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CYLINDRICAL BATTERY AND ELECTRIC APPARATUS INCLUDING CYLINDRICAL BATTERY

Abstract

A cylindrical battery and an electric apparatus, including an electrode assembly. The electrode assembly includes a positive electrode plate, a separator, and a negative electrode plate stacked and wound together. The positive electrode plate includes a positive current collector. The positive current collector has a first surface, the first surface is provided with an active material layer, an insulation layer, and an uncoated foil area arranged in order along an axial direction of the cylindrical battery. The electrode assembly further includes a flattened part, the flattened part being formed by bending and overlapping the uncoated foil area towards a central axis of winding of the electrode assembly and having a flattened surface. The insulation layer provides support for the positive current collector, preventing a short circuit caused by the flattened part folding over to exceed the separator and contact the negative electrode plate.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS [0001] This application is a continuation application of the International Application No. PCT/CN2023/129863, filed on Nov. 6, 2023, which claims the benefit of priority of Chinese patent application 202211379212.6, filed on Nov. 4, 2022, the contents of which are incorporated herein by reference in its entirety.

TECHNICAL FIELD
[0002] This application relates to the field of energy storage apparatuses, and in particular, to a cylindrical battery and an electric apparatus including a cylindrical battery.
BACKGROUND
[0003] In the production process of full-tab batteries (such as cylindrical batteries), a tab flattening process is required. The tab flattening process involves pressing down the originally upright tabs to make them contact each other, enhancing the current collection. Moreover, the flattened tabs lie in the same plane, facilitating subsequent welding work of the current collection plate. However, in existing full-tab batteries, the positive electrode tabs tend to fold over and contact the negative electrode active layer after flattening, causing a short circuit.
SUMMARY
[0004] An objective of this application is to provide a cylindrical battery and an electric apparatus including such cylindrical battery, so as to reduce a risk of short circuits.
[0005] A first aspect of this application provides a cylindrical battery including an electrode assembly. The electrode assembly includes a positive electrode plate, a separator, and a negative electrode plate stacked and wound together. The positive electrode plate includes a positive current collector. The positive current collector has a first surface; the first surface is provided with an active material layer, an insulation layer, and an uncoated foil area arranged in order along an axial direction of the cylindrical battery. The uncoated foil area is bended towards a central winding axis of the electrode assembly to form a flattened part; and the flattened part having a flattened surface.
[0006] The cylindrical battery provided in this application having the insulation layer enhances hardness of the positive current collector on a part where the insulation layer is disposed. The insulation layer provides support for the positive current collector on the part, preventing a short circuit caused by the flattened part folding over to exceed the separator and contact the negative electrode plate.
[0007] According to some embodiments of this application, along the axial direction of the cylindrical battery, a height L of the flattened part is 0.2 mm to 4 mm. When the height L of the flattened part is less than 0.2 mm, a stacked area of the flattened part is severely compressing the insulation layer and may cause the insulation layer to rupture. As a result, the insulation layer cannot support and protect well the positive current collector. When the height L of the flattened part is greater than 4 mm, the uncoated foil area is barely flattened, and thus the uncoated foil area

that is flattened (the flattened part) is prone to rebound up.
[0008] According to some embodiments of this application, along the axial direction of the cylindrical battery, a height W of the insulation layer is 1 mm to 5 mm. When the height W of the insulation layer is less than 1 mm, the insulation layer is too narrow (the height is too small). In this case, application of the insulation layer may be incomplete due to unstable capability of a coating process, and thus the insulation layer cannot support and protect well the positive current collector. Moreover, a larger height W of the insulation layer indicates higher energy density loss for the cylindrical battery.
[0009] According to some embodiments of this application, the height W of the insulation layer is 1.5 mm to 5 mm. In this way, sufficient support strength provided by the insulation layer for the positive current collector can be guaranteed while guaranteeing stable capability of the insulation layer coating process.
[0010] According to some embodiments of this application, the insulation layer has a thickness h, and the active material layer has a thickness H, where $0.1\ H \le h \le H$. When $h < 0.1\ H$, the insulation layer is too thin. In this case, application of the insulation layer may be incomplete due to unstable capability of the coating process, and thus the insulation layer cannot support and protect well the positive current collector.
[0011] According to some embodiments of this application, $0.2\ H \le h \le 0.9\ H$. As a result, sufficient support strength provided by the insulation layer for the positive current collector can be guaranteed while guaranteeing stable capability of the insulation layer coating process. When $h > 0.9\ H$, the insulation layer is too thick. In this case, because the insulation layer has certain hardness and brittleness, it may rupture under a flattening stress, and thus cannot support and protect well the positive current collector.
[0012] According to some embodiments of this application, H is 50 μm to 100 μm.
[0013] According to some embodiments of this application, the positive current collector further includes a second surface opposite to the first surface, and the active material layer, the insulation layer, and the uncoated foil area are also arranged on the second surface.
[0014] According to some embodiments of this application, the insulation layer includes inorganic particles, the inorganic particles including at least one of aluminum oxide, zinc oxide, calcium oxide, silicon dioxide, zirconium oxide, magnesium oxide, titanium oxide, hafnium dioxide, tin oxide, cerium dioxide, nickel oxide, yttrium oxide, silicon carbide, alumina hydroxide, magnesium hydroxide, calcium hydroxide, barium sulfate, or boehmite.
[0015] A second aspect of this application further provides an electric apparatus including the cylindrical battery described above.

