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(54) **COMMUNICATION MODULE**

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(57) **ABSTRACT**

A communication module includes a housing, a circuit board in the housing, a heating element on the circuit board, and a heat dissipating member sandwiched between the inside surface of the housing and the heating element. The inside surface includes protrusions protruding toward the heating element.

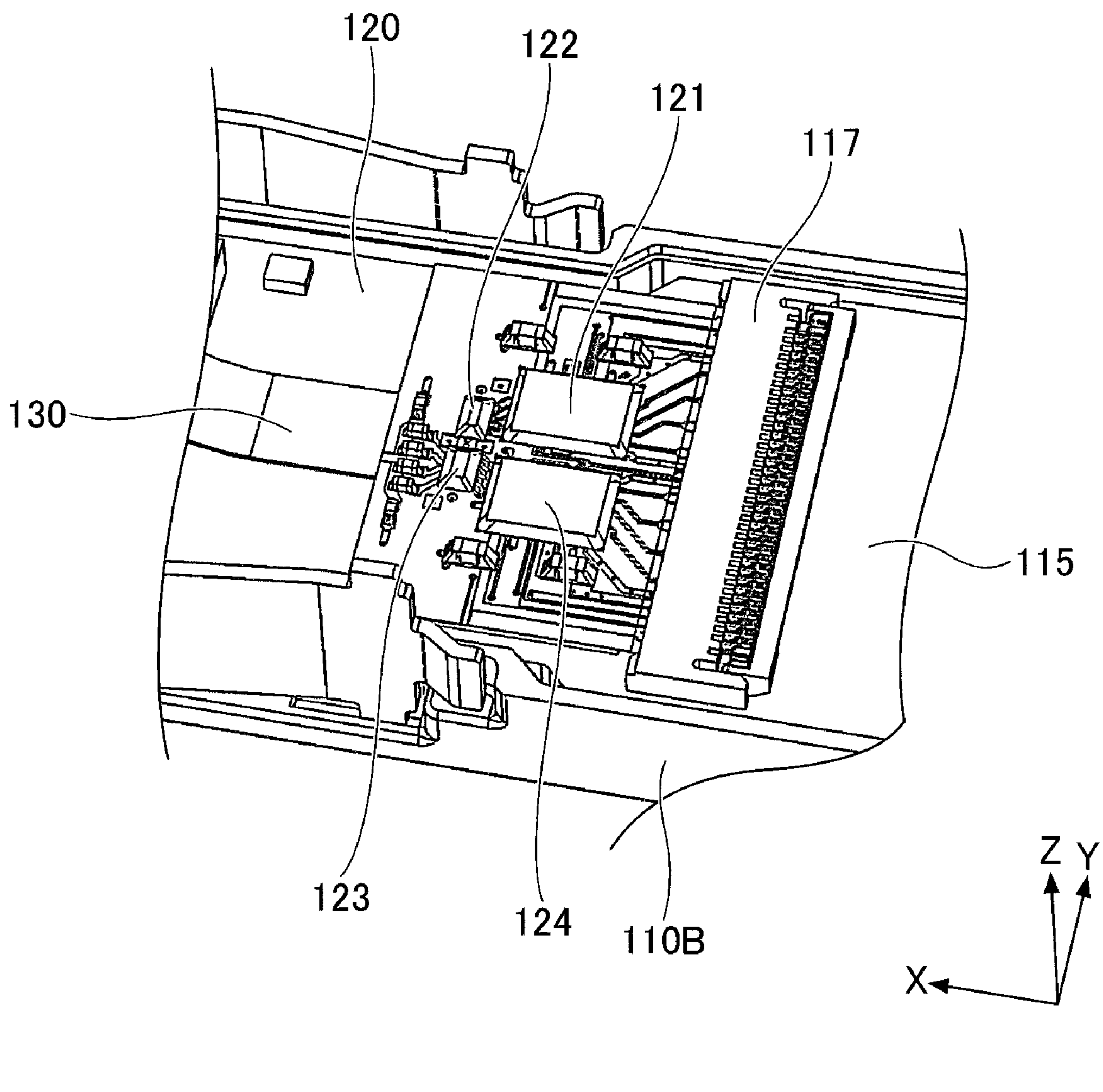

FIG.1

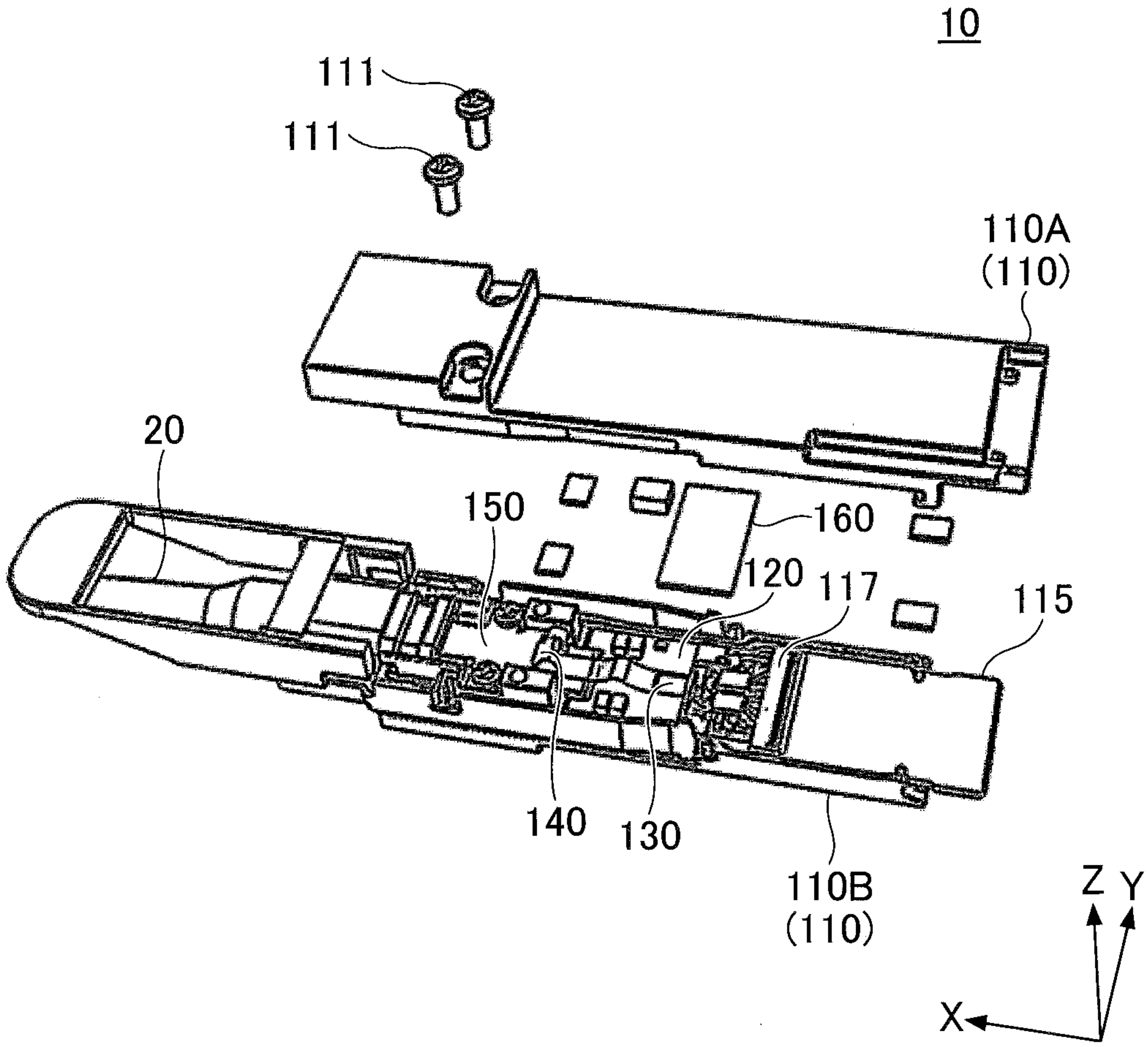

FIG.2

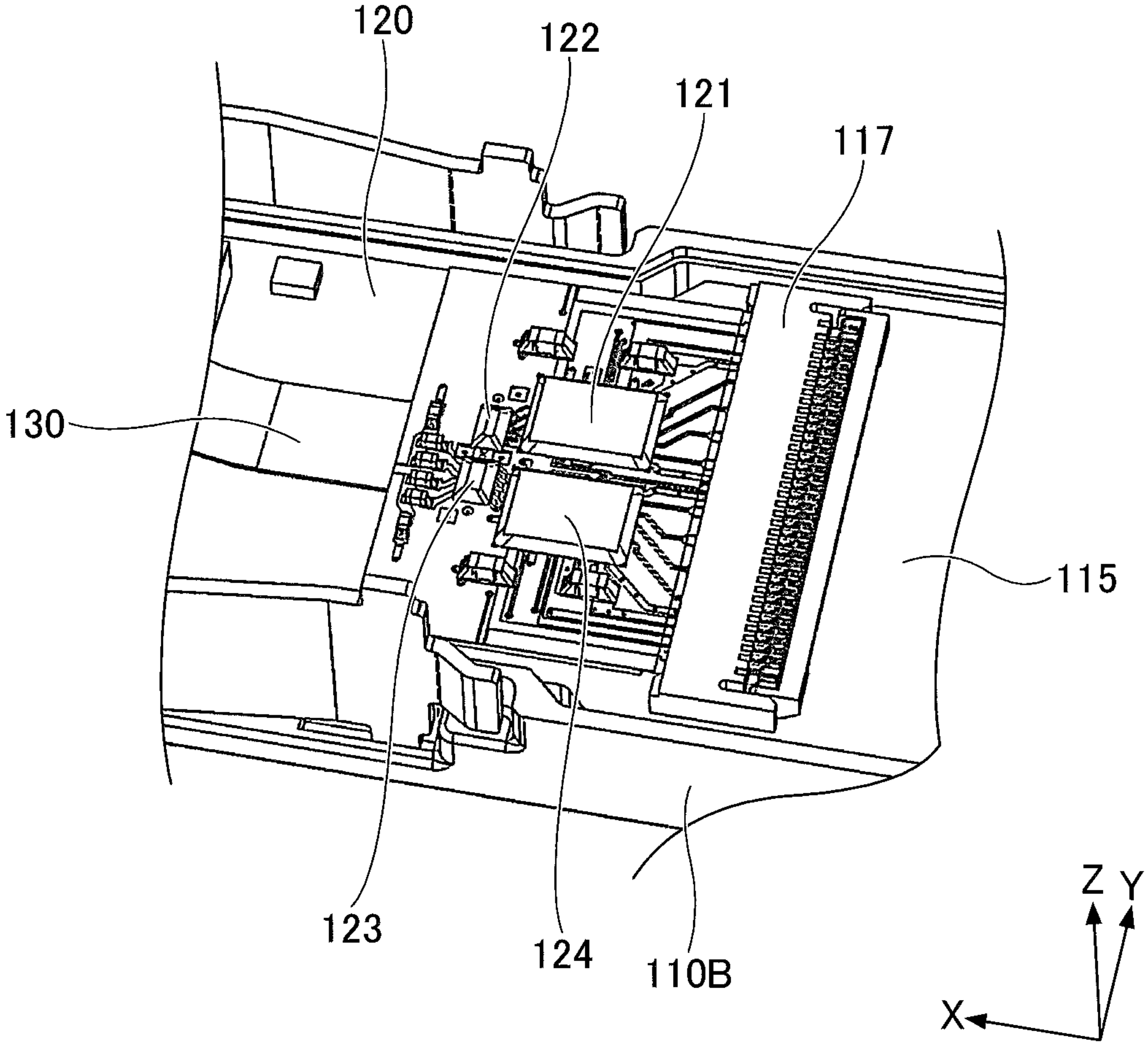

FIG.3

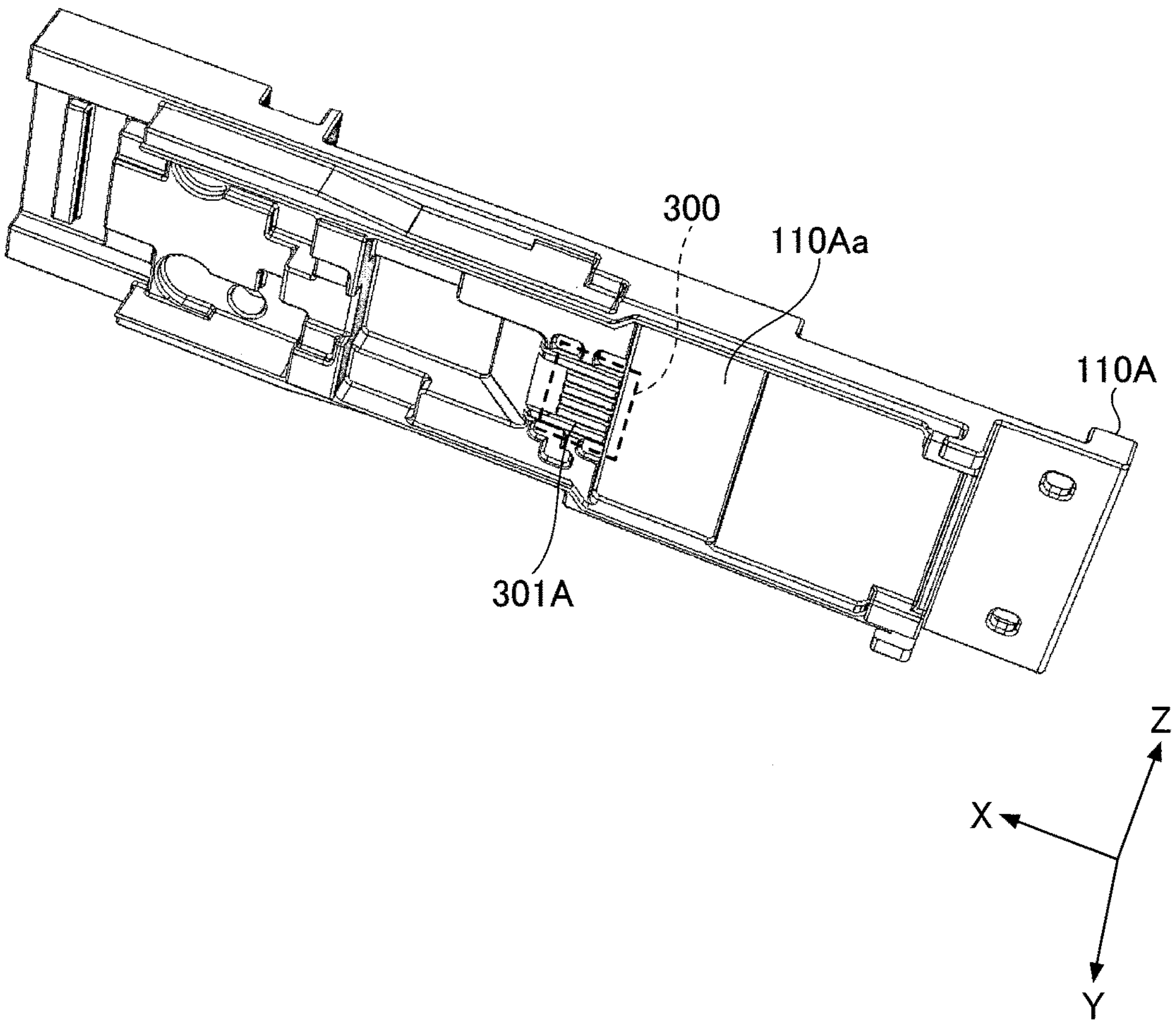

FIG.4

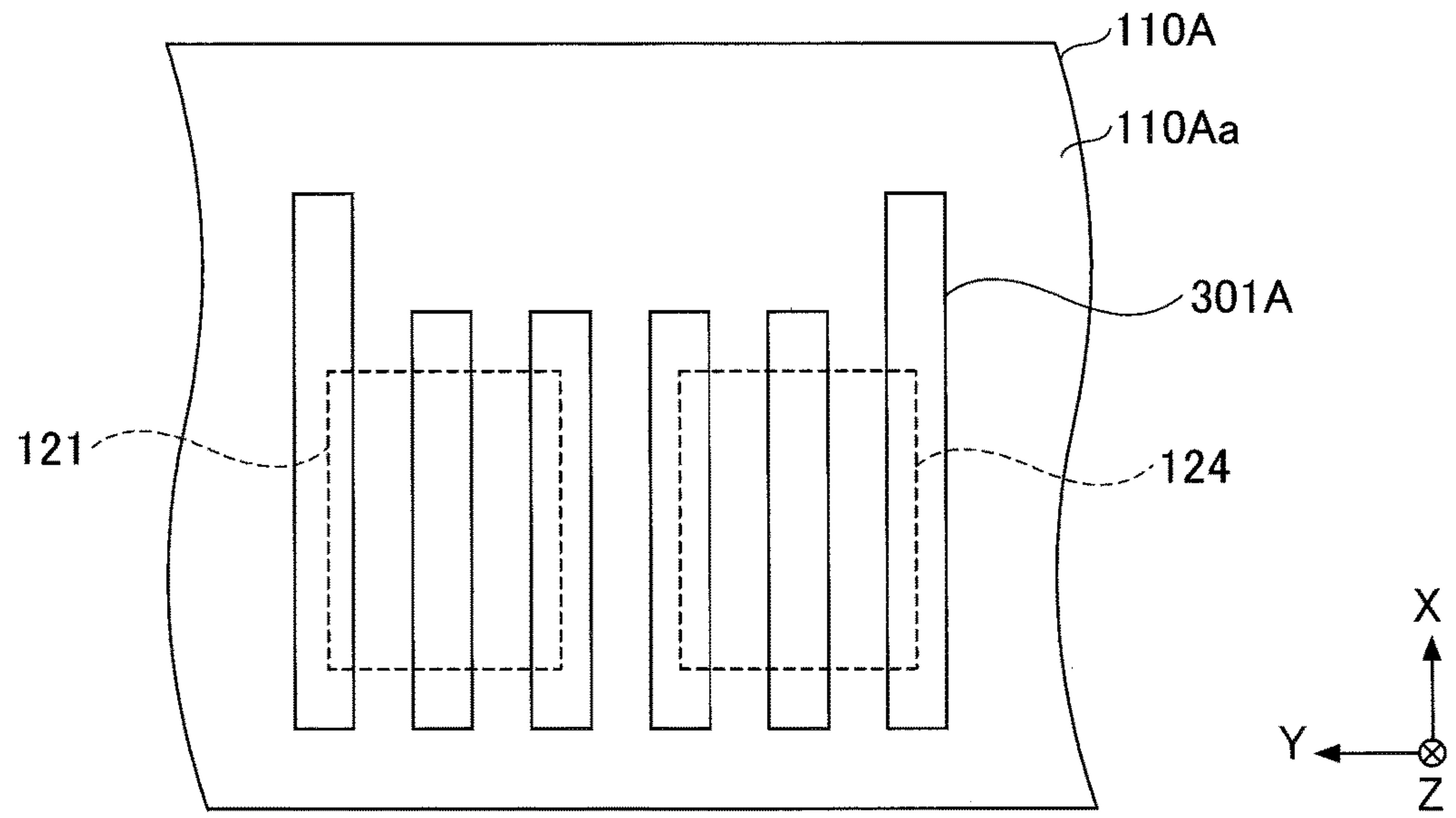
110A
110Aa
301A
121
124
X
Y
Z

FIG.5

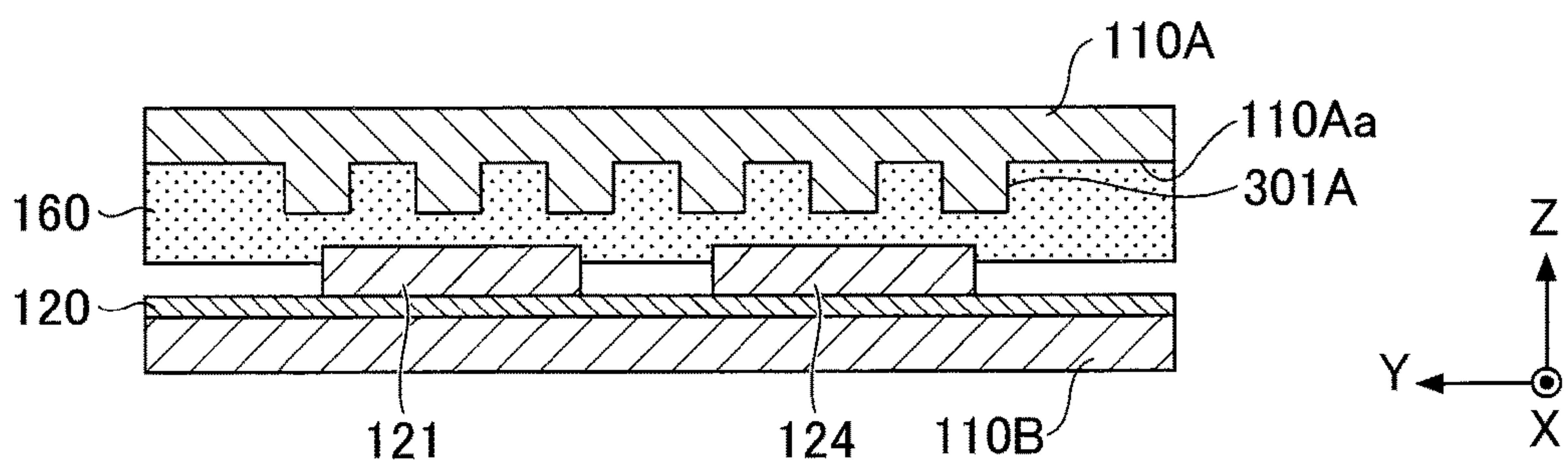
110A
110Aa
301A
160
120
121
124
110B
Z
Y
X

