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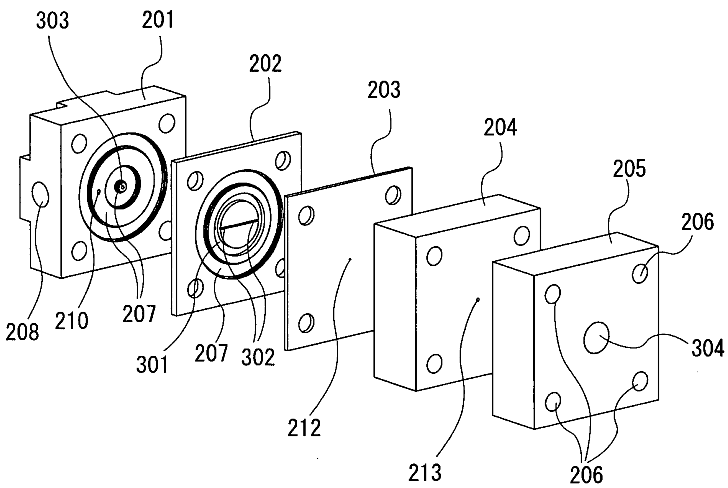
(54) **An emulsification apparatus**

(57) An emulsifying apparatus (104), for emulsifying a first liquid and a second liquid, which is dissoluble in the first liquid, comprises: a first flow channel (210), through which the first liquid flows; and a second flow channel (211), through which the second liquid flows, the first flow channel (210) and the second flow channel (211) being provided on a same plane, while insersecting each other in directions thereof, wherein the first and second liquids are mixed with at a portion where the first flow channel and the second flow channel intersects each other, thereby obtaining emulsion thereof; further comprises: a first member, on which a groove is formed in such a direction that it intersects the first flow channel (210); and a second member, which covers the groove and had a hole penetrating through the first flow channel (210), being laminated on the first member (201), wherein the first member is connected with an introductory member for introducing the first and second liquids, and the second member is connected with a delivery member for delivering an emulsified liquid therefrom, and the first flow channel (210) is communicated with in a direction of laminating the first member (201) and the second member (202).

FIG 3



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Description

BACKGROUND OF THE INVENTION

[0001] The present invention relates to an emulsification apparatus. In general, emulsion is formed, in either an O/W type, wherein an oil (or may be called, a dispersion phase) is dispersed within water (or may be called, a continuous phase), by applying shearing force upon two (2) liquids, which are insoluble with each other, such as, the water and the oil, or a W/O type, wherein the water (or may be called, the dispersion phase) is dispersed within the oil (or may be called, the continuous phase).

[0002] As the conventional method for forming the emulsion is already known a butch method of using a dispersion method therein. This is to obtain a large amount or volume of emulsion, once, by means of a rotating stirrer, while projecting the water and the oil into a large-scaled container. However, with such the method, since the shearing force does not apply upon the liquids, equally, there are problems that a diameter of a particle of the emulsion produced is unequal or luck of uniformity, and that it takes a long time to produce.

[0003] As a method for dissolving such the problems mentioned above, in recent years, there is proposed an emulsion production with using a micro liquid chip.

[0004] For example, in the following Patent Document 1 is already known a method utilizing a liquid shearing velocity, which is generated between the wall surface of a flow path or channel by squeezing the flow channel, in a step-wise manner, while dividing the oil and the water into a large number of flows, to arrange them one another, thereby increasing a contact area between those liquids.

[0005] Also, in the following Patent Document 2 is already known a method for obtaining an emulsion through a cavitations-drop function due to repetition of collision upon the wall surfaces of separation flow channels and pressure drop within the apparatus, while flowing a mixture of two (2) liquids to be emulsified, which are mixed in advance, into that apparatus.

[0006] On the other hand, in the following Non-Patent Document 1 is already known a method for obtaining emulsion through separation of the dispersion phase therefrom, which flows inside a sheath flow, while forming that sheath flow by forming the dispersion phase in an inside and forming the continuous phase in an outside thereof.

[Patent Document 1] Japanese Patent Laying-Open No. 2004-81924 (2004);
[Patent Document 2] Japanese Patent Laying-Open No. 1999-42431 (1999); and
[Non-Patent Document 1] J. Micromech. Microeng. 16 (2006) 23362344.

[0007] With the emulsifying methods described in the Patent Documents 1 and 2, it is possible to obtain an improvement on distribution of particle diameter of the emulsion, comparing to the batch method; however, there is brought about a certain degree of an extent. Also, there is remained a problem that it is difficult to produce an emulsion having a relatively large particle diameter. And, also with the method described in the Patent Document 2, it is necessary to provide a mechanism, separately, for keeping two (2) liquids to be mixed, which should be emulsified.

[0008] On the other hand, with the apparatus described in the Non-Patent Document 1, it is possible to arrange the particle diameter to be equal, and also to obtain an emulsion particle having the relatively large particle diameter; however, with this method, a throughput flow of liquid is small, such as, 1 mL/min or more or less, for example, and therefore it is essential to provide the flow channels in parallel, in order to increase the throughput flow thereof.

[0009] By the way, with the apparatus described in the Non-Patent Document 1, all flow paths or channels are formed on a laminated surface of materials being piled up, including introduction flow channels and combining flow channels of two (2) kinds of liquids, a flow channel for forming the sheath flow, and a flow channel where the sheath flow is divided so as to produce a particle. For this reason, since the direction is restricted only to one (1) direction, into which the parallel channels can be obtained without changing the number of pieces of the plate-like materials to be laminated, and therefore it is impossible to increase the throughput flow, in an effective manner.

[0010] Also, when trying to bring the flow channels in parallel into two (2) directions, since the structure of building up the flow channel in one (1) direction must be piled up further, therefore, the number of layers piled up is increased accompanying with an increase of the number of flow channels to be built up in parallel. For this reason, the processes necessary for that processing are also increased in the number thereof and further because it is apparatus having fine or minute structures, there is caused a difficulty in accuracy of the positioning thereof, and therefore it is also a problem that the processing becomes difficult.

[0011] Also, since the flow channels, within the apparatus described in the Non-Patent Document 1, are formed by laminating the structure after forming a groove through the photolithography thereon, there is necessity of conducting complicated processes for forming the flow channel itself.

[0012] Further, with the method for obtaining the particles through forming such the sheath flow as described in the Non-Patent Document 1, it is necessary to change the velocity of flow or to change a ratio of flow-rates between the dispersion phase and the continuous phase, and also to change flow channel widths of the sheath flow channels, among of those, for the purpose of changing the particle diameter, greatly, it is desirable to change the flow channel widths of the sheath flow channels.

[0013] However, with the structures described in the

Non-Patent Document 1, the flow channels for forming that sheath flow channel and other flow channels are on the same material member, and therefore, for adjusting the particle diameter, with changing the flow channel widths of the sheath flow channels, it is necessary to remake the flow channels as a whole.

BRIEF SUMMARY OF THE INVENTION

[0014] An object is, according to the present invention, to provide an emulsifying apparatus, for enabling to increase the processing throughput for producing an emulsion having a uniform particle diameter.

For accomplishing the object mentioned above, according to the present invention, there is provided an emulsifying apparatus, for emulsifying a first liquid and a second liquid, which is dissoluble in said first liquid, comprising: a first flow channel, through which said first liquid flows; and a second flow channel, through which said second liquid flows, said first flow channel and said second flow channel being provided on a same plane, while insersecting each other in directions thereof, wherein said first and second liquids are mixed with at a portion where said first flow channel and said second flow channel intersects each other, thereby obtaining emulsion thereof; further comprising: a first member, on which a groove is formed in such a direction that it intersects said first flow channel; and a second member, which covers said groove and had a hole penetrating through said first flow channel, being laminated on said first member, wherein said first member is connected with an introductory member for introducing said first and second liquids, and said second member is connected with a delivery member for delivering an emulsified liquid therefrom, and said first flow channel is communicated with in a direction of laminating said first member and said second member.

[0015] Also, for accomplishing the object mentioned above, according to the present invention, there is further provided an emulsifying apparatus for conducting an emulsion by mixing two (2) kinds of liquid, being dissolvable in each other, including a plural number of laminated layers therein, comprising: a dispersion phase inlet flow channel, which is formed on one of said plural number of laminated layers in a direction perpendicular to a plane of that lamination; a mixing flow channel, which is connected with a flow channel on a same axis to said dispersion phase inlet flow channel and is formed in a direction perpendicular to lamination plane of two of said members; and a continuous phase inlet flow channel, which is formed on at least one of said two members, on the lamination plane thereof, so as to join a connection portion of said dispersion phase inlet flow channel and said mixing flow channel.

[0016] Also, for accomplishing the object mentioned above, according to the present invention, within the emulsifying apparatus, as described in the above, said continuous phase inlet flow channels are formed, by a number of at least two (2) or more than that, and are disposed to be axially symmetric to an axis of said dispersion phase inlet flow channel and said mixing flow channel.

