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DESCRIPTION

ACTUATOR, LIQUID DROP DISCHARGE HEAD, INK
CARTRIDGE, INKJET RECORDING DEVICE, MICRO PUMP,
5 OPTICAL MODULATION DEVICE, AND SUBSTRATE

TECHNICAL FIELD

The present invention relates to actuators,
10 liquid drop discharge heads, ink cartridges, inkjet
recording devices, micro pumps, optical modulation
devices, and substrates, and more specifically, to an
electrostatic actuator, liquid drop discharge head,
ink cartridge, inkjet recording device, micro pump,
15 optical modulation device, and substrate which use
the actuator.

BACKGROUND ART

20 In an ink jet recording apparatus used as a
picture recording apparatus or picture forming
apparatus such as a printer, facsimile, or copier, a
liquid drop jet head is used as an ink jet head
configured to discharge (jet out) ink.

25 The ink jet head includes a nozzle, a

discharging room, a common room, and pressure
generating means. An ink drop is discharged by the
nozzle. The nozzle is connected to the discharging
room. The discharging room is called a pressurized
5 liquid room, pressure room, ink channel, or the like.
Discharging fluid (ink) supplied to the discharging
room is received in the common room. The inside of
the discharging room is pressurized by the pressure
generating means, so that discharging energy is given
10 to the ink in the discharging room and thereby the
ink can be discharged from the nozzle. The ink drop
is discharged from the nozzle due to the pressure in
the discharging room generated by the pressure
generating means.

15 Although there are several kinds of pressure
generating means, an electrostatic type pressure
generating means is used for the present invention.
In the electrostatic type pressure generating means,
a vibration plate forming a wall surface of the
20 discharging room is deformed by an electrostatic
force so that an ink drop is discharged. Recently
and continuing, such an electrostatic type pressure
generating means attracts a great deal of attention
from the perspective of the environment because the
25 electrostatic type pressure generating means does not

use lead. In addition, a lot of technologies having little effect on the environment are suggested from the perspective of low consumption of electric power in addition to no lead in the electrostatic type
5 pressure generating means.

In the electrostatic type pressure generating means, a couple of electrodes are provided via a space. There is an example where one of the electrodes works as the vibration plate and ink fills
10 a side opposite to the electrode facing the vibration plate. The electrostatic force works between the electrodes by applying voltage to the electrodes so that the electrode (vibration plate) is deformed. The vibration plate is returned back to the original
15 state by an elastic force based on turning off the voltages so that the ink is discharged based on the elastic force.

Such pressure generating means for pressurizing the discharge fluid is called an
20 actuator. In the electrostatic type ink jet head, the measurement precision of a first space, namely a space of the vibration plate and the electrode which are main parts of the actuator, gives a large amount of influence to the capacity (size) of the pressure
25 generating means. Especially, in a case of the ink

jet heads, the larger the dispersion of the capacity of the actuators is, the more printing precision and reproducibility of image quality are reduced.

It is important to prevent the measurement dispersion of the space in order to obtain a head having high reliability. It is required that the number of processes for determining the space measurement be made as small as possible in order to prevent the measurement dispersion of the space.

Because of this, a technology where the vibration plate, the space and the electrode are formed at a single substrate by applying the sacrificial layer process as a manufacturing method is suggested. See Japanese Laid-Open Patent Application Publications No. WO99/34979 and No. 2001-18383.

In a case of the sacrificial layer process, for example, a deposition method, wherein the sacrificial layer elimination hole, after the sacrificial layer is eliminated, is closed by Ni, SiO₂, or the like by using a PVD method or CVD method with a vacuum device, may be used. However, in this deposition method, a deposition component may invade (seep into) the space. If the deposition component invades the space, a vibration property of the

vibration plate is changed so that a bad influence is given to the reliability. In addition, since the sacrificial layer elimination hole is also used for ensuring the strength of a partition, it is not possible to make the hole small and therefore the hole is not appropriate for being made at a high density.

The sacrificial layer elimination hole may be sealed by a film formed by a deposition method using a vacuum device so that the deposition component can be prevented from invading the space. However, in this method, since a process is performed in the vacuum state, the pressure in the space may be negative when atmospheric exposure occurs. Hence, it is not possible to obtain a desirable amount of bending deformation of the vibration plate and deformation dispersion may be generated due to the dispersion of the bending.

In addition, in a case of vacuum sealing, since there is no damper effect of gas in the space, the dispersion of the vibration deformation against the dispersion of the thickness of the vibration plate becomes large. A structure or process opening to the air is required to solve the above-mentioned problems and this may cause increase of cost or

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decrease of yield rate. Thus, in the related art, it is difficult to obtain the actuator having high precision and using an electrostatic force with high reliability at low cost.

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DISCLOSURE OF THE INVENTION

Accordingly, it is a general object of the present invention to provide a novel and useful
10 actuator, liquid drop discharge head, ink cartridge, inkjet recording device, micro pump, optical modulation device, and substrate.

Another and more specific object of the present invention is to provide an actuator having
15 high precision and reliability, and a liquid drop discharge head, ink cartridge, inkjet recording device, micro pump, and optical modulation device which have the actuator, whereby a sacrificial layer elimination hole is sealed under atmospheric
20 conditions without using a vacuum device so that a deposition film is effectively prevented from invading in a first space.

It is also an object of the present invention to provide a substrate manufactured by
25 using a sacrificial layer process and the substrate

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having a space formed inside of the substrate.

The present invention is achieved by an actuator, including:

5 a vibration plate area displaced by an electrostatic force; and

electrodes facing each other via a first space in the vibration plate area;

wherein the first space is formed by a sacrificial layer process using a sacrificial layer removing hole; and

10

a barrier as a fluid resistance is formed between the first space and a second space situated in the vicinity of the sacrificial layer removing hole.

15 The present invention is also achieved by a liquid drop discharge head, including:

a discharging room which discharges a liquid drop and is connected to a nozzle;

a common liquid room receiving discharge fluid supplied to the discharging room;

20

a pressure generating part configured to give discharging energy to the discharge fluid in the discharging room and thereby the discharge fluid can be discharged from the nozzle;

25 a plurality of actuators, the actuator

including

a vibration plate working as the pressure generating part;

a vibration plate area displaced by an
5 electrostatic force; and

electrodes facing each other via a first space in the vibration plate area;

wherein the first space is formed by a sacrificial layer process using a sacrificial layer
10 removing hole; and

a barrier as a fluid resistance is formed between the first space and a second space situated in the vicinity of the sacrificial layer removing hole.

15 The present invention is also achieved by an ink cartridge, including:

a liquid drop discharge head configured to discharge an ink drop; and

a ink tank configured to supply ink to the
20 liquid drop discharge head;

wherein the liquid drop discharge head, includes

a discharging room which discharges a liquid drop and is connected to a nozzle;

25 a common liquid room receiving discharge

fluid supplied to the discharging room;

a pressure generating part configured to give a discharging energy to the discharge fluid in the discharging room and thereby the discharge fluid
5 can be discharged from the nozzle;

a plurality of actuators, the actuator including

a vibration plate working as the pressure generating part;

10 a vibration plate area displaced by an electrostatic force; and

electrodes facing each other via a first space in the vibration plate area;

wherein the first space is formed by a
15 sacrificial layer process using a sacrificial layer removing hole; and

a barrier as a fluid resistance is formed between the first space and a second space situated in the vicinity of the sacrificial layer removing
20 hole.

The present invention is also achieved by an ink jet recording device, including:

a liquid drop discharge head configured to discharge an ink drop;

25 wherein the liquid drop discharge head,

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includes

a discharging room which discharges a liquid drop and is connected to a nozzle;

a common liquid room receiving discharge
5 fluid supplied to the discharging room;

a pressure generating part configured to give discharging energy to the discharge fluid in the discharging room and thereby the discharge fluid can be discharged from the nozzle;

10 a plurality of actuators, the actuator including

a vibration plate working as the pressure generating part;

a vibration plate area displaced by an
15 electrostatic force; and

electrodes facing each other via a first space in the vibration plate area;

wherein the first space is formed by a sacrificial layer process using a sacrificial layer
20 removing hole; and

a barrier as a fluid resistance is formed between the first space and a second space situated in the vicinity of the sacrificial layer removing hole.

25 The present invention is also achieved by a

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micro pump transporting liquid based on displacement of a vibration plate, including:

at least two pairs of electrodes having a fixed electrode and a movable electrode functioning
5 as the vibration plate; and

a structural part configured to displace the vibration plate based on an electrostatic force acting the electrodes;

wherein the vibration plate is displaced by
10 an actuator, the actuator including:

a vibration plate area displaced by an electrostatic force; and

electrodes facing each other via a first space in the vibration plate area;

15 wherein the first space is formed by a sacrificial layer process using a sacrificial layer removing hole; and

a barrier as a fluid resistance is formed between the first space and a second space situated
20 in the vicinity of the sacrificial layer removing hole.

The present invention is also achieved by an optical modulation device changing a reflection direction of light based on displacement of a mirror,
25 including:

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at least two pairs of electrodes having a fixed electrode and a movable electrode which is connected to a vibration plate and is provided in parallel; and

5 a structural part configured to displace the mirror based on displacement of the vibration plate by using an electrostatic force acting on the electrodes;

wherein the vibration plate is displaced by
10 an actuator, the actuator including

a vibration plate area displaced by an electrostatic force; and

electrodes facing each other via a first space in the vibration plate area;

15 wherein the first space is formed by a sacrificial layer process using a sacrificial layer removing hole; and

a barrier as a fluid resistance is formed between the first space and a second space situated
20 in the vicinity of the sacrificial layer removing hole.

