CLAIMS

We claim:

1. A method of forming a branched metal silicide nanostructure, comprising:
    a. Forming a trunk by:
        i. Providing a substrate;
        ii. Disposing a non-refractory transition metal on said substrate; and
        iii. Exposing said non-refractory transition metal to silane gas wherein at least some of the gas reacts with at least some of the non-refractory transition metal to form a solid primary structure; and
    b. Forming branches by:
        i. Disposing non-refractory transition metal on the outer surface of said solid primary structure; and
        ii. Exposing said non-refractory transition metal to silane gas wherein at least some of the gas reacts with at least some of the non-refractory transition metal to form solid secondary structures, wherein said secondary structures are attached to said primary structure.

2. A method of forming a branched nickel silicide nanostructure according to claim 1, comprising:
    a. Forming a trunk by:
        i. Providing a substrate;
        ii. Disposing nickel on said substrate; and
        iii. Exposing said nickel to silane gas wherein at least some of the gas reacts with at least some of the nickel to form a solid primary structure; and
    b. Forming branches by:
        i. Disposing nickel on the outer surface of said solid primary structure; and
        ii. Exposing said nickel to silane gas wherein at least some of the gas reacts with at least some of the nickel to form solid secondary structures, wherein said secondary structures are attached to said primary structure.

3. A method according to either of claims 1 or 2, wherein said method additionally comprises repeating, in at least one additional instance, the steps for forming branches.

4. A method according to any one of the above claims, wherein said method additionally comprises coating at least a portion of the outside surfaces of said trunk and branches with an electroactive or electrically conductive coating.

5. A method according to claim 4, wherein said electroactive or electrically conductive coating comprises silicon, germanium, nickel, carbon, or a transition metal oxide.

6. A method according to claim 5, wherein said coating comprises amorphous silicon.

7. A method according to either of claims 1 or 2, wherein said nanostructure comprises a core of crystalline silicon and a shell containing both nickel and silicon.

8. A method according to either of claims 1 or 2, wherein at least a portion of said non-refractory transition metal or nickel is incorporated into the trunk and branches.

9. A method according to either of claims 1 or 2, wherein the trunk and each branch of said branched nanostructure is a substantially cylindrical structure whose height exceeds its diameter.

10. A method according to either of claims 1 or 2, wherein said non-refractory transition metal or nickel is disposed in a thin film layer and is liquefied.

11. A method according to claim 10, wherein said non-refractory transition metal or nickel is liquefied by heating.

12. A method according to claim 10, wherein said thin film layer is disposed at a thickness of between about 5 nm and 250 nm.

13. A method according to claim 12, wherein said thin film layer is disposed at a thickness of between about 5 nm and 50 nm.

14. A method according to claim 13, wherein said thin film layer is disposed at a thickness of between about 10 nm and 25 nm.

15. A method according to either of claims 1 or 2, wherein said substrate is a current collecting foil.

16. A method according to claim 15, wherein said current collecting foil is a stainless steel foil.

17. A method of forming a branched metal silicide nanostructure, comprising:
    a. Forming a trunk by:
        i. Providing a stainless steel foil substrate;
        ii. Disposing non-refractory transition metal as a thin film layer on said substrate;
        iii. Liquefying said non-refractory transition metal thin film layer; and
        iv. Exposing said non-refractory transition metal to silane gas wherein at least some of the gas reacts with at least some of the non-refractory transition metal to form a solid primary structure; and
    b. Forming branches by:
        i. Disposing non-refractory transition metal as a thin film layer on the outer surface of said solid primary structure;
        ii. Liquefying said non-refractory transition metal thin film layer; and
        iii. Exposing said non-refractory transition metal to silane gas wherein at least some of the gas reacts with at least some of the non-refractory

transition metal to form solid secondary structures, wherein said secondary structures are attached to said primary structure; and

c. Optionally repeating the steps of b to form additional branches, wherein the additional branches may be formed on either the solid primary structures or the solid secondary structures; and
d. Coating at least a portion of the outside surfaces of said trunk and branches with an electroactive or electrically conductive coating.

