ACOUSTOPHORETIC MULTI-COMPONENT SEPARATION TECHNOLOGY PLATFORM

BACKGROUND

[0001] The present application claims the benefit of U.S. Provisional Patent Application Serial No. 61/611,159, filed March 15, 2012, and of U.S. Provisional Patent Application Serial No. 61/611,240, also filed March 15, 2012, and of U.S. Provisional Patent Application Serial No. 61/754,792, filed January 21, 2013. These three applications are incorporated herein by reference in their entireties.

[0002] Acoustophoresis is the separation of particles using high intensity sound waves. It has long been known that high intensity standing waves of sound can exert forces on particles. A standing wave has a pressure profile which appears to "stand" still in time. The pressure profile in a standing wave varies from areas of high pressure (nodes) to areas of low pressure (anti-nodes). Standing waves are produced in acoustic resonators. Common examples of acoustic resonators include many musical wind instruments such as organ pipes, flutes, clarinets, and horns.

[0003] Efficient separation technologies for multi-component liquid streams that eliminate any waste and reduce the required energy, thereby promoting a sustainable environment, are needed.

BRIEF DESCRIPTION

[0004] The present disclosure relates to systems and devices for acoustophoresis on a large scale. The devices use an ultrasonic transducer as described herein. The transducer is driven at frequencies that produce multiple standing waves.

[0005] In ~~some embodiments~~one aspect, an apparatus including a flow chamber with an inlet and an outlet through which is flowed a mixture of a host fluid and at least one of a second fluid and a particulate is disclosed. An ultrasonic transducer embedded in a wall of said flow chamber or located outside the flow chamber wall is driven by an oscillating, periodic, or pulsed voltage signal of ultrasonic frequencies which drives the transducer in a higher order mode of vibration to create standing waves in the flow channel. The

transducer includes a ceramic crystal. A reflector is located on the wall on the opposite side of the flow chamber from the transducer.

[0006] In ~~other embodiments~~ one aspect, a method of separating a host fluid from at least one of a second fluid and a particulate is disclosed. The method comprises flowing the host fluid into a flow chamber having a resonator and a collection pocket and driving a transducer with an oscillating, periodic, or pulsed voltage signal to create standing waves in the resonator and collect the at least one of the second fluid and particulate in the collection pocket.

[0007] In ~~yet other embodiments~~ another aspect, an apparatus comprises a flow chamber with an inlet and an outlet through which is flowed a mixture of a host fluid and at least one of a second fluid and a particulate. A plurality of ultrasonic transducers are embedded in a wall of said flow chamber or located outside the flow chamber wall. The transducers each include a ceramic crystal driven by an oscillating, periodic, or pulsed voltage signal of ultrasonic frequencies which drives the transducers in a non-uniform ~~higher order~~ mode of displacement ~~vibration~~ to create standing waves in the flow channel. A reflector is located on the wall on the opposite side of the flow chamber from the transducers. In one aspect, a method of separating impurities from a host fluid is provided. The method comprises providing a flow chamber having a source of acoustic energy and, on an opposing side of the flow chamber, a reflector of acoustic energy; flowing the host fluid through the flow chamber; applying the source of acoustic energy to the host fluid to create a plurality of incident waves in the host fluid; and reflecting the plurality of incident waves from the reflector, creating a plurality of reflected waves resonating with the incident waves, forming a plurality of standing waves. In another aspect, an ultrasonic transducer is provided. The ultrasonic transducer comprises a housing; an exposed ceramic crystal at a bottom end; a top plate at a top end of the housing, the top including a connector; and an air gap between the top plate and the ceramic crystal, wherein no backing layer is present within the housing. In yet another aspect, a process for separating a second fluid or particulate from a host fluid is provided. The process comprises flowing the host fluid containing the second fluid or particulate through a flow chamber, wherein an ultrasonic transducer is present in the flow chamber; driving the ultrasonic transducer at a frequency that creates multiple standing waves in the flow chamber, wherein the second fluid or particulate is trapped in

the standing waves and separated.

[0008] These and other non-limiting characteristics are more particularly described below.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The following is a brief description of the drawings, which are presented for the purposes of illustrating the exemplary embodiments disclosed herein and not for the purposes of limiting the same.

[0010] **Figure 1** shows an acoustophoretic separator having one transducer.

[0011] **Figure 2** is a diagram illustrating the function of an acoustophoretic separator.

[0012] **Figure 3** shows an acoustophoretic separator having a plurality of transducers.

[0013] **Figure 4A** is a detail view of a diffuser used as an inlet in the separator of **Figure 3**.

[0014] **Figure 4B** is a detail view of an alternate inlet diffuser that can be used with the separator of **Figure 3**.