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Nomura et al.

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(54) **PRINTING DEVICE**

(56) **References Cited**

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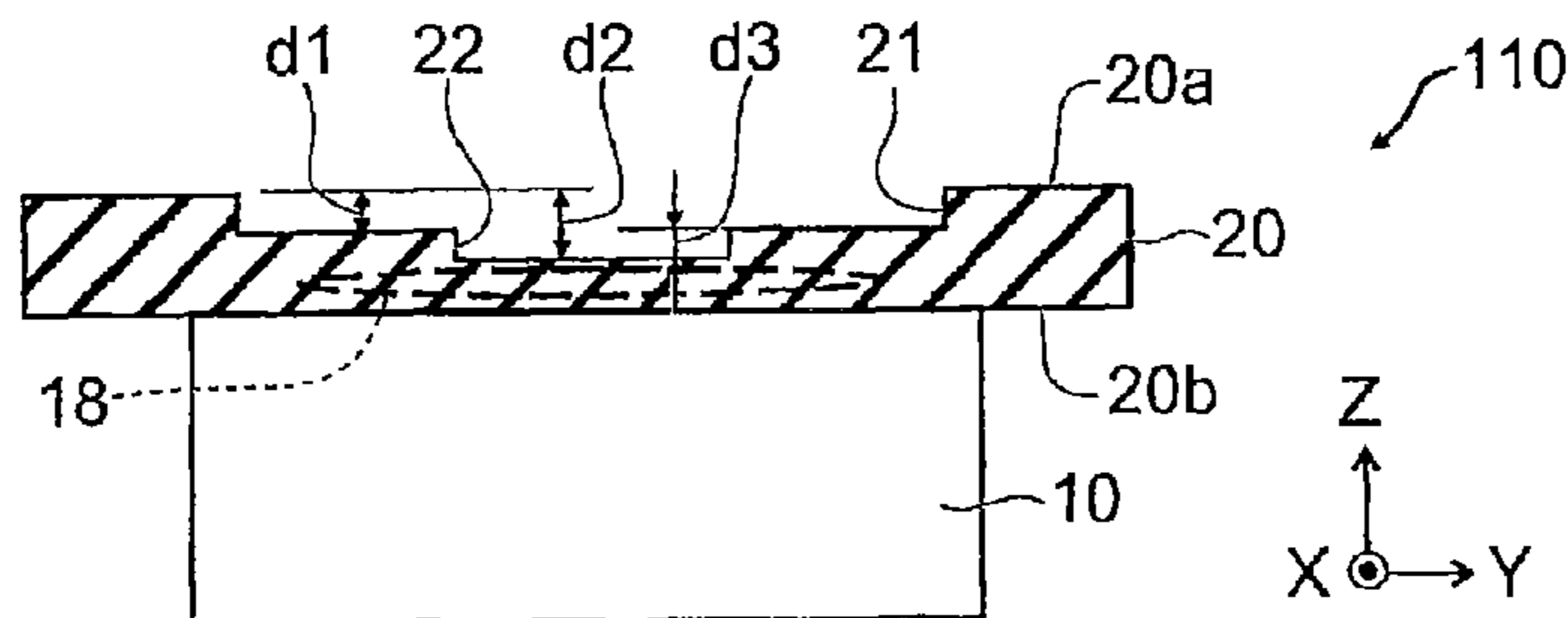
(57) **ABSTRACT**

There is provided a printing device configured to eject a dispersed body containing a solid particle and a liquid. The printing device includes a film and an acoustic head. The film has a first major surface and a second major surface on an opposite side of the first major surface. The first major surface is provided with a first recess accommodating the liquid and a second recess provided on a bottom face of the first recess and accommodating the solid particle. The acoustic head focuses an acoustic wave from a side of the second major surface toward the first recess and the second recess. Thus, even in the case of discharging a dispersed body containing solid particles, it is possible to uniformize the amount of solid particles contained in ejected droplets and it is possible to uniformly make a print.

(52) **U.S. Cl.**
CPC **B41J 2/14008** (2013.01); **B41J 2/0057** (2013.01)

(58) **Field of Classification Search**
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USPC **347/20**
See application file for complete search history.

5 Claims, 4 Drawing Sheets



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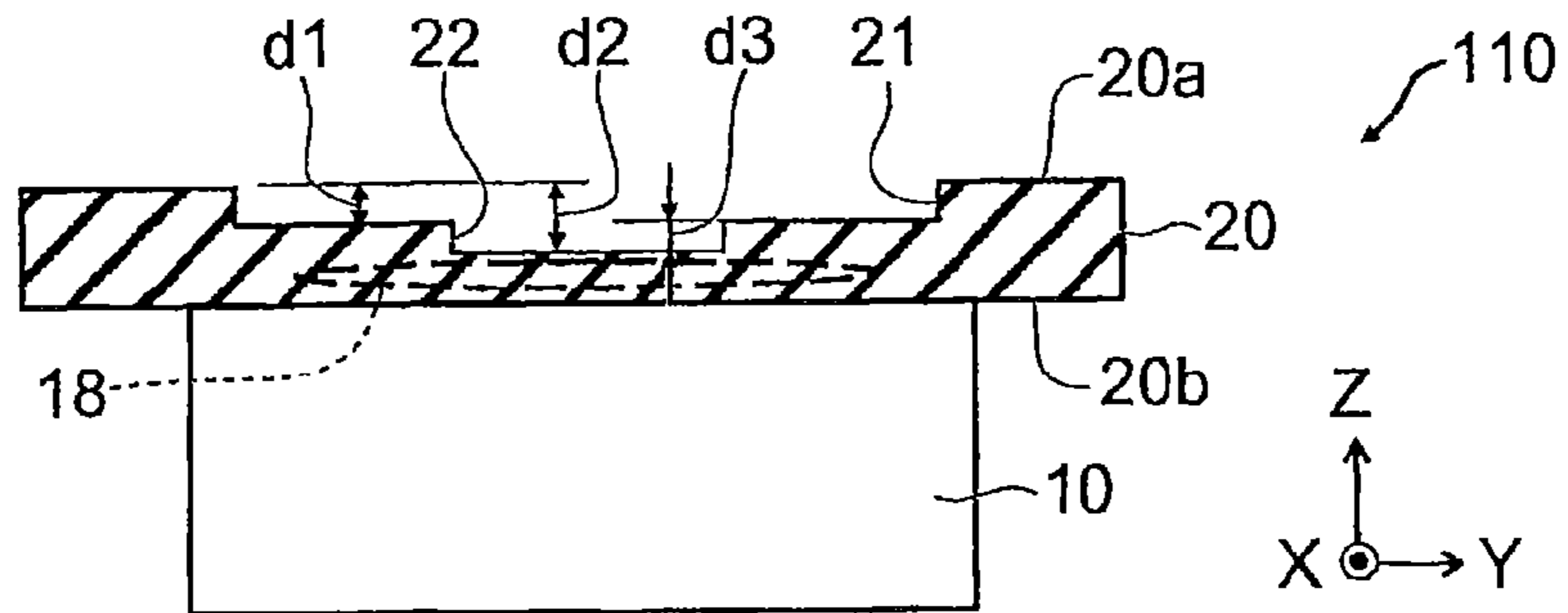


