US010385608B2

(12) United States Patent
Kanno et al.

(10) **Patent No.: US 10,385,608 B2**
(45) **Date of Patent: Aug. 20, 2019**

(54) **DAYLIGHTING DEVICE**

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(72) Inventors: **Toru Kanno**, Sakai (JP); **Tsuyoshi Kamada**, Sakai (JP); **Shun Ueki**, Sakai (JP); **Shumpei Nishinaka**, Sakai (JP); **Hideomi Yui**, Sakai (JP); **Daisuke Shinozaki**, Sakai (JP); **Tomoko Ueki**, Sakai (JP)

(73) Assignee: **SHARP KABUSHIKI KAISHA**, Sakai, Osaka (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **15/532,373**

(22) PCT Filed: **Dec. 3, 2015**

(86) PCT No.: **PCT/JP2015/083973**
§ 371 (c)(1),
(2) Date: **Jun. 1, 2017**

(87) PCT Pub. No.: **WO2016/088823**
PCT Pub. Date: **Jun. 9, 2016**

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US 2017/0362883 A1 Dec. 21, 2017

(30) **Foreign Application Priority Data**

Dec. 4, 2014 (JP) 2014-245745

(51) **Int. Cl.**
E06B 3/67 (2006.01)
E06B 7/02 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***E06B 3/67*** (2013.01); ***E06B 3/6722*** (2013.01); ***E06B 7/02*** (2013.01); ***E06B 7/08*** (2013.01); ***E06B 7/10*** (2013.01); ***E06B 9/24*** (2013.01); ***F21S 11/00*** (2013.01); ***F21S 11/007*** (2013.01); ***F21V 31/03*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC F21S 11/00; F21S 11/002; F21S 11/007
See application file for complete search history.

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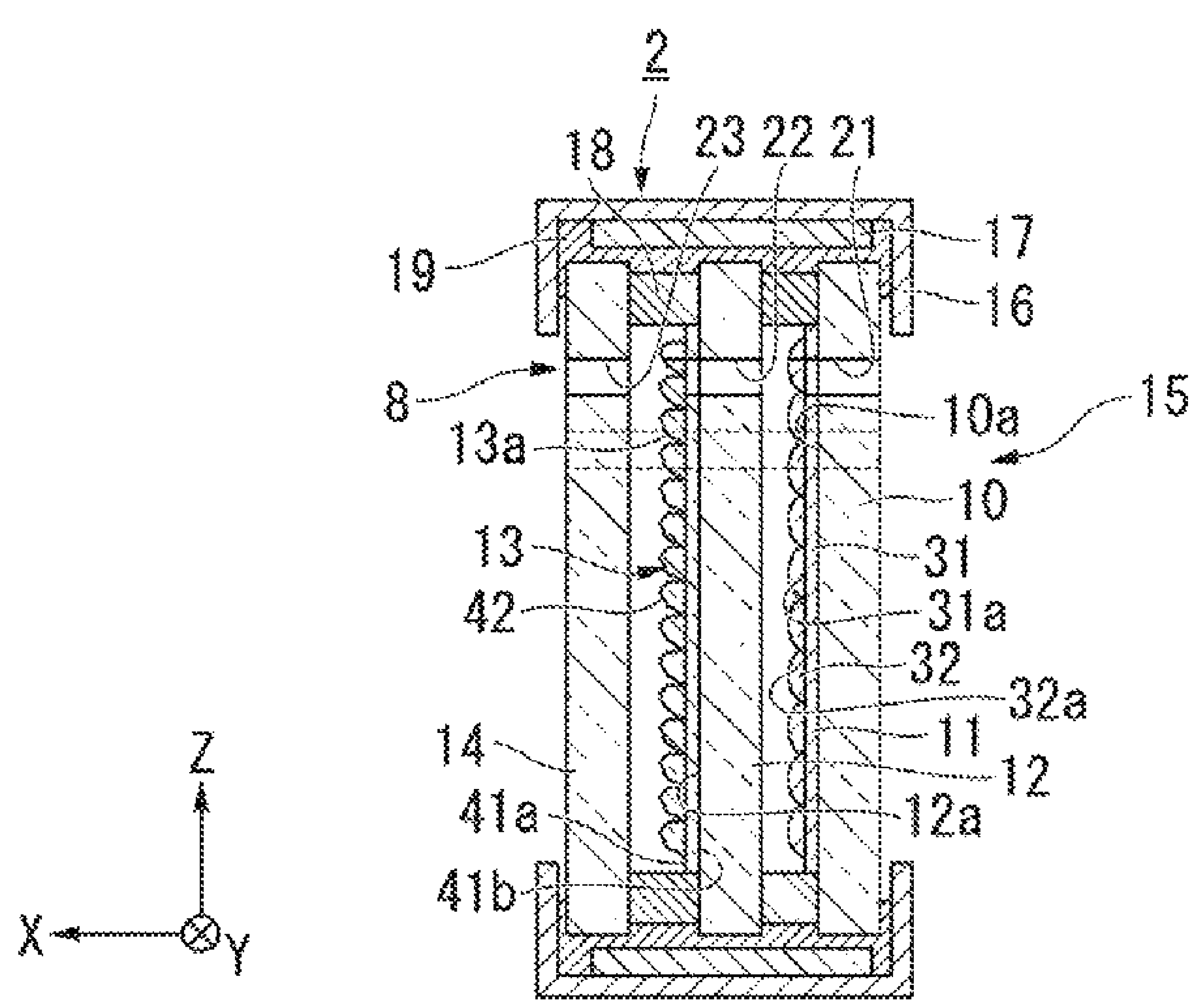
Primary Examiner — Christopher E Mahoney
(74) *Attorney, Agent, or Firm* — ScienBiziP, P.C.

(57) **ABSTRACT**

A daylighting device of the present invention includes: a daylighting member including: a first light-transmitting base member; and a plurality of protruding, light-transmitting daylighting sections provided on a first face or a second face of the first light-transmitting base member; and a ventilation hole configured to enable a space on the first face to communicate with a space on the second face opposite from the first face.

17 Claims, 29 Drawing Sheets



(51) **Int. Cl.**

F21S 11/00	(2006.01)
E06B 7/08	(2006.01)
F21V 31/03	(2006.01)
E06B 7/10	(2006.01)
E06B 9/24	(2006.01)

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

CPC ... *E06B 2007/023* (2013.01); *E06B 2007/026* (2013.01); *E06B 2009/2417* (2013.01); *E06B 2009/2476* (2013.01)

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FIG. 1

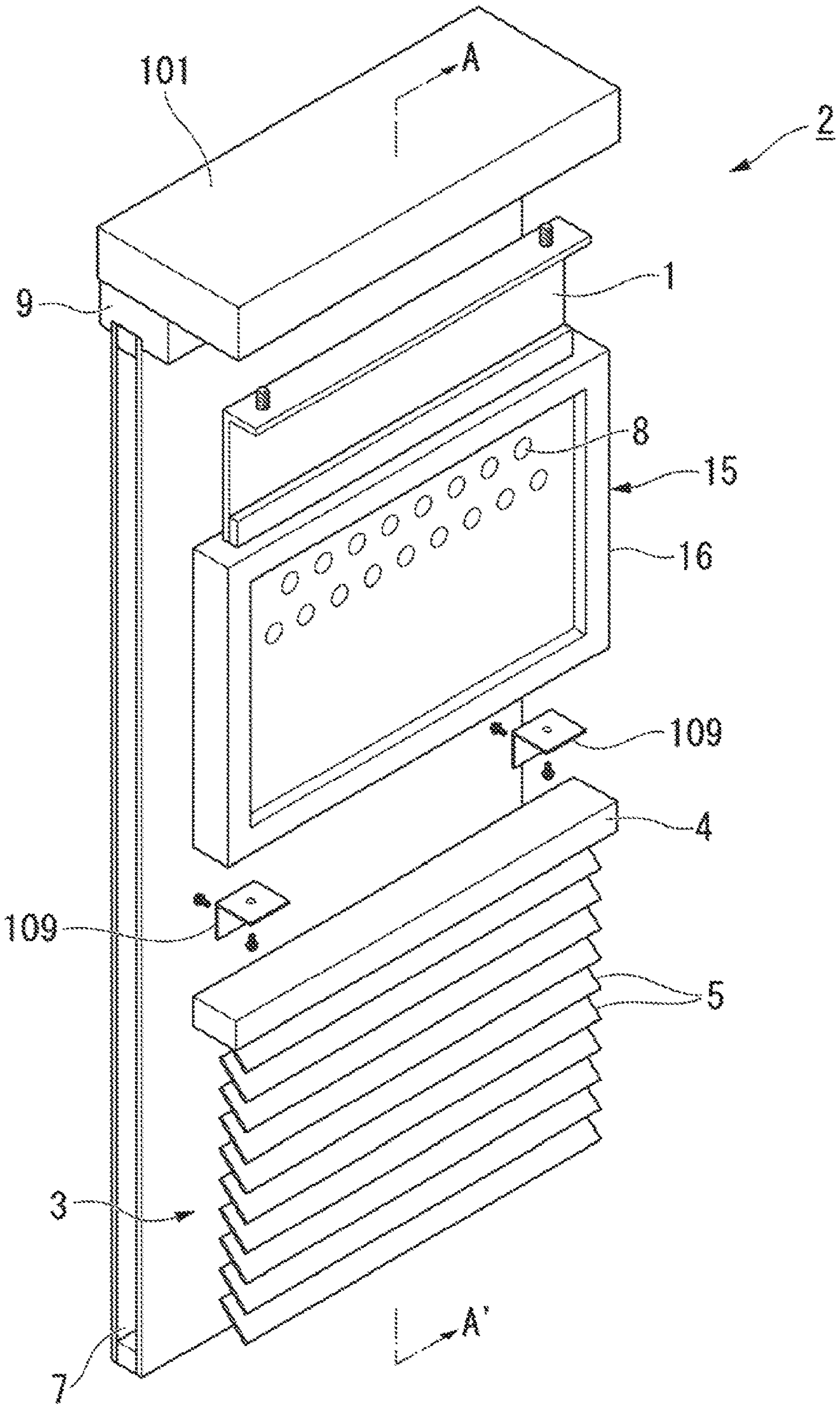


FIG. 2

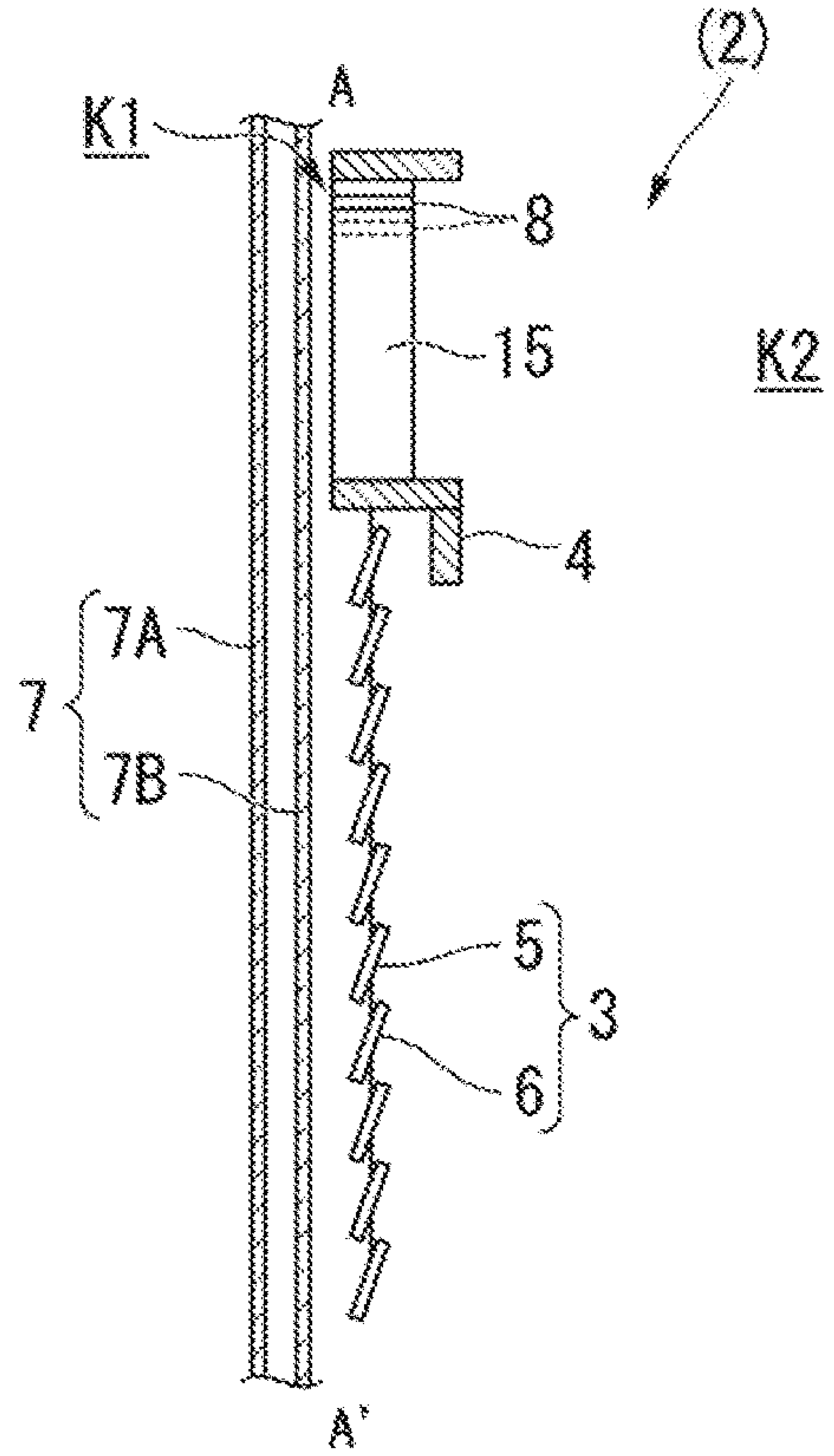

(2)
K1
A
8
15
K2
4
7A
7
7B
5
3
6
A'

FIG. 3

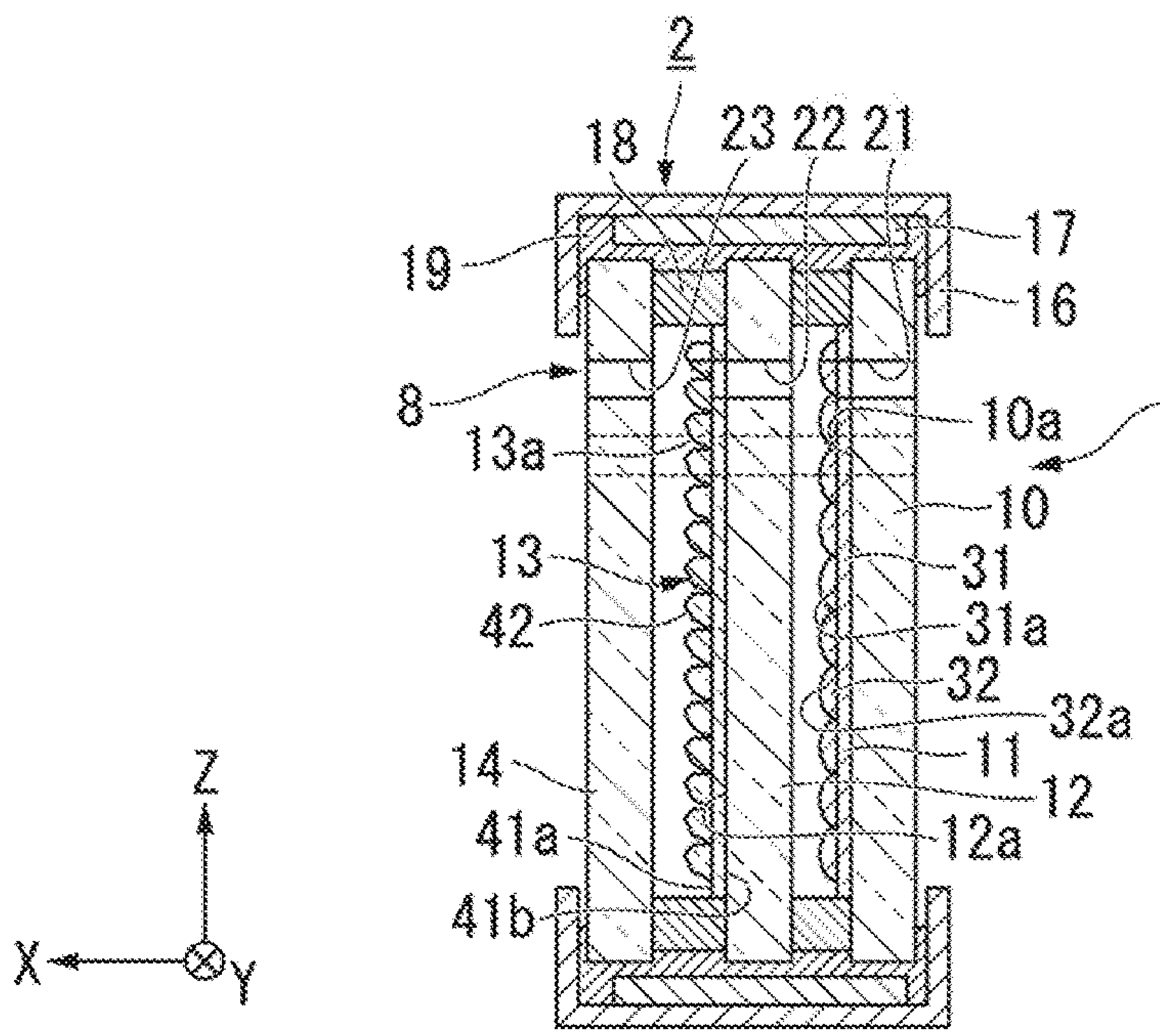

2
18
23
22
21
19
17
16
8
10a
15
13a
10
13
31
42
31a
32
32a
14
11
12
Z
41a
12a
41b
X
Y

