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LIQUID EJECTION HEAD AND RECORDING APPARATUS

Abstract

A first active region is made of a piezoelectric overlaps a midsection of a pressure chamber when viewed in plan through a pressure applying surface. A second active region is made of a piezoelectric member closer than the first active region to the pressure applying surface. The second active region extends over both a peripheral section of the pressure chamber and an outer region located outside the pressure chamber when viewed in plan through the pressure applying surface. A driver controls intensity of a first electric field applied to the first active region and intensity of a second electric field applied to the second active region such that the time period over which the first active region contracts and the time period over which the second active region contracts overlap or coincide with each other. The first electric field is more intense than the second electric field.

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Background/Summary

RELATED APPLICATIONS [0001] This application is a continuation of U.S. patent application Ser. No. 17/915,479 filed on Sep. 29, 2022, which is the National Phase of International Application Number PCT/JP2021/012806, filed Mar. 26, 2021, and claims priority based on Japanese Patent Application Nos. 2020-059483, 2020-059484 and 2020-059485, filed Mar. 30, 2020, the disclosures of which applications are hereby incorporated by reference herein in their entirety. [0002] The disclosure relates to a liquid ejection head and a recording apparatus including the liquid ejection head.

TECHNICAL FIELD
Background of Invention
[0003] Known piezoelectric actuators are, for example, included in ink jet heads (see, for example, Patent Literature 1 and Patent Literature 2). For example, a unimorph piezoelectric actuator includes a diaphragm and piezoelectric layers. The diaphragm covers an upper opening of a pressure chamber filled with liquid (ink). The piezoelectric layers are laid on the diaphragm. The piezoelectric layers expand and contract along a surface. Thus, the piezoelectric actuator, like a bimetal, undergoes bending and deformation. The pressure chamber receives pressure accordingly, and as a result, the liquid is ejected from the pressure chamber. When a voltage is applied to a region being part of the piezoelectric layers and extending over the midsection of the pressure chamber viewed in plan, the piezoelectric layers expand and contract along a surface. Patent Literature 1 and Patent Literature 2 indicate that a voltage is applied also to the diaphragm, which is made of a piezoelectric member. More specifically, a voltage is applied to a region being part of the diaphragm and located on a peripheral portion of the piezoelectric chamber viewed in plan. Patent Literature 3 and Patent Literature 4 disclose techniques by which an electric field is applied to conduct poling process.
CITATION LIST
Patent Literature
[0004] Patent Literature 1: Japanese Unexamined Patent Application Publication No. 2015-182448
[0005] Patent Literature 2: Japanese Unexamined Patent Application Publication No. 2010-155386
[0006] Patent Literature 3: Japanese Unexamined Patent Application Publication No. 2006-158127
[0007] Patent Literature 4: Japanese Unexamined Patent Application Publication No. 2010-228144
SUMMARY
[0008] According to an aspect of the present disclosure, a liquid ejection head includes a channel member, a piezoelectric actuator, and a driver. The channel member has a pressure applying surface and includes a pressure chamber that has an opening defined in the pressure applying surface. The piezoelectric actuator is disposed on the pressure applying surface. The driver is configured to

drive the piezoelectric actuator. The piezoelectric actuator includes a first active region and a second active region. A thickness direction is defined as a direction perpendicular to the pressure applying surface. The first active region is made of a piezoelectric member polarized in the thickness direction and extends over a midsection of the pressure chamber when viewed in plan through the pressure applying surface. The second active region is made of a piezoelectric member polarized in the thickness direction and closer than the first active region to the pressure applying surface. The second active region extends over both a peripheral section of the pressure chamber and an outer region located outside the pressure chamber when viewed in plan through the pressure applying surface. When performing liquid ejection control for ejecting liquid, the driver controls intensity of a first electric field applied to the first active region in the thickness direction and intensity of a second electric field applied to the second active region in the thickness direction. The intensity of each electric field is controlled in such a manner that a time period over which the first active region expands along the pressure applying surface and a time period over which the second active region expands along the pressure applying surface overlap or coincide with each other and a time period over which the first active region contracts along the pressure applying surface and a time period over which the second active region contracts along the pressure applying surface overlap or coincide with each other. When the liquid ejection control is performed, a maximum value of the intensity of the first electric field is greater than a maximum value of the intensity of the second electric field.

[0009] According to an aspect of the present disclosure, a liquid ejection head includes a channel member, a piezoelectric actuator, and a driver. The channel member has a pressure applying surface and includes a pressure chamber that has an opening defined in the pressure applying surface. The piezoelectric actuator is disposed on the pressure applying surface. The driver is configured to drive the piezoelectric actuator. The piezoelectric actuator includes a first active region and a second active region. A thickness direction is defined as a direction perpendicular to the pressure applying surface. The first active region is made of a piezoelectric member polarized in the thickness direction and extends over a midsection of the pressure chamber when viewed in plan through the pressure applying surface. The second active region is made of a piezoelectric member polarized in the thickness direction and closer than the first active region to the pressure applying surface. The second active region extends over both a peripheral section of the pressure chamber and an outer region located outside the pressure chamber when viewed in plan through the pressure applying surface. When performing control for ejecting liquid droplets, the driver controls intensity of an electric field applied to the first active region in the thickness direction and intensity of an electric field applied to the second active region in the thickness direction. The intensity of each electric field is controlled in such a manner that a time period over which the first active region expands along the pressure applying surface and a time period over which the second active region expands along the pressure applying surface overlap or coincide with each other and a time period over which the first active region contracts along the pressure applying surface and a time period over which the second active region contracts along the pressure applying surface overlap or coincide with each other. A second portion being part of the second active region and located outside the pressure chamber is greater in area than a first portion being part of the second active region and extending over the pressure chamber when the second active region is viewed in plan through the pressure applying surface.

[0010] According to an aspect of the present disclosure, a liquid ejection head includes a channel member, a piezoelectric actuator, and a driver. The channel member has a pressure applying surface and includes a pressure chamber that has an opening defined in the pressure applying surface. The piezoelectric actuator is disposed on the pressure applying surface. The driver is configured to drive the piezoelectric actuator. The piezoelectric actuator includes a first active region, a second active region, and an inactive region. A thickness direction is defined as a direction perpendicular to the pressure applying surface. The first active region is made of a piezoelectric member polarized in the thickness direction and extends over a midsection of the pressure chamber when viewed in plan through the pressure applying surface. The second active region is made of a piezoelectric member polarized in the thickness direction and closer than the first active region to the pressure applying surface. The second active region extends over both a peripheral section of the pressure chamber and an outer region located outside the pressure chamber when viewed in plan through the pressure applying surface. The inactive region is made of a piezoelectric member and extends to a perimeter of the first active region. The driver performs liquid ejection control and reorientation control. When performing the liquid ejection control, the driver controls intensity of an electric field applied to the first active region in the thickness direction and intensity of an electric field applied to the second active region in the thickness direction. The intensity of each electric field is controlled in such a manner that a time period over which the first active region expands along the pressure applying surface and a time period over which the second active region expands along the pressure applying surface overlap or coincide with each other and a time period over which the first active region contracts along the pressure applying surface and a time period over which the second active region contracts along the pressure applying surface overlap or coincide with each other. When not performing the liquid ejection control, the driver performs the reorientation control by which an electric field is applied to the inactive region in the thickness direction.

[0011] According to an aspect of the present disclosure, a recording apparatus includes a liquid ejection head and a controller configured to control the liquid ejection head. The liquid ejection head includes a channel member and a piezoelectric actuator. The channel member has a pressure applying surface and includes a pressure chamber that has an opening defined in the pressure applying surface. The piezoelectric actuator is disposed on the pressure applying surface. The piezoelectric actuator includes a first active region and a second active region. A thickness direction is defined as a direction perpendicular to the pressure applying surface. The first active region is made of a piezoelectric member polarized in the thickness direction and extends over a midsection of the pressure chamber when viewed in plan through the pressure applying surface. The second active region is made of a piezoelectric member polarized in the thickness direction and closer than the first active region to the pressure applying surface. The second active region extends over both a peripheral section of the pressure chamber and an outer region located outside the pressure chamber when viewed in plan through the pressure applying surface. When performing liquid ejection control for ejecting liquid, the controller controls intensity of a first electric field applied to the first active region in the thickness direction and intensity of a second electric field applied to the second active region in the thickness direction. The intensity of each electric field is controlled in such a manner that a time period over which the first active region expands along the pressure applying surface and a time period over which the second active region expands along the pressure applying surface overlap or coincide with each other and a time period over which the first active region contracts along the pressure applying surface and a time period over which the second active region contracts along the pressure applying surface overlap or coincide with each other. When the liquid ejection control is performed, a maximum value of the intensity of the first electric field is greater than a maximum value of the intensity of the second electric field.

[0012] According to an aspect of the present disclosure, a recording apparatus includes a liquid ejection head and a controller configured to control the liquid ejection head. The liquid ejection head includes a channel member and a piezoelectric actuator. The channel member has a pressure applying surface and includes a pressure chamber that has an opening defined in the pressure applying surface. The piezoelectric actuator is disposed on the pressure applying surface. The piezoelectric actuator includes a first active region and a second active region. A thickness direction is defined as a direction perpendicular to the pressure applying surface. The first active region is made of a piezoelectric member polarized in the thickness direction and extends over a midsection of the pressure chamber when viewed in plan through the pressure applying surface. The second active region is made of a piezoelectric member polarized in the thickness direction and closer than the first active region to the pressure applying surface. The second active region extends over both a peripheral section of the pressure chamber and an outer region located outside the pressure chamber when viewed in plan through the pressure applying surface. When performing control for ejecting liquid droplets, the controller controls intensity of an electric field applied to the first active region in the thickness direction and intensity of an electric field applied to the second active region in the thickness direction. The intensity of each electric field is controlled in such a manner that a time period over which the first active region expands along the pressure applying surface and a time period over which the second active region expands along the pressure applying surface overlap or coincide with each other and a time period over which the first active region contracts along the pressure applying surface and a time period over which the second active region contracts along the pressure applying surface overlap or coincide with each other. A portion being part of the second active region and extending over the outer region is greater in area than a portion being part of the second active region and extending over the pressure chamber when the second active region is viewed in plan through the pressure applying surface.

[0013] According to an aspect of the present disclosure, a recording apparatus includes a liquid ejection head and a controller configured to control the liquid ejection head. The liquid ejection head includes a channel member and a piezoelectric actuator. The channel member has a pressure applying surface and includes a pressure chamber that has an opening defined in the pressure applying surface. The piezoelectric actuator is disposed on the pressure applying surface. The piezoelectric actuator includes a first active region, a second active region, and an inactive region. A thickness direction is defined as a direction perpendicular to the pressure applying surface. The first active region is made of a piezoelectric member polarized in the thickness direction and extends over a midsection of the pressure chamber when viewed in plan through the pressure applying surface. The second active region is made of a piezoelectric member polarized in the thickness direction and closer than the first active region to the pressure applying surface. The second active region extends over both a peripheral section of the pressure chamber and an outer region located outside the pressure chamber when viewed in plan through the pressure applying surface. The inactive region is made of a piezoelectric member and extends to a perimeter of the first active region. The controller performs liquid ejection control and reorientation control. The controller performs the liquid ejection control in such a way as to control intensity of an electric field applied to the first active region in the thickness direction and intensity of an electric field applied to the second active region in the thickness direction. The intensity of each electric field is controlled in such a manner that a time period over which the first active region expands along the pressure applying surface and a time period over which the second active region expands along the pressure applying surface overlap or coincide with each other and a time period over which the first active region contracts along the pressure applying surface and a time period over which the second active region contracts along the pressure applying surface overlap or coincide with each other. When not performing the liquid ejection control, the controller performs the reorientation control by which an electric field is applied to the inactive region in the thickness direction.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] FIG. **1**A is a side view of a recording apparatus according to a first embodiment.

[0015] FIG. **1**B is a plan view of the recording apparatus according to the first embodiment.

[0016] FIG. **2** is a plan view of part of a liquid ejection head according to the first embodiment.

[0017] FIG. **3** is a sectional view of part of the liquid ejection head taken along line III-III in

[0018] FIG. **2**.

[0019] FIG. **4** is a plan view of a pressure chamber of the liquid ejection head according to the first embodiment.
[0020] FIG. **5** is a schematic sectional view of part of the liquid ejection head according to the first embodiment, illustrating a piezoelectric actuator and an upper part of a channel member.
[0021] FIG. **6** is a schematic sectional view of the piezoelectric actuator in the first embodiment, illustrating polarization directions of piezoelectric layers.
[0022] FIG. **7** is an exploded perspective view of part of the liquid ejection head according to the first embodiment.
[0023] FIG. **8** is an enlarged view of part of the liquid ejection head illustrated in FIG. **7**.
[0024] FIG. **9** is a simplified plan view of the liquid ejection head according to the first embodiment, illustrating a conductor layer of the liquid ejection head.
[0025] FIG. **10** is a sectional view of the liquid ejection head taken along line X-X in FIG. **9**.
[0026] FIG. **11** is a schematic sectional view and illustrates potentials that are applied when liquid droplets are ejected from the liquid ejection head according to the first embodiment.
[0027] FIG. **12** is a schematic sectional view and illustrates potentials that are applied when poling process is conducted in the liquid ejection head according to the first embodiment.
[0028] FIG. **13** is a schematic sectional view of a liquid ejection head according to a second embodiment.
[0029] FIG. **14** is a schematic sectional view of a liquid ejection head according to a third embodiment.
[0030] FIG. **15** is a schematic sectional view of a liquid ejection head according to a fourth embodiment.
[0031] FIG. **16** is a schematic sectional view of a liquid ejection head according to a fifth embodiment.
[0032] FIG. **17**A is a sectional view of a variation of the piezoelectric layer.
[0033] FIG. **17**B is a sectional view of another variation of the piezoelectric layer.

DESCRIPTION OF EMBODIMENTS

[0034] Hereinafter, embodiments of the present disclosure will be described with reference to the accompanying drawings. The accompanying drawings are schematic representations. That is, not every detail may be illustrated in the drawings. Constituent elements are not drawn to scale, and the dimension ratios thereof do not fully correspond to the actual dimension ratios. The relative dimensions and the scale ratio may vary from drawing to drawing. For the purpose of emphasizing a particular shape, the outline of the shape may be illustrated in such a manner that a specific dimension looks greater than it really is.
[0035] Embodiments that follow a first embodiment will be principally described with a focus on their distinctive features only. Unless otherwise noted, these embodiments may be equated with the previously described embodiment or may be understood by analogy to the previously described embodiment. Each element in an embodiment and the corresponding element in another embodiment may be denoted by the same reference sign, irrespective of possible specific differences therebetween.
[0036] The term “similar” may be taken to mean “similar figures” in mathematics but is not limited thereto. In mathematics, two figures are similar figures if one figure whose size is changed by enlargement or reduction (or whose scale remains unchanged) is congruent with the other. In the present disclosure, two figures may also be considered similar figures if their relationship is closely analogous to mathematical similarity when viewed rationally in light of common general technical knowledge. For example, two ellipses are not mathematically similar to each other if one ellipse is located within or outside the other with a constant distance between the peripheries of the ellipses. The reason for this is that the ratio of the major axis to the minor axis of one ellipse is different from that of the other ellipse. The geometrical relationship between these ellipses may be herein considered as similarity.

[0037] The terms used herein to describe various shapes (e.g., circular, elliptic, and rectangular) may be taken to mean the shapes in mathematics but are not limited thereto. For example, the term "elliptic" may be used herein to describe a shape defined by only a curve protruding outward with the longitudinal direction being substantially orthogonal to the short-side direction. The term "rectangular" may be used herein to describe a shape whose corners are chamfered.

First Embodiment

(Overall Configuration of Printer)

[0038] FIG. **1**A is a schematic side view of a color ink jet printer **1**, which is an example of a recording apparatus and includes liquid ejection heads **2** according to an embodiment of the present disclosure. The color ink jet printer **1** and each liquid ejection head **2** may be hereinafter simply referred to as a printer and a head, respectively. FIG. **1**B is a schematic plan view of the printer **1**.

[0039] With regard to the heads **2** or the printer **1**, any direction may be defined as the vertical direction. For convenience, the up-and-down direction on the drawing plane of FIG. **1**A may be defined as the vertical direction in relation to, for example, the terms "upper surface" and "lower surface". Unless otherwise specified, the terms "plan view" and "seen-through plan view" herein mean that an object of interest is viewed in the up-and-down direction on the drawing plane of FIG. **1**A.

[0040] The printer **1** causes printing paper P to move relative to the heads **2**. More specifically, the printing paper P, which an example of a recording medium, is transferred from a paper feed roller **80**A to a take-up roller **80**B. Various kinds of rollers, such as the paper feed roller **80**A and the take-up roller **80**B, constitute a transfer module **85**, which enables the printing paper P to move relative to the heads **2**. The individual rollers will be described later. The heads **2** are controlled by a controller **88** on the basis of print data that may be image or textual data. The controller **88** causes the heads **2** to eject liquid toward the printing paper P in such a manner that liquid droplets are ejected onto the printing paper P. A printed record of the data is produced on the printing paper P accordingly.

[0041] The printer **1** in the present embodiment is a line printer, where the heads **2** are fixed to the printer **1**. In some embodiments, the recording apparatus is a serial printer, which ejects liquid droplets and conveys a sheet of paper in an alternating manner. The liquid droplets are ejected from the heads **2** moving in a direction forming an angle with the direction of conveyance of the printing paper P (e.g., a direction perpendicular to the direction of conveyance of the printing paper P).

[0042] The printer **1** includes four head mounting frames, each of which is denoted by **70** and may be hereinafter simply referred to as a frame. The head mounting frames are each in the form of a flat plate and is fixed to the printer **1** in a manner so as to be substantially parallel to the printing paper P. The frames **70** each have five holes (not illustrated), to which five heads **2** are fitted; that is, each of the heads **2** is fitted to the corresponding one of the holes. The five heads **2** mounted on one frame **70** belongs to a head group **72**. The printer **1** includes four head groups **72**; that is, twenty heads **2** in total are provided.

[0043] The heads **2** each have an ejection region from which liquid is ejected. The heads **2** are mounted on the frames **70** in such a manner that their respective ejection regions face the printing paper P. The heads **2** may be at a distance of about 0.5 to 20 mm from the printing paper P.

[0044] The twenty heads **2** may be connected directly to the controller **88** or may be connected to the controller **88** via one or more distribution modules located therebetween. The one or more distribution modules distribute print data. For example, the controller **88** transmits print data to a distribution module, which then distributes the print data to the twenty heads **2**. Alternatively, the controller **88** distributes print data to four distribution modules, each of which then distributes the print data to the five heads **2** in the corresponding one of the head groups **72**.

