Claims

1. A powder comprising particles for use as an active component of a metal ion battery, the particles comprising a particle core and pillars extending from the particle core, wherein an aspect ratio of the particle core is at least 2:1.

2. A powder according to claim 1 wherein the pillars are formed from a material that, in use, undergoes an volume expansion of at least 10 % upon complete insertion into the material of the metal ions of the metal ion battery.

3. A powder according to claim 1 or 2 wherein the pillars comprise silicon, germanium, tin, antimony or aluminium.

4. A powder according to claim 1, 2 or 3 wherein the core comprises silicon or carbon.

5. A powder according to any preceding claim wherein the particle core is in the form of a flake with an aspect ratio of at least 3:1.

6. A powder according to any preceding claim wherein the particle core has a smallest dimension of at least 0.2 μm and has at least one dimension less than 6 μm.

7. A powder according to any preceding claims wherein the pillars comprise wires, nanowires, rods, filaments, threads, tubes, cone or other elongated structures extending from the particle core.

8. A powder according to any preceding claim wherein the volume of the pillars is at least 20 % of the total volume of the plurality of particles, optionally at least 40 %.

9. A powder according to any preceding claim wherein an average pillar density of the pillars on the particle core is in the range 10-80%.

10. A powder according to any preceding claim wherein the mean average pillar diameter is less than 80 nm.

11. A powder according to any preceding claim wherein opposing surfaces of the particles carry pillars.

12. A powder according to claim 11 wherein an average length of the pillars is less than 5 microns, optionally less than 4 microns.

13. A powder according to any of claims 1-10 wherein only one of two opposing surfaces of the particles carries pillars.

14. A powder according to claim 13 wherein an average length of the pillars is less than 10 microns, optionally less than 8 microns.

15. A powder according to any preceding claim wherein the particles are substantially discrete from one another.

16. A powder according to any preceding claim wherein at least 50% of the total volume of a starting material powder used to form the powder is made up of starting material particles having a particle size of less than 15 microns.

17. A powder according to any preceding claim wherein at least 90% of the total volume of a starting material powder used to form the powder is made up of starting material particles having a particle size of less than 25 microns.

18. A powder according to claim 16 or 17 wherein the particle sizes are as measured by a laser diffraction method in which the particles being measured are assumed to be spherical, and in which particle size is expressed as a spherical equivalent volume diameter.

19. A composition comprising a powder according to any preceding claim and at least one further component.

20. A composition according to claim 19 wherein the at least one further component comprises at least one further active component, optionally active carbon, optionally graphite.

21. A composition according to claim 19 or 20 wherein the at least one further component comprises at least one conductive, non-active component, optionally conductive, non-active carbon.

22. A composition according to any of claims 19-21 wherein the at least one further component comprises a binder.

23. A composition according to any of claims 19-22 wherein the composition has a composite porosity, as a percentage of the total volume of the composite, that is at least the value given by the sum of the volume of pillars multiplied by 2 and the volume of particle cores multiplied by 1.2.

24. A composition according to claim 23 wherein the porosity of the composite in an uncharged state is at least 10% and is no more than 80%.

25. A composition according to any of claims 19-24, wherein the at least one further component comprises a solvent.

26. A metal ion battery comprising an anode, a cathode and an electrolyte between the anode and cathode wherein the anode comprises a powder according to any one of claims 1-18 or a composition according to any of claims 19-25.

27. A metal ion battery according to claim 26 wherein the metal ion battery is a lithium ion battery.

28. A method of forming a metal ion battery according to claim 26 or 27 comprising the step of forming the anode by depositing a composition according to claim ~~26~~25 and evaporating the solvent.

29. A method of forming a powder according to any of claims 1-18 comprising the step of etching particles of a starting material powder to form the pillared particles.

30. A method of forming a powder according to any of claims 1-18 comprising the step of etching a silicon-coated material to form the pillared particles.

31. A method according to claim 29 or 30 wherein the mean average length of pillars is less than 5 microns.

32. A method of forming a powder according to any of claims 1-18 comprising the step of growing pillars on or out of particles of a starting material powder.

33. A method according to claim 32 wherein the pillars are grown on or out of one surface only of the particles of the starting material powder.

Claims

1. A powder comprising particles for use as an active component of a metal ion battery, the particles comprising a particle core and pillars extending from the particle core, wherein an aspect ratio of the particle core is at least 2:1.

2. A powder according to claim 1 wherein the pillars are formed from a material that, in use, undergoes an volume expansion of at least 10 % upon complete insertion into the material of the metal ions of the metal ion battery.

