centrifugation may damage the blood cells, and removes beneficial blood components such as platelets and clotting factors. Some MEMS devices have been used, but rely on very small passages that essentially " line up" ed blood cells and lipid particles for separation. This results in very low throughput, and cannot handle large amounts in bulk.

[0005] There is a need for a separation technology that can efficiently and adequately remove lipids from blood.

BRIEF DESCRIPTION

[0006] The present disclosure relates to systems and devices that use acoustophoresis to trap and separate lipids from blood. The devices use an ultrasonic transducer as described herein.

[0007] Method of separating lipids from blood are disclosed herein. The blood is flowed through a flow chamber. The flow chamber has a source of acoustic energy and, on an opposing side of the flow chamber, a reflector of acoustic energy. The blood contains lipids. The source of acoustic energy is activated to create a plurality of incident waves in the blood. The reflector reflects the plurality of incident waves, creating a plurality of reflected waves resonating with the incident waves, thus forming a plurality of standing waves. Lipids trapped in the standing waves can then be removed from the blood.

[0007A] In one particular embodiment there is provided amethod of separating lipids from blood, the method comprising:

flowing the blood through a flow chamber, wherein the flow chamber has a source of acoustic energy and, on an opposing side of the flow chamber, a reflector of acoustic energy, and wherein the blood contains lipids;

activating the source of acoustic energy to create a plurality of three-dimensional standing waves in the blood; and

removing lipids trapped in the three-dimensional standing waves from the blood,

wherein each three-dimensional 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.

[0008] In other embodiments, an apparatus is disclosed. The apparatus includes a flow chamber with an inlet and an outlet through which is flowed blood containing lipids, 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.

[0009] In yet another embodiment, an apparatus comprises a suction to gather blood from a patient, a flow chamber with an inlet and an outlet through which is flowed the blood, 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

~~CLAIMS:~~

~~1. A method of separating lipids from blood, the method comprising:~~

~~flowing the blood through a flow chamber, wherein the flow chamber has a source of acoustic energy and, on an opposing side of the flow chamber, a reflector of acoustic energy, and wherein the blood contains lipids;~~

~~activating the source of acoustic energy to create a plurality of incident waves in the blood;~~

~~reflecting the plurality of incident waves from the reflector, creating a plurality of reflected waves resonating with the incident waves, thus forming a plurality of standing waves; and~~

~~removing lipids trapped in the standing waves from the blood.~~

~~2. The method of claim 1, wherein the blood 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 lipids in the nodal lines.~~

~~5. The method of claim 4, wherein the lipids trapped in the nodal lines coalesce or agglomerate such that the lipids are separated through enhanced buoyancy.~~

~~6. The method of claim 1, wherein the lipids are collected in a collection pocket at the top of the flow chamber.~~

~~7. The method of claim 1, wherein the blood is mediastinal blood collected via a suction.~~

8. An apparatus comprising:

a flow chamber with an inlet and an outlet through which is flowed blood containing lipids;

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.

9. The apparatus of claim 8, further comprising a collection pocket at the top of the flow chamber.

10. The apparatus of claim 8, further comprising a suction to collect blood from a patient and a pump which flow the blood through the chamber and into the patient.

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

12. The apparatus of claim 8, wherein the transducer has a housing containing the ceramic crystal.

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

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

15. The apparatus of claim 8, wherein the vibration of the transducer forms standing waves in the flow chamber.

~~16. The apparatus of claim 8, wherein the reflector is steel or tungsten.~~

~~17. Theapparatus of claim 8, 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.~~

Claims

1. A method of separating lipids from blood, the method comprising:

flowing the blood through a flow chamber, wherein the flow chamber has a source of acoustic energy and, on an opposing side of the flow chamber, a reflector of acoustic energy, and wherein the blood contains lipids;

activating the source of acoustic energy to create a plurality of three-dimensional standing waves in the blood; and

removing lipids trapped in the three-dimensional standing waves from the blood,

wherein each three-dimensional 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.

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

3. The method of claim 1, wherein the standing waves create nodal lines and the lateral forces trap the lipids in the nodal lines.

4. The method of claim 3, wherein the lipids trapped in the nodal lines coalesce or agglomerate such that the lipids are separated through enhanced buoyancy.

5. The method of claim 1, wherein the lipids are collected in a collection pocket at the top of the flow chamber.

6. The method of claim 1, wherein the blood is mediastinal blood collected via a suction.

7. The method of claim 1, wherein the source of acoustic energy is an ultrasonic transducer located on a wall of the flow chamber, the ultrasonic transducer comprising:

a housing having a top and a bottom end; and

a crystal defining the bottom end of the housing, the crystal being exposed from the exterior of the housing and being able to vibrate when driven by a voltage signal.

8. The method of claim 7, wherein the crystal has a backing made of a substantially acoustically transparent material.

9. The method of claim 8, wherein the substantially acoustically transparent material is balsa wood or cork.

10. The method of claim 8, wherein the substantially acoustically transparent material is in the form of a lattice.

11. The method of claim 7, wherein an exterior surface of the crystal is covered by a wear surface material with a thickness of a half wavelength of less, the wear surface material being a urethane, epoxy, or silicone coating.

12. The method of claim 7, wherein the crystal has no backing layer or wear layer.