CLAIMS

WHAT IS CLAIMED IS:

1. A process of producing one or more nanofiber, the process comprising electrospinning a fluid stock, the fluid stock comprising metal precursor(s) and polymer, and

    a. the weight to weight ratio of the precursor(s) to polymer being at least 1:2;

    b. the fluid stock being aqueous;

    c. the precursor(s) being present in the fluid stock in a concentration of at least 200 mM; or

    d. any combination thereof.

2. The process of claim 1, wherein the fluid stock is (1) a solution; (2) a substantially uniform dispersion; or (3) a substantially homogenous dispersion.

3. The process of any one of the preceding claims, wherein the weight-to-weight ratio of the precursor(s) to polymer in the fluid stock is at least 1:2 and the fluid stock is aqueous.

4. The process of any one of the preceding claims, wherein the weight-to-weight ratio of the precursor(s) to polymer is at least 1:1.

5. The process of any one of the preceding claims, wherein the fluid stock is prepared by combining reagent precursor(s), reagent polymer(s) and water to form the fluid stock comprising the precursor(s) and the polymer, and wherein the reagent precursor(s) and reagent polymer(s) are combined in a weight to weight ratio of over 1:2.

6. The process of claim 4, wherein the reagent precursor(s) and reagent polymer(s) are combined the in a weight-to-weight ratio of at least 1:1.

7. The process of any one of the preceding claims, wherein one or more of the precursor(s) are present in the fluid stock in a polymer-precursor association.

8. The process of claim 6, wherein at least 25% of the polymer is saturated with precursor molecules.

9. The process of either of claims 6 or 7, wherein at least 25% of the precursor molecules are associated with polymer.

10. The process of any one of the preceding claims, wherein the precursor(s) is present in the fluid stock in a concentration of at least 200 mM.

11. The process of any one of the preceding claims, wherein the precursor(s) concentration in the fluid stock is at least 250 mM.

12. The process of claim 8, wherein the precursor(s) concentration in the fluid stock is at least 300 mM.

13. The process of any one of the preceding claims, wherein the metal precursor(s) comprises one or more metal-ligand complex.

14. The process of claim 11, wherein the metal precursor comprises a metal-ligand complex, the metal-ligand complex being in association with the polymer.

15. The process of any one of the preceding claims, wherein the metal precursor comprises metal selected from the group consisting of: Ag, Cu, Ni, Fe, Co, Pb, Au, Sn, Al, Zr, Li, Mn, Cr, Be, Cd, Si, Ti, V, Hf, Sr, Ba, Ge, and combinations thereof.

16. The process of any one of the preceding claims, wherein the metal precursor comprises a transition metal.

17. The process of any one of the preceding claims, wherein the metal precursor comprises a metalloid.

18. The process of any one of the preceding claims, wherein the metal precursor is a metal-ligand complex comprising one or more ligand selected from the group consisting of: a carboxylate, a nitrate, a halide, a diketone, an alkoxide, and combinations thereof.

19. The process of any one of the preceding claims, wherein the reagent precursor, the precursor of the fluid stock, or both comprise one or more metal acetate, metal nitrate, metal chloride, metal methoxide, or a combination thereof.

20. The process of any one of the preceding claims, wherein the polymer is polyvinyl alcohol (PVA), polyvinyl acetate (PVAc), polyethylene oxide (PEO), polyvinyl ether, polyvinyl pyrrolidone, polyglycolic acid, hydroxyethylcellulose (HEC), ethylcellulose, cellulose ethers, polyacrylic acid, polyisocyanate, or a combination thereof.

21. The process of any one of the preceding claims, wherein the polymer is (i) hydrophilic, and (ii) water soluble or water swellable.

22. The process of any of the preceding claims, wherein the polymer is thermally and/or chemically degradable.

23. The process of any one of the preceding claims, wherein the polymer is a polymer comprising a plurality of nucleophilic moieties and the reagent precursor is electrophilic.

24. The process of any one of the preceding claims, wherein the polymer is a polymer comprising a plurality of electrophilic moieties and the reagent precursor is nucleophilic.

25. The process of any one of the preceding claims, wherein electrospinning the fluid stock results in the formation of electrospun nanofiber material comprising metal precursor and polymer.

26. The process of any one of the preceding claims, further comprising calcining the electrospun material to prepare a calcinated nanofiber.