[0017] Also, for accomplishing the object mentioned above, according to the present invention, within the emulsifying apparatus, as described in the above, an enlarged mixing flow channel is provided in a rear portion of said mixing flow channel, so that the flow change is connected with said mixing flow channel on a same axis thereof.

[0018] Also, for accomplishing the object mentioned above, according to the present invention, within the emulsifying apparatus, as described in the above, said mixing flow channel and said enlarged mixing flow channel are formed on separated member, respectively.

[0019] Also, for accomplishing the object mentioned above, according to the present invention, within the emulsifying apparatus, as described in the above, a continuous phase dividing flow channel is formed on the plane having said continuous phase inlet flow channel thereon, for distributively introducing a continuous phase to said continuous phase inlet flow channel.

[0020] Also, for accomplishing the object mentioned above, according to the present invention, within the emulsifying apparatus, as described in the above, said dispersion phase inlet flow channel, said continuous phase inlet flow channel, said mixing flow channel and said enlarged mixing flow channel are disposed in plural numbers thereof, within the laminated members building up them therein.

[0021] Also, for accomplishing the object mentioned above, according to the present invention, within the emulsifying apparatus, as described in the above, a mixture liquid combining flow channel, for combining the liquids flowing through said plural number of mixing flow channel or said enlarged mixing flow channel, is formed on a lamination plane of either one of said member for forming said dispersion phase inlet flow channel thereon or other member laminated neighboring to said member, or on a lamination plane of either one of a member, forming the dispersion dividing flow channel for distributing a dispersion phase to said plural number of dispersion phase inlet flow channels and said mixture flow channel or said enlarged mixture flow channel thereon, or other member laminated neighboring to any one of said members.

[0022] According to the present invention, it is possible to provide an emulsifying apparatus, with which the time for producing the emulsion is shortened.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

[0023] Those and other objects, features and advantages of the present invention will become more readily apparent from the following detailed description when taken in conjunction with the accompanying drawings wherein:

Fig. 1 is a structural view of a system including an emulsifying apparatus therein, according to an embodiment of the present invention;

Fig. 2 is a perspective view for showing the exploded structures of the emulsifying apparatus, in particular, seen from a side of an introductory portion for the continuous phase and the dispersion phase;

Fig. 3 is also a perspective view, in particular, for showing that apparatus from a side of a deliver or outlet portion of emulsion;

Fig. 4 is a perspective view for showing a combining flow channel portion 202 shown in Figs. 2 and 3, in particular, when seeing it from a side of the emulsion outlet portion;

Fig. 5 is a cross-section view of the emulsifying apparatus shown in Figs. 2 and 3, combined with other members, in particular, along with an A-A cutting line shown in Fig. 2;

Fig. 6 is an enlarged view of a portion within a circle shown by "B" in Fig. 5 mentioned above;

Figs. 7(a) and 7(b) are perspective views of inflow channels, each differing from each other in the configuration thereof;

Fig. 8 is an enlarged cross-section view for showing the sheath flow channel, diagrammatically;

Fig. 9 is an exploded perspective view of the emulsifying apparatus including other embodiment therein;

Fig. 10 is a perspective view of the emulsifying apparatus shown in Fig. 9, when seeing it from the side of the emulsion outlet portion;

Fig. 11 is a perspective view of the combining flow channel portion, when seeing it from the side of the emulsion outlet portion; and

Fig. 12 is an enlarged perspective view of a "C" portion shown by a broken line in Fig. 11.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0024] Hereinafter, embodiments according to the present invention will be fully explained by referring to the drawings attached herewith.

<Embodiment 1>

[0025] Fig. 1 is the structural view of a system including an emulsifying apparatus therein, according to one embodiment of the present invention.
However, with the present embodiment, explanation will be made on a case where an O/W emulsion is produced with using water, including a surface active agent therein, as a continuous phase, while using an oil as the dispersion phase.

[0026] In Fig. 1, in raw material tanks 101A and 101B are reserved or retained water and oil, respectively. From those raw material tanks 101A and 101B, liquids are transferred by means of pumps 102A and 102B, respectively. With those pumps 102A and 102B, it is preferable to apply a syringe pump or a gear pump, etc., separately, depending on the purpose thereof. The liquids transferred by the pumps 102A and 102B flow into an emulsifying apparatus 104 through introductory tubes 103A and 103B, respectively, and within this an emulsifying apparatus 104 is produced an emulsion thereof. The emulsion produced is stored within an emulsion tank 106 through a deliver tube 105. Further, if a temperature adjustment is necessary upon producing the emulsion, it is also possible to adopt a method of conducting the temperature adjustment, fulfilling a thermostatic chamber 107 with a heating medium, while providing the emulsifying apparatus 104 within that thermostatic chamber 107, for example. Or, alternatively, a Peltier device or the like may be provided on an outside of the emulsifying apparatus 104.

[0027] Next, explanation will be given on the structures of the emulsifying apparatus 104 and liquid flows within that emulsifying apparatus 104, hereinafter, by referring to Figs. 2 to 6.

[0028] Fig. 2 is a perspective view for showing the exploded structures of the emulsifying apparatus 104, seeing it from a side of an introductory portion of the continuous phase and the dispersion phase.

[0029] Fig. 3 is a perspective view for showing the above, but seeing it from a side of an emulsion deliver portion.

[0030] Fig. 4 is a perspective view for showing a combining flow channel portion 202 shown in Figs. 2 and 3, seeing it from the side of the emulsion deliver portion.

[0031] Fig. 5 is a cross-section view of the emulsifying apparatus shown in Figs. 2 and 3, combined with other members, in particular, along with an A-A cutting line shown in Fig. 2.

[0032] Fig. 6 is an enlarged view of a portion within a circle shown by "B" in Fig. 5 mentioned above.

[0033] The emulsifying apparatus 104 shown in Fig. 1 is constructed with, as is shown in Figs. 2, 3 and 5, a liquid introductory portion 201, a combining flow channel portion 202, a sheath flow channel portion 203, an enlarged flow channel portion 204, and a liquid delivery or outlet portion 205, wherein those are jointed or fastened to one another with using screws (not shown in the figure) penetrating through screw holes 206. On each of the members to be jointed is formed a sealing groove 207, so as to put a sealing member (not shown in the figure) therebetween, thereby to prevent the liquid from leaking therethrough. Or, depending on necessity thereof, it is possible to use them after adhering or bonding between those members. Also, as a material of the members building up the emulsifying apparatus 104, is used a metal or a resin, or a glass, etc., depending upon the sorts of liquids to be transferred therein. Also, there is no necessity that the materials of all the members are same, but they may be changed for each of the members, for example, depending on the characteristics in processing thereof, the thermal conductivity thereof, etc.

[0034] The water to be the continuous phase and the oil to be the dispersion phase are introduced from a continuous phase introductory opening 208 and a dispersion phase introductory opening 209, respectively, into a liquid introductory portion 201. To the continuous phase introductory opening 208 and the dispersion phase introductory opening 209 are connected introductory tubes 103A and 103B, which are shown in Fig. 1, with using a coupling (not shown in the figure), and the liquids are transferred into the emulsifying apparatus 104 by means of the pumps 102A and 102B.

[0035] The water introduced in the emulsifying apparatus 104, passing through a continuous phase introductory flow channel 210, is distributed at a continuous phase dividing flow channel 301 (shown in Figs. 3, 4 and 5), which is formed on the surface of laminated layers of the combining flow channel portion 202. The water distributed herein is introduced into a continuous phase inlet flow channel 302 (shown in Figs. 3 and 4), which is formed on the same plane to the continuous phase dividing flow channel 301 and to be symmetric with respect to an axis of a dispersion phase inlet flow channel 211, from an outside thereof. On the other hand, the oil introduced from the dispersion phase introductory opening 209 (shown in Fig. 5), passing through a dispersion phase introductory flow channel 303 (shown in Figs. 3 and 5), and further passing through the dispersion phase inlet flow channel 211 (shown in Fig. 4), which is formed in such a direction perpendicular to the surface of the laminated layers of a member within the combining flow channel portion 202, flows into a junction of the continuous phase inlet flow channel 302, wherein two (2) liquids are combined.

[0036] In other words, from the dispersion phase inlet flow channel 303 extending in the direction, into which the liquid introductory portion 201, the combining flow channel portion 202, the sheath flow channel portion 203, the enlarged flow channel portion 204 and the liquid delivery portion 205 are laminated, the dispersion phase (i.e., the oil) flows into the dispersion phase inlet flow channel 211, which is provided in the combining flow channel portion 202. Within the combining flow channel portion 202 is provided the continuous phase inlet flow channel 302, in which the continuous phase (i.e., the water) flows. At this intersecting portion, the oil and the water are combined with.