The present invention is also achieved by a substrate having a structure, including:

a space which is formed by a sacrificial
25 layer process using a sacrificial layer removing hole

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and which is provided inside of the substrate; and
a barrier as a fluid resistance formed
between the space and the sacrificial layer removing
hole.

5 Other objects, features, and advantages of
the present invention will become more apparent from
the following detailed description when read in
conjunction with the accompanying drawings.

10 BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view having a
partial cross-sectional view of a liquid drop
discharge head of the present invention;

15 FIG. 2 is a plan view of a substrate of the
present invention forming an actuator of the present
invention;

FIG. 3 is a Y1-Y1 cross-sectional view of
the substrate shown in FIG. 2;

20 FIG. 4-(a) is an X1-X1 cross-sectional view
of the substrate shown in FIG. 2, FIG. 4-(b) is an
X2-X2 cross-sectional view of the substrate shown in
FIG. 2, FIG. 4-(c) is an X3-X3 cross-sectional view
of the substrate shown in FIG. 2;

25 FIG. 5 is a view showing a manufacturing

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process of the substrate, more specifically, FIG. 5-(a) is an X2-X2 cross-sectional view of the substrate shown in FIG. 2, and FIG. 5-(b) is a Y1-Y1 cross-sectional view of the substrate shown in FIG. 2;

5 FIG. 6 is a view showing a manufacturing process of the substrate, more specifically, FIG. 6-(a) is an X2-X2 cross-sectional view of the substrate shown in FIG. 2, and FIG. 6-(b) is a Y1-Y1 cross-sectional view of the substrate shown in FIG. 2;

10 FIG. 7 is a view showing a manufacturing process of the substrate, more specifically, FIG. 7-(a) is an X2-X2 cross-sectional view of the substrate shown in FIG. 2, and FIG. 7-(b) is a Y1-Y1 cross-sectional view of the substrate shown in FIG. 2;

15 FIG. 8 is a view showing a manufacturing process of the substrate, more specifically, FIG. 8-(a) is an X2-X2 cross-sectional view of the substrate shown in FIG. 2, and FIG. 8-(b) is a Y1-Y1 cross-sectional view of the substrate shown in FIG. 2;

20 FIG. 9 is a view showing a manufacturing process of the substrate, more specifically, FIG. 9-(a) is an X2-X2 cross-sectional view of the substrate shown in FIG. 2, and FIG. 9-(b) is a Y1-Y1 cross-sectional view of the substrate shown in FIG. 2;

25 FIG. 10 is a view showing a manufacturing

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process of the substrate, more specifically, FIG. 10-(a) is an X2-X2 cross-sectional view of the substrate shown in FIG. 2, and FIG. 10-(b) is a Y1-Y1 cross-sectional view of the substrate shown in FIG. 2;

5 FIG. 11-(a) is a plan view of a barrier pattern, FIG. 11-(b) is an X2-X2 cross-sectional view of FIG. 11-(a), and FIG. 11-(c) is a Y1-Y1 cross-sectional view of FIG. 11-(a);

 FIG. 12-(a) is a plan view of a barrier
10 pattern, FIG. 12-(b) is an X2-X2 cross-sectional view of FIG. 12-(a), and FIG. 12-(c) is a Y1-Y1 cross-sectional view of FIG. 12-(a);

 FIG. 13-(a) is a plan view of a barrier
 pattern, FIG. 13-(b) is an X2-X2 cross-sectional view
15 of FIG. 13-(a), and FIG. 13-(c) is a Y1-Y1 cross-sectional view of FIG. 13-(a);

 FIG. 14-(a) is a plan view of a barrier, FIG.
 14-(b) is an X2-X2 cross-sectional view of FIG. 14-
 (a), and FIG. 14-(c) is a Y1-Y1 cross-sectional view
20 of FIG. 14-(a);

 FIG. 15-(a) is a plan view of a barrier, FIG.
 15-(b) is an X2-X2 cross-sectional view of FIG. 15-
 (a), and FIG. 15-(c) is a Y1-Y1 cross-sectional view
 of FIG. 15-(a);

25 FIG. 16-(a) is a plan view of a barrier, FIG.

16-(b) is an X2-X2 cross-sectional view of FIG. 16-(a), and FIG. 16-(c) is a Y1-Y1 cross-sectional view of FIG. 16-(a);

FIG. 17-(a) is a plan view of the substrate forming the actuator and FIG. 17-(b) is a Y1-Y1 cross-sectional view of FIG. 17-(a);

FIG. 18 is an X1-X1 cross-sectional view of the substrate shown in FIG. 17;

FIG. 19 is an X2-X2 cross-sectional view of the substrate shown in FIG. 17;

FIG. 20 is an X3-X3 cross-sectional view of the substrate shown in FIG. 17;

FIG. 21 is a view showing a manufacturing process of the substrate, more specifically, FIG. 21-(a) is an X2-X2 cross-sectional view of the substrate shown in FIG. 17, and FIG. 21-(b) is a Y1-Y1 cross-sectional view of the substrate shown in FIG. 17;

FIG. 22 is a view showing a manufacturing process of the substrate, more specifically, FIG. 22-(a) is an X2-X2 cross-sectional view of the substrate shown in FIG. 17, and FIG. 22-(b) is a Y1-Y1 cross-sectional view of the substrate shown in FIG. 17;

FIG. 23 is a view showing a manufacturing process of the substrate, more specifically, FIG. 23-(a) is an X2-X2 cross-sectional view of the substrate

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shown in FIG. 17, and FIG. 23-(b) is a Y1-Y1 cross-sectional view of the substrate shown in FIG. 17;

FIG. 24 is a view showing a manufacturing process of the substrate, more specifically, FIG. 24-
5 (a) is an X2-X2 cross-sectional view of the substrate shown in FIG. 17, and FIG. 24-(b) is a Y1-Y1 cross-sectional view of the substrate shown in FIG. 17;

FIG. 25 is a view showing a manufacturing process of the substrate, more specifically, an X2-X2
10 cross-sectional view of the substrate shown in FIG. 17;

FIG. 26 is a view showing a manufacturing process of the substrate, more specifically, FIG. 26-
(a) is an X2-X2 cross-sectional view of the substrate
15 shown in FIG. 17, and FIG. 26-(b) is a Y1-Y1 cross-sectional view of the substrate shown in FIG. 17;

FIG. 27 is a view showing a manufacturing process of the substrate, more specifically, FIG. 27-
(a) is an X2-X2 cross-sectional view of the substrate
20 shown in FIG. 17, and FIG. 27-(b) is a Y1-Y1 cross-sectional view of the substrate shown in FIG. 17;

FIG. 28-(a) is a plan view of a barrier pattern, FIG. 28-(b) is a Y1-Y1 cross-sectional view of FIG. 28-(a), and FIG. 28-(c) is an X2-X2 cross-
25 sectional view of FIG. 28-(a);

FIG. 29-(a) is a plan view of a barrier pattern, FIG. 29-(b) is a Y1-Y1 cross-sectional view of FIG. 29-(a), and FIG. 29-(c) is an X2-X2 cross-sectional view of FIG. 29-(a);

5 FIG. 30-(a) is a plan view of a barrier pattern, FIG. 30-(b) is a Y1-Y1 cross-sectional view of FIG. 30-(a), and FIG. 30-(c) is an X2-X2 cross-sectional view of FIG. 30-(a);

FIG. 31 is a plan view of a substrate where
10 plural actuators are arranged;

FIG. 32-(a) is a plan view of a buffer room and FIG. 32-(b) is a cross-sectional view of a barrier part in the buffer room;

FIG. 33-(a) is a plan view of a buffer room
15 and FIG. 33-(b) is a cross-sectional view of a barrier part in the buffer room;

FIG. 34 is a perspective view of an ink cartridge;

FIG. 35 is a perspective view of an ink jet
20 recording device;

FIG. 36 is a cross-sectional view of a mechanism part of the ink jet recording device;

FIG. 37 is a cross-sectional view of a micro pump;

25 FIG. 38 is a view for explaining a partial

structure of an optical modulating device; and

FIG. 39 is a view for explaining a whole structure of the optical modulating device.

5 BEST MODE FOR CARRYING OUT THE INVENTION

A description of the present invention and details of drawbacks of the related art are now given, with reference to FIG. 1 through FIG. 39, including
10 embodiments of the present invention.

FIG. 1 is a perspective view having a partial cross-sectional view of a liquid drop discharge head 200 using an actuator of the present invention. An example of a side shooter type head
15 whereby an ink drop is discharged from a nozzle provided on a surface part of a substrate is discussed in this example. The liquid drop discharge head of this example has a laminated structure where three substrates 1, 2 and 3 are stacked.

20 In the first substrate 1, an individual electrode 4 is formed on a <110> silicon substrate by a laminating film. A vibration plate 5 is formed on the individual electrode 4 via a space 7. In other words, as shown in FIG. 1, the vibration plate 5
25 faces the individual electrode 4 via the space 7.

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The space 7 is formed by depositing a sacrificial layer, as well as a material of the individual electrode 4 or vibration plate 5 as the laminating layer, and then removing the sacrificial layer from a
5 sacrificial layer removing hole.

