Claims

1. A membrane emulsification apparatus for dispersing a first phase in a second phase, comprising:

a membrane defining a plurality of apertures connecting a first volume on a first side of the membrane to a second volume on a second, different, side of the membrane, the apparatus being arranged to receive a first phase containing a liquid in the first volume and to receive a second phase in the second volume the apparatus being adapted to generate an emulsion through egression of the first phase into the second phase via the plurality of apertures;

the apparatus also comprising a refiner arranged to receive the emulsion from the membrane; and wherein said refiner comprises an inlet and an outlet wherein an opening adapted to converge flow of the emulsion and to break up droplets of the emulsion into a refined emulsion is located between the inlet and the outlet.

~~2. Membrane emulsification apparatus according to claim 1 wherein the refined emulsion comprises droplets with a diameter of from about 70nm to about 2μm.~~

~~3. Membrane emulsification apparatus according to claim 2 wherein the refined emulsion comprises droplets with a diameter of from about 70 to about 250nm.~~

~~4. Membrane emulsification apparatus according to claim 3 wherein from about 80 to about 90% v/v of the refined emulsion droplets may have a diameter of from about 70 to about 250nm.~~

5. Membrane emulsification apparatus according to claim 2 wherein the refined emulsion comprises droplets with a diameter of from about 1 to about 5μm.

6. Membrane emulsification apparatus according to claim 5 wherein from about 80 to about 90% v/v of the refined emulsion droplets may have a diameter of from about 1 to about 5μm.

7. Membrane emulsification apparatus according to any one of the preceding claims wherein the apparatus is arranged to receive a first phase containing a liquid in the first volume and to receive a second phase in the second volume; the apparatus being adapted to generate an emulsion through egression of the first phase into the second phase via the plurality of apertures.

8. Membrane emulsification apparatus according to any one of the preceding claims wherein the apparatus is arranged so that flow of the second phase in the second volume creates a shear field at the area of egression of the first phase, the shear field being in a direction substantially perpendicular to the direction of egression of the first phase.

9. Membrane emulsification apparatus according to any one of the preceding claims wherein the membrane is tubular in shape and comprises a first end and a second end; wherein the first end is for receiving the second phase; and the refiner is coupled to the second end.

10. Membrane emulsification apparatus according to any one of the preceding claims wherein the refiner is tunable by adjustment of the opening.

~~11. Membrane emulsification apparatus according to claim 10 wherein the adjustable opening in the tunable refiner comprises adjustment means.~~

~~12~~2. Membrane emulsification apparatus according to ~~any one of claims 10 or 11~~ claim 1 wherein the adjustment means in the tunable refiner comprises a differential screw.

~~13~~3. Membrane emulsification apparatus according to claim ~~12~~2 wherein the differential screw comprises a spindle with two external screw threads of differing thread pitch.

~~14~~4. Membrane emulsification apparatus according to claim ~~12~~2 wherein the differential screw comprises a spindle with two external screw threads are generally congruous.

~~15~~5. Membrane emulsification apparatus according to claim ~~12~~2 wherein the differential screw comprises a spindle with two external screw threads of differing handedness.

~~16~~6. Membrane emulsification apparatus according to claim ~~12~~2 wherein nuts are located around two external screw threads of the differential screw.

~~17~~7. Membrane emulsification apparatus according to claim ~~13~~3 wherein the first end of the spindle, adjacent the refiner opening, is smaller than the second end of the spindle, which is distal to the refiner opening.

~~18~~8. Membrane emulsification apparatus according to claim ~~17~~7 wherein the distal end of the spindle is provided with a first external thread, the diameter of which is wider than that of the end of the spindle adjacent the opening, which is provided with a second external thread.

~~19. Membrane emulsification apparatus according to any one of the preceding claims wherein the dimensions of opening are from about 1μm to about 2mm.~~

~~20. Membrane emulsification apparatus according to any one of claims 1 to 9 wherein the refiner is a fixed refiner.~~

~~21. Membrane emulsification apparatus according to claim 20 wherein the dimensions of the opening in the fixed refiner may be by changing the dimensions of parts.~~

~~22. Membrane emulsification apparatus according to claim 20 wherein the dimensions of the opening may be adjusted from about 1μm to about 2mm.~~

~~23. Membrane emulsification apparatus according to any one of the preceding claims wherein the refiner is a separate component to the membrane.~~

~~24. Membrane emulsification apparatus according to any one of claims 1 to 22 wherein the refiner is coupled to the membrane.~~

~~25~~9. Membrane emulsification apparatus according to any one of the preceding claims ~~1 to 22~~ wherein the refiner is integral to the membrane.

