# ACOUSTIC EDGE EFFECT

## BACKGROUND

**[0001]** Separation of biomaterial has been applied in a variety of contexts. For example, separation techniques for separating proteins from other biomaterials are used in a number of analytical processes.

**[0002]** Acoustophoresis is a technique for separating particles and/or secondary fluids from a primary or host fluid using acoustics waves, such as ultrasonic waves. Acoustic waves can exert forces on particles in a fluid when there is a differential in density and/or compressibility, known as the acoustic contrast factor. The pressure profile in an acoustic wave contains areas of local minimum pressure amplitudes at wave nodes and local maxima at wave anti-nodes. Depending on their density and compressibility, the particles can be driven to and trapped at the nodes or anti-nodes of the acoustic wave. Generally, the higher the frequency of the standing wave, the smaller the particles that can be trapped.

## SUMMARY OF INVENTION

[0002a] According to a first aspect of the present invention, there is provided a process for separating materials from a fluid mixture, the process comprising:

flowing a fluid mixture containing the materials into a chamber;

generating an acoustic wave with an acoustic transducer at one end of the chamber;

establishing an interface region near the acoustic wave; and

blocking the materials from flowing with the fluid using an acoustic field generated at the interface region.

[0002b] According to a second aspect of the present invention, there is provided an acoustic separation device, comprising:

an ultrasonic transducer coupled to an end of a chamber suitable for containing a fluid flow;

a controller coupled to the ultrasonic transducer and configured to cause the ultrasonic transducer to generate an acoustic wave at the end of the chamber, such that the acoustic wave has an acoustic field with gradients in a number of directions;

a fluid pump configured to generate a fluid flow in the chamber;

material in the fluid flow interacting with the gradients to form an interface region that blocks the material from passing through the acoustic field.

[0002c] According to a third aspect of the present invention, there is provided a method for separating material from a fluid mixture, comprising:

flowing a fluid mixture containing the material into a chamber in a vertical direction;

actuating an acoustic transducer located at one end of the chamber to generate an acoustic wave across the chamber; and

forming an interface region on an upstream side of the acoustic wave, such that a material concentration is greater upstream of the acoustic wave.

**[0003]** This disclosure describes technologies relating to methods, systems, and apparatus for acoustic separation of materials. The materials being separated may be biomaterials. An acoustic wave is generated in a fluid, forming pressure differentials at different locales. In a flowing fluid, a pressure rise may be generated on an upstream interface region where the acoustic wave interacts with the flowing fluid. The acoustic wave generates an acoustic radiation force acting on material suspended in the fluid. The pressure rise and acoustic radiation force forms a tunable barrier or filter at the interface region. This phenomenon is referred to herein as an interface effect or edge effect, interchangeably. The interface effect the barrier or filter characteristics of the interface effect is located at the upstream of the fluid flow. Characteristics of the acoustic wave may be modified to change or control characteristics of the interface region and interface effect. For example, a frequency of the acoustic wave may be controlled to cause materials with a particular acoustic contrast factor to be blocked by or to be passed through the acoustic wave. As another example, characteristics of the acoustic wave can

**CLAIMS:**

1. A process for separating materials from a fluid mixture, the process comprising:

flowing a fluid mixture containing the materials into a chamber;

generating an acoustic wave with an acoustic transducer at one end of the chamber;

establishing an interface region near the acoustic wave; and

blocking the materials from flowing with the fluid using an acoustic field generated at the interface region.

2. The process of claim 1, wherein the materials are trapped by a multi-directional acoustic standing wave.

3. The process of claim 1, wherein a pressure rise and an acoustic radiation force on the materials are generated at the interface region.

4. The process of claim 1, further comprising recirculating fluid passing through the acoustic wave back to the chamber.

5. The process of claim 2, wherein the multi-directional acoustic standing wave results in an acoustic radiation force having an axial force component and a lateral force component that are of the same order of magnitude.

6. The process of claim 1, wherein the chamber is a vertically oriented column and further comprising utilizing gravity or buoyancy forces to contribute to forming the interface region.

7. The process of claim 1, wherein establishing the interface region further comprises reducing lateral wave force near an upstream side of the acoustic wave.

8. The process of claim 1, further comprising increasing a concentration of the material on the upstream side of the acoustic wave.

9. The process of claim 8, wherein an increased concentration of the material on the upstream side of the acoustic wave forms a pressure differential that contributes to forming the interface region.

10. The process of claim 1, further comprising forming fluids with different characteristics on either side of the interface region.

11. An acoustic separation device, comprising:

an ultrasonic transducer coupled to an end of a chamber suitable for containing a fluid flow;

a controller coupled to the ultrasonic transducer and configured to cause the ultrasonic transducer to generate an acoustic wave at the end of the chamber, such that the acoustic wave has an acoustic field with gradients in a number of directions;

a fluid pump configured to generate a fluid flow in the chamber;

material in the fluid flow interacting with the gradients to form an interface region that blocks the material from passing through the acoustic field.

12. The device of claim 11, further comprising a reflector to reflect the acoustic wave to generate an acoustic standing wave.

13. The device of claim 12, wherein the reflector further comprises facets.

14. The device of claim 12, wherein the acoustic standing wave is a multi-directional acoustic standing wave.

15. The device of claim 11, wherein the acoustic transducer is configured to be excited in a higher order mode.

16. The device of claim 11, further comprising a tunable barrier at the interface region.

17. The device of claim 11, wherein the controller is configured to control the acoustic wave to control characteristics of the interface region.

18. The device of claim 11, wherein the chamber further comprises a vertically oriented column.

19. A method for separating material from a fluid mixture, comprising:

flowing a fluid mixture containing the material into a chamber in a vertical direction;

actuating an acoustic transducer located at one end of the chamber to generate an acoustic wave across the chamber; and

forming an interface region on an upstream side of the acoustic wave, such that a material concentration is greater upstream of the acoustic wave.

20. The method of claim 19, further comprising forming a pressure differential at the interface region.