

**MICROFLUIDIC DEVICES AND METHODS FOR PROVIDING AN
EMULSION OF A PLURALITY OF FLUIDS**

Cross-reference to Related Applications

[0001] The present application claims the benefit of the Singapore patent application No. 201204244-6 filed on 8 June 2012, the entire contents of which are incorporated herein by reference for all purposes.

Technical Field

[0002] Embodiments relate generally to microfluidic devices and methods for providing an emulsion of a plurality of fluids.

Background

[0003] Emulsion is a mixture of two immiscible liquids, where one liquid (which may be referred to as the dispersed phase) is suspended in another liquid (which may be referred to as the continuous phase) in the form of small droplets or colloids. Emulsions may be commonly used in food, cosmetics and pharmaceutical products, for example: for milk, butter, mayonnaise, vinaigrette, cream, and ointment. Thus, there may be a need to provide emulsions in an efficient manner.

Summary

[0004] According to various embodiments, a microfluidic device may be provided. The microfluidic device may include: a microfluidic channel with a plurality of inlets for fluids; and an ultrasound emitter configured to emit ultrasonic waves to the microfluidic channel. According to various embodiments, a first inlet of the plurality of inlets may include or may be an inlet for a gas. According to various embodiments, a second inlet of the plurality of inlets may include or may be an inlet for a liquid (for example for a first liquid, for example for water). According to various embodiments, a third inlet of the plurality of inlets may include or may be an inlet for a liquid (for example for a second liquid, for example for a second liquid different from the first liquid, for example for oil).

[0005] According to various embodiments, an efficient and convenient method for providing an emulsion from a plurality of fluids may be provided. The method may include: providing the plurality of fluids in a microfluidic channel via a plurality of inlets; and emitting ultrasonic waves to the microfluidic channel, for example to create parametric oscillations of interfaces and violent cavitation bubbles for intense mixing. According to various embodiments, a first inlet of the plurality of inlets may include or may be an inlet for a gas. According to various embodiments, a second inlet of the plurality of inlets may include or may be an inlet for a liquid. According to various embodiments, a third inlet of the plurality of inlets may include or may be an inlet for a liquid.

Brief Description of the Drawings

[0006] In the drawings, like reference characters generally refer to the same parts throughout the different views. The drawings are not necessarily to scale, emphasis instead generally being placed upon illustrating the principles of the invention. In the following description, various embodiments are described with reference to the following drawings, in which:

FIG. 1A shows a microfluidic device in accordance with an embodiment;

FIG. 1B shows a microfluidic device in accordance with an embodiment;

FIG. 1C shows a flow diagram illustrating a method for providing an emulsion of a plurality of fluids according to various embodiments;

FIG. 2 shows a mixing system in a microfluidic channel according to various embodiments;

FIG. 3A shows an example of a microfluidic system for creating emulsions according to various embodiments;

FIG. 3B shows an illustration of the inlets and the microchannel in the microfluidic system according to various embodiments;

FIG. 4 shows an illustration of a detailed process of emulsification created by acoustic cavitation bubbles in microfluidics according to various embodiments;

FIG. 5 shows an example of water-in-oil emulsions produced using acoustic cavitation bubbles according to various embodiments;

FIG. 6 shows an example of oil-in-water emulsions produced using acoustic cavitation bubbles according to various embodiments.

Description

[0007] Embodiments described below in context of the devices are analogously valid for the respective methods, and vice versa. Furthermore, it will be understood that the embodiments described below may be combined, for example, a part of one embodiment may be combined with a part of another embodiment.

[0008] An emulsion is a mixture of two immiscible liquids, where one liquid (which may be referred to as the dispersed phase) is suspended in another liquid (which may be referred to as the continuous phase) in the form of small droplets or colloids. Emulsions may be commonly used in food, cosmetics and pharmaceutical products, for example: for milk, butter, mayonnaise, vinaigrette, cream, and ointment. Thus, there may be a need to provide emulsions in an efficient manner. The formation of emulsions (which may be referred to as emulsification) may be obtained through shear rupturing of two immiscible liquids, leading to the fragmentation of one liquid in the other. Commonly used methods for making emulsions may for example include: high-pressure homogenization, membrane emulsification, spontaneous emulsification, phase inversion, and mechanical stirring. In microfluidics, emulsions may be produced by forcing the dispersed phase into the continuous phase. Colloidal droplets may be generated based on coaxial flow or flow focusing methods in a microchannel. Since no active force is applied to the fluids to create high shear flow, the droplet size and the production rate may depend on a geometry of the microchannel, pressures/flowrate and surface tension of the fluids. Despite its ability to produce monodisperse droplets, the production rate of this method may be low.

