(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 486 256 B1

(12) EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention of the grant of the patent:
13.08.1997 Bulletin 1997/33

(51) Int. Cl.[6]: **B41J 2/15**

(21) Application number: **91310423.8**

(22) Date of filing: **12.11.1991**

(54) Printing head for ink-jet printer

Tintenstrahldruckkopf

Tête d'impression pour imprimante à jet d'encre

(84) Designated Contracting States:
DE FR GB

(30) Priority:
13.11.1990 JP 303935/90
26.12.1990 JP 413955/90
27.12.1990 JP 415002/90
08.03.1991 JP 20317/91
08.03.1991 JP 67559/91
26.04.1991 JP 122904/91
17.05.1991 JP 140633/91

(43) Date of publication of application:
20.05.1992 Bulletin 1992/21

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- **PATENT ABSTRACTS OF JAPAN vol. 4, no. 49 (M-7)(531) 15 April 1980**

Description

BACKGROUND OF THE INVENTION

1) Field of the Invention

The present invention relates to a printing head for an ink-jet printer, and more particularly, to a drop-on-demand type ink-jet printing head.

2) Description of the Related Art

As is well known, an ink-jet printer is a typical non-impact printers having a simple construction and suitable for chromatic color printing. Generally, an ink-jet printing head for the ink-jet printer includes a head body having a plurality of pressure chambers formed therein, and a plurality of orifices communicated with the pressure chambers, respectively, a plurality of piezoelectric actuators arranged in the head body to thus partially define the pressure chambers, respectively, and an ink source for supplying an ink to the pressure chambers, which are filled with the ink. When each of the piezoelectric actuators is selectively energized on the basis of image data obtained from a word processor, a personal computer, or the like, a volume of the corresponding pressure chamber is instantly changed and thus an ink-jet drop is ejected from the orifice thereof, and accordingly, an image is recorded on a sheet of paper by the ejected ink-jet drops.

Two drive modes for the ink-jet printing head are known in this field; a Kaiser drive mode and a shearing drive mode.

In the Kaiser drive mode as disclosed in, for example, Examined Japanese Patent Publications No. 53(1978)-12138 and No. 57(1982)-20904, corresponding to US-A-3946398, the piezoelectric actuator, which is constructed as a plate-like bimorph type actuator, is arranged such that it defines a top wall of the pressure chamber, and when this plate-like bimorph type piezoelectric actuator is electrically energized, it is instantly bent in such a manner that a volume of the pressure chamber is reduced, and accordingly, an ink-jet drop is ejected from the orifice. The plate-like bimorph type piezoelectric actuator must have a relative large wide area, to enable a pressure to be generated in the pressure chamber that will cause the ejection of the ink-jet drop from the orifice. Accordingly, the pressure chambers must be disposed at a considerably wider pitch than a fine pitch at which the orifices are located. For this reason, in the Kaiser drive mode ink-jet printing head, a plurality of relative long passages must be formed, to connect the pressure chambers to the orifices to each other, respectively, and thus, the Kaiser drive mode ink-jet printing head has a relative large size, and is further disadvantageous in that a pressure loss occurs due to the long passages formed between the pressure chambers and the orifices.

In the shearing drive mode as disclosed in, for example, Unexamined Japanese Patent Publications No. 63(1988)-247050, corresponding to GB-A-2201229, and No. 63(1988)-247051, corresponding to EP-A-277703, the pressure chambers are disposed side by side, and the piezoelectric actuators are arranged such that they form side walls of the pressure chambers. To generate a pressure at one of the pressure chambers, and eject an ink-jet drop from the orifice thereof, the piezoelectric actuators or side walls of the pressure chamber concerned are electrically energized, and thus instantly deformed, to thereby reduce a volume of the pressure chamber. The deformation of the side walls is carried out in such a manner that these side walls are subjected to a shearing stress. Of course, in this arrangement, the energizing of the piezoelectric actuators or side walls of the pressure chamber concerned affects a pressure of the ink held in the side pressure chambers adjacent thereto. Namely, the ink cannot be statically held in each of the pressure chambers, and thus it is difficult to constantly carry out a stable printing operation. Also, the shearing drive mode ink-jet printing head is disadvantageous in that ink-jet drops cannot be simultaneously ejected from two adjacent orifices, because the two adjacent pressure chambers are bounded by the common piezoelectric actuator therebetween. Further, production of the shearing mode ink-jet printing head is costly because fine and precise cutting work is required when forming pressure chambers having a width of several tens of microns.

A printing head constructed according to the pre-characterising portion of appended claim 1 is disclosed in US Patent No. 4,578,686.

An object of the present invention is to provide a novel ink-jet printing head which can be compactly and simply constructed at low cost, and by which a stable printing operation can be constantly ensured.

The invention provides an ink-jet printing head for a serial ink-jet printer comprising:

an external orifice for the ejection of ink;

a laminated unit including a piezoelectric plate element and having a pressure chamber formed at said piezoelectric plate element for filling with an ink, said piezoelectric plate element having two electrode layers formed on surfaces thereof and surrounding said pressure chamber, the external orifice being in fluid communication with said pressure chamber; and

means for applying a drive pulse voltage to said piezoelectric plate element through the electrode layers thereof,

said piezoelectric plate element being constituted such that a thickness thereof is reduced upon applying said drive voltage pulse thereto, resulting in a decrease of volume of said pressure chamber, whereby in use an ink-jet drop is ejected from said orifice,

characterised in that the laminated unit is integrally formed as a sintered ceramic product and includes a bottom insulating plate element and a top insulating plate element, with said piezoelectric plate element being between the bottom and top insulating plate elements.

BRIEF DESCRIPTION OF THE DRAWINGS

The other objects and advantages of the present invention will be better understood from the following description, with reference to the accompanying drawings, in which:

Figure 1 is an exploded view showing a first embodiment of an ink-jet printing head according to the present invention;
Figure 2 is a cross sectional view taken along a line II-II of Fig. 1;
Figure 3 is a perspective view showing the ink-jet printing head of Fig. 1;
Figure 4 is a cross sectional view taken along a line IV-IV of Fig. 3;
Figure 5 is an exploded view showing a second embodiment of an ink-jet printing head according to the present invention;
Figure 6 is a plane view showing one type of an piezoelectric plate element used in the ink-jet printing head of Fig. 5;
Figure 7 is a plane view showing another type of an piezoelectric plate element used in the ink-jet printing head of Fig. 5;
Figure 8 is a cross sectional view taken along a line VIII-VIII of Fig. 5;
Figure 9 is a perspective view showing a modification of the second embodiment of Fig. 5;
Figure 10 is a cross sectional view taken along a line X-X of Fig. 9;
Figure 11 is a schematic plane view showing a piezoelectric plate element used in the ink-jet printing head of Figs. 5 and 9;
Figure 12 is an exploded view showing a third embodiment of an ink-jet printing head according to the present invention;
Figure 13 is an exploded view showing a fourth embodiment of an ink-jet printing head according to the present invention;
Figure 14 is a perspective view showing the ink-jet printing head of Fig. 13;
Figure 15 is a cross sectional view taken along a line XV-XV of Fig. 14;
Figure 16 is a schematic plane view showing a piezoelectric plate element used in the ink-jet printing head of Fig. 14;
Figure 17 is an exploded view showing a fifth embodiment of an ink-jet printing head according to the present invention;
Figure 18 is an exploded view showing a green sheet assembly for easily producing a laminated unit of the ink-jet printing printer of Fig. 17;
Figure 19 is an exploded view showing a sixth embodiment of an ink-jet printing head according to the present invention;
Figure 20 is a cross sectional view taken along a line XX-XX of Fig. 19;
Figure 21 is a schematic plane view showing a piezoelectric plate element used in the ink-jet printing head of Fig. 19;
Figure 22 is an exploded view showing a seventh embodiment of an ink-jet printing head according to the present invention;
Figure 23 is a partial front view of an ink-jet printing head from which an orifice plate element is removed;
Figure 24 is a view showing a modification of Fig. 23; and
Figure 25 is a view showing another modification of Fig. 23.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figure 1 is an exploded view showing a first embodiment of an ink-jet printing head constructed according to the present invention, and generally indicated by reference numeral 10. This ink-jet printing head 10 is suitable for a serial ink-jet printer, and comprises a flexible wiring sheet 12 provided with a plurality of electric terminal pads and a plurality of electric lead lines. In Fig. 1, only six of the terminal pads are indicated by reference numerals 12a-1, 12a-2, 12a-3, 12a-4, 12a-5, and 12a-6, and the six lead lines extending therefrom are indicated by reference numerals 12b-1, 12b-2, 12b-3, 12b-4, 12b-5, and 12b-6. As apparent from Fig. 1, the terminal pads are disposed along opposing sides of the flexible wiring sheet 12, at the illustrated end zone thereof, and the lead lines are extended from the terminal pads, respectively. Note, a not illustrated end of the flexible wiring sheet 12 is connected to an electric source circuit (not shown).

The ink-jet printing head 10 also comprises a laminated unit including a bottom insulating plate element 14, a top insulating plate element 18, and a lamination core 18 disposed therebetween. As shown in Figure 2, the lamination core 18 includes a plurality of piezoelectric plate elements, only three of which are indicated by reference numerals 20, 22, and 24, and a plurality of intermediate insulating plate elements, only two of which are indicated by reference numerals 26 and 28. Note, in Fig. 1, only the three piezoelectric plate elements 20, 22, and 24 and only the two intermediate insulating plate elements 26 and 28 are shown, for simplicity of illustration. In the lamination core 18, the piezoelectric plate elements and the intermediate insulating plate elements are alternately laminated in such a manner that the two piezoelectric plate elements are positioned at the bottom and top of the lamination core 18. Namely, in the lamination core 18, the number of intermediate insulating plate elements is less than the number of piezoelectric plate elements by one.

The bottom insulating plate element 14 is rectangular, as shown in Fig. 1, and has a plurality of throughholes formed therein and disposed along opposed long sides thereof. In Fig. 1, only six of the throughholes of the plate element 14 are indicated by reference numerals 14-1, 14-2, 14-3, 14-4, 14-5, and 14-6. The throughholes of the plate element 14 are to be in register with the terminal pads of the flexible wiring sheet 12. The top insulating plate element 16 has the same rectangular appearance as the bottom insulating plate element 14, and is provided with an inlet pipe element 16a through which an ink is supplied to the ink-jet printing head 10. Note, as shown in Fig. 2, the top insulating plate element 16 has an opening 16b formed therein in register with the inlet pipe element 14.

Each of the piezoelectric plate elements 20, 22, and 24 also has the same rectangular appearance as the bottom insulating plate element 14, and is provided with a rectangular opening 30 and an elongated opening 32 formed therein. The rectangular opening 30 is in communication with the elongated opening 32 through a restricted passage 34, and the elongated opening 32 is communication with an outside orifice 36. Also, each of the piezoelectric plate elements 20, 22, and 24 is provided with a plurality of throughholes formed therein and disposed along opposed long sides thereof. In Fig. 1, only two of the throughholes of the plate element 20 are indicated by reference numerals 20-1 and 20-2; only four of the throughholes of the plate element 22 by reference numerals 22-1, 22-2, 22-3, and 22-4; and only six of the throughholes of the plate element 24 by reference numerals 24-1, 24-2, 24-3, 24-4, 24-5, and 24-6. An arrangement of each piezoelectric plate element 20, 22, 24 also is registered with that of the terminal pads of the flexible wiring sheet 12. The other piezoelectric plate elements not shown in Fig. 1 are indentical with the piezoelectric plate elements 20, 22, and 24.

The piezoelectric plate elements 20, 22, and 24 are provided with upper and lower electrode layers 20a and 20b; 22a and 22b; and 24a and 24b (Fig. 2) formed on the upper and lower surfaces thereof, respectively, to surround the rectangular opening 30, the restricted passage 34, the elongated opening 32, and the orifice 36. As shown in Fig. 1, the upper electrode layer 20a is partially extended to surround the throughhole 20-1. Although not visible in Fig. 1, the lower electrode layer 20b also is partially extended to surround the throughhole 20-2. Also, the upper electrode layer 22a is partially extended to surround the throughhole 22-3. Further, although not visible in Fig. 1, the lower electrode layer 22b also is partially extended to surroung the throughhole 22-4.

Furthermore, the upper electrode layer 24a is partially extended to surround the throughhole 24-5. Furthermore, although not visible in Fig. 1, the lower electrode layer 24b also is partially extended to surround the throughhole 22-4. Similarly, each of the other piezoelectric plate elements not shown in Fig. 1 is provided with upper and lower electrode layers formed on the upper and lower surfaces thereof, and each of the upper and lower electrode layers is partially extended to surround one of the throughholes.

Each of the intermediate insulating plate elements 26 and 28 also has the same rectangular appearance as the bottom insulating plate element 14, and is provided with a rectangular opening 38 formed therein. The rectangular openings 38 are in register with the rectangular openings 38 of the piezoelectric plate elements 20, 22, and 24. Also each of the intermediate insulating plate elements 26 and 28 is provided with a plurality of throughholes formed therein and disposed along opposing long sides thereof. In Fig. 1, only two of the throughholes of the plate element 26 are indicated by reference numerals 26-1 and 26-2; and only four of the throughholes of the plate element 28 by reference numerals 28-1, 28-2, 28-3, and 28-4. Each intermediate insulating plate element 26 and 28 is also in register with one of the terminal pads of the flexible wiring sheet 12. The other intermediate insulating plate elements, not shown in Fig. 1, are identical to the intermediate insulating plate elements 26 and 28.

According to the present invention, the laminated unit including the bottom insulating plate element 14, the top insulating plate element 18, and the lamination core 18 disposed therebetween, is integrally formed as a sintered ceramic product such as a PZT product, which has a potential piezoelectric effect. In particular, a shaped green sheet for the bottom insulating plate element 12, a shaped green sheet for the top insulating plate element 16, shaped green sheets for the piezoelectric plate elements (20, 22, 24), and shaped green sheets for the intermediate insulating plate elements (26, 28), are previously prepared. Note, these shaped green sheets can be precisely and inexpensively obtained from a green sheet material for, e.g. PZT products, by using punch cutting dies. On each of the shaped green sheets for the piezoelectric plate elements is spread a conductive paste, for the formation of the upper and lower electrode layers (20a, 20b; 22a, 22b; 24a; 24b), and in all of the throughholes of the shaped green sheets for the bottom insulating plate element 12, the piezoelectric plate elements (20, 22, 24), and the intermediate insulating plate elements (26, 28), the inner wall surfaces thereof are coated with a conductive paste. All of the shaped green sheets are laminated and assembled in sequence (Fig. 2), so that the throughholes of the shaped green sheets for the bottom insulating plate element 12, the piezoelectric plate elements (20, 22, 24), and the intermediate insulating plate elements (26, 28) are vertically aligned with each other, respectively. This assembly is then sintered, and thus a laminated unit is obtained as a sintered ceramic product.

The ink-jet printing head 10 is finished by fixing the laminated unit to the flexible wiring sheet 12, in place, with a suitable adhesive, as shown in Figure 3, in which the top insulating plate element 16 is shown to be separated from the head 10 for simplicity. In the finished ink-jet printing head 10, the rectangular openings 30 of the piezoelectric plate elements (20, 22, 24) and the rectangular openings 38 of the intermediary plate elements (26, 28) form an ink reservoir to which an ink is supplied through the inlet pipe element 16a connected to an ink source (not shown) through a flexible tube 40 (Fig. 3). Also, each of the elongated openings 32 of the piezoelectric plate elements (20, 22, 24) form a pressure chamber to be filled with ink supplied from the ink reservoir.

In the finished ink-jet printing head 10, the vertical throughholes of the bottom insulating plate element 14, of the piezoelectric plate elements (20, 22, 24), and of the intermediate insulating plate elements (26, 28) define a plurality of vertical passages, respectively, extending through the lamination core 18 and the bottom insulating plate member 14, and each of the vertical passages has a conductive lining 42 formed around an inner wall surface, as representatively shown in Figure 4. Each of these inner conductive linings (42) is electrically connected to the corresponding electrode layer and the corresponding terminal pad of the flexible wiring sheet 12. For example, the inner conductive linings (42) formed in the vertical passages (20-1, 26-1, 22-1, 28-1, 24-1, 14-1; 20-2, 26-2, 22-2, 28-2, 24-2, 14-2; 20-3, 26-3, 22-3, 28-3, 24-3, 14-3; 20-4, 26-4, 22-4, 28-4, 24-4, 14-4; 20-5, 26-5, 22-5, 28-5, 24-5, 14-5; and 20-6, 26-6, 22-6, 28-6, 24-6, 14-6) are electrically connected to the electrode layers 20a, 20b, 22a, 22b, 24a, and 24b, and the terminal pads 12a-1, 12a-2, 12a-3, 12a-4, 12a-5, and 12a-6, respectively.

In the finished ink-jet printing head 10, it is still impossible to produce a piezoelectric effect from the piezoelectric plate elements (20, 22, 24) until they are electrically polarized by applying a predermined voltage thereto. Namely, the polarization or poling of the piezoelectric plate elements must be carried out before the piezoelectric effect can be produced thereform. For example, when the piezoelectric plate elements are formed as a PZT product, a voltage of about 3000 V/mm is applied to each of the piezoelectric plate elements through the upper and lower electrode layers thereof. In the arrangement of this first embodiment, the poling must be independently and individually performed for the piezoelectric plate elements (20, 22, 24) because, if the poling voltage is simultaneously applied to all of the piezoelectric plate elements (20, 22, 24), the intermediate insulating plate elements (26, 28) would be polarized because an electric field is generated between the two electrode layers on each side of the intermediate insulating plate. Note, if the intermediate plate elements (26, 28) are a ceramic product having no potential piezoelectric effect, it si possible to simultaneously carry out the poling of the piezoelectric plate elements (20, 22, 24).

In the embodiment shown in Figs. 1 to 4, preferably the thickness of the piezoelectric plate elements (20, 22, 24) is substantially equal to that of the intermediate plate elements (26, 28), and this thickness may be from about 60 to about 140 μ m, if necessary. Also, a width of the orifice 36 may be from about 20 to about 50μ m, if necessary.

In operation, when a drive pulse voltage of about 30 to about 40 V is applied to, for example, the piezoelectric plate element 20, through the upper and lower electrode layers 20a and 20b, the thickness of the piezoelectric plate element 20 is instantly reduced, and accordingly, the volume of the pressure chamber 32 is changed, whereby an ink-jet drop 44 is ejected from the orifice 36 as shown in Fig. 3.

As apparent from the above, the ink-jet printing head according to the present invention can be produced at a low cost, because the shaped green sheets can be precisely and inexpensively obtained from the green sheet material by using punch cutting dies. Also, since the ink-jet drop can be directly ejected from the pressure chamber through the orifice, the ink-jet printing head according to the present invention can be compactly designed. Furthermore, since the pressure can be generated at each of the piezoelectric elements without affecting a pressure of the ink held in the pressure chamber adjacent thereto, it is possible to constantly ensure a stable printing.

