

CLAIMS

1. A multiphase microsphere for radioembolization, the multiphase microsphere comprising:
 - a primary phase comprising a first resin; and
 - a first secondary phase surrounded by the primary phase, the first secondary phase comprising a second resin and at least one of a radioactive isotope or a compound including at least one radioactive element.-
2. The multiphase microsphere of claim 1, wherein the first resin is a bioresorbable resin or a biodegradable resin.
3. The multiphase microsphere of claim 1 or claim 2, wherein the first resin is a water-swallowable polymer.
4. The multiphase microsphere of any of the preceding claims, wherein the first resin and the second resin are identical.
5. The multiphase microsphere of any of the preceding claims, wherein the radioactive isotope comprises a beta emitting isotope or a gamma emitting isotope.
6. The multiphase microsphere of any of the preceding claims, wherein the multiphase microsphere further comprises a therapeutic agent.
7. The multiphase microsphere of any of the preceding claims, wherein the primary phase, the secondary phase, or both, further comprises a fluorescent dye.
8. The multiphase microsphere of any of the preceding claims, wherein the first resin is stable to gamma irradiation.
9. The multiphase microsphere of any of the preceding claims, wherein the first resin is impermeable to water.

10. The multiphase microsphere of any of the preceding claims, further comprising a second secondary phase surrounded by the primary phase, the second secondary phase comprising a gas.
11. The multiphase microsphere of claim 10, wherein the gas is air.
12. The multiphase microsphere of claim 10 or 11, wherein the multiphase microsphere is neutrally buoyant in water.
13. The multiphase microsphere of claim 10 or 11, wherein the multiphase microsphere is neutrally buoyant in human blood.
14. A method for forming two-phase microspheres, the method comprising:
 - flowing a first fluid through a first longitudinal conduit toward a first exit opening of the first longitudinal conduit, the first exit opening being in fluidic communication with a first contact zone;
 - flowing a second fluid through a first transverse conduit, the first transverse conduit crossing the first longitudinal conduit at the first contact zone and being in fluidic communication with the first exit opening and with a second exit opening of the first transverse conduit, the second exit opening being in fluidic communication with a second longitudinal conduit, whereby a biphasic stream flows into the second longitudinal conduit toward a third exit opening of the second longitudinal conduit, the third exit opening being in fluidic communication with a second contact zone, the biphasic stream comprising droplets of the first fluid surrounded by a continuous phase of the second fluid;
 - flowing a third fluid through a second transverse conduit, the second transverse conduit crossing the second longitudinal conduit at the second contact zone and being in fluidic communication with the third exit opening and with a fourth exit opening of the second transverse conduit, the fourth exit opening being in fluidic communication with a third longitudinal conduit, whereby a triphasic stream flows into the third longitudinal conduit toward a fifth exit opening of the third longitudinal conduit, the triphasic stream comprising two-phase droplets surrounded by a continuous phase comprising the third fluid, the two-phase

droplets comprising an internal phase comprising the first fluid surrounded by an external phase comprising the second fluid; and
 flowing the two-phase droplets from the fifth exit opening to a curing vessel; and
 curing the two-phase droplets to form two-phase microspheres,

wherein:

the first fluid comprises an uncured first resin and at least one of a radioactive isotope or a compound that can be made radioactive upon neutron irradiation of the compound;

the second fluid comprises an uncured second resin;

the third fluid is immiscible with the second fluid.

15. The method of claim 14, wherein the first resin is a bioresorbable resin or a biodegradable resin.

16. The method of claim 14 or claim 15, wherein the first resin is a water-swelling polymer.

17. The method of any of claims 14 to 16, wherein the first resin and the second resin are identical.

18. The method of any of claims 14 to 17, wherein the radioactive isotope comprises yttrium-90.

19. The method of any of claims 14 to 17, wherein the first fluid comprises the uncured first resin and a compound that can be made radioactive upon neutron irradiation of the compound, the method further comprising neutron irradiating the two-phase microspheres.

20. The method of claim 19, wherein the compound comprises yttrium-89 and the neutron irradiation converts the yttrium-89 to yttrium-90.