A discharging room 6 and a common liquid room 10 are provided on the second substrate 2 formed by a <110> silicon substrate connected on an upper surface of the first substrate 1. The discharging
10 room 6 is a room having a concave-shaped and rectangular parallelepiped configuration. The discharging room 6 is provided on the vibration plate 5 and the vibration plate 5 functions as a bottom wall of the discharging room 6. The common liquid
15 room 10 is provided at one end side of the plural discharging rooms 6 in the second substrate 2 so as to supply ink to the discharging rooms 6.

The third substrate 3 is connected to the upper surface of the second substrate 2. A nickel
20 substrate having a thickness of 50 μ is provided for the third substrate 3. A nozzle hole 8 is formed in the third substrate 3 so as to be connected to the discharging room 6. A groove 9 is provided in the third substrate 3 as fluid resistance for connecting
25 the common liquid room 10 and the discharging rooms 6.

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An ink supply opening 11 is provided in the third substrate 3 so as to be connected to the common liquid room 10.

Next, action of the liquid drop discharge head 200 having the above-mentioned structure is discussed. In a state where the discharging room 6 is filled with the ink, 40 V pulse electric potentials are applied to the individual electrode 4 by an oscillation circuit.

Based on that a surface of the individual electrode 4 is electrostatically charged by the application of the voltage so as to be positive, an electrostatic action works between the vibration plate 5 and the individual electrode 4 so that the vibration plate 5 is bent downward. As a result of this, the ink enters from the common liquid room 10 to the discharging room 6 via the groove 9 forming the fluid resistance.

After that, the pulse voltage to the individual electrode 4 is changed to 0 (zero) V, so that the vibration plate 5 bent downward due to the electrostatic force returns to the original state due to the rigidity of the vibration plate 5. As a result of this, pressure in the discharging room 6 drastically increases so that the ink liquid drop is

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discharged onto a recording paper via the nozzle hole
8. By repeating this, the ink can be continuously
discharged.

A force F working between electrodes is, as
5 shown in the following numerical formula 1, in
inverse proportion to the square of a distance d
between the electrodes. Hence, in order to drive at
a low voltage, it is important to make the space gap
between the individual electrode 4 and the vibration
10 plate 5 narrow.

[Numerical Formula 1]

$$F = (1/2) \times (\epsilon S / d^2) \times V^2$$

ϵ : dielectric constant

15 S: area of the surface of an electrode facing
another electrode

D: distance between the electrodes

V: applied voltage

20 As described below, in the liquid drop
discharge head 200 of the present invention, there is
no entry (invasion) by an upper layer film via the
sacrificial layer eliminating hole. Therefore, it is
possible to stably make the space gap between the
25 individual electrode 4 and the vibration plate 5 with

good precision so that the action of the vibration plate 5 due to the electrostatic force can be made maximum.

A manufacturing method and structure of an actuator as pressure generating means, which is configured for pressurizing a discharge fluid and used as a part of the liquid drop discharge head 200, are discussed.

10 [First example]

<Main part structure of actuator>

A main part structure of the actuator is discussed with reference to FIG. 2 through FIG. 11. FIG. 2 through FIG. 4 show an actuator part of the liquid drop discharge head 200 of the first example. FIG. 2 is a plan view of the actuator part. FIG. 3 is a Y1-Y1 cross-sectional view of the substrate shown in FIG. 2. FIG. 4-(a) is an X1-X1 cross-sectional view of the substrate shown in FIG. 2. FIG. 4-(b) is an X2-X2 cross-sectional view of the substrate shown in FIG. 2. FIG. 4-(c) is an X3-X3 cross-sectional view of the substrate shown in FIG. 2.

FIG. 5-(a) through FIG. 10-(a) are X2-X2 cross-sectional views of the actuator shown in FIG. 2. FIG. 5-(b) through FIG. 10-(b) are Y1-Y1 cross-

sectional views of the actuator shown in FIG. 2.

These drawings are described by following an order of the manufacturing steps of the actuator.

FIG. 11-(a) is a plan view of the vicinity
5 of the sacrificial layer removing hole. FIG. 11-(b) is a Y1-Y1 cross-sectional view of the vicinity of the sacrificial layer removing hole shown in FIG. 11-(a). FIG. 11-(c) is an X2-X2 cross-sectional view of the vicinity of the sacrificial layer removing hole
10 shown in FIG. 11-(a). For the convenience of explanation, only a single actuator is shown in FIG. 2 through FIG. 11. As shown in FIG. 4-(a) through (c), since the actuator having a multilayer structure is transparent and therefore the inside structure of
15 the actuator can be seen through, the structure of the actuator is shown by a solid line in FIG. 2.

The space 7 shown in FIG. 1 corresponds to a first space 24a in FIG. 2. Therefore, a lower part electrode 23a corresponding to the individual
20 electrode 4 shown in FIG. 1 is provided right under the first space 24a. A laminating film 34 is positioned above the first space 24a. The first space 24a is a space having a rectangular plate shaped configuration. The first space 24a is
25 separated from a partition part 36 by a separation

groove 33. A part corresponding to the separation groove 33 filled with a material is shown in FIG. 4-(a) and FIG. 4-(c).

A vibration plate is situated at a part where an outline of the first space 24a is projected on a laminating film positioned above the first space 24a in FIG. 4-(a) and FIG. 4-(c). This vibration plate is an area of a part of the laminating film 26 and therefore is called a vibration plate area 34a. Furthermore, since the first space 24a is an area corresponding to the vibration plate area 34a, the first space 24a is called a vibration plate corresponding area. Therefore, the vibration plate area 34a and the vibration plate corresponding area (the first space 24a) face each other in upper and lower directions and overlap as seen from an upper part.

Although the laminating film 34 forming the vibration plate may be formed as a single layer or plural layers, the laminating layer 34 in this example has a multilayer structure where an insulation film 25, an upper part electrode 26, a film bending prevention film 27, and a resin film 28 are stacked from the lower part.

The separation groove 33 is filled with a

material (an insulation film 44) by the following step. If the width of the separation groove 33 is large, when the separation groove 33 is filled with the material, a part of the lower layer corresponding to the groove width has a step having a concave shaped configuration. This step gives bad influence to layers stacked above the separation layer 33 in the following step so that the thickness of the vibration plate area is uneven. Because of this, the groove width of the separation groove 33 is made as small as possible in order to prevent the generation of the step. In the examples shown in FIG. 2 and FIG. 3, the groove width of the separation groove 33 is made small so that the generation of the step is prevented.

In FIG. 2, a length A of a short side of the vibration plate area 34a is 120 μm and a length B of a long side of the vibration plate area 34a is 800 μm . A voltage can be applied so that the vibration plate area 34a can be displaced by an electrostatic force. The lower part electrode 23a is patterned on a Si substrate 21 via the insulation film 22. An insulation film 40 is formed on the lower part electrode 23a to prevent generation of short-circuit with the upper part electrode 26.

In FIG. 2 and FIG. 4-(b), the sacrificial

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layer removing hole 31 is formed at the outside of the vibration plate area 34a so as to penetrate through the insulation film 25, the upper part electrode 26, and the film bending prevention layer 27 (See claim 2). If the sacrificial layer removing hole 31 or a barrier 29 is arranged in the vibration plate area 34a, the efficiency of the displacement of the vibration plate becomes bad and complex displacement happens and therefore it is difficult to design for obtaining a desirable vibration property. On the other hand, by arranging the sacrificial layer removing hole 31 or the barrier 29 outside of the vibration plate area 34a, it is possible to obtain the desirable vibration property and the liquid drop discharge head 200 and an actuator having high reliability.

Referring to FIG. 2, FIG. 4-(b), and FIG. 4-(c), the vibration plate area 34a forms a vibration plate displaced by an electrostatic force acting between the lower electrode 23a and the upper part electrode 26 in the first space 24a. The lower part electrode 23a faces the vibration plate area 34a via the first space 24a. The first space 24a is formed by a sacrificial layer process using the sacrificial layer removing hole 31. The barrier 29 as a fluid

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resistance is formed between the first space 24a and a second space 24b in the vicinity of the sacrificial layer removing hole 31 (See claim 1 and claim 10).

The sacrificial layer removing hole 31 is sealed by the resin film 28. In a case where the resin film 28 is formed as a wet film of the liquid drop by a spin coating method, the barrier 29 as the fluid resistance and a connecting part 30 are provided between the space 24b in the vicinity of the sacrificial layer removing hole 31 and the space 24a situated under the vibration plate area 34a, so that the resin material 28 is prevented from seeping from the sacrificial layer removing hole 31 into the first space 24a situated under the vibration plate area 34a. This is because if the resin material seeps into the first space 24a situated under the vibration plate area 34a, the vibration plate area 34a is adhered to the lower part electrode 23a and therefore cannot work as an actuator. By providing the barrier 29 in the vicinity of the sacrificial layer removing hole 31, as compared with a structure not having the barrier 29, the resin material 28 can be prevented from seeping into the first space 24a situated under the vibration plate area 34a so that it is possible to obtain a high yield rate.