FIG.6

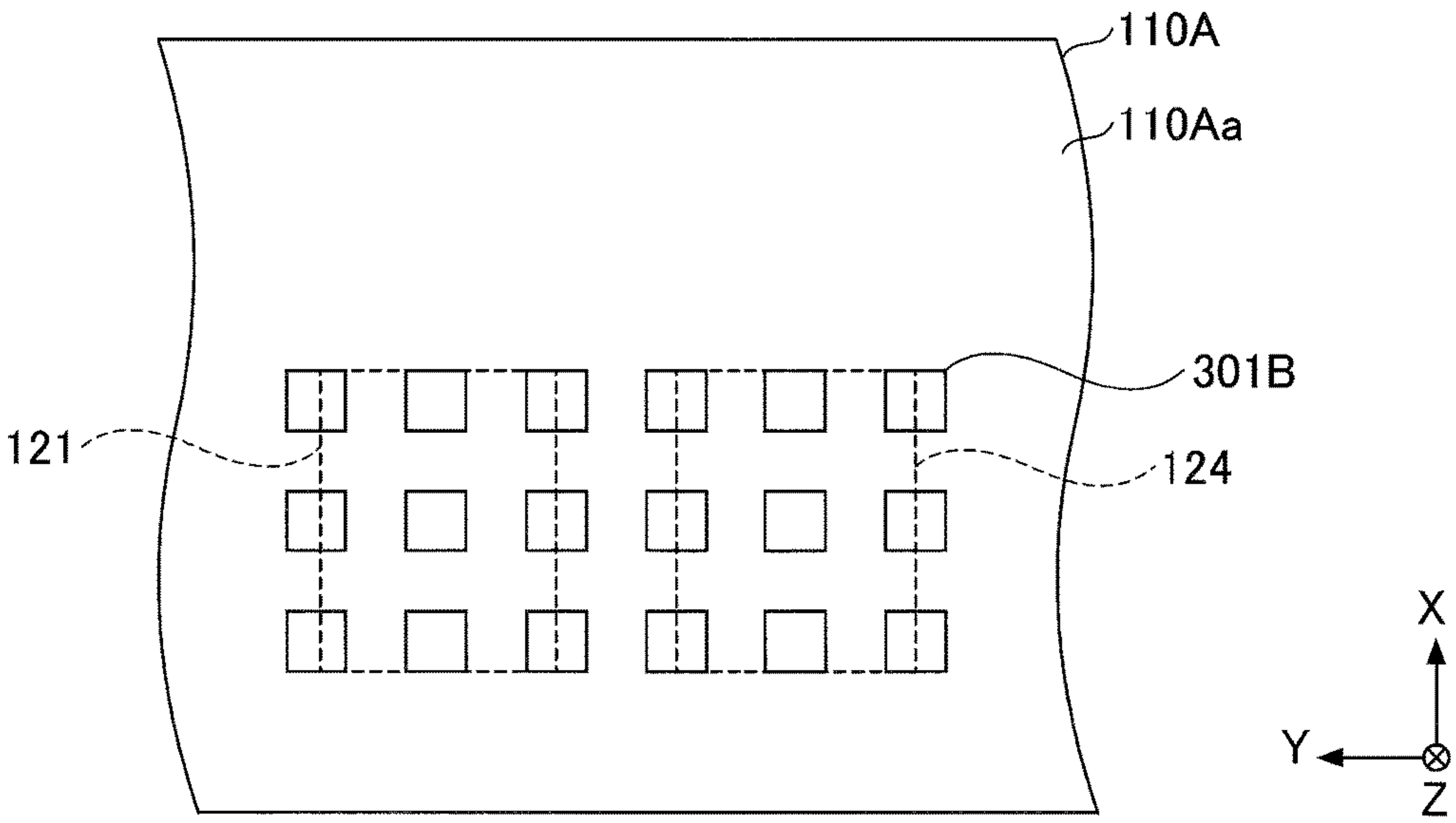
110A
110Aa
301B
121
124
X
Y
Z

FIG.7

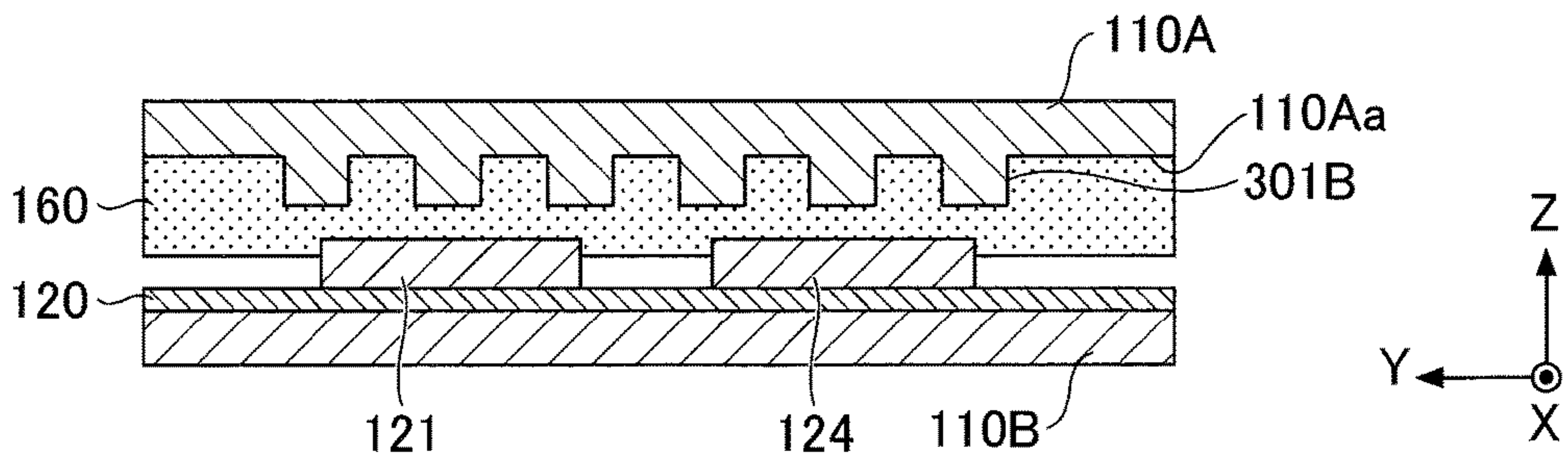
110A
110Aa
301B
160
120
121
124
110B
Z
Y
X

FIG.8

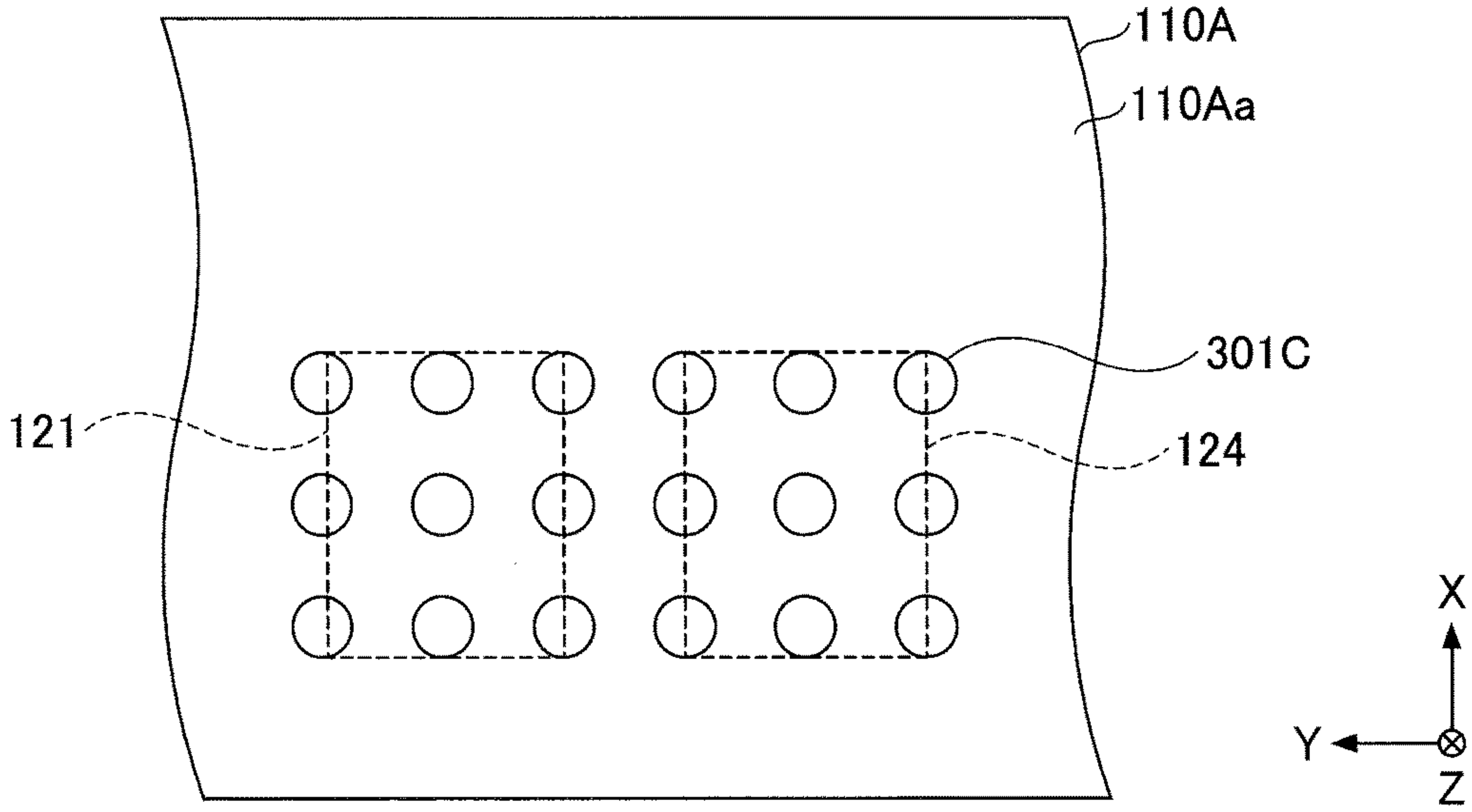
110A
110Aa
301C
121
124
X
Y
Z

FIG.9

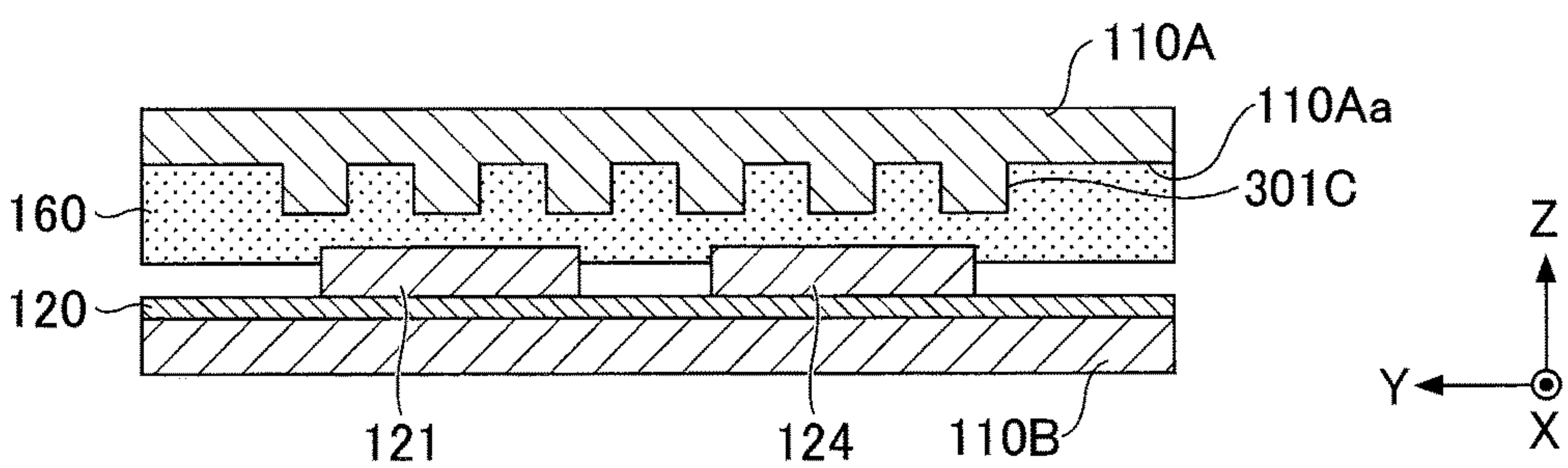
110A
110Aa
301C
160
120
121
124
110B
Z
Y
X

