CLAIMS

What is claimed is:

1. A microfluidic diffusion device comprising:

a cylindrical substrate having a central axis and an outer surface;

a patterned membrane rolled circumferentially over the outer surface of the cylindrical substrate to define a plurality of concentric membrane layers extending radially outwardly from the central axis of the cylindrical substrate,

wherein at least one membrane layer of the plurality of concentric membrane layers is patterned to define a plurality of gas flow channels that are configured to receive a gas,

wherein at least one membrane layer of the plurality of concentric membrane layers is patterned to define a plurality of liquid flow channels that are configured to receive a liquid, and

wherein the at least one membrane layer permits diffusion of:

(a) gas from the plurality of gas flow channels into the liquid within the plurality of liquid flow channels; or

(b) liquid from the plurality of liquid flow channels into the gas within the plurality of gas flow channels; or

(c) both (a) and (b).

2. The microfluidic diffusion device of claim 1, wherein the diffusion device is a microfluidic diffusion device, wherein the plurality of gas flow channels are configured to receive a sweep gas, wherein the plurality of liquid flow channels are configured to receive blood, and wherein the at least one membrane layer permits diffusion of the sweep gas from the plurality of gas flow channels into the blood within the plurality of liquid flow channels.

3. The microfluidic diffusion device of claim 2, wherein the patterned membrane comprises a single contiguous sheet of material.

4. The microfluidic diffusion device of claim 3, wherein the patterned membrane comprises a web or film of polydimethylsiloxane (PDMS).

5. The microfluidic diffusion device of claim 3, wherein the patterned membrane has a maximum thickness ranging from 10 μm to 250 μm.

6. The microfluidic diffusion device of claim 5, wherein the plurality of gas flow channels are patterned to have a thickness ranging from 10 μm to 250 μm.

7. The microfluidic diffusion device of claim 5, wherein the plurality of liquid flow channels are patterned to have a thickness ranging from 5 μm to 250 μm.

8. The microfluidic diffusion device of claim 3, wherein the plurality of gas flow channels and the plurality of liquid flow channels are engraved in respective portions of the patterned membrane.

9. The microfluidic diffusion device of claim 1, wherein at least one membrane layer of the plurality of concentric membrane layers does not comprise gas or liquid flow channels.

10. The microfluidic diffusion device of claim 3, wherein the plurality of concentric membrane layers comprise:

a liquid flow layer bonded to the outer surface of the cylindrical substrate and comprising the plurality of liquid flow channels;

a gas flow layer positioned radially outwardly of the liquid flow layer and bonded to the liquid flow layer, wherein the gas flow layer comprises the plurality of gas flow channels; and

a capping layer positioned radially outwardly of the gas flow layer and bonded to the gas flow layer to cap the plurality of gas flow channels,

wherein the capping layer does not comprise gas or liquid flow channels, and wherein portions of the patterned membrane positioned radially between the plurality of gas flow channels and the plurality of liquid flow channels permit diffusion of gas from the plurality of gas flow channels into the plurality of liquid flow channels.

11. The microfluidic diffusion device of claim 10, wherein plurality of gas flow channels and the plurality of liquid flow channels are oriented parallel or substantially parallel to the central axis.

12. The microfluidic diffusion device of claim 3, wherein the plurality of concentric membrane layers comprises:

a plurality of gas flow layers, each gas flow layer comprising a portion of the plurality of gas flow channels; and

a plurality of liquid flow layers, each liquid flow layer comprising a portion of the plurality of liquid flow channels,

wherein the gas flow layers and the liquid flow layers are positioned in an alternating pattern moving radially outwardly from the central axis.

13. The microfluidic diffusion device of claim 12, wherein the plurality of gas flow channels extend circumferentially about the central axis, and wherein the plurality of liquid flow channels are oriented parallel or substantially parallel to the central axis.

14. The microfluidic diffusion device of claim 12, wherein the plurality of liquid flow channels extend circumferentially about the central axis, and wherein the plurality of gas flow channels are oriented parallel or substantially parallel to the central axis.

