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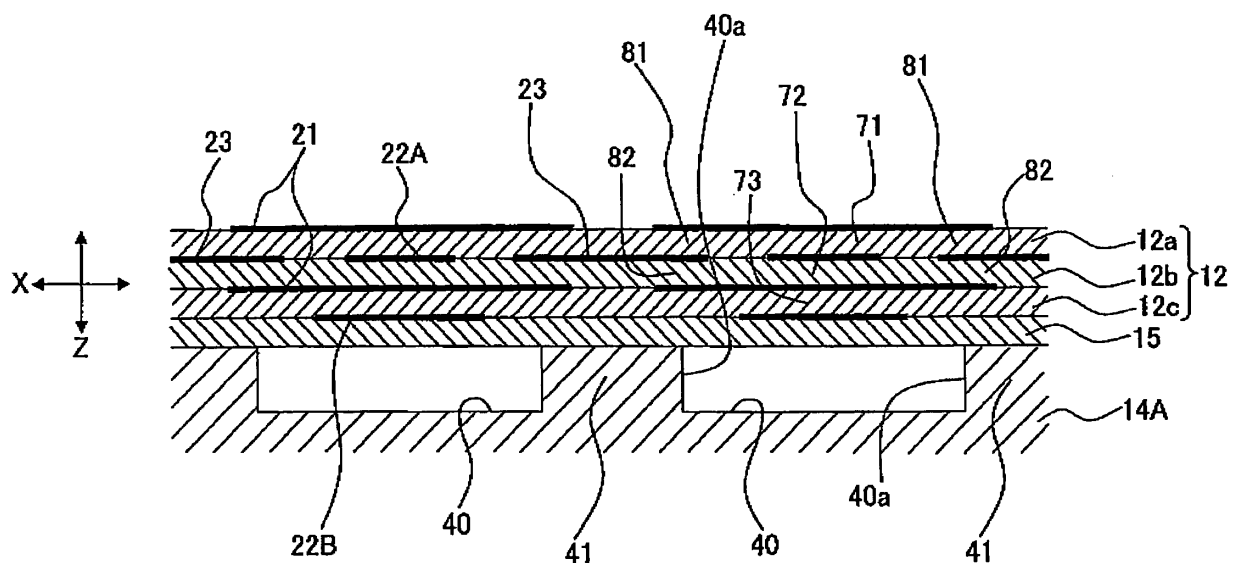
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(54) **Liquid-droplet jetting apparatus and liquid-droplet jetting head**

(57) A piezoelectric actuator includes first active portions corresponding to center portions (71 to 73) in a row direction of pressure chambers (40) and second active portions (81,82) corresponding to left and right portions on outer peripheral sides which are more outside than the center portions of the pressure chambers. When ap-

plying voltage to the first active portions, the first active portions deform to project toward pressure chambers. At this time, the second active portions do not deform and the influence of deformation of the first active portions does not reach the adjacent pressure chambers. Accordingly, effect of suppressing crosstalk is exhibited.

Fig. 4



Description

CROSS-REFERENCE TO RELATED APPLICATIONS

5 **[0001]** This application claims priority from Japanese Patent Application No. 2007-256922, filed on September 29, 2007.

BACKGROUND OF THE INVENTION

10 Field of the Invention

[0002] The present invention relates to a liquid-droplet jetting apparatus such as an ink-jet printer and a liquid-droplet jetting head such as an ink-jet head.

15 Description of the Related Art

[0003] Conventionally, as one of liquid-droplet jetting apparatuses, there is known an ink-jet printer provided with an ink-jet head having a cavity unit in which a plurality of pressure chambers are formed regularly and a piezoelectric actuator joined to the cavity unit for selectively jetting ink in the pressure chambers, and a voltage application mechanism for applying a voltage to the piezoelectric actuator. Then, as the piezoelectric actuator described above, there are known one using a vertical effect actuator of stacked type (see, for example, Japanese Patent Application Laid-open No. 2005-59551), and one using a unimorph actuator (see, for example, Japanese Patent Application Laid-open No. 2005-317952).

25 **[0004]** There are demands for increasing the density of the pressure chambers to secure high image quality or high quality of recording by increasing the number of nozzles in the ink-jet head of such an ink-jet printer. When the pressure chambers are arranged with high density, the distance between adjacent pressure chambers becomes short, and thus the influence to adjacent pressure chambers, a problem of so-called crosstalk occurs while driving.

[0005] Specifically, as shown in Figs. 39, 40 for example, the ink-jet head is formed such that a piezoelectric actuator 912 formed of three piezoelectric material layers 912a, 912b, 912c are joined on an upper side of a cavity unit 914, in which pressure chambers 940 are formed regularly, via a binding plate 915. Then individual electrodes 921 corresponding to the pressure chambers 940 are provided on a side of an upper surface of the piezoelectric material layer 912a, and constant potential electrodes 922 (ground potential) are provided on a side of a lower surface of the piezoelectric material layer 912a. Further, individual electrodes 921 and constant potential electrodes 922 are provided on an upper surface side and a lower surface side of the piezoelectric material layer 912c, respectively. With such a structure, regions (piezoelectric material layers) sandwiched between the individual electrodes 921 and the constant potential electrodes 922 function as active portions S where volumes of the pressure chambers 940 are changed by applying positive potential selectively to the individual electrodes 921 so as to jet ink from nozzle holes 914b. Such deformation for jetting ink affects not only the pressure chambers jetting ink but also the pressure chambers 940 adjacent to these pressure chambers 940 by deformation of the piezoelectric material layers 912a to 912c, as shown in Fig. 41.

40 **[0006]** Accordingly, there has been occurring a problem of fluctuation of jetting characteristics for the adjacent pressure chambers 940 (for example, a problem that unintended jetting of ink occurs from the nozzle holes 914b), namely, a problem of crosstalk.

[0007] To solve such a problem of crosstalk, various measures have been proposed. For example, in Japanese Patent Application Laid-open No. 2002-254640 (Fig. 2), there is described a structure in which a beam portion 100 is provided across partition walls 11 on both sides in a width direction of each pressure generating chamber 12 so as to improve the rigidity of the partition walls 11, and thereby occurrence of crosstalk is prevented between adjacent pressure generating chambers.

45 **[0008]** Further, in Japanese Patent Application Laid-open No. 2002-19113 (Fig. 1), there is described a structure in which an elastic body 7 having a predetermined depth from a nozzle plate 3 and a predetermined width is disposed on a side wall 5 that separates each pressurizing liquid chamber 4, thereby decreasing mechanical crosstalk.

50 **[0009]** However, these measures are becoming no longer perfect as the increase in density of the pressure chambers (ink jetting ch) proceeds.

SUMMARY OF THE INVENTION

55 **[0010]** An object of the present invention is to provide a liquid-droplet jetting apparatus and a liquid-droplet jetting head capable of suppressing crosstalk without increasing the number of individual electrodes, namely, the number of signal lines when structured with high density.

[0011] According to a first aspect of the present invention, there is provided a liquid-droplet jetting apparatus which jets droplets of a liquid, including:

a liquid-droplet jetting head including a cavity unit in which a plurality of pressure chambers arranged regularly are formed and a piezoelectric actuator which is joined to the cavity unit to cover the pressure chambers and which jets the liquid in the pressure chambers selectively, the piezoelectric actuator having first active portions each corresponding to a center portion of one of the pressure chambers and second active portions each corresponding to an outer peripheral portion, of one of the pressure chambers, which covers a portion located outside of the center portion of one of the pressure chambers; and
a voltage application mechanism which applies a voltage to the piezoelectric actuator;

wherein the first active portions and the second active portions expand in a first direction toward the pressure chambers and contract in a second direction orthogonal to the first direction when the voltage is applied to the first and second active portions by the voltage application mechanism; and

when a first voltage is applied to the first active portions the voltage application mechanism does not apply a second voltage to the second active portions, and when the first voltage is not applied to the first active portions the voltage application mechanism applies the second voltage to the second active portions.

[0012] Here, the "active portions" means portions which turn to a deformation state or a non-deformation state by application/non-application of voltage. Further, the "second active portions" include, besides the case of existing across portions corresponding to pressure chambers and portions corresponding to beam portions between the pressure chambers, the case of existing only in the portions corresponding to beam portions out of the portions corresponding to the pressure chambers and the case of existing only in the portions corresponding to the pressure chambers. The "first direction" means a direction in which the pressure chambers and the active portions are aligned, that is, a stacking direction of the piezoelectric actuator and the cavity unit.

[0013] In this manner, according to application/non-application of voltage, deformation occurs in reverse directions in the first active portions corresponding to the center portions of the pressure chambers and the second active portions corresponding to the portions on the outer peripheral sides which are more outside than the center portions of the pressure chambers. When the pressure chambers are arranged with high density and hence adjacent pressure chambers are close to each other, deformation of the first active portions is cancelled, when being transmitted to adjacent pressure chambers, by deformation of the second active portions, thereby suppressing so-called crosstalk which is propagation of deformation of the first active portions to adjacent pressure chambers. The first voltage applied to the first active portions may be same as the second voltage applied to the second active portions.

[0014] In the liquid-droplet jetting apparatus of the present invention, each of the second active portions may cover an inside portion located inside an outer peripheral edge of one of the pressure chambers.

[0015] In this case, not only the first active portions but the second active portions contribute to volumetric changes of the pressure chambers, and thus volumes of the pressure chambers can be changed larger than in the case only by the first active portions. Therefore, it is possible to improve jetting efficiency (jetting amount when voltage is applied) for jetting liquids in the pressure chambers selectively by applying the voltage to the piezoelectric actuator.

[0016] In the liquid-droplet jetting apparatus of the present invention, the piezoelectric actuator may include individual electrodes to which first potential and second potential different from the first potential are applied selectively, first constant potential electrodes to which the first potential is applied, and second constant potential electrodes to which the second potential is applied; each of the first active portions may include a piezoelectric material sandwiched between one of the individual electrodes and one of the first constant potential electrodes; and each of the second active portions may include a piezoelectric material sandwiched between one of the individual electrodes and one of the second constant potential electrodes.

[0017] In this case, just by applying the first potential and the second potential selectively to the individual electrodes, deformation of the first active portions and deformation of the second active portions (returning to an original state) can be made to occur at the same time completely. Thus, an attempt of the deformation of the first active portions to propagate to adjacent pressure chambers is cancelled by the deformation of the second active portions, thereby suppressing crosstalk without requiring highly precise timing control.

[0018] In the liquid-droplet jetting apparatus of the present invention, the individual electrodes may be formed across a first region corresponding to the first active portions and a second region corresponding to the second active portions of the piezoelectric actuator so as to cover the first and second regions; the first constant potential electrodes may be formed to cover the first region of the piezoelectric actuator; and the second constant potential electrodes may be formed to cover the second region of the piezoelectric actuator.

[0019] In this case, the electrodes can be arranged efficiently, and thereby arrangement without a waste becomes possible.

[0020] In the liquid-droplet jetting apparatus of the present invention, the first active portions may be polarized in a

direction same as a direction of an electric field generated the applied voltage when the second potential is applied to the individual electrodes and the first potential is applied to the first constant potential electrodes; and the second active portions may be polarized in a direction same as a direction of an electric field generated by the applied voltage when the first potential is applied to the individual electrodes and the second potential is applied to the second constant potential electrodes.

[0021] In this case, in the first and second active portions, an application direction of voltage during driving and an application direction of voltage during polarization can all be aligned, and the electrodes can be used not only during driving (during deformation of active portions) but for polarization during manufacturing. Further, since the application direction of voltage during driving and the application direction of voltage during polarization (polarization direction) are the same, and a reverse electric field is not applied to a piezoelectric material layer during driving, occurrence of deterioration in deformation of the active portions can be suppressed. Note that, in this description the words "an application direction of voltage" is defined as a direction of an electric field generated by the applied voltage.

[0022] In the liquid-droplet jetting apparatus of the present invention, the first potential may be positive potential and the second potential may be ground potential. Further, the first potential may be ground potential and the second potential may be positive potential.

[0023] In these cases, by applying two kinds of potential, the positive potential and the ground potential selectively to the individual electrodes, driving can be controlled easily.

[0024] In the liquid-droplet jetting apparatus of the present invention, the second constant potential electrodes may be common in two adjacent pressure chambers among the pressure chambers.

[0025] In this case, since the second constant potential electrodes are shared by the adjacent two of the pressure chambers, the number of second constant potential electrodes can be reduced, and thus the electrodes as a whole can be simplified.

[0026] In the liquid-droplet jetting apparatus of the present invention, the piezoelectric actuator may have a piezoelectric material layer; and the individual electrodes may be formed on a side of one surface of the piezoelectric material layer and the first constant potential electrodes and the second constant potential electrodes may be formed on a side of the other surface of the piezoelectric material layer, and the first active portions and the second active portions may be formed on the same piezoelectric material layer. Here, "the piezoelectric material layer" includes, other than a piezoelectric sheet produced by burning a so-called green sheet, one produced by a method such as so-called AD method (aerosol deposition method).

[0027] In this case, an arrangement of required electrodes can be realized by having at least one piezoelectric material layer, and thus it is advantageous in the aspect of material cost.

[0028] In the liquid-droplet jetting apparatus of the present invention, an insulating layer thinner than the piezoelectric material layer may be provided to be sandwiched by the first constant potential electrodes and the second constant potential electrodes formed on the side of the other surface; and the first constant potential electrodes and the second constant potential electrodes may be isolated by the insulating layer.

[0029] In this case, since the first constant potential electrodes and the second constant potential electrodes are isolated sandwiching the insulating layer, the first constant potential electrodes and the second constant potential electrodes do not short circuit even when they are arranged close to each other. Thus, it becomes possible to arrange the first active portions and the second active portions close to each other, which is advantageous for downsizing.

[0030] In the liquid-droplet jetting apparatus of the present invention, the insulating layer may be formed of a material same as the piezoelectric material layer.

[0031] In this case, since the same material as the piezoelectric material layer is used for the insulating layer, manufacturing thereof is easy, which is also advantageous in the aspect of cost.

[0032] In the liquid-droplet jetting apparatus of the present invention, the first constant potential electrodes may be formed to be sandwiched between adjacent two pressure chambers among the pressure chambers to form rows with the two adjacent pressure chambers; and the second constant potential electrodes may be formed only on one side of the two pressure chambers.

[0033] In this case, the second active portions are arranged on one side of the pressure chambers, and crosstalk is suppressed only for the one side.

[0034] In the liquid-droplet jetting apparatus of the present invention, the piezoelectric actuator may have a plurality of piezoelectric material layers; the first constant potential electrodes or the second constant potential electrodes may be formed on a farthest surface not facing the pressure chambers, of a farthest layer, among the plurality of piezoelectric material layers, the farthest layer being located farthest from the pressure chambers; the individual electrodes may be formed on a surface of one of the piezoelectric material layers, the surface being different from the farthest layer; surface electrodes which are to be input terminals to the individual electrodes, respectively, may be formed in areas, of the farthest surface, overlapping with the outer peripheral portions; and the individual electrodes may be conducted to the surface electrodes via a conductive material filled in through holes penetrating the piezoelectric material layers.

[0035] In this case, when having a plurality of piezoelectric material layers, a reasonable arrangement of individual

electrodes can be realized using surface electrodes and through holes.

[0036] In the liquid-droplet jetting apparatus of the present invention, the second active portions may be formed on a layer other than the farthest layer among the plurality of piezoelectric material layers; and each of the surface electrodes may be formed in an area, on the farthest surface, overlapping with a portion between the adjacent pressure chambers.

[0037] In this case, the surface electrodes are formed in regions between adjacent pressure chambers without interfering with the second active portions. Thus, freedom of positions to form the surface electrodes improves.

[0038] According to a second aspect of the invention, there is provided a liquid-droplet jetting apparatus which jets droplets of a liquid, including:

a liquid-droplet jetting head including a cavity unit in which a plurality of pressure chambers arranged regularly are formed and a piezoelectric actuator which is joined to the cavity unit to cover the pressure chambers and jets the liquid in the pressure chambers selectively, the piezoelectric actuator having first portions each located to correspond to a center portion of one of the pressure chambers and second portions each located to correspond to an outer peripheral portion which covers a portion located outside of the center portion of one of the pressure chambers; and a voltage application mechanism which applies a voltage to the piezoelectric actuator;

wherein the voltage application mechanism switches application and non-application of a first voltage to the first portions so as to change a volume of each of the pressure chambers, and switches application and non-application of a second voltage to the second portions so as to suppress that deformation of the first portions generated in a pressure chamber among the pressure chambers due to switching to the application of voltage to the first portions, propagates to another pressure chamber adjacent to the pressure chamber.

[0039] According to the second aspect of the present invention, application and non-application of voltage to the first portions are switched so as to change the volumes of the pressure chambers, and application and non-application of voltage to the second portions are switched so as to suppress that deformation of the first active portions due to this switching propagates to the adjacent pressure chambers, thereby suppressing crosstalk.

[0040] According to the third aspect of the present invention, there is provided a liquid-droplet jetting head which jets droplets of a liquid, including:

a cavity unit in which a plurality of pressure chambers arranged regularly are formed; and a piezoelectric actuator which is joined to the cavity unit to cover the pressure chambers and jets the liquid in the pressure chambers selectively, the piezoelectric actuator having first active portions each corresponding to a center portion of one of the pressure chambers, second active portions each corresponding to an outer peripheral portion, of one of the pressure chambers, which covers a portion located outside of the center portion of one of the pressure chambers, individual electrodes formed to across a first region corresponding to the first active portions and a second region corresponding to the second active portions so as to cover the first and second regions, first constant potential electrodes formed to cover the first region, and second constant potential electrodes formed to cover the second region.

[0041] In this case, deformation in reverse direction occurs according to application/non-application of voltage in the first active portions corresponding to the center portions of the pressure chambers and the second active portions corresponding to the portions on the outer peripheral sides which are more outside than the center portions of the pressure chambers, and hence crosstalk which is propagation of deformation of the first active portions to adjacent pressure chambers is suppressed.

[0042] As described above, the liquid-droplet jetting apparatus and the liquid-droplet jetting head of the present invention, deformation in reverse direction occurs according to application/non-application of voltage in the first active portions corresponding to the center portions of the pressure chambers and the second active portions corresponding to the portions on the outer peripheral sides which are more outside than the center portions of the pressure chambers. Accordingly, even when the pressure chambers are arranged with high density, crosstalk which is propagation of deformation of the active portions to adjacent pressure chambers can be suppressed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0043] Fig. 1A is a schematic structural view showing a schematic structure of an ink-jet printer (liquid-droplet jetting apparatus) according to the present invention, Fig. 1B is an explanatory view showing a relationship among a cavity unit, a piezoelectric actuator and a flexible wiring board (COP) according to the present invention; Fig. 2A, 2B are perspective views showing that the piezoelectric actuator is attached to an upper side of the cavity unit; Fig. 3 is a view showing the cavity unit exploded into plates as component parts, together with a top plate; Fig. 4 is a schematic cross-sectional view of first embodiment;

Fig. 5 is an explanatory view of arrangement of electrodes in piezoelectric material layers of the piezoelectric actuator; Figs. 6A, 6B are explanatory views showing a relationship among a polarization direction, portions (first active portions) which are effective while being turned ON and effective during application of voltage, and portions (second active portions) which are effective while being turned OFF and effective during non-application of voltage, regarding the first embodiment;

5 Figs. 7A, 7B are explanatory views showing respectively volumetric changes of pressure chambers during non-application/application of voltage to first active portions;

Fig. 8 is a view similar to Fig. 4 regarding a modification example of the first embodiment;

Fig. 9 is a view similar to Fig. 4 regarding another modification example of the first embodiment;

Fig. 10 is a view similar to Fig. 4 regarding a different modification example of the first embodiment;

10 Figs. 11A, 11B are views similar to Figs. 6A, 6B respectively regarding the different modification example (see Fig. 10) of the first embodiment; Fig. 12 is a view similar to Fig. 4 regarding a further different modification example of the first embodiment;

Figs. 13A, 13B are views similar to Figs. 6A, 6B respectively regarding the further different modification example of the first embodiment;

15 Fig. 14 is a view similar to Fig. 4 regarding the second embodiment;

Fig. 15 is a view similar to Fig. 4 regarding the third embodiment;

Fig. 16 is a view similar to Fig. 4 regarding the fourth embodiment;

Fig. 17 is a view similar to Fig. 4 regarding the fifth embodiment;

Figs. 18A, 18B are views similar to Figs. 7A, 7B respectively regarding the fifth embodiment;

20 Fig. 19 is a view similar to Fig. 4 regarding the sixth embodiment;

Fig. 20 is a view similar to Fig. 4 regarding the seventh embodiment;

Fig. 21 is a view similar to Fig. 5 regarding the seventh embodiment;

Figs. 22A, 22B are views similar to Figs. 6A, 6B respectively regarding the seventh embodiment;

Fig. 23 is a view similar to Fig. 4 regarding the eighth embodiment;

25 Fig. 24 is a view similar to Fig. 5 regarding the eighth embodiment;

Figs. 25A, 25B are views similar to Figs. 6A, 6B respectively regarding the eighth embodiment;

Figs. 26A, 26B are views similar to Figs. 7A, 7B respectively regarding the eighth embodiment;

Figs. 27A, 27B are timing charts;

Fig. 28 is a view similar to Fig. 4 regarding the ninth embodiment;

30 Fig. 29 is a view similar to Fig. 5 regarding the ninth embodiment;

Figs. 30A, 30B are views similar to Figs. 6A, 6B respectively regarding the ninth embodiment;

Figs. 31A, 31B are views similar to Figs. 7A, 7B respectively regarding the ninth embodiment;

Fig. 32 is a view similar to Fig. 4 regarding the tenth embodiment;

Figs. 33A, 33B are views similar to Figs. 6A, 6B respectively regarding the tenth embodiment;

35 Figs. 34A, 34B are views similar to Figs. 7A, 7B respectively regarding the tenth embodiment;

Fig. 35 is a view similar to Fig. 4 regarding the eleventh embodiment;

Fig. 36 is a view similar to Fig. 5 regarding the eleventh embodiment;

Figs. 37A, 37B are views similar to Figs. 6A, 6B respectively regarding the eleventh embodiment;

Figs. 38A, 38B are views similar to Figs. 7A, 7B respectively regarding the eleventh embodiment;

40 Fig. 39 is a schematic cross-sectional view regarding a conventional example;

Fig. 40 is an explanatory view showing a relationship among a polarization direction, portions which are effective during application of voltage, and portions which are effective during non-application of voltage regarding the conventional example; and

Fig. 41 is an explanatory view showing volumetric changes of pressure chambers when applying voltage to active portions of the conventional example.

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DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0044] Hereinafter, embodiments of the present invention will be explained according to the drawings.

First Embodiment

[0045] Fig. 1A is a schematic structural view showing a schematic structure of an ink-jet printer (liquid-droplet jetting apparatus) according to the present invention, and Fig. 1B is an explanatory view showing a relationship among a cavity unit, a piezoelectric actuator and a flexible wiring board (COP) according to the present invention.

[0046] In the ink-jet printer 1 according to the present invention, as shown in Fig. 1A, an ink-jet head 3 (liquid-droplet jetting head) for recording on a recording paper P (recording medium) is provided on a lower surface of a carriage 2 on which an ink cartridge (not shown) is mounted. The carriage 2 is supported by a carriage shaft 5 and a guide plate (not

shown) provided in a printer frame 4, and reciprocates in a direction B orthogonal to a feeding direction A of the recording paper P. The recording paper P carried in the direction A from a not-shown paper feeding unit is introduced into a space between a platen roller (not shown) and the ink-jet head 3, where predetermined recording is performed with ink jetted toward the recording paper P from the ink-jet head 3, and is discharged thereafter by discharging rollers 6.

[0047] Further, as shown in Fig. 1B, the ink-jet head 3 is provided with a flexible wiring board 13 (signal line), which has a cavity unit 11 and a piezoelectric actuator 12 from a lower side in order, and supplies a drive signal to an upper surface of the piezoelectric actuator 12.

[0048] As shown in Fig. 2, the cavity unit 11 includes a stack 14 formed of a plurality of plate members. A top plate 15 is provided on an upper side of the stack 14. A plate assembly 18 is adhered integrally on a lower side of the stack 14, and the plate assembly 18 is formed by adhering a nozzle plate 16 having nozzle holes 16a and a spacer plate 17 having through holes 17a corresponding to the nozzle holes 16a. Then, a piezoelectric actuator 12 for selectively jetting ink (liquid) in pressure chambers 40 is joined on an upper side of the top plate 15. Further, a filter 19 for catching dust or the like included in the ink is provided on openings 11a of the cavity unit 11. The nozzle plate 16 is a plate of synthetic resin (polyimide resin for example) in which each of the nozzle holes 16a is provided to correspond to one of the pressure chambers 40 of the cavity plate 14A (forming the stack 14). Note that the nozzle plate 16 may be a metal plate.

[0049] As shown in Fig. 3, the stack 14 is formed such that a cavity plate 14A, a base plate 14B, an aperture plate 14C, two manifold plates 14D, 14E, and a damper plate 14F are stacked in this order from an upper side and these plates are bonded by a metal-diffusion bonding. These six plates 14A to 14F are aligned with each other and stacked so that ink channels are formed individually for the nozzle holes 16a, respectively. Here, the cavity plate 14A is a metal plate in which openings functioning as a plurality of pressure chambers 40 are formed regularly corresponding to nozzle rows. The base plate 14B is a metal plate in which there are formed through holes 51a forming parts of communication holes 51 allowing communication between the pressure chambers 40 and manifolds 50 (common ink chambers) which will be explained later, and through holes 52a forming parts of communication holes 52 allowing communication between the pressure chambers 40 and the nozzle holes 16a. On an upper surface of the aperture plate 14C, communication channels 21 allowing communication between the pressure chambers 40 and the manifolds 50 are formed as recessed channels. Further, the aperture plate 14C is a metal plate in which there are provided communication holes 51b forming parts of the communication holes 51, and communication holes 52b forming parts of the communication holes 52. In the manifold plates 14D, 14E, communication holes 50a, 50b defining the manifolds 50 are formed respectively. Furthermore, the manifold plates 14D, 14E are metal plates in which communication holes 52c, 52d forming parts of the communication holes 52 are provided respectively. The damper plate 14F is a metal plate in which communication holes 52e forming parts of the communication holes 52 are provided respectively, and damper chambers 53 which are formed as recesses also provided in a lower surface of the damper plate 14F.

