US 20240264429A1

(19) **United States**

(12) **Patent Application Publication** (10) **Pub. No.: US 2024/0264429 A1**

IDE et al. (43) **Pub. Date: Aug. 8, 2024**

(54) **MIRROR DEVICE**

(71) Applicant: **HAMAMATSU PHOTONICS K.K.**, Hamamatsu-shi (JP)

(72) Inventors: **Tomoyuki IDE**, Hamamatsu-shi (JP); **Daiki SUZUKI**, Hamamatsu-shi (JP)

(73) Assignee: **HAMAMATSU PHOTONICS K.K.**, Hamamatsu-shi (JP)

(21) Appl. No.: **18/432,346**

(22) Filed: **Feb. 5, 2024**

(30) **Foreign Application Priority Data**

Feb. 7, 2023 (JP) 2023-016821

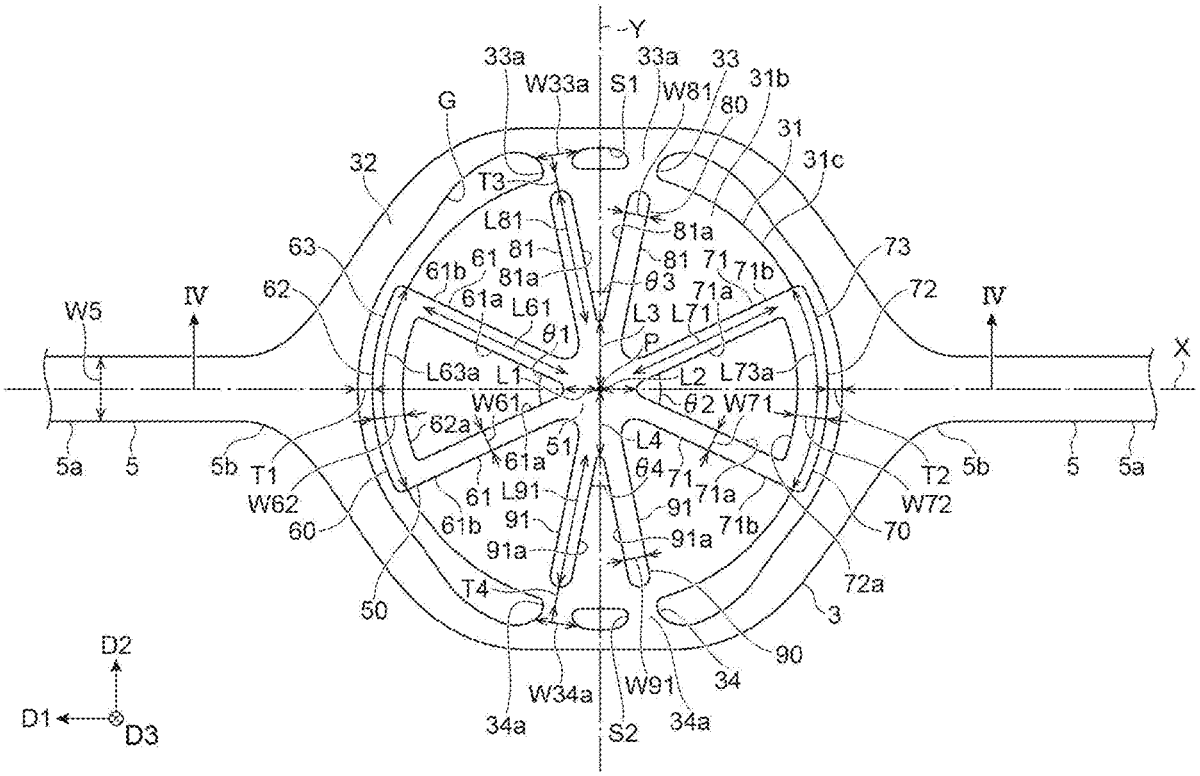
Publication Classification

(51) **Int. Cl.**
G02B 26/08 (2006.01)

(52) **U.S. Cl.**
CPC ***G02B 26/0825*** (2013.01)

(57) **ABSTRACT**

In a mirror device, a first rib portion includes a pair of first portions extending toward one side in a first direction and a first extending portion extending between the first portions. A second rib portion includes a pair of second portions extending toward the other side in the first direction and a second extending portion extending between the second portions. A third rib portion includes a pair of third portions extending toward one side in a second direction. A fourth rib portion includes a pair of fourth portions extending toward the other side in the second direction. A rib portion does not include portions formed between the third portions and between the fourth portions and extending to intersect the second axis when viewed in a third direction. The first to fourth portions are portions different from one another.



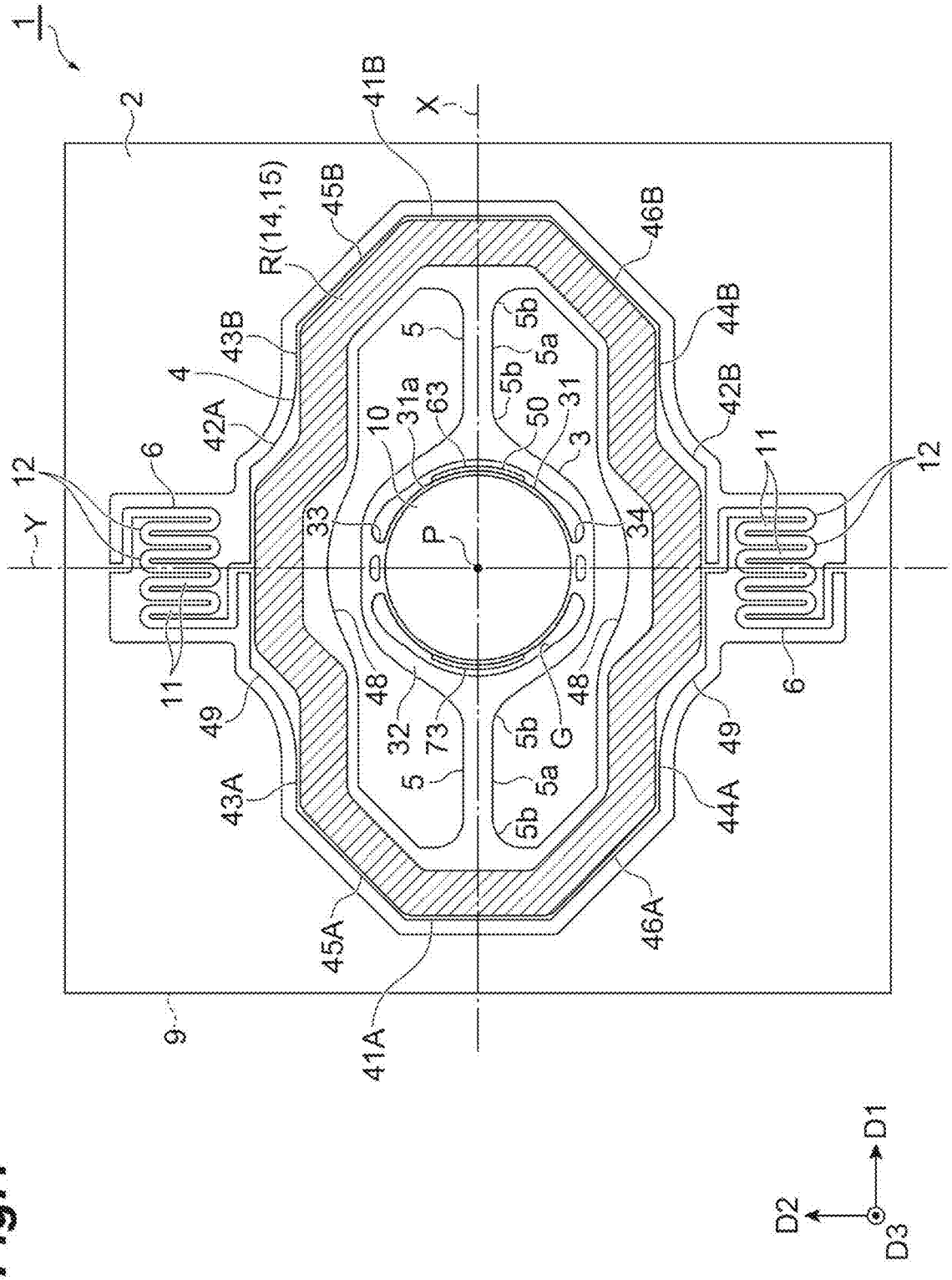

1
2
41B
X
R(14,15)
45B
46B
43B
4
42A
44B
42B
5
5b
5a
31a
63
10
50
31
3
6
12
Y
33
P
34
11
48
32
73
G
49
43A
44A
45A
46A
9
41A
D1
D2
D3

Fig.1

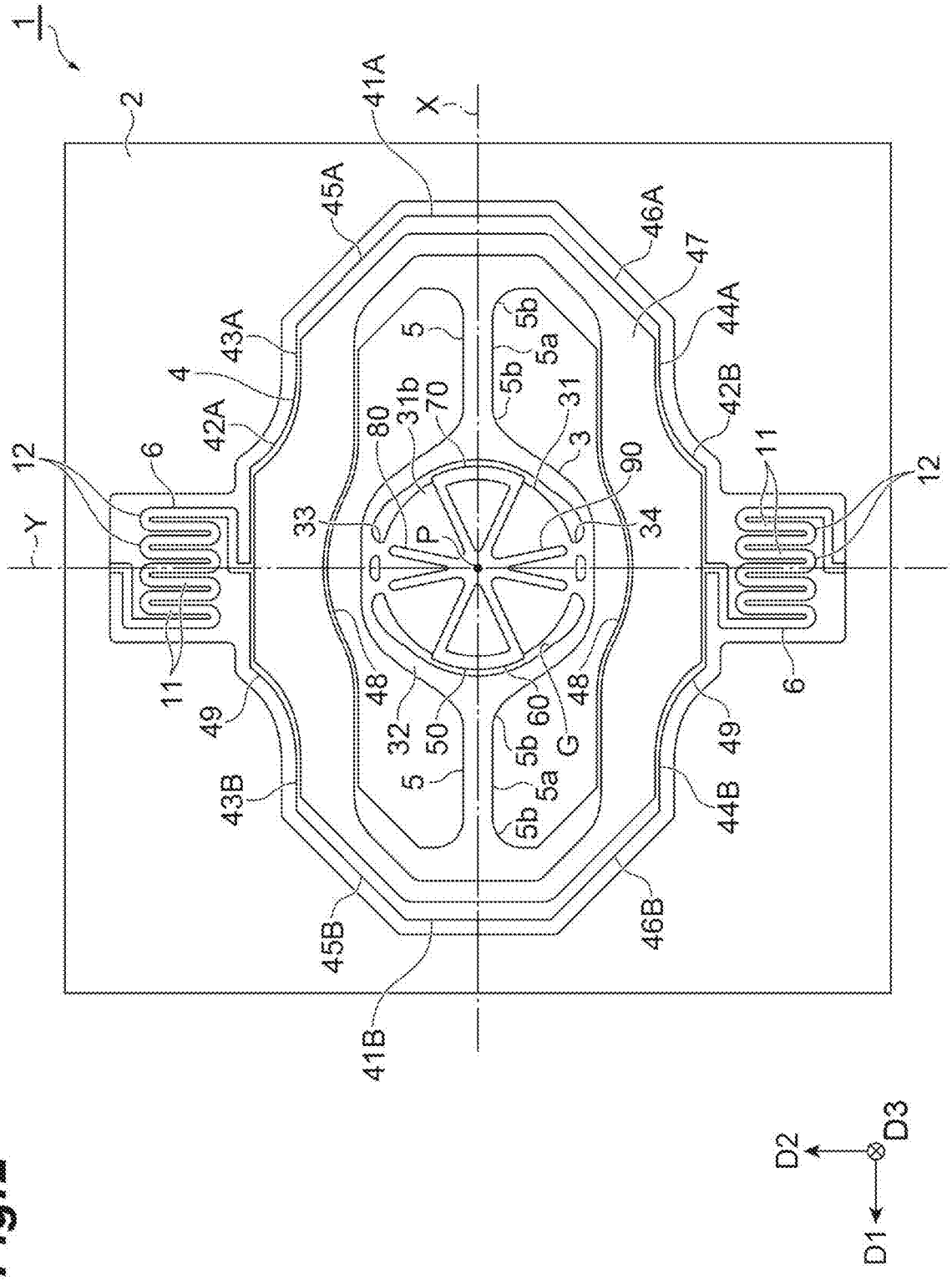

1
2
41A
X
45A
46A
47
44A
43A
4
42A
42B
5
5b
5a
31
31b
70
80
3
90
33
34
P
12
6
11
Y
48
32
50
60
G
49
43B
44B
45B
46B
41B
D2
D3
D1

Fig.2

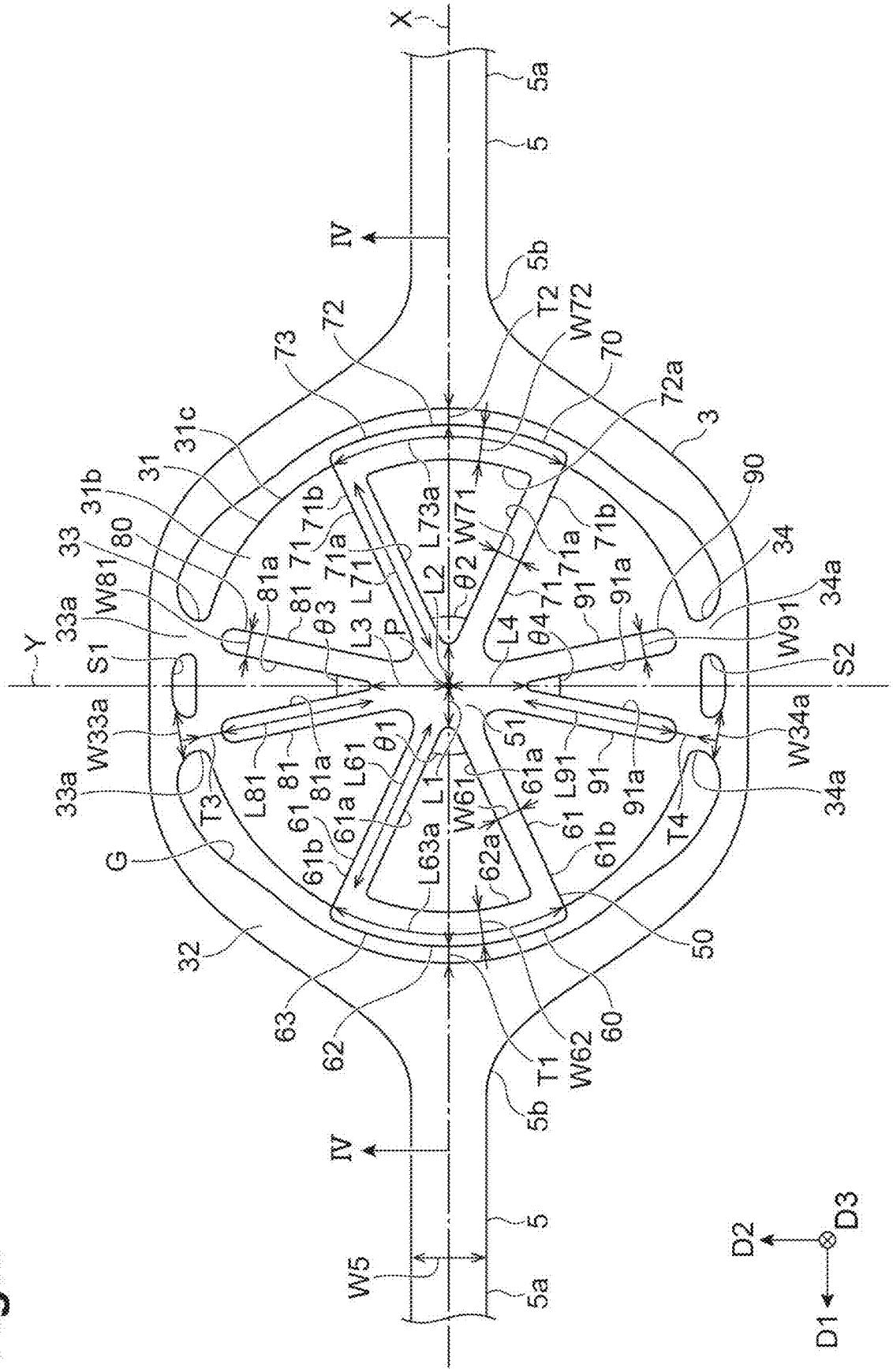

X
Y
IV
IV
5a
5
5b
T2
W72
70
72a
3
90
34
34a
W91
S2
W34a
34a
T4
91a
91
L91
51
61a
W61
L1
L63a
62a
61
61b
50
60
W62
T1
5b
5
5a
W5
63
62
32
G
T3
33a
W33a
33a
S1
W81
80
33
31b
31
31c
73
72
L81
81
81a
61
61b
61a
L61
θ1
71
71b
71a
L71
θ3
P
L3
L2
L73a
W71
θ2
L4
θ4
D2
D3
D1