27. The process of claim 26, wherein the calcining of the electrospun material comprises thermally treating the electrospun material, chemically treating the electrospun material, or both.

28. The process of any of the preceding claims, comprising removing (e.g., by calcination) polymer from the electrospun material.

29. The process of any one of claims 26-28, wherein calcining the electrospun material converts metal precursor to metal.

30. The process of any one of claims 26-28, wherein calcining the electrospun material converts metal precursor to metal oxide.

31. The process of any one of claims 26-28, wherein calcining the electrospun material converts metal precursor to ceramic.

32. The process of any one of claims 26-28, wherein calcining the electrospun material converts a first metal precursor to ceramic and a second metal precursor to metal.

33. The process of any one of claims 26-28, comprising calcining the electrospun material under oxidative conditions, thereby converting metal precursor to metal oxide (e.g., ceramic metal oxide)

34. The process of any one of claims 26-28, comprising electrospun material the nanofiber under inert or reducing conditions, thereby converting metal precursor to metal.

35. The process of any one of the preceding claims, wherein calcining the electrospun material comprises heating the electrospun material to a temperature of at least 400 °C.

36. The process of any one of the preceding claims, wherein the fluid stock is co-axially electrospun with a second fluid.

37. The process of claim 36, wherein the second fluid is a gas (e.g., air).

38. The process of claim 36, wherein the second fluid is a second fluid stock comprising a second metal precursor and a second polymer, wherein the metal precursor and second metal precursor are the same or different and the polymer and second polymer are the same or different, and wherein the process produces a layered nanofiber.

39. An electrospun nanofiber comprising metal precursor and polymer, the metal precursor and polymer being present in a weight-to-weight ratio of at least 1:2 (e.g., at least 1:1).

40. The electrospun nanofiber of claim 39, prepared according to a process of any one of claims 1-24.

41. The electrospun nanofiber of either one of claims 39 or 40, wherein the electrospun nanofiber comprises at least 90% by weight of organic polymer and metal precursor.

42. The electrospun nanofiber of any one of claims 39-41, wherein the electrospun nanofiber comprises at least 10 elemental wt. % metal.

43. A plurality of nanofibers comprising metal, metal oxide, ceramic, or a combination thereof, and:

    a. the nanofibers are at least 1 μm long on average;

    b. the nanofibers have an average aspect ratio of at least about 5;

    c. the nanofibers comprise a continuous matrix of a metal, a metal oxide, ceramic, or a combination thereof;

d. the nanofibers have an average specific surface area between 1 m^2/g and about 1000 m^2/g; or

e. a combination thereof.

44. The nanofibers of claim 43, wherein the nanofibers comprise a continuous matrix of a metal, a metal oxide, ceramic, or a combination thereof.

45. The nanofibers of either one of claims 43 or 44, wherein the nanofibers comprise at least 33% (w/w) of a metal, a metal oxide, a ceramic, or, taken together, a combination thereof.

46. The nanofibers of any one of claims 43-45, wherein the nanofibers are metal nanofibers comprising at least 90 elemental wt. % of metal.

47. The nanofibers of any one of claims 43-45, wherein the nanofibers are metal oxide nanofibers comprising at least 90% metal oxide and at least 30 elemental wt. % of metal.

48. The nanofibers of any one of claims 43-45, wherein the nanofibers are ceramic nanofibers comprising at least 90% ceramic and at least 30 elemental wt. % of metal.

49. The nanofibers of any one of claims 43-45, wherein the nanofibers are metal alloy nanofibers comprising at least 90% metal alloy and at least 30 elemental wt. % of metal.

50. The nanofibers of any one of claims 43-45, wherein the nanofibers are composite nanofibers comprising a first material and a second material, the first material being a continuous matrix material, and one or both of the first material or second material comprising metal, metal oxide, ceramic, or a combination thereof.

51. The nanofibers of claim 50, wherein the second material is a second continuous matrix material (e.g., the first and second continuous matrix materials are coaxial layers).

52. The nanofibers of claim 50, wherein the second material comprises isolated domains of the nanofibers.

53. The nanofibers of any one of claims 50-52, wherein one or both of the first or second materials comprises metal and the nanofibers comprising an average of at least 20 elemental wt. % of metal.