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Thus, by forming the barrier 29, the sacrificial layer removing hole 31 can be sealed with a method not using a vacuum device. When the sacrificial layer removing hole 31 is sealed with the resin film 28, it is possible to prevent the resin film 28 from entering into the space 24a by the fluid resistance of the barrier 29. Since the sacrificial layer removing hole 31 is sealed by the resin film 28 that is a part of the vibration plate forming film, it is not necessary to provided a process for only sealing and therefore the number of processes can be reduced. Because of this, it is possible to obtain the liquid drop discharge head 200 and the actuator having high reliability at low cost.

In this example, (i) the first space 24a for displacing the vibration plate area 34a, (ii) the separation groove 33 including the connection opening connecting between the sacrificial layer removing hole 31 and the first space 24a, and (iii) the second space 24b that is an area surrounded by the barrier 29 have, for example, thicknesses of 0.40 μm . A sacrificial layer process is used for forming the first and second spaces 24a and 24b. The sacrificial layer removing hole 31 is formed in the vibration plate forming film 34 via the upper electrode opening

part 32.

The sacrificial layer removing holes 31 are arranged at even intervals equal to or less than the length of the short side A of the vibration plate area 34a along the long side B of the vibration plate area 34a. The sacrificial layer removing holes 31 are formed at same positions of the sides facing each other. Thus, it is possible to efficiently etch the sacrificial layer so as to form the first and second spaces 24a and 24b, by arranging plural sacrificial layer removing holes 31.

In a case of the liquid drop discharge head 200, generally, an actuator configured to discharge the liquid drop has a long and narrow rectangular shaped configuration and a neighboring actuator is arranged at a long side. Since the sacrificial layer etching is isotropic, removing efficiency of the sacrificial layer is high if the sacrificial layer removing hole 31 is arranged in the center of the vibration plate area 34a. However, if the sacrificial layer removing hole 31 is arranged in the displacement area of the vibration plate, a vibration property of the actuator may be given bad influence. Hence, it is necessary to arrange the sacrificial layer removing hole 31 outside of the vibration plate

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area 34a.

As shown in FIG. 2, in this example, a connection part 30 configured to connect the first space 24a and the second space 24b is provided in the barrier 29 (See claim 3). Because of this structure, when the fluid resistance in the vicinity of the sacrificial layer removing hole 31 is formed, it is possible to sufficiently secure freedom of design from the perspective of processing and structure.

Hence, it is possible to design and manufacture the actuator or the liquid drop discharge head 200 without having a limitation on design of the fluid resistance in the vicinity of the sacrificial layer removing hole 31 and the connection part 30.

Therefore, it is possible to improve yield rate in the manufacturing process and qualities of the liquid drop discharge head 200 and the actuator.

The liquid drop discharge head 200 shown in FIG. 1 includes a discharge room 6, a common liquid room 10 and plural actuators. The discharge room 6 is connected to a nozzle hole 8 configured to discharge the liquid drop. The ink supplied to the discharging room 6 is received in the common room 10. The actuator has the vibration plate as pressure generating means, so that discharging energy is given

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to the ink in the discharging room 6 and thereby the ink can be discharged from the nozzle 8. In the actuator, since the first space is manufactured by a process using the sacrificial method process, it is possible to manufacture the actuator having a high yield rate at a low cost and provide the liquid drop discharge head 200 having high quality and low dispersion (See claim 5).

10 (Manufacturing Process of Actuator)

Next, the manufacturing processes of the actuator are discussed with reference to FIG. 5 through FIG. 10. In FIG. 5 through FIG. 10, (a) is an X2-X2 cross-sectional view of FIG. 2 and (b) is a Y1-Y1 cross-sectional view of FIG. 2.

1. First step (See FIG. 5-(a) and FIG. 5-(b))

The insulation film (thermal oxidation film) 22 having a thickness of $1.6\ \mu\text{m}$ is formed on the Si substrate 21 having a thickness of $400\ \mu\text{m}$. Then, P doped silicon having a thickness of $0.4\ \mu\text{m}$ is formed as the lower part electrode. Then, the lower electrode 23a and a part 36a of the barrier are separately formed by a litho-etching method. After that, an insulation film (CVD oxidation film) 40 of

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lower electrode 23a and the part 36a of the barrier are stacked so as to have a thickness of 0.2 μm . The insulation film 40 works as a mask material protecting the lower part electrode 23a in the sacrificial layer process, and as a protection film preventing an electrical short circuit of the lower part electrode 23a and the upper part electrode 26.

2. Second step (See FIG. 6-(a) and FIG. 6-(b))

The sacrificial layer (non-doped polysilicon) having a thickness of 0.4 μm is deposited by CVD method so as to form a space gap. Then, the separation groove 33 by which an area of the first and second space 24a and 24b and a part 36b of the barrier are separated and the barrier 29 are formed by the litho-etching method. After that, an insulation film (CVD oxidation film) 25 is stacked so as to have a thickness of 0.15 μm . The insulation film 25 works as a mask material protecting the lower part electrode 23a in the sacrificial layer process, and as a protection film preventing an electrical short circuit of the lower part electrode 23a and the upper part electrode 26.

3. Third step (See FIG. 7-(a) and FIG. 7-(b))

P doped silicon having a thickness of $0.2\ \mu\text{m}$ is deposited and then the upper electrode 26a and a part 36c of the barrier are separately formed by the litho-etching method. At the same time, a protection hole (upper part electrode opening part) 32 is opened larger than the sacrificial layer removing hole 31, in order to prevent the upper electrode 26a having the same material as the sacrificial layer 24a from being etched at the time of removal of the sacrificial layer. Then, a nitride layer 27 is deposited as a vibration plate bending prevention layer by LP-CVD method so as to have a thickness of $0.2\ \mu\text{m}$.

4. Fourth step (See FIG. 8-(a) and FIG. 8-(b))

The sacrificial layer removing hole 31 is formed by the litho-etching method and then the resist is removed.

5. Fifth step (See FIG. 9-(a) and FIG. 9-(b))

The sacrificial layer is completely removed by a method having a high selectivity of etching rate of the sacrificial layer of the first and second spaces 24a and 24b and the insulation films 40 and 25, such as a wet etching method using alkali solution,

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so that the first and second spaces 24a and 24b are formed. In a case where TMAH or KOH is used as the alkali solution, it is possible to implement sacrificial layer etching having high selectivity.

5 In addition, it is possible to implement the sacrificial layer etching by SF_6 plasma process or dry etching using XeF_2 gas.

6. Sixth step (See FIG. 10-(a) and FIG. 10-(b))

10 The resin film 28 having a thickness of 1.8 μm is formed as a wet film of the liquid drop by a spin coating method, considering film reduction at the time of pad forming. At this time, the sacrificial layer removing hole 31 is completely
15 sealed by the resin film 28. After that, only an electrode wiring taking pad part (not shown) is opened by the litho-etching method. Any material can be used as the resin film, as long as it has corrosion endurance against the liquid drops such as
20 PBO (Poly-p-phenylene-benzo-bis-oxazole) film or polyimide film, can be formed by a spin coating method, and can completely seal the sacrificial layer removing hole 31.

 Thus, the actuator part corresponding to the
25 substrate 1 shown in FIG. 1 is completed. By

combining this with the substrates 2 and 3 shown in FIG. 1, the liquid drop discharge head 200 is completed.

The resin film 28 seals the sacrificial layer removing hole 31 in air. Therefore, a situation where the space is vacuum sealed with a film deposited by a PVD or CVD method using a vacuum device so that the inside of the gap has a negative pressure due to atmospheric exposure, the vibration plate is bent, and desirable displacement cannot be obtained, can be prevented.

For example, in a case where, in the actuator having the first and second spaces 24a and 24b formed by removing the sacrificial layer by the wet etching method using TMAH, the sacrificial layer removing hole 31 has a cross-sectional area of $4.5 \mu\text{m}^2$ ($3 \times 1.5 \mu\text{m}$) and a resin film material having a coefficient of viscosity of 110cp and a film thickness of $1.8 \mu\text{m}$ is formed in the first and second spaces 24a and 24b having heights g of $0.4 \mu\text{m}$ by a spin coating method, the relationship between V/S ratio and seeping of the resin film material into the sacrificial layer removing hole 31 is shown in the following table 1. Here, "a" and "b" in the table 1 represent measurements of the separation groove 33

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(hereinafter "partition part 33" because the material fills in after the actuator is completed so that the separation groove 33 forms a partition part) in the vicinity of the sacrificial layer removing hole 31 shown in FIG. 11; "c" in the table 1 represents the width of the connection part 30 of the barrier 29; "g" in the table 1 represents heights of the first and second spaces 24a and 24b; "V" in the table 1 represents a volume ($V=a \times b \times g$) of the second spaces 24b surrounded by the barrier 29 in the vicinity of the sacrificial layer removing hole 31 and the partition part 33; and "S" in the table 1 represents an area ($S=c \times g$) of a cross section of the connection part 30 of the barrier 33.