Figures 5 to 8 show a second embodiment of an ink-jet printing head according to the present invention. This ink-jet printing head, generally indicated by reference numeral 46, comprises a flexible wiring sheet 48 constructed in substantially the same manner as the flexible wiring sheet 12. Namely, as shown in Fig. 5, the flexible wiring sheet 48 has a plurality of electric terminal pads and a plurality of electric lead lines formed thereon. The ink-jet printing head 46 also comprises a laminated unit including a bottom insulating plate element 50, a top insulating plate element 52, and a lamination core 54 disposed therebetween. The bottom and top insulating plate elements 50 and 52 are constructed in substantially the same manner as the bottom and top isulating plate elements 14 and 16 of the first embodiment (Fig. 1). Namely, the bottom plate element 50 has a plurality of throughholes formed therein and disposed along opposing long sides thereof, and the top insulating plate element 52 has an inlet pipe element 52a through which an ink is supplied to the ink-jet printing head 46.

In the second embodiment of Figs. 5 to 8, the lamination core 54 includes two kinds of piezoelectric plate elements. In Fig. 5, only two of the piezoelectric plate elements of the first kind are indicated by reference numerals 56 and 58; and only one of the piezoelectric plate elements of the second kind by reference numeral 60. Each of the two kinds of the piezoelectric plate elements (56, 58, 60) has a plurality of throughholes formed therein and disposing along opposing long sides thereof, and these throughholes are in register with the throughholes of the bottom plate element 50.

As shown in Fig. 6, each of the piezoelectric plate elements 56 and 58 has a rectangular opening 61 and an elongated opening 62 formed therein. The rectangular opening 61 is in communication with the elongated opening 62 through a restricted passage 64, and the elongated opening 62 is in communication with an outside through the orifice 66. In this connection, the piezoelectric plate elements 56 and 58 are identical to the other piezoelectric plate elements of the first kind, not shown in Fig. 5. The piezoelectric plate element 56 is provided with upper and lower electrode layer 56a and 56b (Fig. 8) formed on the upper and lower surfaces thereof, respectively, to surround the rectangular opening 61, the restricted passage 64, the elongated opening 62, and the orifice 66. As shown in Fig. 5, the upper electrode-layer 56a is partially extended to surround one of the throughholes of the piezoelectric plate element 56. Although not visible in Fig. 5, the lower electrode layer 56b also is partially extended to surround another throughholes of the piezoelectric plate element 56. Similarly, each of the other piezoelectric plate elements (58) of the first kind is provided with upper and lower electrode layers formed on the upper and lower surfaces thereof, respectively, to surround the rectangular opening, the restricted passage, the elongated opening, and the orifice. Each of these upper and lower electrode layers is partially extended to surround one of the throughholes of the piezoelectric plate element concerned.

Also, as shown in Fig. 7, the piezoelectric plate element 60 has a rectangular opening 68 and an elongated opening 70 formed therein. The rectangular opening 68 is in communication with the elongated opening 70 through a restricted passage 72, and the elongated opening 62 is in communication with the outside through an orifice 74. In this connection, the piezoelectric plate elements 60 are identical to the other piezoelectric plate elements of the second kind, not shown in Fig. 5. The piezoelectric plate element 60 is provided with upper and lower electrode layers 60a and 60b (Fig. 8) formed on the upper and lower surfaces thereof, respectively, to surround the rectangular opening 68, the restricted passage 72, the elongated opening 70, and the orifice 72. As shown in Fig. 5, the upper electrode layer 60a is partially extended to surround one of the throughholes of the piezoelectric plate element 60. Although not visible in Fig. 5, the lower electrode layer 60b also is partially extended to surround another throughholes of the piezoelectric plate element 60. Similarly, each of the other piezoelectric plate elements of the second king is provided with upper and lower electrode layers formed on the upper and lower surfaces thereof, respectively, to surround the rectangular opening, the restricted passage, the elongated opening, and the orifice. Each of these upper and lower electrode layers is partially extended to surround one of the throughholes of the piezoelectric plate element concerned.

In the arrangement of Fig. 5, the rectangular opening 61 of the first kind of piezoelectric plate elements (56, 58) and the rectangular opening 68 of the second kind of piezoelectric plate elements (60) are in register with each other, but the elongated opening 62 of the former and the elongated opening 79 are symmetrically disposed with respect ot a longitudinally central axis of the ink-jet printing head 46.

As apparent from Fig. 5, the lamination core 54 is formed by alternately laminating the piezoelectric plate elements (56, 58) of the first kind and the piezoelectric plate elements (60) of the second kind are alternately laminated with respect to each other. Although the piezoelectric plate element (56) of the first kind is disposed at the top of the lamination core 54, it may be replaced by the piezoelectric plate element (60) of the second kind.

The laminated unit including the bottom insulating plate element 50, the top insulating plate element 52, and the lamination core 54 disposed therebetween, is integrally formed as a sintered ceramic product such as a PZT product, in substantially the same manner as in the first embodiment, except that each of shaped green sheets for the piezoelectric plate elements (56, 58, 60) of the two kinds is coated with an electric insulating material over the upper and lower surfaces thereof. Thus, in the laminated unit obtained as the sintered ceramic product, an electric insulating layer 76 is formed between the two adjacent lamina elements included in the laminated unit, as shown in Fig.8.

Similar to the first embodiment, the ink-jet printing head 46 is finished by fixing the laminated unit to the flexible wiring sheet 48, in place, with a suitable adhesive. In the finished ink-jet printing head 46, an ink reservoir is formed by the rectangular openings (61) of the piezoelectric plate elements (56, 58) of the first kind and the rectangular openings (68) of the piezoelectric plate elements (60) of the second kind, and a pressure chamber is formed by each of the elongated openings (62, 70) of the piezoelectric plate elements (56, 58, 60) of the two kinds. Also, the upper and lower electrode layers of the piezoelectric plate elements (56, 58, 60) of the two kinds are electrically connected to the terminal pads of the flexible wiring sheet 48 in substantially the same manner as in the first embodiment. Furthermore, each of the piezoelectric plate elements (56, 58, 60) of the two kinds is polarized in the same manner as in the first embodiment.

The ink-jet printing head shown in Figs. 5 to 8 is characterized in that the orifices (66, 67) can be disposed at a finer pitch than the orifice pitch of the first embodiment as mentioned above, because an electric insulating plate element (26, 28) is not intervened between the two adjacent piezoelectric plate elements in the second embodiment, and accordingly, the ink-jet printing head 46 is suitable for high resolution printing. For example, when the piezoelectric plate elements (56, 58, 60) have a thickness of 70μ m, it is possible to carry out a printing at 360 dpi (dot per inch). Also, when the piezoelectric plate elements (56, 58, 60) have a thickness of 65 μ m, it is possible to carry out a printing at 400 dpi.

Figure 9 shows a modification of the second embodiment. In this modified embodiment, each of the piezoelectric plate elements (56′ , 58′) of the first kind has two rectangular openings 61a and 61b in the place of the single rectangular opening 61. The rectangular opening 61a is in communication with the elongated opening 62 through a restricted passage (not visible in Fig. 9). Similarly, each of the piezoelectric plate elements (60′) of the second kind also has two rectangular openings, one not being visible in Fig. 9. The visible rectangular opening, indicated by reference numerals 68a, communicates with the elongated opening 70 through a restricted passage 72′.

In Fig. 9, a first ink reservoir is formed by the rectangular openings (61a) of the piezoelectric plate elements (56′, 58′) of the first kind and the rectangular openings (not visible) of the piezoelectric plate elements (60′) of the second kind, and is supplied with an ink through a first inlet pipe element 52a′ of a top insulating plate element 52′. A second ink reservoir is formed by the rectangular openings (61b) of the piezoelectric plate elements (56′ , 58′) of the first kind and the rectangular openings (68a) of the piezoelectric plate elements (60′) of the second kind, and is supplied with an ink through a second inlet pipe element 52b′ of the top insulating plate element 52′.

Also, in the modified embodiment, each of the piezoelectric plate elements (56′ , 58′) of the first kind has an upper electrode layer (56a′) and a lower electrode layer (not visible) formed on the upper and lower surfaces thereof. The upper electrode layer (56a′) surrounds the rectangular openings 61a, the restricted passage (not visible in Fig. 9), the elongated opening 62, and the orifice 66, but it does not reach beyond a longitudinal center line of the piezoelectric plate element. This also is true for the lower electrode layer (not visible). Similarly, each of the piezoelectric plate elements (60′) of the second kind has an upper electrode layer (60a′) and a lower electrode layer (not visible) formed on the upper and lower surface thereof. The upper electrode layer (60a′) surrounds the rectangular openings 68a, the restricted passage 72′, the elongated opening 70, and the orifice 74, but does not reach beyond a longitudinal center line of the piezoelectric plate element. This also is true for the lower electrode layer (not visible). Thus, it is unnecessary to coat each of shaped green sheets for the piezoelectric plate elements (56′ , 58′ , 60′) of the two kinds with an electric insulating material, over the upper and lower surfaces thereof.

Figure 10 is a cross sectional view of an ink-jet printing head constructed on the basis of the embodiments as shown in Figs. 5 to 9. When each of the piezoelectric plate elements is polarized in a direction indicated by an arrow shown in Fig. 10, and when a drive pulse voltage is applied to each of the piezoelectric plate elements so that an electric field is reversely oriented with respect to the direction of poling, the thickness of the piezoelectric plate element is reduced as indicated by a broken line in Fig. 10, so that the volume of the pressure chamber 62, 70 can be reduced.

Nevertheless, a change of volume of the pressure chamber 62, 70 must be sufficient to ensure an ejection of an ink-jet drop from the orifice 66, 74. For example, when the piezoelectric plate element is PZT, and when a drive pulse voltage is 25 V, the pressure chamber 62, 70 preferably has a length L of 20 mm and a width W of 0.5 mm, as shown in Figure 11, for the following reasons:

When the piezoelectric plate element is PZT, a piezoelectric constant d_{33} thereof in a direction of thickness of the piezoelectric plate element is as shown below:

$$d_{33} = 4 \times 10^{-10} \text{ m/V}$$

When the drive pulse voltage of 25 V is applied to the piezoelectric plate element, a change of thickness thereof δ is as shown below:

$$\delta = 0.01 \ \mu\text{m}$$

Note, the value of δ is not related to a thickness of piezoelectric plate element.

Accordingly, a change of volume δP of the pressure chamber is as defined below:

$$\delta P = \delta \times W \times L$$

Since W = 0.5 mm, and L = 20 mm,

$$\delta P = 1 \times 10^{-4} \text{ mm}^3$$

If an ink-jet drop ejected from the orifice 66, 74 has a diameter of 30 μm, a volume of the ink-jet drop Q is as shown below:

$$Q = 1.4 \times 10^{-5} \text{ mm}^3$$

Accordingly, a ratio of δP to Q is 7.

This proves that the change of volume of the pressure chamber is sufficient to ensure an ejection of the ink-jet drop. Note, preferably a width N of the orifice is from about 20 to 30μm.

Figure 12 shows a third embodiment of an ink-jet printing head according to the present invention. This ink-jet printing head comprises: a flexible wiring sheet 78 constructed in substantially the same manner as the flexible wiring sheet 12; a laminated unit including a bottom insulating plate element 80, a top insulating plate element 82, and a lamination core 84 disposed therebetween. The bottom and top insulating plate elements 80 and 82 are constructed in substantially the same manner as the bottom and top insulating plate elements 14 and 16 of the first embodiment (Fig. 1).

In the third embodiment, the lamination core 84 includes two kinds of piezoelectric plate elements. In Fig. 12, only two of piezoelectric plate elements of the first kind are indicated by reference numerals 86; and only two of the piezoelectric plate elements of the second kind by reference numeral 88. The piezoelectric plate elements 86 of the first kind and the piezoelectric plate elements 88 of the second kind are constructed in substantially the same manner as the two kind of piezoelectric plate elements (56, 58; 60) used in the second embodiment (Fig. 5), respectively. The two kinds of piezoelectric plate elements 86, 88 of the two kinds are disposed alternately. The lamination core 84 further includes intermediate insulating plate elements 90 constructed in substantially the same manner as the intermediary insulating plate element (26, 28) used in the first embodiment (Fig. 1). Each of the intermediate insulating plate elements 90 is interposed between the two adjacent piezoelectric plate elements (86) and (88), as shown in Fig. 12. The laminated unit including the bottom insulating plate element 80, the top insulating plate element 82, and the lamination core 84 disposed therebetween, is integrally formed as a sintered ceramic product such as a PZT product in substantially the same manner as in the first embodiment. The ink-jet printing head also is finished by fixing the laminated unit to the flexible wiring sheet 78, in place, with a suitable adhesive.

In the finished ink-jet printing head 46, the upper and lower electrode layers of the two kinds of piezoelectric plate elements (86, 88) are electrically connected to the terminal pads of the flexible wiring sheet 78 in substantially the same manner as in the first embodiment. Furthermore, each of the piezoelectric plate elements (56, 58, 60) of the two kinds is polarized in the same manner as in the first embodiment.

In the ink-jet printing head shown in Fig. 12, the pressure chambers are alternately offset from each other, so that a rigidity of the laminated unit is enhanced, and thus a thickness of the intermediate insulating plate element can be reduced. Accordingly, the orifices can be disposed at a finer pitch than the orifice pitch of the first embodiment as mentioned above.

Figures 13 to 16 show a fourth embodiment of an ink-jet printing head according to the present invention. This ink-jet printing head comprises: a flexible wiring sheet 92 constructed in substantially the same manner as the flexible wiring sheet 12; a laminated unit including a bottom insulating plate element 94, a top insulating plate element 95, and a lamination core 96 disposed therebetween. The bottom and top insulating plate elements 94 and 95 are constructed in substantially the same manner as the bottom and top insulating plate elements 14 and 16 of the first embodiment (Fig. 1).

For simplicity, although the lamination core 96 is shown to include three piezoelectric plate elements 98 and two intermediate insulating plate elements 100, it may be formed by more than three piezoelectric plate elements 98 and by more than two intermediate insulating plate elements 100, as long as the number of piezoelectric plate elements is more than that of the intermediate insulating plate elements, by one. Each of the piezoelectric plate elements 98 has an elongated opening 102 formed therein and open to the outside at one end thereof. The piezoelectric plate elements 98 and the intermediate insulating plate elements 100 are alternately laminated in such a manner that the two piezoelectric plate elements are positioned at the bottom and top of the lamination core 96. Each of the piezoelectric plate elements 98 is provided with upper and lower electrode layers formed on the upper and lower surfaces thereof to surround the corresponding elongated opening 102. In Fig. 13, the upper electrode layer of each piezoelectric plate element 98 is indicated by reference numeral 98a; the lower electrode layer thereof is not visible. Each of the intermediate insulating plate elements 100 has a rectangular opening 104 formed therein.

The laminated unit including the bottom insulating plate element 94, the top insulating plate element 95, and the lamination core 96 disposed therebetween, is integrally formed as a sintered ceramic product, such as PZT product, in substantially the same manner as in the first embodiment. As apparent from Fig. 13, an orifice plate element 106 having three orifices 106a formed therein is attached to a front end face of the laminated unit with a suitable adhesive, whereby the orifices 106a are aligned with the opened ends of the elongated openings 104, respectively. If the orifice plate element 106 is formed of a suitable ceramic material, it may be sintered together with the laminated unit.

The ink-jet printing head is finished by fixing the laminated unit to the flexible wiring sheet 92, in place, with a suitable adhesive, as shown in Fig. 14; in which the top insulating plate element 95 and the orifice plate 106 are shown to be separated from the laminated unit, for simplicity. In this ink-jet printing head, the rectangular openings 104 of the intermediate insulating plate elements 100 cooperate with the closed end zones of the elongated openings 102 to form an ink reservoir to which an ink is supplied through an inlet pipe element 95a of the top insulating plate element 95, which is connected to an ink source (not shown) through a flexible tube 107. Each of the elongated openings 102 of the piezoelectric plate elements 98 form a pressure chamber which is filled with the ink supplied from the ink reservoir. The upper and lower electrode layers of the piezoelectric plate elements 98 are electrically connected to terminal pads of the flexible wiring sheet 92 in substantially the same manner as in the first embodiment. Also, each of the piezoelectric plate elements 98 is polarized in the same manner as in the first embodiment.

Figure 15 is a cross sectional view of an ink-jet printing head shown in Fig. 13. When each of the piezoelectric plate elements 98 is polarized in a direction indicated by an arrow in Fig. 15, and when a drive pulse voltage is applied to each of the piezoelectric plate elements so that an electric field is reversely oriented with respect to the direction of poling, the thickness of the piezoelectric plate element 98 is reduced as indicated by a broken line in Fig. 15, and thus the volume of the pressure chamber 102 is reduced.

For example, when the piezoelectric plate elements 98 is PZT, and when a drive pulse voltage is 25 V, the pressure chambers 102 preferably have a length L of 20 mm and a width W of 0.5 mm, as shown in Figure 16, for the following reasons:

When the piezoelectric plate elements 98 is PZT, a piezoelectric constant d_{33} thereof in the direction of thickness of the piezoelectric plate element is as shown below:

$$d_{33} = 4 \times 10^{-10} \text{ m/V}$$

When the drive pulse voltage of 25 V is applied to the piezoelectric plate element, a change of thickness thereof δ is as shown below:

$$\delta = 0.01 \ \mu \text{m}$$

Note, the value of δ is not related to a thickness of the piezoelectric plate element.

Accordingly, a change of volume δ P of the pressure chamber is as defined below:

$$\delta P = \delta \times W \times L$$

Since W = 0.5 mm, and L = 20 mm,

$$\delta P = 1 \times 10^{-4} \text{ mm}^3$$

If an ink-jet drop ejected from the orifice 106a has a diameter of 30 μ m,

$$Q = 1.4 \times 10^{-5} \text{ mm}^3$$

wherein Q is a volume of the ink-jet drop.

Accordingly, a ratio of δ P to Q is 7.

This proves that the change of volume of the pressure chamber is sufficient to ensure the ejection of the ink-jet drop. Note, preferably a diameter of the orifices 106a is about 30 μ m.

In the first, second, and third embodiments as mentioned above, the fine orifices, which are directly formed in the laminated unit, are easily clogged during the production of the printing head, and as is obvious, if only one of the orifices becomes clogged, the printing head is not longer usable. Therefore, in the fourth embodiment shown in Fig. 13, since the orifice plate element 106 with the fine orifices 106a is produced independently of the production of the laminated unit, a yield rate of the printing head can be increased.

Figure 17 shows a fifth embodiment of an ink-jet printing head according to the present invention. This ink-jet printing head comprises: a flexible wiring sheet 108 constructed in substantially the same manner as the flexibled wiring sheet 12; a laminated unit including a bottom insulating plate element 110, a top insulating plate element 112, and a lamination core 114 disposed therebetween. The bottom and top insulating plate elements 110 and 112 are constructed in substantially the same manner as the bottom and top insulating plate elements 14 and 16 of the first embodiment (Fig. 1).