[0009] According to various embodiments, a rapid method may be provided for forming an emulsion on a nano/microfluidic scale involving the application of ultrasonic excitation to a micro-chamber containing two immiscible fluids and a gas. Furthermore, a device may be provided for mixing and creating the emulsion mentioned.

[0010] According to various embodiments, a surfactant-free emulsification technique in microfluidics may be provided.

[0011] Various embodiments relate to microfluidics and nanofluidics, mixing, emulsification, acoustic bubbles, and fluid dynamics.

[0012] The ability to create intense cavitation in microfluidics may open-up many applications in a micro-scale system. Similar to mechanical stirring or homogenization, the rapidly collapsing cavitation bubbles may create shearing flows, leading to intense mixing and fragmentation of the liquids. According to various embodiments, devices and methods may be provided for developing a technique to create surfactant-free emulsions in microfluidics based on this principle. The cavitation bubbles may be created by exciting gas-liquid interfaces by ultrasound vibrations.

[0013] Devices and methods according to various embodiments may create monodisperse emulsions from very small amount of liquids, i.e. as little as picoliters, without any surfactant. Nevertheless, surfactants may be added to produce more stable emulsions. The production rate may be faster than commonly used microchannel emulsification techniques because of the use of ultrasound vibration as a “stirring” force in the micro-scale. Furthermore, the devices and methods according to various embodiments may be used to create emulsions from very high viscosity liquids. For example, the devices and methods may be used to produce water-in-oil (W/O) and oil-in-

water (O/W) emulsions from water and silicone oil with viscosity of up to 1000 cSt (centistokes), demonstrating the viability of the methods and devices according to various embodiments for mixing fluids with very high viscosity ratio. Viscosity ratio may refer to the ratio of the viscosity of the fluid with higher viscosity (e.g. oil) to the viscosity of the fluid with lower viscosity (e.g. water) in the emulsion.

[0014] FIG. 1A shows a microfluidic device 100 in accordance with an embodiment. The microfluidic device 100 may include a microfluidic channel 102 with a plurality of inlets for fluids and an ultrasound emitter 104 configured to emit ultrasonic waves to the microfluidic channel 102. According to various embodiments, a first inlet of the plurality of inlets may include or may be an inlet for a gas. According to various embodiments, a second inlet of the plurality of inlets may include or may be an inlet for a liquid (for example for a first liquid, for example for water). According to various embodiments, a third inlet of the plurality of inlets may include or may be an inlet for a liquid (for example for a second liquid, for example for a second liquid different from the first liquid, for example for oil).

[0015] In other words, in the microfluidic device 100, ultrasonic waves may be emitted from the ultrasound emitter to the inside of the microfluidic channel 102. It will be understood that the term “microfluidic channel” is not to be considered to be restricted to a particular size of the microfluidic channel, so that also a micro chamber (or microfluidic chamber) may be understood as a microfluidic channel in the context of the microfluidic device 100. A fluid may be a liquid or a gas.

[0016] According to various embodiments, the ultrasound emitter 104 may include or may be a piezoelectric transducer.

[0017] FIG. 1B shows a microfluidic device 106 in accordance with an embodiment. The microfluidic device 106 may, similar to the microfluidic device 100 of FIG. 1A, include a microfluidic channel 102 and an ultrasound emitter 104. The microfluidic device 106 may further include an inlet 108 (or a plurality of inlets 108), like will be described below. The microfluidic device 106 may further include an outlet 110, like will be described below. The microfluidic device 106 may further include a power amplifier 112, like will be described below. The ultrasound emitter 104 and the power amplifier 112 may be coupled with each other, for example via a connection 114, for example an electrical connection, such as for example a cable or a computer bus or via any other suitable electrical connection to exchange electrical signals.

[0018] According to various embodiments, the power amplifier 112 may be configured to drive the piezoelectric transducer at a resonance frequency of the microfluidic device 100.

[0019] According to various embodiments, the piezoelectric transducer may include or may be a ceramic made of Lead oxide, Zirconium oxide, Titanium oxide, and Lanthanum oxide.