~~26~~10. Membrane emulsification apparatus according to claim ~~10~~1 wherein the adjustable opening comprises a refiner plug adjacent the opening, such that movement of the insert rod closer to the opening reduces the size of the opening.

~~27~~11. Membrane emulsification apparatus according to claim ~~26~~10 wherein the end of the insert rod adjacent to the opening comprises a frusto conical member with a terminal protrusion.

~~28~~12. Membrane emulsification apparatus according to claim ~~27~~11 wherein the terminal protrusion comprises a flat end surface.

~~29~~13. Membrane emulsification apparatus according to claim ~~26~~10 wherein the insert rod is adapted to simulate multiple passes of the emulsion through the opening.

~~30. Membrane emulsification apparatus according to claim 20 wherein from 2-5 stages are utilised.~~

~~31. Membrane emulsification apparatus according to any one of the preceding claims wherein the apparatus is used in a batch mode.~~

~~32~~14. Membrane emulsification apparatus according to any one of claims 1 to ~~30~~13 wherein the apparatus is used in a continuous mode.

~~33~~15. Membrane emulsification apparatus according to claim ~~32~~14 wherein the refiner comprises multiples inlets and/ or multiple outlets.

~~34. Membrane emulsification apparatus according to claim 26 wherein the insert rod is stepped.~~

~~35. Membrane emulsification apparatus according to claim 34 wherein the insert rod is stepped and the opposing surface is conical.~~

~~36. Membrane emulsification apparatus according to claim 27 wherein the opening comprises two cones of different angle, such that the inlet end has equal or larger cross sectional area than the outlet end.~~

~~37. Membrane emulsification apparatus according to any one of the preceding claims wherein the surfaces are roughened.~~

~~38. Membrane emulsification apparatus according to any one of the preceding claims wherein the apparatus is provided with a first pump for providing the first phase to the first volume under pressure, and optionally a second pump for providing the second phase to the second volume under pressure.~~

~~39. Membrane emulsification apparatus according to any one of the preceding claims wherein the apparatus is provided with an emulsion pump, in order to generate high pressure at the opening.~~

~~40. Membrane emulsification apparatus according to any one of the preceding claims wherein the apparatus comprises a cross-flow assembly.~~

~~41. Membrane emulsification apparatus according to claim 40 wherein the cross-flow assembly comprises an assembly as described in International patent application No. WO 2019/092461.~~

~~42. A membrane emulsification apparatus for dispersing a first phase in a second phase, wherein the membrane emulsification apparatus comprises a cross-flow apparatus for producing an emulsion or dispersion by dispersing a first phase in a second phase; said cross-flow apparatus comprising:~~

~~an outer tubular sleeve provided with a first inlet at a first end; an emulsion outlet; and a second inlet, distal from and inclined relative to the first inlet;~~

~~a tubular membrane provided with a plurality of pores and adapted to be positioned inside the tubular sleeve; and~~

~~optionally an insert adapted to be located inside the tubular membrane, said insert comprising an inlet end and an outlet end, each of the inlet end and an outlet end being provided with chamfered region; the chamfered region is provided with a plurality of orifices and a furcation plate;~~

~~the apparatus also comprising a tunable refiner arranged to receive the emulsion from the membrane and wherein said refiner comprises an inlet and an outlet wherein an opening adapted to converge flow of the emulsion and to break up droplets of the emulsion into a refined emulsion is located between the inlet and the outlet.~~

~~43. A membrane emulsification apparatus according to claim 42 wherein the refiner is an adjustable refiner.~~

~~44. A membrane emulsification apparatus according to claim 42 wherein the refiner is a fixed refiner.~~

~~45. Membrane emulsification apparatus according to any one of the preceding claims wherein the refined emulsion droplets have a CV of from about 5% to about 50.~~

~~46~~16. A method of preparing a refined emulsion, said method comprising using a membrane emulsification apparatus according to any one of the preceding claims.

~~47~~17. A method of preparing a refined emulsion according to claim ~~46~~16 wherein the method comprises providing a first phase to the first volume of the apparatus;

providing a second phase to the second volume of the apparatus;

causing the egression of the first phase into the second phase via a plurality of apertures in a membrane to preparing an emulsion;

passing the emulsion through an inlet of a refiner and converging the flow of the emulsion through an adjustable opening to break up droplets of the emulsion into a refined emulsion.

