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

(11) EP 2 105 202 A1

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
30.09.2009 Bulletin 2009/40

(21) Application number: **08153497.6**

(22) Date of filing: **28.03.2008**

(51) Int Cl.:
B01F 13/00 *(2006.01)* ***B01F 13/08*** *(2006.01)*
F04B 19/00 *(2006.01)*

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MT NL NO PL PT RO SE SI SK TR
Designated Extension States:
AL BA MK RS

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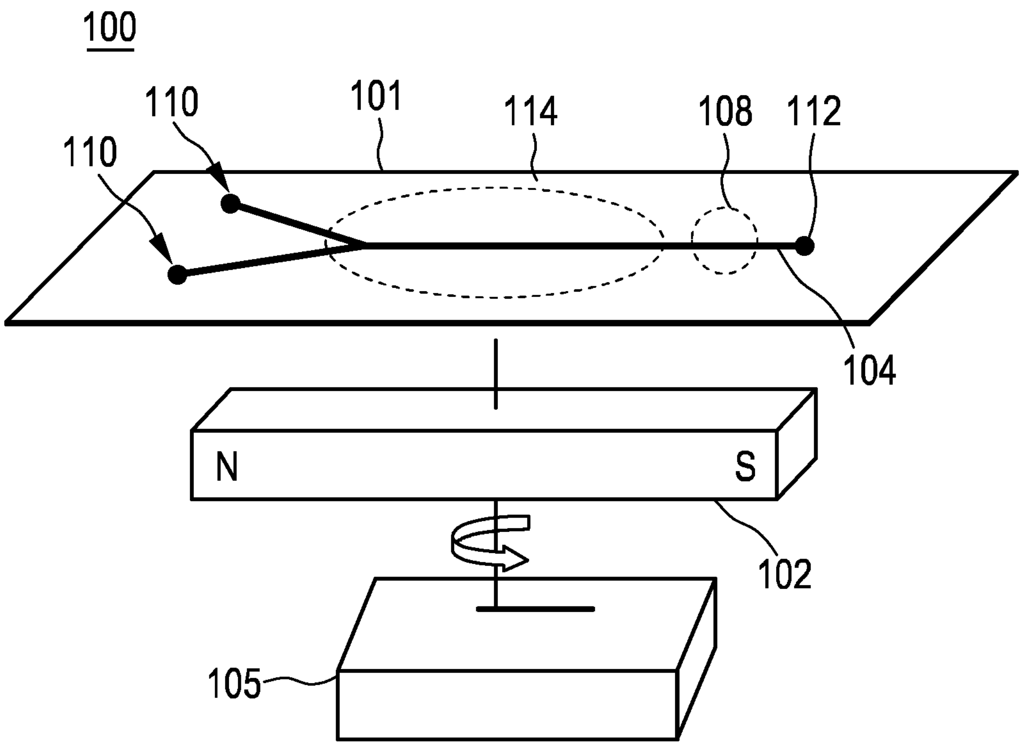
(54) **Apparatus and method for a microfluidic mixer and pump**

(57) The present invention relates to an apparatus (100) and a corresponding method for rapid mixing and pumping of fluids which includes a movable and controllable rotating magnetic field (102), a microfluidic channel (104) including a mixing zone (106) and a pumping chamber (108) within the magnetic field (102), and a plurality of magnetic rods (116) within the micro fluidic channel (104) and the magnetic field (102), whereby the rotating magnetic field (102) applies torque to the magnetic rods (116).

FIG. 2



Printed by Jouve, 75001 PARIS (FR)

Description

FIELD OF THE INVENTION

[0001] The present invention relates to microfluidic systems. More particularly, the invention relates to an apparatus and a corresponding method for rapid mixing and pumping of fluids.

BACKGROUND OF THE INVENTION

[0002] Micro-fluidics is the science and technology of manipulating and analyzing fluid flow in structures of submillimeter dimensions. This field is particularly relevant for the development of lab-on-chip devices, which can be pictured as credit-card-sized fluidic systems containing small channels and chambers, typically with sizes of 0.1 mm or less, in which processes such as pumping, mixing and routing of the liquids, and separation, reaction, and detection of individual components present in these liquids are integrated. In this way a complete large-scale analysis laboratory is miniaturized and combined on a single chip.

[0003] Existing solutions for the required micro-fluidic flow control are the application of a pressure, the use of capillary forces (i.e. surface tension), or the use of valves integrated in the micro-fluidic channels (for example membrane-based valves that are operated using pneumatics). Other options are formed by electro-kinetically driven flows, in which electrodes, integrated in the system, are used to apply electrical fields in the channels which also can drive flows. Finally, the use of "discrete microfluidics" shall be mentioned in which droplets of liquid are manipulated for example using electrical effects (electrowetting) or temperature gradients. All of these solutions may indeed be effective for flow control, in particular pumping or mixing, but they are not very versatile. In other words, the nature of the effects is such that one particular design of the system will result in one particular type of flow generated.