[0037] The water and the oil, combining at the continuous phase inlet flow channel 302, run into the sheath flow channel 212, which is formed on the same axis to the dispersion phase inlet flow channel 211 and in the direction perpendicular to the surface of the laminated layers of the member within the sheath flow channel 203, wherein a sheath flow is formed, i.e., running the oil, the dispersion phase, in an inside, while running the water, the continuous phase, in an outside thereof. Further, this sheath flow flows into an enlarged flow channel 213, which is formed on the same axis to the sheath flow channel 212 and in the direction perpendicular to the surface of the laminated layers of the member within the enlarged flow channel portion 204 that is located in a downstream of the sheath flow portion 203, wherein an emulsion of O/W is produced. The O/W emulsion produced is taken out from there, via an emulsion deliver flow channel 214, from an emulsion deliver opening 304.

[0038] In order to obtain the emulsion, effectively, with utilizing the change of flow velocity, within the enlarged flow channel 213, it is preferable that channel width of the sheath flow channel 212 is finest and that channel widths of others are wider than that of the sheath flow channel 212. Also, with the continuous phase dividing flow channel 301 for delivering the water into the continuous phase inlet flow channel 302, it is desirable to make such design that, the pressure loss generated within the continuous phase inlet flow channel 302 is dominant, by bringing the channel width of the continuous phase dividing flow channel 301 to be wide, sufficiently, with respect to the channel width of the continuous phase inlet flow channel 302, so as to distribute the water to a plural number of the continuous phase inlet flowchannels 302, equallyoruniformly.

[0039] Also, with the cross-section configuration of each flow channel, it should not be limited to the configuration shown in the present embodiment, but for example, the cross-section configuration of the continuous phase introductory flow channel 210, the sheath flow channel 212 or the enlarged flow channel 213 may be a rectangular. However, for the purpose of forming a stable sheath flow and obtaining a uniform emulsion particle, it is desirable that the cross-section configuration of the sheath flow channel 212 and the enlarged flow channel 213 are symmetric to the axis of the flow channel.

[0040] Also, though Figs. 3 and 4 show the figures of arranging two (2) continuous phase inlet channels 302 to be symmetric to the axis of the dispersion phase inlet flow channel 211, with respect to the dispersion phase inlet flow channel 211 formed within the combining flow channel portion 202, but for this continuous phase inlet channel 302, it is not necessary to be shown in Figs. 3 and 4, in the number of dispositions and the detailed configuration thereof, as far as it satisfy the axially symmetrical disposition with respect to the axis of the dispersion phase inlet flow channel 211.

[0041] Next, explanation will be made on the case when changing the number of pieces and/or the configuration of the continuous phase inlet channels 302, by referring to Figs. 7(a) and 7(b).

[0042] Figs. 7 (a) and 7(b) show the perspective views of the continuous phase inlet flow channels, differing from each other in the configuration thereof.

[0043] Figs. 7(a) shows the configuration of providing four (4) sets of the continuous phase inlet flow channels 302 for the dispersion phase inlet flow channel 211, thereby letting the continuous phase to flow into from four (4) directions. In the configuration shown in Fig. 7(b), eight (8) sets of the continuous phase inlet flow channels 302 are built up, and the eight (8) sets of the flow channels are combined on the way thereof. Therefore, it is the configuration of combining the continuous phase directing into the dispersion phase flow channel 211 at a center from all directions on a plane. In any one of the configurations, the continuous phase inlet flow channels 302 are disposed to be symmetric to the axis of the dispersion phase inlet flow channel 211, i.e., the continuous phase is distributed by the continuous phase dividing flow channel 301, which is formed on the same plane, in the structures thereof.

[0044] Next, explanation will be given on the condition of the liquid within the channel of the sheath flow channel 212, by referring to Fig. 8.

[0045] Fig. 8 is an enlarged cross-section view for showing the sheath flow channel, diagrammatically.

[0046] In Fig. 8, the oil discharged from the dispersion phase inlet flow channel 211 is combined with the water running from an outside within the continuous phase flow channels 302, and thereby forming a sheath flow 801 residing the oil inside. This sheath flow 801 residing the oil inside is divided during when it flows within the sheath flow channel 212 and the enlarged flow channel 213 in the downstream thereof, and thereby forming an emulsion particle 802.

[0047] Explanation will be given on a method for controlling the particle diameter of this emulsion particle 802, by referring to Figs. 8, 5 and 6.

[0048] In the figure, the emulsion particle 802 grows up the particle diameter thereof, accompanying with an increase of width occupying within the channel of the oil, in the sheath flow 801 residing the oil inside. Accordingly, as the method for controlling the particle diameter of the emulsion particle 802, there can be considered that of increasing or shortening the width occupied by the oil within the flow channel, in particular, within the sheath flow 801, by changing a flow rate between the water and the oil, which are introduced from the continuous phase inlet opening 208 and the dispersion phase inlet opening 209, respectively, or by changing the channel width of the sheath flow channel 212.

[0049] Herein, according to the present invention, since the sheath flow channel portion 203 having the sheath flow channel 212 therein is built up with a member depending on other members, in case when wishing to change the particle diameter of the emulsion particle 802, it is possible to deal with only by exchanging the sheath flow channel portion 203 depending on the particle diameter desired, while producing a several kinds of sheath flow channel portions 203, each differing from in an inner diameter of the sheath flow channel 212 thereof.

<Embodiment 2>

[0050] Next, explanation will be made on the structures of the apparatus, the detailed conf iguration thereof , in case where a plural number of flow channels, each for obtaining the emulsion with forming the sheath flow, are provided in parallel with, in the emulsifying apparatus 104, and flows of the liquids within the emulsifying apparatus 104, by referring to Figs. 9 to 12 attached herewith.

[0051] Fig. 9 is an exploded perspective view of the emulsifying apparatus including other embodiment therein.

[0052] Fig. 10 is a perspective view of the emulsifying apparatus shown in Fig. 9, when seeing it from the side of the emulsion outlet portion.

[0053] Fig. 11 is a perspective view of the combining flow channel portion, when seeing it from the side of the emulsion outlet portion.

[0054] Fig. 12 is an enlarged perspective view of a "C" portion shown by a broken line in Fig. 11.

[0055] In those figures, the emulsifying apparatus 104 is constructed with, as is shown in Figs. 9 and 10, the liquid introductory portion 201, the combining flow channel portion 202, the sheath flow channel portion 203, the enlarged flow channel portion 204, and the liquid delivery or outlet portion 205, wherein those are jointed or fastened to one another with using screws (not shown in the figure) penetrating through the screw holes 206. On each of the members is formed the sealing groove 207, so as to put the sealing member (not shown in the figure) therebetween, thereby to prevent the liquid from leaking therethrough. Or, depending on necessity thereof, it is possible to use them after adhering or bonding between those members. Also, as a material of the members building up the emulsifying apparatus 104, is used a metal or a resin, or a glass, etc., depending upon the sorts of liquids to be transferred therein. Also, there is no necessity that the materials of all the members are same, but they may be changed for each of the members, for example, depending on the characteristics in processing thereof, the thermal conductivity thereof, etc.

[0056] The water to be the continuous phase and the oil to be the dispersion phase are introduced from a continuous phase introductory opening 208 and a dispersion phase introductory opening 209, respectively, into a liquid introductory portion 201. To the continuous phase introductory opening 208 and the dispersion phase introductory opening 209 is connected the introductory tubes 103, which are shown in Fig. 1, with using a coupling (not shown in the figure), and the liquids are transferred into the emulsifying apparatus 104 by means of the pumps 102.

[0057] The water introduced therein, passing through the continuous phase introductory flow channel 210, is distributed at the continuous phase dividing flow channel 301 (shown in Fig. 10), which is formed on the surface of laminated layers of the combining flow channel portion 202. On the plane forming this continuous phase dividing flow channel 301 thereon are disposed the continuous phase inlet flow channels 302 in plural numbers thereof, and herein, the water, i.e., the continuous phase, is divided to flow into the continuous phase inlet flow channels 302.

[0058] On the other hand, the oil introduced from the dispersion phase introductory opening 209 passes through the dispersion phase introductory flow channel 303. Thereafter, it is distributed through a dispersion phase dividing flow channel 1001, which is formed on the lamination plane of the liquid the liquid introductory portion 201, and passes through the dispersion phase inlet flow channels 211, being formed in plural number thereof, to be perpendicular to the lamination plane, within the combining flow channel portion 202. Thereafter, it flows into a combining portion of the continuous phase inlet flow channel 302, which is disposed to be axially symmetric to the axis of the dispersion phase inlet flow channels 211.