FIG. 4

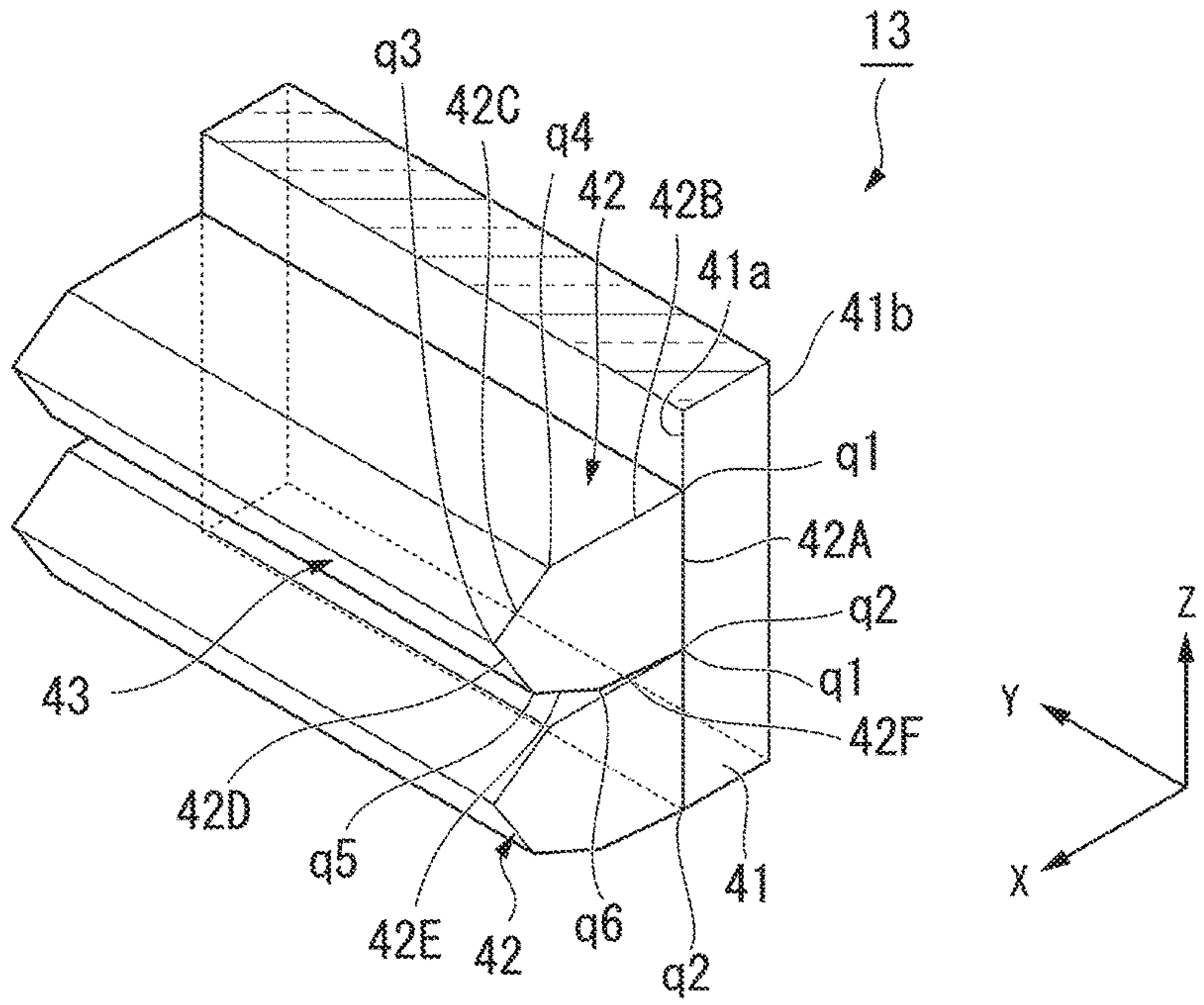

13
q3
42C
q4
42
42B
41a
41b
q1
42A
q2
q1
42F
43
42D
q5
42E
42
q6
q2
41
Z
Y
X

FIG. 5A

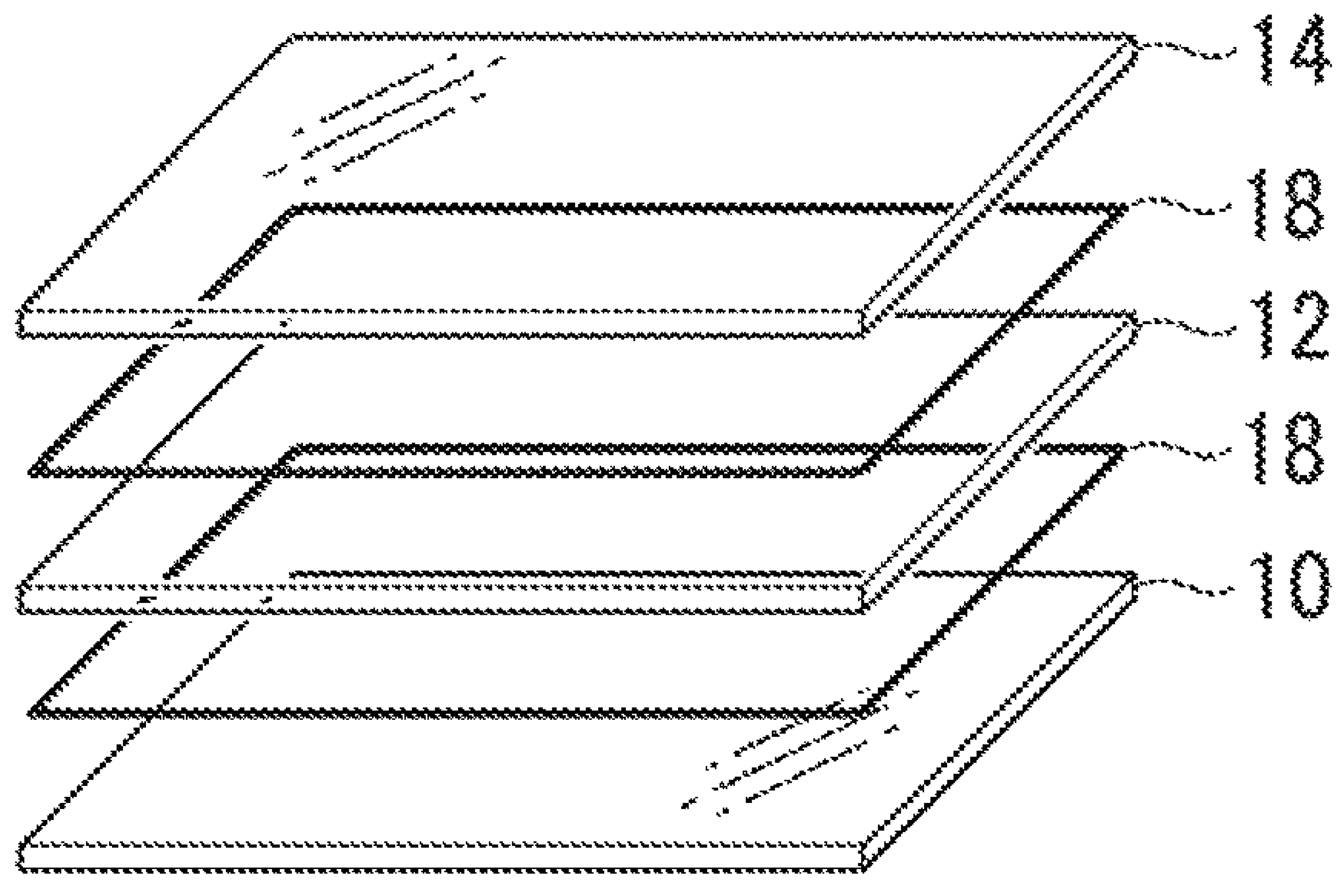


FIG. 5B

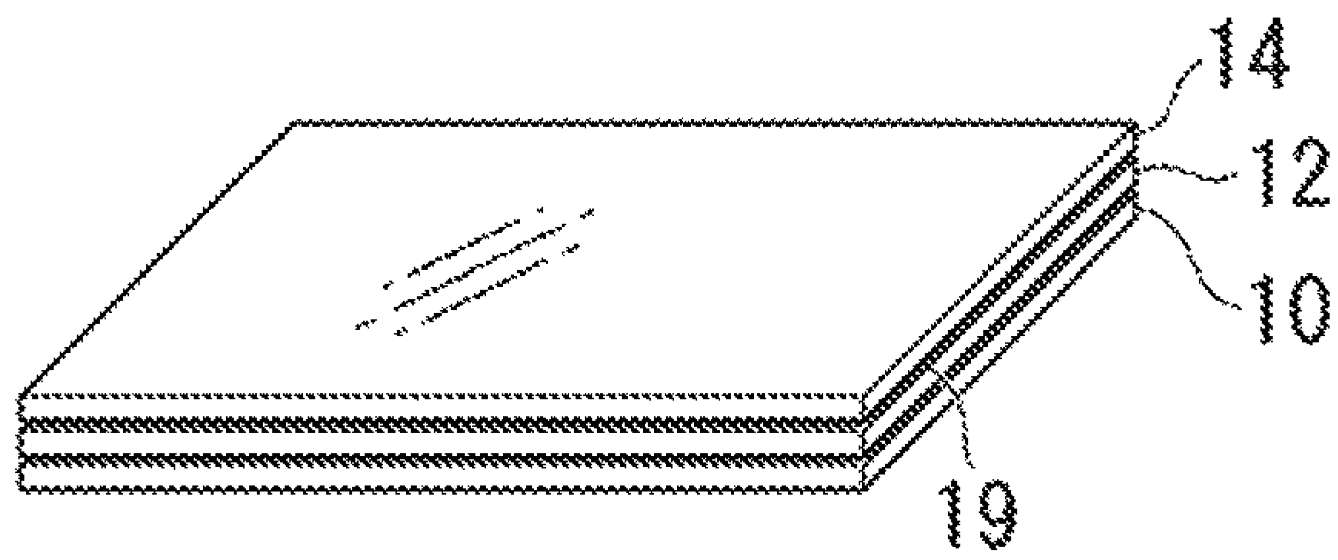


FIG. 5C

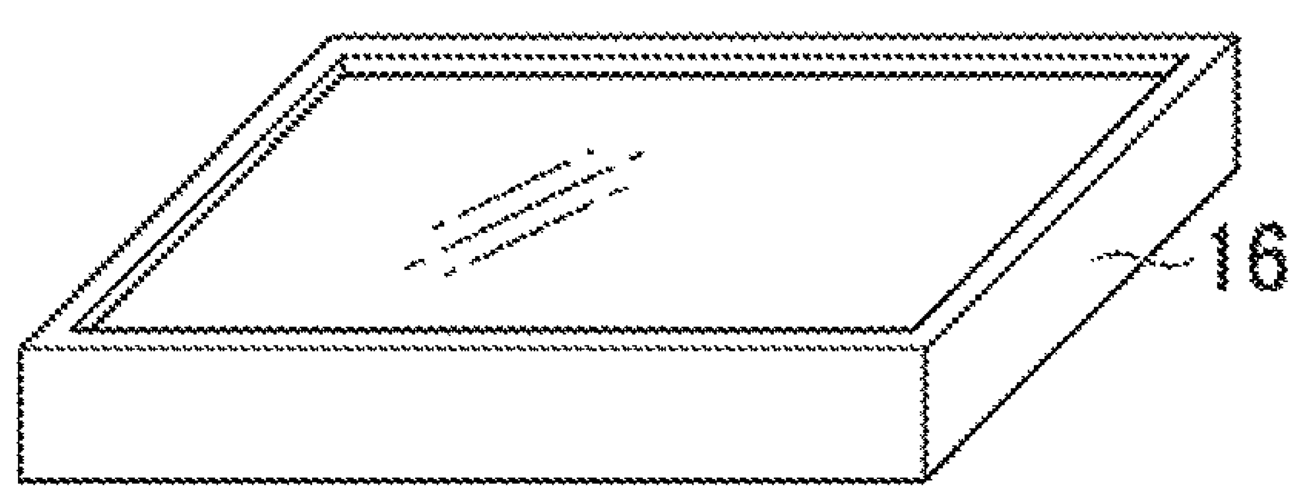


FIG. 6A

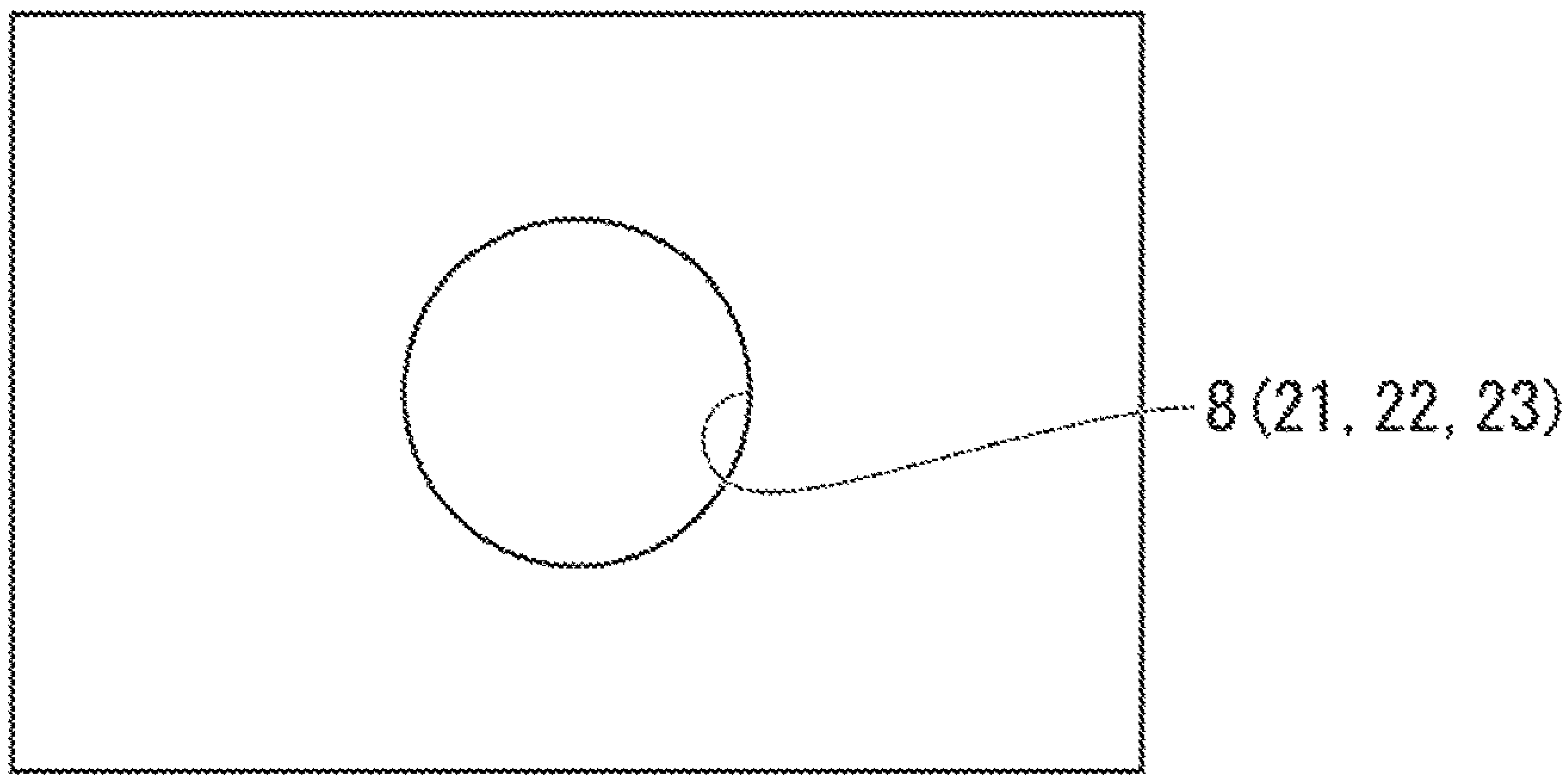


FIG. 6B

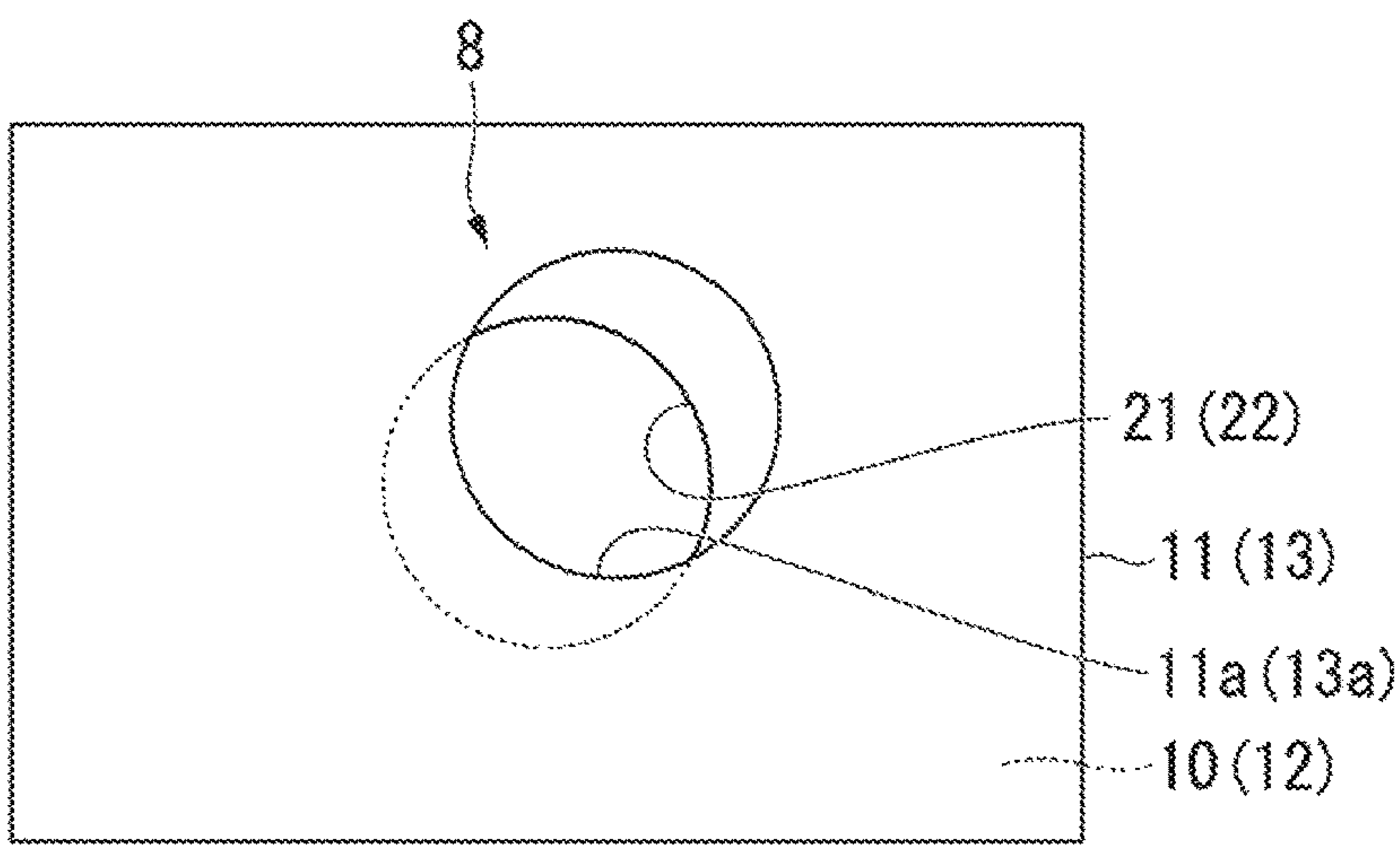


FIG. 7A

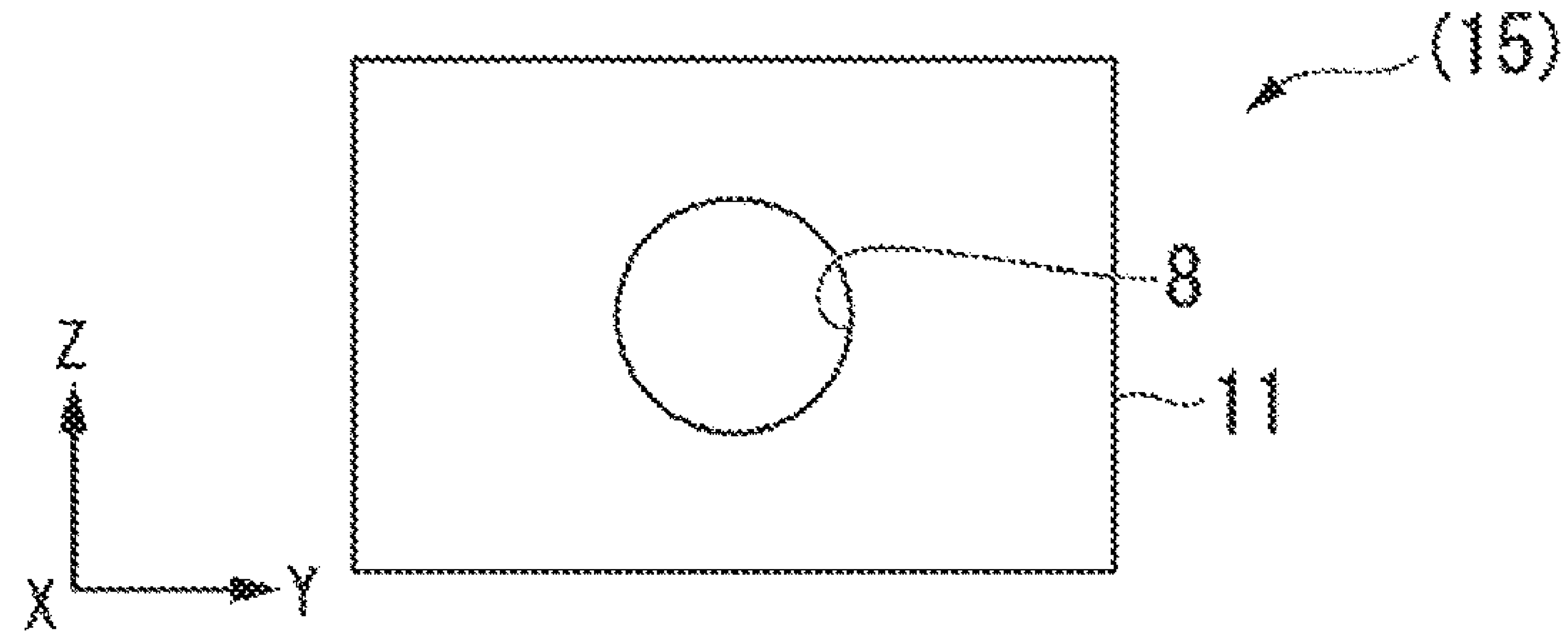


FIG. 7B

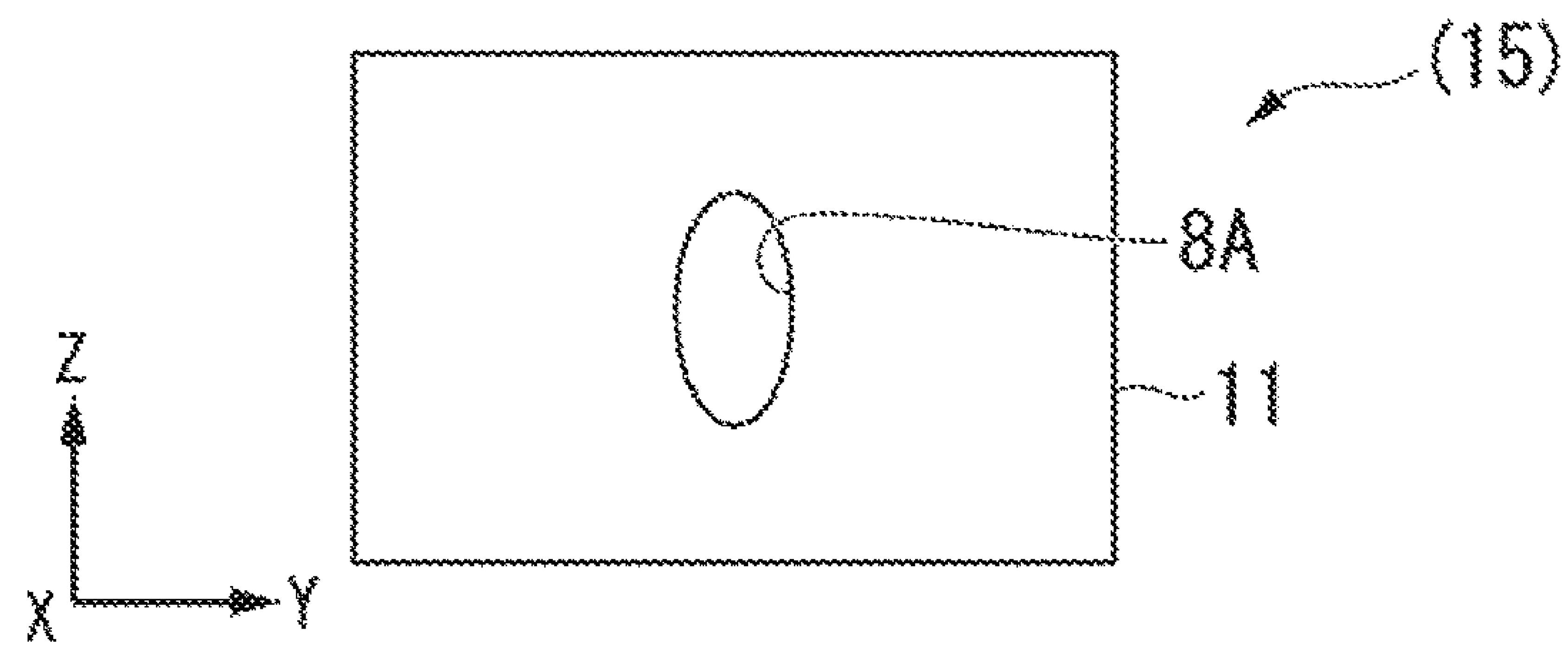


FIG. 7C

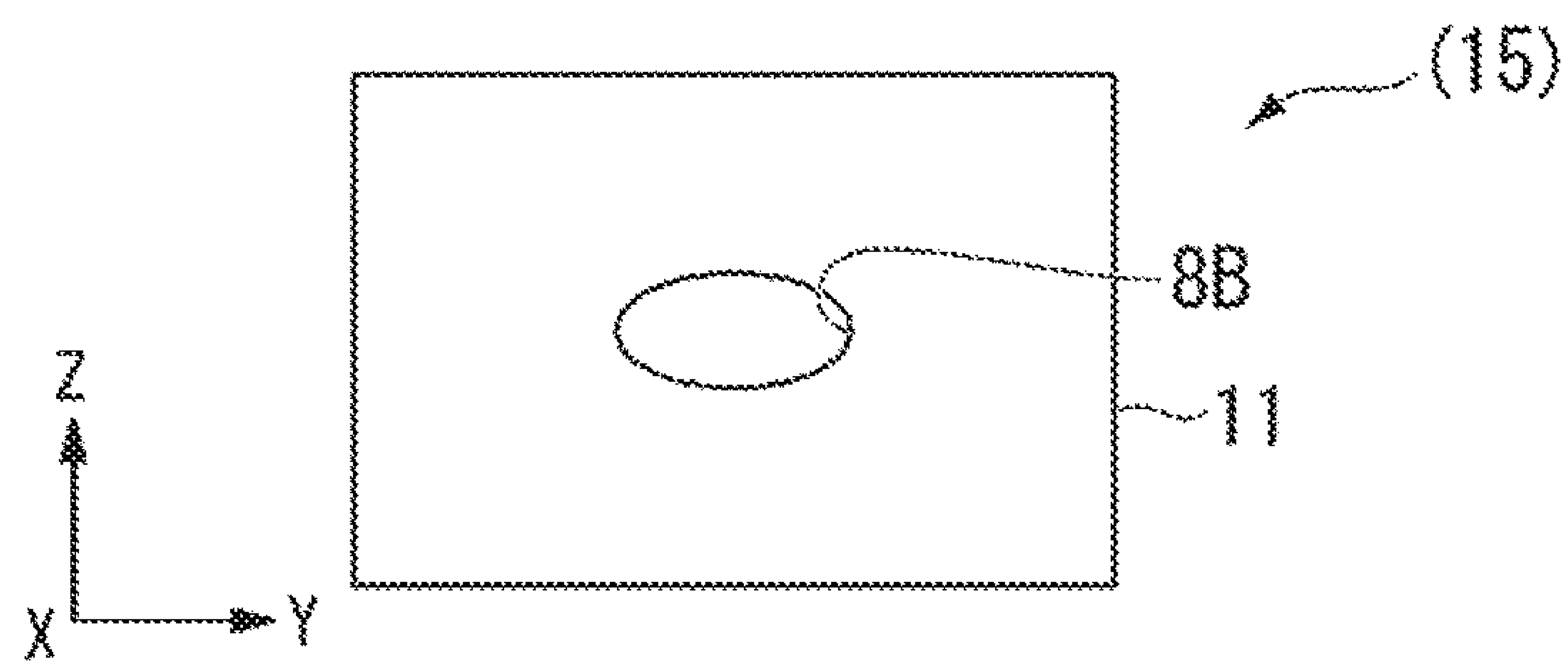


FIG. 7D

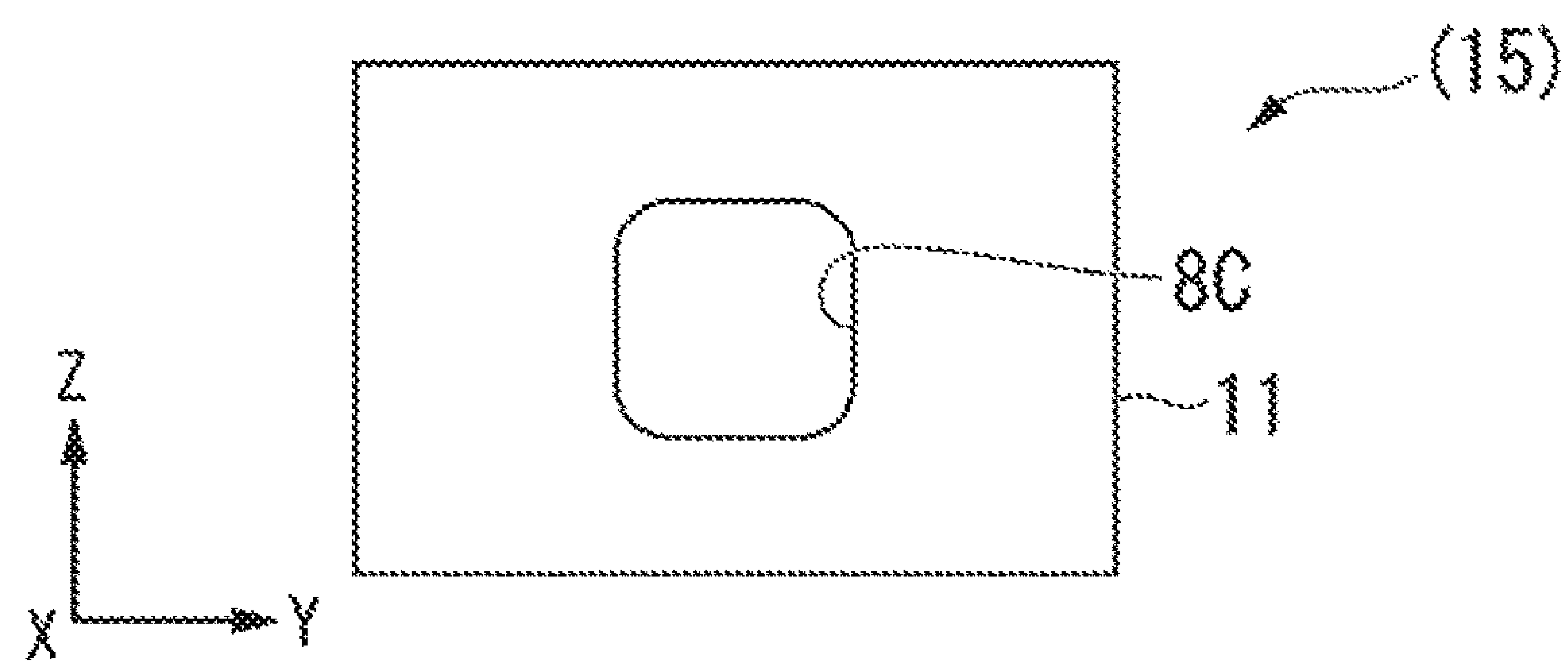


FIG. 7E

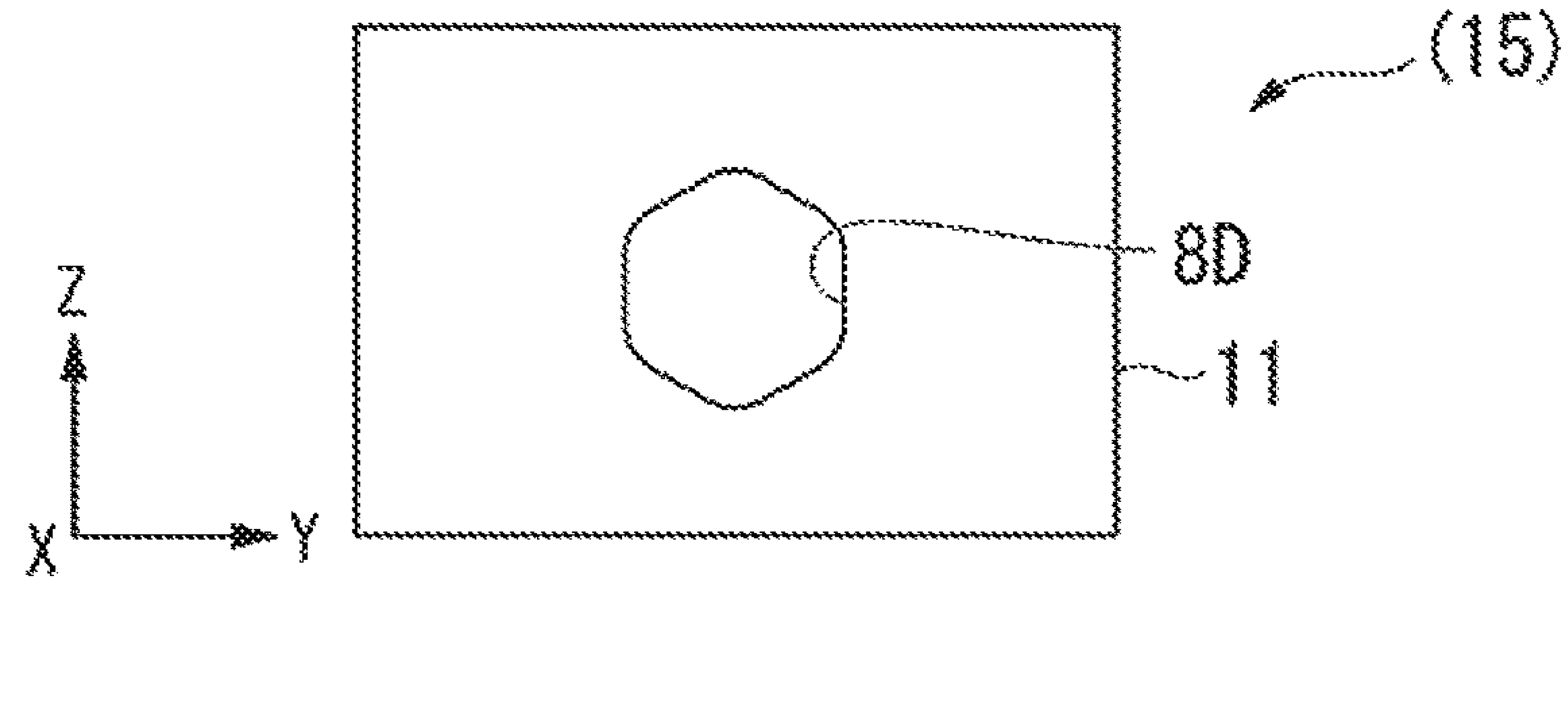


FIG. 8

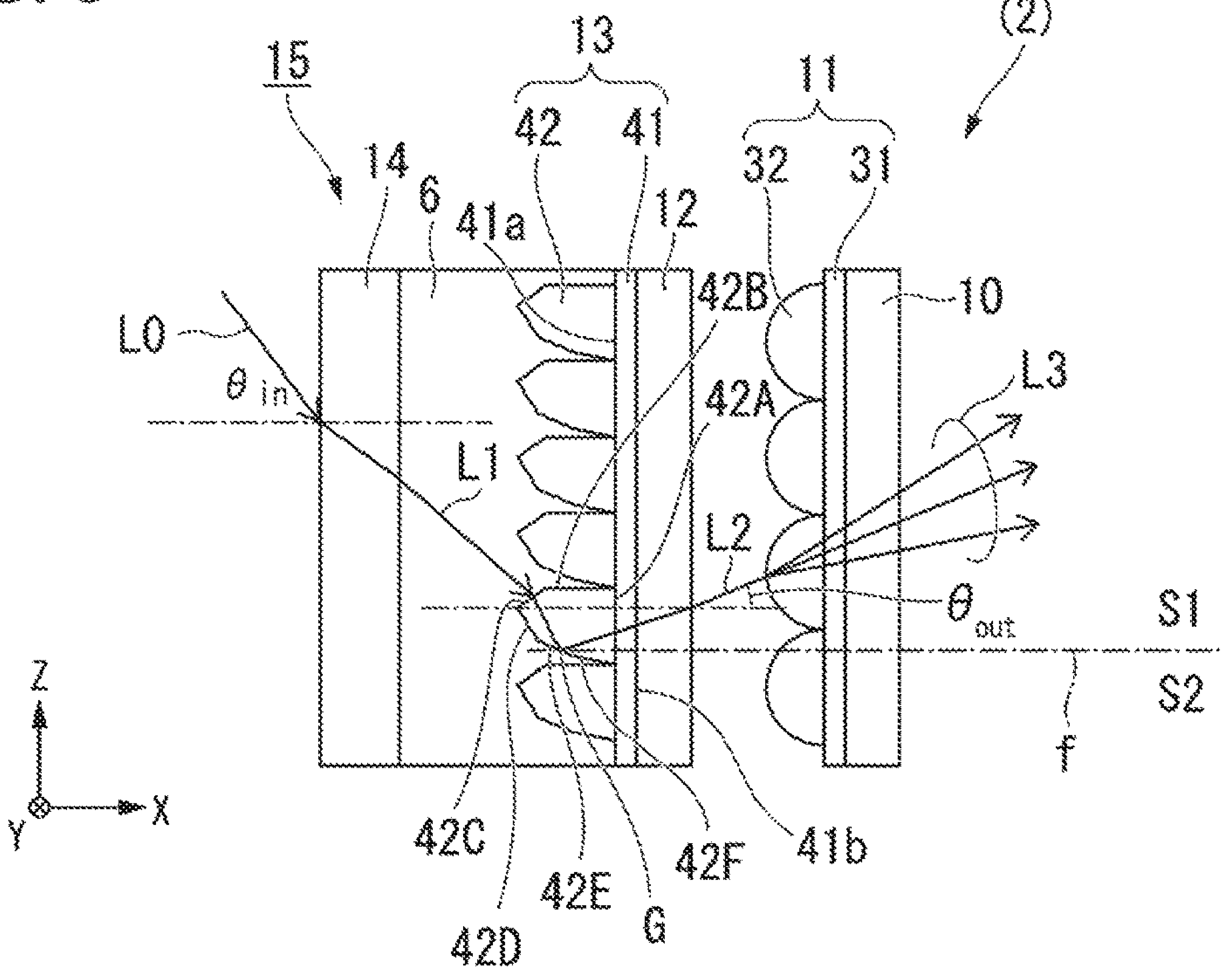

15
13
11
(2)
14
6
41a
42
41
12
32
31
10
L0
θ in
42B
42A
L1
L2
L3
θ out
S1
S2
f
Z
X
Y
42C
42D
42E
G
42F
41b

FIG. 9

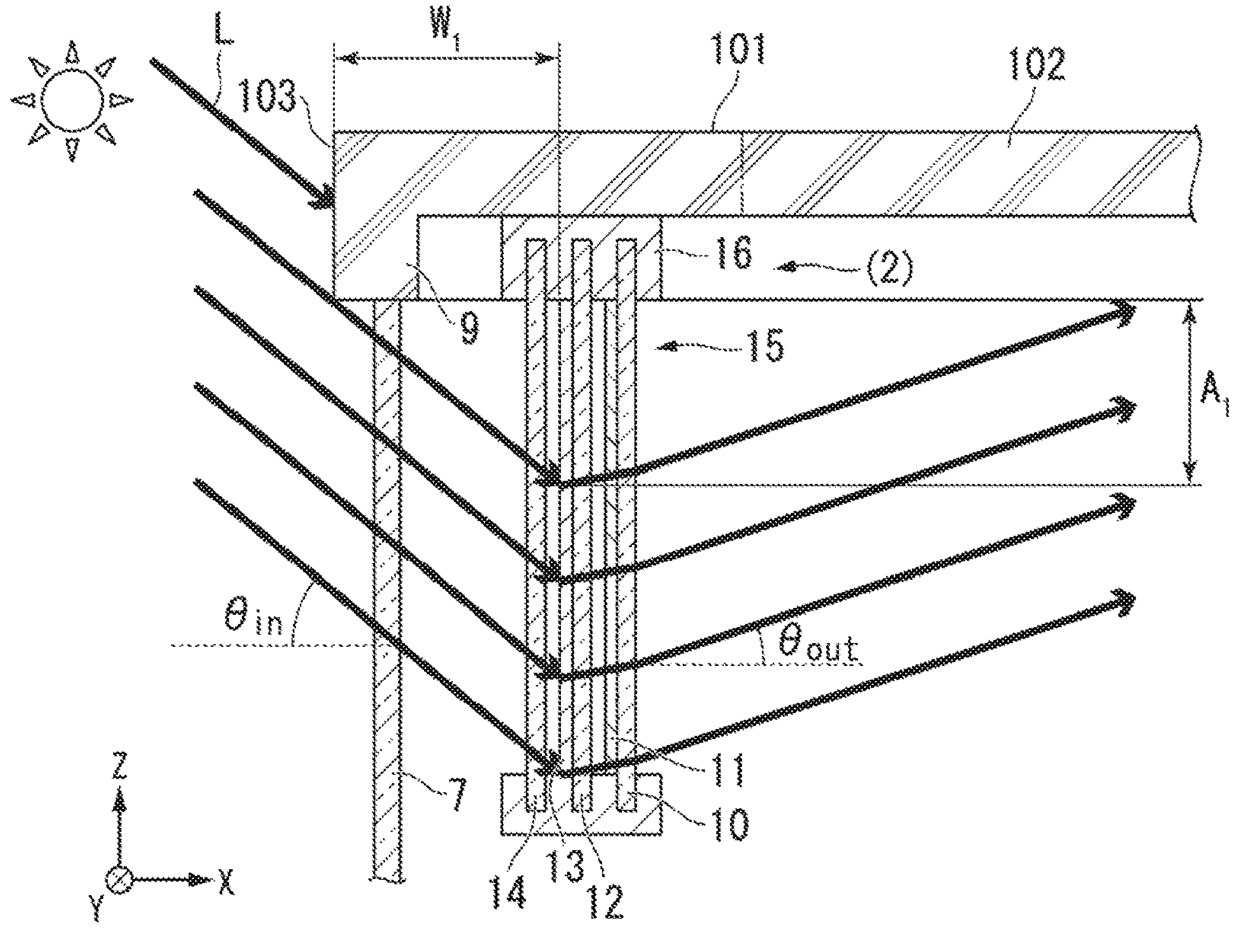

L
W1
101
102
103
16
(2)
9
15
A1
θ in
θ out
11
7
10
14
13
12
Z
X
Y

FIG. 10

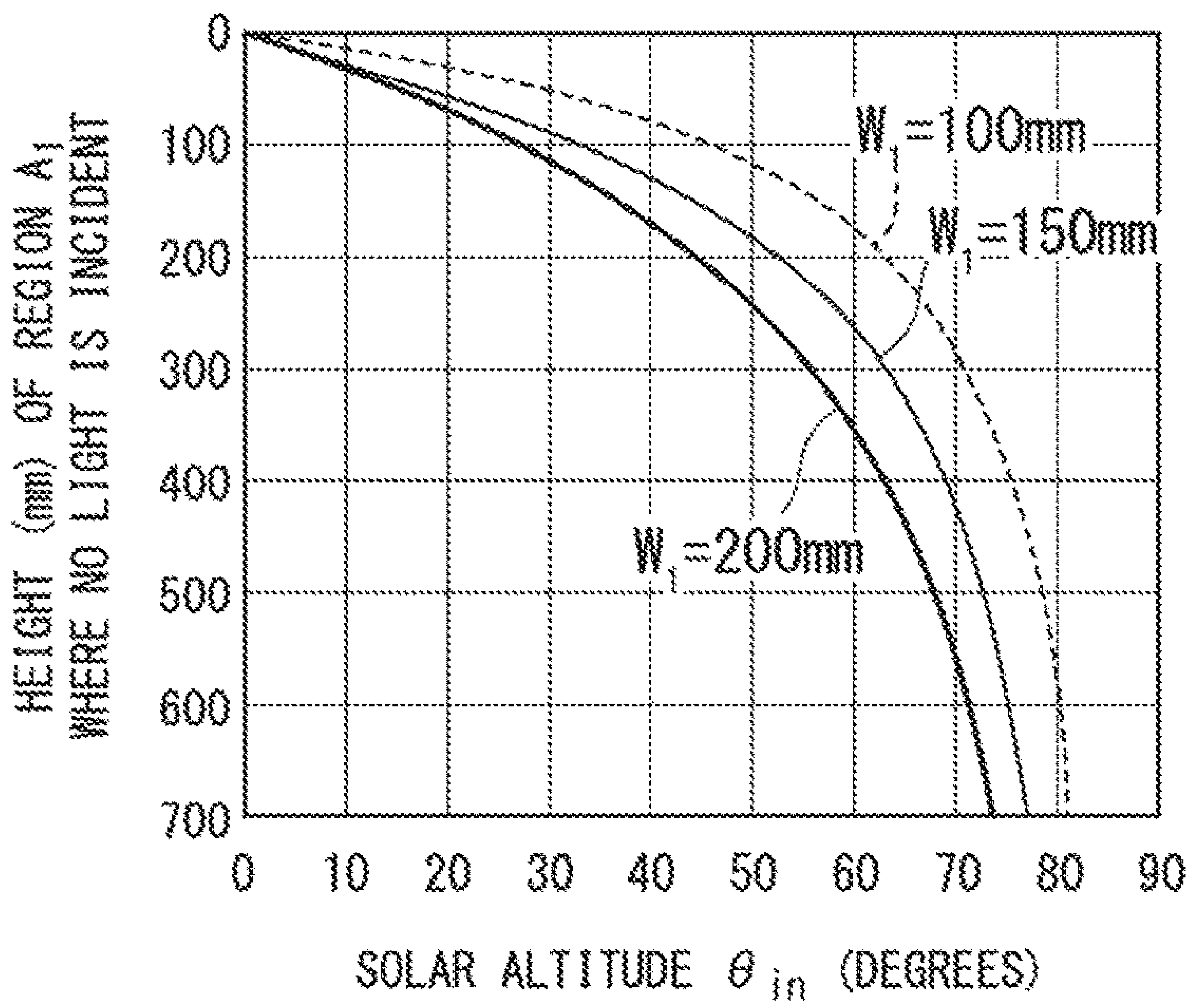

HEIGHT (mm) OF REGION A1 WHERE NO LIGHT IS INCIDENT
0
100
200
300
400
500
600
700
0 10 20 30 40 50 60 70 80 90
SOLAR ALTITUDE θin (DEGREES)
W1=100mm
W1=150mm
W1=200mm

FIG. 11

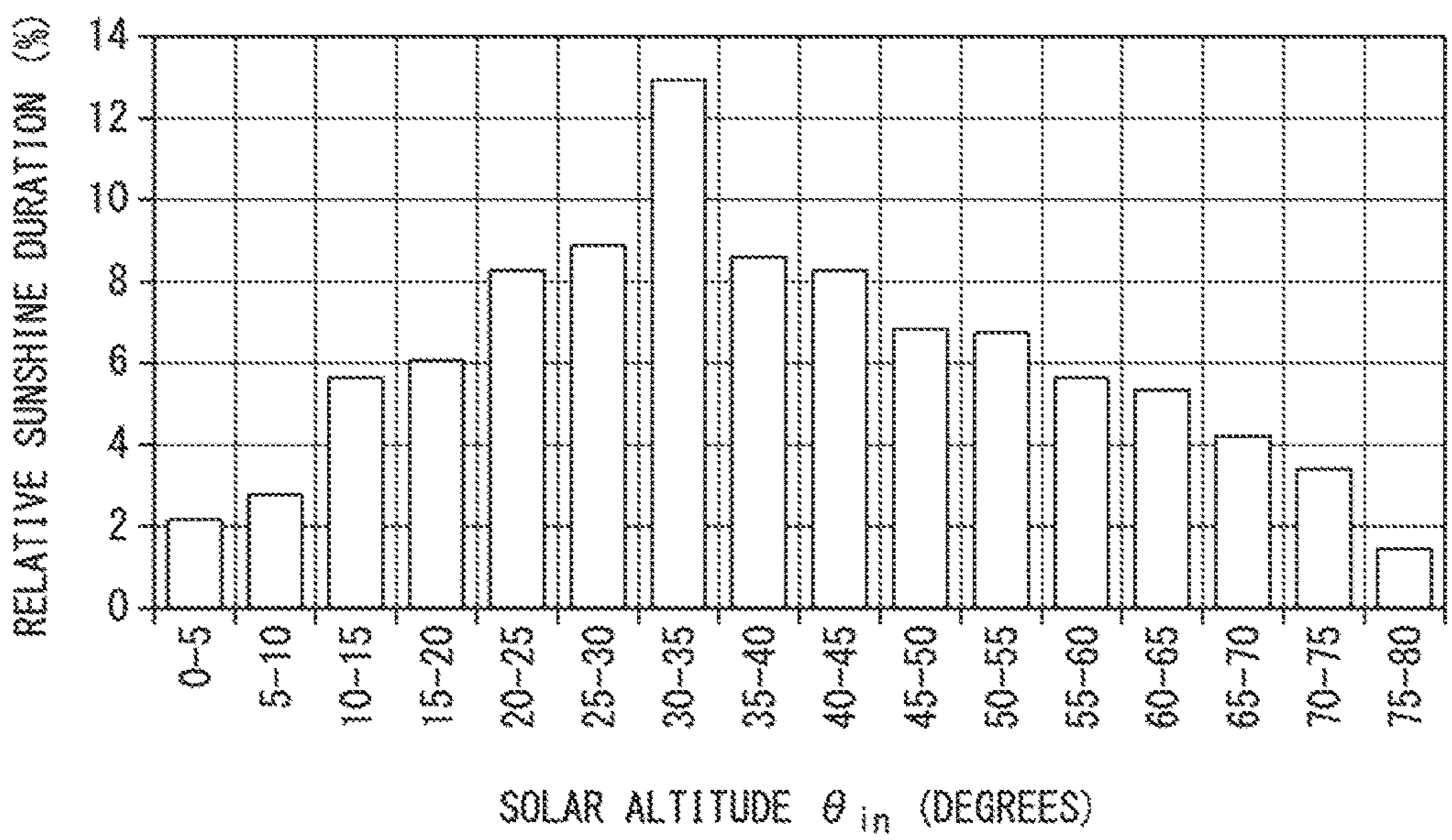

RELATIVE SUNSHINE DURATION (%)
0
2
4
6
8
10
12
14
0-5 5-10 10-15 15-20 20-25 25-30 30-35 35-40 40-45 45-50 50-55 55-60 60-65 65-70 70-75 75-80
SOLAR ALTITUDE θin (DEGREES)