For simplicity, although the lamination core 114 is shown to include three piezoelectric plate elements 116 and two intermediate insulating plate elements 118, it may be formed by more than three piezoelectric plate elements 116 and by more than two intermediate insulating plate elements 118. Each of the piezoelectric plate elements 116 comprises a pair of strip pieces 116a and 116b spaced from each other to form a passage 117 therebetween. The piezoelectric plate elements 116 and the intermediate insulating plate elements 118 are alternately laminated in such a manner that the two piezoelectric plate elements are positioned at the bottom and top of the lamination core 114. Namely, in the lamination core 114, the number of intermediate insulating plate elements is less than the number of piezoelectric plate elements, by one. Each of the strip pieces 116a and 116b is provided with upper and lower electrode layers formed on the upper and lower surfaces thereof. In Fig. 17, the upper electrode layer is indicated by reference numeral 120; the lower electrode layer is not visible. The upper and lower electrode layers extend along the passage 117.

The laminated unit including the bottom insulating plate element 110, the top insulating plate element 112, and the lamination core 114 disposed therebetween, is integrally formed as a sintered ceramic product, such as a PZT product, in substantially the same manner as in the first embodiment. As apparent form Fig. 17, an orifice plate element 121a having three orifices 121a formed therein is attached to a front end face of the laminated unit with a suitable adhesive, so that the orifices 121a are aligned with the passages 117. Also, an ink reservoir block element 122 having a groove 122a formed therein is attached to a rear end face of the laminated unit with a suitable adhesive, so that the groove 122a is communicated with the passage 117. Note, the groove 122a of the block element 122 also serves as an ink reservoir. When the orifice plate element 121 and the ink reservoir block element 122 are formed of a suitable ceramic material, they may be sintered together with the laminated unit.

The ink-jet printing head is finished by fixing the laminated unit to the flexible wiring sheet 108, in place, with a suitable adhesive. In this ink-jet printing head, each of the passages 117 of the piezoelectric plate elements 116 form a pressure chamber filled with an ink supplied from the ink reservoir 122a. The upper and lower electrode layers of the piezoelectric plate elements 116 (strip pieces 116a, 116b) are electrically connected to terminal pads of the flexible wiring sheet 108 in substantially the same manner as in the first embodiment. Also, each of the piezoelectric plate elements 98 is polarized in the same manner as in the first embodiment.

According to the fifth embodiment shown in Fig. 17, when the laminated unit is obtained as a sintered ceramic product, it can be easily and visually inspected because the fine passages 117 of the laminated unit are open at both ends. Namely, it can be rapidly determined whether or not the fine passages 117 are clear.

Figure 18 shows a preferable green sheet assembly for obtaining the laminated unit. The green sheet assembly includes a shaped green sheet 110′ for the bottom insulating plate element 110, a shaped green sheet 112′ for the top insulating plate element 112, three shaped green sheets 116′ for the piezoelectric sheet elements 116, and two shaped green sheets 118′ for the intermediate insulating plate elements 118. Since each of the shaped green sheets 116′ has a closed passage 117′ formed therein, it can be easily positioned during a formation of the green sheet assembly. Note, the shaped green sheets 116′ are previously spread with a conductive paste, for the formation of the upper and lower electrode layers. After the green sheet assembly is sintered, end portions of the sintered ceramic product are cut therefrom, so that each of the closed passages 117′ is open at both ends, and thus the desired laminated unit can be obtained.

Figures 19 to 21 show a sixth embodiment of an ink-jet printing head according to the present invention. This ink-jet printing head comprises: a flexible wiring sheet 124 constructed in substantially the same manner as the flexible wiring sheet 12; a laminated unit including a bottom insulating plate element 126, a top insulating plate element 128, and a lamination core 130 disposed therebetween. The bottom and top insulating plate elements 126 and 128 are constructed in substantially the same manner as the bottom and top insulating plate elements 14 and 16 of the first embodiment (Fig. 1).

For simplicity, although the lamination core 130 is shown to include three pairs of piezoelectric plate elements 132a and 132b, and two intermediate insulating plate elements 134, it may further include more than three pairs of piezoelectric plate elements 132a and 132b and more than two intermediate insulating plate elements 134, as long as the number of pairs of piezoelectric plate elements is more than that of the intermediate insulating plate elements, by one. The piezoelectric plate elements 132a and 132b have elongated opening 136a and 136b formed therein, respectively, each of which is open to the outside at one end thereof. The elongated openings 136a and 136b of each pair of piezoelectric plate elements 132a and 132b are identical to and in register with each other. The three pairs of piezoelectric plate elements 132a and 132b and the two intermediate insulating plate elements 134 are alternately laminated in such a manner that the two pairs of piezoelectric plate elements are positioned at the bottom and top of the lamination core 130. Each pair of piezoelectric plate elements 132a and 132b is provided with two outer electrode layers formed on an outer surface of the piezoelectric plate element 132a and a lower surface of the piezoelectric plate element 132b, respectively, and an intermediate electrode layer between the piezoelectric plate elements 132a and 132b. In Fig. 19, one of the two outer electrode layers (i.e., the electrode layer formed on the upper surface of the piezoelectric plate element 132a) is indicated by reference numeral 132a-1; the intermediate electrode layer is indicated by reference numeral 132b-1; and the other outer electrode layer (i.e. , the electrode layer formed on the lower surface of the piezoelectric plate element 132b) is not visible. Note, the intermediate electrode layer may be formed on the lower surface of the piezoelectric plate element 132a. The outer electrode layer 132a-1 is extended to surround the elongated opening 136a, and the intermediate electrode layer 132b-1 and the other outer electrode layer (not visible) are extended to surround the corresponding elongated opening 136b. Each of the intermediate insulating plate elements 134 has a rectangular opening 138 formed therein.

The laminated unit including the bottom insulating plate element 126, the top insulating plate element 128, and the lamination core 130 disposed therebetween, is integrally formed as a sintered ceramic product, such as a PZT product, in substantially the same manner as in the first embodiment. As apparent form Fig. 19, an orifice plate element 140 having three orifices 140a formed therein is attached to a front end face of the laminated unit with a suitable adhesive, so that the orifices 140a are aligned with the opened ends of the registered elongated openings 136a and 136b of the three pairs of piezoelectric plate elements 132a and 132b, respectively. If the orifice plate element 140 is formed of a suitable ceramic material, it may be sintered together with the laminated unit.

The ink-jet printing head is finished by fixing the laminated unit to the flexible wiring sheet 124, in place with a suitable adhesive. In this ink-jet printing head, the rectangular openings 138 of the intermediate insulating plate elements 134 cooperate with the closed end zones of the three registered elongated openings (136a, 136b) to form an ink reservoir to which ink is supplied through an inlet pipe element 128a of the top insulating plate element 128, which is connected to an ink source (not shown) through a suitable flexible tube (not shown). The registered elongated openings 136a and 136b of each pair of piezoelectric plate elements 132a and 132b cooperate with each other to form a pressure chamber filled with ink supplied from the ink reservoir. The upper electrode layers of the piezoelectric plate elements 132a and the upper and lower electrode layers of the piezoelectric plate elements 132b are electrically connected to terminal pads of the flexible wiring sheet 124 in substantially the same manner as in the first embodiment.

According to this sixth embodiment, although each of the intermediate insulating plate elements 134 is formed as a ceramic product having a potential piezoelectric effect, it is possible to simultaneously polarize all of the piezoelectric plate elements 132a and 132b, because the poling voltage can be applied to all of the piezoelectric plate elements 132a and 132b in such a manner that all of the outer electrode layers thereof have either of a positive or negative polarity, and all of the intermediate electrode layers have an opposite polarity. In particular, during the application of the poling voltage, since the two electrode layers having the intermediate insulating plate elements 134 intervened therebetween have the same electric potential, no electric field is generated between the two electrode layers concerned. Thus, although a simultaneous poling is carried out for all of the piezoelectric plate elements 132a and 132b, the intermediate insulating plate elements 134 cannot be polarized.

According to the poling as mentioned above, for example, as shown in Fig. 20, all of the piezoelectric plate elements 132a are polarized in the same direction indicated by arrows A-1, and all of the piezoelectric plate elements 132b are polarized in the same direction indicated by arrows A-2. Accordingly, when a pulse voltage is applied to the pair of piezoelectric plate elements 132a and 132b, so that an electric field generated in the piezoelectric plate element 132a is reversely oriented with respect to the direction of poling (A-1) and an electric field generated in the piezoelectric plate element 132b is reversely oriented with respect to the direction of poling (A-2), the thicknesses of the pair of piezoelectric plate elements 132a and 132b is reduced as indicated by broken lines in Fig. 20, and thus the volume of the pressure chamber (136a, 136b) is reduced.

In this sixth embodiment, when the pair of piezoelectric plate elements 132a and 132b are PZT, and when a drive pulse voltage is 12.5 V, the pressure chambers (136a, 136b) preferably have a length L of 20 mm and a width W of 0.5 mm, as shown in Fig. 21, for the following reasons:

When each pair of piezoelectric plate elements 132a and 132b is PZT, a piezoelectric constant d_{33} thereof in the direction of thickness of the piezoelectric plate element is as shown below:

$$d_{33} = 4 \times 10^{-10} \text{ m/V}$$

When the drive pulse voltage of 12.5 V is applied to each pair of piezoelectric plate elements 132a and 132b, a change of thickness δ of each piezoelectric plate element (132a, 132b) is as shown below:

$$\delta = 0.005\ \mu\text{ m}$$

Note, the value of δ is not related to a tickness of each piezoelectric plate element (132a, 132b).

Accordingly, a change of volume δ P of the pressure chamber is as defined below:

$$\delta\text{ P} = 2\delta \times \text{W} \times \text{L}$$

Since W = 0.5 mm, and L = 20 mm,

$$\delta\text{ P} = 1 \times 10^{-4} \text{ mm}^3$$

If an ink-jet drop ejected from the orifice 140a has a diameter of 30 μ m,

$$\text{Q} = 1.4 \times 10^{-5} \text{ mm}^3$$

wherein Q is a volume of the ink-jet drop.

Accordingly, a ratio of δ P to Q is 7.

This proves that the change of volume of the pressure chamber is sufficient to ensure the ejection of the ink-jet drop. Note, preferably a diameter of the orifices 140a is about 30 μ m.

Note, although the pressure chamber (136a, 136b) has the same dimension as the pressure chamber 102 of the fourth embodiment (Fig. 16), the value (12.5 V) of the drive pulse voltage is one half of 25 V.

In the sixth embodiment, preferably each pair of piezoelectric plate elements 132a and 132b has substantially the same thickness as each of the intermediate insulating plate elements 134. For example, when the thickness of the intermediate insulating plate elements 134 is about 42μ m, the orifices 140a are disposed at a pitch of about 84 μ m, so that a printing can be carried out at about 300 dpi.

Figure 22 shows a seventh embodiment of an ink-jet printing head according to the present invention, which is arranged as a model suitable for an ink-jet line printer. This ink-jet printing head comprises: a flexible wiring sheet 142 constructed in substantially the same manner as the flexible wiring sheet 12; a laminated unit including a bottom insulating plate element 144, a top insulating plate element 146, and a lamination core 148 disposed therebetween. The bottom and top insulating plate elements 144 and 146 are constructed in substantially the same manner as the bottom and top insulating plate elements 14 and 16 of the first embodiment (Fig. 1).

The lamination core 148 includes three piezoelectric plate elements 150, 152 and 154, and two intermediate insulating plate elements 156 and 158, which are alternately laminated in such a manner that the two piezoelectric plate elements 150 and 154 are positioned at the bottom and top of the lamination core 148, respectively, as shown in Fig. 22.

The piezoelectric plate elements 150, 152 and 154 have three elongated passages 150a, 150b and 150c, three elongated passages 152a, 152b and 152c, and three elongated passages 154a, 154b and 154c, respectively, and each of these passages is open at one end thereof. The elongated passages 150a, 150b and 150c; 152a, 152b and 152c; and 154a, 154b and 154c are laterally disposed at a regular spacing, and extend in parallel with each other. The piezoelectric plate elements 150 are provided with three upper electrode layers and three lower electrode layers formed on upper and lower surfaces thereof to surround the elongated passages 150a, 150b and 150c, respectively; in Fig. 22, the upper electrode layers are indicated by reference numeral 150a′, 150b′ and 150c′; the lower electrode layers are not visible. Also, the piezoelectric plate elements 152 are provided with three upper electrode layers and three lower electrode layers formed on upper and lower surfaces thereof to surround the elongated passages 152a, 152b and 152c, respectively; in Fig. 22, the upper electrode layers are indicated by reference numeral 152a′, 152b′ and 152c′, but the lower electrode layers are not visible. Similarly, the piezoelectric plate elements 154 are provided with three upper electrode layers and three lower electrode layers formed on upper and lower surfaces thereof to surround the elongated passages 154a, 154b and 154c, respectively; in Fig. 22, the upper electrode layers are indicated by reference numeral 154a′, 154b′ and 154c′, but the lower electrode layers are not visible.

The intermediate insulating plate elements 156 have three rectangular openings formed therein and communicate with the elongated passages 150a, 150b and 150c; and 152a, 152b and 152c, respectively; in Fig. 22, only two of these rectangular openings indicated by reference numerals 156b and 156c are shown, and the other rectangular opening is not visible. Also, the intermediate insulating plate elements 158 have rectangular openings formed therein and communicated with the elongated passages 152a, 152b and 152c; and 154a, 154b and 154c, respectively; in Fig. 22, only one of these rectangular openings is indicated by reference numeral 158c, and the other rectangular openings are not visible.

The laminated unit including the bottom insulating plate element 144, the top insulating plate element 146, and the lamination core 148 disposed therebetween, is integrally formed as a sintered ceramic product such as a PZT product in substantially the same manner as in the first embodiment. As is apparent from Fig. 22, an orifice plate element 160 having nine orifices 160-1 to 160-9 formed therein is attached to a front end face of the laminated unit with a suitable adhesive, so that the orifices 160-1, 160-2, 160-3, 160-4, 160-5, 160-6, 160-7, 160-8 and 160-9 are aligned with the open ends of the elongated passages 150a, 150b and 150c; 152a, 152b and 152c; and 154a, 154b and 154c, respectively. This means that an arrangement of the elongated passages 150a, 150b and 150c; 152a, 152b and 152c; and 154a, 154b and 154c corresponds to that of the orifices 160-1, 160-2, 160-3, 160-4, 160-5, 160-6, 160-7, 160-8 and 160-9.

Note, if the orifice plate element 160 is formed of a suitable ceramic material, it may be sintered together with the laminated unit.

The ink-jet printing head is finished by fixing the laminated unit to the flexible wiring sheet 142, in place, with a suitable adhesive. In this ink-jet printing head, the rectangular opening 156c of the intermediate insulating plate elements 156 and the rectangular opening 158c of the intermediate insulating plate elements 158 cooperate with the closed end zones of the elongated openings 150c, 152c and 150c, to form an ink resevoir; the rectangular opening 156b of the intermediate insulating plate elements 156 and the corresponding rectangular opening (not visible) of the intermediate insulating plate elements 158 cooperate with the closed end zones of the elongated openings 150b, 152b and 150b, to form an ink resevoir; and the rectangular opening (not visible) of the intermediate insulating plate elements 156 and the corresponding rectangular opening (not visible) of the intermediate insulating plate elements 158 cooperate with the closed end zones of the elongated openings 150a, 152a and 150a, to form an ink reservoir. These ink reservoirs are supplied with ink through an inlet pipe element 146a of the top insulating plate element 146, which is connected to an ink source (not shown). Each of the elongated passages 150a, 150b and 150c; 152a, 152b and 152c; and 154a, 154b and 154c forms a pressure chamber filled with ink supplied from the corresponding ink reservoir. The upper layers 150a′, 150b′ and 150c′; 152a′, 152b′ and 152c′; and 154a′, 154b′ and 154c′ and the corresponding lower layers (not visible) are electrically connected to terminal pads of the flexible wiring sheet 142, in substantially the same manner as in the first embodiment. Also, each of the piezoelectric plate elements 150, 152 and 154 is polarized in the same manner as in the first embodiment. When a drive pulse voltage is applied between each of the upper layers and the corresponding lower layer, the thickness of the piezoelectric plate element concerned is locally reduced, resulting in a decrease of the volume of the pressure chamber concerned, whereby an ink-jet drop is ejected from the corresponding orifice.

As shown in Fig. 22, when the locations of the orifices 160-7, 160-4, 160-1, and 160-8 are projected onto a common line CL, these projected locations are aligned at a given pitch of P. This also is true for the other orifices 160-5, 160-2, 160-9, 160-6, and 160-3. Namely, the pitch of P represents a dot pitch at which a printing is carried out by the ink-jet printing head.

Figure 23 shows a part of an ink-jet printing head constructed on the basis of the seventh embodiment of Fig. 22, and can be used in an actual ink-jet line printer. This ink-jet printing head comprises eight piezoelectric plate elements 162-1 to 162-8, in each of which a plurality of elongated passages or pressure chambers 164 are formed. Note, these piezoelectric plate elements 162-1 to 162-8 are formed in substantially the same manner as the piezoelectric plate element 150, 152, 154. Also, seven intermediate insulating plate elements 166-1 to 166-7, which are alternately laminated with the pizoelectric plate elements 162-1 to 162-8, are formed in substantially the same manner as the intermediate insulating plate element 156, 158. In Fig. 23, reference numeral 168 indicates an orifice location, and reference numerals 170 and 172 indicate bottom and top insulating plate elements corresponding to the bottom and top insulating plate elements 144 and 146, respectively.

According to the present invention, it is possible to precisely and easily arrange the plurality of elongated passages or pressure chambers 164 at a low cost, because shaped green sheets for the piezoelectric plate elements, the intermediate insulating plate elements, and other elements can be obtained from the green sheet material by using punch cutting dies, as mentioned above.

Figure 24 shows a modification of the embodiment shown in Fig. 23. In this drawing, the elements similar to those of Fig. 23 are indicated by the same reference numerals. This modified embodiment is identical to the embodiment of Fig. 23 except that the pressure chambers are arranged in a different manner.

Figure 25 shows another modification of the embodiment shown in Fig. 23. In this modified embodiment, the pressure chambers are arranged in substantially the same manner as in Fig. 24, but six pair of piezoelectric plate elements 162-1′ to 162-6′, as explained with reference to Fig. 19, are used in place of the eight piezoelectric plate elements 162-1 to 162-8.

Claims

1. An ink-jet printing head for a serial ink-jet printer comprising:

an external orifice for the ejection of ink;

a laminated unit including a piezoelectric plate element (20) and having a pressure chamber (32) formed at said piezoelectric plate element for filling with an ink, said piezoelectric plate element having two electrode layers (20a, 20b) formed on surfaces thereof and surrounding said pressure chamber, the external orifice (36) being in fluid communication with said pressure chamber; and

means (12, 14-1, 14-2, 42) for applying a drive pulse voltage to said piezoelectric plate element through the electrode layers thereof,

said piezoelectric plate element being constituted such that a thickness thereof is reduced upon applying said drive voltage pulse thereto, resulting in a decrease of volume of said pressure chamber, whereby in use an ink-jet drop is ejected from said orifice,

characterised in that the laminated unit is integrally formed as a sintered ceramic product and includes a bottom insulating plate element (14) and a top insulating plate element (16), with said piezoelectric plate element (20) being located between the bottom and top insulating plate elements.