15. The microfluidic diffusion device of claim 13, further comprising: a gas inlet channel extending radially from an outer surface of the patterned membrane toward the cylindrical substrate, wherein the gas inlet channel is positioned in fluid communication with at least a portion of the plurality of gas flow channels; and

a gas outlet channel extending radially from an outer surface of the patterned membrane toward the cylindrical substrate, wherein the gas outlet channel is positioned in fluid communication with at least a portion of the plurality of gas flow channels.

16. The microfluidic diffusion device of claim 1, further comprising a housing defining a liquid inlet, a liquid outlet, a gas inlet, and a gas outlet, wherein the liquid inlet and the liquid outlet are positioned in fluid communication with at least a portion of the plurality of liquid flow channels, and wherein the gas inlet and the gas outlet are positioned in fluid communication with at least a portion of the plurality of gas flow channels.

17. The microfluidic diffusion device of claim 16, wherein the liquid inlet and the liquid outlet are oriented in substantial alignment with the central axis, and wherein the gas inlet and the gas outlet are oriented perpendicularly or substantially perpendicularly to the central axis.

18. The microfluidic diffusion device of claim 16, wherein the liquid inlet and the liquid outlet are oriented perpendicularly or substantially perpendicularly to the central axis, and wherein the gas inlet and the gas outlet are oriented in substantial alignment with the central axis.

19. A method comprising:

positioning a source of blood in fluid communication with the plurality of liquid flow channels of the microfluidic diffusion device of claim 2;

positioning the plurality of gas flow channels of the diffusion device in fluid communication with a source of gas,

wherein gas from the source of gas diffuses from the plurality of gas flow channels into blood within the plurality of liquid flow channels.

20. The method of claim 19, wherein the source of blood is a patient.

21. The method of claim 20, wherein the source of gas is air surrounding the diffusion device.

22. The method of claim 20, wherein the source of gas is a container filled with oxygen gas.

23. The method of claim 19, further comprising selectively adjusting at least one of a blood flow rate, a gas flow rate, or a composition of the gas provided by the gas source.

24. A method of forming a device comprising:

patterning a membrane to define a plurality of flow channels; and

circumferentially rolling the patterned membrane over an outer surface of a cylindrical substrate to define a plurality of concentric membrane layers extending radially outwardly from a central axis of the cylindrical substrate, thereby forming the device,

wherein each flow channel of the plurality of flow channels is configured to receive and permit flow of a fluid,

wherein at least one membrane layer of the plurality of concentric membrane layers is patterned to define a plurality of gas flow channels that are configured to receive a gas, wherein at least one membrane layer of the plurality of concentric

membrane layers is patterned to define a plurality of liquid flow channels that are configured to receive liquid, and wherein the at least one membrane layer permits diffusion of:

(a) gas from the plurality of gas flow channels into the liquid within the plurality of liquid flow channels; or

(b) liquid from the plurality of liquid flow channels into the gas within the plurality of gas flow channels; or

(c) both (a) and (b).

25. The method of claim 24, wherein the plurality of gas flow channels are configured to receive a sweep gas, wherein the plurality of liquid flow channels are configured to receive blood, and wherein the at least one membrane layer permits diffusion of the sweep gas from the plurality of gas flow channels into the blood within the plurality of liquid flow channels.

26. The method of claim 25, wherein the cylindrical substrate and the plurality of concentric membrane layers cooperate to form an artificial lung device.

27. The method of claim 24, wherein the patterned membrane comprises a single contiguous sheet of material.

28. The method of claim 27, wherein the patterned membrane comprises a web or film of polydimethylsiloxane (PDMS).

29. The method of claim 27, further comprising unrolling the membrane before patterning of the membrane.

30. The method of claim 27, wherein the membrane is patterned using a laser, and wherein the plurality of flow channels extend inwardly from an exposed surface of the membrane that is patterned by the laser.

31. The method of claim 29, wherein, before patterning of the membrane, the membrane is provided on a source roller with a carrier layer, wherein the source roller is rotated to advance the membrane and the carrier layer in a processing direction, wherein an exposed surface of the membrane is patterned as the membrane and the carrier layer are advanced in the processing direction, wherein a first take-up roller receives the patterned membrane, and wherein a second take-up roller receives the carrier layer after patterning of the membrane.

