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

(11) EP 1 077 331 A2

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
21.02.2001 Bulletin 2001/08

(21) Application number: **00307094.3**

(22) Date of filing: **18.08.2000**

(51) Int Cl.[7]: **F04B 43/04**, B41J 2/14

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

(30) Priority: **19.08.1999 JP 23327799**
26.07.2000 JP 2000225953

(71) Applicant: **NGK INSULATORS, LTD.**
Nagoya-City, Aichi Prefecture 467-8530 (JP)

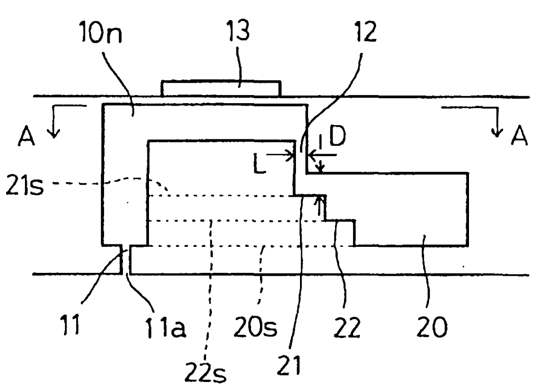
(72) Inventors:
- **Hirota, Toshikazu**
Nagoya City, Aichi Prefecture 467-8530 (JP)
- **Ohnishi, Takao**
Nagoya City, Aichi Prefecture 467-8530 (JP)
- **Noritake, Motoo**
Nagoya City, Aichi Prefecture 467-8530 (JP)

(74) Representative:
Paget, Hugh Charles Edward et al
MEWBURN ELLIS
York House
23 Kingsway
London WC2B 6HP (GB)

(54) **Liquid drop spraying apparatus**

(57) In a liquid drop spraying or ejecting device, an introducing hole 12 is provided in orthogonal direction relative to the lower face of a pressure chamber lOn, and is vertically connected to the upper face of a flow path 20. Immediately underneath the introducing hole 12, a shock wave absorption face 21 with a depth D that is twice the diameter L of the introducing hole 12 is formed as a protrusion of the lower face of the flow path 20. In addition, the shock absorption face 21 is wider than the diameter of the circle of the introducing hole 12, and a stepped portion 22 is formed at its periphery. In this manner, in a device having a plurality of the pressure chambers and the liquid is pressurised by a piezoelectric/electrostrictive element for the purpose of spraying, back flow generated at the flow path from the introducing hole is reduced.

F I G. 1



EP 1 077 331 A2

Description

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to a liquid drop spraying or ejecting apparatus for example a raw material fuel discharge device for a variety of uses, the discharge device treating liquid or operating by discharging a liquid raw material or fuel.

Description of the Prior Art

[0002] In a conventional liquid drop spraying apparatus, a plurality of pressure chambers are connected to an identical flow path via an introducing hole provided at each of the pressure chambers, and liquid drops are discharged from a discharge opening with a volume change of the pressure chamber, thereby performing spraying. The liquid supplied to a plurality of pressure chambers connected to one flow path is stored through the introducing hole formed at each pressure chamber. Liquid drops are discharged from a nozzle hole connected with the other side of each pressure chamber with a volume change of the pressure chamber, and the entirety is sprayed. In particular, a liquid drop spraying apparatus in which a piezoelectric / electrostrictive element is formed at a part of the wall of the pressure chamber, and a pressure change is produced at the element by means of a voltage signal applied to the element has been superior in a liquid drops spraying state. In the case where a large amount of liquid is discharged by use of the raw material fuel discharge device, the number of pressure chambers in which a plurality of liquid drops spraying apparatuses are mounted is increased, and the discharge period is decreased.

Object of the Invention

[0003] In a liquid drops spraying apparatus in which a number of pressure chambers are provided in order to increase a discharge quantity, liquid to be discharge is not flowed to the inside smoothly in the case where liquid is supplied from an introducing hole immediately after discharge because a large amount of back flow caused by the liquid pressurized by a piezoelectric / electrostrictive element for the purpose of spraying is supplied from the introducing hole to the flow path. Thus, there occurs a phenomenon that air bubbles inflows a pressure chamber from the nozzle hole. In addition, there has been a problem that the pressure reducing speed of the pressure chamber becomes slow in order to prevent air bubble entry, and setting must be changed such that the discharge period is lengthened, and therefore, the discharge quantity cannot be increased.

SUMMARY OF THE INVENTION

[0004] The present invention provides a liquid drops spraying apparatus comprising a number of pressure chambers in which liquid pressurized by a piezoelectric / electrostrictive element for the purpose of spraying reduces a back flow generated from an introducing hole to a flow path.

[0005] According to a first aspect of the present invention, there is provided a liquid drops spraying apparatus, a plurality of pressure chambers being connected to an identical flow path via an introducing hole provided in each of these pressure chambers, liquid drops being discharged from a discharge opening with a volume change of the pressure chamber, thereby performing spraying, wherein the depth of the flow path is formed to be selectively shallower than any other portion at a portion provided immediately underneath the introducing hole. Here, the depth of the flow path indicates a distance from an introducing hole to a face opposite to a face of the flow path in which the introducing hole is formed. A portion provided immediately underneath the introducing hole indicates a portion at which an extension line passing the center of the introducing hole crosses an opposite face. In this manner, a shock wave due to a back flow which is propagated from the pressure chamber to the introducing hole for the purpose of spraying first collides with, is absorbed by the bottom face of the shallowly formed flow path, and dispersed into the other flow path. Thus, interference from the other pressure chamber or interference to its own pressure chamber due to the reflection waves can be reduced, liquid can be supplied smoothly, and spraying is stabilized. In addition, a portion provided immediately underneath the introducing hole is formed selectively more shallowly than any other portion. In this manner, when liquid is charged in the entire flow path at the start of spraying, the flow velocity at a shallow portion is increased, and air bubble can be discharged from the pressure chambers through the introducing hole without accumulation. Even if air bubbles remain in the flow path, there can be provided an advantage that air bubbles cannot be entrained at the shallow portion in general spraying operation, thereby making it possible to avoid entraining of air bubbles from the introducing hole to the pressure chambers, and causing a spraying failure. Further, in design in which air bubbles or the like is positively left in the flow path, whereby a pressure change due to back flow in the flow path is absorbed, air bubble entry into the pressure chambers through the introducing hole is efficiently prevented.

[0006] In the case where a spray quantity is increased or the number of pressure chambers is increased, the shock wave due to back flow generated by spraying is propagated from the introducing hole of each pressure chamber, and is collected in the flow path. Then, interference can occur at the other flow path or the pressure chamber provided therein. According to a second aspect of the present invention, there is provided a liquid drops spraying apparatus in which a protrusion having the width of the flow path narrower than any other portion is formed at the flow path. In this manner, pressure chambers connected to the same flow path are divided into two or more groups by a portion at which the protrusion is formed so as to selectively narrow the width of the flow path, the shock wave due to back flow generated in the pressure chambers of one group collides with, and is absorbed and dispersed by a portion at which the protrusion is formed so as to selectively narrow the width of the flow path. Thus, back flow to the pressure chambers of the other group can be reduced, liquid is supplied smoothly, and spraying is stabilized. Here, the width of the flow path denotes a distance between faces mutually opposed orthogonal to the fluid flow direction, and a diameter if the flow cross section is circular or oval. In addition, a portion at which a protrusion is formed so as to selectively narrow the width of the flow path denotes a portion at which a pressure chamber is not coupled via the introducing hole. Further, a fine liquid drops spraying apparatus is often manufactured by means of a laminate layer such as green sheets. Thus, a protrusion portion is formed in the planar direction of at least one laminate body forming the flow path. In this manner, such portion formed so as to selectively narrow the width of the flow path can be easily fabricated even in any planar shape without being limited to stepwise manner. In particular, a width rate between the flow path width provided at the laminate body and the protrusion is preferably 1 : 0.5 to 1 : 0.8. When the width of the protrusion is 0.5 or less relevant to the width of the flow path, the absorption rate of the shock wave is lowered, and an effect of back flow reduction is reduced. In contrast, when the above width is 0.8 or more, the flow of fluid in the flow path is prevented, and smooth liquid supply to the pressure chambers is inhibited irrespective of the presence or absence of shock wave.

[0007] Further, in the case where the spray quantity is increased more significantly, a shock wave may reach the other path over an inlet opening for supplying liquid from a liquid reservoir to the flow path. According to a third aspect of the present invention, there is provided a liquid drops spraying apparatus, wherein the two or more flow paths are connected to each other at an inlet opening, and a portion provided at least immediately underneath the inlet opening is formed selectively more shallowly than any other portion. In this manner, the shock wave generated at one of two or more flow paths collides with a selectively shallowly formed portion, and is dispersed there. Thus, interference with any other flow path over the inlet opening is eliminated, liquid is supplied smoothly, and spraying is stabilized. Such arrangement is preferably adopted in the case where one flow path diverges into two or more flow paths. That is, a multiply layered protrusion shaped portion is formed at a diverging portion in thickness direction, and an original one flow path serves as an inlet opening relevant to two or more diverging flow paths. In this manner, the shock wave generated at these two or more diverging flow paths is prevented from interfering with any other flow path.

