in a plan view. However, the present invention is not limited thereto, and a part of the fixing part **30** may extend to the outside of the outer edge of the piezoelectric drive element **1**.

[0147] In Embodiments 1 and 2 and Modifications 1 and 2 of Embodiment 2 described above, each fixing part **30** is placed in the same range as the gap region G. However, the present invention is not limited thereto, and each fixing part **30** may be placed in a range smaller than the gap region G, within the gap region G. In addition, in Embodiment 3, the modification of Embodiment 3, Embodiment 4, and the modification of Embodiment 4 described above, each fixing part **30** is placed in a range smaller than the gap region G, within the gap region G. However, the present invention is not limited thereto, and each fixing part **30** may be placed in the same range as the gap region G.

[0148] Also, in Embodiments 1 and 2 and Modifications 1 and 2 of Embodiment 2 described above, the end portions **20***b* of the piezoelectric drive parts **20** may be placed so as to surround the movable part **10** as shown in Embodiment 4 and the modification of Embodiment 4 described above. In this case, each gap region G is set as a region that is outside the end portions **20***b* of the piezoelectric drive element **1** and that is located between the pair of piezoelectric drive parts **20**, and the pair of fixing parts **30** are placed in these gap regions G.

[0149] In the embodiments and the modifications described above, the number of first drive portions **21** included in one piezoelectric drive part **20** is one, and the number of second drive portions **22** included in one piezoelectric drive part **20** is 0, 1, or 2. However, the number of first drive portions **21** and the number of second drive portions **22** included in one piezoelectric drive part **20** are not limited thereto. The number of first drive portions **21** included in one piezoelectric drive part **20** may be two or more, and the number of second drive portions **22** included in one piezoelectric drive part **20** may be three or more. Furthermore, a piezoelectric drive part may also be provided on each coupling portion **23** in Embodiment 2, Modifications 1 and 2 thereof, Embodiment 3, the modification thereof, Embodiment 4, and the modification thereof.

[0150] In the embodiments and the modifications described above, the fixing parts **30** are provided in both of the two gap regions G. However, for example, as in a modification shown in FIG. **29** and FIG. **30**, the fixing part **30** may be provided in only one of the two gap regions G.

[0151] As shown in FIG. **29**, in the present modification, as compared to Embodiment 2 shown in FIG. **5**, the fixing part **30** is placed in only the gap region G on the X-axis positive side out of the two gap regions G provided with the rotation axis R**10** located therebetween. In this configuration, the lower surface of the one fixing part **30** is installed on the installation surface B**11** of the base member B**10**. As shown in FIG. **30**, in the present modification, as compared to Embodiment 2 shown in FIG. **5**, the second drive portions **22** located on the X-axis negative side in the piezoelectric drive parts **20** are omitted.

[0152] In the modification shown in FIG. **29** and FIG. **30** as well, since the one fixing part **30** is placed in the one gap region G, the installation area in the X-Y plane of the piezoelectric drive element **1** can be reduced. In addition, as in Embodiment 2, the second drive portions **22** of the present modification are driven in accordance with the first drive control or the second drive control. Accordingly, the rotational width of the movable part **10** can be widened in accordance with the first drive control, and the movable part **10** can be rotated in the direction of the rotation axis R**20** in accordance with the second drive control.

[0153] In addition to the above, various modifications can be made as appropriate to the embodiments of the present invention, without departing from the scope of the technological idea defined by the claims.

What is claimed is:

1. A piezoelectric drive element comprising:

a movable part;

a pair of piezoelectric drive parts each connected at one end thereof to the movable part and configured to rotate the movable part about at least a rotation axis; and

a fixing part to which other ends of the piezoelectric drive parts are connected, wherein

the pair of piezoelectric drive parts are aligned in a direction along the rotation axis with the movable part located therebetween,

a width of the movable part is narrower than a width of each of the pair of piezoelectric drive parts in a plan view, and

the fixing part is placed in a gap region that is outside the movable part and that is located between the pair of piezoelectric drive parts in a plan view.

2. The piezoelectric drive element according to claim **1**, wherein the fixing part is placed in each of the gap regions on both sides of the rotation axis in a plan view.

3. The piezoelectric drive element according to claim **2**, wherein the pair of piezoelectric drive parts each include

a first drive portion connected at one end thereof to the movable part and configured to rotate the movable part about the rotation axis, and

a second drive portion interposed between another end of the first drive portion and the fixing part and configured to drive the other end up and down.

4. The piezoelectric drive element according to claim **3**, wherein the one second drive portion of one of the piezoelectric drive parts and the one second drive portion of the other piezoelectric drive part are respectively placed at positions that are point-symmetrical with respect to the movable part.

5. The piezoelectric drive element according to claim **3**, wherein, in each piezoelectric drive part, the second drive portion is placed at each of positions that are line-symmetrical with respect to the rotation axis.

6. The piezoelectric drive element according to claim **5**, wherein the second drive portion of each piezoelectric drive part on one side with respect to the rotation axis is shared by the pair of piezoelectric drive parts, and the second drive portion of each piezoelectric drive part on another side with respect to the rotation axis is shared by the pair of piezoelectric drive parts.

7. The piezoelectric drive element according to claim **2**, wherein the fixing parts placed in the gap regions on both sides are connected to each other.

8. The piezoelectric drive element according to claim **1**, wherein the piezoelectric drive part includes a meander-type drive portion.

9. The piezoelectric drive element according to claim **1**, wherein the piezoelectric drive part includes a tuning fork-type drive portion.

10. A piezoelectric drive element comprising:

a movable part;

a pair of piezoelectric drive parts each connected at one end thereof to the movable part and configured to rotate the movable part about at least a rotation axis; and

a pair of fixing parts to which other ends of the piezoelectric drive parts are connected, respectively, wherein

the pair of fixing parts are connected to each other at a position displaced relative to the rotation axis only in one direction.

11. The piezoelectric drive element according to claim **10**, wherein the piezoelectric drive part includes a meander-type drive portion.

12. The piezoelectric drive element according to claim **10**, wherein the piezoelectric drive part includes a tuning fork-type drive portion.

* * * * *