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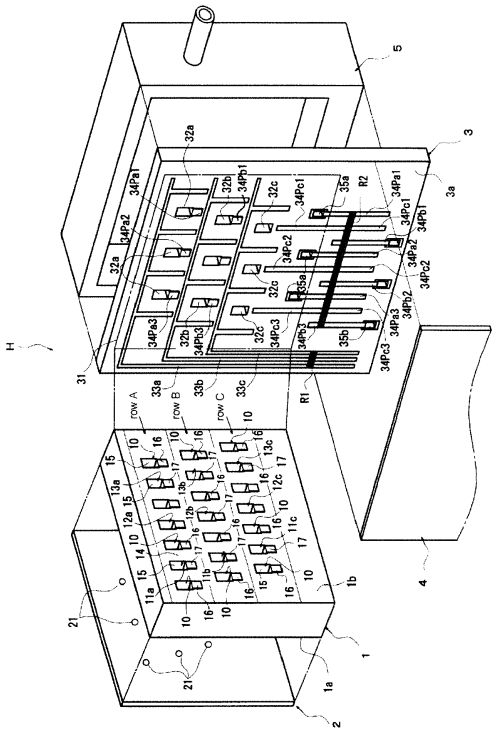
(54) PIEZOELECTRIC ACTUATOR UNIT, INKJET HEAD, INKJET RECORDING APPARATUS, HEAD CHIP, AND WIRING SUBSTRATE

(57) In a piezoelectric actuator unit including a plurality of sets, each set including a plurality of piezoelectric elements a1 to a3, b1 to b3, c1 to c3, individual electrodes Pa1 to Pa3, Pb1 to Pb3, Pc1 to Pc3, each supplying an electrical signal to a corresponding one of the plurality of piezoelectric elements, and a common electrode Ca, Cb, Cc that supplies a common electrical signal to each of the plurality of piezoelectric elements, the individual electrodes and the common electrode of each set being electrically independent of one another, a plurality of the common electrodes are connected to each other by an inter-common electrode resistance R1 in at least one place, and the electric resistivity of the inter-common electrode resistance R1 is higher than the electric resistivity of the common electrodes Ca, Cb, Cc and is lower than the electric resistivity of a member forming a face on which the common electrodes Ca, Cb, Cc are formed.

FIG 2



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Description

TECHNICAL FIELD

[0001] The present invention relates to piezoelectric actuator units, inkjet heads, inkjet recording apparatuses, head chips, and wiring substrates, and, more particularly to a piezoelectric actuator unit, an inkjet head, an inkjet recording apparatus, a head chip, and a wiring substrate that can prevent a reduction in the driving efficiency of a particular piezoelectric element by a very small current generated by an electromotive force of a piezoelectric element without the need to provide an insulating layer between electrodes and can prevent a reduction in yields.

BACKGROUND

[0002] In a piezoelectric actuator unit having a plurality of piezoelectric elements, a piezoelectric element is driven as a result of an electric field being applied to the piezoelectric element sandwiched between a pair of electrodes. As one mode of this piezoelectric actuator unit, there is an inkjet head that causes ink to be discharged by driving of a piezoelectric element. The inkjet head is configured so as to apply pressure for discharge to the ink in a pressure chamber by changing the volume of the pressure chamber corresponding to a piezoelectric element by driving of the piezoelectric element.

[0003] As the inkjet head, there is an on-demand type inkjet head that can individually drive a plurality of piezoelectric elements. This inkjet head is generally an inkjet head in which one of a pair of electrodes provided in a piezoelectric element is an individual electrode which is provided for each piezoelectric element and the other is a common electrode which is shared by the plurality of piezoelectric elements. By applying a predetermined electrical signal to the individual electrode of a piezoelectric element whose driving is desired, on-demand driving of each piezoelectric element is made possible. Moreover, in the case of an inkjet head having a plurality of nozzle rows, an inkjet head in which a common electrode is independently provided for each of the nozzle rows in order to make it possible to make the nozzle rows perform discharge with different discharge timing is known.

[0004] In recent years, in the inkjet head, in order to make higher-resolution image recording possible, the density of piezoelectric elements has become increasingly higher and, accordingly, individual electrodes are starting to be densely disposed. Under such circumstances, it has been found out that a phenomenon may occur in which the driving efficiency of a particular piezoelectric element of the produced inkjet head is reduced. Since a short circuit does not occur between electrodes, driving of each piezoelectric element is possible. However, since a reduction in the driving efficiency of the particular piezoelectric element causes a reduction in the ink ejection speed by that piezoelectric element and results in a defective item, which leads to a reduction in the yield of heads.

[0005] The piezoelectric actuator unit is often produced through processes, such as the application of pressure and the application of heat, which cause deformation of the piezoelectric element. In particular, the inkjet head is produced by bonding a plurality of parts including the piezoelectric element together by the application of pressure and heat. Therefore, it is considered that a reduction in the driving efficiency of a piezoelectric element is caused by the flow of a very small current generated by an electromotive force, which is generated as a result of the piezoelectric element being deformed and distorted in the course of production, into the electrode of another piezoelectric element via the electrode.

[0006] In the past, as measures against an inter-wiring short circuit and an inter-high density wiring short circuit in the production process, the technologies described in JP-A-2007-8044 and JP-A-2015-51587 have been known.

[0007] JP-A-2007-8044 discloses the technology of covering an exposed surface of an adhesion layer forming a common lead electrode with a protective layer leading out of a bonding layer bonding the substrates together in order to prevent a short circuit between an individual lead electrode and the common lead electrode without interfering with the displacement of a piezoelectric element.

[0008] Moreover, JP-A-2015-51587 discloses the technology of providing an insulating layer in such a way as to coat a part passing through an adhesive fillet outside a junction region between a head chip and a wiring substrate in order to prevent a short circuit between electrodes caused by agglomerated conductive particles in an adhesive.

[0009] As a result of the intensive study conducted by the inventor of the present invention, it is considered that the flow of a very small current generated by an electromotive force of a piezoelectric element occurs in a region in which the distance between the adjacent electrodes of different piezoelectric elements is locally narrowed due to variations or the like occurred at the time of the formation of the electrodes or a region in which conductive particles which are used in bonding of the electrodes are agglomerated. However, since the above flow occurs in a part in which the resistance between the electrodes is increased to such an extent that does not affect on-demand driving (for example, a few MΩ or higher), it is very difficult to provide an insulating layer as in the existing technology in a part in which the resistance between the electrodes is increased in an inkjet head with a complicated structure.

PRIOR ART DOCUMENTS

PATENT DOCUMENTS

[0010]

Patent Document 1: JP-A-2007-8044
Patent Document 2: JP-A-2015-51587

SUMMARY OF THE INVENTION

PROBLEM TO BE SOLVED BY THE INVENTION

[0011] Thus, an object of the present invention is to provide a piezoelectric actuator unit that can prevent a reduction in the driving efficiency of a particular piezoelectric element by a very small current generated by an electromotive force of a piezoelectric element without the need to provide an insulating layer between electrodes and can prevent a reduction in the yield of units.

[0012] Moreover, another object of the present invention is to provide an inkjet head that can prevent a reduction in the driving efficiency of a particular piezoelectric element by a very small current generated by an electromotive force of a piezoelectric element without the need to provide an insulating layer between electrodes and can prevent a reduction in the yield of heads.

[0013] Furthermore, still another object of the present invention is to provide an inkjet recording apparatus that can perform high-quality image recording by being provided with an inkjet head in which a reduction in the driving efficiency of a particular piezoelectric element by a very small current generated by an electromotive force of a piezoelectric element is prevented without the need to provide an insulating layer between electrodes.

[0014] In addition, still another object of the present invention is to provide a head chip and a wiring substrate that can prevent a reduction in the driving efficiency of a particular piezoelectric element by a very small current generated by an electromotive force of a piezoelectric element without the need to provide an insulating layer between electrodes and can prevent a reduction in the yield of heads.

[0015] Other objects of the present invention will become apparent from the following description.

MEANS FOR SOLVING PROBLEM

[0016] The above objects are solved by the following aspects of the present invention.

1. A piezoelectric actuator unit including a plurality of sets, each set including a plurality of piezoelectric elements, individual electrodes, each supplying an electrical signal to a corresponding one of the plurality of piezoelectric elements, and a common electrode that supplies a common electrical signal to each of the plurality of piezoelectric elements, the individual electrodes and the common electrode of each set being electrically independent of one another, wherein
a plurality of the common electrodes are connected to each other by an inter-common electrode resistance in at least one place, and
an electric resistivity of the inter-common electrode resistance is higher than an electric resistivity of the common electrodes and is lower than an electric resistivity of a member forming a face on which the common electrodes are formed.

2. The piezoelectric actuator unit according to 1,
wherein
when an electrical signal is transmitted to the piezoelectric elements, a maximum amount of current which is smaller than a maximum amount of current flowing through the common electrodes flows through the inter-common electrode resistance.

3. The piezoelectric actuator unit according to 1 or 2,
wherein
the inter-common electrode resistance is formed of any one of a resin containing conductive particles, an alloy, carbon, a semiconductor, a metal oxide, and a conductive polymer.

4. A piezoelectric actuator unit including a plurality of sets, each set including a plurality of piezoelectric elements, individual electrodes, each supplying an electrical signal to a corresponding one of the plurality of piezoelectric elements, and a common electrode that supplies a common electrical signal to each of the plurality of piezoelectric elements, the individual electrodes and the common electrode of each set being electrically independent of one

another, wherein
a plurality of the individual electrodes are connected to each other by an inter-individual electrode resistance in at least one place, and
an electric resistivity of the inter-individual electrode resistance is higher than an electric resistivity of the individual electrodes and is lower than an electric resistivity of a member forming a face on which the individual electrodes are formed.

5. The piezoelectric actuator unit according to 4,
wherein
when an electrical signal is transmitted to the piezoelectric elements, a maximum amount of current which is smaller than a maximum amount of current flowing through the individual electrodes flows through the inter-individual electrode resistance.