Fig.3

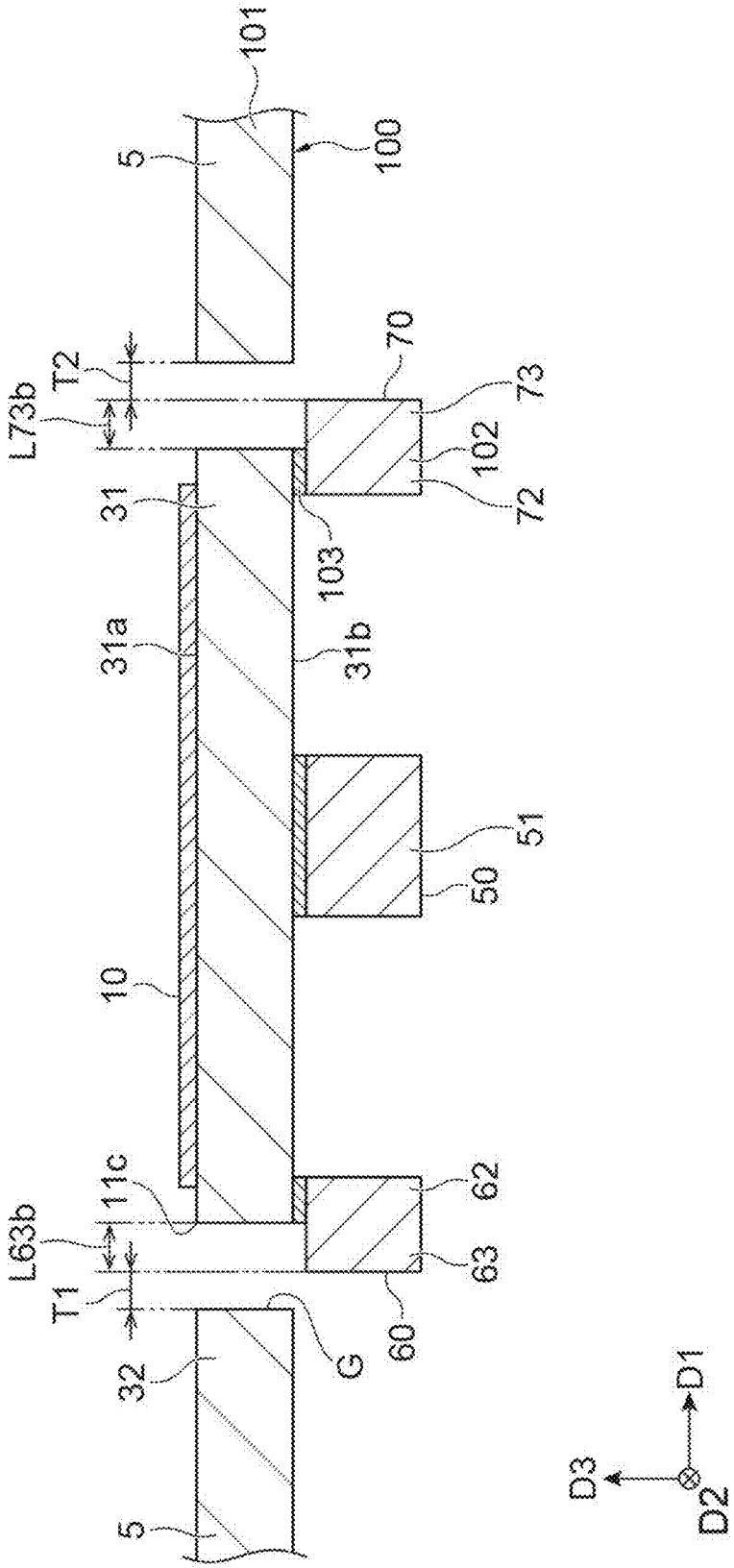

101
100
5
70
T2
L73b
73
102
72
31
103
31a
31b
51
50
10
11c
62
L63b
63
T1
60
G
32
5
D1
D3
D2

Fig.4

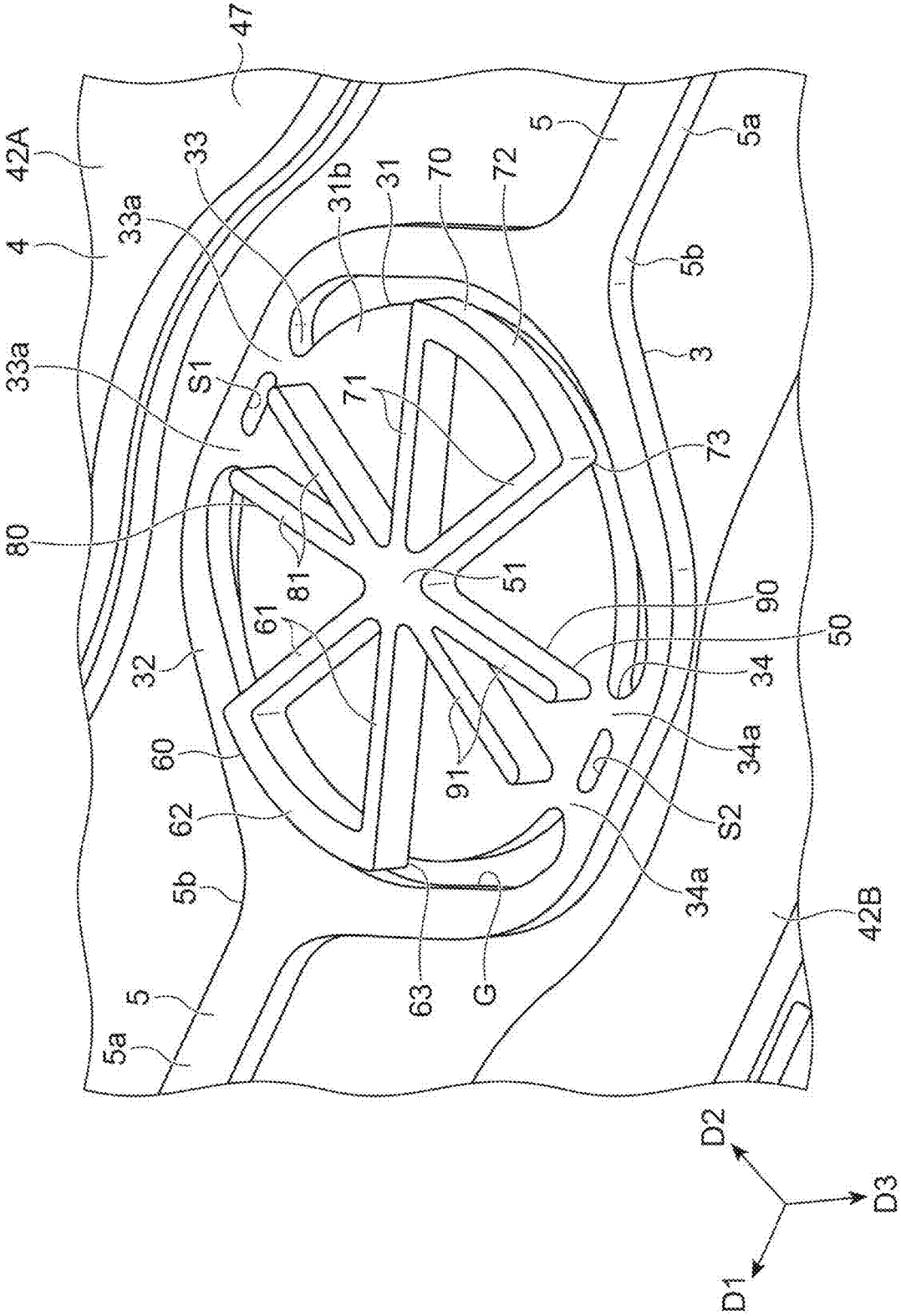

47
42A
4
33
33a
31b
31
70
72
5
5a
5b
3
73
71
S1
80
81
61
51
90
50
32
34
34a
60
91
S2
62
5b
63
G
42B
5
5a
D2
D3
D1