FIG. 12

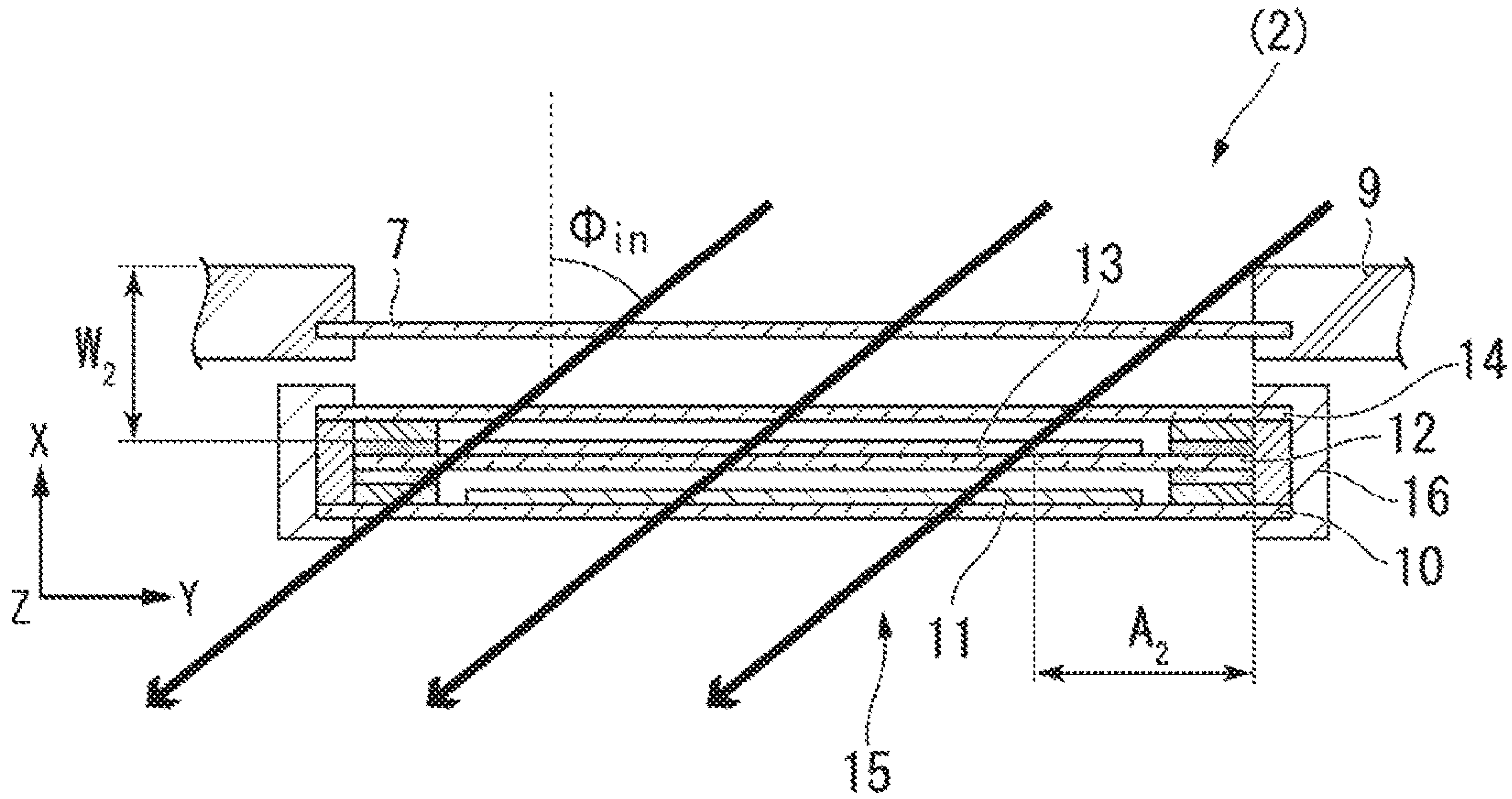

(2)
Φin
7
9
13
14
12
16
10
11
15
W2
A2
X
Y
Z

FIG. 13

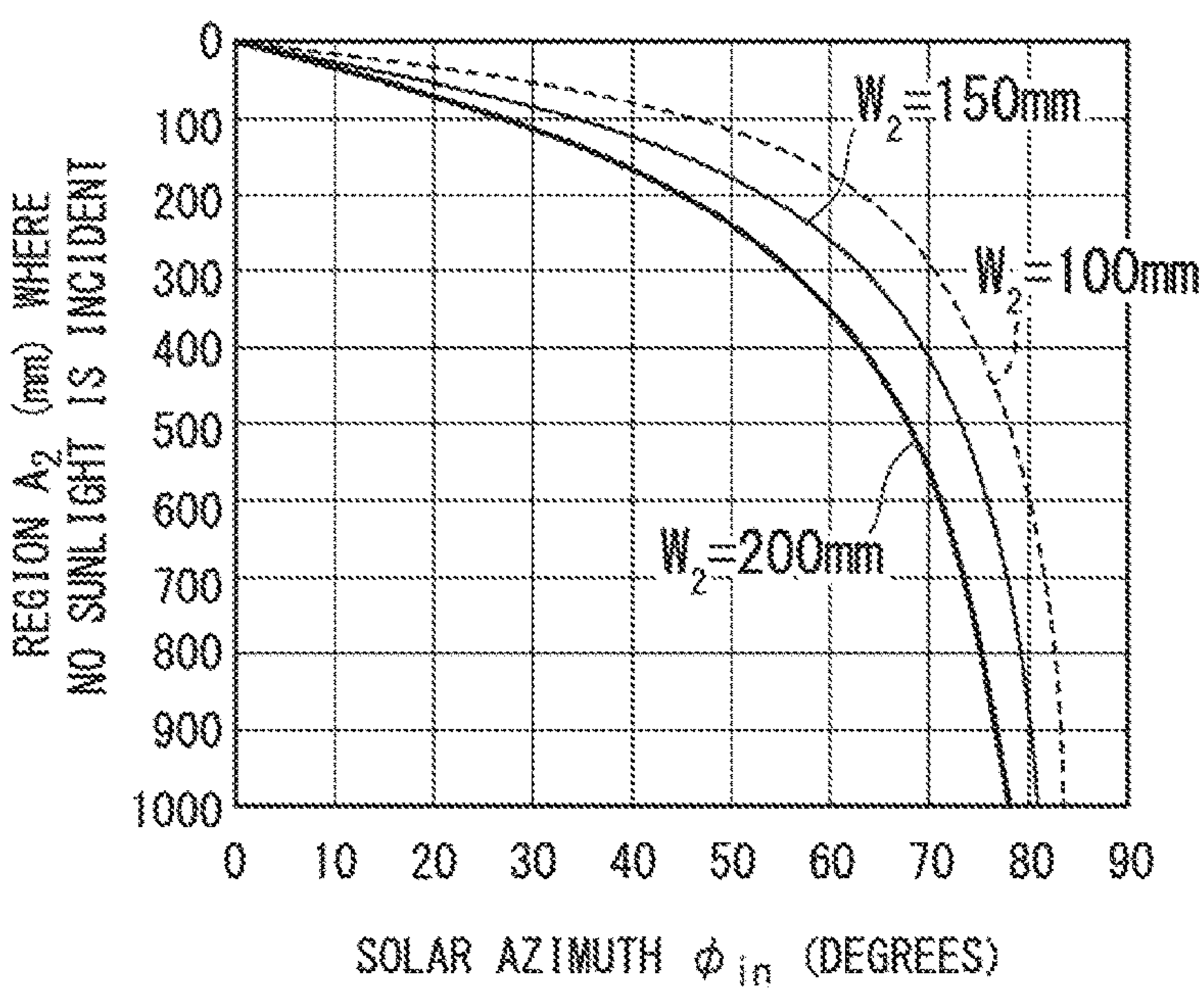

REGION A2 (mm) WHERE NO SUNLIGHT IS INCIDENT
SOLAR AZIMUTH φin (DEGREES)
W2=150mm
W2=100mm
W2=200mm
0
100
200
300
400
500
600
700
800
900
1000
0
10
20
30
40
50
60
70
80
90

FIG. 14A

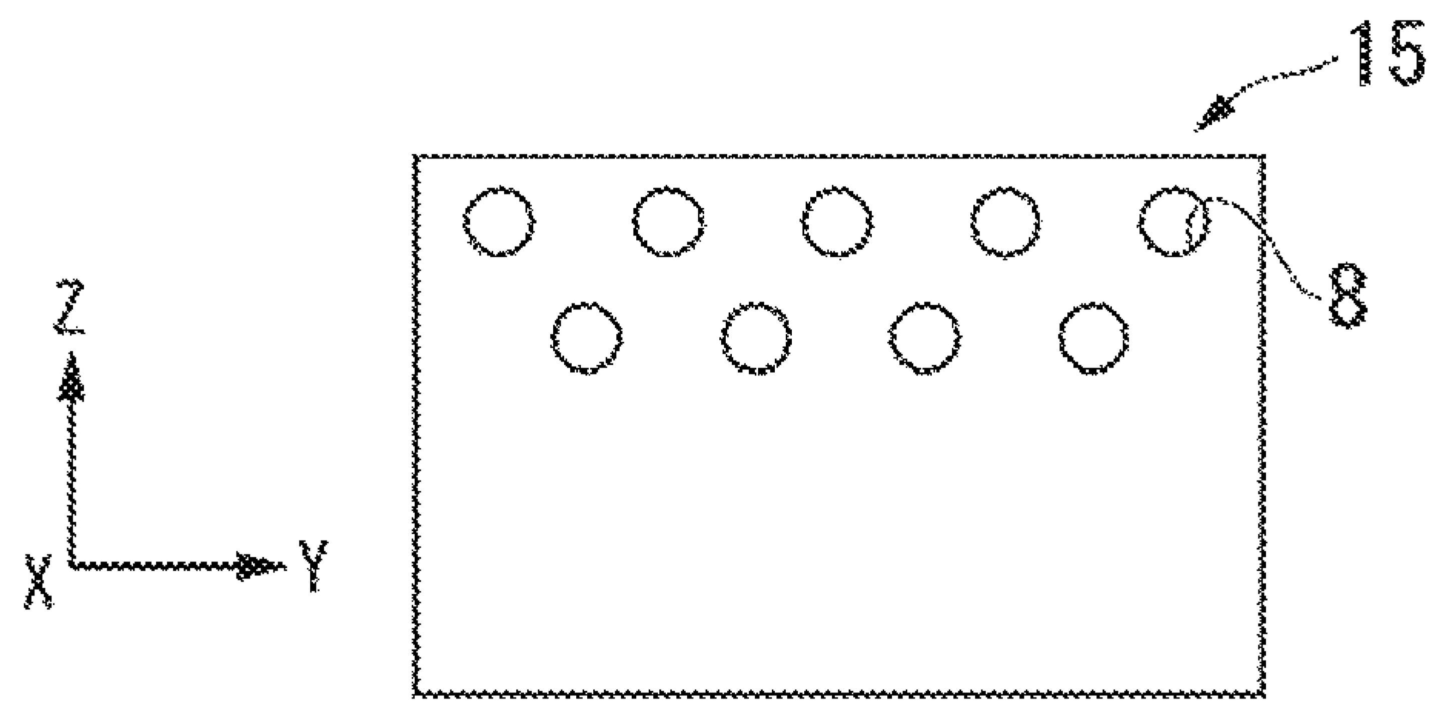


FIG. 14B

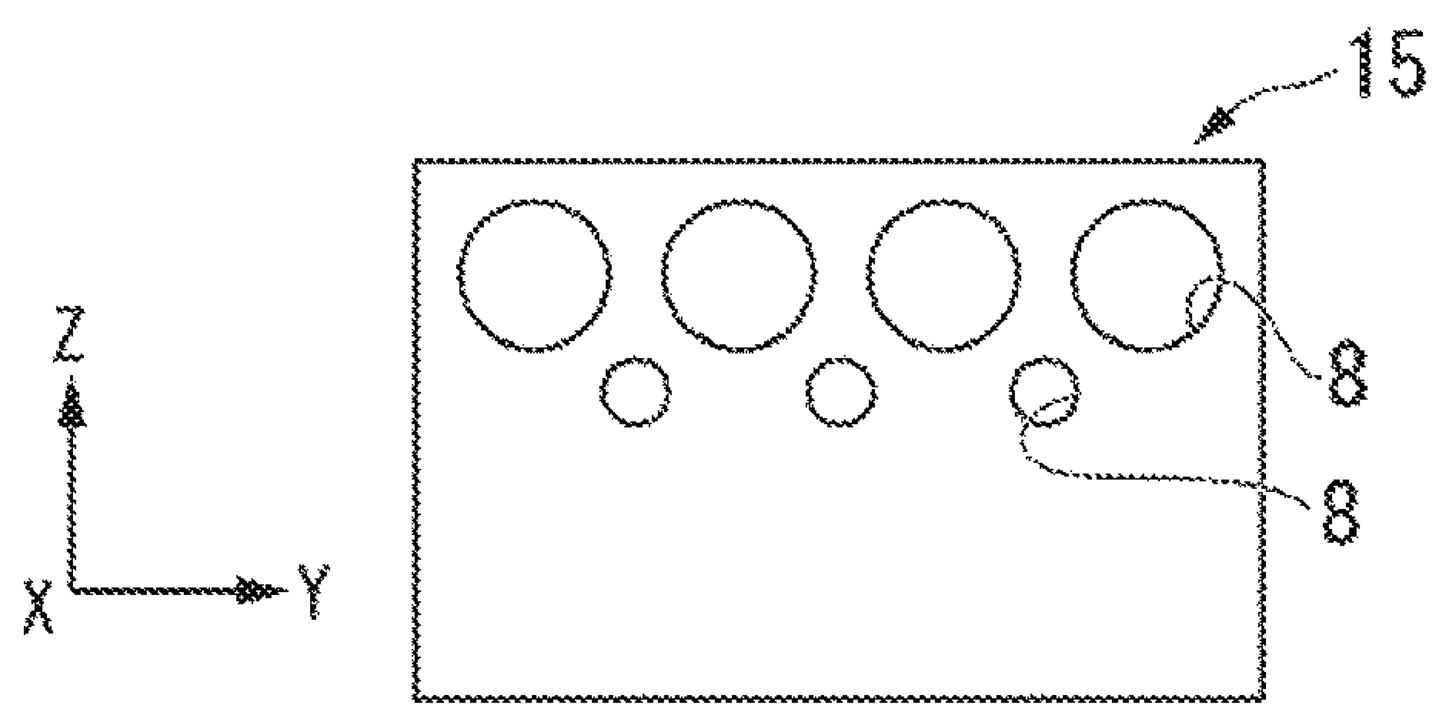


FIG. 14C

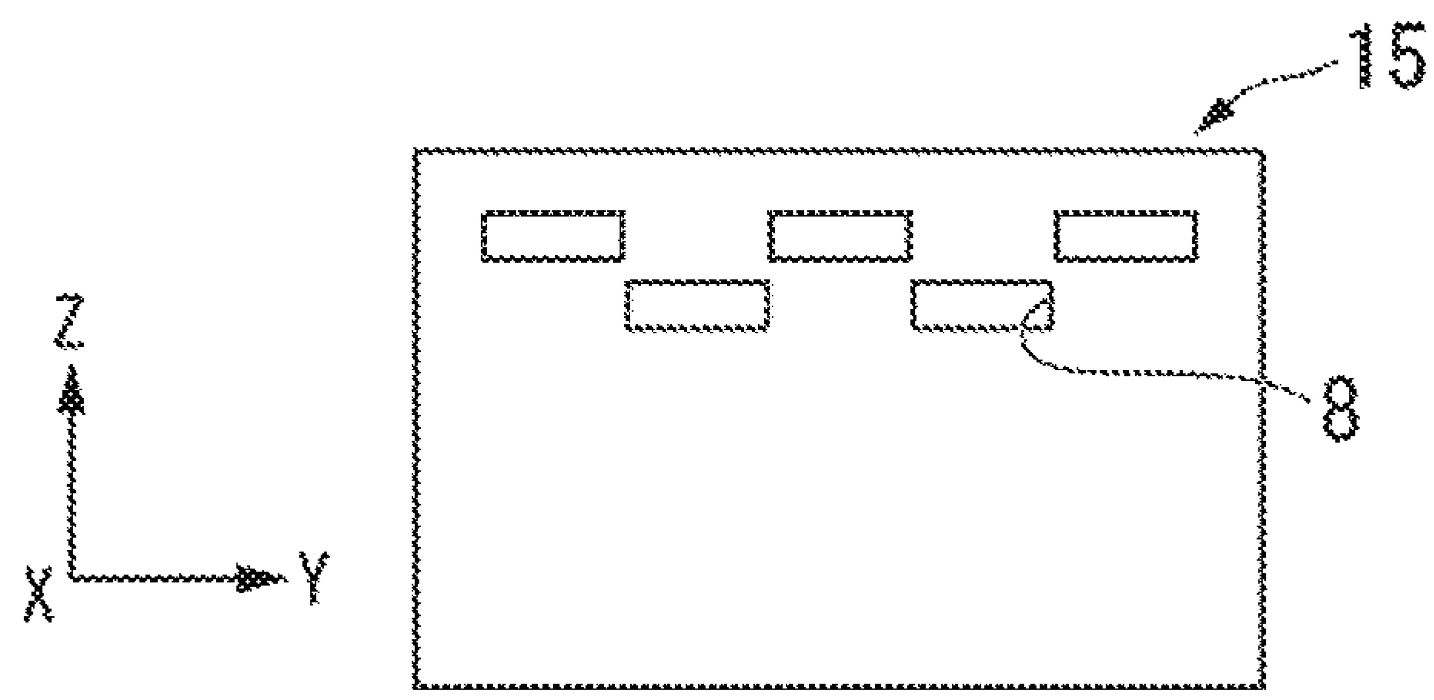


FIG. 14D

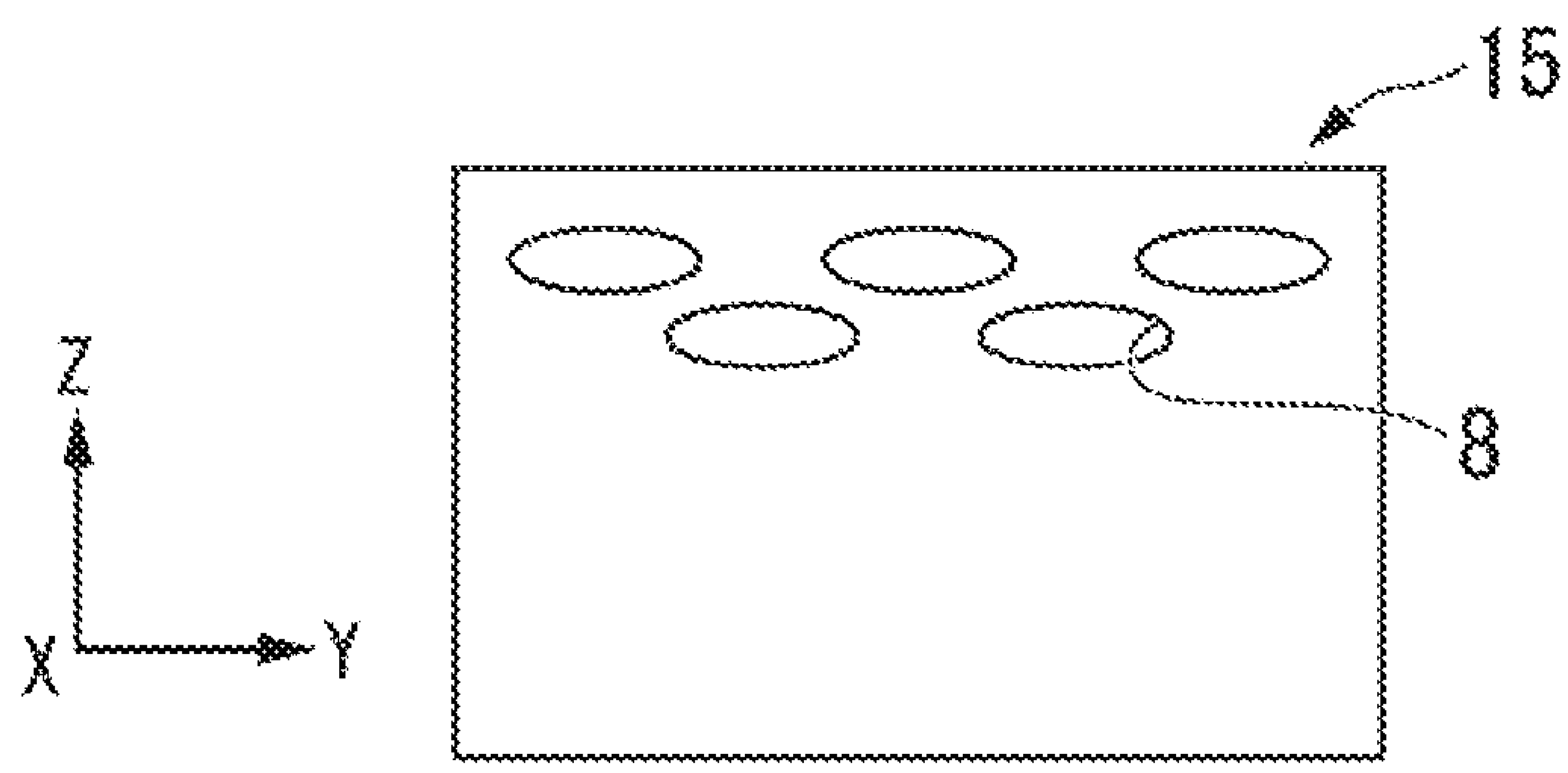


FIG. 14E

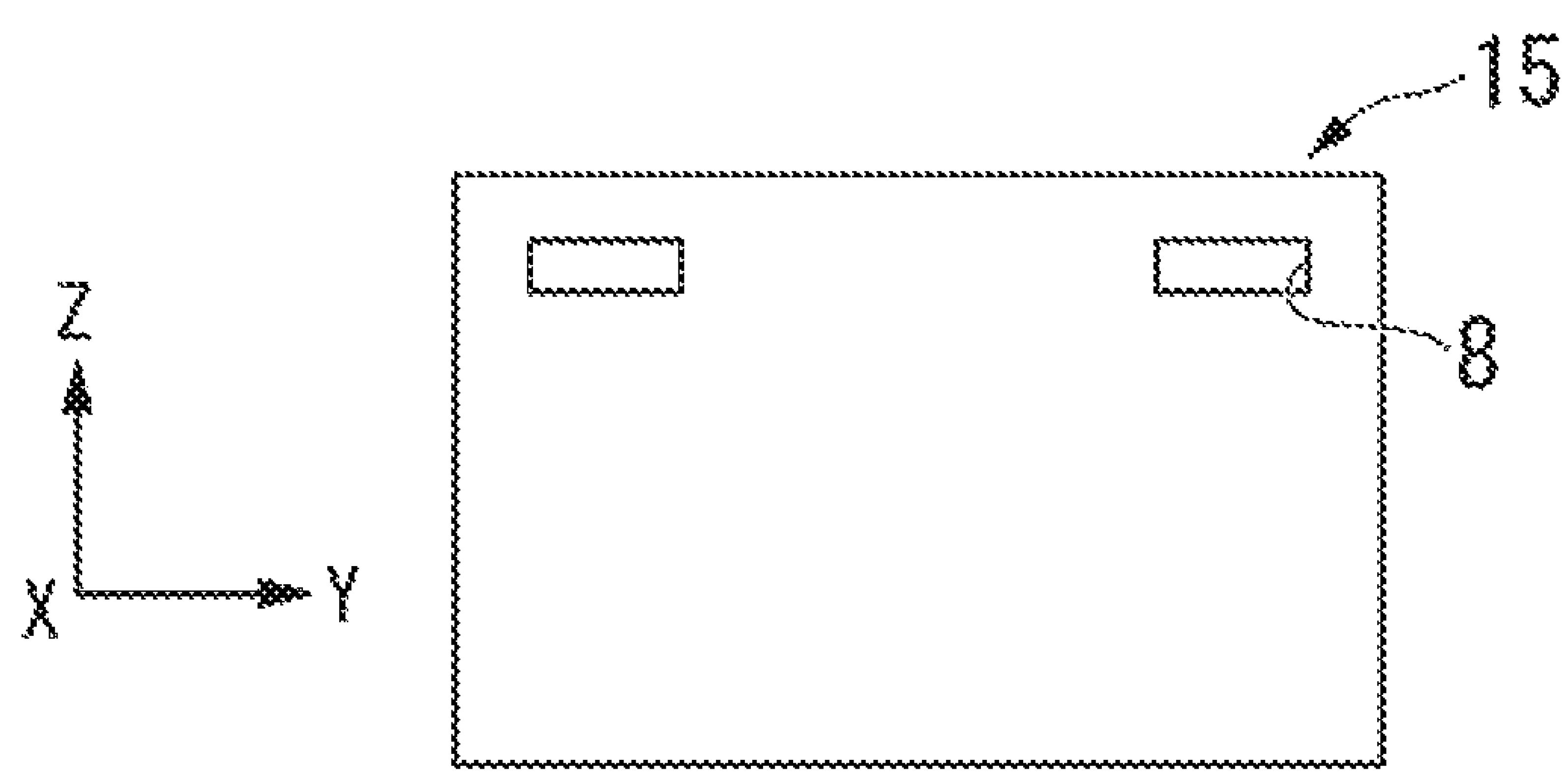


FIG. 15A

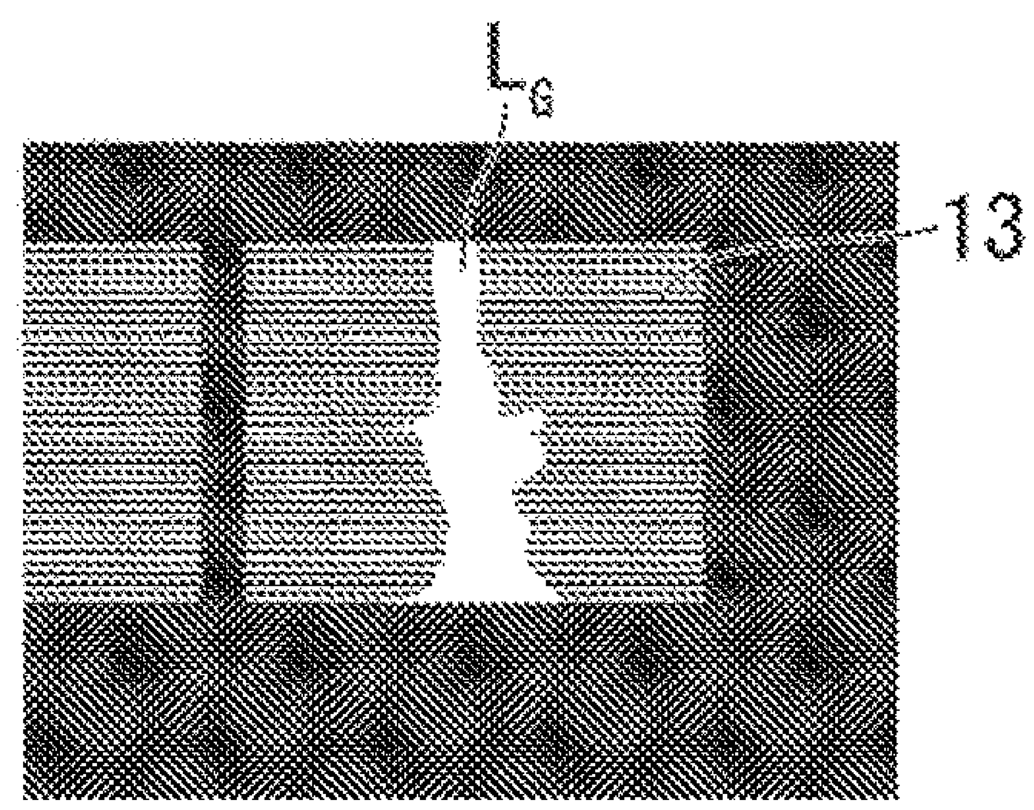


FIG. 15B

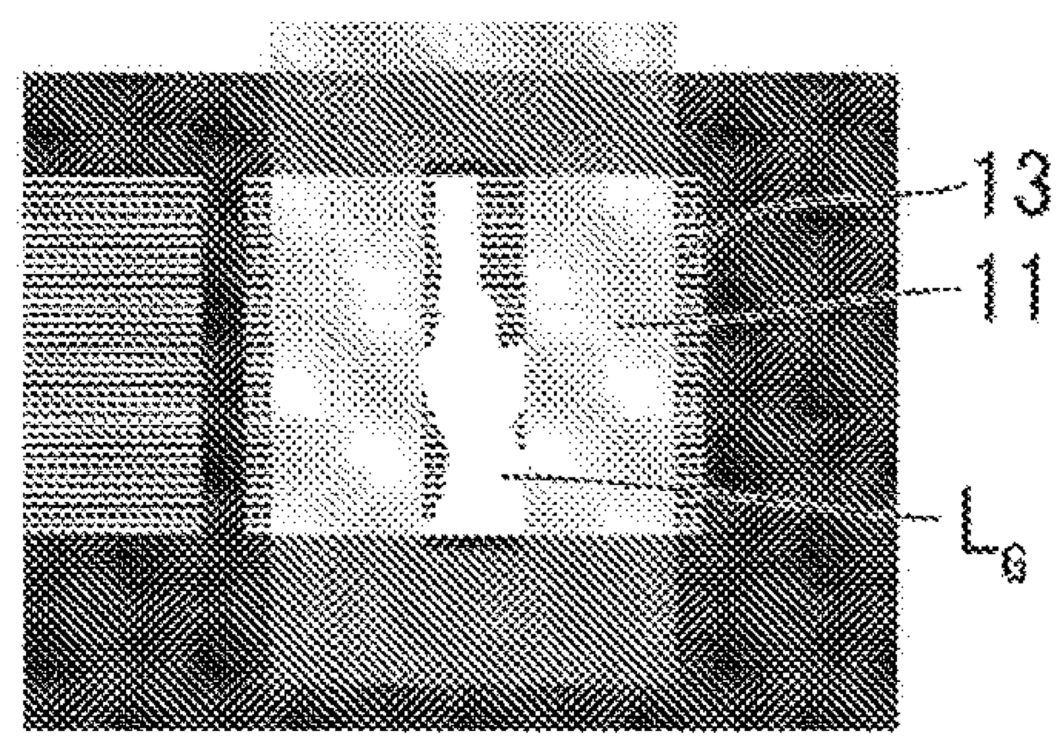


FIG. 15C

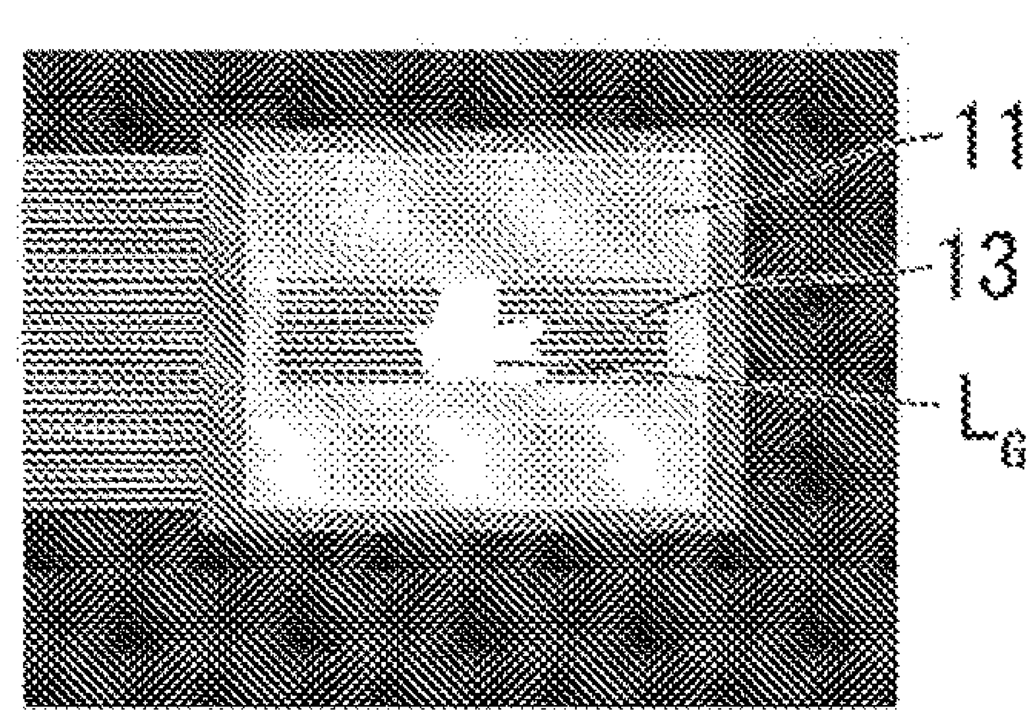


FIG. 16

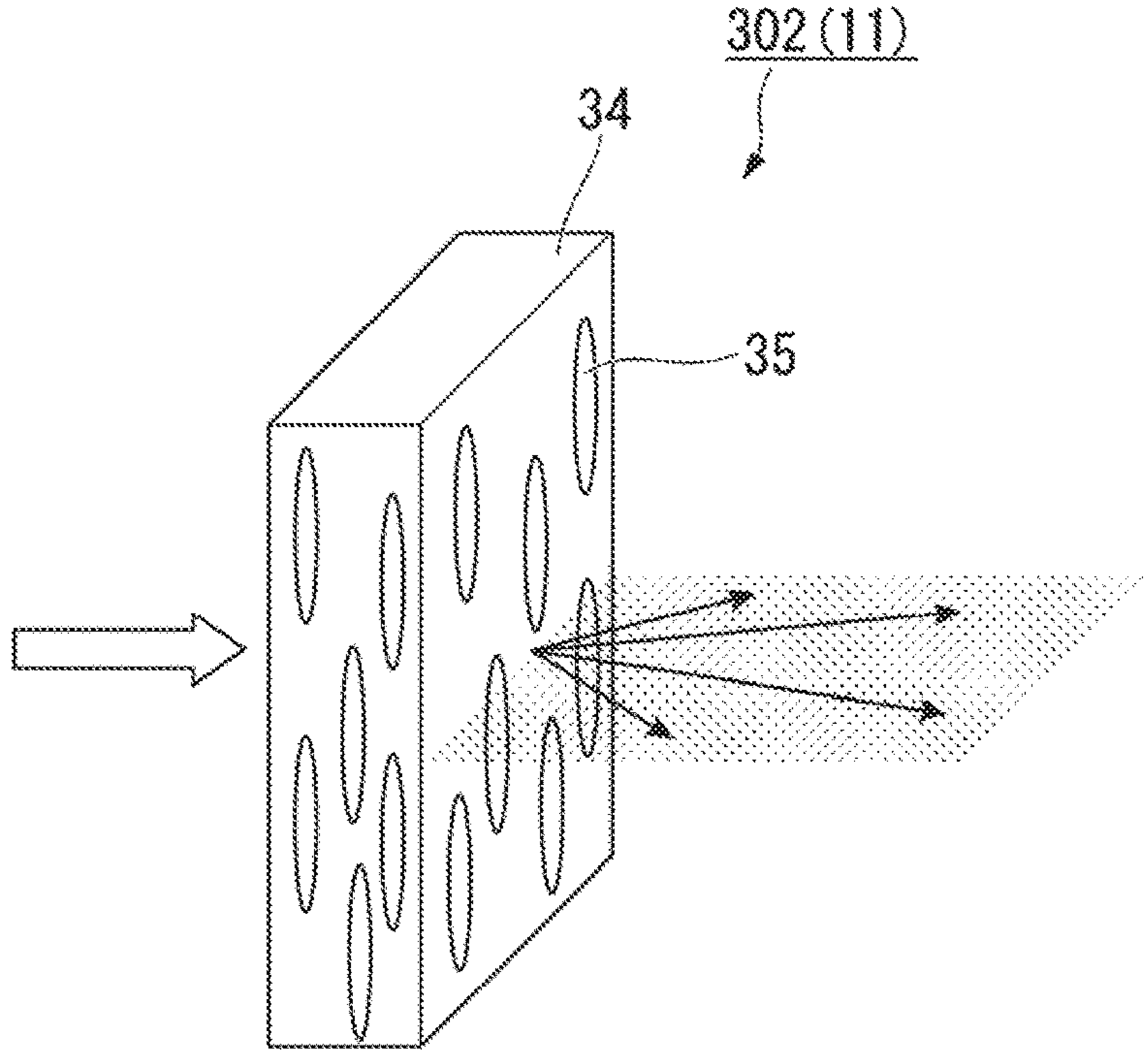

302(11)
34
35

FIG. 17

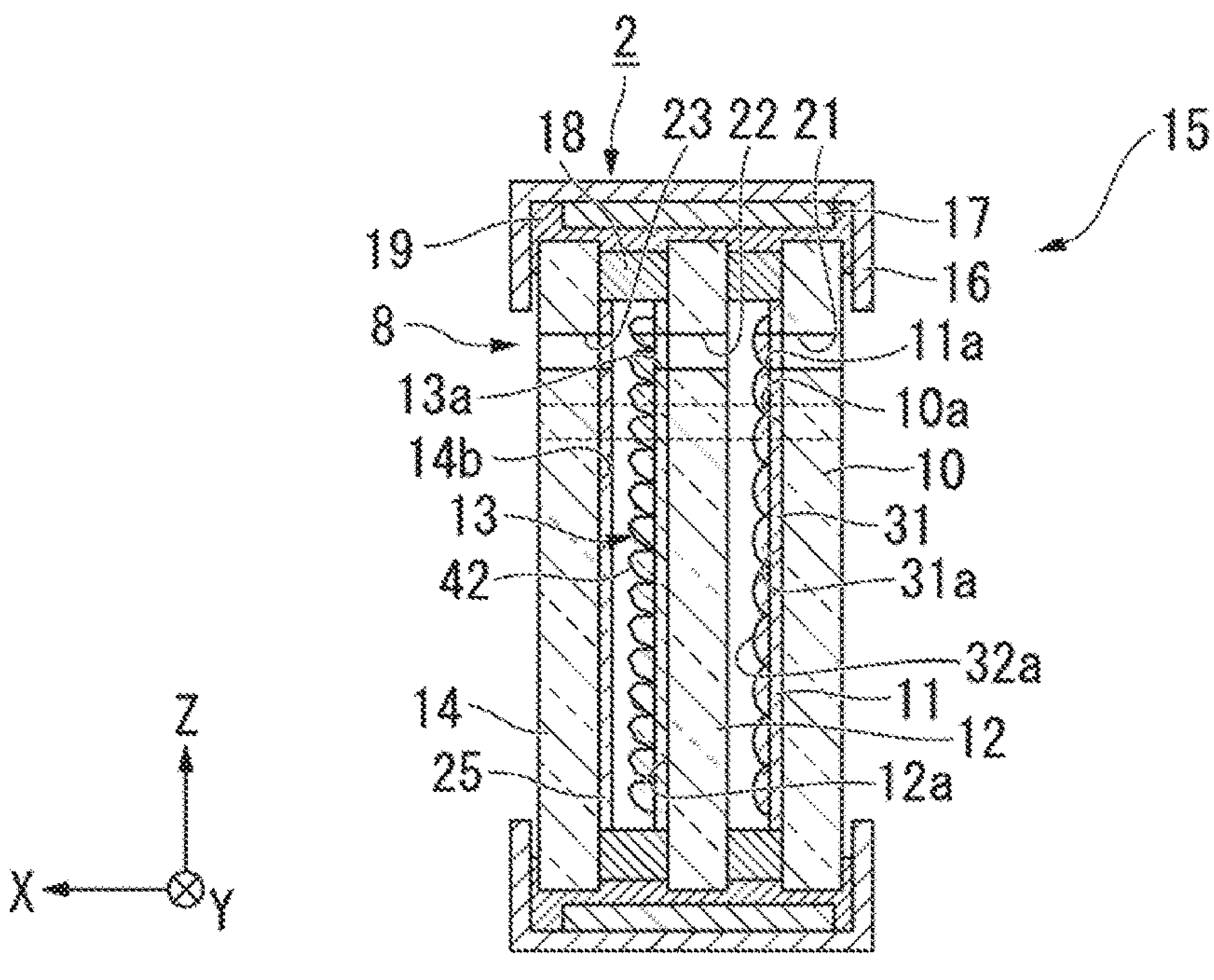

2
18
23
22
21
15
19
17
16
8
11a
13a
10a
14b
10
13
31
42
31a
32a
11
14
12
25
12a
Z
X
Y