[0059] The water and the oil combining at the combining flow portion of each of the continuous phase inlet flow channels 302 and the dispersion phase inlet flow channels 211 run into the sheath flow channels 212 formed in plural numbers thereof, each being on the same axis to the dispersion phase inlet flow channel 211 and perpendicular to the lamination plane of the member, within the sheath flow channel portion 203. The water and the oil running therein form a sheath flow residing the water in an inside while residing the water in an outside thereof. Further, this sheath flow runs into enlarged flow channels 213 formed in plural numbers thereof, each being on the same axis to the sheath flow channel 212 and perpendicular to the lamination plane of the member, within the enlarged flow channel portion 204 located in a downstream of the sheath flow channel portion 203, and thereby producing the O/W emulsion. The O/W emulsion produced is collected by means of an emulsion combining flow channel 901, which is formed on the lamination plane of the liquid delivery or outlet portion 205 locating in the downstream thereof, and it is taken out form the emulsion deliver opening 304, via the emulsion deliver flow channel 214.

[0060] In order to obtain the emulsion, effectively, with utilizing the change of flow velocity, within the enlarged flow channel 213, it is preferable that channel width of the sheath flow channel 212 is finest and that channel widths of others are wider than that of the sheath flow channel 212.

[0061] Also, with the continuous phase dividing flow channels 301 for delivering the water into the plural numbers of continuous phase inlet flow channels 302, and also dispersion phase dividing flow channels 1001 for distributing the oil to the plural number of dispersion phase discharge openings, it is necessary to distribute the water or the oil, equally or uniformly. For that reason, it is desirable to make such design that, the pressure losses generated within the continuous phase inlet flow channel 302 and the dispersion phase inlet flow channel 211 are dominant, by bringing the channel width of the continuous phase dividing flow channel 301 and the dispersion phase dividing flow channel 1001 to be wide, sufficiently, with respect to the channel widths of the continuous phase inlet flow channel 302 and the dispersion phase inlet flow channel 211.

[0062] Also, with the cross-section configuration of each flow channel, it should not be limited to the configuration shown in the present embodiment, but for example, the cross-section configuration of the continuous phase introductory flow channel 210, the sheath flow channel 212 or the enlarged flow channel 213 may be a rectangular. However, for the purpose of forming a stable sheath flow and obtaining a uniform emulsion particle , it is desirable that the cross-section configuration of the sheath flow channel 212 and the enlarged flow channel 213 are symmetric to the axis of the flow channel. Also, in Figs. 10, 11 and 12 is shown a figure of arranging two (2) continuous phase flow channels 302 to be axially symmetrical with each other to the axis of the dispersion phase flow channel 211, with respect to one (1) of the dispersion phase flow channels 211, which are formed within the combining flow channel portion 202. However, with this continuous phase flow channel 302, it should not always have such configuration as shown in each of the figures; for example, it may in such the configuration that four (4) pieces of continuous phase inlet flow channels 302 are disposed to be axially symmetric with, to the axis of the dispersion phase inlet flow channel 211. In any configuration, the present invention should not be restricted to that detailed configuration, as far as satisfying the disposition of brining it to be axially symmetric with, to the axis of the dispersion phase inlet flow channel 211.

[0063] The present invention, in other words, has a limit of increasing the numbers of the dispersion phase inlet flow channels and the continuous phase inlet flow channels, for increasing the throughput of emulsion processing, in particular, in case where the dispersion phase inlet flow channels and the continuous phase inlet flow channels are on the same plane, as was described in the Non-Patent Document.Thus,in particular,since the dispersion phase inlet flow channel is extended in the direction of surface on the drawing paper, the emulsifying apparatus as a whole becomes large in the sizes thereof if aligning the dispersion phase inlet flow channels and the continuous phase inlet flow channels in plural numbers thereof in parallel with.

[0064] Then, according to the present invention, because of adoption of the structure, i.e., extending the dispersion phase inlet flow channels into the depth direction of the drawing paper, as is shown in Fig. 12, it is possible to dispose the plural numbers of the dispersion phase inlet flow channels and the continuous phase inlet flow channels in parallel with, without paying no consideration on the length of the dispersion phase inlet flow channels.

[0065] Therefore, according to the present invention, it is possible to dispose the plural numbers of the dispersion phase inlet flow channels and the continuous phase inlet flow channels, by taking only the number of the continuous phase inlet flow channels into the consideration thereof, and therefore it is possible to increase the throughput of producing the emulsion for that fact.

[0066] According to the present invention, as was mentioned above, since the sheath flow, which is formed by two (2) kinds of liquids, each being indissoluble in each other, can be formed in the direction of lamination of the members, then it is possible to produce the emulsion having a uniform particle diameter and also a large particle diameter to a certain extent, through the sheath flow method.

[0067] Also, it is possible to dispose the flow channels in two (2) directions, once, in a plural number thereof, but without changing the number of pieces of the constituent members thereof , and therefore it is easy to build up the emulsifying apparatus for increasing the throughput thereof. Also, since there is no necessity of chaining the number of pieces of the members to build up the apparatus, the problem of accuracy of positioning can be dissolved.

[0068] Also, because of forming the continuous phase dividing flow channels, for distributively introducing the continuous phase into the existing continuous phase inlet flow channels, upon the plane having the existing continuous inlet flow channels thereon, there is no necessity to form the channels for introducing the continuous phase into each of the continuous phase inlet flow channels after diving the continuous phase, therefore it is easy to machine the flow channels, and thereby easy to build up the emulsifying apparatus for increasing the throughput thereof.

[0069] Also, with having those features therein, the processes necessary for each member is only a process of drilling, or a simple process of gutter machining, and therefore, it is possible to build up the plural number of sheath flow channels with only a simple process, such as, a mechanical machining.

[0070] Also, with having those features therein, the flow channels for forming the sheath flow and flow channels for other than that can be disassembled from each other, and it is possible to achieve the control upon the particle diameter of the emulsion particles, by changing the channel width of the sheath flow channel, through replacement of only the member, which has the combining flow channel, with a member, which has the combining flow channel of different channel width.

[0071] While we have shown and described several embodiments in accordance with our invention, it should be understood that disclosed embodiments are susceptible of changes and modifications without departing from the scope of the invention. Therefore, we do not intend to be bound by the details shown and described herein but intend to cover all such changes and modifications that fall within the ambit of the appended claims.

Claims

1. An emulsifying apparatus (104), for emulsifying a first liquid and a second liquid, which is dissoluble in said first liquid, comprising:

    a first flow channel (210), through which said first liquid flows; and

    a second flow channel (211), through which said second liquid flows, said first flow channel (210) and said second flow channel (211) being provided on a same plane, while intersecting each other in directions thereof,

    wherein said first and second liquids are mixed with at a portion (202) where said first flow channel (210) and said second flow channel (211) intersect each other, thereby obtaining emulsion thereof; further comprising:

    a first member, on which a groove is formed in such a direction that it intersects said first flow channel (210); and a second member, which covers said groove and has a hole penetrating through said first flow channel (210), being laminated on said first member, wherein said first member is connected with an introductory member for introducing said first and second liquids, and said second member is connected with a delivery member for delivering an emulsified liquid therefrom, and

    said first flow channel (210) is communicated with in a direction of laminating said first member and said second member.

2. An emulsifying apparatus (104) for conducting an emulsion by mixing two kinds of liquid, being dissolvable in each other, including a plural number of laminated layers therein, comprising:

    a dispersion phase inlet flow channel (211), which is formed on one (201) of said plural number of laminated layers in a direction perpendicular to a plane of that lamination;

    a mixing flow channel (212), which is connected with a flow channel on a same axis to said dispersion phase inlet flow channel (211) and is formed in a direction perpendicular to lamination plane of two of said members; and

    a continuous phase inlet flow channel (302), which is formed on at least one (202) of said two members, on the lamination plane thereof, so as to join a connection portion of said dispersion phase inlet flow channel (211) and said mixing flow channel (212).

3. The emulsifying apparatus (104), as described in claim 1, wherein
    said continuous phase inlet flow channels (210) are formed, by a number of at least two or more, and are disposed to be axially symmetric to an axis of said dispersion phase inlet flow channel (211) and said mixing flow channel (212).

4. The emulsifying apparatus (104), as described in claim 1 or 2, wherein
    an enlarged mixing flow channel (213) is provided in

a rear portion of said mixing flow channel (212), so that the flow change is connected with said mixing flow channel (212) on a same axis thereof.

5. The emulsifying apparatus (104), as described in claim 4, wherein
said mixing flow channel (212) and said enlarged mixing flow channel (213) are formed on separated member (203, 204), respectively.