FIG. 1A

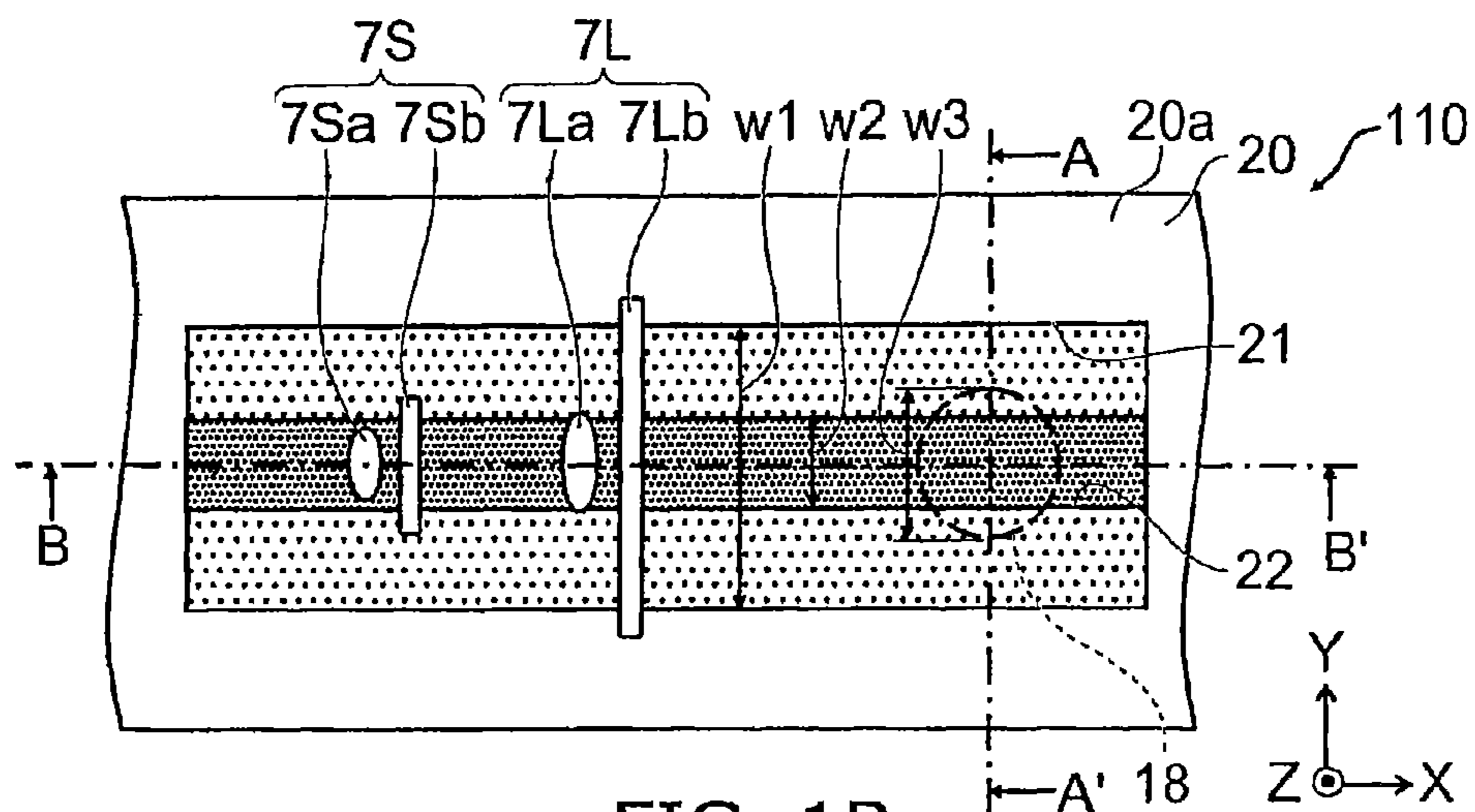


FIG. 1B

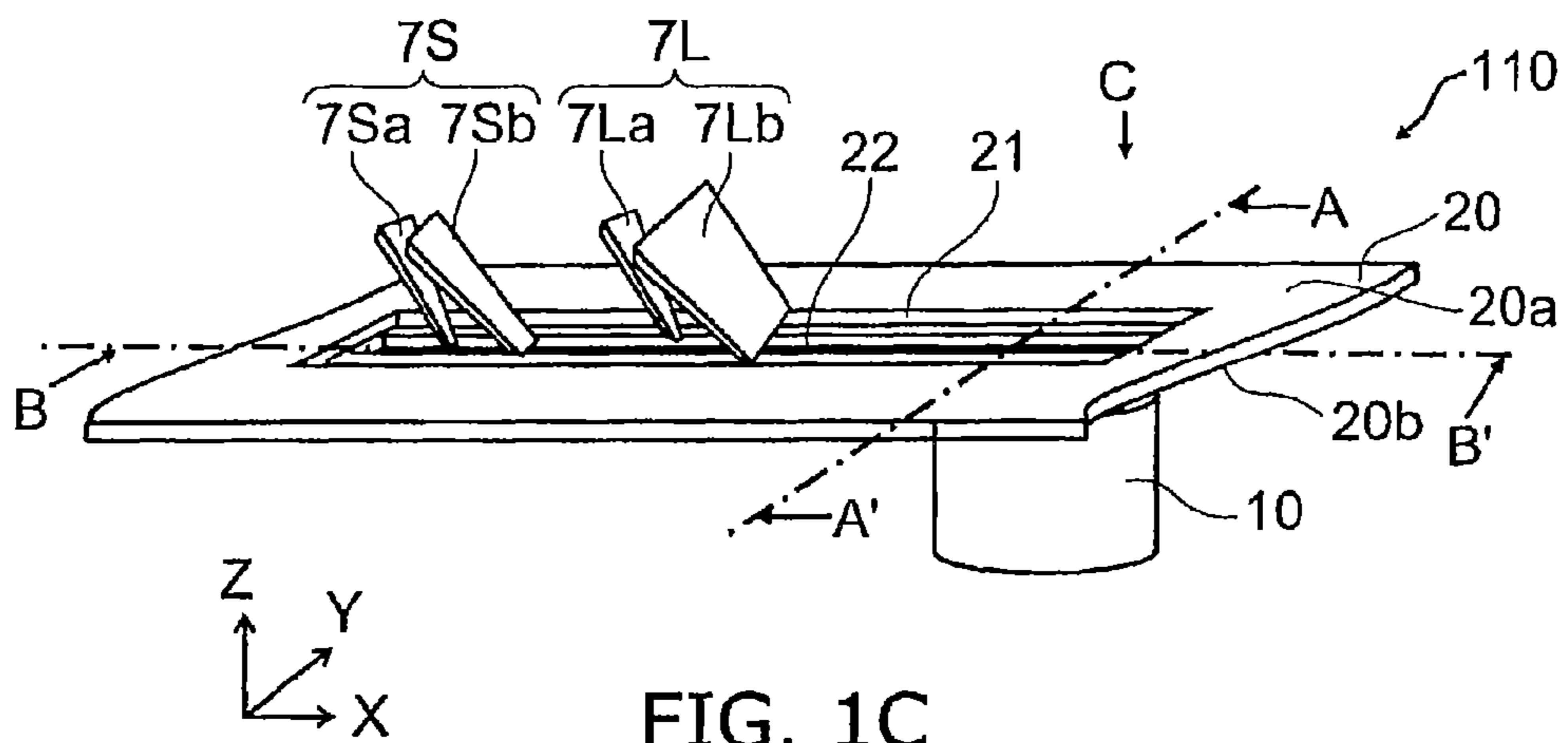


FIG. 1C

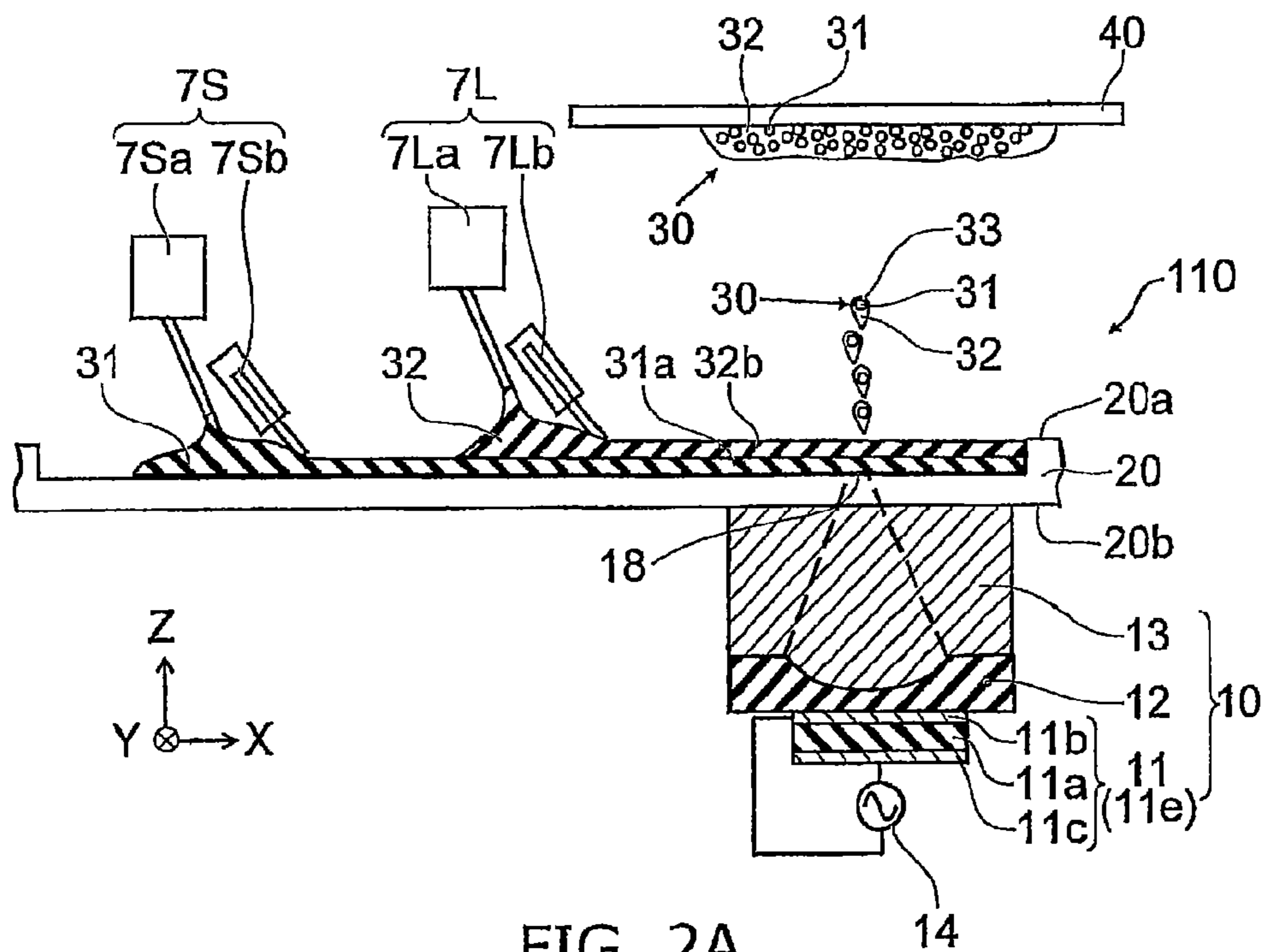