FIG. 18A

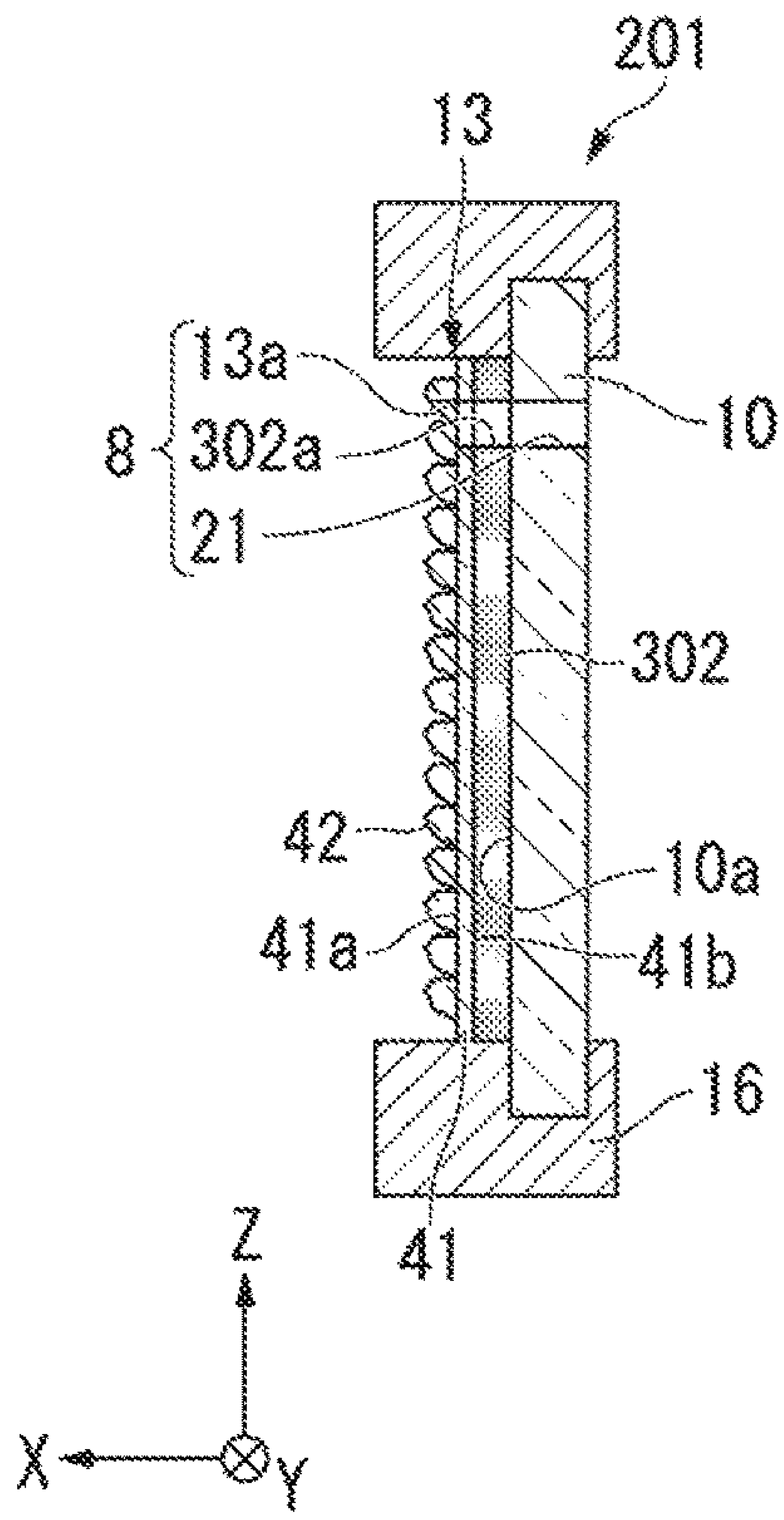


FIG. 18B

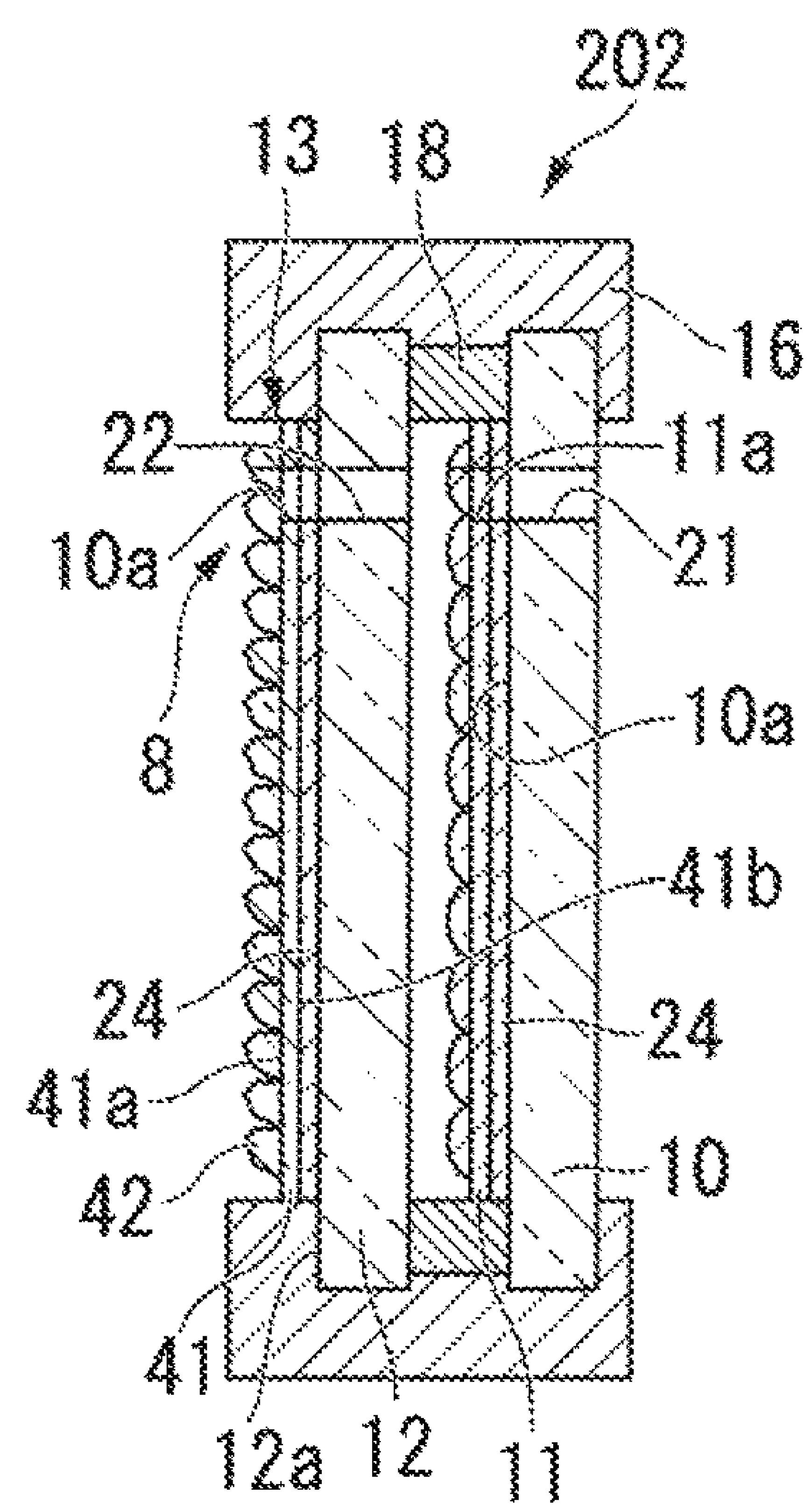


FIG. 18C

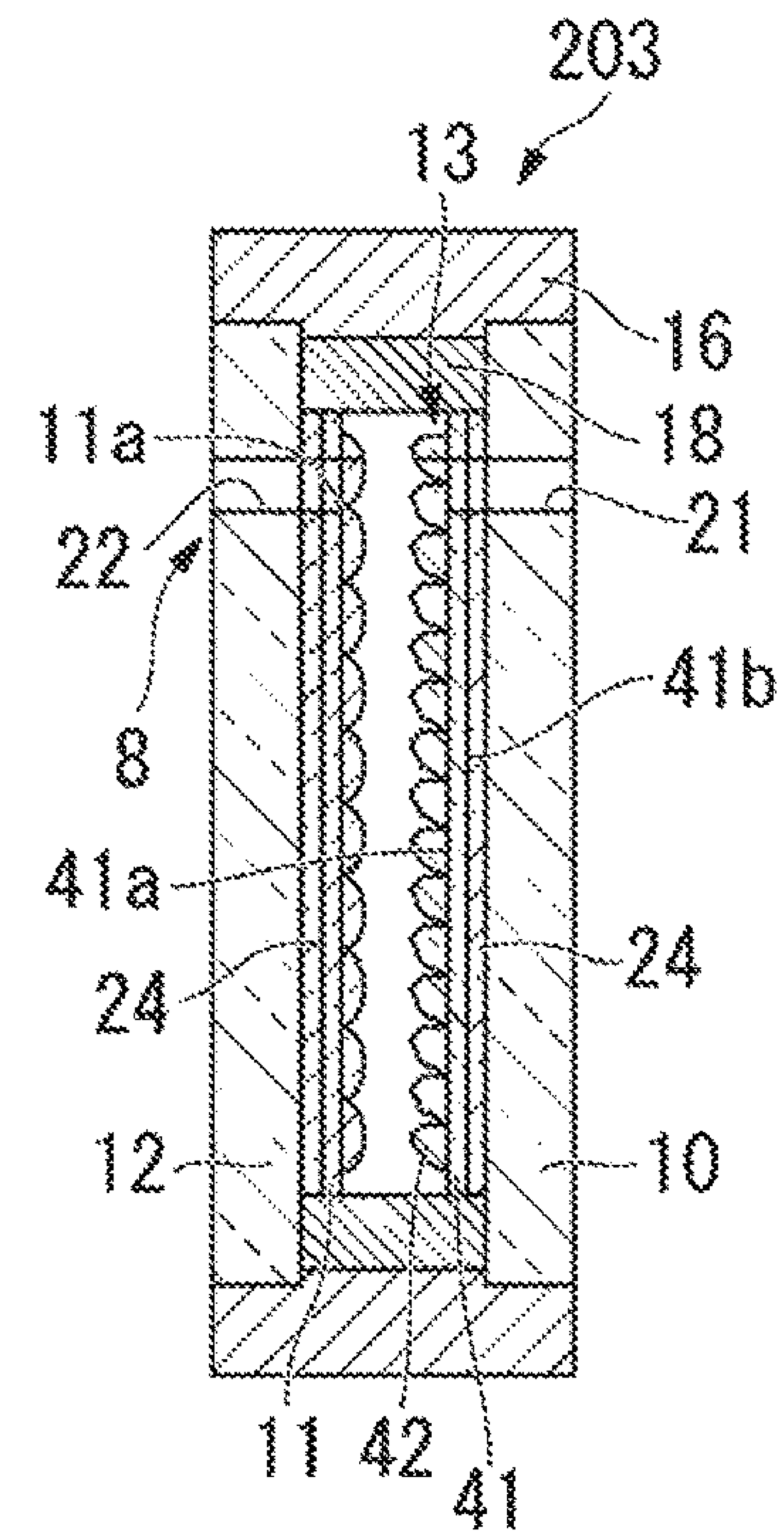


FIG. 18D

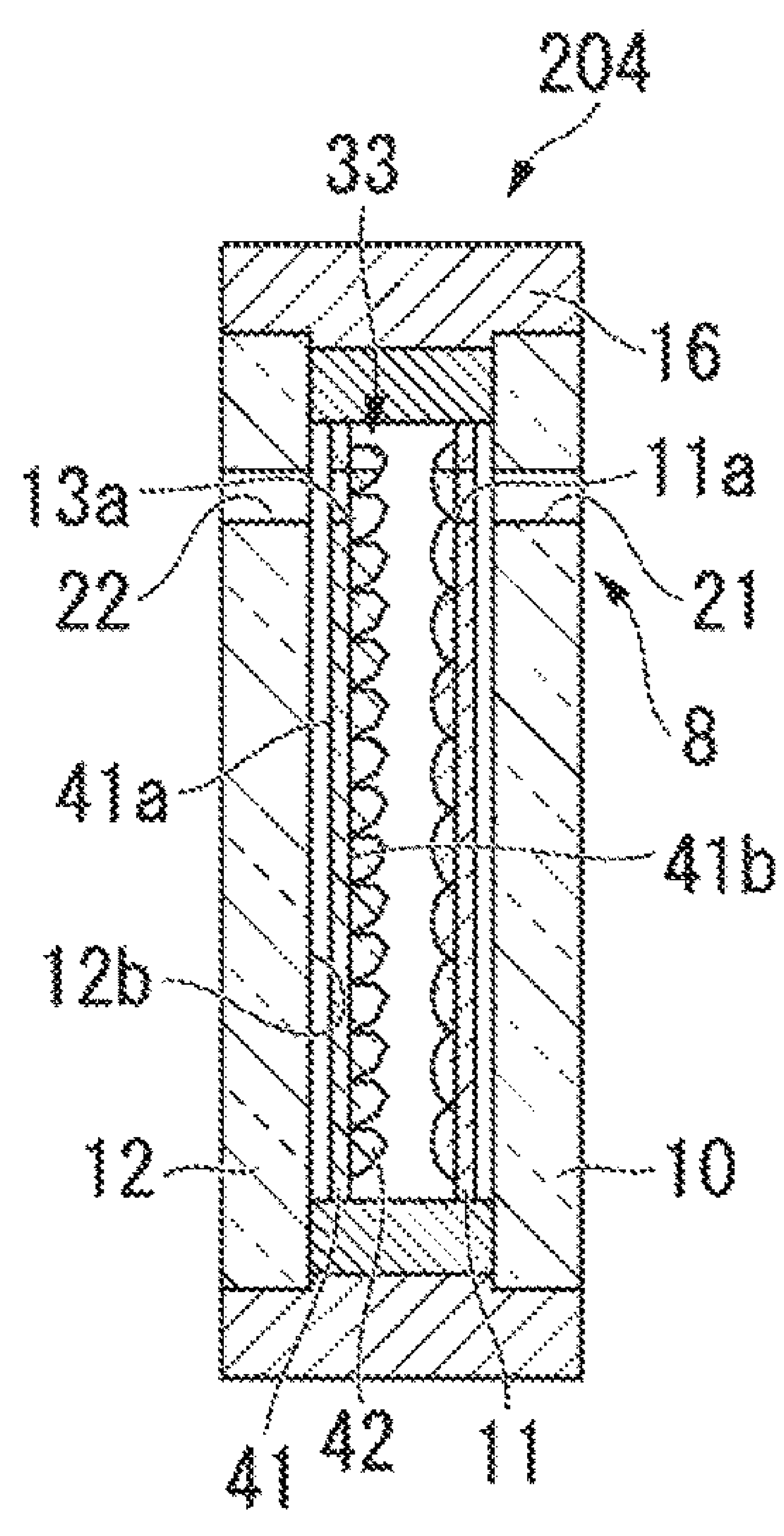


FIG. 19

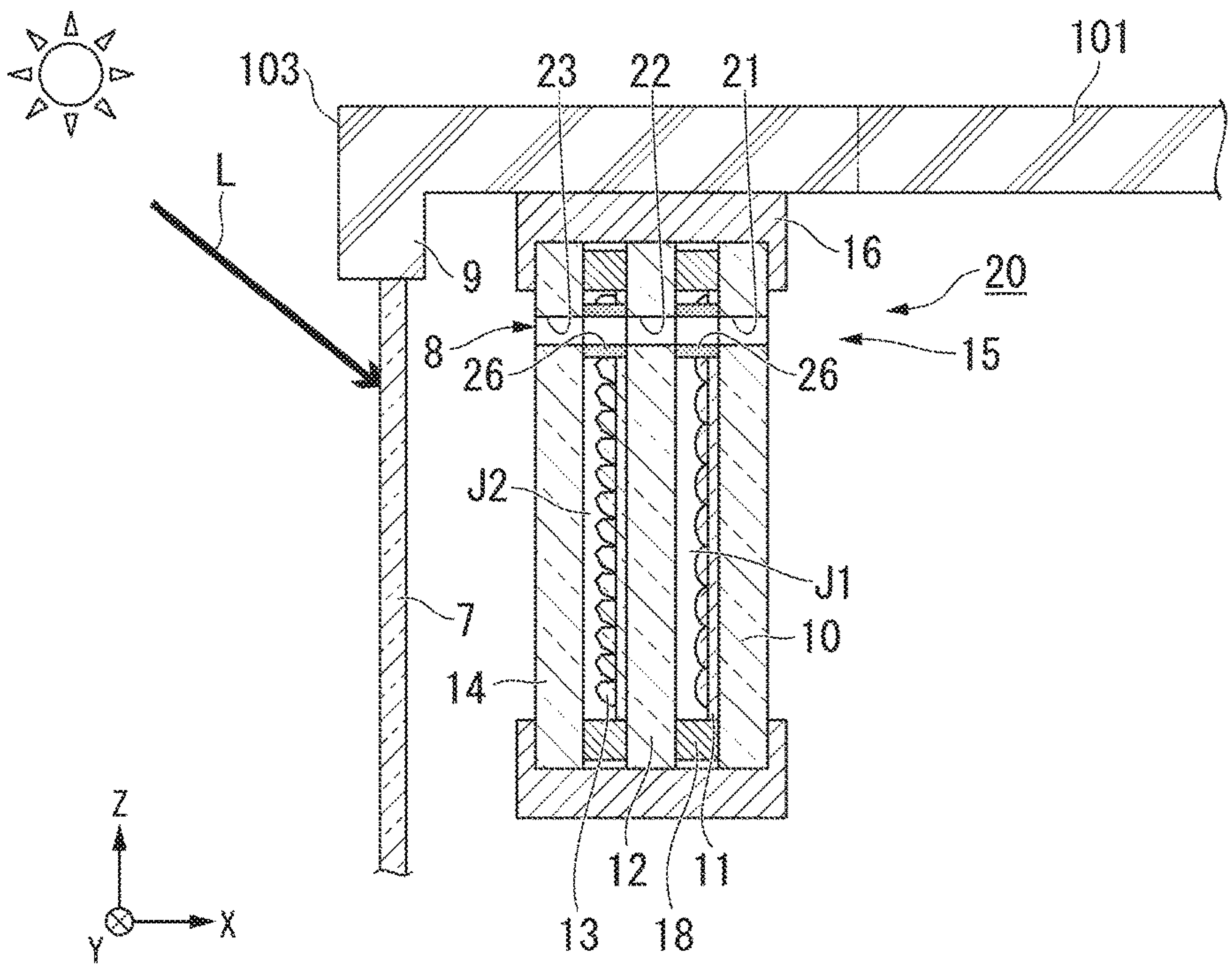


FIG. 20A

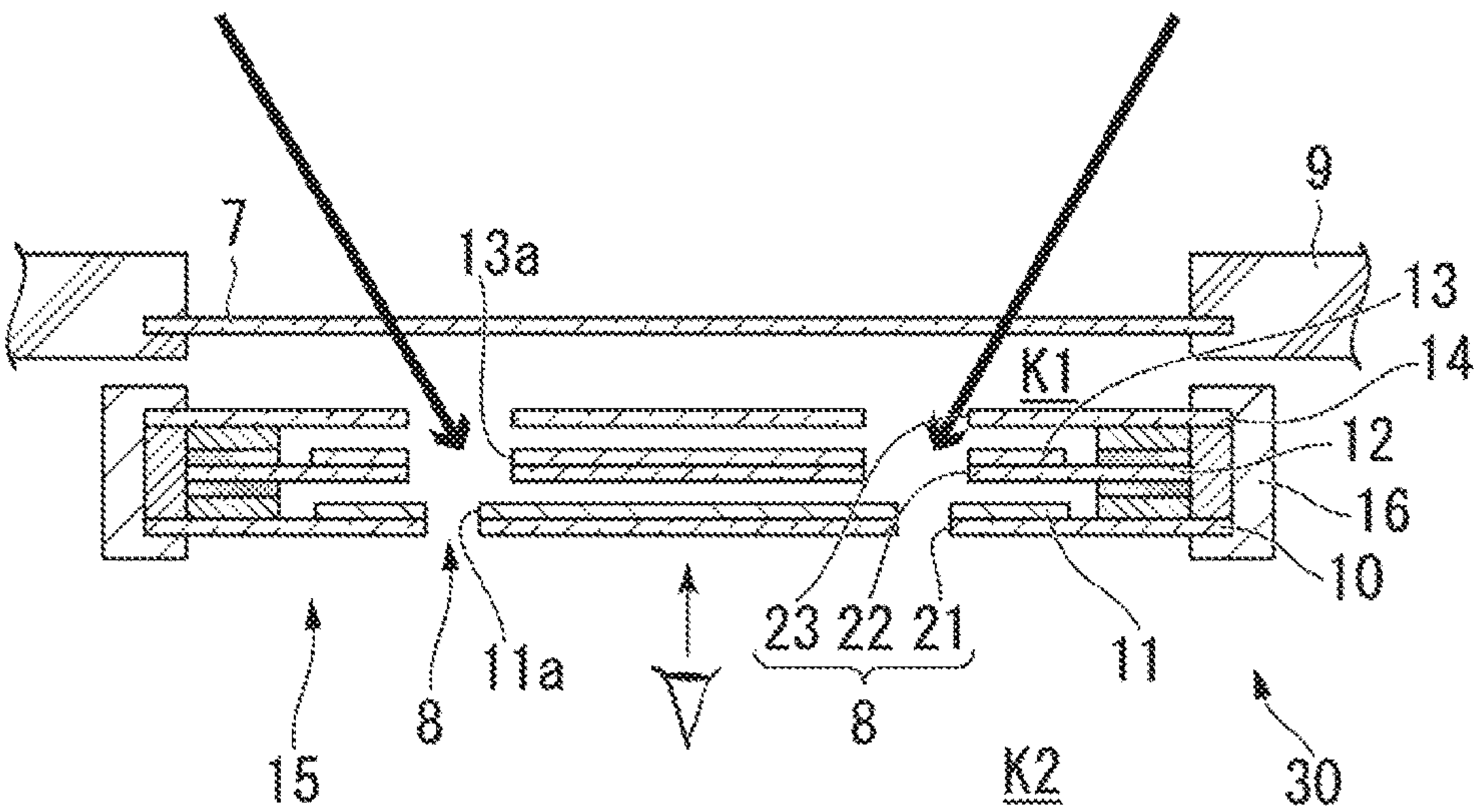


FIG. 20B

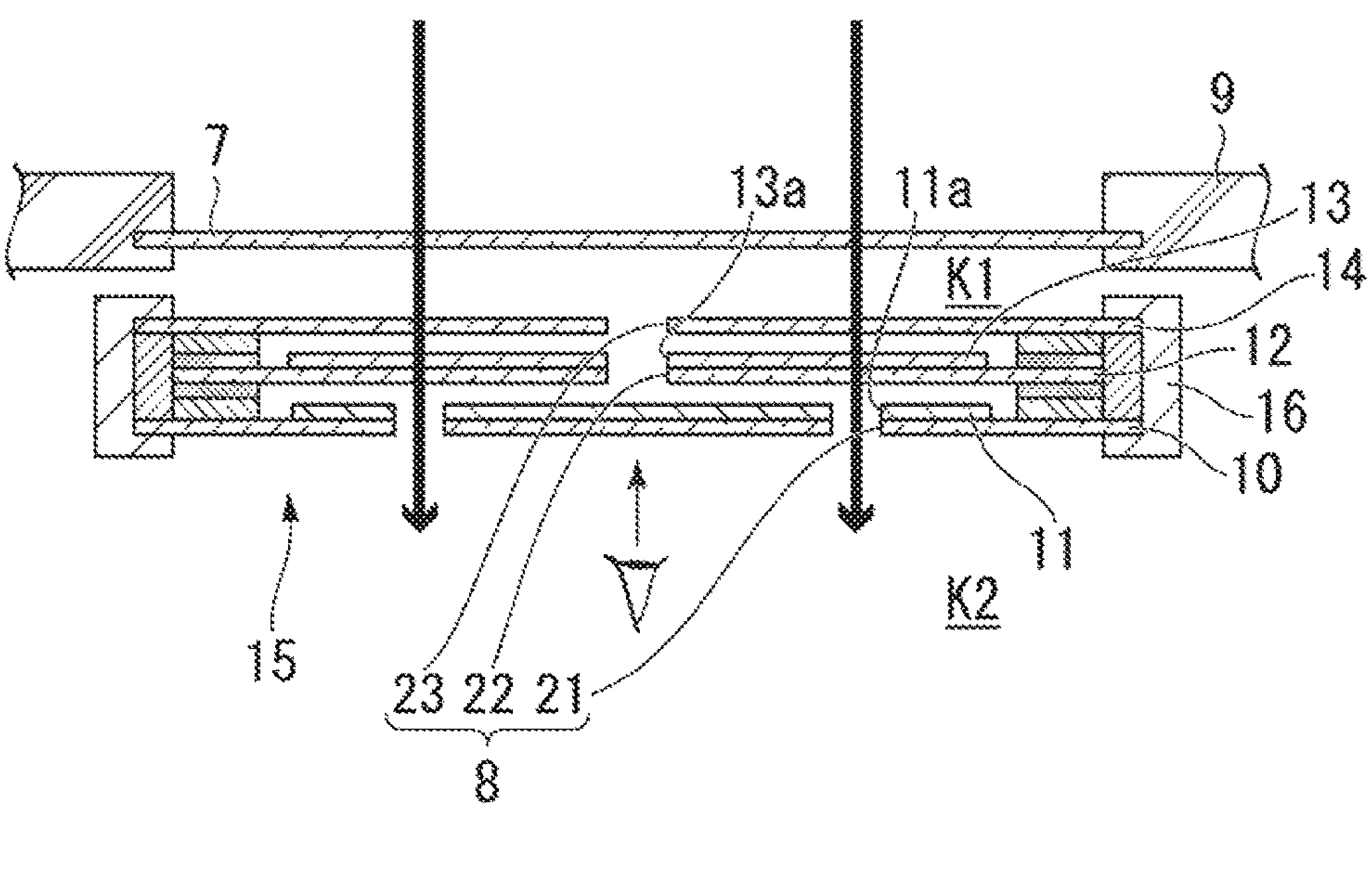


FIG. 21A

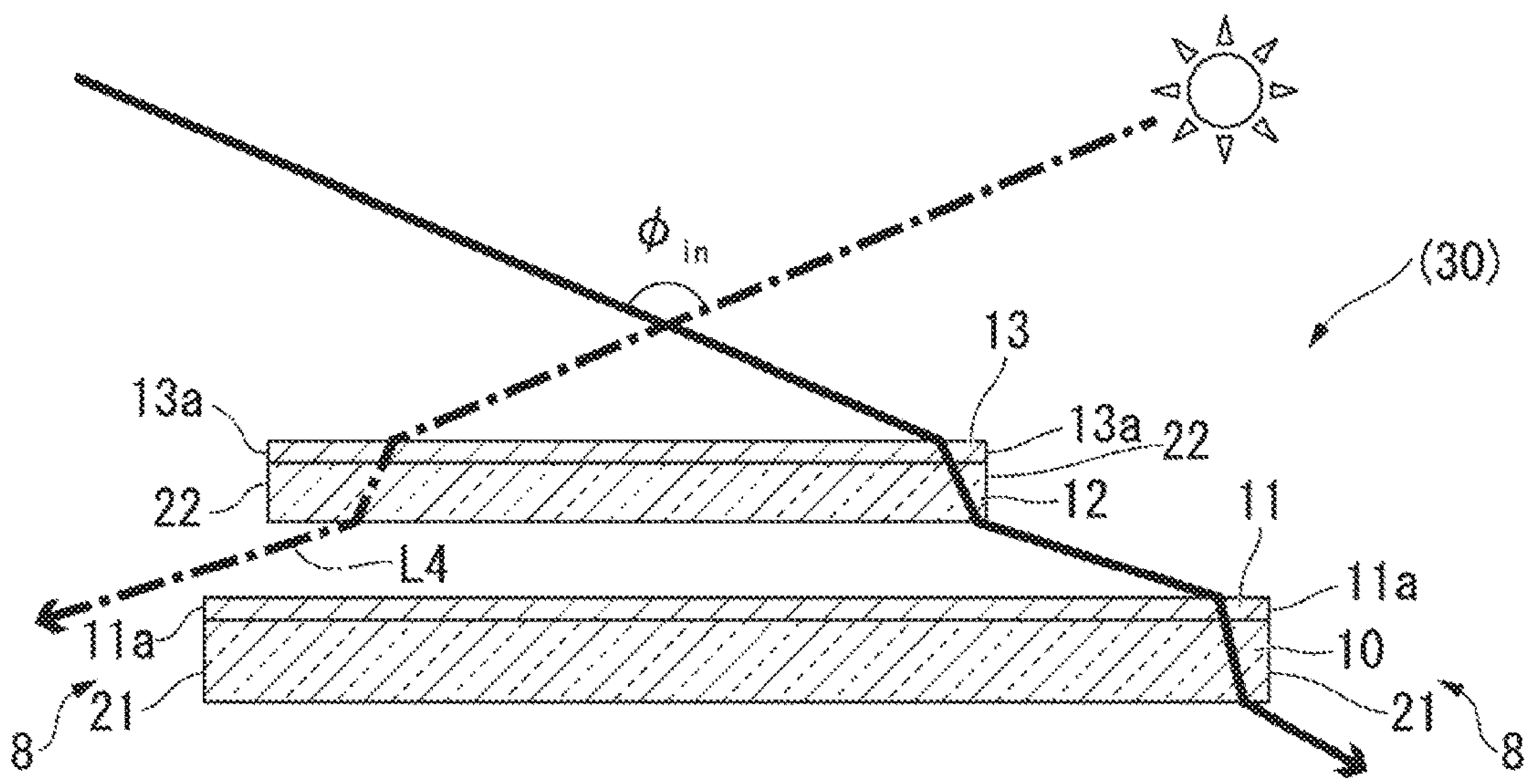


FIG. 21B

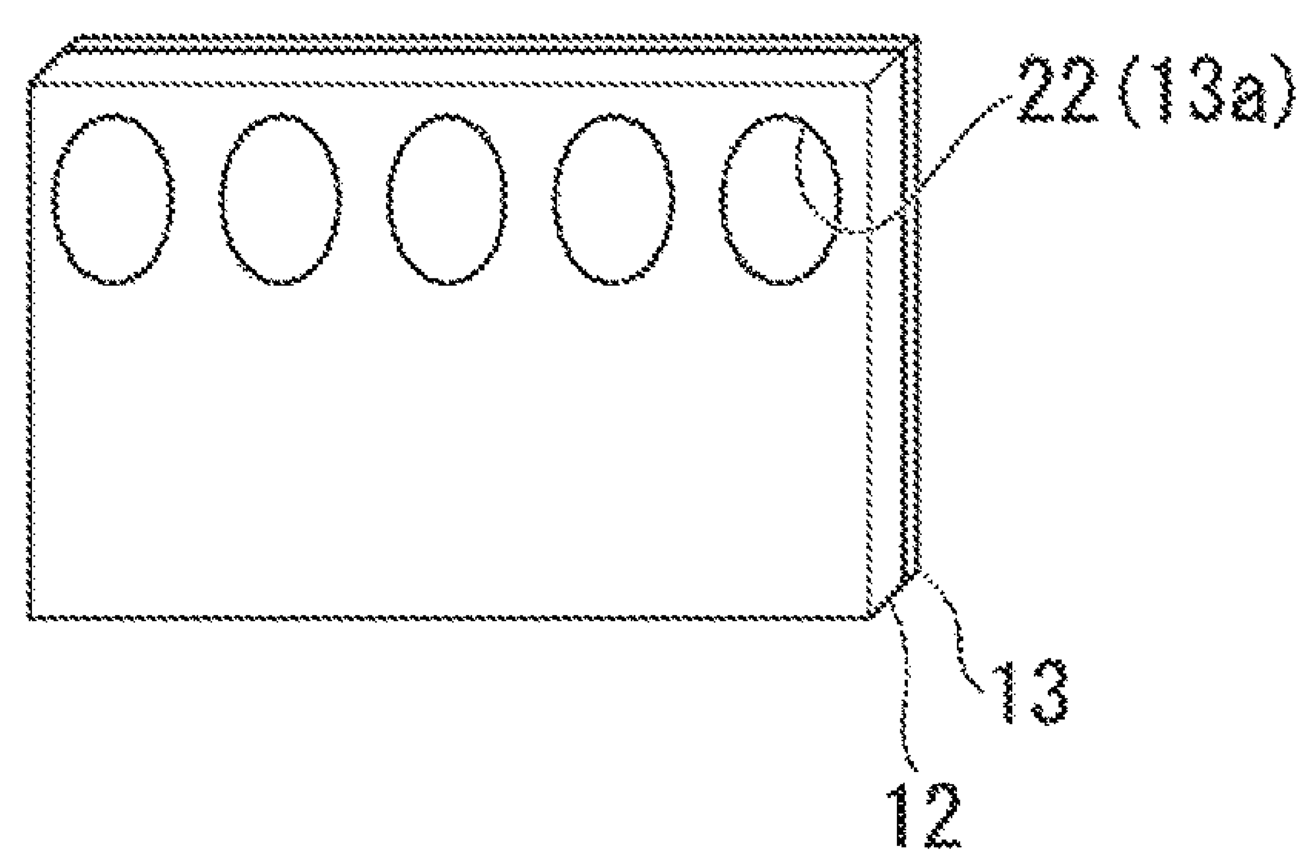


FIG. 21C

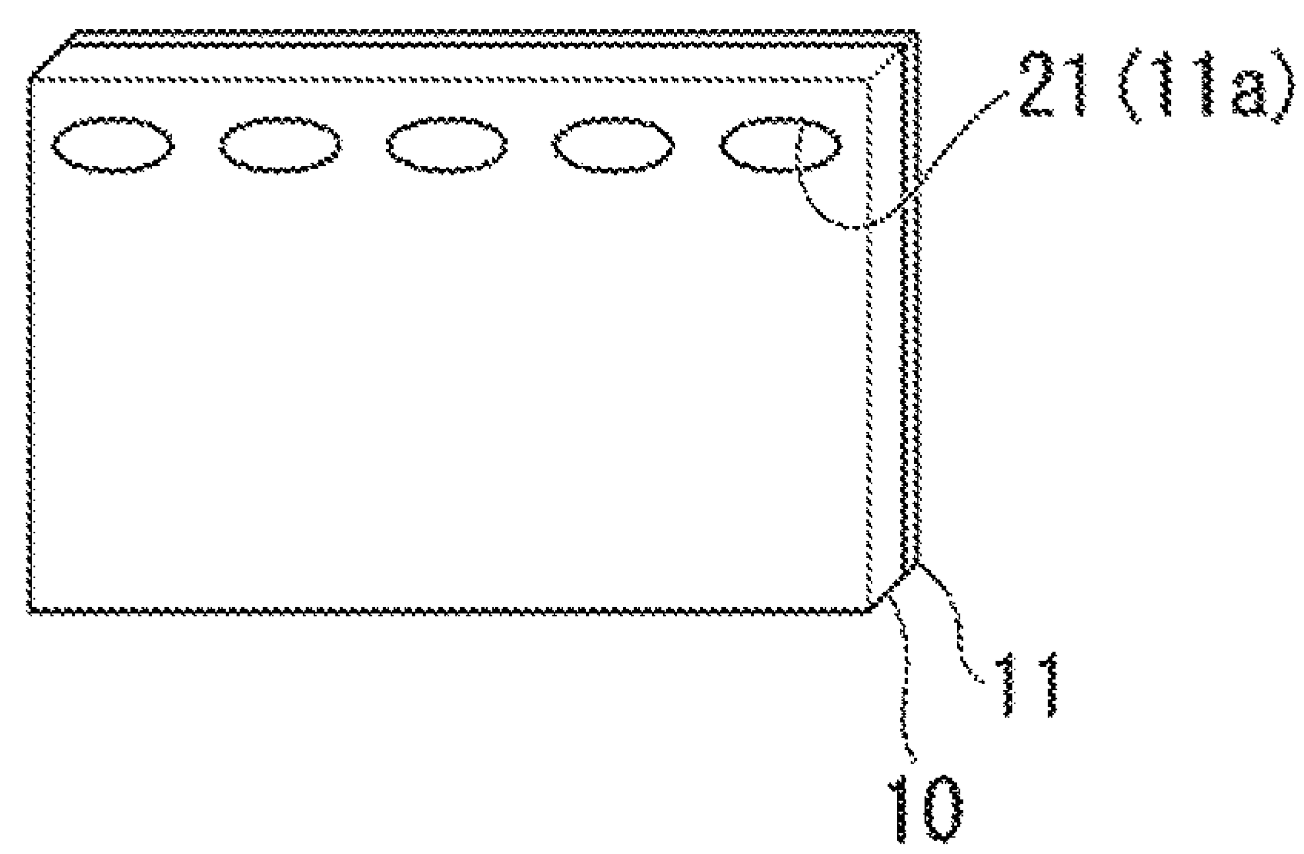


FIG. 22

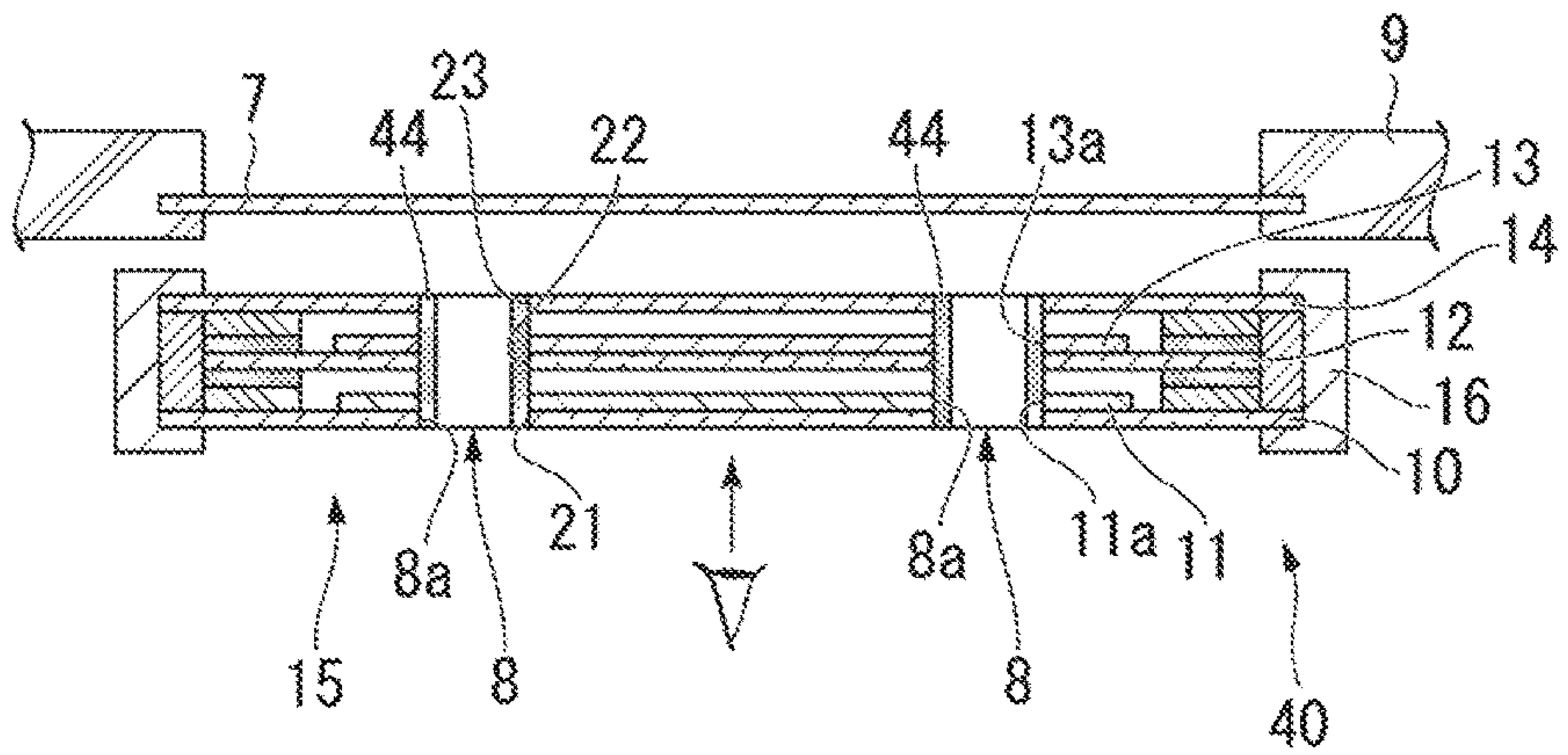

9
7
23
44
22
44
13a
13
14
12
16
10
8a
21
8a
11a
11
15
8
8
40

FIG. 23

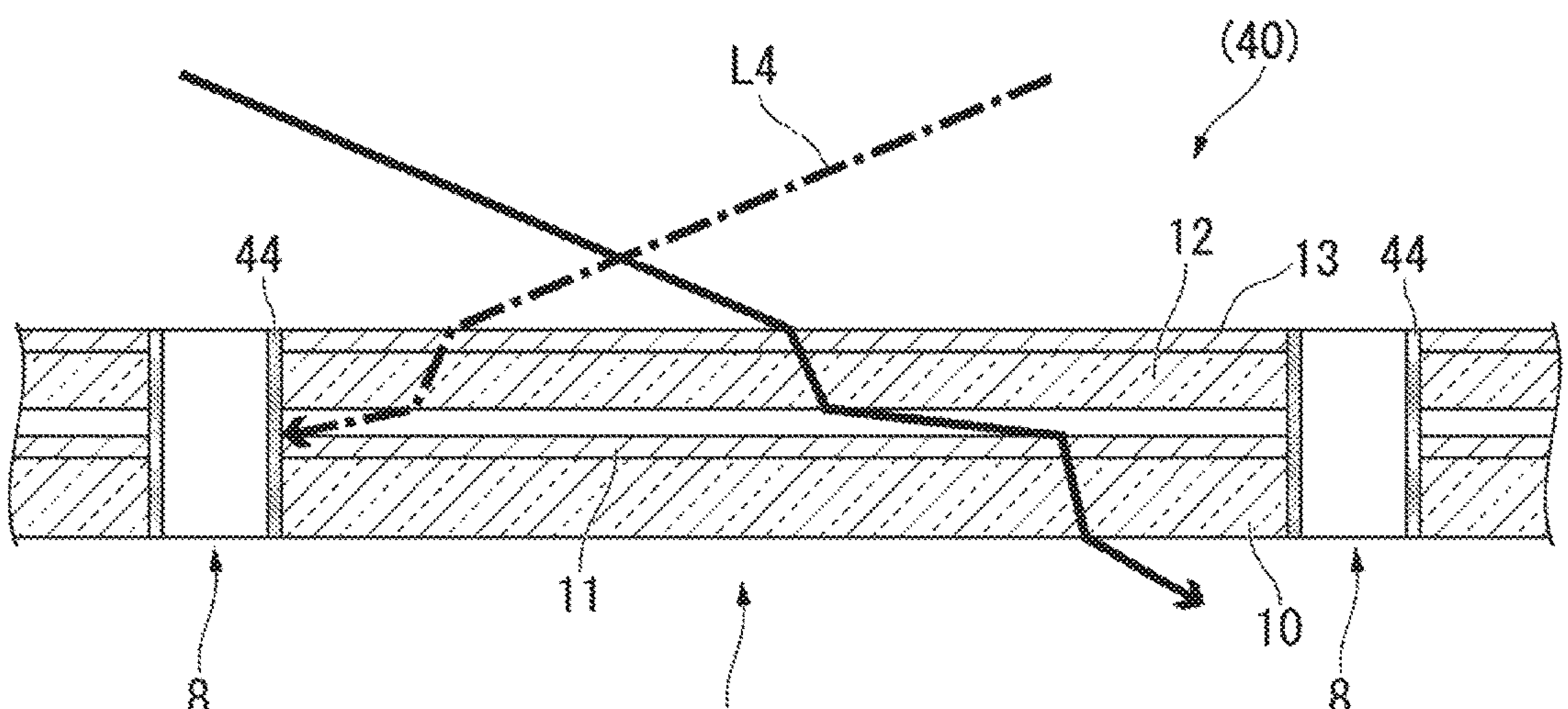

L4
(40)
44
12
13
44
8
11
15
10
8

FIG. 24

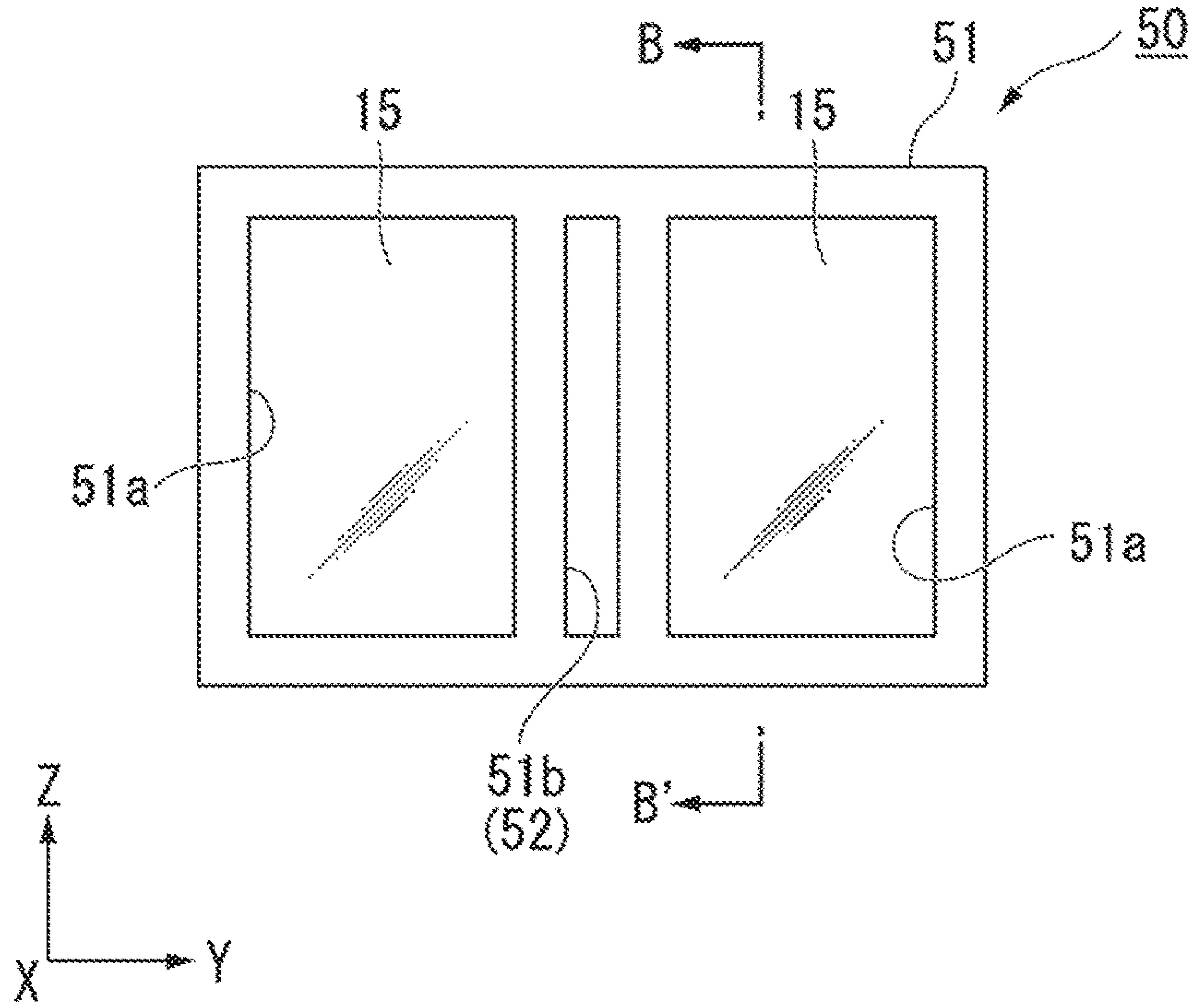


FIG. 25

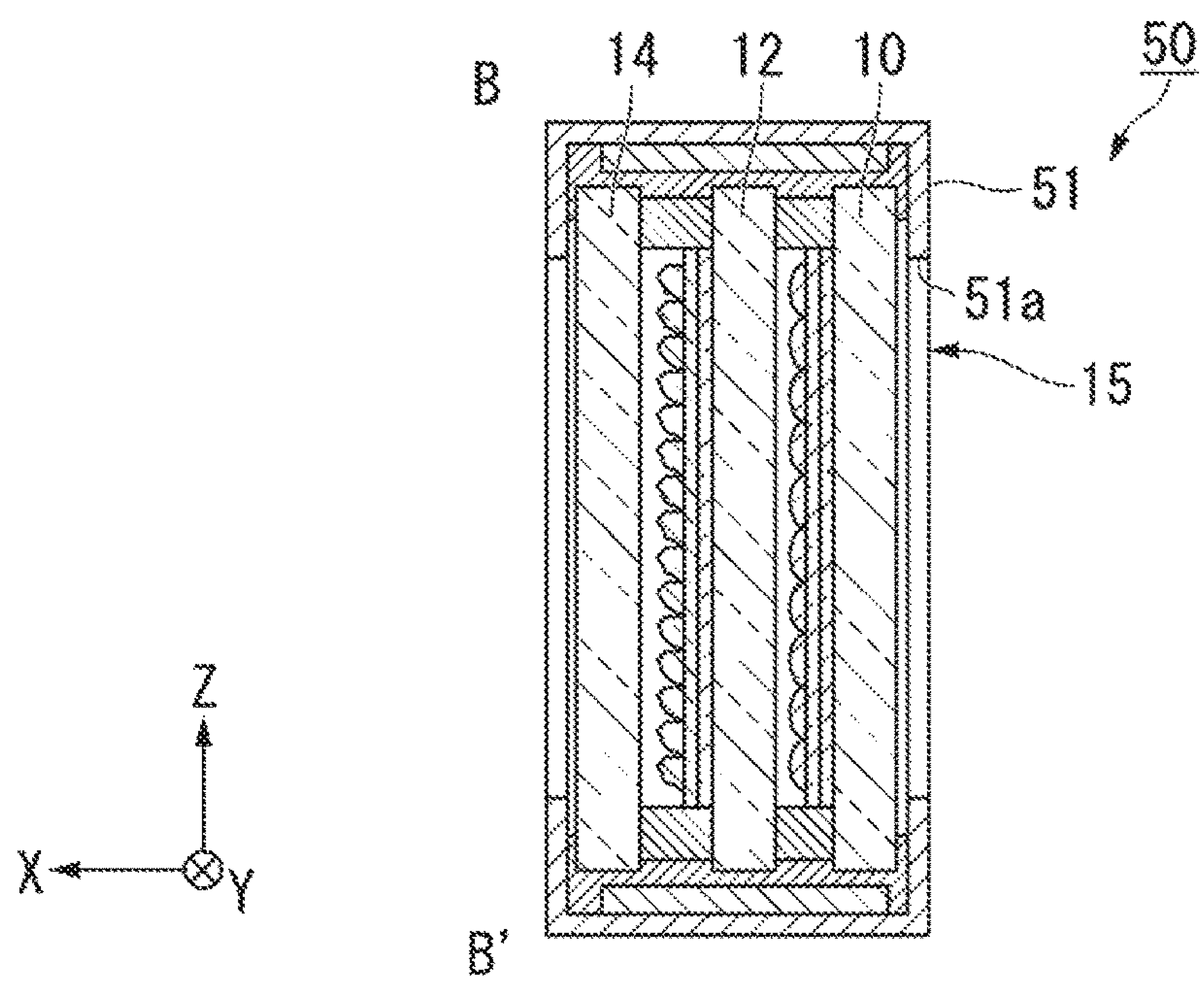


FIG. 26

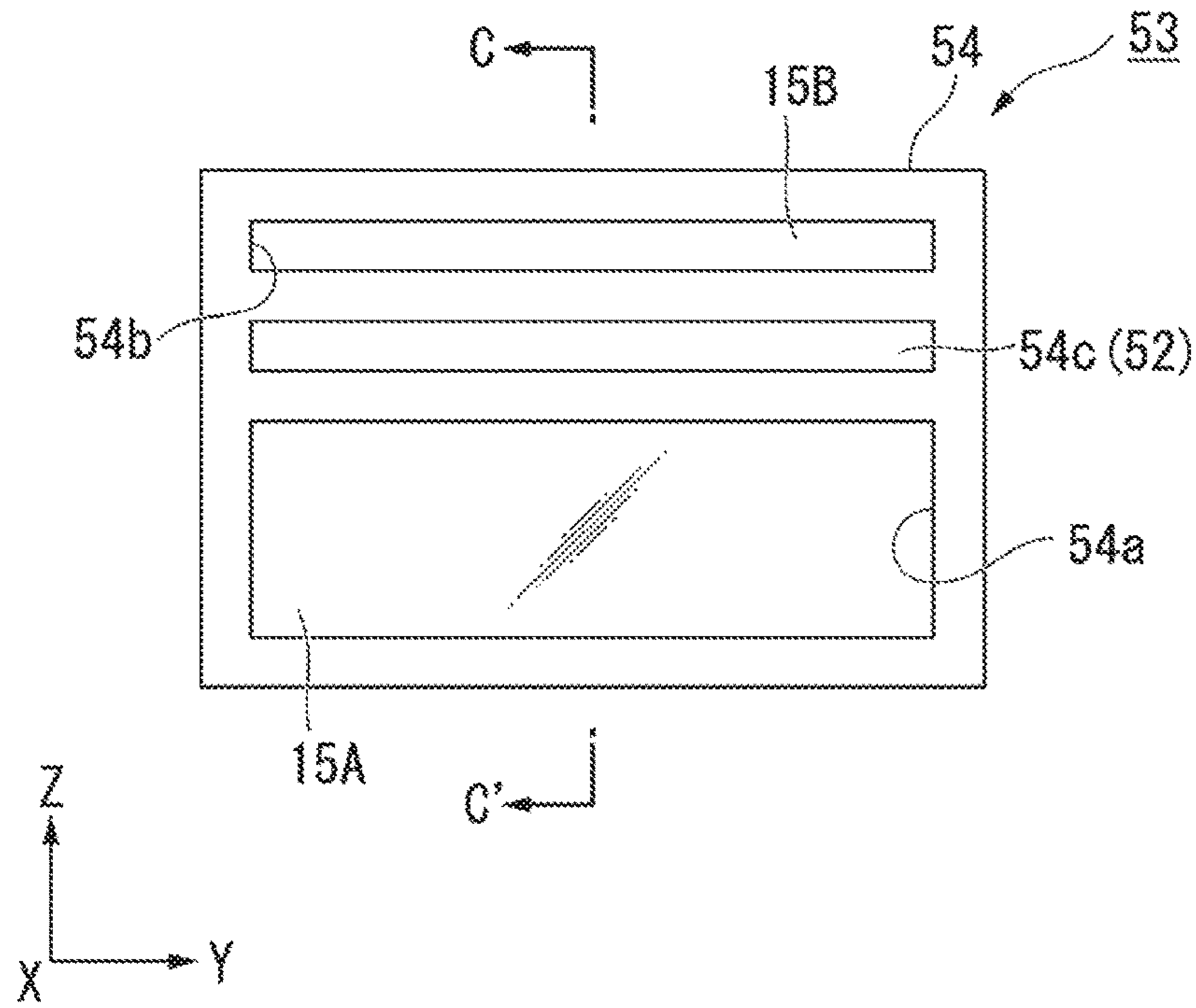

C
54
53
15B
54b
54c (52)
54a
15A
C'
Z
Y
X

FIG. 27

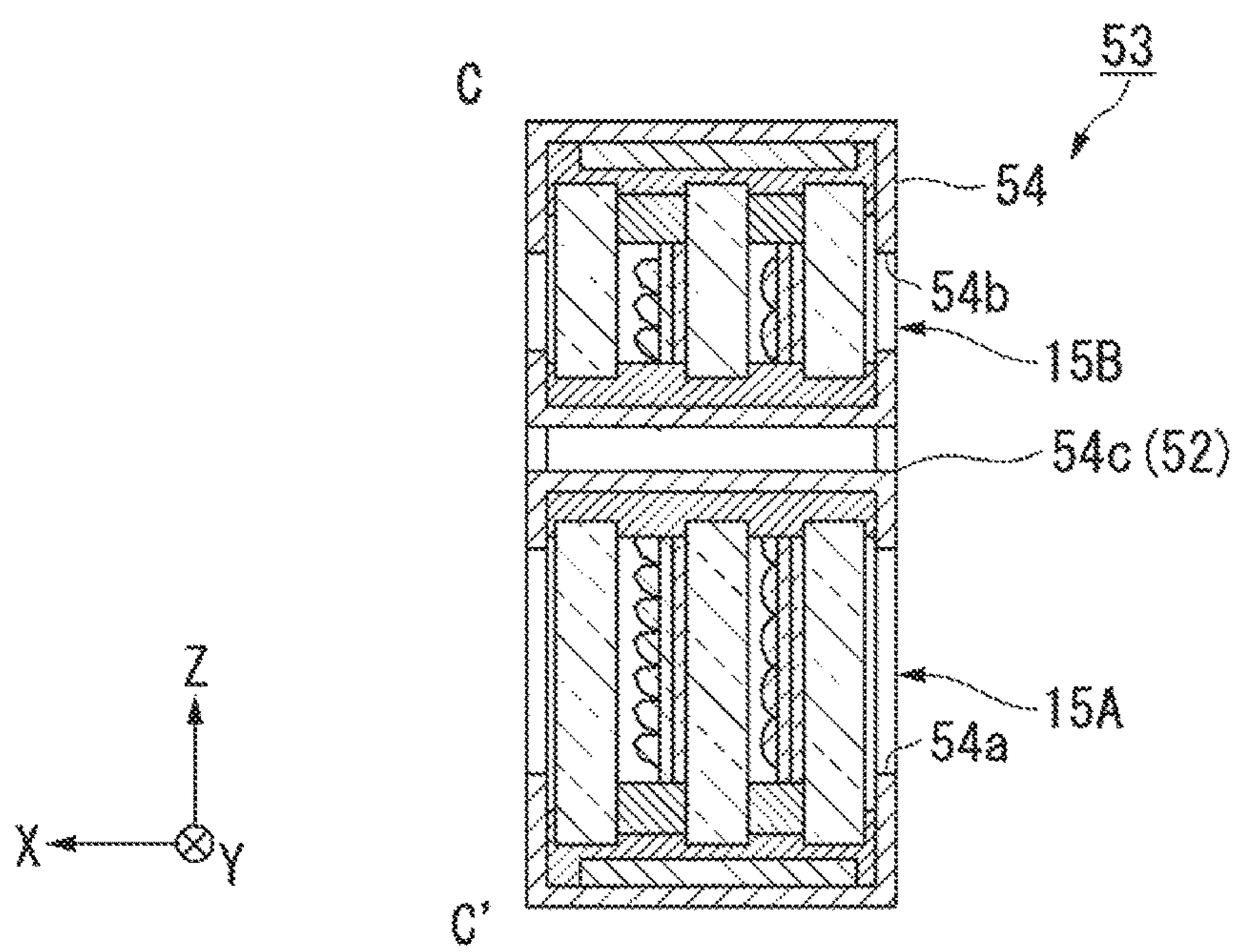

53
C
54
54b
15B
54c (52)
15A
54a
Z
X
Y
C'

FIG. 28

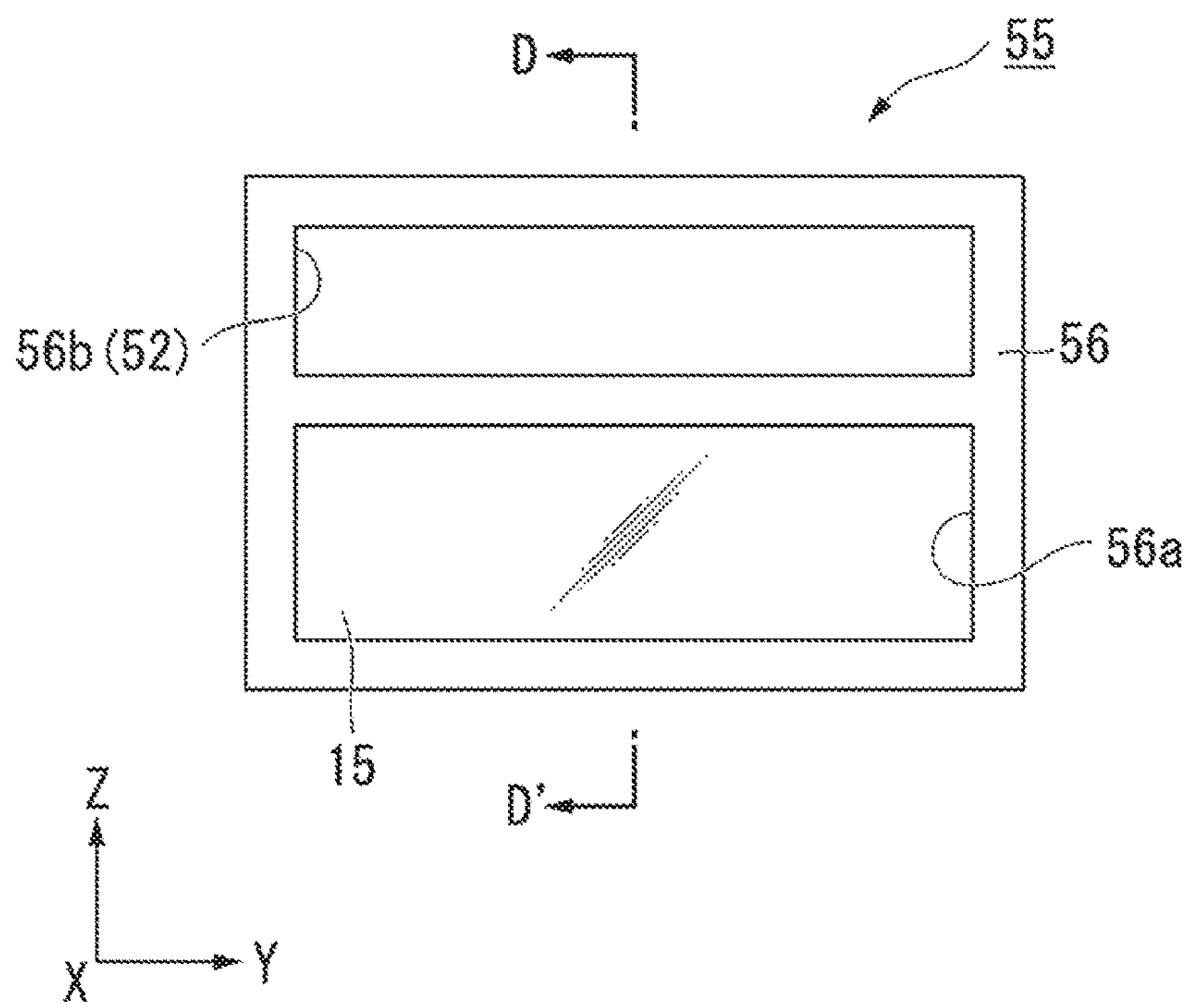


FIG. 29

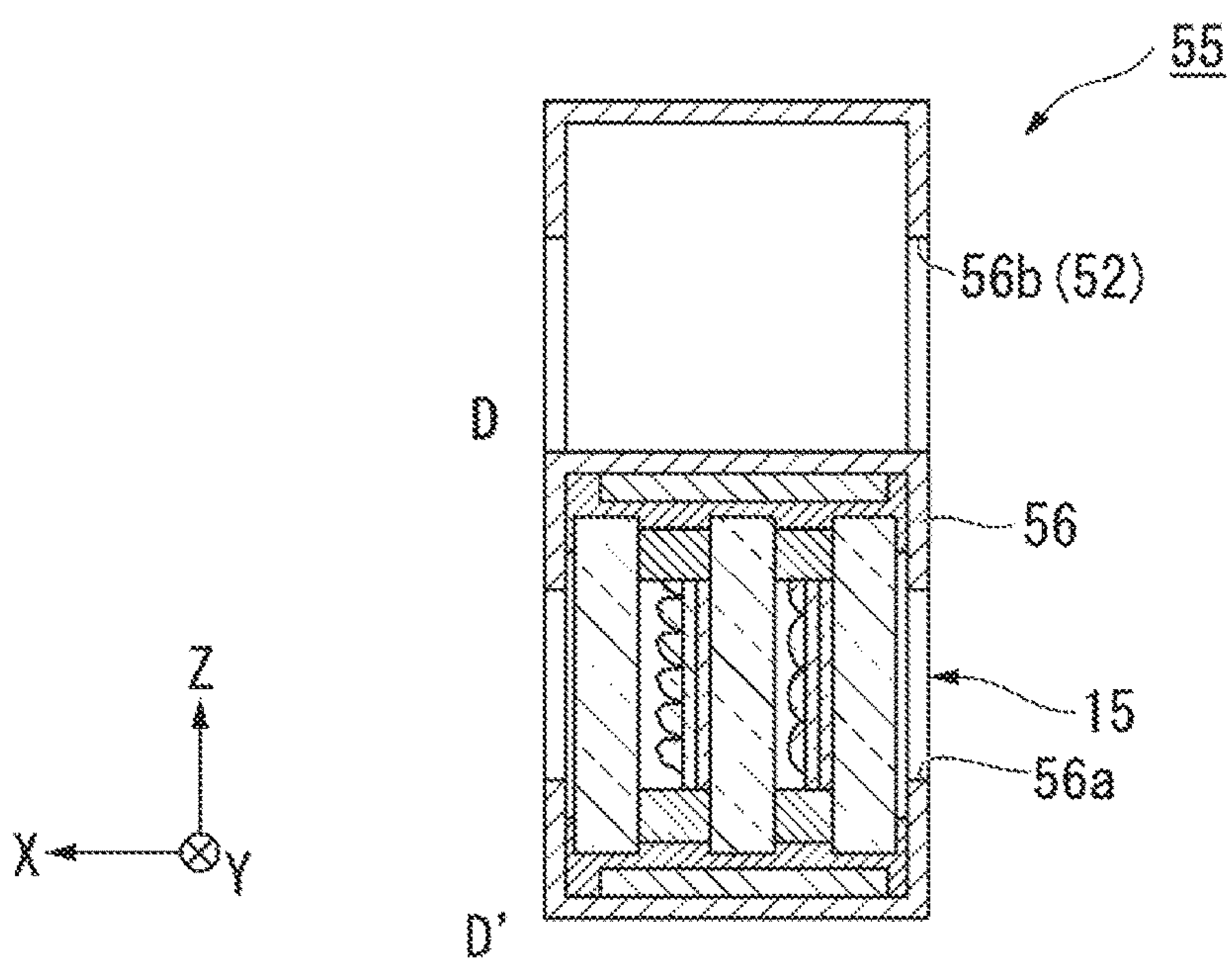


FIG. 30

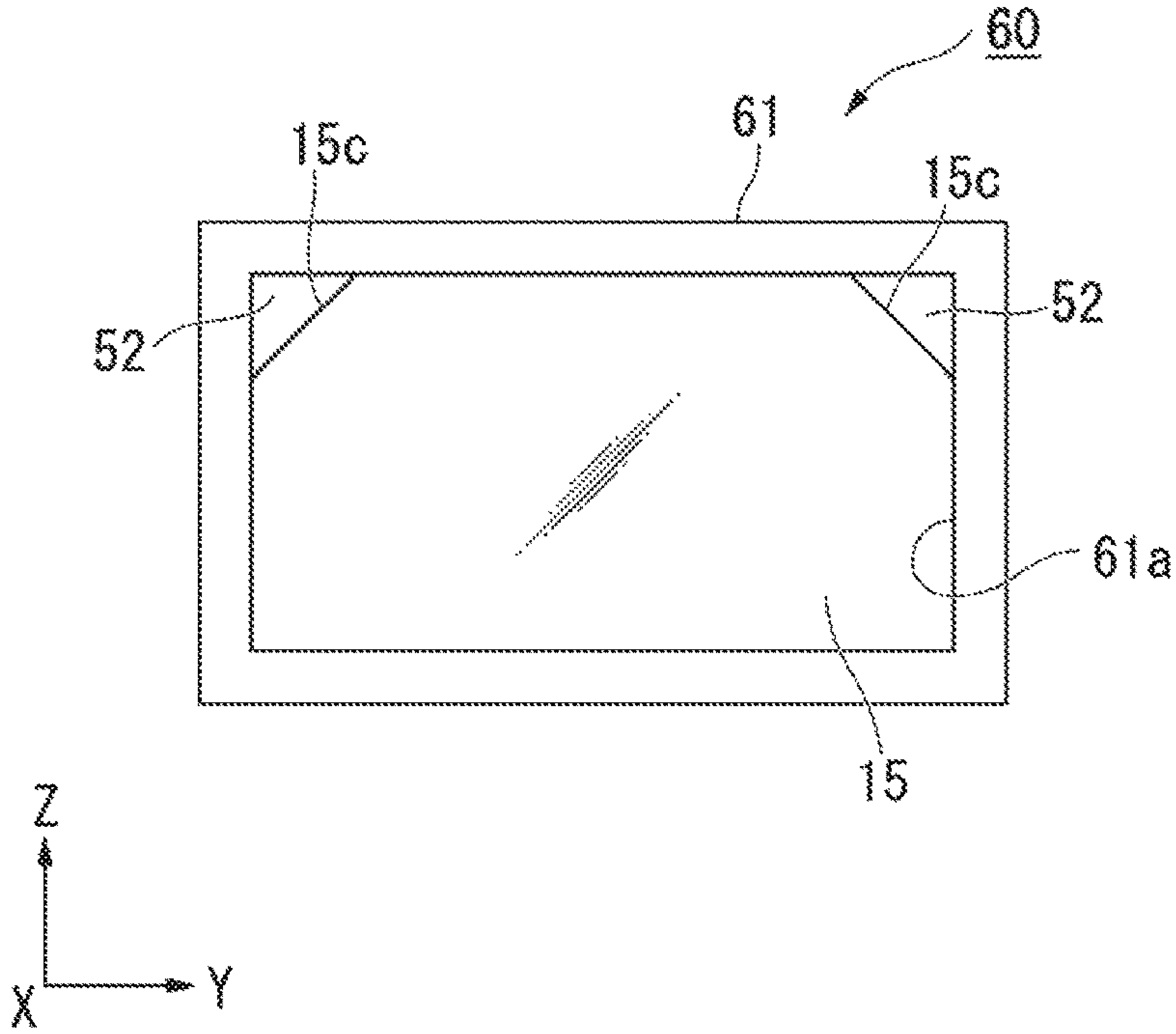


FIG. 31

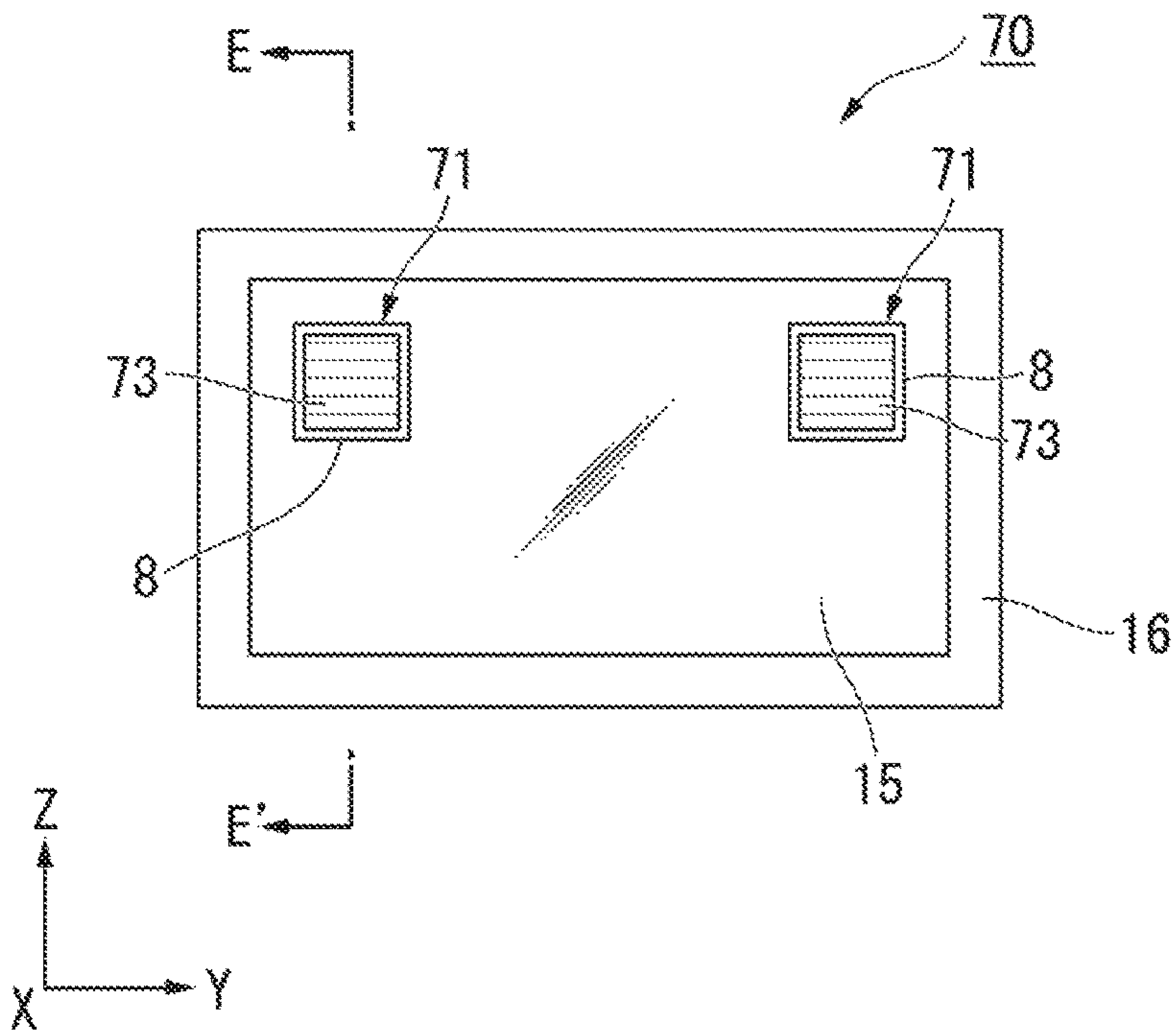


FIG. 32

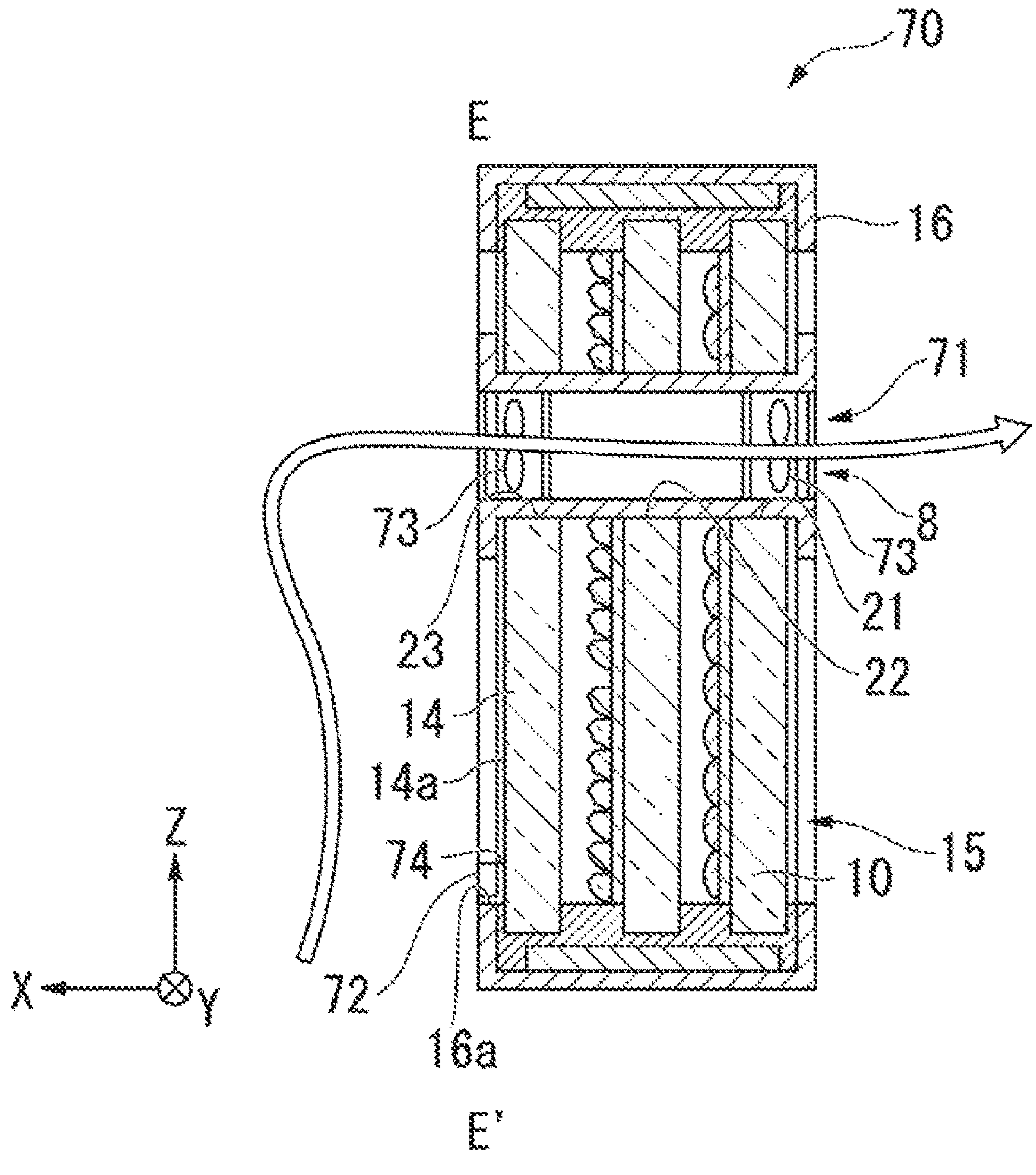


FIG. 33A

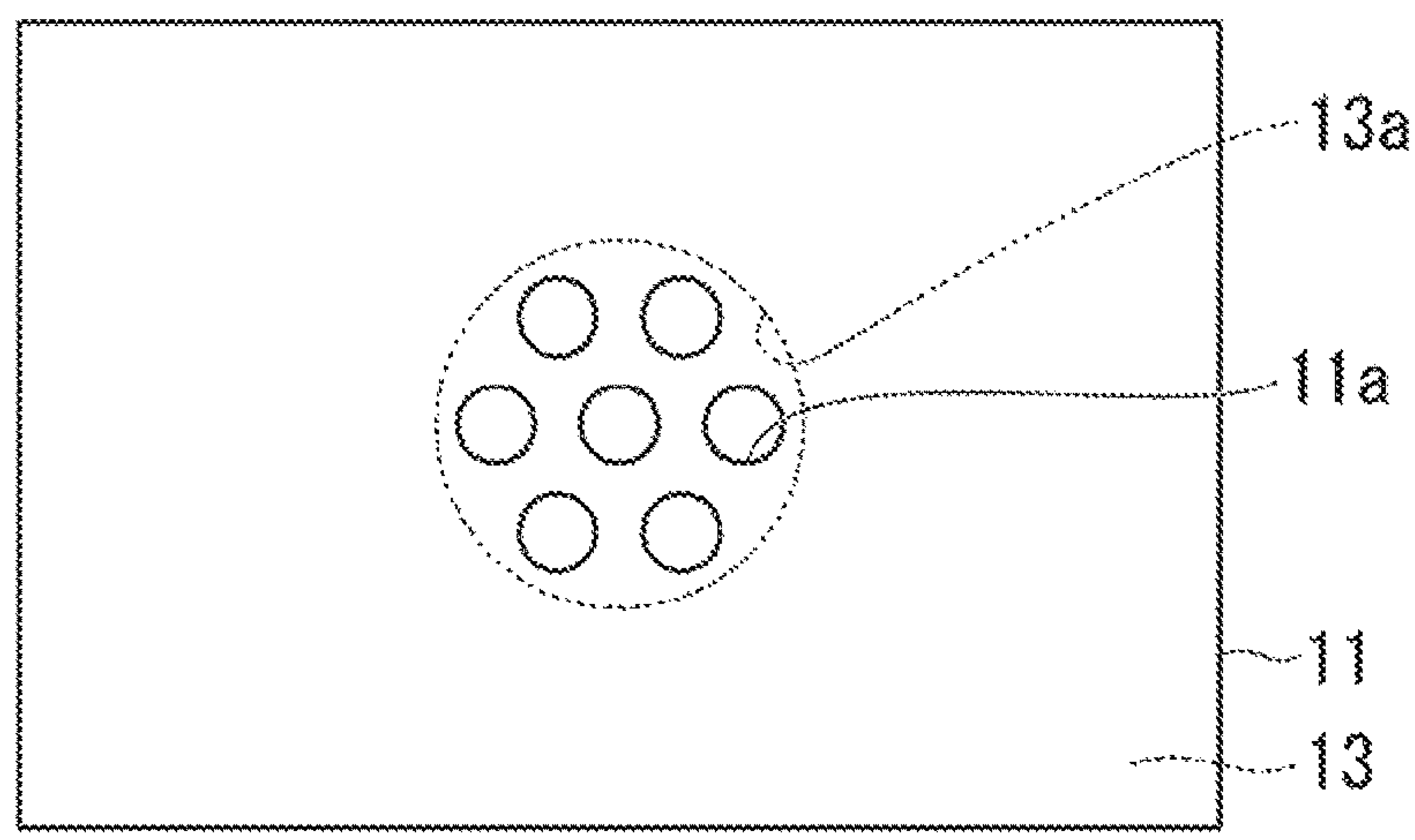


FIG. 33B

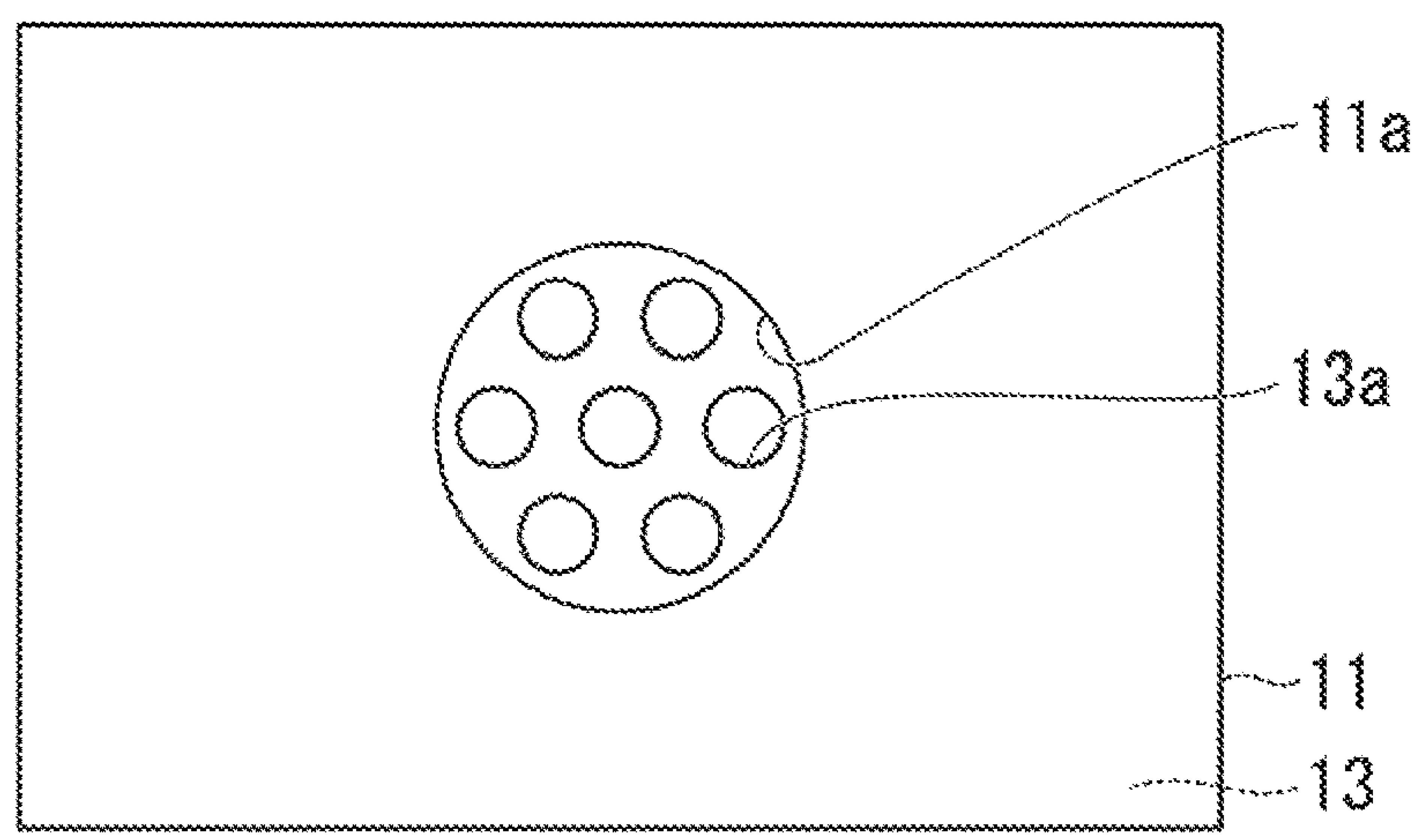
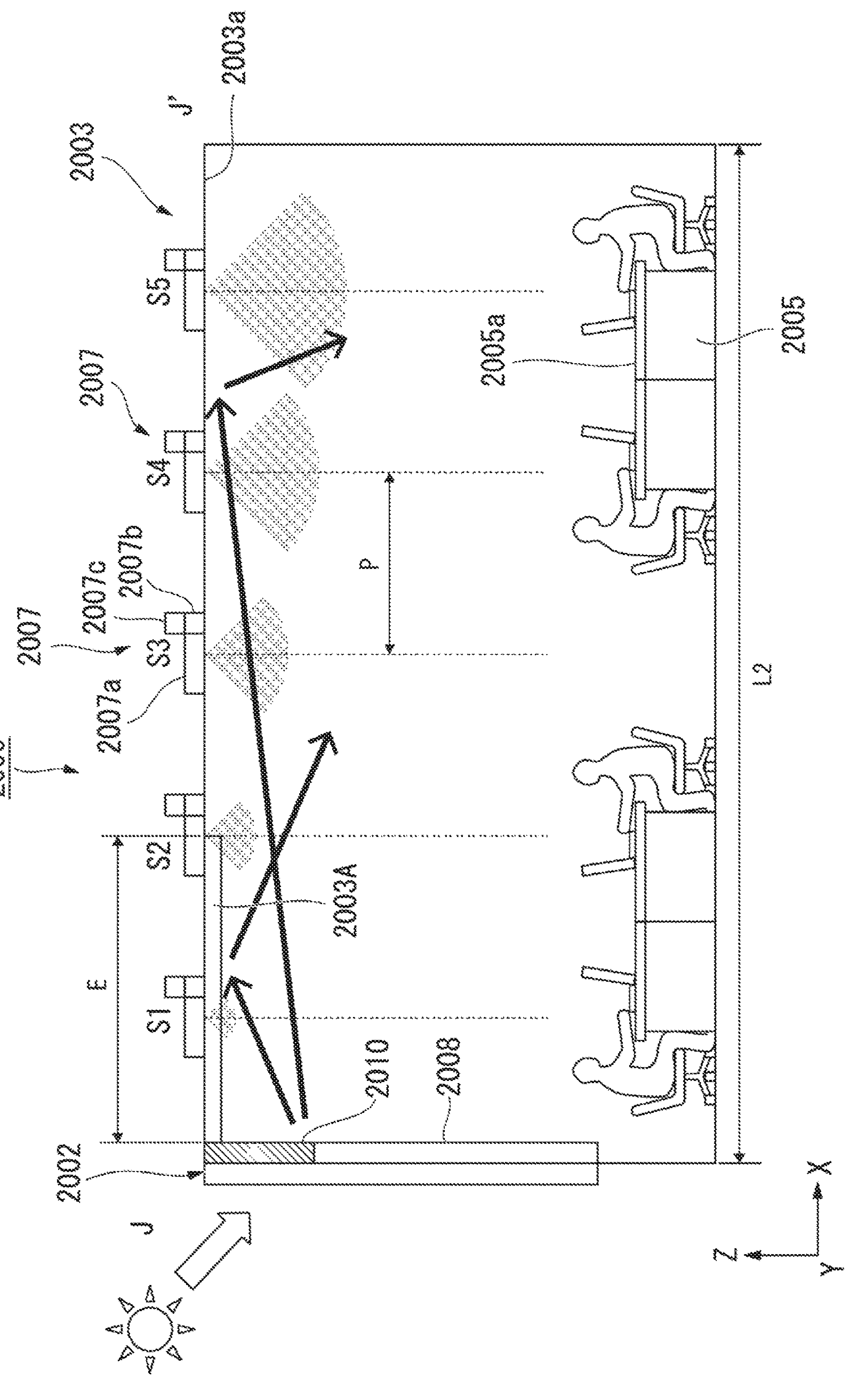


FIG. 34


2000
2002
2003
2003a
2003A
J'
J
S1
S2
S3
S4
S5
2005
2005a
2007
2007
2007a
2007b
2007c
2008
2010
E
P
L2
X
Y
Z

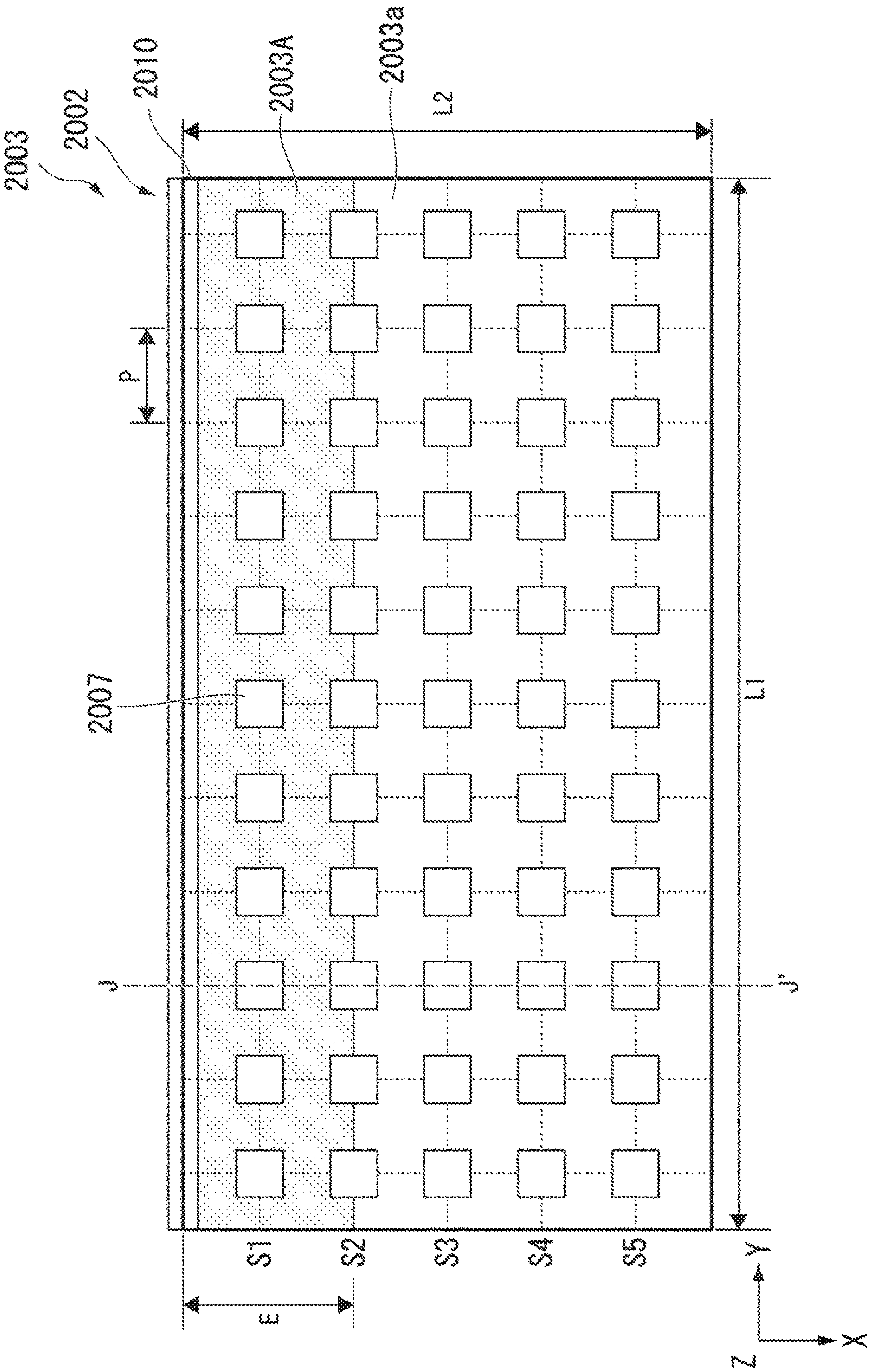


FIG. 35

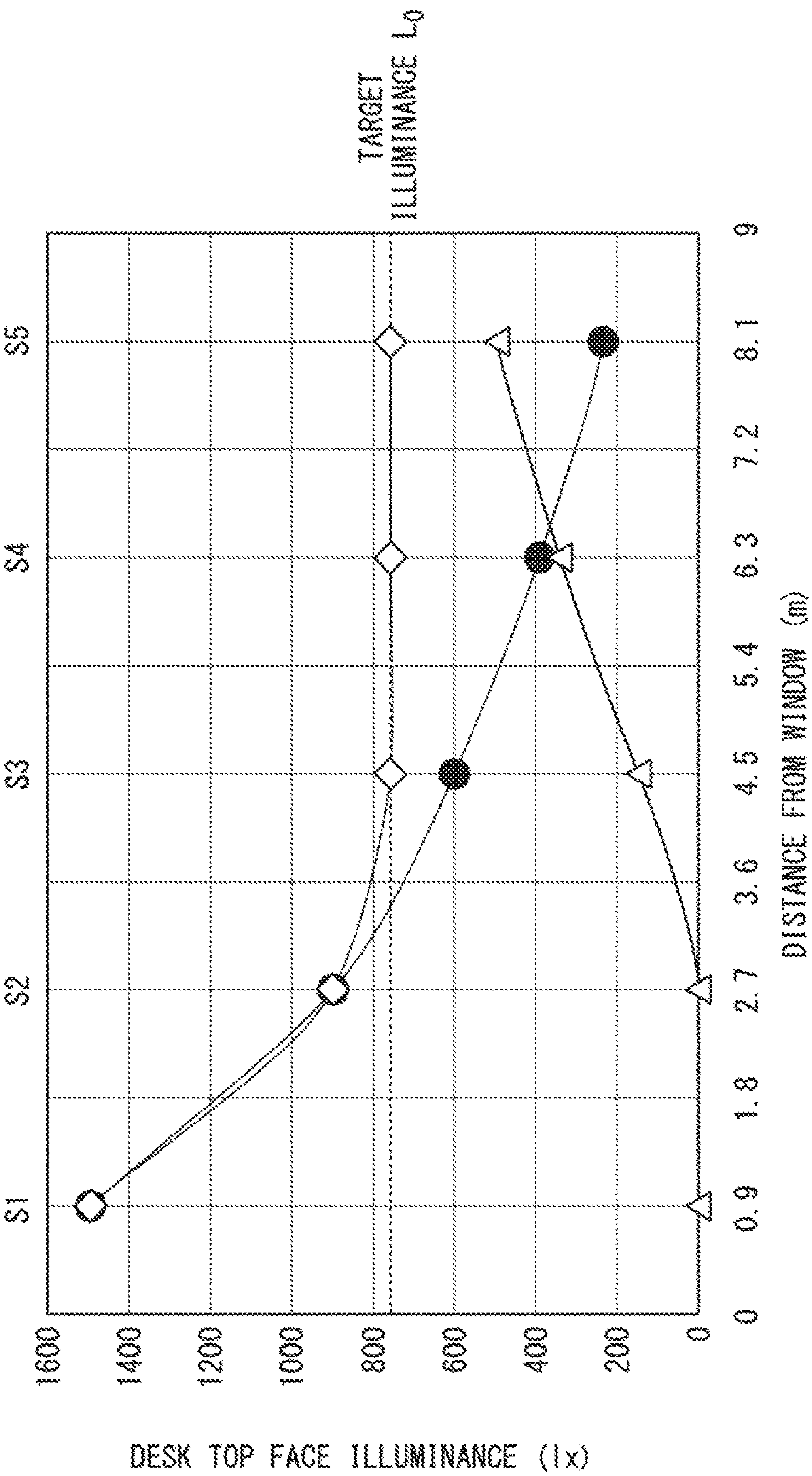

TARGET ILLUMINANCE L_0
S1
S2
S3
S4
S5
DESK TOP FACE ILLUMINANCE (lx)
1600
1400
1200
1000
800
600
400
200
0
DISTANCE FROM WINDOW (m)
0
0.9
1.8
2.7
3.6
4.5
5.4
6.3
7.2
8.1
9

FIG. 36

DAYLIGHTING DEVICE

TECHNICAL FIELD

The present invention relates to daylighting devices.

The present application claims priority to Japanese Patent Application, Tokugan, No. 2014-245745 filed in Japan on Dec. 4, 2014, the entire contents of which are incorporated herein by reference.

BACKGROUND ART

Daylighting films have been proposed for admitting sunlight into a building's interior, for example, through windows of the building. A typical daylighting film includes a light-transmitting support having formed on one of the faces thereof a plurality of unit prisms and a flat face. Sunlight is admitted into the interior through the unit prisms. One can guide external light into the interior to provide a brightly lit space, by attaching such a daylighting film to window glass.

However, if a special daylighting film is attached to a window, there may occur thermal cracking of the window glass. In view of this, Patent Literature 1 describes an insolation adjusting method in which rolling screen sheet materials (daylighting device) having insolation blocking properties are disposed at a distance from the indoor-side glass surface of wire-reinforced window glass.

CITATION LIST

Patent Literature

Patent Literature 1

Japanese Unexamined Patent Application Publication, Tokukai, No. 2012-207444

SUMMARY OF INVENTION

Technical Problem

According to a description in Patent Literature 1, the thermal cracking of the window glass can be suppressed by disposing the daylighting device at a distance from the window glass. However, it is still difficult to completely prevent thermal cracking of glass because of the difference in thermal expansion coefficient between the metal wires and glass. Additionally, in multilayered-glass daylighting devices having a hollow structure providing high thermal insulation, daylighting devices with low thermal conductivity, and other like daylighting devices, there is a chance of air being heated by sunlight irradiation and collecting between the window glass and the daylighting device. In these daylighting devices, it is not only the window glass, but also a substrate in the daylighting device, that may crack under heat.

An aspect of the present invention has been conceived in view of the abovementioned conventional problems and has an object to provide a daylighting device capable of preventing thermal cracking of window glass and a substrate in the daylighting device by suppressing temperature increases between the window glass and the daylighting device.

Solution to Problem

In one aspect, the present invention is directed to a daylighting device including: a daylighting member including: a first base member having light-transmitting properties; and a plurality of protruding daylighting sections having light-transmitting properties and provided on a first face or a second face of the first base member; and a ventilation hole configured to enable a space on the first face to communicate with a space on the second face opposite from the first face.