15 [Table 1]

Structure	g	a	b	c	V	S	V/S	Seeping of Resin Film
	μm	μm	μm	μm	μm^3	μm^2	μm	
1	0.4	8.0	7.0	4.0	22.4	1.6	14.0	×
2	0.4	10.0	7.0	4.0	28.0	1.6	17.5	△
3	0.4	10.5	7.0	4.0	29.4	1.6	18.4	○
4	0.4	11.0	7.0	4.0	30.8	1.6	19.3	○
5	0.4	12.0	7.0	4.0	33.6	1.6	21.0	○
6	0.4	13.0	7.0	4.0	36.4	1.6	22.8	○

×: seeping at all bits

△: seeping at a partial bit

○: no seeping at all bits

Thus, it is found that a condition whereby the resin film 28 does not seep into the sacrificial layer removing hole 31 in the structures shown in table 1 is that the value of V/S is equal to or larger than 18.4. Therefore, in the case where the sacrificial layer removing hole 31 has a cross-sectional area of $4.5 \mu\text{m}^2$ ($3 \times 1.5 \mu\text{m}$) and a resin film material having a coefficient of viscosity of 110cp and a film thickness of $1.8 \mu\text{m}$ is formed in the first and second spaces 24a and 24b having heights g of $0.4 \mu\text{m}$ by the spin coating method, it is possible to prevent the resin film material from seeping into the sacrificial layer removing hole 31 and prevent the yield rate from decreasing in this step, by setting measurements satisfying the following numerical formula 2.

[Numerical formula 2]

$$V/S > 18.4$$

20

It is also possible to prevent the resin film 28 from seeping into the first space 24a by making the cross section of the sacrificial layer removing hole 31 as small as possible in a range where the sacrificial layer can be removed or making

25

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the coefficient of viscosity of the resin film material high. In a case where the sacrificial layer etching method is a method other than the wet etching method of TMAH, since the condition shown in the numerical formula 2 may not be always satisfied, it is necessary to examine a proper value if necessary.

In this example, the barrier 29 is provided and a single connection opening 30 is provided so that the resin film 28 is prevented from seeping into the first and second spaces 24a and 24b. A configuration of the barrier 29 whereby the sacrificial layer can be removed and the fluid resistance is made large (at least "V" and "S" satisfy the numerical formula 2, for example) varies.

In a case where, as shown in FIG. 14 through FIG. 16, a barrier having a configuration where a fluid path enters into the connection part 30 is provided, the fluid resistance between the connection part 30 and the sacrificial layer removing hole 31 is high and therefore it is possible to further prevent the seeping of the resin film into the sacrificial layer removing hole 31 as compared with the examples shown in FIG. 11 through FIG. 13.

In an example shown in FIG. 12, a connection part 30-1 (cross section S1) and a connection part

30-2 (cross section S2) are provided. In this case, the cross section S mentioned in the table 1 and the numerical formula 2 is calculated as $S=S1+S2$.

In an example shown in FIG. 13, a connection
5 part 30-1 (cross section S1), a connection part 30-2 (cross section S2), and a connection part 30-3 (cross section S3) are provided. In this case, the cross section S mentioned in the table 1 and the numerical formula 2 is calculated as $S=S1+S2+S3$.

10 In an example shown in FIG. 14, a single connection part 30 is provided and a barrier 29-1 having a rectangular configuration is provided in the fluid path from the sacrificial layer removing hole 31 to the connection part 30. The fluid surrounds
15 the barrier 29-1 and arrives at the connection part 30.

In an example shown in FIG. 15, a single connection part 30 is provided and plural barriers 29-2a, 29-2b and 29-2c having plate configurations
20 are provided in a maze shape from the sacrificial layer removing hole 31 to the connection part 30, so that the fluid resistance is increased.

In an example shown in FIG. 16, a barrier 29-3 is provided from the sacrificial layer removing
25 hole 31 to the connection part 30 in a shape like a

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rectangle not having one side. Because of this, the fluid path makes a detour so that the fluid resistance is increased and two connection parts 30-1 and 30-2 are formed.

5 In the examples shown in FIG. 12, FIG. 13, and FIG. 16, two or more connection parts configured to connect the first and second spaces 24a and 24b are provided in the barrier (See claim 4). Thus, by providing plural connection parts, it is possible to
10 easily and efficiently remove the sacrificial layer of the vibration plate area. Because of this, it is possible to design easily and freely such as making parts and cross sections of the connection part proper.

15

[Second example]

(Structure of Actuator)

The second example is discussed with reference to FIG. 17 through FIG. 27.

20

FIG. 17-(a) is a plan view of the actuator of the liquid drop discharge head 200 and FIG. 17-(b) is a Y1-Y1 cross-sectional view of FIG. 17-(a). FIG. 18 is an X1-X1 cross-sectional view of the substrate shown in FIG. 17. FIG. 19 is an X2-X2 cross-
25 sectional view of the substrate shown in FIG. 17.

FIG. 20 is an X3-X3 cross-sectional view of the substrate shown in FIG. 17. FIG. 21 through FIG. 27 are views showing a manufacturing process of the substrate. For the convenience of explanation, only
5 a single actuator is shown in FIG. 21 through FIG. 27.

As shown in FIG. 17 through FIG. 20, the vibration plate area 74a is separated from the partition part 66 by the separation groove 63 filled with the material. The vibration plate area 74a has
10 a film structure where the insulation film 65, the upper electrode 66, the film bending prevention film 67 and the resin film 68 are stacked from the lower layer so as to form a laminating film 64. The width of the separation groove 63, as well as the
15 separation groove 33, is made narrow so that a concave (step) is not formed on a surface at a part corresponding to the separation groove 63.

A length A of a short side of the vibration plate area 74a is 120 μm and a length B of a long
20 side of the vibration plate area 74a is 800 μm . A voltage can be applied so that the vibration plate area 74a can be displaced by an electrostatic force. The lower part electrode 63a is patterned on a Si substrate 61 via the insulation film 62.

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An insulation film 40 is formed on the lower part electrode 63a to prevent generation of short-circuit against the upper part electrode 66. The separation groove 33 including the connection part 70
5 connecting between the first space 64a for displacing the vibration plate area 74a and the second space 64b in the vicinity of the sacrificial layer removing hole 71, and the second space 64b that is an area 79 surrounded by the barrier 69 have, for example,
10 thicknesses of 0.40 μm .

The barrier 69 has the same function as the barrier 29 in the first example, that is, a wall of the fluid resistance provided between the first space 64a and the second space 64b in the vicinity of the
15 sacrificial layer removing hole 71 (See claims 1 and 10). In addition, the connection part 70 connecting the first and second spaces 64a and 64b, as well as the connection part 30 in the first example, is provided in the connection part 70 (See claim 3).

20 A sacrificial layer process is used for forming the first and second spaces 64a and 64b. The sacrificial layer removing holes 71 are formed in the vibration plate forming film 64 via the upper electrode opening part 72. The sacrificial layer
25 removing holes 71 are arranged at even intervals

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equal to or less than lengths of the short side A of the vibration plate area 74a along the long side B of the vibration plate area 74a. The sacrificial layer removing holes 71 are formed at same positions of the
5 sides facing each other. Thus, it is possible to efficiently etch the sacrificial layer so as to form the first and second spaces 64a and 64b, by arranging plural sacrificial layer removing holes 71.

In a case of the liquid drop discharge head
10 200, generally, an actuator configured to discharge the liquid drop has a long and narrow rectangular shaped configuration and a neighboring actuator is arranged at a long side. Since the sacrificial layer etching is isotropic, removing efficiency of the
15 sacrificial layer is high if the sacrificial layer removing hole 71 is arranged in the center of the vibration plate area 74a. However, if the sacrificial layer removing hole 71 is arranged in the displacement area of the vibration plate, a vibration
20 property of the actuator may be given bad influence. Hence, it is necessary to arrange the sacrificial layer removing hole 71 outside of the vibration plate area 74a. Thus, as well as the barrier 29 and the sacrificial layer removing hole 31, the barrier 69
25 and the sacrificial layer removing hole 71 are

arranged outside of the vibration plate area 74a (See claim 2).

The sacrificial layer removing hole 61 is sealed by the resin film 68. In a case where the
5 resin film 68 is formed as a wet film of the liquid drop by a spin coating method, the barrier 69 as the fluid resistance and a connecting part 70 are provided between the space 64b in the vicinity of the sacrificial layer removing hole 71 and the space 64a
10 situated under the vibration plate area 74a, so that the resin material 68 is prevented from seeping from the sacrificial layer removing hole 71 into the first space 64a situated under the vibration plate area 74a.

This is because if the resin material seeps
15 into the first space 64a situated under the vibration plate area 74a, the vibration plate area 74a is adhered to the lower part electrode 63a and therefore cannot work as an actuator. By providing the barrier 69 in the vicinity of the sacrificial layer removing
20 hole 71, as compared with a structure not having the barrier 69, the resin material 68 can be prevented from seeping into the first space 64a situated under the vibration plate area 74a so that it is possible to obtain a high yield rate.

It is possible to prevent the resin film 68 from seeping into the first space 64a by making the cross section of the sacrificial layer removing hole 31 as small as possible in a range where the
5 sacrificial layer can be removed or making the coefficient of viscosity of the resin film material high.

(Manufacturing Process of Actuator)

10 Next, the manufacturing processes of the actuator are discussed with reference to FIG. 21 through FIG. 27. In FIG. 21 through FIG. 27, (a) is an X2-X2 cross-sectional view of FIG. 17 and (b) is a Y1-Y1 cross-sectional view of FIG. 17.

15

1. First step (See FIG. 21-(a) and FIG. 21-(b))

 The insulation film (thermal oxidation film) 62 having a thickness of 1.6 μm is formed on the Si substrate 61 having a thickness of 400 μm . Then, P
20 doped silicon having a thickness of 0.4 μm is formed as the lower part electrode. Then, the lower electrode 63a and a part 66a of the barrier are separately formed by a litho-etching method. After that, an insulation film (CVD oxidation film) 60 of
25 lower electrode 63a and the part of the barrier are

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stacked so as to have a thickness of 0.2 μm . The insulation film 60 works as a mask material protecting the lower part electrode 63a in the sacrificial layer process, and as a protection film preventing an electrical short circuit of the lower part electrode 63a and the upper part electrode 66.