FIG.10

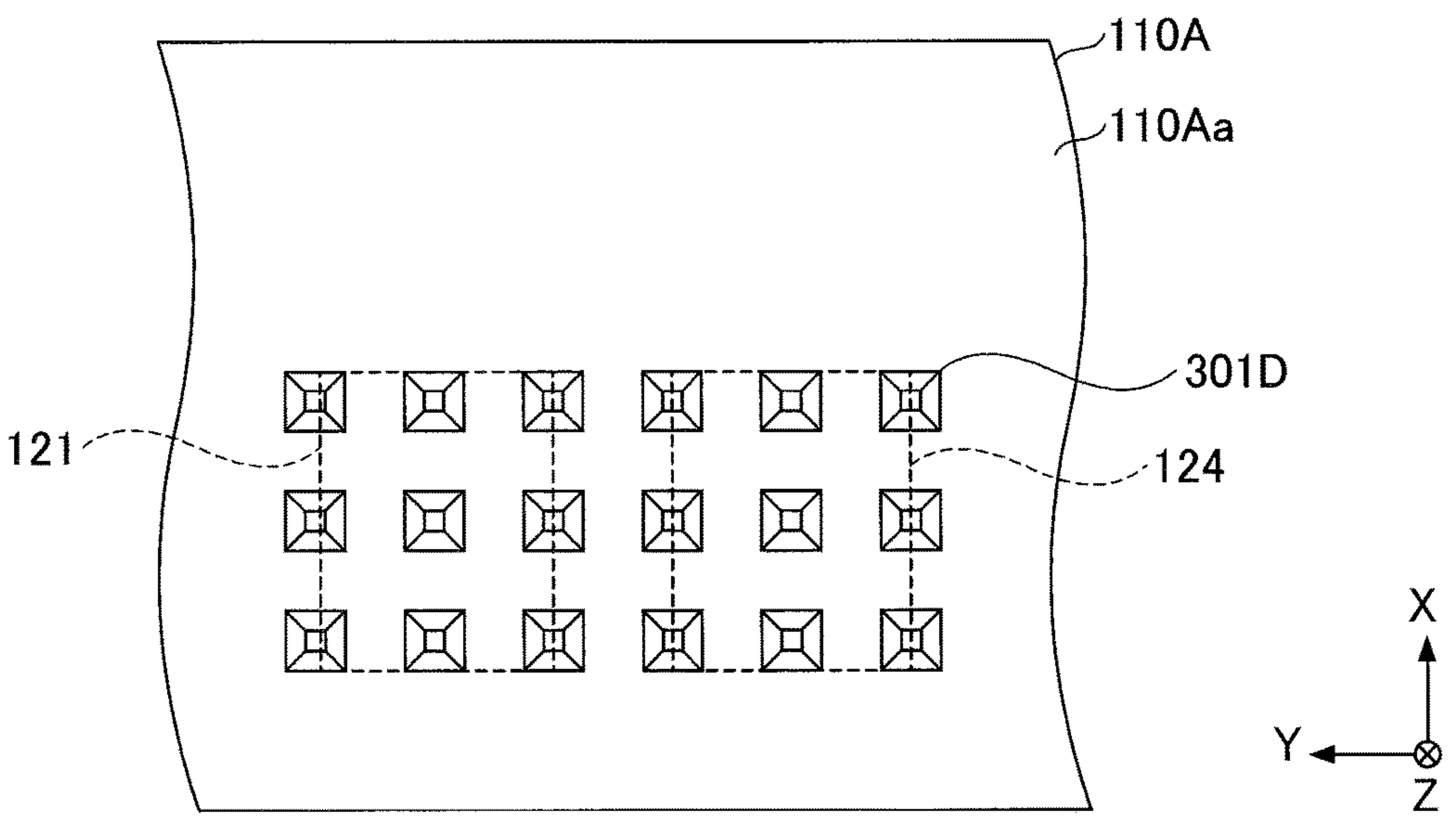
110A
110Aa
301D
121
124
X
Y
Z

FIG.11

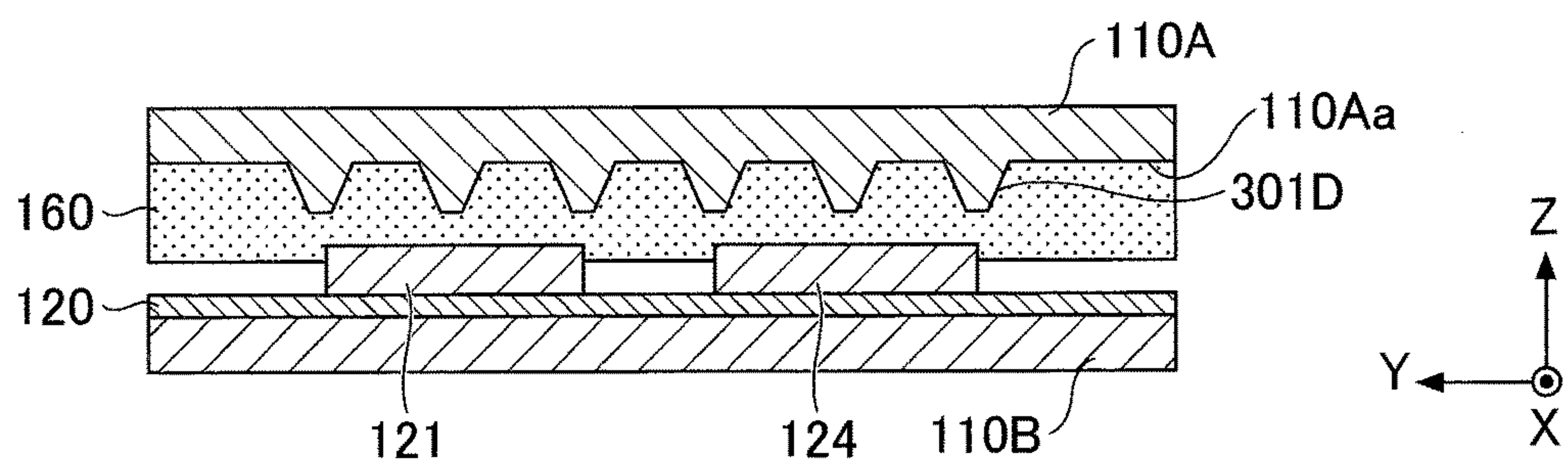
110A
110Aa
160
301D
120
121
124
110B
Z
Y
X

FIG.12

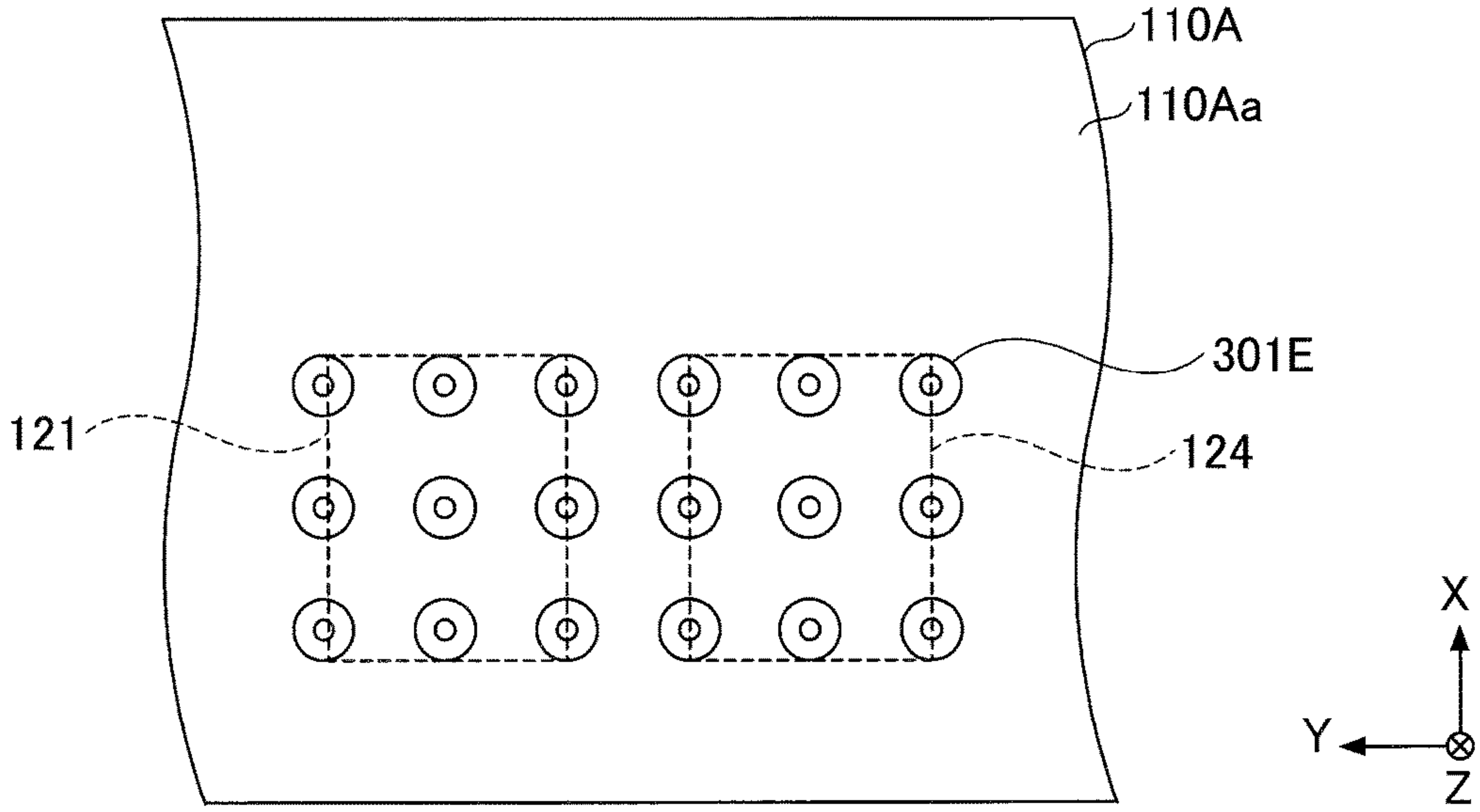
110A
110Aa
301E
121
124
X
Y
Z

FIG.13

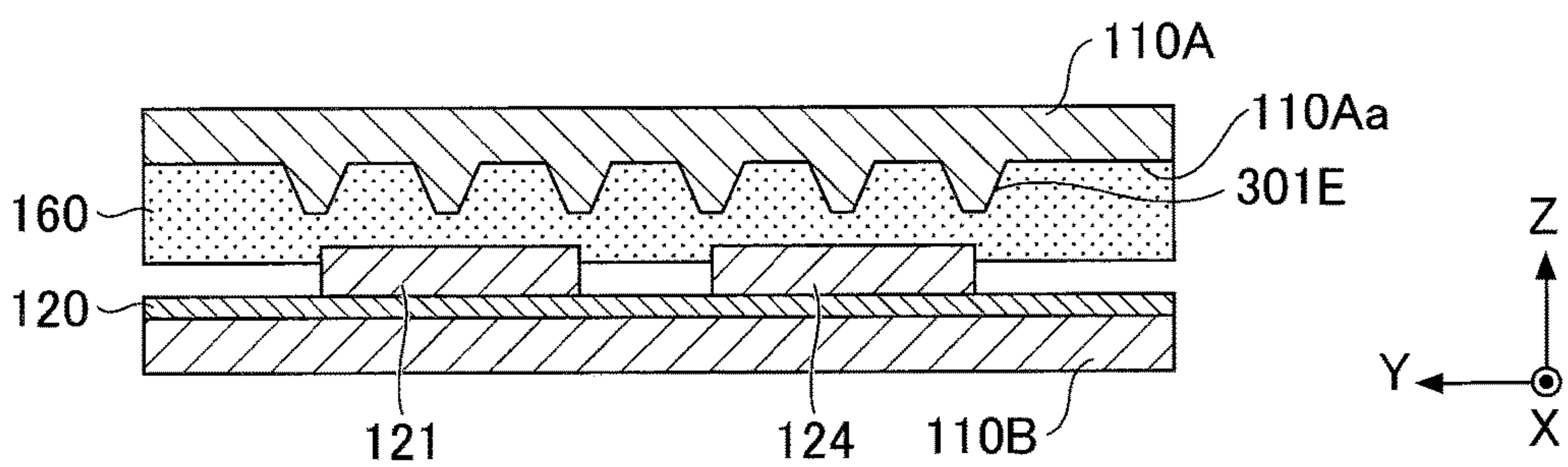
110A
110Aa
301E
160
120
121
124
110B
Z
Y
X