2. An ink-jet printing head according to claim 1 wherein said drive pulse applying means includes two vertical through holes (14-1, 14-2) extending through the piezoelectric plate element and bottom plate insulating element of said laminated unit, each of said through holes having a conductive lining (42) formed therein, the electrode layers of said piezoelectric plate element being partially extended to surround respective ones of said through holes, so that each electrode layer is electrically connected to the conductive lining of a respective through hole.

3. An ink-jet printing head according to claim 2 wherein said drive pulse applying means further includes a wiring sheet (12) having two terminal pads (12a-1, 12b-1) formed thereon, said laminated unit being fixed to said wiring sheet so that the conductive linings of said through holes are electrically connected to respective terminal pads.

4. An ink-jet printing head according to claim 1 wherein said lamination unit comprises a lamination core between said bottom and top insulating plate elements, said lamination core comprising said piezoelectric plate element (20) and at least one further piezoelectric plate element (22, 24), a further pressure chamber (32) being formed at each further piezoelectric plate element for filling with an ink, each further piezoelectric plate element having two electrode layers (22a, 22b; 24a, 24b) formed on surfaces thereof and surrounding said further pressure chamber, each further pressure chamber being in communication with a respective further orifice (36) provided in said laminated unit; and

means (12, 14-n, 42) for applying a drive pulse voltage to a selected piezoelectric plate element through the electrode layers thereof,

each said further piezoelectric plate element being constituted such that a thickness thereof is reduced upon applying said drive voltage pulse thereto, resulting in a decrease of volume of said pressure chamber, whereby an ink-jet drop is ejected from the associated said orifice.

5. An ink-jet printing head according to claim 4 wherein said drive pulse applying means includes a plurality of vertical through holes (14-n) extending through the laminated core and bottom plate insulating element of said laminated unit, each said through hole having a conductive lining (42) formed therein, the electrode layers of the piezoelectric plate elements of the laminated core being partially extended to surround respective ones of said through holes, so that each electrode layer is electrically connected to the conductive lining of a respective through hole.

6. An ink-jet printing head according to claim 5 wherein said drive pulse applying means further includes a wiring sheet (12) having a plurality of terminal pads formed thereon, said laminated unit being fixed to said wiring sheet so that the conductive linings of said through holes are electrically connected to respective terminal pads.

7. An ink-jet printing head according to any one of claims 4 to 6, wherein pressure chambers (62, 70) of adjacent said piezoelectric plate elements are symmetrically disposed on opposite sides of a longitudinal central axis of said laminated unit.

8. An ink-jet printing head according to claim 7 wherein the spatial extent of said electrode layers (56a, 60a) is such that the layers of one said piezoelectric plate element do not overlap those of an adjacent piezoelectric plate element.

9. An ink-jet printing head according to any one of claims 4 to 7 wherein at least one pair of adjacent piezoelectric plate elements is spaced by an intermediate insulating plate element (26,28).

10. An ink-jet printing head according to claim 9 wherein each pair of adjacent piezoelectric plate elements are spaced by a respective intermediate insulating plate element.

11. An ink-jet printing head according to claim 9 or claim 10 wherein at least two adjacent piezoelectric plate elements each comprise two piezoelectric sub-plates (132a, 132b) which are separated by an electrode layer (132b-1) and which have opposed polarisations.

12. An ink-jet printing head according to any preceding claim wherein said laminated unit includes an ink reservoir (30, 38) formed therein in communication with said pressure chamber(s) to supply ink thereto.

13. An ink-jet printing head according to claim 12 as dependent on any one of claims 9 to 11, wherein each said piezoelectric plate includes a reservoir volume (30) in fluid communication with a respective pressure chamber, said intermediate insulating plate element having an opening (38) formed therein cooperating with the reservoir volumes to form the ink reservoir.

14. An ink-jet printing head according to claim 13 wherein there is no restriction between the reservoir volume and the pressure chamber.

15. An ink-jet printing head according to claim 13 wherein there is a restricted passage between the reservoir volume and the pressure chamber.

16. An ink-jet printing head according to any one of claims 1 to 11 wherein said laminated unit includes an ink reservoir block (122) having an ink reservoir (122a) formed therein, said ink reservoir block being securely attached to said laminated unit with the ink reservoir in communication with said pressure chamber(s) to supply ink thereto.

17. An ink-jet printing head according to claim 16 wherein the ink reservoir block is securely attached to a rear end face of said laminated unit.

18. An ink-jet printing head according to any preceding claim, said pressure chamber(s) (32; 117) being elongate with one end in direct fluid communication with said orifice.

19. An ink-jet printing head according to claim 18 and any one of claims 12 to 17, wherein said ink reservoir is in fluid communication with said elongated pressure chamber(s) (117) through the other end(s) of said pressure chamber(s).

20. An ink-jet printing head according to any preceding claim, said orifice(s) (36) being formed in said laminated unit.

21. An ink-jet printing head according to any one of claims 1 to 19, said orifice(s) (106a) being formed in an orifice plate element (106) securely attached to said laminated unit.

22. An ink-jet printing head according to any preceding claim, wherein a plurality of pressure chambers (150a, 150b, 150c; 152a, 152b, 152c; 154a, 154b, 154c) are formed in the or each said piezoelectric plate element (150, 152, 154).

23. An ink-jet printing head according to claim 22, wherein the laminated unit comprises at least two said piezoelectric plate elements each with a said plurality of pressure chambers, and a respective row of spaced orifices (168) for each said plurality of pressure chambers.

24. An ink-jet printing head according to claim 23, wherein the row of orifices corresponding to one said piezoelectric plate element is staggered with respect to the row corresponding to another said piezoelectric plate element.

Patentansprüche

1. Tintenstrahldruckkopf für einen seriellen Tintenstrahldrucker, umfassend:

eine äußere Öffnung zum Ausstoß der Tinte;

eine laminierte Einheit, umfassend ein piezoelektrisches Plattenelement (20) und eine Druckkammer (32), die am piezoelektrischen Plattenelement zur Befüllung mit einer Tinte ausgebildet ist, wobei das piezoelektrische Plattenelement zwei Elektrodenschichten (20a, 20b) aufweist, die an den Oberflächen desselben ausgebildet sind und die Druckkammer umgeben, wobei die äußere Öffnung (36) in Flüssigkeitsverbindung mit der Druckkammer steht; und

Vorrichtungen (12, 14-1, 14-2, 42) zum Anlegen einer Antriebsimpulsspannung an das piezoelektrische Plattenelement durch die Elektrodenschichten desselben,

wobei das piezoelektrische Plattenelement so ausgeführt ist, daß die Dicke desselben beim Anlegen des Antriebsspannungsimpulses daran verringert wird, was zu einer Abnahme des Volumens der Druckkammer führt, wodurch bei Verwendung ein Tintenstrahltropfen aus der Öffnung ausgestoßen wird, dadurch gekennzeichnet, daß die laminierte Einheit auf integrale Weise als ein gesintertes Keramikprodukt gebildet ist und ein unteres, isolierendes Plattenelement (14) und ein oberes isolierendes Plattenelement (16) umfaßt, wobei sich das piezoelektrische Plattenelement (20) zwischen dem unteren und dem oberen isolierenden Plattenelement befindet.

2. Tintenstrahldruckkopf nach Anspruch 1, wobei die Antriebsimpulsanlegevorrichtung zwei vertikale Durchgangsbohrungen (14-1, 14-2) umfaßt, die sich durch das piezoelektrische Plattenelement und das untere isolierende Plattenelement der laminierten Einheit hindurch erstrecken, wobei in jeder der Durchgangsbohrungen eine elektrisch leitfähige Auskleidung (42) ausgebildet ist, wobei die Elektrodenschichten des piezoelektrischen Plattenelementes teilweise verlängert sind, um die jeweiligen Durchgangsbohrungen zu umfassen, so daß jede Elektrodenschicht elektrisch mit der leitfähigen Auskleidung einer jeweiligen Durchgangsbohrung verbunden ist.

3. Tintenstrahldruckkopf nach Anspruch 2, wobei die Antriebsimpulsanlegevorrichtung desweiteren ein Verdrahtungsblech (12) mit zwei darauf ausgebildeten Anschlußflächen (12a-1, 12b-1) umfaßt, wobei die laminierte Einheit am Verdrahtungsblech befestigt ist, so daß die elektrisch leitfähigen Auskleidungen der Durchgangsbohrungen elektronisch mit den jeweiligen Anschlußflächen verbunden sind.

4. Tintenstrahldruckkopf nach Anspruch 1, wobei die laminierte Einheit einen Laminierungskern zwischen dem unteren und dem oberen isolierenden Plattenelement umfaßt, wobei der Laminierungskern das piezoelektrische Plattenelement (20) und mindestens ein weiteres piezoelektrisches Plattenelement (22, 24) umfaßt, wobei eine weitere Druckkammer (32) an jedem weiteren piezoelektrischen Plattenelement zur Befüllung mit einer Tinte ausgebildet ist, wobei jedes weitere piezoelektrische Plattenelement zwei Elektrodenschichten (22a, 22b; 24a, 24b) aufweist, die an Oberflächen desselben ausgebildet sind und jede weitere Druckkammer umgeben, wobei jede weitere Druckkammer in Verbindung mit einer jeweiligen weiteren Öffnung (36) steht, welche in der laminierten Einheit vorhanden ist; und

Vorrichtungen (12, 14-n, 42) zum Anlegen einer Antriebsimpulsspannung an ein ausgewähltes piezoelektrisches Plattenelement durch die Elektrodenschichten desselben, wobei jedes weitere piezoelektrische Plattenelement so ausgeführt ist, daß die Dicke desselben beim Anlegen des Antriebsspannungsimpulses daran verringert wird, was zu einer Abnahme des Volumens der Druckkammer führt, wodurch bei Verwendung ein Tintenstrahltropfen aus der damit zusammenhängenden Öffnung ausgestoßen wird.

5. Tintenstrahldruckkopf nach Anspruch 4, wobei die Antriebsimpulsanlegevorrichtung eine Mehrzahl an vertikalen Durchgangsbohrungen (14-n) umfaßt, die sich durch den laminierten Kern und das untere isolierende Plattenelement der laminierten Einheit hindurch erstrecken, wobei in jeder der Durchgangsbohrungen eine elektrisch leitfähige Auskleidung (42) ausgebildet ist, wobei die Elektrodenschichten des piezoelektrischen Plattenelementes des laminierten Kerns teilweise verlängert sind, um die jeweiligen Durchgangsbohrungen zu umfassen, so daß jede Elektrodenschicht elektrisch mit der leitfähigen Auskleidung einer jeweiligen Durchgangsbohrung verbunden ist.

6. Tintenstrahldruckkopf nach Anspruch 5, wobei die Antriebsimpulsanlegevorrichtung desweiteren ein Verdrahtungsblech (12) mit einer Mehrzahl darauf ausgebildeter Anschlußflächen umfaßt, wobei die laminierte Einheit am Verdrahtungsblech befestigt ist, so daß die elektrisch leitfähigen Auskleidungen der Durchgangsbohrungen elektronisch mit den jeweiligen Anschlußflächen verbunden sind.

7. Tintenstrahldruckkopf nach einem der Ansprüche 4 bis 6, wobei die Druckkammern (62, 70) der benachbarten piezoelektrischen Plattenelemente symmetrisch an gegenüberliegenden Seiten einer länglichen mittigen Achse der laminierten Einheit angeordnet sind.

8. Tintenstrahldruckkopf nach Anspruch 7, wobei die räumliche Ausdehnung der Elektrodenschichten (56a, 60a) dermaßen ist, daß sich die Schichten eines piezoelektrischen Plattenelementes nicht mit jenen eines benachbarten piezoelektrischen Plattenelements überlappen.

9. Tintenstrahldruckkopf nach einem der Ansprüche 4

bis 7, wobei mindestens ein Paar benachbarter piezoelektrischer Plattenelemente durch ein dazwischen befindliches isolierendes Plattenelement (26, 28) beabstandet wird.

10. Tintenstrahldruckkopf nach Anspruch 9, wobei jedes Paar benachbarter piezoelektrischer Plattenelemente durch ein jeweiliges dazwischen befindliches isolierendes Plattenelement beabstandet wird.

11. Tintenstrahldruckkopf nach Anspruch 9 oder Anspruch 10, wobei mindestens zwei benachbarte piezoelektrische Plattenelemente jeweils zwei piezoelektrische Unterplatten (132a, 132b) umfassen, welche durch eine Elektrodenschicht (132b-1) voneinander getrennt sind und welche einander entgegengesetzte Polungen aufweisen.

12. Tintenstrahldruckkopf nach einem der vorhergehenden Ansprüche, wobei die laminierte Einheit einen darin ausgebildeten Tintenbehälter (30, 38) umfaßt, der in Verbindung mit der/den Druckkammer/n steht, um Tinte zu diesem zuzuführen.

13. Tintentstrahldruckkopf nach Anspruch 12 in Abhängigkeit von einem der Ansprüche 9 bis 11, wobei jede piezoelektrische Platte ein Behältervolumen (30) in Flüssigkeitsverbindung mit einer jeweiligen Druckkammer umfaßt, wobei das dazwischenliegende isolierende Plattenelement eine darin ausgebildete Öffnung (38) aufweist, welche mit den Behältervolumen zusammenarbeitet, um den Tintenbehälter zu bilden.

14. Tintenstrahldruckkopf nach Anspruch 13, wobei es keine Begrenzung zwischen dem Behältervolumen und der Druckkammer gibt.

15. Tintenstrahldruckkopf nach Anspruch 13, wobei es einen begrenzten Durchgang zwischen dem Behältervolumen und der Druckkammer gibt.

16. Tintenstrahldruckkopf nach einem der Ansprüche 1 bis 11, wobei die laminierte Einheit einen Tintenbehälterblock (122) mit einem darin ausgebildeten Tintenbehälter (122a) umfaßt, wobei der Tintenbehälterblock sicher an der laminierten Einheit befestigt ist, so daß der Tintenbehälter mit der/den Druckkammer/n in Verbindung steht, um dieser Tinte zuzuführen.

17. Tintenstrahldruckkopf nach Anspruch 16, wobei der Tintenbehälterblock sicher an einer hinteren Endfläche der laminierten Einheit befestigt ist.

18. Tintenstrahldruckkopf nach einem der vorhergehenden Ansprüche, wobei die Druckkammer/n (32; 117) mit einem Ende in direkter Flüssigkeitsverbindung mit der Öffnung verlängert ist/sind.

19. Tintenstrahldruckkopf nach Anspruch 18 und einem der Ansprüche 12 bis 17, wobei der Tintenbehälter in Flüssigkeitsverbindung mit der (den) verlängerten Druckkammer(n) (117) durch das (die) andere(n) Ende(n) der Druckkammer(n) hindurch steht.

20. Tintenstrahldruckkopf nach einem der vorhergehenden Ansprüche, wobei die Öffnung(en) (36) in der laminierten Einheit ausgebildet ist (sind).

21. Tintenstrahldruckkopf nach einem der Ansprüche 1-19, wobei die Öffnung(en) (106a), die in einem Öffnungsplattenelement (106) ausgebildet ist (sind), welches sicher an der laminierten Einheit befestigt ist.

22. Tintenstrahldruckkopf nach einem der vorhergehenden Ansprüche, wobei eine Mehrzahl an Druckkammern (150a, 150b, 150c; 152a, 152b, 152c; 154a, 154b, 154c) in jedem der piezoelektrischen Plattenelemente (150, 152, 154) ausgebildet ist.

23. Tintenstrahldruckkopf nach Anspruch 22, wobei die laminierte Einheit mindestens zwei piezoelektrische Plattenelemente umfaßt, wobei jedes eine Mehrzahl an Druckkammern aufweist, sowie eine entsprechende Reihe beabstandeter Öffnungen (168) für jede Mehrzahl an Druckkammern.

24. Tintenstrahldruckkopf nach Anspruch 23, wobei die Reihe an Öffnungen, welche einem piezoelektrischen Plattenelement entspricht, hinsichtlich der Reihe, welche einem anderen piezoelektrischen Plattenelement entspricht, versetzt ist.

Revendications

1. Tête d'impression à jet d'encre pour une imprimante série à jet d'encre comprenant :

- un orifice externe pour l'éjection d'encre;
- une unité stratifiée comprenant un élément de plaque piézo-électrique (20) et ayant une chambre de pression (32) formée sur ledit élément de plaque piézo-électrique en vue de son remplissage avec de l'encre, ledit élément de plaque piézo-électrique ayant deux couches d'électrodes (20a, 20b) formées sur ses surfaces et entourant ladite chambre de pression, l'orifice externe (36) étant en communication de fluide avec ladite chambre de pression et,
- des moyens (12, 14-1, 14-2, 42) pour appliquer une tension d'impulsion de commande audit élément de plaque piézo-électrique par l'intermédiaire de ses couches d'électrodes,

  ledit élément de plaque piézo-électrique étant constitué de manière qu'une épaisseur de celui-ci soit réduite lors de l'application de ladite impulsion de tension de commande sur celui-ci, entraînant une diminution de volume de ladite chambre de pression afin, qu'en service, une goutte de jet d'encre soit éjectée dudit orifice, caractérisée en ce que l'unité stratifiée est formée d'une pièce en un produit céramique fritté et elle comporte un élément de plaque isolante de fond (14) et un élément de plaque isolante supérieure (16), ledit élément de plaque piézo-électrique (20) étant positionné entre les éléments de plaque isolante de fond et supérieur.

2. Tête d'impression à jet d'encre selon la revendication 1 dans laquelle lesdits moyens d'application de l'impulsion de commande comprennent deux trous verticaux traversant (14-1 , 14-2) s'étendant au travers de l'élément de plaque piézo-électrique et de l'élément isolant de plaque de fond de ladite unité stratifiée, chacun desdits trous traversant ayant un garnissage conducteur (42) qui y est formé, les couches d'électrodes dudit élément de plaque piézo-électrique étant partiellement prolongées de manière à entourer l'un respectif desdits trous traversant afin que chaque couche d'électrodes soit électriquement connectée au garnissage conducteur d'un trou traversant respectif.

3. Tête d'impression à jet d'encre selon la revendication 2 dans laquelle lesdits moyens d'application d'impulsion de commande comportent en outre une feuille de connexion (12) ayant deux plots de bornes (12a-1, 12b-1) qui y sont formés, ladite unité stratifiée étant fixée sur ladite feuille de connexion de manière que les garnissages conducteurs desdits trous traversant soient connectés électriquement aux plots de bornes respectifs.

4. Tête d'impression à jet d'encre selon la revendication 1, dans laquelle ladite unité stratifiée comprend une âme de stratification entre lesdits éléments de plaques isolantes de fond et supérieure, ladite âme de stratification comprenant ledit élément de plaque piézo-électrique (20) et au moins un autre élément de plaque piézo-électrique (22, 24), une autre chambre de pression (32) étant formée sur chaque autre élément de plaque piézo-électrique pour un remplissage par l'encre, chaque autre élément de plaque piézo-électrique comportant deux couches d'électrodes (22a, 22b, 24a, 24b) formées sur des surfaces de celui-ci et entourant ladite autre chambre de pression, chaque autre chambre de pression étant en communication avec un autre orifice respectif (36) prévu dans ladite unité stratifiée et,

- des moyens (12, 14-n, 42) pour appliquer une tension d'impulsion de commande à un élément de plaque piézo-électrique présélectionné par l'intermédiaire des couches d'électrodes de ce dernier,
- chaque autre élément de plaque piézo-électrique étant constitué de manière qu'une épaisseur de celui-ci soit réduite lors de l'application de ladite impulsion de tension de commande ce qui entraîne une diminution du volume de ladite chambre de pression de façon qu'une goutte de jet d'encre soit éjectée dudit orifice associé.

