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

(11) EP 1 029 677 A2

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
**23.08.2000 Bulletin 2000/34**

(51) Int. Cl.[7]: **B41J 2/14**

(21) Application number: **00102986.7**

(22) Date of filing: **14.02.2000**

(84) Designated Contracting States:
**AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE**
Designated Extension States:
**AL LT LV MK RO SI**

(30) Priority: **15.02.1999 JP 3656099**

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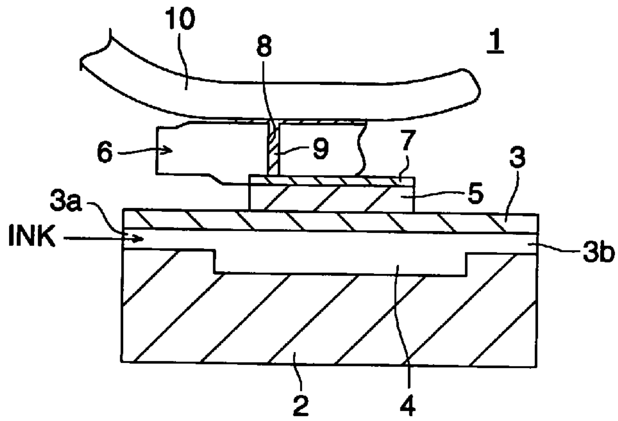
(54) **Ink jet head**

(57) An ink jet head (1), comprises an ink chamber (4) provided with a nozzle through which an ink is jetted; an actuator (5) to jet the ink accommodated in the ink chamber through the nozzle; an electrode (7) to drive the actuator; and a circuit board (6) having a through-hole (8); wherein a part of the electrode is led outside through the through-hole in the circuit board.

FIG. 1

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## Description

## BACKGROUND OF THE INVENTION

**[0001]** This invention relates to an ink jet head which jets ink from a nozzle hole.

**[0002]** There is a letter printing apparatus using the ink jet method which jets ink in an ink chamber from a nozzle hole by driving an actuator.

**[0003]** In respect of driving an actuator, it is done by applying an electric voltage to the electrode; however, the portion for leading the electrode outside is considerably large-sized to such a degree as to make it difficult to get an ink jet head of a compact size. Further, if the ink chamber of the ink jet head is made highly integrated, it is difficult to secure the space for leading the electrodes outside in proportion to the degree of integration.

## SUMMARY OF THE INVENTION

**[0004]** This invention has been done in view of the above-described points, and it is an object of the invention to provide an ink jet head which is compact-sized and has a possibility to have ink chambers highly integrated, and further, has an improved reliability owing to the simplicity of wiring for the electrodes for driving the actuator.

**[0005]** In order to solve the above-mentioned problems and accomplish the object, the structure of this invention has been made as follows:

(1) An ink jet head, comprises:

an ink chamber provided with a nozzle through which an ink is jetted;
an actuator to jet the ink accommodated in the ink chamber through the nozzle;
an electrode to drive the actuator; and
a circuit board having a through-hole;
wherein a part of the electrode is led outside through the through-hole in the circuit board.

(2) In the ink jet head of (1), the circuit board is provided in close proximity to the electrode.
(3) In the ink jet head of (1), the circuit board is provided so as to adjoin to the electrode.
(4) In the ink jet head of (1), the circuit board is made of a ceramic.
(5) In the ink jet head of (4), the actuator is a piezoelectric element.
(6) In the ink jet head of (4), the actuator is a thermal element.
(7) In the ink jet head of (4), the circuit board has a coefficient of thermal expansion not larger than 10 ppm/deg.
(8) In the ink jet head of (7), the circuit board has a coefficient of thermal expansion not larger than 6 ppm/deg.

Further, the above object may be attained by the following preferable structure.

(9) An ink jet head which jets ink in an ink chamber from a nozzle hole by driving an actuator, wherein a part of the electrodes for driving said actuator is led outside through a through-hole in a ceramic circuit board.