FIG.14

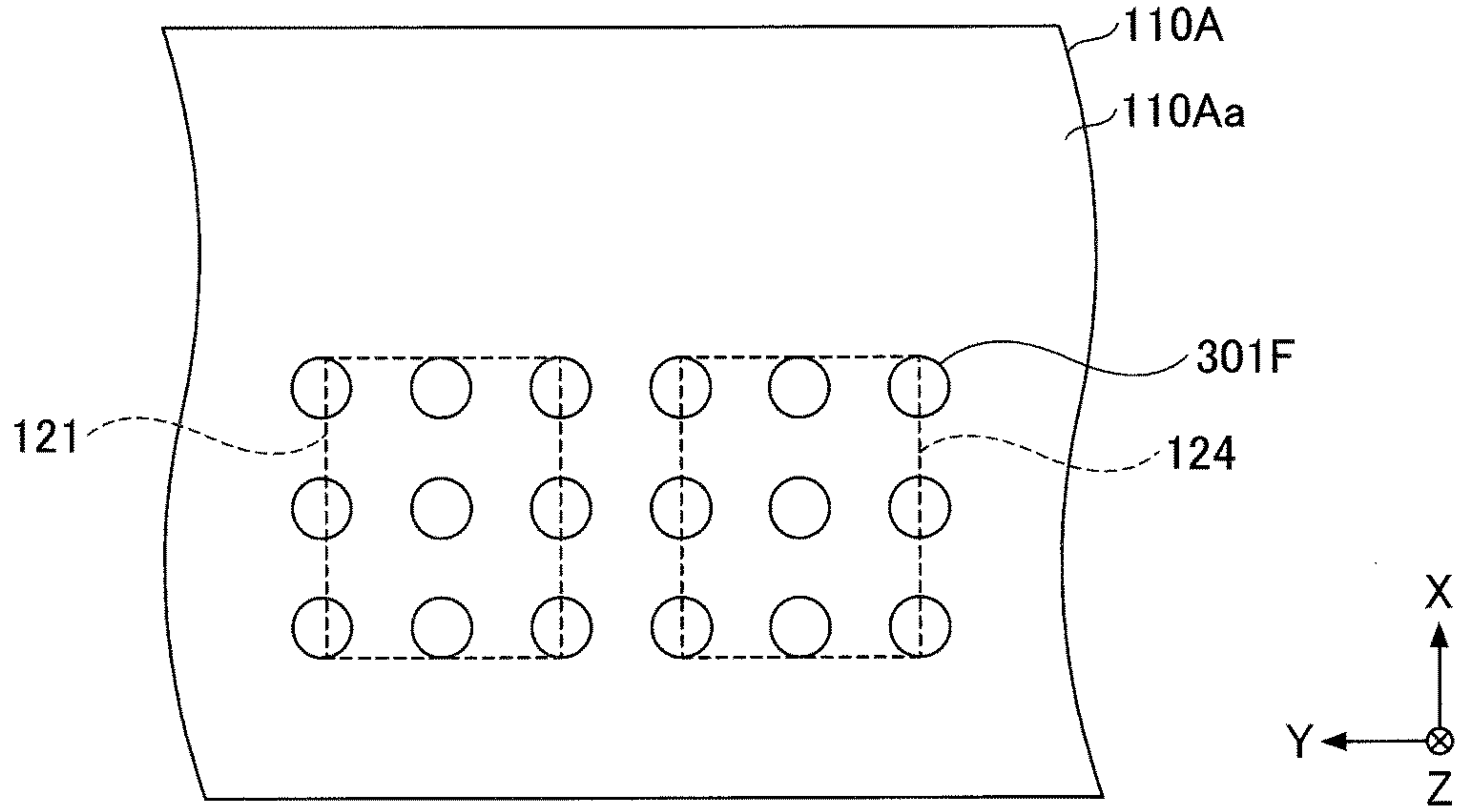
110A
110Aa
301F
121
124
X
Y
Z

FIG.15

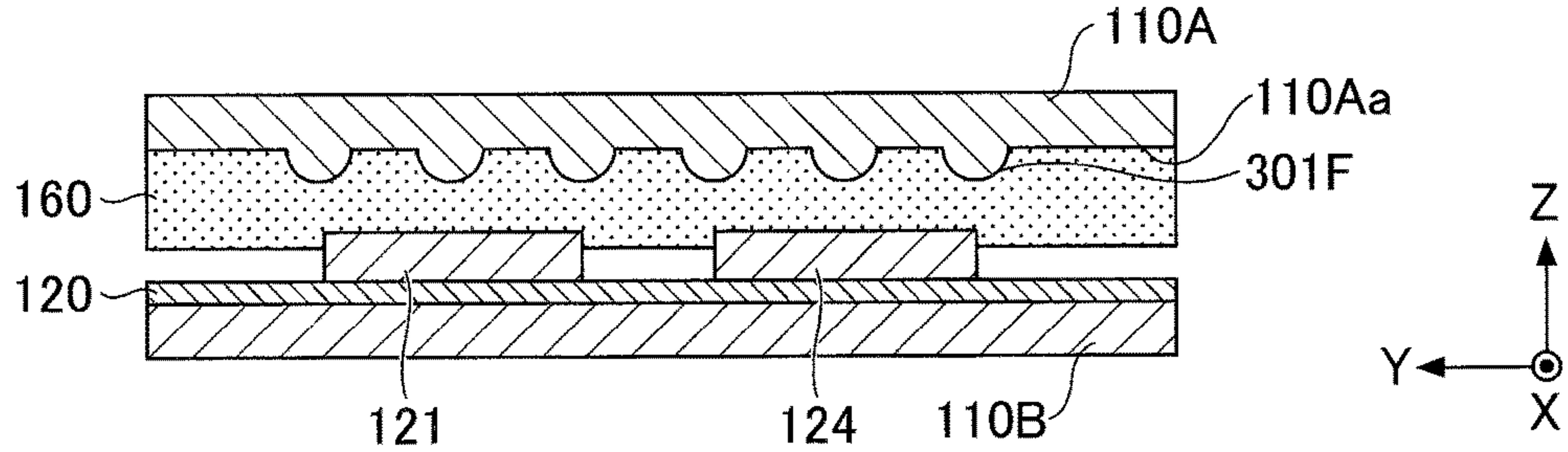
110A
110Aa
301F
160
120
121
124
110B
Z
Y
X

FIG.16

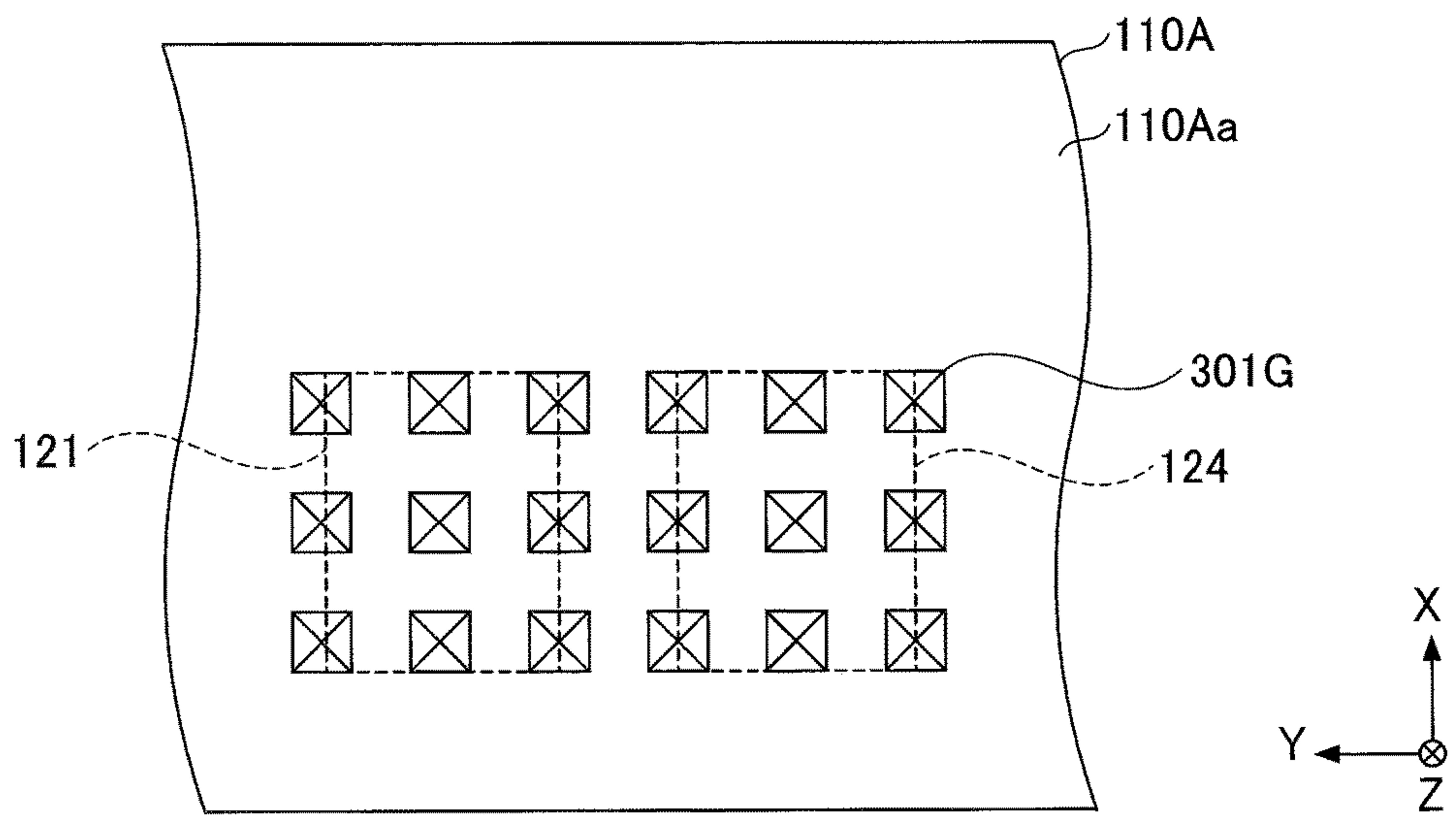
110A
110Aa
301G
121
124
X
Y
Z

FIG.17

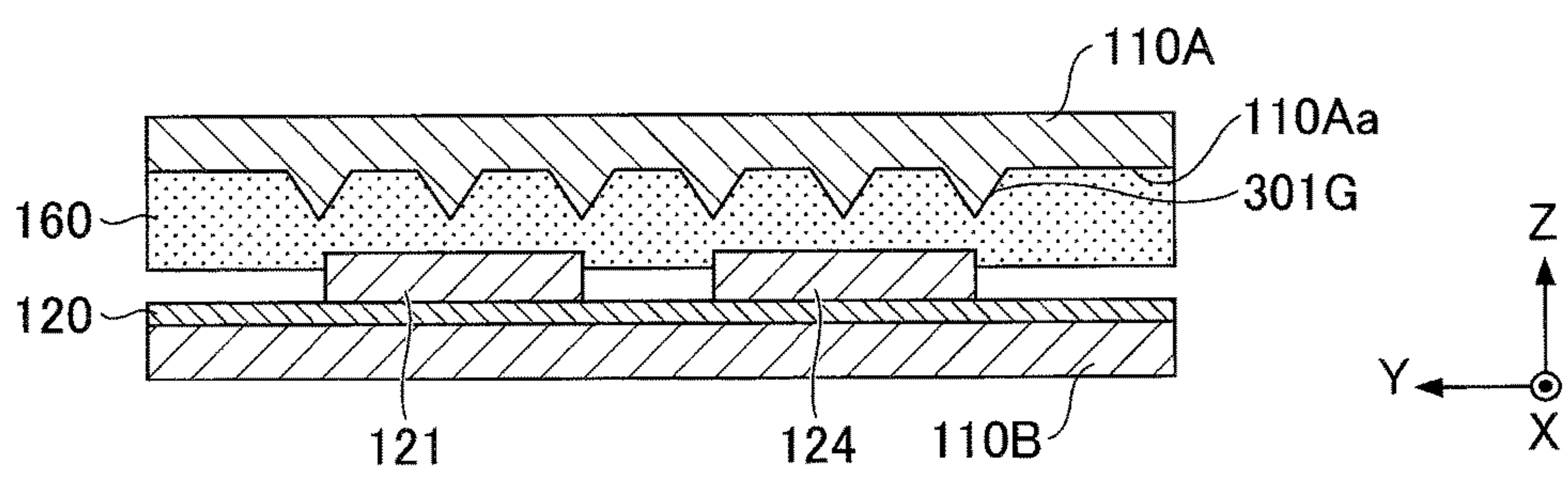
110A
110Aa
301G
160
120
121
124
110B
Z
Y
X