[0045] The heads **2** are narrow and strip-shaped. Each head **2** extends from the front to the back on the drawing plane of FIG. **1**A. In other words, the longitudinal direction of each head **2** coincides with the up-and-down direction in FIG. **1**B. Each head group **72** includes: three heads **2** aligned in

a direction forming an angle with the direction of conveyance of the printing paper P (e.g., a direction perpendicular to the direction of conveyance of the printing paper P); and two heads **2** each being located between adjacent ones of the three heads **2** in a manner so as not to be in alignment with the three heads **2** in the direction of conveyance. In other words, the heads **2** in each head group **72** are arranged in a staggered pattern. The heads **2** are arranged in such a manner that their respective printable ranges lie with no gap therebetween in the width direction of the printing paper P, that is, in the direction forming an angle with the direction of conveyance of the printing paper P or in such a manner that peripheral portions of the printable ranges overlap each other. This arrangement enables printing with no blank spaces in the width direction of the printing paper P.
[0046] The four head groups **72** are arranged in the direction of conveyance of the printing paper P. The heads **2** receive a supply of liquid (ink) from liquid supply tank (not illustrated). The heads **2** belonging to the same head group **72** receive a supply of ink of the same color. The four head groups **72** enable printing with inks of four different colors. For example, the head groups **72** eject magenta (M) ink, yellow (Y) ink, cyan (C) ink, and black (K) ink, respectively. These color inks are ejected onto the printing paper P, on which a color image is printed accordingly.
[0047] The printer **1** may include one head **2**, in which case an image within the printable range of the head **2** is to be printed in monochrome. The number of heads **2** in each head group **72** and the number of head groups **72** may be changed as appropriate, depending on what is to be printed and/or printing conditions. For example, a greater number of head groups **72** enable printing with more colors. Two or more head groups **72** arranged in alternating manner in the direction of conveyance to eject ink of the same color yield an increase in conveyance speed, with no performance variation between the heads **2**. The print area per unit time is increased accordingly. Two or more head groups **72** arranged in a manner so as not to be in positional agreement in a direction forming an angle with the direction of conveyance to eject ink of the same color yield an increase in resolution in the width direction of the printing paper P.
[0048] Instead of color inks, a coating agent in liquid form may be ejected uniformly or in specific patterns by the heads **2** to surface treat the printing paper P. For example, such a coating agent is to form a liquid receiving layer such that a liquid can set on a low-permeability recording medium. Alternatively, such a coating agent is to form a liquid permeation barrier layer such that a liquid is prevented from spreading too much on a high-permeability recording medium or from mixing too much with another liquid ejected onto an adjacent spot on the medium. It is not required that the coating agent be ejected from the heads **2**. The coating agent may be applied uniformly by a coater **76**, which is controlled by the controller **88**.
[0049] The printer **1** is designed for printing on the printing paper P, which is a recording medium. The printing paper P is winded up by the paper feed roller **80**A. The printing paper P on the paper feed roller **80**A is then fed into a path below the heads **2** mounted on the frames **70** and passes between two conveyer rollers **82**C. Finally, the printing paper P is taken up by the take-up roller **80**B. The conveyer rollers **82**C rotate in such a manner that the printing paper P is conveyed at a constant speed while the printing paper P is subjected the printing process carried out by the heads **2**.
[0050] The following describes the details of printer **1**. The printing paper P conveyed through the printer **1** undergoes the following processes, which will be described below in chronological order. Once the printing paper P is fed by the paper feed roller **80**A, the printing paper P passes between two guide rollers **82**A and then under the coater **76**. The coater **76** applies the coating agent to the printing paper P.
[0051] The printing paper P then enters a head chamber **74**, in which the frames **70** fitted with the heads **2** are accommodated. The printing paper P is taken in and discharged through openings, each of which is an interface between the internal space of the head chamber **74** and the outside; nevertheless, the head chamber **74** is substantially isolated from the outside. The temperature, humidity, and atmospheric pressure in the head chamber **74** are examples of control factors that are

controlled by, for example, the controller **88** when necessary. The head chamber **74** is less susceptible to external perturbations than the outside where the printer **1** is installed. Accordingly, the range of variation of each control factor is narrower in the head chamber **74** than on the outside.

[0052] The head chamber **74** accommodates five guide rollers **82**B. The printing paper P is conveyed over the guide rollers **82**B. When viewed laterally, the five guide rollers **82**B are disposed in such a manner that the midsection of each guide roller **82**B protrude toward an array of the frames **70**. Thus, the printing paper P conveyed over the five guide rollers **82**B are arc-shaped when viewed laterally. With the printing paper P being held under tension, portions of the printing paper P that are located between the guide rollers **82**B are flat. Two adjacent ones of the guide rollers **82**B are arranged side by side with one of the frames **70** being located therebetween. The frames **70** are oriented at slightly different angles in a manner so as to be parallel with the printing paper P conveyed under the frames **70**.

[0053] The printing paper P exits the head chamber **74**, passes between the two conveyer rollers **82**C, passes through a dryer **78**, passes between two guide rollers **82**D, and is then taken up by the take-up roller **80**B. The printing paper P may be conveyed at a speed of 100 m/min. Each roller may be controlled by the controller **88** or may be controlled manually.

[0054] Two or more sheets of printing paper P can be winded up together by the take-up roller **80**B after being dried by the dryer **78**, which reduces the possibility that the sheets of printing paper P will stick to each other or the possibility that wet liquid will become blurred by friction of the sheets of printing paper P. High-speed printing requires a high drying speed. The dryer **78** may achieve a high drying speed by employing different drying methods either sequentially or simultaneously. For example, drying by a jet of warm air, infrared radiation, or contact with a heated roller may be conducted. Infrared radiation in a specific frequency range enables quick drying of liquid without causing severe damage to the printing paper P. Conveying the printing paper P along the cylindrical surface of a heated roller can prolong the period over which heat is transferred to the printing paper P in contact with the roller. The dimension of the area of contact between the roller and the printing paper P in the direction of conveyance is preferably equal to or greater than ¼ of the circumference defined by the circumferential surface and is more preferably equal to or greater than ½ of the circumference. One or more UV radiation sources for printing with UV-curable ink UV may be used in place of the dryer **78** or in addition to the dryer **78**. Each of the UV radiation sources may be disposed between adjacent ones of the frames **70**.

[0055] The printer **1** may include a cleaning module for cleaning the heads **2**. The cleaning module is capable of performing wiping and/or capping to clean the heads **2**. Wiping is a process of rubbing a flexible wiper against, for example, an ejection surface **11***a* to remove a deposition of liquid from the surface. The ejection surface **11***a*, which will be described later, is a surface of a portion from which liquid is ejected. The cleaning process involving capping is as follows. For example, the ejection surface **11***a*, from which liquid is ejected, is covered with a cap. This step is called capping. The ejection surface **11***a* and the cap define a substantially hermetically sealed space. Ejection holes **3**, which will be described later, can be clogged with foreign matter and/or liquid that is more viscous than it is under standard conditions. In such a case, liquid may be repeatedly ejected into the space to unclog the ejection holes **3**. Capping eliminates or reduces the possibility that liquid ejected in the cleaning process will splatter on the printer **1** and will deposit on the printing paper P and/or on a conveyance mechanism including the rollers. Upon completion of the cleaning process, the ejection surface **11***a* may undergo wiping. The wiper and/or the cap fitted to the printer **1** may be handled manually to conduct wiping and/or capping for the cleaning process. Alternatively, the cleaning process may be carried out automatically under the control exercised by the controller **88**.

[0056] It is not required that the recording medium be the printing paper P. The recording medium may be cloth in roll form. It is not required that the printing paper P itself be conveyed. In some embodiments, the printer **1** includes a conveyer belt that carries a recording medium placed thereon. In this case, the recording medium may be cut-sheet paper, cut pieces of cloth, lumber, or tiles. Liquid containing electrically conductive particles may be ejected from the heads **2** to print wiring pattern for electric devices. A predetermined amount of chemical agent in liquid form or liquid containing a chemical agent may be ejected from the heads **2** into a reactor to cause a reaction that yields a chemical product.

[0057] The printer **1** may be equipped with a position sensor, a speed sensor, and/or a temperature sensor that provides information about conditions of modules of the printer **1** to the controller **88**, which can thus control the modules on the basis of the conditions. For example, liquid is ejected in accordance with a driving signal, which may be varied on the basis of information about factors affecting the liquid ejection performance (e.g., the ejection amount and/or the ejection rate). Examples of the factors include the temperature of each head **2**, the temperature of the liquid stored in the liquid supply tank for later ejection through the heads **2**, and the pressure exerted on the heads **2** by the liquid in the liquid supply tank.

(Ejection Surface)

[0058] FIG. **2** is a plan view of a representative of the heads **2**, illustrating part of its surface (the ejection surface **11***a*) facing the printing paper P. For convenience, the surface is illustrated with a Cartesian coordinate system defined by three axes, which are herein referred to as a D1 axis, a D2 axis, and a D3 axis, respectively. The D1 axis is parallel to the direction of transfer of the printing paper P relative to the head **2**. In the present embodiment, the D1 axis will be mentioned without distinction of positive and negative in relation to the direction of conveyance of the printing paper P relative to the head **2**. The D2 axis is parallel to the ejection surface **11***a* and the printing paper P and is orthogonal to the D1 axis. As with the D1 axis, the D2 axis will be mentioned without distinction of positive and negative. The D3 axis is orthogonal to the ejection surface **11***a* and the printing paper P. The printing paper P is located on the −D3 side (the front side of the drawing plane of FIG. **2**) with respect to the heads **2**. The D3 direction may be herein used to refer to either one of the +D3 direction (the direction toward the +D3 side) and the −D3 direction (the direction toward the −D3 side). FIG. **2** illustrates one end portion of the head **2** in the longitudinal direction, which is the D2 direction as mentioned above.

[0059] The ejection surface **11***a* of the head **2** may be flat and may be a major part of the surface facing the printing paper P. For example, the ejection surface **11***a* has a substantially rectangular shape whose longitudinal direction is the D2 direction. The ejection surface **11***a* has the ejection holes **3**, through which ink droplets are ejected. The ejection holes **3** are staggered in the direction (the D2 direction) orthogonal to the direction (the D1 direction) of transfer of the printing paper P relative to the head **2**. Ink droplets are ejected through the ejection holes **3** arranged as above while the printing paper P is moved relative to the head **2** by the transfer module **85**. Any desired two-dimensional image may be produced accordingly.

[0060] More specifically, the ejection holes **3** are arranged in an array with multiple rows. Referring to FIG. **2**, sixteen rows of ejection holes are provided. The rows of ejection holes **3** are herein referred to as ejection hole rows **5**. The ejection holes **3** in one ejection hole row **5** and the ejection holes **3** in another ejection hole row **5** are not in positional agreement with each other in the D2 direction. With the ejection holes **3** arranged as above, multiple dots may be formed on the printing paper P, where the dot-to-dot pitch in the D2 direction is smaller than the hole-to-hole pitch in each ejection hole row **5**. In some embodiments, the head **2** includes only one ejection hole row **5**.

[0061] The ejection hole rows **5** are substantially in parallel and are equal in length. Referring to FIG. **2**, the ejection hole rows **5** are in parallel in the direction (the D2 direction) orthogonal to the direction of transfer of the printing paper P relative to the head **2**. Alternatively, the ejection hole rows **5** may form an angle with the D2 direction. The ejection hole rows **5** in FIG. **2** are not equally spaced (in the D1 direction). This is for convenience of arrangement of flow paths in the head **2**. In some embodiments, the ejection hole rows **5** in FIG. **2** are equally spaced.

(Head Main Body)

[0062] FIG. **3** is a sectional view of the head **2** taken along line III-III in FIG. **2**. The printing paper P is to be located on the lower side of the drawing plane of FIG. **3**. FIG. **3** mainly illustrates one ejection hole **3** and elements located therearound. A portion being part of the head **2** and including the ejection surface **11***a* or, more specifically, a head main body **7** (one portion closer than the other portion to the ejection surface **11***a*) is illustrated in FIG. **3**. The head main body **7** itself may be regarded as a liquid ejection head.

[0063] The head main body **7** is a member that is substantially in the form of a plate, whose front or back surface is the ejection surface **11***a*. The thickness of the head main body **7** is, for example, not less than 0.5 mm and not more than 2 mm. The head main body **7** is a piezo head from which liquid is ejected in the form of droplets through application of pressure produced by the mechanical distortion of piezoelectric elements. The head main body **7** includes ejection elements **9**, which have the respective ejection holes **3**. The ejection elements **9** have basically the same structure. The same goes for elements relevant to the ejection elements **9** (e.g., wiring connected to the ejection elements **9**). The ejection elements **9** are arranged two-dimensionally along the ejection surface **11***a*.

[0064] When viewed from another perspective, the head main body **7** includes a channel member **11** and a piezoelectric actuator **13**. The channel member **11** is substantially in the form of a plate. The inside of the channel member **11** includes a channel through which liquid (ink) flows. The piezoelectric actuator **13** applies pressure to the liquid flowing through the channel member **11**. Each ejection element **9** includes the corresponding channel member **11** and the corresponding piezoelectric actuator **13**. The channel member **11** has the ejection surface **11***a*. The other surface of the channel member **11**, that is, the surface opposite the ejection surface **11***a* is hereinafter referred to as a pressure applying surface **11***b*.

[0065] The channel member **11** includes at least one common channel **15** and discrete channels **17** therein. The discrete channels **17**, one of which is illustrated in FIG. **3**, are connected to the common channel **15**. The discrete channels **17** are provided with the respective ejection holes **3**. The discrete channels **17** are also each provided with a connection channel **19**, a pressure chamber **21**, and a segmented channel **23**, which are arranged in this order in the direction of flow from the common channel **15** to the ejection hole **3**.

[0066] The discrete channels **17** and the common channel **15** are filled with liquid. The liquid under the pressure caused by changes in the volumetric capacity of the pressure chambers **21** flows out of the pressure chambers **21** into the segmented channels **23** and is then ejected in the form of droplets through the ejection holes **3**. The pressure chambers **21** are refilled with liquid that flows through the common channel **15** and is then fed into the pressure chambers **21** through the connection channels **19**. The liquid in the pressure chambers **21** is subjected to pressure applied by bending and distortion of the piezoelectric actuator **13** (piezoelectric elements **27**). For example, the piezoelectric actuator **13** is bent and distorted toward the pressure chambers **21**, and/or the piezoelectric actuator **13** becomes flat again after being bent away from the pressure chambers **21**.

[0067] The channel member **11** includes plates stacked in layers. The plates are denoted by **25**A to **25**J (or by **25** without the alphabets A to J). The plates **25** have holes that constitute the discrete channels **17** and the common channel **15**. Although the holes are through-holes in most cases, the holes may be recesses. The thickness of each plate **25** and the number of plates **25** may be set as appropriate in accordance with, for example, the shape of the discrete channels **17** and the shape of the common channel **15**. The plate **25** may be made of any desired material. For example, the plates **25** are made of metal or resin. The thickness of each plate **25** is, for example, not less than 10 μm and not more than 300 μm. The plates **25** are fixed to each other with an adhesive (not illustrated) therebetween.

(Channel Shape)

[0068] The channels in the channel member **11** each may have any specific desired shape and

desired dimensions. The shape and dimension of each channel in the illustrated example are as follows.
[0069] The common channel **15** extends in the longitudinal direction of the head **2** (i.e., the direction passing through the drawing plane of FIG. **3**). One or more common channels **15** may be provided. For example, the common channels **15** extend in parallel. The common channels **15** are rectangular when viewed in cross section.
[0070] The discrete channels **17** (the ejection elements **9**) are aligned in the longitudinal direction of the common channels **15**. The ejection holes **3** included in the discrete channels **17** are aligned along the common channels **15** accordingly. With the ejection holes **3** being arranged as illustrated in FIG. **2**, two opposite sides of each common channel **15** may each be adjacent to two rows of ejection holes **3**. Four common channels **15** may be provided, in which case the ejection holes **3** may be arranged in sixteen rows in total.
[0071] The pressure chambers **21** each have an opening defined in the pressure applying surface **11***b* and are closed with the piezoelectric actuator **13**. Alternatively, the pressure chambers **21** may be closed with one of the plates **25**. When viewed from another perspective, the plate **25** with which the pressure chambers **21** are closed may be regarded as part of either the channel member **11** or the piezoelectric actuator **13**. The layers (plates) located on or above the top of each pressure chamber **21** are regarded as part of the piezoelectric actuator **13**.
[0072] The pressure chambers **21** are geometrically identical to each other. The pressure chambers **21** may have any desired shape. For example, each of the pressure chambers **21** has a thin shape with a constant thickness and extends along the pressure applying surface **11***b*. The pressure chamber **21** may include portions of different thicknesses. The thin shape herein refers to a shape whose thickness is smaller than any diameter of the shape viewed in plan.
[0073] The diameter can be defined as the distance of a segment that is located within a planar figure and that extends across the planer figure in a manner so as to pass through its center. Unless otherwise specified, the term “center” (or “middle”) of a figure viewed in plan (i.e., the center of a planar figure of interest) herein refers to the centroid. The centroid is the center of gravity of the planar figure and is the point where the geometrical moment of area relative to an axis passing through the point becomes zero.
[0074] The shape of each pressure chamber **21** viewed in plan may be a rhombus or an ellipse, whose longitudinal direction and short-side direction are orthogonal to each other. Alternatively, each pressure chamber **21** viewed in plan may have a circular shape or any other shape, where there is no distinction between the longitudinal direction and the short-side direction. The pressure chambers **21** may be arranged in any desired manner in relation to the longitudinal direction and the short-side direction. The shape of each pressure chamber **21** in the present embodiment is a combination of a circle and an ellipse as will be described later. That is, there is a distinction between the longitudinal direction and the short-side direction with regard to the shape concerned. The longitudinal direction of the pressure chambers **21** in the illustrated example is the left-and-right direction in FIG. **3**. The direction concerned forms an angle with (e.g., orthogonal to) the direction in which the common channels **15** extend. When viewed from another perspective, the direction is the short-side direction of the head main body **7**.
[0075] If each pressure chamber **21** is sliced along the pressure applying surface **11***b*, sections of different shapes can appear one after another in the up-and-down direction, in which case the shape of the pressure chamber **21** in the pressure applying surface **11***b* (the opening of the pressure chamber **21**) viewed in plan may be herein regarded as the shape of the pressure chamber **21** viewed in plan. The reason for this is that the pressure applied to the pressure chamber **21** by the piezoelectric actuator **13** is greatly affected by the shape of the pressure chamber **21** in the pressure applying surface **11***b*.
[0076] Each segmented channel **23** extends from the corresponding pressure chamber **21** toward the ejection surface **11***a*. Each of the segmented channels **23** is substantially in the form of a

circular cylinder. The segmented channel **23** in the illustrated example extends from the pressure chamber **21** toward the ejection surface **11***a* in a manner so as to form an angle with the up-and-down direction. Alternatively, the segmented channel **23** may extend with no inclination from the up-and-down direction. The cross-sectional area of the segmented channel **23** may vary from place to place in the up-and-down direction. When viewed in plan, the segmented channel **23** is connected to an end portion in a predetermined direction of the pressure chamber **21** (e.g., in the longitudinal direction of the pressure chamber **21** viewed in plan).

[0077] Each ejection hole **3** defines an opening in a bottom surface of the corresponding segmented channel **23** or, more specifically, an opening in a surface opposite the pressure chamber **21**. The ejection hole **3** is substantially located at the center of the bottom surface of the segmented channel **23**. Alternatively, the ejection hole **3** may be off-center in the bottom surface of the segmented channel **23**. When viewed in longitudinal section, the ejection hole **3** is tapered down toward the ejection surface **11***a*. Alternatively, the ejection hole **3**, in part or in whole, may be reverse tapered.

[0078] The connection channel **19** includes: a portion that extends upward from an upper surface of the common channel **15**; a portion that extends along the plates **25** from the upwardly extending portion; and a portion that extends upward from the portion extending along the plates **25** and is connected to a lower surface of the pressure chamber **21**. The portion extending along the plates **25** acts as flow restriction, where the cross sectional area of the portion is made smaller in the direction orthogonal to the direction of flow. When viewed in plan, the connection channel **19** is connected to an end portion of the lower surface of the pressure chamber **21** in a manner so as to be located opposite the segmented channel **23** with respect to the center of the lower surface of the pressure chamber **21**.

[0079] The arrangement of the pressure chambers **21** may be understood as substantially analogous to the arrangement of the ejection holes **3** described above with reference to FIG. **2**. In some embodiments, the arrangement of the pressure chambers **21** is not analogous to the arrangement of the ejection holes **3**. For example, the segmented channels **23** may have different shapes, which can cause a difference between the arrangement of the pressure chambers **21** and the arrangement of the ejection holes **3**. Unlike the ejection holes **3** in FIG. **3**, the pressure chambers **21** may be arranged uniformly in both the D1 direction and the D2 direction (with a constant pitch between rows of the pressure chambers **21**). The rows of the pressure chambers **21** may be fewer than the ejection hole rows **5**.