6. The piezoelectric actuator unit according to 4 or 5,
wherein
the inter-individual electrode resistance is formed of any one of a resin containing conductive particles, an alloy, carbon, a semiconductor, a metal oxide, and a conductive polymer.

7. A piezoelectric actuator unit including a plurality of sets, each set including a plurality of piezoelectric elements, individual electrodes, each supplying an electrical signal to a corresponding one of the plurality of piezoelectric elements, and a common electrode that supplies a common electrical signal to each of the plurality of piezoelectric elements, the individual electrodes and the common electrode of each set being electrically independent of one another, wherein
a plurality of the common electrodes are connected to each other by an inter-common electrode resistance in at least one place and a plurality of the individual electrodes are connected to each other by an inter-individual electrode resistance,
an electric resistivity of the inter-common electrode resistance is higher than an electric resistivity of the common electrodes and is lower than an electric resistivity of a member forming a face on which the common electrodes are formed, and
an electric resistivity of the inter-individual electrode resistance is higher than an electric resistivity of the individual electrodes and is lower than an electric resistivity of a member forming a face on which the individual electrodes are formed.

8. The piezoelectric actuator unit according to 7,
wherein
when an electrical signal is transmitted to the piezoelectric elements, a maximum amount of current which is smaller than a maximum amount of current flowing through the common electrodes flows through the inter-common electrode resistance, and, when an electrical signal is transmitted to the piezoelectric elements, a maximum amount of current which is smaller than a maximum amount of current flowing through the individual electrodes flows through the inter-individual electrode resistance.

9. The piezoelectric actuator unit according to 7 or 8,
wherein
the inter-common electrode resistance and the inter-individual electrode resistance are formed of any one of a resin containing conductive particles, an alloy, carbon, a semiconductor, a metal oxide, and a conductive polymer.

10. The piezoelectric actuator unit according to any one of 1 to 9, wherein
electrical signals which are input to the plurality of common electrodes are not identical with each other.

11. An inkjet head that is formed of the piezoelectric actuator unit according to any one of 1 to 10 and includes a plurality of pressure chambers to which ink is supplied,
wherein
the inkjet head causes the ink in the pressure chambers to be discharged from nozzles by expanding or contracting volumes of the pressure chambers by driving the piezoelectric elements by an application of electrical signals to the individual electrodes and the common electrodes.

12. The inkjet head according to 11, comprising:
a head chip in which the pressure chambers and the piezoelectric elements are formed; and
a wiring substrate that is bonded to the head chip and forms a connection portion between the wiring substrate and an external wiring substrate for applying the electrical signals,
wherein
the individual electrodes and the common electrodes are formed from a front surface of the head chip to a front surface of the wiring substrate.

13. An inkjet recording apparatus comprising:
the inkjet head according to 11 or 12,
wherein

the inkjet recording apparatus records an image on a recording medium by causing the ink in the pressure chambers to be discharged from the nozzles by applying the electrical signals to the piezoelectric elements of the inkjet head via the common electrodes and the individual electrodes.

14. A head chip that is formed of the piezoelectric actuator unit according to any one of 1 to 10 and includes a plurality of pressure chambers to which ink is supplied, wherein
the head chip causes the ink in the pressure chambers to be discharged from nozzles by expanding or contracting volumes of the pressure chambers by driving the piezoelectric elements by an application of electrical signals to the individual electrodes and the common electrodes.

15. A wiring substrate that forms a connection portion between the wiring substrate and an external wiring substrate for applying electrical signals to a plurality of piezoelectric elements by being bonded to a head chip provided with a plurality of pressure chambers to which ink is supplied and the plurality of piezoelectric elements that expand or contract volumes of the pressure chambers and includes a plurality of sets, each set including individual electrodes, each supplying an electrical signal to a corresponding one of the plurality of piezoelectric elements, and a common electrode that supplies a common electrical signal to the plurality of piezoelectric elements, the individual electrodes and the common electrode of each set being formed so as to be electrically independent of one another, wherein
a plurality of the common electrodes are connected to each other by an inter-common electrode resistance in at least one place, and
an electric resistivity of the inter-common electrode resistance is higher than an electric resistivity of the common electrodes and is lower than an electric resistivity of a member forming a face on which the common electrodes are formed.

16. A wiring substrate that forms a connection portion between the wiring substrate and an external wiring substrate for applying electrical signals to a plurality of piezoelectric elements by being bonded to a head chip provided with a plurality of pressure chambers to which ink is supplied and the plurality of piezoelectric elements that expand or contract volumes of the pressure chambers and includes a plurality of sets, each set including individual electrodes, each supplying an electrical signal to a corresponding one of the plurality of piezoelectric elements, and a common electrode that supplies a common electrical signal to the plurality of piezoelectric elements, the individual electrodes and the common electrode of each set being formed so as to be electrically independent of one another, wherein
a plurality of the individual electrodes are connected to each other by an inter-individual electrode resistance, and
an electric resistivity of the inter-individual electrode resistance is higher than an electric resistivity of the individual electrodes and is lower than an electric resistivity of a member forming a face on which the individual electrodes are formed.

17. A wiring substrate that forms a connection portion between the wiring substrate and an external wiring substrate for applying electrical signals to a plurality of piezoelectric elements by being bonded to a head chip provided with a plurality of pressure chambers to which ink is supplied and the plurality of piezoelectric elements that expand or contract volumes of the pressure chambers and includes a plurality of sets, each set including individual electrodes, each supplying an electrical signal to a corresponding one of the plurality of piezoelectric elements, and a common electrode that supplies a common electrical signal to the plurality of piezoelectric elements, the individual electrodes and the common electrode of each set being formed so as to be electrically independent of one another, wherein
a plurality of the common electrodes are connected to each other by an inter-common electrode resistance in at least one place and a plurality of the individual electrodes are connected to each other by an inter-individual electrode resistance,
an electric resistivity of the inter-common electrode resistance is higher than an electric resistivity of the common electrodes and is lower than an electric resistivity of a member forming a face on which the common electrodes are formed, and
an electric resistivity of the inter-individual electrode resistance is higher than an electric resistivity of the individual electrodes and is lower than an electric resistivity of a member forming a face on which the individual electrodes are formed.

EFFECT OF THE INVENTION

[0017] According to the present invention, it is possible to provide a piezoelectric actuator unit that can prevent a reduction in the driving efficiency of a particular piezoelectric element by a very small current generated by an electromotive force of a piezoelectric element without the need to provide an insulating layer between electrodes and can prevent a reduction in the yield of units.

[0018] Moreover, according to the present invention, it is possible to provide an inkjet head that can prevent a reduction in the driving efficiency of a particular piezoelectric element by a very small current generated by an electromotive force of a piezoelectric element without the need to provide an insulating layer between electrodes and can prevent a reduction in the yield of heads.

[0019] Furthermore, according to the present invention, it is possible to provide an inkjet recording apparatus that can perform high-quality image recording by being provided with an inkjet head in which a reduction in the driving efficiency of a particular piezoelectric element by a very small current generated by an electromotive force of a piezoelectric element is prevented without the need to provide an insulating layer between electrodes.

[0020] In addition, according to the present invention, it is possible to provide a head chip and a wiring substrate that can prevent a reduction in the driving efficiency of a particular piezoelectric element by a very small current generated by an electromotive force of a piezoelectric element without the need to provide an insulating layer between electrodes and can prevent a reduction in the yield of heads.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021]

FIG. 1 is a schematic explanatory diagram depicting the basic configuration of a piezoelectric actuator unit according to the present invention;
FIG. 2 is an exploded perspective view depicting an embodiment of an inkjet head according to the present invention;
FIG. 3 is a diagram of the inkjet head depicted in FIG. 2 when viewed from a back surface side of a wiring substrate;
FIG. 4 is an exploded perspective view depicting another embodiment of the inkjet head according to the present invention;
FIG. 5 is a schematic configuration diagram depicting an embodiment of an inkjet recording apparatus according to the present invention; and
FIG. 6 is an explanatory diagram depicting a wiring substrate used in an example.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0022] Hereinafter, embodiments of the present invention will be described in detail.

(Piezoelectric actuator unit)

[0023] FIG. 1 is a schematic explanatory diagram depicting the basic configuration of a piezoelectric actuator unit according to the present invention.

[0024] In the drawing, A, B, and C denote areas in which a plurality of piezoelectric elements are arranged on a substrate G formed of an insulating material. The piezoelectric elements present in the area A are represented as a1, a2, and a3. Ca denotes a common electrode shared by the piezoelectric elements a1, a2, and a3. Hereinafter, likewise, the plurality of piezoelectric elements present in the area B are represented as b1, b2, and b3 and a common electrode is represented as Cb, and the plurality of piezoelectric elements present in the area C are represented as c1, c2, and c3 and a common electrode is represented as Cc. Moreover, Pa1 to Pa3 are individual electrodes provided individually for the piezoelectric elements a1, a2, and a3, Pb1 to Pb3 are individual electrodes provided individually for the piezoelectric elements b1, b2, and b3, and Pc1 to Pc3 are individual electrodes provided individually for the piezoelectric elements c1, c2, and c3.

[0025] That is, this piezoelectric actuator unit includes a plurality of sets (three sets of the areas A, B, and C in FIG. 1), each having a plurality of piezoelectric elements, individual electrodes individually supplying electrical signals to the plurality of piezoelectric elements, and a common electrode supplying a common electrical signal to the plurality of piezoelectric elements. The individual electrodes Pa1 to Pa3 and the common electrode Ca, the individual electrodes Pb1 to Pb3 and the common electrode Cb, and the individual electrodes Pc1 to Pc3 and the common electrode Cc of these sets are formed in an electrically independent manner in such a way that they are not in contact with one another. The individual electrodes Pa1 to Pa3, Pb1 to Pb3, and Pc1 to Pc3 are arranged in parallel in such a way that the individual electrodes corresponding to the piezoelectric elements a1, b1, and c1 of the different areas A to C are adjacent to one another, the individual electrodes corresponding to the piezoelectric elements a2, b2, and c2 of the different areas A to C are adjacent to one another, and the individual electrodes corresponding to the piezoelectric elements a3, b3, and c3 of the different areas A to C are adjacent to one another.