In another aspect of the present invention, the daylighting device may be configured so that the first through hole is provided in a region where the daylighting member makes no contribution to daylighting.

In yet another aspect of the present invention, the daylighting device may be configured so that: the daylighting member has a first through hole extending through a thickness direction of the daylighting member; and the ventilation hole includes the first through hole.

In still another aspect of the present invention, the daylighting device may be configured to further include a light-diffusion member provided on either a light-entering side or a light-exiting side of the daylighting member, wherein: the ventilation hole includes the first through hole and a second through hole extending through a thickness direction of the light-diffusion member; and the second through hole at least partially overlaps the first through hole when viewed normal to the daylighting member.

In yet still another aspect of the present invention, the daylighting device may be configured so that: the light-diffusion member is provided on the light-exiting side of the daylighting member; and the second through hole is smaller in size than the first through hole.

In a further aspect of the present invention, the daylighting device may be configured so that: the second through hole has such a shape that has a lengthwise direction; and the second through hole resides so that the lengthwise direction thereof is parallel to an extension direction of the daylighting sections.

In yet a further aspect of the present invention, the daylighting device may be configured so that: the light-diffusion member includes an adhesive layer having such anisotropy in light-diffusion properties as to diffuse more light in a direction that intersects the two disposition directions than in the two disposition directions; and the daylighting member is provided on a transparent base member with the light-diffusion member interposed therebetween.

In still a further aspect of the present invention, the daylighting device may be configured so that the ventilation hole forms a single communication hole by including the daylighting member, the light-diffusion member, and an affixing member provided between the daylighting member and the light-diffusion member disposed at a distance from each other.

In yet still a further aspect of the present invention, the daylighting device may be configured so that the ventilation hole is provided in a region through which not much sunlight enters the daylighting member.

In an additional aspect of the present invention, the daylighting device may be configured so that the ventilation hole has an inner face on which there is provided a material having light-blocking properties.

In another aspect of the present invention, the daylighting device may be configured to include a frame containing at least the daylighting member, wherein the ventilation hole is provided between the daylighting member and the frame.

In yet another aspect of the present invention, the daylighting device may be configured to include a frame containing at least the daylighting member, wherein the frame has at least two openings, one containing the daylighting member and the other serving as the ventilation hole.

In a further aspect of the present invention, the daylighting device may be configured to include an exhaust fan in the ventilation hole, the exhaust fan being configured to vent air via the ventilation hole from the light-entering side to the light-exiting side.

Advantageous Effects of Invention

As described in the foregoing, according to one of aspects of the present invention, it is possible to provide a daylighting device capable of preventing thermal cracking of window glass and a substrate in the daylighting device by suppressing temperature increases between the window glass and the daylighting device.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a perspective view of the exterior of a window on which a daylighting device of a first embodiment is installed.

FIG. **2** is a cross-sectional view taken along line A-A' in FIG. **1**.

FIG. **3** is a cross-sectional view of the daylighting device.

FIG. **4** is a perspective view of a daylighting sheet.

FIG. **5**A is a first perspective view illustrating a method of manufacturing the daylighting device.