FIG. 2A

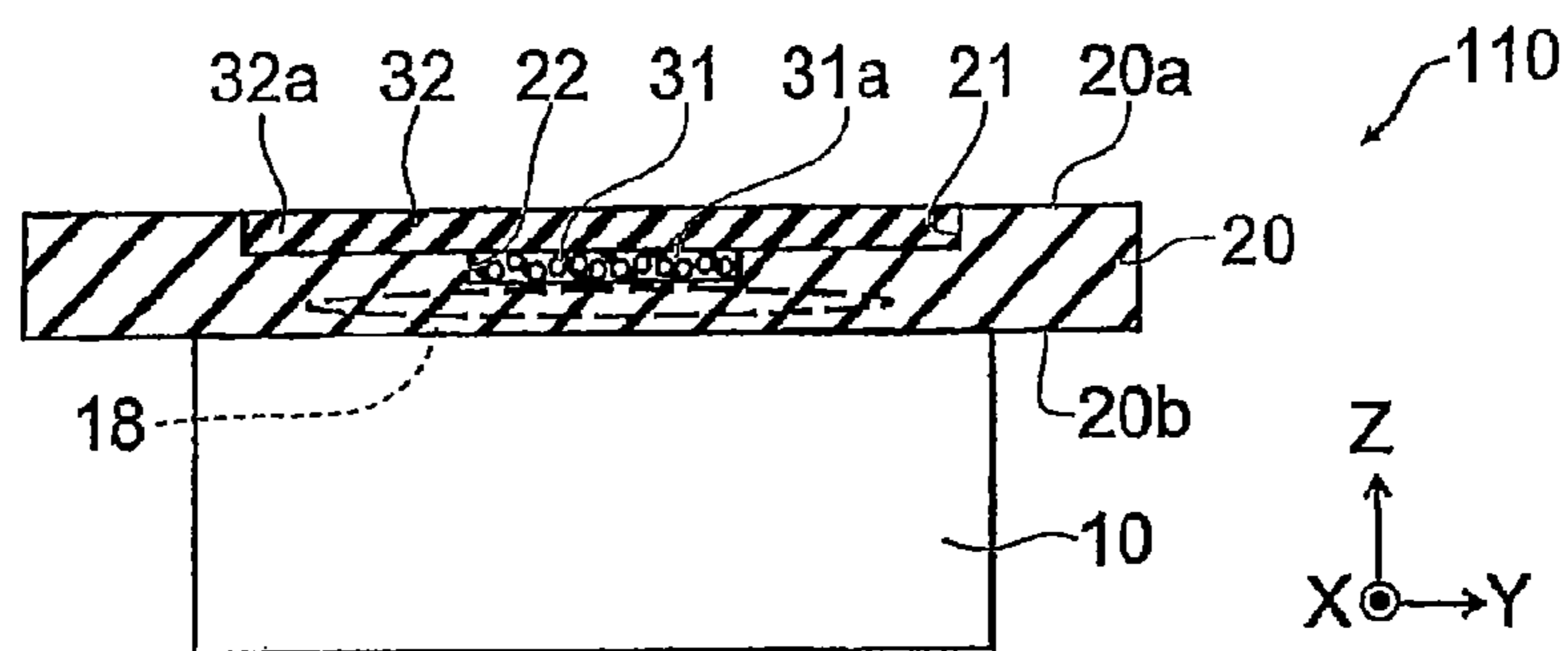


FIG. 2B

FIG. 3A

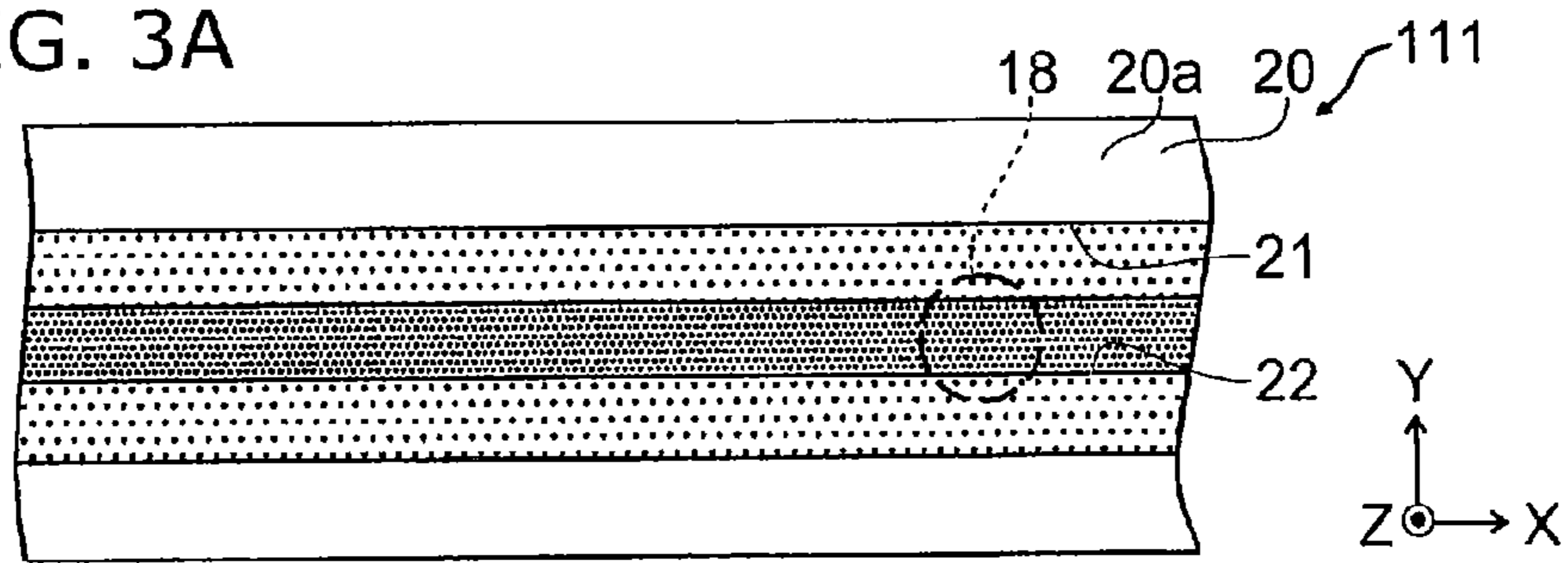


FIG. 3B

