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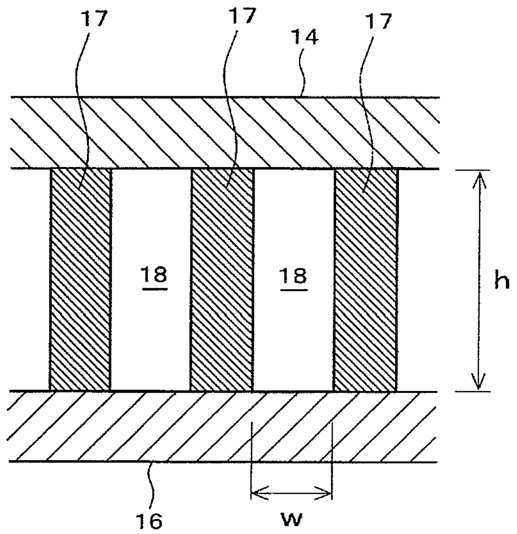
(54) Droplet ejecting head and printing apparatus

(57) A droplet ejecting head is described and comprises an actuator in which multiple ink flow channels (18) and multiple partition walls (17) are alternatively arranged. The partition wall responds to an applied voltage given to an electrode formed on a surface of the partition wall and does deformation motion by which the ink in the ink flow channel is ejected from a nozzle. The ink flow channel has a rectangular cross section and an aspect ratio (vertical length h/ horizontal length w) of the cross sectional shape of the ink flow channel is 5.00 or more and less than 7.75, and a resonance frequency of the partition wall is 1.5 MHz or more.

FIG. 5



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Description

[0001] The present invention relates to a droplet ejecting head, and a printing apparatus, more particularly, a droplet ejecting head that, even if an ink with low viscosity is used, does not cause ink overflow due to crosstalk in the neighboring ink flow channels and makes stable ejecting possible, and a printing apparatus mounting the droplet ejecting head.

[0002] As a droplet ejecting head which eject ink from nozzles, a shear-mode droplet ejecting head is known. In the droplet ejecting head, multiple ink flow channels and multiple partition walls are alternatively arranged, and by the deformation motion of the partition wall, ink in the ink flow channel is ejected from the nozzle. The partition wall is composed of an actuator which responds to applied voltage to the electrode formed on the surface of the partition wall and actuates.

[0003] In Figure 1, an example of a shear-mode droplet ejecting head is shown: (a) is a schematic perspective view, and (b) is a sectional view.

[0004] In the droplet ejecting head 1 shown in Figure 1, 11 is an ink tube, 12 is a nozzle forming member, 13 is a nozzle, 14 is an upper substrate, 15 is an ink feed opening, 16 is a lower substrate, 17 is a partition wall. And, an ink flow channel 18 is formed by the partition wall 17, the upper substrate 14, and the lower substrate 16.

[0005] Each partition wall 17 is formed by its upper part 17a and its lower part 17b both of which composed of piezoelectric materials such as piezoelectric zirconate titanate (PZT) having an opposite direction of polarization to each other. However, the piezoelectric material may be, for example, a part of 17a, and may be at least a part of the partition wall 17. Since the partition wall 17 and the ink flow channel 18 are alternatively arranged, the partition wall 17 is shared by both sides ink flow channels 18 and 18. One end of each ink flow channel 18 is connected to nozzle 13 provided in an open manner to the position responding to each ink flow channel at the nozzle forming member 12, and the other end of each ink flow channel 18 is connected to the ink tank (not shown) via the ink feed opening 15 and the ink tube 11.

[0006] On the surface of the partition wall 17 facing the ink flow channel 18, an electrode (not shown) is formed. When a predetermined driving voltage is applied to the electrode, the partition wall 17 is L-shapely deformed, and gives pressure to be ejected to the ink fed through the ink tube 11 into the ink flow channel 18, and ink in the ink flow channel 18 is ejected as droplets.

[0007] Figure 2 shows motion of the droplet ejecting head 1 during ejecting ink. In this Figure, among many partition walls 17 and many ink flow channels 18, three ink flow channels 18A, 18B, and 18C separated by partition walls 17A, 17B, 17C, and 17D are shown. On the surface of the partition wall 17 facing each ink flow channel 18, electrodes 19A, 19B, and 19C are formed. Each of electrodes 19A, 19B, and 19C is connected to the driving signal generation section 100 to provide the driving signal for driving the partition wall 17 and ejecting ink in the ink flow channel 18.

[0008] Firstly, when the driving signal is applied to neither of electrodes 19A, 19B, and 19C, neither of partition walls 17A, 17B, and 17C is deformed (Figure 2 (a)). While leaving them as they are, if electrodes 19A, and 19C are grounded and the driving signal is applied to the electrode 19B, an electric field is produces in the direction orthogonal to the direction of polarization of the piezoelectric material constituting partition walls 17B and 17C, in each of partition walls 17B and 17C,shear deformation is occurred in the junction plane between upper wall part 17a and lower wall part 17b, then partition walls 17B and 17C deform outwardly to each other, the volume of the ink flow channel 18 is enlarged, a negative pressure is produced in the ink flow channel 18, and ink flows into the ink flow channel 18 (Figure 2 (b)).

[0009] And, when the potential is returned to 0, partition walls 17B and 17C return from the expanded positions to the neutral positions shown in Figure 2 (a), and high pressure is applied to ink in the ink flow channel 18.

[0010] Next, driving signals to deform partition walls 17B and 17C in opposit directions to each other and the volume of the ink flow channel 18 is reduced, a positive pressure is produced in the ink flow channel 18 (Figure 2 (c)).

[0011] Therefore, the meniscus in the nozzle constituted by a part of the ink filling the ink flow channel 18B moves in the direction to be ejected from the nozzle, projects from the nozzle and forms an ink column. Then, during the predetermined period in which this state (Figure 2 (c)) is maintained, the positive pressure in the ink flow channel 18B is soon reversed to the negative pressure. In the step the pressure changes from positive to negative, a power to pull back the meniscus into the ink flow channel 18B is applied, the ink column is torn off at near the nozzle, the ink pushed out becomes into droplets and is ejected and soars. At the timing when the pressure in the ink flow channel 18B once becomes negative then reverses to positive, the partition walls 17B and 17C are returned to the neutral positions shown in Figure 2 (a), a negative pressure is applied to the ink in the ink flow channel 18B, the negative pressure cancels out the reversing pressure in the ink flow channel 18B from negative to positive, brakes the meniscus and inhibits the reverberation pressure by the meniscus.

[0012] Thus, if a droplet ejecting head 1 having a plurality of ink flow channels 18 separated by the partition walls 17 at least partially constituted by a piezoelectric material is driven, when a partition wall of an ink flow channel starts ejecting motion, neighbouring ink flow channels are affected by the motion. Therefore, in general, among a plurality of ink flow channels 18, making two or more groups of ink flow channels 18 separated from each other across one or more ink flow channels 18, and in each group, driving control to operate the droplet ejecting motion sequentially by time sharing is made. For example, in a case a solid image is output by driving all ink flow channels 18, so-called three cycle driving in which ink flow channels 18 are selected alternatively by two ink flow channels and droplet is ejected in three-phase is conducted.