2. Second step (See FIG. 22-(a) and FIG. 22-(b))

The sacrificial layer (non-doped polysilicon) having a thickness of 0.4 μm is deposited by CVD method so as to form a space gap. Then, a part 70 functioning as the connection part 79 is etched by the litho-etching method so as to have a desirable height, and the resist is removed. That is, all of a height direction of the connection part 70 is not opened but the height direction is formed like a dam. On this point, the connection part 70 is different from the connection part 30 in the first example.

Next, the separation groove 63 configured to separate an area of the first and second spaces 64a and 64b and a part 66b of the partition, is formed by the litho-etching method.

3. Third step (See FIG. 23-(a) and FIG. 23-(b))

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An insulation film (CVD oxidation film) 65 is stacked so as to have a thickness of 0.15 μm . The insulation film 65 works as a mask material protecting the lower part electrode 63a in the sacrificial layer process, and as a protection film preventing an electrical short circuit of the lower part electrode 63a and the upper part electrode 66.

4. Fourth step (See FIG. 24-(a) and FIG. 24-(b))

P doped silicon having a thickness of 0.2 μm is deposited and then the upper electrode 66a and a part 66c of the barrier are separately formed by the litho-etching method. At the same time, a protection hole 82 is opened larger than the sacrificial layer removing hole 71, in order to prevent the upper electrode 66a having the same material of the sacrificial layers 64a and 64b from being etched. Then, a nitride layer 67 is deposited as a vibration plate bending prevention layer by LP-CVD method so as to have a thickness of 0.2 μm .

5. Fifth step (See FIG. 25)

The sacrificial layer removing hole 71 is formed by the litho-etching method and then the resist is removed.

6. Sixth step (See FIG. 26)

The sacrificial layer is completely removed by a method having a high selectivity of etching rate of the sacrificial layer of the first and second spaces 64a and 64b and the insulation films 60 and 65, such as a wet etching method using alkali solution, so that the first and second spaces 64a and 64b and the connection part 70 are formed. In a case where TMAH or KOH is used as the alkali solution, it is possible to implement sacrificial layer etching having high selectivity. In addition, it is possible to implement the sacrificial layer etching by SF₆ plasma process or dry etching using XeF₂ gas.

15

7. Seventh step (See FIG. 27)

The resin film 68 having a thickness of 1.8 μ m is formed as a wet film of the liquid drop by a spin coating method, considering film reduction at the time of pad forming. At this time, the sacrificial layer removing hole 71 is completely sealed by the resin film 68. Since the barrier 69 as the fluid resistance and the connection part 70 are provided, the resin film 69 is prevented from seeping from the sacrificial layer removing hole 71 into the

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first and second spaces 64a and 64b. After that,
only an electrode wiring taking pad part (not shown)
is opened by the litho-etching method. Any material
can be used as the resin film, as long as it has
5 corrosion endurance against the liquid drops such as
PBO (Poly-p-phenylene-benzo-bis-oxazole) film or
polyimide film, can be formed by a spin coating
method, and can be completely sealed by the
sacrificial layer removing hole 61.

10 Thus, the actuator part corresponding to the
substrate 1 shown in FIG. 1 is completed. By
combining this to the substrates 2 and 3 shown in FIG.
1, the liquid drop discharge head 200 is completed.

 The resin film 68 seals the sacrificial
15 layer removing hole 71 in air. Therefore, a
situation where the space is vacuum sealed like a
film deposited by a PVD or CVD method using the
vacuum device so that the inside of the gap has a
negative pressure due to atmospheric exposure, the
20 vibration plate is bent, and desirable displacement
cannot be obtained, can be prevented.

 In the first example (FIG. 2 through FIG.
16), in a case where the numerical formula 2 is not
satisfied due to the change of the height of the
25 space 24a or the process, it is necessary to change

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(mask-revise) a measurement of "c" shown in Fig. 11-(a), for example, so that a cross-sectional area of the connection part 30 satisfies the numerical formula 2 and thereby it is possible to prevent the resin film 28 from seeping into the sacrificial layer removing hole 31. This may cause a complex procedure and increasing of the cost. On the other hand, in the second embodiment, a cross-sectional area of the connection part 70 of the first and second spaces 64a and 64b are made proper only by etching the part 70a functioning as a connection part in FIG. 22-(a) so that the part 70a has a desirable height. Hence, it is possible to achieve a desirable effect only by process control without undertaking a complex procedure and cost.

In the second embodiment, the height of the connection part is different from the first example. Examples of the barrier 69 and the connection part are shown in FIG. 28 through FIG. 30. In an example shown in FIG. 28, a single connection part 70 is provided and measurement in a height direction (right and left directions in FIG. 28-(b)) of the connection part 70 is made smaller than the first example shown in FIG. 11.

In an example shown in FIG. 29, three

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connection parts 70-1, 70-2 and 70-3 are provide
corresponding to a single sacrificial layer removing
hole 71 and measurements in a height direction (right
and left directions in FIG. 29-(b)) of the connection
5 parts 70-1, 70-2 and 70-3 are made smaller than the
first example shown in FIG. 11.

In an example shown in FIG. 30, a modified
example of the example shown in FIG. 16, a barrier
69-3 having a configuration of a rectangle not having
10 one side is arranged at a fluid path from the
sacrificial layer removing hole 71 through the
connection part, so that the fluid path is made to
detour so that the fluid resistance is increased and
two connection parts 70-10 and 70-20 are formed.
15 Convex parts 69-10 and 69-20 are formed in the
connection parts 70-10 and 70-20 so that cross-
sectional views of the connection parts 70-10 and 70-
20 have concave configurations as shown in FIG. 30-
(b) and a lot of changing parts of configuration
20 measurement are provided so that the fluid resistance
can be fine-adjusted.

In these examples, the volume V and cross
section S in the numerical formula 2 are calculated
following the first example. As shown in FIG. 28
25 through FIG. 30, size and cross-sectional

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configurations of the connection part are made the same as the configuration of the barrier 69 wherein the sacrificial layer can be removed and the fluid resistance is increased (for example, at least both V
5 and S satisfy the numerical formula 2). Especially, as shown in FIG. 30, in a structure where the barrier 69-3 having the configuration of a rectangle not having one side is arranged at the fluid path so that the fluid path is complex and the convex parts 69-10
10 and 69-20, the fluid resistance is increased and therefore a better effect of prevention of seeping of the resin film into the sacrificial layer removing hole 71 can be achieved than the examples shown in FIG. 28 and FIG. 29.

15 In the examples shown in FIG. 29 and FIG. 30, two or more connection parts connected the first space 64a and the second space 64b are provided (See claim 4). Under this structure, as well as the first example, it is possible to improve the removing
20 efficiency of the sacrificial layer of the vibration plate area.

[Third example]

The third example is discussed with
25 reference to FIG. 31 and FIG. 32. FIG. 31 shows a

part of the liquid drop discharge head 200 wherein a connection tube (substrate) 800 having the first space 24a or 74a of the actuators 90, 91 and 92 formed by the manufacturing method of the actuator in the first and second examples and the first spaces are connected. A buffer room 820 shown in FIG. 32 or a buffer room 821 shown in FIG. 33 is connected to an extended part from the connection tube 800 shown in FIG. 31.

FIG. 32-(a) is a plan view of the buffer room 820 and FIG. 32-(b) is a cross-sectional view of a barrier part in the buffer room. FIG. 33-(a) is a plan view of the buffer room 821 and FIG. 33-(b) is a cross-sectional view of a barrier part in the buffer room.

It is normal that an actuator part (space part) of the liquid drop discharge head including the actuators 90 through 92 shown in FIG. 31 is insulated from the outside in order to prevent degradation of the property due to the entering of moisture and foreign bodies from the outside. However, the pressure in the actuator space that gives an influence to the liquid drop discharge property is sensitive to the change of the external environment and may be influenced by the change of the

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temperature or the pressure.

In order to prevent this, the actuators 90 through 92 are connected to the connection tube 800 shown in FIG. 31 and a part of the connection tube 800 is further connected to the buffer rooms 820 and 821 having a volume much larger than a space volume of the actuator which can absorb the change of the pressure shown in FIG. 32.

The connection tube 800 and the space parts such as the buffer rooms 820 and 821 are formed by a sacrificial layer process the same as the process used for forming the first space corresponding to the vibration plate in the first and second examples. Therefore, the sacrificial layer removing holes 831 (See FIG. 31) and 931 (See FIG. 32 and FIG. 33) and the upper part electrode protection holes 832 (See FIG. 31) and 932 (See FIG. 32 and FIG. 33) are arranged in the connection tube 800 and the buffer rooms 820 and 821, as well as the actuator. In addition, in order to prevent the resin film from seeping into the sacrificial layer removing holes 831 and 931, the burrier 829 (See FIG. 31) and 929 (See FIG. 32 and FIG. 33) and the connection openings 833 (See FIG. 31) and 933 (FIG. 32) are arranged.

