CLAIMS

1. A sensor for determining a flow parameter of a fluid, the sensor comprising:

a polymer membrane;

an elongate microstructure extending from the polymer membrane; and

a hydrogel coupled to at least a portion of the elongate microstructure,

wherein the hydrogel and the elongate microstructure are arranged to cooperate to cause a displacement of the polymer membrane in response to a fluid flowing and interacting with the sensor, and

wherein the sensor is configured to provide a measurement indicative of a flow parameter of the fluid based on the displacement of the polymer membrane.

2. The sensor as claimed in claim 1, wherein the hydrogel at least substantially surrounds the portion of the elongate microstructure.

3. The sensor as claimed in claim 1 or 2, further comprising a plurality of nanofibers at least substantially encapsulated by the hydrogel.

4. The sensor as claimed in claim 3, wherein each nanofiber has a diameter of between about 500 nm and about 1000 nm.

5. The sensor as claimed in claim 3 or 4, wherein each nanofiber comprises caprolactone, or polyvinylidene fluoride, or lead zirconate titanate.

6. The sensor as claimed in any one of claims 1 to 5, further comprising at least one sensing element configured to provide the measurement indicative of the flow parameter of the fluid.

7. The sensor as claimed in claim 6, wherein the at least one sensing element comprises a strain gauge.

8. The sensor as claimed in claim 7, wherein the strain gauge comprises a serpentine shape arranged at least substantially surrounding the elongate microstructure.

9. The sensor as claimed in claim 8, wherein the serpentine shape is defined by a plurality of first elements extending radially from the elongate microstructure, and a plurality of second elements,

wherein a respective second element of the plurality of second elements is arranged in between adjacent first elements of the plurality of first elements.

10. The sensor as claimed in claim 9, wherein each first element has a length that is larger than a length of each second element.

11. The sensor as claimed in claim 9 or 10, wherein each first element has a width that is smaller than a width of each second element.

12. The sensor as claimed in any one of claims 7 to 11, wherein the strain gauge is a single structure.

13. The sensor as claimed in any one of claims 7 to 12, wherein the strain gauge comprises a metal.

14. The sensor as claimed in claim 13, wherein the metal is selected from the group consisting of gold, nickel, nickel-chromium, aluminium and platinum.

15. The sensor as claimed in any one of claims 1 to 14, wherein the elongate microstructure extends at least substantially perpendicular from a surface of the polymer membrane.

16. The sensor as claimed in any one of claims 1 to 15, wherein the elongate microstructure at least substantially contacts the polymer membrane.

17. The sensor as claimed in any one of claims 1 to 16, wherein the hydrogel comprises hyaluronic acid.

18. The sensor as claimed in any one of claims 1 to 17, wherein the elongate microstructure comprises a stereolithographically defined elongate microstructure.

19. The sensor as claimed in any one of claims 1 to 18, wherein the elongate microstructure comprises a polymer.

20. The sensor as claimed in any one of claims 1 to 19, wherein the elongate microstructure has an aspect ratio of between about 6 and about 10.

21. The sensor as claimed in any one of claims 1 to 20, wherein the elongate microstructure has a length of between about 2500 μm and about 4000 μm.

22. The sensor as claimed in any one of claims 1 to 21, wherein the elongate microstructure has a width or diameter of between about 250 μm and about 400 μm.

23. The sensor as claimed in any one of claims 1 to 22, wherein the elongate microstructure has a Young's modulus of between about 2 GPa and about 5 GPa.

24. The sensor as claimed in any one of claims 1 to 23, wherein the polymer membrane has a thickness of between about 10 μm and about 150 μm.

25. The sensor as claimed in any one of claims 1 to 24, wherein the polymer membrane has a Young's modulus of between about 1 GPa and about 3 GPa.

26. The sensor as claimed in any one of claims 1 to 25, wherein the polymer membrane comprises a liquid crystal polymer.

27. The sensor as claimed in any one of claims 1 to 26, further comprising a carrier coupled to the polymer membrane.

28. The sensor as claimed in any one of claims 1 to 27, wherein the fluid is air, and wherein the measurement comprises a voltage change of between about 1.2 mV and about 8 mV for 1 ms^{-1} flow of the air.

29. The sensor as claimed in any one of claims 1 to 28, wherein the fluid is water, and wherein the measurement comprises a voltage change of between about 0.03 V and about 0.12 V for 1 ms^{-1} flow of the water.

