DESCRIPTION

TITLE OF INVENTION: [CURRENT COLLECTOR FOR ELECTRICAL ENERGY STORAGE DEVICE AND METHOD OF FABRICATION THEREOF]

TECHNICAL FIELD

[0001] The present disclosure relates generally to a current collector for an electrical energy storage device and method of fabrication thereof.

BACKGROUND

[0002] Fossil fuels are falling out of favour due to environmental problems associated with their production and use. Consequently, the demand for electrically powered cars is increasing. At the same time, the demand for other mobile devices that are powered with electricity, such as smart phones, tablets and laptops, is also going up. In order to power electric cars and other mobile devices, portable sources of electrical energy are needed and it is desirable that they should provide the electrical energy for as long as possible in between charges.

[0003] Portable sources of electrical energy include electrical energy storage devices such as capacitors and battery cells, for example, as may be found in existing lithium-ion batteries and sodium-ion batteries. In use, the electrical energy storage device should be able to hold as much charge as possible, so that the device can discharge and provide electrical energy for as long as possible before needing to be charged again.

[0004] It is therefore desirable to improve the charge storage capacity of existing electrical energy storage devices so that they need to be charged less frequently and can be used for longer between charges.

SUMMARY

[0005] The present application discloses a current collector configured to increase the amount of charge that the electrical energy storage device can hold.

[0006] According to a first aspect, there is provided a current collector for an electrode of an electrical energy storage device, the current collector comprising: a sheet of conductive metal having a modified first surface for providing positive ions thereon to be in contact with an electrolyte in the electrical energy storage device, wherein the modified first surface has a three-dimensional structure with increased surface area.

[0007] According to a second aspect, there is provided a method of fabricating a current collector for an electrode of an electrical energy storage device, the method comprising:

a) providing a sheet of conductive metal; and
b) modifying a first surface of the sheet of conductive metal using at least one of: a mechanical process, an optical process, a plasma process and a chemical process to create a modified first surface having a three-dimensional structure with increased surface area.

[0008] Step b) may comprise performing a cutting operation on the first surface of the sheet of conductive metal to create the three-dimensional structure followed by one of: chemical etching, laser etching and plasma etching of the three-dimensional structure.

[0009] The method may further comprise a step c) of coating a separator layer on a second surface of the sheet of conductive metal.

[0010] According to a third aspect, there is provided an electrode for an electrical energy storage device, the electrode comprising: a current collector comprising a sheet of conductive metal having a modified first surface for providing positive ions thereon to be in contact with an electrolyte in the electrical energy storage device, wherein the modified first surface has a three-dimensional structure with increased surface area; a substrate provided to support the current collector thereon; and a coating of the positive ions provided on the modified first surface of the current collector.

[0011] According to a fourth aspect, there is provided an electrical energy storage device comprising: two electrodes separated by an electrolyte; wherein at least one of the two electrodes comprises: a current collector comprising a sheet of conductive metal having a modified first surface for providing positive ions thereon to be in contact with the electrolyte,

wherein the modified first surface has a three-dimensional structure with increased surface area; a substrate provided to support the current collector thereon; and a coating of the positive ions provided on the modified first surface of the current collector in contact with the electrolyte.

[0012] For all aspects, the three-dimensional structure may comprise at least one of: a plurality of grooves, a plurality of blind holes, a plurality of protrusions and further comprises one of: a chemically-etched surface, an optically-etched surface and a plasma-etched surface.

[0013] The second surface of the sheet of conductive metal may be coated with a separator layer.

[0014] The separator layer may comprise one of: flexible modified silicone and polyimide adhesive tape.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] In order that the invention may be fully understood and readily put into practical effect there shall now be described by way of non-limitative example only exemplary embodiments of the present invention, the description being with reference to the accompanying illustrative drawings, in which:

[0016] [FIG. 1] is a schematic illustration of an exemplary embodiment of an electrical energy storage device during discharge.

[0017] [FIG. 2] is a schematic illustration of different exemplary embodiments of a current collector of the present invention.

[0018] [FIG. 3] (prior art) is a schematic illustration of a prior art current collector.

[0019] [FIG. 4] is a flowchart of an exemplary method of fabricating the current collector of [FIG. 2].

[0020] [FIG. 5] is a schematic side view of an exemplary current collector having a separator layer coated thereon.

DETAILED DESCRIPTION

[0021] Exemplary embodiments of a current collector 90 of an electrical energy storage device 100 will be described below with reference to [FIG. 1] to [FIG. 5].