[0020] According to various embodiments, the ultrasound emitter 104 may be configured to emit ultrasonic waves to the microfluidic channel 102 along a fluid movement direction in the microfluidic channel 102.

[0021] According to various embodiments, the ultrasound emitter 104 may be configured to emit ultrasonic waves to the microfluidic channel 102 through a common substrate of the ultrasound emitter 104 and the microfluidic channel 102.

[0022] According to various embodiments, the ultrasound emitter 104 may be configured to emit the ultrasonic waves in bursts.

[0023] According to various embodiments, the ultrasound emitter 104 may be configured to generate collapsing cavitation bubbles in the fluids.

[0024] According to various embodiments, the ultrasound emitter 104 may be configured to generate oscillating interfaces and cavitation bubbles in the fluids.

[0025] According to various embodiments, the plurality of inlets may be combined to a (single) inlet 108 for a combination (or for a mixture) of a plurality of fluids. In other words: instead of having a plurality of inlets, the microfluidic device 106 may include a (single) inlet 108 through which all fluids of the plurality of liquids are provided to the microfluidic channel 102. For example, the inlet 108 may be an inlet for a combination of at least one liquid and at least one gas, for example a combination of a plurality of liquids and/ or gases. The inlet 108 may be an inlet to the microfluidic channel 102.

[0026] According to various embodiments, the microfluidic device 106 may include an outlet for an emulsion based on a plurality of liquids input to the microfluidic channel. The outlet 110 may be an outlet from the microfluidic channel 102.

[0027] According to various embodiments, a plurality of microfluidic channels running in parallel may be provided, for example to increase throughput. According to various embodiments, the microfluidic device 106 may further include a plurality of microfluidic channels, each microfluidic channel with a plurality of inlets for fluids. The ultrasound emitter 104 may be configured to emit ultrasonic waves to the plurality of microfluidic channels. A first inlet of the plurality of inlets of each microfluidic channel may include or may be an inlet for a gas. A second inlet of the plurality of inlets of each

microfluidic channel may include or may be an inlet for a liquid. A third inlet of the plurality of inlets of each microfluidic channel may include or may be an inlet for a liquid. It will be understood that, like described above for a microfluidic channel, the plurality of inlets for a microfluidic channel of the plurality of microfluidic channels may be combined (in other words: the microfluidic channel may include a (single) inlet).

[0028] According to various embodiments, the microfluidic device 106 may further include a plurality of ultrasound emitters configured to transmit ultrasonic waves to the one or more microfluidic channels.

[0029] FIG. 1C shows a flow diagram 116 illustrating a method for providing an emulsion of a plurality of fluids according to various embodiments. In 118, the plurality of fluids may be provided in a microfluidic channel via (or using) a plurality of inlets. In 120, ultrasonic waves may be emitted to the microfluidic channel. According to various embodiments, a first inlet of the plurality of inlets may include or may be an inlet for a gas. According to various embodiments, a second inlet of the plurality of inlets may include or may be an inlet for a liquid. According to various embodiments, a third inlet of the plurality of inlets may include or may be an inlet for a liquid.

[0030] According to various embodiments, the ultrasonic waves may be emitted using a piezoelectric transducer.

[0031] According to various embodiments, the microfluidic channel may be provided in a microfluidic device. According to various embodiments, the method may further include driving the piezoelectric transducer at a resonance frequency of the microfluidic device using a power amplifier.

[0032] According to various embodiments, the ultrasonic waves may be emitted using a piezoelectric transducer comprising a ceramic made of Lead oxide, Zirconium oxide, Titanium oxide, and Lanthanum oxide.

[0033] According to various embodiments, the method may further include emitting the ultrasonic waves to the microfluidic channel along a fluid movement direction in the microfluidic channel.

[0034] According to various embodiments, the method may further include emitting the ultrasonic waves to the microfluidic channel through a common substrate of the ultrasonic transducer and the microfluidic channel.

[0035] According to various embodiments, the method may further include emitting the ultrasonic waves in bursts.

[0036] According to various embodiments, the method may further include generating collapsing cavitation bubbles in the fluids.

[0037] According to various embodiments, the method may further include generating oscillating interfaces and cavitation bubbles in the fluids-

[0038] According to various embodiments, the plurality of fluids may be provided in the microfluidic channel using an inlet for a combination (or for a mixture) of the plurality of fluids. In other words: not a plurality of inlets to the microchannel may be provided, but only a single inlet for a combination (or for a mixture) of the plurality of fluids may be provided. For example, the (single) inlet may be an inlet for a combination of at least one liquid and at least one gas, for example a combination of a plurality of liquids and/ or gases.