According to the invention set forth in the above paragraph (9), a part of electrodes for driving an actuator is led outside, utilizing a ceramic board, through a through-hole in the ceramic circuit board; hence, the ink jet head is made compact, has a possibility to have the ink chamber highly integrated, has the wiring for electrodes for driving the actuator simplified, and has an improved reliability.

(10) An ink jet head set forth in the paragraph (9), wherein the aforesaid actuator is a piezoelectric element.

According to the invention set forth in the above paragraph (10), the actuator is a piezoelectric element; hence, a high-speed and high-quality image recording can be carried out.

(11) An ink jet head set forth in the paragraph (9), wherein the aforesaid actuator is a thermal element.

According to the invention set forth in the above paragraph (11), the actuator is a thermal element; hence, a high-speed and high-quality image recording can be carried out.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0006]**

Fig. 1 is a drawing showing the outline of the structure of an ink jet head using a Kaiser method;
Fig. 2 is a drawing showing the outline of the structure of an ink jet head using a bubble method; and
Fig. 3 is a cross-sectional view of an ink jet head of a piezoelectric layer stacking type (MACHA).

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

**[0007]** In the following, the embodiments of an ink jet head and the method of manufacturing of an ink jet head of this invention will be explained; however, the mode of this invention should not be confined to these.

**[0008]** Fig. 1 is a drawing showing the outline of the structure of an ink jet head using a Kaiser method. The ink jet head 1 of this embodiment has the ink chanter 4 formed of the base member 2 and the ink supply member 3. The ink supply member 3 has the ink supply opening 3a and the nozzle hole 3b formed.

**[0009]** Further, in the ink supply member 3, there is provided the piezoelectric element 5 which makes up the actuator, and the ceramic circuit board 6 is connected to this piezoelectric element 5. The drive electrode 7 is provided in the ceramic circuit board 6, and this drive electrode is connected to the outside-leading electrode 9 which is provided in the through-hole 8 of the ceramic circuit board 6.

**[0010]** This outside-leading electrode 9 is connected to the flexible board 10, and a driving electric voltage from this flexible board 10 is applied to the drive electrode 7 through the outside-leading electrode 9; the piezoelectric element 5 is deformed by a shearing force and the ink in the ink chamber 4 is jetted from the ink nozzle 3b.

**[0011]** As described in the above, a part of the electrode for driving the piezoelectric element 5, which makes up the actuator, utilizes the ceramic circuit board 6, and the part of the electrode is led outside through the through-hole 8; therefore, the ink jet head is made compact, has a possibility to have the ink chamber made highly integrated, has the wiring for electrode for driving the actuator simplified, and has an improved reliability. Further, because the actuator is made up of the piezoelectric element 5, a high-speed and high-quality image recording can be carried out.

**[0012]** Fig. 2 is a drawing showing the outline of the structure of an ink jet head using a bubble method. The ink jet head 1 of this embodiment has the ink chamber 22 formed of the ceramic circuit board 20 and the ink supply member 21. The ink supply member 21 has the ink supply opening 21a and the nozzle hole 21b formed.

**[0013]** Further, the thermal element 23 which makes up the actuator is provided in the ceramic circuit board 20, and is disposed facing the ink chamber 22. On the ceramic circuit board 20, the drive electrodes 24 are provided, being connected to the thermal element 23, and are further connected to the outside-leading electrodes 26 which are provided in the through-holes 25 of the ceramic circuit board 20.

**[0014]** These outside-leading electrodes 26 are connected to the flexible board 27, and a driving electric voltage from this flexible board 27 is applied to the drive electrodes 24 through the outside-leading electrodes 26; the thermal element 5 generates heat and the ink in the ink chamber 22 is jetted from the ink nozzle 21b.

**[0015]** As described in the above, a part of the electrodes for driving the thermal element 23, which makes up the actuator, utilizes the ceramic circuit board 20, and the part of the electrodes are led outside through the through-holes 25; therefore, the ink jet head is made compact, has a possibility to have the ink chamber 22 made highly integrated, has the wiring for electrodes for driving the actuators simplified, and has an improved reliability. Further, because the actuator is made up of the thermal element 23, a high-speed and high-quality image recording can be carried out.

