[013] It is an object of an especially preferred form of the present invention to provide for new or improved methods of fabricating anodes and/or lithium-ion batteries, and/or methods of preparing components or materials for use in anodes and/or lithium-ion batteries.
[014] It is an object of another especially preferred form of the present invention to provide for new or improved multi-functional polymer binders, for example that can be used as part of an anode for improved performance of the anode.
[015] Unless the context clearly requires otherwise, throughout the description and the claims, the words “comprise”, “comprising”, and the like are to be construed in an inclusive sense as opposed to an exclusive or exhaustive sense; that is to say, in the sense of “including, but not limited to”.
[016] Although the invention will be described with reference to specific examples it will be appreciated by those skilled in the art that the invention may be embodied in many other forms.

Summary of the Invention

[017] This summary is provided to introduce a selection of concepts in a simplified form that are further described below. This summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used to limit the scope of the claimed subject matter.
[018] According to a first aspect of the present invention, there is provided a method of fabricating an anode for a lithium-ion battery, comprising the steps of:
[019] mixing a silicon/graphite/carbon material, one or more linear polymers, one or more conductive polymers, one or more self-healing polymers, and one or more rubber polymers and a conductive agent to produce a slurry;
[020] coating the slurry onto a metallic member;
[021] drying the metallic member with coated slurry to form the anode;

the one or more linear polymers is sodium carboxymethyl cellulose (CMC), polyacrylic acid (PAA) and combinations thereof;

the one or more conductive polymers is polypyrrole (PPY), PEDOT:PSS and combinations thereof;

the one or more self-healing polymers is dopamine (DA), urea-oligo-amidoamine (UOAA) and combinations thereof;

the one or more rubber polymers is styrene butadiene rubber (SBR); and

the conductive agent is selected from the group consisting of carbon black, carbon nanotubes, graphene, functionalised graphene platelets, nano-carbon fibers and a mixture thereof.

[022] In an embodiment, a method of fabricating an anode for a lithium-ion battery, comprises the steps of:

[023] mixing a silicon/graphite/carbon material with a multi-functional polymer binder comprising one or more linear polymers, one or more conductive polymers, one or more self-healing polymers, and one or more rubber polymers to produce a slurry;

[024] coating the slurry onto a metallic member; and

[025] drying the metallic member with coated slurry to form the anode.

rubber polymers is styrene butadiene rubber (SBR).

[067] According to a second aspect of the present invention there is provided a multi-functional polymer binder for use in an anode for a lithium ion battery, comprising:

[068] one or more linear polymers;

[069] one or more conductive polymers;

[070] one or more self-healing polymers;

a conductive agent; and

[071] one or more rubber polymers, wherein

the one or more linear polymers is sodium carboxymethyl cellulose (CMC), polyacrylic acid (PAA) and combinations thereof;

the one or more conductive polymers is polypyrrole (PPY), PEDOT:PSS and combinations thereof;

the one or more self-healing polymers is dopamine (DA), urea-oligo-amidoamine (UOAA) and combinations thereof;

the one or more rubber polymers is styrene butadiene rubber (SBR); and

the conductive agent is selected from the group consisting of carbon black, carbon nanotubes, graphene, functionalised graphene platelets, nano-carbon fibers and a mixture thereof.

[072] In an especially preferred embodiment, the multi-functional polymer binder comprises 30% CMC, 10% PAA, 10% citric acid, 10% PEDOT-PSS, 10% SHP and 30% SBR.

[073] In an embodiment, the one or more linear polymers have a percentage weight of equal to or between about 15 wt% to about 70 wt%;

[074] the one or more conductive polymers have a percentage weight of equal to or between about 1 wt% to about 30 wt%;

[075] the one or more self-healing polymers have a percentage weight of equal to or between about 5 wt% to about 20 wt%;

[076] the one or more rubber polymers have a percentage weight of equal to or between about 10 wt% to about 40 wt%; and

[077] wherein the total weight percentage of the binder is 100 wt%.