Description

BRIEF DESCRIPTION OF DRAWINGS
[0016] The above and/or additional aspects and advantages of this application will become obvious and easy to understand from the description of the embodiments with reference to the following drawings.
[0017] FIG. **1** is a schematic diagram of a cylindrical battery provided in an embodiment of this application;
[0018] FIG. **2** is a cross-sectional view of the cylindrical battery in FIG. **1** along II-II;
[0019] FIG. **3** is a schematic diagram of an expanded electrode assembly provided in an embodiment of this application;
[0020] FIG. **4** is a cross-sectional view of a positive electrode plate provided in an embodiment of this application; and
[0021] FIG. **5** is a cross-sectional view of a positive electrode plate provided in another

embodiment of this application.
[0022] Cylindrical battery **100** [0023] Electrode assembly **10** [0024] Positive electrode plate **20** [0025] Negative electrode plate **30** [0026] Separator **40** [0027] Positive current collector **21** [0028] Active material layer **22** [0029] Insulation layer **23** [0030] First surface **21***a* [0031] Second surface **21***b* [0032] Uncoated foil area **24**, **31***a* [0033] Flattened part **101** [0034] Flattened surface **102** [0035] First end **211** [0036] Second end **212** [0037] Negative current collector **31** [0038] Negative electrode active material layer **32**

DETAILED DESCRIPTION

[0039] The following clearly describes technical solutions in some embodiments of this application in detail. Apparently, the described embodiments are some rather than all of the embodiments of this application. Unless otherwise defined, all technical and scientific terms used herein shall have the same meanings as commonly understood by those skilled in the art to which this application relates. The terms used herein are intended to merely describe specific embodiments rather than to limit this application.
[0040] The following describes some embodiments of this application in detail. However, this application may be embodied in many different implementations and should not be construed as being limited to the example embodiments set forth herein. Rather, these example embodiments are provided so that this application can be conveyed to those skilled in the art thoroughly and in detail.
[0041] In addition, in the accompanying drawings, sizes or thicknesses of various components and layers may be exaggerated for brevity and clarity. Throughout the text, the same numerical values represent the same elements. As used herein, the term “and/or” includes any and all combinations of one or more of the associated listed items. In addition, it should be understood that when an element A is referred to as being “connected to” an element B, the element A may be directly connected to the element B or an intervening element C may be present therebetween such that the element A and the element B are indirectly connected to each other.
[0042] Further, the use of “may” when describing some embodiments of this application relates to “one or more embodiments of this application.”
[0043] The terminology used herein is merely intended to describe specific embodiments rather than to limit this application. As used herein, the singular forms are intended to include the plural forms as well, unless the context clearly indicates otherwise. It should be further understood that the terms “comprise” or “include” and variations thereof, when used in this specification, specify the presence of stated features, numbers, steps, operations, elements, and/or components but do not preclude the presence or addition of one or more other features, numbers, steps, operations, elements, components, and/or groups thereof.
[0044] Spatial related terms such as “above” may be used herein for ease of description to describe the relationship between one element or feature and another element (a plurality of elements) or feature (a plurality of features) as illustrated in the figures. It should be understood that the spatial terms are intended to encompass different orientations of a device or an apparatus in use or operation in addition to the orientations depicted in the figures. For example, if a device in a figure is turned over, elements described as “over” or “above” other elements or features would then be oriented “beneath” or “below” the other elements or features. Thus, the example term “above” may include both orientations of above and below. It should be understood that although the terms first, second, third, or the like may be used herein to describe various elements, components, areas, layers, and/or parts, these elements, components, areas, layers, and/or parts should not be limited by these terms. These terms are used to distinguish one element, component, area, layer, or parts from another element, component, area, layer, or part. Therefore, a first element, component, area, layer, or part discussed below may be referred to as a second element, component, area, layer, or part without departing from the teachings of the example embodiments.
[0045] Referring to FIGS. **1** and **2**, an embodiment of this application provides a cylindrical battery