**[0016]** Next, the embodiment of an ink jet head of a piezoelectric layer stacking type (MACHA) is shown in Fig. 3. Fig. 3 is a cross-sectional view of an ink jet head of a piezoelectric layer stacking type (MACHA).

**[0017]** The ink jet head 1 of this embodiment has the ink chamber 83 formed of the ink supply member 80, the nozzle plate 81, and the flexible plate 82. The nozzle hole 81a is provided in the nozzle plate 81. The flexible plate 82 is supported by the ceramic circuit board 30, the piezoelectric elements formed of three layers 84 are connected to the deforming portion 82a of the flexible plate 82, and the drive electrode 85 is provided on these piezoelectric elements 84. To this drive electrode 85, the leading electrode 87 provided in the through-hole 86 of the ceramic circuit board 30 is connected. To this leading electrode 87, the outside-leading wire 88 is connected.

**[0018]** When an electric voltage is applied to the drive electrode 85 from the drive circuit board, on which the outside-leading wire 88 is provided, through the outside-leading wire 88 and the leading electrode 87, the ink in the ink chanter 83 is pressed and jetted from the nozzle hole 81a, because the deforming portion 82a of the flexible plate 82 is deformed owing to the deformation of the piezoelectric elements 84 by a shearing force.

**[0019]** In the following, an example of practice of the ceramic circuit board will be explained. For the ceramic circuit board, there is an LTCC non-contracting board, and for example, DU PON GREEN TAPE #951 is used. The contraction ratio is not larger than 0.1 ± 0.005%, and the precision of the wiring pattern is ± 1 to ± 5 μm in terms of accumulated positional deviation. The smoothness is not larger than (10 μm)/(10 mm), and the board is able to be bonded by an adhesive, has enough bonding strength. Further, the LTCC non-contracting board is capable of multi-layer wiring, in which resistors and capacitors are buried in the circuit board and a drive IC can be provided in a concave portion made by boring. Here, "the smoothness is not larger than (10 μm)/(10 mm)" means when a surface roughness is measured by a contact stylus instrument (or contact profile meter, such as an instrument produced by Taristep Corporation), a surface roughness Ra is not larger than 10 μm with a measuring width of 10 mm in any optional direction.

**[0020]** To state the values of the characteristics of the LTCC non-contracting board, the dielectric constant is 7.8 at 10 MHz, the coefficient of thermal expansion is preferably not larger than 10 ppm/deg, more preferably not larger than 6 ppm/deg (in the present embodiment, 5.8 ppm/deg), the thermal conductivity is 30 w/m-deg, and the Young's modulus is 200GPa. The thickness of the pattern conductor is not larger than 30 μm, or should desirably be not larger than 10 μm, or should more desirably be not larger than 5 μm, at which bonding by an adhesive is possible.

**[0021]** The ink jet head of this invention can be brought into practice in an ink jet head of a chevron type of a piezoelectric shearing mode and one of a cantilever type, and further, it can be put into practice in an ink jet head having ink chambers and air chambers formed alternately, or in one having an ink chamber formed without providing an air chamber.

**[0022]** In these ink jet heads of a cantilever type and of a chevron type, for the material of the non-piezoelectric ceramic substrate, it is desirable to select at least one out of alumina, aluminum nitride, zirconia, silicon, silicon nitride, silicon carbide, and quartz; thus, the piezoelectric ceramics can be reliably supported by it even when the partition wall of the ink chamber is deformed by a shearing force.

**[0023]** Further, for the piezoelectric ceramic material, it is desirable a ceramic material such as PZT and PLZT, which is composed of a mixture of micro-crystalline PbOx, ZrOx, and TiOx including a minute amount of a metallic oxide which is known as a softening agent or a hardening agent such as, for example, an oxide of Nb, Zn, Mg, Sn, Ni, La, or Cr.

