PARTICLES FOR USE IN ACOUSTIC STANDING WAVE PROCESSES

BACKGROUND

[0001] The present disclosure relates to particles in the micrometer or nanometer range, which can be used with ultrasonically generated acoustic waves, including traveling and standing waves, to achieve trapping, concentration, and/or transport of the microparticles and nanoparticles to a target location.

[0002] Acoustophoresis is the separation of materials using acoustics, such as acoustic standing waves. Acoustic standing waves can exert forces on particles in a fluid when there is a differential in a parameter of the particles and fluid that can be influenced by acoustics, including density and/or compressibility, otherwise known as the acoustic contrast factor. The pressure profile in a standing wave contains areas of local minimum pressure amplitudes at standing wave nodes and local maxima at standing wave anti-nodes. Depending on their density and compressibility, the particles can be trapped at the nodes or anti-nodes of the standing wave. Generally, the higher the frequency of the standing wave, the smaller the particles that can be trapped.

[0003] At a micro scale, for example with structure dimensions on the order of micrometers, conventional acoustophoresis systems tend to use half or quarter wavelength acoustic chambers, which at frequencies of a few megahertz are typically less than a millimeter in thickness, and operate at very low flow rates (e.g., μL/min). Such systems are not scalable since they benefit from extremely low Reynolds number, laminar flow operation, and minimal fluid dynamic optimization.

[0004] At the macro-scale, planar acoustic standing waves have been used in separation processes. However, a single planar wave tends to trap the particles or secondary fluid such that separation from the primary fluid is achieved by turning off or removing the planar standing wave. Planar waves also tend to heat the media where the waves are propagated due to the energy dissipation into the fluid that is involved with generating a planar wave and the planar wave energy itself. The removal of the planar standing wave may hinder continuous operation. Also, the amount of power that is used to generate the acoustic planar standing wave tends to heat the primary fluid through waste energy, which may be disadvantageous for the material being processed.

SUMMARY

[0004a] In a first aspect, the present disclosure provides a method for selection of target material, comprising: receiving a fluid mixture of particles and the target material in a fluid chamber; binding together the particles and the target material; generating an acoustic wave in the fluid chamber with an ultrasonic transducer that includes a piezoelectric material; retaining the particles in the fluid chamber via the influence of the acoustic wave on the particles; wherein the particles comprise a liquid core.

[0004b] In a second aspect, the present disclosure provides a particle for use in a separation process, comprising: a liquid core; and a lipid shell encapsulating the liquid core.

[0004c] In a third aspect, the present disclosure provides a method for separating target particles from a fluid, comprising: receiving functionalized particles in the fluid in a chamber; receiving target particles in the chamber; permitting the target particles to bind with the functionalized particles; applying an acoustic wave to the chamber to influence the functionalized particles to be collected or blocked by the acoustic wave.

[0004d] In a fourth aspect, the present disclosure provides a device for selection of target material, comprising: a fluid chamber with a fluid region and an acoustic region; an inlet into the fluid region to permit fluid flow through the fluid region and into the acoustic region; an outlet above the acoustic region; an ultrasonic transducer in the acoustic region and configured to generate an acoustic wave across the fluid chamber in the acoustic region; and functionalized particles in the fluid region, wherein the acoustic wave retains the functionalized particles in the fluid region.

CLAIMS:

1. A method for ~~concentrating particles in a primary fluid at a first location~~selection of target material, comprising:

~~flowing~~ receiving a fluid mixture ~~comprising the~~of particles and the target material in a ~~primary~~ fluid chamber; ~~through an acoustophoretic device that comprises:~~

~~an acoustic chamber through which the fluid mixture flows;~~

~~and~~

~~an ultrasonic transducer including a piezoelectric material that can be driven to create an acoustic wave in the acoustic chamber;~~

~~and~~

binding together the particles and the target material;

generating an acoustic wave in the fluid chamber with an ultrasonic transducer that includes a piezoelectric material;

retaining the particles in the fluid chamber via the influence of the acoustic wave on the particles;

wherein the particles comprise a liquid core~~driving the ultrasonic transducer to create the acoustic wave;~~

~~wherein the acoustic wave concentrates the particles at the first location~~.

2. The method of claim 1, wherein the acoustic wave is a multi-dimensional acoustic standing wave, a planar acoustic standing wave, a combination of a multi-dimensional acoustic standing wave and a planar acoustic standing wave, or an acoustic traveling wave.