[0004] A special challenge in micro-fluidic systems is to create efficient mixing flows. Due to the small channel sizes, the Reynolds number is generally low and flows are non-turbulent. On the other hand, the channel size is often too large for molecular diffusion to be effective in mixing within a reasonable time. To obtain efficient mixing, special strategies must therefore be followed. An approach is to create repeatedly stretching and folding flow patterns, leading to so-called chaotic advection that causes effective mixing. The existing micro-mixers can be divided into two general classes, namely passive and active micro-mixers. Passive micro-mixers do not require external energy, and the mixing process relies entirely on chaotic advection or diffusion. The effect is often achieved by special geometrical features like channel shape or corrugations on the channel walls. Active micro-mixers use the disturbance generated by an external field for the mixing process, and thus they require external energy. Examples are: the application of sinusoidal pressure pulses to the micro-channel through the channel inlets, electro-hydrodynamic forcing using integrated electrodes, integrated micro-actuators that are elctrostatically actuated, and acoustic streaming. A particular approach is to use magnetic actuation to achieve active micro-mixing

[0005] In one proposed solution to the problem, belonging to this latter class, (Sibani Lisa Biswal, Alice P. Gast, Anal. Chem. 76, 6448-6455 (2004)), a plurality of superparamagnetic beads was introduced into the fluid in the microchannel on a chip. Under the influence of an applied magnetic field, the particles line up and form strings. Rotation of the magnetic field caused the strings to rotate and act as stirrers. However, this solution functions properly only within a narrow range of parameters which were highly dependent upon magnetic field strength and its rotation rate and the viscosity of the fluids. At low rotation rates there was no effective mixing. At high rotation rates the strings broke apart.

[0006] Further, a prior art system (H. Singh, P.E. Laibinis and T.A. Hatton, Langmuir, 21, 11500-11509, (2005)) that employs colloid-stabilized aggregates shows less stability at high rotation speeds than ferromagnetic rods, and eliminates the requirement for the colloid stabilizers.

[0007] US 2004/0114458 A1 discloses a device for mixing fluids having a mixing chamber, a ferromagnetic core at the center of the chamber, a magnetic field means around the perimeter of the chamber, and a number of paramagnetic beads in the chamber to mix any fluids that may be present. The beads oscillate in a radial pattern around the ferromagnetic core, between the core and the magnetic field means, and thereby mix the fluids. The device requires a ferromagnetic core in the center of the chamber. The oscillating motion of the beads requires a complex control mechanism to compensate for different properties of the fluids to be mixed, in order to provide maximum mixing within the chamber. Further, such a system has no demonstrated efficacy as a pump mechanism.

[0008] The article "Micro Magnetic Stir-Bars Integrated In Parylene Surface-Micromachined Channels For Mixing and Pumping", by Kee Suk Ryu, et al., discloses a monolithic micro-magnetic stir bar modeled on the traditional magnetic stir-bar. The micro stir-bar is manufactured as a single piece with the channel via a multiple layer deposition process, and has a symmetric, fixed point of rotation within the channel. The traditional monolithic construction described requires that the micro stir-bar is manufactured to very closely match the width of the fluid channels. A 50 μm gap between the tip of the micro stir-bar and the inner wall of the channel was identified as being so large as to reduce mixing efficiency. The author discloses how he was able to achieve a gap of only 10 μm, but even that small gap provides room for a laminar flow to avoid the micro stir-bar.

[0009] Further, the author describes the alternative use of the micro stir-bar as a pump to move fluid within the channel. Similar to the mixer application, the pump application discloses that the single-piece micro stir-bar is manufactured together with the channel via a multiple layer deposition process so that the micro stir-bar is captured and has a fixed point of rotation within the channel. The disclosed methods of production are quite expensive and time-consuming, especially for a one-time-use device.

SUMMARY OF THE INVENTION

[0010] It is an object of the present invention to provide an apparatus and method that are capable of both effective mixing and pumping of fluids within a micro fluidic device.

[0011] It is an aim of particular embodiments of the present invention to provide an apparatus and method that are capable of being switched between mixing and pumping modes quickly and easily.

[0012] According to a first aspect of the present invention there is provided an apparatus for rapid mixing and pumping of fluids comprising: a movable and controllable rotating magnetic field; a micro fluidic channel including a mixing zone and a pumping chamber within said magnetic field; and a plurality of magnetic rods within said microfluidic channel and said magnetic field, whereby said rotating magnetic field applies torque to said magnetic rods.

[0013] By providing such a (microfluidic) apparatus that includes both a mixing zone and a pumping zone along with a controllable rotating magnetic field, the configuration of the apparatus may easily be varied from mixing to pumping and back to mixing simply by adjusting the focus of the rotating magnetic field. The apparatus can be manufactured relatively cheaply. Further, the use of multiple magnetic rods (e.g. ferromagnetic, paramagnetic or super-paramagnetic rods) provides more effective mixing and pumping than a single impeller. In addition, due to their shape anisotropy, the magnetic rods have greater stability in a rotating magnetic field than colloid-stabilized aggregates.

[0014] In a preferred embodiment, the apparatus may include a means for moving the rotating magnetic field from the mixing zone to the pumping chamber to change the function of the device from a mixer to a pump.