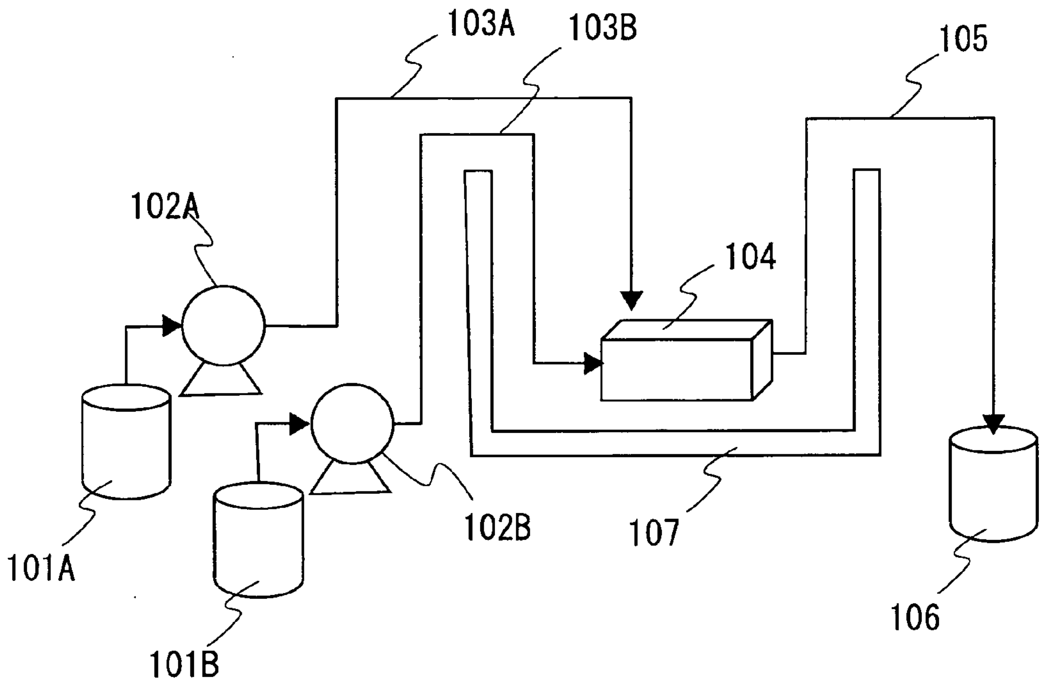
6. The emulsifying apparatus (104), as described in claim 1 or 2, wherein
a continuous phase dividing flow channel is formed on the plane having said continuous phase inlet flow channel (210) thereon, for distributively introducing a continuous phase to said continuous phase inlet flow channel (210).

7. The emulsifying apparatus (104), as described in claim 4, wherein
said dispersion phase inlet flow channel (211), said continuous phase inlet flow channel (210), said mixing flow channel (212) and said enlarged mixing flow channel (213) are disposed in plural numbers thereof, within the laminated members (202, 203, 204) building up them therein.

8. The emulsifying apparatus (104), as described in claim 7, wherein
a mixture liquid combining flow channel (212), for combining the liquids flowing through said plural number of mixing flow channel (212) or said enlarged mixing flow channel (213), is formed on a lamination plane of either one of said member (203) for forming said dispersion phase inlet flow channel (211) thereon or other member (202, 204) laminated neighboring to said member (203), or on a lamination plane of either one of a member, forming the dispersion dividing flow channel (211) for distributing a dispersion phase to said plural number of dispersion phase inlet flow channels (211) and said mixture flow channel (212) or said enlarged mixture flow channel (213) thereon, or other member (202, 204) laminated neighboring to any one of said members.

9. The emulsifying apparatus (104), as described in claim 7, wherein
a mixture liquid combining flow channel (212), for combining the liquids flowing through said plural number of mixing flow channel or said enlargedmixing flow channel (213), is formed on a lamination plane of either one of said member (202) for forming said dispersion phase inlet flow channel (211) thereon or other member (201, 203) laminated neighboring to said member (202), or on a lamination plane of either one of a member, forming the dispersion dividing flow channel (211) for distributing a dispersion phase to said plural number of dispersion phase inlet flow channels (211) and saidmixture flow channel (212) or said enlargedmixture flow channel (213) thereon, or other member laminated neighboring to any one of said members.

FIG 1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102A
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106

FIG 2

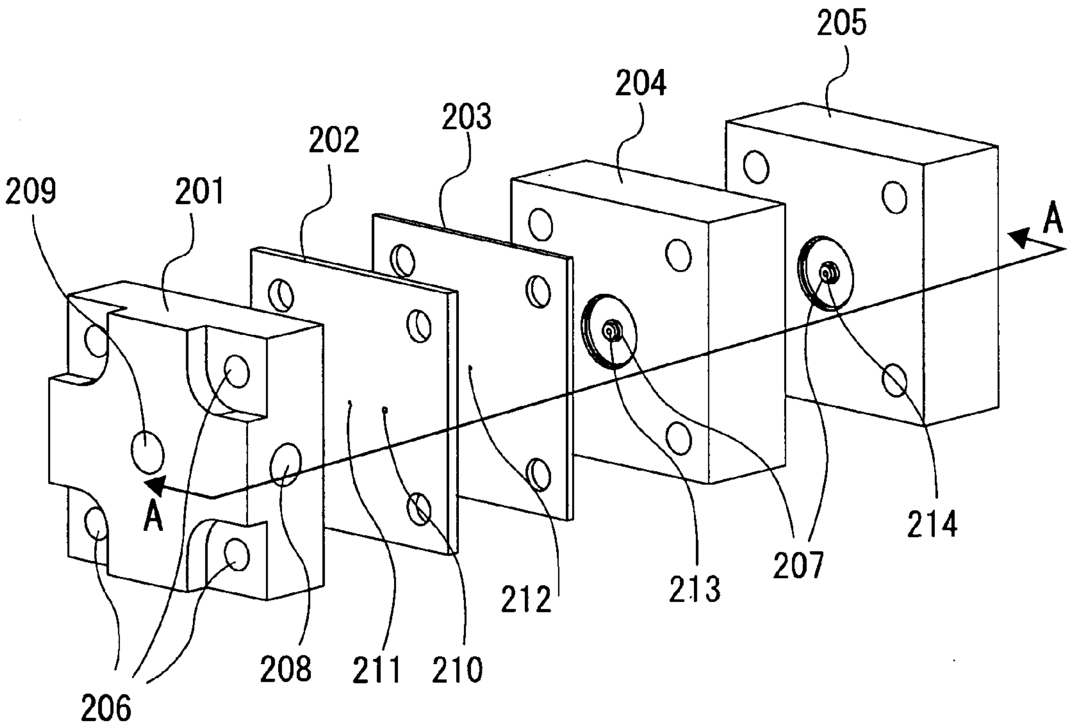
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FIG 3

