FORM 2

THE PATENT ACT, 1970

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THE PATENT RULES, 2003

COMPLETE SPECIFICATION

[SEE SECTION 10 AND RULE 13]

TITLE: METHOD AND SYSTEM FOR IMPLEMENTING DRY ELECTRODE MANUFACTURING TECHNIQUES FOR EFFICIENT LITHIUM-ION BATTERIES	
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The following specification particularly describes the invention and the manner in which it is to be performed

METHOD AND SYSTEM FOR IMPLEMENTING DRY ELECTRODE MANUFACTURING TECHNIQUES FOR EFFICIENT LITHIUM-ION BATTERIES

FIELD OF THE INVENTION

[0001] The present invention generally relates to manufacturing lithium ion batteries. More particularly, the method and system relates to implementing dry electrode manufacturing techniques in lithium-ion batteries.

BACKGROUND OF THE INVENTION

[0002] Lithium-ion battery is a new-type high-energy battery that uses a lithium-intercalation compound as the positive and negative materials, which has many advantages such as high specific energy, high voltage, low self-discharge, good cycle performance and long service life. At present, manufacture of the lithium-ion pole piece is usually carried out by coating, solvent drying, rolling and the like. The process is complicated, and the resultant pole piece has a relatively thin thickness (not more than 300 μm on one side), and the electrode active material carried on the unit area is limited. Moreover, once the electrode material is detached from the current collector and loses electrical connection during battery use, the performance of the battery will significantly deteriorate.

[0003] The problems of efficiency and cost of lithium-ion batteries when used in the field of electric vehicles and large-scale energy storage raise higher demands on the capacity of battery cell. In addition, due to the influence of the electrode material structure, electrolyte properties, etc., side reactions may occur during the use of lithium-ion batteries, resulting in the consumption of electrolyte and active lithium, and the formation and unstable changes of the SEI film on the surface of the electrode material and the current collector. They may cause problems such as battery swelling, internal resistance increasing and so on, and the design of conventional lithium-ion battery structures is difficult to solve such problems.

[0004] Electrical energy storage cells are widely used to provide power to electronic, electromechanical, electrochemical, and other useful devices. Such cells include batteries such as primary chemical cells and secondary (rechargeable) cells, fuel cells, and various species of capacitors, including ultra-capacitors. Increasing the operating power and energy of energy storage devices, including capacitors and batteries, would be desirable for enhancing energy storage, increasing power capability, and broadening real-world use cases.

[0005] Energy storage devices including electrode films combining complimentary attributes may increase energy storage device performance in real-world applications. Furthermore, existing methods of fabrication may impose a practical limit to various structural electrode properties. Thus, new electrode film formulations, and methods for their fabrication, may result in improved performance. Additionally, novel combinations of electrode films may reveal combinations that provide improved performance to an energy storage device.

BRIEF DESCRIPTION OF FIGURES

[0006] FIG. 1 is an illustration of dry lithium battery in accordance with an embodiment of the present invention;

[0007] FIG. 2 is an illustration of schematic representation of the dry lithium battery in accordance with another embodiment of the present invention;

[0008] FIG. 3 is an illustration of pole piece of dry lithium battery in accordance with another embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0009] For purposes of summarizing the disclosure and the advantages achieved over the prior art, certain objects and advantages of the disclosure are described herein. Not all such objects or advantages may be achieved in any particular embodiment. Thus, for example, those skilled in the art will recognize that the invention may be embodied or carried out in a manner that achieves or optimizes one advantage or group of advantages as taught herein without necessarily achieving other objects or advantages as may be taught or suggested herein.

[0010] FIG. 1 is a schematic representation of the dry cell for lithium battery according to the first Example of the present disclosure. The cell-core of the lithium battery comprises several positive electrode pieces 2 and negative electrode pieces 3 that overlap alternately. There is a separating space 4 with a height (h) of 0.1 to 1 mm provided between the positive electrode piece 2 and the negative electrode piece 3, and the separating space 4 may be filled with electrolyte. The positive electrode piece 2 comprises a positive electrode grid 207 having a through-hole grid unit, a cathode surface current-collecting layer 204, and an electric-conductive cathode layer consisting of a first electric-conductive cathode layer 202 and a second electric-conductive cathode layer 203.