[0022] As shown in [FIG. 1], an exemplary electrical energy storage device 100 comprises two electrodes 10, 20 (a cathode 10 and an anode 20) separated by a volume of an electrolyte 30 that ionically connects the cathode 10 (negative electrode) with the anode 20 (positive electrode). In order to avoid shorting, an ion-permeable separator 40 may be provided in the volume of the electrolyte 30 between the cathode 10 and the anode 20 to prevent contact of the cathode 10 with the anode 20. Each electrode 10, 20 comprises a current collector 90 on which a supply of positive ions 50 is provided in contact with the electrolyte 30. The current collector 90 comprises a sheet of conductive metal, such as copper, nickel, aluminium, magnesium, for example. The sheet of conductive metal may be in the form of a metal foil, for example, aluminium foil, if aluminium is the metal used for the current collector 90.

[0023] Each current collector 90 is connected to a terminal 18, 28 of the electrical energy storage device 100. The terminals 18, 28 are provided for connection with an external circuit (not shown). The external circuit may include an external device that is to be powered by the electrical energy storage device 100, or may include an energy source to charge the electrical energy storage device 100. During discharge of the electrical energy storage device 100 when powering the external device, positive ions 50 at the cathode 10 (negative electrode) are released and move through the electrolyte 30 and the separator 40 towards the anode 20 (positive electrode), as indicated by the arrow in [FIG. 1]. This leaves behind electrons (not shown) that flow out of the cathode 10 via its connected terminal 18 to the external device that is being powered, towards the anode 20.

[0024] The electrical energy storage device 100 may comprise a lithium-ion battery cell, a sodium-ion battery cell, or a capacitor, for example. In the case of lithium-ion battery cells,

the supply of positive ions 50 at the cathode 10 (negative electrode) may comprise a coating of lithium provided in a carbon structure (such as graphite) on a first surface 92 of the current collector 90, while the supply of positive ions 50 at the anode 20 (positive electrode) typically comprises a coating of a lithium metal oxide such as lithium nickel oxide, lithium cobalt oxide, and/or lithium manganese oxide on the first surface 92 of the current collector 90. In the case of sodium-ion battery cells, the supply of positive ions 50 at the electrodes 10, 20 comprises sodium ions.

[0025] In order to increase the charge storage capacity of the electrical energy storage device 100, the amount of positive ions 50 in the device 100 needs to be increased. While it is possible to increase the charge storage capacity by simply increasing the size of the current collector 90 so that it can support more positive ions 50 overall, this will increase the size of the electrical energy storage device 100, which is not desirable.

[0026] In the present invention, increasing the amount of positive ions 50 that can be provided in the electrical energy storage device 100 is achieved by increasing the surface area of the first surface 92 of the current collector 90 so that more positive ions 50 can be provided on the current collector 90 without increasing the area or size of the current collector 90 or the electrode 10, 20. Increasing the surface area of the current collector 90 is achieved by modifying the first surface 92 of the current collector 90 on which the positive ions 50 are coated. In this way, it is possible to increase the amount of positive ions 50 provided in the electrical energy storage device 100 without changing the dimensions of the current collectors 90 or the electrodes 10, 20, so that the size of the electrical energy storage device 100 itself can remain the same while its charge storage capacity is increased.

[0027] Exemplary embodiments of the current collector 90 having a modified first surface 92 with increased surface area are shown in [FIG. 2]. The modified first surface 92 has a three-dimensional structure and may comprise grooves 81 or 82 formed on the first surface 92 as shown in [FIGS. 2(a) and 2(b)]. The grooves 81, 82 can have different cross-sectional profiles according to how they are made. For example, the grooves 81 in the first surface 92 of [FIG. 2(a)] have a flat bottom surface and may be made with a cutting tool having a flat tip, whereas the grooves 82 in the first surface 92 of [FIG. 2(a)] may be made using a cutting tool having a rounded tip so that the bottom surface has a radiused contour. Although not

shown, grooves may also be made on the first surface 92 in different directions to give a hatched effect. Alternatively, the first surface 92 may be processed to comprise a plurality of blind holes as shown in [FIG. 2(c)], or processed to comprise a plurality of protrusions 84 as shown in [FIG. 2(d)]. [FIG. 2(e)] shows a chemically etched first surface 92. [FIGS. 2(f) and 2(g)] show modified first surfaces 92 having a plurality of differently shaped grooves 81, 82 that has also been chemically etched. [FIG. 2(h)] shows a modified first surface 92 having a plurality of blind holes that has also been chemically etched. [FIG. 2(i)] shows a modified first surface 92 having a plurality of protrusions 84 that has also been chemically etched. Appreciably, different parts of the modified first surface 92 may be selectively etched. The different ways of modifying the first surface 92 may also be combined in various combinations to increase the surface area of the modified first surface 92. As can be seen, the modified first surface 92 of the current collector 90 provides a three-dimensional structure with increased surface area for supporting the positive ions thereon when compared to the relatively flat and smooth surface of a conventional current collector of the same size.