[0015] The pumping chamber may be asymmetric to enhance the fluid movement. Asymmetry in the geometry of the chamber enhances the pressure difference between the inlet and outlet of the device and improves the pumping characteristics. Asymmetry can be created by placing the focus of the rotating magnetic field toward a side of the channel or by placing the inlet and outlet of the pumping chamber asymmetrically with respect to each other. When the apparatus is switched from a mixer to a pump or vice versa, the heart of the magnetic field is moved from the mixing zone to the pumping chamber or vice versa. In the magnetic gradient that is created, and the magnetic rods will move toward the heart of the magnetic field.

[0016] The inner surface of the microfluidic channel and/or the magnetic rods may include a non-stick coating, e.g., a polymer. This feature is helpful where the rods tend to stick to the walls of the channel, and will encourage more complete and rapid mixing and/or pumping by maximizing the number of rods in motion.

[0017] The rotating magnetic field may be provided by a rotating permanent magnet or by an electromagnet array. The latter may consist of a set of electromagnets that are external to the micro-fluidic device, and that can be separately addressed. It may consist also of magnetic field generating means integrated in the micro-fluidic devices, such as integrated coils or integrated current wires. The rotating permanent magnet provides a mechanical solution to the problem of a rotating magnetic field and provides a low-cost solution. The electromagnetic array provides a space- and time-variable magnetic field that is electronically adjustable and with few, if any, any moving parts.

[0018] The magnetic rods may comprise a large aspect ratio to enhance the automatic and spontaneous formation, under a magnetic field, of enlongated assemblies of numerous rods, and thereby enhance mixing and pumping effectiveness and efficiency.

[0019] The magnetic rods may be manufactured by a templated electrodeposition process. Such a process may include the electrodeposition of Nickel (Ni) in a Whatman Anodisc membrane or a track etch membrane. Upon formation of the rods, the membrane may be etched away to yield a large number of uniform rods which may be suspended in water or another solution for injection into a microfluidic channel.

[0020] The microfluidic channel may include one or more fluid inlets and at least one fluid outlet. Multiple fluids may be introduced into the microfluidic channel in a controlled manner, each fluid having a separate inlet to reduce the likelihood of uncontrolled or unwanted mixing. Alternatively, one or more fluids or dry reagents may be stored in the chip, and released to be mixed with or dissolved in a fluid that is introduced in the channel through an inlet.

[0021] According to a second aspect of the present invention there is provided a method of micro fluidic mixing and pumping comprising the steps of: creating a movable and controllable rotating magnetic field around a microfluidic channel including a mixing zone and a pumping chamber; capturing a plurality of magnetic rods within said magnetic field and inside said microfluidic channel; moving said magnetic field to said mixing zone of said microfluidic channel; applying torque via said magnetic field to a plurality of magnetic rods within said mixing zone of said microfluidic channel to make said magnetic rods rotate; moving said magnetic field to said pumping chamber of said microfluidic channel to make said magnetic rods move to said pumping chamber; and applying torque via said magnetic field to said plurality of magnetic rods within said pumping chamber of said microfluidic channel to make said magnetic rods rotate.

[0022] It shall be understood that the claimed method has similar and/or identical preferred embodiments as the apparatus and as defined in the dependent claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] These and other aspects of the invention will be apparent from and elucidated with reference to the embodiment(s) described hereinafter. In the following drawings

Figs. 1a - 1b show plan views of micro fluidic mixing and pumping devices in accordance with an embodiment of the present invention;

Fig. 2 shows a perspective view of a microfluidic mixing and pumping device in accordance with an embodiment of the present invention;

Figs. 3a - 3c show respective plan and perspective views of embodiments of a pumping chamber for a microfluidic mixing and pumping device in accordance with an embodiment of the present invention; and

Figs. 4a - 4c show plan views of fluid flow through a microfluidic mixing and pumping device in accordance with an embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0024] Figs. 1a - 1b show plan views and Fig. 2 shows a perspective view, respectively, of a microfluidic mixing and pumping device 100 in accordance with embodiments of the present invention. The microfluidic mixing and pumping device 100 includes a substrate 101, e.g., a chip, having a microfluidic channel 104 extending through it. The microfluidic channel 104 includes a mixing zone 106 and a pumping chamber 108. A movable and controllable rotating magnetic field 102 is established so as to include the mixing zone 106 or the pumping chamber 108 within said magnetic field 102. A plurality of magnetic rods 116 are placed into the channel 104 and are influenced by the rotating magnetic field 102. Applied torque from the rotating magnetic field 102 causes the plurality of magnetic rods 116 within the microfluidic channel 104 to rotate. Any fluids present in the microfluidic channel 104 are subject to the rotational influence of the magnetic rods 116. The microfluidic channel 104 may include one or more fluid inlets 110 so that two or more different fluids may be controllably delivered into the micro fluidic channel 104 for mixing and observation. Alternatively, one or more fluids or dry reagents may be stored in the chip, and released to be mixed with or dissolved in a fluid that is introduced in the channel through an inlet.