[0008] In particular, when liquid is charged in the space of the entire flow path when spraying is started, it is required to improve the discharge of bubbles which are pressed to the tip end of liquid flow from the flow path. According to a fourth aspect of the present invention, there is provided a liquid drops spraying apparatus wherein a diameter of an introducing hole and/or an discharge opening positioned most distantly from an inlet opening for injecting liquid into the flow path is formed to be greater than a diameter of any other introducing hole and/or a discharge opening, and/or an exhaust hole is formed on the discharge opening forming face positioned most distantly from an inlet opening for injecting liquid into the flow path. In general, in the liquid drops spraying apparatus of the present invention, the discharge opening forming face is pressure reduced and suctioned when spraying is started, whereby liquid is charged from the inlet opening into the flow path and pressure chamber. In that case, air bubbles may remain at the tip end of the flow path. However, in this manner, when liquid is charged from the inlet opening, air bubbles are discharged from the injection hole and/or discharge opening with its larger diameter positioned most distantly from the inlet opening, and/or exhaust hole. Thus, air bubbles or the like can be discharged from the flow path without being air bubble retained, and a spraying failure does not occur. In particular, when the size of the diameter of the introducing hole and discharge opening is 1.1 times or more than that of any other introducing hole and discharge opening, air bubbles are well removed. When the size is twice or less, liquid leakage never occurs, which is preferable. On the other hand, in the case of an exhaust hole, unlike an introducing hole and/or discharge opening with a pressure chamber interposed on its way, the exhaust hole directly diverges into an ejection face. Thus, when the size of the diameter of the exhaust hole is 0.5 times or more than that of any other discharge opening on the formed face, air bubbles are well removed. Further, in order to prevent liquid leakage from the exhaust hole during spraying, the size of the exhaust hole is preferably twice or less than any other discharge opening associated with spraying. In addition, there are properly adjusted according to the liquid properties, discharge quantity, discharge period or the like, three modes in which the size of diameter of the introducing hole and discharge opening is greater than that of any other introducing hole and discharge opening without forming an exhaust hole; the size of diameter of the introducing hole and discharge opening is substantially equal to that of any other introducing hole and discharge opening, thereby forming an exhaust hole at the tip end of the flow path; and both of them are adopted.

[0009] According to a fifth aspect of the present invention, there is provided a liquid drops spraying apparatus, wherein the depth of a portion at which fluid flows in a direction different from a direction in which the fluid of the introducing hole flows is formed to be selectively shallower than that of any other portion of the flow path in the middle of a first introducing hole communicating with the pressure chambers, and a second introducing hole communicating with the flow path is formed at a portion other than the extension line of the first introducing hole of the portion. Here, the depth denotes a distance from each introducing hole to a portion at which the introducing hole is formed, and a face opposed to the face of the flow path. In this manner, the pressure of the shock wave due to back flow is absorbed and reduced by the portion, and is not propagated into the flow path.

[0010] According to a sixth aspect of the present invention, there is provided a liquid drops spraying apparatus, wherein the periphery of the selectively shallowly formed portion is formed deeply in stepwise manner. Thus, the shock wave that does not collide with the shock wave absorption face and is not absorbed thereby is diminished stepwise, the number of shallow portions is not increased, and the space of the flow path can be prevented from being reduced. In addition, a fine liquid drops spraying apparatus is often manufactured by means of a laminate layer. Thus, such stepwise formation is easy, and in a stepwise structure having a stepped portion corresponding to the thickness of the laminate layer, a peripheral portion close to an inclined face can be formed by increasing the number of laminating steps.

[0011] According to a seventh aspect of the present invention, it is desirable that the selectively shallowly formed portion be equal to or greater than and 5 times or less of the diameter of the introducing hole in depth from the lower end of the introducing hole. This is because, when the depth is more than 5 times, the efficiency of absorption due to collusion with the bottom face drops, or alternatively, when the depth is less than the diameter, the resistance of the flow path during fluid introduction is increased, and the fluid cannot be introduced smoothly.

[0012] According to a eighth aspect of the present invention, there is provided a liquid drops spraying apparatus, wherein the surface roughness of the selectively shallowly formed portion is larger than that of any other flow path interior face. In this manner, an advantageous effect in which the shock wave is absorbed is improved. Methods for roughening the surface roughness of the flow path interior wall includes: forming an uneven shape by physical techniques such as lamination or cutting. Even if such shape is not formed, the surface may be formed by chemical techniques such as changing material quality or the like of the shallow portion, for example, laminating another material or another grain material; or irradiating such shallowly formed portion with another substance or reacting with another substance.

[0013] According to a ninth aspect of the present invention, there is provided a liquid drops spraying apparatus, wherein the flow path is formed of ZrO_2 ceramics, and at least part of the flow path is changed in its shape with the pressure change in the flow path. In this manner, even if the shock wave due to back flow is propagated into the flow path, the pressure change is absorbed by at least part of the flow path formed of ZrO_2 ceramics. Thus, liquid supply can be started speedily.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] For a better understanding of the present invention, reference is made to the following detailed description of the invention, taken in conjunction with the following drawings in which:

FIG. 1 is a longitudinal cross section of a liquid drops spraying apparatus;
FIG. 2 is an illustrative view of another liquid drops spraying apparatus taken along line A-A shown in FIG. 1;
FIG. 3 is an illustrative view of another liquid drops spraying apparatus;
FIG. 4 is an illustrative view of another liquid drops spraying apparatus with its flow path;
FIG. 5 is an illustrative view illustrating another embodiment in which green sheets are laminated;
FIG. 6 is an illustrative view illustrating a plan view of a second laminate body S2 and a third laminate body S3;
FIG. 7 is an illustrative view illustrating a plan view of a fourth laminate body S4 and a fifth laminate body S5;
FIG. 8 is an illustrative view illustrating a plan view of a sixth laminate body S6 and a seventh laminate body S7;
FIG. 9 is an illustrative view illustrating an injection opening of the liquid drops spraying apparatus taken along line B-B shown in FIG. 6 to FIG. 8;
FIG. 10 is an illustrative view showing another liquid drops spraying apparatus;
FIG. 11 is an illustrative view showing another liquid drops spraying apparatus;
FIG. 12 is an illustrative view showing another liquid drops spraying apparatus; and
FIG. 13 is an illustrative view showing another liquid drops spraying apparatus.

PREFERRED EMBODIMENTS OF THE INVENTION

[0015] Hereinafter, liquid drop spraying or ejecting apparatus according to the present invention will be described in detail with reference to the accompanying drawings.

[0016] FIG. 1 is a longitudinal cross section of the liquid drops spraying apparatus. In a pressure chamber 10n, a discharge opening 11 having an outwardly opening nozzle hole 11a is provided downwardly at one end; an introducing hole 12 is provided at the other end at which the discharge opening 11 is provided; and the pressure chamber is connected to a flow path 20 via the introducing hole 12. In addition, in the pressure chamber 10n, a piezoelectric / electrostrictive element 13 is provided at a part of the upper wall thereof, and each piezoelectric / electrostrictive element 13 laminates an upper electrode, a piezoelectric / electrostrictive layer, and a lower electrode. A predetermined voltage signal is applied to the piezoelectric / electrostrictive element 13, whereby the piezoelectric / electrostrictive layer is deformed by an electric field generated between the upper electrode and the lower electrode. By means of a pressurizing force generated in the pressure chamber 10n by deforming the wall of the pressure chamber 10n, the liquid supplied to the pressure chamber 10n is discharged as liquid drops from the discharge opening 11, and liquid drops are sprayed in an atomizing manner by means of a number of discharge openings.

[0017] The introducing hole 12 is provided in orthogonal direction relevant to the lower face of the pressure chamber 10n, and is vertically connected to the upper face of the flow path 20. Immediately underneath the introducing hole 12 connected to the flow path 20, a shock absorption face 21 with its depth D that is twice or more of the diameter L of the introducing hole 12 is formed so as to be protruded from the lower face of the flow path 20. In addition, the shock absorption face 21 is wider than the diameter circle of the introducing hole 12, and its periphery is vertically cut off, and the stepped portion 22 is formed.

[0018] The back flow pressure generated by the pressurization of the pressure chamber 10n, the pressure propagating the introducing hole 12, collides with the shock absorption face 21 and reduces energy after it passes through the introducing hole 12. Then, the back flow pressure is extended by the area for the stepped portion 22, and is finally conveyed to the entirety of the flow path 20.

[0019] In addition, dotted lines 21s, 22s, and 20s each indicate a laminate face during manufacture, and the thickness of the stepped portion corresponds to that of the laminate layer.