5. Tête d'impression à jet d'encre selon la revendication 4 dans laquelle lesdits moyens d'application d'impulsion de commande comportent une pluralité de trous verticaux traversant (14-n) s'étendant au travers de l'âme de stratification et de l'élément isolant de plaque de fond de ladite unité stratifiée, chacun desdits trous traversant ayant un garnissage conducteur (42) qui y est formé, les couches d'électrodes des éléments de plaque piézo-électrique de l'âme stratifiée étant partiellement prolongé pour entourer des trous respectifs faisant partie desdits trous traversant afin que chaque couché d'électrode soit électriquement connectée au garnissage conducteur d'un trou traversant respectif.

6. Tête d'impression à jet d'encre selon la revendication 5 dans laquelle lesdits moyens d'application d'impulsion de commande comprennent en outre une feuille de connexion (12) ayant une pluralité de pots de bornes qui y sont formés, ladite unité stratifiée étant fixée sur ladite feuille de connexion de manière que les garnissages conducteurs desdits trous traversant soient électriquement connectés aux plots de bornes respectifs.

7. Tête d'impression à jet d'encre selon l'une quelconque des revendications 4 à 6 dans laquelle des chambres de pression (62, 70) desdits éléments de plaque piézo-électrique adjacents sont disposées symétriquement sur des côtés opposés d'un axe central longitudinal de ladite unité stratifiée.

8. Tête d'impression à jet d'encre selon la revendication 7 dans laquelle le prolongement spatial desdites couches d'électrodes (56a, 60a) est tel que les couches de l'élément de plaque piézo-électrique ne recouvrent pas celles d'un élément de plaque piézo-électrique adjacent.

9. Tête d'impression à jet d'encre selon l'une quelconque des revendications 4 à 7 dans laquelle une paire au moins d'éléments de plaque piézo-électrique adjacents est espacée par un élément de plaque isolant intermédiaire (26, 28).

10. Tête d'impression à jet d'encre selon la revendication 9 dans laquelle chaque paire d'éléments de

plaque piézo-électrique adjacent est espacée par un élément respectif de plaque isolante intermédiaire.

11. Tête d'impression à jet d'encre selon la revendication 9 ou 10 dans laquelle au moins deux éléments adjacents de plaque piézo-électrique comprennent chacun deux sous-plaques piézo-électriques (132a, 132b) qui sont séparées par une couche d'électrodes (132 b-1) et qui ont des polarisations opposées.

12. Tête d'impression à jet d'encre selon l'une quelconque des revendications précédentes dans laquelle ladite unité statifiée comprend un réservoir d'encre (30, 38) qui y est formé en communication avec la ou lesdites chambres de pression afin d'y délivrer de l'encre.

13. Tête d'impression à jet d'encre selon la revendication 12 lorsqu'elle dépend de l'une quelconque des revendications 9 à 11 dans laquelle chacune desdites plaques piézo-électriques comporte un volume de réservoir (30), en communication de fluide avec une chambre respective de pression, ledit élément de plaque isolante intermédiaire comportant une ouverture (38) qui y est formée et qui coopère avec les volumes de réservoir pour former le réservoir d'encre.

14. Tête d'impression à jet d'encre selon la revendication 13 dans laquelle il n'existe pas de réduction entre le volume de réservoir et la chambre de pression.

15. Tête d'impression à jet d'encre selon la revendication 13 dans laquelle il existe un passage réduit entre le volume de réservoir et la chambre de pression.

16. Tête d'impression à jet d'encre selon l'une quelconque des revendications 1 à 11 dans laquelle ladite unité statifiée comprend un bloc réservoir d'encre (122) ayant un réservoir d'encre (122a) qui y est formé, ledit bloc réservoir d'encre étant fixé à ladite unité stratifiée, le réservoir d'encre étant en communication avec la ou ladite chambre de pression pour y délivrer de l'encre.

17. Tête d'impression à jet d' encre selon la revendication 16 dans laquelle le bloc réservoir d'encre est fixé à une face d'extrémité postérieure de ladite unité stratifiée.

18. Tête d'impression à jet d'encre selon l'une quelconque des revendications précédentes dans laquelle la ou lesdites chambres de pression (32 ; 117) sont allongées avec une extrémité en communication de fluide directe avec ledit orifice.

19. Tête d'impression à jet d'encre selon la revendication 18 et l'une quelconque des revendications 12 à 17 dans laquelle ledit réservoir d'encre est en communication de fluide avec la ou lesdites chambres de pression allongées (117) par l'intermédiaire de la ou des autres extrémités de la ou desdites chambres de pression.

20. Tête d'impression à jet d'encre selon l'une quelconque des revendications précédentes dans laquelle le ou lesdits orifices (36) sont formés dans ladite unité stratifiée.

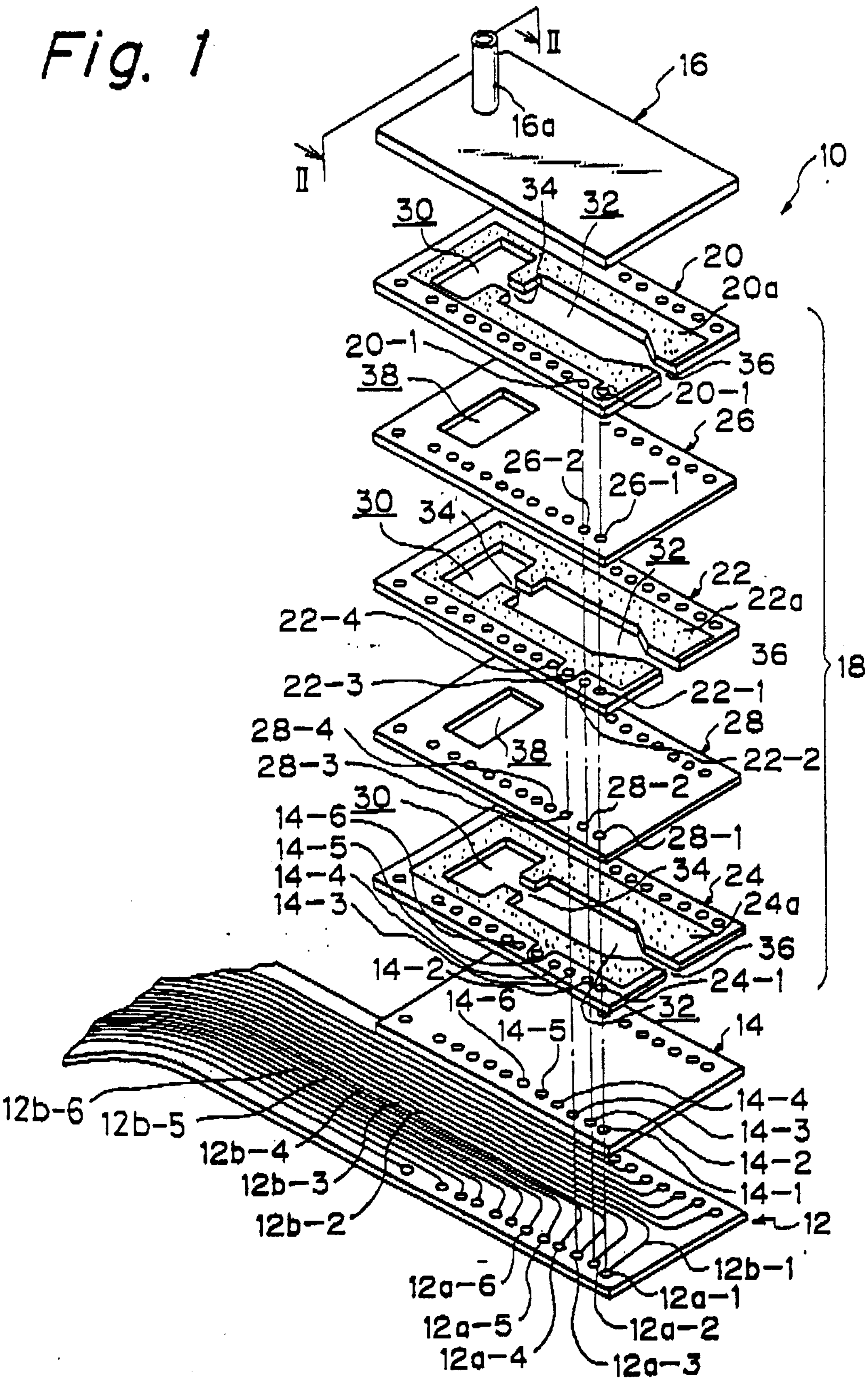
21. Tête d'impression à jet d'encre selon l'une quelconque des revendications 1 à 19 dans laquelle le ou lesdits orifices (106a) sont formés dans un élément de plaque à orifice (106) fixé à ladite unité stratifiée.

22. Tête d'impression à jet d'encre selon l'une quelconque des revendications précédentes dans laquelle une pluralité de chambres de pression (150a, 150b, 150c; 152a, 152b, 152c; 154 a, 154b, 154 c) sont formées dans la, ou dans chaque, élément de plaque piézo-électrique (150, 152, 154).

23. Tête d'impression à jet d'encre selon la revendication 22, dans laquelle l'unité stratifiée comprend au moins deux éléments de plaque piézo-électrique, chacun avec l'une desdites pluralités de chambres de pression et une rangée respective d'orifices espacés (168) pour chacune desdites pluralités de chambres de pression.

24. Tête d'impression à jet d'encre selon la revendication 23, dans laquelle la rangée d'orifices correspondant audit élément de plaque piézo-électrique est décalée par rapport à la rangée correspondante de l'autre élément de plaque piézo-électrique.

Fig. 1



II
16
16a
II
10
34
30
32
20
20a
36
20-1
38
20-1
26
26-2
26-1
30
34
32
22
22a
22-4
36
18
22-3
22-1
28
28-4
38
22-2
28-3
28-2
14-6
30
28-1
14-5
34
24
14-4
24a
14-3
36
14-2
24-1
14-6
32
14-5
14
14-4
12b-6
12b-5
14-3
12b-4
14-2
12b-3
14-1
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12
12b-1
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12a-1
12a-5
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12a-4
12a-3