[0025] Further, the microfluidic channel 104 may include at least one fluid outlet 112, whereby the mixed fluid C may be pumped out of the channel 104. An observation area 114 may be located along the microfluidic channel, to include the area between the mixing zone 106 and the pumping chamber 108.

[0026] The device 100 may include a means 105 for moving the rotating magnetic field 102 from the mixing zone 106 to the pumping chamber 108, or vice versa, whereby the device 100 may be changed from a mixer to a pump or from a pump to a mixer. Towards that end, the focus 103 of the rotating magnetic field 102 may be shifted from the mixing zone 106 to the pumping chamber 108. The means 105 for moving the magnetic field may be electronic or mechanical in nature, or may be a combination of electronic and mechanical controls to properly direct the focus of the magnetic field 103 and thereby the magnetic rods 116 into the desired portion of the microfluidic channel 104. The magnetic rods 116 will move in the magnetic field gradient towards the heart of the rotating magnetic field 102. Alternatively, the substrate 101 having the microfluidic channel 104 may be moved within a stationary rotating magnetic field 102 to move the focus 103 of the rotating magnetic field 102 from the mixing zone 106 to the pumping chamber 108. The magnetic field 102 may be adjusted so that it may be strong enough to prevent the magnetic rods 116 from washing out when the fluids A, B, C flow and weak enough to enable rotation of the rods 116.

[0027] In one embodiment, the rotating magnetic field 102 is created by a rotating permanent magnet. Alternatively, the rotating magnetic field 102 may be established by a stationary or rotating electromagnet array.

[0028] The pumping chamber 108 may be constructed so as to be asymmetric to enhance the pumping efficiency. The inner surface of the microfluidic channel 104 may include a non-stick coating to reduce any tendency of the magnetic rods 116 to stick to the channel 104.

[0029] The magnetic rods 116 may be manufactured so as to comprise a large length-to-diameter aspect ratio. In one embodiment, the magnetic rods 116 have a length of about 25 μm and a width of about 0.4 μm. The rods 116 may be manufactured in a number of very uniform sizes by a templated electrodeposition process. In one embodiment, the rods 116 are made of nickel (Ni) in a Whatman Anodisc membrane. After the membrane is etched away, the rods may be suspended in water or another fluid medium for injection into the microfluidic channel. The magnetic rods 116 may include a non-stick coating to prevent sticking to the wall of the channel 104.

[0030] A method of microfluidic mixing and pumping comprises the steps of:

creating a movable and controllable rotating magnetic field 102 around a micro fluidic channel 104 including a mixing zone 106 and a pumping chamber 108; capturing a plurality of magnetic rods 116 within said magnetic field 102 and inside said microfluidic channel 104; moving said magnetic field 102 to said mixing zone 106 of said microfluidic channel 104; applying torque via said magnetic field 102 to a plurality of magnetic rods 116 within said mixing zone

106 of said micro fluidic channel 104 whereby said magnetic rods 116 rotate; moving said magnetic field 102 to said pumping chamber 108 of said micro fluidic channel 104 whereby said magnetic rods 116 are moved to said pumping chamber 108; and applying torque via said magnetic field 102 to said plurality of magnetic rods 116 within said pumping chamber 108 of said micro fluidic channel 104 whereby said magnetic rods 116 rotate.

[0031] Upon rotation of the magnetic field 102, e.g., at 300 rpm, the magnetic rods 116 will self-assemble and begin to rotate in unison with the rotating magnetic field 102. A number of individual rods may strike the walls of the microfluidic channel 104 and be displaced from the mass of rods, only to reassemble with the mass again. Thus, the magnetic rods 116 contact the walls of the microfluidic channel 104 and destroy any laminar flow that may cling to the walls of the microfluidic channel 104. Observation of the magnetic rods 116 in motion reveals that numerous vortices are created and visible in the fluid flow just after the magnetic rods 116. Further, the use of multiple magnetic rods 116 provides more effective mixing and pumping than a single impeller.

[0032] Figs. 3a - 3c show respective plan and perspective views of embodiments of a pumping chamber 108 for a microfluidic mixing and pumping device 100 in accordance with an embodiment of the present invention. As discussed above, the pumping chamber 108 may be asymmetric to enhance pumping efficiency. This asymmetry can take many forms, as shown in Figs. 3a-3c. A focus point 103 may be designated for the approximate center of the rotating magnetic field 102, whereby the rotation of the magnetic rods 116 may be made more uniform. Uniformity of the rotation of the magnetic rods 116 may enhance the efficiency of the pumping chamber 108. The pumping process may begin when the magnetic rods 116 are moved into the pumping chamber 108. The plurality of magnetic rods 116 is rotated within the pumping chamber 108 at about 100 to over 1000 revolutions per minute, under the influence of the rotating magnetic field 102. The plurality of magnetic rods 116 are rotated together to move and displace the fluids and thereby pump the fluids. There may be a certain amount of relative motion between individual magnetic rods 116, but they continue to rotate together under the influence of the rotating magnetic field 102.