Fig.5

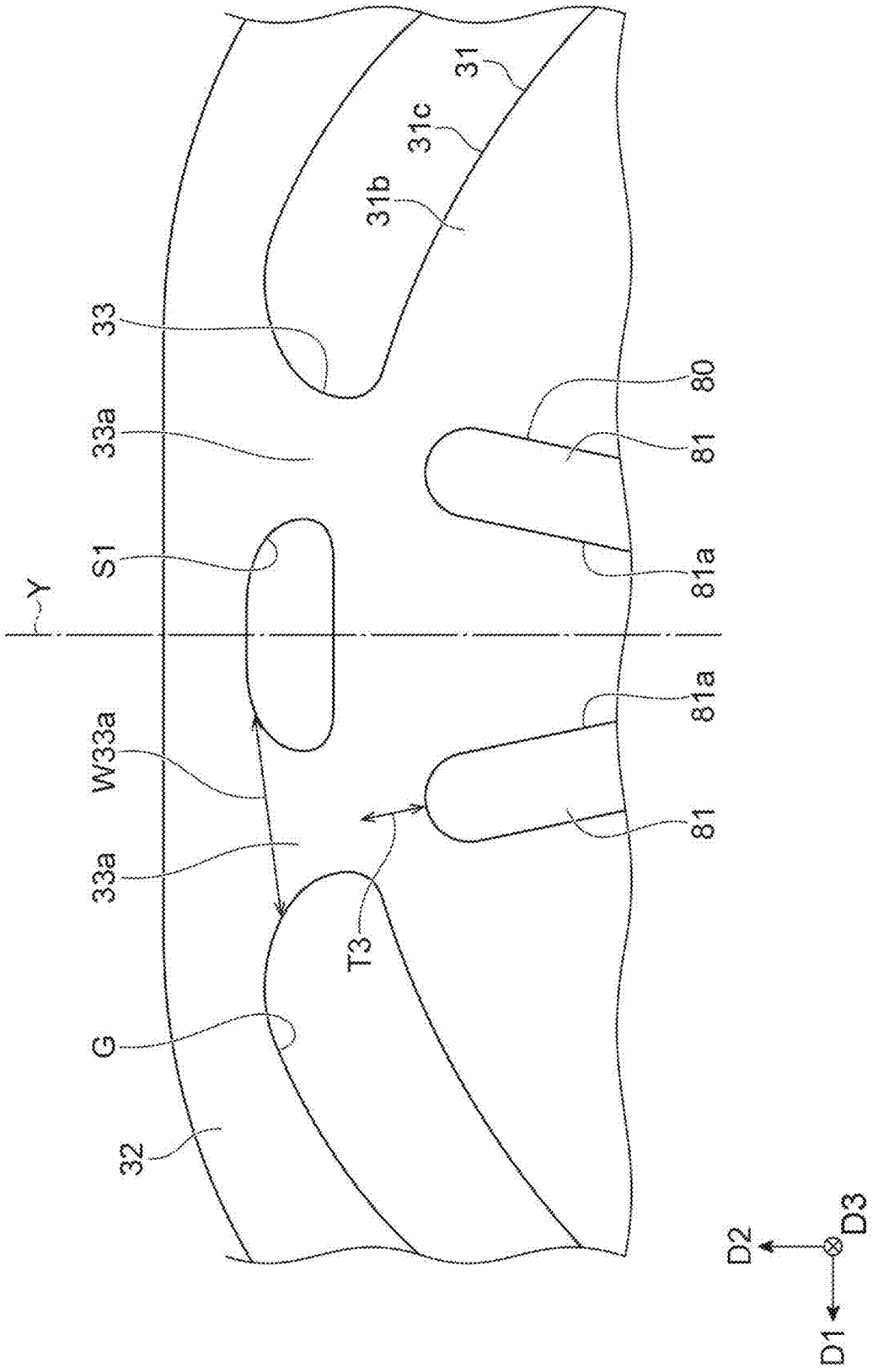


Fig.6

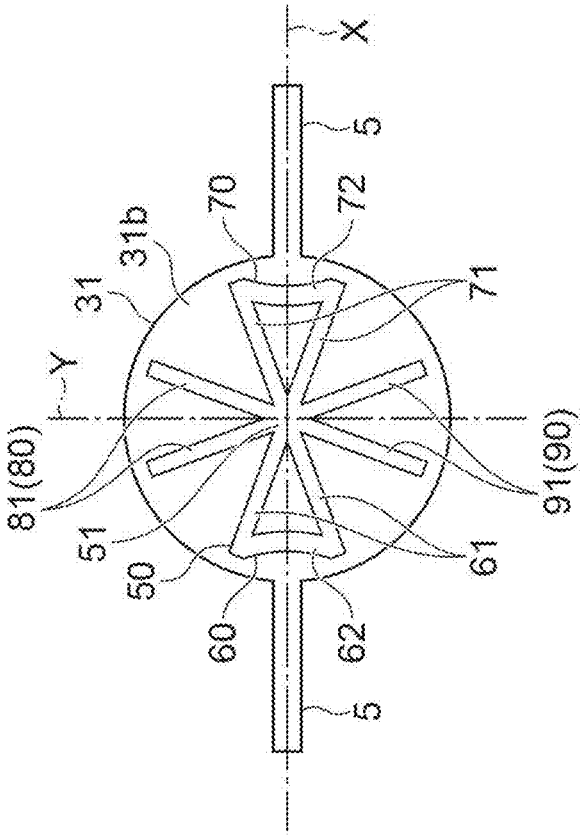

X
5
70
72
31b
31
71
Y
81(80)
91(90)
51
50
61
60
62
5

Fig.7B

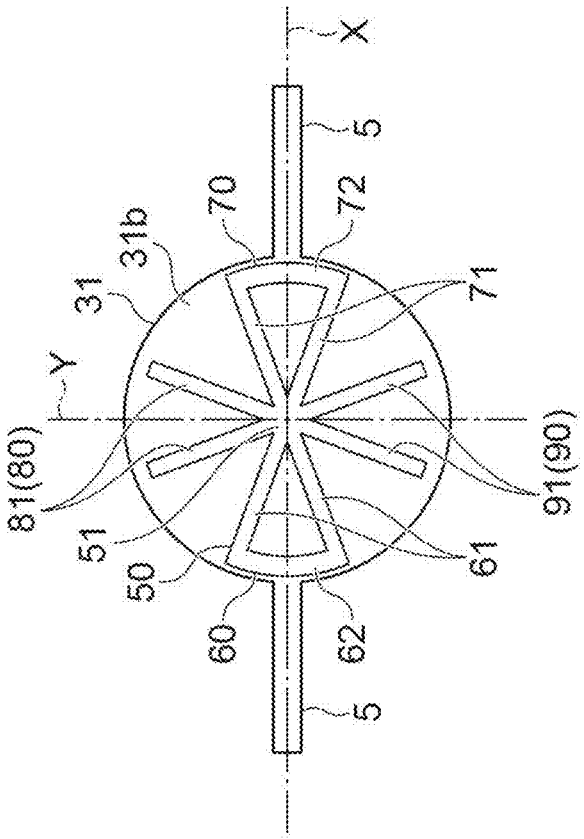

X
5
70
72
31b
31
71
Y
81(80)
91(90)
51
50
61
60
62
5

Fig.7A

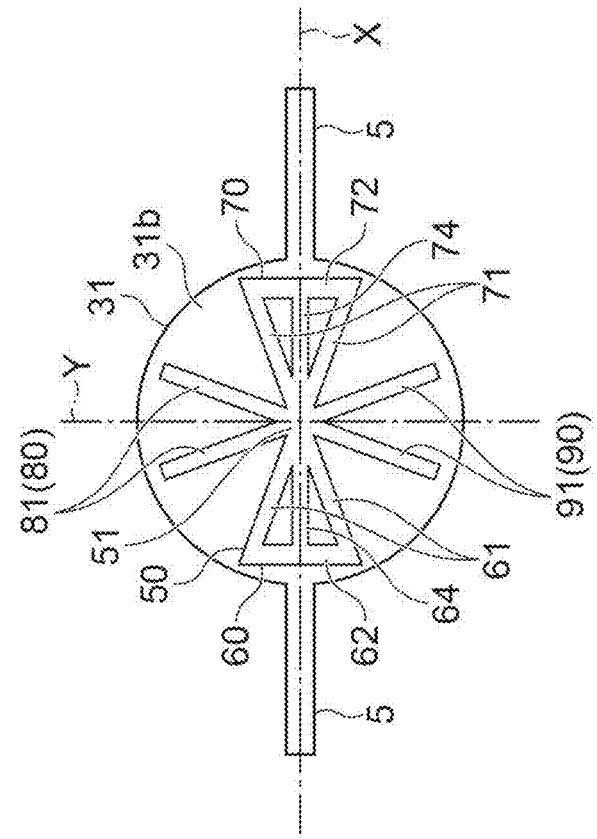

X
5
70
72
74
71
31b
31
Y
81(80)
91(90)
51
50
61
64
60
62
5

Fig.8B

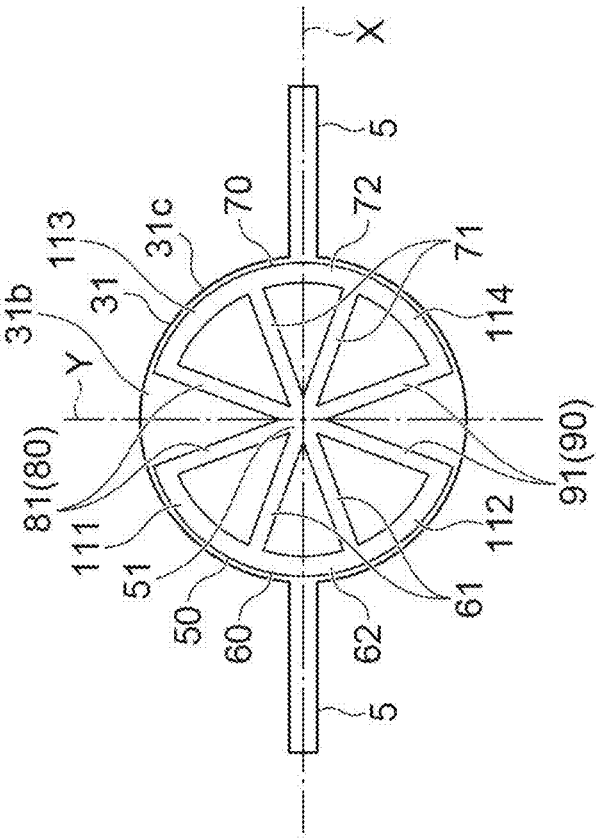

X
5
70
72
71
113
31c
31b
31
114
Y
81(80)
91(90)
111
112
51
50
61
60
62
5

Fig.8A

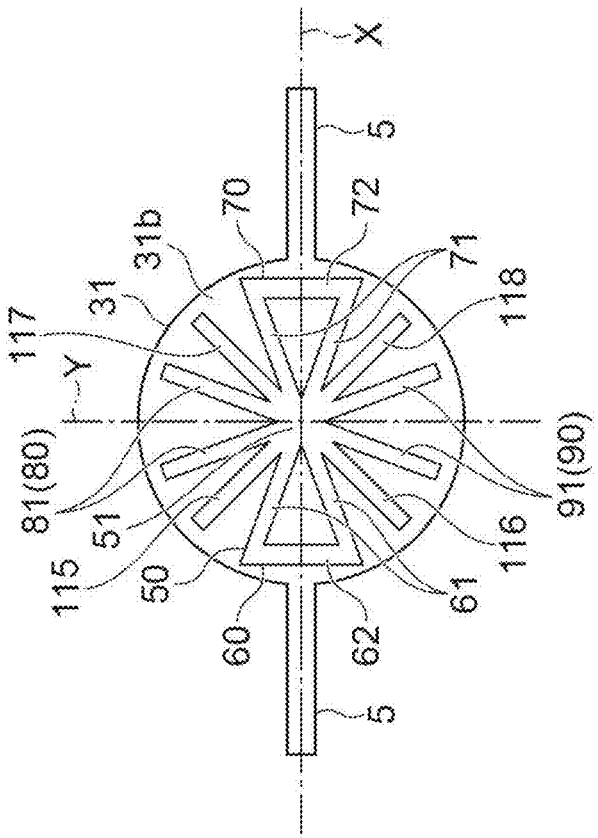

X
5
70
72
31b
71
31
118
117
Y
81(80)
91(90)
51
115
116
50
61
60
62
5

Fig.9B

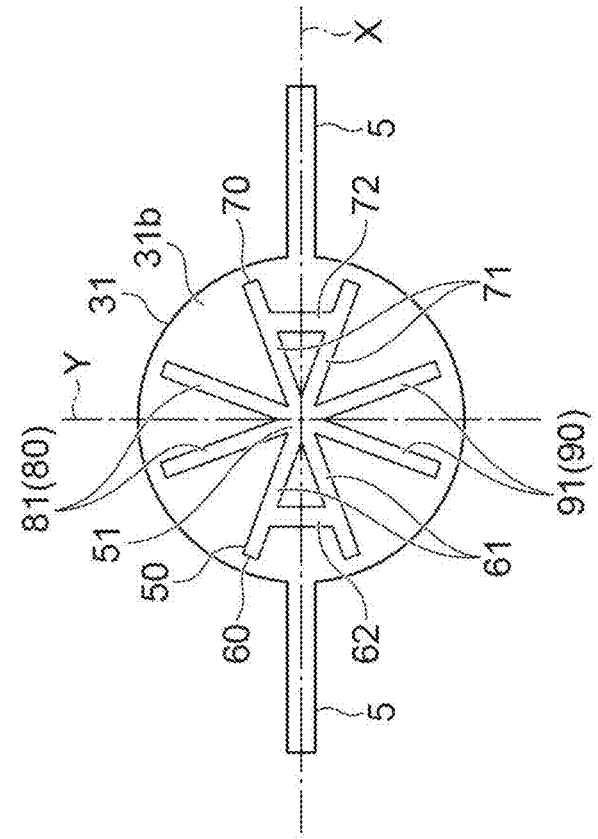

X
5
70
72
31b
71
31
Y
81(80)
91(90)
51
61
50
60
62
5

Fig.9A

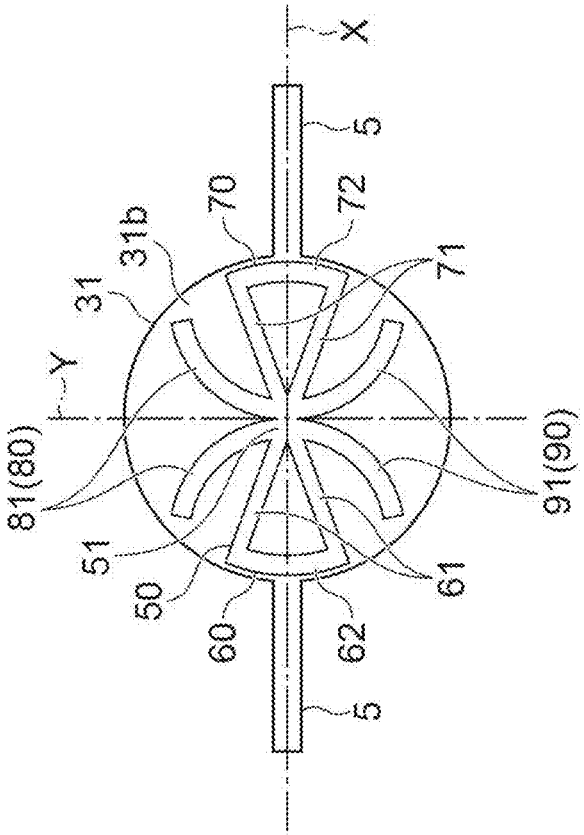


Fig.10B

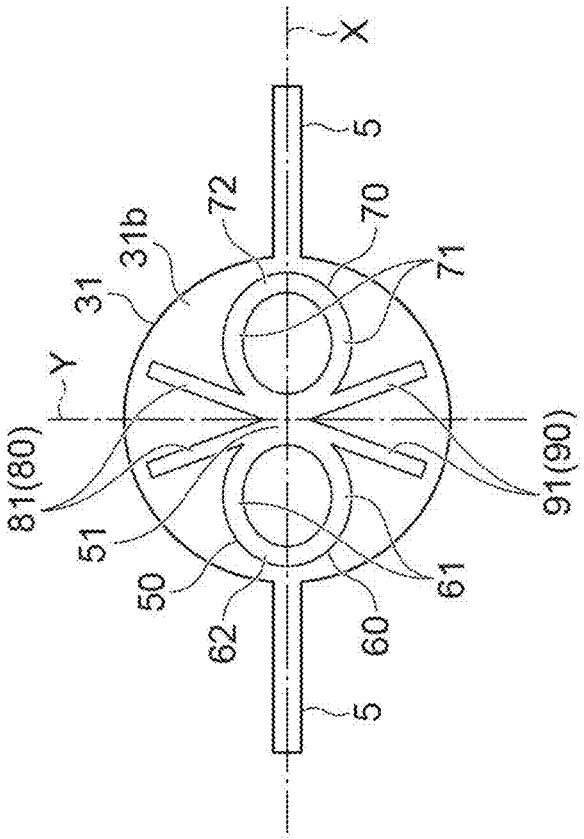


Fig.10A

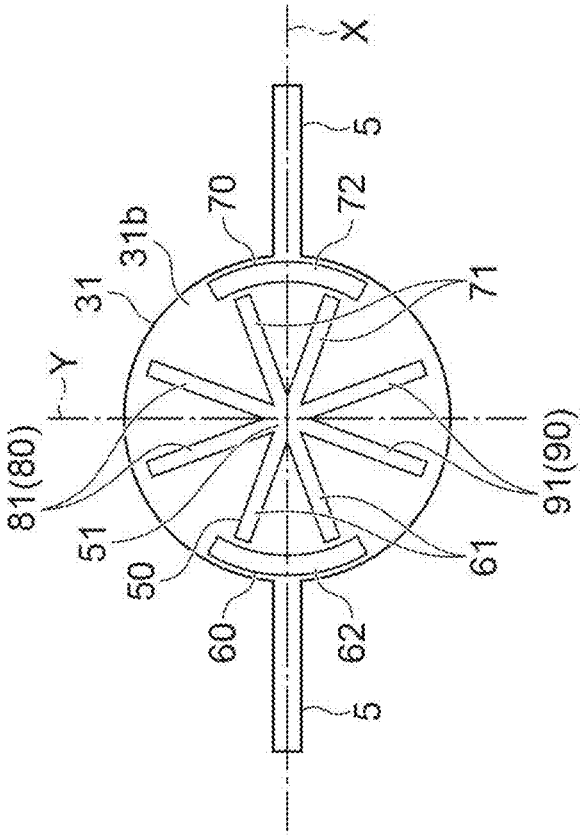


Fig.11B

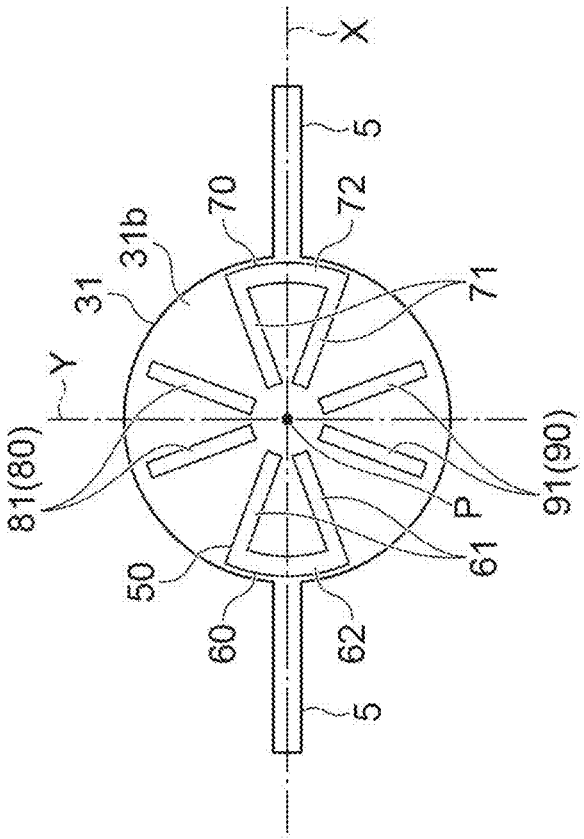


Fig.11A

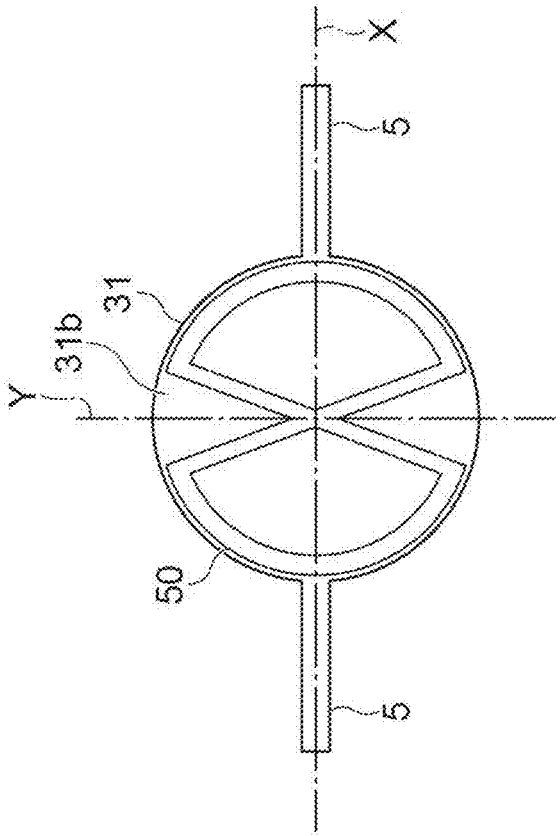


Fig.12B

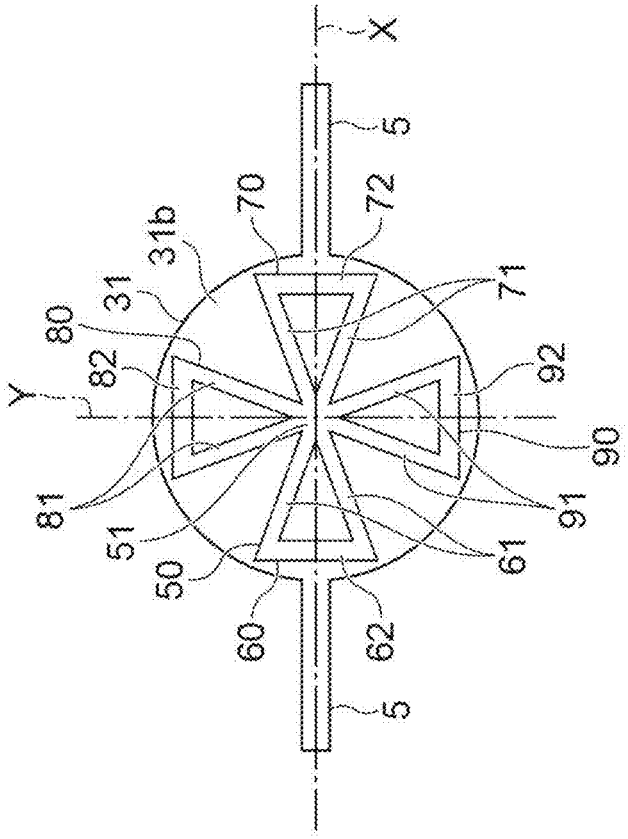


Fig.12A

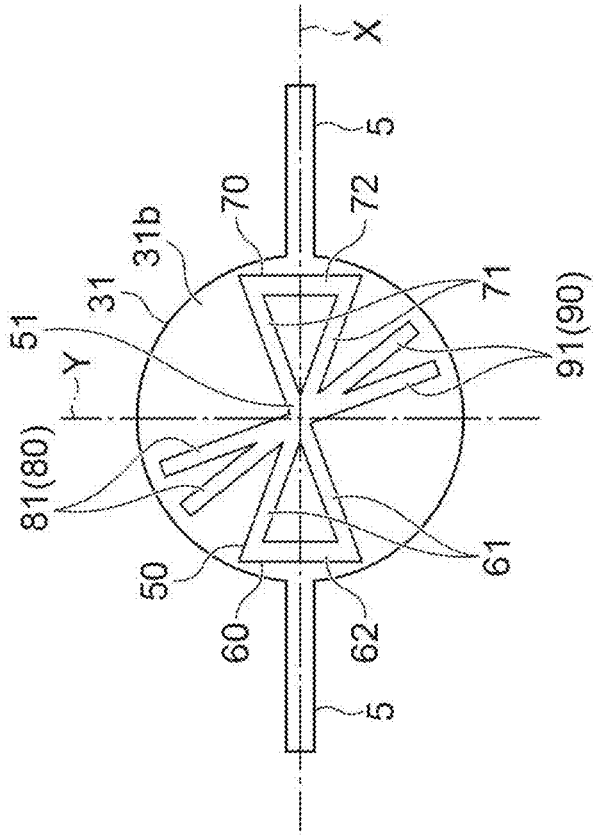


Fig.13B

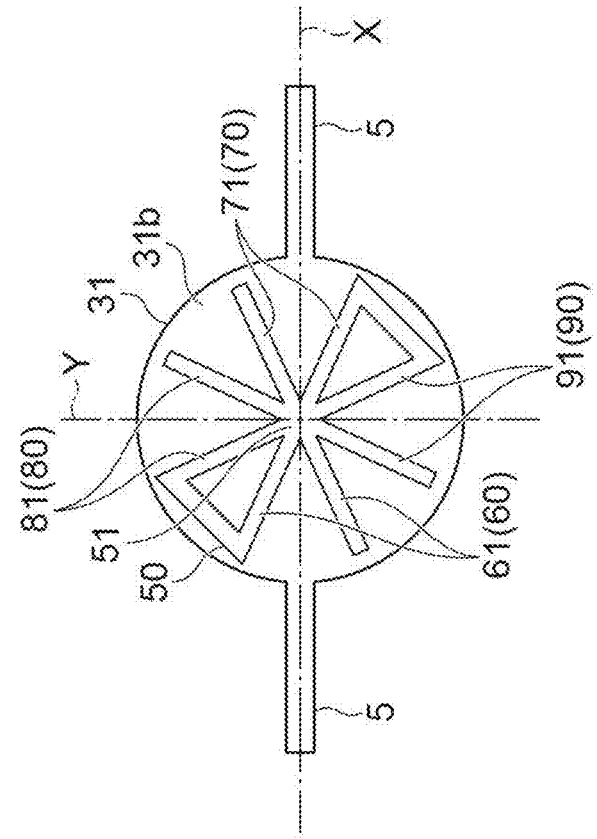


Fig.13A

MIRROR DEVICE

TECHNICAL FIELD

[0001] One aspect of the present disclosure relates to a mirror device.

