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Inventor(s)	MOON; Boo Kyoung

ELECTRODE ASSEMBLY, METHOD FOR FABRICATING ELECTRODE ASSEMBLY, AND SECONDARY BATTERY INCLUDING ELECTRODE ASSEMBLY

Abstract

An electrode assembly, a method for fabricating the electrode assembly, and a secondary battery including the electrode assembly are disclosed. An electrode assembly includes a pair of electrode plates, a separator between the pair of electrode plates, and an electrode tab including a plurality of conductive wires arranged side by side in a width direction, and each of the plurality of conductive wires includes an overlapping part that overlaps an electrode plate of the pair of electrode plates to be bonded to the electrode plate, and a protruding part connected to the overlapping part and protruding to an outside at a boundary of the electrode plates.

Inventors: **MOON; Boo Kyoung (Suwon-si, KR)**

Applicant: **SAMSUNG SDI CO., LTD.** (Yongin-si, KR)

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATION

[0001] The present application claims priority to and the benefit of Korean Patent Application No. 10-2024-0022527, filed on Feb. 16, 2024 in the Korean Intellectual Property Office, the entire disclosure of which is incorporated herein by reference.

BACKGROUND

1. Field

[0002] Aspects of embodiments of the present disclosure relate to an electrode assembly, a method for fabricating the electrode assembly, and a secondary battery including the electrode assembly.

2. Description of the Related Art

[0003] Generally, as the demand for portable electronic products, such as notebook computers, video cameras, and mobile phones, has rapidly increased and the commercialization of robots, electric vehicles, and the like has been accelerated, research on high-performance secondary batteries allowing repeated charging and discharging is actively underway.

[0004] In cylindrical secondary batteries among the secondary batteries, an electrode assembly wound in a jelly roll shape may be accommodated in a cylindrical case. The jelly-roll shaped electrode assembly includes a strip-shaped electrode tab attached to an electrode plate.

[0005] However, the thin electrode plate may be bent as the electrode assembly is wound, and pressed by an edge of an electrode tab. In addition, during repeated charging and discharging of the secondary battery, the electrode plate may swell and may be cracked by the edge of the electrode tab. The crack formed on the electrode plate may grow during repeated charging and discharging processes, thereby shortening the lifespan of the secondary battery.

[0006] The above information disclosed in this Background section is provided for enhancement of understanding of the background of the present disclosure, and, therefore, may contain information that does not constitute related (or prior) art.

SUMMARY

[0007] According to aspects of embodiments of the present disclosure, an electrode assembly in which damage is suppressed, a method for fabricating the electrode assembly, and a secondary battery including the electrode assembly are provided.

[0008] These and other aspects and features of the present disclosure will be described in or will be apparent from the following description of some embodiments of the present disclosure.

[0009] According to one or more embodiments of the present disclosure, an electrode assembly includes a pair of electrode plates, a separator between the pair of electrode plates, and an electrode tab including a plurality of conductive wires arranged side by side in a width direction, wherein each of the plurality of conductive wires includes an overlapping part that overlaps an electrode plate of the pair of electrode plates to be bonded to the electrode plate, and a protruding part connected to the overlapping part and protruding to an outside at a boundary of the electrode plates.

[0010] The pair of electrode plates may include a positive electrode plate and a negative electrode plate having opposite polarities, and the overlapping part may be bonded to the positive electrode plate.

[0011] Each of the electrode plates may include a substrate and an active material applied to the substrate, and the overlapping part may be bonded to an uncoated region of the electrode plate, to which the active material is not applied.

[0012] The pair of electrode plates and the separator may be wound around a winding axis, each of the electrode plates may include an inner side surface facing the winding axis and an outer side surface opposite to the winding axis, and the electrode may be bonded to the inner side surface.
[0013] The conductive wire may extend along a path that is longer than a shortest distance between a first side end and a second side end in a longitudinal direction.
[0014] The conductive wire may extend along a wave path.
[0015] The overlapping part may include a welding part welded to the electrode plate, and a free part not welded to the electrode plate.
[0016] The electrode tab may further include a reinforcing thin plate bonded to the plurality of conductive wires and not bonded to the electrode plate.
[0017] All of the conductive wires may be bonded to the reinforcing thin plate.
[0018] Some of the plurality of conductive wires may not be bonded to the electrode plate.
[0019] A cross-sectional shape of the conductive wires may be a circular shape.
[0020] The conductive wires may be made of aluminum or an aluminum alloy.
[0021] According to one or more embodiments of the present disclosure, a method for fabricating an electrode assembly includes preparing an electrode tab, in which the electrode tab including a plurality of conductive wires arranged side by side in a width direction is prepared, overlapping the electrode tab, in which a part of the electrode tab in a longitudinal direction is placed to overlap an electrode plate, and welding the electrode tab, in which the part of the electrode tab is welded to the electrode plate.
[0022] The preparing of the electrode tab may include overlapping the conductive wire, in which the plurality of conductive wires are arranged side by side in the width direction and placed to overlap a reinforcing thin plate, and welding the conductive wire, in which the conductive wires are welded to the reinforcing thin plate.
[0023] The overlapping of the electrode tab may include placing the electrode tab on the electrode plate such that the plurality of conductive wires face the electrode plate and the plurality of conductive wires are arranged between the reinforcing thin plate and the electrode plate, and the welding of the electrode tab may include welding the conductive wires to the electrode plate while the reinforcing thin plate is spaced apart from the electrode plate.
[0024] In the welding of the conductive wire, all of the conductive wires may be bonded to the reinforcing thin plate, and in the welding of the electrode tab, some of the plurality of conductive wires may not be bonded to the electrode plate.
[0025] The welding of the electrode tab may include welding the conductive wires to the electrode plate with energy of ultrasonic vibrations.
[0026] According to one or more embodiments of the present disclosure, a secondary battery includes a case, and an electrode assembly according to an embodiment of the present disclosure inserted in the case.
[0027] The case may include a cylindrical can having a side open and the electrode assembly inserted therein, and a cap assembly arranged to face the open side of the can.
[0028] The electrode assembly may be wound in a jelly roll shape and accommodated inside the case.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
[0029] The drawings attached to this specification illustrate some embodiments of the present disclosure, and further describe aspects and features of the present disclosure together with the detailed description of the present disclosure. However, the present disclosure should not be construed as being limited to the drawings.