FIG.18

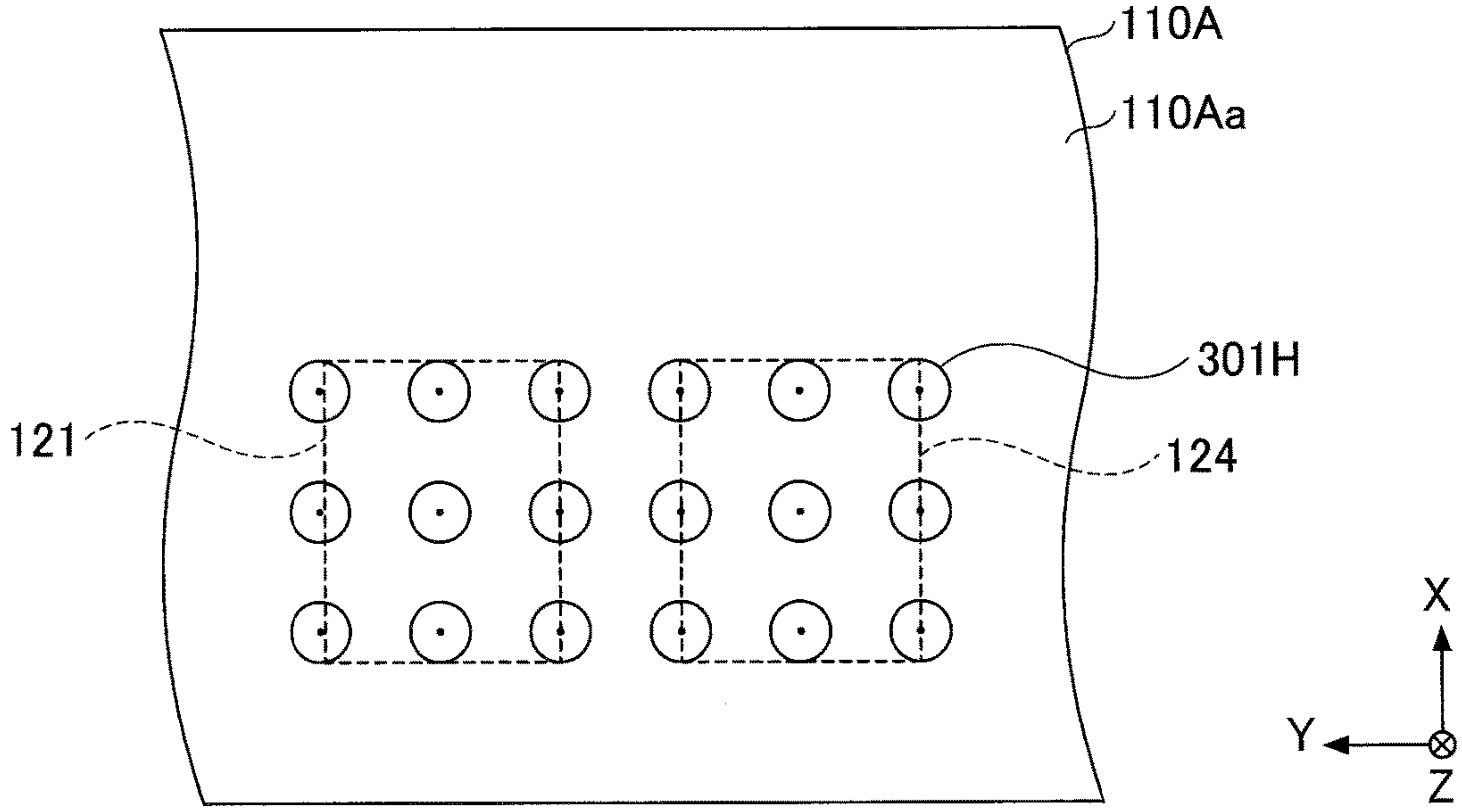
110A
110Aa
301H
121
124
X
Y
Z

FIG.19

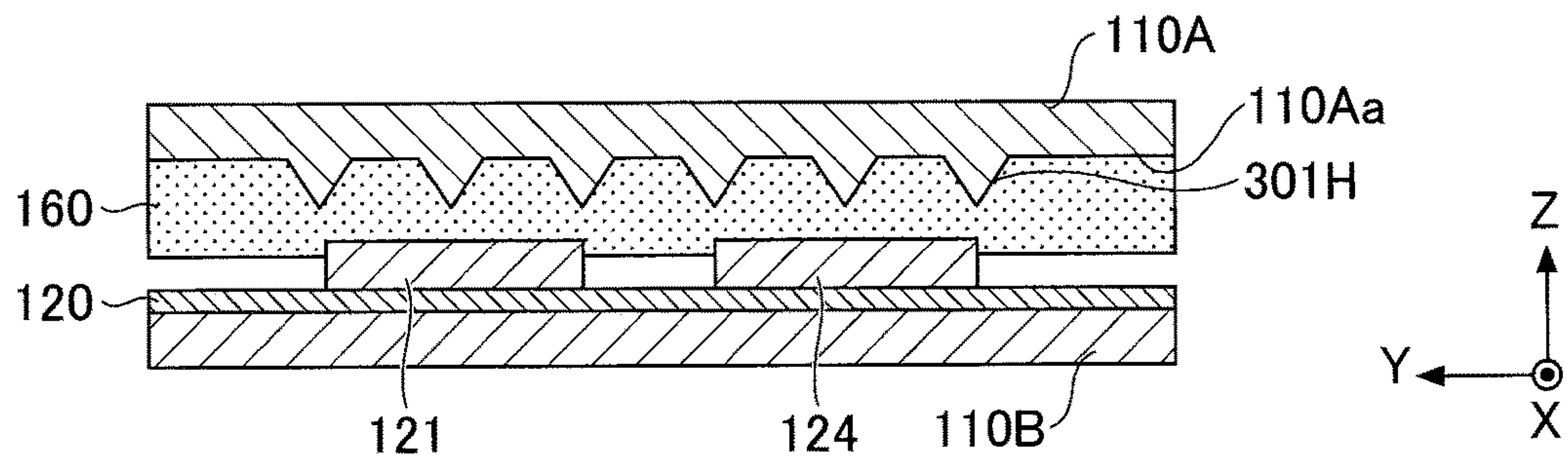
110A
110Aa
301H
160
120
121
124
110B
Z
Y
X

FIG.20

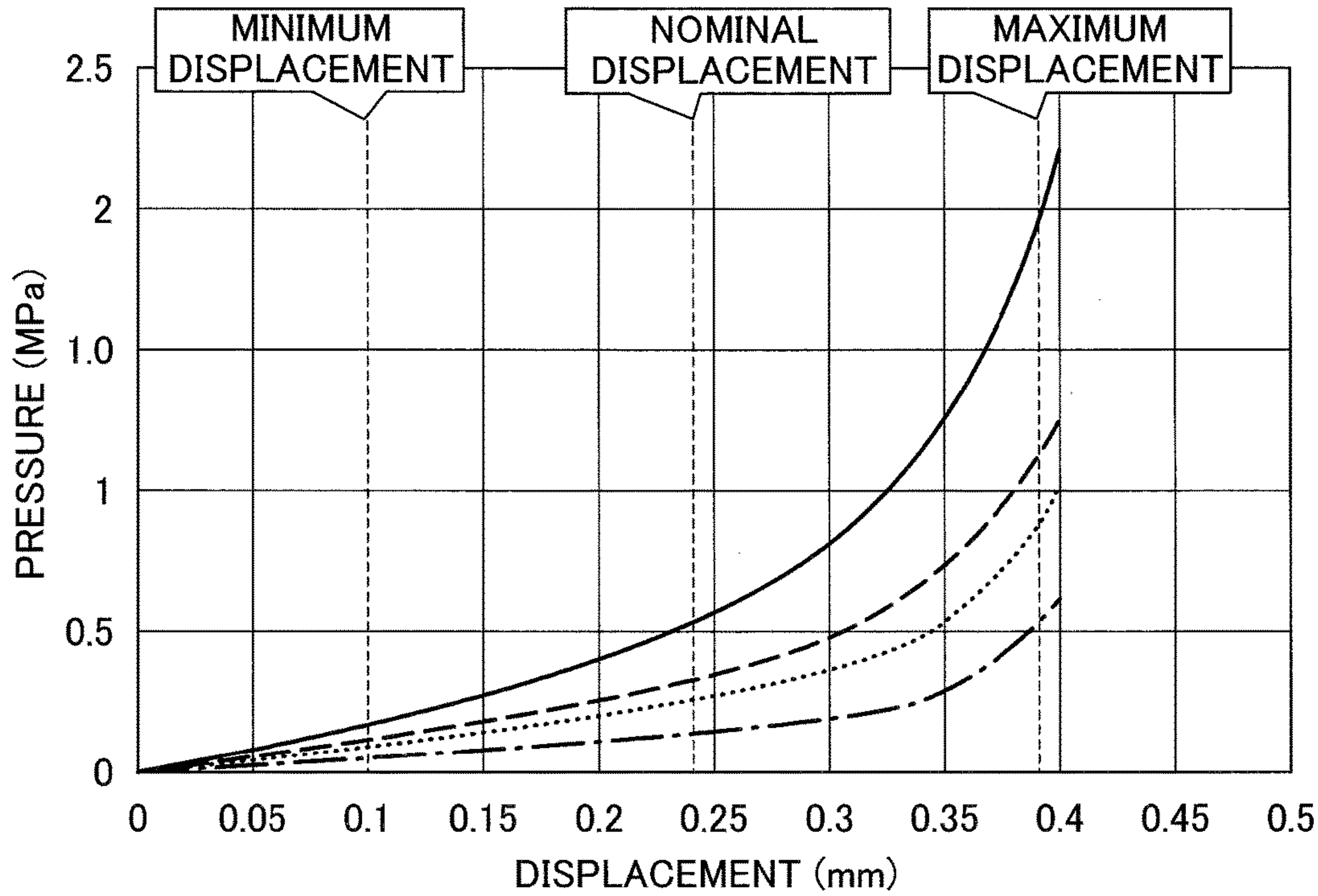

FIG.21

MEASUREMENT POINT	INCREASED TEMPERATURE [°C]				
	COMPARATIVE EXAMPLE 1	EXAMPLE 1	EXAMPLE 2	EXAMPLE 3	COMPARATIVE EXAMPLE 2
DRIVER	73.7	75.7	76.3	79.4	82.0
TIA	70.1	71.7	72.0	74.0	75.4
HOUSING UPPER SURFACE	65.1	65.8	65.8	65.7	65.2

COMMUNICATION MODULE

CROSS-REFERENCE TO RELATED APPLICATION

[0001] The present application is based on and claims priority to Japanese patent application No. 2018-075217, filed on Apr. 10, 2018, the entire contents of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0002] The present invention relates to communication modules.

2. Description of the Related Art

[0003] Communication devices of supercomputers or the like use optical communications to enable high-speed transmission of large-capacity communication data.

[0004] In optical communications, an optical module is used to connect an optical cable to a communication device. The optical module converts an optical signal into an electrical signal, and coverts an electrical signal into an optical signal.

[0005] The optical module includes a light-emitter, a driver that drives the light-emitter, a light-receiver, and a transimpedance amplifier (TIA) that converts an electric current signal into a voltage signal.

[0006] Devices such as a driver and a TIA operate to generate heat. Therefore, for a stable operation of the optical module, it is desired to reduce generation of heat by heating elements. To reduce generation of heat by heating elements, a heat dissipating member is provided between a heating element and a housing to transfer heat from the heating element to the housing to dissipate the heat outside the housing. See Japanese Laid-open Patent Publication No. 2008-306064.