30. A method for forming a sensor for determining a flow parameter of a fluid, the method comprising:

providing a polymer membrane;

forming an elongate microstructure extending from the polymer membrane; and

forming a hydrogel coupled to at least a portion of the elongate microstructure,

wherein the hydrogel and the elongate microstructure are arranged to cooperate to cause a displacement of the polymer membrane in response to a fluid flowing and interacting with the sensor, and

wherein the sensor is configured to provide a measurement indicative of a flow parameter of the fluid based on the displacement of the polymer membrane.

31. The method as claimed in claim 30, wherein the hydrogel at least substantially surrounds the portion of the elongate microstructure.

32. The method as claimed in claim 30 or 31, wherein forming a hydrogel comprises:

drop-casting a hydrogel precursor solution onto the elongate microstructure to form a gel-like material on the portion of the elongate microstructure; and

converting the gel-like material into the hydrogel.

33. The method as claimed in claim 32, wherein converting the gel-like material into the hydrogel comprises:

subjecting the gel-like material to an optical stimulus; and

thereafter, wetting the gel-like material to form the hydrogel.

34. The method as claimed in any one of claims 30 to 33, further comprises forming a plurality of nanofibers,

wherein forming a hydrogel comprises forming the hydrogel at least substantially encapsulating the plurality of nanofibers.

35. The method as claimed in claim 34, wherein forming a plurality of nanofibers comprises electrospinning a spinning solution onto the elongate microstructure, the spinning solution comprising a material constituting the plurality of nanofibers.

36. The method as claimed in claim 34 or 35, wherein the plurality of nanofibers form a pyramidal shape extending from a tip of the elongate microstructure towards the polymer membrane.

37. The method as claimed in any one of claims 34 to 36, wherein each nanofiber has a diameter of between about 500 nm and about 1000 nm.

38. The method as claimed in any one of claims 34 to 37, wherein each nanofiber comprises caprolactone, or polyvinylidene fluoride, or lead zirconate titanate.

39. The method as claimed in any one of claims 30 to 38, further comprising forming at least one sensing element configured to provide the measurement indicative of the flow parameter of the fluid.

40. The method as claimed in claim 39, wherein forming at least one sensing element comprises a lithography process.

41. The method as claimed in claim 39 or 40, wherein the at least one sensing element comprises a strain gauge.

42. The method as claimed in claim 41, wherein the strain gauge comprises a serpentine shape arranged at least substantially surrounding the elongate microstructure.

43. The method as claimed in claim 42, wherein the serpentine shape is defined by a plurality of first elements extending radially from the elongate microstructure, and a plurality of second elements,

wherein a respective second element of the plurality of second elements is arranged in between adjacent first elements of the plurality of first elements.

44. The method as claimed in claim 43, wherein each first element has a length that is larger than a length of each second element.

45. The method as claimed in claim 43 or 44, wherein each first element has a width that is smaller than a width of each second element.

46. The method as claimed in any one of claims 41 to 45, wherein the strain gauge is a single structure.

47. The method as claimed in any one of claims 41 to 46, wherein the strain gauge comprises a metal.

48. The method as claimed in claim 47, wherein the metal is selected from the group consisting of gold, nickel, nickel-chromium, aluminium and platinum.

49. The method as claimed in any one of claims 30 to 48, wherein forming an elongate microstructure comprises stereolithographically defining the elongate microstructure.

50. The method as claimed in any one of claims 30 to 49, wherein the elongate microstructure extends at least substantially perpendicular from a surface of the polymer membrane

51. The method as claimed in any one of claims 30 to 50, wherein the elongate microstructure at least substantially contacts the polymer membrane.

52. The sensor as claimed in any one of claims 30 to 51, wherein the hydrogel comprises hyaluronic acid.

53. The method as claimed in any one of claims 30 to 52, wherein the elongate microstructure comprises a polymer.

54. The method as claimed in any one of claims 30 to 53, wherein the elongate microstructure has an aspect ratio of between about 6 and about 10.

55. The method as claimed in any one of claims 30 to 54, wherein the elongate microstructure has a length of between about 2500 μm and about 4000 μm.

56. The method as claimed in any one of claims 30 to 55, wherein the elongate microstructure has a width or diameter of between about 250 μm and about 400 μm.

57. The method as claimed in any one of claims 30 to 56, wherein the elongate microstructure has a Young's modulus of between about 2 GPa and about 5 GPa.

58. The method as claimed in any one of claims 30 to 57, wherein the polymer membrane has a thickness of between about 10 μm and about 150 μm.

59. The method as claimed in any one of claims 30 to 58, wherein the polymer membrane has a Young's modulus of between about 1 GPa and about 3 GPa.