[0030] FIG. **1** is a perspective view schematically illustrating a configuration of a secondary battery according to one or more embodiments of the present disclosure;
[0031] FIG. **2** is a longitudinal cross-sectional view schematically illustrating a configuration of the secondary battery of FIG. **1**;
[0032] FIG. **3** is a cross-sectional view schematically illustrating a configuration of an electrode assembly according to an embodiment of the present disclosure wound in a jelly roll shape;
[0033] FIG. **4** is a perspective view illustrating an example of an electrode tab included in the electrode assembly of the present disclosure;
[0034] FIG. **5** is an enlarged plan view of the electrode tab of FIG. **4** and a part of an electrode plate to which the electrode tab is attached;
[0035] FIG. **6** is an enlarged cross-sectional view of a part of the electrode assembly according to an embodiment of the present disclosure wound in a jelly roll shape;
[0036] FIG. **7** is a perspective view illustrating another example of the electrode tab included in the electrode assembly of the present disclosure;
[0037] FIG. **8** is an enlarged plan view of the electrode tab of FIG. **7** and a part of the electrode plate to which the electrode tab is attached;
[0038] FIG. **9** is an enlarged cross-sectional view of a part of an electrode assembly according to another embodiment of the present disclosure wound in a jelly roll shape;
[0039] FIG. **10** is a perspective view illustrating another example of the electrode tab included in the electrode assembly of the present disclosure;
[0040] FIG. **11** is an enlarged plan view of the electrode tab of FIG. **10** and a part of the electrode plate to which the electrode tab is attached;
[0041] FIG. **12** is an enlarged cross-sectional view of a part of an electrode assembly according to another embodiment of the present disclosure wound in a jelly roll shape;
[0042] FIG. **13** is a flowchart illustrating a method for fabricating the electrode assembly according to an embodiment of the present disclosure; and
[0043] FIG. **14** is a flowchart illustrating a method for fabricating the electrode assembly according to another embodiment of the present disclosure

DETAILED DESCRIPTION

[0044] Herein, some embodiments of the present disclosure will be described, in further detail, with reference to the accompanying drawings. The terms or words used in this specification and claims should not be construed as being limited to the usual or dictionary meaning and should be interpreted as meaning and concept consistent with the technical idea of the present disclosure based on the principle that the inventor can be his/her own lexicographer to appropriately define the concept of the term.
[0045] The embodiments described in this specification and the configurations shown in the drawings are provided as some example embodiments of the present disclosure and do not necessarily represent all of the technical ideas, aspects, and features of the present disclosure. Accordingly, it is to be understood that there may be various equivalents and modifications that may replace or modify the embodiments described herein at the time of filing this application.
[0046] It is to be understood that when an element or layer is referred to as being
[0047] "on," "connected to," or "coupled to" another element or layer, it may be directly on, connected, or coupled to the other element or layer or one or more intervening elements or layers may also be present. When an element or layer is referred to as being "directly on," "directly connected to," or "directly coupled to" another element or layer, there are no intervening elements or layers present. For example, when a first element is described as being "coupled" or "connected" to a second element, the first element may be directly coupled or connected to the second element or the first element may be indirectly coupled or connected to the second element via one or more intervening elements.
[0048] In the figures, dimensions of the various elements, layers, etc. may be exaggerated for

clarity of illustration. The same reference numerals designate the same or like elements. As used herein, the term “and/or” includes any and all combinations of one or more of the associated listed items. Further, the use of “may” when describing embodiments of the present disclosure relates to “one or more embodiments of the present disclosure.” Expressions, such as “at least one of” and “any one of,” when preceding a list of elements, modify the entire list of elements and do not modify the individual elements of the list. When phrases such as “at least one of A, B, and C,” “at least one of A, B, or C,” “at least one selected from a group of A, B, and C,” or “at least one selected from among A, B, and C” are used to designate a list of elements A, B, and C, the phrase may refer to any and all suitable combinations or a subset of A, B, and C, such as A, B, C, A and B, A and C, B and C, or A and B and C. As used herein, the terms “use,” “using,” and “used” may be considered synonymous with the terms “utilize,” “utilizing,” and “utilized,” respectively. As used herein, the terms “substantially,” “about,” and similar terms are used as terms of approximation and not as terms of degree, and are intended to account for the inherent variations in measured or calculated values that would be recognized by those of ordinary skill in the art.