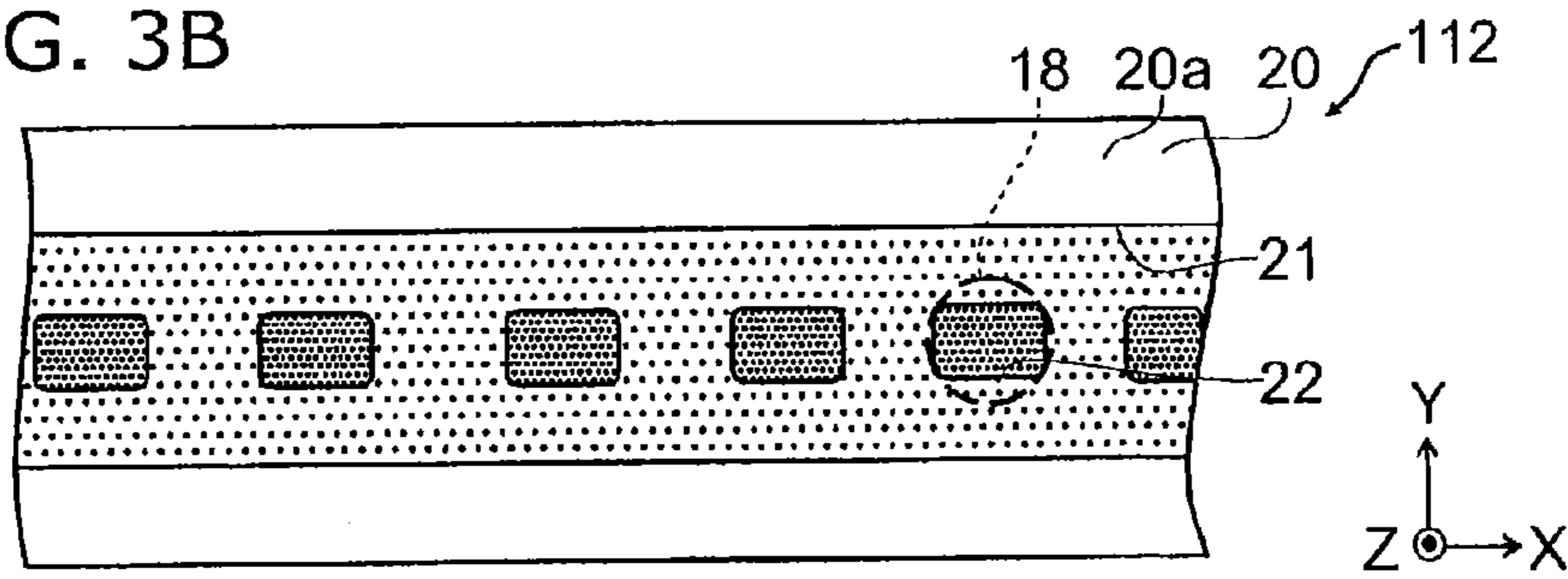


FIG. 3C

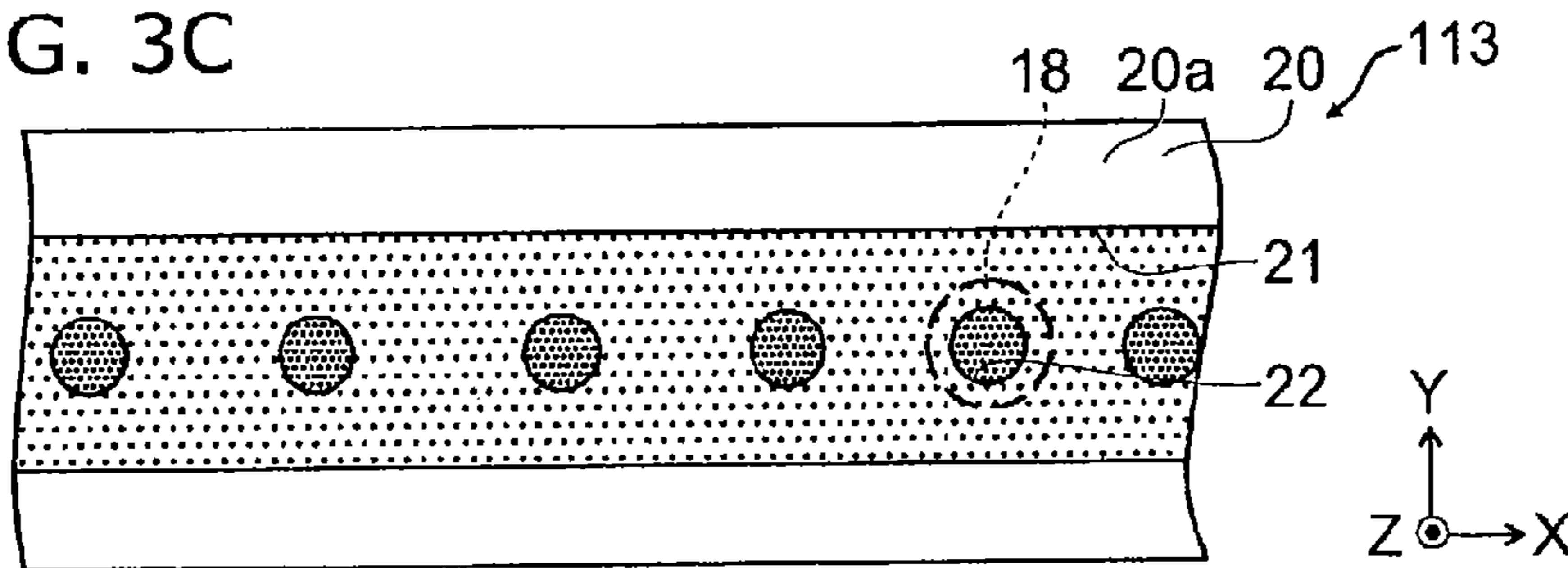
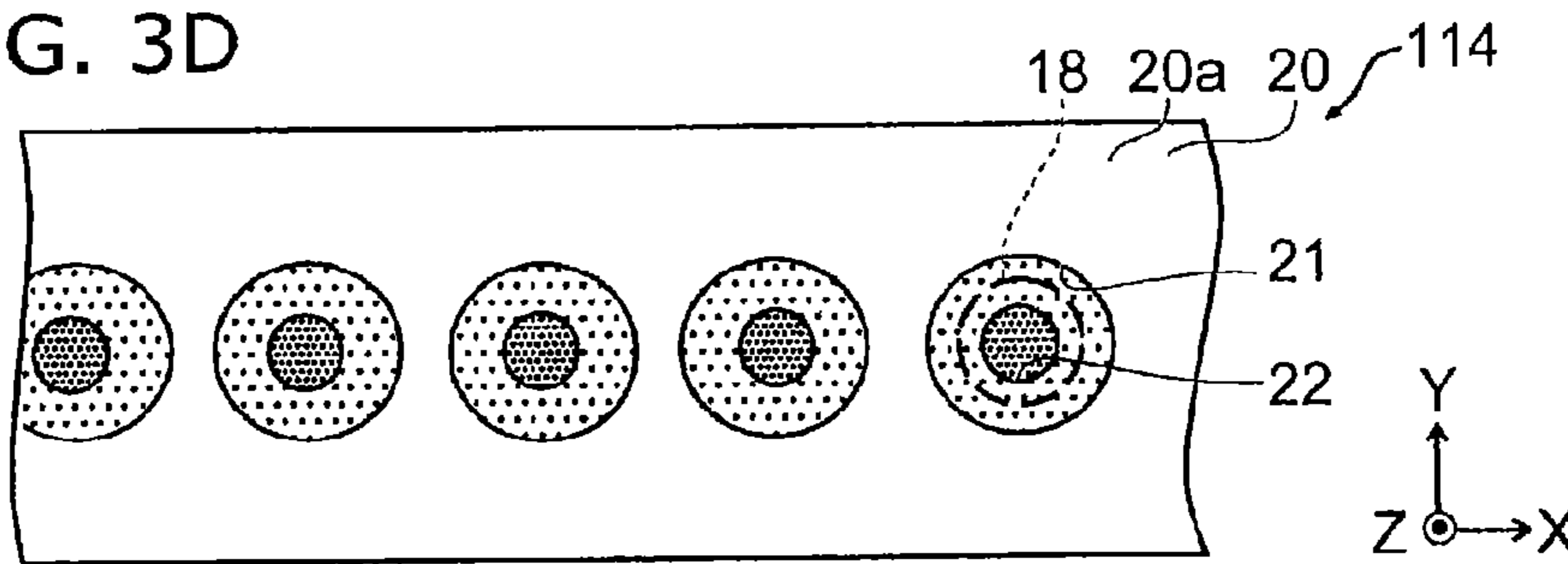