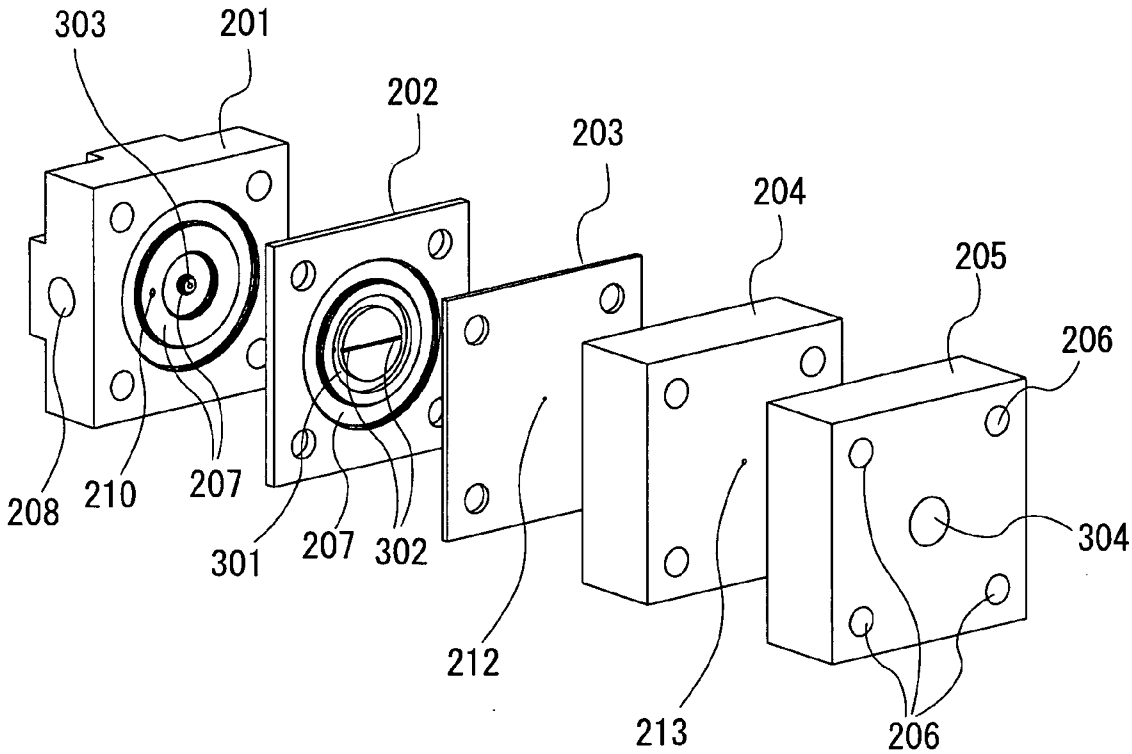
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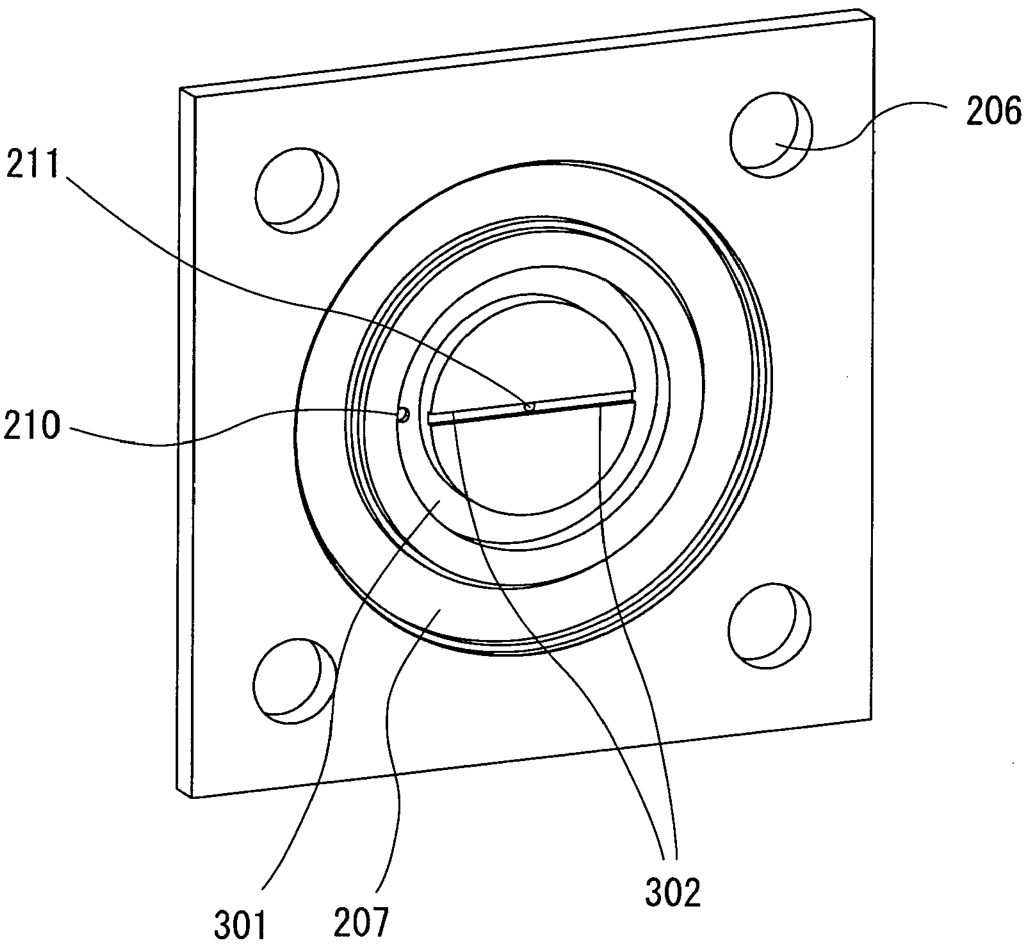
FIG 4



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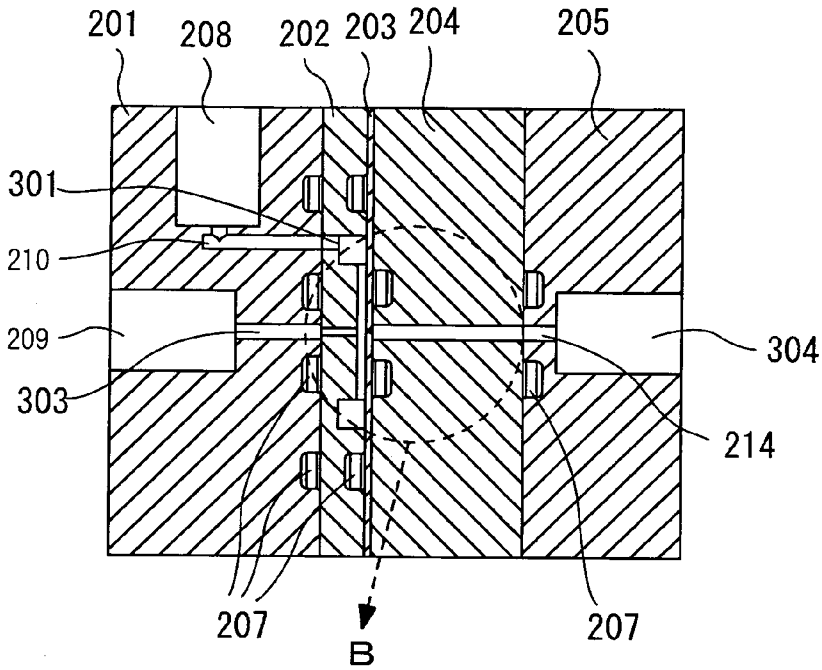
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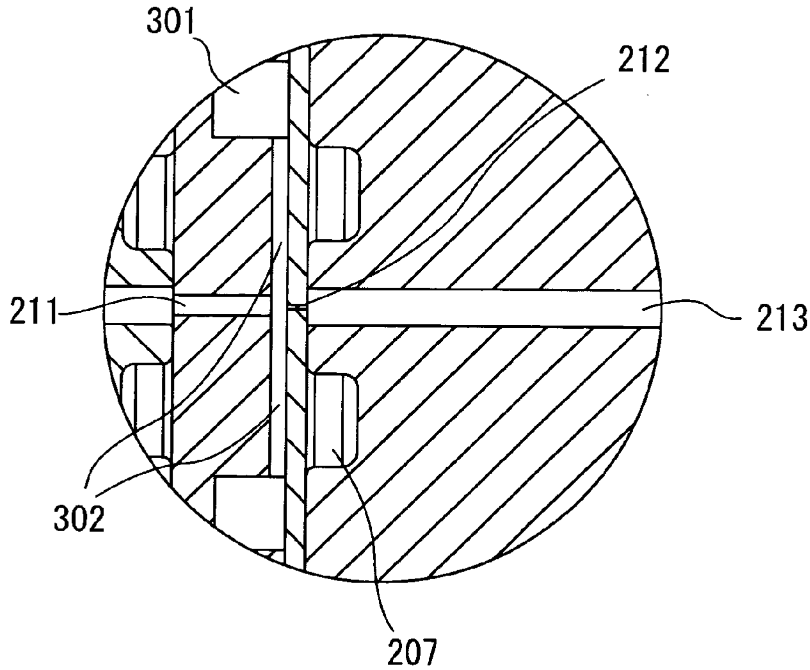
FIG 6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302
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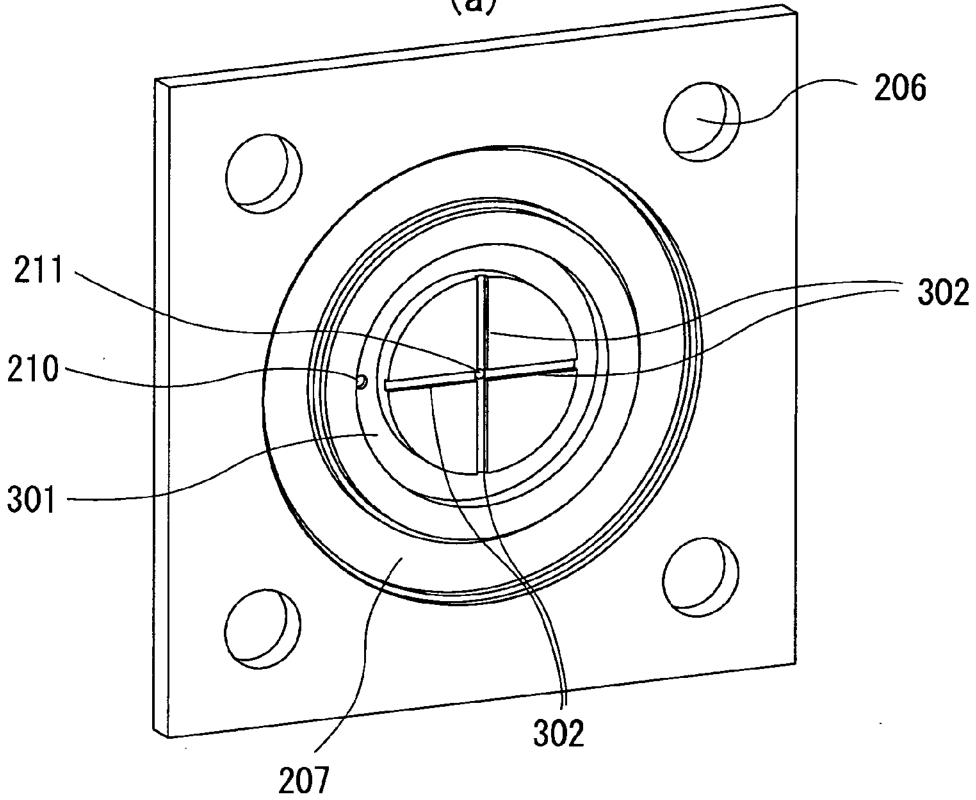
FIG 7