100 including an electrode assembly **10** and a housing (not shown). The housing is approximately columnar in shape, for example, cylindrical, elliptic-cylindrical, square-cylindrical, and the like. The electrode assembly **10** is accommodated in the housing and has a shape fitting the housing. For example, the electrode assembly **10** may be cylindrical, elliptic-cylindrical, or square-cylindrical. The housing is made of a conductive material, such as a metal material. The electrode assembly **10** includes a positive electrode plate **20**, a negative electrode plate **30**, and a separator **40** configured between the positive electrode plate **20** and the negative electrode plate **30**. In the electrode assembly **10**, the positive electrode plate **20**, the separator **40**, and the negative electrode plate **30** are stacked and wound together. That is, the electrode assembly **10** is formed by stacking the positive electrode plate **20**, the separator **40**, and the negative electrode plate **30** in order and then winding them.

[0046] Referring to FIGS. **2** and **4**, the positive electrode plate **20** includes a positive current collector **21**, an active material layer **22**, and an insulation layer **23**, where the active material layer **22** and the insulation layer **23** are arranged on the positive current collector **21**. The positive current collector **21** includes a first surface **21***a* and a second surface **21***b* arranged opposite to each other. The active material layer **22** and the insulation layer **23** are arranged on the first surface **21***a*. The first surface **21***a* includes an uncoated foil area **24** not covered by the active material layer **22** or the insulation layer **23**. The uncoated foil area **24** is a part of the positive current collector **21** and is used as a positive electrode tab. The active material layer **22**, the insulation layer **23**, and the uncoated foil area **24** are arranged in order on the first surface **21***a* along an axial direction X of the cylindrical battery **100**, and the insulation layer **23** connects the active material layer **22** to the uncoated foil area **24**.

[0047] The active material layer **22**, the insulation layer **23**, and the uncoated foil area **24** are also arranged on the second surface **21***b*. The active material layer **22**, the insulation layer **23**, and the uncoated foil area **24** on the second surface **21***b* are arranged in order along the axial direction X of the cylindrical battery **100**, and the insulation layer **23** connects the active material layer **22** to the uncoated foil area **24**. The positions of the active material layer **22**, the insulation layer **23**, and the uncoated foil area **24** on the first surface **21***a* may correspond to the positions of the active material layer **22**, the insulation layer **23**, and the uncoated foil area **24** on the second surface **21***b*, respectively. The positions are not limited by this application. In other embodiments, the active material layer **22**, the insulation layer **23**, and the uncoated foil area **24** may be arranged only on the first surface **21***a* or the second surface **21***b*.

[0048] On the first surface **21***a* or the second surface **21***b*, the insulation layer **23** and the active material layer **22** are touching each other. That is, along the axial direction X of the cylindrical battery **100**, an edge of the insulation layer **23** is in contact with an edge of the active material layer **22**. Referring to FIG. **5**, in other embodiments, the insulation layer **23** on the first surface **21***a* or the second surface **21***b* may partially cover the active material layer **22** and connects to the active material layer **22**. That is, along a thickness direction Y of the electrode assembly **10**, the insulation layer **23** partially overlaps the active material layer **22**. The axial direction X of the cylindrical battery **100** is perpendicular to the thickness direction Y.

[0049] A material of the positive current collector **21** includes at least one of Ni, Ti, Cu, Ag, Au, Pt, Fe, Al, or combinations thereof. The active material layer **22** may include at least one of lithium cobalt oxide, lithium manganate oxide, lithium nickel oxide, lithium nickel cobalt manganate oxide, lithium iron phosphate, lithium manganese iron phosphate, lithium vanadium phosphate, lithium vanadium oxide phosphate, lithium-rich manganese-based material, lithium nickel cobalt aluminum oxide, or combinations thereof.