FIG. **5**B is a second perspective view illustrating the method of manufacturing the daylighting device.

FIG. **5**C is a third perspective view illustrating the method of manufacturing the daylighting device.

FIG. **6**A is a diagram showing an exemplary planar shape of a ventilation hole.

FIG. **6**B is a diagram showing exemplary positions of overlapping through holes.

FIG. **7**A is a first diagram showing an exemplary planar shape of a ventilation hole when viewed normal to a daylighting unit.

FIG. **7**B is a second diagram showing an exemplary planar shape of a ventilation hole when viewed normal to a daylighting unit.

FIG. **7**C is a third diagram showing an exemplary planar shape of a ventilation hole when viewed normal to a daylighting unit.

FIG. **7**D is a fourth diagram showing an exemplary planar shape of a ventilation hole when viewed normal to a daylighting unit.

FIG. **7**E is a fifth diagram showing an exemplary planar shape of a ventilation hole when viewed normal to a daylighting unit.

FIG. **8** is a diagram showing workings of the daylighting device.

FIG. **9** is a vertical cross-sectional view of a first light-entrance-prohibited region where sunlight is prohibited from entering the daylighting device.

FIG. **10** is a graph representing a relationship between the solar altitude and the height of region A_1 where no light is incident.

FIG. **11** is a graph representing a relationship between solar altitudes in Tokyo and relative sunshine durations for these solar altitudes over the course of 1 year.

FIG. **12** is a horizontal cross-sectional view of a second light-entrance-prohibited region where sunlight is prohibited from entering the daylighting device, as the daylighting device is viewed from a ceiling end thereof.

FIG. **13** is a graph representing a relationship between the solar azimuth and the region A_2 where no sunlight is incident.

FIG. **14**A is a first front view showing the positions of ventilation holes formed.

FIG. **14**B is a second front view showing the positions of ventilation holes formed.

FIG. **14**C is a third front view showing the positions of ventilation holes formed.

FIG. **14**D is a fourth front view showing the positions of ventilation holes formed.

FIG. **14**E is a fifth front view showing the positions of ventilation holes formed.

FIG. **15**A is a first representation of sunlight being directed only onto a daylighting sheet as viewed from the interior.

FIG. **15**B is a second representation of sunlight being directed only onto a daylighting sheet as viewed from the interior.

FIG. **15**C is a third representation of sunlight being directed only onto a daylighting sheet as viewed from the interior.

FIG. **16** is a perspective view of an anisotropic light-diffusion sheet made from a particle-dispersed film.

FIG. **17** is a diagram showing an exemplary daylighting member including functional members.

FIG. **18**A is a first diagram showing another exemplary structure for the daylighting device.

FIG. **18**B is a second diagram showing another exemplary structure for the daylighting device.

FIG. **18**C is a third diagram showing another exemplary structure for the daylighting device.

FIG. **18**D is a fourth diagram showing another exemplary structure for the daylighting device.

FIG. **19** is a schematic cross-sectional view of the structure of a daylighting device of a second embodiment.

FIG. **20**A is another schematic cross-sectional view of the structure of the daylighting device of the third embodiment.

FIG. **20**B is a cross-sectional view of a daylighting device that differs from the daylighting device in FIG. **20**A in the positions of the centers of some of the through holes.

FIG. **21**A is a cross-sectional view of optical paths through which incident light is transmitted when sunlight has a large azimuth, as the daylighting device is viewed from a ceiling end thereof.

FIG. **21**B is a perspective view of through holes formed in a daylighting sheet.

FIG. **21**C is a perspective view of through holes formed in a light-diffusion sheet.

FIG. **22** is a cross-sectional view of the overall structure of a daylighting device of a fourth embodiment.

FIG. **23** is a cross-sectional view of optical paths through which incident light is transmitted when sunlight has a large azimuth, as the daylighting device is viewed from a ceiling end thereof.

FIG. **24** is a front view of the overall structure of a daylighting device of a fifth embodiment.

FIG. **25** is a schematic cross-sectional view of the structure of the daylighting device of the fifth embodiment taken along line B-B' in FIG. **24**.