[078] In an embodiment, the one or more linear polymers have a percentage weight of about 15 wt%, 20 wt%, 25 wt %, 30 wt %, 35 wt %, 40 wt%, 45 wt%, 50 wt%, 55 wt%, 60 wt%, 65 wt% or 70 wt%;

[079] the one or more conductive polymers have a percentage weight of about 1 wt%, 2 wt%, 3 wt%, 4 wt%, 5 wt%, 7.5 wt%, 10 wt%, 15 wt%, 20 wt%, 25 wt% or 30 wt%;

[080] the one or more self-healing polymers have a percentage weight of about 5 wt%, 7.5 wt%, 10 wt%, 15 wt% or 20 wt%;

[081] the one or more rubber polymers have a percentage weight of about 10 wt%, 15 wt%, 20 wt%, 30 wt%, 35 wt% or 40 wt%; and

[082] wherein the total weight percentage of the binder is 100 wt%.

[083] In an embodiment, the one or more linear polymers have a percentage weight of about 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69 or 70 wt%;

[084] the one or more conductive polymers have a percentage weight of about 1, 2, 3, 4,

[098] In an embodiment, the one or more conductive polymers are selected from the group consisting of polyaniline (PANI), sodium poly[9,9-bis(3-propanoate)fluorine] (PFCOONa), poly(l-pyrenemethyl methacrylate-co-methacrylic acid) (PPyMAA), polypyrrole (PPY) and 3,4-ethylenedioxythiophene/polystyrene-4-sulfonate (PEDOT:PSS).

[099] In an embodiment, the one or more self-healing polymers are selected from the group consisting of urea-pyrimidinone (UPy), urea-oligo-amidoamine (UOAA), dopamine methacrylamide (DMA) and dopamine (DA). In an embodiment, the one or more self-healing polymers is urea-oligo-amidoamine (UOAA).

[0100] In an embodiment, the one or more rubber polymers are selected from the group consisting of styrene butadiene rubber (SBR), neoprene, nitrile rubber, butyl silicone rubber and polysulfide rubber.

[0101] According to a third aspect of the present invention there is provided a method of producing a multi-functional polymer binder, comprising mixing together one or more linear polymers, one or more conductive polymers, one or more self-healing polymers, a conductive agent, and one or more rubber polymers, wherein:

the one or more linear polymers is sodium carboxymethyl cellulose (CMC), polyacrylic acid (PAA) and combinations thereof;

the one or more conductive polymers is polypyrrole (PPY), PEDOT:PSS and combinations thereof;

the one or more self-healing polymers is dopamine (DA), urea-oligo-amidoamine (UOAA) and combinations thereof;

the one or more rubber polymers is styrene butadiene rubber (SBR); and

the conductive agent is selected from the group consisting of carbon black, carbon nanotubes, graphene, functionalised graphene platelets, nano-carbon fibers and a mixture thereof.

[0102] There is also disclosed a method of fabricating an anode for a lithium-ion battery, comprising the steps of: mixing a silicon/graphite/carbon material and a multi-functional polymer binder (for example including one or more linear polymers, one or more conductive polymers, one or more self-healing polymers, and one or more rubber polymers) to produce a slurry; coating the slurry onto a metallic member; and drying the metallic member with coated slurry to form the anode.

[0103] There is also disclosed an anode for a lithium-ion battery, produced by any of the methods disclosed herein. There is also disclosed an anode for a lithium-ion battery, comprising a Si @ C/graphite/carbon material.

[0104] There is also disclosed a lithium-ion battery, comprising: an anode produced by any of the methods disclosed herein; a cathode; and an electrolyte and/or a separator positioned between the anode and the cathode.

[0105] In another example, the Si @ C/graphite/carbon material is mixed with one or more polymer binders in fabricating the anode. In another example, the anode is formed by: mixing the Si @ C/graphite/carbon material and the one or more polymer binders to produce a slurry; coating the slurry onto a metallic member; and drying the metallic member with

coated slurry to form the anode. In further examples, the metallic member is a metallic foil, strip or grid. In another example, a conductive agent is mixed into the slurry.

[0106] According to a fourth aspect of the present invention there is provided a kit comprising: an emulsion (part 1) comprising mixture of a silicon/graphite/carbon material, one or more linear polymers, one or more conductive polymers, one or more self-healing polymers, and a conductive agent; and an emulsion (part 2) comprising one or more rubber polymers, wherein:

the one or more linear polymers is sodium carboxymethyl cellulose (CMC), polyacrylic acid (PAA) and combinations thereof;

the one or more conductive polymers is polypyrrole (PPY), PEDOT:PSS and combinations thereof;

the one or more self-healing polymers is dopamine (DA), urea-oligo-amidoamine (UOAA) and combinations thereof;

the one or more rubber polymers is styrene butadiene rubber (SBR); and

the conductive agent is selected from the group consisting of carbon black, carbon nanotubes, graphene, functionalised graphene platelets, nano-carbon fibers and a mixture thereof.