[0026] On-demand driving of each of the piezoelectric elements a1 to a3, b1 to b3, and c1 to c3 is performed as a result of a predetermined electrical signal (driving signal) being applied between a corresponding one of the individual electrodes Pa1 to Pa3, Pb1 to Pb3, and Pc1 to Pc3 and a corresponding one of the common electrodes Ca, Cb, and Cc. It is desirable that electrical signals which are input to the common electrodes Ca, Cb, and Cc are not identical with one another. As a result, it is possible to set the driving timing of the piezoelectric elements a1 to a3, b1 to b3, and c1 to c3 individually for each of the areas A to C.

[0027] In such a piezoelectric actuator unit, all the common electrodes Ca, Cb, and Cc are connected to one another

by an inter-common electrode resistance R1 indicated by a long broken line in FIG. 1 and all the individual electrodes Pa1 to Pa3, Pb1 to Pb3, and Pc1 to Pc3 are connected to one another by an inter-individual electrode resistance R2 indicated by a short broken line in FIG. 1.

[0028] The inter-common electrode resistance R1 is formed on the substrate G in the form of a band or a line so as to be brought into intimate contact therewith in such a way as to connect the common electrodes Ca, Cb, and Cc to one another. A material forming the inter-common electrode resistance R1 is a material whose electric resistivity is higher than the electric resistivity of the common electrodes Ca, Cb, and Cc and is lower than the electric resistivity of the substrate G. It goes without saying that this material is a material having an electric resistivity in a range that does not affect the driving of the piezoelectric elements a1 to a3, b1 to b3, and c1 to c3. Here, the substrate G is a member forming a face on which the common electrodes Ca, Cb, and Cc are formed.

[0029] In this inter-common electrode resistance R1, a portion present between the common electrodes Ca, Cb, and Cc functions as a resistance. As a result, when an electrical signal is applied to the piezoelectric elements a1 to a3, b1 to b3, and c1 to c3, the maximum amount of current which is smaller than the maximum amount of current flowing through the common electrodes Ca, Cb, and Cc flows through the inter-common electrode resistance R1.

[0030] On the other hand, the inter-individual electrode resistance R2 is formed on the substrate G in the form of a band or a line so as to be brought into intimate contact therewith in such a way as to connect the individual electrodes Pa1 to Pa3, Pb1 to Pb3, and Pc1 to Pc3 to one another. A material forming the inter-individual electrode resistance R2 is a material whose electric resistivity is higher than the electric resistivity of the individual electrodes Pa1 to Pa3, Pb1 to Pb3, and Pc1 to Pc3 and is lower than the electric resistivity of the substrate G. It goes without saying that this material is also a material having an electric resistivity in a range that does not affect the driving of the piezoelectric elements a1 to a3, b1 to b3, and c1 to c3. Here, the substrate G is a member forming a face on which the individual electrodes Pa1 to Pa3, Pb1 to Pb3, and Pc1 to Pc3 are formed.

[0031] In this inter-individual electrode resistance R2, a portion present between the individual electrodes Pa1 to Pa3, Pb1 to Pb3, and Pc1 to Pc3 functions as a resistance. As a result, when an electrical signal is applied to the piezoelectric elements a1 to a3, b1 to b3, and c1 to c3, the maximum amount of current which is smaller than the maximum amount of current flowing through the individual electrodes Pa1 to Pa3, Pb1 to Pb3, and Pc1 to Pc3 flows through the inter-individual electrode resistance R2.

[0032] As a result of the common electrodes Ca, Cb, and Cc being connected to one another by the inter-common electrode resistance R1 in this manner and the individual electrodes Pa1 to Pa3, Pb1 to Pb3, and Pc1 to Pc3 being connected to one another by the inter-individual electrode resistance R2 in this manner, this piezoelectric actuator unit produces the following effects.

[0033] If an electromotive force caused by distortion is generated in any one of the piezoelectric elements a1 to a3, b1 to b3, and c1 to c3 of the areas A to C, a very small current generated by the electromotive force also flows through all the piezoelectric elements a1 to a3, b1 to b3, and c1 to c3 of the areas A to C through the common electrodes Ca, Cb, and Cc and the inter-common electrode resistance R1 and through the individual electrodes Pa1 to Pa3, Pb1 to Pb3, and Pc1 to Pc3 and the inter-individual electrode resistance R2. As a result, since the very small current spreads over all the piezoelectric elements a1 to a3, b1 to b3, and c1 to c3, it is possible to prevent a reduction in driving efficiency caused by degradation in the piezoelectric performance of a particular piezoelectric element without the need to form an insulating film between the electrodes.

[0034] That is, since the piezoelectric elements a1 to a3, b1 to b3, and c1 to c3 can be regarded as a kind of capacitor, by providing the inter-common electrode resistance R1 and the inter-individual electrode resistance R2, a very small current generated by an electromotive force generated in any one of the piezoelectric elements a1 to a3, b1 to b3, c1 to c3 is discharged. As a result, the balance among the areas A to C is achieved and it is possible to avoid the occurrence of degradation in piezoelectric performance in a particular piezoelectric element and prevent a reduction in the yield of units.

[0035] The reason why the electric resistivity of the inter-common electrode resistance R1 is made higher than the electric resistivity of the common electrodes Ca, Cb, and Cc is as follows. If the electric resistivity of the inter-common electrode resistance R1 is the same as or lower than the electric resistivity of the common electrodes Ca, Cb, and Cc, when an electrical signal is applied to the individual electrodes Pa1 to Pa3, Pb1 to Pb3, and Pc1 to Pc3 and the common electrodes Ca, Cb, and Cc to drive the piezoelectric elements a1 to a3, b1 to b3, and c1 to c3, a large current flows through the inter-common electrode resistance R1, which becomes a cause of a malfunction. Moreover, the reason why the electric resistivity of the inter-common electrode resistance R1 is made lower than the electric resistivity of the substrate G is as follows. If the electric resistivity of the inter-common electrode resistance R1 is higher than the electric resistivity of the substrate G, it is impossible to suppress a phenomenon in which a very small current generated by an electromotive force of any one of the piezoelectric elements a1 to a3, b1 to b3, and c1 to c3 flows into a part in which the interelectrode distance is locally narrowed.

[0036] The common electrodes Ca, Cb, and Cc are generally formed of a metal material such as gold or aluminum, and the electric resistivity thereof is about 1×10^{-7} Ω·cm. Moreover, as the substrate G, a substrate formed of an insulating

material such as glass, ceramic, or plastic is generally used, and the electric resistivity thereof is 1 x 10^{10} Ω·cm or higher. By making the amount of current flowing through the inter-common electrode resistance R1 smaller than the amount of current flowing through the common electrodes Ca, Cb, and Cc, it is possible to curb the influence on the driving of the piezoelectric elements a1 to a3, b1 to b3, and c1 to c3. However, the electrode cross-sectional area of the inter-common electrode resistance R1 having a proportional relationship with a resistance value has to be made smaller than that of the substrate G in light of strength and it is desirable to set the electrode cross-sectional area of the inter-common electrode resistance R1 at an electrode cross-sectional area which is nearly equal to that of the common electrode in light of the production process. Thus, as the inter-common electrode resistance R1, it is necessary to use an inter-common electrode resistance whose electric resistivity is in a range intermediate between the electric resistivity of the common electrodes Ca, Cb, and Cc and the electric resistivity of the substrate G.

[0037] On the other hand, the reason why the electric resistivity of the inter-individual electrode resistance R2 is made higher than the electric resistivity of the individual electrodes Pa1 to Pa3, Pb1 to Pb3, and Pc1 to Pc3 is as follows. As is the case with the inter-common electrode resistance R1, when an electrical signal is applied, a current flows through the inter-individual electrode resistance R2, which becomes a cause of a malfunction. Moreover, the reason why the electric resistivity of the inter-individual electrode resistance R2 is made lower than the electric resistivity of the substrate G is as follows. If the electric resistivity of the inter-individual electrode resistance R2 is higher than the electric resistivity of the substrate G, it is impossible to suppress a phenomenon in which a very small current generated by an electromotive force of any one of the piezoelectric elements a1 to a3, b1 to b3, and c1 to c3 flows into a part in which the interelectrode distance is locally narrowed.

[0038] For the same reason as the inter-common electrode resistance R1, as the inter-individual electrode resistance R2, an inter-individual electrode resistance whose electric resistivity is in a range intermediate between the electric resistivity of the individual electrodes Pa1 to Pa3, Pb1 to Pb3, and Pc1 to Pc3 and the electric resistivity of the substrate G formed of an insulating material is used.

[0039] A material forming the inter-common electrode resistance R1 and the inter-individual electrode resistance R2 is not limited to a particular material as long as the material can exhibit a predetermined high resistance. Examples of such a material include a resin into which conductive particles are mixed, an alloy, carbon, a semiconductor, a metal oxide, and a conductive polymer. Of these materials, it is desirable to use a resin into which conductive particles are mixed because the use thereof allows the inter-common electrode resistance R1 and the inter-individual electrode resistance R2 to be easily formed on the substrate G in the form of a band or a line and facilitates an adjustment to electric resistivity. As the conductive particles, carbon fillers, metal fine particles, or the like can be used. An adjustment to electric resistivity can also be made by adjusting the width or thickness of an interelectrode resistance, but the adjustment can be made easily by adjusting the rate of mixing of the conductive particles.

[0040] Incidentally, as the material of the inter-common electrode resistance R1 and the inter-individual electrode resistance R2, the same material or different materials may be used.

[0041] Moreover, in the above description, the piezoelectric actuator unit in which both the inter-common electrode resistance R1 and the inter-individual electrode resistance R2 are provided has been described as an example. This is the most effective mode, but the interelectrode resistance which is provided in the piezoelectric actuator unit may be only one of the inter-common electrode resistance R1 and the inter-individual electrode resistance R2. If only one of the inter-common electrode resistance R1 and the inter-individual electrode resistance R2 is provided, it is desirable to provide only the inter-common electrode resistance R1. The reason is that simply connecting the common electrodes Ca, Cb, and Cc of the areas A to C by the inter-common electrode resistance R1 makes it possible to connect the plurality of piezoelectric elements a1 to a3, b1 to b3, and c1 to c3 of the areas A to C collectively via the common electrodes Ca, Cb, and Cc.