54. The nanofibers of any one of claims 50-53, wherein the first material is ceramic and the second material is metal.

55. The nanofibers of any one of claims 50-53, wherein the first material is metal and the second material is metal.

56. The nanofibers of any one of claims 50-53, wherein the first material is ceramic and the second material is ceramic.

57. The nanofibers of any one of claims 50-56, wherein the nanofiber comprises an average of at least 30 elemental wt. % of metal.

58. The nanofibers of claim 57, wherein the nanofibers comprises an average of at least 50 elemental wt. % of metal.

59. The nanofibers of any one of claims 43-58, wherein the metal is selected from the group consisting of Ag, Cu, Ni, Fe, Co, Pb, Au, Sn, Al, and combinations thereof.

60. The nanofibers of any one of claims 43-59, wherein the ceramic or metal oxide is selected from the group consisting of Al_2O_3, ZrO_2, Fe_2O_3, CuO, NiO, ZnO, CdO, C, Ge, Si, SiO_2, TiO_2, V_2O_5, VO_2, Fe_3O_4, SnO, SnO_2, CoO, CoO_2, Co_3O_4, HfO_2, $BaTiO_3$, $SrTiO_3$, and $BaSrTiO_3$.

61. The nanofibers of any one of claims 43-60, wherein the nanofibers comprise a metal-non-metal alloy.

62. The nanofibers of any of claims 43-61, wherein the nanofibers comprise a conductive material, wherein the nanofibers have an conductivity of at least about 10% when compared with the conductivity of the conductive material when formed into a sheet.

63. The nanofibers of any one of claims 43-62, wherein the nanofibers comprise a continuous matrix of amorphous ceramic and comprise an average ultimate strength-to-diameter ratio of at least 0.075 MPa/nm; an average Young's modulus-to-diameter ratio of at least 0.15 GPa/nm; and an average fracture toughness of at least 0.6 MPA $MPa \cdot m^{1/2}$.

64. The nanofibers of any one of claims 43-62, wherein the nanofibers comprise a continuous matrix of amorphous ceramic and comprise an average ultimate strength-to-diameter ratio of at least 0.15 MPa/nm; an average Young's modulus-to-diameter ratio of at least 0.3 GPa/nm; and an average fracture toughness of at least 0.7 $MPa \cdot m^{1/2}$.

65. The nanofibers of any one of claims 43-62, wherein the nanofibers comprise a continuous matrix of crystalline ceramic and comprise an average ultimate strength-to-diameter ratio of at least 5 MPa/nm; and an average Young's modulus-to-diameter ratio of at least 1.5 GPa/nm.

66. The nanofibers of any one of claims 43-62, wherein the nanofibers comprise a continuous matrix of crystalline ceramic and comprise an average ultimate strength-to-diameter ratio of at least 12.5 MPa/nm and an average Young's modulus-to-diameter ratio of at least 4 GPa/nm.

67. The nanofibers of either one of claims 65 or 66, wherein the nanofibers have an average fracture toughness of at least 1.8 $MPa \cdot m^{1/2}$.

68. The nanofibers of any one of claims 43-62, wherein the nanofibers comprise a continuous matrix of metal and have an average ultimate strength-to-diameter ratio of at least 0.35 MPa/nm and an average Young's modulus-to-diameter ratio of at least 1.1 GPa/nm.

69. The nanofibers of any one of claims 43-62, wherein the nanofibers comprise a continuous matrix of metal and have an average ultimate strength-to-diameter ratio of at least 0.9 MPa/nm and an average Young's modulus-to-diameter ratio of at least 2.9 GPa/nm.

70. The nanofibers of either one of claims 68 or 69, wherein the nanofibers have an average fracture toughness of at least 3.5 $MPa \cdot m^{1/2}$.

71. The nanofibers of any one of claims 68-70, wherein the nanofibers have a log(S/m) to log(S/m) ratio with an identical bulk material of at least 0.9.

72. The nanofibers of any one of claims 43-71, wherein the nanofibers have an average length of at least 1 microns.

73. The nanofibers of any one of claims 43-72, wherein the nanofibers have an average diameter of 1000 nm or less.

74. The nanofibers of any one of claims 43-72, wherein the nanofibers have an average aspect ratio of at least 5.

75. The nanofibers of claim 74, wherein the nanofibers have an average aspect ratio of at least 1000.

76. The nanofibers of any one of claims 43-75, wherein the nanofibers comprise an average of less than 5% carbon by elemental mass.