[0020] FIG. 2 is an illustrative sectional view illustrating another embodiment taken along line A-A that omits the upper wall face shown in FIG. 1. An introducing hole 12 connected to each pressure chamber 10n is provided at a flow path 20 common to a plurality of pressure chambers 10a, 10b, ... 10n, and a discharge opening 11 for outwardly discharging liquid is punched at the other end. In addition, a piezoelectric / electrostrictive element 13 is provided at a part of the upper wall of the pressure chamber 10n. Flow paths 20 can be provided in one or more arrays relevant to a liquid supply source. In addition, the flow paths 20 are formed so that its face width narrows as they are distant from the liquid supply source. In this manner, when liquid is initially charged in a flow path, the liquid can be charged smoothly by utilizing a capillarity of the flow path. In addition, even if the flow paths are distant from the liquid supply source, there is an advantage that the fluid in the flow path is not slow, whereby air bubbles or the like hardly remains on the wall face.

[0021] A shock absorption face 21 may be formed so that the face width of the shallow portion narrows as the face is distant from the liquid supply source relevant to the flow paths 20, as shown in FIG. 3. In this manner, a flow path resistance from the fluid supply source to each introducing hole is equal to another, the spraying distortion between the pressure chambers is reduced, and stable spraying is performed.

[0022] Further, as shown in FIG. 4A, a side connection of the flow path 20 to the introducing hole 12 is formed in planar and protrusive shape, and is connected to the introducing hole 12 in the vicinity of its apex at its protrusion. In addition, the depth of the protrusion is formed more shallowly than any other portion of the flow path 20 as shown in the end face (B) taken along line A-A shown in FIG. 4A, and may be arranged so that the bottom face is employed as a shock absorption face 21. With such arrangement, when liquid is initially supplied to the flow path, air bubbles gather at a protrusion at which the introducing hole 12 is present, and are easily discharged from its introducing hole 12, which is preferable. In addition, FIG. 4C shows an end face of the introducing hole 12 taken along line B-B orthogonal to line A-A. In the flow path 20 shown in FIG. 4, the introducing hole 12 is disposed at the apex position of the protrusion in the laminated face direction, thereby smoothening the flow of air bubbles. In a direction orthogonal to the laminate face, as shown in FIG. 1, the shock absorption face 21 is formed in stepwise manner, thereby making it possible to form the introducing hole 12 at the shallowest position (C) and utilize the hole.

[0023] FIG. 5 is an illustrative view illustrating another embodiment in which green sheets are laminated, as shown in FIG. 1. A liquid drops spraying apparatus is formed by laminating seven green sheets (hereinafter, referred to as a laminate body) S1 to S7. FIG. 6 to FIG. 8 each shows a plan view of a second laminate body to a seventh laminate body with the exception of a first laminate body at which only an inlet opening 25 is provided. A pressure chamber 10n in which the first laminate body S1 is employed as a cover portion is formed by the second laminate body. The downward oriented discharge opening 11 at one end is coupled with the third to sixth laminate bodies while their diameters are reduced. An outward opening nozzle hole 11a is formed at the seventh laminate body S7. On the other hand, an introducing hole 12 is provided at the other end of a face at which a discharge opening 11 is provided, and a flow path 20 connected via the introducing hole 12 is formed by the third, fourth, and fifth laminate bodies.

[0024] In addition, the first laminate body S1 being the upper wall of the pressure chamber 10n is provided with a piezoelectric / electrostrictive element 13 which laminates an upper electrode, a piezoelectric / electrostrictive layer, and a lower electrode. A predetermined voltage signal is applied to the piezoelectric / electrostrictive element 13, whereby a piezoelectric / electrostrictive layer is deformed by an electric field generated between the upper electrode and the lower electrode, and the upper wall being fixed with pressure chamber 10n is deformed by distance L as indicated by short two dots and long one line. By means of the pressurizing force generated at this pressure chamber 10n, the liquid supplied to the pressure chamber 10n is discharged as liquid drops from the discharge opening 11, and the ejection is repeated at a high speed, whereby liquid drops are ejected in sprayed manner by a number of discharge openings 11 provided on a flat face. Reference numeral 11b denotes a liquid repellent member mounted to the discharge opening 11 so as not to ensure that the liquid drops remain. Even if the liquid drops that have not been scattered adhere to the liquid repellent member 11b, they drop and disappear without rapid growth.

[0025] The dimensions of flow path or the like are shown as an example in FIG. 5. Immediately underneath the introducing hole 12 vertically connected to the flow path 20, a shock absorption face 21 of 0.12 mm in depth that is 3.5 times relevant to L0.034 mm in diameter of the introducing hole 12 is formed to be protruded from the lower face of the flow path 20 by the fifth laminate body S5. In addition, the size of the shock absorption face 21 is formed in width of 0.25 mm wider than L0.034 mm in diameter of the introducing hole 12, and a stepped portion 22 of its periphery is 0.38 mm in the layer thickness of the fifth laminate body S5.

[0026] In this manner, the back flow pressure generated by the pressurization of the pressure chamber 10n and propagating the introducing hole 12 collides with the shock absorption face 21 immediately after the introducing hole 12 has been passed. The back flow pressure reduces its energy, and is conveyed to the entirety of the flow path 20.

[0027] FIG. 6 is a plan view showing the second laminate body S2 and the third laminate body S3, and an inlet opening 25 proceeding from the first laminate body S1 is punched downward of these respective bodies. In addition, a block in which fourteen elongated pressure chambers 10n each having one planar shape formed in arc shape at both ends are made adjacent to each other is arranged in two longitudinal arrays and four horizontal arrays, and a total of 112 pressure chambers 10n are formed. Upwardly of the third laminate body S3, 112 discharge opening 11 of 0.25 mm in diameter and 112 introducing holes 12 of 0.034 mm in diameter are punched corresponding to its pressure chambers 10n.

[0028] FIG. 7 is a plan view showing the fourth laminate body S4 and the fifth laminate body S5. Downward of a respective one of these laminate bodies, the flow paths 20 at one end operating at the inlet opening 25 proceeding from the upper layer are disposed at the left and right according to a diverging portion 25a, and each flow path 20 further diverges at the other end. The flow paths 20 diverging into four sections are coupled with the respective twenty eight introducing holes 12 formed in third laminate bodies S3. In addition, the shock absorption face 21 is provided at the fifth laminate body S5 immediately underneath the introducing hole 12 of the third laminate body S3.

[0029] On the other hand, a discharge opening 11 of 0.15 mm in diameter and a discharge opening of 0.1 mm in diameter are punched at a fourth laminate body S4 and a fifth laminate body S5, respectively, relevant to the discharge opening 11 of the third laminate body S3.

[0030] In addition, the flow path 20 is formed so that the face width of the flow path 20 to which the introducing holes 12 are connected narrows as the flow path is distant from the inlet opening 25 of the liquid supply source. In this manner, when liquid is initially charged in the flow path, the liquid can be charged smoothly by utilizing the capillary action. In addition, even if the flow path is distant from the fluid supply source, the flow rate of the fluid in the flow path is not slow. Thus, there is provided an advantageous effect that air bubbles or the like hardly remains on the wall face. In particular, with respect to the residual air bubbles, the diameter of the introducing hole and/or discharge opening positioned most distantly relevant to the inlet opening for injecting liquid into the flow path may be formed to be larger than the diameter of any other introducing hole and/or discharge opening, and an exhaust hole may be formed on the ejection forming face at the tip end of the flow path 20 positioned most distantly relevant to the inlet opening 25 for injecting liquid into the flow path 20. In this manner, when liquid is charged from the inlet opening 25 when spraying is started, air bubbles are discharged from the introducing hole 12 and/or discharge opening 11 positioned most distantly relevant to the inlet opening 25 and/or exhaust hole. Thus, liquid can be discharged from the flow path 20 without air bubbles being left, and a spray failure does not occur.

[0031] In addition, when the size of diameter of the introducing hole 12 and discharge opening 11 is 1.1 times or more than that of any other introducing hole 12 and discharge opening 11, air bubbles are well removed. In addition, when the size is twice or less, liquid leakage does not occur, which is preferable. On the other hand, when the size of the diameter of exhaust hole is 0.5 time or more than another discharge opening of the formed face, air bubbles are well removed. When the size is twice or less, liquid leakage does not occur, which is preferable. In addition, there are properly adjusted according to the liquid properties, discharge quantity, discharge period or the like, three modes in which the size of diameter of the introducing hole and discharge opening is greater than that of any other introducing hole and discharge opening without forming an exhaust hole; the size of diameter of the introducing hole and discharge opening is substantially equal to that of any other introducing hole and discharge opening, thereby forming an exhaust hole at the tip end of the flow path; and both of them are adopted.