FIG. **26** is a front view of a first variation example of the daylighting device of the fifth embodiment.

FIG. **27** is a cross-sectional view of the daylighting device shown in FIG. **26** taken along line C-C'.

FIG. **28** is a front view of a second variation example of the daylighting device of the fifth embodiment.

FIG. **29** is a cross-sectional view of the daylighting device shown in FIG. **28** taken along line D-D'.

FIG. **30** is a front view of the overall structure of a daylighting device of a sixth embodiment.

FIG. **31** is a front view of the overall structure of a daylighting device of a seventh embodiment.

FIG. **32** is a cross-sectional view of the daylighting device shown in FIG. **31** taken along line E-E'.

FIG. **33**A is a first diagram showing an exemplary structure of a ventilation hole.

FIG. **33**B is a second diagram showing an exemplary structure of a ventilation hole.

FIG. **34** is a cross-sectional view, taken along line J-J' in FIG. **35**, of a room model in which a daylighting device and a lighting-modulation system are installed.

FIG. **35** is a plan view of a ceiling of the room model.

FIG. **36** is a graph representing a relationship between the illuminance produced by daylighting light (natural light) guided into the interior by a daylighting device and the illuminance produced by room lighting devices (lighting-modulation system).

DESCRIPTION OF EMBODIMENTS

The following will describe embodiments of the present invention in reference to drawings. In the drawings used in the following description, various members are drawn to suitable arbitrary scales to show each member with readily recognizable dimensions.

First Embodiment

A daylighting device of the present embodiment is installed, for example, on a part of a window of an office building to guide sunlight into the building's interior.

FIG. **1** is a perspective view of the exterior of a window on which a daylighting device of a first embodiment is installed. FIG. **2** is a cross-sectional view taken along line A-A' in FIG. **1**.

As shown in FIGS. **1** and **2**, a daylighting device **2** is installed on a window frame **101** via an attaching unit **1**, and a window shade **3** is disposed on a lower portion of the daylighting device **2**. Take, as an example, a typical office room with a window that measures 270 cm in height (from the floor to the ceiling). The daylighting device **2** is located over the range of 70 cm from the ceiling. The window shade **3** covers approximately 200 cm below the daylighting device **2**. The window shade **3** is attached to the bottom of the daylighting device **2**, for example, via a pair of fixtures **109**. The fixtures **109** are omitted in FIG. **2**.

The window shade **3** has an upper portion thereof contained in a window shade box **4**. The window shade **3** includes a plurality of slats **5** and ladder cords **6** stringing the slats **5**. Each slat **5** is, for example, approximately 25 mm wide.

The window in this example is constructed from a window sash **9** and multilayered glass **7** set into the window sash **9**. The multilayered glass **7** includes two glass panels **7**A and **7**B. This example employs a multilayered glass structure, which is susceptible to thermal cracking. Other structures, including single-layered glass and wire-reinforced glass, are also susceptible to thermal cracking.

The daylighting device **2**, the window shade **3**, and the multilayered glass **7**, which is a part of the window, have a rectangular shape when viewed from the front. FIG. **2** does not show all the details of the structure of the daylighting device **2**.

FIG. **3** is a cross-sectional view of the daylighting device **2**.

The daylighting device **2** of the present embodiment, as shown in FIG. **3**, includes a daylighting sheet (daylighting member) **13** that causes light having entered through one of the surfaces thereof to exit through the other surface with a predetermined angular distribution. Specifically, the daylighting device **2** of the present embodiment includes a daylighting unit **15** and a frame **16**.

The daylighting unit **15** includes a first glass plate (transparent base member) **10**, a light-diffusion sheet (light-diffusion member) **11**, a second glass plate **12**, the daylighting sheet **13**, a third glass plate **14**, the frame **16**, a buffer material **17**, an adhesive **18**, and a caulking material **19**.

In the present invention, the transparent base member may be, apart from the abovementioned glass plate, a base member made of a transparent resin such as an acrylic, a polycarbonate, or vinyl chloride.

The plurality of glass plates and sheets, namely the first glass plate **10**, the light-diffusion sheet **11**, the second glass plate **12**, the daylighting sheet **13**, and the third glass plate **14**, are arranged in this sequence when viewed from the interior toward the exterior.

The daylighting sheet **13** of the present embodiment corresponds to the daylighting member recited in the claims. The light-diffusion sheet **11** of the present embodiment corresponds to the light-diffusion member recited in the claims.

In the following, for convenience of description, the exterior face of each glass plate will be referred to as the first face, whilst the interior face thereof will be referred to as the second face.

The light-diffusion sheet **11** is for diffusing the light traveling in the direction of a glare region and is attached to a first face **10***a* of the first glass plate **10**. The daylighting sheet **13** is attached to a first face **12***a* of the second glass plate **12**. The first glass plate **10**, the second glass plate **12**, and the third glass plate **14** are glass plates each approximately 3 to 6 mm thick and affixed together by the adhesive **18** with a gap between each other.

A layered body including the three layered glass plates **10**, **12**, and **14** has a peripheral portion thereof covered by the frame **16** made of a material such as aluminum or resin. Therefore, the frame **16** encloses inside thereof the three glass plates **10**, **12**, and **14** to which the light-diffusion sheet **11** and the daylighting sheet **13** are attached. The buffer material **17**, made of rubber as an example, is provided between an end face of the layered body and the frame **16**. The caulking material **19**, composed primarily of a silicone as an example, fills the gap between the peripheral portion of the layered body and the frame **16**.

The daylighting unit **15** is structured in this manner.

FIG. **4** is a perspective view of the daylighting sheet **13**.

As shown in FIG. **4**, the daylighting sheet **13** has formed thereon a fine structure on the scale of tens to hundreds of micrometers to guide external light, specifically sunlight, to the interior. The daylighting sheet **13** includes a film base member (first base member) **41**, a plurality of protruding daylighting sections **42**, and gap portions **43** provided between the daylighting sections **42**. The daylighting sections **42** are arranged like stripes on a first face **41***a* of the film base member **41**. The daylighting sections **42** are arranged to extend in the Y direction (horizontal direction) and sit side by side (parallel to each other) in the Z direction (vertical direction).

The film base member **41** is, for example, a light-transmitting base member made of, for example, a resin such as a thermoplastic polymer, a thermosetting resin, or a photopolymerizable resin. The film base member **41** is a base member having light-transmitting properties, such as an acrylic-based polymer, an olefin-based polymer, a vinyl-based polymer, a cellulose-based polymer, an amide-based polymer, a fluorine-based polymer, a urethane-based polymer, a silicone-based polymer, or an imide-based polymer. Specifically, the film base member **41** is preferably a base member having light-transmitting properties, such as a triacetyl cellulose (TAC) film, a polyethylene terephthalate (PET) film, a cycloolefin polymer (COP) film, a polycarbonate (PC) film, a polyethylene naphthalate (PEN) film, a polyethersulfone (PES) film, or a polyimide (PI) film. In the present embodiment, the film base member **41** is a 100 μm-thick PET film as an example. The film base member **41** preferably has a total light transmittance of, for example, 90% or higher.

This property renders the film base member **41** sufficiently transparent.

The daylighting sections **42** are made of an organic material having light-transmitting properties and photosensitivity, such as an acrylic resin, an epoxy resin, or a silicone resin. The resin is mixed with, for example, a polymerization initiator, a coupling agent, a monomer, and an organic solvent, to obtain a transparent resin mixture for use. The polymerization initiator may contain various additional components such as a stabilizer, an inhibitor, a plasticizer, a fluorescent whitening agent, a release agent, a chain transfer agent, and another photopolymerizable monomer. In the present embodiment, the daylighting sections **42** are made primarily of polymethyl methacrylate (PMMA) as an example. The daylighting sections **42** preferably have a total light transmittance of 90% or higher when measured as specified in JIS K7361-1.

This property renders the daylighting sections **42** sufficiently transparent.

In the present embodiment, the daylighting sections **42** are formed on the film base member **41** by thermal imprinting. The daylighting sections **42** may be formed by any process other than thermal imprinting, including UV imprinting, heat pressing, injection molding, extrusion molding, or compression molding. In melt extrusion, stamping, or another like method, the film base member **41** and the daylighting sections **42** are formed integrally from the same resin. Alternatively, a resin for shape transfer (UV transfer/heat transfer) may be applied onto a PET or like base film so that the structures can be molded by imprinting.

The daylighting sections **42** have a refractive index of around 1.5, ranging in the present embodiment from 1.35 if the primary material is mixed with a fluorine-based additive to approximately 1.6 if the primary material is mixed with a conjugated composition such as allyl groups. Each daylighting section **42** has a refractive index within this range.

Each daylighting section **42** is linearly elongate in one direction (Y direction in FIG. **4**) and has a polygonal cross-section when cut along a plane perpendicular to the length of the daylighting section **42**. Specifically, the cross-section of the daylighting section **42** is a hexagon with six apexes (q**1** to q**6**) and all interior angles smaller than 180°. The daylighting sections **42** are arranged vertically so that the length of the daylighting section **42** becomes parallel to the horizontally extending sides of the rectangular film base member **41**.

The first apex q**1** and the second apex q**2** of the hexagonal cross-section of the daylighting section **42** correspond to both ends of a first face **42**A that contacts with the film base member **41**. The fourth apex q**4**, the fifth apex q**5**, and the sixth apex q**6** are not located on the first face **42**A. The third apex q**3** is located farthest from the first face **42**A. The normal to the first face **42**A that passes through the third apex q**3** is longer than the normals to the first face **42**A that pass the other apexes q**1**, q**2**, and q**4** to q**6**. The daylighting section **42** is asymmetric with respect to the normal to the first face **42**A that passes through the third apex q**3**.

The daylighting section **42** is by no means limited to this shape and may have a pentagonal, trapezoidal, or triangular cross-section when cut perpendicular to the length of the daylighting section **42**.

Referring to FIG. **3**, the daylighting sheet **13** is disposed on the first face **12***a* of the second glass plate **12** so that the daylighting sections **42** have lengths thereof in the horizontal direction and sit side by side in the vertical direction (Z direction). The daylighting sheet **13** has a second face **41***b* side thereof attached to the second glass plate **12**, with the first face **41***a* of the film base member **41** carrying thereon a fine structure formed by the daylighting sections **42** and facing the exterior (the third glass plate **14** side). When the daylighting device **2** is installed on the window, the daylighting sheet **13** is disposed in such an orientation that the daylighting section **42**, having a hexagonal cross-section shown in FIG. **4**, has a second face **42**B and a third face **42**C thereof both facing vertically upward and a fourth face **42**D, a fifth face (reflective face) **42**E, and a sixth face (reflective face) **42**F thereof all facing vertically downward.

The film base member **41** desirably has a refractive index that is substantially equal to the refractive index of the daylighting sections **42** for the following reasons. If, for example, there is a large difference between the refractive index of the film base member **41** and the refractive index of the daylighting sections **42**, light may undesirably be refracted or reflected at the interface between the daylighting sections **42** and the film base member **41** as the light enters the film base member **41** from the daylighting sections **42**. These phenomena could lead to unfavorable results, including reduced luminance and a failure to achieve desired daylighting properties.

The gap portions **43** contain air therein and therefore have a refractive index of approximately 1.0. Specifying the refractive index of the gap portions **43** to 1.0 minimizes the critical angle of an interface (air interface) **43***a* between the daylighting sections **42** and the gap portions **43**.

The light-diffusion sheet **11** has such anisotropy in light-diffusion properties as to exhibit stronger light-diffusion properties in the vertical direction (in the YZ plane) than in the horizontal direction (in the XY plane). Referring to FIG. **3**, the light-diffusion sheet **11** has a lenticular lens structure including a base member **31** and a plurality of convex lens portions **32** provided on a first face **31***a* of the base member **31**. The light-diffusion sheet **11** is attached to the first face **10***a* of the first glass plate **10** (the first face **10***a* faces the second glass plate **12**), in such an orientation that the convex lens portions **32** face the second glass plate **12**. The convex lens portions **32** are arranged to extend in the Y direction (horizontal direction) and sit side by side (parallel to each other) in the Z direction (vertical direction).

Each convex lens portion **32** has a convex face **32***a* having a curvature in the vertical plane and no curvature in the horizontal direction. The convex lens portion **32** therefore has strong light-diffusion properties in the vertical direction (in the YZ plane) and no light-diffusion properties in the horizontal direction (in the XY plane). Hence, the light incident to the light-diffusion sheet **11** is significantly diffused in the vertical direction (in the YZ plane), but hardly diffused in the horizontal direction (in the XY plane) as the light exits the convex lens portions **32**.

The convex lens portions **32** may be fabricated from the first face **31***a* itself of the base member **31** and thus integral to the base member **31** or may be physically separate from the base member **31**. The light-diffusion sheet **11** may have no lenticular lens structure or other like regular structure and may have a plurality of irregularly arranged convex portions. Alternatively, the light-diffusion sheet **11** may be fibrous or ellipsoidal light-diffusion particles dispersed in a light-transmitting resin layer serving as a medium in such a manner that the particles become aligned in the horizontal direction.

In the present embodiment, the light-diffusion sheet **11** is used that has such anisotropy that light is significantly diffused in the vertical direction (in the YZ plane). Alternatively, a light-diffusion sheet may be used that has such anisotropy that light is significantly diffused in the horizontal direction (in the XY plane) or that has isotropic light-diffusion properties.

The following will describe a method of manufacturing the daylighting device **2** having the structure described above, in reference to FIGS. **5**A to **5**C.

To manufacture the daylighting device **2**, the first glass plate **10** to which the light-diffusion sheet **11** is attached, the second glass plate **12** to which the daylighting sheet **13** is attached, and the third glass plate **14** are prepared. None of these sheets are shown. The sheets may be, for example, dry-attached to the first glass plate **10**, the second glass plate **12**, and the third glass plate **14** using an acrylic-based adhesive or water-attached using a water-attaching adhesive while fine-tuning the attaching positions thereof.

Next, the first glass plate **10**, the second glass plate **12**, and the third glass plate **14** to which the three sheets are attached are affixed together with a gap between each other as shown in FIG. **5**A. In the affixing, the front and back faces of the first glass plate **10**, the second glass plate **12**, and the third glass plate **14** are orientated as shown in FIG. **3**. The rubbery adhesive **18** dispensed like a frame is interposed between the first glass plate **10** and the second glass plate **12** and between the second glass plate **12** and the third glass plate **14**. The adhesive **18** affixes the glass plates with each other and also serves as spacer that maintains distances that separate the glass plates.

Now referring to FIG. **5**B, the caulking material **19** is applied around the three affixed glass plates **10**, **12**, and **14** to integrate and prevent the three glass plates **10**, **12**, and **14** from easily becoming loose.

Next, as shown in FIG. **5**C, the frame **16** is attached around the three integrated glass plates **10**, **12**, and **14**. In the attaching of the frame **16**, the buffer material **17** (not shown) is inserted between the three glass plates **10**, **12**, and **14** and the frame **16** to prevent the three glass plates **10**, **12**, and **14** from coming into contact with the frame **16** and mitigate the impact of external force exerted on the frame **16**.

Next, the features of the daylighting device **2** of the present embodiment will be described.

In the present embodiment, the daylighting unit **15** has a plurality of ventilation holes **8** formed therethrough in the thickness direction of the daylighting unit **15** as shown in FIGS. **1** to **3**. These ventilation holes **8** function as holes spatially connecting a space K**1** on the multilayered glass **7** to an indoor-side space K**2** separated from the space K**1** by the daylighting unit **15**.

The ventilation holes **8** include a plurality of through holes formed through structural members. Specifically, each ventilation hole **8** of the present embodiment includes a through hole **21** extending in the thickness direction of the first glass plate **10**, a through hole **22** extending in the thickness direction of the second glass plate **12**, a through hole **23** extending in the thickness direction of the third glass plate **14**, a through hole (second through hole) **11***a* extending in the thickness direction of the light-diffusion sheet **11**, and a through hole (first through hole) **13***a* extending in the thickness direction of the daylighting sheet **13**.

In this embodiment, the through holes **21** may be formed after combining the first glass plate **10** and the light-diffusion sheet **11** together. Alternatively, holes may be formed in advance through the first glass plate **10** and the light-diffusion sheet **11** before the first glass plate **10** and the light-diffusion sheet **11** are combined to each other to form the through holes **21**.

Likewise, the through holes **22** may be formed after combining the second glass plate **12** and the daylighting sheet **13** together. Alternatively, holes may be formed in advance through the second glass plate **12** and the daylighting sheet **13** before the second glass plate **12** and the daylighting sheet **13** are combined to each other to form the through holes **22**.

Depending on fabrication tools and methods, the through holes **21**, **22**, and **23** in the glass plates **10**, **12**, and **14** can be formed in sizes from 3 mm (smallest diameter) or larger. The opening of the holes through the glass plates **10**, **12**, and **14** could lower the structural strength of those parts of the glass plates **10**, **12**, and **14** at which the through holes **21**, **22**, and **23** are formed. The glass plates **10**, **12**, and **14** are preferably made of toughened glass.

FIG. **6**A is a diagram showing an exemplary planar shape of the ventilation hole **8**. FIG. **6**B is a diagram showing exemplary positions of the overlapping through holes **21**, **22**, and **23**.

The through holes **21**, **22**, and **23**, constituting the ventilation hole **8**, are preferably formed in the same size and the same shape and arranged concentrically when viewed normal to the daylighting unit **15** as shown in FIG. **6**A.

This is, however, by no means the only possible configuration. The positions of the centers of the through holes **21**, **22**, and **23**, constituting the ventilation hole **8**, may be slightly out of alignment. For example, as shown in FIG. **6**B, the positions of the centers of the through holes **21** and **11***a* formed in advance in the first glass plate **10** and the light-diffusion sheet **11** may become out of alignment when the first glass plate **10** and the light-diffusion sheet **11** are combined. The same description applies to holes formed in advance in the second glass plate **12** and the daylighting sheet **13**. The through holes **21**, **22**, and **23** function as the ventilation hole **8** of the daylighting unit **15** as long as the through holes **21**, **22**, and **23** at least partially overlap each other when viewed normal to the daylighting unit **15**.

The ventilation hole **8**, as well as the through holes **21**, **22**, and **23** constituting the ventilation hole **8**, has a cornerless planar shape. If the through holes **21**, **22**, and **23** have a planar shape with a corner, cracks could start at the corner and grow to eventually damage the glass plates. Therefore, the through holes **21**, **22**, and **23** have a curved surface with no corners under any conditions.

FIGS. **7**A to **7**E are diagrams showing exemplary planar shapes of ventilation holes when viewed normal to the daylighting unit **15**.

In the present embodiment, the ventilation hole **8** has a circular planar shape as shown in FIG. **7**A. This is, however, by no means the only possible configuration. For example, the ventilation hole **8** may have an elliptical planar shape having a major axis in a direction that intersects the lengthwise direction of the daylighting sections **42** shown in FIG. **4** (e.g., Z direction). See, for example, a ventilation hole **8**A shown in FIG. **7**B. As another example, the major axis may be in the extension direction (Y direction) of the daylighting sections **42**. See, for example, a ventilation hole **8**B shown in FIG. **7**C. Alternatively, the ventilation hole **8** may have a polygonal planar shape with rounded corners. See, for example, ventilation holes **8**C and **8**D shown in FIGS. **7**D and **7**E.

The workings of the daylighting device **2** of the present embodiment will be described in reference to FIG. **8**, which is a diagram showing a part of the daylighting device **2** with the ventilation holes **8** and other members being omitted.

For convenience of description, an incident point G is defined as the point at which an arbitrary single light flux that is part of the light entering the daylighting section **42** shown in FIG. **8** is incident on the fifth face (reflective face) **42**E of the daylighting section **42**. Also, a straight line f is defined as the imaginary straight line that passes through the incident point G and is perpendicular to the first face **41***a* of the film base member **41**. Additionally, a first space S**1** is one of the two spaces bordering at the horizontal plane containing the straight line f in which space there exists light L**1** incident at the incident point G, whilst a second space S**2** is the other one of the two spaces in which space there is no light L**1** incident at the incident point.

Referring to FIG. **8**, light L**0** entering the daylighting device **2** obliquely from above at an angle of incidence $\theta_{in} \geq 0°$ is refracted by the third glass plate **14** and enters the daylighting sheet **13** obliquely from above.

The light L**1** enters the daylighting section **42** in the daylighting sheet **13**, for example, through the third face **42**C and is refracted, travels in the direction of the fifth face **42**E where the light L**1** is reflected, after which the light L**1** exits the second glass plate **12** at an angle of emergence $\theta_{out} \geq 0°$ in the direction of the first space S**1**. Light L**2** exiting the second glass plate **12** enters the light-diffusion sheet **11** and is diffused by the convex lens portion **32** in the vertical plane (in the XZ plane).

Light L**3**, produced by diffusing in the light-diffusion sheet **11**, travels in the direction of the room ceiling and illuminates well deep into the room. Therefore, by using the daylighting device **2**, one can efficiently guide external light (sunlight) in the direction of the room ceiling. That in turn renders the room brighter without causing occupants of the room to feel glare.

The optical paths described above are mere examples. The external light entering the daylighting device **2** enters the daylighting section **42** in the daylighting sheet **13** either through the second face **42**B or through the third face **42**C. The light is then reflected by one of the fourth face **42**D, the fifth face **42**E, and the sixth face **42**F and exits the daylighting section **42** through the first face **42**A. Light can take one of these or other optical paths in passing through the daylighting section **42**.

If the daylighting device **2** is installed with no gap between the daylighting device **2** and the window frame **101** or a nearby ceiling **102** as in the present embodiment, there is a chance that the air heated by sunlight irradiation could remain in the space K**1** between the multilayered glass **7** and the daylighting device **2**. Air has such properties that when its temperature rises, it expands and becomes less dense (relatively light), thereby moving upward, and conversely, when its temperature falls, it becomes denser (relatively heavy), thereby moving downward.

Therefore, if the multilayered glass **7** or the daylighting device **2** is warmed up by sunlight irradiation and there is not a sufficient gap between the daylighting device **2** and the multilayered glass **7**, heat builds up in the space K**1** between the daylighting device **2** and the multilayered glass **7**, creating a local high-temperature condition. This in turn increases temperature difference between those parts of the multilayered glass **7** which face the daylighting device **2** and those which do not face the daylighting device **2**. The increased temperature difference generates stress in the glass surface and renders the multilayered glass **7** susceptible to thermal cracking in which the multilayered glass **7** is partially damaged.

Here, thermal cracking in ordinary window glass will be described in detail. Irradiated regions of window glass where the glass is directly irradiated by sunlight absorb light, heat up, and expand. In contrast, peripheral parts of the window glass are not irradiated by sunlight because these parts are inserted inside a window sash. The peripheral parts also lose heat to the window sash and the window frame. The peripheral parts therefore remain cool and do not expand. For these reasons, the thermal expansion of the irradiated regions is inhibited by the peripheral parts, which means that tensile stress (thermal stress) is generated in the peripheral regions of the window glass. This thermal stress is proportional to the temperature difference between the irradiated regions and the peripheral regions. Thus, when tensile stress grows in excess of the edge strength of the window glass, the window glass is broken. This phenomenon is called thermal cracking.

Window glass is most susceptible to thermal cracking during the morning hours on a sunny winter day because air is clear on many winter days, and insolation increases, especially, on the southern side of the building while the window sash and the periphery thereof have low temperature.

Referring to FIG. **3** again, the daylighting device **2** of the present embodiment includes the glass plates **10**, **12**, and **14** and hence has sealed air layers therein. The daylighting device **2**, having sealed air layers therein, restrains internal air current generation, which effects high thermal insulation. On the other hand, the sealed air layers are likely to become a cause for local temperature increase. This mechanism also renders the glass substrates in the daylighting device **2** susceptible to thermal cracking.

To avoid such problems, in the present embodiment, there are formed the plurality of ventilation holes **8** extending through the thickness of the daylighting unit **15**. The ventilation holes **8** are formed in the upper portion of the daylighting unit **15** and hence can readily catch expanding and ascending warm air thereinto.

The warm air remaining in the space K**1** (see FIG. **2**) between the multilayered glass **7** and the daylighting device **2** can thus flow into the indoor-side space K**2** (see FIG. **2**) via the ventilation holes **8**. That in turn reduces the temperature difference between the space K**1** (located on the multilayered glass **7** side) and the indoor-side space K**2** separated by the daylighting device **2** from the space K**1**. As a result, thermal cracking which could be caused under sunlight irradiation is prevented, and damage to the multilayered glass **7** is prevented.

The daylighting device **2** is often installed at a high place in the room. Therefore, in the space K**1** between the multilayered glass **7** and the daylighting device **2**, temperature tends to rise near the ceiling end thereof. The ventilation holes **8**, provided in large numbers at positions close to the ceiling end as in the daylighting device **2** of the present embodiment, therefore facilitate the flow of the warm air in the space K**1** to the indoor-side space K**2**, which increases ventilation efficiency.

Furthermore, as mentioned earlier, thermal cracking could occur not only in the multilayered-glass structure, not also in other window structures that include, for example, single-layered glass or wire-reinforced glass. The provision of the ventilation holes **8** as in the present embodiment can prevent thermal cracking of, and damage to, the window glass.

Next will be described a relationship between the solar altitude and the positions of the ventilation holes **8**.

FIG. **9** is a vertical cross-sectional view of a first light-entrance-prohibited region A_1 where sunlight is prohibited from entering the daylighting device **2**.

As shown in FIG. **9**, part of sunlight L entering the daylighting device **2** at a predetermined solar altitude (angle of incidence θ_{in}) is in some cases blocked by eaves **103** of the building or the window sash **9**. In other words, in the upper portion of the daylighting device **2**, there can be a region where no sunlight can enter (hereinafter, the "first light-entrance-prohibited region A_1"), depending on the angle of incidence θ_{in} of the sunlight L.

Referring to FIG. **9**, letting W_1 (mm) represent the distance from the exterior face of either the building's eaves **103** or the window sash **9** to the exterior face of the daylighting sheet **13** in the daylighting device **2**, the height (mm) of the first light-entrance-prohibited region A_1 is given by the following mathematical expression:

$$\text{Height (mm) of First Light-entrance-prohibited Region } A_1 = W_1 \tan\theta_{in} \quad (1)$$

FIG. **10** is a graph representing a relationship between the solar altitude and the height of region A_1 where no light is incident. In FIG. **10**, the horizontal axis indicates the solar altitude θ_{in} (degrees), and the vertical axis indicates the height (mm) of the first light-entrance-prohibited region A_1.

The relationship between the solar altitude and the first light-entrance-prohibited region A_1 was studied by changing the distance W_1 from the exterior face of the window frame **101** to the exterior face of the daylighting sheet **13** in the daylighting device **2** to 100 mm, 150 mm, and 200 mm.

It is understood from FIG. **10** that the first light-entrance-prohibited region A_1 increases with an increase in the solar altitude for all the distances W_1 from the exterior face of the window frame **101** to the exterior face of the daylighting sheet **13**. It is also understood that for the same solar altitude, the height of the first light-entrance-prohibited region A_1 decreases with a decrease in the distance W_1 from the exterior face of the window frame **101** to the exterior face of the daylighting sheet **13**, that is, with a decrease in the distance between the multilayered glass **7** and the daylighting device **2**.

FIG. **11** is a graph representing a relationship between solar altitudes in Tokyo and relative sunshine durations for these solar altitudes over the course of 1 year. In FIG. **11**, the horizontal axis indicates the solar altitude θ_{in} (degrees), and the vertical axis indicates the relative sunshine duration (%) for each solar altitude. Here, daily measurement started at 8 o'clock in the morning and finished at 6 o'clock in the evening. (i) Changes in the solar altitude and (ii) the relative sunshine duration for each solar altitude during this time period were measured over the course of 1 year (3,650 hours).

The solar altitude with long sunshine durations over the period of 1 year is in the range of 30° to 35° as shown in FIG. **11**. The relative sunshine duration peaks at solar altitudes of 30° to 35° and changes almost symmetrically above and below that range of solar altitude.

As mentioned earlier, the first light-entrance-prohibited region A_1 of the daylighting device **2** receives no sunlight, achieving no daylighting function. Therefore, the ventilation holes **8** are preferably formed in this first light-entrance-prohibited region A_1. If the first light-entrance-prohibited region A_1 is determined from mathematical expression (1) above by using as the standard the solar altitude at which the sunshine duration is longest over the year, the ventilation holes **8** can be formed without substantially affecting the daylighting function of the daylighting device **2**.

Although the ventilation holes **8** are preferably formed in the first light-entrance-prohibited region A_1, there are other points that should be considered. The daylighting function of the daylighting device **2** deteriorates with an increase in area of the first light-entrance-prohibited region A_1. A smaller first light-entrance-prohibited region A_1 increases the region through which sunlight can enter and hence ensures the daylighting function of the daylighting device **2**. For these reasons, the daylighting device **2** is preferably located close to the multilayered glass **7** to minimize the first light-entrance-prohibited region A_1. This configuration can prevent large increases in the first light-entrance-prohibited region A_1 even when the solar altitude changes, and hence can render the daylighting device **2** more tolerant of large changes of the solar altitude.

In addition, as shown in FIG. **9**, the first light-entrance-prohibited region A_1 will likely form in the upper portion of the daylighting device **2** even when the solar altitude changes. Therefore, the ventilation holes **8** are formed in the top portion of the daylighting unit **15** whenever possible as shown in FIGS. **14**A to **14**E. It is also preferable, but not essential, to provide many ventilation holes **8** in the first light-entrance-prohibited region A_1.

FIG. **12** is a horizontal cross-sectional view of a second light-entrance-prohibited region A_2 where sunlight is prohibited from entering the daylighting device **2**, as the daylighting device **2** is viewed from a ceiling end thereof.

As shown in FIG. **12**, part of the sunlight L entering the daylighting device **2** at a predetermined solar azimuth Φ_{in} is in some cases blocked, for example, by the window sash **9**. In other words, there can be a region A_2 where no sunlight L can enter (hereinafter, the "second light-entrance-prohibited region A_2") along the left or right side of the daylighting device **2**, depending on the azimuth Φ_{in} of the sunlight L.

Referring to FIG. **12**, letting W_2 (mm) represent the distance from the exterior face of the window sash **9** to the exterior face of the daylighting sheet **13** in the daylighting device **2**, the width (mm) of the second light-entrance-prohibited region A_2 is given by the following mathematical expression:

$$\text{Width (mm) of Second Light-entrance-prohibited Region } A_2 = W_2 \tan\Phi_{in} \quad (2)$$

FIG. **13** is a graph representing a relationship between the solar azimuth and the second light-entrance-prohibited region A_2. In FIG. **13**, the horizontal axis indicates the solar azimuth Φ_{in} (degrees), and the vertical axis indicates the height of the second light-entrance-prohibited region A_2.

The relationship between the solar azimuth Φ and the second light-entrance-prohibited region A_2 was studied by changing the distance W_2 from the exterior face of the window sash **9** to the exterior face of the daylighting sheet **13** in the daylighting device **2** to 100 mm, 150 mm, and 200 mm.

It is understood from FIG. **13** that the width (mm) of the second light-entrance-prohibited region A_2 increases with an increase in the solar azimuth Φ_{in} (degrees) for all the distances W_2 from the exterior face of the window sash **9** to the exterior face of the daylighting sheet **13**. It is also understood that for the same solar azimuth, the height of the second light-entrance-prohibited region A_2 decreases with a decrease in the distance from the exterior face of the window sash **9** to the exterior face of the daylighting sheet **13**, that is, with a decrease in the distance between the multilayered glass **7** and the daylighting device **2**.

As mentioned earlier, the second light-entrance-prohibited region A_2 of the daylighting device **2** receives no sunlight, achieving no daylighting function. Therefore, the ventilation holes **8** are preferably formed in this second light-entrance-prohibited region A_2. If the second light-entrance-prohibited region A_2 is determined from mathematical expression (2) above in reference to the graph in FIG. **11** by using as the standard the solar direction at which the sunshine duration is longest over the year, the ventilation holes **8** can be formed without substantially affecting the daylighting function of the daylighting device **2**. Additionally, the daylighting device **2**, if located close to the multilayered glass **7**, can prevent large increases in the second light-entrance-prohibited region A_2 even when the solar azimuth changes, and hence can render the daylighting device **2** more tolerant of large changes of the solar azimuth.

In addition, as shown in FIG. **12**, the second light-entrance-prohibited region A_2 will likely form along one of the left and right sides of the daylighting device **2** even when the solar azimuth changes. Therefore, it is preferable to provide many ventilation holes **8** in the second light-entrance-prohibited region A_2. For example, the ventilation holes **8** are formed along the far left and right sides of the daylighting unit **15** whenever possible as shown in FIG. **14**E.

Next will be described a relationship between through holes in the daylighting sheet **13** and through holes in the light-diffusion sheet **11** in reference to FIGS. **15**A to **15**C.

FIG. **15**A is a representation of sunlight being directed only onto the daylighting sheet **13** as viewed from the interior. FIG. **15**A shows that part of the light exiting the daylighting sheet **13** that is diffused in a direction (Z direction) that intersects the extension direction of the daylighting sections **42** is visually recognized as glare L_G. In other words, the light that has transmitted only through the daylighting sheet **13** is visually recognized as vertical, linear glare L_G by occupants.

Therefore, as shown in FIG. **15**B, if the through holes (second through holes) **11**a in the light-diffusion sheet **11** disposed on the indoor side of the daylighting sheet **13** are arranged so that the lengthwise direction of the through holes **11**a matches the direction (Z direction) that intersects the extension direction of the daylighting sections **42**, the glare L_G passes through the ventilation holes **8** without being obstructed and makes the occupant feel the glaring.

Accordingly, the lengthwise direction of the through holes **11**a in the light-diffusion sheet **11** is matched with the extension direction of the daylighting sections **42** (Y direction) as shown in FIG. **15**C. This configuration allows only part of the glare L_G to pass through the through holes **11**a, which reduces the area in which the vertical, linear glare L_G can be visually recognized by an occupant.

For these reasons, if the through holes **11**a are provided in the light-diffusion sheet **11**, the left/right direction of the light-diffusion sheet **11** preferably matches the lengthwise direction of the through holes **11**a to suppress the glare L_G exiting the daylighting sheet **13** from entering the interior.

The light-diffusion sheet **11** of the present embodiment has a lenticular lens structure. This is, however, by no means the only possible configuration. Alternatively, the light-diffusion sheet **11** may be, apart from the one having the lenticular structure described above, for example, an anisotropic light-diffusion sheet **302** including a particle-dispersed film as shown in FIG. **16**. The particle-dispersed film has a structure in which fibrous or ellipsoidal light-diffusion particles **35** are dispersed in a light-transmitting resin layer **34** serving as a medium in such a manner that the particles **35** become aligned in the vertical direction (Z direction). This particle-dispersed film have such properties as to diffuse light significantly primarily in the left/right directions and slightly in the up/down directions.

In addition, the daylighting device **2** may be configured to include, for example, functional members **25** such as a light-transmitting thermal insulation film (thermal insulation member) that blocks radiant heat from natural light (sunlight), an IR-reflecting film that reflects infrared light (IR), a design sheet, and a light-incidence-angle-controlling member.

FIG. **17** is a diagram showing an exemplary daylighting member including functional members.

As shown in FIG. **17**, for example, the functional members **25** are provided on the light-entering side of the daylighting sheet **13** and on a second face **14**b of the third glass plate **14** (which faces the daylighting sheet **13**). An incidence-angle-controlling member, which is one of the functional members **25**, changes the angle of incidence of light on the daylighting sheet **13** which has good daylighting properties for arbitrary solar altitudes (angles of incidence). The provision of the incidence-angle-controlling member, even if the daylighting device **2** is installed at a different location or in a different orientation, enables correction for changes of incident light having shifted overall so that the light having been subjected to this correction is incident to the daylighting sections **42**. The provision hence makes it possible to maintain good daylighting properties for arbitrary solar altitudes.

The daylighting device **2** includes three glass plates in the present embodiment. This is, however, by no means the only possible configuration.

FIGS. **18**A to **18**D are diagrams showing other exemplary structures for the daylighting device. In these figures, sunlight enters the daylighting device from the left side of the paper.