[0033] Fig. 3a shows a plan view of a linear and planar microfluidic channel 104 that is attached tangentially to the pumping chamber 108. Fig. 3b shows a plan view of a pumping chamber 108 that is attached between two segments of microfluidic channel 104 which are planar along only one axis. Only one segment of the channel 104 is attached tangentially to the pumping chamber 108. Fig. 3c shows a perspective view of a pumping chamber 108 arrangement wherein none of the channel 104 segments are tangentially attached to the pumping chamber 108. Instead, one of the segments is attached to the pumping chamber 108 axially, that is, along the axis of rotation of the magnetic rods. The arrangements of Figs. 3a-3c are exemplary only. Numerous additional configurations are possible within the spirit and scope of the invention.

[0034] Figs. 4a - 4c show plan views of fluid flow through a microfluidic mixing and pumping device 100 in accordance with an embodiment of the present invention.

[0035] Fig. 4a shows the flow of two liquids A, B through the device 100 without the influence of the rotating magnetic field 102 or magnetic rods 116. The two inlets 110 provide a first fluid A and a second fluid B into the channel 104. The mixing zone 106 is identified as the place where mixing could take place in the presence of a rotating magnetic field 102 and magnetic rods 116. Without the influence of the rotating magnetic field 102 and the magnetic rods 116, the two fluids A, B exhibit laminar flow and do not readily mix. The first fluid A and the second fluid B stay along opposite walls. What little mixing occurs is through diffusion, and the diffusion is not fast even on a micro-scale.

[0036] Fig. 4b shows an embodiment of the micro fluidic mixing and pumping device 100 including the rotating magnetic field 102 and the magnetic rods 116. The magnetic rods 116 tend to self-assemble and rotate as a mass under the influence of the rotating magnetic field 102. The large-aspect ratio of the magnetic rods 116 enhances the tendency of the rods 116 to arrange themselves in a parallel manner. Fig. 4b shows that the magnetic rods 116 are arranged generally parallel to each other and aligned with the external magnetic field 102. The orientation of the magnetic field 102 is at an angle to the main axis of the channel 104 and the rods 116 have arranged themselves in a manner to encompass the entire cross-sectional area of the channel 104.

[0037] Fig. 4c shows the same arrangement as Fig. 4b, but with the magnetic rods 116 rotated to an angle perpendicular with the main axis of the channel 104. The arrangement of magnetic rods 116 in Fig. 4b was too large to fit within the channel 104 when oriented in a perpendicular manner. Therefore the rods 116 will automatically and continually rearrange themselves to fit within the available area. Any of the magnetic rods which may be displaced will remain with the plurality of magnetic rods 116, but will find a new placement. In this manner the plurality of rods 116, individually and collectively, act directly upon a large portion of the cross-sectional area of the channel 104. The rotation of the magnetic rods 116 within the generally symmetric mixing zone 106 provides no net pumping effect. The result is that the first and second fluids A, B are subject to forces which destroy their laminar flow, and vortices are visible in the mixed fluid C after the mixing zone 106. Thereby the first and second fluids A, B are mixed completely and rapidly.

[0038] While the invention has been illustrated and described in detail in the drawings and foregoing description, such illustration and description are to be considered illustrative or exemplary and not restrictive; the invention is not limited to the disclosed embodiments. Other variations to the disclosed embodiments can be understood and effected by those skilled in the art in practicing the claimed invention, from a study of the drawings, the disclosure, and the appended claims.

[0039] In the claims, the word "comprising" does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality. A single element or other unit may fulfill the functions of several items recited in the claims. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measured cannot be used to advantage.

[0040] Any reference signs in the claims should not be construed as limiting the scope.

Claims

1. An apparatus (100) for rapid mixing and pumping of fluids comprising:

- a movable and controllable rotating magnetic field (102),
- a microfluidic channel (104) including a mixing zone (106) and a pumping chamber (108) within said magnetic field (102), and
- a plurality of magnetic rods (116) within said microfluidic channel (104) and said magnetic field (102), whereby said rotating magnetic field (102) applies torque to said magnetic rods (116).

2. The apparatus (100) as claimed in claim 1, further comprising means (105) for moving said magnetic field (102) from said mixing zone (106) to said pumping chamber (108) whereby the device (100) is changed from a mixer to a pump.

3. The apparatus (100) as claimed in claim 1, wherein said pumping chamber (108) is asymmetric.

4. The apparatus (100) as claimed in claim 1, wherein an inner surface of said micro fluidic channel (104) comprises a non-stick coating.

5. The apparatus (100) as claimed in claim 1, wherein a rotating permanent magnet provides a means (102) for said rotating magnetic field (102).

6. The apparatus (100) as claimed in claim 1, wherein an electromagnet array provides a means (102) for said rotating magnetic field (102).

7. The apparatus (100) as claimed in claim 1, wherein said magnetic rods (116) comprise a large aspect ratio.

8. The apparatus (100) as claimed in claim 1, wherein said magnetic rods (116) comprise a non-stick coating.

9. The apparatus (100) as claimed in claim 1, wherein said micro fluidic channel (104) comprises one or more fluid inlets (110) and at least one fluid outlet (112).