[0050] The cavity unit 11 includes the plurality of nozzle holes 16a, the plurality of pressure chambers 40 communicating with the nozzle holes 16a respectively and manifolds 50 temporarily storing ink supplied to the pressure chambers 40. Further, the communication holes 51a, 51b communicate with each other and form the communication holes 51 allowing communication between the pressure chambers 40 and the manifolds 50. Furthermore, the communication holes 52a to 52e communicate with each other and form the communication holes 52 allowing communication between the pressure chambers 40 and the nozzle holes 16a.

[0051] The piezoelectric actuator 12 is formed by stacking a plurality of piezoelectric material layers 12a, 12b, 12c as shown in Fig. 4. The piezoelectric material layers 12a to 12c are formed of lead zirconate titanate (PZT) based ceramic materials (piezoelectric sheets) having ferroelectricity, and is polarized in a thickness direction thereof (see Figs. 6A, 6B).

[0052] Then, the piezoelectric actuator 12 includes, as viewed in a plan view (as viewed from a stacking direction of the cavity unit 11 and the piezoelectric actuator 12), first active portions 71, 72, 73 (first portions) corresponding to center portions of the pressure chambers 40 and second active portions 81, 82 (second portions) corresponding to left and right portions on outer peripheral sides which are more outside than the center portions of the pressure chambers 40. Here, as shown in Fig. 4, the first active portions 71, 72, 73 correspond to piezoelectric sheets 12a, 12b, 12c respectively, and the second active portions 81, 82 correspond to left sides and right sides of the pressure chambers 40 respectively. Note that the center portions of the pressure chambers 40 are center portions in a nozzle row direction X in which the nozzle holes 16a are arranged.

[0053] The second active portions 81, 82 include not only regions corresponding to beam portions (girder portions, column portions) 41 which are walls partitioning adjacent pressure chambers 40 but regions corresponding to portions more inside (center portion side) than outer peripheral edges 40a of the pressure chambers 40.

[0054] The first active portions 71 to 73 are, respectively, regions of the piezoelectric sheet 12a between individual electrodes 21A and first constant potential electrodes 22A, regions of the piezoelectric sheet 12b between the first constant potential electrodes 22A and individual electrodes 21B, and regions of the piezoelectric sheet 12c between the individual electrodes 21B and first constant potential electrodes 22B. On the other hand, both of the second active portions 81, 82 are regions of the piezoelectric sheets 12a to 12c between the individual electrodes 21A and the second constant potential electrodes 23. Note that the electrodes 21A, 21B, 22A, 22B are formed of Ag-Pd based metal materials

or the like.

[0055] A driver IC 90 (see Fig. 1B) supplying driving signals is electrically connected to the individual electrodes 21 via the flexible wiring board 13 (signal lines). The driver IC 90 and the flexible wiring board 13 form a voltage application mechanism for applying driving voltage to the first and second active portions 71 to 73, 81, 82 of the piezoelectric actuator 12.

[0056] A first potential (ground potential) and a second potential different therefrom (20 V for example) are applied selectively to the individual electrodes 21 via the flexible wiring board 13 to change volumes of the pressure chambers 40. Further, the first potential (ground potential) is applied constantly to the first constant potential electrodes 22A, 22B, and the second potential (20 V for example) is applied constantly to the second constant potential electrodes 23.

[0057] Thus, the piezoelectric actuator 12 has the individual electrodes 21 corresponding to the pressure chambers 40. The piezoelectric actuator 12 changes the volumes of the pressure chambers 40 to jet ink from the nozzle holes 16a, when the first potential (ground potential) and the second potential (positive potential) are applied selectively to the individual electrodes 21 as drive signals.

[0058] A length of the individual electrodes 21 is shorter than a length of the pressure chambers 40 in a direction Y orthogonal to the nozzle row direction X (see Fig. 6B), but longer than a length of the pressure chambers 40 in the nozzle row direction X. The individual electrodes 21 are formed to range across regions (first region) corresponding to the first active portions 71 to 73 and regions (second region) corresponding to the second active portions 81, 82 so as to cover both of these regions. A length of the first constant potential electrodes 22A, 22B is shorter than a length of the pressure chambers 40 in the nozzle row direction X so as to cover regions corresponding to the first active portions 71 to 73. Then a length of the first constant potential electrodes 22B located on the side of the pressure chambers 40 is longer in the nozzle row direction X than a length of the first constant potential electrodes 22A located away from the pressure chambers 40. That is, the individual electrodes 21 are shared (used commonly) for the first and second constant potential electrodes 22A, 22B, 23.

[0059] The second constant potential electrodes 23 are formed to cover regions corresponding to the second active portions 81, 82 and regions corresponding to the beam portions 41 between the pressure chambers 40 which are adjacent to each other in a direction orthogonal to the nozzle row direction. That is, the second constant potential electrodes 23 extend to regions corresponding to side portions, of the pressure chambers 40, in the nozzle row direction, the side portions including the beam portions 41. Each of the second constant potential electrodes is shared for two pressure chambers 40 which are adjacent to each other in the nozzle row direction.

[0060] Specifically, the individual electrodes 21 are formed on a side of one surface (upper face in Fig. 4) of the piezoelectric material layer 12a which is farthest from the pressure chambers 40, and the first constant potential electrodes 22A and the second constant potential electrodes 23 are formed on a side of the other surface (lower face in Fig. 4) of the piezoelectric material layer 12a. Accordingly, the first active portions 71 and the second active portions 81 are formed side by side in the same piezoelectric material layer 12a. Further, the first constant potential electrodes 22A and the second constant potential electrodes 23 are formed alternately on a side of one surface (upper face in Fig. 4) of the piezoelectric material layer 12b, and the individual electrodes 21 are formed on a side of the other surface (lower face in Fig. 4) of the piezoelectric material layer 12b.

Accordingly, the first active portions 72 and the second active portions 82, corresponding to the first active portions 71 and the second active portions 81 of the piezoelectric material layer 12a, are formed side by side in the same piezoelectric material layer 12b. Furthermore, the individual electrodes 21 are formed on a side of one surface (upper face in Fig. 4) of the piezoelectric material layer 12c which is closest to the pressure chambers 40, and the first constant potential electrodes 22B are formed on a side of the other surface (lower face in Fig. 4) of the piezoelectric material layer 12c. Thus, the first active portions 73 are formed in the piezoelectric material layer 12c. A length of the first active portions 73 is longer than a length of the first active portions 71, 72 in the nozzle row direction, since the constant potential electrodes 22B are longer than the constant potential electrodes 22A in the nozzle row direction X.

[0061] Further, the electrodes 21, 22A, 22B, 23 of the respective piezoelectric sheets 12a to 12c are arranged in a plan view as shown in Fig. 5. Namely, on an upper face side (first layer, third layer) of the piezoelectric sheet 12a (12c), the individual electrodes 21 are arranged at a constant pitch in the nozzle row direction (X direction) corresponding respectively to the pressure chambers 40. A plurality of rows of individual electrodes 21 are arranged in the Y direction. Then, in rows adjacent to each other in the Y direction, the individual electrodes 21 are formed to be shifted by a half pitch from each other in the X direction. Between these rows, on the individual electrodes 21, connection portions 26 to be connected to the connection terminals (not shown) of the flexible wiring board 13 are formed in a zigzag pattern.

[0062] On a lower side (second layer) of the piezoelectric material layer 12a, the first constant potential electrodes 22A are formed at a constant pitch in the nozzle row direction corresponding respectively to the pressure chambers 40. One ends of the first constant potential electrodes 22A are connected to one of first common electrodes 27A which is kept at the ground potential and extends in the nozzle row direction. Further, between the first constant potential electrodes 22A, the second constant potential electrodes 23 are formed respectively, and one ends thereof are also at positive potential (for example 20 V: constant) and connected to one of second common electrodes 28 extending in the nozzle

row direction X. Then between the adjacent pressure chambers 40, middle electrodes 25 are formed in a zigzag form (see Fig. 6B) for electrically connecting the individual electrodes 21 on the upper face side of the piezoelectric material layer 12a to the individual electrodes 21 on the upper face side of the piezoelectric material layer 12c located therebelow using through holes 24 (filled with conductive materials inside).

[0063] In a lower face side of the piezoelectric material layer 12c, the first constant potential electrodes 22B are formed at a constant pitch in the nozzle row direction corresponding respectively to the pressure chambers 40, and one ends thereof are connected to one of first common electrodes 27B at the ground potential extending in the nozzle row direction X. Note that the first constant potential electrodes 22B located on the side of the pressure chambers 40 are formed longer in length in the nozzle row direction X than the first constant potential electrodes 22A located away from the pressure chambers 40.

[0064] Note that as shown in Figs. 6A, 6B, the first active portions 71 to 73 are polarized in the same direction (polarization direction) as the direction of the electric field generated by the applied voltage when the second potential is applied to the individual electrodes 21 and the first potential is applied to the first constant potential electrodes 22A, 22B for deformation. On the other hand, the second active portions 81, 82 are polarized in the same direction as the direction of the electric field generated by the applied voltage when the first potential is applied to the individual electrodes 21 and the second potential is applied to the second constant potential electrodes 23 for deformation. That is, the directions of the electric field generated by the applied voltage and the polarization directions are the same. Here, in Figs. 6A, 6B, portions which are "effective while being turned ON" correspond respectively to the first active portions to which voltage (20 V) is applied when the second potential is applied to the individual electrodes 21, and portions which are "effective while being turned OFF" correspond respectively to the second active portions to which voltage (20 V) is applied when the first potential is applied to the individual electrodes 21.

[0065] The first constant potential electrodes 22A, 22B are always at the first potential (ground potential), and the second constant potential electrodes 23 are always at the second potential (positive potential). Then, the first potential (ground potential) and the second potential (positive potential) are applied to the individual electrodes 21 selectively for changing the volumes of the pressure chambers 40. That is, as shown in Table 1 below, the direction of the electric field generated by the applied voltage is the same during polarization and during driving. However, the first constant potential electrodes 22A, 22B are always at the ground potential (0 V), the second constant potential electrodes 23 are always at the positive potential (20 V: constant), and to the individual electrodes 21, the positive potential (20 V: constant) is applied or this application is released (see Fig. 27A). Therefore, when the positive potential is applied to the individual electrodes 21, the voltage is applied to the first active portions 71 to 73 but the voltage is not applied to the second active portions 81, 82. On the other hand, when the positive potential is not applied to the individual electrodes 21 and the individual electrodes 21 are at the ground potential, the voltage is not applied to the first active portions 71 to 73, and the voltage is applied to the second active portions 81, 82. Here, the voltage applied between electrodes during driving is, as shown in Table 1, smaller than the voltage applied during polarization, thereby suppressing deterioration due to repeated application of voltage between electrodes.

[0066]

[Table 1]

TYPE OF ELECTRODE	APPLIED POTENTIAL DURING POLARIZATION	APPLIED POTENTIAL DURING DRIVING
INDIVIDUAL ELECTRODE 21	50 V	20 V (ON/OFF)
FIRST CONSTANT POTENTIAL ELECTRODES 22A, 22B	0 V	0 V
SECOND CONSTANT POTENTIAL ELECTRODE 23	100 V	20 V (CONSTANT)

[0067] Since the electrodes 21, 22A, 22B, 23 are arranged as described above, during non-application of voltage to the first active portions 71 to 73 (during standby) in which the second potential (ground potential) is applied to the individual electrodes 21 by the voltage application mechanism, the first active portions 71 to 73 are in a state of non-expand/non-contract (non-deform) in the first and second directions Z, X. At this time, the second active portions 81, 82 are in a voltage applied state, and attempt to expand in a stacking direction Z (first direction) toward the pressure chambers 40 and contract in the nozzle row direction X (second direction) orthogonal to the stacking direction Z. Thus, by the operation of the top plate 15 as a binding plate (a restraint plate), the second active portions 81, 82 located at the side portions in the nozzle row directions deform to bend in a direction to depart from the pressure chambers 40. As shown in Fig. 7A, this deformation of the second active portions 81, 82 contributes to increasing of volumetric changes

of the pressure chambers 40, and contributes to sucking of a large amount of ink from the manifolds 50 to the pressure chambers 40.

[0068] On the other hand, during application of voltage (during driving) to the first active portions 71 to 73 in which the first potential (positive potential: 20 V) is applied to the individual electrodes 21, the first active portions 71 to 73, being applied with voltage in the same direction as the polarization direction, expand in the stacking direction Z toward the pressure chambers 40 and contract in the nozzle row direction X orthogonal to the stacking direction Z thereof by piezoelectric lateral effect. Accordingly, the first active portions 71 to 73 turn to a state of projecting and deforming in a direction toward insides of the pressure chambers 40. On the other hand, as the top plate 15 does not contract spontaneously because it is not influenced by electric field, a difference is made in distortion in the polarization direction and in the vertical direction between the piezoelectric material layer 12c located on the upper side and the top plate 15 located on the lower side. This and the top plate 15 being fixed to the cavity plate 14A together cause the piezoelectric material layer 12c and the top plate 15 to attempt to deform so as to project toward the side of the pressure chambers 40 (unimorph deformation). Accordingly, the volumes of the pressure chambers 40 decrease, the pressure of ink increases, and the ink is jetted from the nozzle holes 16a.

[0069] In this application period of voltage to the first active portions 71 to 73, the second active portions 81, 82 turn to a non application state of voltage, and hence return to a state of non-expand/non-contract (non-deform) in the first and second directions Z, X. Thus, when the first active portions 71 to 73 project and deform in the direction toward the pressure chambers 40, the second active portions 81, 82 return to a state of not deforming. Therefore, as shown in Fig. 7B, the influence of deformation of the first active portions 71 to 73 is cancelled by the second active portions 81, 82 and hardly reaches the pressure chambers 40 adjacent thereto, thereby suppressing crosstalk. That is, application and non-application of voltage to the second active portions 81, 82 are switched so as to suppress that deformation of the first active portions 71 to 73 due to switching of application and non-application of voltage to the first active portions 71 to 73 propagates to the adjacent pressure chambers 40.

[0070] Thereafter, when the individual electrodes 21 are returned to the same potential (ground potential) as the first constant potential electrodes 22A, 22B, the first active portions 71 to 73 turn to a state of not deforming as described above. Then, the second active portions 81, 82 deform to bend in a direction to depart from the pressure chambers 40, and the volumes of the pressure chambers 40 return to the original volumes. Thus, the ink is sucked into the pressure chambers from the manifolds 50.

[0071] The jetting operation of ink is repeated by such deformation of the first active portions 71 to 73 and the second active portions 81, 82, and volumetric changes of the pressure chambers 40 are made to be large in each jetting operation, thereby increasing jetting efficiency and suppressing crosstalk in the three directions.

[0072] Incidentally, the ratio of changes of cross-sectional areas of adjacent pressure chambers were obtained in the first embodiment and the conventional example (see Fig. 40). As shown in Table 2, it is 11% in the case of the first embodiment while it is 24% in the case of the conventional example. The change ratio in the case of the first embodiment decreases to almost half as compared to the conventional example, and it can be seen that the effect of suppressing crosstalk is exhibited.

[0073]

[Table 2]

	ELECTRODE WIDTH (μm)			CROSS-SECTIONAL AREA CHANGE (μm ²)	ADJACENT CROSS AREA CHANGE (μm ²)	ADJACENT CHANGE RATIO
	INDIVIDUAL ELECTRODE	FIRST CONSTANT POTENTIAL ELECTRODE	SECOND CONSTANT POTENTIAL ELECTRODE			
CONVENTIONAL EXAMPLE	250	FULL	-	5.82	1.38	24%
first embodiment	480,320	120	188	6.02	0.69	11%
second embodiment	480,320	220	220	6.56	0.74	11%
fifth embodiment	408	140	300	5.10	0.10	2%
eighth embodiment	408	FULL	250	5.63	0.70	12%
eleventh embodiment	480	FULL	250	5.89	0.18	3%

[0074] In the first embodiment, the second active portions 81, 82 are arranged across the first regions and the second regions, the first regions corresponding to the portions on the outer peripheral sides which are more outside than the center portions of the pressure chambers 40 in the nozzle row direction X, and the second regions corresponding to the beam portions 41. However, it is also possible to structure as shown in Fig. 8. That is, it is also possible to structure such that the second constant potential electrodes 23A are provided only in the regions corresponding to the beam portions 41 irrelevantly to the regions corresponding to the pressure chambers 40, and second active portions 81a, 82a exist only in the regions corresponding to the beam portions 41. In this case, even when voltage is applied to the second active portions 81a, 82a and the second active portions 81a, 82a deform, it does not contribute to increasing of the volumes of the pressure chambers 40, but the effect of suppressing crosstalk is exhibited.

[0075] Conversely, as shown in Fig. 9, it is also possible to structure such that second active portions 81b, 82b exist only in the regions corresponding to portions on the outer peripheral sides of the pressure chambers 40. That is, the second constant potential electrodes 23B can be provided only in the regions corresponding to the portions on the outer peripheral sides which are more outside than the center portions of the pressure chambers 40 irrelevantly to the regions corresponding to the beam portions 41. In this case, lengths of the second active portions 81b, 82b in the nozzle row direction become shorter, as compared to the structure in which the above-described second active portions 81, 82 are arranged across the first regions and the second regions, the first regions corresponding to the portions on the outer peripheral sides which are more outside than the center portions of the pressure chambers 40, and the second regions corresponding to the beam portions 41 (see Fig. 4). Therefore, although being lower in effect of suppressing crosstalk and effect of contributing to volumetric changes, the point that these effects are exhibited is the same as described above.

[0076] Furthermore, as shown in Fig. 10, it can also be a structure in which a piezoelectric material layer 12d is provided, without providing the top plate, on the upper side of the cavity plate 14A via an insulating layer 12e having a small layer thickness, and first and second active portions are formed in this piezoelectric material layer 12d. In this case, in the piezoelectric material layer 12d, similarly to the piezoelectric material layer 12b, the first and second constant potential electrodes 22A, 23 are formed alternately on one surface (upper surface), and the individual electrodes 21 are formed on the other surface (lower surface). Accordingly, there are formed first active portions 71, 72, 73a, 74 corresponding respectively to the center portions of the pressure chambers 40, and second active portions 81, 82, 83, 84 corresponding respectively to portions on outer peripheral sides thereof.

[0077] Incidentally, a relationship among the polarization direction, portions (first active portions) which are effective while being turned ON and effective during application of voltage and portions (second active portions) which are effective while being turned OFF and effective during non-application of voltage is shown in Figs. 11A, 11B.

[0078] In this manner, the first active portions 71, 72, 73a, 74 and the second active portions 81, 82, 83, 84 both perform deformation of vertical effect, not the uniform deformation, and hence the second active portions 81 to 84 cannot deform to bend away from the pressure chambers 40 like the uniform deformation (that is, deformation in a direction to enlarge the pressure chambers 40). Therefore, the effect of suppressing crosstalk can be obtained, but the effect of increasing volumetric changes of the pressure chambers 40 cannot be obtained.

[0079] Further, also regarding the structure in which the second constant potential electrodes 23A are provided only in the regions corresponding to the beam portions 41 (see Fig. 8), similarly it can also be a structure as a matter of course in which the piezoelectric material layer 12d is provided on the side of the pressure chambers 40 via the insulating layer 12e having a small layer thickness. In this case, as shown in Fig. 12, in the piezoelectric material layer 12d, similarly to the piezoelectric material layer 12b, the first and second constant potential electrodes 22A, 23A are arranged alternately on one surface (upper surface), and the individual electrodes 21 are arranged on the other surface (lower surface). Accordingly, there are formed first active portions 71, 72, 73a, 74 corresponding respectively to the center portions of the pressure chambers 40, and second active portions 81, 82, 83, 84 corresponding respectively to portions on outer peripheral sides thereof.

[0080] Incidentally, a relationship among the polarization direction, portions (first active portions) which are effective while being turned ON and effective during application of voltage and other portions (second active portions) which are effective while being turned OFF and effective during non-application of voltage is shown in Figs. 13A, 13B.

[0081] As in the first embodiment, when forming the first and second constant potential electrodes 22A, 23 on the same surface alternately in the nozzle row direction X, it is not possible to take large intervals between these electrodes, and hence the lengths of these electrodes in the nozzle row direction cannot be taken long. However, as shown in the next second embodiment, an insulating layer with a small layer thickness can be used to increase the lengths of them.

Second embodiment

[0082] In this embodiment, as shown in Fig. 14, the piezoelectric actuator has a stacked structure in which an insulating layer 12f having a smaller layer thickness than the piezoelectric material layers 12a, 12b is sandwiched between the piezoelectric material layer 12a and the piezoelectric material layer 12b. Note that this insulating layer 12f can be formed of the same material as the piezoelectric material layers 12a to 12d.

[0083] Only first constant potential electrodes 22B are formed on one surface (upper surface) side of this insulating layer 12f at a constant pitch, and only second constant potential electrodes 23 are formed on the other surface (lower surface) side thereof at a constant pitch. Accordingly, the first constant potential electrodes 22B and the second constant potential electrodes 23 are electrically isolated with the insulating layer 12f, but similarly to the case of the first embodiment, they are formed between the piezoelectric material layer 12a and the piezoelectric material layer 12b. Thus, there are formed first active portions 71a, 72a, 73 corresponding respectively to the center portions of the pressure chambers 40, and second active portions 81c, 82 corresponding respectively to portions on outer peripheral sides thereof.

[0084] In this manner, since the first constant potential electrodes 22B and the second constant potential electrodes 23 are isolated by being sandwiching the insulating layer 12f therebetween, the lengths in the nozzle row direction of the first constant potential electrodes 22B formed between the piezoelectric material layer 12a and the piezoelectric material layer 12b can be made long, thereby realizing an electrode arrangement which is advantageous for increasing volumetric changes of the pressure chambers 40. Also in the case of the second embodiment, as shown in Table 2, the ratio of changes of cross-sectional areas of adjacent pressure chambers is 11%. Similarly to the case of the first embodiment, the change ratio decreases to almost half as compared to the case of the conventional example, and it can be seen that the effect of suppressing crosstalk is exhibited.

[0085] Using such an insulating layer with a small layer thickness, it can also be a structure as described in the next third embodiment.

Third embodiment

[0086] In this embodiment, as shown in Fig. 15, the uppermost piezoelectric material layer 12a in the second embodiment is omitted, and instead, another insulating layer 12g with a small layer thickness similar to the insulating layer 12f is arranged between the piezoelectric material layer 12c and the top plate 15. Second constant potential electrodes 23 are formed on an upper surface side of the insulating layer 12g, and first constant potential electrodes 22B are formed on a lower surface side thereof. In this case, the first and second constant potential electrodes 22B, 23 are formed symmetrically sandwiching the individual electrodes 21 arranged on the lower surface side of the piezoelectric material layer 12b. Accordingly, there are formed first active portions 72a, 73a corresponding respectively to the center portions of the pressure chambers 40, and second active portions 82, 83 corresponding respectively to portions on outer peripheral sides thereof.

[0087] Further, only one layer may exist as the piezoelectric material layers described above, and it can also be a structure as described in the next forth embodiment.

Forth embodiment

[0088] In this example, as shown in Fig. 16, individual electrodes 21 are formed on one surface (upper surface) side of a piezoelectric material layer 12a, and first and second constant potential electrodes 22B, 23 are formed alternately in the nozzle row direction on the other surface (lower surface) side. Accordingly, there are formed first active portions 71a corresponding respectively to the center portions of the pressure chambers 40, and second active portions 81, 81 corresponding respectively to both sides of portions on outer peripheral sides thereof.

[0089] With this structure, the top plate 15 functions as a binding plate. Although the number of piezoelectric material layers is smaller than in the first to third embodiments and the amount of deformation becomes smaller, excellent jetting efficiency can be realized by unimorph deformation even with one piezoelectric material layer 12a.

[0090] Also in such a case of having one piezoelectric material layer, as described in the next fifth embodiment, it is also possible to have a structure using an insulating layer with a small layer thickness.

Fifth embodiment

[0091] In this embodiment, as shown in Fig. 17, there is provided a structure sandwiching an insulating layer 12h between the piezoelectric material layer 12a and the top plate 15. Individual electrodes 21 are formed on an upper surface side of the piezoelectric material layer 12a, and second constant potential electrodes 23 are formed on a lower surface side thereof. Then first constant potential electrodes 22B are formed on a lower surface side of the insulating layer 12h. Accordingly there are formed first active portions 71b corresponding respectively to the center portions of the pressure chambers 40, and second active portions 81 corresponding respectively to portions on outer peripheral sides thereof.

[0092] Also in this case, it can be seen that the effect of suppressing crosstalk is exhibited by application/non-application of voltage as shown in Figs. 18A, 18B. In the case of the fifth embodiment, as shown in Table 2, the ratio of changes of cross-sectional areas of adjacent pressure chambers is 2%, and this change ratio decreases significantly as compared to the conventional example. It can be seen that the effect of suppressing crosstalk is quite large.

