CLAIMS

1. A particulate material consisting of a plurality of composite particles, wherein the composite particles comprise:

(a) a porous particle framework comprising micropores and/or mesopores, wherein the total pore volume of micropores and mesopores as measured by gas adsorption is in the range from 0.4 to 2.2 cm^3/g;

(b) a plurality of electroactive material domains and a plurality of modifier material domains disposed within the internal pore volume of the porous particle framework, wherein at least a portion of the modifier material domains are located between adjacent electroactive material domains.

2. A particulate material according to claim 1, wherein the total pore volume of micropores and mesopores in the porous particle framework is in the range from 0.45 to 2.2 cm^3/g, or from 0.5 to 2 cm^3/g, or from 0.55 to 2 cm^3/g, or from 0.6 to 1.8 cm^3/g, or from 0.65 to 1.8 cm^3/g, or from 0.7 to 1.6 cm^3/g, or from 0.7 to 1.5 cm^3/g, or from 0.7 to 1.4 cm^3/g.

3. A particulate material according to claim 1 or claim 2, wherein the PD_{50} pore diameter of the porous particle framework is no more than 30nm, or no more than 25 nm, or no more than 20 nm, or no more than 15 nm, or no more than 12 nm, or no more than 10 nm, or no more than 8 nm, or no more than 6 nm, or no more than 5 nm, or no more than 4 nm, or no more than 3 nm, or no more than 2.5 nm, or no more than 2 nm, or no more than 1.5 nm, and/or

wherein the PD_{30} pore diameter of the porous particle framework is no more than 25 nm, or no more than 20 nm, or no more than 15 nm, or no more than 12 nm, or no more than 10 nm, or no more than 8 nm, or no more than 6 nm, or no more than 5 nm, or no more than 4 nm, or no more than 3 nm, or no more than 2.5 nm, or no more than 2 nm, or no more than 1 nm.

4. A particulate material according to any preceding claim, wherein the porous particle framework has a BET surface area in the range from 100 m^2/g to 4,000 m^2/g, or from 500 m^2/g to 4,000 m^2/g, or from 750 m^2/g to 3,500 m^2/g, or from 1,000 m^2/g to 3,250 m^2/g, or from 1,000 m^2/g to 3,000 m^2/g, or from 1,000 m^2/g to 2,500 m^2/g, or from 1,000 m^2/g to 2,000 m^2/g.

5. A particulate material according to any preceding claim, wherein the porous particle framework is a conductive porous particle framework, preferably wherein the conductive

porous particle framework is a conductive porous carbon particle framework, more preferably wherein the conductive porous carbon particle framework comprises at least 80 wt% carbon, or at least 85 wt% carbon, or at least 90 wt% carbon, or at least 95 wt% carbon.

6. A particulate material according to any preceding claim, wherein the porous particle framework has a volumetric ratio of micropores to mesopores of from 90:10 to 30:70, or from 85:15 to 40:60, or from 80:20 to 50:50, or from 70:30 to 55:45.

7. A particulate material according to any preceding claim, wherein the PD_{10} pore diameter of the porous particle framework is no more than 10 nm, or no more than 9 nm, or no more than 8 nm, or no more than 7 nm, or no more than 6 nm, or no more than 5 nm, or no more than 4 nm, or no more than 3 nm, or no more than 2.5 nm, or no more than 2 nm, or no more than 1.5 nm, or no more than 1 nm, and/or

wherein the PD_{90} pore diameter of the porous particle framework is no more than 35 nm, or no more than 30 nm, or no more than 25 nm, or no more than 20 nm, or no more than 15 nm, or no more than 12 nm, or no more than 10 nm, or no more than 8 nm, or no more than 6 nm, or no more than 5 nm, or no more than 4 nm, or no more than 3 nm, or no more than 2.5 nm, or no more than 2 nm.

8. A particulate material according to any preceding claim, wherein each of the electroactive material domains comprises an electroactive material independently selected from silicon, tin, germanium, aluminium, and mixtures and alloys thereof, and/or

wherein at least a portion of the electroactive material domains comprise or consist of silicon, or wherein all of the electroactive material domains comprise or consist of silicon.