**[0024]** PZT is the mixture of lead titanate and lead zirconate, and it is a desirable material owing to a large packing density, a large piezoelectric constant, and a good workability. When the temperature is lowered after burning, PZT has its crystalline structure suddenly varied to make the atoms deviate, and becomes an aggregate of micro-crystals in the form of dipoles each having a positive pole at one end and a negative pole at the other end. In such spontaneous polarization, dipoles have random directions to cancel their dipole moment one another; therefore, a further polarizing process is required.

**[0025]** In the polarizing process, a thin plate of PZT is placed between electrodes, is dipped in a silicone oil, and is polarized by the application of a high electric field in the range of 10 to 35 kV/cm. When an electric field is applied to a polarized PZT plate in the direction perpendicular to the direction of its polarization, the side walls are deformed by the shearing force in an oblique direction to a doglegged shape by piezoelectric slipping effect to make the volume of the ink chamber expand.

**[0026]** In the following, the values of the physical properties of the non-piezoelectric ceramic substrate and the piezoelectric ceramics will be explained.

**[0027]** The density [g/cm$^3$] of the piezoelectric ceramics is 8.2, and the density [g/cm$^3$] of the non-piezoelectric ceramic substrate is let to be equal to or smaller than 3.0; however, the density [g/cm$^3$] of the non-piezoelectric ceramic substrate should desirably be smaller, for example, equal to or smaller than a half of the above; thus, the head as a whole becomes lighter to make it possible to obtain a compact head.

**[0028]** The Young's modulus or the elastic constant [GPa] of the piezoelectric ceramics is 6.5, and the Young's modulus [GPa] of the non-piezoelectric ceramic substrate is let to be 190 to 390; however, the Young's modulus [GPa] of the non-piezoelectric ceramic substrate should desirably be larger, for example, equal to or larger than 200; thus, it can support the displacement of the partition wall of the piezoelectric ceramics firmly, and can make an efficient driving to enable the lowering of applied voltage owing to the small deformation of itself.

**[0029]** The thermal expansion coefficient [ppm/deg] of the piezoelectric ceramics is 2.0, and the thermal expansion coefficient [ppm/deg] of the non-piezoelectric ceramic substrate is let to be 0.6 to 7.0; however, the difference between the both should desirably be equal to or smaller than 5.0, or more desirably should be equal to or smaller than 3.0; thus, it can be prevented the breakdown by the bending and the stress owing to the difference between the thermal expansions of the substrates which are caused to occur by the heat generation in driving and with the variation of the environment temperature.

**[0030]** The thermal conductivity [W/cm • deg] of the piezoelectric ceramics is 0.01, and the thermal conductivity [W/cm • deg] of the non-piezoelectric ceramic substrate is let to be 0.03 to 0.3; however, the thermal conductivity [W/cm • deg] of the non-piezoelectric ceramic substrate should desirably be larger, and it becomes more desirable the larger it is, because the heat generated in driving the piezoelectric ceramics can be let to dissipate to the outside through the non-piezoelectric ceramic substrate.

**[0031]** The dielectric constant of the piezoelectric ceramics is 3,000 and the dielectric constant of the non-piezoelectric ceramic substrate is let to be 4.0 to 50; however, it becomes more desirable the smaller it is, and it should desirably be equal to or smaller than 10; further, by putting the electrode pattern for driving the piezoelectric ceramics on the non-piezoelectric ceramic substrate, an additional capacitance is produced on top of the capacitance of the piezoelectric ceramics itself; hence, the capacitance of the ink chamber is increased to cause the heat generation to increase and the driving efficiency to decrease. In this case, the additional capacitance can be made smaller the smaller the dielectric constant of the non-piezoelectric ceramics becomes.

**[0032]** The hardness [Hv] of the piezoelectric ceramics is 500, and the hardness [Hv] of the non-piezoelectric ceramic substrate is let to be equal to or larger than 1,000; however, the hardness [Hv] of the non-piezoelectric ceramic substrate should desirably be larger, that is, should desirably be equal to or larger than 1.5 times the above value; thus, the lowering of the yield owing to the breaking in the manufacturing process can be prevented.