77. The process of any of claims 1-42, wherein a nanofiber of any of claims 43-76 is produced.

78. The nanofiber of any of claims 43-76 for use in a sensor, a battery, a fuel cell, a solar cell, ultracapacitor, catalyst, membrane, or electrode.

79. An aqueous fluid composition comprising (a) a polymer, and (b) a metal precursor; the fluid composition being (i) a solution, (ii) a composition comprising a substantially uniform dispersion of metal precursor, or (c) a composition comprising a substantially homogeneous dispersion of metal precursor; and (1) the weight to weight ratio of the precursor to polymer being at least 1:2 (e.g., at least 1:1), or (2) the concentration of precursor being at least 200 mM (e.g., at least 250 mM).

CLAIMS

WHAT IS CLAIMED IS:

1. A process for producing one or more nanofiber, the process comprising electrospinning a fluid stock, the fluid stock comprising metal precursor(s) and polymer, the weight to weight ratio of the precursor(s) to polymer being at least 1:2; and the fluid stock being aqueous.

2. The process of claim 1, wherein the fluid stock is co-axially electrospun with a gas.

3. The process of claim 2, wherein the gas is a high-speed gas.

4. The process of claim 3, wherein the high speed gas is high speed air having a velocity of about 100 m/s.

5. The process of any one of the preceding claims, wherein the weight-to-weight ratio of the precursor(s) to polymer is at least 1:1.

6. The process of claim 5, wherein the weight-to-weight ratio of the precursor(s) to polymer is at least 1.5:1.

7. The process of claim 5, wherein the weight-to-weight ratio of the precursor(s) to polymer is at least 2:1.

8. The process of any one of the preceding claims, wherein one or more of the precursor(s) are present in the fluid stock in a polymer-precursor association.

9. The process of claim 8, wherein at least 25% of the polymer is saturated with precursor molecules.

10. The process of any one of the preceding claims, wherein the precursor(s) is present in the fluid stock in a concentration of at least 200 mM.

11. The process of any one of the preceding claims, wherein the precursor(s) is present in the fluid stock in a concentration of at least 250 mM.

12. The process of any one of the preceding claims, wherein the precursor(s) is present in the fluid stock in a concentration of at least 300 mM.

13. The process of any one of the preceding claims, wherein the metal precursor comprises Ag, Cu, Ni, Fe, Co, Pb, Au, Sn, Al, Zr, Li, Mn, Cr, Be, Cd, Si, Ti, V, Hf, Sr, Ba, Ge, or combinations thereof.

14. The process of any one of the preceding claims, wherein the metal precursor comprises one or more metal acetate, metal nitrate, metal chloride, metal methoxide, or a combination thereof.

15. The process of any one of the preceding claims, wherein the polymer is polyvinyl alcohol (PVA), polyvinyl acetate (PVAc), polyethylene oxide (PEO), polyvinyl ether, polyvinyl pyrrolidone, polyglycolic acid, hydroxyethylcellulose (HEC), ethylcellulose, cellulose ethers, polyacrylic acid, polyisocyanate, or a combination thereof.

16. The process of any one of the preceding claims, wherein the metal precursor comprises metal acetate and the polymer comprises polyvinyl alcohol (PVA).

17. The process of any one of the preceding claims, further comprising calcining the electrospun material to prepare a calcinated nanofiber.

18. The process of claim 17, wherein the calcining of the electrospun material comprises thermally treating the electrospun material, chemically treating the electrospun material, or both.

19. The process of claim 18, wherein thermally treating the electrospun material comprises heating the electrospun material to at least 400 °C.

20. The process of claim 18, wherein chemically treating the electrospun material comprises treating the electrospun material with oxygen.

21. The process of claim 18, wherein calcining the electrospun material comprises heating the electrospun material to at least 400 °C and treating the electrospun material with oxygen.

22. The process of any one of claims 18-21, wherein calcining the electrospun material comprises removing polymer from the electrospun material and converting metal precursor to metal, metal oxide, and/or ceramic.

23. A nanofiber prepared according to a process of any one of claims 1-17 and comprising a continuous matrix of metal, metal alloy, metal oxide, or ceramic.

24. A nanofiber prepared according to a process of any one of claims 1-11 and comprising metal precursor(s) and polymer.

25. A nanofiber comprising metal precursor(s) and polymer, the weight to weight ratio of the precursor(s) to polymer being at least 1.5:1.