[0028] In particular, as the positive ions may be provided in particulate form as one or more of the lithium metal oxides or sodium metal oxides, the three-dimensional structure of the modified first surface 92 advantageously traps and holds the particles more effectively than a smooth and flat surface, and also establishes more surface area contact between the modified first surface 92 and the particles containing the positive ions. Notably, the choice of modification that is made to the first surface 92 may be selected to accord with the particle shape and size of the positive ions that will be provided on it. For example, where the particles are known to be generally spherical, the modified first surface 92 may comprise a three-dimensional structure with radiused surfaces, such as that shown in [FIGS. 2(b), 2(c), 2(g) and 2(h)]. Where the particles have irregular shapes with flat sides, the modified first surface 92 having a three-dimensional structure comprising a plurality of flat surfaces at different angles to each other such as that shown in [FIGS. (2(a) and 2(f)) may be preferred. Matching the type of surface modification with the particle shape increases the contact area between the modified first surface 92 of the current collector 90 with the positive ions 50, so that not only are more positive ions 50 provided on the current collector 90, conductivity is also improved as a result of the increased contact area between the current collector 90 and the positive ions 50.

[0029] To increase its surface area, the first surface 92 of the current collector 90 may be modified by one or more mechanical, optical, plasma and/or chemical methods. Such methods may include chemical etching, optical etching with a laser beam, plasma etching, embossing with a mechanical forming or pressing machine, or mechanical cutting using one or more cutting tools such as an end mill, a drill, a CNC machine, a water jet cutter, for example. [FIG. 4] depicts an exemplary method 200 of fabricating the current collector 90 having a modified first surface 92 with increased surface area. In a first step 210, a sheet of conductive metal that has a relatively smooth and flat surface as shown in [FIG. 3] (prior art) is provided. A surface of the sheet of conductive metal is then modified by at least one of: a mechanical process, an optical process, a plasma process and a chemical process to create a modified first surface 92 having a three-dimensional structure with increased surface area 220. In an exemplary embodiment, the first surface 92 may be modified by first performing a cutting operation on the first surface 92 to create a three-dimensional structure, followed by chemical etching of the three-dimensional structure to form the modified first surface 92. Alternatively, the first surface 92 may be laser-etched or plasma-etched after performing the cutting operation on the first surface 92.

[0030] Subsequently, coating the positive ions 50 onto the modified first surface 92 of the current collector 90 using conventional coating methods accordingly fabricates the electrode (that may be an cathode 10 or a anode 20 as may be desired) of the electrical energy storage device.

[0031] By modifying the first surface 92 of the current collector 90 as described above, the surface area of the modified first surface 92 is increased beyond its geometric area as calculated from the dimensions and shape of the current collector 90. For example, a current collector that is a rectangular sheet of copper having a length of 4 cm a width of 2cm has a geometric area of 8 cm^2. However, by modifying the surface of this sheet of copper using the methods described above, the surface area of the modified first surface 92 can be increased significantly beyond its geometric area of 8cm^2.

[0032] Preferably, modifying the first surface 92 of the current collector 90 is performed without resulting in through holes being made in the current collector 90. In this way, mechanical strength of the current collector 90 is retained for ease of handling and application

of the current collector 90 onto a substrate (not shown) that is provided to support the current collector 90 in the electrical energy storage device.

[0033] In addition to modifying the first surface 92 of the current collector 90 to increase its surface area, a second surface 94 of the current collector 90 may optionally be coated with a separator layer 80 as shown in [FIG. 5]. The separator layer 80 may comprise a layer of flexible modified silicone, or polyimide adhesive tape applied on the second surface 94 of the current collector 90, for example. Providing the separator layer 80 on the current collector 90 serves to strengthen the sheet of conductive metal that forms the current collector 90. The separator layer 80 also provides an insulating function, thereby eliminating the need to provide separators between multiple units of the electrical energy storage device in certain applications. For example, where the electrical energy storage device comprises a battery cell or a capacitor, providing the separator layer 80 on the second surface 94 of the current collector 90 eliminates the need to provide separators between adjacent battery cells in a battery or between adjacent capacitor layers. In this way, useful electrical contact area of the battery or capacitor is increased, thereby increasing its electrical power.