9. A particulate material according to any preceding claim, wherein the modifier material comprises one or more of carbon, nitrogen, and oxygen.

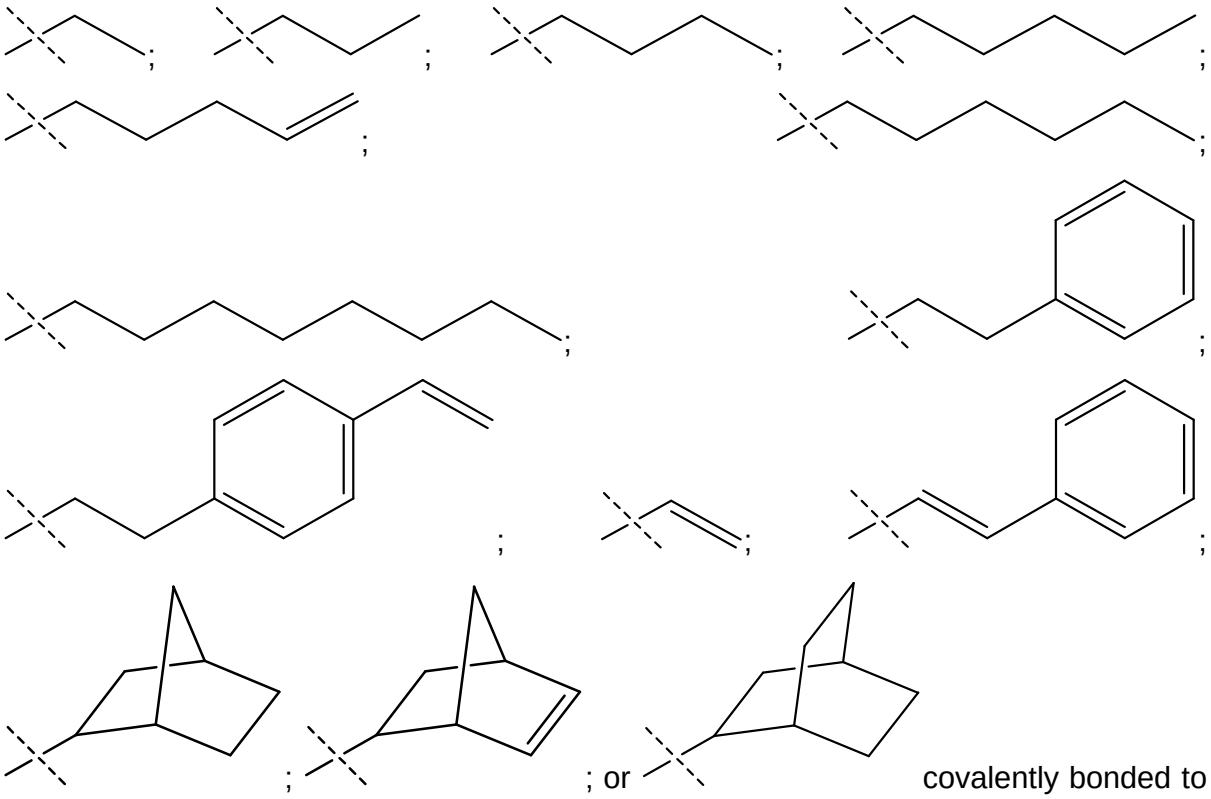
10. A particulate material according to any preceding claim, wherein the modifier material is an oxide, nitride, oxynitride or carbide passivation layer formed on the surface of at least a portion of the electroactive material domains, preferably wherein the modifier material is an oxide selected from SiO_x, wherein $0 < x \leq 2$ or a nitride selected from SiN_x, wherein $0 < x \leq 4/3$, or a carbide selected from SiC_x, wherein $0 < x \leq 1$, more preferably wherein the modifier material is a nitride passivation layer formed on the surface of at least a portion of the electroactive material domains optionally having the formula SiNx, wherein $0 < x \leq 4/3$.