[0039] According to various embodiments, the method may further include outputting from the microfluidic channel an emulsion based on the plurality of liquids.

[0040] According to various embodiments, the method may further include: providing the plurality of fluids in a plurality of microfluidic channels via a plurality of inlets; and emitting ultrasonic waves to the plurality of microfluidic channels. Each microfluidic channel of the plurality of microfluidic channels may include a plurality of inlets. A first inlet of the plurality of inlets of each microfluidic channel may include or may be an inlet for a gas. A second inlet of the plurality of inlets of each microfluidic channel may include or may be an inlet for a liquid. A third inlet of the plurality of inlets of each microfluidic channel may include or may be an inlet for a liquid.

[0041] According to various embodiments, the method may further include transmitting ultrasonic waves to the one or more microfluidic channels using a plurality of ultrasound emitters.

[0042] FIG. 2 shows a mixing system in a microfluidic channel 200 according to various embodiments. For example, a first liquid 202 (for example oil), a second liquid 204 (for example water) and gas 206 are supplied into a single (microfluidic) channel 200. Upon excitation from ultrasound like indicated by arrow 208, cavitation bubbles are generated in a portion 210 of the microfluidic channel 200, and they oscillate to create the emulsion 214 as shown. FIG. 2 illustrates a further portion 212 of the microfluidic channel 200, and this may be not to scale.

[0043] When ultrasound, for example strong ultrasound, for example driven at the system resonance frequency is applied to the system, the interfaces (for example between gas and water and/ or between water and oil) may become unstable. Small gas bubbles

may be ejected from the gas-liquid interface and subsequently induce strong mixing in the micro-chamber to create emulsion.

[0044] According to various embodiments, the system may include a microfluidic device and piezoelectric transducer(s) attached on a solid surface (e.g. a glass slide). The microfluidic device may be made of polydimethylsiloxane (PDMS) or other soft material. The microchannel may be designed such that the gas pockets are present in the channel, for example, in the form of gas-liquid interfaces or crevices. The channel height may be configured to be sufficient low for surface instability to take place, e.g. typically in the range of a few micrometers to a few ten micrometers. The piezoelectric transducers may be attached near the microchannel. An RF power amplifier may be used to drive the transducer at its resonance frequency.

[0045] FIG. 3A shows an example of a microfluidic system 300 for creating emulsions according to various embodiments. The system has one or more (for example two) piezoelectric materials, for example one or more (for example two) piezoelectric transducers, for example a first piezoelectric transducer 312 and a second piezoelectric transducer 314, and a microfluidic device (including a microchannel 302) attached on a glass substrate 316, for example a microscope slide. The first transducer 312 and/ or the second transducer 314 may include or may be a ceramic made of Lead oxide, Zirconium oxide, Titanium oxide, and Lanthanum oxide. The transducers 312 and 314 may be glued onto the glass substrate 316, at the sides of the microchannel 302, for example using a very thin layer of epoxy glue. The microfluidic device may be made of PDMS (Polydimethylsiloxane), for example using standard soft lithography techniques. The microchannel 302 may have one outlet 310 and three inlets, for example an inlet 304 for

oil, an inlet 306 for water, and an inlet 308 for gas. The inlets 304, 306, 308 may be connected to the main channel 302 in such a way that gas-liquids interfaces are formed along the channel 302.

[0046] FIG. 3B shows an illustration 318 of the inlets 304, 306, 308 and the microchannel 302 in the microfluidic system (which also may be referred to as a microfluidic device) according to various embodiments. For example, the inlet 306 for water may be provided so that it surrounds the oil in the microchannel. For example, the inlet 308 for gas may be provided so that it surrounds the water in the microchannel. For example, a gas-water interface 320 and 326 and a water-oil interface 322 and 324 is shown. It will be understood that FIG. 3B shows a cross-section, so that in the illustration two inlets are shown for gas and two inlets are shown for water, and also two gas-water interfaces and two water-oil interfaces are shown. FIG. 3B shows the schematic of exemplary gas-liquids interfaces, for example of exemplary gas-water-oil-water-gas interfaces created in the microchannel. The thickness of liquid films may be varied by adjusting the flowrate and/ or the pressure of the liquids and gas supplies.