18. A method of forming a branched nickel silicide nanostructure according to claim 17, comprising:
    a. Forming a trunk by:
        i. Providing a stainless steel foil substrate;
        ii. Disposing nickel as a thin film layer on said substrate;
        iii. Liquefying said nickel thin film layer; and
        iv. Exposing said nickel to silane gas wherein at least some of the gas reacts with at least some of the nickel to form a solid primary structure; and
    b. Forming branches by:
        i. Disposing nickel as a thin film layer on the outer surface of said solid primary structure;
        ii. Liquefying said nickel thin film layer; and
        iii. Exposing said nickel to silane gas wherein at least some of the gas reacts with at least some of the nickel to form solid secondary structures, wherein said secondary structures are attached to said primary structure; and
    c. Optionally repeating the steps of b to form additional branches, wherein the additional branches may be formed on either the solid primary structures or the solid secondary structures; and
    d. Coating at least a portion of the outside surfaces of said trunk and branches with an electroactive or electrically conductive coating.

19. A method according to claim 17 or claim 18, wherein said thin film layer is disposed at a thickness of between about 5 nm and 250 nm.

20. A method according to claim 19, wherein said thin film layer is disposed at a thickness of between about 5 nm and 50 nm.

21. A method according to claim 19, wherein said thin film layer is disposed at a thickness of between about 10 nm and 25 nm.

22. A method according to claim 17 or claim 18, wherein said electroactive or electrically conductive coating comprises silicon, germanium, nickel, carbon, or a transition metal oxide.

23. A method according to claim 22, wherein said electroactive or electrically conductive coating comprises amorphous silicon.

24. A method for use in forming a lithium-ion battery, comprising:
    a. forming branched non-refractory transition metal silicide nanostructures according to the method of any one of the claims above;
    b. coating at least a portion of the outside surfaces of said nanostructures with an electroactive or electrically conductive coating; and
    c. integrating said coated branched nanostructures into a lithium-ion battery.

25. A method according to claim 24, wherein said non-refractory transition metal is nickel.

26. A method according to claim 24 or 25 wherein the trunk and each branch of said branched nanostructure is a substantially cylindrical structure whose height exceeds its diameter.

27. A method according to claim 24 or 25, wherein said electroactive or electrically conductive coating comprises silicon, germanium, nickel, carbon, or a transition metal oxide.

28. A method according to claim 27, wherein said electroactive or electrically conductive coating comprises amorphous silicon.

29. A lithium-ion battery electrode, comprising:
    a. A substrate;
    b. A plurality of branched non-refractory transition metal silicide nanostructures, formed according to the method of any one of the claims above, grown on said substrate; and
    c. An electroactive or electrically conductive coating on at least a portion of the outside of said branched non-refractory transition metal silicide nanostructures.

30. A lithium-ion battery electrode according to claim 29, wherein said non-refractory transition metal is comprised of nickel.

31. A lithium-ion battery electrode of claim 30 wherein the trunk and each branch of said branched nanostructure is a substantially cylindrical structure whose height exceeds its diameter.

32. A lithium-ion battery electrode according to claim 30, wherein said electroactive or electrically conductive coating comprises silicon, germanium, nickel, carbon, or a transition metal oxide.

33. A lithium-ion battery electrode according to claim 32, wherein said electroactive or electrically conductive coating comprises amorphous silicon.

34. A component for a lithium-ion battery, comprising:
    a. A substrate;
    b. A plurality of branched non-refractory transition metal silicide nanostructures, formed according to the method of any one of claims 1 to 28, grown on said substrate; and
    c. An electroactive or electrically conductive coating on at least a portion of the outside of said branched non-refractory transition metal silicide nanostructures.

35. A component for a lithium-ion battery according to claim 34, wherein said non-refractory transition metal is nickel.

36. A component for a lithium-ion battery of claim 34 or 35 wherein the trunk and each branch of said branched nanostructure is a substantially cylindrical structure whose height exceeds its diameter.

37. A component for a lithium-ion battery according to claim 34 or 35, wherein said electroactive or electrically conductive coating comprises silicon, germanium, nickel, carbon, or a transition metal oxide.