[0013] The motion of this three cycle driving is further explained by using Figure 3. In the case shown in Figure 3, the droplet ejecting head is assumed to be constituted with nine ink flow channels 18 of A1, B1, C1, A2, B2, C2, A3, B3, and C3. And, timing diagrams of pulse waveforms applied to each group of ink flow channels 18 of A, B, and C are shown in Figure 4.

[0014] When droplets are ejected, firstly the voltage is applied to each electrode of each ink flow channel of group A (A1, A2, and A3), and electrodes of both side ink flow channels are grounded. For example, if a driving signal constituted of a square wave of a positive voltage with 1AL width + V_{on} is applied to ink flow channels of group A, partition walls of ink flow channels of group A deform outwardly, and a negative pressure is occurred in the ink flow channel 18. Due to this negative pressure, ink is drawn from the ink tank into the ink flow channel 18 (Draw).

[0015] If this state is maintained for the duration of 1AL, the pressure is reversed to positive, and the electrodes are grounded at this timing, deformation of partition walls returns to the original state, a high pressure is applied to ink in the ink flow channels of group A (Release). Furthermore, if a square wave of a negative voltage - V_{off} is applied to each electrode of each ink flow channel of group A at the same timing, partition walls deform inwardly, a much higher pressure is applied to the ink (Reinforce), and an ink column is pushed out from the nozzle. After the duration of 1AL, the pressure is reversed and becomes negative in the ink flow channel 18, furthermore after the duration of 1AL, the pressure is reversed and becomes positive in the ink flow channel 18, if the electrodes are grounded at this timing (after the duration of 2AL), deformation of partition walls returns to the original state, and remaining pressure waves are canceled out.

[0016] In these cases, as for the voltages of the driving signals, $|V_{on}| >= |V_{off}|$.

[0017] Next, each ink flow channel of group B (B1, B2, and B3), then each ink flow channel of group C (C1, C2, and C3) are actuated in the same way described above.

[0018] As relevant information, AL (Acoustic Length) means 1/2 of acoustic resonant period of the ink flow channel. This AL is obtained as the pulse width which makes the soar velocity of droplet maximum when a square wave with a voltage pulse is applied to the partition wall, a means to convert electrical energy to mechanical energy, the velocities of ejected droplets are measured, with the voltage of the square wave kept constant and pulse width of the square wave is changed. In addition, a pulse is defined as a square wave with a constant voltage crest value, and when 0 V is called as 0% and the crest value voltage is called as 100%, the pulse width is defined as the time between the timing of rising 10% from 0% and the timing of falling 0% from 100%. Furthermore, the square wave means a wave in which both of its rise time and fall time between 10% and 90% are within 1/2 of AL, preferably within 1/4 of AL.

[0019] By the way, the pressure applied for ejecting ink is remained in the ink flow channel after ink is dispersed and vibrates, and the pressure applied to ink in the nozzle fluctuates and the meniscus vibrates. Depending on the pressure variation, if a positive pressure is applied to ink in the nozzle, meniscus moves in the direction to project from the nozzle. The meniscus projected from the nozzle is pulled back into the nozzle by the negative pressure reversed from the positive pressure. This vibration is repeated a few times, the movement of the meniscus is gradually attenuated and settles in, next ejecting becomes possible.

[0020] However, especially when ink is ejected continuously, meniscus may be projected excessively. Such excessively projected meniscus causes no problem when the ink has high viscosity, but when an ink with low viscosity, especially less than 6 cp, is used, due to vibration of the meniscus, the ink is largely projected from the nozzle and overflows, as the result, in some cases, ejecting became unstable.

[0021] The present inventor eagerly investigated the causes of overflow of ink and unstable ejecting due to projection of meniscus in shear mode droplet ejecting heads, and found out two causes.

[0022] Firstly, for ejecting inks with low viscosity, conventional heads have insufficient viscosity resistance, conventional technology cannot inhibit overflow of ink sufficiently. Since viscosity resistance is proportional to the viscosity of the ink and squared cross-section of the ink flow channel inverse number, when the viscosity falls to one-half, also the viscosity resistance falls to one-half. Therefore, vibration of meniscus during ejecting becomes larger, and the meniscus is largely projected from the nozzle, and the ink overflows.

[0023] Secondly, in general, a shear mode droplet ejecting head cannot drive two ink flow channels neighboring across a partition wall simultaneously. However, for example, as described above, three-cycle driving is conducted, neighboring ink flow channels are driven continuously. For example, in the case of Figure 2, if ink flow channel 18B is driven for ejecting, movements of partition walls 17B and 17C respond to the movements of neighboring ink flow channels 18A and 18C, and crosstalk occurs, half of the vibration of the ink flow channel 18B is transmitted to neighboring ink flow channels 18A and 18C, and also in nozzles of ink flow channels 18A and 18C, vibration of meniscus occurs. When neighboring ink flow channels are driven continuously, these meniscus vibrations are transmitted to whole the head, complicated pressure waves having many layers are produced. Since such complicated pressure waves are added, depending on with or without continuous driving in neighboring ink flow channels, the pressure applied to the ink flow channel changes, and the ejecting velocity changes, and ejecting becomes unstable.

[0024] In order to inhibit overflow of ink due to projection of meniscus, it is advisable to enlarge viscosity resistance.

In order to enlarge viscosity resistance, according to the following equation of motion of flow channels, to reduce the cross section is advisable. However, when the cross section is reduced, the amount of droplets to be ejected is also reduced almost proportionately, the droplet ejecting head becomes not appropriate.

[formula 1]

$$L\frac{dQ}{dt} + RQ + \frac{1}{C}\int Q\,dt = P$$

$L = \rho\int (1/S)\ dl$: Ink flow channel inertance

$R = \mu\int F\ (1)(1/S)^2\ dl$: Viscosity resistance

$C = \frac{\pi r^4}{8\sigma}$: Capillary force

Q : Ink flow rate

S : Cross section of ink flow

F : Shape factor

r : Radius of nozzle

ρ : Ink density

μ : Ink viscosity

σ : Ink surface tension

[0025] The present inventor focused on the shape factor of viscosity resistance in above formula and eagerly investigated, and found that as for an ink flow channel with rectangular cross section, when the depth direction parallel to the surface of the partition wall is defined as the vertical direction, the arranged direction of the partition wall perpendicular to the depth direction is defined as the horizontal direction, and when the aspect ratio calculated from the vertical length/ the horizontal length is large, even if the absolute cross section is not so large, viscosity resistance becomes large. That is, the present inventor found a droplet ejecting head having large viscosity resistance without sacrificing its droplet ejecting amount, which inhibits overflow of ink with low viscosity and makes stable ejecting possible.

[0026] The considerable reasons are as follows. It is known that viscosity of ink is shear-rate dependent and becomes smaller in a high shear rate region during actual ejecting than in static state. In a shear mode droplet ejecting head, the high shear rate region in the ink flow channel which contacts to ink and actually vibrates with high speed is the partition wall section including the piezoelectric material, and this partition wall section is considered to give larger effect on viscosity resistance than the ceiling wall section and the bottom wall section give. That is, it was found that, in the cross section shape of the ink flow channel, the partition wall section provides the effect to reduce the cross section and another effect.