[0032] FIG. 8 is a plan view showing a sixth laminate body S6 and a seventh laminate body S7. The sixth laminate body S6 can be employed as a bottom face of the flow path 20. In addition, a discharge opening 11 of 0.05 mm in diameter and a discharge opening 11 of 0.031 mm in diameter are punched at a sixth laminate body S6 and a seventh laminate body S7, respectively, relevant to the discharge opening 11 of the fifth laminate body S5.

[0033] FIG. 9 is a sectional view when laminate bodies S1 to S7 are formed in laminated manner, and are cut taken along line B-B shown in FIG. 6 to FIG. 8. A diverging portion 25a is formed in the flow path 20 at a portion provided immediately underneath the inlet opening 25, and is selectively shallower than any other portion of the flow path 20 by remaining the fourth laminate body S4 and the fifth laminate body S5. In this manner, a face 20d on which the diverging portion 25a is orthogonal to the flow direction of the flow path 20 absorbs the shock wave conveyed to the flow path 20, thereby preventing interference with the other flow path. The width of the diverging portion 25a is narrow relevant to the liquid supplied from the inlet opening 25, and thus, the supply resistance is eliminated.

[0034] Functional tests of the liquid drops spraying apparatus shown in FIG. 3 to FIG. 9 were performed, and the following results were obtained. As a discharge liquid, there were employed class 2 petroleum analogous sorbent (specific gravity: 0.76 and surface tension: 20 dyn/cm). In addition, as shown in FIG. 5, the vertical displacement quantity L at the surface of the piezoelectric body 13 was measured with respect to the deformation quantity of the upper wall.

[0035] A frequency of a drive signal is merely adjusted while the displacement quantity of the piezoelectric / electrostrictive element is kept constant, whereby the spray quantity can be changed, and a large amount of spray is made possible.

Table 1

Displacement quantity of upper wall (microns)	Discharge frequency (kHz)	Spray quantity (cc/min)
0.2	18	5.0
0.2	9	2.5
0.2	1	0.3
0.1	18	2.6

[0036] FIG. 10 shows another embodiment of the fourth laminate body S4 and fifth laminate body S5 shown in FIG. 7. In the fourth laminate body S4 and fifth laminate body S5, a respective one of the flow paths 20 diverged into four sections in its destination is coupled with twenty eight introducing holes 12 of the third laminate body S3 respectively. A protrusion 20e in which the flow width is selectively narrower than that of any other portion is formed in planer direction in the middle of the portion to be coupled with. At a position at which the protrusion 20 is formed, an array of introducing holes 12 are divided into two sections by 14 pieces. Thus, pressure chambers connected to the same flow path are divided into two groups by the protrusion 20e. The shock wave due to the back flow generated in the pressure chambers of one group collides with the protrusion 20e, and is dispersed there. Thus, the back flow to the pressure chambers that are in the other group can be reduced, the liquid is supplied smoothly, and spraying is stabilized.

[0037] FIG. 11 is an illustrative view showing another embodiment in the same manner as that shown in FIG. 1. A pressure reducing chamber 14 for changing the fluid flow direction is formed in a first introducing hole 12a formed in vertical direction on the lower face of the pressure chamber of the liquid drops spraying apparatus. Then, the depth of the pressure reducing chamber 14 is equal to or larger than the diameter of the first introducing hole 12a or is 5 times or less, whereby the shock force of the back flow is absorbed by the bottom face of the pressure reducing chamber. In addition, a second introducing hole 12b communicating with the flow path 20 is formed on a bottom face other than the portion provided immediately underneath the first introducing hole 12a. In this manner, the shock wave due to the back flow is absorbed and reduced by the pressure reducing chamber 14, and is not propagated to the flow path 20. A direction in which the flow of the fluid is changed is not limited to a direction orthogonal to the extension line passing through the center immediately after the fluid has entered the introducing hole. This direction can be properly adjusted in consideration of the fluid properties, flow rate, flow velocity or the like.

[0038] FIG. 12 and FIG. 13 are illustrative views each illustrating another embodiment in the same manner as that shown in FIG. 1. There is provided a liquid drops spraying apparatus, wherein a flow path 20 of the liquid drops spraying apparatus is formed of ZrO_2 ceramics, and at least part of the flow path 20 is changed in its shape due to the pressure change in the flow path. In this manner, even if the shock wave due to the back flow is propagated to the flow path, the pressure change is absorbed by changing its shape of at least part of the flow path having its wall face formed of ZrO_2 ceramic. Thus, liquid supply can be started speedily. In more detail, in FIG. 12, part of the lower face of the flow path 20 is formed at the thin portion 20a, in FIG. 13, a hollow portion 20b is formed upward of the flow path 20, and a thin portion 20c is formed between the flow path 20 and the hollow portion 20b. If a back flow is generated at the flow path 20, the thin portions 20a and 20c are deformed as indicated by dotted line, thereby absorbing the back flow.

[0039] As has been described above, according to a first aspect of the present invention, the depth of a flow path of a liquid drops spraying apparatus is selectively formed more shallowly than any other portion at least at a portion provided immediately underneath the introducing hole. In this manner, the shock wave due to the back flow, propagated from the pressure chamber to the introducing hole for the purpose of spraying first collides with the bottom face of the shallowly formed flow path, and is absorbed thereby. Thereafter, the shock wave is diverged into another flow path. Thus, interference from any other pressure chamber or interference to its own pressure chamber with reflection wave can be reduced, liquid is supplied smoothly, and spraying is stabilized without any intermittence.

[0040] According to a second aspect of the present invention, a protrusion at which the width of the flow path is selectively narrower than any other portion is formed at a flow path of the liquid drops spraying apparatus. In this manner, the shock wave due to the back flow generated in a pressure chamber provided at a flow path reaching a tip end from a portion at which a protrusion for selectively narrowing the flow path collides with a portion at which such protrusion for selectively narrowing the flow path, is absorbed thereby, and is dispersed. Thus, the back flow to any other portion can be reduced, liquid is supplied smoothly, and spraying is stabilized.

[0041] Further, according to a third aspect of the present invention, two or more flow paths of the liquid drops spraying apparatus are connected to each other at an inlet opening, and at least a portion provided immediately underneath the inlet opening is formed to be selectively shallower than any other portion. In this manner, the shock wave generated at one of the two or more flow paths collides with such selectively shallowly formed portion, and is dispersed. Thus, interference to another flow path over an injection opening is eliminated, liquid is supplied smoothly, and spraying is stabilized.

[0042] According to a forth aspect of the present invention, the diameter of the introducing hole and/or discharge opening positioned most distantly from an inlet opening for injecting liquid into a flow path of the liquid drops spraying apparatus is formed to be larger than that of any other introducing hole and/or discharge opening; and/or an exhaust path is formed at the discharge opening forming face at the tip end of the flow path positioned most distantly from the inlet opening for injecting liquid into the flow path. In this manner, when liquid is charged from the inlet opening when spraying is started, air bubbles are removed from the introducing hole and/or discharge opening with its larger diameter positioned most distantly from the injection opening; and/or from the exhaust hole. Thus, the liquid can be discharged from the flow path without air bubbles or the like being left, and a spraying failure does not occur.

[0043] According to a fifth aspect of the present invention, there is provided a liquid drops spraying apparatus, wherein a pressure reducing chamber for changing the fluid flow direction is formed in a first introducing hole communicating with the pressure chamber, and a second introducing hole communicating with the flow path is formed at a portion other than a portion provided immediately underneath the first introducing hole of the pressure reducing chamber. In this manner, the shock wave due to the back flow is absorbed and reduced by the pressure reducing chamber, and the shock wave is not propagated into the flow path.

[0044] According to a sixth aspect of the present invention, there is provided a liquid drops spraying apparatus, wherein the periphery of the selectively shallowly formed portion is formed deeply in stepwise manner. Thus, the shock wave that has not collided with the shock wave absorption face and has not been absorbed thereby is eliminated in stepwise direction, the number of such shallow portions is not increased, and the capacity of the entire pressure chamber can be prevented from being reduced. In addition, in the case where a fine liquid drops spraying apparatus is often manufactured by a laminate layer. Thus, in a stepwise shaped structure having a stepped portion corresponding to the thickness of the laminate layer, the number of laminating steps is increased, whereby a peripheral portion close to an inclined face can be formed.

[0045] According to a seventh aspect of the present invention, it is desirable that the selectively shallowly formed portion is equal to or greater than the diameter of the introducing hole or 5 times or less in depth from the lower end of the introducing hole. In this manner, the back flow pressure in the extension direction of the introducing hole collides with a portion shallowly formed prior to scattering in horizontal direction, and decreases.

[0046] According to a eighth aspect of the present invention, there is provided a liquid drops spraying apparatus, wherein the surface roughness of the selectively shallowly formed portion is rougher than that of any other portion of the interior wall of the flow path. In this manner, the efficiency of which the shock wave is absorbed is improved.