(Shape of Pressure Chamber Viewed in Plan)

[0080] FIG. **4** is a plan view of the pressure chamber **21**. The pressure chamber **21** is denoted by a solid line.

[0081] The shape of the pressure chamber **21** viewed plan is a combination of a region defined by a circle C**1** and regions R**2**. The regions R**2**, one of which is hatched, protrude from the circle C**1** to the respective sides in a predetermined direction (the up-and-down direction of the drawing plane). The regions R**2** are each defined by two peripheries, one of which is opposite the circle C**1** and is curved outward. The periphery is denoted by a solid line. For example, the curvature of the curve (the mean value of the curvature for the case in which the curve is a line of inconstant curvature) is greater than the curvature of the circle C**1**.

[0082] The shape of the pressure chamber **21** viewed in plan can be regarded as a combination of an overlap between the circle C**1** and an ellipse C**2** (the region enclosed with a dotted line) and regions (each being enclosed with a solid line and a dotted line) that do not overlap each other. When the circle C**1** and the ellipse C**2** are regarded as closed curves in a Venn diagram, the shape of the pressure chamber **21** viewed in plan is the union (logical disjunction) of the circular region and the elliptic region.

[0083] More specifically, the center of the circle C**1** coincides with the center of the ellipse C**2** (see the center denoted by O**1**). The major axis of the ellipse C**2** is longer than the radius of the circle C**1**; that is, rL is longer than r1. The minor axis of the ellipse C**2** is shorter than the radius of the circle C**1**; that is, rS is shorter than r1. The regions R**2** on the respective sides in the longitudinal direction of the ellipse C**2** are located outside the circle C**1**.

[0084] The curvature of the periphery of each region R**2** opposite the circle C**1** (the periphery denoted by a solid line) may be constant. In other words, it is not required that the regions R**2** be regarded as both ends of an ellipse, and each region R**2** may be regarded as part of a circle whose radius is smaller than the radius of the circle C**1**.

[0085] The dimensions of these shapes (e.g., relative lengths of the radius r1, the major axis rL, and the minor axis rS) may be set to desired values. Specific examples are as follows. The major axis rL is not less than 1.2 times the radius r1 and not more than 1.8 times the radius r1. The curvature radius derived from the mean value of the curvature of the periphery of each region R**2** opposite the circle C**1** is not less than 0.3 times the radius r1 and not more than 0.6 times the radius r1.

[0086] The periphery of the pressure chamber **21** having the shape described above is mostly (or entirely) arc-shaped. For example, the periphery of the pressure chamber **21** includes a circular arc that subtends an angle of 180° or more at the center of the pressure chamber **21**.

[0087] The terms “midsection” and “peripheral section” are hereinafter used in relation to the pressure chamber **21**. The pressure chamber **21** has a midsection **21***a*. Referring to FIG. **4**, the outer edge of the midsection **21***a* is denoted by the dash-dot-dot line Ln**1**. When viewed in plan, the center O**1** of the pressure chamber **21** is located in the midsection **21***a*, and the periphery of the pressure chamber **21** is farther than the outer edge of the midsection **21***a* from the center O**1**. The pressure chamber **21** has a peripheral section **21***b*. Referring to FIG. **4**, the inner edge of the peripheral section **21***b* is denoted by the dash-dot-dot line Ln**1**, and the outer edge of the peripheral section **21***b* coincides with the solid line denoting the periphery of the pressure chamber **21**. When viewed in plan, the peripheral section **21***b* touches (essentially the entirety of) the periphery of the pressure chamber **21** and is located away from the center of the pressure chamber **21**.

[0088] The midsection **21***a* and the peripheral section **21***b* may be defined as follows: the outer edge of the midsection **21***a* and the inner edge of the peripheral section **21***b* are discretely located away from each other. Alternatively, the outer edge of the midsection **21***a* and the inner edge of the peripheral section **21***b* may coincide with each other. Still alternatively, the peripheral portion of the midsection **21***a* and the inner edge portion of the peripheral section **21***b* may overlap each other. For convenience, embodiments will be described in which the midsection **21***a* and the peripheral section **21***b* are defined in such that the outer edge of the midsection **21***a* and the inner edge of the peripheral section **21***b* coincide with each other.

[0089] The midsection **21***a* and the peripheral section **21***b* each may have any desired shape and desired dimensions when viewed in plan. For convenience, the position and dimensions of the midsection **21***a* and the position and dimensions of the peripheral section **21***b* may be herein used as a reference against which to compare the positions and dimensions of modules or members that will be described later (e.g., various kinds of electrodes that will be described later). The converse of the above is possible for actual product design, where the positions and dimensions of the modules or members may be used as a reference for specifying the position and dimensions of the midsection **21***a* and the position and dimensions of the peripheral section **21***b*. Thus, the shape and dimensions of the midsection **21***a* and the shape and dimensions of the peripheral section **21***b* may be understood by analogy to the shapes and dimensions of the modules or members that will be described later.

[0090] The region whose inner edge is the periphery of the pressure chamber **21** and whose outer edge is denoted by a dash-dot-dot line Ln**2** in FIG. **4** may be hereinafter referred to as an outer region **11***e* located outside the pressure chamber **21**. Although a region in which the pressure chamber **21** is not located may be regarded as an outer region (located outside the pressure chamber **21**) in a broader sense, adjacent areas of the pressure chamber **21** may be hereinafter specifically referred to as the outer region **11***e*. Thus, the shape and dimensions of the outer region **11***e* may be understood by analogy to the shapes and dimensions of the modules or members that will be described later.

(Piezoelectric Actuator)

[0091] Referring back to FIG. **3**, the piezoelectric actuator **13** is substantially in the form of a flat plate and is large enough to extend across all of the pressure chambers **21**. The piezoelectric actuator **13** has a first surface **13***a* and a second surface **13***b*, which are a front surface and a back surface respectively of the plate-like shape. In the present embodiment, the first surface **13***a* is located opposite the channel member **11**, and the second surface **13***b* is closer than the first surface **13***a* to the channel member **11**. The piezoelectric actuator **13** includes piezoelectric elements **27**, each of which applies pressure to the corresponding one of the ejection elements **9** (the corresponding one of the pressure chambers **21**). The piezoelectric elements **27** of the piezoelectric actuator **13** are arranged along the first surface **13***a*.

[0092] The piezoelectric actuator **13** includes two or more members extending along the second surface **13***b* and stacked in layers. Specifically, the piezoelectric actuator **13** includes first to fourth piezoelectric layers, which are denoted by **29**A to **29**D and are hereinafter also simply referred to as piezoelectric layers **29**. The first to fourth piezoelectric layers (the piezoelectric layers **29**A to **29**D) are arranged in this order from closest to the first surface **13***a* (i.e., in order farthest from the second surface **13***b*). The piezoelectric actuator **13** also includes first to fifth conductor layers, which are denoted by **31**A to **31**E and are hereinafter also simply referred to as conductor layers **31**. The first to fifth conductor layers (the conductor layers **31**A to **31**E) are located on or between the piezoelectric layers **29** and are arranged in this order from the closest to the first surface **13***a* (i.e., in this order from the farthest from the second surface **13***b*). The piezoelectric actuator **13** may include an insulating layer (not illustrated) that covers the first conductor layer **31**A. For example, the insulating layer is a solder resist.

[0093] The piezoelectric layers **29** extend over the pressure chambers **21** (the piezoelectric elements **27**) substantially with no gap between one part and another part of each piezoelectric layer **29**. The term “substantially” implies that through-conductors may extend through the piezoelectric layer **29** (insulating layer) to form a connection between the conductor layers. The same applies hereinafter. The through-conductors will be described later. The conductor layers **31** have any desired planar shape. For example, the conductor layers **31** include electrodes, each of which is provided for the corresponding one of the pressure chambers **21**, as will be described later.

(Overview of Working Principle of Piezoelectric Actuator)

[0094] FIG. **5** is a schematic sectional view of the piezoelectric actuator **13** and an upper part of the channel member **11** (the plate **25**J). The section illustrated in FIG. **5** and the section illustrated in FIG. **3** (i.e., the section taken along line III-III in FIG. **2**) are oriented in different directions. For example, FIG. **5** illustrates a section taken along line V-V in FIG. **4**. Hatching lines for indicating a cut surface are not drawn in FIG. **5**. In the state illustrated in FIG. **5**, the piezoelectric actuator **13** is bent due to an electric field applied to a first active region **53**A and a second active region **53**B, as will be described later. Without an application of an electric field, the piezoelectric actuator **13** is substantially flat.

[0095] The first piezoelectric layer **29**A and the second piezoelectric layer **29**B in FIG. **3** are regarded (illustrated) as a primary piezoelectric layer **51**A (see FIG. **5**). The third piezoelectric layer **29**C and the fourth piezoelectric layer **29**D in FIG. **3** are regarded (illustrated) as a secondary piezoelectric layer **51**B (see FIG. **5**). The primary piezoelectric layer **51**A and the secondary piezoelectric layer **51**B are simply referred to as piezoelectric layers **51** when there is no need to distinguish one from another.

[0096] The piezoelectric layers **51** each include active regions **53** (**53**A and **53**B) and inactive regions **55** (**55**A to **55**C) (see FIG. **6** for the location of the inactive region **55**C). When liquid droplets are ejected, the active regions **53** are activated, whereas the inactive regions **55** are not activated. The active regions **53** are polarized regions, and an electric field is applied to the active regions **53** in the polarization direction or in the direction opposite the polarization direction when

liquid droplets are ejected. The inactive regions **55** are unpolarized regions, and/or an electric field is applied neither in the polarization direction nor in the direction opposite the polarization direction when liquid droplets are ejected. The polarized regions are areas in which the direction of spontaneous polarization is made somewhat uniform by poling process.
[0097] More specifically, the primary piezoelectric layer **51**A includes the first active region **53**A and a first inactive region **55**A, which are adjacent to each other. The first active region **53**A extends over the midsection **21***a* of the pressure chamber **21** in a see-through plan view. The first inactive region **55**A is on the outer side with respect to the first active region **53**A. The secondary piezoelectric layer **51**B includes a second inactive region **55**B and the second active region **53**B, which are adjacent to each other. The second inactive region **55**B extends over the midsection **21***a* of the pressure chamber **21** in a see-through plan view. The second active region **53**B is on the outer side with respect to the second inactive region **55**B. When viewed from another perspective, the first inactive region **55**A and the second active region **53**B extend over the peripheral section **21***b* of the pressure chamber **21** and the outer region **11***e* located outside the pressure chamber **21** in a see-through plan view.
[0098] The polarization direction of the first active region **53**A is the thickness direction (i.e., the D3 direction). When an electric field is applied to the first active region **53**A in the direction that coincides with the polarization direction, the first active region **53**A contracts along the surface. The direction of contract is denoted by arrows in FIG. **5**. The term "electric field" may be read as voltage. The same applies hereinafter. Meanwhile, the second inactive region **55**B does not contract. As a result, the first active region **53**A and the second inactive region **55**B as a whole, like a bimetal, undergo bending and deformation. As denoted by arrows on both ends of the portion concerned, these regions are bent toward the pressure chamber **21**.
[0099] The polarization direction of the second active region **53**B is the thickness direction (i.e., the D3 direction). When an electric field is applied to the second active region **53**B in the direction that coincides with the polarization direction, the second active region **53**B contracts along the surface. The direction of contract is denoted by arrows in FIG. **5**. Meanwhile, the first inactive region **55**A does not contract. As a result, the second active region **53**B and the first inactive region **55**A as a whole, like a bimetal, undergo bending and deformation. As illustrated in FIG. **5**, these regions are bent toward the pressure chamber **21** (see FIG. **5**).
[0100] The second active region **53**B and the first inactive region **55**A include the respective portions that are located outside the pressure chamber **21** and joined to the plate **25**J. The portions are thus restrained from undergoing bending and deformation. One of the portions that belongs to the second active region **53**B may also be referred to as a second portion **53**Bb. The other portion of the second active region **53**B and the other portion of the first inactive region **55**A overlap the pressure chamber **21**. One of the portions that belongs to the second active region **53**B may be referred to as a first portion **53**Ba. When the second active region **53**B and the first inactive region **55**A undergo bending and deformation in a manner so as to be bowed toward the pressure chamber **21**, the portions concerned act as cantilevers and are bent toward the pressure chamber **21** as illustrated in FIG. **5**. Consequently, the first active region **53**A and the second inactive region **55**B undergo displacement toward the pressure chamber **21**.
[0101] The application of an electric field to the first active region **53**A in the polarization direction and the application of an electric field to the second active region **53**B in the polarization direction cause the central position of the first active region **53**A to shift further toward the pressure chamber **21** than would be possible by the application of an electric field to only the first active region **53**A in the polarization direction. Consequently, the volumetric capacity of the pressure chamber **21** is further decreased. Conversely, the volumetric capacity of the pressure chamber **21** may be increased in the following manner: an electric field is applied to the first active region **53**A in the direction opposite the polarization direction, and an electric field is applied to the second active region **53**B in the direction opposite the polarization direction, in which case the first active region

53A and the second active region **53**B expand along the surface. Consequently, the central position of the first active region **53**A undergoes a larger displacement, and the volumetric capacity of the pressure chamber is further increased accordingly.

[0102] A neutral plane that may be defined in relation to the flexural rigidity of the piezoelectric actuator **13** may be located at any desired position in the thickness direction. For example, the neutral plane is substantially in the interface between the primary piezoelectric layer **51**A and the secondary piezoelectric layer **51**B. The allowable distance between the interface and the neutral plane may be less than ¼ of the thickness of the primary piezoelectric layer **51**A or the secondary piezoelectric layer **51**B, whichever is thinner.

(Shapes of Active Regions and Inactive Regions Viewed in Plan)

[0103] The shape of each active region **53** is not necessarily uniform throughout in the thickness direction (i.e., the D3 direction) when the piezoelectric actuator has a specific structure. As will be mentioned below, the first piezoelectric layer **29**A and the second piezoelectric layer **29**B that are included in the first active region **53**A in the present embodiment may have different shapes when viewed in plan. In the following example, the shape of each active region **53** (or each inactive regions **55**) viewed in plan is substantially uniform throughout in the thickness direction. In another example (not illustrated), the shape of each active region **53** (or each inactive region **55**) viewed in plan is not uniform throughout in the thickness direction. In such a case, the following description about the planar shape is applicable to the planar shape at any position in the thickness direction, such as the planar shape with the smallest area in a see-through plan view.

[0104] In a see-through plan view, the first inactive region **55**A and/or the second active region **53**B surrounds the first active region **53**A and/or the second inactive region **55**B. More specifically, the first inactive region **55**A and/or the second active region **53**B extends all along the periphery of the first active region **53**A and/or the periphery of the second inactive region **55**B. In some embodiments, the first inactive region **55**A and/or the second active region **53**B extends along only part of the periphery of the first active region **53**A and/or part of the periphery of the second inactive region **55**B. For example, the angle subtended by the first inactive region **55**A and/or the second active region **53**B at the center of the first active region **53**A and/or the second inactive region **55**B is not less than 270° and not more than 360°.

[0105] In a see-through plan view, (the outer edge portion of) the first active region **53**A and (the inner edge portion of) the second active region **53**B may be discretely located away from each other, may be adjacent to each other (as in the illustrated example), or may overlap each other. When viewed from another perspective, the first active region **53**A and the second inactive region **55**B on the inner side with respect to the second active region **53**B have the same shape and are equal in dimension (as in the illustrated example), or the first active region **53**A and the second inactive region **55**B have different shapes and are not equal in dimension. Likewise, the first inactive region **55**A on the outer side with respect to the first active region **53**A and the second active region **53**B have the same shape and are equal in dimension (as in the illustrated example), or the first inactive region **55**A and the second active region **53**B have different shapes and are not equal in dimension.

[0106] For convenience, the midsection **21***a* of the pressure chamber **21** in the present embodiment is defined such that the outer edge of the first active region **53**A and the outer edge of the midsection **21***a* of the pressure chamber **21** coincide with each other. For convenience, the midsection **21***a* and the peripheral section **21***b* in the present embodiment are defined in such that they are adjacent to each other, as mentioned above. Thus, the first active region **53**A does not overlap the peripheral section **21***b* of the pressure chamber **21**. The second active region **53**B extends over at least the outer edge portion or the entirety of the peripheral section **21***b* and does not extend over the center or the entirety of the midsection **21***a*. As mentioned above, the outer edge portion of the first active region **53**A and the inner edge portion of the second active region **53**B may be located with or without an overlap therebetween. Thus, the second active region **53**B may extend over the peripheral section **21***b* except for the inner edge portion thereof, may extend over the entirety of the peripheral section **21***b* (as in the illustrated example), or may extend over the peripheral section **21***b* and the peripheral portion of the midsection **21***a*.

[0107] The first active region **53**A may have any desired planar shape and desired dimensions (see the shape and the dimensions of the midsection **21***a* in FIG. **4**). The planar shape of the first active region **53**A may be geometrically similar to the planar shape of the pressure chamber **21** (as in the illustrated example) or may be geometrically different from the planar shape of the pressure chamber **21**. In either case, the planar shape of the first active region **53**A may be understood as analogous to the planar shape of the pressure chamber **21**. In a see-through plan view, the center of the first active region **53**A may be substantially in positional agreement with the center of the pressure chamber **21** (as in the illustrated example), or the center of the first active region **53**A may be off the center of the pressure chamber **21**.

[0108] The first active region **53**A viewed in plan may have any desired size. In a see-through plan view, the proportion of the area of the first active region **53**A in the area of the pressure chamber **21** is not less than 40% or not less than 50% and is not more than 70% or not more than 80%. Any desired combination of these lower and upper limits may be applied. For example, the proportion is not less than 50% and not more than 70%. The diameter of the first active region **53**A is not less than 0.6 times or not less than 0.7 times the diameter of the pressure chamber **21** and is not more than 0.9 times the diameter of the pressure chamber **21**, where the diameters are measured in the same direction. Any desired combination of these lower and upper limits may be applied. In a case where the first active region **53**A and the pressure chamber **21** are not circular in cross section, the word "diameter" may be read as "equivalent circle diameter".

[0109] The second active region **53**B may have any desired planar shape and desired dimensions (see the shape and the dimensions of an annular region defined by the dash-dot-dot line Ln**1** and the dash-dot-dot line Ln**2** in FIG. **4**). When viewed in plan, the second active region **53**B is an annular region with which the first active region **53**A is surrounded. The term "annular" does not necessarily mean that the region is circular or elliptic. For example, the inner edge and/or the outer edge of the annular region may be uneven and/or may be polygonal (e.g., rectangular).

[0110] The inner edge and/or the outer edge of the second active region **53**B may be geometrically similar to the planar shape of the pressure chamber **21** and/or the planar shape of the first active region **53**A (as in the illustrated example) or may be geometrically different from the planar shape of the pressure chamber **21** and/or the planar shape of the first active region **53**A. In either case, the inner edge and the outer edge of the second active region **53**B may be understood as analogous to the planar shape of the pressure chamber **21**. In a see-through plan view, the center of the shape defined by the outer edge of the second active region **53**B may be substantially in the positional agreement with the center of the pressure chamber **21** and/or the center of the first active region **53**A (as in the illustrated example), or the center of the shape defined by the outer edge of the second active region **53**B may be off the center of the pressure chamber **21** and/or the center of the first active region **53**A.

[0111] In a see-through plan view, the outer edge of the first active region **53**A and the inner edge of the second active region **53**B may be located with any desired distance therebetween. For example, the distance is not less than 10% or not less than 5% of the diameter (e.g., the minimum diameter, the maximum diameter, or the equivalent circle diameter) of the first active region **53**A. The upper limit value is applicable to both of the following cases: (i) the outer edge of the first active region **53**A is located on the inner side with respect to the inner edge of the second active region **53**B; and (ii) the outer edge of the first active region **53**A is located on the outer side with respect to the inner edge of the second active region **53**B.