[0034] As conventional conductive metal sheets and surface processing methods may be used to fabricate 100 the above-disclosed current collector 90 without requiring use of costly specialised materials and processes, the above-disclosed current collector 90 and its method of fabrication 100 thereof thus provide a cost effective and efficient way to increase charge storage capacity of an electrical energy storage device without increasing its size.

[0035] While there has been described in the foregoing description exemplary embodiments of the present invention, it will be understood by those skilled in the technology concerned that many variations in details of design, construction and/or operation may be made without departing from the present invention

CLAIMS

[Claim 1] A current collector for an electrode of an electrical energy storage device, the current collector comprising:

a sheet of conductive metal having a modified first surface for providing positive ions thereon to be in contact with an electrolyte in the electrical energy storage device,

wherein the modified first surface has a three-dimensional structure with increased surface area.

[Claim 2] The current collector of claim 1, wherein the three-dimensional structure comprises at least one of: a plurality of grooves, a plurality of blind holes, a plurality of protrusions and at least one of: a chemically-etched surface, an optically-etched surface, and a plasma-etched surface.

[Claim 3] The current collector of claim 1 or claim 2, wherein a second surface of the sheet of conductive metal is coated with a separator layer.

[Claim 4] The current collector of any one of the preceding claims, wherein the separator layer comprises one of: flexible modified silicone and polyimide adhesive tape.

[Claim 5] A method of fabricating a current collector for an electrode of an electrical energy storage device, the method comprising:

a) providing a sheet of conductive metal; and

b) modifying a first surface of the sheet of conductive metal using at least one of: a mechanical process, an optical process, a plasma process and a chemical process to create a modified first surface having a three-dimensional structure with increased surface area.

[Claim 6] The method of claim 5, wherein step b) comprises performing a cutting operation on the first surface of the sheet of conductive metal to create the three-dimensional structure followed by one of: chemical etching, laser etching and plasma etching of the three-dimensional structure.

[Claim 7] The method of claim 5 or claim 6, further comprising the step of:
c) coating a separator layer on a second surface of the sheet of conductive metal.

[Claim 8] The method of claim 7, wherein the separator layer comprises one of: flexible modified silicone and polyimide adhesive tape.

[Claim 9] The method of any one of claims 5 to 9, wherein the three-dimensional structure comprises at least one of: a plurality of grooves, a plurality of blind holes, a plurality of protrusions and further comprises one of: a chemically-etched surface, an optically-etched surface and a plasma-etched surface.

[Claim 10] An electrode for an electrical energy storage device, the electrode comprising:
a current collector comprising a sheet of conductive metal having a modified first surface for providing positive ions thereon to be in contact with an electrolyte in the electrical energy storage device, wherein the modified first surface has a three-dimensional structure with increased surface area;
a substrate provided to support the current collector thereon; and
a coating of the positive ions provided on the modified first surface of the current collector.

[Claim 11] The electrode of claim 10, wherein the three-dimensional structure comprises at least one of: a plurality of grooves, a plurality of blind holes, a plurality of protrusions and further comprises one of: a chemically-etched surface, an optically-etched surface and a plasma-etched surface.

[Claim 12] The electrode of claim 10 or claim 12, wherein a second surface of the sheet of conductive metal is coated with a separator layer.

[Claim 13] The electrode of any one of claims 10 to 12, wherein the separator layer comprises one of: flexible modified silicone and polyimide adhesive tape.

[Claim 14] An electrical energy storage device comprising:

two electrodes separated by an electrolyte; wherein at least one of the two electrodes comprises:

a current collector comprising a sheet of conductive metal having a modified first surface for providing positive ions thereon to be in contact with the electrolyte, wherein the modified first surface has a three-dimensional structure with increased surface area;

a substrate provided to support the current collector thereon; and

a coating of the positive ions provided on the modified first surface of the current collector in contact with the electrolyte.

[Claim 15] The electrical energy storage device of claim 14, wherein the three-dimensional structure comprises at least one of: a plurality of grooves, a plurality of blind holes, a plurality of protrusions and further comprises one of: a chemically-etched surface, an optically-etched surface and a plasma-etched surface.

[Claim 16] The electrical energy storage device of claim 14 or claim 15, wherein a second surface of the sheet of conductive metal is coated with a separator layer.

[Claim 17] The electrical energy storage device of any one of claims 14 to 16, wherein the separator layer comprises one of: flexible modified silicone and polyimide adhesive tape.