**[0033]** The bending strength [Kgf/cm$^2$] of the piezoelectric ceramics is 1,000, and the bending strength [Kgf/cm$^2$] of the non-piezoelectric ceramic substrate is let to be 3,000 to 9,000; however, the bending strength [Kgf/cm$^2$] of the non-piezoelectric ceramic substrate should be larger, that is, should desirably be equal to or larger than 2 times the above value, because a long-sized ink jet head can be more stably manufactured the stronger against the warping and bending the non-piezoelectric substrate is.

**[0034]** The volume resistivity [Ω • cm] of the piezoelectric ceramics is 1, and the volume resistivity [Ω • cm] of the non-piezoelectric ceramic substrate is let to be 7 to 10; however, the volume resistivity [Ω • cm] of the non-piezoelectric ceramic substrate should desirably be larger, that is, it is better the larger it is in order to decrease the leakage current as an electronic device.

**[0035]** Further, the surface roughness Ra of the bonding surfaces between the non-piezoelectric ceramic substrate and the piezoelectric ceramics is equal to or smaller than 1.0 μm, and should desirably be equal to or smaller than 0.3 μm, or more desirably should be equal to or smaller than 0.1 μm; if the surface roughness Ra exceeds 1.0 μm, an excessive amount of a soft high-molecular adhesive (an epoxy adhesive, for example) is injected between the bonding surfaces to cause the driving force of the piezoelectric ceramics to be lowered, and it is not desirable to bring about the lowering of the sensitivity and the up-rising of the required electric voltage.

**[0036]** Further, the bonding surfaces between the non-piezoelectric ceramic substrate and the piezoelectric ceramics are subjected to a plasma processing or a UV processing. The plasma processing is a processing in which the non-piezoelectric substrate or the piezoelectric ceramics is placed in a vacuum chamber, and any one or the mixture of Ar, $N_2$, and $O_2$ gases, is introduced in it, and is brought into the state of plasma by the electromagnetic field applied from the outside; a fluorinated hydrocarbon gas such as $CF_4$ may be used in order to enhance the susceptibility to etching of the surfaces. Further, the UV processing is a processing in which the non-piezoelectric ceramic substrate or the piezoelectric ceramics is directly irradiated by an ultraviolet ray emitting lamp, and it may be carried out in an $O_2$ environment in order to produce a cleaning effect by ozone.

**[0037]** As described in the above, by subjecting the bonding surfaces to the plasma processing and UV processing, organic contamination can be cleaned off, wetting performance of the adhesive to the whole surface is improved, and poor bonding such as remaining minute bubbles can be removed; thus, owing to those effects, poor driving of the piezoelectric ceramics can be eliminated, and stable ink jet heads can be manufactured.

**[0038]** As described in the foregoing, according to the invention set forth in the paragraph (1), a part of electrodes for driving an actuator is led outside, utilizing a ceramic board, through a through-hole in the ceramic circuit board; hence, the ink jet head is made compact, has a possibility to have the ink chamber made highly integrated, has the wiring for electrodes for driving the actuator simplified, and has an improved reliability.
According to the invention set forth in the paragraph (2), the actuator is a piezoelectric element; hence, a high-speed and high-quality image recording can be carried out.

**[0039]** According to the invention set forth in the paragraph (3), the actuator is a thermal element; hence, a high-speed and high-quality image recording can be carried out.

**Claims**

**1.** An ink jet head, comprising:

an ink chamber provided with a nozzle through which an ink is jetted;
an actuator to jet the ink accommodated in the ink chamber through the nozzle;
an electrode to drive the actuator; and
a circuit board having a through-hole;
wherein a part of the electrode is led outside through the through-hole in the circuit board.