[0093] When it is not necessary to provide, as in the above-described embodiments, the second active portions on both sides of the first active portions, and it is just needed to exhibit the effect of suppressing crosstalk only on one sides of the first active portions, the second active portions can be provided only on one sides of the first active portions, as described in sixth embodiment.

Sixth embodiment

[0094] In this embodiment, as shown in Fig. 19, individual electrodes 21A are arranged in parts of regions corresponding to the pressure chambers 40 and regions corresponding to the beam portions 41.

[0095] Then the individual electrodes 21A are formed on one surface (upper surface) side of the piezoelectric material layer 12a, and first and second constant potential electrodes 22A, 23A are formed corresponding respectively to side portions of the individual electrodes 21A on the other surface (lower surface) side thereof. Further, individual electrodes 21A are formed on an upper surface side of the piezoelectric material layer 12c, and first constant potential electrodes 22A are formed on a lower surface side thereof. Accordingly, there are formed first active portions 71, 72, 73a corresponding respectively to the center portions of the pressure chambers 40, and second active portions 81c, 82c corresponding respectively to portions of outer peripheral sides thereof.

[0096] With such a structure, the effect of suppressing crosstalk can be exhibited only on the side where the second active portions 81c, 82c are arranged.

[0097] Further, as in the next seventh embodiment, it is also possible to form first constant potential electrodes extending along the nozzle row direction, and to have them in common for the pressure chambers formed in rows in the nozzle row direction.

Seventh embodiment

[0098] In this example, as shown in Fig. 20, there are provided four piezoelectric material layers 12a to 12d. Individual electrodes 21 are formed on one surface (upper surface) side of the piezoelectric material layer 12a farthest from the pressure chambers 40, and second constant potential electrodes 23 are formed on the other surface (lower surface) side thereof. Then first constant potential electrodes 22C are formed on one surface side of a piezoelectric material layer 12c that is third one from the piezoelectric material layer 12a toward the pressure chambers 40, and individual electrodes 21B are formed on the other surface side thereof. Then first constant potential electrodes 22C are formed on a side of the pressure chambers 40 of a piezoelectric material layer 12d that is fourth one from the piezoelectric material layer 12a toward the pressure chambers 40. Accordingly, there are formed first active portions 171, 73, 74 corresponding respectively to the center portions of the pressure chambers 40, and second active portions 181 corresponding respectively to portions on outer peripheral sides thereof.

[0099] Then the electrodes 21, 22B, 22C, 23 of the respective piezoelectric material layers 12a to 12d are arranged as shown in Fig. 21 in a plan view. Namely, on an upper surface side (first layer) of the piezoelectric material layer 12a and a lower surface side (third layer) of the piezoelectric material layer 12c, individual electrodes 21, 21B are formed at a constant pitch in the nozzle row direction X corresponding respectively to the pressure chambers 40. Then the adjacent individual electrodes 21, 21B are formed to be shifted by a half pitch in the nozzle row direction. Between these rows, connection terminals 26, 26B of the individual electrodes 21, 21B are formed in a zigzag pattern. Then connection terminals (not shown) of the flexible wiring board 13 are connected to connection terminal portions 26 of the individual electrodes 21. These connection terminal portions 26 of the individual electrodes 21 are connected electrically to the connection terminal portions 26B of the respective individual electrodes 21B via through holes 24 (filled with conductive materials inside) penetrating the piezoelectric material layers 12a to 12c and via middle electrodes 25 formed on a lower surface side of the piezoelectric material layer 12a and an upper surface side of the piezoelectric material layer 12c (see Fig. 22B). Note that the individual electrodes 21 on the upper surface side of the piezoelectric material layer 12a are formed longer than the individual electrodes 21B on the lower surface side of the piezoelectric material layer 12c in length in the nozzle row direction.

[0100] Further, on the lower surface side of the piezoelectric material layer 12a, second constant potential electrodes 23 are formed at a constant pitch in the nozzle row direction corresponding to the pressure chambers 40, and one ends thereof are connected to one of common electrodes 28 extending in the nozzle row direction. Further, on the upper surface side of the piezoelectric material layer 12c and on a lower surface side of the piezoelectric material layer 12d, first constant potential electrodes 22C are formed to extend in the nozzle row direction corresponding respectively to the pressure chambers 40.

[0101] Thus, since the first constant potential electrodes 22C are formed in the nozzle row direction X and are shared by the pressure chambers 40 in the nozzle row direction, the arrangement of the electrodes 21, 21B, 22C, 23 becomes simple, which is advantageous for making the apparatus compact. Incidentally, a relationship among the polarization direction, portions (first active portions) which are effective while being turned ON and effective during application of

voltage and portions (second active portions) which are effective while being turned OFF and effective during non-application of voltage is shown in Figs. 22A, 22B.

[0102] In the above-described first, second, forth to seventh embodiments, since the connection portions to the flexible wiring board 13 are arranged on the piezoelectric material layer 12a which is farthest from the pressure chambers, there is a fear that during connection with solder, dispersion of deformation characteristics due to flowing in of the solder occurs. Accordingly, as in the next eighth embodiment, such a problem can be avoided by arranging the individual electrodes between the piezoelectric material layer 12a and the piezoelectric material layer 12b located more inside, similarly to the case of the third embodiment.

Eighth embodiment

[0103] In this embodiment, among the plurality of piezoelectric material layers forming the piezoelectric actuator, surface individual electrodes for connection are formed on one surface (farthest surface) side of the piezoelectric material layer (farthest layer) which is farthest from the pressure chambers, and individual electrodes are formed on the other surface side thereof.

[0104] As shown in Fig. 23, individual electrodes 21 and surface individual electrodes 29 are conducted to each other by conductive materials filled in through holes 24 penetrating the piezoelectric material layer 12a. Then first constant potential electrodes 22D are formed on a surface on the side of the pressure chambers 40 of the piezoelectric material layer 12c which is closest to the pressure chambers 40. On the other hand, second constant potential electrodes 23A are formed on a farthest surface 31, which is a surface on a side opposite to the pressure chambers 40, of the piezoelectric material layer 12a located farthest from the pressure chambers 40 of the plurality of piezoelectric material layers 12a to 12c.

[0105] The individual electrodes 21 are formed on a surface on the side of the pressure chambers 40 of the piezoelectric material layer 12a. That is, they are formed on a surface, which is a surface different from the farthest surface 31, of one of the piezoelectric material layers 12a to 12c and is a surface on the side of the pressure chambers 40 of the piezoelectric material layer 12a (farthest layer). Then the surface individual electrodes 29 to be input terminals to the individual electrodes 21 are formed in regions (regions corresponding to the beam portions 41) more outside than outer peripheral edges of the pressure chambers 40 of the farthest surface 31. These surface individual electrodes 29 and the individual electrodes 21 conduct to each other via the conductive materials 24 filled in the through holes penetrating the piezoelectric material layer 12a. The surface individual electrodes 29 are formed in regions of the farthest surface 31 between the adjacent pressure chambers 40 (regions corresponding to the so-called beam portions 41).

[0106] Accordingly, there are formed first active portions 71, 72 corresponding respectively to the center portions of the pressure chambers 40, and second active portions 182 corresponding respectively to portions on outer peripheral sides thereof. Therefore, the second active portions 182 are formed in the piezoelectric material layers 12b, 12c on the side of the pressure chambers 40, which are layers other than the farthest layer (piezoelectric material layer 12a) of the plurality of piezoelectric material layers 12a to 12c.

[0107] Further, the electrodes 21, 22D, 23A formed on the surfaces of the piezoelectric material layers 12a to 12c are arranged as shown in Fig. 24, in a plan view. Specifically, on the upper surface sides of the piezoelectric material layers 12a, 12c (first layer, third layer), the second constant potential electrodes 23A are formed at a constant pitch in the nozzle row direction corresponding respectively to the pressure chambers 40, and the adjacent second constant potential electrodes 23A are formed to be shifted by a half pitch in the nozzle row direction. Then the surface individual electrodes 29 are formed corresponding respectively to the individual electrodes 21 between the second constant potential electrodes 23A in the nozzle row direction on the upper surface side of the piezoelectric material layer 12a. End portions of the surface individual electrodes 29 on sides opposite to the second constant potential electrodes 23A are formed in a zigzag pattern as connection terminal portions 26B which extend to portions between the adjacent pressure chambers 40 to be connected to the connection terminals of the flexible wiring board 13.

[0108] On the lower surface side of the piezoelectric material layer 12a, the individual electrodes 21 are formed at a constant pitch in the nozzle row direction corresponding respectively to the pressure chambers 40, and connection terminal portions 26 thereof are connected respectively to the connection terminals 26B of the surface individual electrodes 29 using the conductive materials filled in the through holes 24 penetrating the piezoelectric material layer 12a (see Fig. 25A).

[0109] On the lower surface side of the piezoelectric material layer 12c, the first constant potential electrodes 22D which are in common to two adjacent rows of pressure chambers 40 are formed so as to extend in the nozzle row direction.

[0110] Thus, since the connection terminal portions 26B to which the connection terminals of the flexible wiring board 13 are connected are formed in the regions corresponding to the beam portions 41 which do not deform while driving, dispersion of deformation characteristics for the respective first active portions does not easily occur if solder flows in during connection with the connection terminals of the flexible wiring board 13.

[0111] Incidentally, a relationship among the polarization direction, portions (first active portions) which are effective

while being turned ON and effective during application of voltage and portions (second active portions) which are effective while being turned OFF and effective during non-application of voltage is shown in Figs. 25A, 25B. Then it can be seen that the effect of suppressing crosstalk is exhibited by application/non-application of voltage as shown in Figs. 26A, 26B. In the case of eighth embodiment, as shown in Table 2, the ratio of changes of cross-sectional areas of adjacent pressure chambers is 12%, and it can be seen that, similarly to the case of the first embodiment, the change ratio decreases to almost half as compared to the conventional example, and the effect of suppressing crosstalk is exhibited.

[0112] Then, in the above-described first to seventh embodiments, jetting occurs when voltage is applied to the first active portions (that is, when the second potential is applied to the individual electrodes) as shown in Fig. 27A, but in the case of the eighth embodiment and the tenth embodiment which will be explained later, as shown in Fig. 27B, conversely jetting occurs when application of voltage to the first active portions is released (that is, when the first potential is applied to the individual electrodes).

[0113] Further, when using the surface individual electrodes similarly to the eighth embodiment, it is also possible to make jetting occur when voltage is applied to the first active portions similarly to the first to seventh embodiments by having a structure in the following ninth embodiment (see Fig. 27A).

Ninth embodiment

[0114] In this embodiment, as shown in Fig. 28, the piezoelectric actuator is made as a two-layer structure, in which second constant potential electrodes 23C are formed on an upper surface side of the piezoelectric material layer 12a on an upper side, and individual electrodes 21 are formed on a lower surface side thereof. Then first constant potential electrodes 22C are formed on a lower surface side of the piezoelectric material layer 12b on a lower side. Accordingly, there are formed first active portions 72 corresponding respectively to the center portions of the pressure chambers 40, and the second active portions 81 corresponding respectively to portions on outer peripheral sides thereof.

[0115] In this manner, individual surface electrodes 21c to be connection portions with the flexible wiring board 13 (COP) are formed in regions corresponding to the beam portions 41 between the pressure chambers 40 as shown in Fig. 29. In addition, a time to apply voltage between the second constant potential electrodes 23C and the individual electrodes 21 is short, and hence short-circuit by migration is avoided.

[0116] Further, the electrodes on upper and lower surfaces of the piezoelectric material layers 12a, 12b are arranged as shown in Fig. 29 in a plan view. That is, on the upper surface side of the piezoelectric material layer 12a, the second constant potential electrodes 23C are formed corresponding respectively to the pressure chambers 40 at a constant pitch in the nozzle row direction, and both side portions thereof in a direction orthogonal to the nozzle row direction are connected by common electrodes 28A, 28B respectively. Then the adjacent second constant potential electrodes 23C are formed to be shifted by a half pitch in the nozzle row direction, and surface individual electrodes 29A to be connected to the connection terminals of the flexible wiring board 13 are formed between the adjacent common electrodes 28A, 28B on a side opposite to the side on which the second constant potential electrodes 23C are formed.

[0117] On a lower surface side of the piezoelectric material layer 12a, individual electrodes 21 are formed at a constant pitch in the nozzle row direction corresponding respectively to the pressure chambers 40. Parts of the individual electrodes 21 are formed to project to be connection terminal portions 26, and are connected electrically to the surface individual electrodes 29A on the upper surface of the piezoelectric material layer 12a via through holes 24 filled with conductive materials inside.

[0118] On a lower surface side of the piezoelectric material layer 12b, first constant potential electrodes 22C are formed at a constant pitch in the nozzle row direction corresponding respectively to the pressure chambers 40, and end portions thereof are connected to the adjacent first constant potential electrodes 22C mutually via connection portions 27C.

[0119] Incidentally, a relationship among the polarization direction, portions (first active portions) which are effective while being turned ON and effective during application of voltage and portions (second active portions) which are effective while being turned OFF and effective during non-application of voltage is shown in Figs. 30A, 30B. Then it can be seen that the effect of suppressing crosstalk is exhibited by application/non-application of voltage as shown in Figs. 31A, 31B.

[0120] Further, with a structure as in the next tenth embodiment, short-circuit due to migration can be prevented similarly to the ninth embodiment, and the surface individual electrodes can be used to make jetting occur when application of voltage to the first active portions is released, similarly to the eighth embodiment (see Fig. 27B).

Tenth embodiment

[0121] In this example, as shown in Fig. 32, first constant potential electrodes 22D are formed on an upper surface side of the piezoelectric material layer 12a, and individual electrodes 21 are formed on a lower surface side thereof. Further, second constant potential electrodes 23D are formed on an upper surface side of the piezoelectric material layer 12c, and first constant potential electrodes 22E are formed on a lower surface side thereof. The individual electrodes

21 are connected respectively to the surface individual electrodes 29A using through holes 24 (filled with conductive materials inside) penetrating the piezoelectric material layer 12a (see Fig. 33B). Accordingly, there are formed second active portions 82 corresponding respectively to the center portions of the pressure chambers 40, and first active portions 71, 172 on portions on outer peripheral sides thereof respectively.

[0122] In this case, a relationship among the polarization direction, portions (first active portions) which are effective while being turned ON and effective during application of voltage and portions (second active portions) which are effective while being turned OFF and effective during non-application of voltage is as shown in Figs. 33A, 33B. Then it can be seen that the effect of suppressing crosstalk is exhibited by application/non-application of voltage as shown in Figs. 34A, 34B.

[0123] In this case also, similarly to the ninth embodiment, dispersion of deformation characteristics during the connection due to flowing in of solder can be avoided. Further, a time in which a potential difference is generated between the first constant potential electrodes 22D, 22E and the individual electrodes 21 is short, and hence short-circuit by migration is avoided.

[0124] Furthermore, with a structure as in the next example 11, it is possible to have a less number of stacks without using surface individual electrodes or through holes, and to make jetting occur when application of voltage to the first active portions is released, similarly to the eighth and tenth embodiments (see Fig. 27B).

Eleventh embodiment

[0125] In this embodiment, as shown in Fig. 35, individual electrodes 21 are formed on an upper surface side of the piezoelectric material layer 12a, and second constant potential electrodes 23E are formed on a lower surface side thereof. First constant potential electrodes 22F are formed on a lower surface side of the piezoelectric material layer 12b. Accordingly, there are formed first active portions 81 corresponding respectively to the center portions of the pressure chambers 40, and second active portions 171 on portions on outer peripheral sides thereof. Note that it is the same as the eighth and tenth embodiments in that the ground potential is applied to the individual electrodes 21 during standby.

[0126] Further, the electrodes on the upper and lower surfaces of the piezoelectric material layers 12a, 12b are arranged as shown in Fig. 36 in a plan view. That is, on the upper surface side of the piezoelectric material layer 12a, the individual electrodes 21 are formed corresponding respectively to the pressure chambers 40 at a constant pitch in the nozzle row direction, and parts of the individual electrodes project between the arrays of the individual electrodes 21. These projecting portions are formed in a zigzag pattern to be connection terminal portions 26 connected to the connection terminals of the flexible wiring board 13.

[0127] On the lower surface side of the piezoelectric material layer 12a, the second constant potential electrodes 23E are formed at a constant pitch in the nozzle row direction corresponding respectively to the pressure chambers 40, and one ends thereof are connected electrically to one of common electrodes 23Ea located therebetween. Further, on the lower surface side of the piezoelectric material layer 12b, there are formed first constant potential electrodes 22E extending in the nozzle row direction to be electrodes common to the pressure chambers 40 in the nozzle row direction.

[0128] Incidentally, a relationship among the polarization direction, portions (first active portions) which are effective while being turned ON and effective during application of voltage and portions (second active portions) which are effective while being turned OFF and effective during non-application of voltage is as shown in Figs. 37A, 37B. Then it can be seen that the effect of suppressing crosstalk is exhibited by application/non-application of voltage as shown in Figs. 38A, 38B. In the case of the eleventh embodiment, as shown in Table 2, the ratio of changes of cross-sectional areas of adjacent pressure chambers is 3%, and the change ratio decreases significantly as compared to the conventional example. It can be seen that it has excellent effect of suppressing crosstalk.

[0129] In such a structure, since there is no junctions via through holes and the number of stacks is small, production at low cost is possible. Also, changes of cross-sectional areas become large, but there is excellent effect of suppressing crosstalk.

[0130] The above embodiments are explained for the case where the liquid-droplet jetting apparatus is an ink-jet type recording apparatus, but the present invention is not limited to this. It may also be applied to another liquid-droplet jetting apparatus for applying a colored liquid with micro liquid-droplets, for forming a wiring pattern by jetting electrically conductive liquid, or the like.

[0131] Further, as the recording medium, not only the recording paper but various kinds of materials such as resin, cloth, and the like can be applied, and as the liquid to be jetted, not only the ink but various kinds of liquids such as colored liquid, functional liquid, and the like can be applied.

Claims

1. A liquid-droplet jetting apparatus which jets droplets of a liquid, comprising:

a liquid-droplet jetting head including a cavity unit in which a plurality of pressure chambers arranged regularly are formed and a piezoelectric actuator which is joined to the cavity unit to cover the pressure chambers and which jets the liquid in the pressure chambers selectively, the piezoelectric actuator having first active portions each corresponding to a center portion of one of the pressure chambers and second active portions each corresponding to an outer peripheral portion, of one of the pressure chambers, which covers a portion located outside of the center portion of one of the pressure chambers; and
 a voltage application mechanism which applies a voltage to the piezoelectric actuator;

wherein the first active portions and the second active portions expand in a first direction toward the pressure chambers and contract in a second direction orthogonal to the first direction when the voltage is applied to the first and second active portions by the voltage application mechanism; and when a first voltage is applied to the first active portions the voltage application mechanism does not apply a second voltage to the second active portions, and when the first voltage is not applied to the first active portions the voltage application mechanism applies the second voltage to the second active portions.

2. The liquid-droplet jetting apparatus according to claim 1, wherein each of the second active portions covers an inside portion located inside an outer peripheral edge of one of the pressure chambers.
3. The liquid-droplet jetting apparatus according to claim 1 or 2, wherein the piezoelectric actuator includes individual electrodes to which first potential and second potential different from the first potential are applied selectively, first constant potential electrodes to which the first potential is applied, and second constant potential electrodes to which the second potential is applied;
 each of the first active portions includes a piezoelectric material sandwiched between one of the individual electrodes and one of the first constant potential electrodes; and
 each of the second active portions includes a piezoelectric material sandwiched between one of the individual electrodes and one of the second constant potential electrodes.
4. The liquid-droplet jetting apparatus according to one of claims 1 to 3, wherein the individual electrodes are formed across a first region corresponding to the first active portions and a second region corresponding to the second active portions of the piezoelectric actuator so as to cover the first and second regions; the first constant potential electrodes are formed to cover the first region of the piezoelectric actuator; and the second constant potential electrodes are formed to cover the second region of the piezoelectric actuator.
5. The liquid-droplet jetting apparatus according to claim 3 or 4, wherein the first active portions are polarized in a direction same as a direction of an electric field generated by the applied voltage when the second potential is applied to the individual electrodes and the first potential is applied to the first constant potential electrodes; and the second active portions are polarized in a direction same as a direction of an electric field generated by the applied voltage when the first potential is applied to the individual electrodes and the second potential is applied to the second constant potential electrodes.
6. The liquid-droplet jetting apparatus according to one of claims 3 to 5, wherein the first potential is a positive potential and the second potential is a ground potential.
7. The liquid-droplet jetting apparatus according to one of claims 3 to 5, wherein the first potential is a ground potential and the second potential is a positive potential.
8. The liquid-droplet jetting apparatus according to one of claims 3 to 7, wherein each of the second constant potential electrodes is common in two adjacent pressure chambers among the pressure chambers.
9. The liquid-droplet jetting apparatus according to one of claims 3 to 8, wherein the piezoelectric actuator has a piezoelectric material layer; and the individual electrodes are formed on a side of one surface of the piezoelectric material layer and the first constant potential electrodes and the second constant potential electrodes are formed on a side of the other surface of the piezoelectric material layer, and the first active portions and the second active portions are formed on the same piezoelectric material layer.
10. The liquid-droplet jetting apparatus according to one of claims 3 to 9, wherein an insulating layer thinner than the piezoelectric material layer is provided to be sandwiched by the first constant potential electrodes and the second

constant potential electrodes formed on the side of the other surface; and the first constant potential electrodes and the second constant potential electrodes are isolated by the insulating layer.

11. The liquid-droplet jetting apparatus according to claim 10, wherein the insulating layer is formed of a material same as the piezoelectric material layer.

12. The liquid-droplet jetting apparatus according to one of claims 3 to 11, wherein the first constant potential electrodes are formed to be sandwiched between adjacent two pressure chambers among the pressure chambers to form rows with the two adjacent pressure chambers; and the second constant potential electrodes are formed only on one side of the two pressure chambers.

13. The liquid-droplet jetting apparatus according to one of claims 3 to 12, wherein the piezoelectric actuator has a plurality of piezoelectric material layers; the first constant potential electrodes or the second constant potential electrodes are formed on a farthest surface not facing the pressure chambers, of a farthest layer, among the plurality of piezoelectric material layers, the farthest layer being located farthest from the pressure chambers; the individual electrodes are formed on a surface of one of the piezoelectric material layers, the surface being different from the farthest layer; surface electrodes which are to be input terminals to the individual electrodes, respectively, are formed in areas, of the farthest surface, overlapping with the outer peripheral portions; and the individual electrodes are conducted to the surface electrodes via a conductive material filled in through holes penetrating the piezoelectric material layers.

14. The liquid-droplet jetting apparatus according to claim 13, wherein the second active portions are formed on a layer other than the farthest layer among the plurality of piezoelectric material layers; and each of the surface electrodes is formed in an area, on the farthest surface, overlapping with a portion between the adjacent pressure chambers.

15. A liquid-droplet jetting apparatus which jets droplets of a liquid, comprising:

a liquid-droplet jetting head including a cavity unit in which a plurality of pressure chambers arranged regularly are formed and a piezoelectric actuator which is joined to the cavity unit to cover the pressure chambers and jets the liquid in the pressure chambers selectively, the piezoelectric actuator having first portions each located to correspond to a center portion of one of the pressure chambers and second portions each located to correspond to an outer peripheral portion which covers a portion located outside of the center portion of one of the pressure chambers; and a voltage application mechanism which applies a voltage to the piezoelectric actuator;

wherein the voltage application mechanism switches application and non-application of a first voltage to the first portions so as to change a volume of each of the pressure chambers, and switches application and non-application of a second voltage to the second portions so as to suppress that deformation of the first portions generated in a pressure chamber among the pressure chambers due to switching to the application of voltage to the first portions, propagates to another pressure chamber adjacent to the pressure chamber.

16. A liquid-droplet jetting head which jets droplets of a liquid, comprising:

a cavity unit in which a plurality of pressure chambers arranged regularly are formed; and a piezoelectric actuator which is joined to the cavity unit to cover the pressure chambers and jets the liquid in the pressure chambers selectively, the piezoelectric actuator having first active portions each corresponding to a center portion of one of the pressure chambers, second active portions each corresponding to an outer peripheral portion, of one of the pressure chambers, which covers a portion located outside of the center portion of one of the pressure chambers, individual electrodes formed to across a first region corresponding to the first active portions and a second region corresponding to the second active portions so as to cover the first and second regions, first constant potential electrodes formed to cover the first region, and second constant potential electrodes formed to cover the second region.