[0027] On the other hand, the present inventor eagerly investigated the aspect ratio in cross sectional shape of the ink flow channel and found that the aspect ratio also has a harmful effect. As described above, when the aspect ratio is large, without sacrificing the droplet ejecting amount, viscosity resistance becomes large, but at the same time, crosstalk between neighboring ink flow channels becomes enormously large, and such a droplet ejecting head cannot be utilized in practical use.

[0028] As the cause, it is considered that, with keeping the thickness of the partition wall, when the aspect ratio becomes larger, that is, when the partition wall becomes higher, the structure of the ink flow channel becomes softer, and primary resonance happens, variation of pressure becomes too large. Then the present inventor eagerly investigated and found that when the partition wall has certain level of hardness, specifically, the partition wall has certain level of hardness which makes resonance frequency of the partition wall a certain value or more, the problem is reduced, and established this invention.

[0029] Conventionally, in order to solve the problem of overflow in using low viscosity ink, no technology has focused on aspect ratio of the ink flow channel structure nor hardness required by the partition wall.

[0030] For example, patent document 1 discloses a droplet ejecting head shown in Figure 9. In this droplet ejecting head, the ink flow channels are composed of firing ink flow channels 501 having nozzles 505 and not- firing ink flow channels 502 without nozzles 505. The firing ink flow channels and the not- firing ink flow channels are arranged alternatively with a shift in the direction orthogonal to the longitude direction and row direction of the ink flow channels. The firing ink flow channels 501 are T-shaped in cross section composed of broad ink flow channel parts 501a with not-moving side walls 503 and narrow ink flow channel parts 501b with moving side walls 504, and reduce the effect of crosstalk between neighboring ink flow channels.

[0031] In this patent document 1, it is described that narrow ink flow channel parts 501b with firing side walls 504 have the aspect ratio of about 5 or more. However, nothing about hardness of moving side walls 504 being partition walls is described, and there is no disclosure about inhibiting ink overflow due to projection of meniscus when a low-viscosity ink is used.

[0032] Based on the actual confirmation by the present inventor, the cross sectional width of the ink flow channel parts 501 across not-moving side wall 503 was too large and its viscosity resistance was too small, if an ink with low viscosity of less than 6 cp was used, overflow of the ink occurred, and the head cannot be utilized in practical use. Furthermore, since its structure is complex and its cost is high, the head was never possible to be utilized in practical use.

[0033] Also, in patent document 2, resonance frequencies of partition walls constituting a droplet eject head are described. However, this technique is, by measuring impedances of partition walls and determining the frequency making the impedance minimum and causing resonance, to test the component, did not refer to reducing crosstalk with focusing on the resonance frequencies of the partition walls and reducing overflow of ink due to projection of meniscus, and could not solve the problems.

[0034] Furthermore, in patent document 3, aspect ratios and resonance frequencies of partition walls constituting the droplet ejecting head are described. However, this technique is, for example, by specifying the Young's modulus of the partition wall and resonance frequency of the partition wall and making the density of the piezoelectric ceramics and the Young's modulus of the piezoelectric ceramics satisfying the predetermined relation, to improve them, and making stiffness of all partition walls within the range suitable for ejecting and homogenizing the ejecting performance, did not refer to reducing crosstalk in using inks with low viscosity and reducing overflow of ink by specifying aspect ratio of the ink flow channel structure and resonance frequency of the partition wall, and also could not solve the problems.

[Patent document 1] Japanese Unexamined Patent Application Publication (Translation of PCT Application) No. 2009-500209
[Patent document 2] Japanese Patent No. 2632061
[Patent document 3] Japanese Unexamined Patent Application Publication No. 2003-246064

[0035] A problem to be solved by the present invention is to provide, in a shear-mode droplet ejecting head in which multiple ink flow channels and multiple partition walls are alternatively arranged, and by the deformation motion of the partition wall, ink in the ink flow channel is ejected from the nozzle, a droplet ejecting head which, by specifying the structure of the ink flow channel and resonance frequency of the partition wall, even if an ink with low viscosity is used, can inhibit variation of ejecting speed due to crosstalk, and can reduce overflow of ink from the nozzle, and can conduct stable ejecting, and a printing apparatus using thereof.

[0036] Other problems to be solved by the present invention will be obvious in the following descriptions.

[0037] Problems described above will be solved by each of the following inventions.

1. A droplet ejecting head comprised of an actuator in which multiple ink flow channels to which ink is provided and multiple partition walls are alternatively arranged, the partition wall between the neighboring ink flow channels responds to an applied voltage given to an electrode formed on surface of the partition wall and does deformation motion, and by the deformation motion of the partition wall, the ink in the ink flow channel is ejected from a nozzle communicated with the ink flow channel:

   wherein the ink flow channel is rectangularly formed in cross section in the arranged direction ,and when the depth direction parallel to the surface of the partition wall is defined as the vertical direction, the arranged direction of the partition wall perpendicular to the depth direction is defined as the horizontal direction, an aspect ratio (vertical length/ horizontal length) in the cross sectional shape of the ink flow channel rectangularly formed is 5.00 or more and less than 7.75, a resonance frequency of the partition wall is 1.5 MHz or more.

2. The droplet ejecting head according to 1, wherein the aspect ratio of the ink flow channel is 6.00 or more and 7.00 or less.
3. The droplet ejecting head according to 1 or 2, wherein the width between both sides partition walls of the ink flow channel is 40 μm or more and 60μm or less.

4. The droplet ejecting head according to any one of 1 to 3, wherein an insulating and protective coating composed of an organic material is formed on the surface of the electrode on the partition wall of the ink flow channel.
5. The droplet ejecting head according to any one of 1 to 4, wherein the viscosity of the ink is less than 6 cp.
6. A printing apparatus provided with the droplet ejecting head according to any one of 1 to 5 which conducts printing by landing the ink ejected from the nozzle on a printing medium.

[0038] According to the present invention, in a shear mode droplet ejecting head in which multiple ink flow channels and multiple partition walls are alternatively arranged, and by the deformation motion of the partition wall, ink in the ink flow channel is ejected from the nozzle, a droplet ejecting head and a printing apparatus which can ,even if an ink with low viscosity (for example, an ink with viscosity of less than 6 cp) is used, inhibit speed variation due to crosstalk, and can reduce overflow of the ink from the nozzle, and can conduct stable ejecting, be provided.
[0039] Embodiments of the invention are described in detail, by way of example only, and with reference to the accompanying drawings, in which:

FIG. 1 (a) is a schematic perspective view showing an example of a shear-mode droplet ejecting head and 1(b) is a sectional view.
Figure 2 shows motion during ink ejecting of the droplet ejecting head shown in Figure 1.
Figure 3 explains three cycle driving motion of the droplet ejecting head shown in Figure 1.
Figure 4 is a graph showing an example of a driving signal used during three cycle driving.
Figure 5 is a sectional view along the (v)-(v) line in Figure 1 (a) showing the vertical cross sectional shape of the ink flow channel.
Figure 6 explains the resonance frequency.
Figure 7 is a perspective view with partial cutout showing another example of a droplet ejecting head.
Figure 8 shows a schematic configuration of a printing apparatus.
Figure 9 is a sectional view showing the ink flow channel structure of conventional droplet ejecting head.