[0107] In some embodiments, the emulsion (part 1) further comprises an acid, preferably an organic acid such as citric acid. In further embodiments, the emulsion (part 1) comprises one or more linear polymers selected from carboxymethyl cellulose (CMC) and poly aery lie acid (PAA), one or more self-leading polymers selected from urea-oligo- amidoamine (UOAA), dopamine (DA) and combinations thereof, one or more conductive polymers selected from PEDOT:PSS; and citric acid. In certain embodiments, the emulsion (part 2) comprises one or more rubber polymers selected from styrene butadiene rubber (SBR).

[0108] In some embodiments, each of the emulsion (part 1) and emulsion (part 2) is independently an aqueous emulsion or a non-aqueous emulsion. In certain embodiments, each of the emulsion (part 1) and emulsion (part 2) is independently dispersed in a suitable solvent. In some embodiments, the solvent can be one or more one of ethylene glycol (EG), 1-pentanol, propylene glycol, polyacrylic acid, toluene, xylene, quinoline, pyridine and tetrahydrofuran (THF), diethyl ether, di-isopropyl ether, methylethyl ether, dioxane, methanol, ethanol, 1 -propanol, isopropanol, n-butanol, t-butanol, ethyl acetate, dimethylacetamide (DMA), dimethylformamide (DMF), dimethylsulfoxide (DMSO), pentane, n-hexanes, cyclohexane, acetonitrile, acetone, chloroform, dichloromethane, carbon tetrachloride, or mixtures thereof or similar. In some embodiments, the solvent selected from

the group consisting of water, a polar solvent and combinations thereof. In certain embodiments, the polar solvent is selected from the group consisting of acetic acid, n-butanol, isopropanol, n-propanol, ethanol, methanol, acetone, formic acid, dimethyl sulfoxide, dimethylformamide, acetonitrile, dichloromethane, tetrahydrofuran, ethyl acetate and combinations thereof.

[0109] In preferred embodiments, the emulsion (part 1) is an aqueous emulsion and the emulsion (part 2) is a non-aqueous emulsion.

[0110] Other aspects, features, and advantages will become apparent from the following descriptive sections when taken in conjunction with the accompanying drawings, which

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A method of fabricating an anode for a lithium-ion battery, comprising the steps of:

mixing a silicon/graphite/carbon material, one or more linear polymers, one or more conductive polymers, one or more self-healing polymers, and one or more rubber polymers and a conductive agent to produce a slurry;

coating the slurry onto a metallic member;

drying the metallic member with coated slurry to form the anode;

the one or more linear polymers is sodium carboxymethyl cellulose (CMC), polyacrylic acid (PAA) and combinations thereof;

the one or more conductive polymers is polypyrrole (PPY), PEDOT:PSS and combinations thereof;

the one or more self-healing polymers is dopamine (DA), urea-oligo-amidoamine (UOAA) and combinations thereof;

the one or more rubber polymers is styrene butadiene rubber (SBR); and

the conductive agent is selected from the group consisting of carbon black, carbon nanotubes, graphene, functionalised graphene platelets, nano-carbon fibers and a mixture thereof.

2. A method according to claim 1, wherein the silicon/graphite/carbon material is a Si@C/graphite/carbon material.

3. A method according to claim 1, wherein the metallic member is a metallic foil, strip or grid.

4. A method according to any one of claims 1 to 3, wherein the one or more linear polymers, the one or more conductive polymers, the one or more self-healing polymers, the conductive agent, and the one or more rubber polymers are firstly mixed together where:

the one or more linear polymers have a percentage weight of equal to or between about 15 wt% to about 70 wt%;

the one or more conductive polymers have a percentage weight of equal to or between about 1 wt% to about 30 wt%;

the one or more self-healing polymers have a percentage weight of equal to or

between about 5 wt% to about 20 wt%;

the one or more rubber polymers have a percentage weight of equal to or between about 10 wt% to about 40 wt%;

the conductive agent has a percentage weight of equal to or between about 1 wt% to about 10 wt%;

wherein total weight percentage of the one or more linear polymers, one or more conductive polymers, one or more self-healing polymers, the conductive agent and one or more rubber polymers is 100 wt%.