[0011] The electric-conductive cathode particles of the first electric-conductive cathode layer 202 penetrate into the pores of the cathode surface current-collecting layer 204, and the second electric-conductive cathode layer 203 is located between the two first electric-conductive cathode layers 202. The second electric-conductive cathode layer 203 comprises electric-conductive cathode particles without adhesive bonding. The negative electrode piece 3 comprises a first anode current-collecting layer 304 and an electric-conductive lithium-inter anode layer 301, and the electric-conductive lithium-inter anode layer 301 comprises electric-conductive lithium-inter anode particles without adhesive bonding.

[0012] FIG. 2 is a schematic representation of the dry cell for lithium battery according to the second Example of the present disclosure. The cell-core of the lithium battery includes a plurality of positive electrode pieces, a plurality of negative electrode pieces, and separating layer 5 between the positive electrode piece and the negative electrode piece. Therein, the plurality of negative electrode pieces and the plurality of positive electrode pieces are stacked alternatively to form a dry cell. In this example, the positive electrode piece is a multi-grid positive electrode piece 206, and the negative electrode piece is a lithium-containing metal body 302. The multi-grid positive electrode piece 206 comprises a cathode surface current-collecting layer 204 and a positive electrode grid 207, and the cathode surface current-collecting layer 204 is in close electrical contact with the positive electrode grid 207. The grid unit 208 of the positive electrode grid has a recesslike blind-hole structure, and the electric-conductive cathode particles are located in the grid unit 208 of the positive electrode grid 207.

[0013] FIG. 3 is a schematic representation of the dry cell for lithium battery according to the third Example of the present disclosure. The cell of the lithium battery comprises a plurality of positive electrode pieces, a plurality of negative electrode pieces, and separating layer 5 between the positive electrode piece and the negative electrode piece. Therein, the plurality of negative electrode pieces and the plurality of positive electrode pieces are stacked to form a dry cell. In this example, the positive electrode piece is a multi-grid positive electrode piece 206, and the negative electrode piece is a lithium-containing metal body 302. The multi-grid positive electrode piece 206 comprises a cathode surface current-collecting layer 204 and a positive electrode grid 207, and the cathode surface current-collecting layer 204 is in close electrical contact with the positive electrode grid 207. The grid unit 208 of the positive electrode grid has a through-hole structure, and the electric-conductive cathode particles are located in the grid unit 208 of the positive electrode grid 207.

[0014] Embodiments include batteries including an electrode made by a dry process that have a specific energy density of at least 250 Wh/kg, or an energy density of at least 600 Wh/L. Embodiments include dry electrode formulations and fabrication processes that achieve electrode films having a higher density of active materials, a greater electrode film thickness, a higher electrode film density, and/or a higher electronic density (for example, such as energy density, specific energy density, areal energy density, areal capacity and/or specific capacity). An electrode film with a higher electrode film density will generally include more active materials in a smaller electrode film volume. Specifically, smaller particle sizes and more intimate contact of active materials, binders, and additives may be realized in dry electrode processing.

[0015] Dry electrode processing methods traditionally used a high shear and/or high pressure processing step to break up and commingle electrode film materials, which may contribute to the structural advantages. In some embodiments, such dry electrode processes may enable electrode films with substantially higher electrode densities (about 1.55 g/cm3) and lower electrode porosities (about 26%) with high loadings compared to conventional wet slurry cast and compressed electrode process densities (about 1.3 g/cm3 or less) and porosities (about 37% or more). However, as seen in FIG. 22, electrodes made from traditional dry electrode processes provide electrode films with decreasing densities as electrode material loading is increased, which limit energy and power densities in high loading electrode cells. Some embodiments of the present disclosure provide dry fabrication methods and formulations for controlling electrode film densities (about 1.79 g/cm3) and porosities (about 16%) independently of electrode loading.

[0016] Formulations are modified by varying electrode material compositions, such as varying active materials, polymer binders and additives. Fabrication methods are modified through dry coating process parameters, such as calendering temperature, calendering pressure, calender roll gap, and number of passes. Embodiments utilizing such processes and compositions show significantly improved electrode film density at high loadings. In some embodiments, calendering may be performed at about ambient temperature. In some embodiments, high loadings and high electrode film densities are achieved without defects such as cracking and/or delamination of the electrode.