Fig. 1A

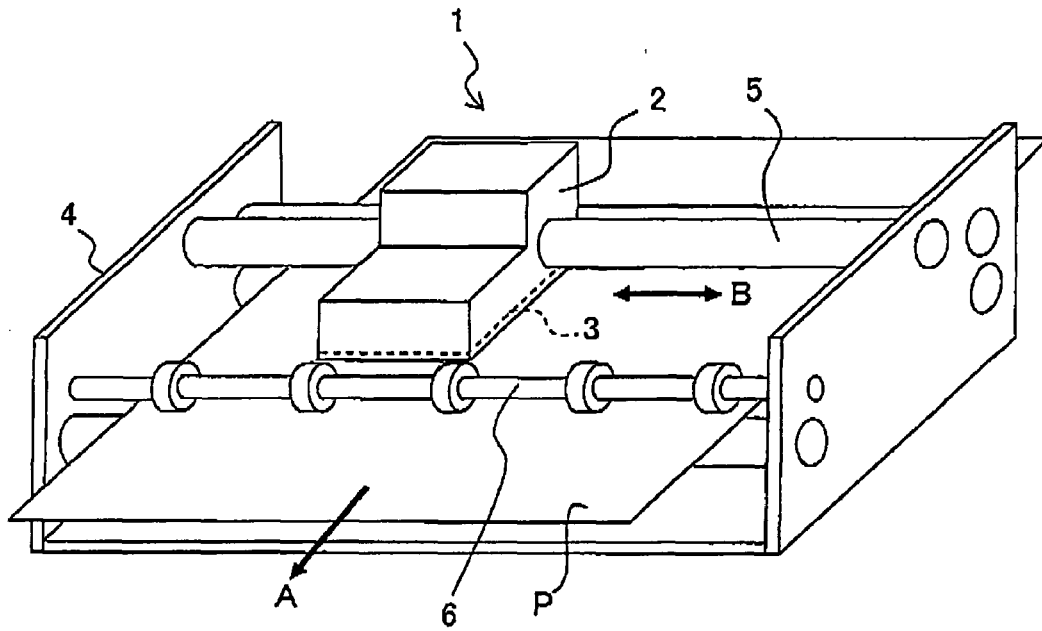


Fig. 1B

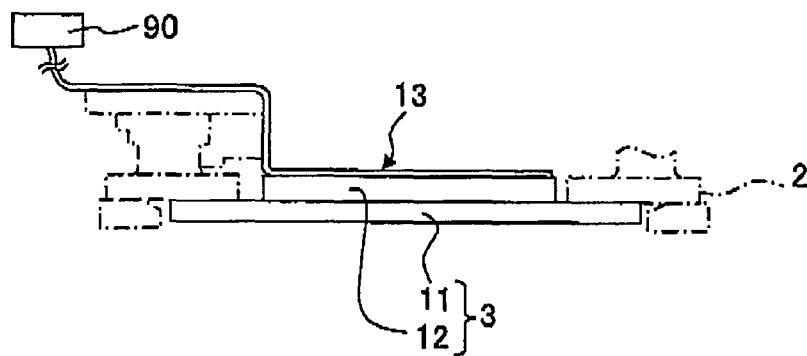


Fig. 2A

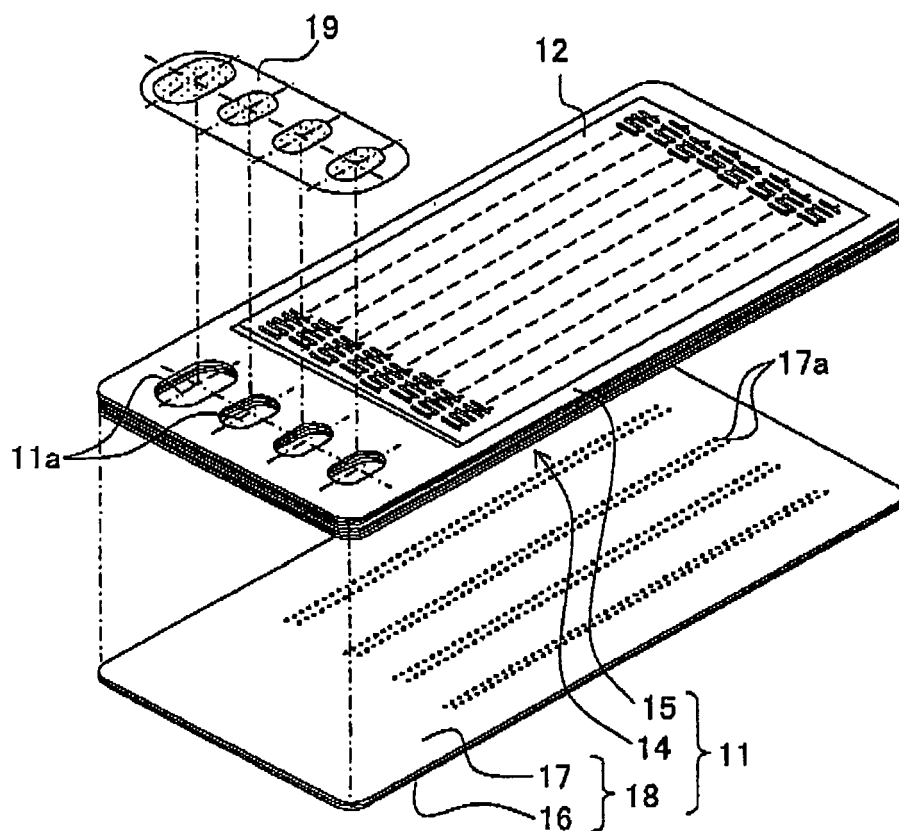


Fig. 2B

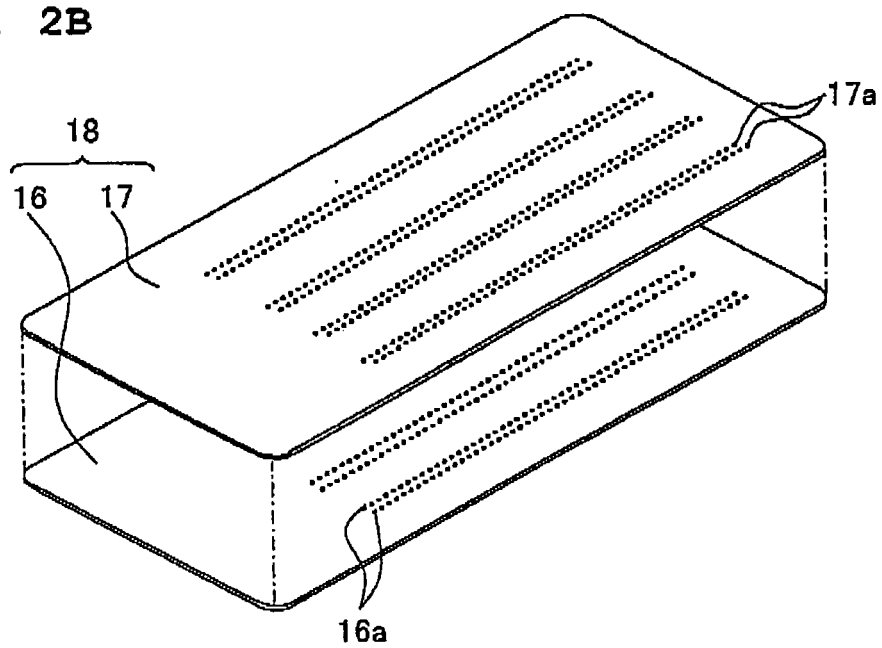


Fig. 3

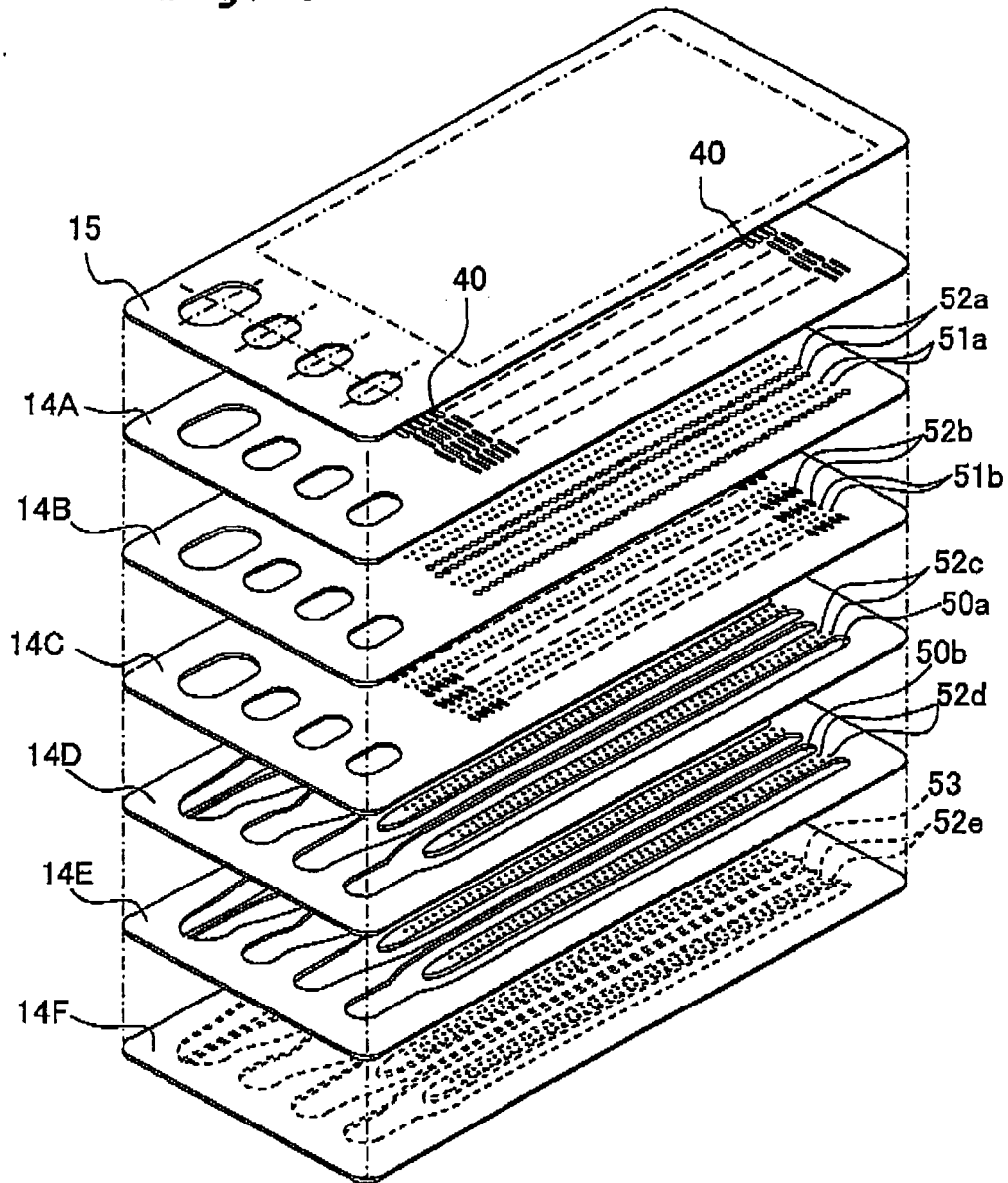


Fig. 4

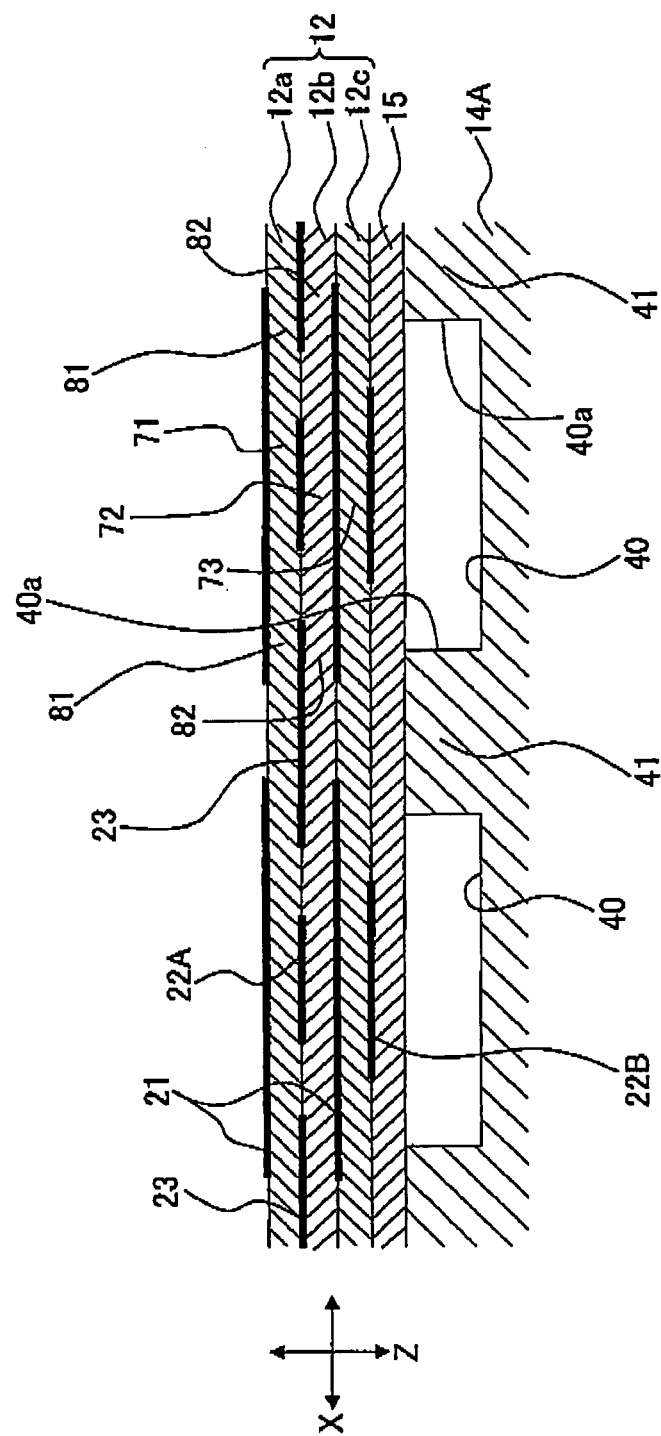


Fig. 5

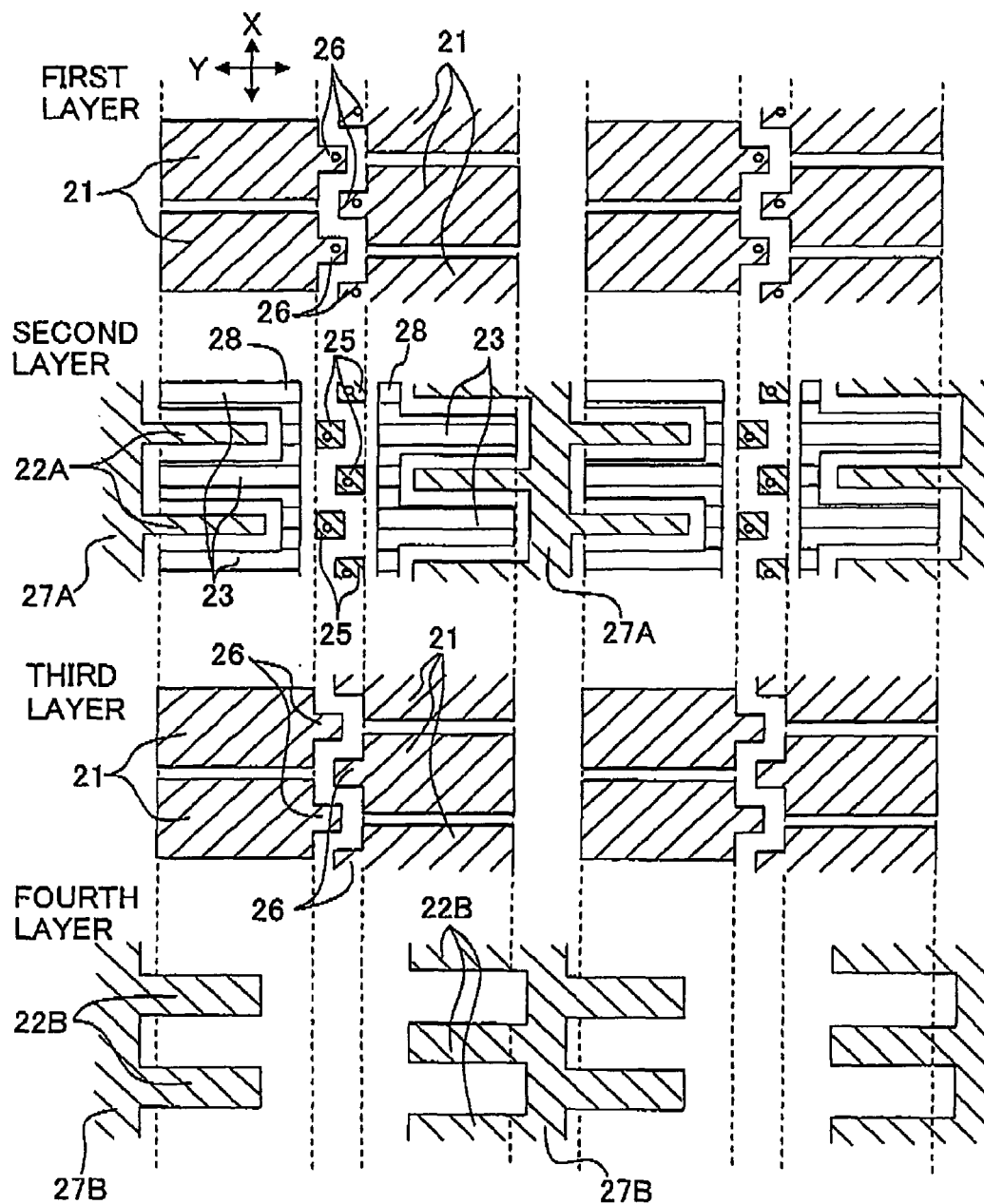


Fig. 6A

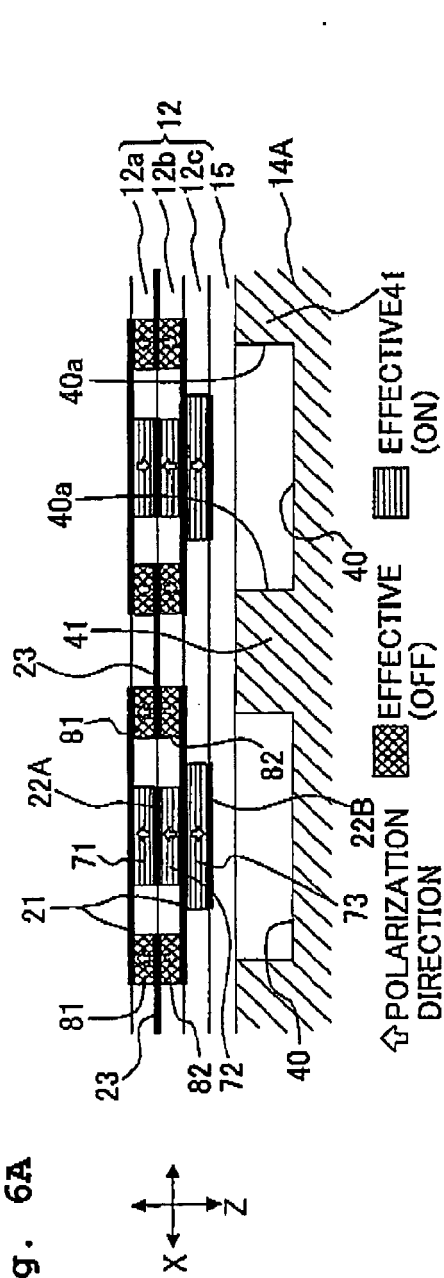


Fig. 6B

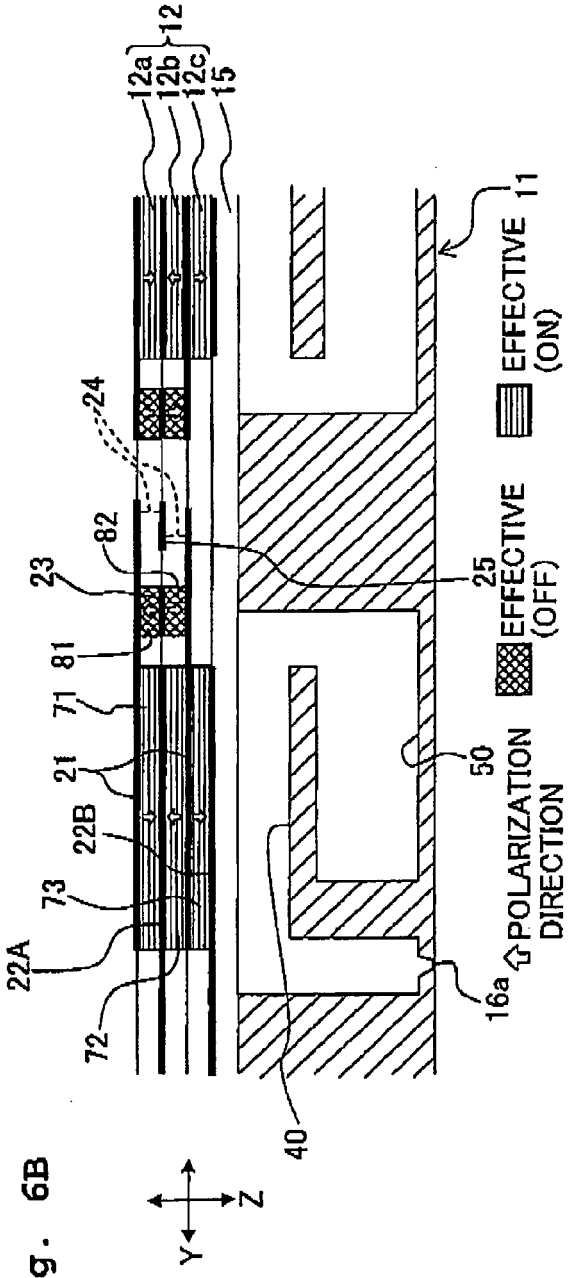
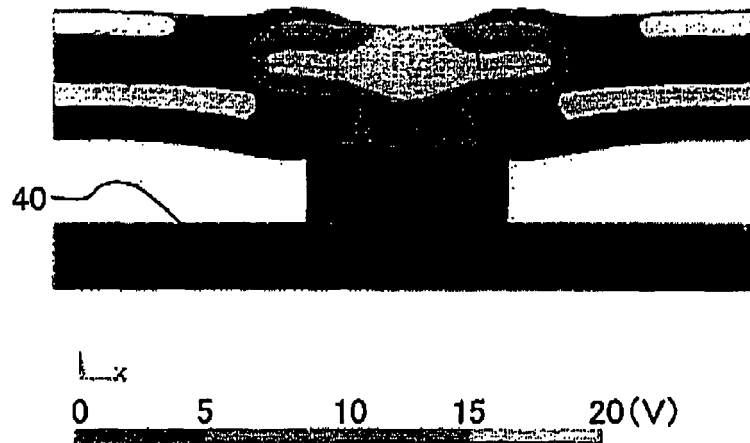
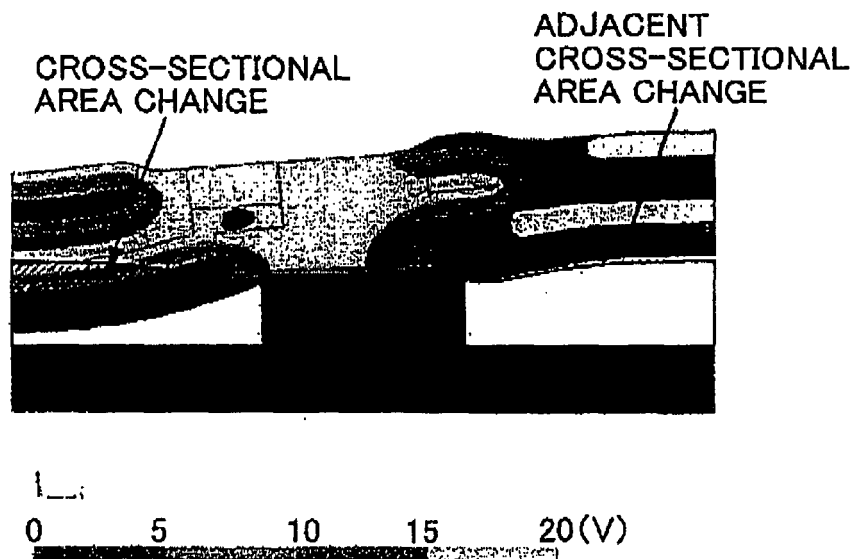