10. A method of fluidic mixing and pumping comprising the steps of:

- creating a movable and controllable rotating magnetic field (102) around a microfluidic channel (104) including a mixing zone (106) and a pumping chamber (108),
- capturing a plurality of magnetic rods within said magnetic field (102) and inside said microfluidic channel (104),
- moving said magnetic field (102) to said mixing zone (106) of said microfluidic channel (104),
- applying torque via said magnetic field (102) to a plurality of magnetic rods within said mixing zone (106) of said microfluidic channel (104) to make said magnetic rods rotate,
- moving said magnetic field (102) to said pumping chamber (108) of said microfluidic channel (104) whereby said magnetic rods (116) are moved to said pumping chamber (108), and
- applying torque via said magnetic field (102) to said plurality of magnetic rods (116) within said pumping chamber (108) of said microfluidic channel (104) to make said magnetic rods (116) rotate.

FIG. 1a

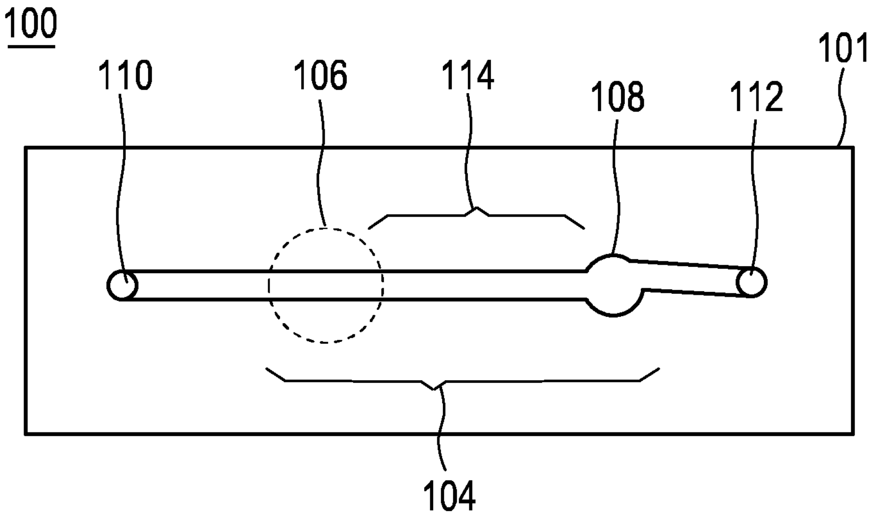


FIG. 1b

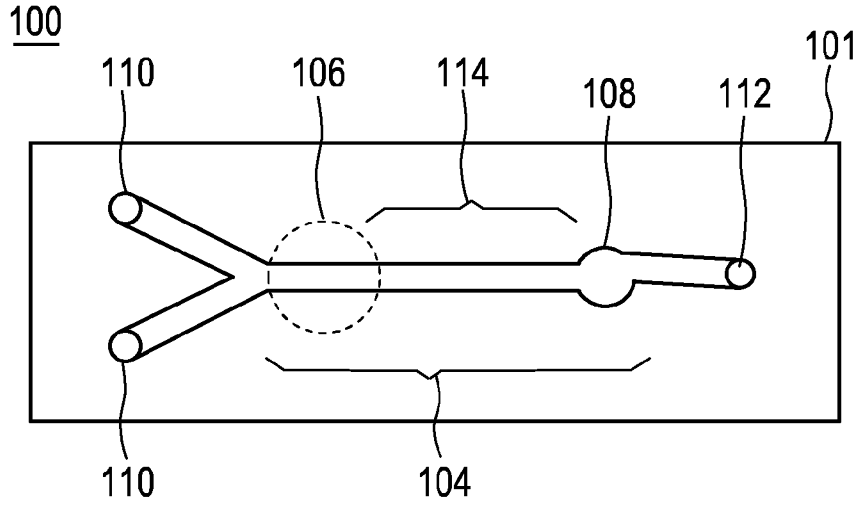

100
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FIG. 2

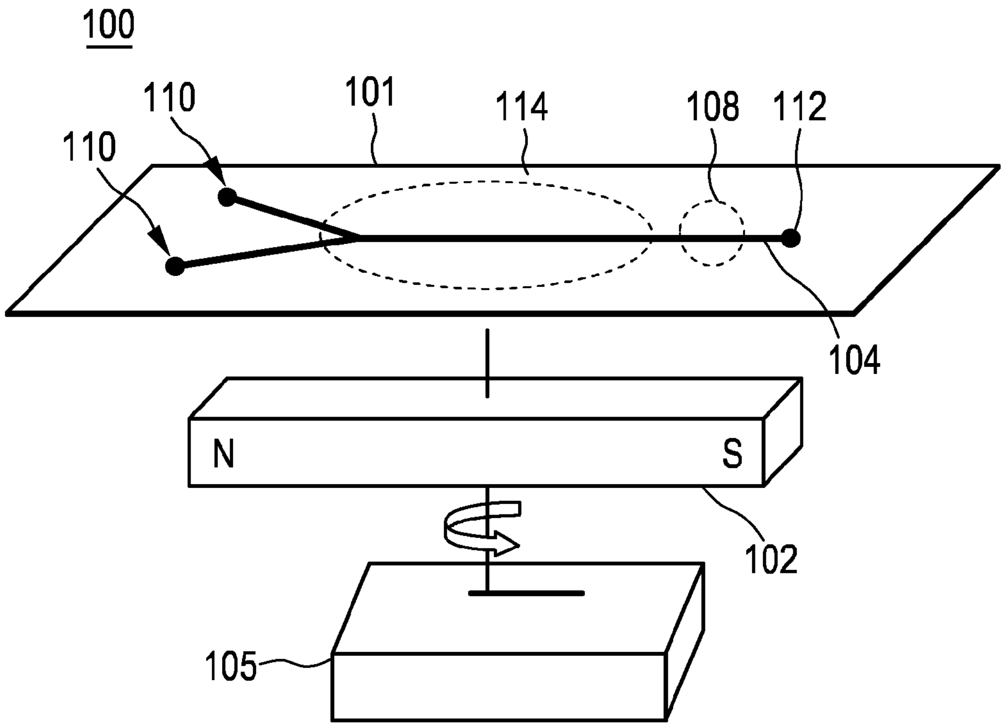
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FIG. 3a