Vibration areas of the buffer rooms 820 and

821 larger than the vibration plate areas of the actuators 90, 91, and 92 shown in FIG. 31 are formed simultaneously with the sacrificial layer removing process of the actuator part. Therefore, the
5 sacrificial layer removing holes 931 are formed on the buffer rooms 820 and 821 with a equal interval and two-dimensionally. The connection tube 800 shown in FIG. 31 and the buffer rooms 820 and 821 shown in FIG. 32 and FIG. 33 are formed by a manufacturing
10 method similar with the manufacturing method of the first example.

In FIG. 32, by proving plural connection openings 933 for a single sacrificial layer removing hole 931, it is possible to remove the connection
15 tube 800 and the sacrificial layer in the buffer room 820 more efficiently than a case where a single connection opening is provided.

In this example, for the sacrificial layer removing holes 831 and 931, each of the connection
20 openings 833 and 933 are provided on four sides of the burrier 829 and 929. However, the present invention is not limited to this. There is no limitation about the number and arrangement of the connection openings 831 and 931 as long as the resin
25 film does not seep in and the sacrificial layer of

the connection tube 800 and the buffer room 820 can be efficiently removed.

The buffer room 820 shown in FIG. 32 has a structural film 950 having a structure the same as the vibration plate of the actuator. However, since this structural film 950 is fixed to the base layer 951 by the barrier 929, it is not possible to bend the structural film 950 of the buffer room 820 and to change the volume of the buffer room 820.

On the other hand, the buffer room 821 shown in FIG. 33 is formed by the manufacturing method of the second example. A structural film 960 is separated from a base layer 961 by a connection part 939. Hence, it is possible to bend the structural film 960 of the buffer room 821 and to change the volume of the buffer room 821. Therefore, a pressure change of the first space of the actuator 90, 91 and 92 due to drastic atmospheric change can be absorbed by bending the structural film 960 of the buffer room 821 and it is possible to follow the atmospheric change as compared with the buffer room 820 and secure a more stable liquid drop discharge property.

Here, it is necessary to only provide space inside of the connection tube 800 and connect the connection tube 800 to the first space of the

actuators 90, 91 and 92. Therefore, the connection tube 800 is formed by a sacrificial layer process using the sacrificial layer removing hole and an electrode is not provided. The barrier 829

5 functioning as the fluid resistance is provided between the space forming the connection part and the sacrificial layer removing hole 831 as discussed in the first example, and thereby the substrate is manufactured by a method the same as the method in

10 the first example in a state where the space is prevented from being closed in a sealing process of the sacrificial layer removing hole (See claim 12). Thus, the substrate having a simple space can be easily manufactured with high precision.

15 The actuators 90, 91 and 92 connected to the buffer room 820 or 821 via the connection tube 800 can be manufactured by the method discussed in the first or second example. The buffer rooms 800 and 821 which have large areas and prevent a vibration

20 property dispersion due to the atmospheric change of the actuators 90, 91 and 92 and connection tube 800 can be efficiently formed by a sacrificial layer process. Furthermore, by making a part and a cross section of the connection part proper, it is possible

25 to efficiently remove the sacrificial layer of the

buffer room and the connection part by a process the same as the process for removing a sacrificial layer of the vibration plate area and to reduce the number of the processes. Thus, it is possible to obtain an actuator and liquid drop discharge head having a high function, high quality, and less dispersion of the property, at a low cost.

[Fourth example]

Next, an ink cartridge of the present invention is discussed with reference to FIG. 34. This ink cartridge is formed by unifying the liquid drop discharge head having the nozzle 8 and others and discussed in the first through third example and the ink tank 815 supplying the ink to the liquid drop discharge head 200 (See claim 6).

Thus, in the case of an ink tank unifying type liquid drop discharge head, low cost and reliability of the head leads to low cost and reliability of the entire ink cartridge. Hence, it is possible to improve the yield rate and reliability of the ink cartridge by reducing cost and the amount of bad manufacturing, and thereby it is possible to reduce the cost for the head unifying type ink cartridge.

[Fifth example]

Next, an example of an ink jet recording apparatus in which the ink jet head of the present invention is used is discussed with reference to FIG. 35 and FIG. 36. FIG. 35 is a perspective view of the ink jet recording device in which the ink jet head of the present invention is provided. FIG. 36 is a cross-sectional view of a mechanism part of the ink jet recording device in which the ink jet head of the present invention is provided. The ink jet recording device includes a recording device body part 81 and a printing mechanism part 250. The printing mechanism part 250 is housed in the recording apparatus body part 81. A carriage movable inside of the recording device body part 81 in the main scanning direction, a recording head including the ink jet head of the present invention mounted on the carriage, an ink cartridge for supplying the ink to the recording head, and others are housed in the printing mechanism part 250.

A paper supply cassette 84 (or a paper supply tray) capable of loading a lot of paper 83 from a front side can be detachably connected at a lower part of the recording device body part 81. In

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addition, a manual paper supply tray 85 for supplying the paper 83 manually can be opened at the lower part of the recording device body part 81.

The paper 83 is taken from the paper supply cassette 84 or the manual paper supply tray 115 in the printing mechanism part 250. A picture is recorded by the printing mechanism part 250 and then discharged to a paper discharge tray 86 connected to a back surface side of the recording device body part 81.

In the printing mechanism part 250, a carriage 193 is slideably held in a main scanning direction namely a direction perpendicular to the paper of FIG. 25 by a guide member. The guide member is connected to left and right side boards not shown in FIG. 35. The guide member includes a main guide rod 191 and a sub guide rod 192. In the carriage 193, a recording head 94 is arranged in a direction where plural ink discharging opening parts (nozzles) cross in the main scanning direction. Ink drops having colors of yellow (Y), cyan (C), magenta (M), and black (Bk), for example, are discharged by the ink jet head. The recording head 94 is mounted in a state where the direction of the ink jet faces downward. In the carriage 193, respective ink

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cartridges 95 supplying ink having the respective colors to the recording head 94 are detachably connected.

An air opening connected to the atmosphere is provided at an upper part of the ink cartridge 95. A supply opening part supplying the ink to the ink jet head is provided at a lower part of the ink cartridge 95. The ink is supplied to the ink jet head by a capillary of a porous body maintaining a slightly negative pressure. Although the heads 94 for the respective colors are used as the recording head in this embodiment, a single head having a nozzle jetting the respective colors may be used.

The back side, namely the lower side in the paper carriage direction, of the carriage 193 is slideably clamped by the main guide rod 191. In addition, the front side, namely the upper side in the paper carriage direction, of the carriage 193 is slideably connected by the sub guide rod 192. In order to make the carriage 193 move to scan in the main scanning direction, a timing belt 100 is stretch-connected between a driving pulley 98 rotationally driven by a main scan motor 97 and a driven pulley 99. The timing belt 100 is fixed at the carriage 193 and the carriage 163 moves and

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returns by forward and backward rotations of the main scan motor 97.

On the other hand, in order to carry the paper 83 set at the paper supply cassette 84 to the lower side of the recording head 94, a supply paper roller 1010, a friction pad 1020, a guide member 1030, a carry roller 1040, a small roller 1050, and a head end roller 1060 are provided in the ink jet recording device separately. Each of the sheets of paper 83 is carried from the supply paper cassette 84. The paper 83 is guided by the guide member 1030. The paper 83 is carried by being turned over by the carry roller 1040. The small roller 1050 is pushed on a circumferential surface of the carry roller 1040. A pushing angle on the paper 83 by the carry roller 1040 is determined by the head end roller 1060. The carry roller 1040 is rotationally driven by a sub scan motor 1070 via a gear line.

The paper 83 pushed by the carry roller 1040 corresponding to a moving area in the main scanning direction of the carriage 193 is received by a print receiving member 1090 as a paper guide member guiding in a lower direction of the recording head 94. A carry roller 1111 rotationally driven to carry the paper 83 in a discharge paper direction and a spur

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1120, a discharge paper roller 1130 for carrying the paper 83 to the paper discharge tray 86, a spur 1140, and guide members 1150 and 1160 forming a paper discharge path are provided at the lower side of the paper carrying direction of the print receiving member 1090.

At the time of recording, the recording head 94 is driven based on a picture signal while the carriage 193 is moved. The ink is discharged onto the paper 83 which does not move so that one line is recorded on the paper 83. After that, the paper 83 is moved a designated distance and the next line is recorded. The recording operation is finished by receiving a record finishing signal or a signal indicating that the rear end part of the paper 83 has arrived at the recording area, so that the paper 83 is discharged.

A recovery apparatus 1170 for recovering from bad discharging of the recording head 94 is arranged at an outside position of the recording area, namely the right end side of the moving direction of the carriage 93. The recovery apparatus 1170 includes capping means, absorption means, and cleaning means. During waiting for ready for printing, the carriage 193 is moved to the side of

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the recovery apparatus 1170. The recording head 94 is capped by the capping means. The bad discharging based on an ink dry condition can be prevented by maintaining the jet opening part in a wet state. In addition, the ink not used for recording is discharged during recording, so that ink viscosities of all of the discharging opening parts are kept constant, and thereby a stable jetting ability can be maintained.

10 In a case where a bad discharging occurs, the discharging opening part such as the nozzle of the head 94 is sealed by the capping means. The bubble with the ink is absorbed from the discharging opening part through a tube by the absorption means.