[0050] Referring to FIGS. **1** and **2**, the electrode assembly **10** further includes a flattened part **101**. The flattened part **101** is formed through a flattening process performed on the uncoated foil area **24**, that is, by bending the uncoated foil area **24** towards a central winding axis OO′ of the electrode assembly **10**. The flattened part **101** is formed by bending and overlapping the uncoated foil area

24 is bended towards the central winding axis of the electrode assembly **10** to form a flattened part **101**, the flattened part **101** has a flattened surface **102**. The flattened surface **102** of the flattened part **101** is formed at an end of the axial direction X of the cylindrical battery **100**. The flattened surface **102** is approximately a flat surface and is configured to connect a current collector plate (not shown). It should be noted that the "flat surface" in this application indicates not only a completely flat surface, but also a surface that is uneven or rough to the extent that the uncoated foil area **24** and the current collector plate can be joined.

[0051] The insulation layer **23** provided in this application enhances hardness of the positive current collector **21** on a part where the insulation layer **23** is disposed. The insulation layer **23** provides support for the positive current collector **21** on the part, preventing a short circuit caused by the flattened part **101** folding over to exceed the separator **40** and contact the negative electrode plate **30**.

[0052] In some embodiments, the insulation layer **23** includes inorganic particles and a binder, the inorganic particles including at least one of aluminum oxide, zinc oxide, calcium oxide, silicon dioxide, zirconium oxide, magnesium oxide, titanium oxide, hafnium dioxide, tin oxide, cerium dioxide, nickel oxide, yttrium oxide, silicon carbide, alumina hydroxide, magnesium hydroxide, calcium hydroxide, barium sulfate, or boehmite. The binder is selected from at least one of polyvinylidene fluoride, vinylidene fluoride-hexafluoropropylene copolymer, polyamide, polyacrylonitrile, polyacrylate, polyacrylic acid, polyacrylate salt, polyvinylpyrrolidone, polymethyl methacrylate, polytetrafluoroethylene, or polyhexafluoropropylene. Presence of the inorganic particles enhances the hardness of the insulation layer **23**, thereby improving the support effect for the flattened part **101**.

[0053] Referring to FIG. **3**, along the axial direction X of the cylindrical battery **100**, a height of the flattened part **101** is L. In some embodiments, L is 0.2 mm to 4 mm. When L is less than 0.2 mm, a stacked area of the flattened part **101** is severely compressing the insulation layer **23** and may cause the insulation layer **23** to rupture. As a result, the insulation layer **23** cannot support and protect well the positive current collector **21**. When Lis greater than 4 mm, the uncoated foil area **24** is barely flattened, and thus the uncoated foil area **24** that is flattened (the flattened part **101**) is prone to rebound up. Moreover, the larger L is, the more the cylindrical battery **100** loses energy density. For example, when the cylindrical battery **100** has a height of 70 mm, the energy density decreases by 5.4% when L=4 mm compared to when L=0.2 mm.

[0054] Referring to FIGS. **3** and **4**, along the axial direction X of the cylindrical battery **100**, a height of the insulation layer **23** on the first surface **21*a*** or the second surface **21*b*** is W. In some embodiments, W is 1 mm to 5 mm. When W is less than 1 mm, the insulation layer **23** is too narrow (the height is too small). In this case, application of the insulation layer **23** may be incomplete due to unstable capability of a coating process, and thus the insulation layer **23** cannot support and protect well the positive current collector **21**. Moreover, the larger W is, the more the cylindrical battery **100** loses energy density. For example, when the height of the cylindrical battery **100** is 70 mm, the energy density decreases by 5.7% when W=5 mm compared to when W=1 mm.

[0055] In some embodiments, W is 1.5 mm to 5 mm. As a result, sufficient support strength provided by the insulation layer **23** for the positive current collector **21** can be guaranteed while guaranteeing stable capability of the coating process for the insulation layer **23**.