Fig. 2

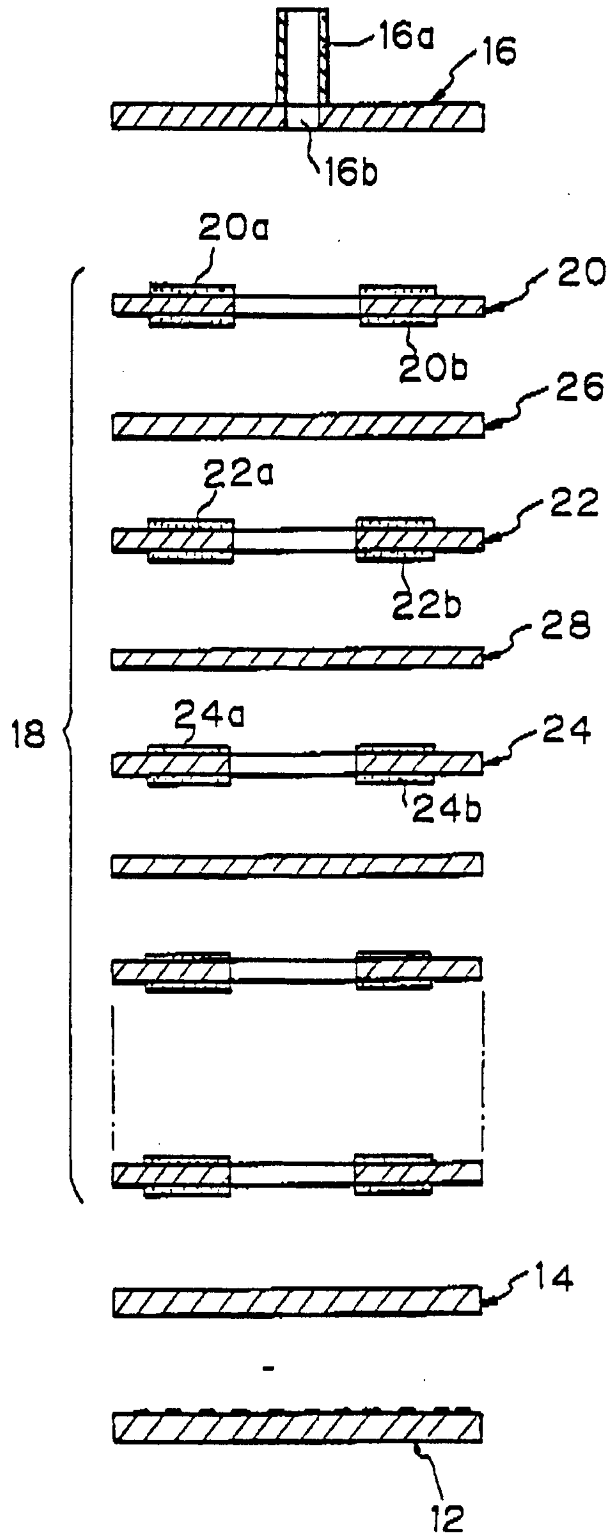


Fig. 3

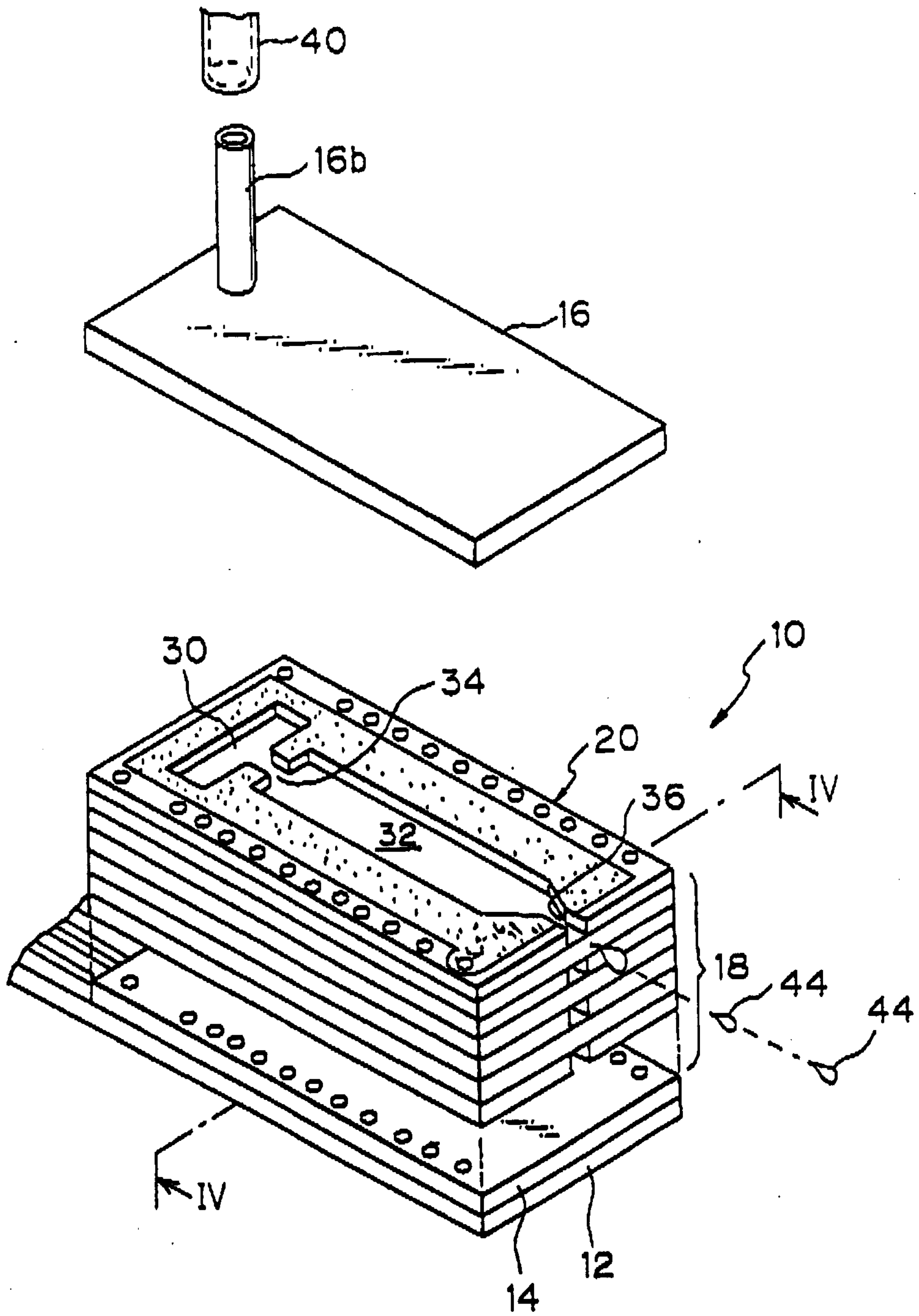


Fig. 4

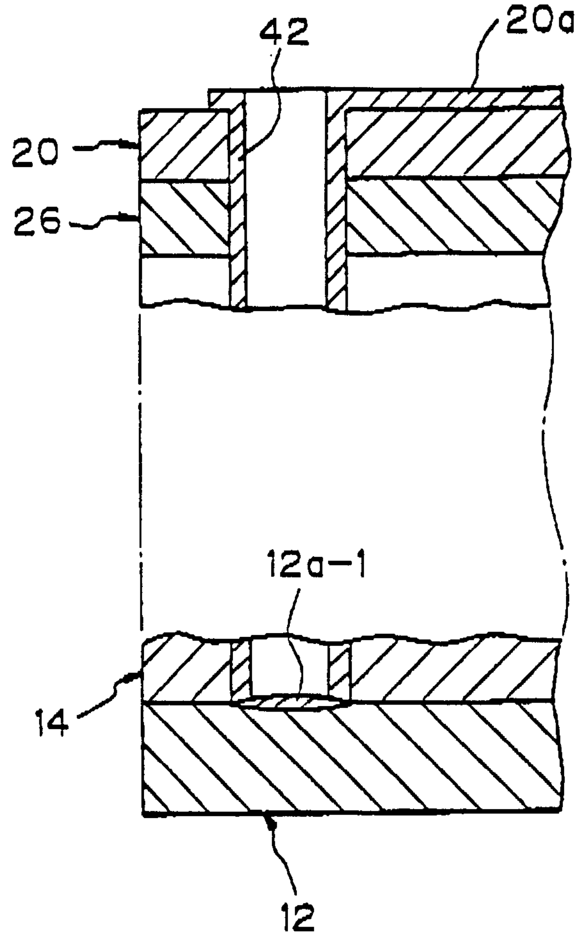


Fig. 5

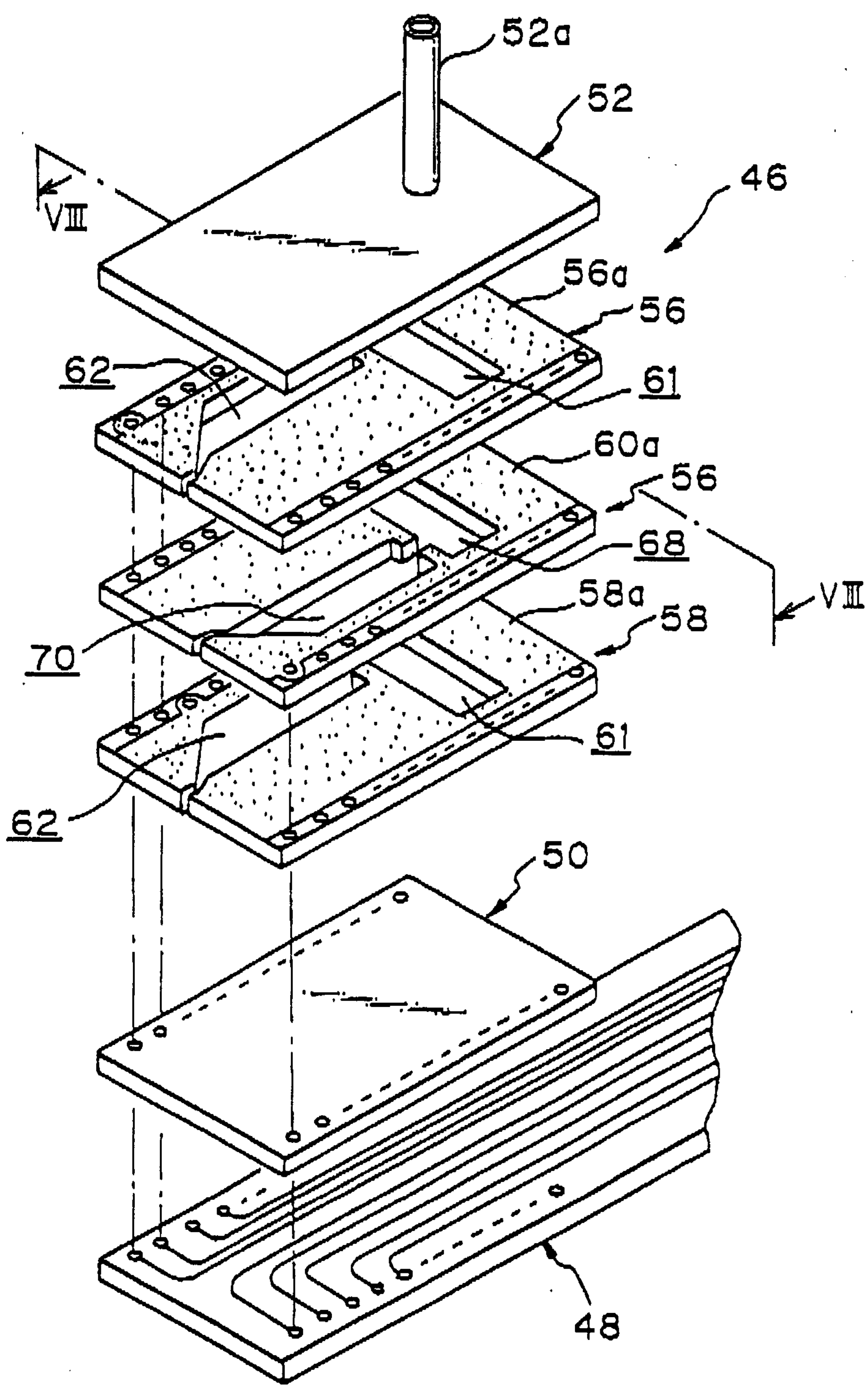


Fig. 6

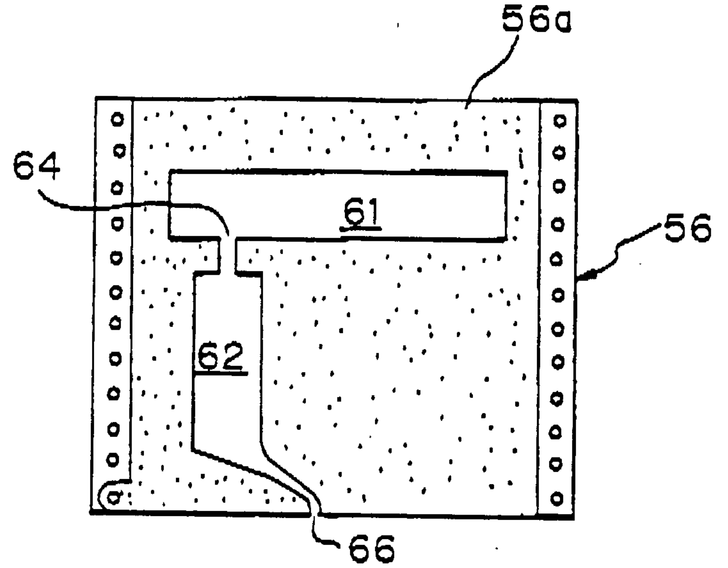


Fig. 7

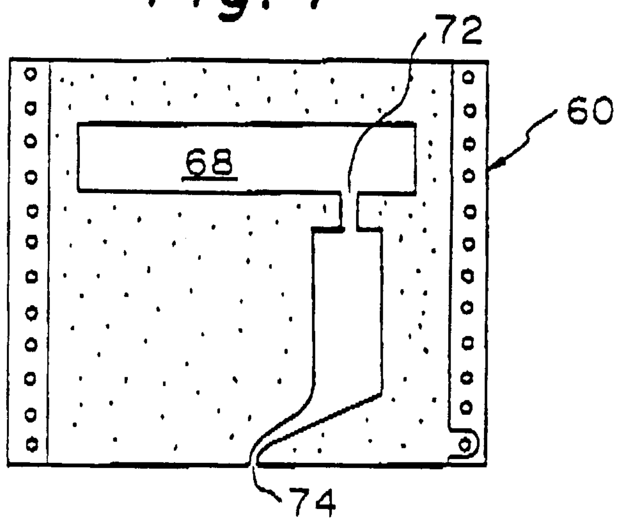


Fig. 8

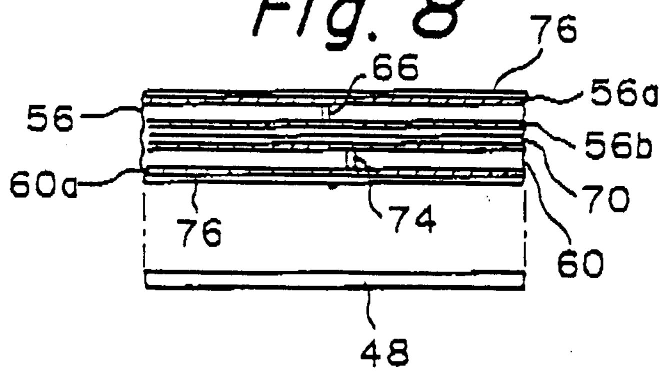


Fig. 9

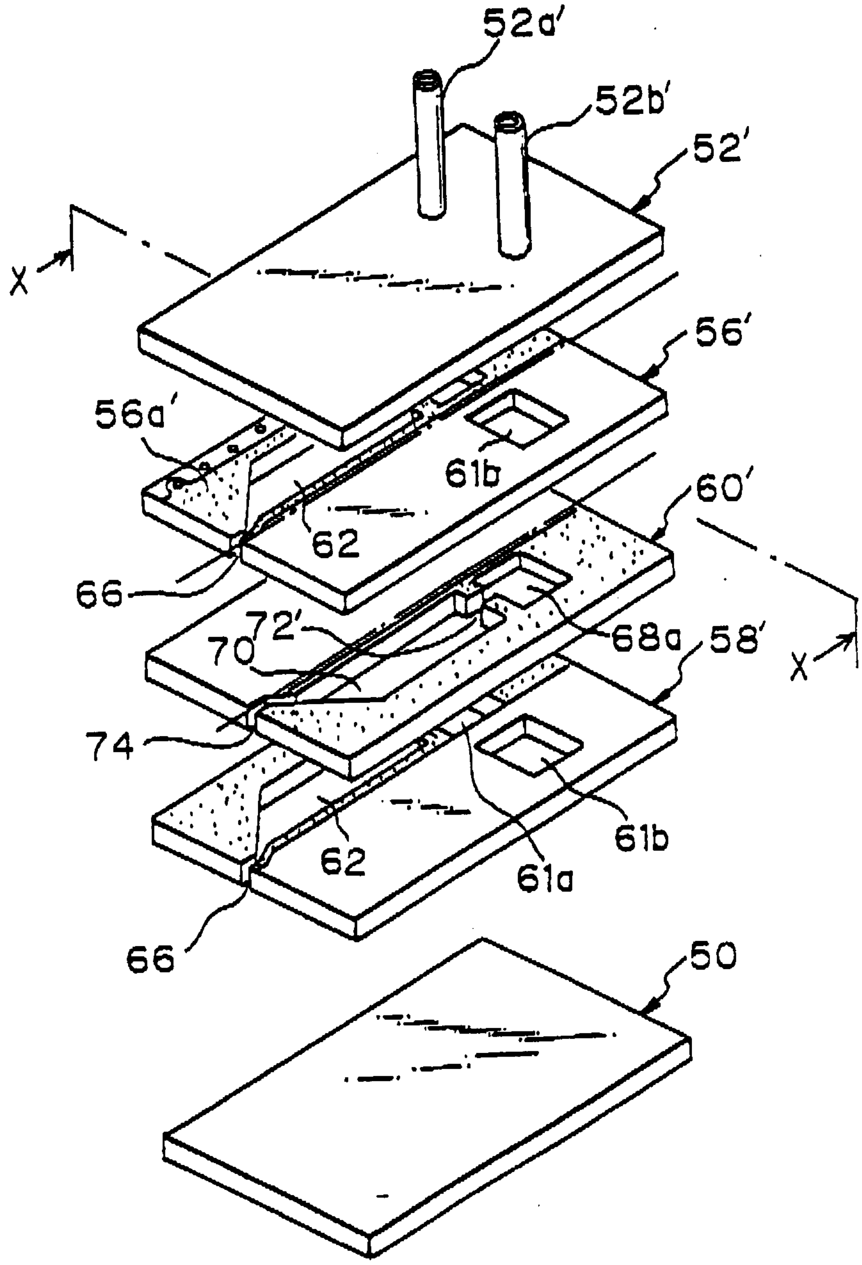


Fig. 10

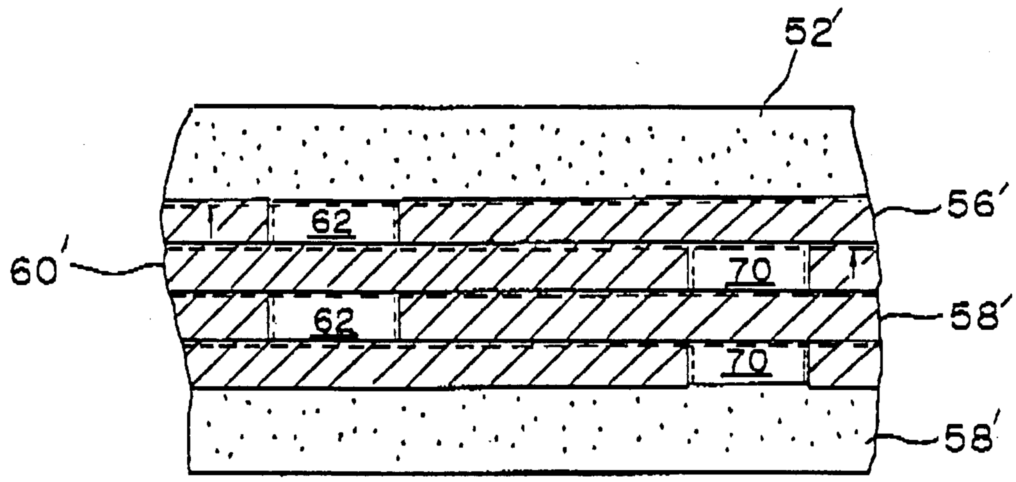


Fig. 11

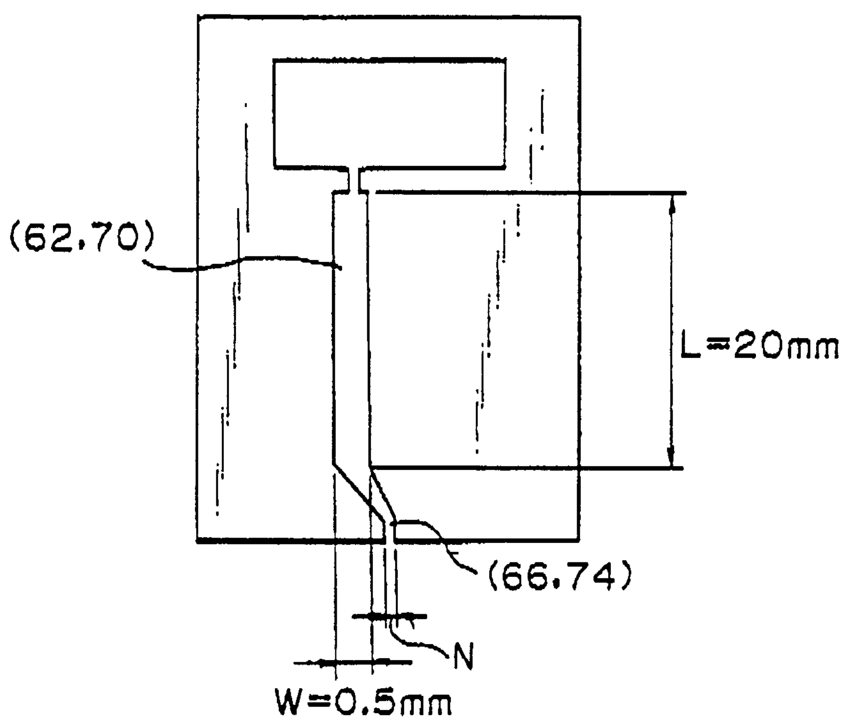


Fig. 12

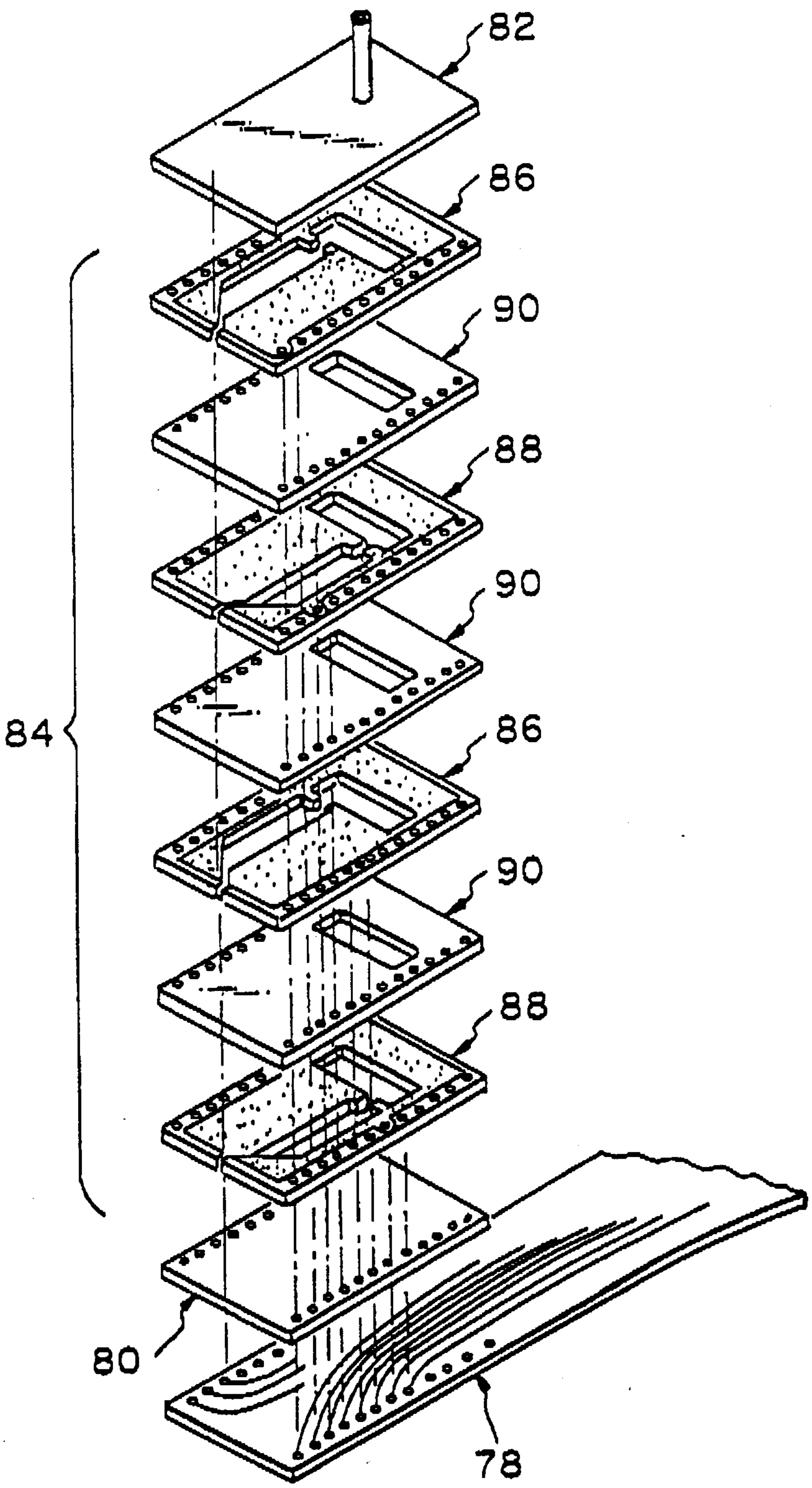


Fig. 13