32. The method of claim 31, further comprising, after patterning of the membrane, applying a surface treatment to the exposed surface of the membrane to activate bonding activity of the membrane.

33. The method of claim 32, wherein the surface treatment comprises plasma, ultraviolet, ozone, corona, or chemical treatment, or combinations thereof.

34. The method of claim 27, wherein the patterned membrane has a maximum thickness ranging from 10 μm to 250 μm.

35. The method of claim 34, wherein the plurality of gas flow channels are patterned to have a thickness ranging from 10 μm to 250 μm.

36. The method of claim 34, wherein the plurality of liquid flow channels are patterned to have a thickness ranging from 5 μm to 250 μm.

37. The method of claim 27, wherein the plurality of gas flow channels and the plurality of liquid flow channels are engraved in respective portions of the patterned membrane.

38. The method of claim 27, wherein at least one membrane layer of the plurality of concentric membrane layers does not comprise gas or liquid flow channels.

39. The method of claim 27, wherein the plurality of concentric membrane layers comprise:

a liquid flow layer bonded to the outer surface of the cylindrical substrate and comprising the plurality of liquid flow channels;

a gas flow layer positioned radially outwardly of the liquid flow layer and bonded to the liquid flow layer, wherein the gas flow layer comprises the plurality of gas flow channels; and

a capping layer positioned radially outwardly of the gas flow layer and bonded to the gas flow layer to cap the plurality of gas flow channels,

wherein the capping layer does not comprise gas or liquid flow channels, and wherein portions of the patterned membrane positioned radially between the plurality of gas flow channels and the plurality of liquid flow channels permit diffusion of gas from the plurality of gas flow channels into the plurality of liquid flow channels.

40. The method of claim 39, wherein the plurality of gas flow channels and the plurality of liquid flow channels are oriented parallel or substantially parallel to the central axis.

41. The method of claim 27, wherein the plurality of concentric membrane layers comprises:

a plurality of gas flow layers, each gas flow layer comprising a portion of the plurality of gas flow channels; and

a plurality of liquid flow layers, each liquid flow layer comprising a portion of the plurality of liquid flow channels,

wherein the gas flow layers and the liquid flow layers are positioned in an alternating pattern moving radially outwardly from the central axis.

42. The method of claim 41, wherein the plurality of gas flow channels extend circumferentially about the central axis, and wherein the plurality of liquid flow channels are oriented parallel or substantially parallel to the central axis.

43. The method of claim 41, wherein the plurality of liquid flow channels extend circumferentially about the central axis, and wherein the plurality of gas flow channels are oriented parallel or substantially parallel to the central axis.

44. The method of claim 42, further comprising:

forming a gas inlet channel extending radially from an outer surface of the patterned membrane toward the cylindrical substrate, wherein the gas inlet channel is positioned in fluid communication with at least a portion of the plurality of gas flow channels; and

forming a gas outlet channel extending radially from an outer surface of the patterned membrane toward the cylindrical substrate, wherein the gas outlet channel is positioned in fluid communication with at least a portion of the plurality of gas flow channels.

45. The method of claim 27, further comprising positioning the device within a housing, the housing defining a liquid inlet, a liquid outlet, a gas inlet, and a gas outlet, wherein the liquid inlet and the liquid outlet are positioned in fluid communication with at least a portion of the plurality of liquid flow channels, and wherein the gas inlet and the gas outlet are positioned in fluid communication with at least a portion of the plurality of gas flow channels.

46. The method of claim 45, wherein the liquid inlet and the liquid outlet are oriented in substantial alignment with the central axis, and wherein the gas inlet and the gas outlet are oriented perpendicularly or substantially perpendicularly to the central axis.

47. The method of claim 45, wherein the liquid inlet and the liquid outlet perpendicularly or substantially perpendicularly to the central axis, and wherein the gas inlet and the gas outlet are oriented in substantial alignment with the central axis.