(a)



(b)

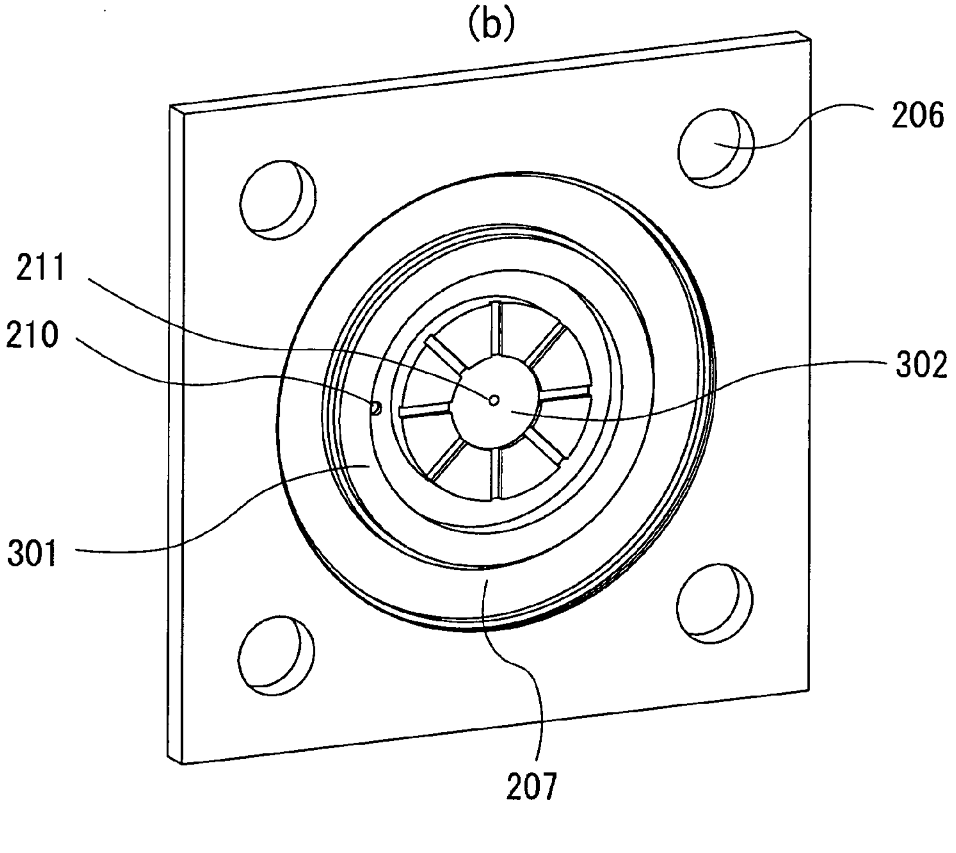


FIG 8

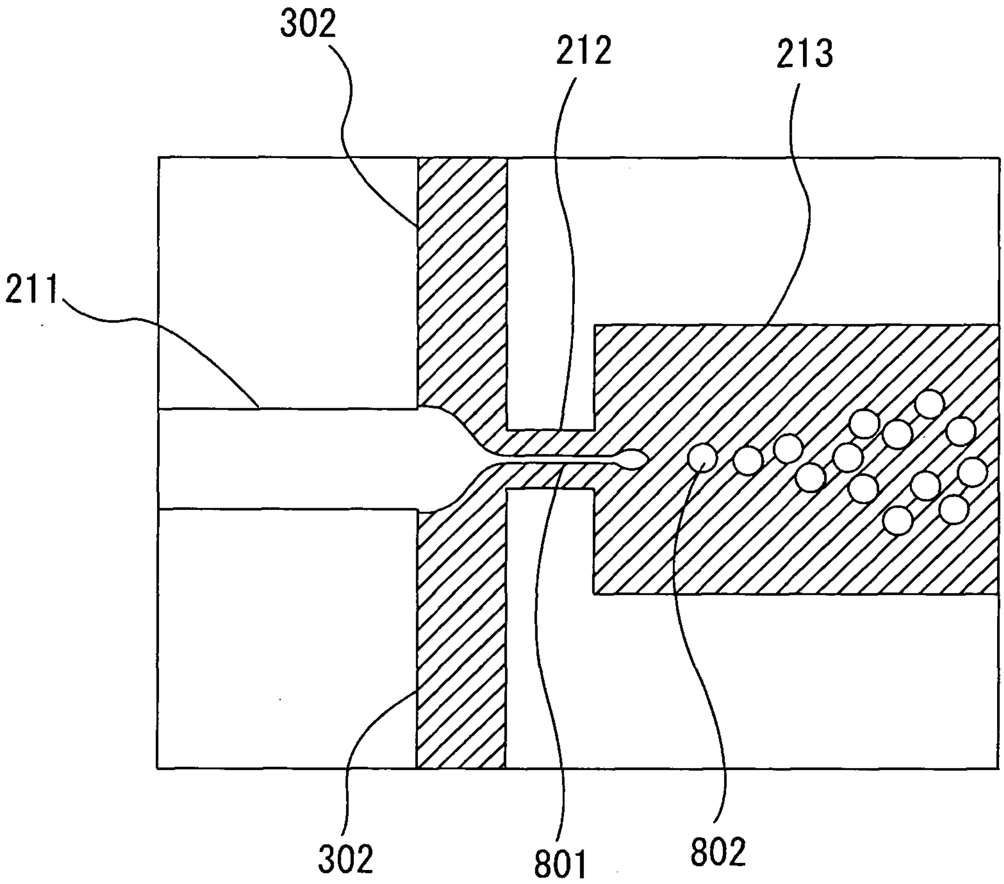


FIG 9

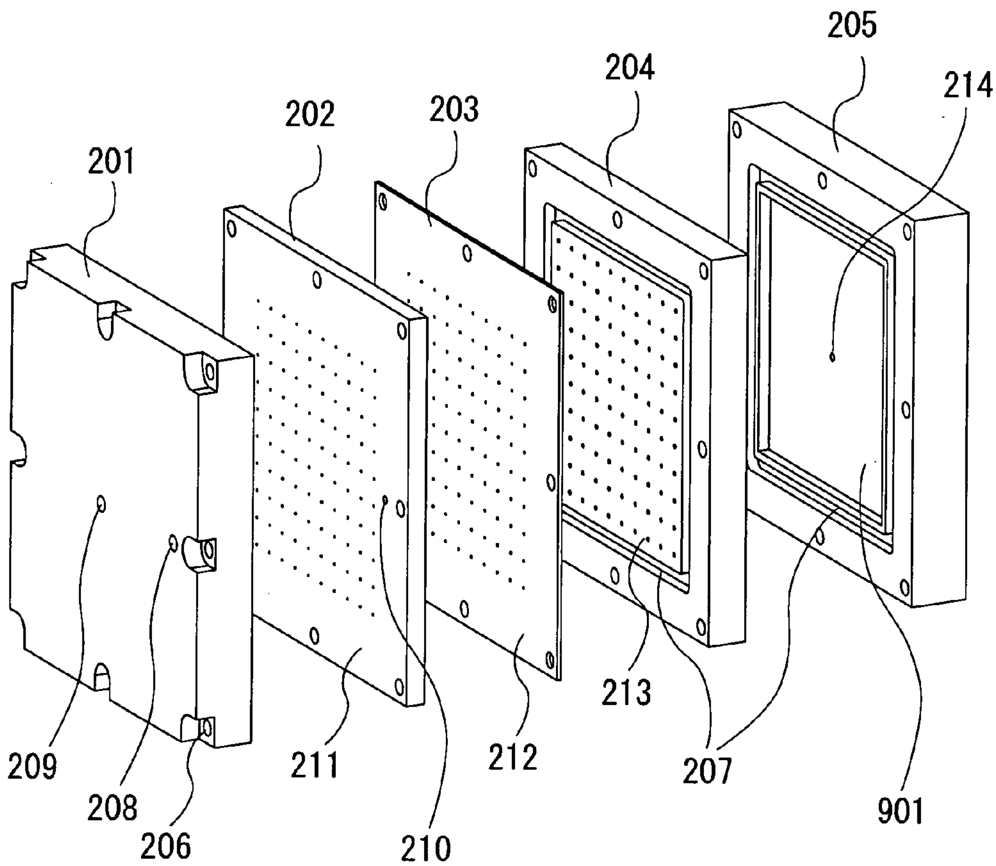


FIG 10

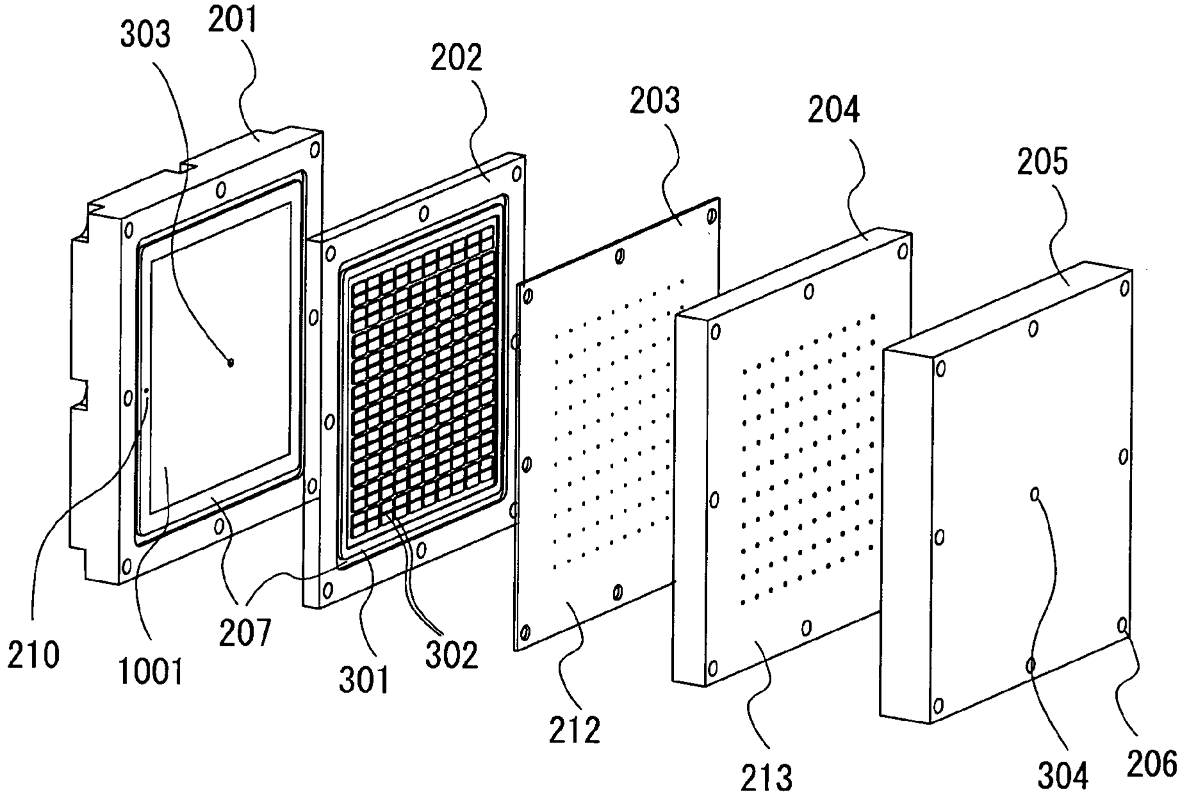


