CLAIMS:

1. A method of separating impurities from a host fluid, the method comprising:

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.

2. The method of claim 1, wherein the host fluid is continuously flowed through the flow chamber.

3. The method of claim 1, wherein the standing wave has an axial force and a lateral force with respect to the source of acoustic energy, the lateral force being at least the same order of magnitude as the axial force.

4. The method of claim 3, wherein the standing waves create nodal lines and the lateral forces trap the impurities in the nodal lines.

5. The method of claim 4, wherein the impurities trapped in the nodal lines coalesce or agglomerate such that heavier than water impurities are separated through enhanced gravitational settling and lighter than water particles are separated through enhanced buoyancy.

6. An apparatus comprising:

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;

an ultrasonic transducer on a wall of the flow chamber, the transducer including a ceramic crystal that defines a side of the transducer, the transducer being driven by an oscillating, periodic, or pulsed voltage signal of ultrasonic frequencies

~~which drives the transducer to create standing waves in the flow chamber; and~~

~~a reflector located on a wall on the opposite side of the flow chamber from the transducer.~~

~~7. The apparatus of claim 6, wherein the crystal is driven in a non-uniform displacement mode.~~

~~8. The apparatus of claim 7, wherein the crystal is driven in a higher order mode shape having more than one node.~~

~~9. The method of claim 6, wherein the ceramic crystal of the transducer is directly exposed to fluid flowing through the flow chamber.~~

~~10. The apparatus of claim 6, wherein the ceramic crystal is made of PZT-8.~~

~~11. The apparatus of claim 6, wherein the transducer has a housing containing the ceramic crystal.~~

~~12. The apparatus of claim 11, wherein the housing includes a top and an air gap, the air gap being disposed between the top and the ceramic crystal.~~

~~13. The apparatus of claim 12, wherein the ceramic crystal does not have a backing layer.~~

~~14. The apparatus of claim 6, wherein the vibration of the transducer forms standing waves in the flow chamber.~~

~~15. The apparatus of claim 6, wherein the flow chamber has a collection pocket in a wall of the flow chamber.~~

~~16. The apparatus of claim 6, wherein the reflector is steel or tungsten.~~

~~17. The apparatus of claim 6, wherein the standing waves in the flow channel exert an axial force and a radial force on the at least one second fluid or particulate.~~

~~18. The apparatus of claim 6, wherein the flow chamber further includes a diffuser at the inlet.~~

~~19. The apparatus of claim 18, wherein the diffuser has a grid device for uniform flow.~~

~~20. The apparatus of claim 6, wherein the ceramic crystal is square.~~

~~21. An apparatus comprising:~~

~~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 located on a wall of the flow chamber, the transducers each including a ceramic crystal driven by an oscillating, periodic, or pulsed voltage signal of ultrasonic frequencies which drives the transducers to vibrate in a non-uniform mode of displacement to create standing waves in the flow channel; and~~

~~a reflector located on the wall on the opposite side of the flow chamber from the transducers.~~

~~22. The apparatus of claim 21, wherein the transducers span the width of the flow chamber.~~

~~23. The apparatus of claim 22, wherein each of the plurality of ultrasonic transducers is square.~~

~~24. The apparatus of claim 22, wherein each of the plurality of ultrasonic transducers is rectangular.~~

~~25. The apparatus of claim 21, wherein at least one of the crystals is air backed.~~

~~26. The apparatus of claim 21, wherein at least one of the crystals is backed by a substantially acoustically transparent material.~~

~~27. The apparatus of claim 26, wherein the substantially acoustic material is one of balsa wood or cork.~~

~~28. The apparatus of claim 21, wherein at least one of the crystals is backed by a lattice structure attached at at least some of a plurality of nodes created by vibrating the crystal in a higher order modal displacement.~~

~~29. The apparatus of claim 21, wherein the ultrasonic transducers have a face that contacts the host fluid, the face coated with a wear layer comprising one of chrome, electrolytic nickel, or electroless nickel, p-xylxyene, and urethane.~~

~~30. An ultrasonic transducer, comprising:~~

~~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.~~

~~31. A process for separating a second fluid or particulate from a host fluid, comprising:~~

~~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.~~

~~32. The method of claim 31, wherein the second fluid or partiulate trapped in the standing waves coalesce or agglomerate such that heavier than water impurities are separated through enhanced gravitational settling and lighter than water particles are separated through enhanced buoyancy.~~

CLAIMS:

1. A method of separating impurities from a host fluid, the method comprising:

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 an ultrasonic standing wave in the host fluid; and

reflecting the standing wave from the reflector, forming a three dimensional acoustic standing wave, wherein the three-dimensional acoustic standing wave results in an acoustic radiation force having an axial component and a lateral component that are of the same order of magnitude.

2. The method of claim 1, wherein the host fluid is continuously flowed through the flow chamber.

3. The method of claim 1, wherein the three dimensional standing wave creates nodal lines and lateral forces trap the impurities in the nodal lines.

4. The method of claim 3, wherein the impurities trapped in the nodal lines coalesce or agglomerate such that heavier than water impurities are separated through enhanced gravitational settling and lighter than water particles are separated through enhanced buoyancy.