SUMMARY OF THE INVENTION

[0007] According to an aspect of the present invention, a communication module includes a housing, a circuit board in the housing, a heating element on the circuit board, and a heat dissipating member sandwiched between the inside surface of the housing and the heating element. The inside surface includes protrusions protruding toward the heating element.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIGS. **1** and **2** are an exploded perspective view and a partial enlarged view, respectively, of an optical module according to an embodiment;

[0009] FIG. **3** is a diagram illustrating the inside surface of an upper casing of the optical module according to the embodiment;

[0010] FIG. **4** is a diagram illustrating protrusions according to the embodiment;

[0011] FIG. **5** is a cross-sectional view of the optical module according to the embodiment;

[0012] FIG. **6** is a diagram illustrating protrusions according to a first variation;

[0013] FIG. **7** is a cross-sectional view of the optical module according to the first variation;

[0014] FIG. **8** is a diagram illustrating protrusions according to a second variation;

[0015] FIG. **9** is a cross-sectional view of the optical module according to the second variation;

[0016] FIG. **10** is a diagram illustrating protrusions according to a third variation;

[0017] FIG. **11** is a cross-sectional view of the optical module according to the third variation;

[0018] FIG. **12** is a diagram illustrating protrusions according to a fourth variation;

[0019] FIG. **13** is a cross-sectional view of the optical module according to the fourth variation;

[0020] FIG. **14** is a diagram illustrating protrusions according to a fifth variation;

[0021] FIG. **15** is a cross-sectional view of the optical module according to the fifth variation;

[0022] FIG. **16** is a diagram illustrating protrusions according to a sixth variation;

[0023] FIG. **17** is a cross-sectional view of the optical module according to the sixth variation;

[0024] FIG. **18** is a diagram illustrating protrusions according to a seventh variation;

[0025] FIG. **19** is a cross-sectional view of the optical module according to the seventh variation;

[0026] FIG. **20** is a graph illustrating the characteristic of a load on a heating element according to examples; and

[0027] FIG. **21** is a table illustrating the temperature characteristic of the heating element according to the examples.

DESCRIPTION OF THE EMBODIMENTS

[0028] According to JP 2008-306064, a metal casing includes multiple protrusions and depressions that are closely formed where the metal casing contacts a thermally conductive sheet, and presses the thermally conductive sheet with the protrusions. Because of the pointed ends of the protrusions, a vertical pressure is horizontally distributed to reduce mechanical stress on an electronic component. However, J P 2008-306064 focuses only on reduction in mechanical stress, and does not simultaneously attempt to further improve the heat dissipation efficiency of the electronic component.

[0029] According to an aspect of the present invention, a communication module that can improve the efficiency of heat dissipation through a heat dissipating member while reducing a load applied to a heating element from a housing is provided.

[0030] An embodiment is described below with reference to the drawings. In the following description, a Z direction, an X direction, and a Y direction in the drawings are referred to as a vertical direction, a longitudinal direction, and a lateral direction, respectively.

[0031] FIGS. **1** and **2** are an exploded perspective view and a partial enlarged view, respectively, of the optical module **10** according to the embodiment. The optical module **10** is an example of a communication module. The optical module **10** is a device attached to an optical cable **20** to connect the optical cable **20** to a communication device of, for example, a supercomputer. By connecting the optical module **10** to the communication device, optical signals can be transmitted to and received from the communication device. The optical module **10** converts an electrical signal output from the communication device into an optical signal, and transmits the optical signal to the optical cable **20**.

The optical module **10** converts an optical signal transmitted from the optical cable **20** into an electrical signal, and outputs the electrical signal to the communication device.

[0032] Referring to FIG. **1**, the optical module **10** includes a housing **110**, a printed circuit board **115**, a flexible printed circuit (FPC) **120**, an optical waveguide **130**, a ferrule **140**, a clip **150**, and a heat dissipating sheet **160**.

[0033] The housing **110** is a vertically thin box-shaped member having a substantially parallelepiped shape. A metal material such as an aluminum or zinc die casting is used for the housing **110**. The housing **110** includes an upper casing **110**A and a lower casing **110**B that are separable from each other. The casing **110**B is a member that is open on the upper side. The casing **110**A is a lid-shaped member that closes the opening of the casing **110**B. The board **115**, the FPC **120**, and the sheet **160** are incorporated into the housing **110**. The optical cable **20** extends from a first end of the housing **110**. The board **115** is exposed at a second end of the housing **110**. The casing **110**A and the casing **110**B are fixedly coupled with screws **111**.

[0034] The board **115** is provided at an end of the casing **110**B. The board **115** lies between the communication device and the FPC **120**. The FPC **120** is electrically connected to a connector **117** provided on the board **115**.

[0035] The FPC **120** is a circuit board constituting an electronic circuit that implements the functions of the optical module **10**. Circuit parts are mounted on the FPC **120**. The FPC **120** is a film-shaped member having interconnects sandwiched between resin materials such as polyimide. Referring to FIG. **2**, a driver **121**, a light-emitter (emitter) **122**, a light-receiver (receiver) **123**, and a TIA **124** are mounted on the FPC **120**.

[0036] The driver **121** is an integrated circuit (IC) that drives the emitter **122** in accordance with an electrical signal input from the communication device. The emitter **122** is driven by the driver **121** to emit laser light according to the input electrical signal. A vertical-cavity surface-emitting laser (VCSEL) may be used as the emitter **122**. The emitted laser light is guided to the optical cable **20** via the optical waveguide **130**.

[0037] The receiver **123** receives laser light from the optical cable **20** via the optical waveguide **130**, and outputs a current signal commensurate with the amount of received light. A photodiode (PD) may be used as the receiver **123**. The TIA **124** is an IC that converts the output current signal of the receiver **123** into a voltage signal, and outputs the voltage signal to the communication device via the board **115**.

[0038] The TIA **124** and the driver **121**, which are examples of heating elements, are laterally arranged on the FPC **120**. The TIA **124** and the driver **121** have respective horizontal flat surfaces. Heat emitted from the TIA **124** and the driver **121** is transferred to the housing **110** via the sheet **160** to be dissipated outside the housing **110**.

[0039] The optical waveguide **130** is formed of a flexible film formed of a polymer such as polyimide in which cores for propagating laser light are formed. The optical waveguide **130** is connected to the FPC **120** and the ferrule **140**.

[0040] The ferrule **140** includes a lens ferrule with lenses connected to the optical waveguide **130** and a mechanically transferable (MT) ferrule connected to the optical cable **20**. The ferrule **140** is fastened to the casing **110**B by the clip **150** with an end face of the lens ferrule and an end face of the MT ferrule butted against each other.

[0041] The sheet **160** is an example of a heat dissipating member, and is held between an inside surface **110**Aa of the casing **110**A and each of the driver **121** and the TIA **124**. The sheet **160** dissipates the heat of the driver **121** and the TIA **124** via the housing **110**. A material such as silicon is used for the sheet **160**.

[0042] FIG. **3** is a diagram illustrating the surface **110**Aa. The sheet **160** is held between each of the driver **121** and the TIA **124** and a region **300** of the surface **110**Aa that faces the driver **121** and the TIA **124**. Protrusions **301**A protruding toward the driver **121** and the TIA **124** are formed at regular intervals in the region **300**, that is, gaps formed one between each adjacent two of the protrusions **301**A are uniform in width. The protrusions **301**A are integrally formed with the casing **110**A by forming the casing **110**A using a mold in which shapes complementary to the shapes of the protrusions **301**A are formed.

[0043] FIG. **4** is a diagram illustrating the protrusions **301**A. The protrusions **301**A are formed in the surface **110**Aa in such a manner as to overlap the driver **121** and the TIA **124** in a plan view. Each protrusion **301**A has a quadrangular prism shape, and the top of each protrusion **301**A has a rectangular planar shape elongated in the longitudinal direction. By way of example, the six protrusions **301**A are laterally arranged at regular intervals in FIG. **4**.

[0044] FIG. **5** is a cross-sectional view of the optical module **10**, illustrating its heat dissipation structure. When the casings **110**A and **110**B are joined, the sheet **160** is pressed and fills in the gap between the casing **110**A and each of the driver **121** and the TIA **124**. A part of the casing **110**A that applies a load on the sheet **160** is in particular the top planar surface of each protrusion **301**A. According to the configuration of FIG. **5** where the protrusions **301**A are placed at regular intervals, the area of the casing **110**A that applies a load on the sheet **160** can be reduced compared with the case where the entirety of the surface **110**Aa with no protrusions provided thereon applies a load on the sheet **160**. Therefore, according to FIG. **5**, a load applied onto the driver **121** and the TIA **124** from the casing **110**A via the sheet **160** can be reduced.

[0045] Furthermore, according to the configuration of FIG. **5**, the surface area of the surface **110**Aa can be increased by the protrusions **301**A. Further, the top ends of the protrusions **301**A can be brought closer to the driver **121** and the TIA **124** while reducing a load applied on the driver **121** and the TIA **124**, so that the distance between the casing **110**A and the driver **121** and the TIA **124** can be reduced compared with the case of providing no protrusions in the surface **110**Aa. Therefore, heat emitted from the driver **121** and the TIA **124** is more likely to be transferred to the casing **110**A, so that the heat dissipation efficiency can be improved.

[0046] In particular, according to the configuration of FIG. **5**, the top of each protrusion **301**A has a planar shape having a certain area. Therefore, the area of the top of each protrusion **301**A, which is closest to the driver **121** and the TIA **124**, can be increased, so that a sufficient surface area for transferring heat emitted from the driver **121** and the TIA **124** to the casing **110**A can be ensured. Accordingly, the efficiency of dissipating heat from the driver **121** and the TIA **124** can be improved.

[Variations]

[0047] Variations of the protrusions **301**A are described with reference to FIGS. **6** through **19**.

[First Variation]

[0048] FIG. **6** is a diagram illustrating protrusions **301**B according to a first variation. The protrusions **301**B are formed in the surface **110**Aa in such a manner as to overlap the driver **121** and the TIA **124** in a plan view. Each protrusion **301**B has a quadrangular prism shape, and has a square top. The protrusions **301**B are arranged at regular intervals in longitudinal and lateral arrays. Eighteen protrusions **301**B are arranged in a 3×6 matrix in FIG. **6**.

[0049] FIG. **7** is a cross-sectional view of the optical module **10** according to the first variation. According to the first variation, when the casings **110**A and **110**B are joined, the top surface of each protrusion **301**B in particular applies a load onto the sheet **160**.

[0050] According to the first variation, the area of the casing **110**A that applies a load on the sheet **160** can be reduced, so that a load applied onto the driver **121** and the TIA **124** from the casing **110**A via the sheet **160** can be reduced compared with the case of providing no protrusions in the surface **110**Aa.

[0051] The protrusions **301**B can increase the surface area of the surface **110**Aa, and reduce the shortest distance between the casing **110**A and each of the driver **121** and the TIA **124**. Therefore, heat emitted from the driver **121** and the TIA **124** is more likely to be transferred to the casing **110**A, so that the heat dissipation efficiency can be improved.

[0052] In FIG. **7**, the top of each protrusion **301**B has a planar shape having a certain area. Therefore, a sufficient surface area for transferring heat emitted from the driver **121** and the TIA **124** to the casing **110**A can be ensured at a position closer to the driver **121** and the TIA **124**, so that the efficiency of dissipating heat from the driver **121** and the TIA **124** can be improved.

[Second Variation]

[0053] FIG. **8** is a diagram illustrating protrusions **301**C according to a second variation. The protrusions **301**C are formed in the surface **110**Aa in such a manner as to overlap the driver **121** and the TIA **124** in a plan view. Each protrusion **301**C has a circular cylindrical shape and a circular top planar surface. The number of the protrusions **301**C and their arrays are the same as in the first variation.

[0054] FIG. **9** is a cross-sectional view of the optical module **10** according to the second variation. According to the second variation, the top surface of each protrusion **301**C applies a load onto the sheet **160** when the casings **110**A and **110**B are joined. Therefore, compared with the case of providing no protrusions in the surface **110**Aa, the area of the casing **110**A that applies a load on the sheet **160** can be reduced, so that a load applied onto the driver **121** and the TIA **124** from the casing **110**A can be reduced.

[0055] Furthermore, according to the second variation, the protrusions **301**C can increase the surface area of the surface **110**Aa, and reduce the shortest distance between the casing **110**A and each of the driver **121** and the TIA **124**. Therefore, heat emitted from the driver **121** and the TIA **124** is more likely to be transferred to the casing **110**A, so that the heat dissipation efficiency can be improved.

[0056] In FIG. **9**, the top of each protrusion **301**C has a planar shape having a certain area. Therefore, a sufficient surface area for transferring heat emitted from the driver **121** and the TIA **124** to the casing **110**A can be ensured at a position closer to the driver **121** and the TIA **124**, so that the efficiency of dissipating heat from the driver **121** and the TIA **124** can be improved.