~~48~~18. A method of preparing a refined emulsion according to claim ~~46~~16 wherein the membrane emulsification apparatus for dispersing a first phase in a second phase, comprises:

a membrane defining a plurality of apertures connecting a first volume on a first side of the membrane to a second volume on a second, different, side of the membrane, the apparatus being arranged to receive a first phase containing a liquid in the first volume and to receive a second phase in the second volume the apparatus being adapted to generate an

emulsion through egression of the first phase into the second phase via the plurality of apertures;

the apparatus also comprising a tunable refiner arranged to receive the emulsion from the membrane; and wherein said refiner comprises an inlet and an outlet wherein an adjustable opening adapted to converge flow of the emulsion and to break up droplets of the emulsion into a refined emulsion is located between the inlet and the outlet.

~~49. A method of preparing a refined emulsion according to any one of claims 46 to 48 wherein the refined emulsion comprises droplets with a diameter of from about 70nm to about 2µm.~~

~~50. A method of preparing a refined emulsion according to claim 49 wherein the refined emulsion comprises droplets with a diameter of from about 70 to about 250nm.~~

~~51. A method of preparing a refined emulsion according to claim 50 wherein from about 80 to about 90% v/v of the refined emulsion droplets may have a diameter of from about 70 to about 250nm.~~

~~52. A method of preparing a refined emulsion according to claim 49 wherein the refined emulsion comprises droplets with a diameter of from about 1 to about 5µm.~~

~~53. A method of preparing a refined emulsion according to claim 52 wherein from about 80 to about 90% v/v of the refined emulsion droplets may have a diameter of from about 1 to about 5µm.~~

~~54~~19. A method of preparing a refined emulsion according to any one of claims ~~46 to 53~~ 16 to 18 wherein the apparatus is arranged to receive a first phase containing a liquid in the first volume and to receive a second phase in the second volume; the apparatus being adapted to generate an emulsion through egression of the first phase into the second phase via the plurality of apertures.

~~55~~20. A method of preparing a refined emulsion according to any one of claims ~~46 to 54~~16 to 19 wherein the apparatus is arranged so that flow of the second phase in the second volume creates a shear field at the area of egression of the first phase, the shear field being in a direction substantially perpendicular to the direction of egression of the first phase.

~~56~~21. A method of preparing a refined emulsion according to any one of claims ~~46 to 55~~16 to 20 wherein the membrane is tubular in shape and comprises a first end and a second end; wherein the first end is for receiving the second phase; and the refiner is coupled to the second end.

~~57. A method of preparing a refined emulsion according to any one of claims 46 to 56 wherein the refiner is tunable by adjustment of the opening.~~

~~58. A method of preparing a refined emulsion according to any one of claims 46 to 57 wherein the adjustable opening in the tunable refiner comprises adjustment means.~~

~~59. A method of preparing a refined emulsion according to any one of claims 46 to 58 wherein the adjustment means in the tunable refiner comprises a differential screw.~~

~~60. A method of preparing a refined emulsion according to claim 59 wherein the differential screw comprises a spindle with two external screw threads of differing thread pitch.~~

~~61. A method of preparing a refined emulsion according to claim 59 wherein the differential screw comprises a spindle with two external screw threads are generally congruous.~~

~~62. A method of preparing a refined emulsion according to claim 59 wherein the differential screw comprises a spindle with two external screw threads of differing handedness.~~

~~63. A method of preparing a refined emulsion according to claim 60 wherein nuts are located around the two external screw threads of the differential screw.~~

~~64. A method of preparing a refined emulsion according to claim 63 wherein the first end of the spindle, adjacent the refiner opening, is smaller than the second end of the spindle, which is distal to the refiner opening.~~

~~65. A method of preparing a refined emulsion according to claim 64 wherein the distal end of the spindle is provided with a first external thread, the diameter of which is wider than that of the end of the spindle adjacent the opening, which is provided with a second external thread.~~

66. A method of preparing a refined emulsion according to any one of claims 46 to 65 wherein the dimensions of opening are from about 70nm to about 2µm.

67. A method of preparing a refined emulsion according to any one of claims 46 to 56 wherein the refiner is a fixed refiner.

68. A method of preparing a refined emulsion according to claim 67 wherein the dimensions of the opening in the fixed refiner may be by changing the dimensions of parts.

69. A method of preparing a refined emulsion according to claim 67 wherein the dimensions of the opening may be adjusted from about 1µm to about 2mm.

70. A method of preparing a refined emulsion according to any one of claims 46 to 69 wherein the refiner is a separate component to the membrane.