[0040] A droplet ejecting head according to the present invention is composed of an actuator in which multiple ink flow channels to which ink is provided and multiple partition walls are alternatively arranged, the partition wall between the neighboring ink flow channels responds to an applied voltage given to an electrode formed on surface of the partition wall and does deformation motion. In such a droplet ejecting head, an actuator is composed of a polarized piezoelectric material such as PZT, and the actuator responds to the applied voltage and does deformation motion L-shapely, that is, the droplet ejecting head is a so-called shear mode droplet ejecting head, and by the deformation motion of the partition wall, a pressure is applied to the ink in the ink flow channel, and eject as droplet from the nozzle communicated with the ink flow channel.
[0041] In the present invention, as an example of inks, inks with low viscosity of less than 6 cp (viscosity at the temperature of the ink to be ejected) are subjects, and the ink with such low viscosity is provided into the ink flow channel and fills it.
[0042] As relevant information, viscosity of ink is in general the viscosity at ordinary temperature (25°C). However, it is known that viscosity of ink is temperature-dependent, and in some cases, a heating apparatus is furnished to the ink providing means or the ejecting head, and by heating the ink and reducing the viscosity, and the ink is used. In these cases, the viscosity of the ink is the viscosity at the heated temperature of the ink to be used.
[0043] Figure 5 is a cross-sectional view taken along the line (v)-(v) in Figure 1(b). This figure shows the vertical cross-sectional shape taken along the depth direction to the surface of the partition wall 17 and the arranged direction of the partition wall 17. By using this figure, the structure of the ink flow channel 18 in the present invention is explained. The ink flow channel 18 in the present invention is, when the depth direction to the surface of the partition wall 17 is defined as the vertical direction h, the arranged direction of the partition wall 17 perpendicular to the depth direction is defined as the horizontal direction w, the partition wall 17 is rectangularly formed in vertical cross section in the arranged direction and the aspect ratio (vertical length h/ horizontal length w) in the vertical cross sectional shape is 5.00 or more and less than 7.75.
[0044] In this case, the width (w) of the ink flow channel is the width of the area where ink is filled. That is, it means the width of the final ink flow channel which was formed and the electrode was formed on the surface of the partition wall and it became to be used. This width can be determined by examining the vertical cross sectional shape obtained with cutting the ink flow channel along the depth direction to the surface of the partition wall and the arranged direction of the partition wall by observation apparatus such as a microscope.
[0045] In an ink flow channel, if there is variability at least in either of vertical length (h) or horizontal length (w), it is preferable to measure at plural points in the longitudinal direction in the ink flow channel, and use the means.
[0046] When the aspect ratio of the ink flow channel is within the range described above, without reducing the cross section of ink flow channel and sacrificing the droplet ejecting amount, it is possible to make viscosity resistance large.

And thus overflow of ink may be inhibited.

[0047] When the aspect is smaller than 5.00, the ratio of partition wall vibrating at high speed becomes smaller, even at the same cross section, viscosity resistance becomes smaller, and inhibition of ink overflow becomes difficult. In addition, when the aspect is 7.75 or larger, the ink flow channel is too long in vertical direction and becomes soft in structure, even if the resonance frequency described later is satisfied, preventing the primary resonance becomes difficult, and crosstalk becomes larger. More preferable aspect ratio is from 6.00 to 7.00.

[0048] In general, ink flow channels are formed, with a grinding blade such as a grindstone, by grinding vadums with predetermined depth to be ink flow channels in parallel on a substrate. Therefore, ink flow channels with aspect ration within the range described above may be formed by appropriately selecting or adjusting the thickness of the grinding blade and grinding depth.

[0049] The droplet ejecting head in the present invention is not limited to have the structure, as shown in Figure 1, in which the flow channel 18 has a vadum part 18a becoming shallower in opposite side to the nozzle end where a nozzle 13 is displaced, and ink is provided from the direction (upper side in Figure 1) perpendicular to the longitudinal direction of the ink flow channel 18, but as shown in Figure 7, may be formed straightly from the nozzle end to the opposite end, and ink may be provided from the opposite end along the longitudinal direction of the ink flow channel 18. In Figure 7, sections shown by the same signs as Figure 1 have the same composition.

[0050] In addition, in the case of a droplet ejecting head having a vadum part 18a in the ink flow channel 18 as shown in Figure 1, the aspect ratio of the ink flow channel 18 is the aspect ratio of the part of effective actuating length (L length) with constant depth shown in Figure 1 (b).

[0051] In this ink flow channel, the width (w) of the flow channel between both sides partition walls is preferably from 40 μm to 60 μm. When the width is in the range, even if an ink with its viscosity of 6 cp or less is used, sufficient viscosity resistance can be obtained and ejecting becomes stable. If the width is smaller than 40 μm, viscosity resistance may become too large, and fluid volume may be insufficient, while if the width is larger than 60 μm, viscosity resistance may be insufficient and an ink with 6 cp may not be ejected stably.

[0052] The partition wall in the present invention has its resonance frequency of 1.5 MHz or more. When the resonance frequency is 1.5 MHz or more, the partition wall has so-called hardness. Therefore, primary resonance is effectively prevented, crosstalk is reduced. When the resonance frequency is smaller than 1.5 MHz, inhibiting primary resonance of the partition wall becomes difficult, and reducing crosstalk is difficult.

[0053] In this description, resonance frequency of the partition wall is the primary resonance frequency of the partition wall (primary resonance) (Figure 6) obtained by applying a variable frequency voltage to the electrode on the surface of the partition wall and giving deformation motion to the partition wall, during which measured by measuring instruments such as impedance analyzer, network analyzer, or impedance/LCR meter. As for all partition walls of the droplet ejecting head, measurement is performed, the resonance frequency was obtained from the mean.

[0054] Resonance frequency of the partition wall is adjustable depending on shape of the partition wall and characteristics of the piezoelectric material. For example, if aspect ratio of the piezoelectric material in the partition wall part is made larger (for example, height of the partition wall is made higher), stiffness of the partition wall is reduced, and the Resonance frequency becomes smaller. On the contrary, if aspect ratio of the piezoelectric material in the partition wall part is made smaller (for example, thickness of the partition wall is made larger), stiffness of the partition wall is enlarged, and the resonance frequency becomes larger. Accordingly, in order to make resonance frequency of the partition wall the value described above or larger, by making aspect ratio of the piezoelectric material in the partition wall part smaller (for example, thickness of the partition wall is made larger), adjusting is possible. In addition, by using a piezoelectric element with large Young's modulus or with small mechanical compliance, making stiffness higher and making resonance frequency larger are possible.

[0055] Additionally, when an electrode furnished on side surface of the partition wall is formed by the plating method, if the thickness of the plating is made thicker, stiffness of the partition wall becomes higher, and the resonance frequency can be made larger. Thus, the resonance frequency of the partition wall may be adjusted into the range of the present invention through appropriately combining these methods.

[0056] In the present invention, in order to avoid the electrode from directly contacting to the ink, on the surface of electrode facing into the ink flow channel, an insulating and protective coating composed of an organic material may be further formed. As such insulating and protective coating, a coating formed by vapor deposition such as chemical vapor deposition method is preferable, and especially, a coating constituted by poly(para-xylylene) or its derivatives is appropriate.

[0057] When such an insulating and protective coating is formed on the surface of the electrode, the width (w) of the ink flow channel in the present invention is the final width of the ink flow channel after formation of the protective layer.