[0042] When both the inter-common electrode resistance R1 and the inter-individual electrode resistance R2 are provided, though not depicted in the drawing, the inter-common electrode resistance R1 and the inter-individual electrode resistance R2 may be connected to each other.

[0043] Moreover, the inter-common electrode resistance R1 and the inter-individual electrode resistance R2 are not limited to those formed on the upper surfaces of the common electrodes Ca, Cb, and Cc and the upper surfaces of the individual electrodes Pa1 to Pa3, Pb1 to Pb3, and Pc1 to Pc3, respectively. Though not depicted in the drawing, the inter-common electrode resistance R1 and the inter-individual electrode resistance R2 may be formed on the lower surfaces of the common electrodes Ca, Cb, and Cc and the lower surfaces of the individual electrodes Pa1 to Pa3, Pb1 to Pb3, and Pc1 to Pc3, respectively. For example, the inter-common electrode resistance R1 and the inter-individual electrode resistance R2 may be formed in advance on the front surface of the substrate G which is in contact with the common electrodes Ca, Cb, and Cc and the individual electrodes Pa1 to Pa3, Pb1 to Pb3, and Pc1 to Pc3; then, the common electrodes Ca, Cb, and Cc and the individual electrodes Pa1 to Pa3, Pb1 to Pb3, and Pc1 to Pc3 may be formed thereon. In this case, by forming the interelectrode resistance on the front surface of the substrate G in the form of a film over the common electrodes Ca, Cb, and Cc and the individual electrodes Pa1 to Pa3, Pb1 to Pb3, and Pc1 to Pc3, a state in which the inter-common electrode resistance R1 and the inter-individual electrode resistance R2 are

connected to each other as described above may be obtained.

(Inkjet head)

[0044] Next, as a specific example of the piezoelectric actuator unit, an embodiment in a case in which the present invention is applied to an inkjet head will be described by using the drawings.

[0045] FIG. 2 is an exploded perspective view of an inkjet head according to the present invention, and FIG. 3 is a diagram of the inkjet head depicted in FIG. 2 when viewed from a back surface side of a wiring substrate.

[0046] In the drawings, H denotes an inkjet head, 1 denotes a head chip, 2 denotes a nozzle plate which is joined to a front face 1a of the head chip 1, 3 denotes a wiring substrate which is joined to a rear face 1b of the head chip 1, 4 denotes a flexible substrate (FPC) which is connected to an end 3a of the wiring substrate 3, and 5 denotes a manifold member which is joined to the back surface of the wiring substrate 3, the manifold member in which ink is stored. Incidentally, FIG. 2 depicts a state in which the inkjet head H is opened into right and left between the head chip 1 and the wiring substrate 3.

[0047] The head chip 1 is formed as a hexahedron and has a plurality of channels, each being a pressure chamber, which are arranged side by side. This head chip 1 has three channel rows: rows A to C, each being a channel row in which a plurality of channels are arranged side by side, but the number of channel rows is not limited to a particular number as long as there are a plurality of channel rows. The channel rows, the rows A to C, correspond to the areas A to C in the above-described piezoelectric actuator unit. In the following description, a is added to the end of a letter or numeral indicating a channel in the row A, b is added to the end of a letter or numeral indicating a channel in the row B, and c is added to the end of a letter or numeral indicating a channel in the row C. Since the channel rows have the same configuration, the configuration of the channel row will be further described by taking up a channel row in the row A as an example.

[0048] Each channel row is formed of driving channels and dummy channels. In the present embodiment, a case in which one channel row is formed of three driving channels 11a, 12a, and 13a and four dummy channels 10 is taken up as an example. One channel row is formed as a result of the driving channels 11a, 12a, and 13a and the dummy channels 10 being alternately disposed. Each channel row has the dummy channels 10 as channels at both ends thereof. A partition wall between the adjacent channels in the channel row (between the driving channel 11a, 12a, or 13a and the dummy channel 10) is a driving wall 14 formed of a piezoelectric element.

[0049] Each of the driving channels 11a, 12a, and 13a and the dummy channels 10 is formed like a straight line from the front face 1a to the rear face 1b of the head chip 1 and has openings in the front face 1a and the rear face 1b. Of the wall surfaces facing the inside of each of the driving channels 11a, 12a, and 13a and each dummy channel 10, at least on the surface of the driving wall 14, a driving electrode 15 is formed.

[0050] This head chip 1 is an independently driven head chip in which the driving channels 11a to 13a and the dummy channels 10, the driving channels 11b to 13b and the dummy channels 10, and the driving channels 11c to 13c and the dummy channels 10 are alternately disposed in the channel rows: the rows A to C, respectively. As a result of an electrical signal (a driving signal) having a predetermined voltage being applied to each driving electrode 15, shear deformation appears in the driving wall 14 sandwiched between a pair of driving electrodes 15 and 15. This gives a pressure change for discharge to the ink supplied to the inside of the driving channels 11a to 13a, 11b to 13b, and 11c to 13c and causes the ink to be discharged, as ink droplets, from nozzles 21 of the nozzle plate 2 joined to the front face 1a of the head chip 1.

[0051] In the rear face 1b of the head chip 1, connection electrodes 16, each having one end electrically connected to the driving electrode 15 in each dummy channel 10, and connection electrodes 17, each having one end electrically connected to the driving electrode 15 in each of the driving channels 11a to 13a, 11b to 13b, and 11c to 13c, are provided independently of one another. The other end of each of the connection electrodes 16 and 17 remains in an area of the channel row in which each of the connection electrodes 16 and 17 is provided and does not spread over the other adjacent areas.

[0052] Each connection electrode 16 is an electrode which is electrically connected to a corresponding one of common electrodes 33a to 33c on the wiring substrate 3, which will be described later, and, as a result of being electrically connected to a corresponding one of the common electrodes 33a to 33c, forms part of a common electrode in the present invention which is electrically connected to the driving electrode 15 in each dummy channel 10. Moreover, each connection electrode 17 is an electrode which is electrically connected to a corresponding one of individual electrodes 34Pa1 to 34Pa3, 34Pb1 to 34Pb3, and 34Pc1 to 34Pc3 on the wiring substrate 3, which will be described later, and, as a result of being electrically connected to a corresponding one of the individual electrodes 34Pa1 to 34Pa3, 34Pb1 to 34Pb3, and 34Pc1 to 34Pc3, forms part of an individual electrode in the present invention which is electrically connected to the driving electrode 15 in each of the driving channels 11a to 13a, 11b to 13b, and 11c to 13c.

[0053] The wiring substrate 3 is joined to the rear face 1b in such a way as to cover all the channels disposed on the rear face 1b of the head chip 1. The wiring substrate 3 joined to the head chip 1 extends to the outside of a junction region 31 in which the wiring substrate 3 is joined to the head chip 1 and greatly hangs over laterally (laterally downward

in FIG. 2) in a direction in which the channel rows of the head chip 1 are arranged.

[0054] The wiring substrate 3 is a flat-shaped substrate formed of an appropriate insulating material such as glass, ceramic, or plastic. In particular, a glass substrate is desirable because it possesses proper stiffness and is inexpensive and easy to be processed.

[0055] The wiring substrate 3 has through holes 32a to 32c for supplying ink from the back surface side of the wiring substrate 3, the through holes 32a to 32c which are individually formed only in positions corresponding to the driving channels 11a to 11c, 12a to 12c, and 13a to 13c of the head chip 1. On the other hand, such through holes are not formed in parts corresponding to the dummy channels 10. As a result, the dummy channels 10 are covered with the wiring substrate 3.

[0056] In the wiring substrate 3, the common electrodes 33a to 33c and the individual electrodes 34Pa1 to 34Pa3, 34Pb1 to 34Pb3, and 34Pc1 to 34Pc3 are formed. That is, the wiring substrate 3 is a member forming a face on which the common electrodes 33a to 33c and the individual electrodes 34Pa1 to 34Pa3, 34Pb1 to 34Pb3, and 34Pc1 to 34Pc3 are formed.

[0057] The common electrodes 33a to 33c are formed on the front surface of the wiring substrate 3 on which the wiring substrate 3 is joined to the head chip 1. One end of the common electrode 33a branches off into four parts so as to correspond to the connection electrodes 16 of the dummy channels 10 of the row A, one end of the common electrode 33b branches off into four parts so as to correspond to the connection electrodes 16 of the dummy channels 10 of the row B, and one end of the common electrode 33c branches off into four parts so as to correspond to the connection electrodes 16 of the dummy channels 10 of the row C; these parts are electrically connected to the corresponding connection electrodes 16. The other ends of the common electrodes 33a to 33c are arranged in parallel independently of one another at the end 3a of the wiring substrate 3 on the lower side in the drawing after passing through the outside of the junction region 31 in which the wiring substrate 3 is joined to the head chip 1.

[0058] The individual electrodes 34Pa1 to 34Pa3 are provided in such a way that there is a one-to-one correspondence between the individual electrodes 34Pa1 to 34Pa3 and the connection electrodes 17 of the driving channels 11a to 13a of the row A, the individual electrodes 34Pb1 to 34Pb3 are provided in such a way that there is a one-to-one correspondence between the individual electrodes 34Pb1 to 34Pb3 and the connection electrodes 17 of the driving channels 11b to 13b of the row B, and the individual electrodes 34Pc1 to 34Pc3 are provided in such a way that there is a one-to-one correspondence between the individual electrode 34Pc1 to 34Pc3 and the connection electrodes 17 of the driving channels 11c to 13c of the row C.

[0059] Incidentally, in this inkjet head H, the driving walls 14 of the channel row: the row A, the common electrodes 33a, and the individual electrodes 34Pa1 to 34Pa3, the driving walls 14 of the channel row: the row B, the common electrodes 33b, and the individual electrodes 34Pb1 to 34Pb3, and the driving walls 14 of the channel row: the row C, the common electrodes 33c, and the individual electrodes 34Pc1 to 34Pc3 each form a set in the present invention. Therefore, this inkjet head H has three sets, each including a plurality of driving walls (piezoelectric elements), a common electrode, and individual electrodes.