[0056] Referring to FIG. **4**, along the thickness direction Y of the electrode assembly **10**, a thickness of the insulation layer **23** on the first surface **21*a*** or the second surface **21*b*** is h, and a thickness of the active material layer on the first surface **21*a*** or the second surface **21*b*** is H. In some embodiments, 0.1 H≤h≤H. When h<0.1 H, the insulation layer **23** is too thin. In this case, application of the insulation layer **23** may be incomplete due to unstable capability of the coating process, and thus the insulation layer **23** cannot support and protect well the positive current collector **21**.

[0057] In some embodiments, 0.2 H≤h≤0.9 H. As a result, sufficient support strength provided by the insulation layer **23** for the positive current collector **21** can be guaranteed while guaranteeing stable capability of the coating process for the insulation layer **23**. When h>0.9 H, the insulation layer **23** is too thick. In this case, because the insulation layer **23** has certain hardness and brittleness, it may rupture under a flattening stress, and thus cannot support and protect well the positive current collector **21**. In some embodiments, H is 50 μm to 100 μm.

[0058] Referring to FIGS. **3** and **4**, along a winding direction Z of the electrode assembly **10**, the positive current collector **21** includes a first end **211** and a second end **212** opposite to the first end **211**. The insulation layer **23** on the first surface **21***a* or the second surface **21***b* is arranged from the first end **211** to the second end **212**. In other words, in the winding direction Z of the electrode assembly **10**, the insulation layer **23** overlaps all the first surface **21***a* or the second surface **21***b* of the positive current collector **21**.

[0059] Referring to FIGS. **2** and **3**, the negative electrode plate **30** includes a negative current collector **31** and a negative electrode active material layer **32** arranged on the negative current collector **31**. The negative electrode active material layer **32** may be arranged on two surfaces opposite to each other or on only one surface of the negative current collector **31**, which is not limited by this application. The negative current collector **31** includes an uncoated foil area **31***a* not covered by the negative electrode active material layer **32**. The uncoated foil area **31***a* is used as a negative electrode tab and is connected to the housing. In some embodiments, the insulation layer **23** may also be arranged on the uncoated foil area **31***a* and cover a part of the uncoated foil area **31***a* to provide support for the negative current collector **31***a*. The insulation layer **23** may be arranged on the negative electrode plate **30** in the same manner as arranged on the positive electrode plate **20**. Details are not further described now.

[0060] A material of the negative current collector **31** may include at least one of Ni, Ti, Cu, Ag, Au, Pt, Fe, Al, or combinations thereof. A material of the negative electrode active material layer **32** may be selected from at least one of a graphite material, an alloy material, a lithium metal, or a lithium alloy. The graphite material may be selected from at least one of artificial graphite or natural graphite. The alloy material may be selected from at least one of silicon, silicon oxide, tin, or titanium sulfide.

[0061] The separator **40** is configured to prevent the positive electrode plate **20** and the negative electrode plate **30** from direct contact, thereby reducing the risk of short circuit caused by the positive electrode plate **20** contacting the negative electrode plate **30**. The separator **40** includes an insulating material selected from at least one of polypropylene, polyethylene, polyvinylidene fluoride, vinylidene fluoride-hexafluoropropylene copolymer, polymethylmethacrylate, or polyethylene glycol.

[0062] Some embodiments of this application also provide an electric apparatus including the cylindrical battery **100**. Specifically, the electric apparatus refers to a mobile phone, a portable device, a notebook computer, an electric bicycle, an electric vehicle, a ship, a spacecraft, an electric toy, an electric tool, or the like. It can be understood that the electric apparatus is not limited thereto, but may alternatively be any electric device using the cylindrical battery **100**.

[0063] The following will describe performance of the battery provided by this application in detail with reference to specific examples and comparative examples.

Example 1

[0064] An electrode assembly **10** shown in FIG. **2** was mounted into a housing, and then a finished battery was obtained after electrolyte injection. Therein, a height L of a flattened part **101** was 0.2 mm, a height W of an insulation layer **23** was 2 mm, a thickness h of the insulation layer **23** was 40 μm, and a thickness H of an active material layer **22** was 50 μm.

[0065] A Hi-pot test (insulation internal resistance test) was performed on the finished battery made in Example 1 by applying a voltage of 250 V, lasting for 2 seconds, between positive and negative electrode tabs of the electrode assembly **10** and testing the resistance. If the resistance is ≥20 MΩ (megohm), the Hi-pot test was considered to be passed. If the resistance <20 MΩ (megohm), the

Hi-pot test was considered to fail, and the battery was a Hi-pot-defective product.
Comparative Example 1

[0066] A finished battery approximately the same as that in Example 1 was made, with the difference that no insulation layer **23** was provided on a positive current collector **21** and an uncoated foil area **24** was directly connected to an active material layer **22**.