FIG 11

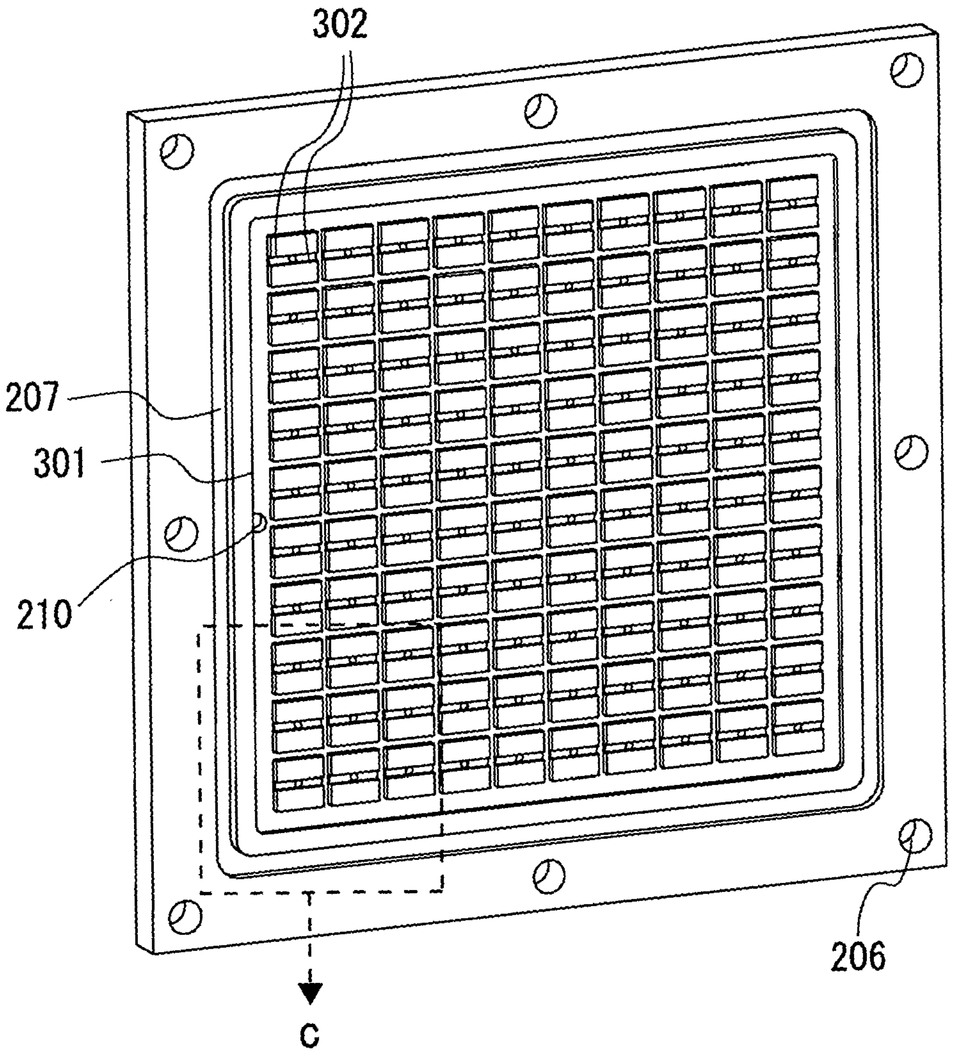
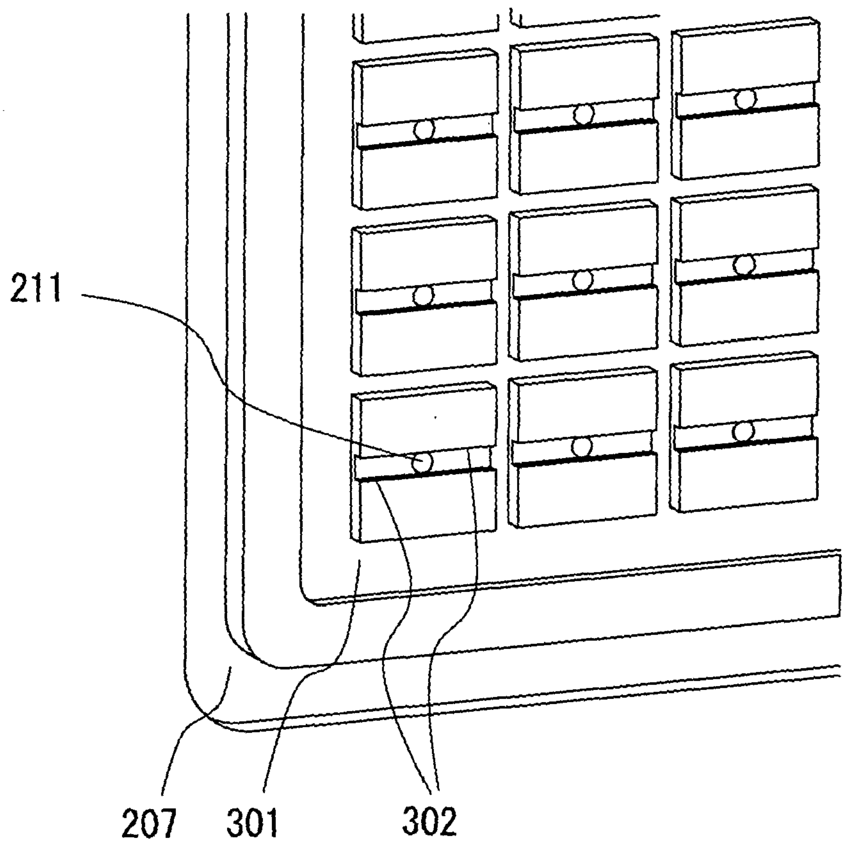


FIG 12



REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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