[0112] The outer edge of the second active region **53**B may be located at any desired distance from the periphery of the pressure chamber **21**. For example, the distance is not less than 1/20, 1/10, or ⅕ of the diameter (e.g., the minimum diameter, the maximum diameter, or the equivalent circle diameter) of the pressure chamber **21**. The distance is not more than the diameter of the pressure chamber **21** or is not more than ½, ⅓, or ⅕ of the diameter of the pressure chamber **21**. Any desired combination of these lower and upper limits may be applied unless there is a contradiction between them. The diameter of the pressure chamber **21** may be equal to or greater than 200 μm and equal to or less than 400 μm, in which case the distance between the periphery of the pressure chamber **21** and the outer edge of the second active region **53**B may be equal to or greater than 50 μm and equal to or less than 200 μm.

[0113] Referring to FIG. **4**, w1 may be greater or less than w2, where w1 denotes the distance between the periphery of the pressure chamber **21** and the inner edge of the second active region **53**B, and w2 denotes the distance between the periphery of the pressure chamber **21** and the outer edge of the second active region **53**B. The distance w1 may also be regarded as the width of the first portion **53**Ba, which is part of the second active region **53**B and extends over part of the pressure chamber **21**. The distance w2 may also be regarded as the width of the second portion **53**Bb, which is part of the second active region **53**B and is located outside the pressure chamber **21**. Although the distances w1 and w2 are defined as above in relation to the plan view, a comparison of the distance w1 and the distance w2 may be made on a (cross-) section (see FIG. **3**) passing through the center of the pressure chamber **21** and orthogonal to the pressure applying surface **11***b*.

[0114] In the present embodiment, the distance w1 is shorter than the distance w2. The region in which the distance w1 is shorter than the distance w2 may extend all along the second active region **53**B in the circumferential direction or mostly along the second active region **53**B in the circumferential direction. Both of these cases may be herein construed as examples of the state in which the distance w1 is shorter than the distance w2. What is suggested here is that the second active region **53**B may include a portion having distinguishing characteristics arising from the shape of the pressure chamber **21** or the shape of wiring for proving potential to electrodes. When the region concerned extends mostly along the second active region **53**B in the circumferential direction, the angle subtended at the center of the pressure chamber **21** by the region is not less than 270°, not less 300°, or not less than 330°. With the distance w1 being shorter than the distance w2, the ratio of the distance w1 to the distance w2 may be set to any desired value. For example, the distance w1 is not more than 0.9 times, not more than 0.8 times, or not more than 0.7 times the distance w2.

[0115] In a see-through plan view, the area of the first portion **53**Ba may be greater or less than the area of the second portion **53**Bb, where the first portion **53**Ba is part of the second active region **53**B and extends over part of the pressure chamber **21**, and the second portion **53**Bb is part of the second active region **53**B and is located outside the pressure chamber **21**. In the present embodiment, the area of the first portion **53**Ba is less than the area of the second portion **53**Bb. The ratio of the area of the first portion **53**Ba to the area of the second portion **53**Bb may be set to any desired value. For example, the area of the first portion **53**Ba is not more than 0.9 times, not more than 0.8 times, or not more than 0.7 times the area of the second portion **53**Bb.

[0116] In a case where the shape of the first portion **53**Ba and the shape of the second portion **53**Bb are similar figures, the second portion **53**Bb is located on the outer side with respect to the first portion **53**Ba. The second portion **53**Bb is therefore longer in the circumferential direction than the first portion **53**Ba. When the distance w1 is equal to the distance w2, the area of the first portion **53**Ba is less than the area of the second portion **53**Bb. This suggests that there is a possible case (not illustrated) in which the area of the first portion **53**Ba is less than the area of the second portion **53**Bb when the distance w1 is greater than the distance w2.

[0117] As for products introduced on the market, the difference between the area of the first portion **53**Ba and the area of the second portion **53**Bb and the difference between the distance w1 and the distance w2 each may be measured by any desired means. For example, X-ray computed tomography (CT) may be employed to measure the area of each electrode and the misalignment between the electrode and the pressure chamber **21** without the need to disassemble the head main body **7**. The area of the first portion **53**Ba, the area of the second portion **53**Bb, the distance w1, and the distance w2 may be measured accordingly. Alternatively, sections obtained by cutting the head main body **7** may be observed under an electron microscope to measure the area of each electrode and the misalignment between the electrode and the pressure chamber **21**. The area of the first portion **53**Ba, the area of the second portion **53**Bb, the distance w1, and the distance w2 may be measured accordingly.

[0118] The first inactive region **55**A may be defined as a region being part of the primary piezoelectric layer **51**A and extending over the second active region **53**B in a see-through plan view, where the first inactive region **55**A does not overlap the first active region **53**A in the primary piezoelectric layer **51**A. Thus, the inner edge of the first inactive region **55**A coincides with the outer edge of the first active region **53**A, and the outer edge of the first inactive region **55**A coincides with the outer edge of the second active region **53**B. In the present embodiment, the outer edge of the first active region **53**A and the inner edge of the second active region **53**B substantially coincide with each other in a see-through plan view. Thus, the first inactive region **55**A and the second active region **53**B have substantially the same shape and are substantially equal in dimension when viewed in plan.

[0119] The second inactive region **55**B may be defined as a region being part of the secondary piezoelectric layer **51**B and extending over the pressure chamber **21**, where the second inactive region **55**B does not overlap the second active region **53**B in the secondary piezoelectric layer **51**B. In a case where the second active region **53**B is annular, the second inactive region **55**B is surrounded with the second active region **53**B, and the outer edge of the second inactive region **55**B coincides with the inner edge of the second active region **53**B.

(Piezoelectric Layers)

[0120] Referring back to FIG. **3**, the piezoelectric layers **29** may each be made of a ferroelectric ceramic material. Examples of the ceramic material include lead zirconate titanate (PZT) materials, NaNbO.sub.3 materials, BaTiO.sub.3 materials, (BiNa)TiO.sub.3 materials, and BiNaNb.sub.5O.sub.15 materials. It is not required that the piezoelectric layers **29** be made of a ceramic material. The piezoelectric layers **29** may each be made of a single-crystal material, a polycrystalline material, an inorganic material, an organic material, a ferroelectric material, a nonferroelectric material, a pyroelectric material, or a nonpyroelectric material. The piezoelectric layers **29** may be made of the same material or different materials.

[0121] The piezoelectric layers **29** each have a substantially constant thickness and extend substantially in a planar fashion. In other words, each piezoelectric layer **29** is in the form of a flat plate. Each piezoelectric layer **29** is substantially equal in area to the piezoelectric actuator **13**. The piezoelectric layers **29** may each have any desired thickness. The piezoelectric layers **29** may have the same thickness (as in the illustrated example) or may have different thicknesses. For example, the thickness of each piezoelectric layer **29** is not less than 10 μm and not more than 40 μm.

[0122] In the illustrated example, the piezoelectric layers **29** have the same thickness. When viewed from another perspective, the sum of the thickness of the third piezoelectric layer **29**C and the thickness of the fourth piezoelectric layer **29**D is greater than the thickness of the first piezoelectric layer **29**A and is also greater than the thickness of the second piezoelectric layer **29**B. The piezoelectric layers **29** may have different thicknesses, as long as this relation holds. With regard to two or more of the piezoelectric layers **29** of the same thickness, there may exist a thickness difference that falls within allowable tolerances. The same holds for the thickness of the conductor layers **31**.

[0123] FIG. **6** is a schematic sectional view and illustrates polarization directions of the piezoelectric layers **29**. As with FIG. **5**, FIG. **6** illustrates a section taken along line V-V in FIG. **4**. The polarization directions are indicated by hollow arrows. Hatching lines for indicating a cut surface are not drawn in FIG. **6**.

[0124] The piezoelectric actuator **13** includes the first active region **53**A, the second active region

53B, the first inactive region **55**A, and the second inactive region **55**B, which have been described above and are denoted by dotted lines. A region extending across the first to fourth piezoelectric layers (denoted by **29**A to **29**D) and located outside the first inactive region **55**A and the second active region **53**B is hereinafter referred to as a third inactive region **55**C.

[0125] In the first active region **53**A, the first piezoelectric layer **29**A and the second piezoelectric layer **29**B are polarized in opposite directions. When electric fields are applied to the first piezoelectric layer **29**A and the second piezoelectric layer **29**B in the first active region **53**A in opposite directions, the first piezoelectric layer **29**A and the second piezoelectric layer **29**B contract in conjunction with each other (see FIG. **5**) or expand in conjunction with each other.

[0126] In the first active region **53**A, one of the first piezoelectric layer **29**A and the second piezoelectric layer **29**B is polarized in the +D3 direction, and the other is polarized the −D3 direction. The first piezoelectric layer **29**A and the second piezoelectric layer **29**B in the present embodiment are polarized in the −D3 direction and the +D3 direction, respectively.

[0127] In the second active region **53**B, the third piezoelectric layer **29**C and the fourth piezoelectric layer **29**D are polarized in the same direction. When subjected to application of the same electric field, the third piezoelectric layer **29**C and the fourth piezoelectric layer **29**D in the second active region **53**B contract in conjunction with each other (see FIG. **5**) or expand in conjunction with each other.

[0128] The second active region **53**B is polarized in the +D3 direction or the −D3 direction. The polarization direction of the second active region **53**B coincides with the polarization direction of the first piezoelectric layer **29**A or the second piezoelectric layer **29**B in the first active region **53**A. In the present embodiment, the polarization direction of the second active region **53**B coincides with the polarization direction of the first piezoelectric layer **29**A in the first active region **53**A.

[0129] The inactive regions **55** (**55**A to **55**C) may be polarized or unpolarized. In the illustrated example, the first inactive region **55**A is polarized, whereas the second inactive region **55**B and the third inactive region **55**C are unpolarized.

[0130] The first inactive region **55**A is polarized in the thickness direction (i.e., the D3 direction). The first inactive region **55**A is polarized in either the +D3 direction or the −D3 direction, whichever is desired in relation to the polarization direction of the first active region **53**A and the polarization direction of the second active region **53**B. For example, the first inactive region **55**A and the second active region **53**B may be polarized in the same direction or in opposite directions. In the present embodiment, the polarization direction of the first inactive region **55**A coincides with the polarization direction of the second active region **53**B.

(Conductor Layers)

[0131] Referring back to FIG. **3**, the conductor layers are arranged as follows. The first conductor layer **31**A is located on an upper surface of the first piezoelectric layer **29**A. The second conductor layer **31**B is located between the first piezoelectric layer **29**A and the second piezoelectric layer **29**B. The third conductor layer **31**C is located between the second piezoelectric layer **29**B and the third piezoelectric layer **29**C. The fourth conductor layer **31**D is located between the third piezoelectric layer **29**C and the fourth piezoelectric layer **29**D. The fifth conductor layer **31**E is located between the fourth piezoelectric layer **29**D and the channel member **11** (the plate **25**J).

[0132] The conductor layers **31** may each be made of any desired metal. Examples of the metal include alloys of Ag and Pd and alloys of Au. The conductor layers **31** may be made of the same material or different materials. Each conductor layer **31** may be a monolithic layer of a single material or may include layers made of different materials and arranged in a stack. Each conductor layer **31** has no variation in material in the planar direction. Alternatively, each conductor layer **31** may include portions made of the respective materials.

[0133] The conductor layers **31** each have a substantially constant thickness and extend substantially in a planar fashion. The conductor layers **31** may each have any desired thickness. The conductor layers **31** may have the same thickness or may have different thicknesses. Each conductor layer **31** may be thinner than each piezoelectric layer **29**. For example, the thickness of each conductor layer **31** is not less than 0.5 μm and not more than 3 μm

(Shape of Conductor Layers)

[0134] FIGS. **7** and **8** are exploded perspective views of the piezoelectric actuator **13** and the upper part (the plate **25**J) of the channel member **11**. FIG. **7** illustrates a region that is part of the head main body **7** viewed in plan, and some of the piezoelectric elements **27** are located in the region. FIG. **8** illustrates a region in which one of the piezoelectric elements **27** is located. For convenience, surfaces of the conductor layers **31** are hatched.

[0135] Referring to FIGS. **7** and **8**, the piezoelectric actuator **13** includes individual plate members, each of which is a combination of two layers (the piezoelectric layer **29** and the conductor layer **31** on an upper surface (on the +D3 side) of the piezoelectric layer **29**) with the exception that the fifth conductor layer **31**E is illustrated as a discrete member. The four plate members are presented for convenience of illustration and are not necessarily prepared in the actual production process. For example, each conductor layer **31** may be disposed on a lower surface (on the −D3) of the corresponding piezoelectric layer **29** in the actual production process.

(First Conductor Layer)

[0136] The first conductor layer **31**A includes first electrodes **33** and reorientation electrodes **35**. For example, each of the first electrodes **33** and each of the reorientation electrodes **35** are provided for the corresponding one of the pressure chambers **21** (the piezoelectric elements **27**). When liquid droplets are ejected, the first electrodes **33** are involved in application of voltage to the first active region **53**A or, more specifically, a region being part of the first piezoelectric layer **29**A. When no liquid droplet is ejected, the reorientation electrodes **35** are involved in poling process to which the second inactive region **55**B is (partially or mostly) subjected. This reduces the possibility that the characteristics of the piezoelectric actuator **13** will degrade.

[0137] The first electrode **33** and the reorientation electrode **35** in each piezoelectric element **27** are separate from each other and are placed at the respective potentials independently of each other. The distance between the first electrode **33** and the reorientation electrode **35** may be set to any desired value. For example, the distance between the first electrode **33** and the reorientation electrode **35** may be as close as possible to each other without the occurrence of any short circuits.

(First Electrodes)

[0138] The first electrodes **33** are individual electrodes. The first electrodes **33** are geometrically and electrically separate from one another. The first electrodes **33** can thus be placed at different potentials.

[0139] The first electrodes **33** each include an electrode main part **33***a* and an extended part **33***b*. The electrode main part **33***a* is involved in application of voltage to the first active region **53**A. The extended part **33***b* forms a connection between the electrode main part **33***a* and external signal lines located outside the piezoelectric actuator **13**. The external signal lines (not illustrated) are in the form of a wiring pattern included in a flexible wiring board oriented toward the first surface **13***a* of the piezoelectric actuator **13**. The flexible wiring board is hereinafter also referred to as a flexible printed circuit (FPC). The term “first electrode” may refer to the electrode main part **33***a* only, in which case the extended part **33***b* may be regarded as wiring.

[0140] The electrode main part **33***a* and the first active region **53**A have substantially the same shape and are substantially equal in dimension when viewed in plan. Thus, the shape and dimensions of the electrode main part **33***a* viewed in plan may be understood as analogous to the shape and dimensions of the first active region **53**A viewed in plan. As mentioned above, the active regions **53** are polarized regions, and an electric field is applied to the active regions **53** when liquid droplets are ejected. The outer edge of the region included in the first active region **53**A and being part of the first piezoelectric layer **29**A coincides with the periphery of the electrode main part **33***a* or is located on the inner side with respect to the periphery of the electrode main part **33***a*.

[0141] In a see-through plan view, the extended part **33***b* extends from the electrode main part **33***a* to the outside of the pressure chamber **21**. For example, an end of the extended part **33***b* and the external signal lines are joined to each other at a site outside the pressure chamber **21**. The end is farther than the other end of the extended part **33***b* from the electrode main part **33***a*. The joining has little influence on the pressure applied to the pressure chamber **21** by the piezoelectric element **27**.

[0142] The extended part **33***b* each may have any specific desired shape and desired dimensions and may be placed at any desired position. For example, the extended part **33***b* extends in a straight line toward one side in a predetermine direction (e.g., in the D1 direction in the illustrated example) from one end of the electrode main part **33***a* that is closer than the other end of the electrode main part **33***a* to the one side. The predetermined direction may be any desired direction. The predetermined direction in the illustrated example is the longitudinal direction of the electrode main part **33***a*. The width of the extended part **33***b* may be substantially constant and may be smaller than the diameter (e.g., the minimum diameter) of the electrode main part **33***a*. The extended part **33***b* in another example (not illustrated) includes a bent portion or a curved portion. One part including an end of the extended part **33***b* farther than the other end of the extended part **33***b* from the electrode main part **33***a* may be wider than the other part of the extended part **33***b*. In a see-through plan view, the extended part **33***b* may be located within the shape defined by the outer edge of the second active region **53**B (as in the illustrated example) or extend off the outer edge.

(Reorientation Electrodes)

[0143] The reorientation electrodes **35** are geometrically and electrically separate from each other. The reorientation electrodes **35** are individual electrodes. As will be inferred from the following examples, the reorientation electrodes **35** may be placed at the same potential. That is, the first conductor layer **31**A in an example (not illustrated) includes wiring that forms a connection between adjacent ones of the reorientation electrodes **35**. In another example, the first conductor layer **31**A may include a reorientation electrode (analogous to the fourth conductor layer **31**D) that extends over the first piezoelectric layer **29**A except for the region overlaid with the first electrode **33**, with no gap between one part and another part of the reorientation electrode.

[0144] When viewed in plan, the region to which a voltage is applied by the reorientation electrode **35** may be substantially the entirety of the second inactive region **55**B or only part of the second inactive region **55**B (e.g., an inner edge portion, a middle portion, or an outer edge portion) or may include the second inactive region **55**B and the third inactive region **55**C.

[0145] The reorientation electrode **35** in the illustrated example is capable of applying a voltage to substantially the entirety of the first inactive region **55**A and does not apply a voltage to the third inactive region **55**C. In a see-through plan view, the shape of the reorientation electrode **35** is substantially in perfect agreement with the shape of the first inactive region **55**A. Thus, the shape and dimensions of the reorientation electrode **35** viewed in plan may be understood as analogous to the shape and dimensions of the first inactive region **55**A viewed in plan, with the following exception.

[0146] Unlike the first inactive region **55**A, the reorientation electrode **35** is C-shaped, with a clearance in the region in which the extended part **33***b* of the first electrode **33** is located. The term “C-shaped” does not necessarily mean that the inner edge and/or the outer edge is circular or elliptic, as in the case with the term “annular”.

[0147] A region being part of the first piezoelectric layer **29**A and located outside the electrode main part **33***a* viewed in plan is not subjected to application of voltage when liquid droplets are ejected. Thus, the region concerned is regarded as the first inactive region **55**A. The inner edge of the reorientation electrode **35** is on the outer side with respect to the outer edge of the electrode main part **33***a* with a clearance therebetween in such a manner as to eliminate the possibility that the reorientation electrode **35** will become shorted to the first electrode **33**. As mentioned above, the reorientation electrode **35** extends over substantially the entirety of the first inactive region

55A; nevertheless, the inner edge of the reorientation electrode **35** is closer than the inner edge of the region included in the first inactive region **55**A and being part of the first piezoelectric layer **29**A to the outer edge of the region concerned.

[0148] In other examples (not illustrated) in which the planar shape of the reorientation electrode **35** (except for the clearance) and the planar shape of the first active region **53**A are similar figures, the outer edge of the reorientation electrode **35** is located on the inner side or the outer side with respect to the outer edge of the first inactive region **55**A (i.e., the edge coinciding with the outer edge of the second active region **53**B as mentioned above). In other words, part of the outer edge portion of the first inactive region **55**A does not undergo the poling process, or the third inactive region **55**C as well as the first inactive region **55**A undergoes the poling process.

(Second Conductor Layer)

[0149] The second conductor layer **31**B includes second electrodes **37** and lines **39**. Each of the second electrodes **37** is provided for the corresponding one of the pressure chambers **21** (the piezoelectric elements **27**). Each of the lines **39** forms a connection between adjacent ones of the second electrodes **37**. When liquid droplets are ejected upon application of pressure to the pressure chambers **21**, the second electrodes **37** are involved in application of voltage to the first active region **53**A or, more specifically, to both the first piezoelectric layer **29**A and the second piezoelectric layer **29**B. The lines **39** are involved in application of potential to the second electrodes **37**.