[0049] It is to be understood that, although the terms “first,” “second,” “third,” etc. may be used herein to describe various elements, components, regions, layers, and/or sections, these elements, components, regions, layers, and/or sections are not to be limited by these terms. These terms are used to distinguish one element, component, region, layer, or section from another element, component, region, layer, or section. Thus, a first element, component, region, layer, or section discussed below may be termed a second element, component, region, layer, or section without departing from the teachings of example embodiments.

[0050] Spatially relative terms, such as “beneath,” “below,” “lower,” “above,” “upper,” and the like, may be used herein for ease of description to describe one element or feature's relationship to another element(s) or feature(s) as illustrated in the figures. It is to be understood that the spatially relative terms are intended to encompass different orientations of the device in use or operation in addition to the orientation depicted in the figures. For example, if the device in the figures is turned over, elements described as “below” or “beneath” other elements or features would then be oriented “above” or “over” the other elements or features. Thus, the term “below” may encompass both an orientation of above and below. The device may be otherwise oriented (e.g., rotated 90 degrees or at other orientations), and the spatially relative descriptors used herein should be interpreted accordingly.

[0051] The terminology used herein is for the purpose of describing embodiments of the present disclosure and is not intended to be limiting of the present disclosure. As used herein, the singular forms “a” and “an” are intended to include the plural forms as well, unless the context clearly indicates otherwise. It is to be further understood that the terms “includes,” “including,” “comprises,” and/or “comprising,” when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof.

[0052] Also, any numerical range disclosed and/or recited herein is intended to include all sub-ranges of the same numerical precision subsumed within the recited range. For example, a range of “1.0 to 10.0” is intended to include all sub-ranges between (and including) the recited minimum value of 1.0 and the recited maximum value of 10.0, that is, having a minimum value equal to or greater than 1.0 and a maximum value equal to or less than 10.0, such as, for example, 2.4 to 7.6. Any maximum numerical limitation recited herein is intended to include all lower numerical limitations subsumed therein, and any minimum numerical limitation recited in this specification is intended to include all higher numerical limitations subsumed therein. Accordingly, Applicant reserves the right to amend this specification, including the claims, to expressly recite any sub-range subsumed within the ranges expressly recited herein.

[0053] References to two compared elements, features, etc. as being “the same” may mean that they are the same or substantially the same. Thus, the phrase “the same” or “substantially the same” may include a case having a deviation that is considered low in the art, for example, a deviation of 5% or less. In addition, when a certain parameter is referred to as being uniform in a given region, it may mean that it is uniform in terms of an average.

[0054] Throughout the specification, unless otherwise stated, each element may be singular or plural.

[0055] When an arbitrary element is referred to as being disposed (or located or positioned) on the “above (or below)” or “on (or under)” a component, it may mean that the arbitrary element is placed in contact with the upper (or lower) surface of the component and may also mean that another component may be interposed between the component and any arbitrary element disposed (or located or positioned) on (or under) the component.

[0056] In addition, it is to be understood that when an element is referred to as being “coupled,” “linked,” or “connected” to another element, the elements may be directly “coupled,” “linked,” or “connected” to each other, or one or more intervening elements may be present therebetween, through which the element may be “coupled,” “linked,” or “connected” to another element. In addition, when a part is referred to as being “electrically coupled” to another part, the part may be directly electrically connected to another part or one or more intervening parts may be present therebetween such that the part and the another part are indirectly electrically connected to each other.

[0057] Throughout the specification, when “A and/or B” is stated, it means A, B, or A and B, unless otherwise stated. That is, “and/or” includes any or all combinations of a plurality of items enumerated. When “C to D” is stated, it means C or more and D or less, unless otherwise specified.

[0058] FIG. **1** is a perspective view schematically illustrating a configuration of a secondary battery according to one or more embodiments of the present disclosure; FIG. **2** is a longitudinal cross-sectional view schematically illustrating a configuration of the secondary battery of FIG. **1**; and FIG. **3** is a cross-sectional view schematically illustrating a configuration of an electrode assembly according to an embodiment of the present disclosure wound in a jelly roll shape.

[0059] Referring to FIGS. **1** to **3**, a secondary battery **10** according to an embodiment of the present disclosure may include a case and an electrode assembly **100**.

[0060] Herein, a case in which the secondary battery **10** is a lithium-ion secondary battery having a cylindrical shape will be described as an example. However, the present disclosure is not limited thereto, and the secondary battery **10** may be a lithium polymer battery or a prismatic battery, for example.

[0061] The case may form a schematic exterior of the secondary battery **10** and support (e.g., entirely support) the electrode assembly **100** to be described below. In an embodiment, the case may include a can **12**, a cap assembly **30**, and a gasket **38**.

[0062] In an embodiment, the can **12** may have a cylindrical shape. In an embodiment, the can **12** may include a bottom part **14** having a generally circular shape and a cylindrical side wall **15** extending by a length (e.g., a predetermined length) upward from a circumference of the bottom part **14**. The can **12** may be formed with a side open. Accordingly, the electrode assembly **100**, which will be described below, may be inserted into the can **12** together with an electrolyte during an assembly process of the secondary battery **10**. In an embodiment, the can **12** may be provided to be electrically conductive. For example, the can **12** may include at least one material selected from the group consisting of steel, stainless steel, aluminum, and an aluminum alloy.