[0060] One end of each of the individual electrodes 34Pa1 to 34Pa3 is disposed near the corresponding through hole 32a on the front surface of the wiring substrate 3 and is electrically connected to the corresponding connection electrode 17. The other end of each of the individual electrodes 34Pa1 to 34Pa3 reaches the back surface of the wiring substrate 3 by using each through hole 32a and extends toward the end 3a of the wiring substrate 3. In the junction region 31 of the wiring substrate 3, in a part in which no interference with the channels and the connection electrodes 16 and 17 of the head chip 1 occurs, wiring through holes 35a of the same number as the through holes 32a are formed. The other end of each of the individual electrodes 34Pa1 to 34Pa3 routed to the back surface of the wiring substrate 3 reaches the front surface of the wiring substrate 3 again through the corresponding wiring through hole 35a and extends to the end 3a of the wiring substrate 3 from the wiring through hole 35a.

[0061] One end of each of the individual electrodes 34Pb1 to 34Pb3 is disposed near the corresponding through hole 32b on the front surface of the wiring substrate 3 and is electrically connected to the corresponding connection electrode 17. The other end of each of the individual electrodes 34Pb1 to 34Pb3 reaches the back surface of the wiring substrate 3 by using each through hole 32b and extends toward the end 3a of the wiring substrate 3. At the end 3a of the wiring substrate 3, wiring through holes 35b of the same number as the through holes 32b are formed. The other end of each of the individual electrodes 34Pb1 to 34Pb3 routed to the back surface of the wiring substrate 3 reaches the front surface of the wiring substrate 3 again through the corresponding wiring through hole 35b and extends toward the head chip 1 from the wiring through hole 35b.

[0062] The individual electrodes 34Pc1 to 34Pc3 are formed only on the front surface of the wiring substrate 3. One end of each of the individual electrodes 34Pc1 to 34Pc3 is disposed near the corresponding through hole 32c and is electrically connected to the corresponding connection electrode 17. The other end of each of the individual electrodes 34Pc1 to 34Pc3 extends toward the end 3a of the wiring substrate 3.

[0063] As a result, the other end of each of the individual electrodes 34Pa1 to 34Pa3, the other end of each of the individual electrodes 34Pb1 to 34Pb3, and the other end of each of the individual electrodes 34Pc1 to 34Pc3 are arranged

in parallel independently of one another on the front surface side of the wiring substrate 3 at the end 3a thereof. These individual electrodes 34Pa1 to 34Pa3, 34Pb1 to 34Pb3, and 34Pc1 to 34Pc3 are arranged in parallel in such a way that the individual electrodes corresponding to the driving electrodes 15 of the different channel rows are adjacent to one another.

[0064] Since the individual electrodes 34Pa1 to 34Pa3 and 34Pb1 to 34Pb3 are routed on the front surface side of the wiring substrate 3 at the end 3a thereof after passing through the back surface of the wiring substrate 3, there is no possibility of an interelectrode short circuit, and the individual electrodes 34Pa1 to 34Pa3, 34Pb1 to 34Pb3, and 34Pc1 to 34Pc3 can be densely arranged on the front surface of the wiring substrate 3. The FPC 4 is joined in such a way as to be electrically connected to the common electrodes 33a to 33c and the individual electrodes 34Pa1 to 34Pa3, 34Pb1 to 34Pb3, and 34Pc1 to 34Pc3 arranged in parallel on the front surface side of the wiring substrate 3 at the end 3a thereof.

[0065] In addition, on the front surface of the wiring substrate 3, all the common electrodes 33a to 33c are connected to one another by one inter-common electrode resistance R1 and all the individual electrodes 34Pa1 to 34Pa3, 34Pb1 to 34Pb3, and 34Pc1 to 34Pc3 are connected to one another by one inter-individual electrode resistance R2. The details of these inter-common electrode resistance R1 and the inter-individual electrode resistance R2 have already been described above.

[0066] Therefore, if an electromotive force caused by distortion is generated in any one of the driving walls (piezoelectric elements) 14 of the channel rows: the rows A to C, a very small current generated by the electromotive force flows through all the driving walls 14 of the channel rows through the common electrodes 33a to 33c and the inter-common electrode resistance R1 and through the individual electrodes 34Pa1 to 34Pa3, 34Pb1 to 34Pb3, and 34Pc1 to 34Pc3 and the inter-individual electrode resistance R2. As a result, since the very small current spreads over all the driving walls 14, it is possible to prevent a reduction in driving efficiency caused by degradation in the piezoelectric performance of a particular driving wall 14 without the need to form an insulating film between the electrodes and prevent a reduction in the yield of heads.

[0067] Also in this inkjet head H, as is the case with the above-described piezoelectric actuator unit, only one of the inter-common electrode resistance R1 and the inter-individual electrode resistance R2 may be provided. Moreover, the inter-common electrode resistance R1 and the inter-individual electrode resistance R2 may be connected to each other. Furthermore, the interelectrode resistance may be formed in the form of a film on the front surface of the wiring substrate 3 and the common electrodes 33a to 33c and the individual electrodes 34Pa1 to 34Pa3, 34Pb1 to 34Pb3, and 34Pc1 to 34Pc3 may be formed thereon.

[0068] FIG. 4 depicts another embodiment of the inkjet head. Since the parts identified with the same letters or numerals as those in FIGs. 2 and 3 indicate the parts having the same configuration, the above explanations are also applied here except for a configuration different from that in FIGs. 2 and 3 and explanations are omitted in the following description.

[0069] This inkjet head H differs from the inkjet head H depicted in FIGs. 2 and 3 in that the common electrodes 33a to 33c are formed on the rear face 1b of the head chip 1. The inter-common electrode resistance R1 is provided in such a way as to connect all the common electrodes 33a to 33c on the rear face 1b of the head chip 1. Moreover, the inter-individual electrode resistance R2 is provided in such a way as to connect all the individual electrodes 17 on the rear face 1b of the head chip 1. In this case, the head chip 1 is a member that forms a face (a rear face 1b) on which the common electrodes 33a to 33c and the individual electrodes 17 are formed.

[0070] Also in this inkjet head H, the effect similar to that described above can be obtained. Moreover, also in this inkjet head H, only one of the inter-common electrode resistance R1 and the inter-individual electrode resistance R2 may be provided. Furthermore, the inter-common electrode resistance R1 and the inter-individual electrode resistance R2 may be connected to each other. In addition, the interelectrode resistance may be formed in the form of a film on the rear face 1b of the head chip 1 and the common electrodes 33a to 33c and the individual electrodes 17 may be formed thereon.

[0071] In the above-described embodiments of the piezoelectric actuator unit and the inkjet head, a mode in which all of the three common electrodes are connected by the inter-common electrode resistance has been described, but the mode of connection of the inter-common electrode resistance is not limited thereto. The plurality of common electrodes simply have to be connected by the inter-common electrode resistance in at least one place. Moreover, the number of common electrodes connected by the inter-common electrode resistance is not limited to a particular number.

[0072] Here, modes in which the plurality of common electrodes are connected by the inter-common electrode resistance in at least one place include a mode in which at least two common electrodes of the plurality of common electrodes are connected to each other in one place and a mode in which the plurality of common electrodes are connected to each other by inter-common electrode resistances in two or more places. In the case of a mode in which at least two common electrodes are connected to each other in one place, it is desirable to connect a common electrode in a set in which a malfunction has occurred and a common electrode in a set adjacent thereto by the inter-common electrode resistance.

(Inkjet recording apparatus)

[0073] FIG. 5 is a schematic configuration diagram depicting an embodiment of an inkjet recording apparatus according to the present invention.

[0074] In an inkjet recording apparatus 100, a recording medium 200 is sandwiched between a transport roller pair 101a of a transport mechanism 101 and is transported in a Y direction (a subscanning direction) depicted in the drawing by a transport roller 101b which is driven and rotated by a transport motor 101c.

[0075] Between the transport roller 101b and the transport roller pair 101a, the above-described inkjet head H is provided. The inkjet head H is mounted on a carriage 102 in such a way that the nozzle face side thereof faces the recording medium 200 and is electrically connected to an unillustrated control unit via a flexible cable 103. The carriage 102 is provided so as to be able to reciprocate in an X-X' direction (a main scanning direction) depicted in the drawing, the X-X' direction nearly orthogonal to the transport direction (the subscanning direction) in which the recording medium 200 is transported, along a guide rail 104 put across in a width direction of the recording medium 200 by an unillustrated driver.

[0076] This inkjet recording apparatus 100 records a desired inkjet image on the recording medium 200 as a result of the inkjet head H causing ink in the channels (the driving channels) to be discharged from the nozzles in the course of the inkjet head H moving in the main scanning direction. As described earlier, since a reduction in the driving efficiency of a particular piezoelectric element by a very small current generated by an electromotive force of a piezoelectric element is prevented in the inkjet head H without the need to form an insulating film between the electrodes, it is possible to perform high-quality image recording.

EXAMPLES

[0077] Hereinafter, the effect of the present invention will be illustrated by using examples.

(Example 1)

[0078] A shear mode-type head chip similar to that of FIG. 2 was fabricated by using PZT as a driving wall material. The head chip was a head chip having a total of six channel rows (a total number of driving channels: 1776), three rows on each of the L side and the R side, as depicted in FIG. 6 by joining, above the head chip depicted in FIG. 2, the same head chip in a state in which the head chip is flipped vertically. On the rear face of the head chip, connection electrodes (Al, thickness: 3 μm) corresponding to the channels were formed.

[0079] A glass substrate was used as a wiring substrate which was joined to the rear face of the head chip, and, as in the case of the wiring substrates depicted in FIGs. 2, 3, and 6, common electrodes (Au, thickness: 3 μm) and individual electrodes (Au, thickness: 3 μm) corresponding to the six channel rows of the head chip, three rows of common electrodes at an upper end and three rows of common electrodes at a lower end and three rows of individual electrodes at an upper end and three rows of individual electrodes at a lower end, were arranged.