[0047] According to a ninth aspect of the present invention, there is provided a liquid drops spraying apparatus, wherein the flow path is formed of ZrO_2 ceramics, and at least part of the flow path is changed in its shape due to the pressure change in the flow path. In this manner, even if the shock wave due to the back flow is propagated into the flow path, the pressure change is absorbed by at least part of the flow path formed of ZrO_2. Thus, liquid supply can be started speedily.

Claims

1. A liquid drop spraying apparatus having pressure chambers connected to a common flow path via an introducing hole provided at each pressure chamber, liquid drops being discharged from a discharge opening due to volume change of the pressure chambers, wherein the depth of the flow path is selectively shallower than other portions at least at a portion immediately underneath the introducing hole.

2. A liquid drop spraying apparatus having a plurality of pressure chambers connected to a common flow path via an introducing hole provided at each pressure chamber, liquid drops being discharged from a discharge opening due to volume change of the pressure chambers, wherein a protrusion makes the width of the flow path selectively narrower at one portion than other portions.

3. A liquid drop spraying apparatus having a plurality of pressure chambers connected to a common flow path via an introducing hole provided at each pressure chamber, liquid drops being discharged from a discharge opening due to volume change of the pressure chambers, wherein two or more flow paths are connected to each other at an inlet opening, thereby forming at least a portion immediately underneath the inlet opening which is selectively shallower than other portions.

4. A liquid drop spraying apparatus having a plurality of pressure chambers connected to a common flow path via an introducing hole provided at each pressure chamber, liquid drops being discharged from a discharge opening due to volume change of the pressure chambers, wherein the diameter of an introducing hole and/or discharge opening positioned most distantly from an inlet opening for injecting liquid into the flow path is larger than that of other introducing hole and/or discharge openings; and/or an exhaust hole is provided on a discharge opening forming face of the tip end of the flow path positioned most distant from the inlet opening for injecting liquid into the flow path.

5. A liquid drop spraying apparatus having a plurality of pressure chambers being connected to a common flow path via an introducing hole provided at each pressure chamber, liquid drops being discharged from a discharge opening due to volume change of the pressure chambers, wherein there is a portion for changing the fluid flow direction in the middle of the introducing hole, and the depth of the portion is selectively shallower than other portions of the flow path.

6. A liquid drop spraying apparatus as claimed in any of claims 1, 3 and 5, wherein the periphery of the selectively shallower portion changes depth in stepwise manner.

7. A liquid drop spraying apparatus as claimed in any of claims 1, 3 and 5, wherein said selectively shallower portion is 5 times or less of the diameter of the introducing hole in depth from the lower end of the introducing hole.

8. A liquid drop spraying apparatus as claimed in any of claims 1, 3 and 5, wherein the surface roughness of said selectively shallower portion is rougher than that of other portions of the interior wall of the flow path.

9. A liquid drop spraying apparatus as claimed in any of claims 1 to 5, wherein said flow path is formed of ZrO_2 ceramics, and at least part of the flow path is changed in its shape due to the pressure change in the flow path.

FIG. 1

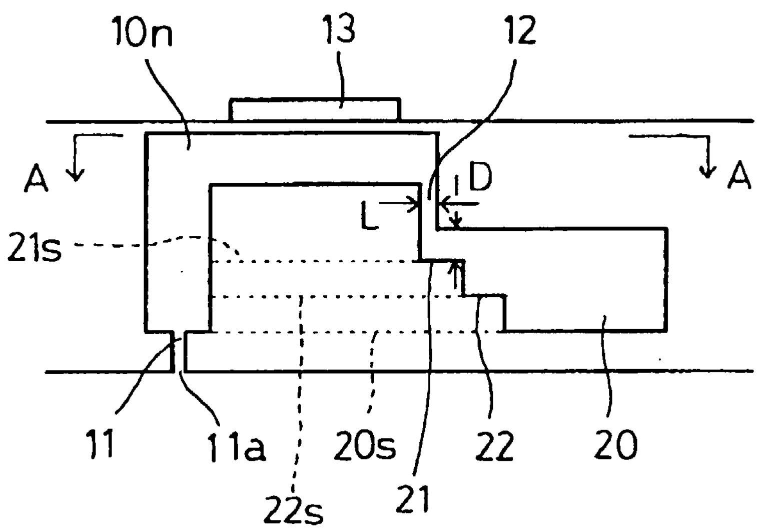
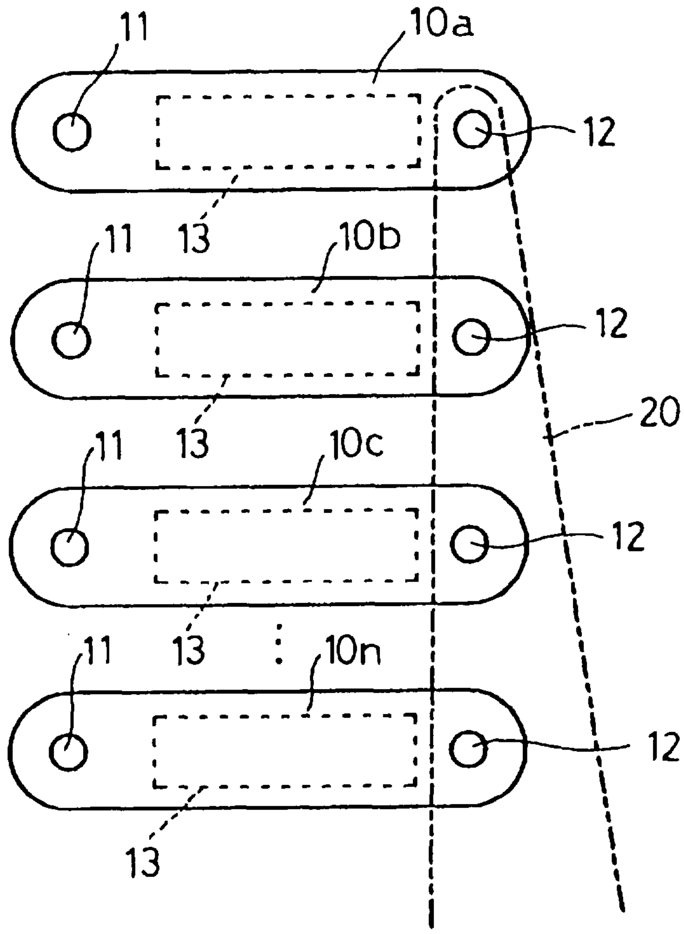
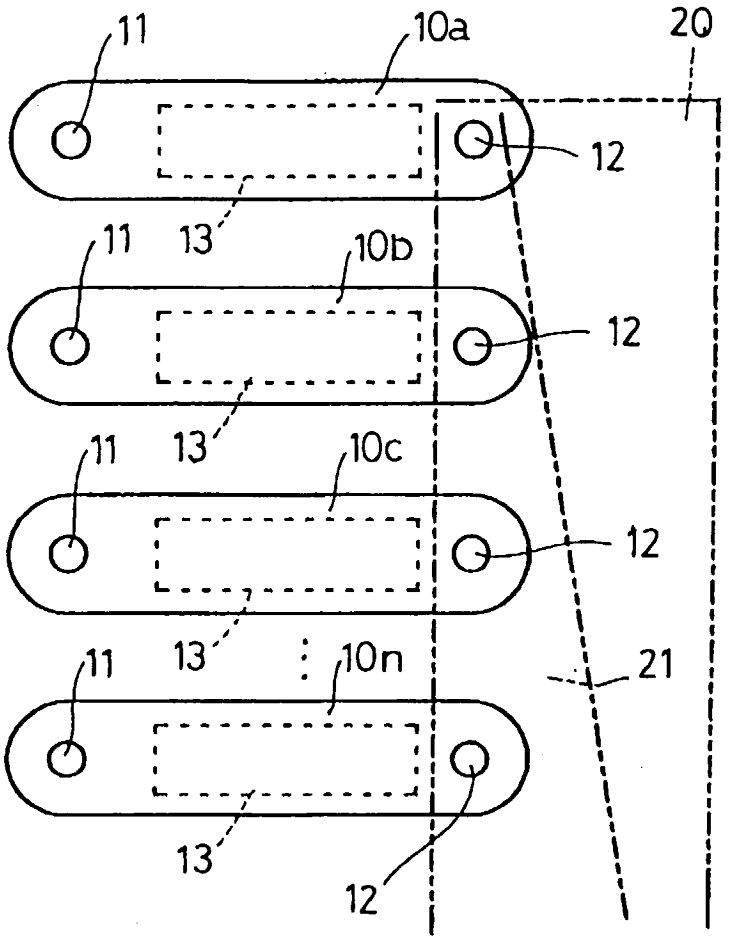