11. A particulate material according to any one of claims 1 to 9, wherein the modifier material is a passivation layer comprising a carbon-containing organic moiety covalently bonded to the surface of at least a portion of the electroactive material domains, or

wherein the modifier material comprises a C_{2-22} hydrocarbyl covalently bonded to the surface of at least a portion of the electroactive material domains, or

wherein the modifier material comprises a C_{2-22} alkyl, C_{2-22} alkenyl, C_{2-22} alkynyl, C_{3-22} cycloalkyl, C_{3-22} cycloalkenyl C_{3-22} cycloalkynyl or C_{6-22} aralkyl covalently bonded to the surface of at least a portion of the electroactive material domains, or

wherein the modifier material is selected from the group consisting of:


; ; ; ; ; ; ; ; ; ; ; ; ; ; or

covalently bonded to the surface of at least a portion of the electroactive material domains, or

wherein the modifier material comprises a pyrolytic carbon material.

12. A particulate material according to any of claims 1 to 8, wherein the modifier material comprises a conductive metal or metal alloy, or

wherein the modifier material comprises an electroactive material comprising a dopant selected from boron and phosphorus.

13. A particulate material according to any preceding claim, further comprising outer modifier material domains located between the outermost electroactive material domains and the exterior of the composite particles, optionally wherein the modifier material is selected from the modifier materials described in any of claims 9 to 12.

14. A particulate material according to any preceding claim, wherein the composite particles comprise from 5 to 85 wt%, or from 10 to 85 wt%, or from 15 to 85 wt%, or from 20 to 80 wt%, or from 25 to 80 wt%, or from 30 to 75 wt%, or from 35 to 75 wt%, or from 40 to 70 wt%, or from 45 to 65 wt% of the electroactive material based on the total mass of the composite particles, and or

wherein the composite particles comprise from 40 to 70 wt%, or from 45 to 70 wt%, or from 48 to 70 wt%, or from 50 to 70 wt%, or from 40 to 65 wt%, or from 45 to 65 wt%, or from 48 to 65 wt%, or from 50 to 65 wt%, or from 40 to 60 wt%, or from 45 to 60 wt%, or from 48 to 60 wt%, or from 50 to 60 wt% of the electroactive material based on the total mass of the composite particles.

15. A particulate material according to any preceding claim, wherein the composite particles comprise from 10 to 85 wt%, or from 15 to 85 wt%, or from 20 to 80 wt%, or from 25 to 80 wt%, or from 30 to 75 wt%, or from 35 to 75 wt%, or from 40 to 70 wt%, or from 45 to 65 wt% of silicon based on the total mass of the composite particles, and/or

wherein the composite particles comprise from 40 to 70 wt%, or from 45 to 70 wt%, or from 48 to 70 wt%, or from 50 to 70 wt%, or from 40 to 65 wt%, or from 45 to 65 wt%, or from 48 to 65 wt%, or from 50 to 65 wt%, or from 40 to 60 wt%, or from 45 to 60 wt%, or from 48 to 60 wt%, or from 50 to 60 wt% of silicon based on the total mass of the composite particles.

16. A particulate material according to any preceding claim, wherein the amount of electroactive material occupies at least 25% and up to 90% of the internal pore volume of the porous particle framework, and/or

wherein at least 85 wt%, more preferably at least 90 wt%, more preferably at least 95 wt%, more preferably at least 98 wt% of the electroactive material mass in the composite particles is located within the internal pore volume of the porous particle framework.

17. A particulate material according to any preceding claim, wherein the composite particles have a D_{50} particle diameter in the range from 0.5 to 30 µm, or from 1 to 25 µm, or

from 1 to 20 µm, or from 1 to 18 µm, or from 1 to 16 µm, or from 2 to 16 µm, or from 2 to 14 µm, or from 2 to 12 µm, or from 2 to 10 µm, or from 2 to 8 µm, and/or

wherein the composite particles have a BET surface area in the range from 0.1 to 100 m^2/g, or from 0.1 to 80 m^2/g, or from 0.5 to 60 m^2/g, or from 0.5 to 40 m^2/g, or from 1 to 30 m^2/g, or from 1 to 25 m^2/g, or from 2 to 20 m^2/g.