[0080] For the inkjet head thus obtained, by connecting two adjacent individual electrodes on the wiring substrate to each other by an interelectrode resistance (200 kΩ), a defective condition in which the flow of a very small current generated by an electromotive force of a piezoelectric element easily occurred was intentionally created. The interelectrode resistance used here was formed by using a material obtained by mixing 2% (volume mixing ratio) conductive particles (carbon) into a base resin (epoxy) such that the interelectrode resistance had a width of 50 μm, a thickness of 10 μm, and a length of 40 μm (an interelectrode distance).

[0081] Furthermore, the three common electrodes on the L side and the three common electrodes on the R side, the common electrodes being arranged on the upper and lower ends of the wiring substrate, were connected by an inter-common electrode resistance (1 MΩ) on each of the L side and the R side. Each inter-common electrode resistance was formed by using what was obtained by mixing 1% (volume mixing ratio) conductive particles (carbon) into a base resin (epoxy) such that the inter-common electrode resistance had a width of 50 μm, a thickness of 10 μm, and a length of 100 μm (an interelectrode distance).

[0082] Ten similar inkjet heads were produced, and all the inkjet heads were inspected for a reduction in the driving efficiency of a piezoelectric element by measuring the electric capacitance of the channels. A non-defective item/defective item judgment was made with reference to the presence or absence of a channel whose electric capacitance value was reduced, and, by calculating the percentage of non-defective items in all the products, head yields were obtained. The result is shown in Table 1.

(Example 2)

[0083] All of the three common electrodes on the L side and the three common electrodes on the R side of Example

1 were connected to one another by an inter-common electrode resistance (1 MΩ).

[0084] Ten similar inkjet heads were produced, and head yields were obtained by performing processing similar to that of Example 1 on all the inkjet heads. The result is shown in Table 1.

(Example 3)

[0085] In place of the inter-common electrode resistance of Example 1, the individual electrodes arranged on the L side at the upper end of the wiring substrate were connected to one another by an inter-individual electrode resistance (1.3 MΩ) and the individual electrodes arranged on the R side at the lower end of the wiring substrate were connected to one another by an inter-individual electrode resistance (1.3 MΩ). Each inter-individual electrode resistance was formed by using what was obtained by mixing 1% (volume mixing ratio) conductive particles (carbon) into a base resin (epoxy) such that the inter-individual electrode resistance had a width of 30 μm, a thickness of 5 μm, and a length of 40 μm (an interelectrode distance).

[0086] Ten similar inkjet heads were produced, and head yields were obtained by performing processing similar to that of Example 1 on all the inkjet heads. The result is shown in Table 1.

(Example 4)

[0087] The inter-common electrodes of the rows on the L side and the inter-common electrodes of the rows on the R side depicted in Example 1 were connected by an inter-common electrode resistance (1 MΩ) independently on the L side and the R side. In addition, in a manner similar to Example 3, the individual electrodes arranged on the L side at the upper end of the wiring substrate were connected by an inter-individual electrode resistance (1.3 MΩ) and the individual electrodes arranged on the R side at the lower end of the wiring substrate were connected by an inter-individual electrode resistance (1.3 MΩ).

[0088] Ten similar inkjet heads were produced, and head yields were obtained by performing processing similar to that of Example 1 on all the inkjet heads. The result is shown in Table 1.

(Example 5)

[0089] In addition to the inter-common electrode resistance of Example 2, in a manner similar to Example 3, the individual electrodes arranged on the L side at the upper end of the wiring substrate were connected to one another by an inter-individual electrode resistance (1.3 MΩ) and the individual electrodes arranged on the R side at the lower end of the wiring substrate were connected to one another by an inter-individual electrode resistance (1.3 MΩ).

[0090] Ten similar inkjet heads were produced, and head yields were obtained by performing processing similar to that of Example 1 on all the inkjet heads. The result is shown in Table 1.

(Comparative example)

[0091] An inkjet head was produced in a manner similar to Example 1 except that none of the inter-common electrode resistance and the inter-individual electrode resistance was formed.

[0092] Ten similar inkjet heads were produced, and head yields were obtained by performing processing similar to that of Example 1 on all the inkjet heads. The result is shown in Table 1.

[Table 1]

	Inter-common electrode resistance	Inter-individual electrode resistance	Head yields
Comparative example	None	None	80%
Example 1	Independently connecting the common electrodes on the L side and the R side	None	100%
Example 2	Connecting all the common electrodes	None	100%
Example 3	None	Independently connecting the individual electrodes on the L side and the R side	100%
Example 4	Independently connecting the common electrodes on the L side and the R side	Independently connecting the individual electrodes on the L side and the R side	100%

(continued)

	Inter-common electrode resistance	Inter-individual electrode resistance	Head yields
Example 5	Connecting all the common electrodes	Independently connecting the individual electrodes on the L side and the R side	100%

[0093] As shown in Table 1, with the inkjet heads of Examples 1 to 3, it is possible to prevent a reduction in the driving efficiency of a particular piezoelectric element caused by the flow of a very small current generated by an electromotive force of a piezoelectric element and prevent a reduction in head yields.

EXPLANATIONS OF LETTERS OR NUMERALS

[0094]

A, B, C: area
G: substrate
Ca, Cb, Cc: common electrode
Pa1 to Pa3, Pb1 to Pb3, Pc1 to Pc3: individual electrode
a1 to a3, b1 to b3, c1 to c3: piezoelectric element
R1: inter-common electrode resistance
R2: inter-individual electrode resistance
H: inkjet head
1: head chip

- 10: dummy channel
- 11a, 12a, 13c: driving channel
- 14: driving wall
- 15: driving electrode
- 16, 17: connection electrode

2: nozzle plate

- 21: nozzle

3: wiring substrate

- 31: junction region
- 32a to 32c: through hole
- 33a to 33c: common electrode
- 34Pa1 to 34Pa3, 34Pb to 34Pb3, 34Pc to 34Pc3: individual electrode
- 35a, 35b: wiring through hole

4: FPC
5: manifold member
100: inkjet recording apparatus

- 101: transport mechanism
- 101a: transport roller pair
- 101b: transport roller
- 101c: transport motor
- 102: carriage
- 103: flexible cable
- 104: guide rail

200: recording medium

Claims

1. A piezoelectric actuator unit including a plurality of sets, each set including a plurality of piezoelectric elements, individual electrodes, each supplying an electrical signal to a corresponding one of the plurality of piezoelectric elements, and a common electrode that supplies a common electrical signal to each of the plurality of piezoelectric elements, the individual electrodes and the common electrode of each set being electrically independent of one another, wherein
a plurality of the common electrodes are connected to each other by an inter-common electrode resistance in at least one place, and
an electric resistivity of the inter-common electrode resistance is higher than an electric resistivity of the common electrodes and is lower than an electric resistivity of a member forming a face on which the common electrodes are formed.

2. The piezoelectric actuator unit according to claim 1,
wherein
when an electrical signal is transmitted to the piezoelectric elements, a maximum amount of current which is smaller than a maximum amount of current flowing through the common electrodes flows through the inter-common electrode resistance.

3. The piezoelectric actuator unit according to claim 1 or 2, wherein
the inter-common electrode resistance is formed of any one of a resin containing conductive particles, an alloy, carbon, a semiconductor, a metal oxide, and a conductive polymer.

4. A piezoelectric actuator unit including a plurality of sets, each set including a plurality of piezoelectric elements, individual electrodes, each supplying an electrical signal to a corresponding one of the plurality of piezoelectric elements, and a common electrode that supplies a common electrical signal to each of the plurality of piezoelectric elements, the individual electrodes and the common electrode of each set being electrically independent of one another, wherein
a plurality of the individual electrodes are connected to each other by an inter-individual electrode resistance in at least one place, and
an electric resistivity of the inter-individual electrode resistance is higher than an electric resistivity of the individual electrodes and is lower than an electric resistivity of a member forming a face on which the individual electrodes are formed.

5. The piezoelectric actuator unit according to claim 4,
wherein
when an electrical signal is transmitted to the piezoelectric elements, a maximum amount of current which is smaller than a maximum amount of current flowing through the individual electrodes flows through the inter-individual electrode resistance.

6. The piezoelectric actuator unit according to claim 4 or 5, wherein
the inter-individual electrode resistance is formed of any one of a resin containing conductive particles, an alloy, carbon, a semiconductor, a metal oxide, and a conductive polymer.

7. A piezoelectric actuator unit including a plurality of sets, each set including a plurality of piezoelectric elements, individual electrodes, each supplying an electrical signal to a corresponding one of the plurality of piezoelectric elements, and a common electrode that supplies a common electrical signal to each of the plurality of piezoelectric elements, the individual electrodes and the common electrode of each set being electrically independent of one another, wherein
a plurality of the common electrodes are connected to each other by an inter-common electrode resistance in at least one place and a plurality of the individual electrodes are connected to each other by an inter-individual electrode resistance,
an electric resistivity of the inter-common electrode resistance is higher than an electric resistivity of the common electrodes and is lower than an electric resistivity of a member forming a face on which the common electrodes are formed, and
an electric resistivity of the inter-individual electrode resistance is higher than an electric resistivity of the individual electrodes and is lower than an electric resistivity of a member forming a face on which the individual electrodes are formed.

8. The piezoelectric actuator unit according to claim 7,
wherein
when an electrical signal is transmitted to the piezoelectric elements, a maximum amount of current which is smaller than a maximum amount of current flowing through the common electrodes flows through the inter-common electrode resistance, and, when an electrical signal is transmitted to the piezoelectric elements, a maximum amount of current which is smaller than a maximum amount of current flowing through the individual electrodes flows through the inter-individual electrode resistance.

9. The piezoelectric actuator unit according to claim 7 or 8, wherein
the inter-common electrode resistance and the inter-individual electrode resistance are formed of any one of a resin containing conductive particles, an alloy, carbon, a semiconductor, a metal oxide, and a conductive polymer.

10. The piezoelectric actuator unit according to any one of claims 1 to 9, wherein
electrical signals which are input to the plurality of common electrodes are not identical with each other.