BACKGROUND

[0002] For example, Japanese Unexamined Patent Publication No. 2004-325578 describes a deflection mirror in which a movable portion having a mirror surface is swingably coupled to a support portion. In the deflection mirror described in Patent Literature 1, in order to reduce distortion of the mirror surface during driving, a rib is formed on a back surface of the movable portion.

[0003] In the mirror device described above, effectively suppressing distortion of the mirror surface, and being able to satisfactorily swing the movable portion or ensuring reliability are required.

SUMMARY

[0004] Therefore, an object of one aspect of the present disclosure is to provide a mirror device capable of effectively suppressing distortion of a mirror surface and ensuring reliability while realizing good swinging of a movable portion.

[0005] [1] According to one aspect of the present disclosure, there is provided a mirror device including: "a support portion; a movable portion having a first surface and a second surface opposite to the first surface, a mirror surface being formed on the first surface and a rib portion being formed on the second surface; and a coupling portion that couples the movable portion to the support portion such that the movable portion is swingable around a first axis. The rib portion includes a first rib portion, a second rib portion, a third rib portion, and a fourth rib portion. When a direction parallel to the first axis is a first direction, an axis perpendicular to both the first direction and a third direction passing through a center of the movable portion when viewed in the third direction perpendicular to the second surface is a second axis, and a direction parallel to the second axis is a second direction, the first rib portion includes a pair of first portions extending from a side of a reference position toward one side in the first direction and facing each other with the first axis interposed between the pair of first portions in the second direction, and a first extending portion extending between the pair of first portions to intersect the first axis when viewed in the third direction, the second rib portion includes a pair of second portions extending from the side of the reference position toward the other side in the first direction and facing each other with the first axis interposed between the pair of second portions in the second direction, and a second extending portion extending between the pair of second portions to intersect the first axis when viewed in the third direction, the third rib portion includes a pair of third portions extending from the side of the reference position toward one side in the second direction and facing each other with the second axis interposed between the pair of third portions in the first direction, and the fourth rib portion includes a pair of fourth portions extending from the side of the reference position toward the other side in the second direction and facing each other with the second axis interposed between the pair of fourth portions in the first direction. The rib portion does not include a portion formed between the pair of third portions and extending to intersect the second axis when viewed in the third direction, and a portion formed between the pair of fourth portions and extending to intersect the second axis when viewed in the third direction. The pair of first portions, the pair of second portions, the pair of third portions, and the pair of fourth portions are portions different from one another."

[0006] In the mirror device, the rib portion includes the first rib portion, the second rib portion, the third rib portion, and the fourth rib portion. The first rib portion includes the pair of first portions extending from the side of the reference position toward the one side in the first direction and facing each other with the first axis interposed between the pair of first portions in the second direction, and the first extending portion extending between the pair of first portions to intersect the first axis when viewed in the third direction, the second rib portion includes the pair of second portions extending from the side of the reference position toward the other side in the first direction and facing each other with the first axis interposed between the pair of second portions in the second direction, and the second extending portion extending between the pair of second portions to intersect the first axis when viewed in the third direction, the third rib portion includes the pair of third portions extending from the side of the reference position toward the one side in the second direction and facing each other with the second axis interposed between the pair of third portions in the first direction, and the fourth rib portion includes the pair of fourth portions extending from the side of the reference position toward the other side in the second direction and facing each other with the second axis interposed between the pair of fourth portions in the first direction. Accordingly, the rib portion can be disposed on the movable portion in a well-balanced manner, and distortion of the movable portion (in other words, distortion of the mirror surface) can be effectively suppressed. On the other hand, when the movable portion swings, stress generated in the coupling portion may be transmitted to the rib portion, and from the viewpoint of preventing the rib portion from being damaged or peeled off due to the stress, reinforcing the rib portion can be considered. However, for example, when the rib portion is reinforced simply by connecting rib portions, the moment of inertia of the movable portion around the first axis may increase depending on the connection location. In this regard, in the mirror device, the first rib portion includes the first extending portion extending between the pair of first portions to intersect the first axis when viewed in the third direction, and the second rib portion includes the second extending portion extending between the pair of second portions to intersect the first axis when viewed in the third direction, whereas the rib portion does not include a portion formed between the pair of third portions and extending to intersect the second axis when viewed in the third direction, and a portion formed between the pair of fourth portions and extending to intersect the second axis when viewed in the third direction. In such a manner, the rib portion extending to intersect the second axis is not formed in a region between the pair of third portions and a region between the pair of fourth portions which have a relatively large influence on the moment of inertia of the movable portion around the first axis, whereas the first extending portion and the second extending portion are formed in a region between the pair of first portions and a region between the pair of second

portions, respectively, which have a relatively small influence, so that reliability can be ensured through the reinforcement of the rib portion while realizing good swinging of the movable portion through the suppression of an increase in the moment of inertia of the movable portion around the first axis. In addition, a decrease in the resonance frequency of the movable portion around the first axis can be suppressed by suppressing an increase in the moment of inertia of the movable portion around the first axis. Therefore, according to the mirror device, distortion of the mirror surface can be effectively suppressed, and reliability can be ensured while realizing good swinging of the movable portion.

[0007] [2] In the mirror device according to one aspect of the present disclosure, according to [1], "the first extending portion may be connected to the pair of first portions, and the second extending portion may be connected to the pair of second portions." In this case, distortion of the movable portion can be more effectively suppressed. In addition, the rigidity of the first rib portion and the second rib portion can be increased, and damage to the rib portion or the peeling of the rib portion can be suppressed.

[0008] [3] In the mirror device according to one aspect of the present disclosure, according to [1] or [2], "the pair of first portions may be connected to each other on the side of the reference position, and the pair of second portions may be connected to each other on the side of the reference position." In this case, the rigidity of the first rib portion and the second rib portion can be increased, and damage to the rib portion or the peeling of the rib portion can be suppressed.

[0009] [4] In the mirror device according to one aspect of the present disclosure, according to any one of [1] to [3], "the pair of third portions may be connected to each other on the side of the reference position, and the pair of fourth portions may be connected to each other on the side of the reference position." In this case, the rigidity of the third rib portion and the fourth rib portion can be increased, and damage to the rib portion or the peeling of the rib portion can be suppressed.

[0010] [5] In the mirror device according to one aspect of the present disclosure, according to any one of [1] to [4], "the rib portion may include a reference portion disposed at the reference position when viewed in the third direction. The pair of first portions, the pair of second portions, the pair of third portions, and the pair of fourth portions may be connected to the reference portion." In this case, the rigidity of the rib portion can be increased, and damage to the rib portion or the peeling of the rib portion can be suppressed.

[0011] [6] In the mirror device according to one aspect of the present disclosure, according to any one of [1] to [5], "when viewed in the third direction, the first extending portion may be curved to be convex toward the one side in the first direction, and the second extending portion may be curved to be convex toward the other side in the first direction." In this case, distortion of the body portion can be more effectively suppressed.

[0012] [7] In the mirror device according to one aspect of the present disclosure, according to any one of [1] to [6], "the first extending portion may be connected to end portions on an opposite side of the pair of first portions from the reference position, and the second extending portion may be connected to end portions on an opposite side of the pair of second portions from the reference position." In this case, distortion of the body portion can be more effectively suppressed.

[0013] [8] In the mirror device according to one aspect of the present disclosure, according to any one of [1] to [7], "each of the pair of first portions, the pair of second portions, the pair of third portions, and the pair of fourth portions may extend straight. When viewed in the direction perpendicular to the second surface, if an angle between the pair of first portions is **θ1**, an angle between the pair of second portions is **θ2**, an angle between the pair of third portions is **θ3**, and an angle between the pair of fourth portions is **θ4**, each of **θ1** and **θ2** may be larger than each of **θ3** and **θ4**." In this case, since the region between the pair of first portions and the region between the pair of second portions become wider, the first extending portion and the second extending portion can be lengthened, and as a result, distortion of the movable portion can be more effectively suppressed.

[0014] [9] In the mirror device according to one aspect of the present disclosure, according to [8], "the following relationships may be satisfied."

$$\theta 3 < \theta 1 < 3 \times \theta 3$$

$$\theta 4 < \theta 1 < 3 \times \theta 4$$

$$\theta 3 < \theta 2 < 3 \times \theta 3$$

$$\theta 4 < \theta 2 < 3 \times \theta 4$$

[0015] In this case, since the length of the first extending portion and the second extending portion can be made less than or equal to a predetermined length, distortion of the movable portion can be suppressed while suppressing an increase in the moment of inertia of the movable portion around the first axis.

[0016] [10] In the mirror device according to one aspect of the present disclosure, according to any one of [1] to [9], "each of a length of the pair of first portions and a length of the pair of second portions may be longer than each of a length of the pair of third portions and a length of the pair of fourth portions." In this case, an increase in the moment of inertia of the movable portion around the first axis can be further suppressed.

[0017] [11] In the mirror device according to one aspect of the present disclosure, according to any one of [1] to [10], "the reference position may coincide with the center of the movable portion when viewed in the third direction." In this case, the rib portion can be disposed on the movable portion in a well-balanced manner, and distortion of the movable portion can be effectively suppressed.

[0018] [12] In the mirror device according to one aspect of the present disclosure, according to [2], "when viewed in the third direction, an inner edge of the first extending portion may be smoothly connected to inner edges of the pair of first portions, and an inner edge of the second extending portion may be smoothly connected to inner edges of the pair of second portions." The closer a portion on the movable portion is to an outer edge portion, the more likely distortion is to occur at the portion; however, with such a configuration as described [12], stress can be dispersed, and damage to the first rib portion and the second rib portion or the peeling of the first rib portion and the second rib portion can be suppressed.

[0019] [13] In the mirror device according to one aspect of the present disclosure, according to [4], "when viewed in the third direction, inner edges of the pair of third portions may be smoothly connected to each other, and inner edges of the pair of fourth portions may be smoothly connected to each other." Since the rib portion is not formed in the region between the pair of third portions and the region between the pair of fourth portions, the third rib portion and the fourth rib portion are likely to become structurally weak, particularly, stress is likely to concentrate on the connection location between the pair of third portions and the connection location between the pair of fourth portions; however, with such a configuration as described in [13], stress can be dispersed, and damage to the third rib portion and the fourth rib portion or the peeling of the third rib portion and the fourth rib portion can be suppressed.

[0020] [14] In the mirror device according to one aspect of the present disclosure, according to any one of [1] to [10], "the movable portion may include a body portion including the first surface and the second surface, an ring-shaped portion surrounding the body portion with a gap interposed between the ring-shaped portion and the body portion when viewed in the third direction, and connected to the coupling portion, and a connection portion that connects the ring-shaped portion to the body portion. The mirror surface may be formed on the first surface of the body portion, and the rib portion may be formed on the second surface of the body portion." In this case, since the movable portion is connected to the coupling portion via the ring-shaped portion, the occurrence that stress generated in the coupling portion during swinging of the movable portion is transmitted to the movable portion can be suppressed, and dynamic distortion of the movable portion can be suppressed. In addition, the transmission of the stress to the rib portion can be suppressed, and damage to the rib portion or the peeling of the rib portion can be suppressed.

[0021] [15] In the mirror device according to one aspect of the present disclosure, according to [14], "the movable portion may include a first connection portion and a second connection portion as the connection portion, the first connection portion may be disposed on the one side in the second direction with respect to the body portion, and the second connection portion may be disposed on the other side in the second direction with respect to the body portion. The first connection portion may include a pair of first connection regions separated from each other by a space, each of the pair of first connection regions may be connected to the body portion and the ring-shaped portion, the second connection portion may include a pair of second connection regions separated from each other by a space, and each of the pair of second connection regions may be connected to the body portion and the ring-shaped portion. The pair of third portions may extend toward the pair of respective first connection regions, and the pair of fourth portions may extend toward the pair of respective second connection regions." In this case, since the first connection portion includes the pair of first connection regions and the second connection portion includes the pair of second connection regions, the occurrence that stress generated in the coupling portion during swinging of the movable portion is transmitted to the movable portion and the rib portion can be further suppressed. In addition, rigidity is likely to be low in the vicinities of the first connection regions and the second connection regions; however, since the pair of third portions extend toward the pair of respective first connection regions and the pair of fourth portions extend toward the pair of respective second connection regions, rigidity in the vicinities of the first connection regions and the second connection regions can be increased.

[0022] [16] In the mirror device according to one aspect of the present disclosure, according to [15], "when viewed in the third direction, the pair of third portions may not reach the pair of first connection regions, and the pair of fourth portions may not reach the pair of second connection regions." Since relatively large dynamic distortion occurs in the ring-shaped portion or the first connection regions and the second connection regions, with such a configuration, damage to the third rib portion and the fourth rib portion or the peeling of the third rib portion and the fourth rib portion can be suppressed.

[0023] [17] In the mirror device according to one aspect of the present disclosure, according to [16], "a distance between the pair of third portions and the pair of first connection regions may be smaller than a maximum width of each of the pair of first connection regions, and a distance between the pair of fourth portions and the pair of second connection regions may be smaller than a maximum width of each of the pair of second connection regions." In this case, rigidity in the vicinities of the first connection regions and the second connection regions can be increased.

[0024] According to one aspect of the present disclosure, it is possible to provide the mirror device capable of effectively suppressing distortion of the mirror surface and ensuring reliability while realizing good swinging of the movable portion.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025] FIG. **1** is a plan view of a mirror device according to an embodiment.

[0026] FIG. **2** is a bottom view of the mirror device.

[0027] FIG. **3** is a partial enlarged view of FIG. **2**.

[0028] FIG. **4** is a cross-sectional view taken along line IV-IV in FIG. **3**.

[0029] FIG. **5** is a perspective view of a peripheral portion of a first movable portion.

[0030] FIG. **6** is a partial enlarged view of FIG. **3**.

[0031] FIGS. **7**A and **7**B are views showing a first modification example and a second modification example.

[0032] FIGS. **8**A and **8**B are views showing a third modification example and a fourth modification example.

[0033] FIGS. **9**A and **9**B are views showing a fifth modification example and a sixth modification example.

[0034] FIGS. **10**A and **10**B are views showing a seventh modification example and an eighth modification example.

[0035] FIGS. **11**A and **11**B are views showing a ninth modification example and a tenth modification example.

[0036] FIGS. **12**A and **12**B are views showing a first comparative example and a second comparative example.

[0037] FIGS. **13**A and **13**B are views showing a third comparative example and a fourth comparative example.

DETAILED DESCRIPTION

[0038] Hereinafter, an embodiment of the present disclosure will be described in detail with reference to the drawings. In the following description, the same reference signs are used for the same or equivalent elements, and duplicate descriptions will be omitted.

[0039] As shown in FIGS. **1** to **4**, a mirror device **1** includes a support portion **2**, a first movable portion **3**, a second movable portion **4**, a pair of first torsion bars (first coupling portions) **5**, a pair of second torsion bars (second coupling portions) **6**, and a magnetic field generation portion **9**. In the mirror device **1**, the first movable portion **3** having a mirror surface **10** swings around each of an X-axis (first axis) and a Y-axis (second axis perpendicular to the first axis) orthogonal to each other. The mirror device **1** can be used, for example, in an optical switch for optical communication, an optical scanner, and the like. In the following description, a direction parallel to the X-axis is a direction D**1** (first direction), a direction parallel to the Y-axis is a direction D**2** (second direction), and a direction perpendicular to both the direction D**1** and the direction D**2** is a direction D**3** (third direction). Incidentally, in FIG. **2**, the illustration of the magnetic field generation portion **9** is omitted.

[0040] The support portion **2**, the first movable portion **3**, the second movable portion **4**, the pair of first torsion bars **5**, and the pair of second torsion bars **6** are integrally formed, for example, from a silicon on insulator (SOI) substrate **100** (refer to FIG. **4**). Namely, the mirror device **1** is configured as a MEMS device manufactured by processing a semiconductor substrate using MEMS technology (patterning, etching, and the like). The SOI substrate **100** includes a first semiconductor layer **101**; a second semiconductor layer **102**; and an insulating layer **103** disposed between the first semiconductor layer **101** and the second semiconductor layer **102**. For example, the first semiconductor layer **101** and the second semiconductor layer **102** are made of silicon, and the insulating layer **103** is made of silicon dioxide.