[0063] The cap assembly **30** may be formed to have a generally plate shape and may be disposed to face the open side of the can **12**. In an embodiment, the open side of the can **12** may be an upper side of the can **12**. In an embodiment, the cap assembly **30** may be provided to be electrically conductive. For example, the cap assembly **30** may include at least one material selected from the group consisting of steel, stainless steel, aluminum, and an aluminum alloy. The cap assembly **30** may include a cap-up, a safety vent, a cap-down, an insulating member, and a sub-plate, but is not

limited thereto, and may be modified in various forms.
[0064] The gasket **38** may be disposed between the can **12** and the cap assembly **30**. The gasket **38** may be formed of an electrically insulating material, such as rubber, silicone, or the like. The gasket **38** may be disposed such that an inner side surface thereof surrounds (e.g., entirely surrounds) a circumferential surface of the cap assembly **30**. The inner side surface of the gasket **38** may be fixed to the circumferential surface of the cap assembly **30** by any of various types of coupling methods, such as adhesion, welding, pressing, and the like.
[0065] The case may further include a beading part **16** formed to be inwardly recessed from an outer side surface of the can **12**, and a crimping part **18** bent and extending from an upper part of the beading part **16**.
[0066] The beading part **16** may be formed by pressing inward a circumference of an outer circumferential surface of the can **12** at the open side of the can **12**. The beading part **16** may be disposed between the cap assembly **30** and the electrode assembly **100**. The beading part **16** may prevent or substantially prevent movement of the electrode assembly **100** inside the can **12**, and may determine a position in which the cap assembly **30** is seated on the upper side of the can **12**.
[0067] The crimping part **18** may be bent and extend from an upper part of the beading part **16**. An inner side surface of the crimping part **18** may be disposed to surround (e.g., entirely surround) an outer side surface of the gasket **38**. The crimping part **18** may press an edge of the cap assembly **30** through the gasket **38** to firmly fix the cap assembly **30** to the can **12**.
[0068] The electrode assembly **100** may function as a unit structure for performing a power charging and discharging operation in the secondary battery **10**.
[0069] The electrode assembly **100** may include a pair of electrode plates **110** and **130** overlapping each other, a separator **101**, and an electrode tab **200**. The pair of electrode plates **110** and **130** may include a positive electrode plate **130** and a negative electrode plate **110**.
[0070] The positive electrode plate **130** may function as a positive electrode of the electrode assembly **100**. The positive electrode plate **130** may be formed in the form of a thin film. A type, size, and shape of the positive electrode plate **130** are not particularly limited as long as the positive electrode plate **130** has conductivity and does not cause chemical changes in the secondary battery **10**.
[0071] The positive electrode plate **130** may include a positive electrode substrate **131** and a positive electrode active material layer **133** stacked on at least one of both side surfaces of the positive electrode substrate **131**. The positive electrode substrate **131** may be, for example, a foil made of a metal material, such as aluminum or an aluminum alloy.
[0072] The positive electrode plate **130** may include a positive electrode coated region **140** to which the positive electrode active material layer **133** is applied, and a positive electrode uncoated region **145** to which the positive electrode active material layer **133** is not applied. A plurality of positive electrode coated regions **140** and a plurality of positive electrode uncoated regions **145** may be provided. In an embodiment, the plurality of positive electrode coated regions **140** and the plurality of positive electrode uncoated regions **145** may be alternately disposed in a longitudinal direction of the positive electrode plate **130** in which the positive electrode plate **130** extends.
[0073] In an embodiment, the positive electrode active material layer **133** may be applied to both side surfaces of the positive electrode coated region **140**, but, alternatively, the positive electrode active material layer **133** may be applied to only one side surface of the positive electrode coated region **140**.
[0074] The positive electrode active material layer **133** may include a positive electrode active material. The positive electrode active material may include a compound (lithiated intercalation compound) capable of reversibly intercalating and deintercalating lithium. In an embodiment, the positive electrode active material may include one or more types of composite oxides of lithium and a metal selected from cobalt, manganese, nickel, iron, and a combination thereof.
[0075] For example, the positive electrode active material may include at least one of lithium-iron-