71. A method of preparing a refined emulsion according to any one of claims 46 to 69 wherein the refiner is coupled to the membrane.

72. A method of preparing a refined emulsion according to any one of claims 46 to 69 wherein the refiner is integral to the membrane.

73. A method of preparing a refined emulsion according to any one of claims 46 to 72 wherein the adjustable opening comprises a refiner plug adjacent the opening, such that movement of the insert rod closer to the opening reduces the size of the opening.

~~74. A method of preparing a refined emulsion according to any one of claims 46 to 73 wherein the end of the insert rod adjacent to the opening comprises a frusto conical member with a terminal protrusion.~~

~~75. A method of preparing a refined emulsion according to claim 74 wherein the terminal protrusion comprises a flat end surface.~~

~~76. A method of preparing a refined emulsion according to claim 74 wherein the insert rod is adapted to simulate multiple passes of the emulsion through the opening.~~

~~77. A method of preparing a refined emulsion according to claim 76 wherein from 2-5 passes are utilised.~~

~~78. A method of preparing a refined emulsion according to any one of claims 46 to 77 wherein the apparatus is used in a batch mode.~~

~~79~~22. A method of preparing a refined emulsion according to any one of claims ~~46 to 77~~16 to 21 wherein the apparatus is used in a continuous mode.

~~80~~23. A method of preparing a refined emulsion according to claim ~~79~~22 wherein the refiner comprises multiples inlets and/ or multiple outlets.

~~81. A method of preparing a refined emulsion according to claim 76 wherein the insert rod is stepped.~~

~~82. A method of preparing a refined emulsion according to claim 81 wherein the insert rod is stepped and the opposing surface is conical.~~

~~83. A method of preparing a refined emulsion according to claim 75 wherein the opening comprises two cones of different angle, such that the inlet end has equal or larger cross sectional area than the outlet end.~~

~~84. A method of preparing a refined emulsion according to any one of claims 46 to 83 wherein the surfaces are roughened.~~

~~85. A method of preparing a refined emulsion according to any one of claims 46 to 84 wherein the apparatus is provided with a first pump for providing the first phase to the first volume under pressure, and optionally a second pump for providing the second phase to the second volume under pressure.~~

~~86. A method of preparing a refined emulsion according to any one of claims 46 to 85 wherein the apparatus is provided with an emulsion pump, in order to generate high pressure at the opening.~~

~~87. A method of preparing a refined emulsion according to any one of claims 46 to 86 wherein the apparatus comprises a cross-flow assembly.~~

~~88. A method of preparing a refined emulsion according to claim 87 wherein the cross-flow assembly comprises an assembly as described in International patent application No. WO 2019/092461.~~

~~89~~24. A method of preparing a refined emulsion, said method comprising using a membrane emulsification apparatus for dispersing a first phase in a second phase, wherein the membrane emulsification apparatus comprises a cross-flow apparatus for producing an emulsion or dispersion by dispersing a first phase in a second phase; said cross-flow apparatus comprising:

an outer tubular sleeve provided with a first inlet at a first end; an emulsion outlet; and a second inlet, distal from and inclined relative to the first inlet;

a tubular membrane provided with a plurality of pores and adapted to be positioned inside the tubular sleeve; and

optionally an insert adapted to be located inside the tubular membrane, said insert comprising an inlet end and an outlet end, each of the inlet end and an outlet end being provided with chamfered region; the chamfered region is provided with a plurality of orifices and a furcation plate;

the apparatus also comprising a refiner arranged to receive the emulsion from the membrane and wherein said refiner comprises an inlet and an outlet wherein an opening adapted to converge flow of the emulsion and to break up droplets of the emulsion into a refined emulsion is located between the inlet and the outlet.

~~90. A method of preparing a refined emulsion according to claim 89 wherein the refiner is an adjustable refiner.~~

~~91. A method of preparing a refined emulsion according to claim 89 wherein the refiner is a fixed refiner.~~

~~92. A method of preparing a refined emulsion according to any one of claims 46 to 91 wherein the refined emulsion droplets have a CV of from about 5% to about 50.~~

~~93. A method of preparing a refined emulsion according to any one of claims 46 to 92 wherein the refined emulsion droplets are prepared with a single pass of the emulsion through the refiner.~~

~~94. A refined emulsion prepared using a method according to any one of claims 46 to 93.~~

~~95. A membrane emulsification apparatus, method or refined emulsion as herein described with reference to the accompanying description and drawings.~~