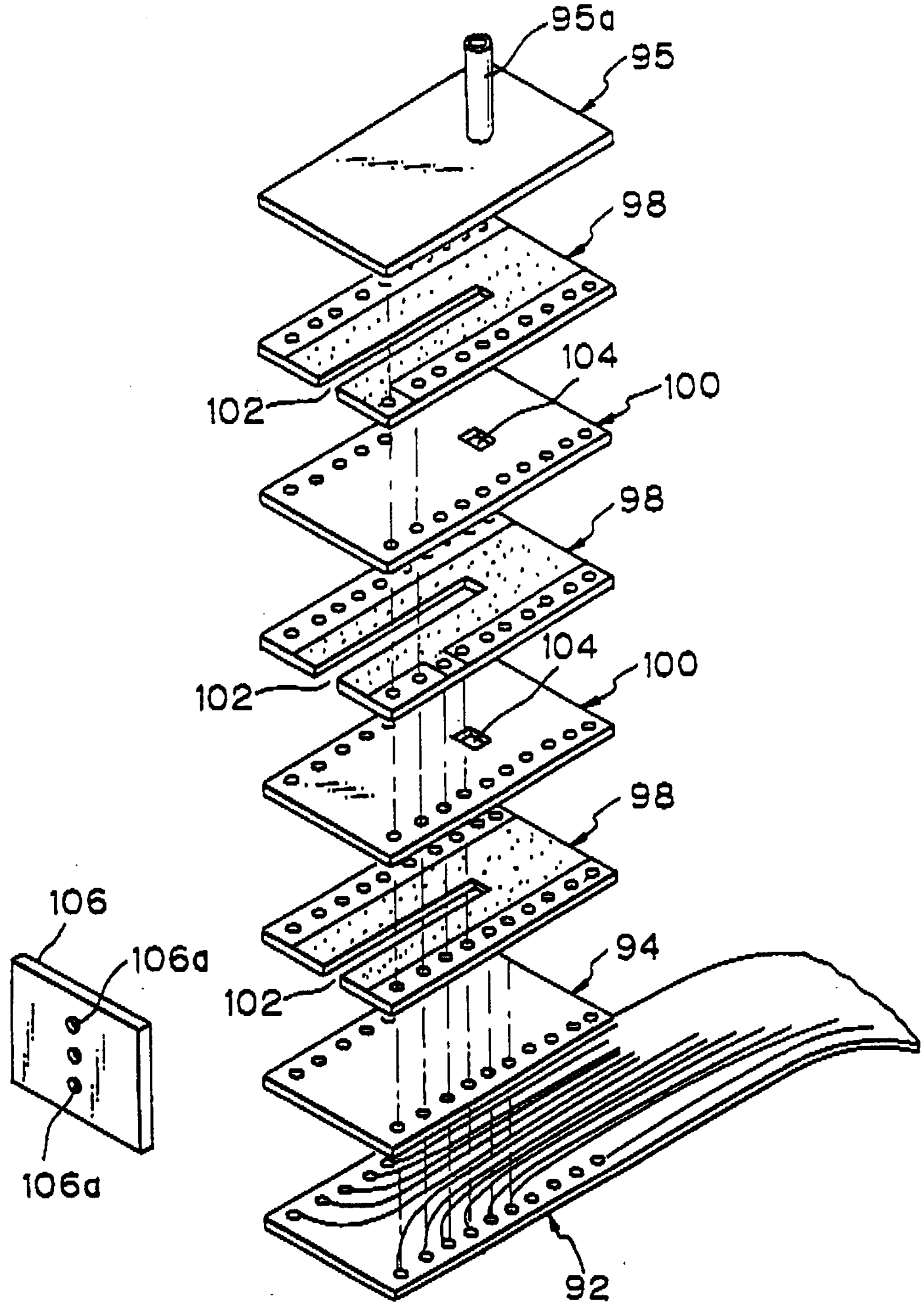


Fig. 14

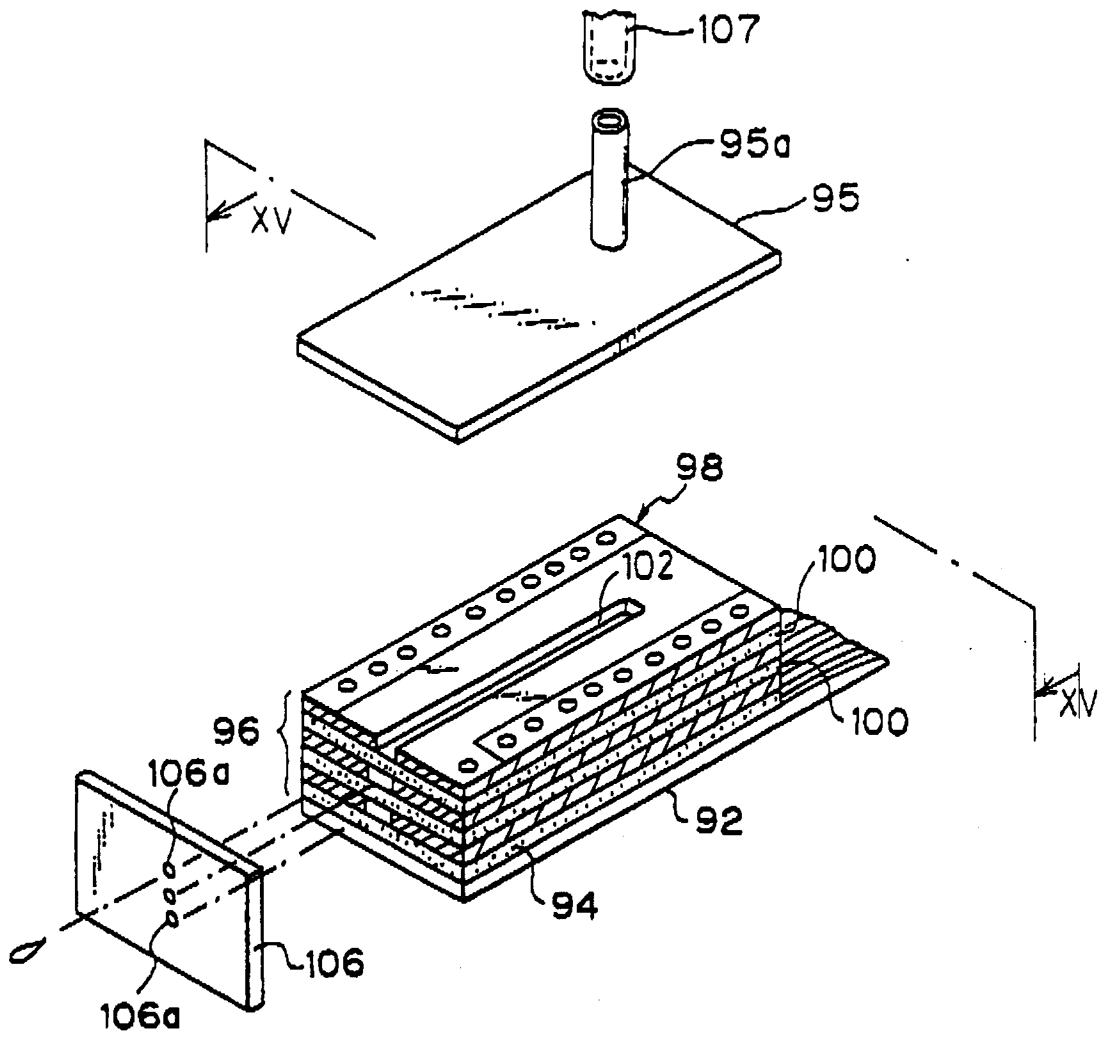


Fig. 15

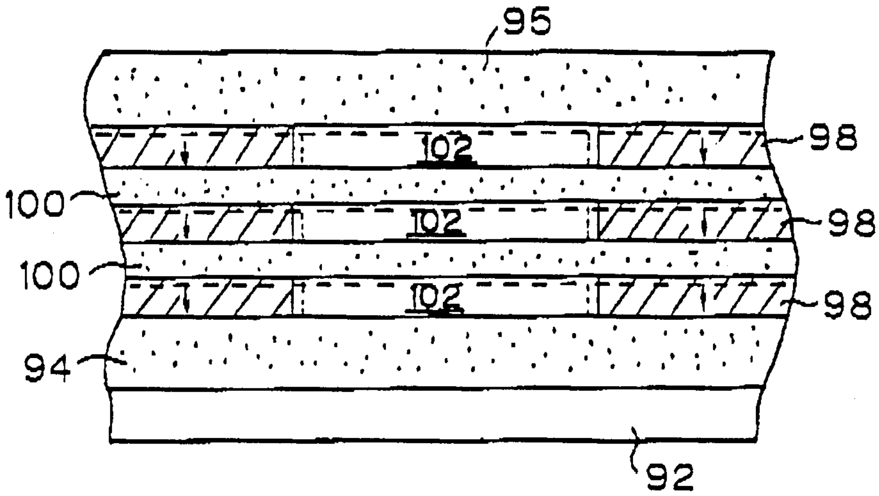


Fig. 16

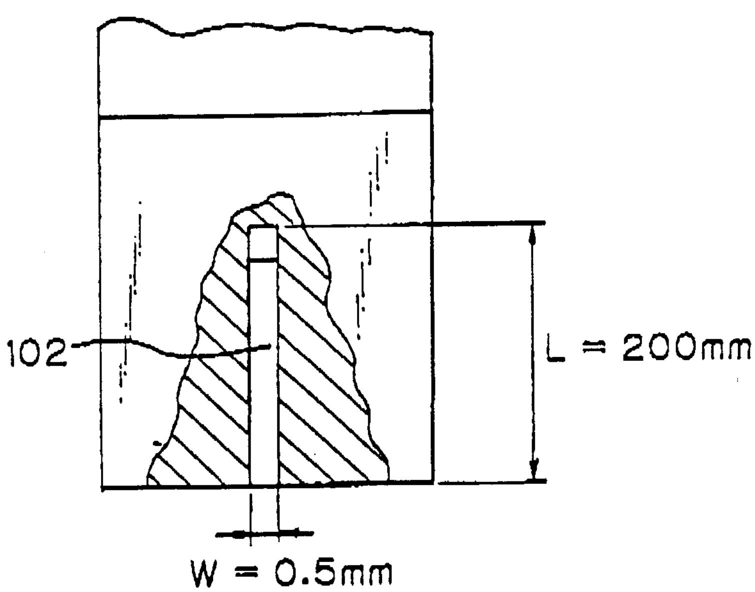


Fig. 17

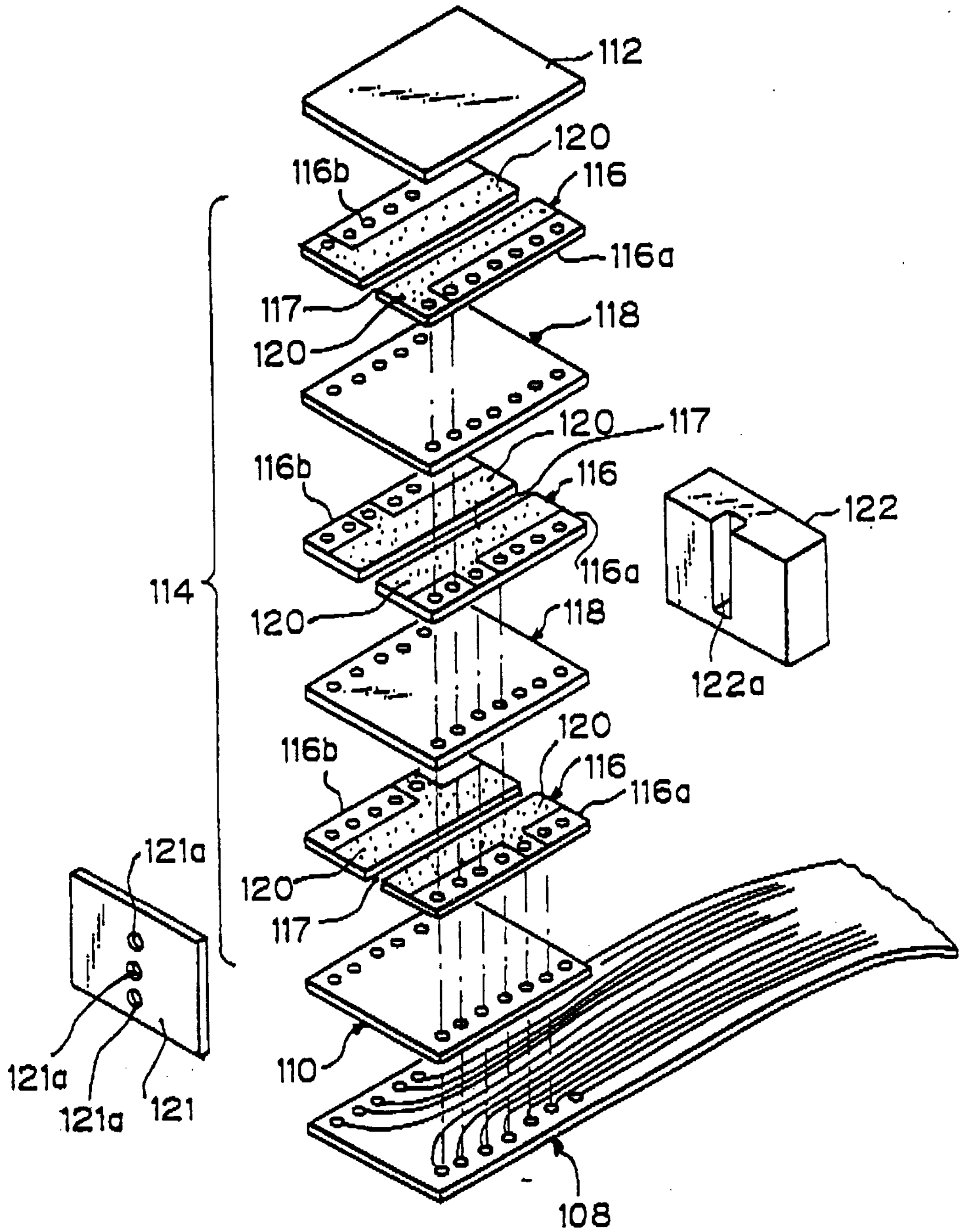

112
120
116b
116
116a
117
120
118
120
117
116b
116
116a
120
118
122
122a
114
120
116b
116
116a
121a
120
117
121a
121a
121
110
108

Fig. 18

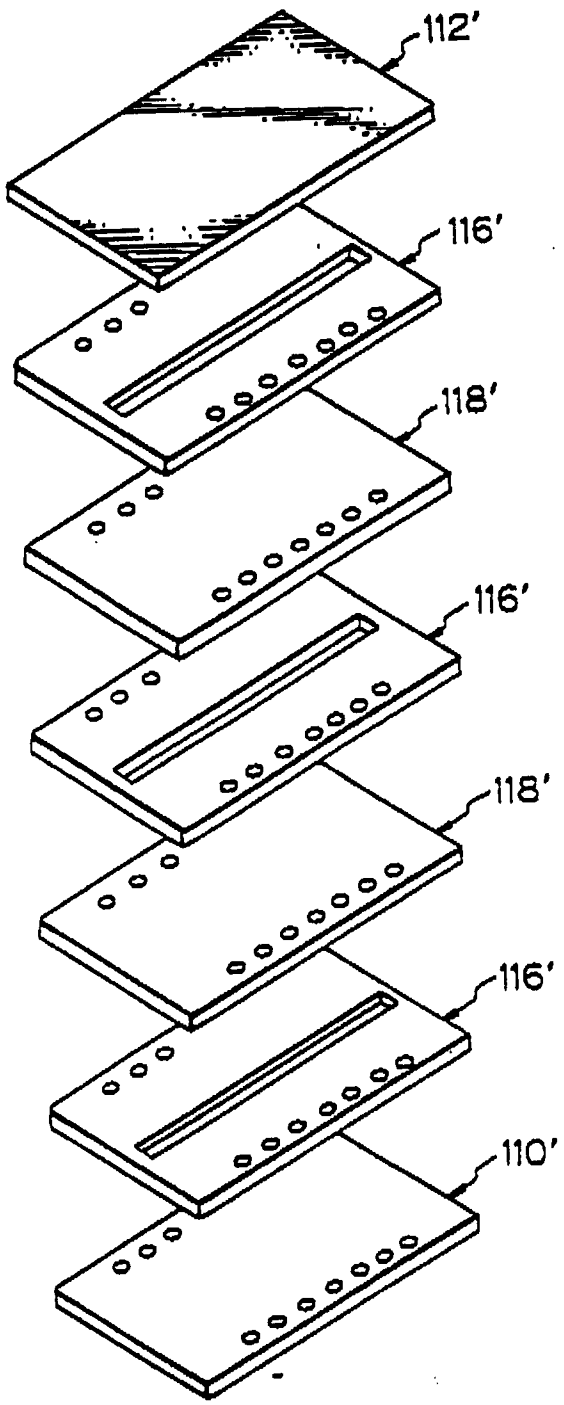


Fig. 19

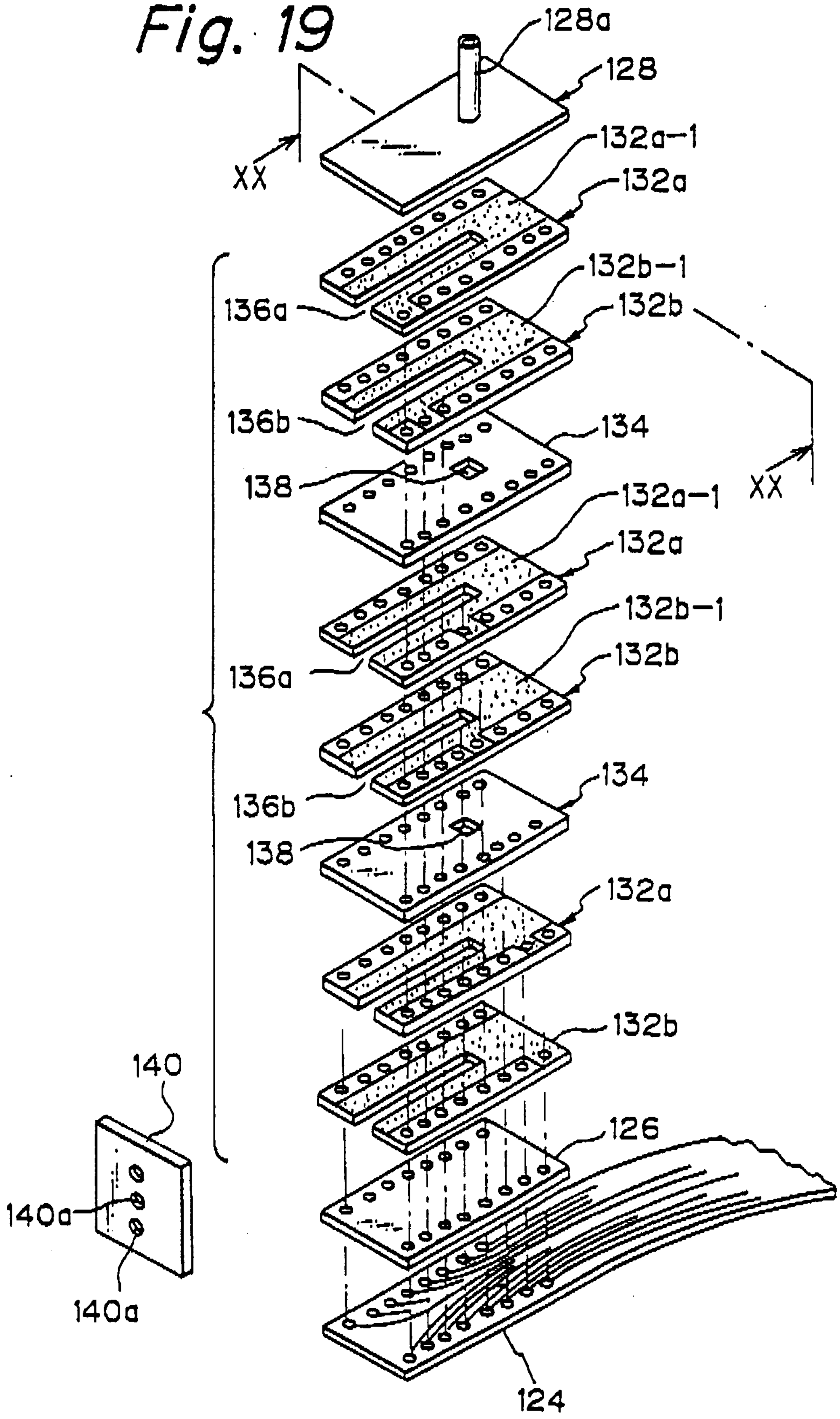

128a
128
XX
132a-1
132a
136a
132b-1
132b
136b
134
138
XX
132a-1
132a
136a
132b-1
132b
136b
134
138
132a
132b
140
126
140a
140a
124