phosphate oxide ($LiFePO_4$, LFP), lithium-manganese-iron-phosphate oxide ($LiMnFePO_4$, LMFP), and lithium-nickel-cobalt-manganese oxide ($LiNi_xCo_yMn_zO_2$, NCM). Here, conditions of $0<x<1$, $0<y<1$, $0<z<1$, and $x+y+z=1$ may be satisfied. The positive electrode active material may include any one of $LiFePO_4$, $LiMnFePO_4$, and $LiNi_xCo_yMn_zO_2$, and may also include two or all of $LifePO_4$, $LiMnFePO_4$, and $LiNi_xCo_yMn_zO_2$.
[0076] The positive electrode active material layer **133** may further include a positive electrode conductive material. The positive electrode conductive material is used to impart conductivity to the positive electrode active material layer **133**, and any suitable electrically conductive material that does not cause a chemical change in the battery may be used. Examples of the positive electrode conductive material may include a carbon-based material, such as natural graphite, artificial graphite, carbon black, acetylene black, ketjen black, carbon fiber, carbon nanofiber, carbon nanotubes, and the like; a metal-based material of a metal powder or metal fiber including copper, nickel, aluminum, silver, and the like; a conductive polymer, such as a polyphenylene derivative; or a mixture thereof.
[0077] The positive electrode active material layer **133** may further include a positive electrode binder. The positive electrode binder adheres particles constituting the positive electrode active material to each other well, and may adhere the positive electrode active material to the positive electrode plate **130** well.
[0078] Examples of the positive electrode binder may include a non-aqueous binder, an aqueous binder, a dry binder, or a combination thereof. The non-aqueous binder may include polyvinylchloride, carboxylated polyvinylchloride, polyvinylfluoride, an ethylene propylene copolymer, polystyrene, polyurethane, polytetrafluoroethylene, polyvinylidene fluoride, polyethylene, polypropylene, polyamideimide, polyimide, or a combination thereof.
[0079] The aqueous binder may be selected from styrene-butadiene rubber, (meth)acrylated styrene-butadiene rubber, (meth)acrylonitrile-butadiene rubber, (meth)acrylic rubber, butyl rubber, a fluororubber, polyethylene oxide, polyvinylpyrrolidone, polyepichlorohydrin, polyphosphazene, poly(meth)acrylonitrile, an ethylene propylene diene copolymer, polyvinylpyridine, chlorosulfonated polyethylene, latex, a polyester resin, a (meth)acrylic resin, a phenolic resin, an epoxy resin, polyvinyl alcohol, and a combination thereof.
[0080] When the aqueous binder is used as a positive electrode binder, a cellulose-based compound capable of imparting viscosity may be further included. The cellulose-based compound may include one or more of carboxymethyl cellulose, hydroxypropylmethyl cellulose, methyl cellulose, or alkali metal salts thereof. The alkali metal may include Na, K, or Li.
[0081] The dry binder may be a fibrous polymer material, and, for example, polytetrafluoroethylene, polyvinylidene fluoride, a polyvinylidene fluoride-hexafluoropropylene copolymer, polyethylene oxide, or a combination thereof.
[0082] The negative electrode plate **110** may function as a negative electrode of the electrode assembly **100**. The negative electrode plate **110** may be formed in the form of a thin film. The negative electrode plate **110** may be disposed to be spaced apart from the positive electrode plate **130** by a certain distance to face the positive electrode plate **130**. A type, size, and shape of the negative electrode plate **110** are not particularly limited as long as the negative electrode plate **110** has conductivity and does not cause chemical changes in the secondary battery **10**.
[0083] The negative electrode plate **110** may include a negative electrode substrate **111** and a negative electrode active material layer **113** stacked on at least one of both side surfaces of the negative electrode substrate **111**. The negative electrode substrate **111** may be, for example, a foil made of a metal material, such as copper, a copper alloy, nickel, or a nickel alloy.
[0084] The negative electrode plate **110** may include a negative electrode coated region **120** to which the negative electrode active material layer **113** is applied, and a negative electrode uncoated region **125** to which the negative electrode active material layer **113** is not applied. A plurality of

negative electrode coated regions **120** and a plurality of negative electrode uncoated regions **125** may be provided. In an embodiment, the plurality of negative electrode coated regions **120** and the plurality of negative electrode uncoated regions **125** may be alternately disposed in an extending direction of the negative electrode plate **110** in which the negative electrode plate **110** extends.

[0085] In an embodiment, the negative electrode active material layer **113** may be applied to both side surfaces of the negative electrode coated region **120**, and, alternatively, may be applied to only one side surface of the negative electrode coated region **120**.

[0086] The negative electrode active material layer **113** may include a negative electrode active material. The negative electrode active material may be a material that reversibly intercalates/deintercalates lithium ions, a lithium metal, a lithium metal alloy, a material capable of doping and dedoping lithium, or a transition metal oxide.

[0087] The material that reversibly intercalates/deintercalates lithium ions may be a carbon-based negative electrode active material, and examples thereof may include crystalline carbon, amorphous carbon, or a combination thereof. Examples of the crystalline carbon may include graphite, such as amorphous, plate-shaped, flake-shaped, spherical-shaped or fiber-shaped natural graphite or artificial graphite. Examples of the amorphous carbon may include soft carbon or hard carbon, a mesophase pitch carbonized product, calcined coke, and the like.

[0088] The lithium metal alloy may be an alloy of lithium and a metal selected from Na, K, Rb, Cs, Fr, Be, Mg, Ca, Sr, Si, Sb, Pb, In, Zn, Ba, Ra, Ge, Al, and Sn.

[0089] A Si-based negative electrode active material or a Sn-based negative electrode active material may be used as the material capable of doping and dedoping lithium. The Si-based negative electrode active material may include silicon, a silicon-carbon composite, SiO_x ($0<x<2$), a Si—Q alloy (where, Q is selected from an alkali metal, an alkaline-earth metal, a Group 13 element, a Group 14 element (excluding Si), a Group 15 element, a Group 16 element, a transition metal, a rare-earth element, and a combination thereof), or a combination thereof. The Sn-based negative electrode active material may include Sn, SnO_2, a Sn-based alloy, or a combination thereof.