A daylighting device **201** shown in FIG. **18**A has a single-glass-plate structure and includes a first glass plate **10**, an anisotropic light-diffusion sheet (adhesive layer) **302**, a daylighting sheet **13**, and a frame **16**. The daylighting sheet **13** and the anisotropic light-diffusion sheet **302** are provided on a first face **10**a of the single first glass plate **10**, and all these members are held together by the frame **16**. The anisotropic light-diffusion sheet **302** in this example is adhesive. The daylighting sheet **13** is attached to the first glass plate **10** via the anisotropic light-diffusion sheet **302**. Each ventilation hole **8** includes a plurality of through holes **13**a, **302**a, and **21** extending respectively through the daylighting sheet **13**, the anisotropic light-diffusion sheet **302**, and the first glass plate **10**.

A daylighting device **202** shown in FIG. **18**B has a double-glass-plate structure and includes a first glass plate (transparent substrate) **10** including a light-diffusion sheet **11** on a first face **10**a thereof and a second glass plate (transparent substrate) **12** including a daylighting sheet **13** on a first face **12**a thereof. The first and second glass plates **10** and **12** are attached together via an adhesive (affixing member) **18** and held inside a frame **16**. The daylighting sheet **13** and the light-diffusion sheet **11** are attached respectively to the glass plates **10** and **12** via an adhesive layer **24**. Each ventilation hole **8** includes a plurality of through holes formed respectively in the daylighting sheet **13**, the second glass plate **12**, the light-diffusion sheet **11**, and the first glass plate **10**.

A daylighting device **203** shown in FIG. **18**C is the same as the daylighting device **202** shown in FIG. **18**B in that both have a double-glass-plate structure, but differs in that the light-diffusion sheet **11** is provided on a light-entering side of the daylighting sheet **13**. The relative positions of the daylighting sheet **13** and the light-diffusion sheet **11** may be reversed in this manner. In this daylighting device **203**, the first glass plate **10** and the second glass plate **12** are arranged so that the daylighting sheet **13** and the light-diffusion sheet **11** face each other.

A daylighting device **204** shown in FIG. **18**D differs from the daylighting devices **201** and **202** shown in FIGS. **18**A and **18**B in that the daylighting sheet **33** and the light-diffusion sheet **11** are provided independently between two glass plates.

The daylighting sheet **33** and the light-diffusion sheet **11** are provided between the first glass plate **10** and the second glass plate **12** at a distance from the first and second glass plates **10** and **12**. There is a gap between the daylighting sheet **33** and the light-diffusion sheet **11** which are individually arranged in a light-transmitting direction and held inside a frame **16**. The light-diffusion sheet **11** is disposed on the light-exiting side of the daylighting sheet **33** in this example. Alternatively, the light-diffusion sheet **11** may be disposed on the light-entering side of the daylighting sheet **33**. Each ventilation hole **8** includes through holes **21**, **11***a*, **13***a*, and **22** extending respectively through the first glass plate **10**, the light-diffusion sheet **11**, the second glass plate **12**, and the daylighting sheet **33**. The through hole **21** in the first glass plate **10** and the through hole **22** in the second glass plate **12** correspond to a third through hole of the present invention.

Additionally, the daylighting sheet **33** shown in FIG. **18**D includes a plurality of daylighting sections **42** on a second face **4** lb of a film base member **41**. The daylighting sheet **13** described earlier includes the plurality of daylighting sections **42** on the first face **41***a* of the film base member **41** which faces the window. In this example, however, the plurality of daylighting sections **42** are provided on the indoor side of the film base member **41**. The daylighting sheet **33** is disposed in such an orientation that the first face **41***a* of the film base member **41** faces the second face **12***b* of the second glass plate **12**. The daylighting sections **42** may be orientated to face the interior in this manner.

Second Embodiment

Next will be described the structure of a daylighting device in accordance with a second embodiment of the present invention.

FIG. **19** is a schematic cross-sectional view of the structure of the daylighting device of the second embodiment.

A daylighting device **20** of the present embodiment has a basic structure that is substantially the same as that of the daylighting device of the first embodiment, but differs in that the gaps between glass plates in which through holes are formed are sealed. The following description will elaborate on differences and skip over common features.

As shown in FIG. **19**, in the daylighting device **20**, there are provided sealing members **26**, one between the first glass plate **10** and the second glass plate **12** and another between the second glass plate **12** and the third glass plate **14**, so as to constitute a part of each ventilation hole **8**. The ventilation hole **8** includes a through hole **21** in the first glass plate **10**, a through hole **22** in the second glass plate **12**, a through hole **23** in the third glass plate **14**, and the pair of sealing members **26**, to constitute a single communication hole.

The sealing members **26** are made from an adhesive material and combine the glass plates **10**, **12**, and **14**. The sealing members **26** may be made from a material similar to the adhesive **18** provided on the peripheries of the glass plates **10**, **12**, and **14**.

In the present embodiment, a sealed space J1 is formed between the first glass plate **10** and the second glass plate **12** in such a manner as to be surrounded by these glass plates **10** and **12**, sealing members **26**, and adhesive **18**. A sealed space J2 is also formed between the second glass plate **12** and the third glass plate **14** in such a manner as to be surrounded by these glass plates **12** and **14**, sealing members **26**, and adhesive **18**.

The structure of the present embodiment, similarly to the previous embodiment, can prevent thermal cracking of the multilayered glass **7** and the daylighting unit **15**. Furthermore, the provision of the sealing members **26** between the glass plates can prevent dust, waste, and other unwanted material from moving into the gaps between the glass plates **10**, **12**, and **14** through the ventilation holes (communication holes) **8**. If there were dust, waste, or other unwanted material sticking to the surfaces of the daylighting sheet **13** and the light-diffusion sheet **11**, the optical functions of the daylighting sheet **13** and the light-diffusion sheet **11** could be degraded. In the present embodiment, however, dust, waste, and other unwanted material are prevented from sticking to the surfaces of the daylighting sheet **13** and the light-diffusion sheet **11**, by the structure that does not allow exposure of the surfaces of the daylighting sheet **13** and the light-diffusion sheet **11** to open air. Therefore, stable optical functions can be maintained over an extended period of time. This structure also increases maintainability of the daylighting sheet **13** and the light-diffusion sheet **11**.

In addition, the sealing members **26**, provided between the glass plates **10**, **12**, and **14** and having a sufficient thickness, can maintain the distances separating the glass plates **10**, **12**, and **14**.

Third Embodiment

Next will be described the structure of a daylighting device in accordance with a third embodiment of the present invention.

FIG. **20**A is a schematic cross-sectional view of the structure of the daylighting device of the third embodiment. FIG. **20**A is a cross-sectional view of the daylighting device as viewed from a ceiling end thereof.

A daylighting device **30** of the present embodiment has a basic structure that is substantially the same as that of the daylighting device of the first embodiment, but differs in that the through hole(s) formed in one/some of the glass plates has/have a different size from the size of the through holes formed in the other glass plates. The following description will elaborate on differences and skip over common features.

As shown in FIG. **20**A, in the daylighting device **30**, the through hole **21** in the first glass plate **10** having the light-diffusion sheet **11** thereon is smaller in size than the through holes **22** and **23** formed in other glass plates **12** and **14** in the cross-sectional view of the daylighting unit **15**.

The through hole **13***a* formed in the daylighting sheet **13** has the same size and shape as the through hole **22**. The through hole **11***a* formed in the light-diffusion sheet **11** has the same size and shape as the through hole **21**. The following description will elaborate on the through holes **21**, **22**, and **23** in the glass plates **10**, **12**, and **14**. The centers of the through holes **21**, **22**, and **23**, constituting the ventilation hole **8**, are aligned also in the present embodiment.

The daylighting device **30** of the present embodiment, similarly to those of the previous embodiments, can prevent thermal cracking of the multilayered glass **7** and the daylighting unit **15**. Furthermore, in the present embodiment, since the through hole **21**, located closest to the interior, has the smallest size, the light exiting the daylighting sheet **13** is unlikely to pass through the through hole **21** and produce glare without being obstructed. In other words, most light exiting the daylighting sheet **13** passes through the light-diffusion sheet **11**, which can diffuse the light that would otherwise produce glare and hence prevent occupants from feeling glare.

FIG. **20**B is a cross-sectional view of a daylighting device in which the position(s) of the center(s) of one/some of the through holes is/are different, as the daylighting device is viewed from a ceiling end thereof.

In FIG. **20**B, the through hole **21** formed in the first glass plate **10** having the light-diffusion sheet **11** thereon is provided completely out of alignment with the through holes **22** and **23** formed in the other, second glass plate **12** and third glass plate **14**. In other words, the daylighting sheet **13** is visible through the through hole **21** in the first glass plate **10**. The light exiting the daylighting sheet **13** may therefore be emitted to the interior through the through hole **21** without being obstructed. This light will cause glare, which is undesirable. In addition, air flow is disrupted, and ventilation efficiency decreases because the ventilation hole **8** does not constitute a single continuous communication hole.

In contrast to this, in the daylighting device **30** of the present embodiment shown in FIG. **20**A, the through holes **21**, **22**, and **23** having aligned centers constitute each single ventilation hole **8**. Therefore, even when one/some of the through holes (through hole **21**) is/are smaller in size, air flow is not disrupted, and ventilation efficiency does not decrease between the space K**1** (located on the multilayered glass **7** side) and the indoor-side space K**2** separated by the daylighting device **30** from the space K**1**.

Now will be described approximately how much smaller in size the through hole **21** on the light-diffusion sheet **11** side needs to be than the through hole **22** on the daylighting sheet **13** side.

FIG. **21**A is a cross-sectional view of optical paths through which incident light is transmitted when sunlight has a large azimuth, as the daylighting device is viewed from a ceiling end thereof. FIG. **21**B is a perspective view of through holes formed in a daylighting sheet. FIG. **21**C is a perspective view of through holes formed in a light-diffusion sheet.

As shown in FIG. **21**A, sunlight is incident to the daylighting device **30** at varying azimuths over the year. Therefore, as shown in FIGS. **21**B and **21**C, even when the through hole **21** in the first glass plate **10** having the light-diffusion sheet **11** thereon is smaller in size than the through hole **22** in the second glass plate **12** having the daylighting sheet **13** thereon, if the solar azimuth Φ_{in} is large, as shown in FIG. **21**A, light L**4** exiting the daylighting sheet **13** may reach the interior through the through hole **21** without passing through the light-diffusion sheet **11** or otherwise being obstructed.

Therefore, the daylighting sheet **13** is preferably not visually recognizable to an occupant so that the light exiting the daylighting sheet **13** enters the light-diffusion sheet **11** as much as possible. In other words, the through holes **21** on the light-diffusion sheet **11** side are formed in such a small size, relative to the size of the through holes **22** on the daylighting sheet **13** side, that the daylighting sheet **13** is not visible through the through holes **21** to an occupant no matter where the occupant is in the interior. This configuration can further prevent the light exiting the daylighting sheet **13** from being guided directly into the interior.

Fourth Embodiment

Next will be described a daylighting device in accordance with a fourth embodiment of the present invention.

The daylighting device of the present embodiment described below has a basic structure that is substantially the same as that of the daylighting device of the first embodiment, but differs in that the ventilation holes has an inner face made of a material having light-blocking properties. The following description will elaborate on differences from the structure of the first embodiment and skip over common features. In addition, in the figures used in the description, those elements that are the same as those in any of the previous embodiments are given the same reference signs.

FIG. **22** is a cross-sectional view of the overall structure of the daylighting device of the fourth embodiment.

As shown in FIG. **22**, a daylighting device **40** is characterized in that the ventilation holes **8** formed in the daylighting unit **15** each have an inner face **8***a* on which there is provided a light-blocking member **44**.

The light-blocking member **44** is provided to cover the inner faces of the through holes **22** and **11***a* formed in the first glass plate **10** and the light-diffusion sheet **11**, the through holes **22** and **13***a* formed in the second glass plate **12** and the daylighting sheet **13**, and the through holes **23** formed in the third glass plate **14**, the through holes **22**, **11***a*, **22**, **13***a*, and **23** constituting the ventilation holes **8**, and to fill in the gaps between, and join, the glass plates **10**, **12**, and **14** together. In this manner, the ventilation holes **8** are formed that are continuous throughout the glass plates **10**, **12**, and **14**.

The light-blocking member **44** may be, for example, a caulking material having light-blocking properties. This is by no means the only possible configuration. Alternatively, the light-blocking member **44** may be a light-blocking cover capable of covering gaps between the glass plates **10**, **12**, and **14**.

FIG. **23** is a cross-sectional view of optical paths through which incident light is transmitted when sunlight has a large azimuth, as the daylighting device is viewed from a ceiling end thereof.

As shown in FIG. **23**, sunlight is incident to the daylighting device **40** at varying azimuths over the year. As mentioned in the third embodiment, the light exiting the daylighting sheet **13** may therefore be guided to the interior through the ventilation holes **8** without passing through the light-diffusion sheet **11** or otherwise being obstructed.

In the present embodiment, the light L**4**, which is part of the light exiting the daylighting sheet **13**, but which is not incident to the light-diffusion sheet **11**, is blocked by the light-blocking member **44**. Therefore, useless glare can be suppressed that directly enters the eye of an occupant.

In the present embodiment, each ventilation hole **8** in the daylighting unit **15** has the light-blocking member **44**. This is by no means the only possible configuration. Alternatively, for example, some of the ventilation holes **8** may have the light-blocking member **44**, and the other ventilation holes **8** have no light-blocking member **44**.

Fifth Embodiment

Next will be described a daylighting device in accordance with a fifth embodiment of the present invention.

FIG. **24** is a front view of the overall structure of the daylighting device of the fifth embodiment. FIG. **25** is a schematic cross-sectional view of the structure of the daylighting device of the fifth embodiment taken along line B-B' in FIG. **24**.

The daylighting device of the present embodiment described below has a basic structure that is substantially the same as that of the daylighting device of the first embodiment, but differs in that there are provided a plurality of daylighting units in a single frame. The following description will elaborate on differences from the structure of the first embodiment and skip over common features. In addition, in the figures used in the description, those elements that are the same as those in any of the previous embodiments are given the same reference signs.

As shown in FIGS. **24** and **25**, a daylighting device **50** of the present embodiment includes: a frame **51** having a plurality of openings; and two daylighting units **15** of the same size. The daylighting units **15** may be any of the daylighting units of the abovementioned embodiments.

The frame **51** is a frame body, rectangular in a plan view, having two large openings **51***a* and a small opening **51***b* provided between the large openings **51***a*. Each large opening **51***a* contains a different one of the daylighting units **15**. Meanwhile, the small opening **51***b* contains no daylighting unit **15** and serves as an air hole **52**.

The daylighting device **50** is disposed so that the frame **51** has a length thereof (Y direction) in the left/right direction of the window.

In this configuration, one of the daylighting units **15** is located in the left side of the window, and the other daylighting unit **15** is located in the right side of the window. An air hole (ventilation hole) **52** that extends in the up/down direction is provided at the center of the window.

The daylighting device **50** of the present embodiment is applicable to large-sized windows because the plurality of daylighting units **15** are contained in the single frame **51**. Each daylighting unit **15** has numerous ventilation holes **8**. Ventilation efficiency however needs to be further increased if the daylighting device **50** is installed on a large-sized window. In the present embodiment, the air hole **52** is provided between the pair of daylighting units **15**, the frame **51** separating the air hole **52** from the pair of daylighting units **15**. Therefore, even if the daylighting device **50** is installed on a large-sized window, ventilation efficiency is further increased between the window-side space and the indoor-side space separated by the daylighting device **50**, and thermal cracking and other damage can be prevented in the multilayered glass and the glass plates **10**, **12**, and **14** in the daylighting device **50**.

The following will describe variation examples of the daylighting device of the present embodiment.

First Variation Example of Daylighting Device

FIG. **26** is a front view of a first variation example of the daylighting device of the fifth embodiment. FIG. **27** is a cross-sectional view of the daylighting device shown in FIG. **26** taken along line C-C'.

Referring to FIGS. **26** and **27**, a daylighting device **53** of the first variation example includes: a frame **54** having a plurality of openings; and two daylighting units **15**A and **15**B of different sizes.

The frame **54** has a first opening **54***a*, a second opening **54***b*, and a third opening **54***c* each having a different opening area. These first opening **54***a*, second opening **54***b*, and third opening **54***c* are arranged in the up/down direction (Z direction) of the frame **54** as viewed in reference to the orientation of the installed daylighting device **53**.

Specifically, the first opening **54***a*, having the largest opening area, is located in the bottom portion of the frame **54** and contains the daylighting unit **15**A therein. The second opening **54***b*, having a smaller opening area than the first opening **54***a*, is located in the top portion of the frame **54** and contains the daylighting unit **15**B therein. The third opening **54***c*, having a smaller opening area than the second opening **54***b*, is located at the center of the frame **54** between the first opening **54***a* and the second opening **54***b*. This third opening **54***c* contains no daylighting unit **15** and serves as the air hole **52**.

In the structure of the present embodiment, the warm air collecting in the ceiling end can be likewise efficiently discharged indoors through the air hole **52** located higher than the center of the daylighting device **53**.

Second Variation Example of Daylighting Device

A structure in which a single frame contains a plurality of daylighting units was described above. This is by no means the only possible structure. Alternatively, as an example, a single frame may contain one daylighting unit and one air hole.

FIG. **28** is a front view of a second variation example of the daylighting device of the fifth embodiment. FIG. **29** is a cross-sectional view of the daylighting device shown in FIG. **28** taken along line D-D'.

Referring to FIGS. **28** and **29**, for example, a daylighting device **55** of the second variation example includes: a frame **56** having a first opening **56***a* and a second opening **56***b;* and a single daylighting unit **15**.

The first opening **56***a* and the second opening **56***b* are arranged in the up/down direction (Z direction) of the frame **56** as viewed in reference to the orientation of the installed daylighting device **55**. The first opening **56***a* located in the lower portion of the frame **56** contains the daylighting unit **15**. In contrast, the second opening **56***b* located in the upper portion of the frame **56** contains no daylighting unit **15** and serves as the air hole **52**.

In the present embodiment, the warm air collecting in the ceiling end can be likewise efficiently discharged indoors through the air hole **52** located in the upper portion of the daylighting device **55**.

Sixth Embodiment

Next will be described a daylighting device of a sixth embodiment of the present invention. FIG. **30** is a front view of the overall structure the daylighting device of the sixth embodiment.

The daylighting device of the present embodiment described below has a basic structure that is substantially the same as that of the daylighting device of the first embodiment, but differs in the external shape of the daylighting unit and the shape of the opening of the frame. The following description will elaborate on differences from the structure of the first embodiment and skip over common features. In addition, in the figures used in the description, those elements that are the same as those in any of the previous embodiments are given the same reference signs.

Referring to FIG. **30**, a daylighting device **60** of the present embodiment includes: a rectangular frame **61** having a single opening **61***a;* and a daylighting unit **15** contained in the opening **61***a* of the frame **61**. In the present embodiment, the daylighting unit **15** may likewise be any of the daylighting units of the abovementioned embodiments.

The daylighting unit **15** of the present embodiment does not have a rectangular planar shape when viewed normal to the daylighting unit **15**. Two of the four corners of the daylighting unit **15** have notches **15***c* and **15***c*. Therefore, air holes **52** and **52** formed by notches **15***c* and **15***c* are located between the frame **61** and the daylighting unit **15**.

The air holes **52** and **52** are located in the upper portion of the frame **61** as viewed in reference to the orientation of the installed daylighting device **60**. When viewed from the interior, one of the air holes **52** is in the right side of the multilayered glass, and the other air hole **52** is in the left side of the multilayered glass. This configuration enables ventilation between the window-side space and the indoor-side space separated by the daylighting device **60** without compromising on daylighting function even in seasons and time periods when the solar azimuth is large.

Seventh Embodiment

Next will describe a seventh embodiment of the present invention. FIG. **31** is a front view of the overall structure of a daylighting device of the seventh embodiment. FIG. **32** is a cross-sectional view of the daylighting device shown in FIG. **31** taken along line E-E'.

The daylighting device of the present embodiment described below has a basic structure that is substantially the same as that of the daylighting device of the first embodiment, but differs in that there are provided fan units. The following description will elaborate on differences from the structure of the first embodiment and skip over common features. In addition, in the figures used in the description, those elements that are the same as those in any of the previous embodiments are given the same reference signs.

Referring to FIGS. **31** and **32**, a daylighting device **70** of the present embodiment includes: a daylighting unit **15**; a frame **16** holding the daylighting unit **15**; a plurality of fan units **71**; and solar cells **72**.

The daylighting unit **15** has a pair of ventilation holes **8**. In each ventilation hole **8** is there disposed a different one of the fan units **71** each composed of two exhaust fans **73**. The ventilation hole **8** has an inner face thereof on which there is provided a light-blocking member **44** described above. In the present embodiment, the daylighting unit **15** may likewise be any of the daylighting units of the abovementioned embodiments.

One of the two exhaust fans **73** and **73** in the fan units **71** is disposed inside the through hole **21** in the first glass plate **10**, and the other exhaust fan **73** is disposed inside the through hole **23** in the third glass plate **14**.

The solar cells **72** are fixed on an open face **16***a* via, for example, an adhesion material **74**. The open face **16***a* is open in a part of the second face **14***b* of the third glass plate **14** located closest to the light-entering face of the daylighting unit **15** and is located in the lower portion of the frame **16**. The solar cells **72** receive sunlight and generate electric power to drive the exhaust fans **73**.

Since the fan units **71** are disposed in the ventilation holes **8** in the daylighting unit **15**, the daylighting device **70** of the present embodiment is capable of forcibly ejecting the air between the multilayered glass and the daylighting device **70** to the interior.

The window glass, the daylighting device **70**, and the space between the window glass and the daylighting device **70** are especially heated in the time periods when sunlight shines on the daylighting device **70**. Therefore, the exhaust fans **73** only need to be driven during daytime while sunlight is shining on the daylighting device **70**. Accordingly, the present embodiment is configured so that the solar cells **72** generate electric power on which the exhaust fans **73** are driven.

In this configuration, the exhaust fans **73** are driven by the solar cells only in the time periods when there is sunlight irradiation and automatically stopped after sunset. The exhaust fans **73** are automatically driven and stopped in this manner, which lowers power consumption. When there is no sunlight shining on the daylighting device **70**, such as during night time, the exhaust fans **73** are not driven. This poses no problems because the window glass is not locally heated.

There are provided light-blocking members **44** in the ventilation holes **8** in the present embodiment. Therefore, dust and waste are unlikely to stick to the surfaces of the daylighting sheet **13** and the light-diffusion sheet **11**.

Each ventilation hole **8** in the present embodiment contains two exhaust fans **73**. Alternatively, each ventilation hole **8** may contain only one exhaust fan **73**.

In addition, the present embodiment includes the solar cells **72** as a means to drive the exhaust fans **73**. Alternatively, the present embodiment may include another driving means.

The preferred embodiments of the present invention have been so far described in reference to the attached drawings. The present invention is by no means limited to the embodiments and examples described above. The person skilled in the art could obviously conceive variations and modifications within the scope of the claims. The variations and modifications are encompassed in the technical scope of the claims. The embodiments may be combined in a suitable manner.

FIGS. **33**A and **33**B are diagrams showing exemplary structures of a ventilation hole.

In the previous embodiments, the ventilation hole is composed of a plurality of through holes each formed in a different member. Alternatively, one/some of the members may have a plurality of through holes formed therein.

For example, as shown in FIG. **33**A, the daylighting sheet **13** may have a single through hole **13***a* formed therein, whereas the light-diffusion sheet **11** may have a plurality of through holes **11***a* formed therein. The through holes **11***a* each have a smaller diameter than the diameter of the through hole **13***a*. In this example, the plurality of through holes **11***a* are formed so that almost all of them overlap the through hole **13***a* when viewed normal to the daylighting sheet **13** and the light-diffusion sheet **11**.

Conversely, as shown in FIG. **33**B, the daylighting sheet **13** may have a plurality of through holes **13***a*, whereas the light-diffusion sheet **11** may have a single through hole **11***a*.

The multilayered glass **7** is not necessarily transparent and may be, for example, wire-reinforced glass or multilayered glass.

Lighting-modulation System

FIG. **34** is a cross-sectional view, taken along line J-J' in FIG. **35**, of a room model **2000** in which a daylighting device and a lighting-modulation system are installed. FIG. **35** is a plan view of a ceiling of the room model **2000**.

In the room model **2000**, a room **2003** into which external light is guided has a ceiling **2003***a* constituted partly by a ceiling material that may have high light-reflecting properties. Referring to FIGS. **34** and **35**, the ceiling **2003***a* of the room **2003** is provided with a light-reflecting ceiling material **2003**A as the ceiling material having such light-reflecting properties. The light-reflecting ceiling material **2003**A is for facilitating the guiding of external light from a daylighting device **2010** installed on a window **2002** deep into the interior. The light-reflecting ceiling material **2003**A is disposed on a part of the ceiling **2003***a* that is close to the window, specifically, on a predetermined part E of the ceiling **2003***a* (approximately up to 3 meters from the window **2002**).

The light-reflecting ceiling material **2003**A, as described above, serves to efficiently direct deep into the interior the external light guided indoors through the window **2002**, on which the daylighting device **2010** (any of the daylighting devices of the abovementioned embodiments) is installed. The external light guided toward the indoor ceiling **2003***a* by the daylighting device **2010** is reflected by the light-reflecting ceiling material **2003**A, hence changing direction and illuminating a desk top face **2005***a* of a desk **2005** placed deep in the interior. Thus, the light-reflecting ceiling material **2003**A has an effect that the desk top face **2005***a* is brightly lit up.

The light-reflecting ceiling material **2003**A may be either diffuse reflective or specular reflective. Preferably, the light-reflecting ceiling material **2003**A is a suitable mix of these properties to achieve both the effect that the desk top face **2005***a* of the desk **2005** placed deep in the interior is brightly lit up and the effect that glare, uncomfortable to occupants, is suppressed.

Much of the light guided into the interior by the daylighting device **2010** travels in the direction of the part of the ceiling that is close to the window **2002**. Still, the part of the interior that is close to the window **2002** often has sufficient lighting. Therefore, the light that strikes the ceiling near the window (part E) can be partially diverted to a deep part of the interior where lighting is poor compared to the part near the window, by additionally using the light-reflecting ceiling material **2003**A described here.

The light-reflecting ceiling material **2003**A may be manufactured, for example, by embossing irregularities each of approximately several tens of micrometers on an aluminum or similar metal plate or by vapor-depositing aluminum or a similar metal onto the surface of a resin substrate having formed thereon similar irregularities to form a thin film of the metal. Alternatively, the embossed irregularities may be formed from a curved surface with a higher cycle.

Furthermore, the embossed shape formed on the light-reflecting ceiling material **2003**A may be changed as appropriate to control light distribution properties thereof and hence resultant indoor light distribution. For example, if stripes extending deep into the interior are embossed, the light reflected by the light-reflecting ceiling material **2003**A is spread to the left and right of the window **2002** (in the directions that intersect the length of the irregularities). When the window **2002** of the room **2003** is limited in size or orientation, these properties of the light-reflecting ceiling material **2003**A are useful in diffusing light in horizontal directions and at the same time reflecting the light deep into the room.

The daylighting device **2010** is used as a part of a lighting-modulation system for the room **2003**. The lighting-modulation system includes, for example, the daylighting device **2010**, a plurality of room lighting devices **2007**, an insolation adjustment device **2008** installed on the window, a control system for these devices, the light-reflecting ceiling material **2003**A disposed on the ceiling **2003***a*, and other structural members of the whole room.

The window **2002** of the room **2003** has the daylighting device **2010** installed on the upper portion thereof and the insolation adjustment device **2008** installed on the lower portion thereof. In this example, the insolation adjustment device **2008** is a window shade, which is by no means intended to be limiting to the scope of the invention.

The room lighting devices **2007** are arranged in the room **2003** in a lattice in the left/right direction (Y direction) of the window **2002** and in the depth direction of the room (X direction). These room lighting devices **2007**, as well as the daylighting device **2010**, constitute an illumination system for the whole room **2003**.

Referring to FIGS. **34** and **35** illustrating the office ceiling **2003***a*, for example, the window **2002** has a length L_1 of 18 meters in the left/right direction (Y direction), and the room **2003** has a length (depth) L_2 of 9 meters in the X direction. The room lighting devices **2007** in this example are arranged in a lattice in the length (Y direction) and depth (X direction) of the ceiling **2003***a* at intervals P each of 1.8 meters. More specifically, a total of 50 room lighting devices **2007** are arranged in a lattice of 10 lines (Y direction) and 5 (X direction) columns.

Each room lighting device **2007** includes an interior lighting fixture **2007***a*, a brightness detection unit **2007***b*, and a control unit **2007***c*. The brightness detection unit **2007***b* and the control unit **2007***c* are integrated into the interior lighting fixture **2007***a* to form a single structure.

Each room lighting device **2007** may include two or more interior lighting fixtures **2007***a* and two or more brightness detection units **2007***b*, with one brightness detection unit **2007***b* being provided for each interior lighting fixture **2007***a*. The brightness detection unit **2007***b*, receiving a reflection off the face illuminated by the interior lighting fixture **2007***a*, detects illuminance on that face. In this example, the brightness detection unit **2007***b* detects illuminance on the desk top face **2005***a* of the desk **2005** placed in the interior.

The control units **2007***c*, each for a different one of the room lighting devices **2007**, are connected to each other. In each room lighting device **2007**, the control unit **2007***c*, connected with the other control units **2007***c*, performs feedback control to adjust the light output of an LED lamp in the interior lighting fixture **2007***a* so that the illuminance on the desk top face **2005***a* detected by the brightness detection unit **2007***b* is equal to a predetermined target illuminance L**0** (e.g., an average illuminance: 750 1×).

FIG. **36** is a graph representing a relationship between the illuminance produced by the daylighting light (natural light) guided into the interior by the daylighting device and the illuminance produced by the room lighting devices (lighting-modulation system). In FIG. **36**, the vertical axis indicates illuminance (1×) on the desk top face, and the horizontal axis indicates distance (meters) from the window. The broken line in the figure indicates the target indoor illuminance. Each black circle denotes an illuminance produced by the daylighting device, each white triangle denotes an illuminance produced by the room lighting devices, and each white diamond denotes a total illuminance.

Referring to FIG. **36**, the desk top face illuminance attributable to the daylighting light guided by the daylighting device **2010** is highest at the window and decreases with increasing distance from the window. This illuminance distribution in the depth direction of the room is caused during daytime by natural daylight coming through a window in the room in which the daylighting device **2010** is installed. Accordingly, the daylighting device **2010** is used in combination with the room lighting devices **2007** which enhance the indoor illuminance distribution. Each room lighting device **2007**, disposed on the interior ceiling, detects an average illuminance below that device by means of the brightness detection unit **2007***b* and lights up in a modulated manner so that the desk top face illuminances across the whole room are equal to the predetermined target illuminance L**0**.

Therefore, a column S**1** and a column S**2** near the window only dimly light up, whereas a column S**3**, a column S**4**, and a column S**5** light up to produce output that increases with increasing depth into the room (increases in the order of the column S**3**, the column S**4**, and the column S**5**). Consequently, the desk top faces across the whole room are lit up by the sum of the illumination by natural daylight and the illumination by the room lighting devices **2007** at a desk top face illuminance of 750 1×, which is regarded as sufficient for desk work (see, JIS Z9110, General Rules of Recommended Lighting Levels, Recommended Illuminance at Offices).

As described above, light can be delivered deep into the interior by using both the daylighting device **2010** and the lighting-modulation system (room lighting devices **2007**) together. This can in turn further improve indoor brightness and ensure a sufficient desk top face illuminance for desk work across the whole room, hence realizing a more stable, brightly lit-up environment independently from the season or the weather.

INDUSTRIAL APPLICABILITY

The present invention, in an aspect thereof, is applicable to, for example, a daylighting device that needs to suppress temperature increases between window glass and the daylighting device and hence prevent thermal cracking of the window glass and a substrate of the daylighting device.

REFERENCE SIGNS LIST

2, **20**, **30**, **40**, **50**, **53**, **55**, **60**, **70**, **201**, **202**, **203**, **204**, and **2010**: Daylighting Device
8, **8**A, **8**B, and **8**C: Ventilation Hole (Communication Hole)
8*a*: Inner Face
11*a*, **13***a*, **21**, **22**, and **23**: Through Hole
L: Sunlight
10: First Glass Plate (Transparent Base Member)
11: Light-diffusion Sheet (Light-diffusion Member)
11*a*: Through Hole (Second Through Hole)
13: Daylighting Sheet (Daylighting Member)
13*a*: Through Hole (First Through Hole)
16, **51**, **54**, **56**, and **61**: Frame
18: Adhesive (Affixing Member)
24: Adhesive Layer
41: Film Base Member (First Base Member)
41*a*: First Face
41*b*: Second Face
42: Daylighting Section
42E: Fifth Face (Reflective Face)
42F: Sixth Face (Reflective Face)
52: Air Hole (Ventilation Hole)
61*a*: Opening
73: Exhaust Fan
K**1** and K**2**: Space
302: Anisotropic Light-diffusion Sheet (Adhesive Layer)

What is claimed is:

1. A daylighting device, comprising:
a daylighting member comprising:
a first base member having light-transmitting properties; and
a plurality of protruding daylighting sections having light-transmitting properties and provided on a first face of the first base member; and
at least one ventilation hole configured to enable a first space to communicate with a second space on a second face opposite from the first face, the at least one ventilation hole being provided at the first base member and the plurality of protruding daylighting sections,
wherein the at least one ventilation hole is only formed in an upper portion of the daylighting device.

2. The daylighting device according to claim **1**, wherein the ventilation hole is provided in a region where the daylighting member makes no contribution to daylighting.

3. The daylighting device according to claim **1**, wherein:
the daylighting member has a first through hole extending through a thickness direction of the daylighting member; and
the ventilation hole comprises the first through hole.

4. The daylighting device according to claim **3**, further comprising a light-diffusion member provided on either a light-entering side or a light-exiting side of the daylighting member, wherein:
the ventilation hole comprises the first through hole and a second through hole extending through a thickness direction of the light-diffusion member; and
the second through hole at least partially overlaps the first through hole when viewed normal to the daylighting member.

5. The daylighting device according to claim **4**, wherein:
the light-diffusion member is provided on the light-exiting side of the daylighting member; and
the second through hole is smaller in size than the first through hole.

6. The daylighting device according to claim **4**, wherein:
the second through hole has such a shape that has a lengthwise direction; and
the second through hole resides so that the lengthwise direction thereof is parallel to an extension direction of the daylighting sections.

7. The daylighting device according to claim **4**, wherein:
the light-diffusion member comprises an adhesive layer having such anisotropy in light-diffusion properties as to diffuse more light in a direction that intersects the two disposition directions than in the two disposition directions; and
the daylighting member is provided on a transparent base member with the light-diffusion member interposed therebetween.

8. The daylighting device according to claim **4**, wherein the ventilation hole forms a single communication hole by comprising the daylighting member, the light-diffusion member, and an affixing member provided between the daylighting member and the light-diffusion member disposed at a distance from each other.

9. The daylighting device according to claim **1**, wherein the ventilation hole is provided in a region through which not much sunlight enters the daylighting member.

10. The daylighting device according to claim **1**, wherein the ventilation hole has an inner face on which there is provided a material having light-blocking properties.

11. The daylighting device according to claim **1**, further comprising a frame containing at least the daylighting member, wherein the ventilation hole is provided between the daylighting member and the frame.

12. The daylighting device according to claim **1**, further comprising a frame containing at least the daylighting member, wherein the frame has at least two openings, one containing the daylighting member and the other serving as the ventilation hole.

13. The daylighting device according to claim **1**, further comprising an exhaust fan in the ventilation hole, the exhaust fan being configured to vent air via the ventilation hole from a light-entering side to a light-exiting side.

14. The daylighting device according to claim **1**,
wherein the at least one ventilation hole is a plurality of ventilation holes provided along an extension direction of the plurality of protruding daylighting sections.

15. The daylighting device according to claim **14**,
wherein each of the plurality of ventilation holes has a cornerless planar shape.

16. The daylighting device according to claim **14**, wherein the at least one ventilation hole comprises at least three ventilation holes, and

the at least three ventilation holes are provided along the extension direction of the plurality of protruding daylighting sections.

17. The daylighting device according to claim **1**, further comprising:

a caulking material provided at a peripheral portion of the first base member.

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