(Second Electrodes)

[0150] The second electrodes **37** are geometrically separate from one another. When viewed from another perspective, no conductor is located between two adjacent ones of the second electrodes **37**. The second electrodes **37** are thus regarded as individual electrodes in terms of their geometric shapes. Unlike the first electrodes **33**, the second electrodes **37** are placed at the same potential due to the presence of the lines **39**, each of which forms a connection between adjacent ones of the second electrodes **37** as mentioned above.

[0151] Each of the second electrodes **37** and the electrode main part **33***a* of the corresponding one of the first electrodes **33** have substantially the same shape and are substantially equal in dimension. When viewed in plan, the shape of the second electrode **37** is substantially in perfect agreement with the shape of the electrode main part **33***a*. In other words, the outer edge of the second electrode **37** and the outer edge of the electrode main part **33***a* substantially coincide with each other in a see-through plan view. When viewed from another perspective, the second electrode **37** and the reorientation electrode **35** do not overlap each other in a see-through plan view. The shape and dimensions of the second electrode **37** viewed in plan may be understood as analogous to the shape and dimensions of the electrode main part **33***a* (the first active region **53**A) viewed in plan, where appropriate.

[0152] To be more precise, the outer edge of the second electrode **37** in a see-through plan view may partially or entirely coincide with the outer edge of the electrode main part **33***a* or the inner edge of the reorientation electrode **35** or may be located between the outer edge of the electrode main part **33***a* and the inner edge of the reorientation electrode **35**. In any of these cases, the outer edge of the second electrode **37** and the outer edge of the electrode main part **33***a* may be herein considered to coincide with each other (or to be in perfect agreement with each other). When the outer edge of the second electrode **37** and the outer edge of the electrode main part **33***a* coincide with each other in a strict sense, there may exist a misalignment that falls within allowable tolerances. The same holds for the other electrodes.

[0153] In an example (not illustrated), the outer edge of the second electrode **37** is slightly off the outer edge of the electrode main part **33***a* or, more specifically, is located on the inner side or the outer side with respect to the outer edge of the electrode main part **33***a*. In other words, the region being part of the first piezoelectric layer **29**A and subjected to application of voltage is not necessarily in perfect agreement with the region being part of the second piezoelectric layer **29**B and subjected to application of voltage. This will be inferred from the following examples. When viewed from another perspective, the region being part of the first piezoelectric layer **29**A and included in the first active region **53**A and the region being part of the second piezoelectric layer **29**B and included in the first active region **53**A may differ in area as long as the regions subjected to application of voltage are polarized.

(Traces Included in Second Conductor Layer)

[0154] Any desired number of lines **39** may be placed in any desired arrangement, and each line **39** may have any desired shape and desired dimensions. Each line **39** may form a connection between the second electrodes **37** that are adjacent to each other in the D2 direction (as in the illustrated example). Alternatively, each line **39** may form a connection between the second electrodes **37** that are adjacent to each other in a direction other than the D2 direction (i.e., the D1 direction or a direction that forms an angle with the D1 direction). Two or more of these connection patterns may be used in combination. In the illustrated example, each line **39** extends in a direction that forms an angle with (or orthogonal to) the longitudinal direction of the extended part **33***b* of the first electrode **33**. The line **39** does not overlap the extended part **33***b*.

[0155] The line **39** may extend in the form of a straight line (as in the illustrated example) or may be bent or curved. The width of the line **39** is substantially constant throughout in the longitudinal direction of the line **39** (as in the illustrated example) or may vary from place to place in the longitudinal direction of the line **39**. The width of each line **39** is smaller than the diameter of each second electrode **37** in the direction of the width of each line **39** such that the second electrodes **37** are adjacent to each other with a clearance therebetween (such that the second electrodes **37** are regarded as individual electrodes in terms of their shapes). The width of each line **39** is not more than ½, ⅓, or ¼ of the diameter of each second electrode **37**.

(Third Conductor Layer)

[0156] The third conductor layer **31**C includes third electrodes **41**, each of which is provided for the corresponding one of the pressure chambers **21** (the piezoelectric elements **27**). When liquid droplets are ejected upon application of pressure to the pressure chambers **21**, the third electrodes **41** are involved in application of voltage to the first active region **53**A or, more specifically, to a region being part of the second piezoelectric layer **29**B and are also involved in the application of voltage to the second active region **53**B or, more specifically, to both the third piezoelectric layer **29**C and the fourth piezoelectric layer **29**D. As with the first electrodes **33**, the third electrodes **41** are individual electrodes. The third electrodes **41** are geometrically and electrically separate from one another.

[0157] For example, the third electrodes **41** each have a planar shape that is substantially a combination of the planar shape of the first electrode **33** and the planar shape of the reorientation electrode **35** (i.e., a combination of the planar shape of the first active region **53**A and the planar shape of the second active region **53**B). This relation holds for the dimensions of each of the third electrodes **41** and the dimensions of the combination of the planar shapes. In a see-through plan view, the shape of the third electrode **41** is substantially in perfect agreement with a combination of the shape of the first electrode **33**, the shape of the reorientation electrode **35**, and the shape of the clearance between the first electrode **33** and the reorientation electrode **35** (i.e., a combination of the shape of the first active region **53**A and the second active region **53**B). The shape and dimensions of each of the third electrodes **41** viewed in plan may be understood as analogous to the shape and dimensions of the outer edge of the second active region **53**B.

[0158] The shape of the third electrode **41** viewed in plan may be different from the shape defined by the outer edge of the reorientation electrode **35**. Likewise, the dimensions of the third electrode **41** viewed in plan may be different from the dimensions of the shape defined by the outer edge of the reorientation electrode **35**. In a see-through plan view, the outer edge of the reorientation electrode **35** may be located on the inner side or the outer side with respect to the outer edge of the third electrode **41**. In some embodiments, the third electrodes **41** each have a slit. In a see-through plan view, the slit extends between the electrode main part **33***a* and the reorientation electrode **35** and along the periphery of the electrode main part **33***a*

(Fourth Conductor Layer)

[0159] The fourth conductor layer **31**D is involved in equalization of the structural characteristics of the piezoelectric actuator **13** between a portion closer to the first surface **13***a* and a portion closer to the second surface **13***b*. As will be inferred from the following description about the working mechanism, the fourth conductor layer **31**D in the present embodiment is not involved in application of voltage to the piezoelectric layers **29**. Thus, the fourth conductor layer **31**D is optionally provided.

[0160] The shape, dimensions, and position of the fourth conductor layer **31**D are set in such a manner that in a see-through plan view, the fourth conductor layer **31**D does not overlap electrodes involved in application of voltage to the piezoelectric layers **29**. In the present embodiment, the first electrodes **33**, the reorientation electrodes **35**, the second electrodes **37**, the third electrodes **41**, and fourth electrodes **45**, which will be described later, are involved in application of voltage. The fourth conductor layer **31**D is less likely to interfere with the application of voltage to the piezoelectric layers **29** by the electrodes.

[0161] The fourth conductor layer **31**D may overlap one or more of the electrodes. For example, the fourth conductor layer **31**D overlaps the reorientation electrodes **35**, where the overlap is located on the outer side with respect to the outer edges of the third electrodes **41** and the outer edges of the fourth electrodes **45** and is in the third inactive region **55**C. In this case, the fourth conductor layer **31**D may be involved in reorientation of a region included in the third inactive region **55**C and being part of the first piezoelectric layer **29**A, part of the second piezoelectric layer **29**B, and part of the third piezoelectric layer **29**C.

[0162] The fourth conductor layer **31**D may have any desired shape and desired dimensions. The fourth conductor layer **31**D in the illustrated example has openings **43**, each of which is provided for the corresponding one of the pressure chambers **21** (the piezoelectric elements **27**). In other words, the fourth conductor layer **31**D except for the openings **43** is in the form of a solid layer and extends over the fourth piezoelectric layer **29**D with no gap between one part and another part of the fourth conductor layer **31**D.

[0163] For example, the openings **43** each have a planar shape that is substantially identical to the planar shape of each of the third electrodes **41** (i.e., logical disjunction of the first active region **53**A and the second active region **53**B). This relation holds for the dimensions of each of the openings **43** and the dimensions of each of the third electrodes **41**. When viewed in plan, the shape of the opening **43** is substantially in perfect agreement with the shape of the third electrode **41**. The shape and dimensions of each of the opening **43** viewed in plan may be understood as analogous to the shape and dimensions of the outer edge of the second active region **53**B.

[0164] Each opening **43** may be greater than the corresponding third electrode **41**. In this case, the third electrodes **41** (and the other electrodes) are less likely to overlap the fourth conductor layer **31**D. Increasing the size of the openings **43** may serve the purpose of equalizing the structural characteristics between the portion closer to the first surface **13***a* and the portion closer to the second surface **13***b*. The shape of each opening **43** greater than the corresponding third electrode **41** may be geometrically similar to the shape of the third electrode **41** (the pressure chamber **21**) or may be geometrically different from the shape of the third electrode **41**.

[0165] It is not required that the openings **43** be provided; that is, the fourth conductor layer **31**D may be provided in varying shapes (patterns) when viewed in plan. For example, the fourth conductor layer **31**D may include linear patterns extending in any desired direction or a mash pattern with openings as well as the openings **43** when viewed in plan.

(Fifth Conductor Layer)

[0166] The fifth conductor layer **31**E includes the fourth electrodes **45**, each of which is provided for the corresponding one of the pressure chambers **21** (the piezoelectric elements **27**). When liquid

droplets are ejected upon application of pressure to the pressure chambers **21**, the fourth electrodes **45** are involved in application of voltage to the second active region **53**B or, more specifically, to both the third piezoelectric layer **29**C and the fourth piezoelectric layer **29**D. When no liquid droplet is ejected, the fourth electrodes **45** are involved in poling process to which the second inactive region **55**B is (partially or mostly) subjected. This reduces the possibility that the characteristics of the piezoelectric actuator **13** will degrade.
[0167] The fourth electrodes **45** are geometrically separate from one another. The fourth electrodes **45** are thus regarded as individual electrodes in terms of their geometric shapes. Unlike the first electrodes **33**, the fourth electrodes **45** are placed at the same potential. Specifically, the plate **25**J in the illustrated example is made of metal and forms an electrical connection between the fourth electrodes **45**. In some embodiments, the plate **25**J is made of resin such that the pressure applying surface **11***b* provides insulation, in which case the fourth electrodes **45** are not electrically connected to one another through the channel member **11**. For example, the fourth electrodes **45** each have a planar shape that is substantially identical to the planar shape of each of the reorientation electrodes **35**. This relation holds for the dimensions of each of the fourth electrode **45** and the dimensions of each of the reorientation electrodes **35**. When viewed from another perspective, the fourth electrodes **45** each have a planar shape that is substantially identical to the planar shape of the peripheral region of each of the third electrodes **41**, where the peripheral region does not overlap the electrode main part **33***a* of the first electrode **33**. This relation holds for the dimensions of each of the fourth electrodes **45** and the dimensions of the peripheral region of each of the third electrodes **41**. When viewed from still another perspective, the fourth electrodes **45** each have a planar shape that is substantially identical to the planar shape of the second active region **53**B. This relation holds for the dimensions of each of the fourth electrodes **45** and the dimensions of the second active region **53**B. The shape and dimensions of each of the fourth electrodes **45** viewed in plan may be understood as analogous to the shape and dimensions of the second active region **53**B viewed in plan.
[0168] In a see-through plan view, the inner edge of the fourth electrode **45** substantially coincides with the outer edge of the electrode main part **33***a* (the inner edge of the reorientation electrode **35**) and the outer edge of the second electrode **37**. To be more precise, the inner edge of the fourth electrode **45** as well as the outer edge of the second electrode **37** in a see-through plan view may partially or entirely coincide with the outer edge of the electrode main part **33***a* or the inner edge of the reorientation electrode **35** or may be located between the outer edge of the electrode main part **33***a* and the inner edge of the reorientation electrode **35**. In any of these cases, the inner edge of the fourth electrode **45** and the outer edge of the electrode main part **33***a* may be herein considered to coincide with each other. In an example, the inner edge of the fourth electrode **45** is slightly off the outer edge of the electrode main part **33***a* or the outer edge of the second electrode **37** or, more specifically, is located on the inner side or the outer side with respect to the outer edge of the electrode main part **33***a* or the outer edge of the second electrode **37**.
[0169] In a see-through plan view, the outer edge of the fourth electrode **45** substantially coincides with the outer edge of the reorientation electrode **35**, the outer edge of the third electrode **41**, and the edge of the opening **43**. The positional relationship between the reorientation electrode **35** and the fourth electrode **45** may be similar to the positional relationship between the reorientation electrode **35** and the third electrode **41**; that is, the outer edge of the reorientation electrode **35** may be located on the inner side or the outer side with respect to the outer edge of the fourth electrode **45**. As mentioned above, each opening **43** may be greater than the corresponding third electrode **41**. Likewise, each opening **43** may be greater than the corresponding fourth electrode **45**. The outer edge of the fourth electrode **45** may be off the outer edge of the third electrode **41** or, more specifically, may be located on the inner side or the outer side with respect to the outer edge of the third electrode **41**.
(Electrical Connection Between Conductor Layers)

[0170] As mentioned above, the first electrodes **33**, each of which is provided for the corresponding one of the piezoelectric elements **27**, are placed at the respective potentials (receive driving signals) independently of one another. The FPC (not illustrated) oriented toward the first surface **13***a* of the piezoelectric actuator **13** applies potential to the extended part **33***b*. For example, the end of the extended part **33***b* that is farther than the other end of the extended part **33***b* from the electrode main part **33***a* is joined to the wiring pattern of the FPC with a bump (not illustrated) therebetween. The bump may be made of solder (e.g., lead-free solder).
[0171] The third electrodes **41**, each of which is provided for the corresponding one of the piezoelectric elements **27** as mentioned above, are placed at the respective potentials (receive driving signals) independently of one another. As for each of the piezoelectric elements **27** in the present embodiment, the third electrode **41** and the first electrode **33** in the piezoelectric element **27** concerned are placed at the same potential. For example, each of the first electrodes **33** and the corresponding one of the third electrodes **41** in the piezoelectric actuator **13** are electrically connected to each other such that these electrodes are placed at the same potential.
[0172] Each of the first electrodes **33** and the corresponding one of the third electrodes **41** may be connected to each other by any desired conductor. Referring to FIG. **3**, the first electrode **33** and the third electrode **41** are connected to each other by a through-conductor **47**, which extends through the first piezoelectric layer **29**A and the second piezoelectric layer **29**B. Referring to FIG. **8**, a dotted line extends from an interface between the through-conductor **47** and the first electrode **33** to an interface between the through-conductor **47** and the third electrode **41**. In a see-through plan view, the interface between the through-conductor **47** and the first electrode **33** may be a region being part of the extended part **33***b* and located outside the pressure chamber **21** or, more specifically, may be part of the outer region **11***e* located outside the pressure chamber **21**. The interface between the through-conductor **47** and the third electrode **41** may be located directly below the interface between the through-conductor **47** and the extended part **33***b*.
[0173] In an example (not illustrated), a through-conductor extending through the first piezoelectric layer **29**A and connected to the first electrode **33** and a through-conductor extending through the second piezoelectric layer **29**B and connected to the third electrode **41** may be connected to each other by a layer conductor located between the first piezoelectric layer **29**A and the second piezoelectric layer **29**B. In another example, the first electrode **33** and the third electrode **41** are placed at different potentials, in which case the third electrode **41** may include an extended part. In a see-through plan view, an end of the extended part does not overlap the reorientation electrode **35**. The extended part is connected to a through-conductor that is exposed at the first surface **13***a* of the piezoelectric actuator **13**. The through-conductor or a pad laid on the through-conductor may be joined to the wiring pattern of the FPC (not illustrated).
[0174] As with the first electrode **33**, the reorientation electrode **35** is joined to the FPC (not illustrated) with a bump therebetween such that a potential is applied to the reorientation electrode **35**. Any desired part of the reorientation electrode **35** may be joined to the FPC. For example, the joint part of the reorientation electrode **35** is located opposite the extended part **33***b* with the electrode main part **33***a* therebetween, and/or the joint part does not overlap the pressure chamber **21** in a see-through plan view. As is the case with the extended part **33***b* joined to the external signal lines, the joining has little influence on the pressure applied to the pressure chamber **21**.
[0175] In an example (not illustrated), the reorientation electrode **35** includes an extended part that extends away from the pressure chamber **21**, and the FPC is joined to the extended part. It is not required that the reorientation electrodes **35** be placed at the respective potentials independently of one another. The reorientation electrodes **35** may be connected to one another by wiring, and all the reorientation electrodes **35** may be connected a pad that is joined to the FPC.
[0176] As mentioned above, the fourth electrodes **45** in the present embodiment are electrically connected to one another by the plate **25**J made of metal and are placed at the same potential. For example, the plate **25**J is placed at a reference potential. The plate **25**J may be connected to frame

ground or signal ground (e.g., a reference potential part of the FPC (not illustrated) connected to the piezoelectric actuator **13**). Alternatively, the plate **25**J may be connected to both the frame ground and the signal ground. In the latter case, the plate **25**J may be connected directly to the frame ground and the signal ground, or the plate **25**J may be connected to one of the frame ground and the signal ground with the other ground located therebetween. The connection may be formed by any means.

[0177] As mentioned above, the second electrodes **37** are connected to one another by the lines **39** and are placed at the same potential. Although the fourth conductor layer **31**D has the openings **43**, the fourth conductor layer **31**D is principally one conductor pattern. Thus, every part of the fourth conductor layer **31**D is placed at the same potential. In the present embodiment, the second electrodes **37** and the fourth conductor layer **31**D are placed at the same potential. The second electrodes **37** and the fourth conductor layer **31**D may be electrically connected to the FPC (not illustrated) oriented toward the first surface **13***a* of the piezoelectric actuator **13**. To that end, through-conductors extending through the piezoelectric layers **29** may be provided. The through-conductors may be in any desired form. Specific examples are as follows.

[0178] FIG. **9** is an enlarged perspective view of part of the second conductor layer **31**B. FIG. **9** illustrates only two of the rows of second electrodes **37**, where the second electrodes **37** in each low are aligned in the D2 direction. For convenience of illustration, each row includes four second electrodes **37**.

[0179] As mentioned above, the second electrodes **37** in each row are connected to each other by the lines **39**. The both ends of each row is connected with lines, each of which is denoted by **39** and extends outward from the row (to the −D2 side or the +D2 side). The lines **39** on the ends of each row are connected to common lines **49**, which extend in a direction (the D1 direction) forming an angles with the rows of second electrodes **37**. Thus, the rows are connected to each other. Each common line **49** is part of the second conductor layer **31**B.

[0180] FIG. **10** is a sectional view of the liquid ejection head, taken along line X-X in FIG. **9**.

[0181] Referring to FIGS. **9** and **10**, through-conductors extending through the piezoelectric layers **29** are provided and denoted by **57**. In a see-through plan view, the through-conductors **57** are each located in the common lines **49**. More specifically, the through-conductors **57** extend through the second piezoelectric layer **29**B and the third piezoelectric layer **29**C, as illustrated in FIG. **10**. The through-conductors **57** connect each common line **49** to the fourth conductor layer **31**D. The second electrodes **37** and the fourth conductor layer **31**D are placed at the same potential accordingly.

[0182] Through-conductors extending through the first piezoelectric layer **29**A are also provided and denoted by **57**. Thus, the FPC (not illustrated) oriented toward the first surface **13***a* of the piezoelectric actuator **13** is electrically connectable to the second electrodes **37** and the fourth conductor layer **31**D. Specifically, the through-conductors **57** extending through the first piezoelectric layer **29**A are each provided with a pad **59**. The pad **59** is connected to the signal lines of the FPC (not illustrated) with a bump (not illustrated) therebetween.

[0183] As denoted by dotted lines in FIG. **9**, the through-conductors **57** are aligned along the common lines **49**. This arrangement stabilizes the potential of the electrodes that are to be placed at the same potential. It is not required that the through-conductor **57** be provided in more than one place. Each of the through-conductors **57** located above the common lines **49** and the corresponding one of the through-conductors **57** located below the common lines **49** overlap each other or do not overlap each other in a see-through plan view.