5. An apparatus comprising:

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;

an ultrasonic transducer on a wall of the flow chamber, the transducer including a ceramic crystal that defines a side of the transducer, the transducer being driven by an oscillating, periodic, or pulsed voltage signal of ultrasonic frequencies which drives the transducer to create a three dimensional acoustic standing wave in the

flow chamber, wherein the three-dimensional acoustic standing wave results in an acoustic radiation force having an axial component and a lateral component that are of the same order of magnitude; and

a reflector located on a wall on the opposite side of the flow chamber from the transducer.

6. The apparatus of claim 5, wherein the crystal is driven in a non-uniform displacement mode.

7. The apparatus of claim 6, wherein the crystal is driven in a higher order mode shape having more than one nodal trapping line.

8. The method of claim 5, wherein the ceramic crystal of the transducer is directly exposed to fluid flowing through the flow chamber.

9. The apparatus of claim 5, wherein the ceramic crystal is made of PZT-8.

10. The apparatus of claim 5, wherein the transducer has a housing containing the ceramic crystal.

11. The apparatus of claim 10, wherein the housing includes a top and an air gap, the air gap being disposed between the top and the ceramic crystal.

12. The apparatus of claim 5, wherein the vibration of the transducer forms standing waves in the flow chamber.

13. The apparatus of claim 5, wherein the flow chamber has a collection pocket in a wall of the flow chamber.

14. The apparatus of claim 5, wherein the reflector is steel or tungsten.

15. The apparatus of claim 5, wherein the standing waves in the flow channel exert an axial force and a radial force on the at least one second fluid or particulate.

16. The apparatus of claim 5, wherein the flow chamber further includes a diffuser at the inlet.

17. The apparatus of claim 16, wherein the diffuser has a grid device for uniform flow.

18. The apparatus of claim 5, wherein the ceramic crystal is square.

19. An apparatus comprising:

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 located on a wall of the flow chamber, each transducer including a ceramic crystal driven by an oscillating, periodic, or pulsed voltage signal of ultrasonic frequencies which drives the transducer to vibrate in a non-uniform mode of displacement to create a three-dimensional acoustic standing wave in the flow channel wherein each three-dimensional acoustic standing wave results in an acoustic radiation force having an axial component and a lateral component that are of the same order of magnitude; and

a reflector located on the wall on the opposite side of the flow chamber from the transducers.

20. The apparatus of claim 19, wherein the transducers span the width of the flow chamber.

21. The apparatus of claim 20, wherein each of the plurality of ultrasonic transducers is square.

22. The apparatus of claim 20, wherein each of the plurality of ultrasonic transducers is rectangular.

23. The apparatus of claim 19, wherein at least one of the crystals is air backed.

24. The apparatus of claim 19, wherein at least one of the crystals is backed by a substantially acoustically transparent material.

25. The apparatus of claim 24, wherein the substantially acoustically transparent material is one of balsa wood or cork.

26. An apparatus comprising:

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 located on a wall of the flow chamber, the transducers each including a ceramic crystal driven by an oscillating, periodic, or pulsed voltage signal of ultrasonic frequencies which drives the transducers to vibrate in a non-uniform mode of displacement to create standing waves in the flow channel; and

a reflector located on the wall on the opposite side of the flow chamber from the transducers;

wherein at least one of the crystals is backed by a lattice structure attached at at least some of a plurality of nodes created by vibrating the crystal in a higher order modal displacement.

27. The apparatus of claim 19, wherein the ultrasonic transducers have a face that contacts the host fluid, the face coated with a wear layer comprising one of chrome, electrolytic nickel, electroless nickel, p-xylylene, and urethane.

28. A process for separating a second fluid or particulate from a host fluid, comprising:

flowing the host fluid containing the second fluid or particulate through a flow chamber of an apparatus, the flow chamber having an inlet and an outlet, and the apparatus further comprising:

an ultrasonic transducer embedded in a wall of the flow chamber; and

a reflector located on a wall on an opposite side of the flow chamber from the transducer;

driving the ultrasonic transducer at a frequency that creates a three-dimensional acoustic standing wave in the flow chamber, wherein the three-dimensional acoustic standing wave results in an acoustic radiation force having an axial component and a lateral component that are of the same order of magnitude;

wherein the second fluid or particulate is trapped in the three-dimensional acoustic standing wave and separated.

29. The method of claim 28, wherein the second fluid or particulate trapped in the standing waves coalesce or agglomerate such that heavier than water impurities are separated through enhanced gravitational settling and lighter than water particles are separated through enhanced buoyancy.

30. The method of claim 28, wherein the ultrasonic transducer comprises:

a housing;

a ceramic crystal at a bottom end that is exposed from an exterior of the housing;

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.

31. The method of claim 30, wherein the ceramic crystal has a backing made of a substantially acoustically transparent material.

32. The method of claim 31, wherein the substantially acoustically transparent material is balsa wood or cork.

33. The method of claim 31, wherein the substantially acoustically transparent material is in the form of a lattice.

34. The method of claim 30, wherein the transducer has no wear plate or backing.

35. The method of claim 30, wherein the ceramic crystal vibrates in a higher order mode shape.

36. The method of claim 28, wherein the ultrasonic transducer is driven by an oscillating, periodic, or pulsed voltage signal.

37. The method of claim 28, wherein the ultrasonic transducer is driven at a frequency ranging from 100s of kHz to several MHz.

38. The method of claim 28, wherein the second fluid or particulate has a particle size distribution from 600 microns to 0.3 microns.