18. A particulate material according to any preceding claim, wherein the composite particles comprise a total oxygen content of less than 15 wt%, or less than 10 wt%, or less than 5 wt%, or less than 4 wt%, or less than 3 wt%, or less than 2 wt%, or less than 1 wt%, or less than 0.5 wt% based on the total mass of the composite particles, and/or

wherein the composite particles comprise a total chlorine content of less than 100 ppm, or less than 90 ppm, or less than 80 ppm, or less than 70 ppm based on the total mass of the composite particles.

19. A particulate material according to any preceding claim, wherein the composite particles comprise a total content of transition metals and alkali metals of less than 0.5 wt% based on the total weight of the composite particle, and/or

wherein the composite particles comprise from 0.0001 to 0.5 wt% of zirconium based on the total weight of the composite particle.

20. A particulate material according to any preceding claim, wherein the composite particles have a D_{10} particle diameter of at least 0.5 µm, or at least 0.8 µm, or at least 1 µm, and/or

wherein the composite particles have a D_{90} particle diameter of no more than 50 µm, or no more than 40 µm, or no more than 30 µm, or no more than 25 µm, or no more than 20 µm, or no more than 15 µm.

21. A particulate material according to any preceding claim, wherein the composite particles have a particle size distribution span $(D_{90}-D_{10})/D_{50}$ of 5 or less, or 4 or less, or 3 or less, or 2 or less, or 1.5 or less, and/or

wherein the composite particles have a total volume of micropores and mesopores of no more than 0.35 cm^3/g, or no more than 0.25 cm^3/g, or no more than 0.15 cm^3/g, or no more than 0.1 cm^3/g, or no more than 0.05 cm^3/g, or no more than 0.03 cm^3/g, or no more than 0.02 cm^3/g.

22. A particulate material according to any preceding claim, wherein the electroactive material is silicon and no more than 10 wt%, or no more than 8 wt%, or no more than 6 wt%, or no more than 5 wt%, or no more than 4 wt%, or no more than 3 wt%, or no more than 2 wt%, or no more than 1.5 wt% of the silicon is coarse bulk silicon as determined by thermogravimetric analysis.

23. A particulate material according to any preceding claim, wherein the electroactive material is silicon and at least 20 wt%, or at least 22 wt%, or at least 25 wt%, or at least 30 wt%, or at least 35 wt%, or at least 40 wt%, or at least 45 wt% of the silicon is surface silicon as determined by thermogravimetric analysis.

24. A process for preparing composite particles, the process comprising the steps of:

(a) providing a plurality of porous particles comprising micropores and/or mesopores, wherein the total pore volume of micropores and mesopores as measured by gas adsorption is in the range from 0.4 to 2.2 cm^3/g;

(b) contacting the porous particles with a precursor of an electroactive material at a temperature effective to cause deposition of a plurality of electroactive material domains in the pores of the porous particles;

(c) forming a plurality of modifier material domains in the pores of the porous particles and adjacent to the electroactive material domains deposited in step (b).

(d) contacting the particles from step (c) with a precursor of an electroactive material at a temperature effective to cause deposition of further electroactive material domains in the pores of the porous particles and adjacent to the modifier material domains formed in step (c).

25. A process according to claim 24, wherein the porous particles have any of the features described for the porous particle framework in claims 2 to 7.

26. A process according to claim 24 or claim 25, wherein the porous particles have a D_{50} particle diameter in the range from 0.5 to 30 µm, or from 1 to 25 µm, or from 1 to 20 µm, or from 2 to 25 µm, or from 2 to 20 µm, or from 2 to 18 µm, or from 2 to 15 µm, or from 2 to 12 µm, or from 2.5 to 15 µm, or from 2.5 to 12 µm, or from 2 to 10 µm.