[0058] The droplet ejecting head in the present invention is not limited to aspects shown in Figure 1 and Figure 7 in which nozzle 13 is allocated to the longitude direction end of the ink flow channel 18, but may be the aspect (not shown) in which the nozzle opens at the part of the upper substrate 14 responding to the midway part of the ink flow channel 18.

[0059] In the present invention, an ink with viscosity of less than 6 cp shows generally liquids which may be ejected from a nozzle of a shear mode droplet ejecting head. For example, image formation inks, and functional liquids used for various industrial applications such as manufacturing apparatus of color filters for liquid-crystal panels and semiconductor devices.

[0060] Next, an example of printing apparatus relating to the present invention is shown in Figure 8.

[0061] Figure 8 is a figure showing the schematic formation of printing apparatus which forms images on the recording medium. In the printing apparatus 200, the recording medium P is sandwiched by a pair of conveyance rollers 201, furthermore conveyed in the Y direction (shown) by the conveyance roller 203 rotation driven by the conveyance motor 202.

[0062] The droplet ejecting head 1 is furnished to oppose the recording surface PS of the recording medium P among the conveyance roller 203 and the pair of conveyance rollers 201. The droplet ejecting head 1 is mounted on the carriage 205 with its nozzle side opposed to the recording surface PS of the recording medium P, and is electrically connected to the driving signal generation section 100 (cf. Figure 2) through a flexible cable 206. The carriage 205 is reciprocating movable in the shown X-X' direction (main scanning direction) almost perpendicular to the conveyance direction of the recording medium P (vertical scanning direction) by the driving means not shown along the guide rail 204 built over in the width direction of the recording medium P.

[0063] The droplet ejecting head 1, associated with movement of the carriage 205 in the main scanning direction, moves on the recording surface PS of the recording medium P in the shown X-X' direction, during the movement, ejects droplets from the nozzle, and forms the desired inkjet images.

[0064] Examples of the present invention are explained as follows, but the present invention is not limited to the following examples.

Examples 1 to 5, Comparative Examples I to 11

[0065] A set of a piezoelectric material substrate composed of PZT (H8H, made by Sumitomo Metal Electronics Devices Inc.,) and polarized and a lower substrate were bonded with an adhesive agent with each direction of polarization of the piezoelectric material substrate different. Then, from the surface of the piezoelectric material substrate, multiple groove-like ink flow channels with the depths perpendicular to the bonded plane and constant from an end of the piezoelectric material substrate to another end were formed with a grind stone and made ink flow channels and partition walls alternative and parallel, and on side of each partition wall, an electrode and parylene protective layer were formed. Then, upper face of each ink flow channel was covered by an upper substrate, and produced multiple droplet ejecting heads in which each ink flow channel is straight as shown in Figure 5.

[0066] Each droplet ejecting head had the same resolution of 180 dpi and length of ink flow channel of 5 mm.

[0067] Furthermore, each droplet ejecting head had different aspect ratio as shown in Table 1 by changing the thickness of the grindstone and the grinding depth, and by changing the thickness of the partition wall as shown in Table 1, had different resonance frequency as shown in Table 1.

[0068] Measurement of resonance frequencies was performed by applying variable frequency voltage to each electrode and driving each partition wall, and measuring the resonance frequency of primary resonance with an impedance analyzer (FRA1260, made by Toyo Corporation), and calculating the mean of all resonance frequencies of all partition walls.

[0069] As relevant information, the piezoelectric material had the density of 8.02 g/cm^3 and Young's modulus of 109.9 GPa.

Evaluation

[0070] For each droplet ejecting head, its ejecting stability, with or without overflow of ink, and crosstalk ratio were evaluated.

Ejecting stability

[0071] By using a water based ink with viscosity of 5.7 cp (surface tension, 41 dyn/cm) and conducting a three cycle driving at 7.2 kHz shown in Figure 3, ejecting ink from each ink flow channel was performed. During the test, ejecting was stopped several times, and the amount of ejected droplets was measured with a precision balance, the mean ejecting amount/droplet was determined, and changing of ejecting amount when the ejecting rate was changed was evaluated based on the criterion described below. The results are shown in Table 1.

[0072] Good, even at ejecting speed of 6 to 10 m/sec or more, variation in ejecting amount during ejecting is 10% or smaller;

[0073] Fair, at ejecting speed of about 8 m/sec, variation in ejecting amount during ejecting is 10% or smaller, and at ejecting speed of more than 8 m/sec, variation in ejecting amount during ejecting is more than 10%;

[0074] Poor, at ejecting speed of about 8 m/sec or less, variation in ejecting amount during ejecting is more than 10%.

With or without overflow of ink

[0075] By conducting continuous ejecting for 10 minutes from 128 nozzles more than half of all nozzles, with or without insufficiency of nozzle due to ink overflow was examined and evaluated based on the criterion described below. Even if insufficiency of nozzle occurred at only one nozzle, the result was Poor. The results are shown in Table 1.
[0076] Good, no overflow occurred;
Poor, overflow occurred and insufficiency of nozzle occurred.

Crosstalk ratio

[0077] Dispensing was performed from an ink flow channel at the ejecting speed of 6 m/sec, and simultaneously did driving of both side or neighboring ink flow channels total of 60 ink flow channels in sequence, difference values of ejecting speed were measured, and evaluated based on the criterion described below. The results are shown in Table 1.
[0078] Good, the difference value is less than 15%;
Fair, the difference value is 15% or more and less than 20%;
Poor, the difference value is 20% or more (cannot be utilized in practical use).

TABLE 1

	Height of channel (vertical direction) μm	Partition wall Horizontal thickness μm	Channel width (horizontal direction) μm	Resonance frequency MHz	Aspect ratio (vertical length/horizontal length) in the channel cross section	Dispensing stability	Overflow	Crosstalk ratio % (speed difference)
Comparative Example 1	200	62	70	240	286	Poor	Overflow, NG	Good:142%
Comparative Example 2	250	62	70	167	357	Poor	Overflow, NG	Fair:183%
Comparative Example 3	285	62	70	157	407	Poor	Overflow, NG	Fair:195%
Comparative Example 4	310	62	70	142	443	Poor	Overflow, NG	Poor:229%
Comparative Example 5	200	72	60	250	333	Poor	Overflow, NG	Good:142%
Comparative Example 6	250	72	60	177	417	Poor	Overflow, NG	Fair:188%
Comparative Example 7	285	72	60	1 57	475	Poor	Overflow, NG	Fair:197%
Comparative Example 8	310	72	60	1 42	517	Poor	Good	Poor:229%
Comparative Example 9	200	82	50	270	400	Insufficiency of refilling Poor	Good	Good:120%
Example 1	250	82	50	207	500	Good	Good	Fair:157%
Example 2	285	82	50	1 67	570	Good	Good	Fair:194%
Comparative Example 10	310	82	50	148	620	Good	Good	Poor:21 4%
Example 3	200	92	40	290	500	Good	Good	God:11 2%
Example 4	250	92	40	232	625	Good	Good	Good:140%

(continued)

	Height of channel (vertical direction) μm	Partition wall Horizontal thickness μm	Channel width (horizontal direction) μm	Resonance frequency MHz	Aspect ratio (vertical length/horizontal length) in the channel cross section	Dispensing stability	Overflow	Crosstalk ratio % (speed difference)
Example 5	285	92	40	1 77	713	Good	Good	Fair:183%
Comparative Example 11	310	92	40	142	775	Good	Good	Poor:201%

Examples 6, 7, Comparative Examples 12 to 14

[0079] Except that each droplet ejecting head had the same resolution of 300 dpi and length of ink flow channel of 2 mm, each droplet ejecting head had different aspect ratio and different resonance frequency as shown in Table 2. In the same way described above, ejecting stability, with or without overflow of ink, and crosstalk ratio of each droplet ejecting head were measured. These results are shown in Table 2.