[0184] Through-conductors (not illustrated) extending through the fourth piezoelectric layer **29**D may also be provided and denoted by **57**. With the through-conductors **57** extending through the fourth piezoelectric layer **29**D, the plate **25**J (the fourth electrodes **45**) may be electrically connected to the second electrodes **37** and the fourth conductor layer **31**D.

(Potentials Applied to Conductor Layers)

[0185] FIG. **11** is a schematic sectional view and illustrates potentials that are applied to the conductor layers **31** when liquid droplets are ejected. FIG. **12** is a schematic sectional view and illustrates potentials that are applied to the conductor layers **31** when the first inactive region **55**A undergoes poling process. As with FIG. **5**, FIGS. **11** and **12** each illustrate a section taken along line V-V in FIG. **4**. Hatching lines for indicating a cut surface are not drawn in FIGS. **11** and **12**. Arrows extending through the piezoelectric layers **29** viewed in section denote the direction in which potentials (electric fields) are applied at a predetermined point in time in the cycle of ejecting liquid droplets.
[0186] A driver **61** (see FIGS. **11** and **12**) supplies the piezoelectric actuator **13** with power to drive the piezoelectric actuator **13**. The configuration of the driver **61** is presented for convenience of easy-to-understand illustration of potentials applied to the conductor layers **31**. Thus, the configuration of the driver **61** may be changed for actual product design.
[0187] The driver **61** includes an integrated circuit (IC). When being intend for installation in the head **2**, the driver **61** is mounted on the FPC (not illustrated) oriented toward the first surface **13***a* of the piezoelectric actuator **13**. It is not required that the driver **61** be installed in the head **2**. Various roles may be divided between the driver **61** and the controller **88** as appropriate. For example, some or all of the following actions of the driver **61** may be performed by the controller **88**. The driver **61** may be implemented by hardware configuration that is hardly indistinguishable from the controller **88**. The driver **61** and the controller **88** as a whole may be regarded as a controller.
[0188] The driver **61** includes a first signal source **63**, a second signal source **65**, and a switch part **67**. The first signal source **63** is capable of outputting power for ejection of liquid droplets. The second signal source **65** is capable of outputting power for poling process. The switch part **67** controls connections of the signal sources to the piezoelectric actuator **13**. The switch part **67** is presented for easy-to-understand illustration of supply of power to the piezoelectric actuator **13**, with a distinction between the power for ejection of liquid droplets and the power for poling process. Actual product design is possible without the switch part **67**, in which case the operation of the first signal source **63** and the second signal source **65** enables selection between power output for ejection of liquid droplets and power output for poling process. As for the first signal source **63** and the second signal source **65**, part of one may be part of the other.
[0189] Referring to FIGS. **11** and **12**, a reference potential part, which is provided as signal ground and/or frame ground, is denoted by **69**. The conductor layers **31** that are to be placed at the reference potential may be connected to the reference potential part **69** with or without the driver **61** therebetween. The connections concerning the reference potential part **69** are presented for convenience of easy-to-understand illustration of potential difference between the conductor layers **31**.
(Liquid Ejection Control)
[0190] As described above with reference to FIG. **5**, ejection of liquid involves application of voltage (electric field) to the first active region **53**A and the second active region **53**B in the polarization direction (or in the direction opposite the polarization direction). The voltage is applied by the first signal source **63**. As described above with reference to FIG. **6**, the polarization directions in the present embodiment are as follows: the first piezoelectric layer **29**A and the second piezoelectric layer **29**B in the first active region **53**A are polarized in opposite directions; and the polarization of the second active region **53**B coincides with the polarization direction of the region included in the first active region **53**A and being part of the first piezoelectric layer **29**A. The driver **61** (the first signal source **63**) applies potential to the conductor layers **31** in directions denoted by arrows y1 and arrows y2 in FIG. **11**. In the first active region **53**A, the voltage applied to the first piezoelectric layer **29**A is opposite in direction to the voltage applied to the second piezoelectric layer **29**B. The direction in which voltage applied to the second active region **53**B coincides with the direction in which voltage is applied to the region included in the first active

region **53**A and being part of the first piezoelectric layer **29**A.

[0191] More specifically, the second electrode **37** and the fourth electrode **45** in the illustrated example are placed at the reference potential. The first electrode **33** and the third electrode **41** are each placed at a potential above the reference potential (i.e., at a positive potential). Thus, the voltage applied between the first electrode **33** and the second electrode **37**, that is, the voltage applied to the region included in the first active region **53**A and being part of the first piezoelectric layer **29**A is in the direction from the first electrode **33** to the second electrode **37**. The voltage applied between the second electrode **37** and part of the third electrode **41** (an overlap between the second electrode **37** and the third electrode **41**), that is, the voltage applied to the region included in the first active region **53**A and being part of the second piezoelectric layer **29**B) is in the direction from the third electrode **41** to the second electrode **37**. The voltage applied between part of the third electrode **41** (an overlap between the third electrode **41** and the fourth electrode **45**) and the fourth electrode **45** is in the direction from the third electrode **41** to the fourth electrode **45**.

[0192] In the above example, the direction of voltage application coincides with the polarization direction. The converse is also possible; that is, the direction of voltage application is opposite to the polarization direction. To that end, the first electrode **33** and the third electrode **41** are placed at a potential below the reference potential (i.e., at a negative potential). The above example has been described on the basis of the polarization direction illustrated in FIG. **6**. In a case where the polarization direction is reversed, the relationship between the polarization and the application of a high (positive) potential or a low (negative) potential is the reverse of the above.

[0193] As mentioned above, the second electrode **37** and the fourth electrode **45** in the illustrated example are placed at the reference potential. In a case where the fourth electrode **45** is not electrically connected to the plate **25**J made of metal (as in another embodiment that will be described later), it is not required that the second electrode **37** and the fourth electrode **45** each be placed at the reference potential. For example, the second electrode **37** and the fourth electrode **45** may be place at a potential different from the potential of the first electrode **33** and the third electrode **41** and above or below the reference potential. Alternatively, the first electrode **33** and the third electrode **41** may be placed at the reference potential, and the second electrode **37** and the fourth electrode **45** each may be placed at a potential above or below the reference potential, in which case the conductor layers **31** and the arrangement of the through-holes are to be adjusted in such a way that the second electrode **37** and the fourth electrode **45** are placed at the respective potentials independently of each other. The present embodiment can be generalized as follows: the first electrode **33** and the third electrode **41** are placed at the same potential (first potential), and the second electrode **37** and the fourth electrode **45** are placed at the same potential (second potential), where the potential difference is created to form electric fields including: an electric field (a first electric field) that is to be applied to the first active region **53**A; and an electric field (a second electric field) that is to be applied to the second active region **53**B.

[0194] The first active region **53**A and the second active region **53**B each may be energized with a voltage applied in the polarization direction in a manner different from the above. For example, the first electrode **33** and the third electrode **41** are not connected to each other and are placed at different potentials above (or below) the potential of the second electrode **37**. Alternatively, the second electrode **37** and the fourth electrode **45** are placed at different potentials below (or above) the potential of the third electrode **41**.

[0195] A voltage may be applied to eject liquid droplets in a state in which the reorientation electrode **35** and the fourth conductor layer **31**D are placed at the reference potential or are electrically floating (without deliberate application of voltage). The reorientation electrode **35** in the example FIG. **11** is electrically floating. As mentioned above, the fourth conductor layer **31**D in the present embodiment is connected to the second electrode **37** and is thus placed at the reference potential.

[0196] The piezoelectric elements **27** are driven such that pressure is applied to the pressure chambers **21**. Examples of the method by which the piezoelectric elements **27** are driven include various well-known methods and methods into which various well-known methods are adopted. Pull-push method is typically used to drive such elements. When the pull-push method is adopted, the driver **61** operates as follows.

[0197] Prior to ejection of liquid droplets, the driver **61** applies potential in advance in such a way that the first electrodes **33** and the third electrodes **41** are at a potential above the reference potential. The second electrodes **37** and the fourth electrodes **45** are placed at the reference potential, and the same applies to the following. In this state, the piezoelectric elements **27** undergo bending and deformation toward the pressure chambers **21**. At the start timing of liquid droplets ejection operation, the driver **61** applies the reference potential to the first electrodes **33** and the third electrodes **41**. Then, the piezoelectric elements **27** start becoming flat again, causing an increase in the volumetric capacity of the pressure chambers **21**. When viewed from another perspective, the piezoelectric elements **27** starts vibrating at the natural frequency. Once the volumetric capacity of the pressure chambers **21** reaches its upper limit, the volumetric capacity starts decreasing. As the volumetric capacity decreases, the pressure in the pressure chambers **21** rises. When the pressure in the pressure chambers **21** reaches almost its peak, the first electrodes **33** and the third electrodes **41** are placed at a potential above the reference potential. The resultant vibration and the previously applied vibration add up to exert higher pressure to the pressure chambers **21**. The driver **61** inputs driving signals in the form of pulses to the first electrodes **33** and the third electrodes **41**. For a certain period of time, the potential of the driving signals are low with respect to a reference point that is above the potential of the second electrodes **37** and the fourth electrodes **45**.

[0198] The driver **61** changes the amplitude or number of driving signals in the form of pulses in accordance with the size of dots that are to be formed on the recording medium. In this way, the size of liquid droplets that are to be ejected may be increased, or more than one droplet may be ejected per dot.

[0199] As can be understood from the above description, the voltage applied to the first active region **53**A and the voltage applied to the second active region **53**B vary in the same way when liquid droplets are ejected. Thus, the first active region **53**A and the second active region **53**B expand for the same period of time, and the first active region **53**A and the second active region **53**B contract for the same period of time. In other words, the time period over which the first active region **53**A expands and time period over which the second active region **53**B expands coincide with each other, and the time period over which the first active region **53**A contracts and time period over which the second active region **53**B contracts coincide with each other. This can be generalized as follows: the time period over which the first active region **53**A expands and the time period over which the second active region **53**B expands overlap or coincide with each other; and the time period over which the first active region **53**A contracts and the time period over which the second active region **53**B contracts overlap or coincide with each other.

[0200] As can be understood from the description about the pull-push method, voltages are not necessarily applied deliberately to the first active region **53**A and the second active region **53**B while the first active region **53**A and the second active region **53**B contract or expand. For example, the first active region **53**A and the second active region **53**B may start contracting or expanding when the first electrode **33** and the third electrode **41** are placed at the reference potential at the start timing of liquid droplets ejection operation. That is, the time period over which the first active region **53**A and the second active region **53**B contract or expand may be regarded as the time period over which no voltage is applied to the first active region **53**A and the second active region **53**B. When performing liquid ejection control, the driver **61** controls the intensity of the electric field applied to the first active region **53**A and the intensity of the electric field applied to the second active region **53**B in such a manner that the time period over which the first active region **53**A expands and the time period over which the second active region **53**B expands overlap or coincide with each other and the time period over which the first active region **53**A contracts and the time period over which the second active region **53**B contracts overlap or coincide with each other.

[0201] It is not always required that the time period over which the first active region **53**A is energized with voltage coincide with the time period over which the second active region **53**B is energized with voltage. For example, the piezoelectric actuator is configured in such a way as to be able to apply potential to the fourth electrodes **45** independently of one another. In the case where the pull-push method is employed, the fourth electrodes **45** and the third electrodes **41** are placed at the same potential prior to ejection of liquid droplets, where contraction of the second active region **53**B is not utilized. When the third electrodes **41** are placed at a potential above the reference potential again, the fourth electrodes are placed at the reference potential such that contraction of the second active region **53**B is utilized. Alternatively, contraction of the second active region **53**B may be utilized prior to ejection of liquid droplets. The choice of whether or not to utilize contraction of the second active region **53**B may be made in accordance with the amount of liquid droplets that are to be ejected (the size of dots that are to be formed on the recording medium on the basis of the image data). In any case, the time period over which the first active region **53**A expands and the time period over which the second active region **53**B expands overlap or coincide with each other, and the time period over which the first active region **53**A contracts and the time period over which the second active region **53**B contracts overlap or coincide with each other.

[0202] The second electrodes **37** and the fourth electrodes **45** are placed at the same potential (the reference potential). Thus, the potential difference between the third electrodes **41** and the second electrodes **37** is equal to the potential difference between the third electrodes **41** and the fourth electrodes **45**. In other words, the voltage applied to the region included in the first active region **53**A and being part of the second piezoelectric layer **29**B is equal in magnitude to the voltage applied to the second active region **53**B. The former voltage is applied across the thickness of one piezoelectric layer **29** (the piezoelectric layer **29**B), whereas the latter voltage is applied across the thicknesses of two piezoelectric layers (the piezoelectric layers **29**C and **29**D). The electric field created by the former voltage is therefore more intense than the electric field created by the latter voltage. The same holds for the relation between the second active region **53**B and the region included in the first active region **53**A and being part of the first piezoelectric layer **29**A. When viewed from another perspective, (the amount of change in) the electric field intensity in the first active region **53**A is greater than (the amount of change in) the electric field intensity in the second active region **53**B when liquid is ejected.

[0203] During the liquid ejection control in the present embodiment, the electric field intensity in the first active region **53**A increases or decreases together with the electric field intensity in the second active region **53**B. In some embodiments, the electric field intensities in the respective regions do not change in like manner. A comparison of the electric field intensity in the first active region **53**A and the electric field intensity in the second active region **53**B may be made on the basis of the respective maximum values. Although there may be exceptions depending on the specific driving wave form, the intensity of the electric field applied immediately before the ejection timing (and not during ejection) under the pull-push method may be regarded as the maximum value of the electric field intensity in the active regions **53** during the liquid ejection control. Due to the electric field concerned, the piezoelectric elements **27** are kept bent toward the pressure chambers **21**. The application of electric field to the first active region **53**A and the application of electric field to the second active region **53**B may be controlled independently of each other, in which case the electric field intensity at a point in time in one of the regions of interests for comparison and the electric field intensity at another point in time in the other region may be regarded as the maximum values of the electric field intensities in the respective regions.

(Reorientation Control)

[0204] The bending and deformation of the piezoelectric elements **27** exert stress on the first inactive region **55**A repeatedly along the surface, thus causing shifts of a domain wall (domain switching). The amount of displacement of the piezoelectric elements **27** is reduced accordingly. To inhibit such a reduction in the amount of displacement, the first inactive region **55**A is subjected to poling process such that the state of polarization in the first inactive region **55**A is kept constant.

[0205] The poling process in which the reorientation electrodes **35** are involved may be conducted at any desired timing while no liquid droplet is ejected. The poling process may be triggered by the user's operation on the printer **1** while printing is not performed. That is, the poling process may be conducted at any desired timing. The controller **88** may count the number of print jobs and may conduct the poling process upon completion of a predetermined number of print jobs. The printer **1** may be shipped with no poling process conducted on the first inactive region **55**A. Alternatively, the first inactive region **55**A may be in a polarized state similar to the state that can be caused by the poling process in which reorientation electrodes **35** are involved.

[0206] As described above with reference to FIG. **6**, the first inactive region **55**A in the present embodiment is polarized in the thickness direction. In the poling process, a voltage (direct current) is applied in the polarization direction of the first inactive region **55**A by the driver **61** (the second signal source **65**), as denoted by arrows in FIG. **12**. For example, the voltage to be applied is such that an electric field whose intensity is greater than the intensity of the coercive electric field in the first inactive region **55**A is created, or the voltage to be applied is at or above the voltage at which polarization becomes saturated.

[0207] To that end, the reorientation electrodes **35** in the illustrated example are placed at a potential above the reference potential (i.e., at a positive potential). Each of the third electrodes **41** is electrically floating. Each of the fourth electrodes **45** is placed at the reference potential. An electric field is created between the reorientation electrode **35** and the fourth electrode **45** accordingly. The creation of the electric field is less affected by the third electrode **41**, which is located between the reorientation electrode **35** and the fourth electrode **45** and is electrically floating. The electric field is applied to the first inactive region **55**A and the second active region **53**B.

[0208] The polarization direction in the example described above is a downward direction, as illustrated in FIG. **6**. In a case where the polarization direction is reversed, the reorientation electrodes **35** may be placed at a potential below the reference potential (i.e., at a negative potential). The fourth electrodes **45** may be placed at a potential different from the reference potential in a state in which the fourth electrodes **45** are not electrically connected to the plate **25**J made of metal, where the fourth electrodes **45** and the reorientation electrodes **35** are involved in the creation of the electric field. In this case, the reorientation electrodes **35** may be placed at the reference potential or may be placed at any other potential.

[0209] A voltage may be applied to conduct the poling process in a state in which the first electrodes **33**, the second electrode **37**, and the fourth conductor layer **31**D are placed at the reference potential or are electrically floating. As mentioned above, the first electrodes **33** in the present embodiment are electrically connected to the third electrodes **41** and are thus electrically floating. The second electrodes **37** and the fourth conductor layer **31**D are placed at the reference potential.

[0210] The method for manufacturing the head main body **7** may be analogous to any of various well-known methods and methods into which various well-known methods are adopted. For example, the piezoelectric actuator **13** may be obtained in the following manner: ceramic green sheets that are to be formed into the piezoelectric layers **29** are each coated with conductive paste that is to be formed into the conductor layers **31** and the through-conductors, and the ceramic green sheets are stacked in layers and are then fired. The channel member **11** may be obtained in the following manner: through-holes that are to be formed into channels are provided in the plates **25** by, for example, etching, and the plates **25** are then bonded together with an adhesive. The piezoelectric actuator **13** and the channel member **11** are then bonded together with an adhesive to obtain the head main body **7**.

[0211] The poling process may be conducted on the active regions **53** at any desired timing after the piezoelectric actuator **13** is obtained by firing (e.g., after the piezoelectric actuator **13** is bonded to the channel member **11**). In the poling process, direct current is applied to the first electrodes **33**, the second electrodes **37**, the third electrodes **41**, and the fourth electrodes **45** in such a way as to apply the electric fields denoted by the arrows y1 and y2 in FIG. **11**. For example, the voltage to be applied is such that an electric field whose intensity is greater than the intensity of the coercive electric field in the active regions **53** is created, or the voltage to be applied is at or above the voltage at which polarization becomes saturated.

[0212] As mentioned above, the liquid ejection heads **2** according to the present embodiment each include the channel member **11**, the piezoelectric actuator **13**, and the driver **61**. The channel member **11** has the pressure applying surface **11***b* and includes the pressure chamber **21** that has an opening defined in the pressure applying surface **11***b*. The piezoelectric actuator **13** is disposed on the pressure applying surface **11***b*. The driver **61** is configured to drive the piezoelectric actuator **13**. The piezoelectric actuator **13** includes the first active region **53**A and the second active region **53**B. With a thickness direction being defined as the (D3) direction perpendicular to the pressure applying surface **11***b*, the first active region **53**A is made of a piezoelectric member polarized in the thickness direction. The first active region **53**A extends over the midsection **21***a* of the pressure chamber **21** when viewed in plan through the pressure applying surface **11***b*. The second active region **53**B is made of a piezoelectric member polarized in the thickness direction and closer than the first active region **53**A to the pressure applying surface **11***b*. The second active region **53**B extends over both the peripheral section **21***b* of the pressure chamber **21** and the outer region **11***e* located outside the pressure chamber **21** when viewed in plan through the pressure applying surface **11***b*. When performing the liquid ejection control, the driver **61** controls the intensity of the first electric field applied to the first active region **53**A in the thickness direction (and denoted by the arrows y1 in FIG. **11**) and the intensity of the second electric field applied to the second active region **53**B in the thickness direction (and denoted by the arrows y2 in FIG. **11**) in such a manner that the time period over which the first active region **53**A expands along the pressure applying surface **11***b* and the time period over which the second active region **53**B expands along the pressure applying surface **11***b* overlap or coincide with each other and the time period over which the first active region **53**A contracts along the pressure applying surface **11***b* and the time period over which the second active region **53**B contracts along the pressure applying surface **11***b* overlap or coincide with each other. When the liquid ejection control is performed, the maximum value of the intensity of the first electric field is greater than the maximum value of the intensity of the second electric field.