[0041] The magnetic field generation portion **9** is made up of, for example, a plurality of permanent magnets arranged in a Halbach array. The magnetic field generation portion **9** generates a magnetic field acting on coils **14** and **15** to be described later. The support portion **2** has, for example, a quadrangular outer shape in a plan view (when viewed in the direction D**3**), and is formed in a frame shape. The support portion **2** is formed from the first semiconductor layer **101**, the second semiconductor layer **102**, and the insulating layer **103**. The support portion **2** is disposed on one side of the magnetic field generation portion **9** in the direction D**3**. The support portion **2** supports the first movable portion **3**, the second movable portion **4**, and the like. The first movable portion **3** is disposed inside the support portion **2** in a state where the first movable portion **3** is separated from the magnetic field generation portion **9**. The first movable portion **3** has a shape that is symmetrical with respect to each of the X-axis and the Y-axis in a plan view. The first movable portion **3** includes a body portion **31**, an ring-shaped portion **32**, a first connection portion **33**, and a second connection portion **34**. The body portion **31**, the ring-shaped portion **32**, the first connection portion **33**, and the second connection portion **34** are formed from the first semiconductor layer **101**.

[0042] The body portion **31** is formed, for example, in a circular shape in a plan view. A center P (center of gravity) of the body portion **31** (center of the first movable portion **3**) in a plan view coincides with the intersection point of the X-axis and the Y-axis. Namely, the X-axis and the Y-axis pass through the center P. The body portion **31** has a first surface **31***a* and a second surface **31***b* opposite to the first surface **31***a* (refer to FIG. **4**). The first surface **31***a* is a surface on the one side in the direction D**3**, and is a surface opposite to the magnetic field generation portion **9**. In this example, the first surface **31***a* and the second surface **31***b* are flat surfaces parallel to each other, and extend perpendicularly to the direction D**3**. The mirror surface **10** having a circular shape is formed on the first surface **31***a*. The mirror surface **10** is formed, for example, of a surface of a metal film made of aluminum. The mirror surface **10** is formed on substantially the entirety of the first surface **31***a*, but may be formed on a part of the first surface **31***a*.

[0043] The ring-shaped portion **32** is formed in a ring shape in a plan view, and surrounds the body portion **31** with a gap G interposed therebetween. The ring-shaped portion **32** has, for example, a substantially octagonal outer shape and a substantially circular inner shape in a plan view. The ring-shaped portion **32** is connected to the pair of first torsion bars **5** on the X-axis.

[0044] The first connection portion **33** is disposed on one side in the direction D**2** with respect to the body portion **31** (upper side in FIG. **1**), and the second connection portion **34** is disposed on the other side in the direction D**2** with respect to the body portion **31** (lower side in FIG. **1**). Each of the first connection portion **33** and the second connection portion **34** connects the ring-shaped portion **32** to the body portion **31**. The gap G (space) is formed between the ring-shaped portion **32** and the body portion **31** except for locations where the first connection portion **33** and the second connection portion **34** are disposed. In a plan view, the gap G includes a portion at which the width (width in a direction perpendicular to an extending direction of the gap G) becomes wider as the gap G extends from an X-axis side toward a first connection portion **33** (second connection portion **34**) side in the direction D**2**. In addition, in a plan view, the ring-shaped portion **32** includes a portion at which the width (width in a direction perpendicular to an extending direction of the ring-shaped portion **32**) becomes narrower as the ring-shaped portion **32** extends from the X-axis side toward the first connection portion **33** (second connection portion **34**) side in the direction D**2**. Since the width of the ring-shaped portion **32** is gradually narrowed as the ring-shaped portion **32** extends from the X-axis side toward the first connection portion **33** (second connection portion **34**) side, dynamic distortion that occurs in the first torsion bars **5** and the second torsion bars **6** during swinging and that is transmitted to the ring-shaped portion **32**, or static distortion that occurs due to the formation of a coil or the like in the second movable portion **4** and that is transmitted to the ring-shaped portion **32** via the first torsion bars **5** can be suitably relieved by the ring-shaped portion **32**. Note that unlike the torsion bars (coupling portions) that couple the movable portions so as to be swingable around the axes, the first connection portion **33** and the second connection portion **34** are not intended to swingably couple the body portion **31** to the ring-shaped portion **32**.

[0045] As shown in FIG. **3**, the first connection portion **33** includes a pair of first connection regions **33***a* separated from each other by a space S**1** (through-hole). In this example, the space S**1** is located on the Y-axis, and the pair of first connection regions **33***a* face each other with the Y-axis interposed therebetween in the direction D**1**. Each of the first connection regions **33***a* is connected to the body portion **31** and the ring-shaped portion **32**. The second connection portion **34** includes a pair of second connection regions **34***a* separated from each other by a space S**2**

(through-hole). In this example, the space S2 is located on the Y-axis, and the pair of second connection regions **34***a* face each other with the Y-axis interposed therebetween in the direction D1. Each of the second connection regions **34***a* is connected to the body portion **31** and the ring-shaped portion **32**.

[0046] The second movable portion **4** is formed in a frame shape, and is disposed inside the support portion **2** to surround the first movable portion **3** in a state where the second movable portion **4** is separated from the magnetic field generation portion **9**. The second movable portion **4** includes a pair of first connection portions **41**A and **41**B, a pair of second connection portions **42**A and **42**B, a pair of first linear portions **43**A and **43**B, a pair of second linear portions **44**A and **44**B, a pair of third linear portions **45**A and **45**B, and a pair of fourth linear portions **46**A and **46**B. Each of these portions is formed from the first semiconductor layer **101**. The second movable portion **4** has a shape that is symmetrical with respect to each of the X-axis and the Y-axis in a plan view.

[0047] The first connection portions **41**A and **41**B are located on both sides of the first movable portion **3** in the direction D1, and extend along the direction D2. The second connection portions **42**A and **42**B are located on both sides of the first movable portion **3** in the direction D2, and extend along the direction D1. An inner edge of each of the second connection portions **42**A and **42**B in a plan view includes a concave portion **48** recessed in the direction D2, and an outer edge of each of the second connection portions **42**A and **42**B in a plan view includes a convex portion **49** protruding in the direction D2. The concave portion **48** and the convex portion **49** are located on the Y-axis in a plan view.

[0048] The first linear portions **43**A and **43**B are located on both sides of the second connection portion **42**A in the direction D1, and extend along the direction D1 to be connected to the second connection portion **42**A. The second linear portions **44**A and **44**B are located on both sides of the second connection portion **42**B in the direction D1, and extend along the direction D1 to be connected to the second connection portion **42**B.

[0049] The third linear portions **45**A and **45**B are located opposite to the second connection portion **42**A with respect to the first linear portions **43**A and **43**B, respectively, and are connected to the first linear portions **43**A and **43**B and the first connection portions **41**A and **41**B, respectively. The fourth linear portions **46**A and **46**B are located opposite to the second connection portion **42**B with respect to the second linear portions **44**A and **44**B, respectively, and are connected to the second linear portions **44**A and **44**B and the first connection portions **41**A and **41**B, respectively. The third linear portions **45**A and **45**B and the fourth linear portions **46**A and **46**B extend along a direction inclined at 45 degrees with respect to the X-axis and the Y-axis in a plan view.

[0050] A rib portion **47** is formed on surfaces on a magnetic field generation portion **9** side of the connection portions **41**A to **42**B and the linear portions **43**A to **46**B (refer to FIG. **2**). The rib portion **47** is formed from the second semiconductor layer **102** and the insulating layer **103**. The rib portion **47** extends in an annular shape to surround the first movable portion **3** in a plan view. A width of the rib portion **47** on the first connection portions **41**A and **41**B and the linear portions **45**A to **46**B is narrower than a width of the rib portion **47** on the second connection portions **42**A and **42**B and the linear portions **43**A to **44**B.

[0051] The first torsion bars **5** and the second torsion bars **6** are formed from the first semiconductor layer **101**. The pair of first torsion bars **5** are disposed on both sides of the first movable portion **3** on the X-axis. The first torsion bars **5** couple the first movable portion **3** (ring-shaped portion **32**) to the second movable portion **4** on the X-axis such that the first movable portion **3** is swingable around the X-axis (with the X-axis as a center line). In addition, the first torsion bars **5** are connected to the support portion **2** via the second movable portion **4** and the second torsion bars **6**. Namely, the first torsion bars **5** can also be deemed to couple the first movable portion **3** to the support portion **2** such that the first movable portion **3** is swingable around the X-axis. The pair of first torsion bars **5** are connected to the second movable portion **4** at the first connection portions **41**A and **41**B, respectively. In this example, the first torsion bars **5** are formed in a plate shape extending along a plane parallel to the mirror surface **10**, and are torsionally deformed when the first movable portion **3** swings around the X-axis.

[0052] Each of the first torsion bars **5** includes a linear portion **5***a* extending along the X-axis and having a constant width, and a pair of widened portions **5***b* connected to both ends of the linear portion **5***a*. The first torsion bars **5** is connected to the first movable portion **3** at one widened portion **5***b*, and is connected to the second movable portion **4** at the other widened portion **5***b*. In a plan view, the width of the one widened portion **5***b* becomes wider as the one widened portion **5***b* approaches the first movable portion **3**, and the width of the other widened portion **5***b* becomes wider as the other widened portion **5***b* approaches the second movable portion **4**. Each of the widened portions **5***b* is provided to relieve stress acting on a connection location between the first torsion bar **5** and the first movable portion **3** or the second movable portion **4** when the first movable portion **3** swings around the X-axis. Namely, since the widened portions **5***b* are provided, stress when the first movable portion **3** swings around the X-axis is relieved by the widened portions **5***b*, and stress acting on the first movable portion **3** (ring-shaped portion **32**) is reduced, so that dynamic distortion in the body portion **31** can be suppressed. Incidentally, at least one of the pair of widened portions **5***b* may not be provided.

[0053] The pair of second torsion bars **6** are disposed on both sides of the second movable portion **4** on the Y-axis. The second torsion bars **6** couple the second movable portion **4** to the support portion **2** on the Y-axis such that the second movable portion **4** is swingable around the Y-axis (with the Y-axis as a center line). The pair of second torsion bars **6** are connected to the second movable portion **4** at the second connection portions **42**A and **42**B, respectively. The second torsion bars **6** are torsionally deformed when the second movable portion **4** swings around the Y-axis. In this example, the second torsion bars **6** extend in a meandering manner in a plan view. Each of the second torsion bars **6** includes a plurality of linear portions **11** and a plurality of folded portions **12**. The plurality of linear portions **11** extend along the direction D2, and are disposed side by side in the direction D1. The plurality of folded portions **12** alternately couple both ends of the linear portions **11** adjacent to each other.

[0054] In this example, for the purpose of increasing the resonance frequency around the X-axis, a spring constant of

the first torsion bars **5** is set to be larger than a spring constant of the second torsion bars **6**. When the cross-sectional area (cross-sectional area in a cross-section perpendicular to an extending direction) of each torsion bar is increased, the spring constant increases. In this example, the first torsion bars **5** and the second torsion bars **6** have substantially the same thickness in the direction D**3**, whereas the first torsion bars **5** has a larger width (width in a direction perpendicular to the extending direction), and as a result, the cross-sectional area of the first torsion bars **5** is increased.

[0055] The mirror device **1** further includes a pair of the coils **14** and **15**. Each of the coils **14** and **15** is provided in the second movable portion **4** to surround the first movable portion **3**, and extends in a spiral shape in a plan view. The coils **14** and **15** are disposed along a plane including the X-axis and the Y-axis. Each of the coils **14** and **15** is wound around the first movable portion **3** a plurality of times. For example, the coils **14** and **15** are alternately arranged in a width direction of the second movable portion **4** in a plan view. The coils **14** and **15** are configured, for example, as Damascene wirings embedded in the second movable portion **4**.

[0056] In FIG. **1**, a disposition region R where the coils **14** and **15** are disposed is shown by hatching. The coils **14** and **15** extend in the connection portions **41**A to **42**B and the linear portions **43**A to **46**B of the second movable portion **4** along extending directions thereof. For example, each of the coils **14** and **15** is electrically connected to an electrode pad on the support portion **2** via wirings extending through the second torsion bars **6**, and is electrically connected to a drive source or the like disposed outside the mirror device **1**. The coils **14** and **15** can be used not only as drive coils, but also as monitor coils for checking the vibration state of the device by measuring a counter-electromotive force generated in the coils **14** and **15**.

[0057] In the mirror device **1** configured as described above, when a drive signal for linear motion is input to the coil **14**, a Lorentz force acts on the coil **14** due to interaction with a magnetic field generated by the magnetic field generation portion **9**. By using the balance between the Lorentz force and the elastic force of the second torsion bars **6**, the first movable portion **3** (mirror surface **10**) can be linearly moved around the Y-axis together with the second movable portion **4**.

[0058] On the other hand, when a drive signal for resonance motion is input to the coil **15**, a Lorentz force acts on the coil **15** due to interaction with a magnetic field generated by the magnetic field generation portion **9**. By using the resonance of the first movable portion **3** at a resonance frequency in addition to the Lorentz force, the first movable portion **3** (mirror surface **10**) can be resonantly moved around the X-axis. Specifically, when a drive signal with a frequency equal to the resonance frequency of the first movable portion **3** around the X-axis is input to the coil **15**, the second movable portion **4** vibrates slightly around the X-axis at the frequency. The vibration is transmitted to the first movable portion **3** via the first torsion bars **5**, so that the first movable portion **3** can swing around the X-axis at the frequency.

[0059] As shown in FIGS. **2** to **6**, a rib portion **50** (rib) is formed on the second surface **31***b* of the body portion **31** of the first movable portion **3**. The rib portion **50** is a reinforcing rib for reinforcing the first movable portion **3**, and is configured as a reinforcing structure extending along a predetermined direction. The rib portion **50** is formed from the second semiconductor layer **102** and the insulating layer **103**. In this example, the rib portion **50** has a shape that is symmetrical with respect to each of the X-axis and the Y-axis in a plan view. The rib portion **50** includes a central portion **51**, a first rib portion **60**, a second rib portion **70**, a third rib portion **80**, and a fourth rib portion **90**.

[0060] The central portion **51** is a reference portion disposed at a reference position in a plan view. In this example, the reference position coincides with the center P of the body portion in a plan view, and the central portion **51** is disposed on the center P. In the present embodiment, the central portion **51** has an elongated shape in the direction D**2** in a plan view. The central portion **51** may be formed such that a width in the direction D**1** and a width in the direction D**2** are substantially the same. A distance L**1** from the center P of the central portion **51** to a location where inner edges **61***a* of a pair of first portions **61** of the first rib portion **60** to be described later are connected is larger than a width W**61** of the first portions **61**. Accordingly, sufficient rigidity can be ensured at the central portion **51**, and damage to the rib portion **50** or the peeling of the rib portion **50** from the body portion **31** can be prevented. The same applies to a second rib portion **70** side. Namely, a distance L**2** from the center P of the central portion **51** to a location where inner edges **71***a* of a pair of second portions **71** of the second rib portion **70** to be described later are connected is larger than a width W**71** of the second portions **71**. In addition, a distance L**3** from the center P of the central portion **51** to a location where inner edges **81***a* of a pair of third portions **81** of the third rib portion **80** to be described later are connected is larger than a width W**81** of the third portions **81**. Even with this configuration, sufficient rigidity can be ensured at the central portion **51**, and damage to the rib portion **50** or the peeling of the rib portion **50** from the body portion **31** can be prevented. The same applies to a fourth rib portion **90** side. Namely, a distance L**4** from the center P of the central portion **51** to a location where inner edges **91***a* of a pair of fourth portions **91** of the fourth rib portion **90** to be described later are connected is larger than a width W**91** of the fourth portions **91**.

[0061] The first rib portion **60** includes the pair of first portions **61** and a first extending portion **62** (first connecting portion). The pair of first portions **61** extend from the central portion **51** (from the side of the center P that is a reference position) toward one side (left side in FIG. **3**) in the direction D**1**, and face each other with the X-axis interposed therebetween in the direction D**2**. The pair of first portions **61** extend straight along directions inclined with respect to the direction D**1** and the direction D**2** in a plan view. In this example, the pair of first portions **61** extend along a radial direction of a circle centered on the center P.

[0062] The pair of first portions **61** are connected to each other at the central portion **51** (at the side of the center P that is a reference position). In this example, the pair of first portions **61** are connected to each other via the central portion **51** (integrated). In a plan view, the inner edges **61***a* of the pair of first portions **61** are smoothly connected to each other. The fact that "edges A and B are smoothly connected" means that there is no sharp location (for example, the vertex of a corner (including all cases of an acute angle, a right angle, and an obtuse angle)) between the edges A and B and the edges A and B are connected such that the curvature is continuous between the edges A and B. In

this example, the inner edges **61***a* are smoothly connected by an outer edge of the central portion **51** formed in an arc shape.