TABLE 2

	Height of channel (vertical direction) μm	Partition wall Horizontal thickness μm	Channel width (honzontal direction) μm	Resonance frequency MHz	Aspect ratio (vertical length/horizontal length) in the channel cross section	Dispensing stability	Overflow	Crosstalk ratio % (speed difference)
Comparative Example 12	150	43	32	377	469	Insufficiency of refilling Poor	Good	Good:8 6%
Example 6	200	43	32	219	625	Fair	Good	Good:14 8%
Example 7	230	43	32	170	719	Good	Good	Fair:19 1%
Comparative Example 13	250	43	32	146	781	Good	Good	Poor:22 2%
Comparative Example 14	300	43	32	107	938	Fair	Good	Poor:30 5%

[0080] As shown in Table 1 and 2, as for three items of ejecting stability, with or without overflow of ink, and crosstalk ratio, all of Examples 1 to 7 showed satisfactory results. While Comparative Examples 1 to 14 showed unsatisfactory results as for at least one item, and did not indicate the effects of the present invention.

[0081] Especially in Comparative Examples 9 and 12, insufficiency of refilling of ink to the ink flow channel occurred, and the droplet dispersing heads could not be utilized in practical use.

[0082] In addition, as for cross section of ink flow channels, for example, that of Example 2 was $285 \times 50 = 14250$ μm^2 that of Comparative Example 1 was $200 \times 70 = 14000$ μm^2, and both were almost same. However, as for three items, Example 2 showed good results, while Comparative Example 1 showed bad results in both items of ejecting stability and with or without overflow of ink. This result indicated the shape effect in viscosity resistance.

[0083] Furthermore, Comparative Examples 10 and 11 indicated that resonance frequency of 1.5 MHz or more is required, and Comparative Examples 7 and 12 indicated that aspect ratio of 5.00 or more is required.

<u>Explanations of Letters or Numerals</u>

[0084]

1,	droplet ejecting head
11,	ink tube
12,	nozzle forming material
13,	nozzle
14,	upper substrate
15,	ink feed opening
16,	lower substrate
17,	partition wall
17a,	upper wall part
17b,	lower wall part
18,	ink flow channel
19A to 19C,	electrode
100,	driving signal generation section
200,	printing apparatus
201,	a pair of conveyance rollers
202,	conveyance motor
203,	conveyance roller
204,	guide rail
205,	carriage
206,	flexible cable
P,	recording medium
PS,	recording surface

Claims

1. A droplet ejecting head comprised of an actuator in which multiple ink flow channels to which ink is provided and multiple partition walls are alternatively arranged, the partition wall between the neighboring ink flow channels responds to an applied voltage given to an electrode formed on a surface of the partition wall and does deformation motion, and by the deformation motion of the partition wall, the ink in the ink flow channel is ejected from a nozzle communicated with the ink flow channel:

   wherein the ink flow channel is rectangularly formed in cross section in the arranged direction, and when the depth direction parallel to the surface of the partition wall is defined as the vertical direction, the arranged direction of the partition wall perpendicular to the depth direction is defined as the horizontal direction, an aspect ratio (vertical length/ horizontal length) in the cross sectional shape of the ink flow channel rectangularly formed is 5.00 or more and less than 7.75, a resonance frequency of the partition wall is 1.5 MHz or more.

2. The droplet ejecting head according to claim 1, wherein the aspect ratio of the ink flow channel is 6.00 or more and 7.00 or less.

3. The droplet ejecting head according to claim 1 or claim 2, wherein the width between both side partition walls of the

ink flow channel is 40μm or more and 60μm or less.

4. The droplet ejecting head according to any one of claims 1 to 3, wherein an insulating and protective coating composed of an organic material is formed on the surface of the electrode on the partition wall of the ink flow channel.

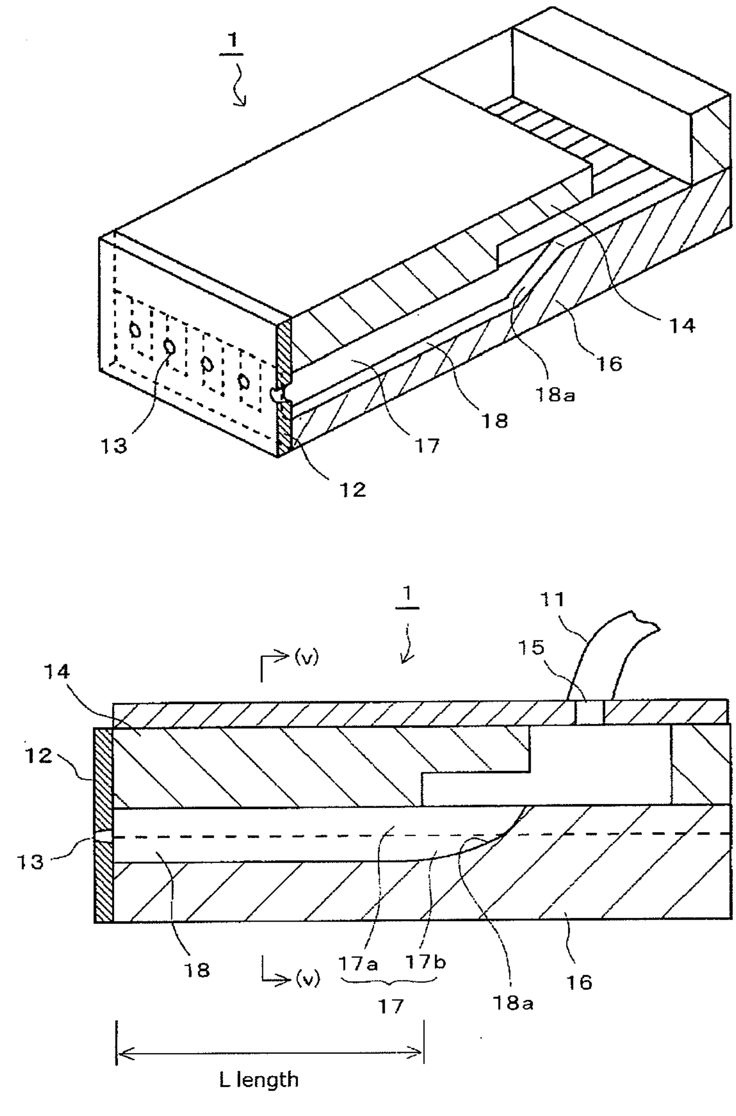
5. The droplet ejecting head according to any one of claims 1 to 4, wherein the viscosity of the ink is less than 6 cp.