3. A powder according to claim 1 or 2 wherein the pillars comprise silicon, germanium, tin, antimony or aluminium.

4. A powder according to claim 1, 2 or 3 wherein the core comprises silicon or carbon.

5. A powder according to any preceding claim wherein the particle core is in the form of a flake with an aspect ratio of at least 3:1.

6. A powder according to any preceding claim wherein the particle core has a smallest dimension of at least 0.2 µm and has at least one dimension less than 6 µm.

7. A powder according to any preceding claims wherein the pillars comprise wires, nanowires, rods, filaments, threads, tubes, cone or other elongated structures extending from the particle core.

8. A powder according to any preceding claim wherein the volume of the pillars is at least 20 % of the total volume of the plurality of particles, optionally at least 40 %.

~~9. A powder according to any preceding claim wherein a BET value of the pillared particles is less than 200 m^2 / g, optionally less than 100 m^2 / g, optionally less than 60 m^2 / g, optionally less than 35 m^2 / g.~~

~~10~~9. A powder according to any preceding claim wherein an average pillar density of the pillars on the particle core is in the range 10-80%.

~~11~~10. A powder according to any preceding claim wherein the mean average pillar diameter is less than 80 nm.

~~12~~11. A powder according to any preceding claim wherein opposing surfaces of the particles carry pillars.

~~13~~12. A powder according to claim ~~12~~11 wherein an average length of the pillars is less than 5 microns, optionally less than 4 microns.

~~14~~13. A powder according to any of claims 1-~~11~~10 wherein only one of two opposing surfaces of the particles carries pillars.

~~15~~14. A powder according to claim ~~14~~13 wherein an average length of the pillars is less than 10 microns, optionally less than 8 microns.

~~16~~15. A powder according to any preceding claim wherein the particles are substantially discrete from one another.

~~17~~16. A powder according to any preceding claim wherein at least 50% of the total volume of a starting material powder used to form the powder is made up of starting material particles having a particle size of less than 15 microns.

~~18~~17. A powder according to any preceding claim wherein at least 90% of the total volume of a starting material powder used to form the powder is made up of starting material particles having a particle size of less than 25 microns.

~~19~~18. A powder according to claim ~~17~~16 or ~~18~~17 wherein the particle sizes are as measured by a laser diffraction method in which the particles being measured are assumed to be spherical, and in which particle size is expressed as a spherical equivalent volume diameter.

~~20~~19. A composition comprising a powder according to any preceding claim and at least one further component.

~~21~~20. A composition according to claim ~~20~~19 wherein the at least one further component comprises at least one further active component, optionally active carbon, optionally graphite.

~~22~~21. A composition according to claim ~~20~~19 or ~~21~~20 wherein the at least one further component comprises at least one conductive, non-active component, optionally conductive, non-active carbon.

~~23~~22. A composition according to any of claims ~~20~~19-~~22~~21 wherein the at least one further component comprises a binder.

~~24~~23. A composition according to any of claims ~~20~~19-~~23~~22 wherein the composition has a composite porosity, as a percentage of the total volume of the composite, that is at least the value given by the sum of the volume of pillars multiplied by 2 and the volume of particle cores multiplied by 1.2.

~~25~~24. A composition according to claim ~~24~~23 wherein the porosity of the composite in an uncharged state is at least 10% and is no more than 80%.

~~26~~25. A composition according to any of claims ~~20~~19-~~25~~24, wherein the at least one further component comprises a solvent.

~~27~~26. A metal ion battery comprising an anode, a cathode and an electrolyte between the anode and cathode wherein the anode comprises a powder according to any one of claims 1-~~19~~18 or a composition according to any of claims ~~20~~19-~~26~~25.

~~28~~27. A metal ion battery according to claim ~~27~~26 wherein the metal ion battery is a lithium ion battery.

~~29~~28. A method of forming a metal ion battery according to claim ~~27~~26 or ~~28~~27 comprising the step of forming the anode by depositing a composition according to claim 26 and evaporating the solvent.

~~30~~29. A method of forming a powder according to any of claims 1-~~19~~18 comprising the step of etching particles of a starting material powder to form the pillared particles.

~~31~~30. A method of forming a powder according to any of claims 1-~~19~~18 comprising the step of etching a silicon-coated material to form the pillared particles.

~~32~~31. A method according to claim ~~30~~29 or ~~31~~30 wherein the mean average length of pillars is less than 5 microns.

~~33~~32. A method of forming a powder according to any of claims 1-~~19~~18 comprising the step of growing pillars on or out of particles of a starting material powder.

~~34~~33. A method according to claim ~~33~~32 wherein the pillars are grown on or out of one surface only of the particles of the starting material powder.