**2.** The ink jet head of claim 1, wherein the circuit board is provided in close proximity to the electrode.

**3.** The ink jet head of claim 1, wherein the circuit board is provided so as to adjoin to the electrode.

**4.** The ink jet head of claim 1, wherein the circuit board is made of a ceramic.

**5.** The ink jet head of claim 4, wherein the actuator has a piezoelectric element.

**6.** The ink jet head of claim 4, wherein the actuator has a thermal element.

**7.** The ink jet head of claim 4, wherein the circuit board has a coefficient of thermal expansion not larger than 10 ppm/deg.

**8.** The ink jet head of claim 7, wherein the circuit board has a coefficient of thermal expansion not larger than 6 ppm/deg.

FIG. 1

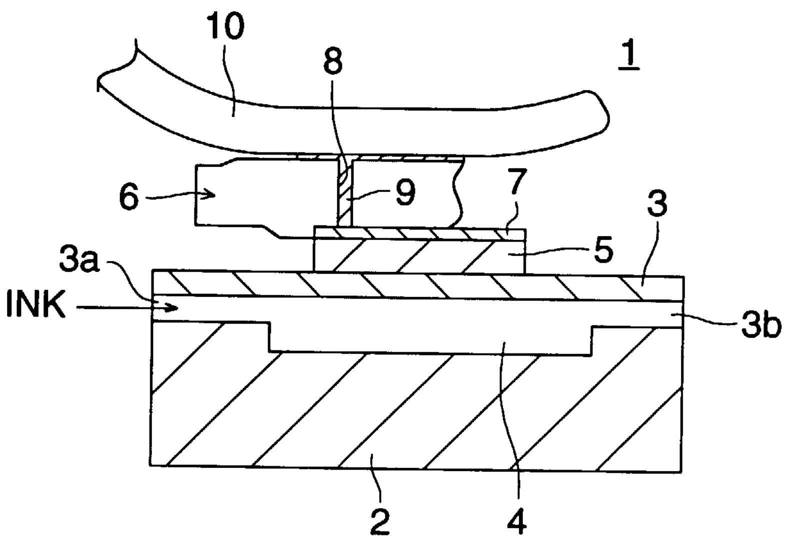

FIG. 2

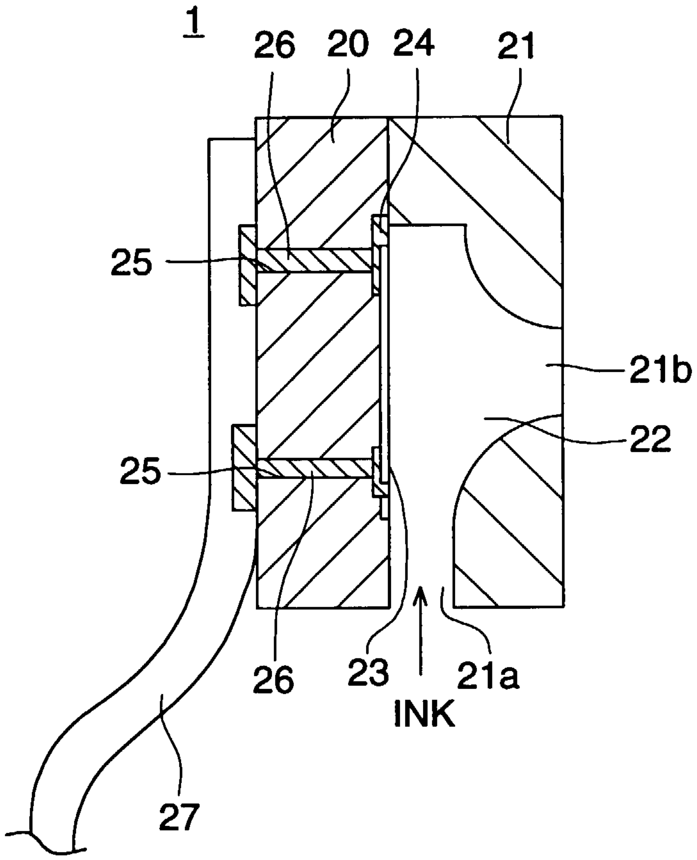

FIG. 3