[0063] The first extending portion **62** extends between the pair of first portions **61** in a plan view. In this example, the first extending portion **62** extends to intersect the X-axis in a plan view, and is connected to the pair of first portions **61**. In more detail, the first extending portion **62** is connected to end portions **61***b* on an opposite side of the pair of first portions **61** from the central portion **51**. In a plan view, an inner edge **62***a* of the first extending portion **62** is smoothly connected to the inner edges **61***a* of the pair of first portions **61**. In this example, an R portion that is curved in an arc shape is formed between the inner edges **61***a* and **62***a*, and accordingly, the inner edges **61***a* and **62***a* are smoothly connected. The first extending portion **62** extends along an outer edge **31***c* of the body portion **31** of the first movable portion **3** in a plan view. In addition, the first extending portion **62** is curved to be convex toward the one side (side opposite to the central portion **51**) in the direction D**1** in a plan view. In this example, the outer edge **31***c* has an arc shape, and the first extending portion **62** is formed in an arc shape that is convex toward the one side in the direction D**1**.

[0064] A width W**62** of the first extending portion **62** is wider than the width W**61** of each of the first portions **61**. The width W**61** of the first portion **61** is a width of the first portion **61** along a direction perpendicular to an extending direction (direction from the center P toward the end portion **61***b*) of the first portion **61** in a plan view. The width W**62** of the first extending portion **62** is a width of the first extending portion **62** along a direction perpendicular to an extending direction (direction along the outer edge **31***c*) of the first extending portion **62** in a plan view. These points also apply to the width W**71** of the second portions **71** and a width W**72** of a second extending portion **72** to be described later, as well as the width W**81** of the third portions **81** and the width W**91** of the fourth portions **91** described above.

[0065] Each of the width W**61** of the first portions **61** and the width W**71** of the second portions **71** is more than or equal to each of the width W**81** of the third portions **81** and the width W**91** of the fourth portions **91**. Accordingly, the strength of the first rib portion **60** and the second rib portion **70** can be sufficiently ensured while suppressing an increase in the moment of inertia around the X-axis. It is more preferable that each of the width W**61** and the width W**71** is larger than each of the width W**81** and the width W**91**. In addition, each of the width W**62** of the first extending portion **62** and the width W**72** of the second extending portion **72** is more than or equal to each of the width W**81** of the third portions **81** and the width W**91** of the fourth portions **91**. Accordingly, the strength of the first rib portion **60** and the second rib portion **70** can be sufficiently ensured while suppressing an increase in the moment of inertia around the X-axis. It is more preferable that each of the width W**62** and the width W**72** is larger than each of the width W**81** and the width W**91**.

[0066] The first extending portion **62** includes a protrusion portion **63** protruding outward (side opposite to the center P) from the outer edge **31***c* (boundary between the body portion **31** and the gap G) of the body portion **31** in a plan view. Namely, the protrusion portion **63** is located outside the outer edge **31***c* in a plan view. An inner portion (portion other than the protrusion portion **63**) of the first extending portion **62** does not protrude outward from the outer edge **31***c*. In a plan view, the entirety of a region surrounded by the first extending portion **62**, the pair of first portions **61**, and the central portion **51** overlaps the body portion **31**. The region is a region where the rib portion **50** is not formed (region with no rib). Since the region where the rib portion **50** is not formed is provided on the body portion **31** in such a manner, the strength of the rib portion **50** can be improved while suppressing an increase in the moment of inertia in the first movable portion **3**.

[0067] The protrusion portion **63** extends along the outer edge **31***c* of the body portion **31**. In this example, the protrusion portion **63** is provided over the entirety of the first extending portion **62** in the extending direction (direction along the outer edge **31***c*) of the first extending portion **62**, and is formed in an arc shape that is convex toward the one side (side opposite to the central portion **51**) in the direction D**1**. Namely, the protrusion portion **63** is provided to extend between the pair of first portions **61** in the direction along the outer edge **31***c*, and protrudes outward from the outer edge **31***c* on the X-axis (intersects the X-axis in a plan view). The protrusion portion **63** can also be deemed to extend along the outer edge **31***c* from the X-axis toward the one side and the other side in the direction D**2**. The protrusion portion **63** overlaps the gap G formed between the body portion **31** and the ring-shaped portion **32** of the first movable portion **3** in a plan view. The protrusion portion **63** is not in contact with portions other than the body portion **31** (for example, the ring-shaped portion **32**, the first torsion bars **5**, the first connection portion **33**, the second connection portion **34**, and the like). Namely, in this example, the protrusion portion **63** is a portion floating in space without being supported by the portions other than the body portion **31**. The protrusion portion **63** does not overlap the ring-shaped portion **32** in a plan view (does not reach the ring-shaped portion **32**), and there is a gap between the protrusion portion **63** and the ring-shaped portion **32** in a plan view.

[0068] A distance T**1** between the protrusion portion **63** and the ring-shaped portion **32** on the X-axis is smaller than a minimum width W**5** of the first torsion bars **5** in the direction D**2**. A length L**63***a* of the protrusion portion **63** along the outer edge **31***c* of the body portion **31** is larger than the minimum width W**5** of the first torsion bars **5** in the direction D**2**. The length L**63***a* is larger than the width W**62** of the first extending portion **62**. The length L**63***a* is larger than the distance T**1**. The length L**63***a* is larger than a maximum width W**33***a* of the first connection regions **33***a* that connect the ring-shaped portion **32** and the body portion **31**. The length L**63***a* is larger than a maximum width of the entirety of the first connection portion **33** (region formed by the pair of first connection regions **33***a* and the space S**1**). A protrusion length L**63***b* of the protrusion portion **63** from the outer edge **31***c* of the body portion **31** (refer to FIG. **4**) is smaller than the minimum width W**5** of the first torsion bars **5** in the direction D**2**. The width of the first torsion bars **5** is a width of the first torsion bars **5** along the direction (in this example, the direction D**2**) perpendicular to the extending direction (in this example, the direction D**1**) of the first torsion bars **5** in a plan view. The protrusion length L**63***b* is a maximum protrusion length (maximum width) of the protrusion portion **63** in a direction (in this example, a radial direction of a circle centered on the center P) perpendicular to an extending direction (in this example, a circumferential direction of the circle centered on the center P) of the outer

edge **31***c* in a plan view. Namely, when the outer edge **31***c* has a curvature, the extending direction of the outer edge **31***c* is a tangential direction. This point also applies to a protrusion length L**73***b* of a protrusion portion **73** to be described later.

[0069] The second rib portion **70** has a shape that is symmetrical to the first rib portion **60** with respect to the Y-axis. The second rib portion **70** includes the pair of second portions **71** and the second extending portion **72** (second connecting portion). The pair of second portions **71** extend from the central portion **51** (from the side of the center P that is a reference position) toward the other side (right side in FIG. **3**) in the direction D**1**, and face each other with the X-axis interposed therebetween in the direction D**2**. The second portions **71** extend straight along directions inclined with respect to the direction D**1** and the direction D**2** in a plan view. In this example, the pair of second portions **71** extend along a radial direction of a circle centered on the center P. In a plan view, one second portion **71** (the second portion **71** on the upper side in FIG. **3**) is located on the same straight line as one first portion **61** (the first portion **61** on the lower side in FIG. **3**) of the first rib portion **60**, and the other second portion **71** (the second portion **71** on the lower side in FIG. **3**) is located on the same straight line as the other first portion **61** (the first portion **61** on the upper side in FIG. **3**) of the first rib portion **60**. The first rib portion **60** and the second rib portion **70** as a whole have a ribbon shape in a plan view.

[0070] The pair of second portions **71** are connected to each other at the central portion **51** (at the side of the center P that is a reference position). In this example, the pair of second portions **71** are connected to each other via the central portion **51** (integrated). In a plan view, the inner edges **71***a* of the pair of second portions **71** are smoothly connected to each other. In this example, the inner edges **71***a* are smoothly connected by the outer edge of the central portion **51** formed in an arc shape.

[0071] The second extending portion **72** extends between the pair of second portions **71** in a plan view. In this example, the second extending portion **72** extends to intersect the X-axis in a plan view, and is connected to the pair of second portions **71**. In more detail, the second extending portion **72** is connected to end portions **71***b* on an opposite side of the pair of second portions **71** from the central portion **51**. In a plan view, an inner edge **72***a* of the second extending portion **72** is smoothly connected to the inner edges **71***a* of the pair of second portions **71**. In this example, an R portion that is curved in an arc shape is formed between the inner edges **71***a* and **72***a*, and accordingly, the inner edges **71***a* and **72***a* are smoothly connected. The second extending portion **72** extends along the outer edge **31***c* of the body portion **31** of the first movable portion **3** in a plan view. In addition, the second extending portion **72** is curved to be convex toward the other side (side opposite to the central portion **51**) in the direction D**1** in a plan view. In this example, the outer edge **31***c* has an arc shape, and the second extending portion **72** is formed in an arc shape that is convex toward the other side in the direction D**1**.

[0072] The width W**72** of the second extending portion **72** is wider than the width W**71** of each of the second portions **71**. The second extending portion **72** includes the protrusion portion **73** protruding outward (side opposite to the center P) from the outer edge **31***c* of the body portion **31** in a plan view. Namely, the protrusion portion **73** is located outside the outer edge **31***c* in a plan view. An inner portion (portion other than the protrusion portion **73**) of the second extending portion **72** does not protrude outward from the outer edge **31***c*. In a plan view, the entirety of a region surrounded by the second extending portion **72**, the pair of second portions **71**, and the central portion **51** overlaps the body portion **31**.

[0073] The protrusion portion **73** extends along the outer edge **31***c* of the body portion **31**. In this example, the protrusion portion **73** is provided over the entirety of the second extending portion **72** in an extending direction (direction along the outer edge **31***c*) of the second extending portion **72**, and is formed in an arc shape that is convex toward one side (side opposite to the central portion **51**) in the direction D**1**. Namely, the protrusion portion **73** is provided to extend between the pair of second portions **71** in the direction along the outer edge **31***c*, and protrudes outward from the outer edge **31***c* on the X-axis (intersects the X-axis in a plan view). The protrusion portion **73** can also be deemed to extend along the outer edge **31***c* from the X-axis toward the one side and the other side in the direction D**2**. The protrusion portion **73** overlaps the gap G formed between the body portion **31** and the ring-shaped portion **32** of the first movable portion **3** in a plan view. The protrusion portion **73** is not in contact with portions other than the body portion **31** (for example, the ring-shaped portion **32**, the pair of first torsion bars **5**, the first connection portion **33**, the second connection portion **34**, and the like). Namely, in this example, the protrusion portion **73** is a portion floating in space without being supported by the portions other than the body portion **31**.

[0074] A distance T**2** between the protrusion portion **73** and the ring-shaped portion **32** on the X-axis is smaller than the minimum width W**5** of the first torsion bars **5** in the direction D**2**. A length L**73***a* of the protrusion portion **73** along the outer edge **31***c* of the body portion **31** is larger than the minimum width W**5** of the first torsion bars **5** in the direction D**2**. The length L**73***a* is larger than the width W**72** of the second extending portion **72**. The length L**73***a* is larger than the distance T**2**. A protrusion length L**73***b* of the protrusion portion **73** from the outer edge **31***c* of the body portion **31** (refer to FIG. **4**) is smaller than the minimum width W**5** of the first torsion bars **5** in the direction D**2**.

[0075] The third rib portion **80** includes the pair of third portions **81**. The pair of third portions **81** extend from the central portion **51** (from the side of the center P that is a reference position) toward the one side (upper side in FIGS. **2** and **3**) in the direction D**2**, and face each other with the Y-axis interposed therebetween in the direction D**1**. The third portions **81** extend straight along directions inclined with respect to the direction D**1** and the direction D**2** in a plan view. In this example, the pair of third portions **81** extend along a radial direction of a circle centered on the center P.

[0076] The pair of third portions **81** are connected to each other at the central portion **51** (at the side of the center P that is a reference position). In this example, the pair of third portions **81** are connected to each other via the central portion **51** (integrated). In a plan view, the inner edges **81***a* of the pair of third portions **81** are smoothly connected to each other. In this example, an R portion that is curved in an arc shape is formed between the inner edges **81***a*, and accordingly, the inner edges **81***a* are smoothly connected.

[0077] The pair of third portions **81** extend toward the pair of respective first connection regions **33***a* of the first con-

nection portion **33** of the first movable portion **3**. In a plan view, the third portions **81** do not reach the first connection regions **33***a*, and are separated from the first connection regions **33***a*. A distance T**3** (shortest distance) between the third portions **81** and the first connection regions **33***a* is smaller than the maximum width W**33***a* of the first connection regions **33***a* (refer to FIGS. **3** and **6**). The maximum width W**33***a* of the first connection regions **33***a* is a maximum width of the first connection regions **33***a* in directions perpendicular to directions in which the body portion **31** and the ring-shaped portion **32** are connected by the first connection regions **33***a* (extending directions of the first connection regions **33***a*). This point also applies to a maximum width W**34***a* of the second connection regions **34***a* to be described later.

[0078] The rib portion **50** is not formed between the pair of third portions **81**. Namely, the rib portion **50** does not include a portion formed between the pair of third portions **81**. The fact that "the rib portion **50** does not include a portion formed between the pair of third portions **81**" means, for example, that the rib portion **50** is not formed in a region between the pair of third portions **81** in a plan view. The central portion **51** does not correspond to "a portion formed between the pair of third portions **81**". These points also apply to the fourth portions **91** to be described later.

[0079] The fourth rib portion **90** includes the pair of fourth portions **91**. The pair of fourth portions **91** extend from the central portion **51** (from the side of the center P that is a reference position) toward the other side (lower side in FIG. **3**) in the direction D**2**, and face each other with the Y-axis interposed therebetween in the direction D**1**. The fourth portions **91** extend straight along directions inclined with respect to the direction D**1** and the direction D**2** in a plan view. In this example, the pair of fourth portions **91** extend along a radial direction of a circle centered on the center P. In a plan view, one fourth portion **91** (the fourth portion **91** on the left side in FIG. **3**) is located on the same straight line as one third portion **81** (the third portion **81** on the right side in FIG. **3**) of the third rib portion **80**, and the other fourth portion **91** (the fourth portion **91** on the right side in FIG. **3**) is located on the same straight line as the other third portion **81** (the third portion **81** on the left side in FIG. **3**) of the third rib portion **80**. The third rib portion **80** and the fourth rib portion **90** as a whole have an X shape in a plan view.

[0080] The pair of fourth portions **91** are connected to each other at the central portion **51** (at the side of the center P that is a reference position). In this example, the pair of fourth portions **91** are connected to each other via the central portion **51** (integrated). In a plan view, the inner edges **91***a* of the pair of fourth portions **91** are smoothly connected to each other. In this example, an R portion that is curved in an arc shape is formed between the inner edges **91***a*, and accordingly, the inner edges **91***a* are smoothly connected.

[0081] The pair of fourth portions **91** extend toward the pair of respective second connection regions **34***a* of the second connection portion **34** of the first movable portion **3**. In a plan view, the fourth portions **91** do not reach the second connection regions **34***a*, and are separated from the second connection regions **34***a*. A distance T**4** (shortest distance) between the fourth portions **91** and the second connection regions **34***a* is smaller than the maximum width W**34***a* of the second connection regions **34***a* (refer to FIG. **3**). The rib portion **50** is not formed between the pair of fourth portions **91**. Namely, the rib portion **50** does not include a portion formed between the pair of fourth portions **91**.

[0082] In the rib portion **50**, the first portions **61**, the second portions **71**, the third portions **81**, and the fourth portions **91** extend radially around the center P. The first portions **61**, the second portions **71**, the third portions **81**, and the fourth portions **91** are different portions from one another (not shared with one another). Each of a length L**61** of the first portions **61** and a length L**71** of the second portions **71** is longer than each of a length L**81** of the third portions **81** and a length L**91** of the fourth portions **91**. In this example, the lengths L**61** and L**71** are equal to each other, and the lengths L**81** and L**91** are equal to each other.

[0083] In a plan view, an angle between the pair of first portions **61** is θ**1**, an angle between the pair of second portions **71** is θ**2**, an angle between the pair of third portions **81** is θ**3**, and an angle between the pair of fourth portions **91** is θ**4**, the following relationships are satisfied.

$$\theta 3 < \theta 1 < 3 \times \theta 3$$

$$\theta 4 < \theta 1 < 3 \times \theta 4$$

$$\theta 3 < \theta 2 < 3 \times \theta 3$$

$$\theta 4 < \theta 2 < 3 \times \theta 4$$

[0084] Namely, each of θ**1** and θ**2** is larger than each of θ**3** and θ**4**, and is smaller than three times each of θ**3** and θ**4**. In this example, θ**1** and θ**2** are equal to each other, and θ**3** and θ**4** are equal to each other. Preferably, θ**1** and θ**2** are larger than 30 degrees, and are smaller than 90 degrees. Preferably, θ**3** and θ**4** are larger than 10 degrees, and are smaller than 30 degrees.