[0090] The silicon-carbon composite may be a composite of silicon and amorphous carbon. According to an embodiment, the silicon-carbon composite may be in the form of silicon particles and amorphous carbon coated on a surface of the silicon particles. For example, the silicon-carbon composite may include a secondary particle (core) in which silicon primary particles are agglomerated and an amorphous carbon coating layer (shell) located on the surface of the secondary particle. The amorphous carbon may also be located between the silicon primary particles, such that, for example, the silicon primary particles are coated with amorphous carbon. The secondary particles may be dispersed in an amorphous carbon matrix.

[0091] The silicon-carbon composite may further include crystalline carbon. For example, the silicon-carbon composite may include a core including crystalline carbon and silicon particles and an amorphous carbon coating layer located on a surface of the core.

[0092] The Si-based negative electrode active material or the Sn-based negative electrode active material may be used by being mixed with a carbon-based negative electrode active material.

[0093] The negative electrode active material layer **113** may further include a negative electrode conductive material and a negative electrode binder. The negative electrode conductive material is used to impart conductivity to the negative electrode active material layer **113**, and any electrically conductive material that does not cause a chemical change in the battery may be used. Examples of the negative electrode conductive material include a carbon-based material such as natural graphite, artificial graphite, carbon black, acetylene black, ketjen black, carbon fiber, carbon nanofiber, carbon nanotubes, and the like; a metal-based material of a metal powder or metal fiber including copper, nickel, aluminum, silver, and the like; a conductive polymer such as a polyphenylene derivative; or a mixture thereof.

[0094] The negative electrode binder adheres particles constituting the negative electrode active

material to each other well, and to adhere the negative electrode active material to the negative electrode plate **110** well. Examples of the negative electrode binder may include a non-aqueous binder, an aqueous binder, a dry binder, or a combination thereof.
[0095] The non-aqueous binder may include polyvinylchloride, carboxylated polyvinylchloride, polyvinylfluoride, an ethylene propylene copolymer, polystyrene, polyurethane, polytetrafluoroethylene, polyvinylidene fluoride, polyethylene, polypropylene, polyamideimide, polyimide, or a combination thereof.
[0096] The aqueous binder may be selected from any of styrene-butadiene rubber, (meth)acrylated styrene-butadiene rubber, (meth)acrylonitrile-butadiene rubber, (meth)acrylic rubber, butyl rubber, a fluororubber, polyethylene oxide, polyvinylpyrrolidone, polyepichlorohydrin, polyphosphazene, poly(meth)acrylonitrile, an ethylene propylene diene copolymer, polyvinylpyridine, chlorosulfonated polyethylene, latex, a polyester resin, a (meth)acrylic resin, a phenolic resin, an epoxy resin, polyvinyl alcohol, and a combination thereof.
[0097] When the aqueous binder is used as a negative electrode binder, a cellulose-based compound capable of imparting viscosity may be further included. The cellulose-based compound may include one or more of carboxymethyl cellulose, hydroxypropylmethyl cellulose, methyl cellulose, or alkali metal salts thereof. In an embodiment, the alkali metal may include Na, K, or Li.
[0098] The dry binder may be a fibrous polymer material, and, for example, polytetrafluoroethylene, polyvinylidene fluoride, a polyvinylidene fluoride-hexafluoropropylene copolymer, polyethylene oxide, or a combination thereof.
[0099] The separator **101** may be interposed between the pair of electrode plates **110** and **130**, that is, between the positive electrode plate **130** and the negative electrode plate **110**. The separator **101** may prevent or substantially prevent a short circuit between the positive electrode plate **130** and the negative electrode plate **110** while allowing the movement of lithium ions between the positive electrode plate **130** and the negative electrode plate **110**.
[0100] In an embodiment, the separator **101** may be made of polyethylene, polypropylene, polyvinylidene fluoride, or a multilayer film of two or more layers thereof, and may be made of a mixed multilayer film, such as, a polyethylene/polypropylene double-layered separator, a polyethylene/polypropylene/polyethylene three-layered separator, and a polypropylene/polyethylene/polypropylene three-layered separator.
[0101] The separator **101** may include a porous substrate, and a coating layer including an organic material, an inorganic material, or a combination thereof located on one surface or both surfaces of the porous substrate.
[0102] The porous substrate may be a polymer film formed of a polymer, or a copolymer or mixture of two or more selected from polyolefins, such as polyethylene, polypropylene, and the like, a polyester, such as polyethylene terephthalate, polybutylene terephthalate, and the like, polyacetal, polyamide, polyimide, polycarbonate, polyetheretherketone, polyaryletherketone, polyetherimide, polyamideimide, polybenzimidazole, polyether sulfone, polyphenylene oxide, a cyclic olefin copolymer, polyphenylene sulfide, polyethylene naphthalate, glass fiber, Teflon, and polytetrafluoroethylene.
[0103] The organic material may include a polyvinylidene fluoride-based polymer or a (meth)acrylic-based polymer.
[0104] The inorganic material may include inorganic particles selected from Al_2O_3, SiO_2, TiO_2, SnO_2, CeO_2, MgO, NiO, CaO, GaO, ZnO, ZrO_2, Y_2O_3, $SrTiO_3$, $BaTiO_3$, $Mg(OH)_2$, boehmite, and a combination thereof, but the present disclosure is not limited thereto.
[0105] The organic and inorganic materials may be present by being mixed in one coating layer or may be present in a form in which a coating layer including organic materials and a coating layer including inorganic materials are laminated.
[0106] The electrode assembly **100** may have a shape that is wound around a winding axis C. The

positive electrode plate **130** and the negative electrode plate **110** may be wound clockwise or counterclockwise around the winding axis C while first surfaces thereof are disposed to face each other. Accordingly, the electrode assembly **100** may have substantially a jelly roll shape. A cross-sectional shape of the electrode assembly **100** may be changed in design into any of various shapes, such as an elliptical shape, a polygonal shape, or the like, in addition to a circular shape as shown in FIG. **3**.