FIG. 3D



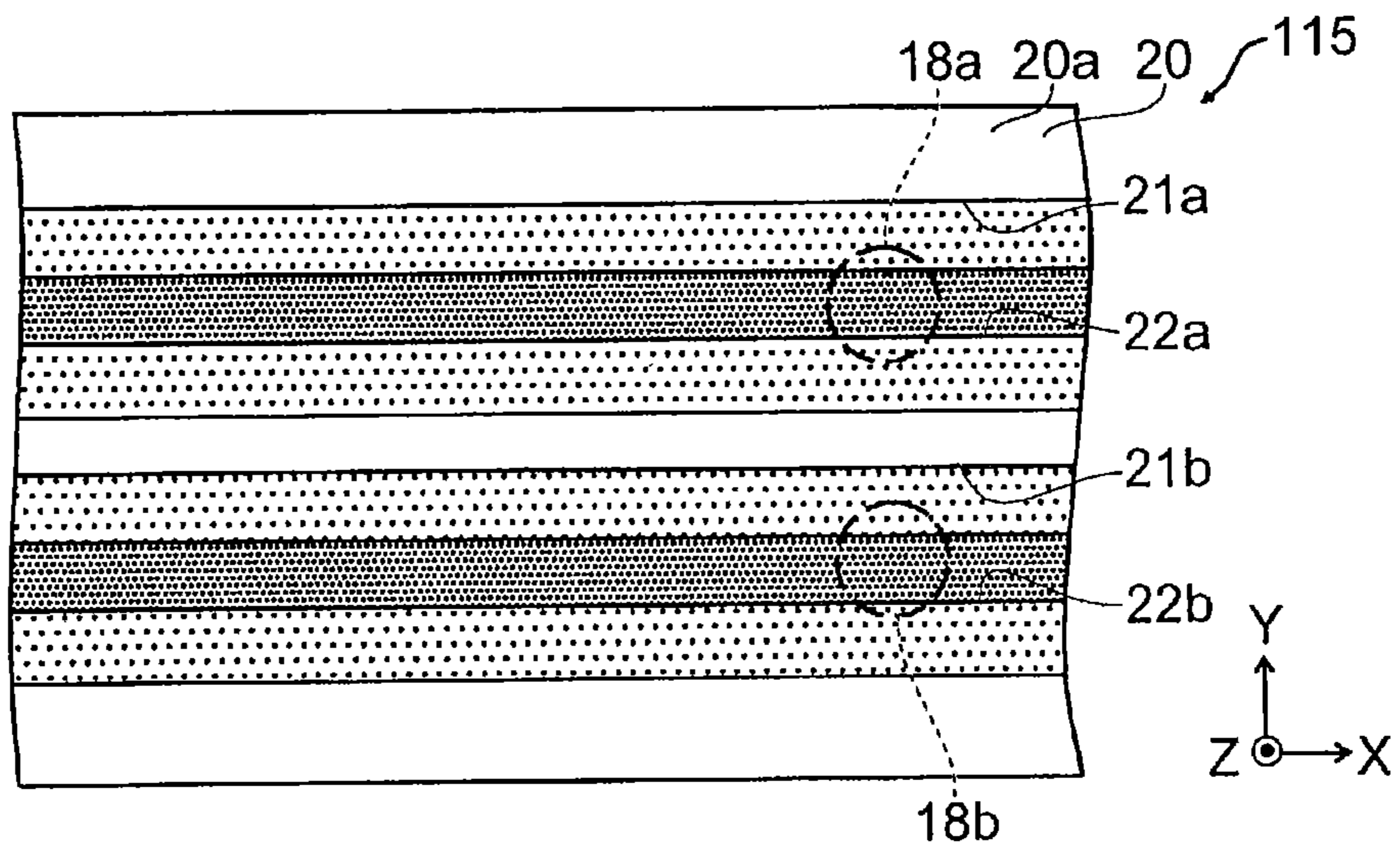


FIG. 4A

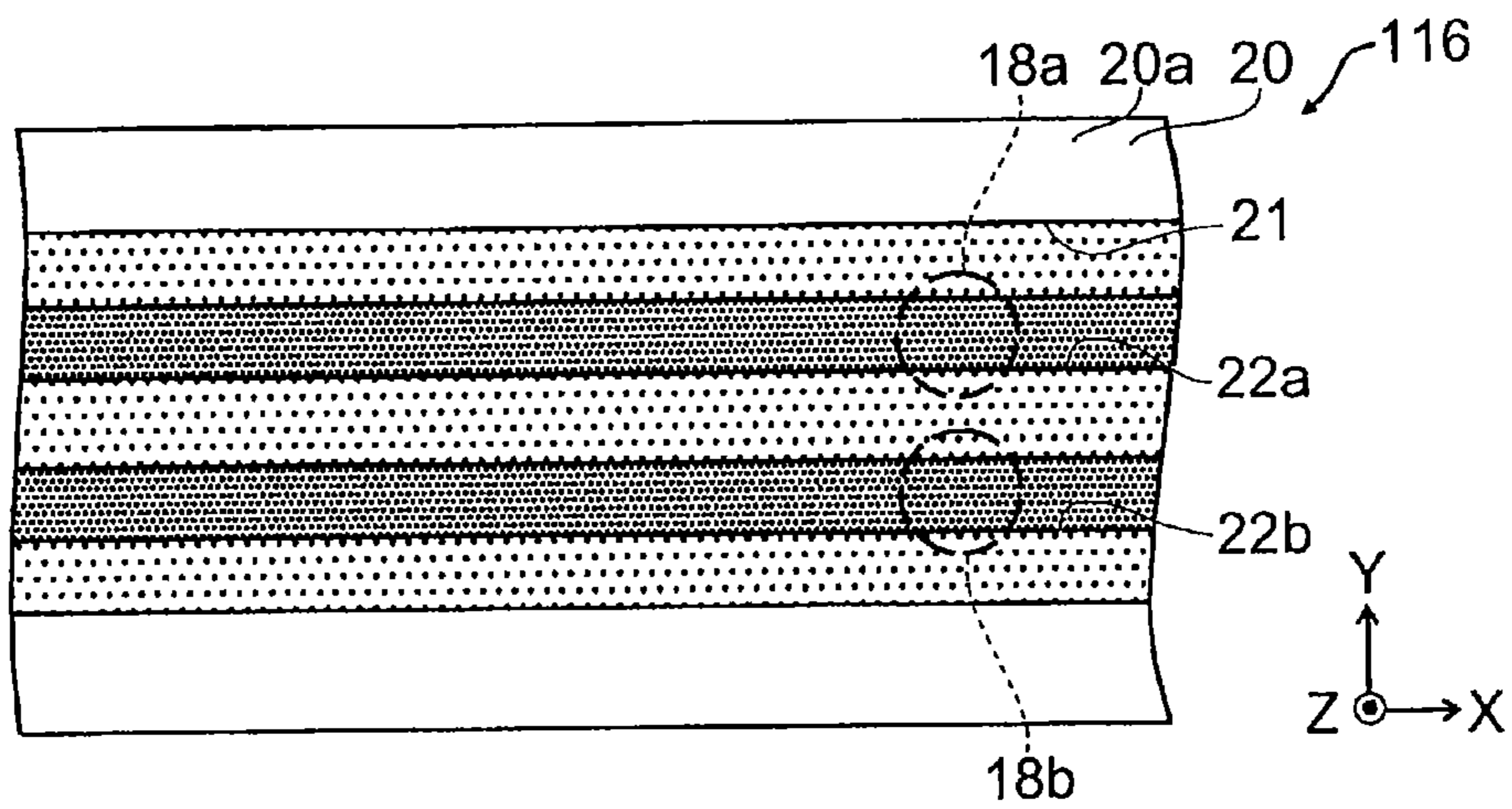


FIG. 4B

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PRINTING DEVICE

Matter enclosed in heavy brackets [] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue; a claim printed with strikethrough indicates that the claim was canceled, disclaimed, or held invalid by a prior post-patent action or proceeding.

The present reissue application is a reissue application of U.S. Pat. No. 8,628,167, issued on Jan. 14, 2014.

TECHNICAL FIELD

This invention relates to a printing device.

BACKGROUND ART

A printing device that jets a liquid in small droplets and deposits the droplets on a substrate is known as an ink jet printing device, for example. Such a printing device is widening the use range not only to printing pictures on a paper sheet, but also to industrial fields such as coating a liquid electronic material and direct patterning.

Patent Document 1 discloses an ink jet recording device in a configuration in which an acoustic wave is focused on a film applied with ink. In this technique, nozzles are not clogged because the technique uses no nozzles, and the restrictions on ink characteristics are relaxed. In such an ink jet printing device, it is expected to further improve variations in the amount of solid particles in ejected droplets as in the case of using ink (a dispersed body) containing solid particles in particular.

CITATION LIST

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SUMMARY OF INVENTION

Technical Problem

The invention is to provide a printing device that can uniformize the amount of solid particles contained in ejected droplets and uniformly make a print in the case of discharging a dispersed body containing solid particles.

Solution to Problem

According to an aspect of the invention, there is provided a printing device configured to eject a dispersed body containing a solid particle and a liquid, comprising: a film having: a first major surface; and a second major surface on an opposite side of the first major surface, the first major surface being provided with: a first recess accommodating the liquid; and a second recess provided on a bottom face of the first recess and accommodating the solid particle; and an acoustic head configured to focus an acoustic wave from a side of the second major surface toward the first recess and the second recess.

Advantageous Effects of Invention

According to the invention, there is provided a printing device that can uniformize the amount of solid particles con-

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tained in ejected droplets and uniformly make a print in the case of discharging a dispersed body containing solid particles.

BRIEF DESCRIPTION OF DRAWINGS

FIGS. 1A to 1C are schematic views showing a printing device.

FIGS. 2A and 2B are schematic cross-sectional views showing the operation of the printing device.

FIGS. 3A to 3D are schematic plan views showing another printing device.

FIGS. 4A to 4B are schematic plan views showing another printing device.

DESCRIPTION OF EMBODIMENTS

In the following, an embodiment of the invention will be described in detail with reference to the drawings.

The drawings are schematic or conceptual; and the relationships between the thickness and width of portions, the proportional coefficients of sizes among portions, etc., are not necessarily the same as the actual values thereof.

Further, the dimensions and ratios may be illustrated differently among drawings, even for identical portions.

In the specification and drawings, components similar to those described or illustrated in a drawing thereinabove are marked with like reference numerals, and a detailed description is omitted as appropriate.

Embodiment

FIGS. 1A to 1C are schematic views illustrating the configuration of a printing device according to an embodiment of the invention.

Namely, FIG. 1C is a schematic perspective view, FIG. 1A is a cross-sectional view on a line A-A' shown in FIG. 1C, and FIG. 1B is a schematic plan view seen from the direction of an arrow C in FIG. 1(c).

FIGS. 2A and 2B are schematic cross-sectional views illustrating the operation of the printing device according to the embodiment of the invention.

Namely, FIG. 2A is a cross-sectional view on a line B-B' in FIG. 1C. FIG. 2A also illustrates a material to be printed onto which a dispersed body 30 is deposited using a printing device 110. FIG. 2B is a schematic view illustrating the disposition state of solid particles 31 and a liquid 32 of the dispersed body 30 on a film 20, which is a schematic cross-sectional view corresponding to FIG. 1A.

As illustrated in FIG. 1A to FIG. 2C, the printing device 110 according to the embodiment is a printing device that ejects the dispersed body 30 containing the solid particles 31 and the liquid 32.

The printing device 110 includes the film 20 and an acoustic head 10.

The film 20 has a first major surface 20a and a second major surface 20b on the opposite side of the first major surface 20a.

The first major surface 20a is provided with a first recess 21 and a second recess 22. The second recess 22 is provided on the bottom face of the first recess 21. A depth d2 of the second recess 22 seen from the first major surface 20a is deeper than a depth d1 of the first recess 21. Namely, the distance (the depth d2) between the first major surface 20a and the bottom face of the second recess 22 is longer than the distance (the depth d1) between the first major surface 20a and the bottom face of the first recess 21. Here, a depth d3 of the second

recess 22 seen from the bottom face of the first recess 21 is a difference between the depth d2 and the depth d1, i.e. (d2-d1).

The first recess 21 accommodates the liquid 32 that is a part of the dispersed body 30.

The second recess 22 accommodates the solid particles 31 that are the other part of the dispersed body 30.

The acoustic head 10 focuses an acoustic wave from the surface side of the second major surface 20b of the film 20 toward the first recess 21 and the second recess 22. More specifically, the acoustic head 10 focuses the generated acoustic wave from the surface side of the second major surface 20b of the film 20 toward the first recess 21 and the second recess 22. For example, the acoustic wave is focused on an acoustic wave focusing region 18 on the first major surface 20a side including the first recess 21 and the second recess 22.

For the solid particles 31, given solid particles can be used including conductive particles such as metal, semiconductor particles, inorganic conductive or insulating particles, organic conductive or insulating particles, colored particles such as various pigments, and various fluorescent particles.

On the other hand, for the liquid 32, given liquids can be used including a liquid containing various resins that remain as a binder after deposited on the material to be printed 40 as the dispersed body 30 together with the solid particles 31, for example, as well as various solvents that are substantially removed as by vaporization, for example, after deposited on the material to be printed 40 as the dispersed body 30 together with the solid particles 31. The liquid 32 has a function that efficiently transmits the acoustic wave generated and focused by the acoustic head 10 and efficiently ejects the solid particles 31 together with the solid particles 31 in the form of droplets 33 of the dispersed body 30.

The printing device 110 can further include a solid particle layer forming unit 7S and a liquid layer forming unit 7L.

The solid particle layer forming unit 7S disposes the solid particles 31 in the second recess 22 of the film 20.

The liquid layer forming unit 7L then disposes the liquid 32 in the first recess 21 of the film 20.

The solid particle layer forming unit 7S can have a solid particle supply unit 7Sa that supplies the solid particles 31 and a solid particle layer uniformizing unit 7Sb that uniformizes the thickness of a solid particle layer 31a of the solid particles 31 supplied by the solid particle supply unit 7Sa, for example. Various dispensers, for example, can be used for the solid particle supply unit 7Sa, and various scrapers or the like, for example, can be used for the solid particle layer uniformizing unit 7Sb.

The liquid layer forming unit 7L can have a liquid supply unit 7La that supplies the liquid 32 and a liquid layer uniformizing unit 7Lb that uniformizes the thickness of the liquid layer 32a of the liquid 32 supplied by the liquid supply unit 7La, for example. Various dispensers, for example, can also be used for the liquid supply unit 7La, and various scrapers or the like, for example, can also be used for the liquid layer uniformizing unit 7Lb.

The solid particle layer uniformizing unit 7Sb and the liquid layer uniformizing unit 7Lb may be omitted.

In the printing device 110, the pressure of the acoustic wave generated and focused by the acoustic head 10 forms meniscus on the surface of the dispersed body 30 that is a mixture of the solid particles 31 accommodated in the second recess 22 of the film 20 and the liquid 32 accommodated in the first recess 21, a part of the dispersed body 30 is separated as the droplets 33, the droplets 33 jet from the film 20 toward the

material to be printed 40, and the dispersed body 30 is deposited on the material to be printed 40.

For example, the relative position between the film 20 and the acoustic head 10 is then changed within the plane parallel to the second major surface 20b. Thus, the acoustic wave is focused on the first recess 21 and the second recess 22 in different regions of the film 20, and new solid particles 31 and liquid 32 are sequentially formed in droplets 33 for discharging the dispersed body 30.