38. A component for a lithium-ion battery according to claim 37, wherein said electroactive or electrically conductive coating comprises amorphous silicon.

CLAIMS

1. A method of forming a branched metal silicide nanostructure, comprising:
    a. Forming a trunk by:
        i. Providing a substrate;
        ii. Disposing a non-refractory transition metal on said substrate; and
        iii. Exposing said non-refractory transition metal to silane gas wherein at least some of the gas reacts with at least some of the non-refractory transition metal to form a solid primary structure; and
    b. Forming branches by:
        i. Disposing non-refractory transition metal on the outer surface of said solid primary structure; and
        ii. Exposing said non-refractory transition metal to silane gas wherein at least some of the gas reacts with at least some of the non-refractory transition metal to form solid secondary structures, wherein said secondary structures are attached to said primary structure.

2. A method of forming a branched nickel silicide nanostructure according to claim 1, comprising:
    a. Forming a trunk by:
        i. Providing a substrate;
        ii. Disposing nickel on said substrate; and
        iii. Exposing said nickel to silane gas wherein at least some of the gas reacts with at least some of the nickel to form a solid primary structure; and
    b. Forming branches by:
        i. Disposing nickel on the outer surface of said solid primary structure; and
        ii. Exposing said nickel to silane gas wherein at least some of the gas reacts with at least some of the nickel to form solid secondary structures, wherein said secondary structures are attached to said primary structure.

3. A method according to either of claims 1 or 2, wherein said method additionally comprises repeating, in at least one additional instance, the steps for forming branches.

4. A method according to any one of claims 1 to 3, wherein said method additionally comprises coating at least a portion of the outside surfaces of said trunk and branches with an electroactive or electrically conductive coating.

5. A method according to claim 4, wherein said electroactive or electrically conductive coating comprises silicon, germanium, nickel, carbon, or a transition metal oxide.

6. A method according to claim 5, wherein said coating comprises amorphous silicon.

7. A method according to either of claims 1 or 2, wherein said nanostructure comprises a core of crystalline silicon and a shell containing both nickel and silicon.

8. A method according to either of claims 1 or 2, wherein at least a portion of said non-refractory transition metal or nickel is incorporated into the trunk and branches.

9. A method according to either of claims 1 or 2, wherein the trunk and each branch of said branched nanostructure is a cylindrical structure whose height exceeds its diameter.

10. A method according to either of claims 1 or 2, wherein said non-refractory transition metal or nickel is disposed in a thin film layer and is liquefied.

11. A method according to claim 10, wherein said non-refractory transition metal or nickel is liquefied by heating.

12. A method according to claim 10, wherein said thin film layer is disposed at a thickness of between 5 nm and 250 nm.

13. A method according to claim 12, wherein said thin film layer is disposed at a thickness of between 5 nm and 50 nm.

14. A method according to claim 13, wherein said thin film layer is disposed at a thickness of between 10 nm and 25 nm.

15. A method according to either of claims 1 or 2, wherein said substrate is a current collecting foil.

16. A method according to claim 15, wherein said current collecting foil is a stainless steel foil.

17. A method of forming a branched metal silicide nanostructure, comprising:
    a. Forming a trunk by:
        i. Providing a stainless steel foil substrate;
        ii. Disposing non-refractory transition metal as a thin film layer on said substrate;
        iii. Liquefying said non-refractory transition metal thin film layer; and
        iv. Exposing said non-refractory transition metal to silane gas wherein at least some of the gas reacts with at least some of the non-refractory transition metal to form a solid primary structure; and
    b. Forming branches by:

i. Disposing non-refractory transition metal as a thin film layer on the outer surface of said solid primary structure;
ii. Liquefying said non-refractory transition metal thin film layer; and
iii. Exposing said non-refractory transition metal to silane gas wherein at least some of the gas reacts with at least some of the non-refractory transition metal to form solid secondary structures, wherein said secondary structures are attached to said primary structure; and

c. Coating at least a portion of the outside surfaces of said trunk and branches with an electroactive or electrically conductive coating.