15 The ink, the dust or the like that adheres to the discharging opening surface is removed by the cleaning means so that bad discharging is recovered from. In addition, the ink that is absorbed is discharged to a waste ink saver (not shown) arranged

20 at a lower part of the body, so that the ink is absorbed and maintained by an ink absorption body inside of the waste ink saver (See claim 7).

Thus, since the ink jet head using the liquid drop discharging head 200 of the above-

25 discussed first through third examples is mounted on

this ink jet recording device, it is possible to prevent an ink drop from bad discharging due to bad driving of the vibration means and therefore a stable ink drop discharging property is obtained so that an image quality is improved. In addition, since the recording head driven at a low voltage is mounted, it is possible to reduce the consumption of electric power of the whole of the ink jet recording device.

Although the present invention is applied to the ink jet head as a liquid drop jet head in the above embodiments, the present invention may be applied to a liquid drop jet head other than the ink jet head such as a liquid drop jet head configured to discharge a liquid resist for patterning.

15

[Sixth embodiment]

In this embodiment, the present invention is applied to a micro pump. An action principle is discussed with reference to FIG. 37. Plural vibration plates are provided so as to face the fixed electrodes 1302. Fluid goes through the fluid path 1350. By driving the vibration plates 1307 in turn from a right side, the fluid in the fluid path 1333 flows in a direction shown by an arrow in FIG. 37 so that the fluid can be transported. Not only the

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plural vibration plates but also only a single vibration plate may be provided. A valve may be provided so that transportation efficiency can be improved.

5 The vibration plates 1307 correspond to the vibration plate areas 24a and 64a in the first through third embodiments. The fixed electrode 1302 corresponds to the lower electrodes 23a and 63a of the first and second embodiments. In the micro pump
10 transporting liquid based on displacement of the vibration plate 1307, the above discussed actuator can be used as a structural part (See claim 8). Since the vibration plate is displaced based on an electrostatic force acting on the electrodes, it is
15 possible to realize a micro pump having a small size and electrodes having low consumption of electric power.

[Seventh example]

20 In this example, the present invention is applied to an optical device. As shown in FIG. 38, plural vibration plates face the electrodes 1402. The vibration plate 1430 also functions as a mirror. It is preferable that a dielectric multilayer film or
25 a metal film be formed on a surface of the vibration

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plate 1430 so that a reflection rate is increased.
Light from a light source 1431 is irradiated on the
vibration plate (mirror) 1430 via a lens 1434. In a
case where the vibration plate (mirror) 1430 is not
5 driven, the light is reflected at the same angle as
an incident angle. In a case where the vibration
plate (mirror) 1430 is driven, the mirror is a convex
mirror and therefore the reflection light is
dispersion light.

10 The vibration plate 1430 in this example
corresponds to the vibration plate areas 24a and 64a
in the first and second example. Similarly, a fixed
electrode 1402 in this example corresponds to the
lower part electrodes 23a and 63a in the first and
15 second example. Under this structure, an optical
modulation device can be realized (See claim 9).

Next, an application example to this optical
modulation device is discussed with reference to FIG.
38. Light from the light source 1431 is irradiated
20 on the vibration plate (mirror) 1430 via the lens
1434. The light going to a part where the vibration
plate (mirror) is not driven is incident on a
projection lens 1432.

On the other hand, since the place where the
25 vibration plate (mirror) 1430 is displaced by

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applying a voltage to the electrode 1402 is a convex mirror, the light is dispersed and most of the light is not incident on the projection lens 1432. The light incident on the projection lens 1432 is
5 projected on a screen (not shown in FIG. 38). FIG. 39 shows a two-dimensional arrangement of this structure.

In FIG. 39, pairs of the electrodes 1502 and the mirrors 1530 facing the electrodes 1502 are
10 arranged lengthways and sideways. Each of the pairs is independently driven so that an image can be shown on the screen. An arrangement of 4 by 4 is shown as an example in FIG. 39, but the present invention is not limited to this. A lot of rows can be arranged.
15 The actuator including the vibration plate used in this example may have a structure as discussed in the first and second example. In addition, the actuator may be driven under the structure discussed in the third example.

20 The present invention is used for the liquid drop discharge head, the micro pump or the light modulation device and the vibration plate is displaced by the electrostatic force acting between the electrodes. Hence, it is possible to realize a
25 light modulation device having a small size and

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electrodes having low consumption of electric power.
The present invention is not limited to the above-
discussed embodiments, but variations and
modifications may be made without departing from the
5 scope of the present invention. For example, the
present invention can be applied to an optical device
other than the above discussed device, a micro
actuator, or the like.

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CLAIMS

1. An actuator, comprising:
a vibration plate area displaced by an
5 electrostatic force; and
electrodes facing each other via a first
space in the vibration plate area;
wherein the first space is formed by a
sacrificial layer process using a sacrificial layer
10 removing hole; and
a barrier as a fluid resistance is formed
between the first space and a second space situated
in the vicinity of the sacrificial layer removing
hole.
15
2. The actuator as claimed in claim 1,
wherein the barrier and the sacrificial
layer removing hole are provided outside of the
vibration plate area.
20
3. The actuator as claimed in claim 1,
wherein a single connection part configured
to connect the first space and the second space is
provided in the barrier.
25

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4. The actuator as claimed in claim 1,
wherein a plurality of connection parts
configured to connect the first space and the second
space is provided in the barrier.

5

5. A liquid drop discharge head, comprising:
a discharging room which discharges a liquid
drop and is connected to a nozzle;
a common liquid room receiving discharge
10 fluid supplied to the discharging room;
a pressure generating part configured to
give discharging energy to the discharge fluid in the
discharging room and thereby the discharge fluid can
be discharged from the nozzle;
15 a plurality of actuators, the actuator
including
a vibration plate working as the pressure
generating part;
a vibration plate area displaced by an
20 electrostatic force; and
electrodes facing each other via a first
space in the vibration plate area;
wherein the first space is formed by a
sacrificial layer process using a sacrificial layer
25 removing hole; and

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a barrier as a fluid resistance is formed between the first space and a second space situated in the vicinity of the sacrificial layer removing hole.

5

6. An ink cartridge, comprising:

a liquid drop discharge head configured to discharge an ink drop; and

a ink tank configured to supply ink to the
10 liquid drop discharge head;

wherein the liquid drop discharge head,
includes

a discharging room which discharges a liquid drop and is connected to a nozzle;

15 a common liquid room receiving discharge fluid supplied to the discharging room;

a pressure generating part configured to give a discharging energy to the discharge fluid in the discharging room and thereby the discharge fluid
20 can be discharged from the nozzle;

a plurality of actuators, the actuator including

a vibration plate working as the pressure generating part;

25 a vibration plate area displaced by an

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electrostatic force; and

electrodes facing each other via a first space in the vibration plate area;

wherein the first space is formed by a
5 sacrificial layer process using a sacrificial layer removing hole; and

a barrier as a fluid resistance is formed between the first space and a second space situated in the vicinity of the sacrificial layer removing
10 hole.

7. An ink jet recording device, comprising:
a liquid drop discharge head configured to discharge an ink drop;

15 wherein the liquid drop discharge head, includes

a discharging room which discharges a liquid drop and is connected to a nozzle;

a common liquid room receiving discharge
20 fluid supplied to the discharging room;

a pressure generating part configured to give discharging energy to the discharge fluid in the discharging room and thereby the discharge fluid can be discharged from the nozzle;

25 a plurality of actuators, the actuator

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including

a vibration plate working as the pressure generating part;

a vibration plate area displaced by an
5 electrostatic force; and

electrodes facing each other via a first space in the vibration plate area;

wherein the first space is formed by a sacrificial layer process using a sacrificial layer
10 removing hole; and

a barrier as a fluid resistance is formed between the first space and a second space situated in the vicinity of the sacrificial layer removing hole.

15

8. A micro pump transporting liquid based on displacement of a vibration plate, comprising:

at least two pairs of electrodes having a fixed electrode and a movable electrode functioning
20 as the vibration plate; and

a structural part configured to displace the vibration plate based on an electrostatic force acting the electrodes;

wherein the vibration plate is displaced by
25 an actuator, the actuator including:

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a vibration plate area displaced by an electrostatic force; and

electrodes facing each other via a first space in the vibration plate area;

5 wherein the first space is formed by a sacrificial layer process using a sacrificial layer removing hole; and

 a barrier as a fluid resistance is formed between the first space and a second space situated
10 in the vicinity of the sacrificial layer removing hole.

 9. An optical modulation device changing a reflection direction of light based on displacement
15 of a mirror, comprising:

 at least two pairs of electrodes having a fixed electrode and a movable electrode which is connected to a vibration plate and is provided in parallel; and

20 a structural part configured to displace the mirror based on displacement of the vibration plate by using an electrostatic force acting on the electrodes;

 wherein the vibration plate is displaced by
25 an actuator, the actuator including

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a vibration plate area displaced by an electrostatic force; and

electrodes facing each other via a first space in the vibration plate area;

5 wherein the first space is formed by a sacrificial layer process using a sacrificial layer removing hole; and

 a barrier as a fluid resistance is formed between the first space and a second space situated
10 in the vicinity of the sacrificial layer removing hole.

 10. A substrate having a structure, comprising:

15 a space which is formed by a sacrificial layer process using a sacrificial layer removing hole and which is provided inside of the substrate; and

 a barrier as a fluid resistance formed between the space and the sacrificial layer removing
20 hole.