[0017] A dry or self-supporting electrode film as provided herein may provide improved characteristics relative to a typical electrode film. For example, a dry or self-supporting electrode film as provided herein may provide one or more of improved material loading or electrode material loading (which may be expressed as mass of electrode film per unit area of electrode film or current collector), improved active material loading (which may be expressed as mass of active material per unit area of electrode film or current collector), improved areal capacity (which may be expressed as capacity per unit area of electrode film or current collector), improved areal energy density (which may be expressed as energy per unit area of electrode film or current collector), improved specific energy density (which may be expressed as energy per unit mass of electrode film), or improved energy density (which may be expressed as energy per unit volume of electrode film). For further example, a dry or self-supporting electrode film as provided herein may provide improved efficiency.

[0018] Conditional language, such as “can,” “could,” “might,” or “may,” unless specifically stated otherwise, or otherwise understood within the context as used, is generally intended to convey that certain embodiments include, while other embodiments do not include, certain features, elements, and/or steps. Thus, such conditional language is not generally intended to imply that features, elements, and/or steps are in any way required for one or more embodiments or that one or more embodiments necessarily include logic for deciding, with or without user input or prompting, whether these features, elements, and/or steps are included or are to be performed in any particular embodiment.

[0019] Conjunctive language such as the phrase “at least one of X, Y, and Z,” unless specifically stated otherwise, is otherwise understood with the context as used in general to convey that an item, term, etc. may be either X, Y, or Z. Thus, such conjunctive language is not generally intended to imply that certain embodiments require the presence of at least one of X, at least one of Y, and at least one of Z.

[0020] Language of degree used herein, such as the terms “approximately,” “about,” “generally,” and “substantially” as used herein represent a value, amount, or characteristic close to the stated value, amount, or characteristic that still performs a desired function or achieves a desired result. For example, the terms “approximately”, “about”, “generally,” and “substantially” may refer to an amount that is within less than 10% of, within less than 5% of, within less than 1% of, within less than 0.1% of, and within less than 0.01% of the stated amount, depending on the desired function or desired result.

[0021] The headings provided herein, if any, are for convenience only and do not necessarily affect the scope or meaning of the devices and methods disclosed herein.

[0022] The scope of the present disclosure is not intended to be limited by the specific disclosures of preferred embodiments in this section or elsewhere in this specification, and may be defined by claims as presented in this section or elsewhere in this specification or as presented in the future. The language of the claims is to be interpreted broadly based on the language employed in the claims and not limited to the examples described in the present specification or during the prosecution of the application, which examples are to be construed as non-exclusive.

I/WE CLAIM:

1. A method for implementing dry electrode technique for an efficient lithium ion battery, comprising:

a dry active material; and

a dry binder;

wherein the dry electrode wafer is free-standing, and

wherein the dry electrode wafer is greater than 90 µm in its dimension.

2. The dry electrode technique for lithium ion battery as claimed in claim 1, wherein the electrode wafer porosity of the dry electrode wafer is at most about 15%.

3. The dry electrode technique for lithium ion battery as claimed in claim 1, wherein the electrode wafer is at least 0.4 g/cm3 in electrode wafer density.

4. The dry electrode technique for lithium ion battery as claimed in claim 1, wherein the electrode material loading of the electrode film is at least about 40 mg/cm2.

5. The dry electrode film for lithium ion battery as claimed in claim 1, wherein the dry electrode film is used to make lithium ion batteries.

ABSTRACT

METHOD AND SYSTEM FOR IMPLEMENTING DRY ELECTRODE MANUFACTURING TECHNIQUES FOR EFFICIENT LITHIUM-ION BATTERIES

The present invention provides an approach for implementing dry electrode manufacturing techniques for providing improved lithium-ion batteries. The present invention provides energy storage devices such as batteries comprising at least one dry process, self-supporting electrode film having improved operation. The improved operation may be realized as improved electrode material loading, improved active material loading, improved active material density, improved areal capacity, improved specific capacity, improved areal energy density, improved energy density, improved specific energy density, or improved efficiency.