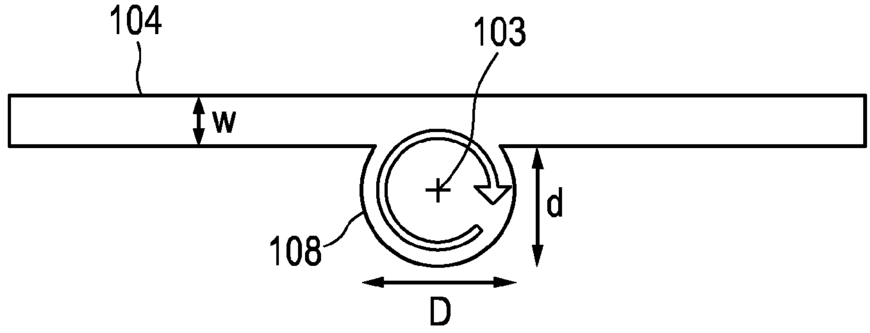


FIG. 3b

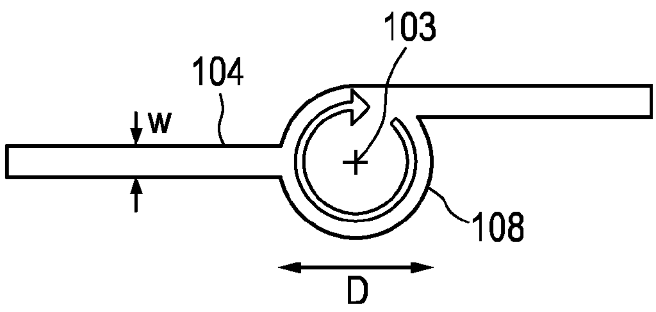


FIG. 3c

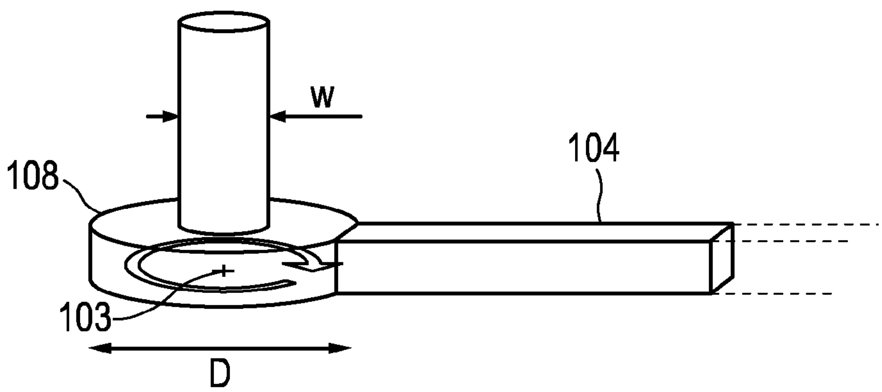


FIG. 4a

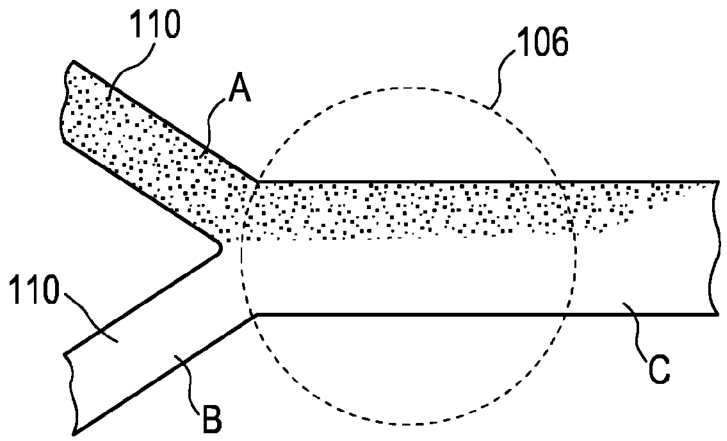


FIG. 4b

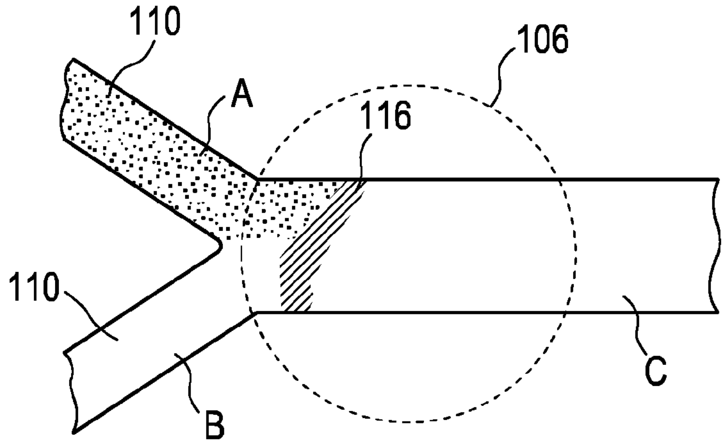
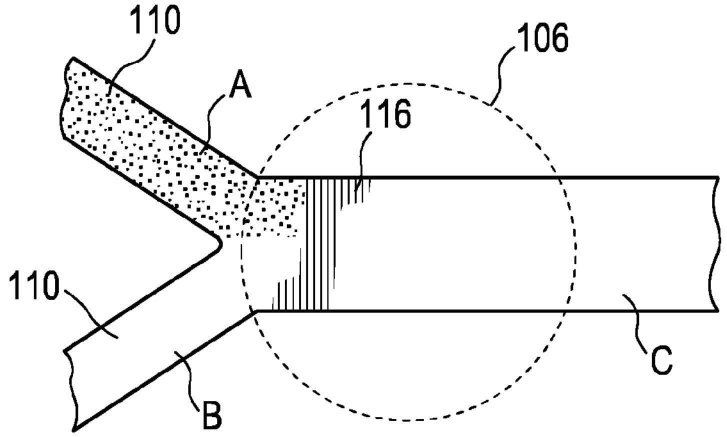


FIG. 4c



European Patent Office

PARTIAL EUROPEAN SEARCH REPORT

which under Rule 63 of the European Patent Convention shall be considered, for the purposes of subsequent proceedings, as the European search report

Application Number EP 08 15 3497

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A,D	KEE SUK RYU ET AL: "Micro magnetic stir-bar mixer integrated with parylene microfluidic channels" LAB ON A CHIP, ROYAL SOCIETY OF CHEMISTRY, CAMBRIDGE, GB, vol. 4, 14 October 2004 (2004-10-14), pages 608-613, XP002435817 ISSN: 1473-0197 * the whole document * -----	1-10	INV. B01F13/00 B01F13/08 F04B19/00
A	US 2003/072647 A1 (LUM PAUL [US]) 17 April 2003 (2003-04-17) * paragraph [0002] * * paragraph [0016] - paragraph [0017] * * paragraph [0036] - paragraph [0039] * * figure 1 * -----	1-10	
A	DE 197 28 520 A1 (IMB INST FUER MOLEKULARE BIOTE [DE]) 7 January 1999 (1999-01-07) * column 2, line 26 - column 3, line 39 * * figures 1a,1b * -----	1-10	

TECHNICAL FIELDS SEARCHED (IPC)

B01F
F04B
B01J
B01L

INCOMPLETE SEARCH

The Search Division considers that the present application, or one or more of its claims, does/do not comply with the EPC to such an extent that a meaningful search into the state of the art cannot be carried out, or can only be carried out partially, for these claims.

Claims searched completely :

Claims searched incompletely :

Claims not searched :

Reason for the limitation of the search:

see sheet C

2

Place of search	Date of completion of the search	Examiner
The Hague	31 July 2008	Real Cabrera, Rafael

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

European Patent Office

INCOMPLETE SEARCH SHEET C

Application Number
EP 08 15 3497

The following feature of claim 1 appears to be inconsistent with the description and with the dependent apparatus claim 1 and the method claim 10: "a microfluidic channel including a mixing zone and a pumping chamber within said magnetic field".

In accordance with the wording used for said feature, both the mixing zone and the pumping zone are simultaneously in the area of influence (i.e. the focus) of said magnetic field. However, in accordance with what is described in the description (cf. e.g. page 3, lines 27-30) and in claims 2 and 10, is that the apparatus comprises a mixing zone and a pumping zone, and that the focus of the magnetic field can be adjusted (i.e. moved) from one zone to the other in order to change the operating mode from mixing to pumping.

Therefore, the search has been based on the concept involving said interpretation and not on the wording used in said feature of claim 1.

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 08 15 3497

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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31-07-2008

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