[0213] Thus, the amount of displacement of the piezoelectric elements **27** as a whole may be increased by driving not only the first active region **53**A but also the second active region **53**B. The channel member **11** restricts the deformation of the region included in the second active region **53**B and extending over the outer region **11***e* located outside the pressure chamber **21**. Accordingly, the region closer to the periphery of the pressure chamber **21** tends to be subjected to a greater stress. This problem can be averted when the electric field applied to the first active region **53**A is more intense than the electric field applied to the second active region **53**B. Thus, the stress exerted on the second active region **53**B is reduced while the piezoelectric elements **27** as a whole can keep undergoing a large amount of displacement as mentioned above. The reduction in the stress exerted on the second active region **53**B leads to an increase in the durability of the head **2**.

[0214] The head **2** according to the present embodiment includes three or more electrodes (i.e., the electrodes **33**, **37**, **41**, and **45**). The three or more electrodes are at different positions in the thickness direction. The three or more electrodes each apply the first electric field to the first active region **53**A and/or apply the second electric field to the second active region **53**B. Of the three or more electrodes, two electrodes that are adjacent to each other in the thickness direction and apply the first electric field are arranged at a first distance from each other in the thickness direction. For example, the first distance refers to the distance between the electrodes **33** and **37** in the thickness direction and/or the distance between the electrodes **37** and **41** in the thickness direction. Of the three or more electrodes, two electrodes adjacent to each other in the thickness direction and apply the second electric field are arranged at a second distance from each other in the thickness direction. For example, the second distance refers to the distance between the electrodes **41** and **45** in the thickness direction. The first distance is shorter than the second distance.

[0215] When the voltage (potential difference) inducing the first electric field applied to the first active region **53**A is equal in magnitude to the voltage (potential difference) inducing the second electric field applied to the second active region **53**B, the first electric field is more intense than the second electric field. This feature provides the ease of ensuring that the first electric field is more intense than the second electric field.

[0216] The liquid ejection control in the present embodiment involves, in addition to the distance relationship between the electrodes, the following feature: the maximum value of the potential difference between the two electrodes applying the first electric field to the first active region **53**A (the potential difference between the electrodes **33** and **37** and/or the potential difference between the electrodes **37** and **41**) is equal to the maximum value of the potential difference between the two electrodes (i.e., the electrodes **41** and **45**) applying the second electric field to the second active region **53**B.

[0217] Thus, one of the two electrodes that apply the first electric field and one of the two electrodes that apply the second electric field are connectable to each other (or can be integrated into one electrode), and the other electrode that applies the first electrode and the other electrode that applies the second electric field are connectable to each other. With such structural simplicity, the first electric field can be made more intense than the second electric field.

[0218] The piezoelectric actuator in the present embodiment includes the first to fourth piezoelectric layers (denoted by **29**A to **29**D), the first electrode **33**, the second electrode **37**, and the third electrode **41**, and the fourth electrode **45**. One of two surfaces of the piezoelectric actuator **13** that is farther than the other surface of the piezoelectric actuator **13** from the channel member **11** is located on a first side (+D3 side), whereas the other surface of the piezoelectric actuator **13** (the surface closer to the channel member **11**) is located on a second side (−D3 side). The first piezoelectric layer **29**A, the second piezoelectric layer **29**B, the third piezoelectric layer **29**C, and the fourth piezoelectric layer **29**D are stacked in sequence from the first side to the second side. The first electrode **33** is disposed on the first piezoelectric layer **29**A to lie on a surface of the first piezoelectric layer **29**A on the first side and extends over the midsection **21***a* of the pressure chamber **21** in a see-through plan view. The second electrode **37** is disposed on the first piezoelectric layer **29**A to lie on a surface of the first piezoelectric layer **29**A on the second side and extends over the midsection **21***a* in a see-through plan view. The third electrode **41** is disposed on the second piezoelectric layer **29**B to lie on a surface of the second piezoelectric layer **29**B on the second side and extends over the midsection **21***a*, the peripheral section **21***b* of the pressure chamber **21**, and the outer region **11***e* located outside the pressure chamber **21** in a see-through plan view. The fourth electrode **45** is disposed on the fourth piezoelectric layer **29**D to lie on a surface of the fourth piezoelectric layer **29**D on the second side and extends over the peripheral section **21***b* and the outer region **11***e* in a see-through plan view. The first active region **53**A includes: a region that is part of the first piezoelectric layer **29**A and that is located between the first electrode **33** and the second electrode **37**; and a region that is part of the second piezoelectric layer **29**B and that is located between the second electrode **37** and a portion included in the third electrode **41** and extending over the midsection **21***a*. The second active region **53**B includes a region that is part of the third piezoelectric layer **29**C and the fourth piezoelectric layer **29**D and that is located between the fourth electrode **45** and a portion included in the third electrode **41** and extending over the peripheral section **21***b* and the outer region **11***e*.

[0219] This enables the adoption of a simple approach by which the first electric field applied to the first active region **53**A is made greater in strength than the second electric field applied to the second active region **53**B. For example, three electrodes (the electrodes **33**, **37**, and **41**) that are at different positions in the thickness direction applies a voltage to two piezoelectric layers **29** (the piezoelectric layers **29**A and **29**B) in the first active region **53**A, and two electrodes apply a voltage to two piezoelectric layers **29** (the piezoelectric layer **29**C and the piezoelectric layer **29**D) in the second active region **53**B. This approach provides the ease with which the distance between two electrodes that apply a voltage to the first active region **53**A can, as mentioned above, be made shorter than two electrodes that apply a voltage to the second active region **53**B. With the effects produced by the distance relationship, the voltage applied to the first active region **53**A (the piezoelectric layers **29**A and **29**B) and the voltage applied to the second active region **53**B (the piezoelectric layer **29**C and the piezoelectric layer **29**D) are made equal in magnitude, in which case structural simplicity may be achieved without substantial increase in potential. The third electrode **41** is involved in both application of voltage to the first active region **53**A and application of voltage to the second active region **53**B. This feature enables a reduction in the number of electrodes (conductor layers **31**).
[0220] In the present embodiment, the region being part of the first piezoelectric layer **29**A and included in the first active region **53**A and the region being part of the second piezoelectric layer **29**B and included in the first active region **53**A are polarized in opposite directions. The region being part of the third piezoelectric layer **29**C and part of the fourth piezoelectric layer **29**D and included in the second active region **53**B and the region being part of the first piezoelectric layer **29**A and included in the first active region **53**A are polarized in the same direction. With the first electrode **33** and the third electrode **41** placed at the same potential and the second electrode **37** and the fourth electrode **45** placed at the same potential, the liquid ejection control is performed in such a manner that a difference between the potential of the first electrode **33** and the third electrode **41** and the potential of the second electrode **37** and the fourth electrode **45** causes application of the first electric field to the first active region **53**A and application of the second electric field to the second active region **53**B.
[0221] For example, three regions are subjected to application of electric fields. One is the region included in the first active region **53**A and being part of the first piezoelectric layer **29**A. Another is the region included in the first active region **53**A and being part of the second piezoelectric layer **29**B. The other is the second active region **53**B. In this case, only two different potentials may be used to apply electric fields to the three regions in their respective polarization directions (or in directions opposite to the respective polarization directions). The piezoelectric actuator **13** and the driver **61** can achieve structural simplicity accordingly.
[0222] In the present embodiment, the sum of the thickness of the third piezoelectric layer **29**C and the thickness of the fourth piezoelectric layer **29**D is greater than the thickness of the first piezoelectric layer **29**A and is greater than the thickness of the second piezoelectric layer **29**B.
[0223] When viewed from another perspective, the distance between the first electrode **33** and the second electrode **37** and the distance between the second electrode **37** and the third electrode **41** are each shorter than the distance between the third electrode **41** and the fourth electrode **45**. This feature provides the ease with which the electric field applied to the region included in the first active region **53**A and being part of the first piezoelectric layer **29**A and the electric field applied to the region included the first active region **53**A and being part of the second piezoelectric layer **29**B are each made greater in strength than the electric field applied to the second active region **53**B.
[0224] The piezoelectric actuator **13** in the present embodiment includes the conductor pattern (the fourth conductor layer **31**D) that is disposed on the third piezoelectric layer **29**C to lie on a surface of the third piezoelectric layer **29**C on the second side (the −D3 side) and that is located on the outer side with respect to the second active region **53**B in a see-through plan view.
[0225] As mentioned above, the present embodiment involves the use of three electrodes (the

electrodes **33**, **37**, and **41**) for application of voltage to the first active region **53**A and two electrodes (the electrodes **41** and **45**) for application of voltage to the second active region **53**B, where the third electrode **41** serves both of the purposes. In the piezoelectric actuator **13**, the volume of the conductor on the first side (the +D3 side) is thus likely to be greater than the volume of the conductor on the second side. The imbalance can be averted by the addition of the fourth conductor layer **31**D, which provides the ease with which the volume of the conductor (the proportion of the conductor in the piezoelectric layers) on the +D3 side becomes equal to the volume of the conductor on the −D3 side. This feature reduces the possibility that contraction associated with firing and/or expansion and contraction associated with temperature variations during periods of use will cause unintended bending and deformation.

[0226] When the first portion **53**Ba and the second portion **53**Bb in the present embodiment are viewed in plan through the pressure applying surface **11***b*, the second portion **53**Bb is greater in area than the first portion **53**Ba, where the first portion **53**Ba is part of the second active region **53**B and extends over part of the pressure chamber **21**, and the second portion **53**Bb is part of the second active region **53**B and is located outside the pressure chamber.

[0227] If the outer edge of the second active region **53**B (the outer edge of the second portion **53**Bb) is close to the periphery of the pressure chamber **21**, stress would be likely to concentrate in a region close to the periphery of the pressure chamber **21**. Making the second portion **53**Bb greater in area than the first portion **53**Ba is an uncomplicated way to increase the distance between the outer edge of the second active region **53**B and the periphery of the pressure chamber **21**. The concentration of stress will be reduced accordingly. This reduces the possibility that the junction between the piezoelectric actuator **13** and the channel member **11** will deteriorate along the periphery of the pressure chamber **21**. As mentioned above, the stress exerted on the second active region **53**B may be reduced when the first electric field applied to the first active region **53**A is greater in strength than the second electric field applied to the second active region **53**B (i.e., when the second electric field is made relatively weak). The concentration of stress in the region close to the periphery of the pressure chamber **21** may be further reduced accordingly.

[0228] In the present embodiment, the periphery of the pressure chamber **21** viewed in plan through the pressure applying surface **11***b* includes a circular arc that subtends an angle of 180° or more at the center of the pressure chamber **21**.

[0229] In this case, the stress is uniformly distributed along the circular arc in a plan view. In other words, exceptionally high stress is less likely to be exerted. The concentration of stress may be further reduced accordingly. The effect may be enhanced especially when the planar shape of the pressure chamber **21** is circular, that is, when the shape of the pressure chamber **21** is defined by only the circle C**1** in FIG. **4**.

[0230] In the present embodiment, the width w2 of the second portion **53**Bb is greater than the width w1 of the first portion **53**Ba in a sectional view taken along a line passing through the center of the pressure chamber **21** and orthogonal to the pressure applying surface **11***b*.

[0231] In this case, the distance between the outer edge of the second active region **53**B and the periphery of the pressure chamber **21** is increased correspondingly. This feature enables the stress concentration reduction that has been mentioned above in relation to the effect of making the second portion **53**Bb greater in area than the first portion **53**Ba. The concentration of stress therefore may be further reduced when both of the following conditions are satisfied: (i) the second portion **53**Bb is greater in area than the first portion **53**Ba; and (ii) the width w2 is greater than the width w1.

[0232] The piezoelectric actuator **13** in the present embodiment includes the inactive region (the first inactive region **55**A). The first inactive region **55**A is made of a piezoelectric member and extends to the perimeter of the first active region **53**A. The driver **61** performs the reorientation control (see FIG. **12**). When not performing the liquid ejection control, the driver **61** performs the reorientation control by which an electric field is applied to the first inactive region **55**A in the thickness direction.

[0233] Although domain switching in the first inactive region **55**A causes a reduction in the amount of displacement as mentioned above, the poling process inhibits such a reduction in the amount of displacement. Domain switching is likely to occur in the first inactive region **55**A, which is subject to both the stress exerted by the first active region **53**A and the stress exerted by the second active region **53**B. The poling process conducted on the first inactive region **55**A effectively inhibits the reduction in the amount of displacement. As mentioned above, the stress exerted on the second active region **53**B may be reduced when the first electric field applied to the first active region **53**A is greater in strength than the second electric field applied to the second active region **53**B (i.e., when the second electric field is made relatively weak). Consequently, the stress exerted on the first inactive region **55**A by the second active region **53**B may be reduced. As a result, the probability of occurrence of domain switching in the first inactive region **55**A is reduced, in which case the poling process may be conducted on the first inactive region **55**A less frequently.

[0234] The piezoelectric actuator **13** in the present embodiment includes the reorientation electrode **35**, an intermediate electrode (the third electrode **41**), and a lower electrode (the fourth electrode **45**). The reorientation electrode **35** is disposed on the inactive region (the first inactive region **55**A) to lie on the side (the +D3 side) opposite the pressure applying surface **11***b*. The third electrode **41** is located between the first inactive region **55**A and the second active region **53**B. The fourth electrode **45** is disposed on the second active region **53**B to lie on the side (the −D3 side) on which the pressure applying surface **11***b* is located. When performing the liquid ejection control, the driver **61** applies an electric field to the second active region **53**B by applying a voltage to the third electrode **41** and the fourth electrode **45**. When performing the reorientation control, the driver **61** applies an electric field to the first inactive region **55**A by applying a voltage to the reorientation electrode **35** and one of the third electrode **41** and the fourth electrode **45**. In the present embodiment, the driver **61** applies a voltage to the reorientation electrode **35** and the fourth electrode **45**.

[0235] In this case, the fourth electrode **45** (or the third electrode **41**) serves both the purpose of applying an electric field to eject liquid droplets and the purpose of applying an electric field to conduct the poling process. The piezoelectric actuator **13** can achieve structural simplicity accordingly.

[0236] The piezoelectric actuator **13** in the present embodiment includes, in addition to the aforementioned constituent elements, an upper electrode (the second electrode **37**). The second electrode **37** is closer than the intermediate electrode (the third electrode **41**) to the side (the +D3 side) opposite the pressure applying surface **11***b*, and the second electrode **37** is opposite the third electrode **41** with at least part of the first active region **53**A located therebetween. When performing the liquid ejection control, the driver **61** applies an electric field to the first active region **53**A by applying a voltage to the second electrode **37** and the third electrode **41**. When performing the reorientation control, the driver **61** applies an electric field to the inactive region (the first inactive region **55**A) by applying a voltage to the reorientation electrode **35** and the fourth electrode **45**, without applying a potential to the third electrode **41**.

[0237] When the control for ejecting liquid droplets is performed, the third electrode **41** serves both the purpose of applying an electric field to the first active region **53**A and the purpose of applying an electric field to the second active region **53**B. The piezoelectric actuator **13** can achieve structural simplicity accordingly. When the poling process is conducted, the third electrode **41** is electrically floating and is thus less likely to interfere with the electric field applied by the reorientation electrode **35** and the fourth electrode **45**. The poling process is conducted by using the reorientation electrode **35** and the fourth electrode **45**, in which case not only the first inactive region **55**A but also the second active region **53**B is subjected to the poling process. Accordingly, the characteristics of the piezoelectric actuator are less susceptible not only to the domain switching in the first inactive region **55**A but also to the domain switching in the second active region **53**B.

[0238] As mentioned above, the piezoelectric actuator in the present embodiment includes the first to fourth piezoelectric layers (denoted by **29**A to **29**D), the first electrode **33**, the second electrode **37**, the third electrode **41**, and the fourth electrode **45** such that the first active region **53**A and the second active region **53**B are defined in the piezoelectric actuator. The inactive region (the first inactive region **55**A) includes a region being part of the first piezoelectric layer **29**A and part of the second piezoelectric layer **29**B and located between the reorientation electrode **35** and the fourth electrode **45**.

[0239] This enables the adoption of the aforementioned simple approach by which the electric field applied to the first active region **53**A is made greater in strength than the electric field applied to the second active region **53**B. With such structural simplicity, the stress exerted on the second active region **53**B and the stress exerted on the first inactive region **55**A by the second active region **53**B may be reduced accordingly.

Second Embodiment

[0240] FIG. **13** is a schematic sectional view of a head **207** according to a second embodiment. FIG. **13** is analogous to FIG. **12** relevant to the first embodiment; that is, FIG. **13** illustrates a state in which potentials are applied to the conductor layers **31** when the poling process is conducted on the first inactive region **55**A.

[0241] The poling process in the first embodiment involves the application of an electric field to the first inactive region **55**A by the reorientation electrodes **35** and the fourth electrodes **45**. The poling process in the second embodiment involves the application of an electric field to the first inactive region **55**A by the reorientation electrodes **35** and the third electrodes **41**. More specifically, the reorientation electrodes **35** in the illustrated example are placed at a potential above the reference potential (i.e., at a positive potential). The third electrodes **41** are placed at the reference potential.

[0242] The polarization direction in the example described above is a downward direction, as illustrated in FIG. **6**. In a case where the polarization direction is reversed, the reorientation electrodes **35** may be placed at a potential below the reference potential (i.e., at a negative potential). The third electrodes **41** may be placed at a potential different from the reference potential. In this case, the reorientation electrodes **35** may be placed at the reference potential or may be placed at any other potential.

[0243] As mentioned above, a voltage may be applied to conduct the poling process in a state in which the first electrodes **33**, the second electrodes **37**, the fourth electrodes **45**, and the fourth conductor layer **31**D are placed at the reference potential or are electrically floating. As mentioned above, the first electrodes **33** are electrically connected to the third electrode **41**. Thus, the first electrodes **33** in the present embodiment are placed at the reference potential. The second electrodes **37**, the fourth electrodes **45**, and the fourth conductor layer **31**D are placed at the reference potential.

Third Embodiment

[0244] FIG. **14** is a schematic sectional view of a head **307** according to a third embodiment and is analogous to FIG. **11** relevant to the first embodiment.

[0245] The fifth conductor layer **31**E (the fourth electrodes **45**) in the first embodiment is in contact with the channel member **11** (the plate **25**J) and is exposed in the pressure chambers **21**. In the present embodiment, an insulating layer **30** is located between the fifth conductor layer **31**E and the channel member **11**. When viewed from another perspective, the insulating layer **30** is located between the second active region **53**B and the channel member **11**. The insulating layer **30** may be regarded as part of the piezoelectric actuator **13**, as part of the channel member **11**, or as a member different from the piezoelectric actuator **13** and the channel member **11**. Referring to FIG. **14**, the insulating layer **30** is regarded as a member different from the piezoelectric actuator **13** and the channel member **11** and is thus denoted by its own reference numeral.