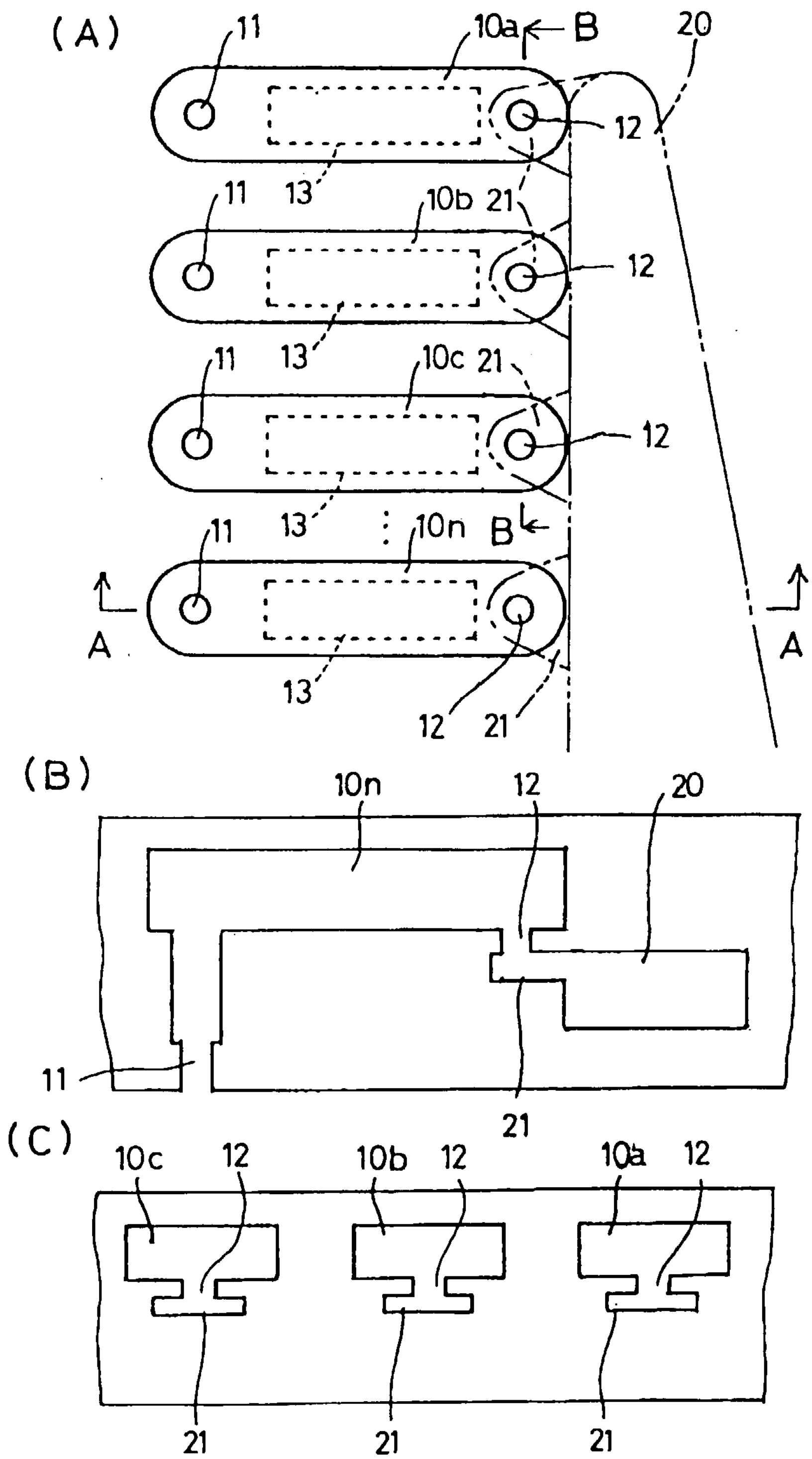
FIG. 2



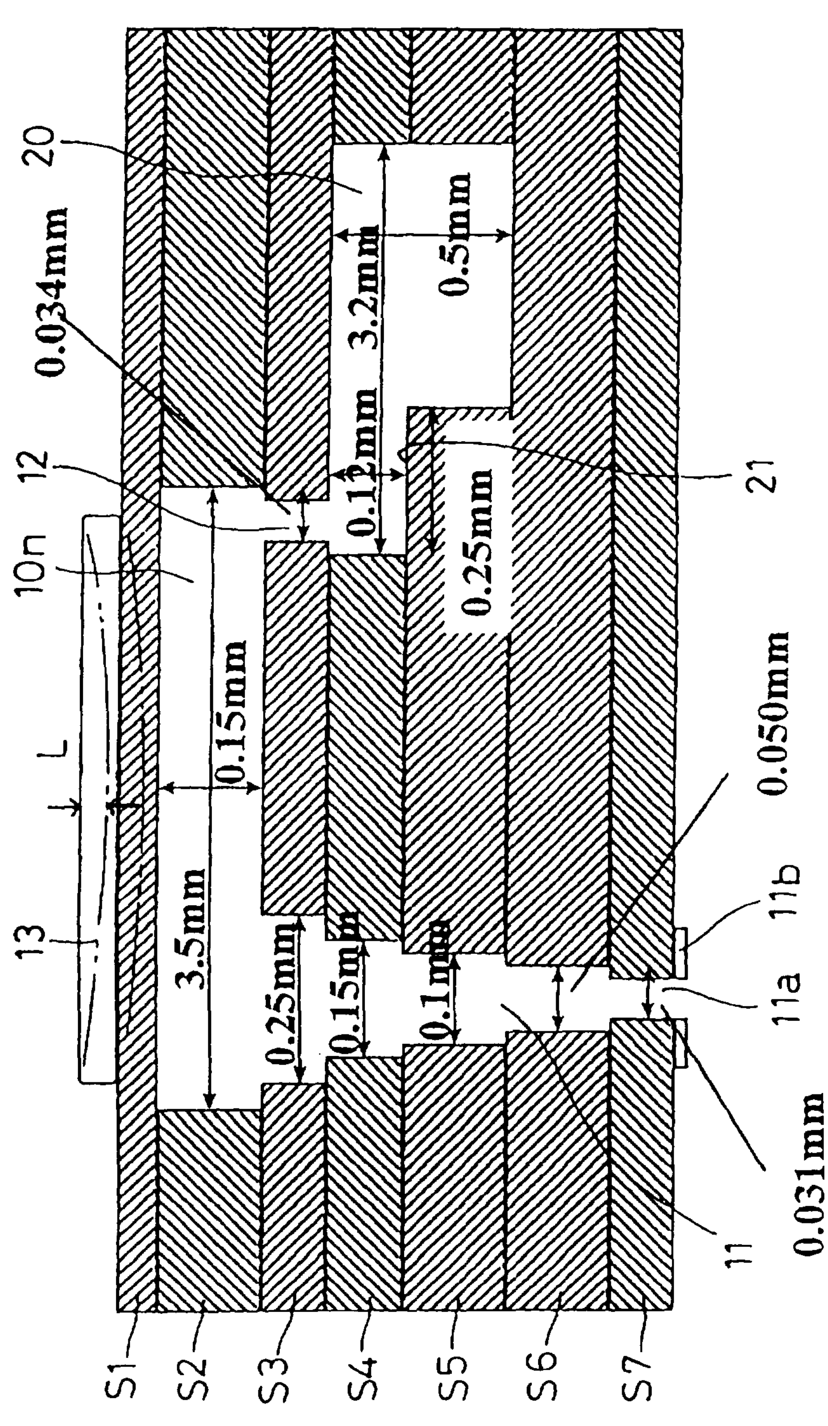
F I G. 3



F I G. 4



F I G. 5



20
0.034mm
3.2mm
0.5mm
12
0.15mm
21
10n
0.25mm
0.15mm
L
0.050mm
13
3.5mm
0.25mm
0.15mm
0.1mm
11b
11a
0.031mm
11
S1
S2
S3
S4
S5
S6
S7