[0047] FIG. 4 shows an illustration 400 of a detailed process of emulsification created by cavitation bubbles in microfluidics according to various embodiments. Cavitation bubbles may be initiated at gas-liquid interface. The bubbles may then be brought into the other liquid phase. Emulsion may be formed due to the high shear generated by the oscillating bubbles that fragments the liquid film attached on the bubbles surface and along the interfaces.

[0048] As an example, the detailed mechanism of the emulsification (e.g. for water-in-oil emulsion) will be described. In a first stage 402, gas-liquid interfaces between gas

404 and water 406 may be provided. When the interfaces (for example as shown in FIG. 3B) are excited with ultrasound vibrations (for example an acoustic wave like indicated by arrow 408), surface instability may occur at gas-water interfaces resulting in parametric oscillations of the interfaces. In a second stage 410, the nonlinear surface oscillation may entrap gas bubbles 412 which may move towards liquid phases and later serve as cavitation nuclei. As the bubbles 412 oscillate and collapse violently, the intense mixing may take place in the whole microchannel. In a third stage 414, when the oscillating bubbles travel from water to oil phase 416, they may carry a thin layer of water on their surfaces. Those layers may subsequently be fragmented into small water droplets due to shearing flow generated by the cavitation bubbles, resulting in the formation of water-in-oil-emulsion 420 in a fourth stage 418. In addition, the thin layer of water along the oscillating interfaces may also be the source of water droplets in the continuous phase (oil). Conversely, if the bubbles or interfaces carry a thin layer of oil, then oil-in-water emulsions will be obtained. The type of emulsion may be controlled by the thickness of liquid film injected into the microchannel 318. The dispersed phase may typically be the one with thin film (or less liquid). For example: to create oil-in-water emulsions, the oil layer 304 may be made as thin as possible. On the contrary, the water layer 306 may be made as thin as possible to produce water-in-oil emulsions.

[0049] In the following, experimental results will be described, for example of experiments with a microfluidic device, for example as shown in FIG. 2A. The transducer (which may for example include Plumbum Zirconate Titanate material, and may be a disc transducer, with 25 mm diameter with 2.1-mm thickness) may be driven by an amplifier, which may be connected to a function generator. The driving voltage of the transducers

may be set at 200 V at the resonance frequency of the microfluidic device 100 of about 100 kHz. The ultrasound may be exposed in a burst mode to prevent overheating of the transducer. The total exposure duration may range from milliseconds to seconds. Emulsions may be obtained from water and silicone oils with different viscosity ranging from 10 to 1000 cSt (it will be understood that viscosity of water is 1 cSt).

[0050] The following results describe the emulsions obtained from water and oil with viscosity of 100 cSt.

[0051] Images of the emulsions produced according to various embodiments are shown in FIG. 5 and FIG. 6 for water-in-oil and oil-in-water emulsions, respectively. The images were taken by a camera connected to an objective lens with a 100x magnification. The zoom of a small region is given on the right of each image.

[0052] FIG. 5 shows an illustration 500 of water-in-oil emulsions produced using acoustic cavitation bubbles according to various embodiments. A scale 504 of a photo 502 of the emulsion is given. The driving voltage of the piezoelectric transducer is 200 V and the driving frequency is about 100 kHz. The exposure duration is less than 1 second. The emulsions were obtained from water and 100 cSt silicone oil. A zoom picture 506 on the right of FIG. 5 shows the monodisperse emulsions in an enlarged scale 508.

[0053] FIG. 6 shows an illustration 600 of oil-in-water emulsions produced using acoustic cavitation bubbles according to various embodiments. A scale 604 of a photo 602 of the emulsion is given. The driving voltage of the piezoelectric transducer is 200 V and the driving frequency is about 100 kHz. The exposure duration is less than 1 second. The emulsions were obtained from water and 100 cSt silicone oil. A zoom picture 606 on the right of FIG. 6 shows the oil-in-water emulsions in an enlarged scale 608.

[0054] The water-in-oil emulsions are monodisperse with a size of about 1.4 μm . However, the size of the oil droplets in oil-in-water emulsions may not be uniform, ranging from submicron to few microns size. This may be explained by the non-homogeneous shear stress generated by violent cavitation bubbles. The coalescence of two or more adjacent droplets may also deteriorate the uniformity of the emulsions. For example, monodisperse emulsions may be achieved by increasing the exposure duration and/or adding surfactant.