Here, for convenience of explanation, it is supposed that the film 20 is flat in a portion where the film 20 and the acoustic head 10 are faced to each other. The direction in which the relative position between the film 20 and the acoustic head 10 is changed is an X-axis direction (a first direction). Namely, the X-axis direction is parallel to the second major surface 20b. A direction parallel to the second major surface 20b and vertical to the X-axis direction is a Y-axis direction (a second direction). A direction vertical to the X-axis direction and the Y-axis direction is a Z-axis direction (a third direction). Namely, the film 20 and the acoustic head 10 are faced to each other along the Z-axis direction.

It is noted that the film 20 may be provided in an arc shape around the acoustic head 10, for example. Also in this case, in the central portion of the portion where the film 20 and the acoustic head 10 are faced to each other, the film 20 can be considered to be substantially flat, and the above-mentioned X-, Y-, and Z-axis directions can be similarly defined.

In the specific example, the first recess 21 and the second recess 22 have a groove shape extending along the X-axis direction. However, the invention is not limited thereto. The shape and disposition of the first recess 21 and the second recess 22 are optional. In the following, the case will be explained where the first recess 21 and the second recess 22 have a groove shape extending along the X-axis direction.

In the printing device 110 according to the embodiment having such a configuration, since the solid particles 31 are accommodated in the second recess 22 of the film 20 and the liquid 32 is accommodated in the first recess 21, amounts of the solid particles 31 and the liquid 32 per unit area in the first major surface 20a of the film 20 are constant.

Namely, the volume of the second recess 22 per unit area is a volume ($w_2 \times (d_2 - d_1) \times \text{unit length in the X-axis direction}$) based on a product of a width w_2 of the second recess 22 along the Y-axis direction and the depth d_3 of the second recess 22 seen from the bottom face of the first recess 21 (i.e. $d_2 - d_1$), and the volume of the solid particles 31 accommodated in this space is made constant.

On the other hand, the volume of the first recess 21 per unit area is a volume ($w_1 \times d_1 \times \text{unit length in the X-axis direction}$) based on a product of a width w_1 of the first recess 21 in the Y-axis direction and the depth d_1 of the first recess 21 seen from the first major surface 20a, and the volume of the liquid 32 accommodated in this space is also made constant.

For this reason, the ratio between the solid particles 31 and the liquid 32 is made constant based on the shapes of the first recess 21 and the second recess 22. Thus, the concentration of the solid particles 31 in the dispersed body 30 having the solid particles 31 and the liquid 32 can be highly accurately controlled. Therefore, it is possible to eject the droplets 33 with a stable amount of the solid particles 31 in the dispersed body 30. As described above, according to the printing device 110, in the case of discharging a dispersed body containing solid particles, it is possible to uniformize the amount of solid particles contained in ejected droplets and implement uniform printing.

It is noted that the second recess 22 can accommodate the liquid 32 therein together with the solid particles 31. For

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example, when the solid particles **31** are disposed in the second recess **22** and then the liquid **32** is disposed in the first recess **21**, the liquid **32** enters the first recess **21** as well as enters the space between the solid particles **31** in the second recess **22**. In this entering, since a constant amount of the solid particles **31** is accommodated in the second recess **22**, the volume of the liquid **31** accommodated in the second recess **22** is also made constant because the volume of the space between the solid particles **31** is also constant. As described above, also in the case where the liquid **32** is accommodated in the second recess **22**, the ratio between the solid particles **31** and the liquid **32** is made constant based on the shapes of the first recess **21** and the second recess **22**.

For example, in the case of a comparative example using a film having only one kind of recess, such a dispersed body **30** is used in which solid particles **31** and a liquid **32** are mixed with each other beforehand and the solid particles **31** are dispersed. In the case where such a dispersed body **30** is then disposed in a recess and an acoustic wave is generated and focused from an acoustic head **10** for discharging droplets **33**, variations in the dispersion of the solid particles **31** in the dispersed body **30** cause an uneven concentration of the solid particles **31** contained in the droplets **33**, and variations sometimes occur in the amount or dispersion of the solid particles **31** contained in the dispersed body **30** deposited on a material to be printed **40**. Moreover, when the concentration of the solid particles **31** in the dispersed body **30** fluctuates, the damping amount of the acoustic wave transmitted through the dispersed body **30** fluctuates. Thus, energy necessary to eject the droplets **33** also fluctuates, which might be a cause of variations in discharging droplets. In the case where the dispersion of the solid particles **31** into the liquid **32** is poor, such variations become more noticeable, and fluctuations in the concentration of the solid particles **31** contained in the droplets **33** to be ejected are more increased. In addition to this, energy necessary in ejection fluctuates to lead to such cases where the splattering (burst), satellites, or the like of the droplets **33** occur because of excessive energy, and the droplets **33** are not ejected because of less energy.

On the contrary, in the printing device **110** according to the embodiment, the first recess **21** and the second recess **22** are provided on the film **20**, so that the ratio between the solid particles **31** and the liquid **32** is made constant, the concentration of the solid particles **31** contained in the droplets **33** is made uniform, and energy necessary in ejection is also made constant. Thus, it is possible to also suppress the splattering (burst) and satellites of the droplets **33** and non-ejected droplets **33**, and it is possible to implement a stable ejection of droplets in a uniform amount.

In the printing device **110**, desirably, the solid particles **31** are accommodated in the second recess **22**, and then the liquid **32** is accommodated in the first recess **21**.

Namely, desirably, the solid particle layer forming unit **7S** disposes the solid particles **31** in the second recess **22**, and then the liquid layer forming unit **7L** disposes the liquid **32** in the first recess **21**.

Thus, the solid particles **31** can be reliably accommodated in the inside of the second recess **22**, and the amount of the solid particles **31** can be made uniform per unit length in the X-axis direction. After reliably accommodating the solid particle **31** in the second recess **22**, the liquid **32** is disposed in the first recess **21**, so that the space of the first recess **21** is made constant, and the amount of the liquid **32** per unit length in the X-axis direction can also be made uniform. Therefore, it is possible to more highly accurately control the ratio between the solid particles **31** and the liquid **32**.

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It is noted that as illustrated in FIG. **2A**, the acoustic head **10** of the printing device **110** according to the specific example can have an acoustic wave generating unit **11**, an acoustic wave focusing unit **12**, and an acoustic wave transmitting unit **13**.

The acoustic wave generating unit **11** generates an acoustic wave. The acoustic wave focusing unit **12** focuses the acoustic wave generated at the acoustic wave generating unit **11** on an acoustic wave focusing position (namely, the acoustic wave focusing region **18**). The acoustic wave transmitting unit **13** advances the acoustic wave toward the first recess **21** and the second recess **22** of the film **20**.

For the acoustic wave generating unit **11**, an acoustic element **11e** can be used, which includes a pair of electrodes **11b** and **11c** and a piezoelectric element **11a** provided therebetween. For the acoustic wave generating unit **11**, a single disk-shaped acoustic element, for example, may be used, a plurality of acoustic elements arranged in a linear array may be used, or a plurality of acoustic elements arranged in a two-dimensional array may be used.

For the piezoelectric element **11a**, piezoelectric ceramics such as lead zirconate titanate (PZT), lead titanate, and barium titanate, a piezoelectric single crystal such as lithium niobate and lithium tantalate, a polymer piezoelectric element such as polyvinylidene fluoride (PVDF), and a piezoelectric semiconductor such as zinc oxide, for example, can be used.

A driver **14** that drives the acoustic wave generating unit **11** is connected to the pair of the electrodes **11b** and **11c**. The driver **14** applies a voltage to the piezoelectric element **11a** based on an electric signal externally supplied. Thus, the acoustic wave is generated from the acoustic wave generating unit **11**. The aforementioned electric signal includes signals based on various items of picture data or the like and signals based on patterns of the deposition shape of the dispersed body **30** to be ejected on the material to be printed **40**.

The acoustic wave focusing unit **12** has a function that focuses the acoustic wave generated at the acoustic wave generating unit **11** on the acoustic wave focusing region **18**, which is the acoustic wave focusing position. A concave lens, for example, made of glass can be used for the acoustic wave focusing unit **12**. The concave lens is formed by polishing the major surface of a piece of disk-shaped glass, for example, in an arc shape. For the acoustic wave focusing unit **12**, an inorganic material such as glass, an organic material such as epoxy resin, or the like can be used, for example. In addition, for the acoustic wave focusing unit **12**, such a product can also be used that the surface of glass or resin is subjected to surface treatment to form a metal film, a metal oxide film, a nitride film, a polyolefin resin film, or the like for improving durability.

The acoustic wave transmitting unit **13** is a portion where the acoustic wave having been generated at the acoustic wave generating unit **11** and being focused at the acoustic wave focusing unit **12** is advancing. For the acoustic wave transmitting unit **13**, such a product can be used that the space between the acoustic wave focusing unit **12** and the film **20** is filled with an acoustic wave transmitter. Preferably, the acoustic wave transmitter has a small acoustic wave damping; a liquid such as water, for example, can be preferably used.

As described above, the acoustic wave generated at the acoustic wave generating unit **11** is focused by the acoustic wave focusing unit **12**, and focused on a predetermined acoustic wave focusing position through the acoustic wave transmitting unit **13**. This acoustic wave focusing position is set in the acoustic wave focusing region **18** of the film **20** disposed as faced to the acoustic head **10**. Namely, the film **20**

is disposed at a position a predetermined distance apart from the acoustic wave focusing unit **12**, for example, of the acoustic head **10**, the acoustic wave is focused from the second major surface **20b** side of the film **20** toward the first recess **21** to and the second recess **22**, and the acoustic wave is focused on the acoustic wave focusing region **18**, which is the acoustic wave focusing position.

The focal point of the acoustic wave emitted from the acoustic head **10** is formed on a predetermined acoustic wave focusing position (corresponding to the acoustic wave focusing region **18** of the film **20**), and acoustic pressure distribution is generated at the acoustic wave focusing position. A beam width W of the acoustic wave near this focal point is expressed by $W=A1 \cdot \lambda 1 \cdot F1/D1$, using a constant $A1$ for the shape of the acoustic wave generating unit **11**, a wavelength $\lambda 1$ of the acoustic wave, a focal length $F1$ of the acoustic wave, and a diameter $D1$. It is noted that the aforementioned constant $A1$ is 2.44 in the case where the shape of the acoustic wave generating unit **11** is a disk shape. In the case where the acoustic wave generating unit **11** is a disk shape, the beam width W of the acoustic wave is equivalent to the beam diameter of the acoustic wave.