18. A method of forming a branched nickel silicide nanostructure according to claim 17, comprising:

a. Forming a trunk by:
i. Providing a stainless steel foil substrate;
ii. Disposing nickel as a thin film layer on said substrate;
iii. Liquefying said nickel thin film layer; and
iv. Exposing said nickel to silane gas wherein at least some of the gas reacts with at least some of the nickel to form a solid primary structure; and

b. Forming branches by:
i. Disposing nickel as a thin film layer on the outer surface of said solid primary structure;
ii. Liquefying said nickel thin film layer; and
iii. Exposing said nickel to silane gas wherein at least some of the gas reacts with at least some of the nickel to form solid secondary structures, wherein said secondary structures are attached to said primary structure; and

c. Coating at least a portion of the outside surfaces of said trunk and branches with an electroactive or electrically conductive coating.

19. A method according to claim 17 or claim 18, further comprising the step below: repeating the steps of b to form additional branches, wherein the additional branches may be formed on either the solid primary structure or the sold secondary structures between the step b and the step c.

20. A method according to any one of claims 17 to 19, wherein said thin film layer is disposed at a thickness of between 5 nm and 250 nm.

21. A method according to claim 20, wherein said thin film layer is disposed at a thickness of between 5 nm and 50 nm.

22. A method according to claim 20, wherein said thin film layer is disposed at a thickness of between 10 nm and 25 nm.

23. A method according to any one of claims 17 to 19, wherein said electroactive or electrically conductive coating comprises silicon, germanium, nickel, carbon, or a transition metal oxide.

24. A method according to claim 23, wherein said electroactive or electrically conductive coating comprises amorphous silicon.

25. A method for use in forming a lithium-ion battery, comprising:
    a. forming branched non-refractory transition metal silicide nanostructures according to the method of any one of claims 1 to 24;
    b. coating at least a portion of the outside surfaces of said nanostructures with an electroactive or electrically conductive coating; and
    c. integrating said coated branched nanostructures into a lithium-ion battery.

26. A method according to claim 25, wherein said non-refractory transition metal is nickel.

27. A method according to claim 25 or 26 wherein the trunk and each branch of said branched nanostructure is a cylindrical structure whose height exceeds its diameter.

28. A method according to claim 25 or 26, wherein said electroactive or electrically conductive coating comprises silicon, germanium, nickel, carbon, or a transition metal oxide.

29. A method according to claim 28, wherein said electroactive or electrically conductive coating comprises amorphous silicon.

30. A lithium-ion battery electrode, comprising:
    a. A substrate;
    b. A plurality of branched non-refractory transition metal silicide nanostructures, formed according to the method of any one of claims 1 to 29, grown on said substrate; and
    c. An electroactive or electrically conductive coating on at least a portion of the outside of said branched non-refractory transition metal silicide nanostructures.

31. A lithium-ion battery electrode according to claim 30, wherein said non-refractory transition metal is comprised of nickel.

32. A lithium-ion battery electrode of claim 31 wherein the trunk and each branch of said branched nanostructure is a cylindrical structure whose height exceeds its diameter.

33. A lithium-ion battery electrode according to claim 31, wherein said electroactive or electrically conductive coating comprises silicon, germanium, nickel, carbon, or a transition metal oxide.

34. A lithium-ion battery electrode according to claim 33, wherein said electroactive or electrically conductive coating comprises amorphous silicon.

35. A component for a lithium-ion battery, comprising:
    a. A substrate;
    b. A plurality of branched non-refractory transition metal silicide nanostructures, formed according to the method of any one of claims 1 to 29, grown on said substrate; and
    c. An electroactive or electrically conductive coating on at least a portion of the outside of said branched non-refractory transition metal silicide nanostructures.

36. A component for a lithium-ion battery according to claim 35, wherein said non-refractory transition metal is nickel.

37. A component for a lithium-ion battery of claim 35 or 36 wherein the trunk and each branch of said branched nanostructure is a cylindrical structure whose height exceeds its diameter.

38. A component for a lithium-ion battery according to claim 35 or 36, wherein said electroactive or electrically conductive coating comprises silicon, germanium, nickel, carbon, or a transition metal oxide.

39. A component for a lithium-ion battery according to claim 38, wherein said electroactive or electrically conductive coating comprises amorphous silicon.