27. A process according to any of claims 24 to 26, wherein the electroactive material deposited in steps (b) and (d) is independently selected from silicon, tin, germanium,

aluminium and mixtures and alloys thereof, preferably wherein the electroactive material deposited in at least one of steps (b) and (d) the electroactive material is silicon, and/or

wherein the electroactive material deposited in each of steps (b) and (d) is the same electroactive material, preferably wherein the electroactive material deposited in each of steps (b) and (d) is silicon.

28. A process according to any of claims 24 to 27, wherein the precursor of an electroactive material in each of steps (b) and (d) is independently selected from silane (SiH_4), disilane (Si_2H_6), trisilane (Si_3H_8), tetrasilane (Si_4H_{10}), methylsilane, dimethylsilane and chlorosilanes.

29. A process according to any of claims 24 to 28, wherein steps (b) and (d) are independently carried out at a temperature in the range from 300 to 800 ºC, or from 350 to 800 ºC, or from 380 to 700 ºC, or from 380 to 650 ºC, or from 380 to 600 ºC, or from 380 to 550 ºC, or from 380 to 500 ºC, or from 400 to 450 ºC, or from 450 to 500 ºC.

30. A process according to any of claims 24 to 29, wherein step (b) and/or step (d) further comprises separating by-products from the particles.

31. A process according to any of claims 24 to 30, wherein step (c) comprises contacting the intermediate particles from step (b) with a passivating agent.

32. A process according to claim 31, wherein the passivating agent is selected from (i) an oxygen containing gas; (ii) ammonia; (iii) a gas comprising ammonia and oxygen; and (iv) phosphine, preferably wherein the passivating agent is ammonia, or

wherein the passivating agent is selected from:

(i) R^1-CH=CH-R^1;

(ii) R^1-C≡C-R^1;

(iii) O=CR^1R^1;

(iv) HX-R^2, and

(v) HX-C(O)-R^1,

wherein X represents O, S, NR^1 or PR^1; and

wherein each R^1 independently represents H or an unsubstituted or substituted aliphatic or aromatic hydrocarbyl group having from 1 to 20 carbon atoms, or wherein two R^1 groups form an unsubstituted or substituted ring structure comprising from 3 to 8 carbon atoms in the ring;

wherein R^2 represents an unsubstituted or substituted aliphatic or aromatic hydrocarbyl group having from 1 to 20 carbon atoms, or wherein R^1 and R^2 together form an unsubstituted or substituted ring structure comprising from 3 to 8 carbon atoms in the ring, or

wherein the passivating agent is selected from the group consisting of ethylene, propylene, 1-butene, butadiene, 1-pentene, 1,4-pentadiene, 1-hexene, 1-octene, styrene, divinylbenzene, acetylene, phenylacetylene, norbornene, norbornadiene and bicyclo[2.2.2]oct-2-ene.

33. A process according to any of claims 24 to 32, wherein step (c) comprises contacting the intermediate particles from step (b) with a carbon-containing precursor at a temperature effective to cause deposition of a pyrolytic carbon material in the pores of the intermediate particles.

34. A process according to any of claims 24 to 33, wherein steps (c) and (d) are repeated one or more times.

35. A process according to any of claims 24 to 34, further comprising the step of:

(e) forming a plurality of modifier material domains in the pores and/or on the outer surface of the composite particles from step (d), preferably

wherein step (e) comprises contacting the surface of the composite particles from the final step (d) with a passivating agent, optionally wherein the passivating agent is as defined in claim 32.

36. A process according to claim 35, wherein step (e) comprises combining the composite particles from step (d) with a pyrolytic carbon precursor; and heating the pyrolytic carbon precursor to a temperature effective to cause the deposition of a pyrolytic conductive carbon material into the pores and/or onto the outer surface of the composite particles.

37. A process according to any of claims 24 to 36, wherein the porous particles have a particle size distribution span $(D_{90}-D_{10})/D_{50}$ of 5 or less, or 4 or less, or 3 or less, or 2 or less, or 1.5 or less.

38. A composition comprising the particulate material of any of claims 1 to 23 and at least one other component.

39. An electrode comprising the particulate material of any of claims 1 to 23 or the composition of claim 38.

40. A rechargeable metal-ion battery comprising the electrode of claim 39.