[0107] Here, the winding axis C may be a straight line passing through a central part of the electrode assembly **100** and disposed perpendicular to the open surface of the case.

[0108] In an embodiment, a pair of separators **101** may be provided. The pair of separators **101** may be disposed to face both surfaces of the positive electrode plate **130** or the negative electrode plate **110**. The pair of separators **101** may be wound around the winding axis C together with the positive electrode plate **130** and the negative electrode plate **110**.

[0109] The electrode assembly **100** may be disposed in the case, or inside the can **12**. The winding axis C of the electrode assembly **100** may be disposed coaxially with a central axis of the can **12**. A lower end part and an upper end part of the electrode assembly **100** may be disposed to face the bottom part **14** and the beading part **16** of the can **12**, respectively.

[0110] In an embodiment, a center pin **50** may be additionally installed inside the electrode assembly **100**. The center pin **50** may have the form of a hollow circular pipe. The center pin **50** may be coupled to approximately a center of the electrode assembly **100**, and a central axis thereof may be disposed to coincide with the winding axis C of the electrode assembly **100**. The center pin **50** may include at least one of materials such as steel, stainless steel, aluminum, an aluminum alloy, or polybutylene terephthalate, for example. The center pin **50** may suppress deformation of the electrode assembly **100** during charging and discharging of the battery, and may function as a moving path for a gas generated inside the secondary battery **10**. However, in one or more embodiments, the center pin **21** may be omitted.

[0111] The electrode tab **200** may be electrically conductively connected to the electrode plates **110** and **130**. The electrode tab **200** electrically connects the case to the electrode assembly **100**.

[0112] In an embodiment, the electrode tab **200** may extend parallel to the winding axis C of the electrode assembly **100**. A side of the electrode tab **200** in a longitudinal direction may be disposed inside the electrode plates **110** and **130**, and another side of the electrode tab **200** in the longitudinal direction may protrude to an outside of the electrode assembly **100**.

[0113] A plurality of electrode tabs **200** may be provided. As an example, a pair of electrode tabs **200** may be provided. A first electrode tab **200** of the pair of electrode tabs **200** is disposed between the positive electrode plate **130** and the separator **101**, and both, or opposite, sides of the first electrode tab **200** in the longitudinal direction may be connected to the positive electrode plate **130** and the cap assembly **30**.

[0114] A second electrode tab **200** of the pair of electrode tabs **200** is disposed between the negative electrode plate **110** and the separator **101**, and both, or opposite, sides of the second electrode tab **200** in the longitudinal direction may be connected to the negative electrode plate **110** and the can **12**.

[0115] FIG. **4** is a perspective view illustrating an example of the electrode tab included in the electrode assembly of the present disclosure; FIG. **5** is an enlarged plan view of the electrode tab of FIG. **4** and a part of the electrode plate to which the electrode tab is attached; and FIG. **6** is an enlarged cross-sectional view of a part of an electrode assembly according to an embodiment of the present disclosure wound in a jelly roll shape.

[0116] Referring to FIGS. **3** to **6**, an electrode tab **200** according to an example, which is included in the electrode assembly **100**, includes a plurality of conductive wires **201** arranged side by side in a width direction. Herein, a case in which the electrode tab **200** is bonded to the positive electrode plate **130** will be described as an example, but the electrode tab **200** may be similarly applied to the negative electrode plate **110**.