60. The method as claimed in any one of claims 30 to 59, wherein the polymer membrane comprises a liquid crystal polymer.

61. The method as claimed in any one of claims 30 to 60, further comprising coupling a carrier to the polymer membrane.

62. A method of controlling a sensor, the method comprising:

positioning a sensor in a flowing fluid, wherein an elongate microstructure extending from a polymer membrane of the sensor and a hydrogel coupled to at least a portion of the elongate microstructure cooperate to cause a displacement of the polymer membrane in response to the flowing fluid interacting with the sensor; and

providing a measurement indicative of a flow parameter of the flowing fluid based on the displacement of the polymer membrane.

63. The method as claimed in claim 62, wherein the measurement comprises a change in a resistance associated with the sensor.

64. The method as claimed in claim 62 or 63, wherein the flow parameter comprises a flow velocity of the flowing fluid.

CLAIMS

1. A sensor for determining a flow parameter of a fluid, the sensor comprising:

a polymer membrane;

an elongate microstructure extending at least substantially perpendicularly from a surface of the polymer membrane; and

a strain gauge formed on the polymer membrane;

wherein the elongate microstructure is arranged to cause a displacement of the polymer membrane in response to a fluid flowing and interacting with the sensor, and

wherein the strain gauge is configured to provide a measurement indicative of a flow parameter of the fluid based on the displacement of the polymer membrane.

2. The sensor as claimed in claim 1, wherein the strain gauge is formed on the surface of the polymer membrane.

3. The sensor as claimed in claim 1 or 2, wherein the strain gauge comprises a serpentine shape and is arranged at least substantially surrounding the elongate microstructure.

4. The sensor as claimed in claim 3, wherein the serpentine shape is defined by a plurality of first elements extending radially from the elongate microstructure, and a plurality of second elements arranged circumferentially around the elongate microstructure,

wherein each respective second element of the plurality of second elements is arranged in between respective adjacent first elements of the plurality of first elements and connects the respective adjacent first elements.

5. The sensor as claimed in claim 4, wherein each first element has a radial length that is larger than a circumferential length of each second element.

6. The sensor as claimed in claim 4 or 5, wherein each first element has a width that is smaller than a width of each second element.

7. The sensor as claimed in any one of claims 1 to 6, wherein the elongate microstructure has a length of between about 2500 μm and about 4000 μm.

8. The sensor as claimed in any one of claims 1 to 7, wherein the elongate microstructure has an aspect ratio of between about 6 and about 10.

9. The sensor as claimed in any one of claims 1 to 8, wherein the elongate microstructure comprises a stereolithographically defined elongate microstructure.

10. The sensor as claimed in any one of claims 1 to 9, wherein the elongate microstructure comprises a polymer.

11. The sensor as claimed in any one of claims 1 to 10, wherein the elongate microstructure has a cylindrical structure.

12. The sensor as claimed in any one of claims 1 to 11, wherein the polymer membrane comprises a liquid crystal polymer.

13. The sensor as claimed in claim 12, wherein the liquid crystal polymer has a circular shape.

14. The sensor as claimed in any one of claims 1 to 13, further comprising a hydrogel coupled to at least a portion of the elongate microstructure, the portion being an end of the elongate microstructure distal to the polymer membrane.

15. The sensor as claimed in claim 14, further comprising a plurality of nanofibers at least substantially encapsulated by the hydrogel.

16. The sensor as claimed in claim 15, wherein each nanofiber has a diameter of between about 500 nm and about 1000 nm.

17. A method for forming a sensor for determining a flow parameter of a fluid, the method comprising:

providing a polymer membrane;

forming an elongate microstructure extending at least substantially perpendicularly from a surface of the polymer membrane;

forming a strain gauge on the polymer membrane;

wherein the elongate microstructure is arranged to cause a displacement of the polymer membrane in response to a fluid flowing and interacting with the sensor, and

wherein the strain gauge is configured to provide a measurement indicative of a flow parameter of the fluid based on the displacement of the polymer membrane.

18. The method as claimed in claim 17, wherein forming an elongate microstructure comprises stereolithographically defining the elongate microstructure.

19. The method as claimed in claim 17 or 18, further comprising forming a hydrogel coupled to at least a portion of the elongate microstructure, the portion being an end of the elongate microstructure distal to the polymer membrane.

20. The method as claimed in claim 19, further comprises forming a plurality of nanofibers,

wherein forming a hydrogel comprises forming the hydrogel at least substantially encapsulating the plurality of nanofibers.