[Third Variation]

[0057] FIG. **10** is a diagram illustrating protrusions **301**D according to a third variation. The protrusions **301**D are formed in the surface **110**Aa in such a manner as to overlap the driver **121** and the TIA **124** in a plan view. Each protrusion **301**D has a truncated pyramid shape and a square top planar surface. The number of the protrusions **301**D and their arrays are the same as in the first variation.

[0058] FIG. **11** is a cross-sectional view of the optical module **10** according to the third variation. According to the third variation, when the casings **110**A and **110**B are joined, the top planar surface of each protrusion **301**D in particular applies a load onto the sheet **160**. Therefore, according to the third variation, the area of the casing **110**A that applies a load on the sheet **160** can be reduced compared with the case of providing no protrusions in the surface **110**Aa, so that a load applied onto the driver **121** and the TIA **124** from the casing **110**A via the sheet **160** can be reduced.

[0059] According to the third variation, the protrusions **301**D can increase the surface area of the surface **110**Aa, and reduce the shortest distance between the casing **110**A and each of the driver **121** and the TIA **124**. Therefore, heat emitted from the driver **121** and the TIA **124** is more likely to be transferred to the casing **110**A, so that the heat dissipation efficiency can be improved.

[0060] According to the third variation, the top of each protrusion **301**D has a planar shape having a certain area. Therefore, a sufficient surface area for transferring heat emitted from the driver **121** and the TIA **124** to the casing **110**A can be ensured at a position closer to the driver **121** and the TIA **124**, so that the heat dissipation efficiency can be improved.

Fourth Embodiment

[0061] FIG. **12** is a diagram illustrating protrusions **301**E according to a fourth variation. The protrusions **301**E are formed in the surface **110**Aa in such a manner as to overlap the driver **121** and the TIA **124** in a plan view. Each protrusion **301**E has a truncated cone shape and a circular top planar surface. The number of the protrusions **301**E and their arrays are the same as in the first variation.

[0062] FIG. **13** is a cross-sectional view of the optical module **10** according to the fourth variation. According to the fourth variation, when the casings **110**A and **110**B are joined, the top of each protrusion **301**E in particular applies a load onto the sheet **160**. Therefore, according to the fourth variation, the area of the casing **110**A that applies a load on the sheet **160** can be reduced compared with the surface **110**Aa with no protrusions, so that a load applied onto the driver **121** and the TIA **124** from the casing **110**A via the sheet **160** can be reduced.

[0063] Furthermore, according to the fourth variation, the protrusions **301**E can increase the surface area of the surface **110**Aa, and reduce the shortest distance between the casing **110**A and each of the driver **121** and the TIA **124**. Therefore, heat emitted from the driver **121** and the TIA **124** is more likely to be transferred to the casing **110**A, so that the heat dissipation efficiency can be improved.

[0064] According to the fourth variation, the top of each protrusion **301**E has a planar shape having a certain area. Therefore, a sufficient surface area for transferring heat emitted from the driver **121** and the TIA **124** to the casing **110**A can be ensured at a position closer to the driver **121** and the TIA **124**. Thus, according to the configuration of FIG. **13**, the efficiency of dissipating heat from the driver **121** and the TIA **124** can be improved.

[0065] The protrusions of the optical module **10** are not limited to a shape having a planar surface at their top. The following fifth through seventh variations discuss the cases of using protrusions having a shape other than a planar surface at their top in the optical module **10**.

[Fifth Variation]

[0066] FIG. **14** is a diagram illustrating protrusions **301**F according to the fifth variation. The hemispherical protrusions **301**F are formed in the surface **110**Aa in such a manner as to overlap the driver **121** and the TIA **124** in a plan view. The number of the protrusions **301**F and their arrays are the same as in the first variation.

[0067] FIG. **15** is a cross-sectional view of the optical module **10** according to the fifth variation. According to the fifth variation, the protrusions **301**F apply a load onto the sheet **160** when the casings **110**A and **110**B are joined. Therefore, according to the fifth variation, the area of the casing **110**A that applies a load on the sheet **160** can be reduced compared with the surface **110**Aa with no protrusions, so that a load applied onto the driver **121** and the TIA **124** from the casing **110**A via the sheet **160** can be reduced.

[0068] Furthermore, according to the fifth variation, the protrusions **301**F can increase the surface area of the surface **110**Aa, and reduce the shortest distance between the casing **110**A and each of the driver **121** and the TIA **124**. Therefore, heat emitted from the driver **121** and the TIA **124** is more likely to be transferred to the casing **110**A, so that the heat dissipation efficiency can be improved.

[Sixth Variation]

[0069] FIG. **16** is a diagram illustrating protrusions **301**G according to the sixth variation. The pyramidal protrusions **301**G are formed in the surface **110**Aa in such a manner as to overlap the driver **121** and the TIA **124** in a plan view. The number of the protrusions **301**G and their arrays are the same as in the first variation.

[0070] FIG. **17** is a cross-sectional view of the optical module **10** according to the sixth variation. In the sixth variation, the protrusions **301**G apply a load onto the sheet **160** when the casings **110**A and **110**B are joined. According to the sixth variation, the area of the casing **110**A that applies a load on the sheet **160** can be reduced compared with the surface **110**Aa with no protrusions, so that a load applied onto the driver **121** and the TIA **124** from the casing **110**A via the sheet **160** can be reduced.

[0071] Furthermore, according to the sixth variation, the protrusions **301**G can increase the surface area of the surface **110**Aa, and reduce the shortest distance between the casing **110**A and each of the driver **121** and the TIA **124**. Therefore, heat emitted from the driver **121** and the TIA **124** is more likely to be transferred to the casing **110**A, so that the heat dissipation efficiency can be improved.

[Seventh Variation]

[0072] FIG. **18** is a diagram illustrating protrusions **301**H according to the seventh variation. The conical protrusions **301**H are formed in the surface **110**Aa in such a manner as to overlap the driver **121** and the TIA **124** in a plan view. The number of the protrusions **301**H and their arrays are the same as in the first variation.

[0073] FIG. **19** is a cross-sectional view of the optical module **10** according to the seventh variation. According to the seventh variation, the protrusions **301**H apply a load onto the sheet **160** when the casings **110**A and **110**B are joined. Therefore, according to the seventh variation, the area of the casing **110**A that applies a load on the sheet **160** can be reduced compared with the surface **110**Aa with no protrusions, so that a load applied onto the driver **121** and the TIA **124** from the casing **110**A via the sheet **160** can be reduced.

[0074] According to the seventh variation, the protrusions **301**H can increase the surface area of the surface **110**Aa, and reduce the shortest distance between the casing **110**A and each of the driver **121** and the TIA **124**. Therefore, heat emitted from the driver **121** and the TIA **124** is more likely to be transferred to the casing **110**A, so that the efficiency of dissipating heat from the driver **121** and the TIA **124** can be improved.

EXAMPLES

[0075] Examples of the optical module **10** are described below with reference to FIGS. **20** and **21**. Specifically, with respect to Examples 1 through 3 and Comparative Examples 1 and 2 as set forth below, the sheet **160** was interposed between the casing **110**A and each of the driver **121** and the TIA **124** which are the heating element, and a load on the heating element and the increased temperature of the heating element were measured.

Examples 1 Through 3

[0076] In Examples 1 through 3, the protrusions **301**B having a quadrangular prism shape according to the first variation are provided in the surface **110**Aa. According to Example 1, the total area of the surface of the protrusions **301**B contacting the heating element via the sheet **160** is 60% of the area of the surface **110**Aa. According to Example 2, the total area of the surface of the protrusions **301**B contacting the heating element via the sheet **160** is 50% of the area of the surface **110**Aa. According to Example 3, the total area of the surface of the protrusions **301**B is 25% of the area of the surface **110**Aa.

Comparative Examples 1 and 2

[0077] In Comparative Examples 1 and 2, no protrusions are provided in the surface **110**Aa. According to Comparative Example 1, the surface **110**Aa is brought close to the heating element with the casings **110**A and **110**B being joined. According to Comparative Example 2, the surface **110**Aa is not brought close to the heating element with the casings **110**A and **110**B being joined.

[Implementation Results: Load Characteristic]

[0078] FIG. **20** is a graph illustrating the characteristic of a load on the heating element. In FIG. **20**, the solid line, the dashed line, the dotted line, and the one-dot chain line indicate load characteristics according to Comparative Example 1, Example 1, Example 2, and Example 3, respectively.

[0079] As illustrated in FIG. **20**, according to Examples 1 through 3, a load on the heating element can be lower than in Comparative Example 1 irrespective of the amount of displacement. In particular, according to Examples 1 through 3, a decrease in the load on the heating element can be increased as the amount of displacement increases, compared with Comparative Example 1. Furthermore, according to Examples 1 through 3, the load on the heating element can be reduced as the total area of the planar surface contacting the heating element decreases.

[0080] For example, when the target value of a load on the heating element at nominal displacement is 0.5 MPa, the load on the heating element according to Comparative Example 1 is 0.54 MPa, which exceeds the target value.

[0081] In contrast, according to Examples 1 through 3, their loads on the heating element are 0.32 MPa, 0.26 MPa, and 0.14 MPa, respectively, which are lower than the target value.

[0082] According to the optical module **10**, a load on a heating element can be easily controlled to a target value by adjusting at least one of the number, installation position, installation interval, shape, and size of the protrusions **301**B.

[Implementation Results: Temperature Characteristic]

[0083] FIG. **21** is a table illustrating the temperature characteristic of the heating element. As illustrated in FIG. **21**, the increased temperature of the heating element was measured with respect to each of Examples 1 through 3 and Comparative Examples 1 and 2. The increased temperature was measured at the driver **121**, the TIA **124**, and the upper surface of the casing **110**A.

[0084] As illustrated in FIG. **21**, the increased temperature of the heating element can be lower in Examples 1 through 3 than in Comparative Example 2. In particular, according to Examples 1 through 3, the increased temperature of the heating element can be lowered as the total area of the planar surface contacting the heating element increases.

[0085] According to Comparative Example 2, the increased temperature of the driver **121** is 82.0° C. and the increased temperature of the TIA **124** is 75.4° C. In contrast, according to Example 1, the increased temperature of the driver **121** is 75.7° C. and the increased temperature of the TIA **124** is 71.7° C., and the heat dissipation efficiency can be better than in Comparative Example 2. According to Example 2, the increased temperature of the driver **121** is 76.3° C. and the increased temperature of the TIA **124** is 72.0° C., and the heat dissipation efficiency can be better than in Comparative Example 2. According to Example 3, the increased temperature of the driver **121** is 79.4° C. and the increased temperature of the TIA **124** is 74.0° C., and the heat dissipation efficiency can be better than in Comparative Example 2.

[0086] According to the optical module **10**, the increased temperature of a heating element can be easily controlled to a target temperature by adjusting at least one of the number, installation position, installation interval, shape, and size of the protrusions **301**B.

[0087] Although the one or more embodiments of the present invention have been described heretofore, the present invention is not limited to these embodiments, and various variations and modifications may be made without departing from the scope of the present invention.

[0088] For example, the number, position, interval, shape, and size of protrusions are not limited to those described in the embodiment.

[0089] While the above-described embodiment illustrates an optical module, embodiments of the present invention may also be applied to any types of communication modules.

[0090] The present invention may also be applied to heating elements other than a driver or a TIA. Furthermore, embodiments of the present invention may use any heat dissipating member other than a heat dissipating sheet.

What is claimed is:

1. A communication module comprising:

a housing;

a circuit board in the housing;

a heating element on the circuit board; and

a heat dissipating member sandwiched between an inside surface of the housing and the heating element,

wherein the inside surface includes a plurality of protrusions protruding toward the heating element.

2. The communication module as claimed in claim **1**, wherein the protrusions are formed at regular intervals.

3. The communication module as claimed in claim **1**, wherein each of the protrusions has a planar top.

4. The communication module as claimed in claim **1**, wherein each of the protrusions has a rounded top.

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