5. A method according to any one of claims 1 to 4, further comprising an acid.

6. A method according to claim 5, wherein the acid is an organic acid.

7. A method according to any one of claims 1 to 6, wherein the silicon/graphite/carbon material, the conductive agent, and a mixed combination of the one or more linear polymers, the one or more conductive polymers, the one or more self-healing polymers and the one or more rubber polymers, are mixed together in a mass ratio (silicon/graphite/carbon material : conductive agent : mixed combination of polymers) of equal to or between about 80-96:1-10:3-10.

8. A method according to any one of claims 1 to 7, wherein the silicon/graphite/carbon material, and a mixed combination of the one or more linear polymers, the one or more conductive polymers, the one or more self-healing polymers and the one or more rubber polymers, are mixed together in a mass ratio (silicon/graphite/carbon material : mixed combination of polymers) of about 80-99:1-20.

9. A multi-functional polymer binder for use in an anode for a lithium ion battery comprising:

one or more linear polymers;

one or more conductive polymers;

one or more self-healing polymers,

a conductive agent; and

one or more rubber polymers, wherein

the one or more linear polymers is sodium carboxymethyl cellulose (CMC),

polyacrylic acid (PAA) and combinations thereof;

the one or more conductive polymers is polypyrrole (PPY), PEDOT:PSS and combinations thereof;

the one or more self-healing polymers is dopamine (DA), urea-oligo-amidoamine (UOAA) and combinations thereof;

the one or more rubber polymers is styrene butadiene rubber (SBR); and

the conductive agent is selected from the group consisting of carbon black, carbon nanotubes, graphene, functionalised graphene platelets, nano-carbon fibers and a mixture thereof.

10. A multi-functional polymer binder according to claim 9, wherein:

the one or more linear polymers have a percentage weight of equal to or between about 15 wt% to about 70 wt%;

the one or more conductive polymers have a percentage weight of equal to or between about 1 wt% to about 30 wt%;

the one or more self-healing polymers have a percentage weight of equal to or between about 5 wt% to about 20 wt%;

the conductive agent has a percentage weight of equal to or between about 1 wt% to 10 wt%; and

the one or more rubber polymers have a percentage weight of equal to or between about 10 wt% to about 40 wt%, wherein the total weight percentage of the binder is 100 wt%.

11. A multi-functional polymer binder according to claim 9 or 10, further comprising an acid.

12. A multi-functional polymer binder according to claim 11, wherein the acid is an organic acid.

13. A method of producing a multi-functional polymer binder, comprising mixing together one or more linear polymers, one or more conductive polymers, one or more self-healing polymers, a conductive agent, and one or more rubber polymers, wherein:

the one or more linear polymers is sodium carboxymethyl cellulose (CMC), polyacrylic acid (PAA) and combinations thereof;

the one or more conductive polymers is polypyrrole (PPY), PEDOT:PSS and combinations thereof;

the one or more self-healing polymers is dopamine (DA), urea-oligo-amidoamine (UOAA) and combinations thereof;

the one or more rubber polymers is styrene butadiene rubber (SBR); and

the conductive agent is selected from the group consisting of carbon black, carbon nanotubes, graphene, functionalised graphene platelets, nano-carbon fibers and a mixture thereof.

14. A kit comprising:

an emulsion (part 1) comprising mixture of a silicon/graphite/carbon material, one or more linear polymers, one or more conductive polymers, one or more self-healing polymers, and a conductive agent; and

an emulsion (part 2) comprising one or more rubber polymers, wherein:

the one or more linear polymers is sodium carboxymethyl cellulose (CMC), polyacrylic acid (PAA) and combinations thereof;

the one or more conductive polymers is polypyrrole (PPY), PEDOT:PSS and combinations thereof;

the one or more self-healing polymers is dopamine (DA), urea-oligo-amidoamine (UOAA) and combinations thereof;

the one or more rubber polymers is styrene butadiene rubber (SBR); and

the conductive agent is selected from the group consisting of carbon black, carbon nanotubes, graphene, functionalised graphene platelets, nano-carbon fibers and a mixture thereof.

15. A kit according to claim 14, wherein the emulsion (part 1) further comprises an acid.

16. A kit according to claim 15, wherein the acid is an organic acid.