Fig. 20

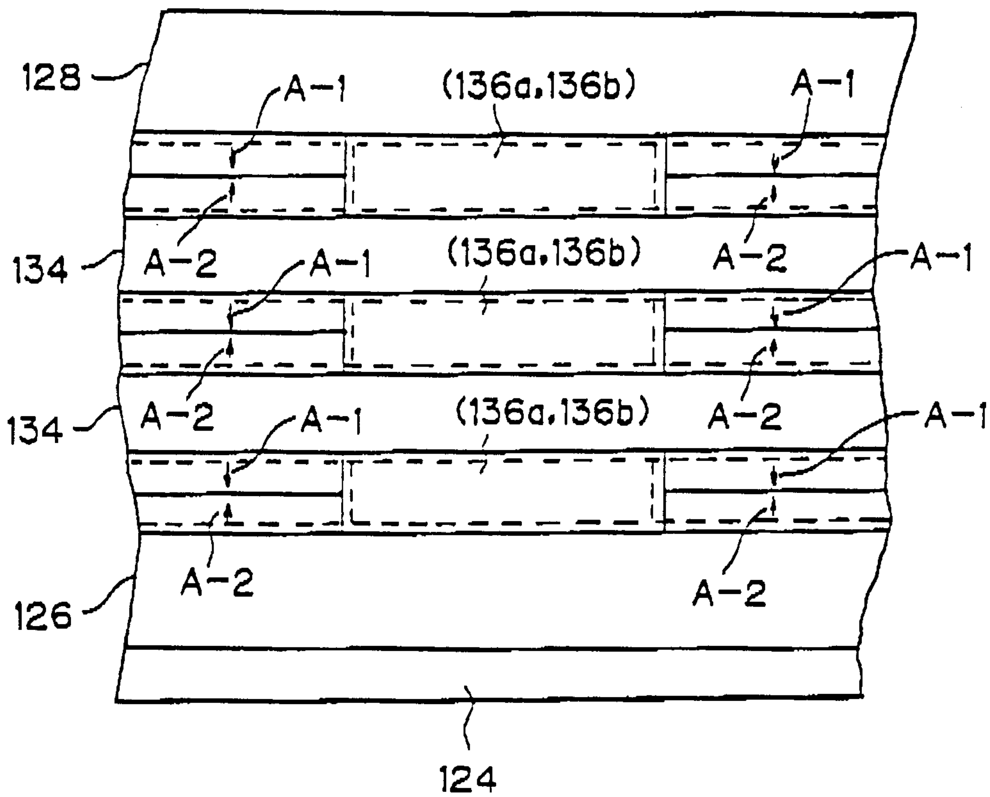

128
A−1
(136a,136b)
A−1
134
A−2
A−1
(136a,136b)
A−2
A−1
134
A−2
A−1
(136a,136b)
A−2
A−1
126
A−2
A−2
124

Fig. 21

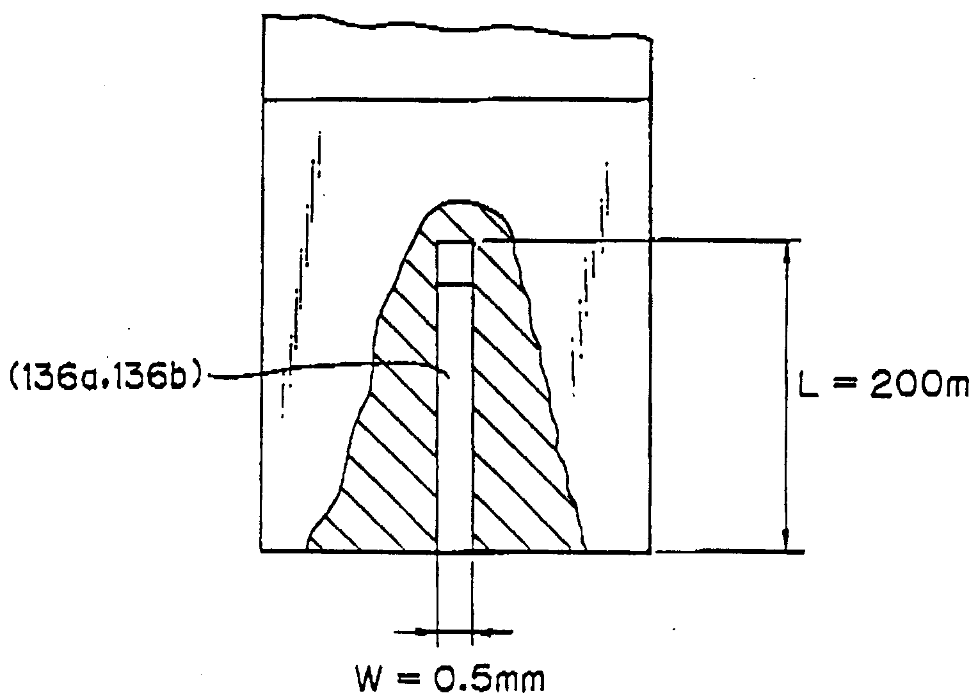


Fig. 22

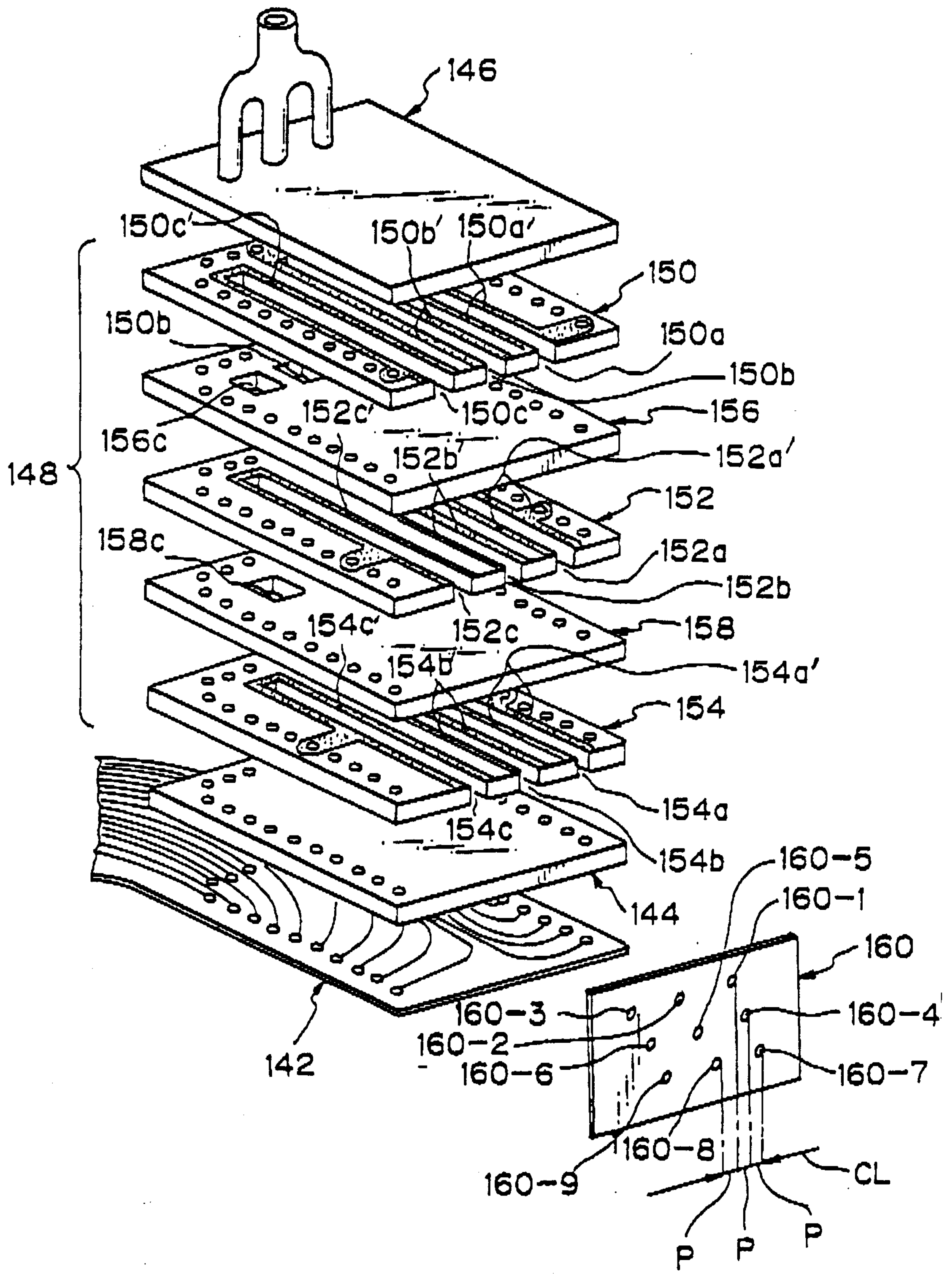
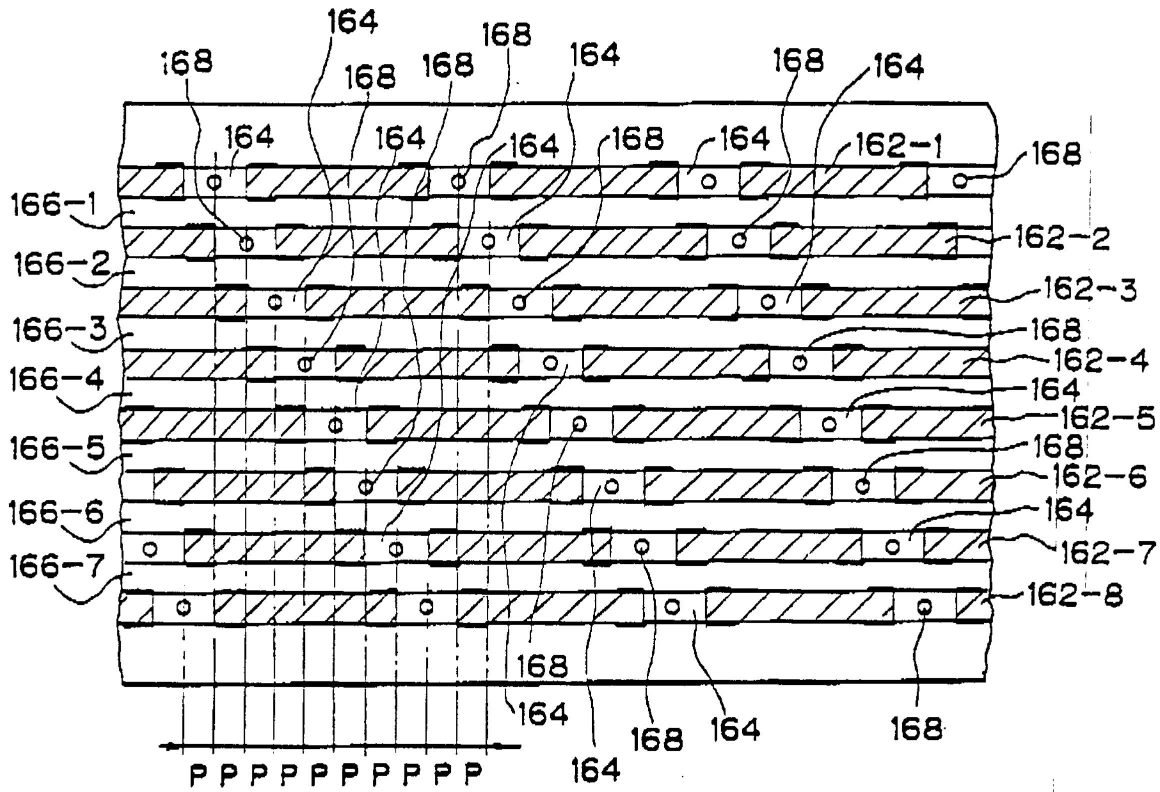

146
150c'
150b'
150a'
150
150b
150a
150b
150c
156
156c
152c'
152b'
152a'
148
152
158c
152a
152b
154c'
152c
158
154b'
154a'
154
154a
154c
154b
160-5
160-1
144
160
160-3
160-4
160-2
142
160-6
160-7
160-8
160-9
CL
P
P
P

Fig. 23


168
164
168
168
168
164
168
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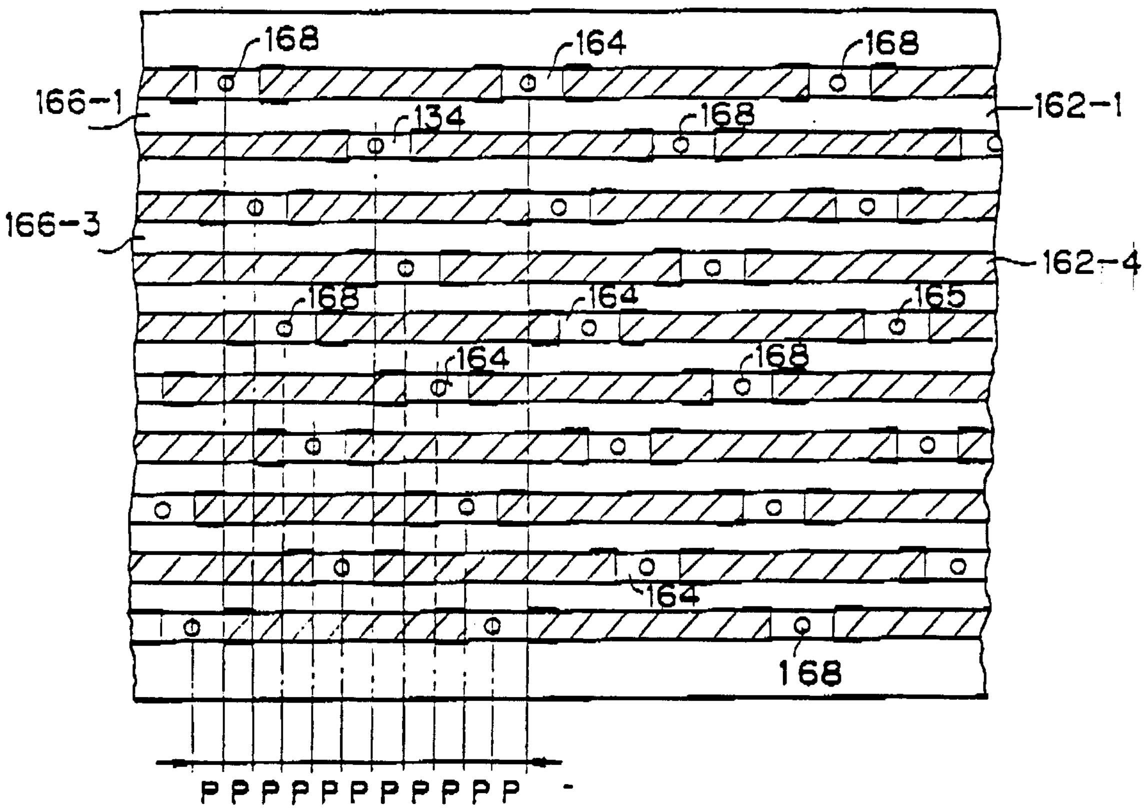
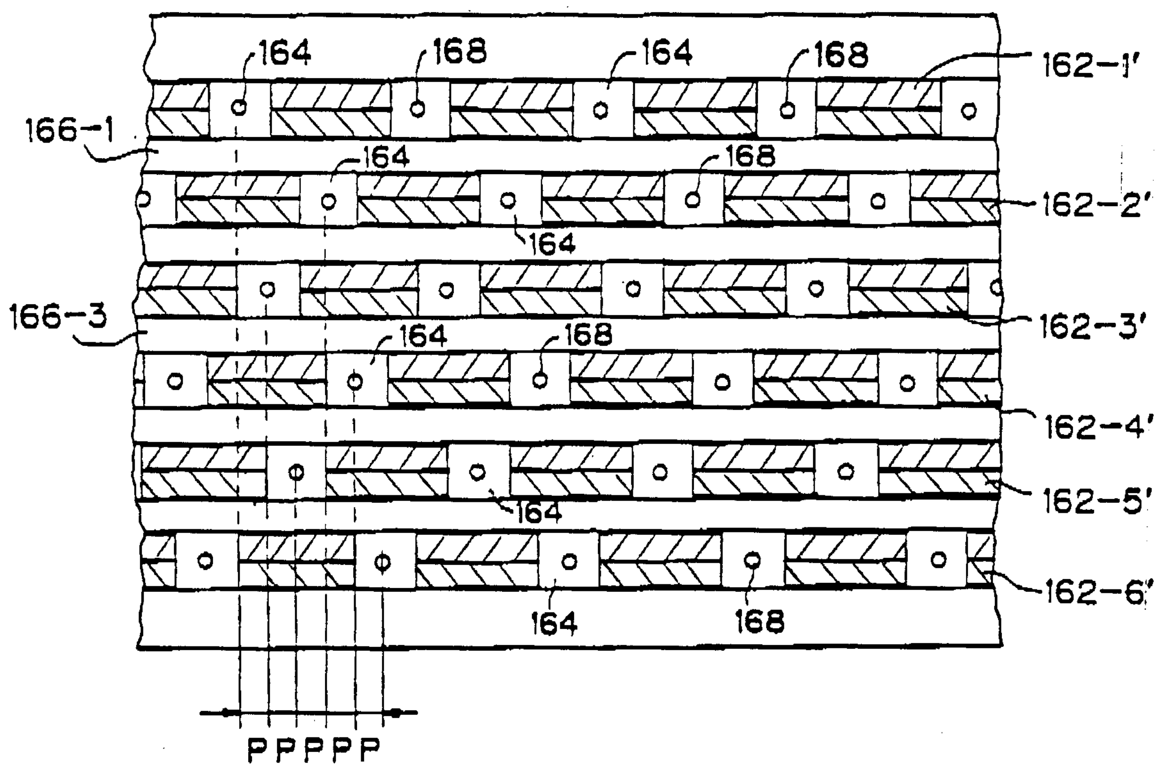
164
164
164
168
164
162-1
168
166-1
162-2
166-2
162-3
166-3
168
162-4
166-4
164
162-5
166-5
168
162-6
166-6
164
162-7
166-7
162-8
168
164
168
164
164
168
P P P P P P P P P P

Fig. 24



168
164
168
166-1
134
168
162-1
166-3
162-4
168
164
165
164
168
164
168
P P P P P P P P P P P

Fig. 25


164
168
164
168
162-1'
166-1
164
168
162-2'
164
162-3'
166-3
164
168
162-4'
162-5'
164
162-6'
164
168
P P P P P