Fig. 7A



A = 0V

Fig. 7B



A = 20V

Fig. 8

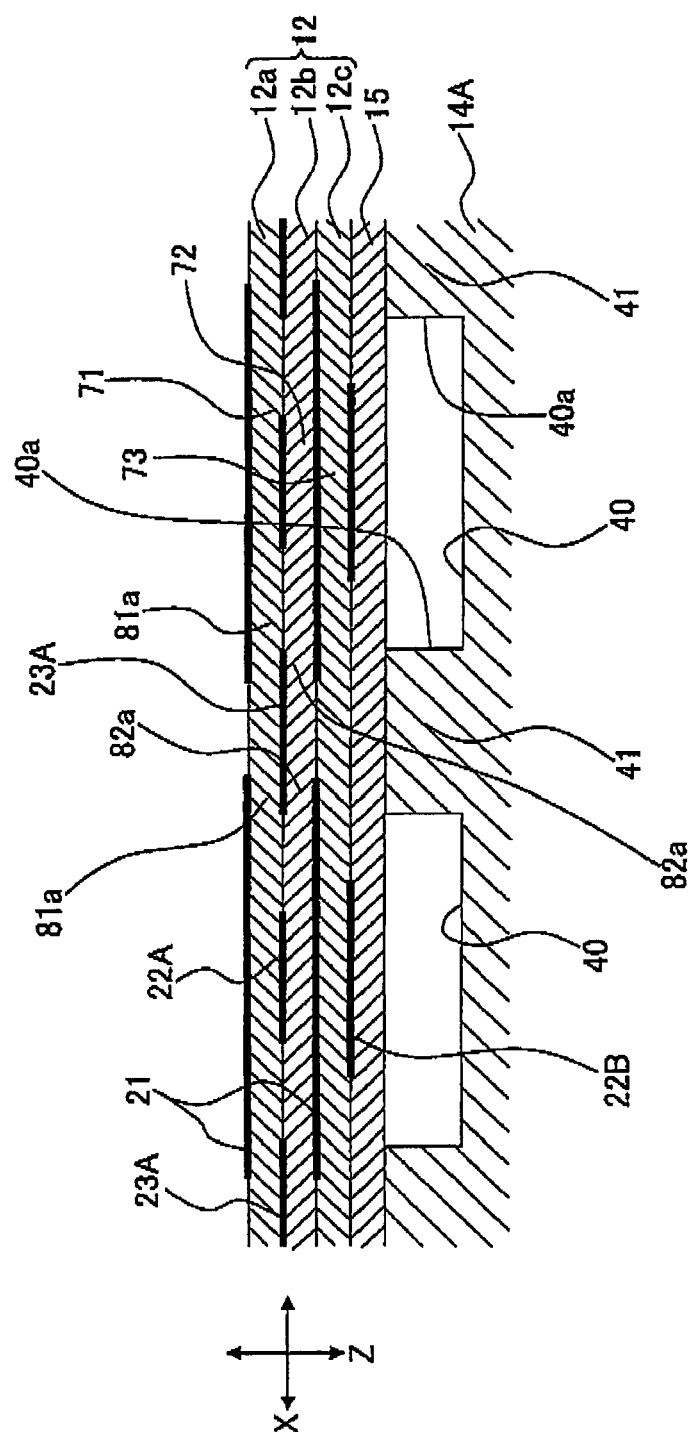


Fig. 9

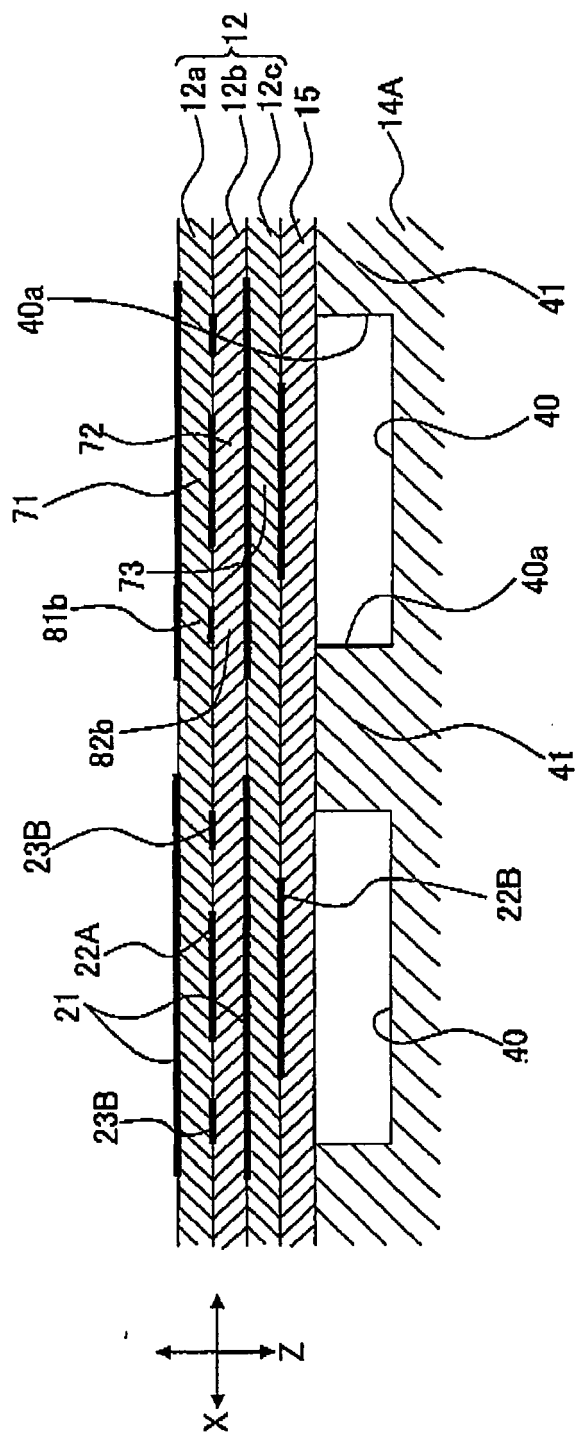


Fig. 10

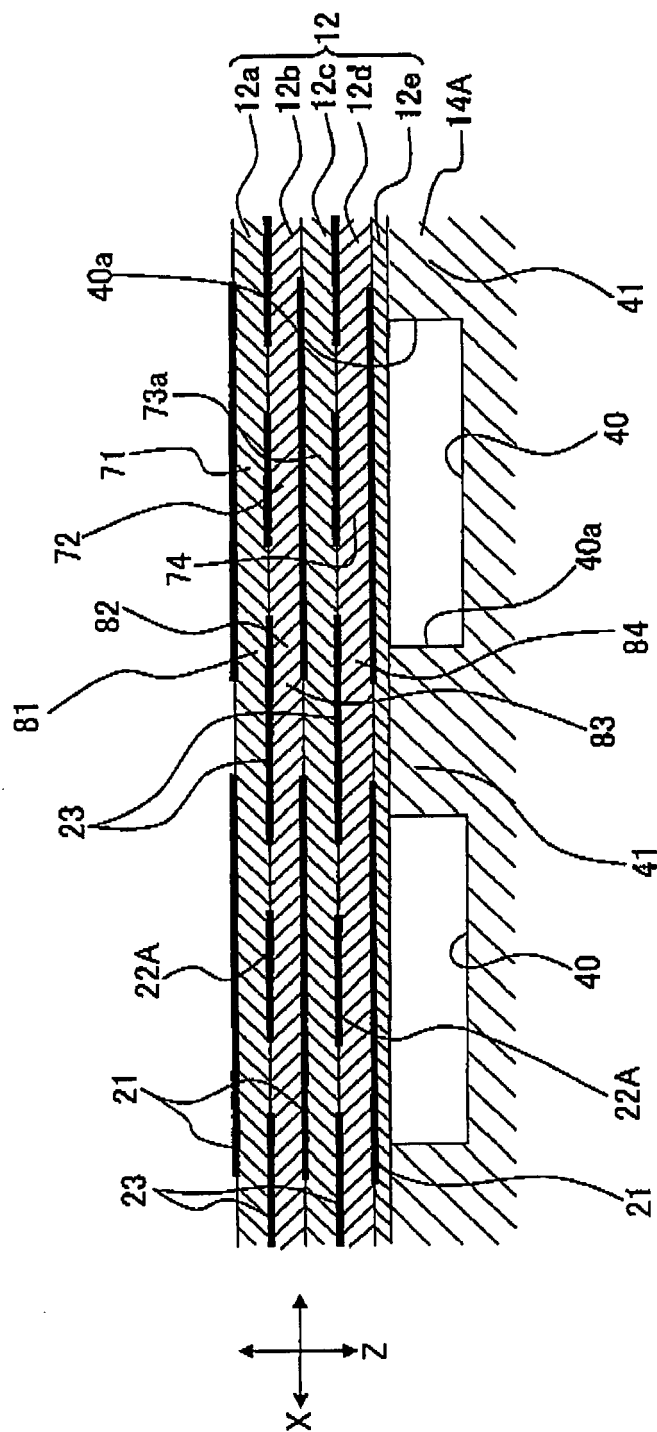


Fig. 11A

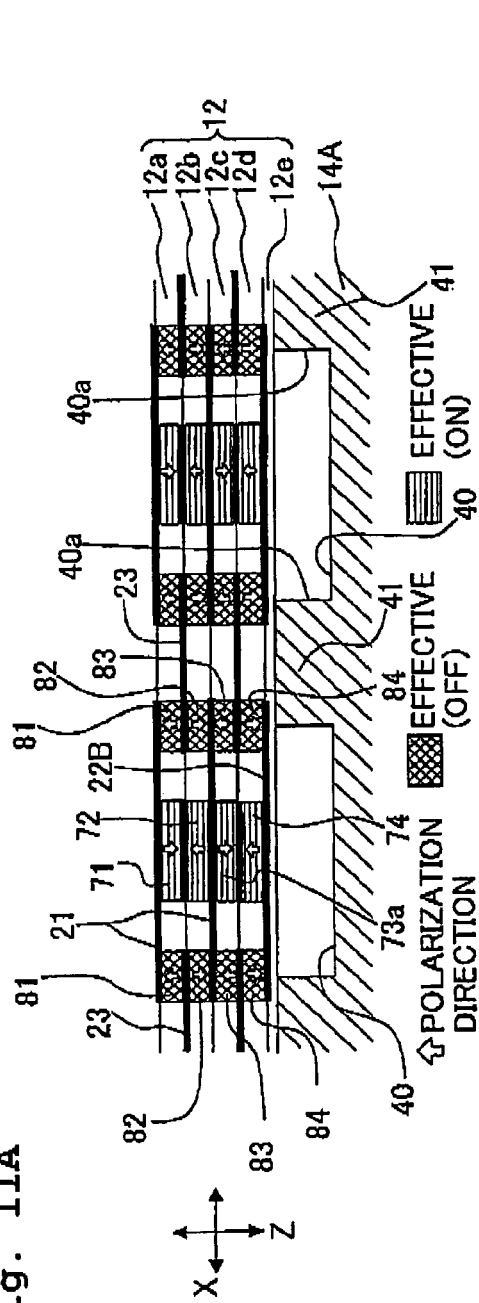


Fig. 11B

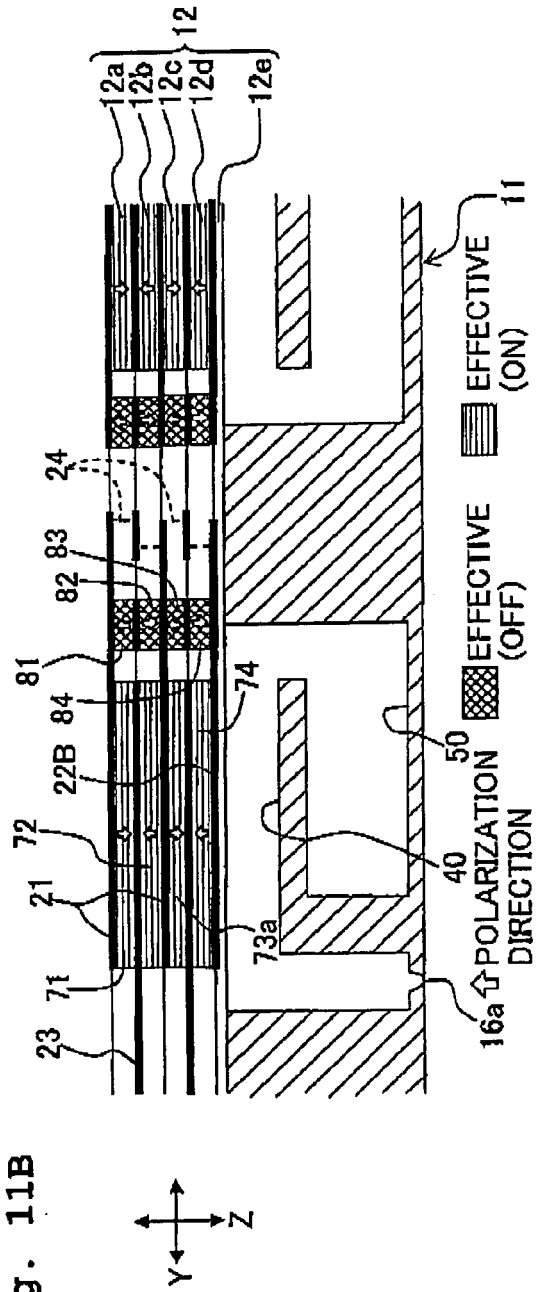


Fig. 12

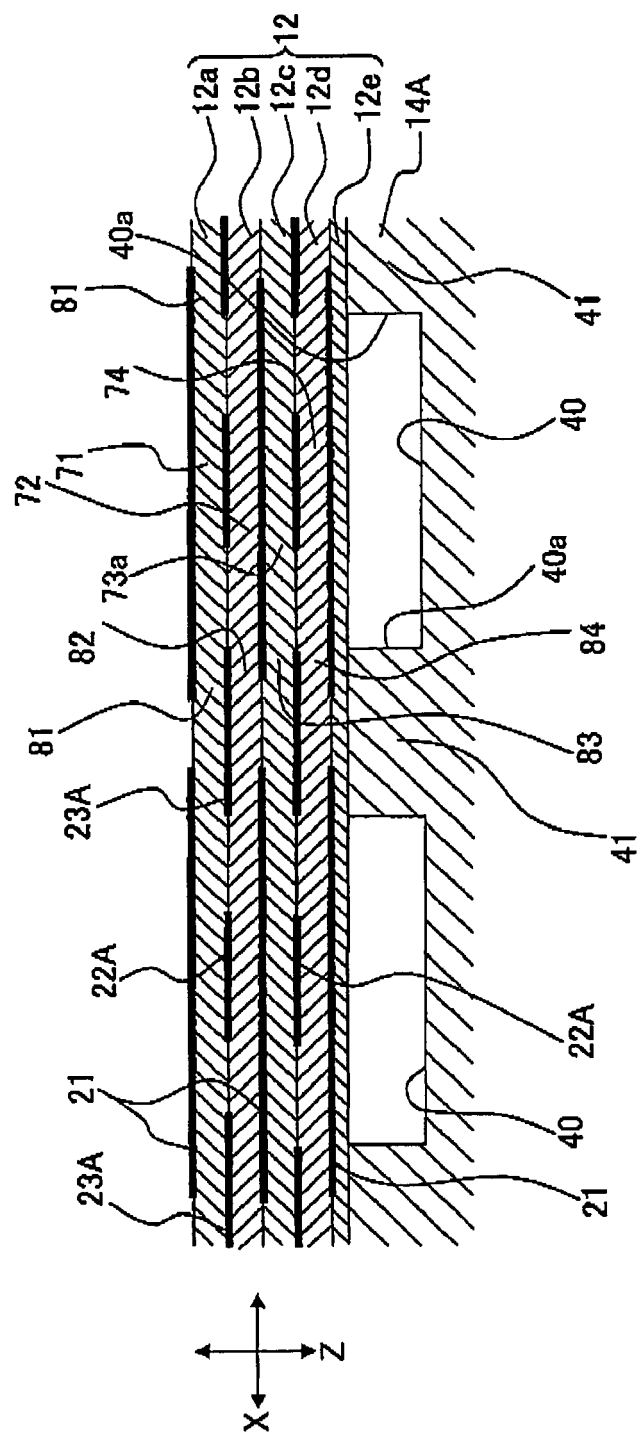


Fig. 13A

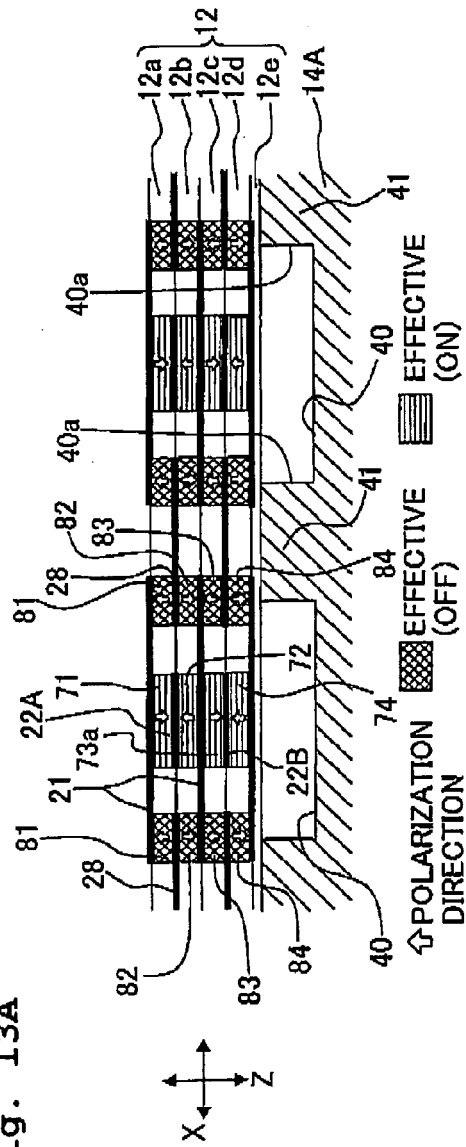


Fig. 13B

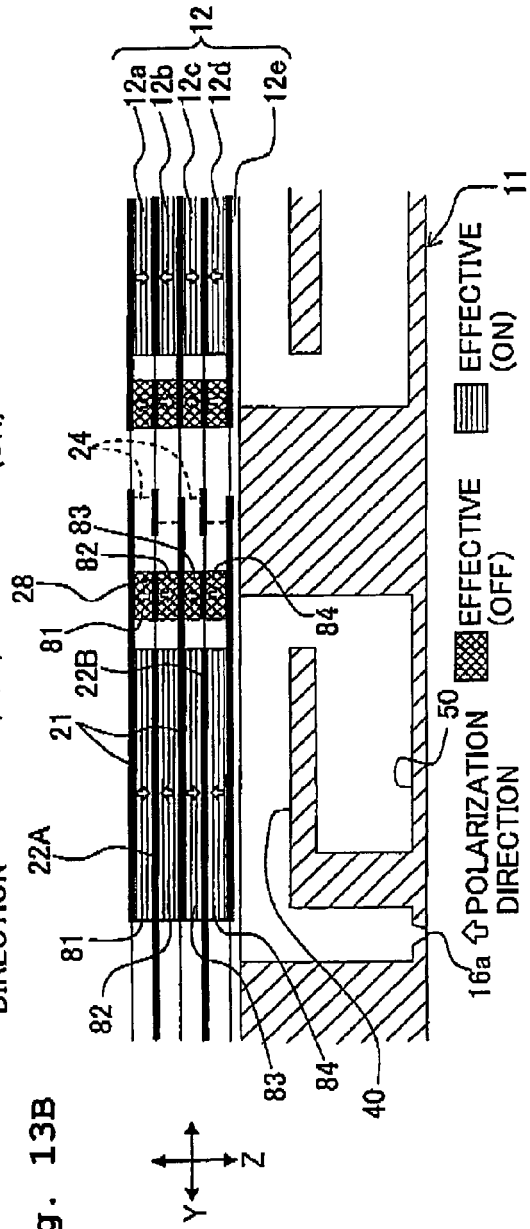


Fig. 14

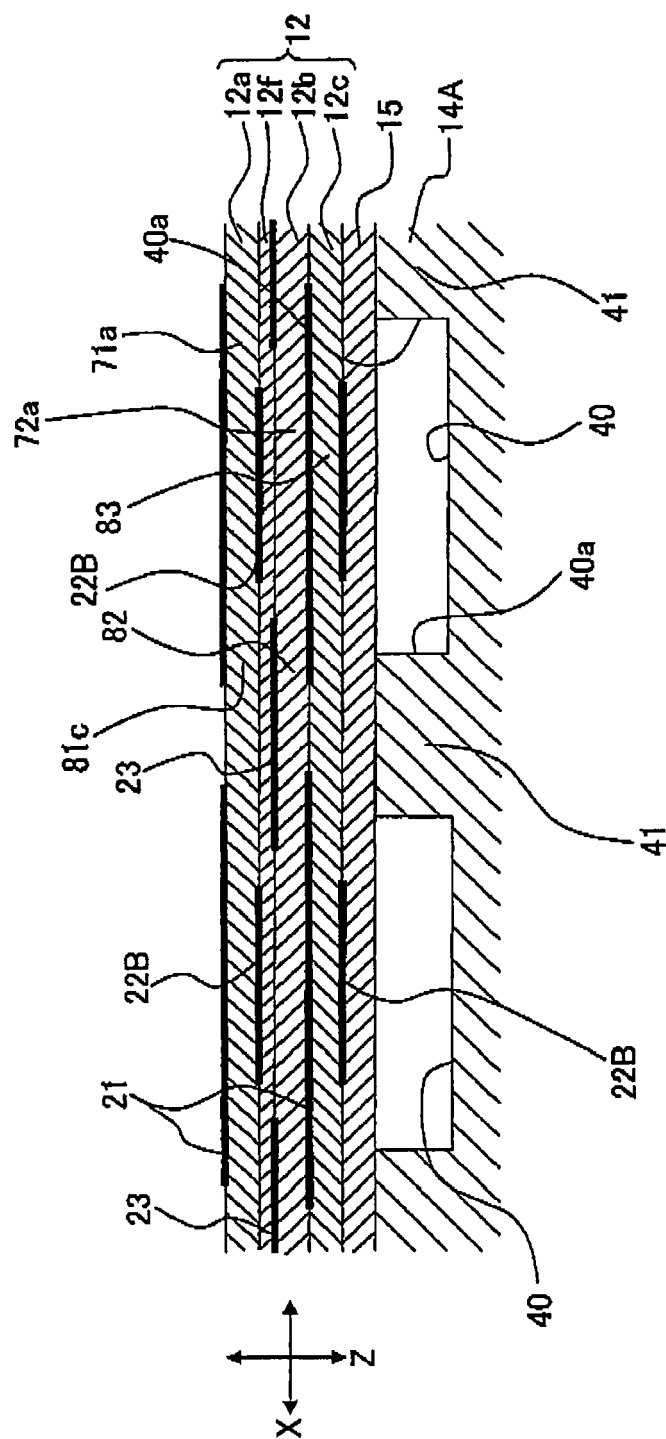


Fig. 15

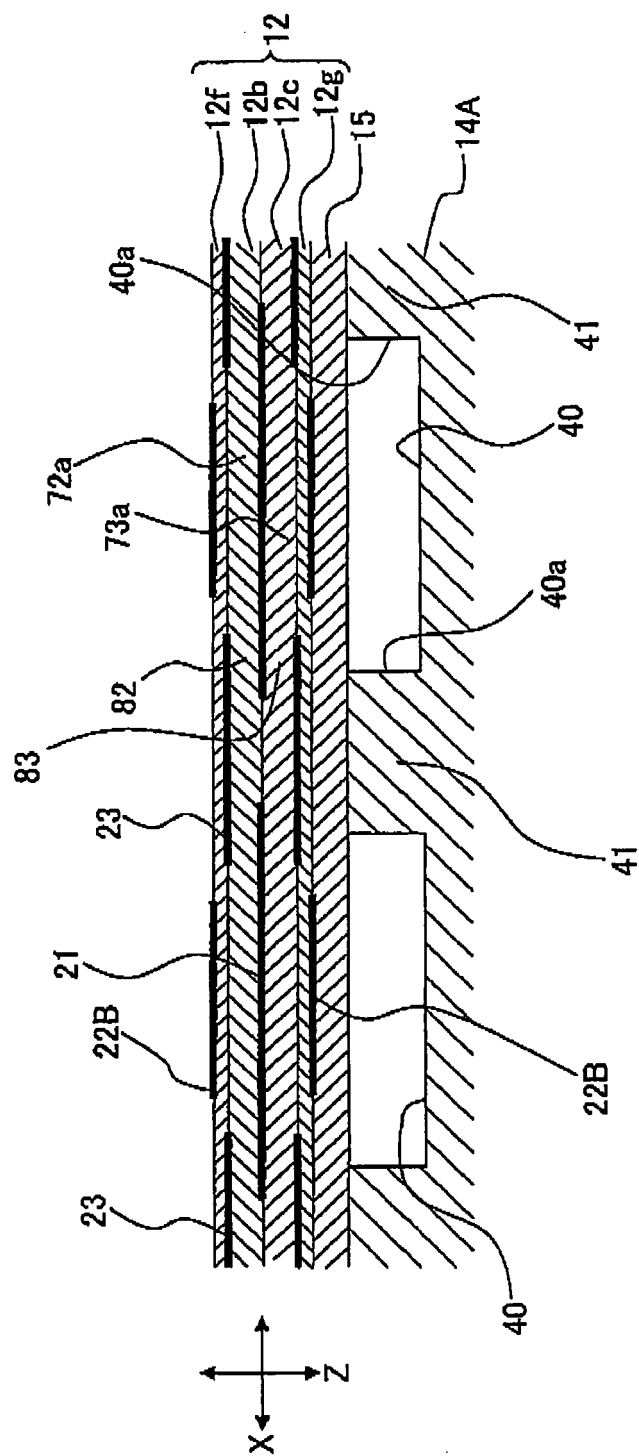


Fig. 16

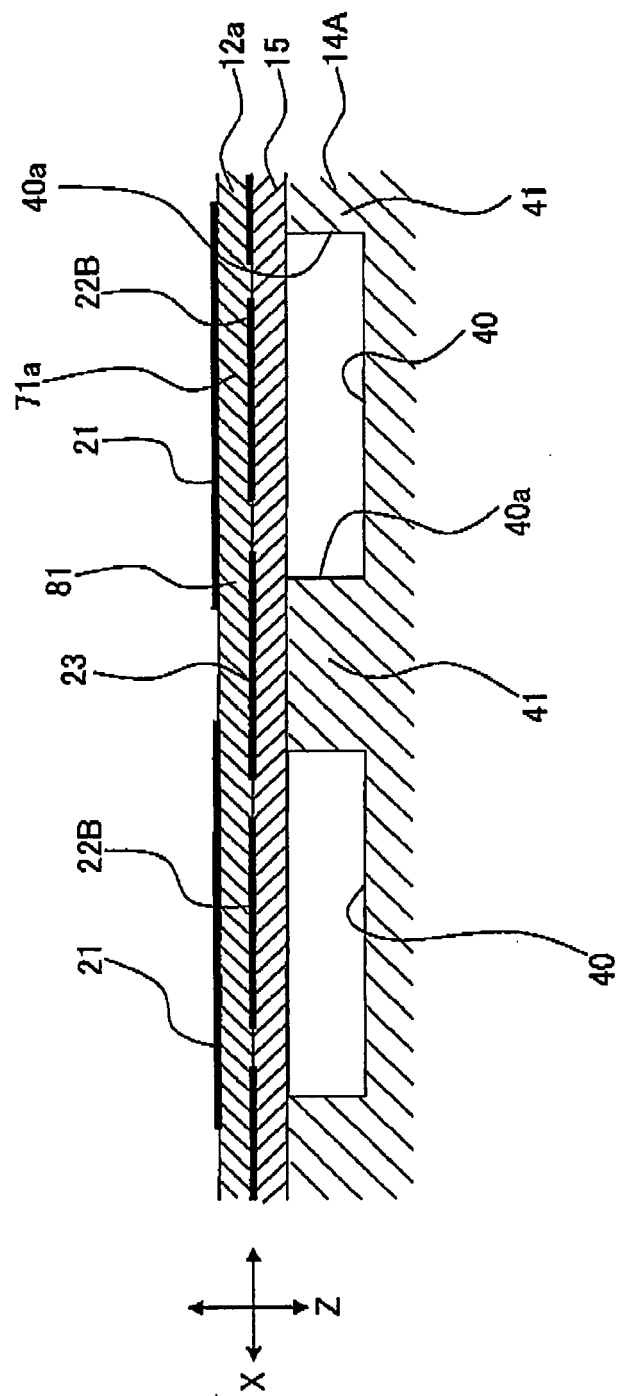


Fig. 17

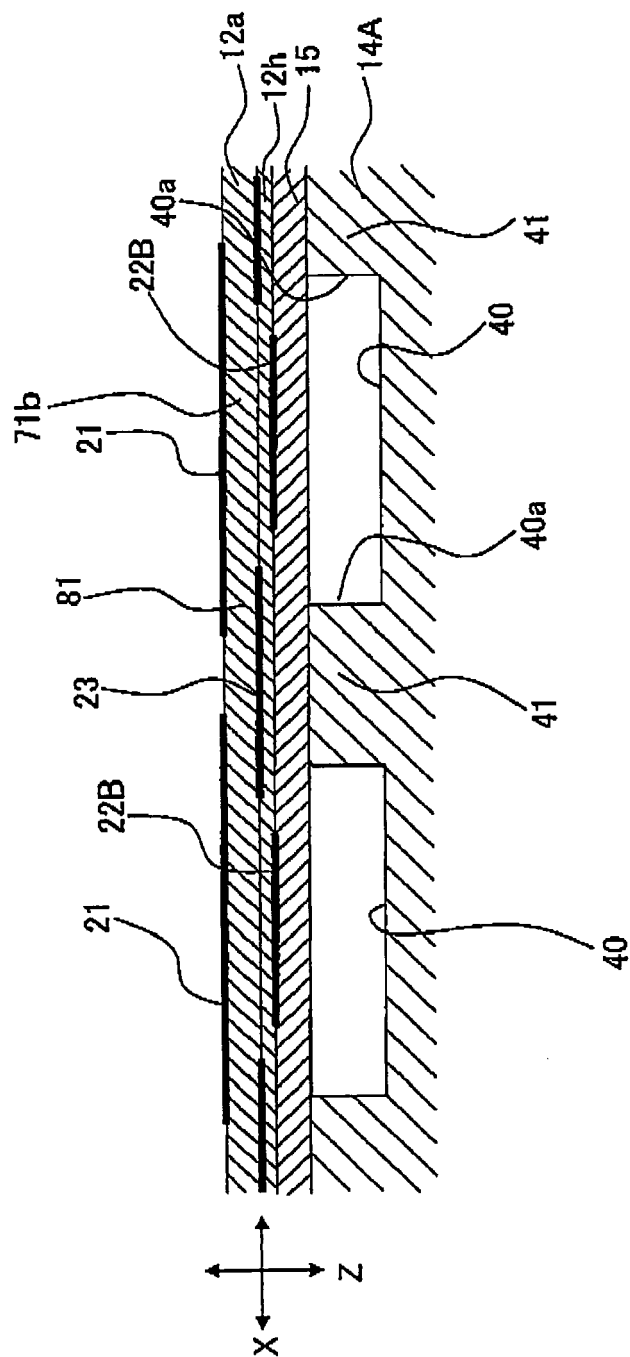


Fig. 18A

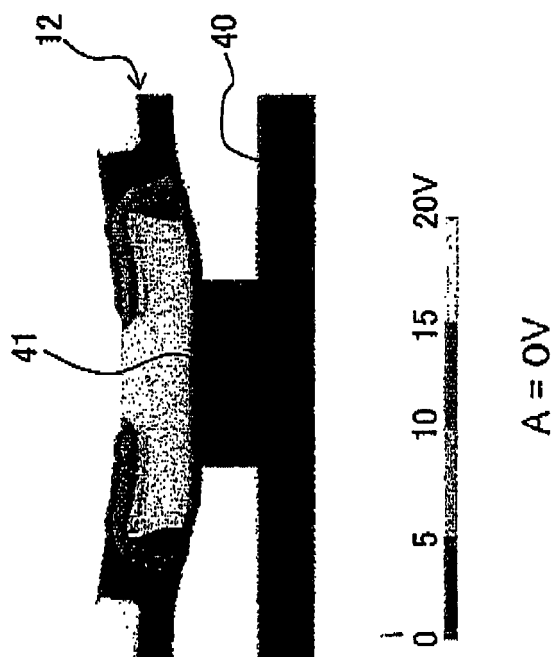