~~3. The method of claim 1, wherein the particles contain a payload.~~

~~4. The method of claim 3, wherein the payload is a virus, a nucleic acid, a cytokine, a pharmaceutical molecule, a liquid, a gas, or mixtures thereof.~~

~~5. The method of claim 3, further comprising releasing the payload from the particles at the first location.~~

~~6. The method of claim 1, wherein the particles are solid, cellular, hollow, or a foam.~~

~~7. The method of claim 1, wherein the particles are made of one or more polymeric materials, ionomers, ceramics, or glass.~~

~~8. The method of claim 7, wherein the one or more polymeric materials are selected from the group consisting of polyethylene, polypropylene, polystyrene, divinylbenzene, poly methyl methacrylate, polysaccharide, polylactic acid (PLA), and poly(lactic-co-glycolic acid) (PLGA).~~

~~9. The method of claim 1, wherein the particles are formed from multiple layers of polymeric materials.~~

~~10. The method of claim 1, wherein the particles are hollow, and are made of glass, and have an ablative polymer coating an exterior surface of the glass.~~

~~11. The method of claim 10, wherein the ablative polymer is a polysaccharide that is functionalized with an antigen, antibody, or protein.~~

~~12.~~3. The method of claim 1, wherein the particles comprise:

~~a liquid core; and~~

a lipid shell encapsulating the liquid core.

~~13.~~4. The method of claim ~~12~~1, wherein the liquid in the liquid core comprises a perfluorocarbon.

~~14.~~5. The method of claim ~~13~~4, wherein the perfluorocarbon is perfluoropentane, perfluorohexane, perfluorooctane, perfluorooctyl bromide, perfluorodichlorooctane, or perfluorodecalin.

~~15.~~6. The method of claim ~~12~~3, wherein the lipid shell is formed from dipalmitoylphosphatidylcholine (DPPC), 1,2-palmitoyl-phosphatidic acid (DPPA), a lipid-polyethylene glycol conjugate, or a complex of a lipid with albumin.

~~16.~~7. The method of claim ~~12~~3, wherein the lipid shell is functionalized with streptavidin, biotin, avidin, or an antibody.

~~17.~~8. A particle for use in a separation process, comprising:

a liquid core; and

a lipid shell encapsulating the liquid core.

~~18.~~9. The particle of claim ~~17~~8, wherein the liquid in the liquid core comprises a perfluorocarbon.

~~19.~~10. The particle of claim ~~18~~9, wherein the perfluorocarbon is perfluoropentane, perfluorohexane, perfluorooctane, perfluorooctyl bromide, perfluorodichlorooctane, or perfluorodecalin.

~~20.~~11. The particle of claim ~~17~~8, wherein the lipid shell is formed from dipalmitoylphosphatidylcholine (DPPC), 1,2-palmitoyl-phosphatidic acid (DPPA), a lipid-polyethylene glycol conjugate, or a complex of a lipid with albumin.

~~21.~~12. The particle of claim ~~17~~8, wherein the lipid shell is functionalized with streptavidin, biotin, avidin, or an antibody.

~~22.~~13. A method for separating target particles from a fluid, comprising:

receiving functionalized particles in the fluid in a chamber;

receiving target particles in the chamber;

permitting the target particles to bind with the functionalized particles;

applying an acoustic wave to the chamber to influence the functionalized particles to be collected or blocked by the acoustic wave.

~~23.~~14. The method of claim ~~22~~13, wherein the functionalized particles comprise a perfluorocarbon that is one or more of perfluoropentane, perfluorohexane, perfluorooctane, perfluorooctyl bromide, perfluorodichlorooctane, or perfluorodecalin.

15. The method of claim 13, wherein the functionalized particles comprise a lipid shell encapsulating a liquid core.

16. A device for selection of target material, comprising:

a fluid chamber with a fluid region and an acoustic region;

an inlet into the fluid region to permit fluid flow through the fluid region and into the acoustic region;

an outlet above the acoustic region;

an ultrasonic transducer in the acoustic region and configured to generate an acoustic wave across the fluid chamber in the acoustic region; and

functionalized particles in the fluid region, wherein the acoustic wave retains

the functionalized particles in the fluid region.

17. The device of claim 16, wherein the fluid chamber comprises a column.

18. The device of claim 16, further comprising a reflector across the fluid chamber from the ultrasonic transducer to permit the establishment of a standing acoustic wave in the acoustic region.

19. The device of claim 16, wherein the functionalized particles comprise a liquid core and a lipid shell encapsulating the liquid core.

20. The device of claim 19, wherein the liquid core comprises a perfluorocarbon.