[0085] One example of the dimensions of each portion is as follows. The distance T**1** between the protrusion portion **63** and the ring-shaped portion **32** on the X-axis is equal to the distance T**2** between the protrusion portion **73** and the ring-shaped portion **32** on the X-axis, and is approximately 10 μm to 100 μm. The width W**61** of the first portions **61** is equal to the width W**71** of the second portions **71**, the width W**81** of the third portions **81**, and the width W**91** of the fourth portions **91**, and is approximately 10 μm to 100 μm. The width W**62** of the first extending portion **62** is equal to the width W**72** of the second extending portion **72**, and is approximately 20 μm to 200 μm. The length L**61** of the first portions **61** is equal to the length L**71** of the second portions **71**, and is approximately 100 μm to 1000 μm. The distance L**1** from the center P of the central portion **51** to the location where the inner edges **61***a* of the pair of first portions **61** are connected is equal to the distance L**2** from the center P to the location where the inner edges **71***a* of the pair of second portions **71** are connected, and is approximately 20 μm to 200 μm. The distance L**3** from the center P to the location where the inner edges **81***a* of the pair of third portions **81** described later are connected is equal to the distance L**4** from the center P to the location where the inner edges **91***a* of the pair of fourth portions **91** are connected, and is approximately 30 μm to 300 μm.

[0086] The length L**63***a* of the protrusion portion **63** along the outer edge **31***c* of the body portion **31** is equal to the length L**73***a* of the protrusion portion **73** along the outer edge **31***c* of the body portion **31**, and is approximately 100 μm to 1000 μm. The maximum width W**33***a* of the first

connection regions **33***a* is equal to the maximum width W**34***a* of the second connection regions **34***a*, and is approximately 20 μm to 200 μm. The distance T**3** between the third portions **81** and the first connection regions **33***a* is equal to the distance T**4** between the fourth portions **91** and the second connection regions **34***a*, and is approximately 10 μm to 100 μm. The protrusion length L**63***b* of the protrusion portion **63** from the outer edge **31***c* of the body portion **31** is equal to the protrusion length L**73***b* of the protrusion portion **73** from the outer edge **31***c* of the body portion **31**, and is approximately 5 μm to 60 μm. A thickness of the first semiconductor layer **101** is approximately 20 μm to 200 μm. A thickness of the rib portion **50** is approximately 20 μm to 200 μm.

[Functions and Effects]

[0087] In the mirror device **1**, the rib portion **50** includes the first rib portion **60**, the second rib portion **70**, the third rib portion **80**, and the fourth rib portion **90**. The first rib portion **60** includes the pair of first portions **61** extending from the central portion **51** (from the side of the reference position) toward the one side in the direction D**1** (direction parallel to the X-axis) and facing each other with the X-axis (first axis) interposed therebetween in the direction D**2** (direction parallel to the Y-axis), and the first extending portion **62** extending between the pair of first portions **61** to intersect the X-axis in a plan view. The second rib portion **70** includes the pair of second portions **71** extending from the central portion **51** toward the other side in the direction D**1** and facing each other with the X-axis interposed therebetween in the direction D**2**, and the second extending portion **72** extending between the pair of second portions **71** to intersect the X-axis in a plan view. The third rib portion **80** includes the pair of third portions **81** extending from the central portion **51** toward the one side in the direction D**2** and facing each other with the Y-axis (second axis) interposed therebetween in the direction D**1**. The fourth rib portion **90** includes the pair of fourth portions **91** extending from the central portion **51** toward the other side in the direction D**2** and facing each other with the Y-axis interposed therebetween in the direction D**1**. Accordingly, the rib portion **50** can be disposed on the first movable portion **3** in a well-balanced manner, and distortion of the first movable portion **3** (in other words, distortion of the mirror surface **10**) can be effectively suppressed. On the other hand, when the first movable portion **3** swings, stress generated in the first torsion bars **5** may be transmitted to the rib portion **50**, and from the viewpoint of preventing the rib portion **50** from being damaged or peeled off due to the stress, reinforcing the rib portion **50** can be considered. However, for example, when the rib portion **50** is reinforced simply by connecting rib portions, the moment of inertia of the first movable portion **3** around the X-axis may increase depending on the connection location. In this regard, in the mirror device **1**, the first rib portion **60** includes the first extending portion **62** extending between the pair of first portions **61** to intersect the X-axis in a plan view (when viewed in the direction D**3** perpendicular to the second surface **31***b*), and the second rib portion **70** includes the second extending portion **72** extending between the pair of second portions **71** to intersect the X-axis in a plan view, whereas the rib portion **50** does not include a portion formed between the pair of third portions **81** and a portion formed between the pair of fourth portions **91**. In such a manner, the rib portion is not formed in a region between the pair of third portions **81** and a region between the pair of fourth portions **91** which have a relatively large influence on the moment of inertia of the first movable portion **3** around the X-axis, whereas the first extending portion **62** and the second extending portion **72** are formed in a region between the pair of first portions **61** and a region between the pair of second portions **71**, respectively, which have a relatively small influence, so that reliability can be ensured through the reinforcement of the rib portion **50** while realizing good swinging of the first movable portion **3** through the suppression of an increase in the moment of inertia of the first movable portion **3** around the X-axis. In addition, a decrease in the resonance frequency of the first movable portion **3** around the X-axis can be suppressed by suppressing an increase in the moment of inertia of the first movable portion **3** around the X-axis. Therefore, according to the mirror device **1**, distortion of the mirror surface **10** can be effectively suppressed, and reliability can be ensured while realizing good swinging of the first movable portion **3**.

[0088] The first extending portion **62** is connected to the pair of first portions **61**, and the second extending portion **72** is connected to the pair of second portions **71**. Accordingly, distortion of the first movable portion **3** can be more effectively suppressed. In addition, the rigidity of the first rib portion **60** and the second rib portion **70** can be increased, and damage to the rib portion **50** or the peeling of the rib portion **50** can be suppressed.

[0089] The pair of first portions **61** are connected to each other at the central portion **51** (at the side of the reference position), and the pair of second portions **71** are connected to each other at the central portion **51**. Accordingly, the rigidity of the first rib portion **60** and the second rib portion **70** can be increased, and damage to the rib portion **50** or the peeling of the rib portion **50** can be suppressed.

[0090] The pair of third portions **81** are connected to each other at the central portion **51**, and the pair of fourth portions **91** are connected to each other at the central portion **51**. Accordingly, the rigidity of the third rib portion **80** and the fourth rib portion **90** can be increased, and damage to the rib portion **50** or the peeling of the rib portion **50** can be suppressed.

[0091] The rib portion **50** includes the central portion **51** (reference portion) disposed at the reference position in a plan view, and the pair of first portions **61**, the pair of second portions **71**, the pair of third portions **81**, and the pair of fourth portions **91** are connected at the central portion **51**. Accordingly, the rigidity of the rib portion **50** can be increased, and damage to the rib portion **50** or the peeling of the rib portion **50** can be suppressed.

[0092] In a plan view, the first extending portion **62** is curved to be convex toward the one side in the direction D**1**, and the second extending portion **72** is curved to be convex toward the other side in the direction D**1**. Accordingly, distortion of the body portion **31** can be more effectively suppressed. Particularly, dynamic distortion and static distortion that occur remarkably at the outer edge portion of the body portion **31** can be effectively suppressed.

[0093] Distortion that occurs in the body portion **31** includes dynamic distortion and static distortion. The dynamic distortion is distortion that occurs when the first torsion bars **5** are torsionally deformed to cause the first movable portion **3** to swing. The dynamic distortion also occurs because stress generated in the first torsion bars **5** when the first torsion bars **5** are torsionally deformed is

transmitted to the body portion **31** via the ring-shaped portion **32**. The static distortion is distortion that occurs due to the formation of the mirror surface **10** and the protection film. The static distortion also occurs due to a difference in thermal expansion coefficient between different materials (for example, silicon that is the material of the SOI substrate **100**, SiN that is the material of the insulating layer, a metal material constituting the coils **14** and **15**, and the like). Both the dynamic distortion and the static distortion are particularly likely to occur at the outer edge portion of the body portion **31**. Specifically, the dynamic distortion is likely to occur in the vicinities of the connection locations between the first movable portion **3** and the first torsion bars **5** where stress occurs during swinging of the first movable portion **3**, or at a position away from the X-axis (swing axis) which is strongly affected by the moment of inertia. The static distortion is likely to occur at the outer edge portion of the body portion **31** due to the influence of a metal film or an inorganic material film laminated on the body portion **31**. In addition, the static distortion is also likely to occur in the vicinities of the connection locations between the first movable portion **3** and the first torsion bars **5**. The reason is that distortion occurring in the second movable portion **4** due to the formation of the coils **14** and **15** (or a piezoelectric element in the case of piezoelectric drive) can be transmitted to the first movable portion **3** via the first torsion bars **5**. When distortion occurs in the body portion **31** (mirror surface **10**), an adverse influence such as the distortion of a laser rib with which the mirror surface **10** is irradiated can occur. In this regard, in the mirror device **1**, as described above, the first extending portion **62** and the second extending portion **72** are provided, so that rigidity at the outer edge portion of the body portion **31** can be increased, and distortion (dynamic distortion and static distortion) of the body portion **31** can be suppressed.

[0094] The first extending portion **62** is connected to the end portions **61***b* on the opposite side of the pair of first portions **61** from the central portion **51** (reference position), and the second extending portion **72** is connected to the end portions **71***b* on the opposite side of the pair of second portions **71** from the central portion **51**. Accordingly, distortion of the first movable portion **3** can be more effectively suppressed. In addition, since the first extending portion **62** and the second extending portion **72** are formed in regions close to the outer edge **31***c* of the body portion **31**, distortion of the first movable portion **3** can be more effectively suppressed.

[0095] Each of the pair of first portions **61**, the pair of second portions **71**, the pair of third portions **81**, and the pair of fourth portions **91** extends straight, and in a plan view, each of the angle θ**1** between the pair of first portions **61** and the angle θ**2** between the pair of second portions **71** is larger than each of the angle θ**3** between the pair of third portions **81** and the angle θ**4** between the pair of fourth portions **91**. Accordingly, since the region between the first portions **61** and the region between the second portions **71** become wider, the first extending portion **62** and the second extending portion **72** can be lengthened, and as a result, distortion of the body portion **31** can be more effectively suppressed.

[0096] The following relationships can be satisfied.

$$\theta 3 < \theta 1 < 3 \times \theta 3$$

$$\theta 4 < \theta 1 < 3 \times \theta 4$$

-continued

$$\theta 3 < \theta 2 < 3 \times \theta 3$$

$$\theta 4 < \theta 2 < 3 \times \theta 4$$

[0097] Accordingly, since the length of the first extending portion **62** and the second extending portion **72** can be made less than or equal to a predetermined length, distortion of the body portion **31** can be suppressed while suppressing an increase in the moment of inertia of the first movable portion **3** around the X-axis.

[0098] Each of the length L**61** of the first portions **61** and the length L**71** of the second portions **71** is longer than each of the length L**81** of the third portions **81** and the length L**91** of the fourth portions **91**. Accordingly, an increase in the moment of inertia of the first movable portion **3** around the X-axis can be further suppressed.

[0099] The reference position coincides with the center P of the first movable portion **3** in a plan view. Accordingly, the rib portion **50** can be disposed on the first movable portion **3** in a well-balanced manner, and distortion of the first movable portion **3** can be effectively suppressed. In a plan view, the inner edge **62***a* of the first extending portion **62** is smoothly connected to the inner edges **61***a* of the pair of first portions **61**, and the inner edge **72***a* of the second extending portion **72** is smoothly connected to the inner edges **71***a* of the pair of second portions **71**. The closer a portion on the first movable portion **3** is to the outer edge portion, the more likely distortion is to occur at the portion; however, with such a configuration, stress can be dispersed, and damage to the first rib portion **60** and the second rib portion **70** or the peeling of the first rib portion **60** and the second rib portion **70** can be suppressed.

[0100] In a plan view, the inner edges **81***a* of the pair of third portions **81** are smoothly connected to each other, and the inner edges **91***a* of the pair of fourth portions **91** are smoothly connected to each other. Since the rib portion **50** is not formed in the region between the third portions **81** and the region between the fourth portions **91**, the third rib portion **80** and the fourth rib portion **90** are likely to become structurally weak, particularly, stress is likely to concentrate on the connection location between the pair of third portions **81** and the connection location between the pair of fourth portions **91**; however, with such a configuration, stress can be dispersed, and damage to the third rib portion **80** and the fourth rib portion **90** or the peeling of the third rib portion **80** and the fourth rib portion **90** can be suppressed.

[0101] The first movable portion **3** includes the body portion **31** including the first surface **31***a* and the second surface **31***b*; the ring-shaped portion **32** surrounding the body portion **31** with the gap G interposed therebetween in a plan view, and connected to the first torsion bars **5**; and the first connection portion **33** and the second connection portion **34** that connect the ring-shaped portion **32** to the body portion **31**. The mirror surface **10** is formed on the first surface **31***a*, and the rib portion **50** is formed on the second surface **31***b*. Accordingly, the first movable portion **3** is connected to the first torsion bars **5** via the ring-shaped portion **32**, so that the occurrence that stress generated in the first torsion bars **5** during swinging of the first movable portion **3** is transmitted to the first movable portion **3** can be suppressed, and dynamic distortion of the first movable portion **3** can be suppressed. In addition, the transmission of

the stress to the rib portion **50** can be suppressed, and damage to the rib portion **50** or the peeling of the rib portion **50** can be suppressed.

[0102] The first connection portion **33** is disposed on the one side in the direction D**2** with respect to the body portion **31**, and the second connection portion **34** is disposed on the other side in the direction D**2** with respect to the body portion **31**. The first connection portion **33** includes the pair of first connection regions **33***a* separated from each other by the space S**1**, and each of the first connection regions **33***a* is connected to the body portion **31** and the ring-shaped portion **32**. The second connection portion **34** includes the pair of second connection regions **34***a* separated from each other by the space S**2**, and each of the second connection regions **34***a* is connected to the body portion **31** and the ring-shaped portion **32**. The pair of third portions **81** extend toward the pair of respective first connection regions **33***a*, and the pair of fourth portions **91** extend toward the pair of respective second connection regions **34***a*. Accordingly, the first connection portion **33** includes the pair of first connection regions **33***a* and the second connection portion **34** includes the pair of second connection regions **34***a*, so that the occurrence that stress generated in the first torsion bars **5** during swinging of the first movable portion **3** is transmitted to the first movable portion **3** and the rib portion **50** can be further suppressed. Namely, stress can be effectively relieved by intentionally forming portions with a small width and low rigidity such as the first connection regions **33***a* and the second connection regions **34***a*. In addition, rigidity is likely to be low in the vicinities of the first connection regions **33***a* and the second connection regions **34***a*; however, since the pair of third portions **81** extend toward the pair of respective first connection regions **33***a* and the pair of fourth portions **91** extend toward the pair of respective second connection regions **34***a*, rigidity in the vicinities of the first connection regions **33***a* and the second connection regions **34***a* can be increased.

[0103] In a plan view, the third portions **81** do not reach the first connection regions **33***a*, and fourth portions **91** do not reach the second connection regions **34***a*. Since relatively large dynamic distortion occurs in the ring-shaped portion **32** or the first connection regions **33***a* and the second connection regions **34***a*, with such a configuration, damage to the third rib portion **80** and the fourth rib portion **90** or the peeling of the third rib portion **80** and the fourth rib portion **90** can be suppressed.

[0104] The distance T**3** between the third portions **81** and the first connection regions **33***a* is smaller than the maximum width W**33***a* of the first connection regions **33***a*, and the distance T**4** between the fourth portions **91** and the second connection regions **34***a* is smaller than the maximum width W**34***a* of the second connection regions **34***a*. Accordingly, rigidity in the vicinities of the first connection regions **33***a* and the second connection regions **34***a* can be increased.

Modification Examples

[0105] As in a first modification example shown in FIG. **7**A, the first movable portion **3** may include only the body portion **31** without including the ring-shaped portion **32**, the first connection portion **33**, and the second connection portion **34**. In the first modification example, the first torsion bars **5** are directly connected to the body portion **31**. The first extending portion **62** and the second extending portion **72** do not include the protrusion portions **63** and **73**, and the entirety of the rib portion **50** overlaps the body portion **31** in a plan view. According to a second modification example shown in FIG. **7**B, in the first modification example, the first extending portion **62** and the second extending portion **72** are curved in an arc shape to be convex toward a central portion **51** side in the direction D**1** in a plan view.

[0106] According to a third modification example shown in FIG. **8**A, in the first modification example, the rib portion **50** further includes a portion **111** connected to one first portion **61** of the first rib portion **60** and one third portion **81** of the third rib portion **80**; a portion **112** connected to the other first portion **61** of the first rib portion **60** and one fourth portion **91** of the fourth rib portion **90**; a portion **113** connected to one second portion **71** of the second rib portion **70** and the other third portion **81** of the third rib portion **80**; and a portion **114** connected to the other second portion **71** of the second rib portion **70** and the other fourth portion **91** of the fourth rib portion **90**. The portions **111** to **114** extend along the outer edge **31***c* of the body portion **31**.