Fig. 18B

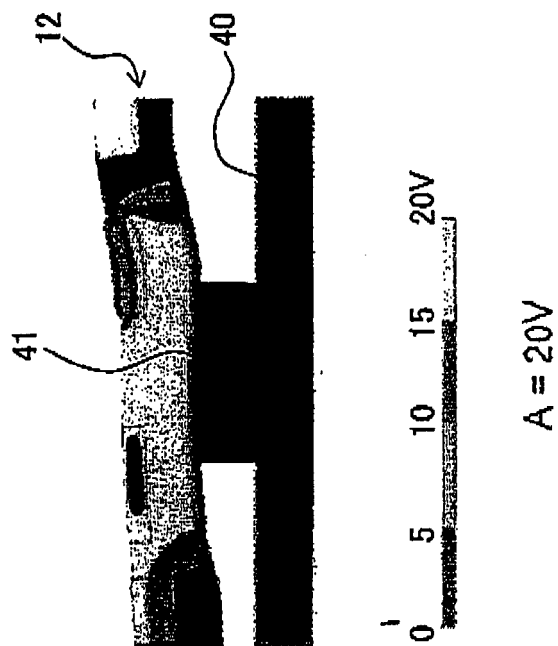


Fig. 19

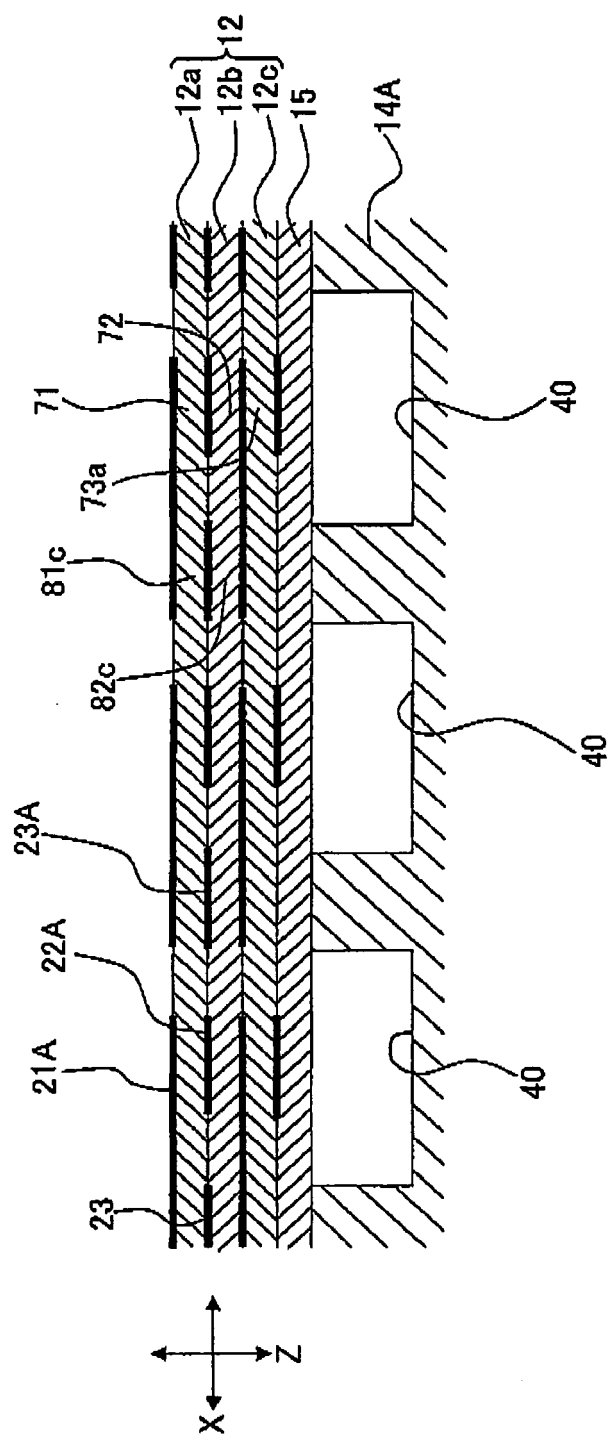


Fig. 20

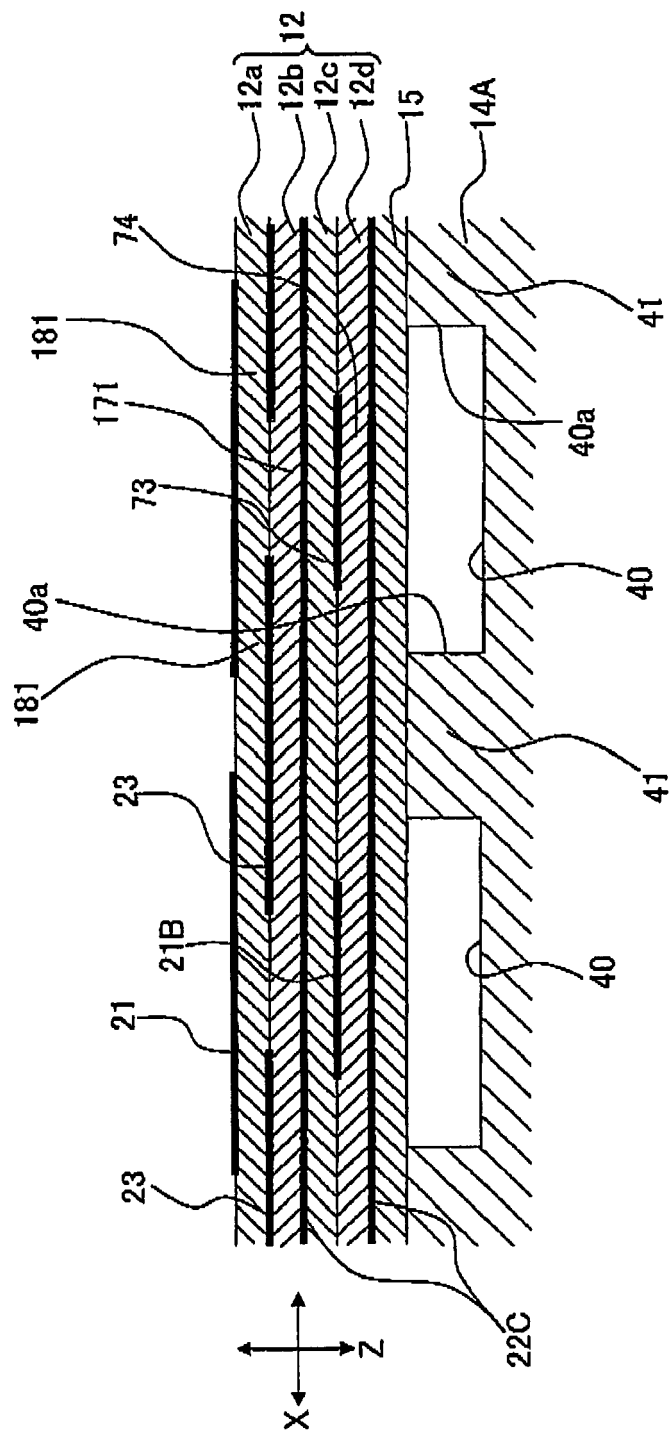


Fig. 21

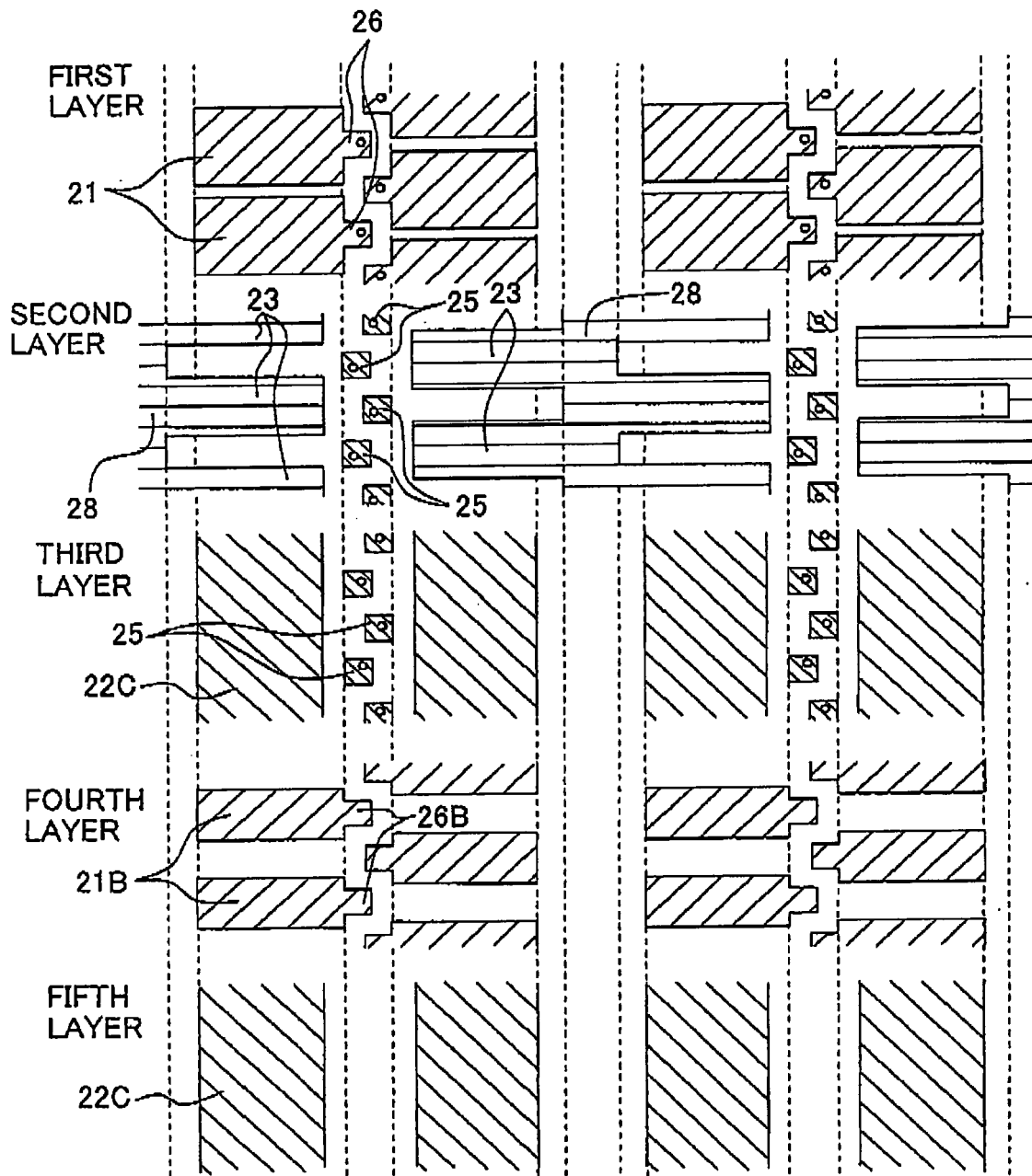


Fig. 22A

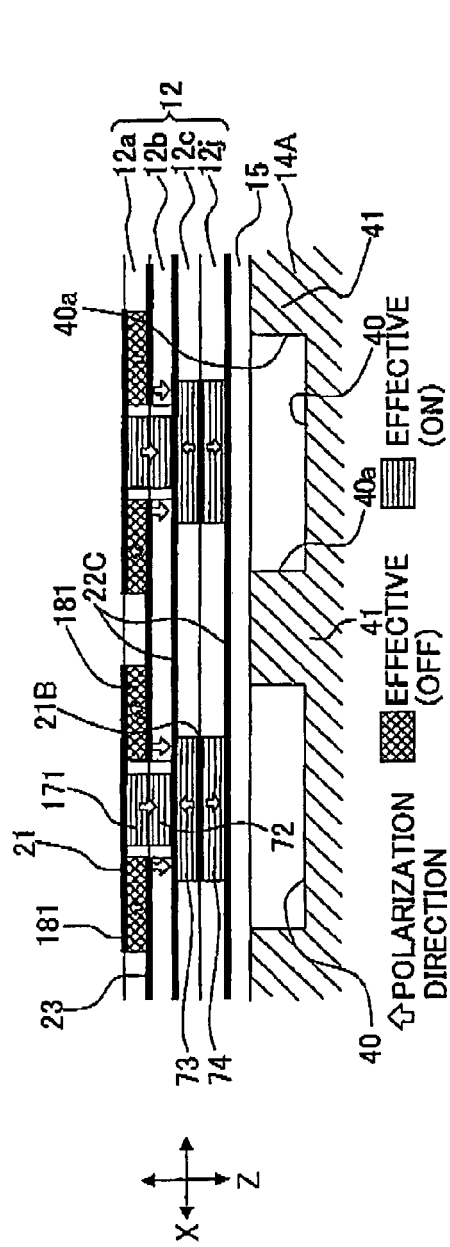


Fig. 22B

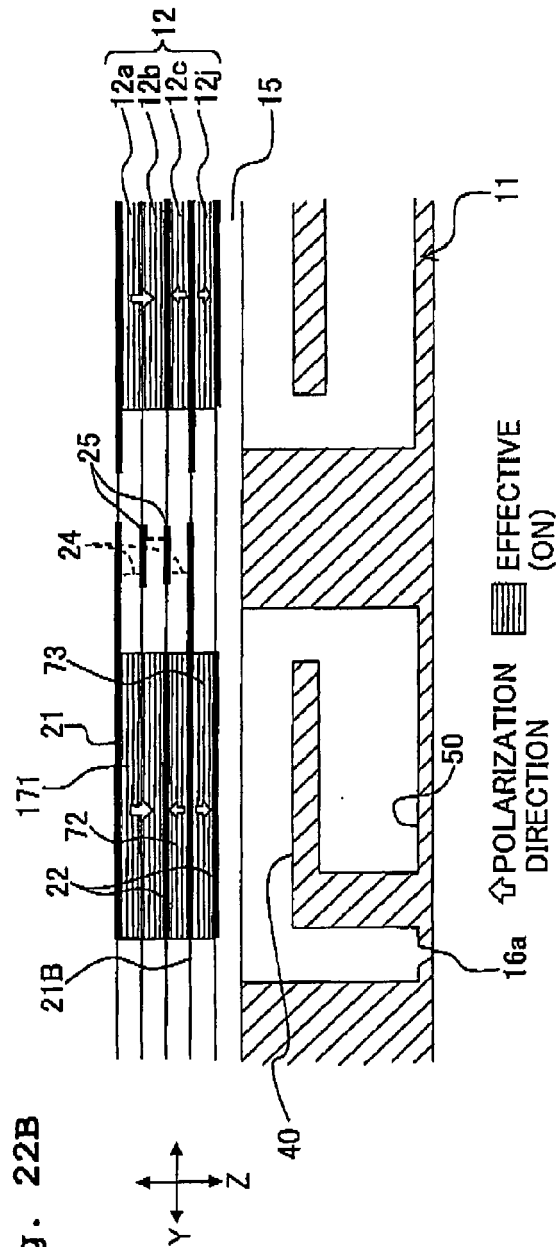


Fig. 23

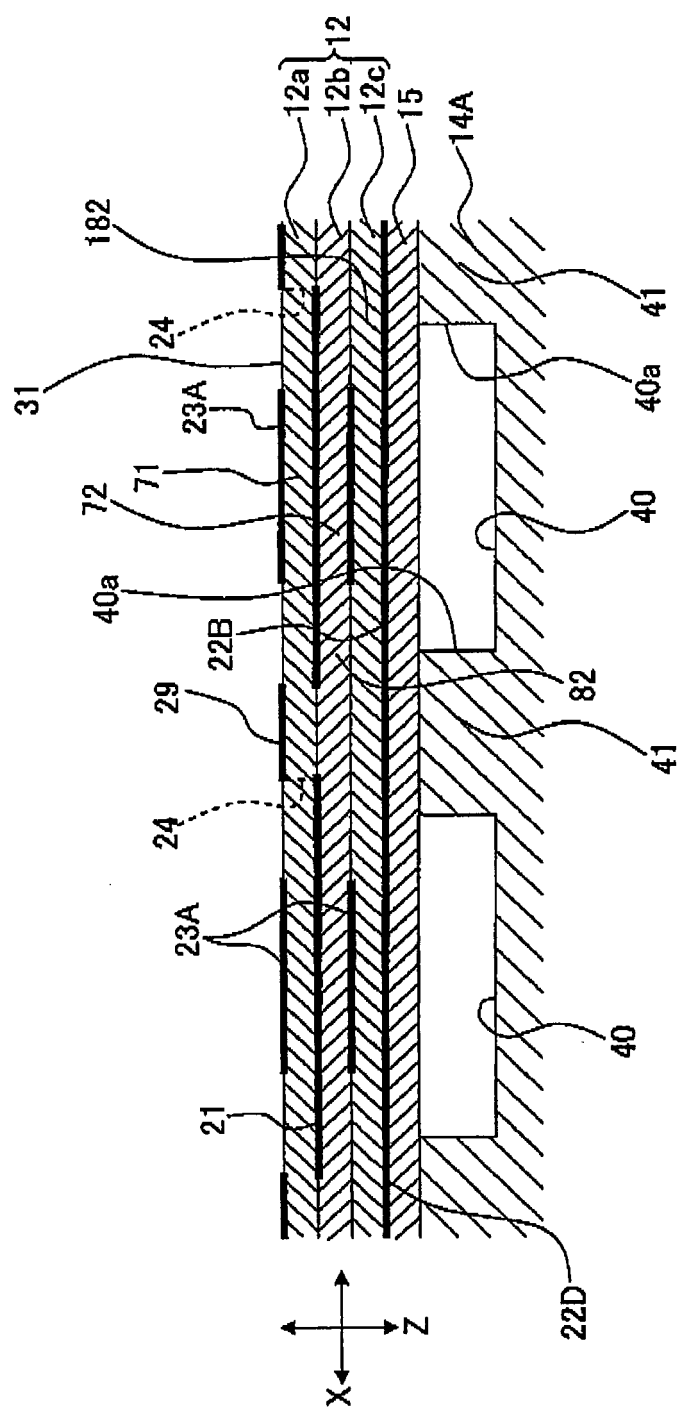


Fig. 24

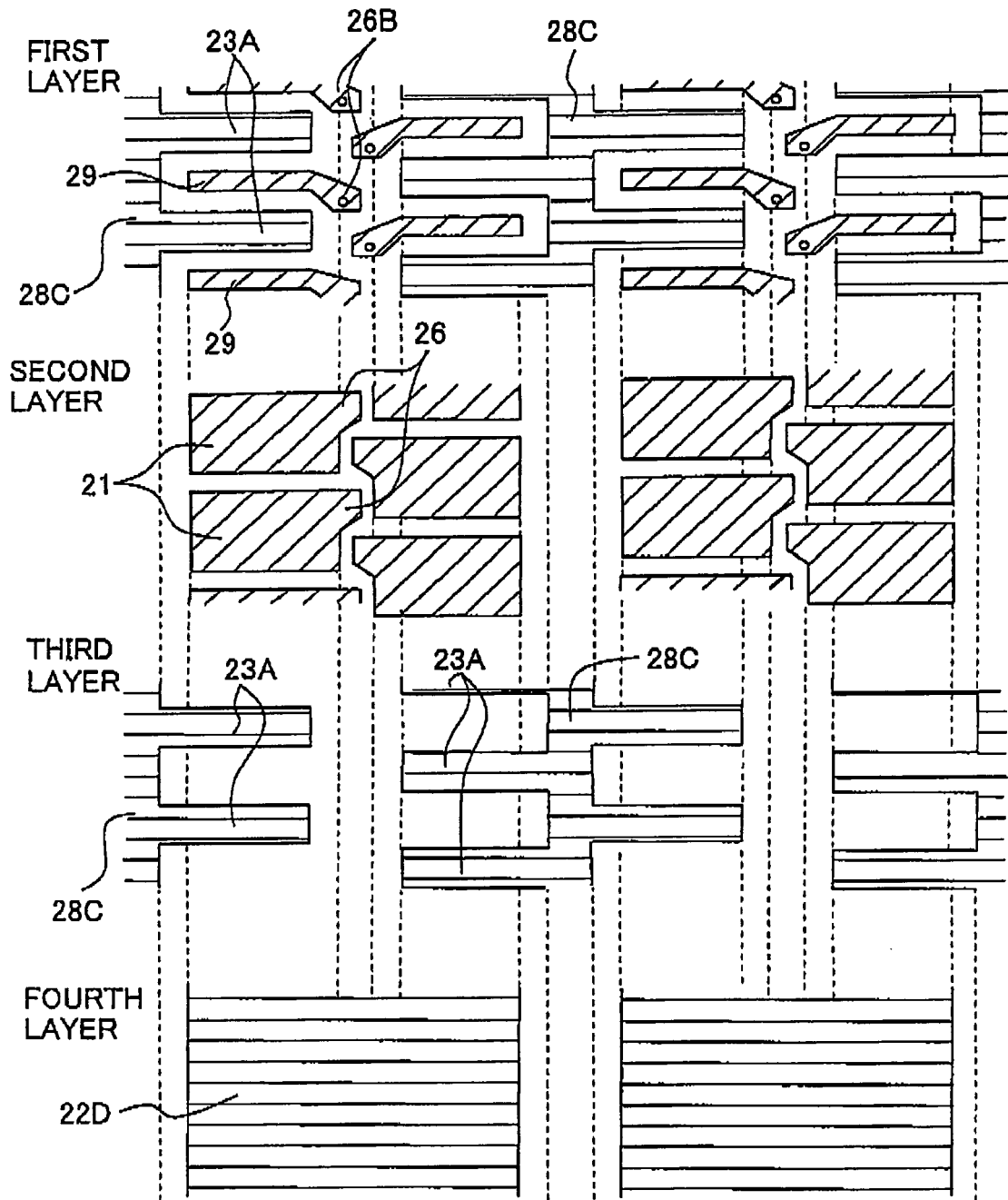


Fig. 25A

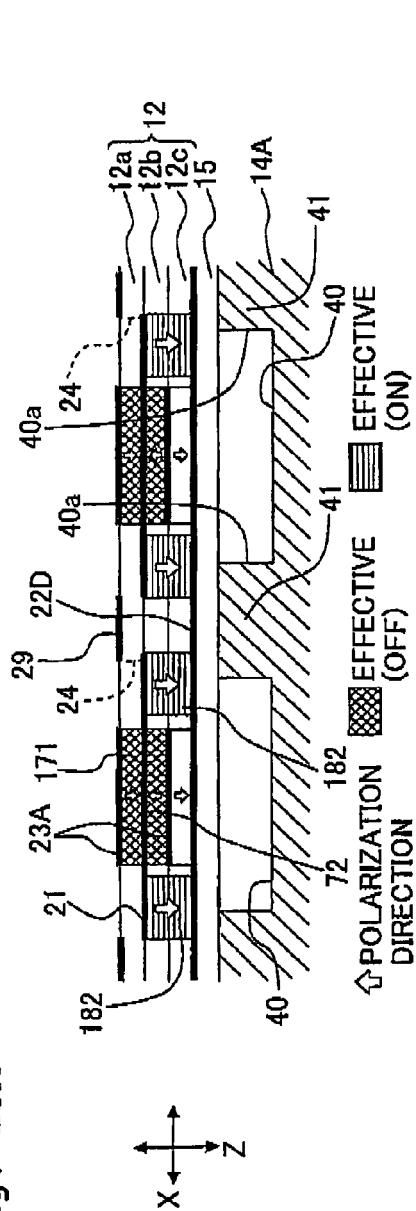


Fig. 25B

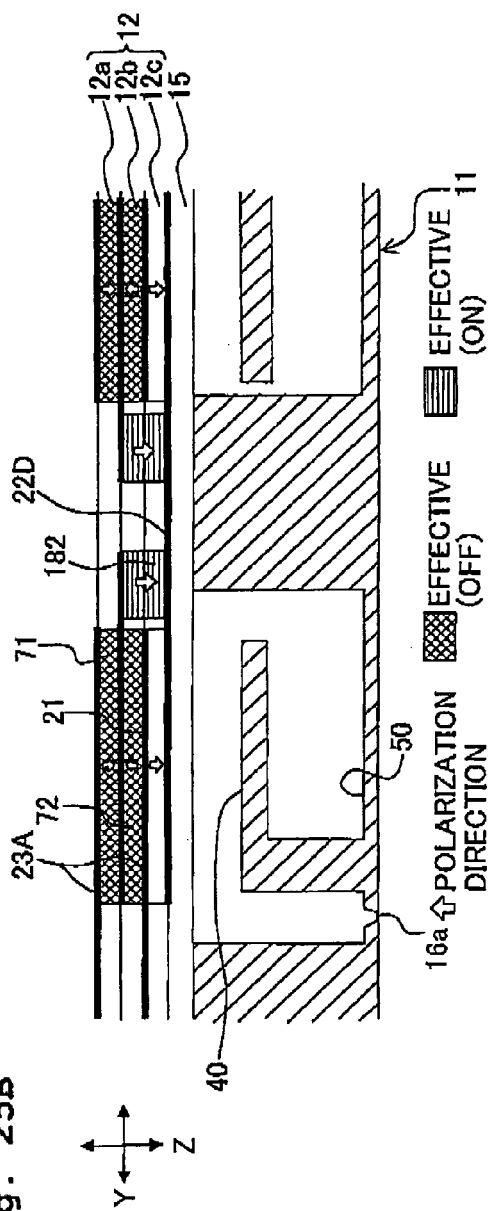


Fig. 26B

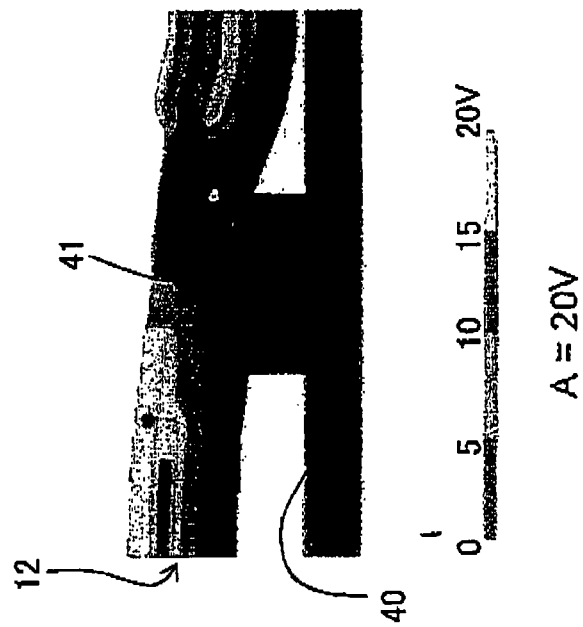


Fig. 26A

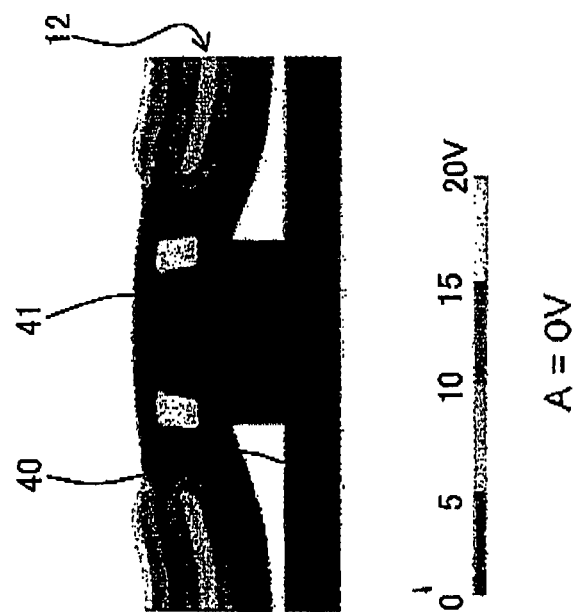


Fig. 27A

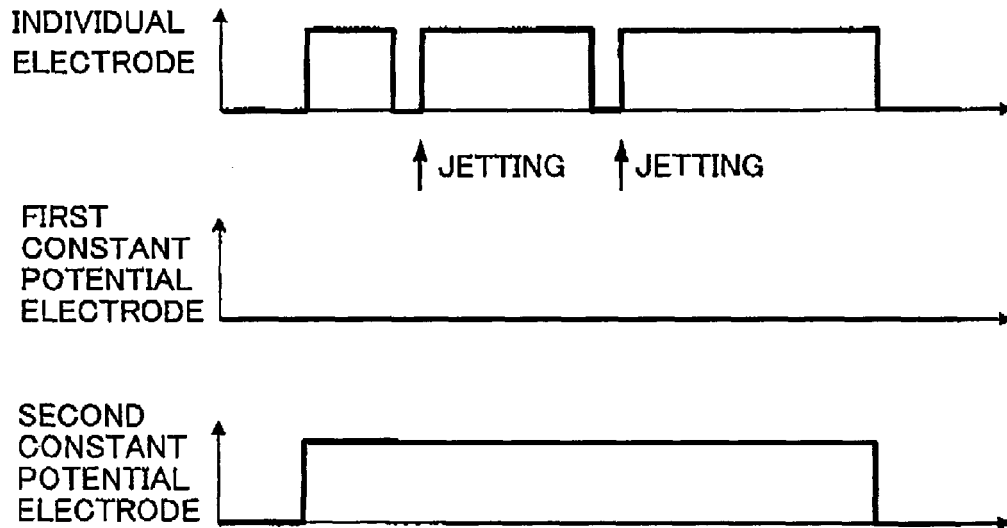


Fig. 27B