[0067] Examples 2 to 8 differ from Example 1 in the height L of the flattened part **101**.

[0068] Specific parameters and Hi-pot test results of Examples 1 to 8 and Comparative Example 1 are shown in Table 1.

TABLE-US-00001 TABLE 1 Hi-pot test L/mm W/mm h/μm H/μm pass rate Example 1 0.2 2 40 50 20/20 Example 2 0.6 2 40 50 20/20 Example 3 1 2 40 50 20/20 Example 4 2 2 40 50 20/20 Example 5 3 2 40 50 20/20 Example 6 4 2 40 50 20/20 Example 7 0.15 2 40 50 18/20 Example 8 5 2 40 50 20/20 Comparative 2.2 — — 50 10/20 Example 1 Note: X/20 indicates that X batteries out of 20 samples tested passed the Hi-pot test.

[0069] In Example 1 and Comparative Example 1, the same flattening process was employed to flatten the uncoated foil area **24** to make the flattened part **101**. Because no insulation layer **23** is arranged on the positive current collector **21** in Comparative Example 1, during flattening, the uncoated foil area **24** in Comparative Example 1 is more likely to fold over and come into contact with the negative electrode active layer, resulting in a short circuit and thereby causing the Hi-pot test to fail. According to Example 1 and Comparative Example 1, arranging the insulation layer **23** greatly increases the Hi-pot test pass rate and reduces the risk of short circuit.

[0070] According to Examples 1 to 8, when the height L of the flattened part **101** is 0.2 mm to 4 mm, the Hi-pot test pass rate is 100%. When the height L of the flattened part **101** is less than 0.2 mm, a stacked area of the flattened part **101** is severely compressing the insulation layer **23** and may cause the insulation layer **23** to rupture, leading to a low Hi-pot test pass rate. When the height L of the flattened part **101** is greater than 4 mm, although the Hi-pot test pass rate is 100%, energy density loss is relatively high.

[0071] Examples 9 to 14 differ from Example 2 in the height W of the insulation layer **23**. Specific parameters and Hi-pot test results are shown in Table 2.

TABLE-US-00002 TABLE 2 Hi-pot test L/mm W/mm h/μm H/μm pass rate Example 2 0.6 2 40 50 20/20 Example 9 0.6 1.2 40 50 16/20 Example 10 0.6 1.5 40 50 20/20 Example 11 0.6 3 40 50 20/20 Example 12 0.6 5 40 50 20/20 Example 13 0.6 0.8 40 50 13/20 Example 14 0.6 5.5 40 50 20/20

[0072] According to Table 2, when the height W of the insulation layer **23** is 1 mm to 5 mm, the Hi-pot test pass rate is relatively high; when the height W of the insulation layer **23** is 1.5 mm to 5 mm, the Hi-pot test pass rate is 100%. When W is less than 1 mm, application of the insulation layer **23** may be incomplete due to unstable capability of a coating process, reducing the Hi-pot test pass rate. When W is greater than 5 mm which is over-large, although the Hi-pot test pass rate is 100%, volumetric energy density loss of the battery is relatively high because more space is occupied.

[0073] Examples 15 to 21 differ from Example 2 in the ratio of the thickness h of the insulation layer **23** to the thickness H of the active material layer **22**. Specific parameters and Hi-pot test results are shown in Table 3.

TABLE-US-00003 TABLE 3 h/H Hi-pot test L/mm W/mm h/μm H/μm ratio pass rate Example 2 0.6 2 40 50 0.8 20/20 Example 15 0.6 2 20 50 0.4 20/20 Example 16 0.6 2 10 50 0.2 20/20 Example 17 0.6 2 30 50 0.6 20/20 Example 18 0.6 2 45 50 0.9 20/20 Example 19 0.6 2 5 50 0.1 15/20 Example 20 0.6 2 4 50 0.08 13/20 Example 21 0.6 2 50 50 1 17/20

[0074] According to Table 3, when $0.1\ H \leq h \leq H$, the Hi-pot test pass rate is relatively high and within an acceptable range; when $0.2\ H \leq h \leq 0.9\ H$, the Hi-pot test pass rate reaches 100%. When $h < 0.1\ H$, the insulation layer **23** is too thin and its application may be incomplete due to unstable capability of the coating process, reducing the Hi-pot test pass rate; when $h > 0.9\ H$, the insulation

layer **23** is too thick and may rupture under a flattening stress, reducing the Hi-pot test pass rate.
[0075] The descriptions disclosed above are only some preferred embodiments of this application, and certainly do not constitute limitation on this application. Accordingly, any equivalent changes made in accordance with this application still fall within the scope of this application.