11. An inkjet head that is formed of the piezoelectric actuator unit according to any one of claims 1 to 10 and includes a plurality of pressure chambers to which ink is supplied, wherein
the inkjet head causes the ink in the pressure chambers to be discharged from nozzles by expanding or contracting volumes of the pressure chambers by driving the piezoelectric elements by an application of electrical signals to the individual electrodes and the common electrodes.

12. The inkjet head according to claim 11, comprising:

a head chip in which the pressure chambers and the piezoelectric elements are formed; and
a wiring substrate that is bonded to the head chip and forms a connection portion between the wiring substrate and an external wiring substrate for applying the electrical signals,
wherein
the individual electrodes and the common electrodes are formed from a front surface of the head chip to a front surface of the wiring substrate.

13. An inkjet recording apparatus comprising:

the inkjet head according to claim 11 or 12,
wherein
the inkjet recording apparatus records an image on a recording medium by causing the ink in the pressure chambers to be discharged from the nozzles by applying the electrical signals to the piezoelectric elements of the inkjet head via the common electrodes and the individual electrodes.

14. A head chip that is formed of the piezoelectric actuator unit according to any one of claims 1 to 10 and includes a plurality of pressure chambers to which ink is supplied, wherein
the head chip causes the ink in the pressure chambers to be discharged from nozzles by expanding or contracting volumes of the pressure chambers by driving the piezoelectric elements by an application of electrical signals to the individual electrodes and the common electrodes.

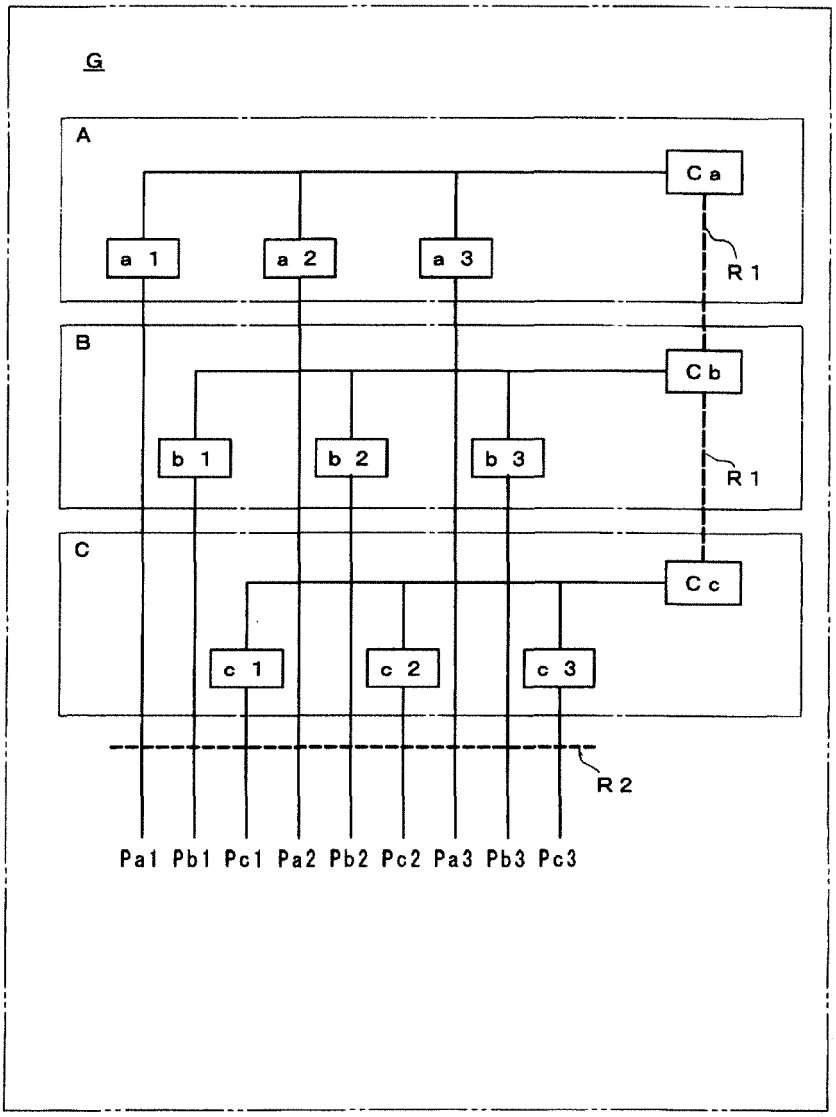
15. A wiring substrate that forms a connection portion between the wiring substrate and an external wiring substrate for applying electrical signals to a plurality of piezoelectric elements by being bonded to a head chip provided with a plurality of pressure chambers to which ink is supplied and the plurality of piezoelectric elements that expand or contract volumes of the pressure chambers and includes a plurality of sets, each set including individual electrodes, each supplying an electrical signal to a corresponding one of the plurality of piezoelectric elements, and a common electrode that supplies a common electrical signal to the plurality of piezoelectric elements, the individual electrodes and the common electrode of each set being formed so as to be electrically independent of one another, wherein
a plurality of the common electrodes are connected to each other by an inter-common electrode resistance in at least one place, and
an electric resistivity of the inter-common electrode resistance is higher than an electric resistivity of the common electrodes and is lower than an electric resistivity of a member forming a face on which the common electrodes are formed.

16. A wiring substrate that forms a connection portion between the wiring substrate and an external wiring substrate for

applying electrical signals to a plurality of piezoelectric elements by being bonded to a head chip provided with a plurality of pressure chambers to which ink is supplied and the plurality of piezoelectric elements that expand or contract volumes of the pressure chambers and includes a plurality of sets, each set including individual electrodes, each supplying an electrical signal to a corresponding one of the plurality of piezoelectric elements, and a common electrode that supplies a common electrical signal to the plurality of piezoelectric elements, the individual electrodes and the common electrode of each set being formed so as to be electrically independent of one another, wherein a plurality of the individual electrodes are connected to each other by an inter-individual electrode resistance, and an electric resistivity of the inter-individual electrode resistance is higher than an electric resistivity of the individual electrodes and is lower than an electric resistivity of a member forming a face on which the individual electrodes are formed.

17. A wiring substrate that forms a connection portion between the wiring substrate and an external wiring substrate for applying electrical signals to a plurality of piezoelectric elements by being bonded to a head chip provided with a plurality of pressure chambers to which ink is supplied and the plurality of piezoelectric elements that expand or contract volumes of the pressure chambers and includes a plurality of sets, each set including individual electrodes, each supplying an electrical signal to a corresponding one of the plurality of piezoelectric elements, and a common electrode that supplies a common electrical signal to the plurality of piezoelectric elements, the individual electrodes and the common electrode of each set being formed so as to be electrically independent of one another, wherein a plurality of the common electrodes are connected to each other by an inter-common electrode resistance in at least one place and a plurality of the individual electrodes are connected to each other by an inter-individual electrode resistance,
an electric resistivity of the inter-common electrode resistance is higher than an electric resistivity of the common electrodes and is lower than an electric resistivity of a member forming a face on which the common electrodes are formed, and
an electric resistivity of the inter-individual electrode resistance is higher than an electric resistivity of the individual electrodes and is lower than an electric resistivity of a member forming a face on which the individual electrodes are formed.

FIG 1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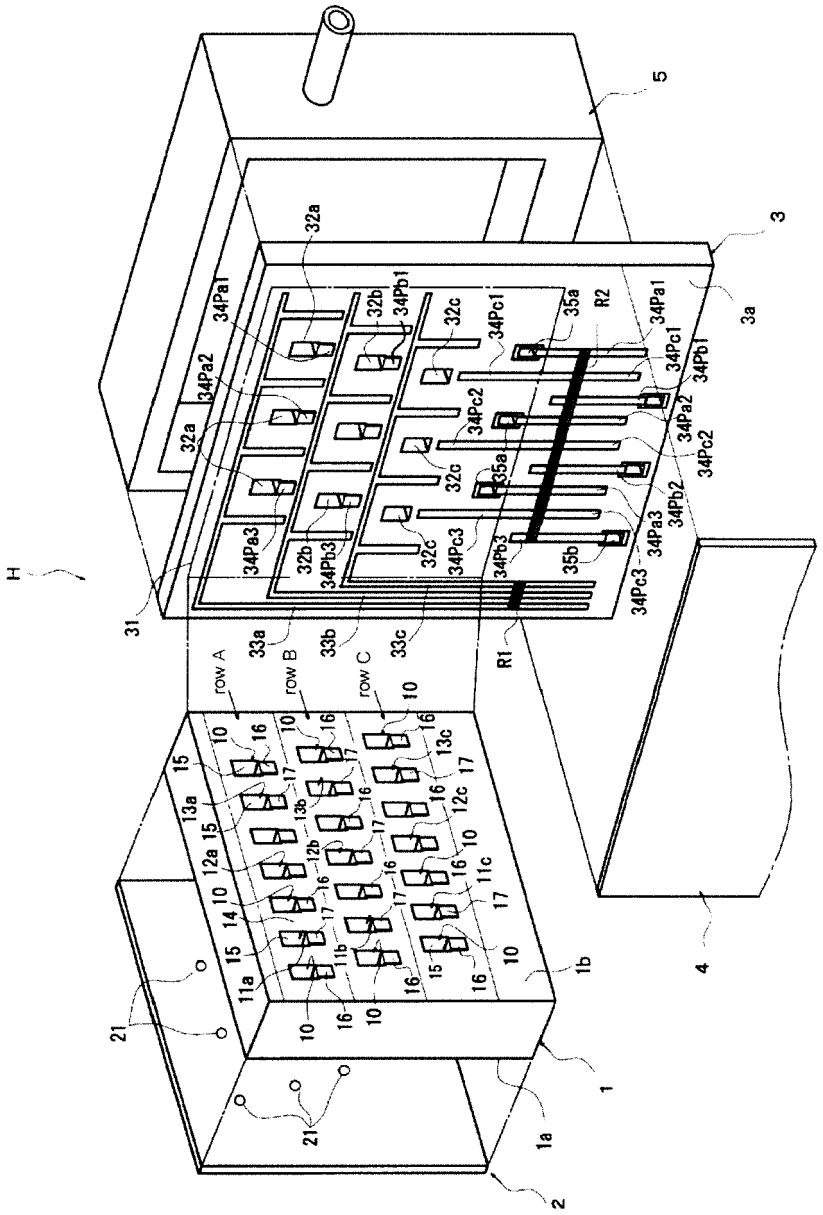
a 1
a 2
a 3
R 1
B
Cb
b 1
b 2
b 3
R 1
C
Cc
c 1
c 2
c 3
R 2
Pa1 Pb1 Pc1 Pa2 Pb2 Pc2 Pa3 Pb3 Pc3