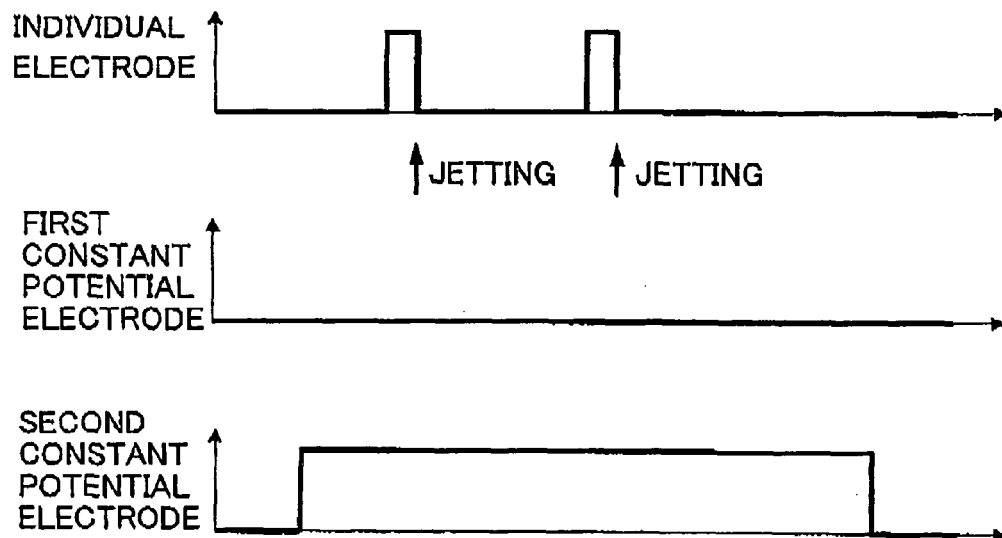


Fig. 28

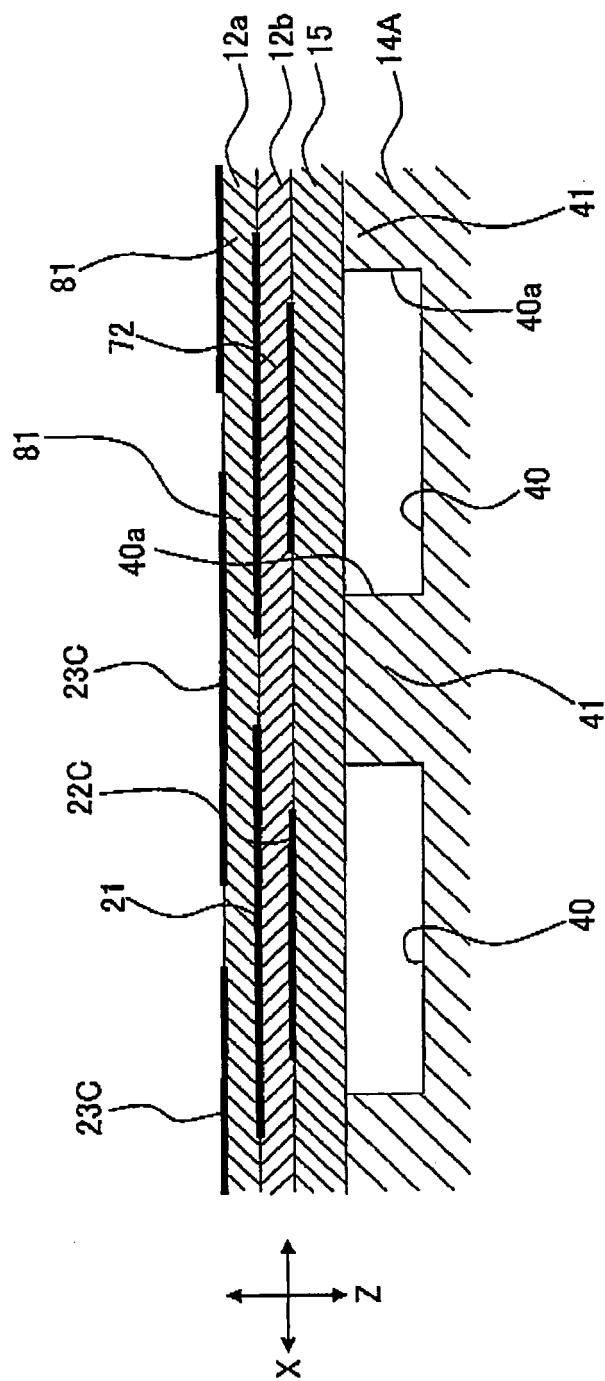


Fig. 29

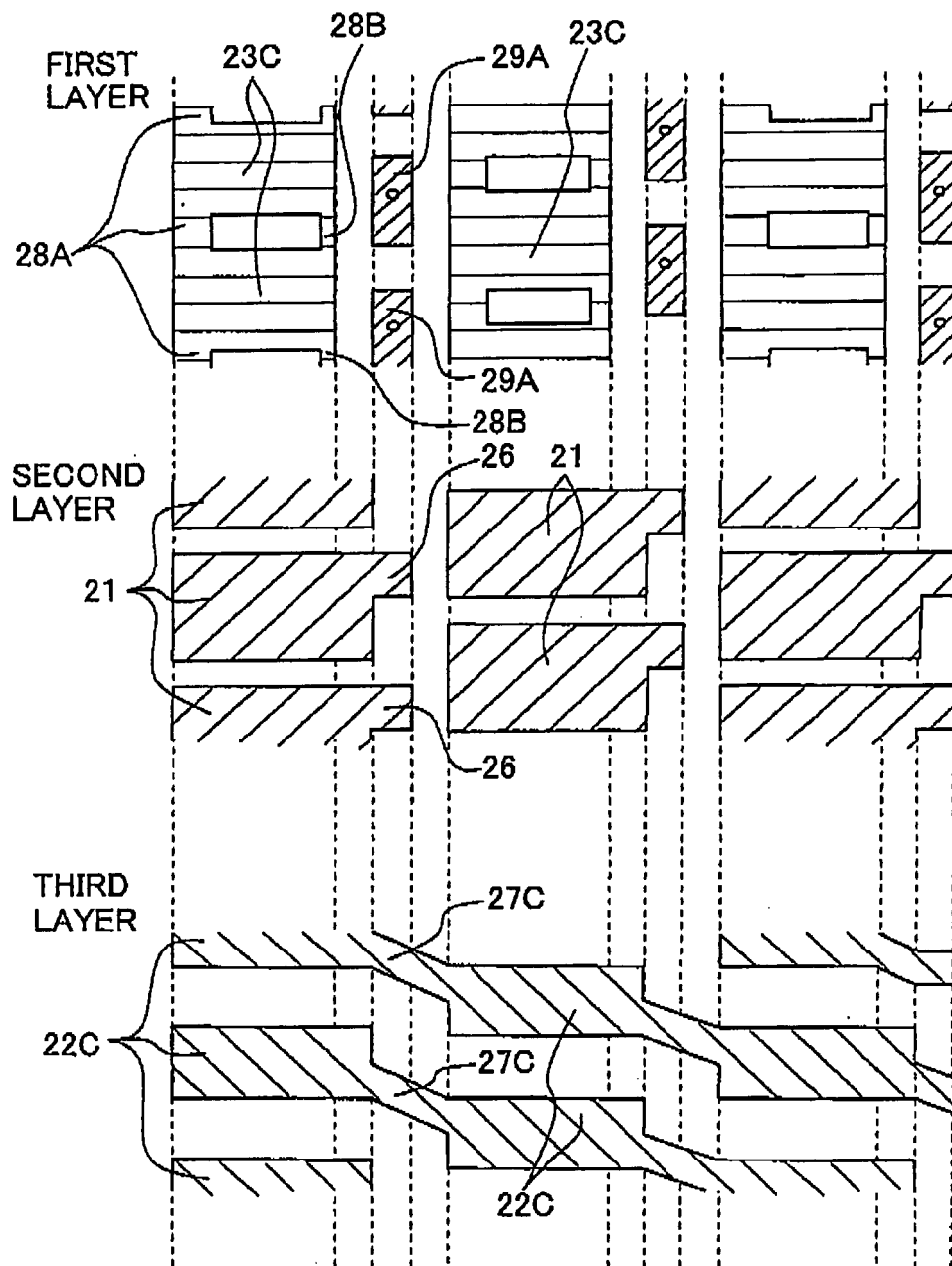


Fig. 30A

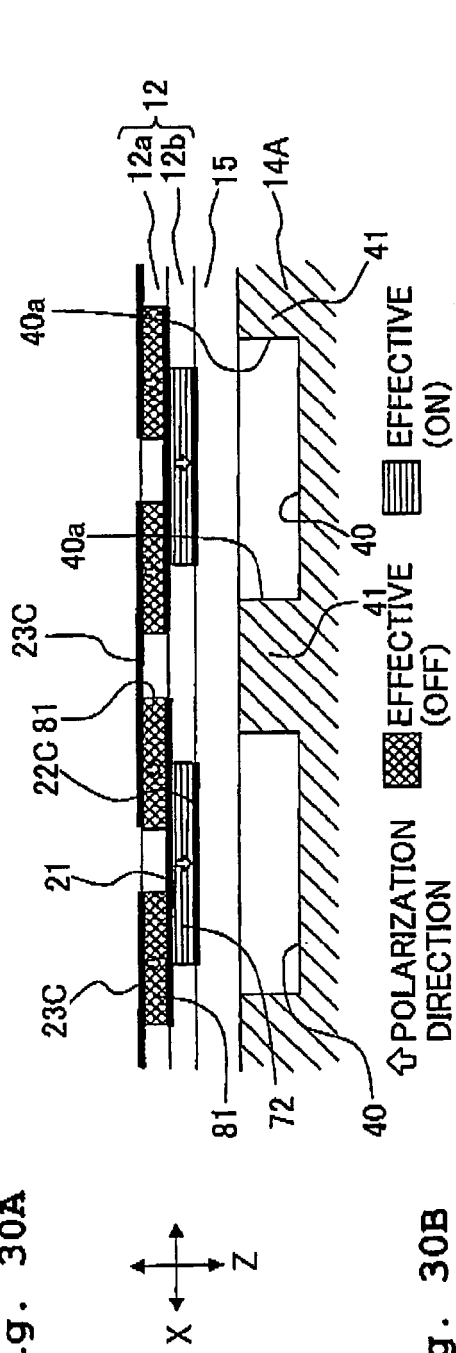


Fig. 30B

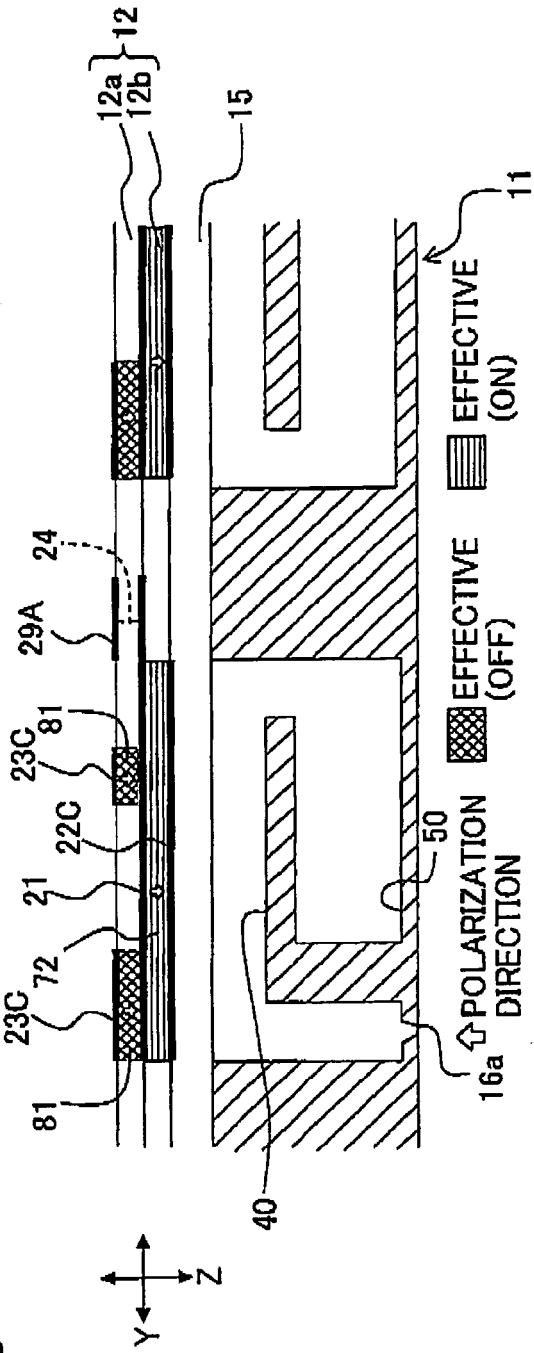


Fig. 31B

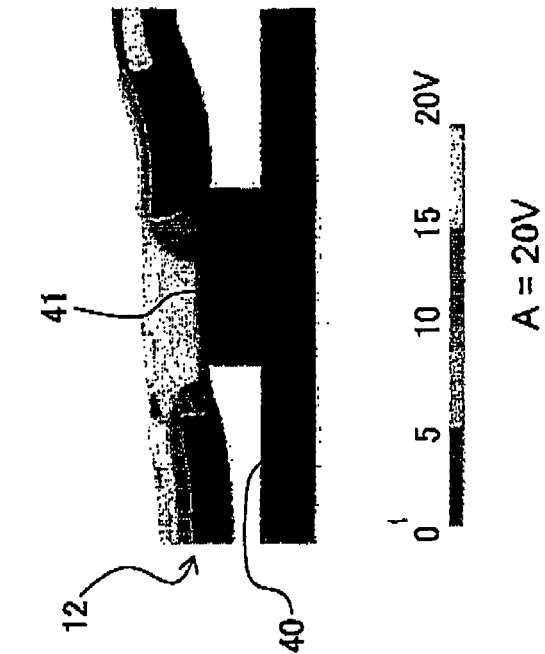


Fig. 31A

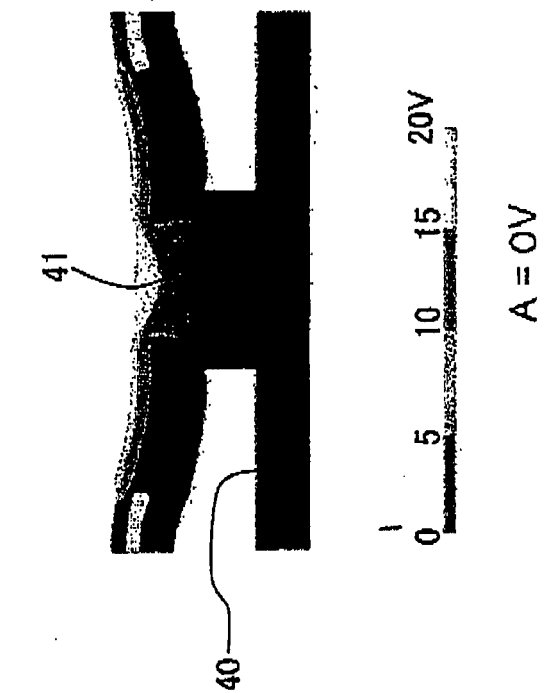


Fig. 32

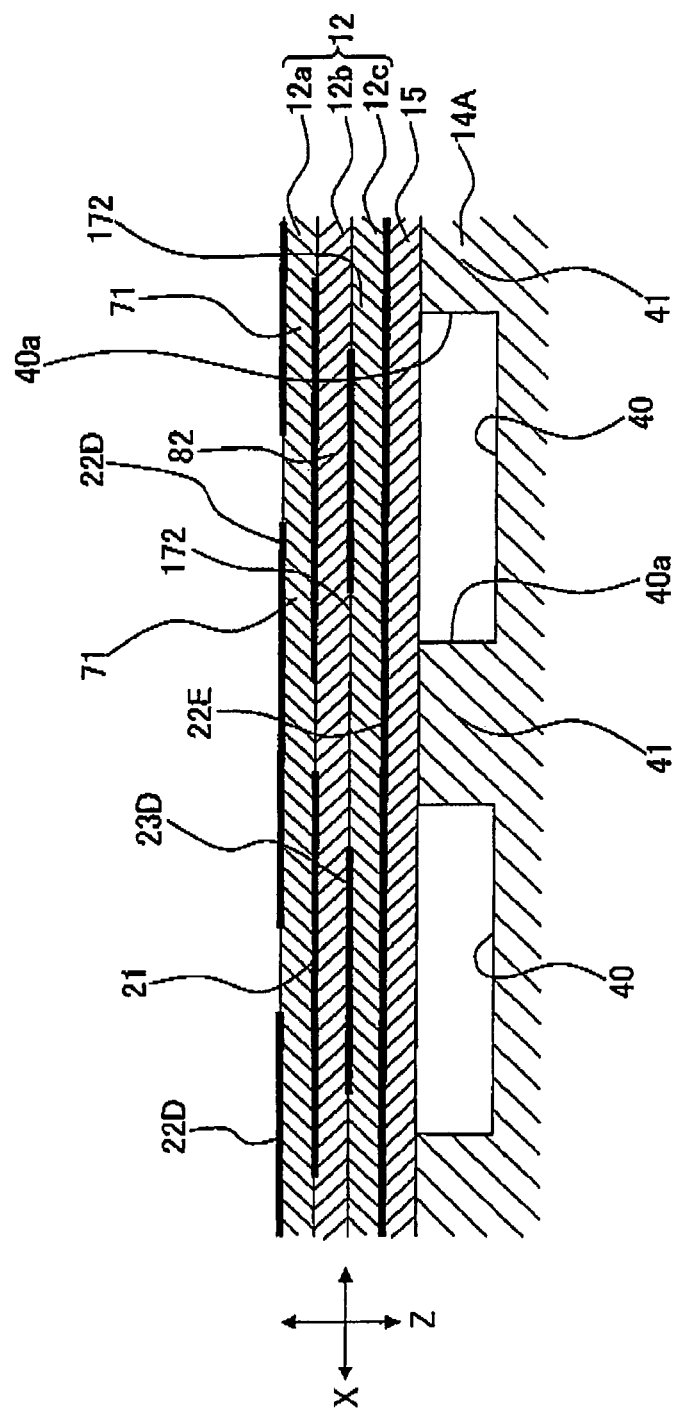


Fig. 33A

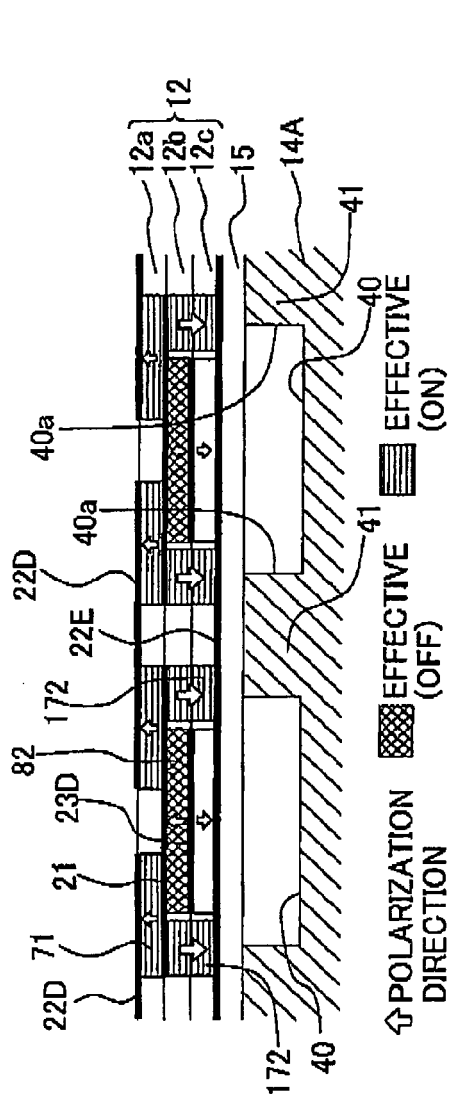


Fig. 33B

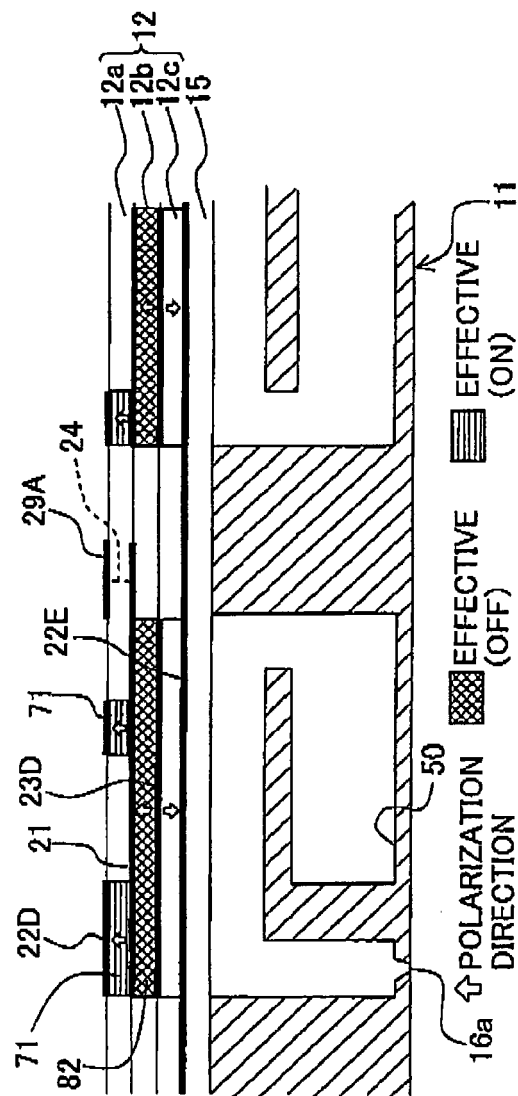
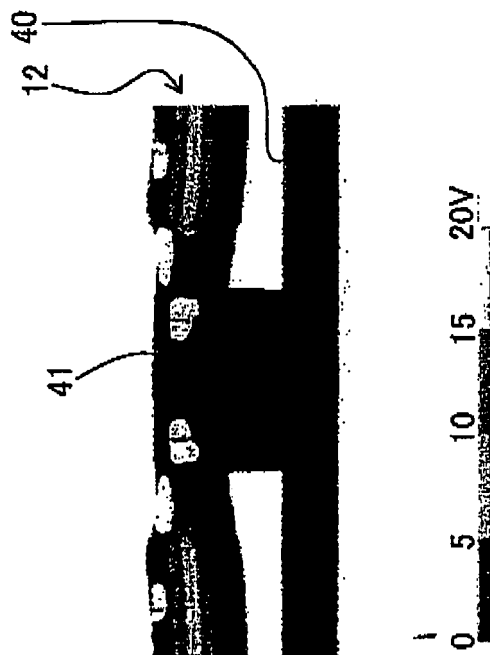
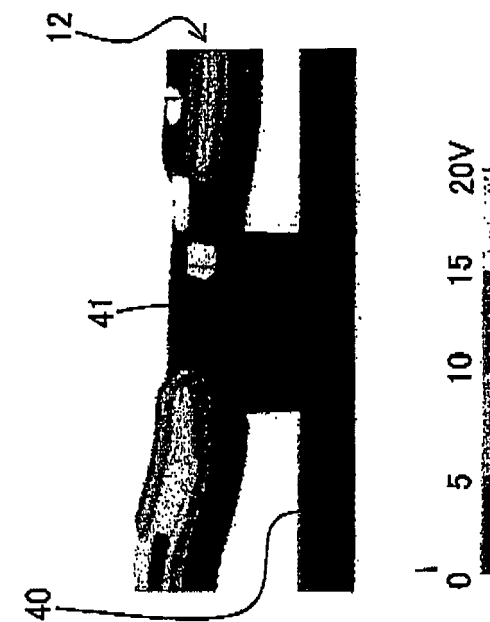


Fig. 34A



$A = 0V$

Fig. 34B



$A = 20V$

Fig. 35

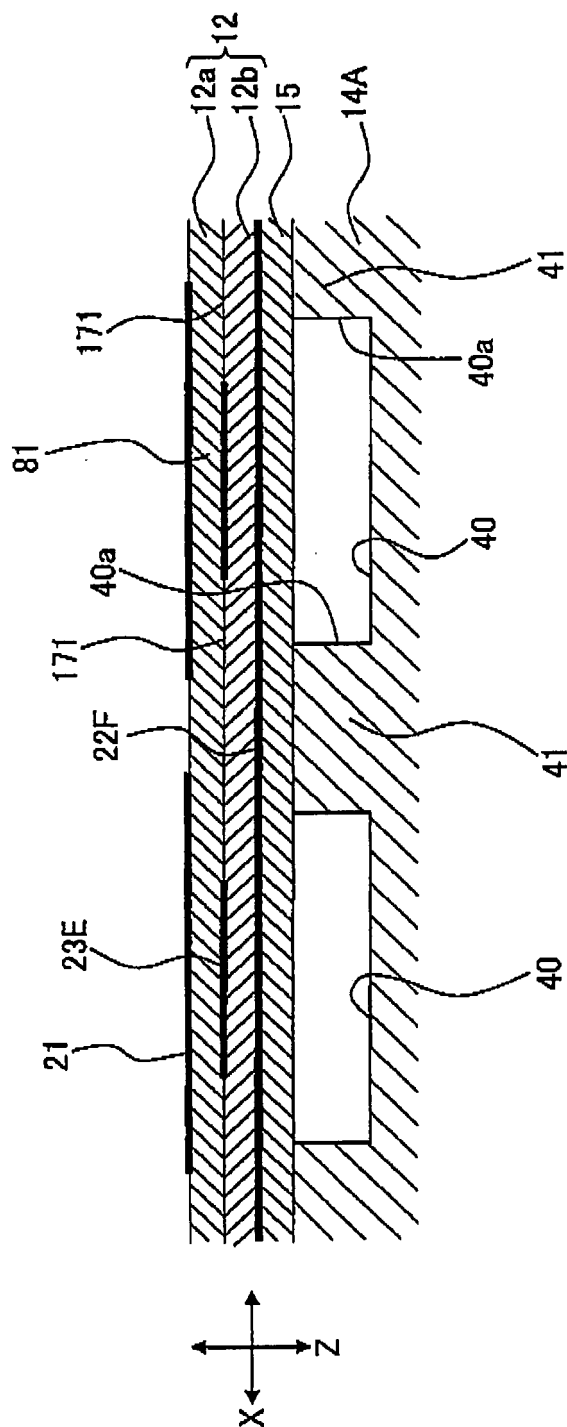


Fig. 36

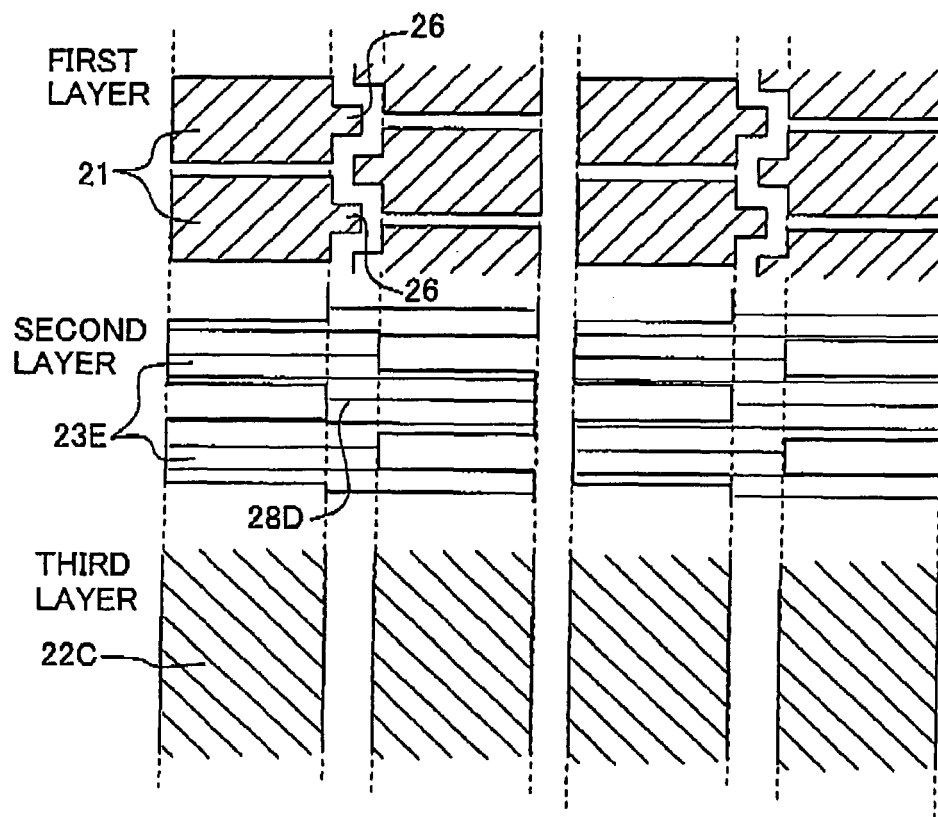