Claims

1. A cylindrical battery comprising an electrode assembly; the electrode assembly comprising a positive electrode plate, a separator, and a negative electrode plate stacked and wound together; wherein, the positive electrode plate comprises a positive current collector, the positive current collector having a first surface; the first surface is provided with an active material layer, an insulation layer, and an uncoated foil area; wherein the active material layer, the insulation layer, and the uncoated foil area are arranged in order along an axial direction of the cylindrical battery; and the uncoated foil area is bended towards a central winding axis of the electrode assembly to form a flattened part; and the flattened part having a flattened surface.
2. The cylindrical battery according to claim 1, wherein along the axial direction of the cylindrical battery, a height L of the flattened part is 0.2 mm to 4 mm.
3. The cylindrical battery according to claim 1, wherein along the axial direction of the battery, a height W of the insulation layer is 1 mm to 5 mm.
4. The cylindrical battery according to claim 3, wherein the height W of the insulation layer is 1.5 mm to 5 mm.
5. The cylindrical battery according to claim 4, wherein the height W of the insulation layer is 1.5 mm to 3 mm.
6. The cylindrical battery according to claim 1, wherein the insulation layer has a thickness h, and the active material layer has a thickness H, $0.1\ H \leq h \leq H$.
7. The cylindrical battery according to claim 6, wherein $0.2\ H \leq h \leq 0.9\ H$.
8. The cylindrical battery according to claim 6, wherein H is 50 μm to 100 μm.
9. The cylindrical battery according to claim 6, wherein h is 10 μm to 45 μm.
10. The cylindrical battery according to claim 1, wherein the positive current collector further comprises a second surface opposite to the first surface; and the active material layer, the insulation layer, and the uncoated foil area are also arranged on the second surface.
11. The cylindrical battery according to claim 1, wherein the insulation layer comprises inorganic particles; the inorganic particles comprising at least one of aluminum oxide, zinc oxide, calcium oxide, silicon dioxide, zirconium oxide, magnesium oxide, titanium oxide, hafnium dioxide, tin oxide, cerium dioxide, nickel oxide, yttrium oxide, silicon carbide, alumina hydroxide, magnesium hydroxide, calcium hydroxide, barium sulfate, or boehmite.
12. An electric apparatus, comprising a cylindrical battery, the cylindrical battery comprising an electrode assembly, the electrode assembly comprising a positive electrode plate, a separator, and a negative electrode plate stacked and wound together; wherein, the positive electrode plate comprises a positive current collector, the positive current collector having a first surface; the first surface is provided with an active material layer, an insulation layer, and an uncoated foil area, wherein the active material layer, the insulation layer, and the uncoated foil area are arranged in order along an axial direction of the cylindrical battery; and the uncoated foil area is bended towards a central winding axis of the electrode assembly to form a flattened part; and the flattened part having a flattened surface.
13. The electric apparatus according to claim 12, wherein along the axial direction of the cylindrical battery, a height L of the flattened part is 0.2 mm to 4 mm.
14. The electric apparatus according to claim 12, wherein along the axial direction of the battery, a height W of the insulation layer is 1 mm to 5 mm.
15. The electric apparatus according to claim 14, wherein the height W of the insulation layer is 1.5

mm to 5 mm.

16. The electric apparatus according to claim 15, wherein the height W of the insulation layer is 1.5 mm to 3 mm.

17. The electric apparatus according to claim 12, wherein the insulation layer has a thickness h, and the active material layer has a thickness H, $0.1\ H \leq h \leq H$.

18. The electric apparatus according to claim 17, wherein $0.2\ H \leq h \leq 0.9\ H$.

19. The electric apparatus according to claim 17, wherein H is 50 μm to 100 μm.

20. The electric apparatus according to claim 17, wherein h is 10 μm to 45 μm.