6. A printing apparatus provided with the droplet ejecting head according to any one of claims 1 to 5 which conducts printing by landing the ink ejected from the nozzle on a printing medium.

FIG. 1

(a)

(b)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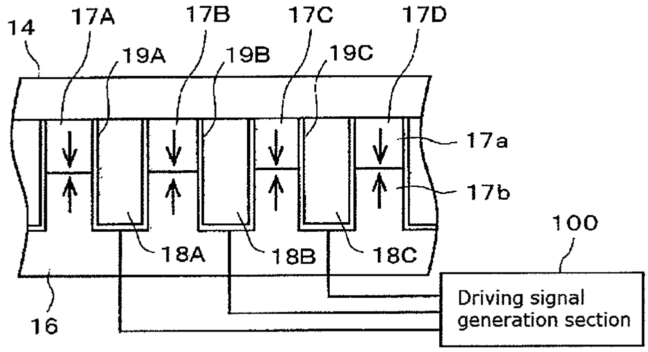
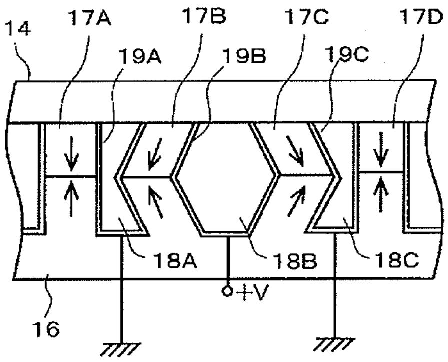
14
16
18a
18
17
13
12
1
11
15
14
12
13
18
17a
17b
17
18a
16
(v)
(v)
L length

FIG. 2

(a)


14
17A
17B
17C
17D
19A
19B
19C
17a
17b
100
18A
18B
18C
16
Driving signal generation section

(b)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17A
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17D
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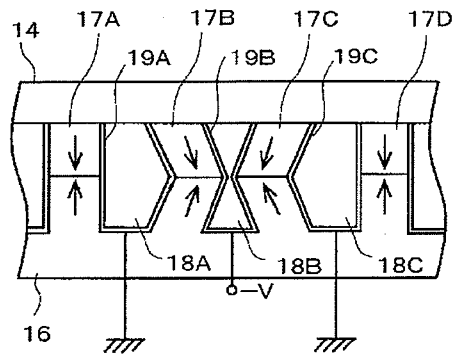
19B
19C
18A
18B
18C
+V
16

(c)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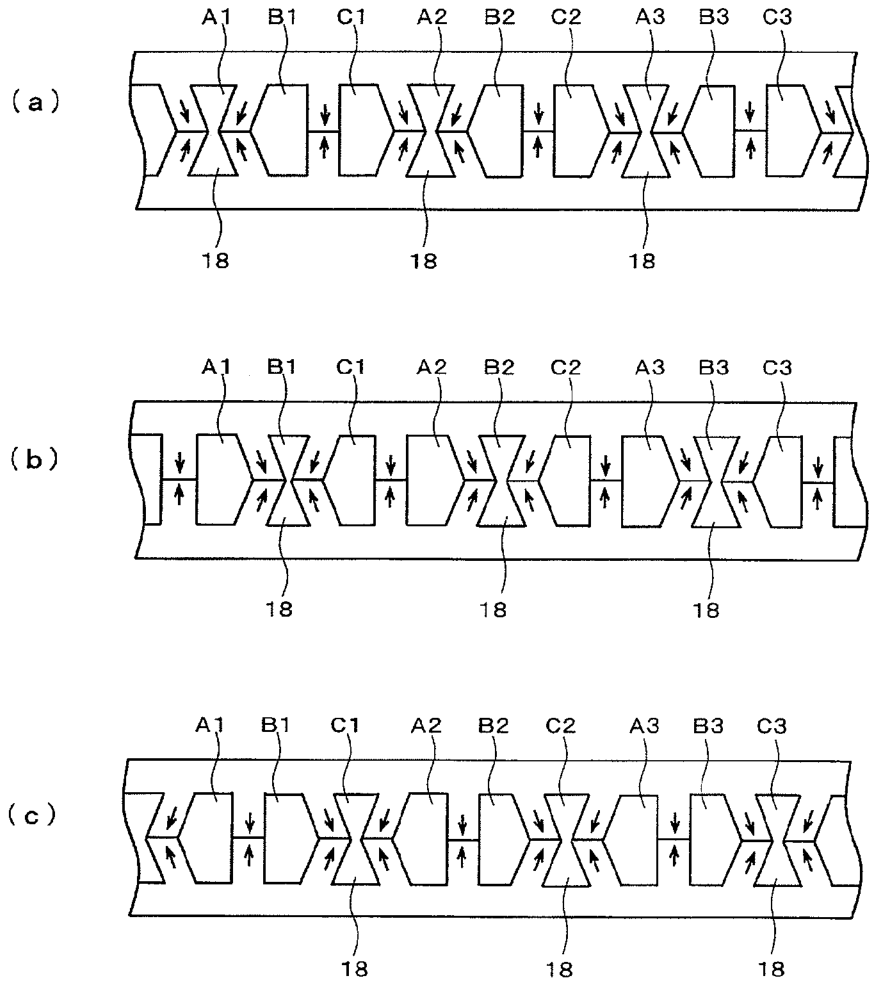
17C
17D
19A
19B
19C
18A
18B
18C
−V
16

FIG. 3


(a)
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18 18 18
(b)
A1 B1 C1 A2 B2 C2 A3 B3 C3
18 18 18
(c)
A1 B1 C1 A2 B2 C2 A3 B3 C3
18 18 18

FIG. 4

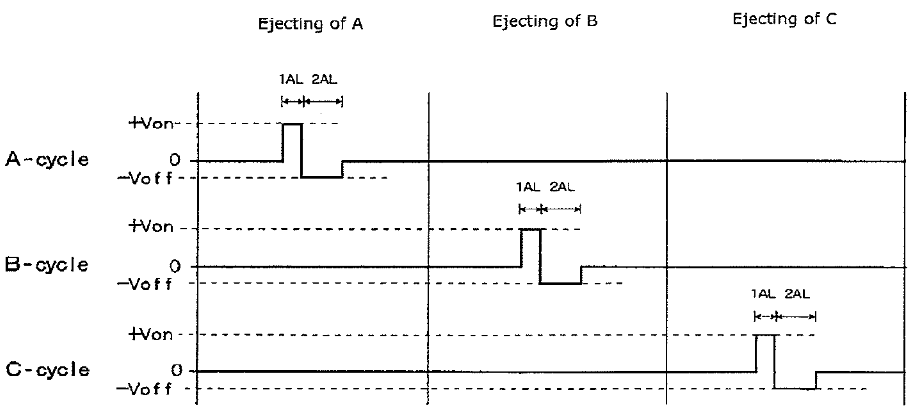

Ejecting of A
Ejecting of B
Ejecting of C
1AL 2AL
+Von
A-cycle
0
-Voff
B-cycle
C-cycle