A maximum acoustic pressure can be obtained within the range of the beam width W of the acoustic wave, whereas the acoustic pressure is decreased out of the range. When the surface of the liquid **32**, for example, swells at the center of the focal point and the acoustic pressure exceeds the surface tension of the liquid **32**, the droplet **33** containing the solid particles **31** and the liquid **32** is separated from the surface of the liquid **32**, and the droplet **33** containing the solid particles **31** and the liquid **32** is ejected.

It is noted that for efficient transmission of the acoustic wave from the acoustic wave generating unit **11** to the acoustic wave transmitting unit **13**, desirably, an acoustic impedance Zf of the acoustic wave focusing unit **12** is set to a value between an acoustic impedance ZP of the piezoelectric element **11a** for use in the acoustic wave generating unit **11** and an acoustic impedance ZL of the acoustic wave transmitting unit **13**. For example, more desirably, the acoustic impedance Zf of the acoustic wave focusing unit **12** is close to a geometric mean (i.e. $(ZP \cdot ZL)^{1/2}$) of the acoustic impedance ZP of the piezoelectric element **11a** and the acoustic impedance ZL of the acoustic wave transmitting unit **13** for efficient transmission of the acoustic wave from the acoustic wave.

As already explained, the relative position between the film **20** and the acoustic head **10** is changed within the plane parallel to the second major surface **20b**. Namely, the relative position between the film **20** and the acoustic head **10** is changed along the X-axis direction. For example, the position of the acoustic head **10** is fixed, and the position of the film **20** is changed along the X-axis direction. Moreover, for example, the position of the film **20** is fixed, and the position of the acoustic head **10** is changed along the X-axis direction. Furthermore, for example, the positions of both of the film **20** and the acoustic head **10** are changed, and the relative position between the film **20** and the acoustic head **10** is changed along the X-axis direction.

At this time, as illustrated in FIGS. **1A** and **1B**, desirably, the width $w2$ of the second recess **22** along the Y-axis direction is set smaller than a width $w3$ of the acoustic wave focusing region **18**, on which the acoustic wave is focused on the first major surface **20a**, along the Y-axis direction. It is noted that the width $w3$ is equivalent to the beam width W of the acoustic wave (namely, $A1 \cdot \lambda 1 \cdot F1/D1$) as already explained.

Thus, it is possible to reduce energy necessary to form and separate the droplets **33**. Although the acoustic pressure

greatly fluctuates in a peripheral portion around the acoustic wave focusing region **18**, the amount of the solid particles **31** corresponding to this peripheral portion can be reduced, so that it is possible to form the droplets **33** containing the solid particles **31** with excellent reproducibility in a uniform amount.

Namely, for example, in the case where the relative position between the acoustic head **10** and the film **20** is changed along the X-axis direction, the width $w2$ of the second recess **22** along the Y-axis direction is always disposed in the inside of the acoustic wave focusing region **18**. Thus, a substantially uniform acoustic pressure is applied to all the solid particles **31**, the droplets **33** containing a constant amount of the solid particles **31** can be ejected, and variations in the concentration of the solid particles **31** can be further suppressed.

Desirably, the width $w1$ of the first recess **21** along the Y-axis direction is set greater than the width $w3$ of the acoustic wave focusing region **18** along the Y-axis direction. Thus, for example, even in the case where the position of the acoustic wave focusing region **18** fluctuates along the Y-axis direction in some degree, the amount of the liquid **32** to be applied with an acoustic pressure is determined by the width $w3$ of the acoustic wave focusing region **18** along the Y-axis direction, so that the amount of the liquid **32** in the droplets **33** is made constant. Therefore, it is possible to eject the droplets **33** in more uniform concentration.

As described above, in the embodiment, a printing method is carried out, in which the acoustic wave is focused from the second major surface **20b** side of the film **20** toward the first recess **21** and the second recess **22**, whereby the dispersed body **30** containing the liquid and the solid particles **31** is ejected, the film **20** having the first major surface **20a** including the first recess **21** having the liquid **32** accommodated in the first recess **21** and the second recess **22** provided on the bottom face of the first recess **21** and having the solid particles **31** accommodated in the second recess **22** and the second major surface **20b** on the opposite side of the first major surface **20a**. According to this printing method, in the case of discharging a dispersed body containing solid particles, it is possible to uniformize the amount of solid particles contained in ejected droplets, and it is possible to uniformly make a print.

Moreover, this printing method can include a process that the solid particles **31** are disposed in the second recess **22** and then the liquid **32** is disposed in the first recess **21**. Thus, it is possible to more highly accurately control the ratio between the solid particles **31** and the liquid **32**.

In the aforementioned printing device **110**, the relative position between the film **20** and the acoustic head **10** is relatively changed along the one-dimensional X-axis direction, and the first recess **21** and the second recess **22** have a belt shape extending in the X-axis direction.

However, the invention is not limited thereto. The relative position between the film **20** and the acoustic head **10** may be two-dimensionally changed within the plane parallel to the second major surface **20b**. In this case, the relative position between the film **20** and the acoustic head **10** can be relatively changed along both of the X-axis direction and the Y-axis direction, for example.

In this case, the first recess **21** and the second recess **22** can have a spot-like shape. Desirably, the width of the spot of the second recess **22** along the Y-axis direction is set smaller than the width of the acoustic wave focusing region **18** along the Y-axis direction, and the width of the spot of the second recess **22** along the X-axis direction is set smaller than the width of the acoustic wave focusing region **18** along the X-axis direction. Moreover, desirably, the width of the spot of the first

recess 21 along the Y-axis direction is set larger than the width of the acoustic wave focusing region 18 along the Y-axis direction, and the width of the spot of the first recess 21 along the X-axis direction is set larger than the width of the acoustic wave focusing region 18 along the X-axis direction.

In the specific example, the film 20 is flat. However, the invention is not limited thereto. The shape of the film 20 is optional. Such a configuration may be possible in which the film 20 surrounds the acoustic head 10, for example, the film 20 has a cylindrical shape having a center axis in the Y-axis direction in a space including the acoustic head 10, for example, and the relative position between the film 20 and the acoustic head 10 is changed along the circumference of this cylinder.

Moreover, such a configuration may be possible in which the film 20 is provided in a wound shape in a roll, the film 20 extends from a first reel to a second reel, for example, and the film 20 and the acoustic head 10 are faced to each other at a position between the first reel and the second reel.

It is noted that the change in the relative position between the film 20 and the acoustic head 10 as described above is carried out by a driving unit, not shown.

Various resin films, for example, can be used for the film 20. More particularly, films can be used such as polyimide resin, polyamide resin, and polyester resin having high solvent resistance.

The thickness of the film 20 (the distance between the first major surface 20a and the second major surface 20b where the first recess 21 and the second recess 22 are not provided) is optional; the thickness can range from 10 μm to 300 μm or the like, for example. As described above, in the specification, the term "film" is not limited to having a thickness of 200 μm or less and a thickness of 10 mils (250 μm) or less, which has a given thickness and includes all of given film products that can hold the shape by themselves.

In order to efficiently transmit the acoustic wave passing through the film 20 to the solid particles 31 and the liquid 32, desirably, the thickness of the bottom face portion of the second recess 22 of the film 20 is thin to some extent, desirably, 100 μm or less, for example, and more desirably, about 50 μm . In order to maintain the mechanical strength of the film 20, desirably, the thickness of the film 20 is thick to some extent, and the thickness of the film 20 is desirably 15 μm or more. However, the thickness of the film 20 is appropriately set based on the depth d1 of the first recess 21, the depth d3 of the second recess 22, and so on, according to the diameter of the solid particles 31 for use and the ratio between the amount of the solid particles 31 and the amount of the liquid 32 for use, and so on.

The depth d3 of the second recess 22 seen from the bottom face of the first recess 21 can be a depth about two to three times the mean value of the diameter of the solid particles 31 for use. For example, in the case where the mean value of the diameter of the solid particles 31 is 15 μm , the depth d3 of the second recess 22 can be set ranging from about 20 μm to 50 μm .

The depth d1 of the first recess 21 seen from the first major surface 20a can be set ranging from 10 μm to 100 μm , for example.

The solid particles 31 can be disposed in the second recess 22 of the film 20 on demand.

The solid particle layer forming unit 7S and the liquid layer forming unit 7L that dispose the solid particles 31 and the liquid 32 in the second recess 22 and the first recess 21 of the film 20, respectively, may be disposed in separate components from the acoustic head 10. In this case, for example, such a configuration may be possible in which a film 20,

which the solid particles 31 and the liquid 32 are disposed in the second recess 22 and the first recess 21 by the solid particle layer forming unit 7S and the liquid layer forming unit 7L, respectively, is first prepared, this film 20 is used to dispose the acoustic head 10 on the second major surface 20b side of the film 20, and an acoustic wave is focused toward the first recess 21 and the second recess 22 of the film 20. As described above, the solid particle layer forming unit 7S and the liquid layer forming unit 7L of the printing device 110 may be disposed at positions different from the acoustic head 10.

Preferably, the viscosity of the liquid 32 to be a part of the dispersed body 30 is a viscosity to an extent that the liquid 32 does not flow on the first major surface 20a of the film 20.

The wettability to the liquid 32 on the surface of the first major surface 20a is made different from the wettability to the liquid 32 on the surfaces of the side surface and the bottom face of the first recess 21, so that it is possible to suppress the overflow of the liquid 32 out of the first recess 21. Namely, this can suppress the flow of the liquid 32 on the first major surface 20a of the film 20. In this case, it is possible to relax demands for the viscosity of the liquid 32 for use.