FIG. 6

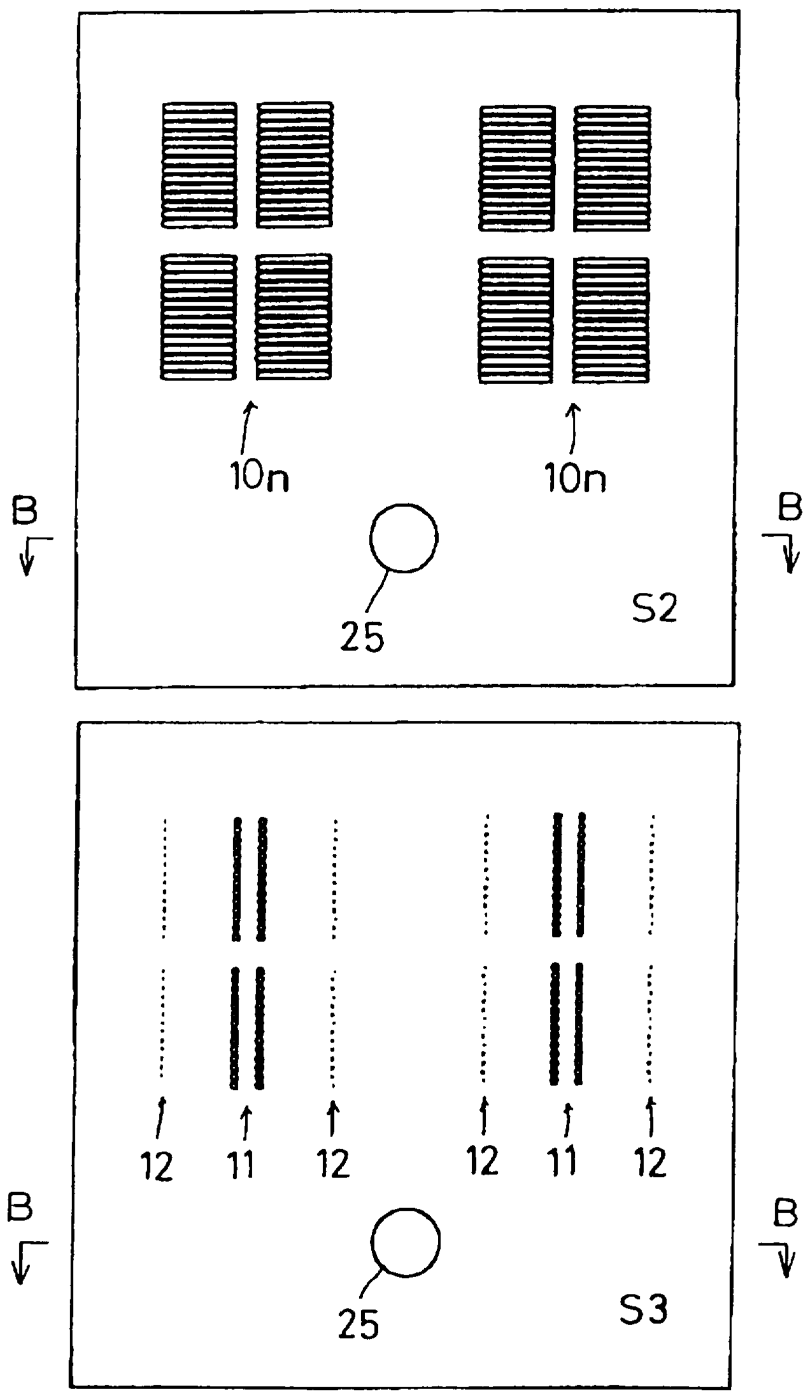


FIG. 7

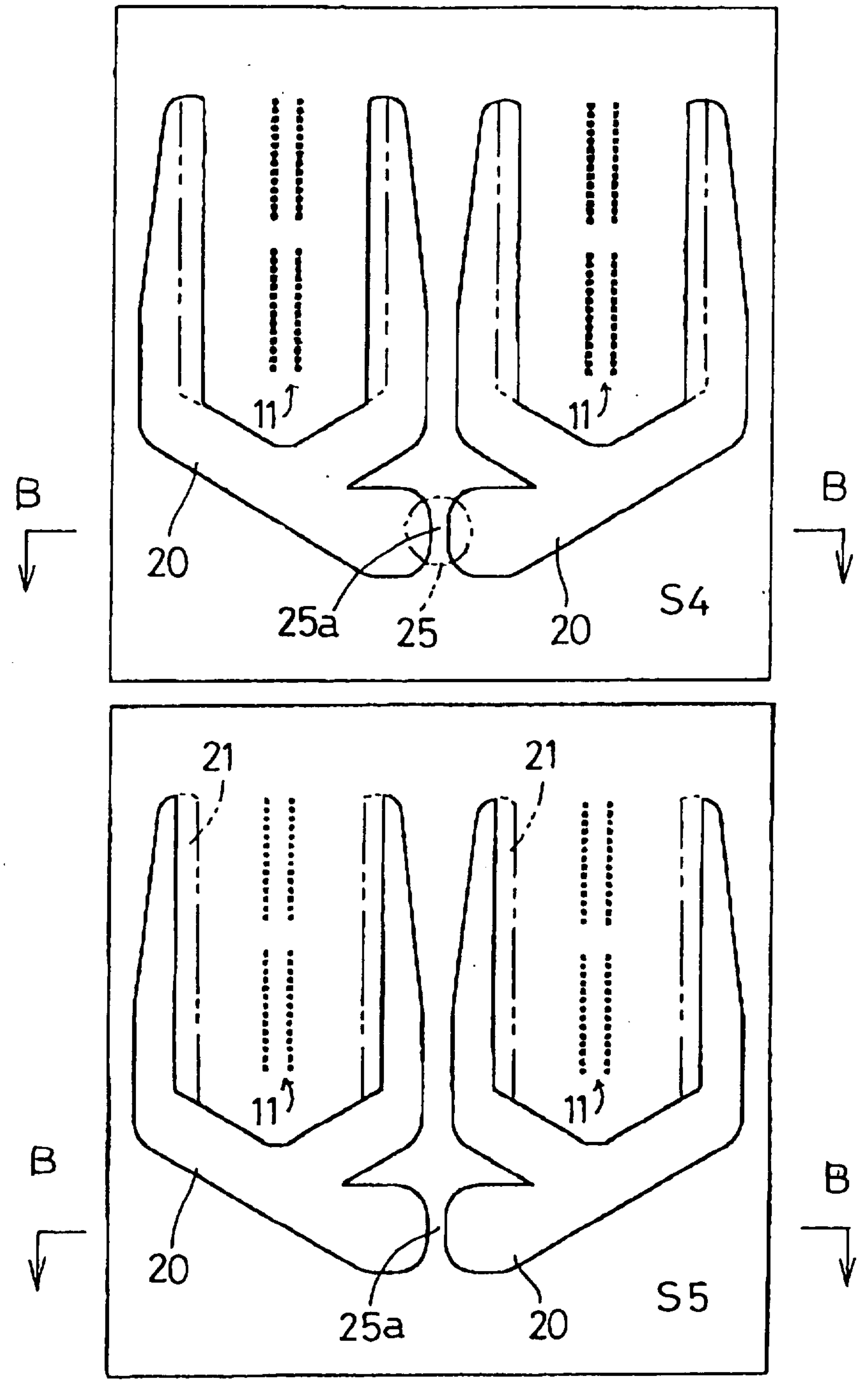
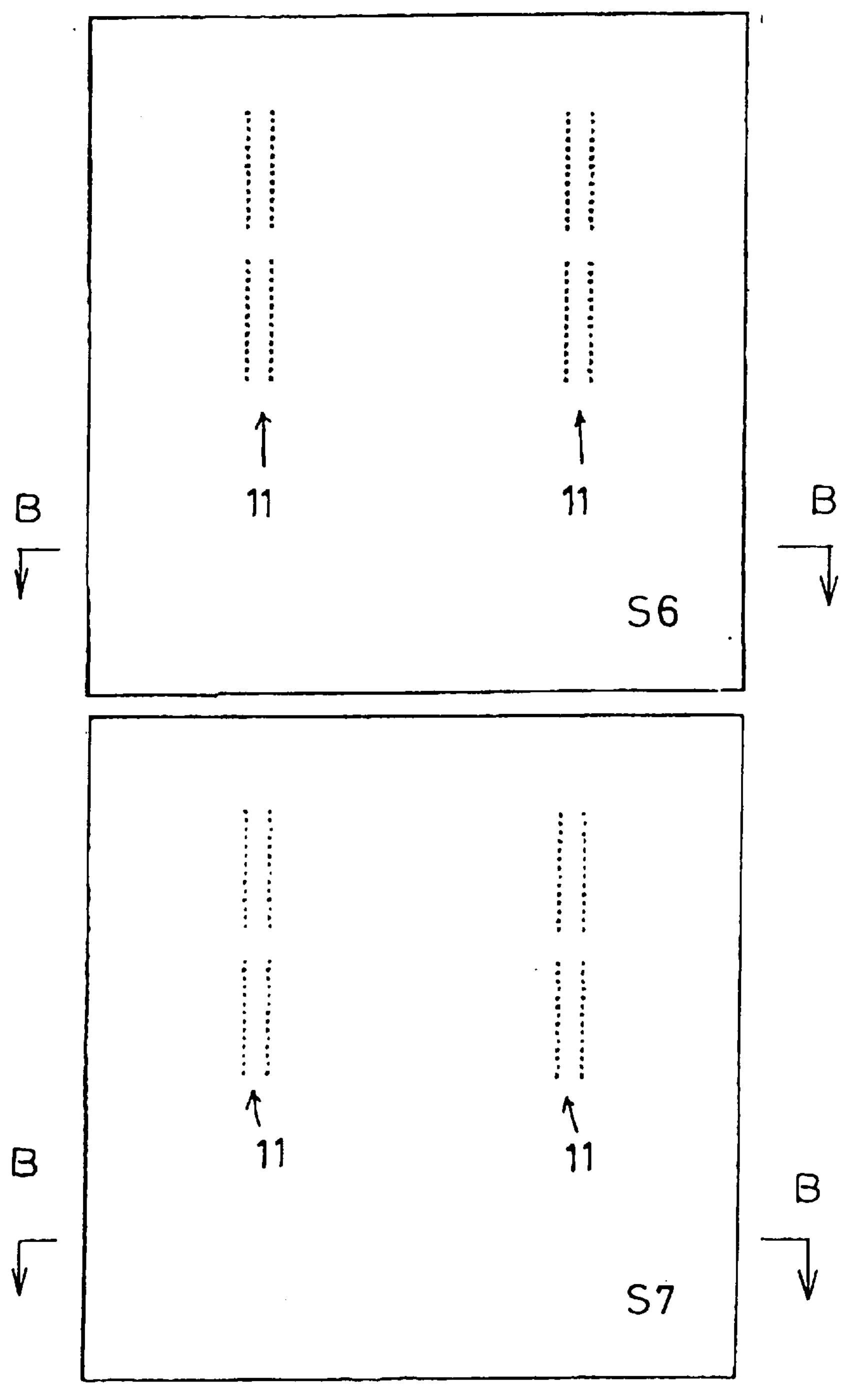