FIG. 5

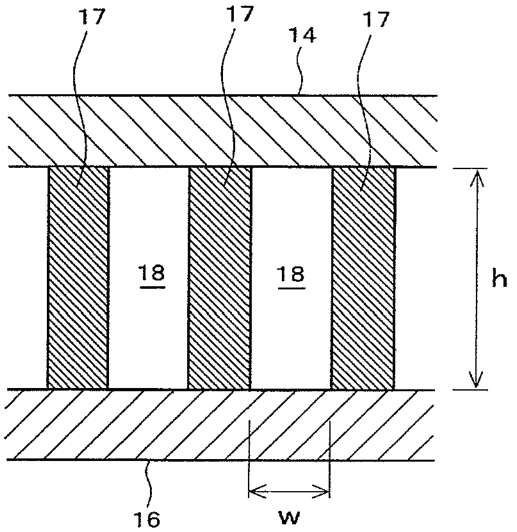

17
17
14
17
18
18
h
16
w

FIG. 6

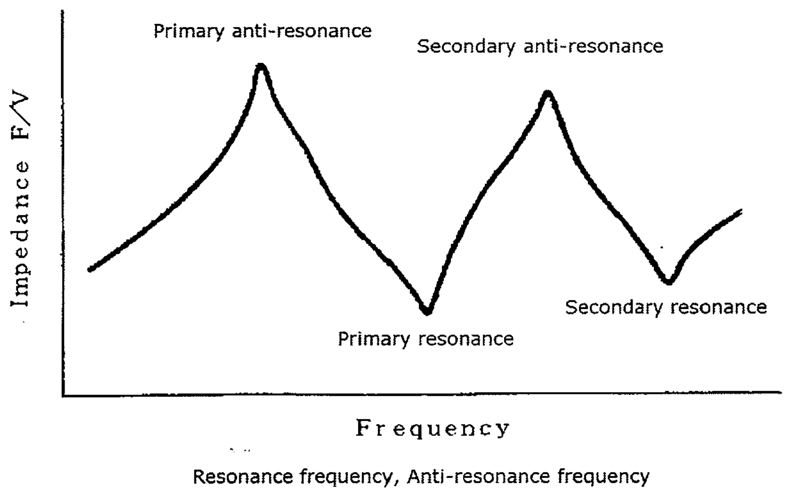

Primary anti-resonance
Secondary anti-resonance
Impedance F/V
Primary resonance
Secondary resonance
Frequency
Resonance frequency, Anti-resonance frequency

FIG. 7

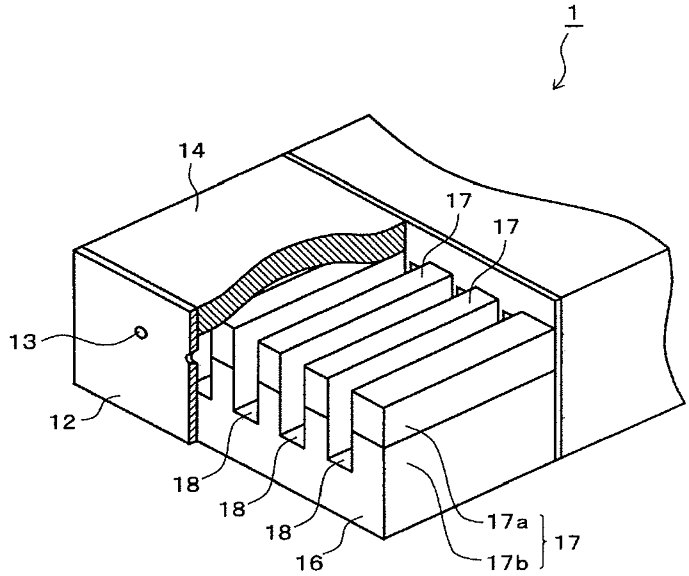

1
14
17
17
13
12
18
18
18
16
17a
17b
17

FIG. 8

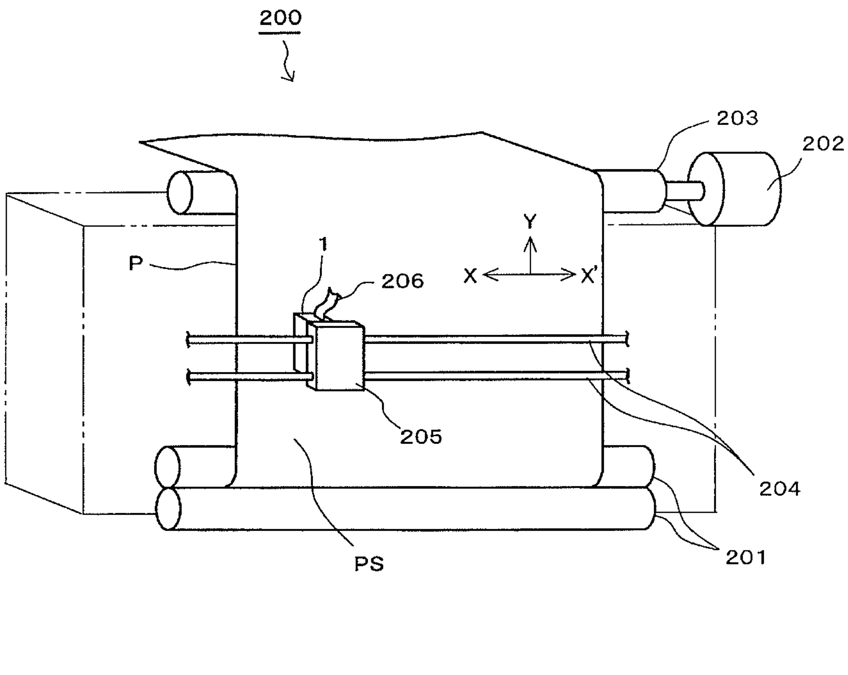
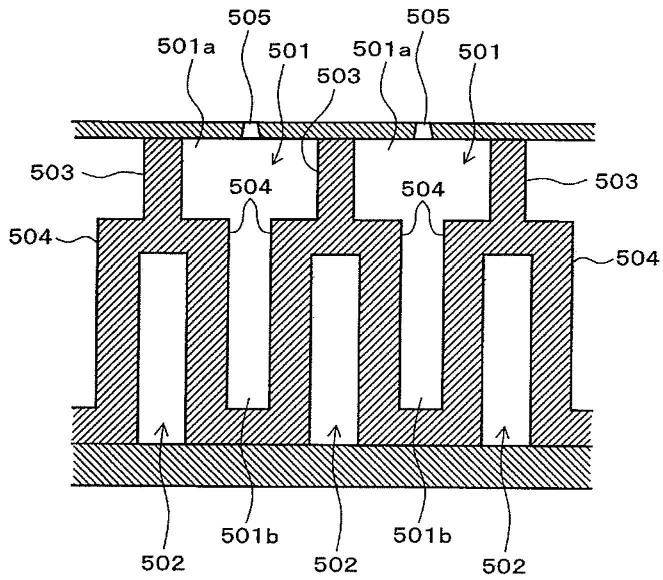

200
203
202
Y
P
1
206
X
X'
205
204
201
PS

FIG. 9


505
505
501a
501
501a
501
503
503
503
504
504
504
504
501b
501b
502
502
502

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EUROPEAN SEARCH REPORT

Application Number
EP 12 19 4830

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			TECHNICAL FIELDS SEARCHED (IPC)
			B41J

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	7 March 2013	Bonnin, David

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07-03-2013

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