TITLE

ACOUSTIC TRANSDUCER DRIVER AND CONTROLLER

BACKGROUND

Acoustophoresis is the use of acoustics to perform separation of materials. For example, particles and secondary fluids can be separated from a primary or host fluid using acoustic standing waves. Acoustic standing waves can exert forces on particles in a fluid when there is a differential in 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.

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 slow 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.

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. 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

A first aspect of the present disclosure provides a method of operating an acoustophoretic system comprising controlling a frequency of a drive signal applied to

an acoustic transducer based on reactance minima or maxima determined from a feedback signal from the acoustic transducer.

A second aspect of the present disclosure provides a method for determining an operating setpoint of an acoustic system that includes an acoustic transducer and an acoustic chamber, comprising determining a reactance value for at least some of a range of frequencies, such that a minimum reactance value is determined for the range of frequencies; and applying a drive signal to the acoustic transducer at a frequency associated with the minimum reactance value.

A third aspect of the present disclosure provides acoustophoretic system, comprising an acoustic chamber; an acoustic transducer coupled to the acoustic chamber and configured to generate an acoustic standing wave in the acoustic chamber; wherein the acoustic transducer is controlled according to the method of the first aspect.

An electrical source, which may include an oscillator and an amplifier, may be utilized to perturb a piezoelectric material that may be utilized to generate acoustic waves. When a reflector is utilized in conjunction with the piezoelectric material, the acoustic

CLAIMS

1. A method of operating an acoustophoretic system comprising controlling a frequency of a drive signal applied to an acoustic transducer based on reactance minima or maxima determined from a feedback signal from the acoustic transducer.

2. A method for determining an operating setpoint of an acoustic system that includes an acoustic transducer and an acoustic chamber, comprising:

determining a reactance value for at least some of a range of frequencies, such that a minimum reactance value is determined for the range of frequencies; and

applying a drive signal to the acoustic transducer at a frequency associated with the minimum reactance value.

3. The method according to claim 2, further comprising:

identifying a subset of frequencies in the range of frequencies, the frequency associated with the minimum reactance value being located in the subset; and

determining a new frequency within the subset associated with the minimum reactance value; and

applying the drive signal to the acoustic transducer at the new frequency.

4. The method according to claim 1, further comprising locating a anti-resonance frequency.

5. The method according to claim 4, further comprising locating reactance minima or maxima adjacent to the anti-resonance frequency.

6. The method according to claim 1, further comprising:

identifying a reactance minimum from the reactance minima or a reactance maximum from the reactance maxima; and

providing the drive signal at a first frequency associated with the reactance minimum or the reactance maximum.

7. The method according to claim 6, further comprising:

evaluating reactance values near the first frequency for a new reactance minimum or new reactance maximum; and

selecting a new frequency associated with the new reactance minimum or new reactance maximum.

8. The method according to claim 7, further comprising evaluating the reactance by conducting a narrow range frequency sweep near the first frequency.

9. The method according to claim 8, further comprising adjusting a range of the narrow range frequency sweep based on the new reactance minimum or the new reactance maximum.

10. The method according to claim 8, further comprising controlling one or more of a step size or number of steps of frequencies within the range of the narrow range frequency sweep.

11. The method according to claim 8, further comprising controlling the narrow range frequency sweep with a control loop.

12. The method according to claim 11, further comprising controlling parameters of the control loop to increase convergence to the new reactance minimum or the new reactance maximum.

13. The method according to claim 11, further comprising increasing convergence to the new reactance minimum or the new reactance maximum by increasing step size farther from the new reactance minimum or new reactance maximum and decreasing step size closer to the new reactance minimum or the new reactance maximum.

14. The method according to claim 7, wherein evaluating reactance values further comprises approximating a tangent to the reactance minimum or the reactance maximum and modifying the first frequency to obtain the new frequency where the tangent approximation is maintained.

15. The method according to claim 1, further comprising determining one or more of voltage, current, resistance, reactance, power or phase angle from the feedback signal.

16. The method according to claim 1, further comprising controlling the drive signal to

maintain a power setpoint.

17. The method according to claim 1, further comprising:

flowing a mixture of a host fluid and particles or a mixture of the host fluid and secondary fluid into the acoustophoretic system; and

adjusting the frequency of the drive signal based on reactance minima or reactance maxima.

18. The method according to claim 17, further comprising:

generating an acoustic wave with the acoustic transducer;

retaining material in the acoustic wave such that a loading on the acoustic transducer changes; and

controlling the drive signal applied to the acoustic transducer based on a new reactance minima or maxima associated with the loading change on the acoustic transducer.

19. An acoustophoretic system, comprising:

an acoustic chamber;

an acoustic transducer coupled to the acoustic chamber and configured to generate an acoustic standing wave in the acoustic chamber;

wherein the acoustic transducer is controlled according to the method of claim 1.