21. The method of any of the claims 14 to 20, wherein the first fluid, the second fluid, or both, further comprises a therapeutic agent.

22. The ~~multiphase-microsphere~~method of any of the ~~preceding~~preceding claims 14 to 21, wherein the first fluid, the second fluid, or both, further comprises a fluorescent dye.

23. A method for forming three-phase microspheres, the method comprising:
- flowing a first fluid through a first longitudinal conduit toward a first exit opening of the first longitudinal conduit, the first exit opening being in fluidic communication with a first contact zone;
 - flowing a second fluid through a first transverse conduit, the first transverse conduit crossing the first longitudinal conduit at the first contact zone and being in fluidic communication with the first exit opening and with a second exit opening of the first transverse conduit, the second exit opening being in fluidic communication with a second longitudinal conduit, whereby a biphasic stream flows into the second longitudinal conduit toward a third exit opening of the second longitudinal conduit, the third exit opening being in fluidic communication with a second contact zone, the biphasic stream comprising droplets of the first fluid surrounded by a continuous phase of the second fluid;
 - flowing a third fluid through a second transverse conduit, the second transverse conduit crossing the second longitudinal conduit at the second contact zone and being in fluidic communication with the third exit opening and with a fourth exit opening of the second transverse conduit, the fourth exit opening being in fluidic communication with a third longitudinal conduit, whereby a triphasic stream flows into the third longitudinal conduit toward a fifth exit opening of the third longitudinal conduit, the fifth exit opening being in fluidic communication with a third contact zone, the triphasic stream comprising two-phase droplets surrounded by a continuous phase comprising the third fluid, the two-phase droplets comprising an internal phase comprising the first fluid surrounded by an external phase comprising the second fluid; and
 - flowing a fourth fluid through a third transverse conduit, the third transverse conduit crossing the third longitudinal conduit at the third contact zone and being in fluidic communication with the fifth exit opening and with a sixth exit opening of the third transverse conduit, the sixth exit opening being in fluidic communication with a fourth longitudinal conduit, whereby a tetraphasic stream flows into the fourth longitudinal conduit toward a seventh exit opening of the fourth longitudinal conduit, the tetraphasic stream comprising three-phase droplets surrounded by a continuous phase comprising the fourth fluid, the three-phase droplets comprising a first internal phase comprising the first fluid, a

second internal phase comprising the second fluid, and an external phase comprising the third fluid, the first internal phase and the second internal phase being surrounded by the external phase; and
 flowing the three-phase droplets from the seventh exit opening to a curing vessel; and
 curing the three-phase droplets to form three-phase microspheres,
 wherein:
 the first fluid comprises a gas or an uncured first resin;
 the second fluid comprises an uncured second resin;
 at least one of the first fluid, the second fluid, or both, comprises a radioactive isotope or a compound that can be made radioactive upon neutron irradiation of the compound;
 the third fluid comprises an uncured third resin; and
 the fourth fluid is immiscible with the third fluid.

24. The method of claim 23, wherein the first resin is a bioresorbable resin or a biodegradable resin.
25. The method of claim 23 or claim 24, wherein the first resin is a water-swelling polymer.
26. The method of any of claims 23 to 25, wherein the first uncured resin and the second uncured resin are identical.
27. The method of any of claims 23 to 26, wherein the radioactive isotope wherein the radioactive isotope comprises a beta emitting isotope or a gamma emitting isotope.
28. The method of any of claims 23 to 27, wherein the first fluid comprises the uncured first resin and a compound that can be made radioactive upon neutron irradiation of the compound, the method further comprising neutron irradiating the ~~threetwo~~-phase microspheres.
29. The method of claim 28, wherein the compound comprises yttrium-89 and the neutron irradiation converts the yttrium-89 to yttrium-90.
30. The method of any of ~~the~~ claims 23 to 29, wherein the first fluid, the second fluid, or both, further comprises a therapeutic agent.

31. The method of any of claims 23 to 30, wherein the first fluid, the second fluid, or both, further comprises a fluorescent dye.
32. The method of any of ~~the~~ claims 23 to 30~~31~~, wherein the first fluid is a gas.
33. The ~~multiphase-microspheremethod~~ method of claim 32, wherein the gas is air.