FIG. 8



F I G. 9

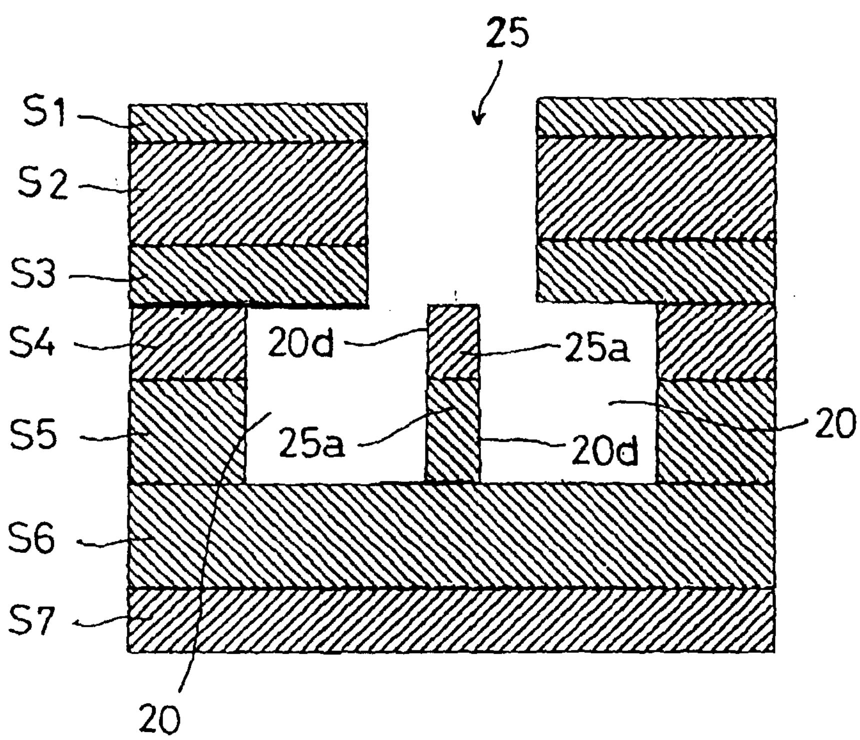
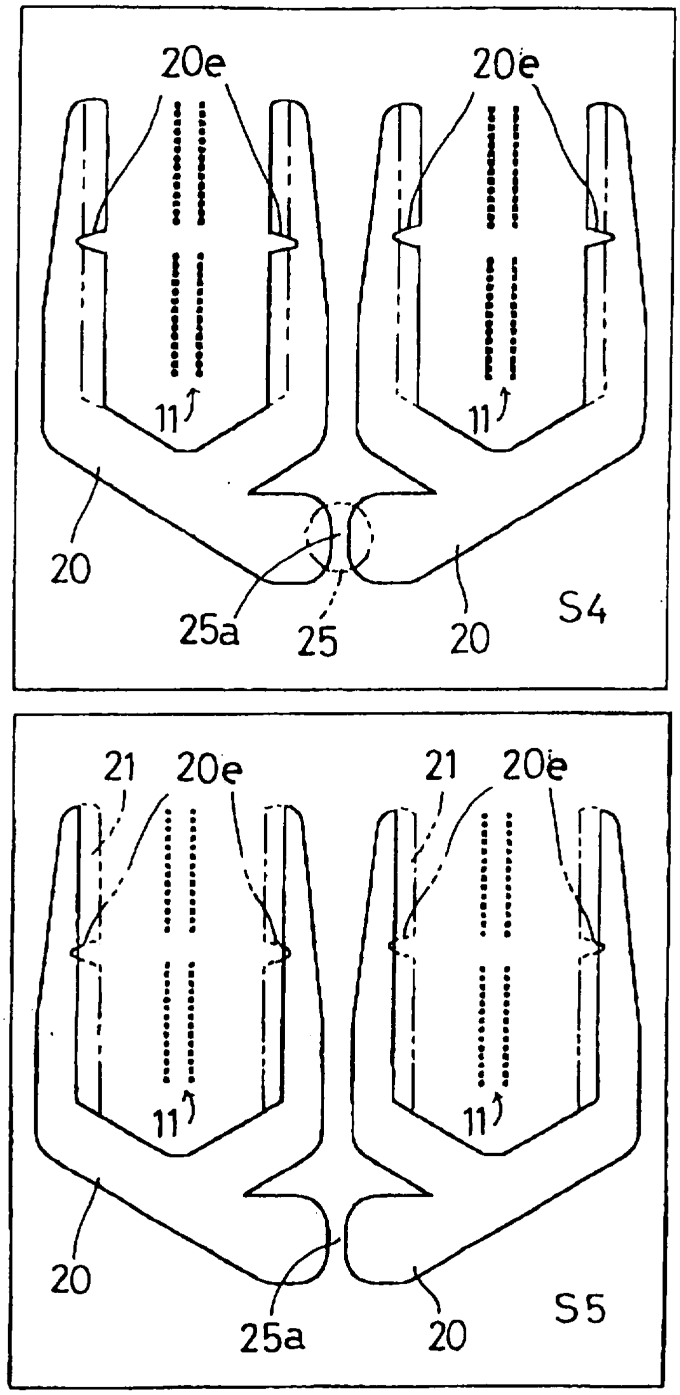


FIG. 10



F I G. 1 1

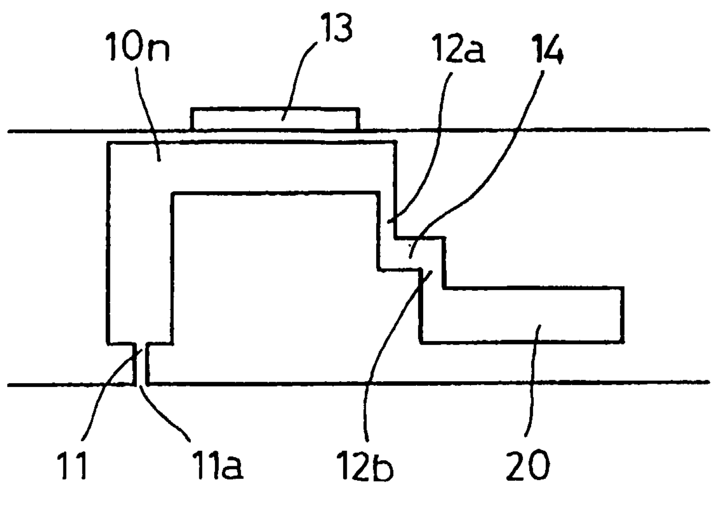


FIG. 12

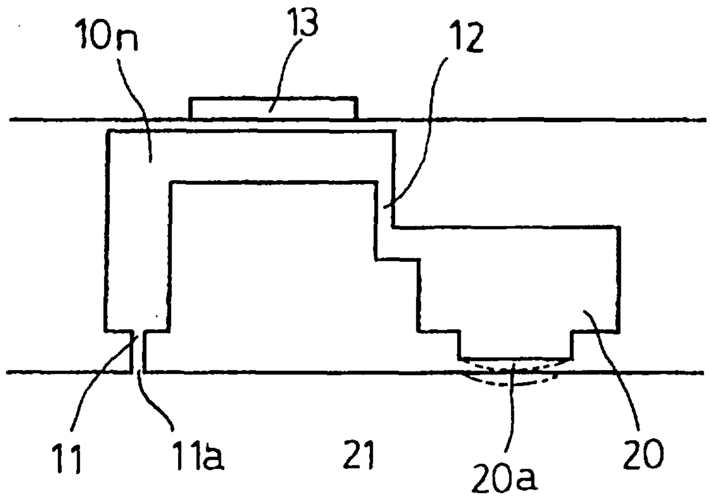


FIG. 13