Claims

We claim:

1. A nozzle assembly, comprising:

a vessel defining a pressurizable chamber, wherein the vessel includes a distal end and a proximal end;

an inlet of the pressurizable chamber at the proximal end of the vessel;

a nozzle positioned within the pressurizable chamber, wherein the nozzle includes an inlet tube in fluid communication with the inlet of the pressurizable chamber, wherein the nozzle includes an outlet aperture, wherein the nozzle is adjustable to alter a distance between the proximal end of the vessel and the outlet aperture of the nozzle, and wherein the nozzle is adjustable to alter an angle between a longitudinal axis of the vessel and a longitudinal axis of the nozzle; and

an outlet of the pressurizable chamber at the distal end of the vessel.

2. The nozzle assembly of claim 1, further comprising:

a second inlet of the pressurizable chamber at the proximal end of the vessel.

3. The nozzle assembly of any one of claims 1 or 2, wherein the inlet of the pressurizable chamber is in fluid communication with a first reservoir and a second reservoir.

4. The nozzle assembly of any one of claims 2 or 3, wherein the inlet of the pressurizable chamber is in fluid communication with a first reservoir, and wherein the second inlet of the pressurizable chamber is in fluid communication with a second reservoir.

5. The nozzle assembly of any one of claims 1-4, wherein a shape of the outlet aperture of the nozzle creates a vortex within the nozzle.

6. The nozzle assembly of any one of claims 1-5, wherein the inlet tube of the nozzle has an inner diameter with a range from about 1.5875 mm to about 6.35 mm.

7. The nozzle assembly of any one of claims 1-6, further comprising:

a motor coupled to the nozzle, wherein the motor is configured to alter the distance between the proximal end of the vessel and the outlet aperture of the nozzle.

8. The nozzle assembly of claim 7, wherein the motor is further configured to alter the angle between a longitudinal axis of the vessel and a longitudinal axis of the nozzle.

9. A particle production system, comprising:

one or more nozzle assemblies of any one of claims 1-8;

a sonic energy source positioned adjacent to the outlet aperture of each nozzle;

one or more particle filtration systems in communication with one or more nozzle assemblies; and

one or more particle collection devices in communication with the one or more particle filtration systems.

10. The particle production system of claim 9, wherein the one or more particle filtration systems comprise a tandem particle filtration system including at least one high pressure harvesting filter system and at least one low pressure collection filter system in tandem and downstream to the harvesting filter.

11. The particle production system of claim 10, comprising at least two particle harvesting filters, two particle collection filters and two collection devices.

12. The particle production system of any one of claims 9-11, wherein the one or more particle collection devices comprise:

a collection vessel defining a chamber, wherein the collection vessel includes a distal end and a proximal end;

an inlet port extending from the proximal end of the collection vessel, wherein the inlet port is in fluid communication with the chamber; and

an outlet port extending from the proximal end of the collection vessel, wherein the inlet port is in fluid communication with the chamber, and wherein the outlet port includes a porous material positioned between the chamber and the outlet port.

13. The particle production system of any one of claims 9-12, further comprising:

a sampling system configured to measure one or more particles collected in the collection device.

14. A method comprising:

providing a nozzle assembly including (i) a vessel defining a pressurizable chamber, wherein the vessel includes a distal end and a proximal end, (ii) a first inlet of the pressurizable chamber at the proximal end of the vessel, (iii) a nozzle positioned within the pressurizable chamber, wherein the nozzle includes an inlet tube in fluid communication with the first inlet of the pressurizable chamber, wherein the nozzle includes an outlet aperture, wherein the nozzle is adjustable to alter a distance between the proximal end of the vessel and the outlet aperture of the nozzle, and wherein the nozzle is adjustable to alter an angle between a longitudinal axis of the vessel and a longitudinal axis of the nozzle, and (iv) an outlet of the pressurizable chamber at the distal end of the vessel;

positioning a sonic energy source within the pressurizable chamber adjacent to the outlet aperture of the nozzle;

receiving a first fluid and a second fluid into the pressurizable chamber, wherein the first fluid is transported through the outlet aperture of the nozzle and onto the sonic energy source, and wherein the second fluid is transported through a second inlet of the pressurizable chamber to thereby create a plurality of particles within the pressurizable chamber;

receiving the plurality of particles through the outlet of the pressurizable chamber;

collecting the plurality of particles in a collection device; and

determining a size of one or more of the plurality of particles.

15. The method of claim 14, further comprising:

determining a difference between a desired size of the one or more particles and the determined size of the one or more particles.

16. The method of claim 15, further comprising:

in response to the determined difference, adjusting at least one of the distance between the proximal end of the vessel and the outlet aperture of the nozzle and the angle between a longitudinal axis of the vessel and a longitudinal axis of the nozzle.

17. The method of any one of claims 14-16, wherein a flow rate of the first liquid through the nozzle has a range from about 0.5 mL/min to about 30 mL/min.

18. The method of any one of claims 14-17, wherein the plurality of particles formed within the pressurizable chamber contain high pressure fluid suspension.

19. The method of any one of claims 14-18, wherein the sonic energy source produces sonic energy with an amplitude between about 10% and about 100% of the maximum sonic energy output of the sonic energy source.

20. A non-transitory computer readable medium having stored thereon instructions, that when executed by one or more processors, causes the nozzle assembly of any one of claims 1-8 to perform operations comprising:

receiving a first fluid and a second fluid into the pressurizable chamber, wherein the first fluid is transported through the outlet aperture of the nozzle and onto the sonic energy source, and wherein the second fluid is transported through a second inlet of the pressurizable chamber to thereby create a plurality of particles within the pressurizable chamber;

receiving the plurality of particles through the outlet of the pressurizable chamber;

collecting the plurality of particles in a collection device; and

determining a size of one or more of the plurality of particles,

wherein the operations further comprise:

determining a difference between a desired size of the one or more particles and the determined size of the one or more particles, and

wherein the operations further comprise:

in response to the determined difference, adjusting at least one of the distance between the proximal end of the vessel and the outlet aperture of the nozzle and the angle between a longitudinal axis of the vessel and a longitudinal axis of the nozzle.