[0107] According to a fourth modification example shown in FIG. **8**B, in the first modification example, the first extending portion **62** and the second extending portion **72** extend parallel to the direction D**2**. In addition, the first rib portion **60** further includes a portion **64** extending from the central portion **51** to reach the first extending portion **62** on the X-axis, and the second rib portion **70** further includes a portion **74** extending from the central portion **51** to reach the second extending portion **72** on the X-axis. According to a fifth modification example shown in FIG. **9**A, in the first modification example, the first extending portion **62** extends parallel to the direction D**2**, and is connected to intermediate portions of the pair of first portions **61**. In addition, the second extending portion **72** extends parallel to the direction D**2**, and is connected to intermediate portions of the pair of second portions **71**. According to a sixth modification example shown in FIG. **9**B, in the fourth modification example, in a plan view, the rib portion **50** further includes a portion **115** extending between the first rib portion **60** and the third rib portion **80**; a portion **116** extending between the first rib portion **60** and the fourth rib portion **90**; a portion **117** extending between the second rib portion **70** and the third rib portion **80**; and a portion **118** extending between the second rib portion **70** and the fourth rib portion **90**. The portions **115** to **118** extend straight along directions inclined with respect to the direction D**1** and the direction D**2** in a plan view. Unlike the fourth modification example, the rib portion **50** of the sixth modification example does not include the portions **64** and **74**.

[0108] According to a seventh modification example shown in FIG. **10**A, in the first modification example, the first rib portion **60** and the second rib portion **70** are formed in a circular shape in a plan view. In this case as well, the first rib portion **60** can be deemed to include the pair of first portions **61** and the first extending portion **62** extending therebetween, and the second rib portion **70** can be deemed to include the pair of second portions **71** and the second extending portion **72** extending therebetween. In such a manner, the first portions **61** and the second portions **71** may extend curvedly. In the example of FIG. **10**A, the first portions **61** and the second portions **71** are curved in an arc shape to be convex toward the one side or the other side in the direction D**2** in a plan view. According to an eighth modification example shown in FIG. **10**B, in the first modification example, the pair of third portions **81** of the third rib

portion **80** extend curvedly in an arc shape to be further separated from each other as the pair of third portions **81** extend away from the central portion **51** in a plan view. In addition, the pair of fourth portions **91** of the fourth rib portion **90** extend curvedly in an arc shape to be further separated from each other as the pair of fourth portions **91** extend away from the central portion **51** in a plan view.

[0109] According to a ninth modification example shown in FIG. **11**A, in the first modification example, the rib portion **50** does not include the central portion **51**. In the ninth modification example, the pair of first portions **61** are not connected to each other on the side of the center P (the side of the reference position) (separated from each other). Similarly, the pair of second portions **71** are not connected to each other, the pair of third portions **81** are not connected to each other, and the pair of fourth portions **91** are not connected to each other on the side of the center P. In such a manner, the first portions **61** and the second portions **71** may extend from the side of the reference position toward the one side or the other side in the direction D**1**, and the third portions **81** and the fourth portions **91** may extend from the side of the reference position toward the one side or the other side in the direction D**2**.

[0110] According to a tenth modification example shown in FIG. **11**B, in the first modification example, the first portions **61** are not connected to the first extending portion **62**, and there is a gap between the first portions **61** and the first extending portion **62**. In addition, the second portions **71** are not connected to the second extending portion **72**, and there is a gap between the second portions **71** and the second extending portion **72**. In the tenth modification example as well, the first extending portion **62** extends between the pair of first portions **61**. In the tenth modification example, the first extending portion **62** extends in a region between line segments obtained by extending the pair of first portions **61** toward the side opposite to the central portion **51** along the respective extending directions. More specifically, an intermediate portion of the first extending portion **62** is disposed in this region. In such a manner, the fact that "the first extending portion extends between the pair of first portions" includes not only the case where "the first extending portion extends in the region between the pair of first portions" as in the above-described embodiment, but also the case where "the first extending portion extends in the region between the line segments obtained by extending the pair of first portions toward the side opposite to the reference position along the respective extending directions" as in the tenth modification example. This point also applies to the second extending portion and the second portions of the second rib portion. Namely, in the tenth modification example as well, the second extending portion **72** extends between the pair of second portions **71**. In addition, the fact that "the rib portion does not include a portion formed between the pair of third portions" means not only that "the rib portion does not include a portion formed in the region between the pair of third portions", but also that "the rib portion does not include a portion formed in a region between line segments obtained by extending the pair of third portions toward the side opposite to the reference position along the respective extending directions". This point also applies to the fourth portions of the fourth rib portion. Incidentally, in the ninth modification example as well, the pair of first portions **61** and the first extending portion **62** can be deemed to form a region (region with no rib) where the rib portion **50** is not formed thereinside. In the tenth modification example as well, the pair of second portions **71** and the second extending portion **72** can be deemed to form a region (region with no rib) where the rib portion **50** is not formed thereinside.

[0111] In the first to tenth modification examples as well described above, similarly to the above-described embodiment, distortion of the mirror surface **10** can be effectively suppressed, and reliability can be ensured while realizing good swinging of the first movable portion **3**.

[0112] In a first comparative example shown in FIG. **12**A, unlike the mirror device **1** of the embodiment, the rib portion **50** includes a portion **82** formed between the pair of third portions **81**, and a portion **92** formed between the pair of fourth portions **91**. The portions **82** and **92** extend to intersect the Y-axis (in this example, to be orthogonal). In a second comparative example shown in FIG. **12**B, the rib portion **50** does not include the pair of first portions **61**, the first extending portion **62**, the pair of second portions **71**, the second extending portion **72**, the pair of third portions **81**, and the pair of fourth portions **91** as in the mirror device **1** of the embodiment. The rib portion **50** of the second comparative example can be deemed to have a configuration in which in the rib portion **50** of the embodiment, one first portion **61** is integrally formed with one third portion **81** (configured as one portion) (shared with each other), the other first portion **61** is integrally formed with one fourth portion **91**, one second portion **71** is integrally formed with the other third portion **81**, and the other second portion **71** is integrally formed with the other fourth portion **91**. Namely, the rib portion **50** of the second comparative example does not include the pair of first portions **61**, the pair of second portions **71**, the pair of third portions **81**, and the pair of fourth portions **91** configured as portions different from one another.

[0113] In a third comparative example shown in FIG. **13**A, the rib portion **50** does not include a portion extending between the pair of first portions **61** of the first rib portion **60** (namely, a portion extending to intersect the X-axis between the pair of first portions **61**), and a portion extending between the pair of second portions **71** of the second rib portion **70** (namely, a portion extending to intersect the X-axis between the pair of second portions **71**). In a fourth comparative example shown in FIG. **13**B, the pair of third portions **81** of the third rib portion **80** do not face each other with the Y-axis interposed therebetween, and the pair of fourth portions **91** of the fourth rib portion **90** do not face each other with the Y-axis interposed therebetween.

[0114] The present disclosure is not limited to the above-described embodiment and modification examples. In the above-described embodiment, the rib portion **50** is not formed at all between the pair of third portions **81**; however, the rib portion **50** may only not include a portion formed between the pair of third portions **81** and extending to intersect the Y-axis in a plan view, for example, a portion extending not to intersect the Y-axis in a plan view (portion extending while being away from the Y-axis) may be formed between the pair of third portions **81**. In such a case as well, similarly to the above-described embodiment, reliability can be ensured by reinforcing the rib portion **50** while realizing good swinging of the first movable portion **3** by suppressing an increase in the moment of inertia of the first movable portion **3** around the X-axis. However, as in the above-described embodiment, when the rib portion **50** is not formed at all between the pair of third portions **81**, an

increase in the moment of inertia of the first movable portion **3** around the X-axis can be further suppressed. Similarly, in the above-described embodiment, the rib portion **50** is not formed at all between the pair of fourth portions **91**; however, the rib portion **50** may only not include a portion formed between the pair of fourth portions **91** and extending to intersect the Y-axis in a plan view, for example, a portion extending not to intersect the Y-axis in a plan view (portion extending while being away from the Y-axis) may be formed between the pair of fourth portions **91**.

[0115] The material and shape of each configuration are not limited to the material and shape described above, and various materials and shapes can be adopted. For example, the body portion **31**, the ring-shaped portion **32**, and the mirror surface **10** may be formed in any shape such as a circular shape, an elliptical shape, a quadrangular shape, or a rhombus shape. The shape of the second movable portion **4** is not limited to the above-described shape.

[0116] The first extending portion **62** may only extend between the pair of first portions **61**, and may not be connected to the pair of first portions **61**. The second extending portion **72** may only extend between the pair of second portions **71**, and may not be connected to the pair of second portions **71**.

[0117] Each of the angle θ**1** between the pair of first portions **61** and the angle θ**2** between the pair of second portions **71** may be equal to or smaller than the angle θ**3** between the pair of third portions **81** and the angle θ**4** between the pair of fourth portions **91**. Each of the angles θ**1** and θ**2** may be larger than three times the angles θ**3** and θ**4**. Each of the length L**61** of the first portions **61** and the length L**71** of the second portions **71** may be equal to or shorter than the length L**81** of the third portions **81** and the length L**91** of the fourth portions **91**.

[0118] The reference position where the central portion **51** is disposed may be set at any position, and may not necessarily coincide with the center P of the body portion **31** in a plan view. In a plan view, the inner edge **62***a* of the first extending portion **62** may not be smoothly connected to the inner edges **61***a* of the pair of first portions **61**, and the inner edge **72***a* of the second extending portion **72** may not be smoothly connected to the inner edges **71***a* of the pair of second portions **71**. In a plan view, the inner edges **81***a* of the pair of third portions **81** may not be smoothly connected, and the inner edges **91***a* of the pair of fourth portions **91** may not be smoothly connected.

[0119] The first connection portion **33** may not include the pair of first connection regions **33***a* separated from each other by the space S**1**, and may be made up of one region that is not separated by a space. Similarly, the second connection portion **34** may not include the pair of second connection regions **34***a* separated from each other by the space S**2**, and may be made up of one region that is not separated by a space. The pair of third portions **81** may not extend toward the pair of first connection regions **33***a*, and the pair of fourth portions **91** may not extend toward the pair of second connection regions **34***a*. The body portion **31** may only be formed from at least the first semiconductor layer **101**, and the rib portion **50** may only be formed from at least the second semiconductor layer **102**. For example, the body portion **31** may be formed from the first semiconductor layer **101** and the insulating layer **103**, and the rib portion **50** may be formed from the second semiconductor layer **102**.

[0120] The drive elements of the first movable portion **3** and the second movable portion **4** are not limited to the coils **14** and **15**, and may be, for example, piezoelectric elements. The coil **15** may be provided in the first movable portion **3** (for example, the ring-shaped portion **32**). The motion of the first movable portion **3** may be linear motion (non-resonance motion). The second movable portion **4** and the second torsion bars **6** may be omitted. In this case, the first movable portion **3** may be directly coupled to the support portion **2** by the first torsion bars **5**. In this case, the motion of the first movable portion **3** may be resonance motion or linear motion. Namely, in the above-described embodiment, the mirror device **1** includes a resonance axis and a linear axis; however, the mirror device **1** may include only one of the resonance axis and the linear axis. The first axis around which the first movable portion **3** swings and the second axis around which the second movable portion **4** swings may intersect each other at an angle other than being perpendicular, may be parallel to each other, or may be located on the same straight line. The mirror surface **10** may be configured as a diffraction grating that diffracts or reflects light. In this case, the mirror surface **10** may be formed, for example, by a metal film formed along a predetermined diffraction grating pattern. Alternatively, the mirror surface **10** may be formed by etching silicon (first semiconductor layer **101**) (may be formed of a surface of the first semiconductor layer **101**).

What is claimed is:

1. A mirror device comprising:

a support portion;

a movable portion having a first surface and a second surface opposite to the first surface, a mirror surface being formed on the first surface and a rib portion being formed on the second surface; and

a coupling portion that couples the movable portion to the support portion such that the movable portion is swingable around a first axis,

wherein the rib portion includes a first rib portion, a second rib portion, a third rib portion, and a fourth rib portion,

when a direction parallel to the first axis is a first direction, an axis perpendicular to both the first direction and a third direction passing through a center of the movable portion when viewed in the third direction perpendicular to the second surface is a second axis, and a direction parallel to the second axis is a second direction, the first rib portion includes a pair of first portions extending from a side of a reference position toward one side in the first direction and facing each other with the first axis interposed between the pair of first portions in the second direction, and a first extending portion extending between the pair of first portions to intersect the first axis when viewed in the third direction, the second rib portion includes a pair of second portions extending from the side of the reference position toward the other side in the first direction and facing each other with the first axis interposed between the pair of second portions in the second direction, and a second extending portion extending between the pair of second portions to intersect the first axis when viewed in the third direction, the third rib portion includes a pair of third portions extending from the side of the reference position toward one side in the second direction and facing each other with the second axis

interposed between the pair of third portions in the first direction, and the fourth rib portion includes a pair of fourth portions extending from the side of the reference position toward the other side in the second direction and facing each other with the second axis interposed between the pair of fourth portions in the first direction,

the rib portion does not include a portion formed between the pair of third portions and extending to intersect the second axis when viewed in the third direction, and a portion formed between the pair of fourth portions and extending to intersect the second axis when viewed in the third direction, and

the pair of first portions, the pair of second portions, the pair of third portions, and the pair of fourth portions are portions different from one another.

2. The mirror device according to claim **1**,

wherein the first extending portion is connected to the pair of first portions, and the second extending portion is connected to the pair of second portions.

3. The mirror device according to claim **1**,

wherein the pair of first portions are connected to each other on the side of the reference position, and the pair of second portions are connected to each other on the side of the reference position.

4. The mirror device according to claim **1**,

wherein the pair of third portions are connected to each other on the side of the reference position, and the pair of fourth portions are connected to each other on the side of the reference position.

5. The mirror device according to claim **1**,

wherein the rib portion includes a reference portion disposed at the reference position when viewed in the third direction, and

the pair of first portions, the pair of second portions, the pair of third portions, and the pair of fourth portions are connected to the reference portion.

6. The mirror device according to claim **1**,

wherein when viewed in the third direction, the first extending portion is curved to be convex toward the one side in the first direction, and the second extending portion is curved to be convex toward the other side in the first direction.

7. The mirror device according to claim **1**,

wherein the first extending portion is connected to end portions on an opposite side of the pair of first portions from the reference position, and the second extending portion is connected to end portions on an opposite side of the pair of second portions from the reference position.

8. The mirror device according to claim **1**,

wherein each of the pair of first portions, the pair of second portions, the pair of third portions, and the pair of fourth portions extends straight, and

when viewed in the direction perpendicular to the second surface, if an angle between the pair of first portions is **θ1**, an angle between the pair of second portions is **θ2**, an angle between the pair of third portions is **θ3**, and an angle between the pair of fourth portions is **θ4**, each of **θ1** and **θ2** is larger than each of **θ3** and **θ4**.

9. The mirror device according to claim **8**,

wherein the following relationships are satisfied.

$$\theta 3 < \theta 1 < 3 \times \theta 3$$

$$\theta 4 < \theta 1 < 3 \times \theta 4$$

$$\theta 3 < \theta 2 < 3 \times \theta 3$$

$$\theta 4 < \theta 2 < 3 \times \theta 4$$

10. The mirror device according to claim **1**,

wherein each of a length of the pair of first portions and a length of the pair of second portions is longer than each of a length of the pair of third portions and a length of the pair of fourth portions.

11. The mirror device according to claim **1**,

wherein the reference position coincides with the center of the movable portion when viewed in the third direction.

12. The mirror device according to claim **2**,

wherein when viewed in the third direction, an inner edge of the first extending portion is smoothly connected to inner edges of the pair of first portions, and an inner edge of the second extending portion is smoothly connected to inner edges of the pair of second portions.

13. The mirror device according to claim **4**,

wherein when viewed in the third direction, inner edges of the pair of third portions are smoothly connected to each other, and inner edges of the pair of fourth portions are smoothly connected to each other.

14. The mirror device according to claim **1**,

wherein the movable portion includes a body portion including the first surface and the second surface, a ring-shaped portion surrounding the body portion with a gap interposed between the ring-shaped portion and the body portion when viewed in the third direction, and connected to the coupling portion, and a connection portion that connects the ring-shaped portion to the body portion, and

the mirror surface is formed on the first surface of the body portion, and the rib portion is formed on the second surface of the body portion.

15. The mirror device according to claim **14**,

wherein the movable portion includes a first connection portion and a second connection portion as the connection portion, the first connection portion is disposed on the one side in the second direction with respect to the body portion, and the second connection portion is disposed on the other side in the second direction with respect to the body portion,

the first connection portion includes a pair of first connection regions separated from each other by a space, each of the pair of first connection regions is connected to the body portion and the ring-shaped portion, the second connection portion includes a pair of second connection regions separated from each other by a space, and each of the pair of second connection regions is connected to the body portion and the ring-shaped portion, and

the pair of third portions extend toward the pair of respective first connection regions, and the pair of fourth portions extend toward the pair of respective second connection regions.

16. The mirror device according to claim **15**,
wherein when viewed in the third direction, the pair of third portions do not reach the pair of first connection regions, and the pair of fourth portions do not reach the pair of second connection regions.

17. The mirror device according to claim **16**,
wherein a distance between the pair of third portions and the pair of first connection regions is smaller than a maximum width of each of the pair of first connection regions, and a distance between the pair of fourth portions and the pair of second connection regions is smaller than a maximum width of each of the pair of second connection regions.

* * * * *