Fig. 37A

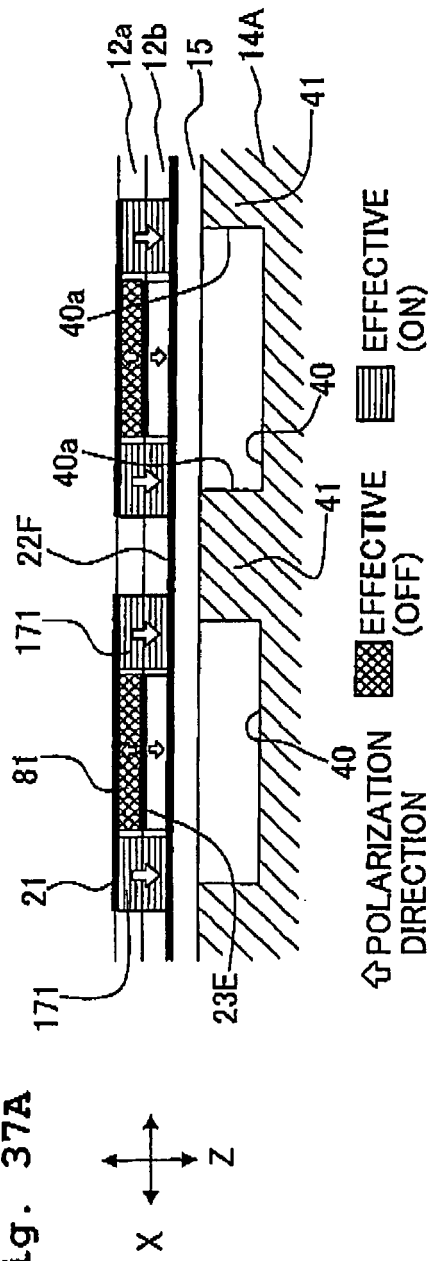


Fig. 37B

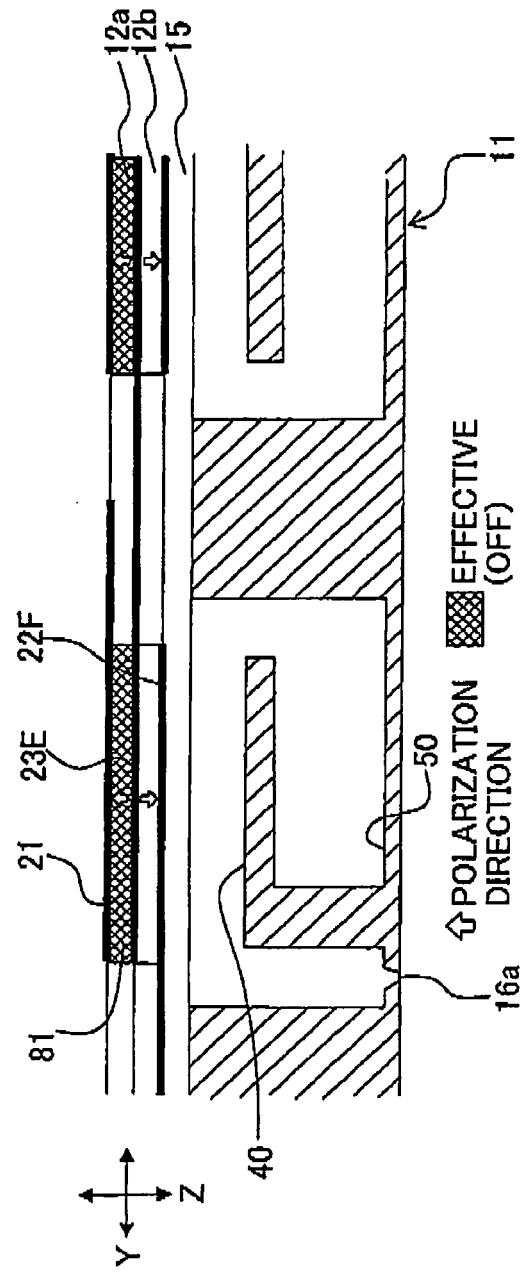
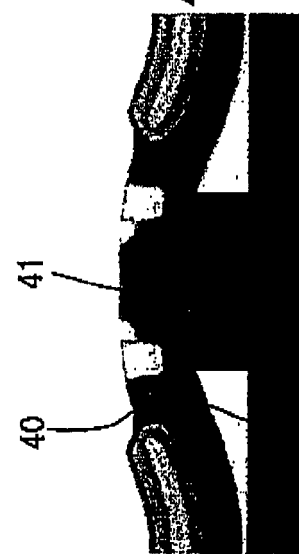
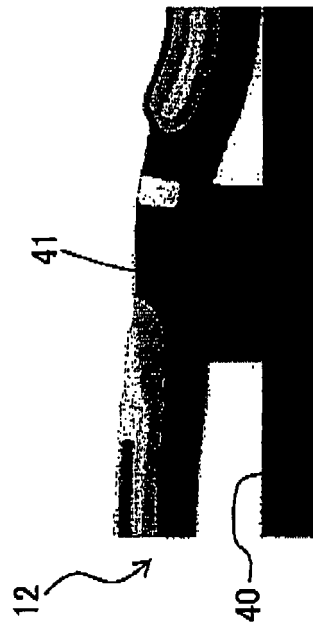


Fig. 38A



A = 0V

Fig. 38B



A = 20V

Fig. 39

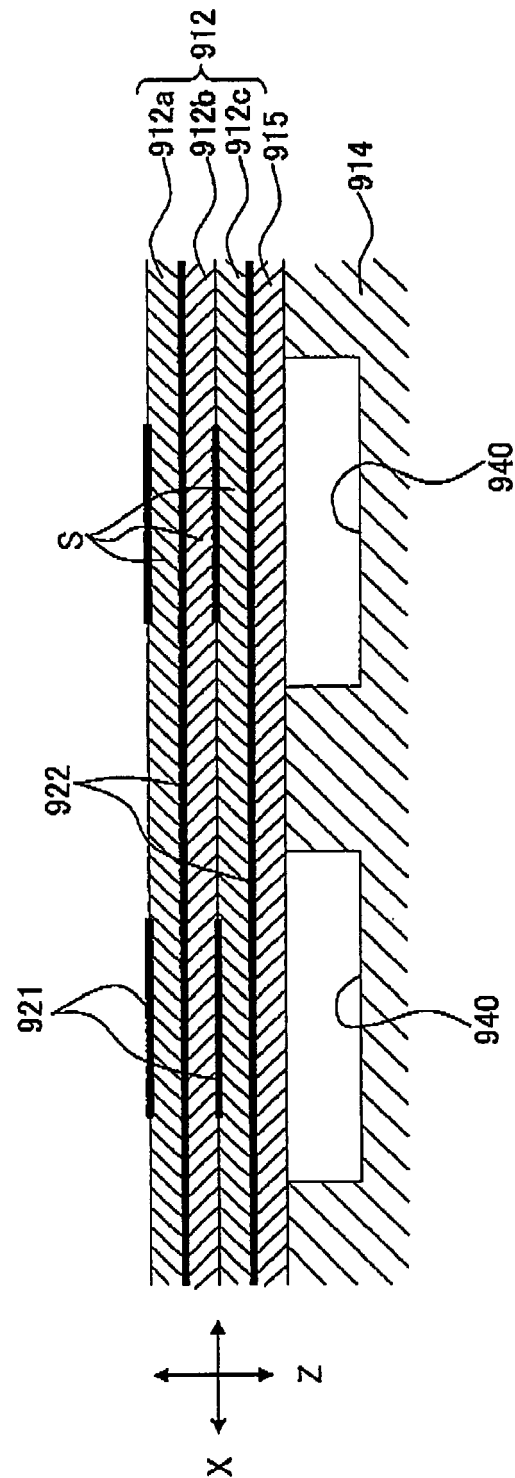


Fig. 40

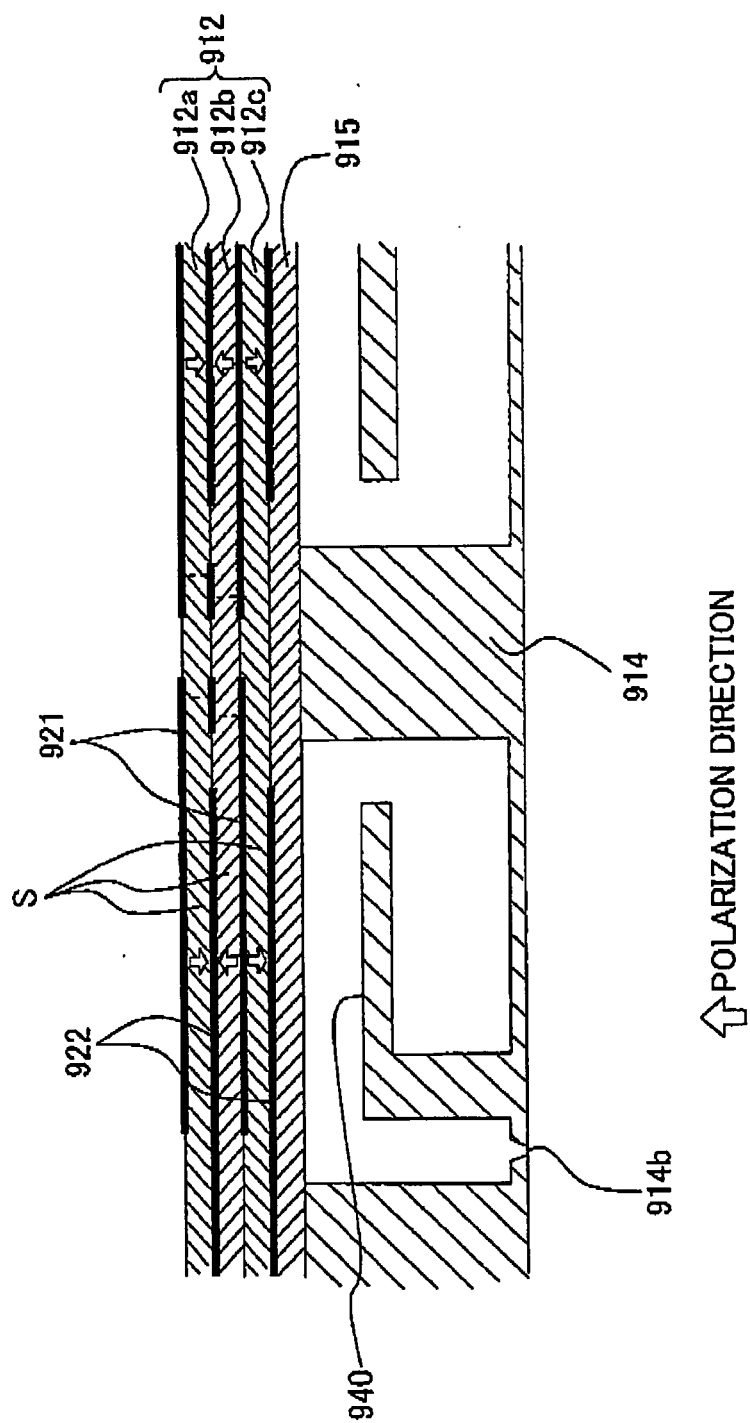
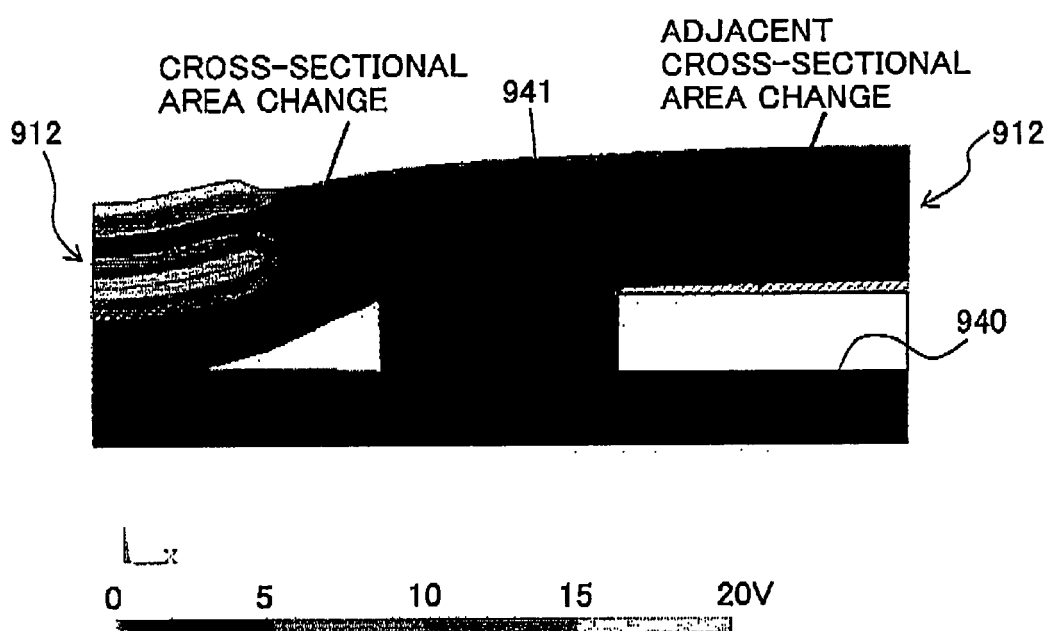


Fig. 41





EUROPEAN SEARCH REPORT

Application Number
EP 08 01 7146

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The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 22 January 2009	Examiner Bonnin, David
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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