FIG 2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32b
34Pb1
32c
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R2
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34Pa3
34Pc3
34Pb3
35b
H
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33b
33c
R1
row A
row B
row C
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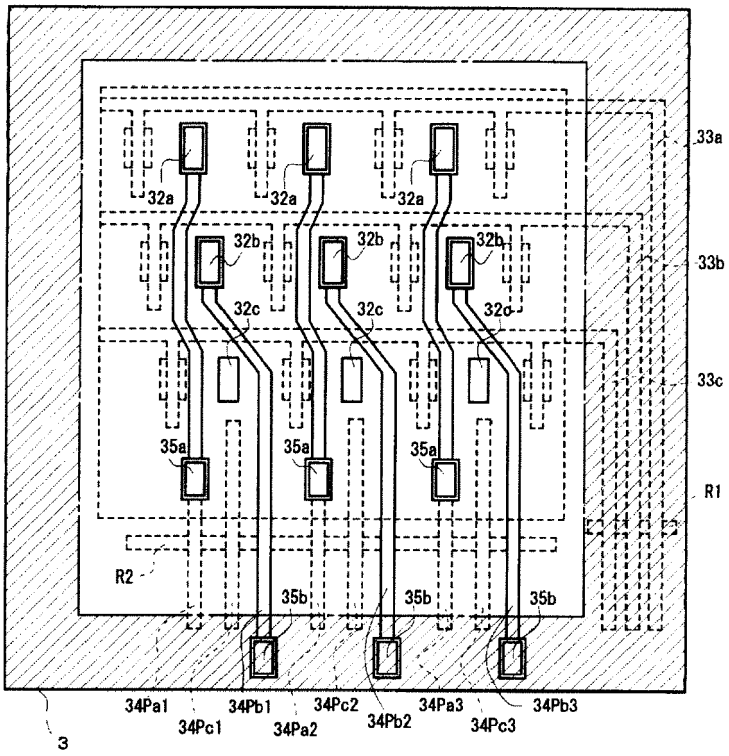
1b
1
1a
2
21

FIG 3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34Pc3
34Pb3
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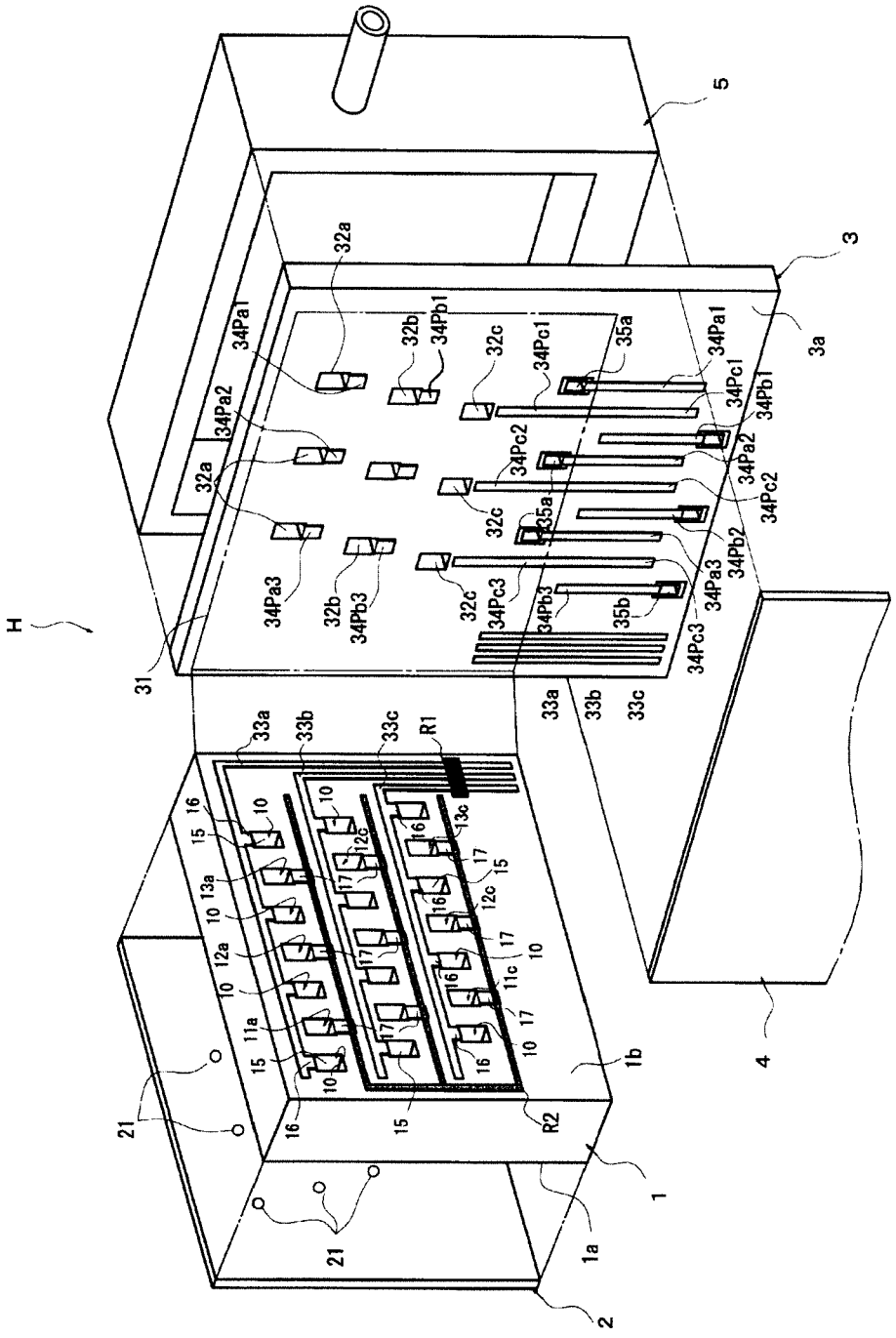
FIG 4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33b
33c
R1
R2
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11c
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12c
13a
13c
15
16
17

FIG 5

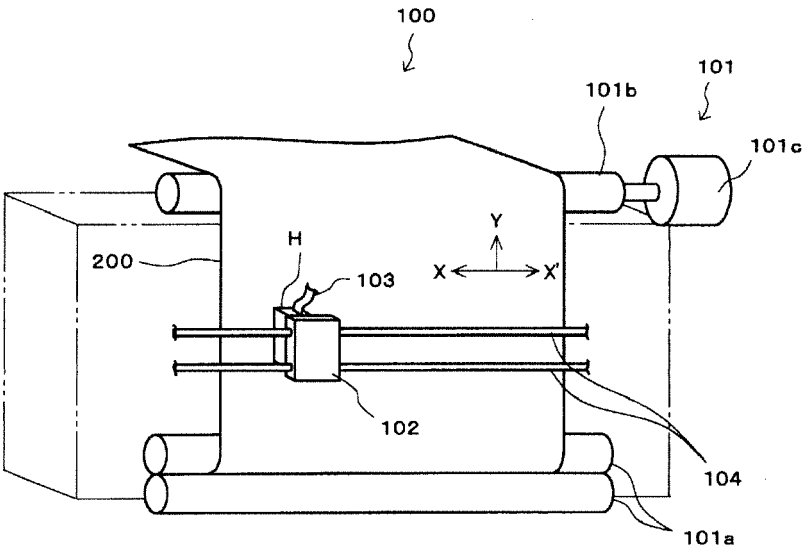
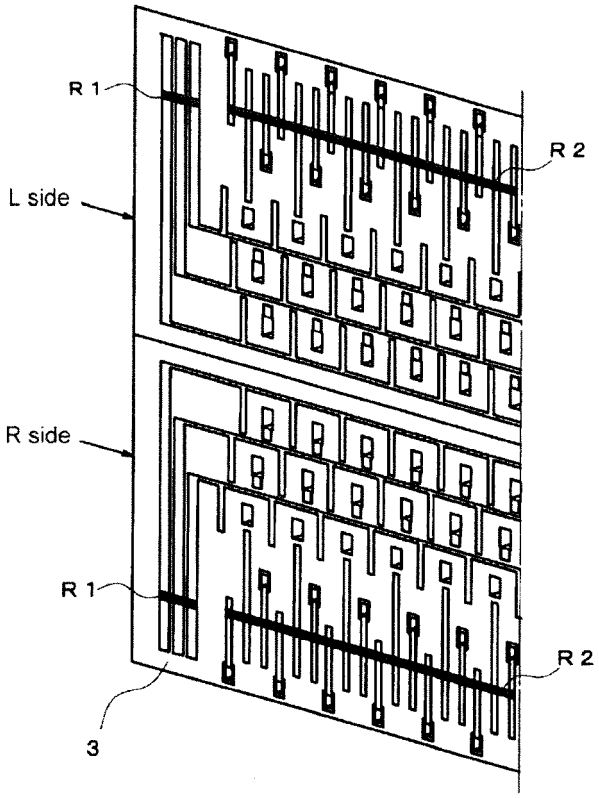


FIG 6



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EUROPEAN SEARCH REPORT

Application Number
EP 16 18 8279

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A	EP 0 820 871 A2 (SEIKO EPSON CORP [JP]) 28 January 1998 (1998-01-28) * column 7, line 29 - column 8, line 34 * * figure 7 *	1,4,7, 15-17	INV. B41J2/14
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	15 March 2017	Didenot, Benjamin

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