[0246] The insulating layer **30** may be made of an inorganic material or an organic material. The

inorganic material may be a piezoelectric material or a material other than piezoelectric materials. The piezoelectric material of the insulating layer **30** may be identical to or different from the material of the piezoelectric layers **29**. The insulating layer **30** may be fired together with or independently of the piezoelectric the piezoelectric layers **29**. An example of the inorganic material other than piezoelectric materials is SiO.sub.2. An example of the organic material is resin. In a case where the insulating layer **30** is not obtained by firing a piezoelectric material, the insulating layer **30** may be formed on a lower surface of the piezoelectric actuator **13** by chemical vapor deposition (CVD) or any other method for forming a thin film or may be bonded to the piezoelectric actuator **13** or the channel member **11** with an adhesive.
[0247] As with the piezoelectric layers **29**, the insulating layer **30** has a constant thickness and extends over the pressure chambers **21** substantially without a gap between one part and another part of the insulating layer **30**. The insulating layer **30** can be laid only over and around a region immediately below the second active region **53**B (the fourth electrodes **45**) on condition that the insulating layer **30** is relatively thin. The insulating layer **30** may have any desired thickness. The insulating layer **30** may be thinner than each of the piezoelectric layer **29** as in the illustrated example. The insulating layer **30** may be equal in thickness to each of the piezoelectric layers **29** or may be thicker than each of the piezoelectric layers **29**. The thickness of the insulating layer **30** may be set to any desired value, in light of expected effects (intensity and/or insulating properties, which will be described later) and/or with consideration given to the possible influence that the insulating layer **30** exerts on the position of the neutral plane of the piezoelectric actuator **13**.
[0248] As with the second electrodes **37**, the fourth electrodes **45** are connected to each other by wiring. More specifically, the fourth electrodes **45** are connected to each other by wiring included in the fifth conductor layer **31**E. In some embodiments (not illustrated), the fourth electrodes **45** are individually connected, by wiring and through-conductors, to the signal lines of the FPC (not illustrated) oriented toward the first surface **13***a* of the piezoelectric actuator **13**.
[0249] As mentioned above, the head **307** includes the insulating layer **30** located between the second active region **53**B and the channel member **11**.
[0250] The stress exerted on the second active region **53**B by the channel member **11** may be reduced by the insulating layer **30**. For example, a portion that belongs to the second active region **53**B and extends over the outer region **11***e* located outside the pressure chamber **21** is restrained from undergoing deformation by the channel member **11** such that a region extending on the periphery of the pressure chamber **21** is likely to be subjected to great stress. The stress may be reduced by the insulating layer **30**. The electrodes (the fourth electrodes **45**) that apply a voltage to the second active region **53**B in the thickness direction are covered with the insulating layer **30**. The fourth electrodes **45** are thus insulated from the channel member **11** made of metal. Another advantage is that the fourth electrodes **45** are kept from contact with liquid in the pressure chambers **21**. Thus, the fourth electrodes **45** are more protected from corrosion caused by the liquid, although this is not always true for every type of liquid.
Fourth Embodiment
[0251] FIG. **15** is a schematic sectional view of a head **407** according to a fourth embodiment and is analogous to FIG. **11** relevant to the first embodiment.
[0252] The piezoelectric actuator in the present embodiment is denoted by **413** and does not include the fifth conductor layer **31**E, which has been described above in relation to the first embodiment. The fourth conductor layer **31**D in the present embodiment includes fourth electrodes **445**, which correspond to the fourth electrodes **45** in the first embodiment. The second active region **53**B is part of the third piezoelectric layer **29**C and corresponds to an overlap between each of the third electrodes **41** and the corresponding one of the fourth electrodes **445**; that is, the fourth piezoelectric layer **29**D is not included in the second active region **53**B. The present embodiment may be understood as analogous to the third embodiment in the following respect: an insulating layer (the fourth piezoelectric layer **29**D in the present embodiment) is located between the second

active region **53**B and the channel member **11**.

[0253] Each of the fourth electrode **445** may have any desired shape, although it is required that there be an overlap between the fourth electrode **445** and the second active region **53**B. The shape of the fourth electrodes **445** may be a combination of the shape of the fourth electrode **45** in the first embodiment and the shape of the fourth conductor layer **31**D in the first embodiment. In other words, the fourth conductor layer **31**D in the present embodiment is defined such that the perimeter of each opening **43** in the fourth conductor layer **31**D in the first embodiment substantially coincides with the outer edge of each electrode main part **33***a* and/or the outer edge of each second electrode **37**. The fourth electrodes **445** may be geometrically analogous to the fourth electrodes **45** in the first embodiment. As with the second electrodes **37**, the fourth electrodes **445** are connected to each other by wiring. More specifically, the fourth electrodes **445** are connected to each other by lines included in the fourth conductor layer **31**D. The fourth electrodes **445** may be connected to any desired wiring and through-conductors in such a way as to be able to be placed at the respective potentials independently of one another.

[0254] The potential at which the fourth electrodes **445** are placed for ejection of liquid and for the poling process may be understood as analogous to the potential of the fourth electrodes **45** in the first embodiment. In the illustrated example, the distance between the electrodes in the first active region **53**A is substantially equal to the distance between the electrodes in the second active region **53**B. Thus, the intensity of the electric field applied to the first active region **53**A is substantially equal to the intensity of the electric field applied to the second active region **53**B.

[0255] As has been described above in relation to the first embodiment, the electric field applied to the first active region **53**A may be more intense than the electric field applied to the second active region **53**B. The same holds for the present embodiment. The relationship between the electric field intensities may be adjusted in various ways. In an example, the third piezoelectric layer **29**C is thicker than the first piezoelectric layer **29**A and is thicker than the second piezoelectric layer **29**B, and potentials are applied to the electrodes as in the first embodiment. In another example, each of the second electrodes **37** is not connected to the corresponding one of the fourth electrodes **445** such that these electrodes are able to be placed at different potentials. In this state, potentials may be applied in such a manner that the potential difference between the third electrode **41** and the second electrode **37** is greater than the potential difference between the third electrode **41** and the fourth electrode **445**.

[0256] As mentioned above, the head **407** may be understood as analogous to the head according to the third embodiment in the following respect: the head **407** includes an insulating layer (the fourth piezoelectric layer **29**D) located between the second active region **53**B and the channel member **11**. This feature produces effects equivalent to those produced in the third embodiment.

Fifth Embodiment

[0257] FIG. **16** is a schematic sectional view of a head **507** according to a fifth embodiment and is analogous to FIG. **11** relevant to the first embodiment. As in FIG. **6**, the polarization directions are indicated by hollow arrows in FIG. **16**.

[0258] In the first embodiment, two piezoelectric layers **29** are partially included in the first active region **53**A, and the other two piezoelectric layers **29** are partially included in the second active region **53**B. The piezoelectric actuator in the present embodiment is denoted by **513** and includes a fifth piezoelectric layer **29**E and a sixth piezoelectric layer **29**F. The first active region **53**A and the second active region **53**B each include one piezoelectric layer **29**; that is, the fifth piezoelectric layer **29**E is partially included in the first active region **53**A, and the sixth piezoelectric layer **29**F is partially included in the second active region **53**B.

[0259] Given this structure, the present embodiment may adopt varying combinations of polarization directions, electrode structures, and potentials to achieve the workings of the first active region **53**A and the second active region **53**B that have been described above with reference to FIG. **5**. An example combination adopted in the illustrated examples is as follows.

[0260] As with the piezoelectric actuator in the first embodiment, the piezoelectric actuator **513** includes the first electrode **33** (and the reorientation electrode **35**), the third electrode **41**, and the fourth electrode **45** that are arranged in this order from the closest to the upper surface (i.e., in this order from the farthest from the lower surface). The first active region **53**A is part of the fifth piezoelectric layer **29**E and located between the first electrode **33** and the third electrode **41**. The second active region **53**B is part of the sixth piezoelectric layer **29**F and located between the third electrode **41** and the fourth electrode **45**. The fourth electrode **45** is insulated from the channel member **11** by the insulating layer **30** and is thus able to be placed at a potential different from the reference potential.
[0261] The first active region **53**A and the second active region **53**B are polarized in opposite directions. The liquid ejection control involves application of the reference potential to the third electrode **41** located between the first active region **53**A and the second active region **53**B. The first electrode **33** and the fourth electrode **45** are placed at potentials that are of the same polarity with respect to the reference potential. Thus, the first active region **53**A and the second active region **53**B contract in conjunction with each other or expand in conjunction with each other.
[0262] A driver **561** includes a signal source **63**A and a signal source **63**B. The signal source **63**A applies a potential to the first electrode **33**, and the signal source **63**B applies a potential to the fourth electrode **45**. The first electrode **33** and the fourth electrode **45** are thus able to be placed at different potentials. Thus, the present embodiment produces the effect similar to that is produced by the first embodiment; that is, the electric field applied to the first active region **53**A may be greater in strength than the electric field applied to the second active region **53**B. In another example (not illustrated), the first electrode **33** and the fourth electrode **45** are connected to each other and are placed at the same potential.
(Variations of Piezoelectric Layers)
[0263] FIG. **17**A is a sectional view of a variation of the piezoelectric layer **29** and is an enlarged view of a region XVII in FIG. **10**.
[0264] An upper surface of the first piezoelectric layer **29**A may have grooves **29***v*, each of which is located between the corresponding one of the first electrodes **33** and the corresponding one of the reorientation electrodes **35**. For example, the groove **29***v* extends along the outer edge of the first electrode **33** in a manner so as to surround the first electrode **33**. In other words, the groove **29***v* is loop-shaped. The groove **29***v* may have a gap between one part and another part of it. For example, it is not required that the groove **29***v* be located at a position that is opposite the electrode main part **33***a* with the extended part **33***b* located therebetween.
[0265] The groove **29***v* may have any desired width within a range not greater than the gap between the first electrode **33** and the reorientation electrode **35**. The width of the groove **29***v* may be constant throughout in the longitudinal direction of the groove **29***v* or may vary from place to place in the longitudinal direction of the groove **29***v*. The groove **29***v* may have any desired depth within a range not greater than the thickness of the first piezoelectric layer **29**A. For example, the depth of the groove **29***v* may be less than one half of the thickness of the first piezoelectric layer **29**A or may be equal to or greater than one half of the thickness of the first piezoelectric layer **29**A. The groove **29***v* may be equal in thickness to the first piezoelectric layer **29**A.
[0266] The grooves **29***v* may be formed by any desired means. For example, the grooves **29***v* may be formed in a ceramic green sheet that is to be formed into the first piezoelectric layer **29**A. Alternatively, the grooves **29***v* may be formed by laser machining after the first piezoelectric layer **29**A is fired.
[0267] The grooves **29***v* reduce the possibility that metallic materials of the first electrodes **33** and the reorientation electrodes **35** will get into the region between these electrodes (migration of metallic materials). Thus, the first electrodes **33** and the reorientation electrodes **35** are less likely to short-circuit. The alternative view is that this feature provides ease of conducting the poling process on part of the first inactive region **55**A or, more specifically, on a region adjacent to the

first active region **53**A in a state in which each of the first electrodes **33** and the corresponding one of the reorientation electrodes **35** are close to each other when viewed in plan. The effect of the poling process is enhanced accordingly; that is, the characteristics of the piezoelectric actuator are less likely to be impaired. The term “migration” herein refers to electromigration and/or electrochemical migration.

[0268] FIG. **17**B is a sectional view of another variation of the piezoelectric layer **29** and is an enlarged view analogous to FIG. **17**A.

[0269] The groove **29***v* may be provided with an insulator **32**. The insulator **32** is made of a material that reduces the probability of occurrence of migration of the electrode materials further than would be possible with the material of the first piezoelectric layer **29**A. For example, the insulator **32** is made of resin. Resin may be applied to the grooves **29***v* by CVD or any other desired means.

[0270] The probability of occurrence of migration is further reduced by the insulator **32**. While reducing the probability of occurrence of migration, the insulator **32** also reduces the possibility that the grooves **29***v* will cause a shortage of strength of the piezoelectric actuator.

[0271] In each of the embodiments described above, the third electrode **41** is an example of the intermediate electrode, and the fourth electrode **45** or **445** is an example of the lower electrode.

[0272] The technique disclosed herein is not limited to the embodiments described above and may be implemented in various forms.

[0273] For example, the first inactive region is not necessarily subjected to the poling process. That is, the heads may come without the components specially designed for poling process. The liquid ejection control involves a control other than the control (a first control) in which the time period over which the first active region expands and the time period over which the second active region expands overlap or coincide with each other and the time period over which the first active region contracts and the time period over which the second active region contracts overlap or coincide with each other. For example, the liquid ejection control involves a control (a second control) in which the time period over which the first active region expands and the time period over which the second active region contracts overlap or coincide with each other and the time period over which the first active region contracts and the time period over which the second active region expands overlap or coincide with each other. The first control may be performed to eject large liquid droplets, whereas the second control may be performed to eject small liquid droplets. In some embodiments, liquid circulates through the heads.

[0274] Various concepts can be derived from the embodiments of the present disclosure. For example, the following concept is derived in relation to the liquid ejection head: the second portion being part of the second active region and located outside the pressure chamber is greater in area than the first portion being part of the second active region and extending over the pressure chamber when the second active region is viewed in plan through the pressure applying surface. The following concept is also derived in relation to the liquid ejection head: the piezoelectric actuator includes an inactive region (made of a piezoelectric member) extending to the perimeter of the first active region; and when not performing the liquid ejection control, the driver performs the reorientation control by which an electric field is applied to the inactive region in the thickness direction. The liquid ejection head according to these concepts may differ from the liquid ejection heads according to the embodiments described above in the following respect: the maximum value of the intensity of the electric field (the first electric field) applied to the first active region is equal to the maximum value of the intensity of the electric field (the second electric field) applied to the second active region, or the latter is greater than the former.

Claims

1. A liquid ejection head, comprising: a channel member comprising a pressure applying surface, and a pressure chamber comprising an opening defined in the pressure applying surface; a piezoelectric actuator disposed on the pressure applying surface, wherein a thickness direction is perpendicular to the pressure applying surface, the piezoelectric actuator comprises comprising: a first active region made of a piezoelectric member polarized in the thickness direction, the first active region extending over a midsection of the pressure chamber when viewed in a plan view through the pressure applying surface, and a second active region made of another piezoelectric member polarized in the thickness direction and closer than the first active region to the pressure applying surface, the second active region extending over both a peripheral section located inside the pressure chamber and an outer region located outside the pressure chamber when viewed in the plan view through the pressure applying surface; an insulating layer located between the second active region and the channel member; and a driver configured to drive the piezoelectric actuator and to perform liquid ejection control for ejecting liquid, the liquid ejection control including control of an intensity of a first electric field applied to the first active region in the thickness direction and an intensity of a second electric field applied to the second active region in the thickness direction in such a manner that, when one of expansion and contraction in a direction along the pressure applying surface is referred to as a first deformation and another as a second deformation, a time period over which the first active region causes the first deformation and a time period over which the second active region causes the first deformation due to a change in the second electric field overlap or coincide with each other.
2. The liquid ejection head according to claim 1, wherein the insulating layer is thinner than a piezoelectric layer constituting the first active region.
3. The liquid ejection head according to claim 1, wherein the insulating layer is thinner than a piezoelectric layer constituting the second active region.
4. The liquid ejection head according to claim 1, wherein the piezoelectric actuator includes a plurality of first active region electrodes stacked in the thickness direction to apply an electric field to the first active region, and a plurality of second active region electrodes stacked in the thickness direction to apply an electric field to the second active region, and an electrode most on a side of the pressure applying surface of the plurality of first active region electrodes and an electrode most opposite to the pressure surface of the plurality of second active region electrodes are located in a same layer and are electrically connected to form a shared electrode.
5. The liquid ejection head according to claim 4, wherein an electrode of the plurality of first active region electrodes that faces the shared electrode and the electrode of the plurality of second active region electrodes that faces the shared electrode are electrically connected.
6. The liquid ejection head according to claim 1, wherein a piezoelectric material, located on an opposite side of the pressure applying surface with respect to the second active region and connected to an outer perimeter of the first active region, is an inactive region over a thickness of the first active region.
7. The liquid ejection head according to claim 1, wherein a piezoelectric material, located on a side of the pressure applying surface with respect to the first active region and inside the second active region, is an inactive region over a thickness of the second active region.
8. The liquid ejection head according to claim 1, wherein the liquid ejection control waits in a standby state, and after ejection, returns to the standby state, and the first deformation caused by the second active region in the liquid ejection control is an expansion that extends from the standby state or a contraction that contracts from the standby state.
9. The liquid ejection head according to claim 1, wherein a timing at which the first active region transitions to a state of the first deformation and a timing at which the second active region transitions to a state of the first deformation coincide.
10. The liquid ejection head according to claim 1, further comprising three or more electrodes at

different positions in the thickness direction, the three or more electrodes each applying the first electric field and/or the second electric field, wherein two electrodes of the three or more electrodes that are adjacent in the thickness direction and that apply the first electric field are separated by a distance in the thickness direction, two electrodes of the three or more electrodes that are adjacent in the thickness direction and that apply the second electric field are arranged at another distance from each other in the thickness direction, and the distance between the two electrodes that apply the first electric field is shorter than the other distance between the two electrodes that apply the second electric field.

11. The liquid ejection head according to claim 1, wherein a maximum value of potential difference between two electrodes that apply the first electric field is equal to a maximum value of potential difference between two electrodes that apply the second electric field in the liquid ejection control.

12. The liquid ejection head according to claim 1, wherein one surface of the piezoelectric actuator located on a first side is farther from the channel member than another surface of the piezoelectric actuator located on a second side, the piezoelectric actuator comprises a first piezoelectric layer and a second piezoelectric layer stacked in sequence from the first side to the second side, a first electrode disposed on a surface of the first piezoelectric layer on the first side, the first electrode extending over the midsection in a see-through plan view, a second electrode disposed on a surface of the first piezoelectric layer on the second side, the second electrode extending over the midsection in the see-through plan view, and a third electrode disposed on a surface of the second piezoelectric layer on the second side, the third electrode extending over the midsection, the peripheral section, and the outer region in the see-through plan view, the first active region comprises a region of the first piezoelectric layer that is located between the first electrode and the second electrode, and a region-of the second piezoelectric layer that is located between the second electrode and a portion included in the third electrode that extends over the midsection, and the second active region is located on the second side of a portion of the third electrode that overlaps the peripheral section and the outer region.

13. The liquid ejection head according to claim 12, wherein the piezoelectric actuator comprises a third piezoelectric layer and a fourth piezoelectric layer stacked in sequence from the second piezoelectric layer to the second side, a fourth electrode disposed on a surface of the fourth piezoelectric layer on the second side, the fourth electrode extending over the peripheral section and the outer region in the see-through plan view, the second active region comprises a region of the third and fourth piezoelectric layers that is located between the fourth electrode and a portion included in the third electrode that extends over the peripheral section and the outer region.

14. The liquid ejection head according to claim 13, wherein the region of the first piezoelectric layer that is included in the first active region and the region of the second piezoelectric layer and that is included in the first active region are polarized in opposite directions, the region of the third and fourth piezoelectric layers that are included in the second active region and the region of the first piezoelectric layer that is included in the first active region are polarized in a same direction, and with the first electrode and the third electrode placed at a first potential, and the second electrode and the fourth electrode placed at a second potential, the liquid ejection control is performed in such a manner that a difference between the first potential and the second potential causes application of the first electric field and the second electric field.

15. The liquid ejection head according to claim 13, wherein a sum of a thickness of the third piezoelectric layer and a thickness of the fourth piezoelectric layer is greater than a thickness of the first piezoelectric layer and is greater than a thickness of the second piezoelectric layer.

16. The liquid ejection head according to claim 13, wherein the piezoelectric actuator comprises a conductor pattern disposed on a surface of the third piezoelectric layer on the second side and located on an outer side with respect to the second active region in the see-through plan view.

17. The liquid ejection head according to claim 1, wherein a periphery of the pressure chamber viewed in the plan through the pressure applying surface comprises a circular arc subtending an

angle of 180° or more at a center of the pressure chamber.
18. The liquid ejection head according to claim 1, wherein in a sectional view taken along a line passing through a center of the pressure chamber and orthogonal to the pressure applying surface, a width of a second portion of the second active region that is located outside the pressure chamber is greater than a width of a first portion of the second active region that extends over the pressure chamber.
19. The liquid ejection head according to claim 1, wherein when the liquid ejection control is performed, a maximum value of the intensity of the first electric field is greater than a maximum value of the intensity of the second electric field.
20. A recording apparatus, comprising: a liquid ejection head according to claim 1; and a controller configured to control the liquid ejection head.