The wettability to the liquid 32 on the surfaces of the side surface and the bottom face of the first recess 21 is made equal to the wettability to the liquid 32 on the surfaces of the side surface and the bottom face of the second recess 22. Thus, it is possible to promote the liquid 32 to enter the second recess 22, and it is possible to suppress the generation of an air layer to hamper transmission of an acoustic wave to the region around the solid particles 31 disposed in the second recess 22.

It is noted that metal, rubber, resin or the like having a small friction to the film 20 can be used for a scraper, for example, used for the solid particle layer uniformizing unit 7Sb and the liquid layer uniformizing unit 7Lb. Thus, it is possible to stabilize the operations of the solid particle layer forming unit 7S and the liquid layer forming unit 7L.

It is noted that the solid particles 31 can also be reused by collecting the solid particles 31 excessively supplied using the solid particle layer uniformizing unit 7Sb. Moreover, the liquid 32 can also be reused by collecting the liquid 32 excessively supplied using the liquid layer uniformizing unit 7Lb. In this collection, the collected solid particles 31 and the liquid 32 may be subjected to various processes such as stirring, addition of additives, filtration of agglomerates, and filtration of impurities, for example. A method of adding at least one of new solid particles 31 and new liquid 32 may be applied to the solid particles 31 and the liquid 32.

FIGS. 3A to 3D are schematic plan views illustrating the configuration of other printing devices according to the embodiment of the invention.

Namely, FIG. 3A to FIG. 3D illustrate the configuration of a film 20 in other printing devices 111 to 114 according to the embodiment, illustrating schematic plan views seen from a direction corresponding to the arrow C in FIG. 1C.

As illustrated in FIG. 3A, in the printing device 111, a first recess 21 and a second recess 22 of the film 20 have a belt shape along the X-axis direction. Such a shape can be prepared by continuously forming grooves to be the first recess 21 and the second recess 22 on the film 20, in which the film 20 is shaped while applying a pressure to a material to be a base of the film 20 with a first projection and a second projection of a roller, using the roller having the first projection along the circumference of the roller and the second projection provided on the top of the first projection along the circumference, for example.

As illustrated in FIG. 3B and FIG. 3C, in the printing devices 112 and 113, although a first recess 21 of the film 20

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has a belt shape along the X-axis direction, a second recess **22** is disposed on the bottom face of the first recess **21** in a discontinuous shape. In the printing device **112**, the second recess **22** has a nearly square two-dimensional pattern shape, and in the printing device **113**, the second recess **22** has a circular two-dimensional pattern shape. Such shapes can be prepared by forming the first recess **21** continuously and the second recess **22** discretely on the film **20**, in which the film **20** is shaped while applying a pressure to a material to be a base of the film **20** with a first projection and a second projection of a roller, using the roller having the first projection along the circumference of the roller and the second projection provided discretely on the top of the first projection, for example.

As illustrated in FIG. 3D, in the printing device **114**, a first recess **21** and a second recess **22** of the film **20** are discontinuously disposed. Such a shape can be prepared by discretely forming the first recess **21** and the second recess **22** on the film **20**, in which the film **20** is shaped while applying a pressure to a material to be a base of the film **20** with a first projection and a second projection of a roller, using the roller having the first projection discretely provided on the circumference of the roller and the second projection provide on the top of the first projection, for example.

In addition, also in the case of these printing devices **111** to **114**, desirably, a width w_2 of the second recess **22** along the Y-axis direction is set smaller than a width w_3 of an acoustic wave focusing region **18** along the Y-axis direction. Desirably, a width w_1 of the first recess **21** along the Y-axis direction is set greater than the width w_3 of the acoustic wave focusing region **18** along the Y-axis direction.

FIGS. 4A and 4B are schematic plan views illustrating the configuration of other printing devices according to the embodiment of the invention.

Namely, FIG. 4A and FIG. 4B illustrate the configuration of a film **20** in other printing devices **115** and **116** according to the embodiment, illustrating schematic plane views seen from a direction corresponding to the arrow C in FIG. 1C.

As illustrated in FIG. 4A, in the printing device **115**, the film **20** is provided with two first recesses, that is, a first recess **21a** and a first recess **21b**. A second recess **22a** is provided on the bottom face of the first recess **21a**, and a second recess **22b** is provided on the bottom face of the first recess **21b**. As described above, the film **20** can be provided with a plurality of first recesses (for example, the first recess **21a** and the first recess **21b**), and each of a plurality of first recesses can be provided with a second recess.

As illustrated in FIG. 4B, in the printing device **116**, the film **20** is provided with a single first recess **21**, and two second recesses, that is, a second recesses **22a** and a second recess **22b** provided on the bottom face of the first recess **21**. As described above, a plurality of second recesses (for example, the second recesses **22a** and the second recess **22b**) can be provided on the bottom face of the single first recess **21**.

In the printing devices **115** and **116**, acoustic wave focusing regions **18a** and **18b** are disposed as corresponding to the positions of the second recesses **22a** and **22b**, for example. Namely, in this case, an acoustic head **10**, for example, has a plurality of acoustic elements **11e** arranged along the Y-axis direction. Thus, a plurality of acoustic wave focusing regions (the acoustic wave focusing regions **18a** and **18b**) can be formed. As described above, the plurality of acoustic elements **11e** are provided and the plurality of acoustic wave focusing regions **18** are formed, so that the efficiency of the ejection of a dispersed body **30** is improved, and the efficiency of printing is improved.

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In the printing devices **115** and **116**, both of the first recess and the second recess have a belt shape extending along the X-axis direction. However, as explained as to the printing device **112** to **114**, such a configuration may be possible in which at least one of the first recess and the second recess is discretely provided and pluralities of discrete first recesses and second recesses are provided on a first major surface **20a** of the film **20**.

In a typical ink jet printing device, a problem arises in that nozzles are clogged because of the condensation of ink due to the evaporation or vaporization of a solvent of liquid ink and the ejection of droplets is hindered. However, the aforementioned printing devices according to the embodiment also have a feature in that this problem does not arise because the devices use no nozzles. Particularly, in the applications to the industrial field, a dispersed body containing various solid particles is often used. Thus, this feature is particularly useful. There are a few restrictions on the dispersed body **30** usable.

Since the film **20** is used to supply the solid particles **31** and the liquid **32** to be the dispersed body **30**, there are features in that an ink layer having a smooth thickness can be formed and the accuracy of adjusting the position of the acoustic head **10** to the film **20** is relaxed.

As described above, an embodiment of the invention is explained with reference to specific examples. However, the invention is not limited to these specific examples. For example, as to the specific configurations of the components such as the acoustic head, the acoustic wave generating unit, the acoustic wave focusing unit, the acoustic wave transmitting unit, the acoustic element, the electrode, the driver, the film, the solid particle layer forming unit, and the liquid layer forming unit constituting the printing device, these specific configurations are included in the scope of the invention as long as a person skilled in the art may appropriately select configurations from the publicly known range to similarly carry out the invention for obtaining the similar effect.

Further, any two or more components of the specific examples may be combined within the extent of technical feasibility and are included in the scope of the invention to the extent that the purport of the invention is included.

Moreover, all printing devices obtainable by an appropriate design modification by a person skilled in the art based on the foregoing printing devices described as an embodiment of the invention are also within the scope of the invention to the extent that the purport of the invention is included.

Various other variations and modifications can be conceived by those skilled in the art within the spirit of the invention, and it is understood that such variations and modifications are also encompassed within the scope of the invention.

INDUSTRIAL APPLICABILITY

According to the invention, there is provided a printing device that can uniformize the amount of solid particles contained in ejected droplets and uniformly make a print in the case of discharging a dispersed body containing solid particles.

REFERENCE SIGNS LIST

- 7S solid particle layer forming unit
- 7Sa solid particle supply unit
- 7Sb solid particle layer uniformizing unit
- 7L liquid layer forming unit
- 7La liquid supply unit
- 7Lb liquid layer uniformizing unit

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10 acoustic head
11 acoustic wave generating unit
11a piezoelectric element
11b, 11c electrode
11e acoustic element
12 acoustic wave focusing unit
13 acoustic wave transmitting unit
14 driver
18, 18a, 18b acoustic wave focusing unit
20 film
20a first major surface
20b second major surface
21, 21a, 21b first recess
22, 22a, 22b second recess
30 dispersed body
31 solid particles
31a solid particle layer
32 liquid
32a liquid layer
33 droplet
40 material to be printed
110 to 116 printing device
d1 to d3 depth
w1 to w3 width

The invention claimed is:

1. A printing device configured to eject a dispersed body containing a solid particle and a liquid, comprising:

a film having:

a first major surface; and

a second major surface on an opposite side of the first major surface, the first major surface being provided with:

a first recess configured to accommodate the liquid; and

a second recess provided on a bottom face of the first recess and configured to accommodate the solid particle, wherein a distance between the first major

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surface and a bottom face of the second recess, in a direction [perpendicular to a direction] from the second major surface to the first major surface, is longer than a distance between the first major surface and a bottom face of the first recess in said direction; and

an acoustic head configured to focus an acoustic wave from a side of the second major surface toward the first recess and the second recess.

2. The printing device according to claim 1, further comprising:

a solid particle layer forming unit configured to dispose the solid particle in the second recess; and

a liquid layer forming unit configured to dispose the liquid in the first recess.

3. The printing device according to claim 2,

wherein after the solid particle layer forming unit disposes the solid particle in the second recess, the liquid layer forming unit disposes the liquid in the first recess.

4. The printing device according to claim 3, wherein:

a relative position between the film and the acoustic head is changed within a plane parallel to the second major surface; and

a width of the second recess along a second direction vertical to a first direction of a change in the relative position is smaller than a width of an acoustic wave focusing region along the second direction, the acoustic wave being focused on the acoustic wave focusing region on the first major surface.

5. The printing device according to claim 4,

wherein a width of the first recess along the second direction is larger than the width of the acoustic wave focusing region along the second direction.

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