[0055] While the invention has been particularly shown and described with reference to specific embodiments, it should be understood by those skilled in the art that various changes in form and detail may be made therein without departing from the spirit and scope of the invention as defined by the appended claims. The scope of the invention is thus indicated by the appended claims and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced.

Claims

What is claimed is:

1. A microfluidic device comprising:
a microfluidic channel with a plurality of inlets for fluids; and
an ultrasound emitter configured to emit ultrasonic waves to the microfluidic channel;
wherein a first inlet of the plurality of inlets comprises an inlet for a gas;
wherein a second inlet of the plurality of inlets comprises an inlet for a liquid; and
wherein a third inlet of the plurality of inlets comprises an inlet for a liquid.
2. The microfluidic device of claim 1,
wherein the ultrasound emitter comprises a piezoelectric transducer.
3. The microfluidic device of claim 2, further comprising:
a power amplifier configured to drive the piezoelectric transducer at a resonance frequency of the microfluidic device.
4. The microfluidic device of claim 2,
wherein the piezoelectric transducer comprises a ceramic made of Lead oxide, Zirconium oxide, Titanium oxide, and Lanthanum oxide.

5. The microfluidic device of claim 1,
wherein the ultrasound emitter is configured to emit ultrasonic waves to the microfluidic channel through a common substrate of the ultrasound emitter and the microfluidic channel.
6. The microfluidic device of claim 1,
wherein the ultrasound emitter is configured to emit the ultrasonic waves in bursts.
7. The microfluidic device of claim 1,
wherein the ultrasound emitter is configured to generate oscillating interfaces and cavitation bubbles in the fluids.
8. The microfluidic device of claim 1,
wherein the plurality of inlets are combined to an inlet for a combination of a plurality of fluids.
9. The microfluidic device of claim 1, further comprising:
an outlet for an emulsion based on a plurality of liquids input to the microfluidic channel.
10. The microfluidic device of claim 1, further comprising:

a plurality of microfluidic channels, each microfluidic channel with a plurality of inlets for fluids; and

wherein the ultrasound emitter is configured to emit ultrasonic waves to the plurality of microfluidic channels;

wherein a first inlet of the plurality of inlets of each microfluidic channel comprises an inlet for a gas;

wherein a second inlet of the plurality of inlets of each microfluidic channel comprises an inlet for a liquid; and

wherein a third inlet of the plurality of inlets of each microfluidic channel comprises an inlet for a liquid.

11. A method for providing an emulsion of a plurality of fluids, the method comprising:

providing the plurality of fluids in a microfluidic channel via a plurality of inlets; and

emitting ultrasonic waves to the microfluidic channel;

wherein a first inlet of the plurality of inlets comprises an inlet for a gas;

wherein a second inlet of the plurality of inlets comprises an inlet for a liquid; and

wherein a third inlet of the plurality of inlets comprises an inlet for a liquid.

12. The method of claim 11,

wherein the ultrasonic waves are emitted using a piezoelectric transducer.

13. The method of claim 12,
wherein the microfluidic channel is provided in a microfluidic device;
driving the piezoelectric transducer at a resonance frequency of a microfluidic device using a power amplifier.
14. The method of claim 12,
wherein the ultrasonic waves are emitted using a piezoelectric transducer comprising a ceramic made of Lead oxide, Zirconium oxide, Titanium oxide, and Lanthanum oxide.
15. The method of claim 12, further comprising:
emitting the ultrasonic waves to the microfluidic channel through a common substrate of the ultrasonic transducer and the microfluidic channel.
16. The method of claim 11, further comprising:
emitting the ultrasonic waves in bursts.
17. The method of claim 11, further comprising:
generating oscillating interfaces and cavitation bubbles in the fluids.
18. The method of claim 11,
wherein the plurality of fluids are provided in the microfluidic channel using an inlet for a combination of the plurality of fluids.

19. The method of claim 11, further comprising:
outputting from the microfluidic channel an emulsion based on the plurality of liquids.
20. The method of claim 11, further comprising:
providing the plurality of fluids in a plurality of microfluidic channels via a plurality of inlets; and
emitting ultrasonic waves to the plurality of microfluidic channels;
wherein a first inlet of the plurality of inlets of each microfluidic channel comprises an inlet for a gas;
wherein a second inlet of the plurality of inlets of each microfluidic channel comprises an inlet for a liquid; and
wherein a third inlet of the plurality of inlets of each microfluidic channel comprises an inlet for a liquid.