[0117] The conductive wire **201** may be formed of, for example, an aluminum or aluminum alloy material. However, the conductive wire **201** may also be formed of any of other suitable types of electrically conductive metal materials other than aluminum and an aluminum alloy.
[0118] In an embodiment, a cross-sectional shape of the conductive wire **201** may be a circular shape with a constant diameter. However, in another embodiment, the cross-sectional shape of the conductive wire **201** may be a polygonal shape of a pentagon or more sides. The conductive wire **201** may extend in a direction parallel to a longitudinal direction of the winding axis C. The direction parallel to the longitudinal direction of the winding axis C may be a width direction of the positive electrode plate **130** and the negative electrode plate **110**.
[0119] The plurality of conductive wires **201** may be arranged side by side in the width direction perpendicular to a longitudinal direction thereof. The plurality of conductive wires **201** may be arranged back-to-back such that outer circumferential surfaces thereof are in contact with each other, or may be arranged to be spaced apart from each other such that a fine gap is formed between the adjacent conductive wires **201**. The width direction of the conductive wire **201** may be the same as the longitudinal direction of the positive electrode plate **130** and the negative electrode plate **110**.
[0120] The conductive wire **201** includes an overlapping part **210** that overlaps the electrode plates **110** and **130** to be bonded to the electrode plates **110** and **130**, and a protrusion part **230** connected to the overlapping part **210** and protruding outward at a boundary of the electrode plates **110** and **130**.
[0121] The protrusion part **230** may be bonded to the cap assembly **30** illustrated in FIGS. **1** and **2**, and the protrusion part **230** of the electrode tab **200** bonded to the negative electrode plate **110** may be bonded to the bottom part **14** of the can **12**.
[0122] The overlapping part **210** may be bonded to the positive electrode uncoated region **145** in the positive electrode plate **130**.
[0123] In an embodiment, the overlapping part **210** may be welded to the positive electrode uncoated region **145**. For example, ultrasonic welding may be applied to weld the conductive wire **201** to the positive electrode uncoated region **145** with energy of ultrasonic vibrations.
[0124] By placing an ultrasonic horn (not shown) to overlap the overlapping parts **210** of the plurality of conductive wires **201** that overlap the positive electrode uncoated region **145**, and applying pressure toward the positive electrode uncoated region **145** while operating the ultrasonic horn, the overlapping parts **210** of the conductive wires **201** may be melted and bonded to the positive electrode uncoated region **145** by energy of ultrasonic vibrations.
[0125] Ultrasonic welding using an ultrasonic horn may be advantageous in that the plurality of conductive wires **201** can be concurrently (e.g., simultaneously) welded to the positive electrode uncoated region **145**, thereby improving working speed and reducing working costs.
[0126] An end part of the ultrasonic horn applied to the welding operation of the electrode tab **200** may have a narrow and long rectangular cross-sectional shape. Thus, in order to concurrently (e.g., simultaneously) weld the plurality of conductive wires **201**, a distance between the conductive wire **201** at an outermost side and the conductive wire **201** at another outermost side in a width direction of the conductive wire **201** should be less than or equal to a width of the end part of the ultrasonic horn.
[0127] In FIG. **5**, a region indicated by a dash-double dotted line and designated by a reference numeral “H**1**” represents an ultrasonic horn region H**1** in which the ultrasonic horn overlaps the plurality of conductive wires **201**. In FIG. **6**, a region indicated by a dash-double dotted line and designated by a reference numeral “W**1**” represents a welding part W**1** at which the overlapping parts **210** of the plurality of conductive wires **201** and the positive electrode uncoated region **145** are welded.
[0128] However, the ultrasonic welding is provided as an example of a method of bonding the conductive wires **201** to the positive electrode uncoated region **145**. In another embodiment, the

conductive wires **201** may be bonded to the positive electrode uncoated region **145** by another suitable methods, such as attaching the plurality of conductive wires **201** one by one to the positive electrode uncoated region **145** by laser welding.

[0129] Each of the conductive wires **201** may extend along a shortest path connecting a first side end **203** and a second side end **204** thereof in the longitudinal direction. In an embodiment, each of the conductive wires **201** may extend along a straight path parallel to each other.

[0130] The positive electrode plate **130**, the negative electrode plate **110**, and the

[0131] separator **101** may be wound around the winding axis C. Both, or opposite, side surfaces of the positive electrode plate **130** may be divided into a positive electrode inner side surface **136** facing the winding axis C, and a positive electrode outer side surface **138**, which is a side surface opposite to the positive electrode inner side surface **136**, i.e., opposite to the winding axis C. Both, or opposite, side surfaces of the negative electrode plate **110** may be divided into a negative electrode inner side surface **116** facing the winding axis C, and a negative electrode outer side surface **118**, which is a side surface opposite to the negative electrode inner side surface **116**, i.e., opposite to the winding axis C.

[0132] The electrode tab **200** bonded to the positive electrode plate **130** may be bonded to the positive electrode inner side surface **136** of the positive electrode uncoated region **145**. The electrode tab **200** bonded to the negative electrode plate **110** may be bonded to the negative electrode inner side surface **116** of the negative electrode uncoated region **125**.

[0133] In an embodiment, any conductive wire **201** may not be bonded to another adjacent conductive wire **201**.

[0134] When the electrode plates **110** and **130** are bent during winding of the electrode assembly **100**, or when the electrode plates **110** and **130** are expanded during charging and discharging of the secondary battery **10**, in the electrode tab **200**, the conductive wires **201** are spaced apart from each other or a gap therebetween is reduced, thereby mitigating stress on the electrode plates **110** and **130** caused by the electrode tab **200**.

[0135] Further, since the electrode plates **110** and **130** come into contact with and press a curved outer circumferential surface of the conductive wire **201** having a circular or circular-like cross-sectional shape, the stress on the electrode plates **110** and **130** caused by the electrode tab **200** is mitigated. Accordingly, cracking of the electrode plates **110** and **130** due to close contact with the electrode tab **200** may be suppressed, and durability of the secondary battery **10** including the electrode assembly **100** may be improved.

[0136] In an embodiment, the electrode tab **200** is illustrated in FIGS. **3** and **6** as being bonded to the positive electrode inner side surface **136** or the negative electrode inner side surface **116**, but, in another embodiment, unlike the illustrated configuration, the electrode tab **200** may be bonded to the positive electrode outer side surface **138** or the negative electrode outer side surface **118**.

[0137] FIG. **7** is a perspective view illustrating another example of the electrode tab included in the electrode assembly of the present disclosure; FIG. **8** is an enlarged plan view of the electrode tab of FIG. **7** and a part of the electrode plate to which the electrode tab is attached; and FIG. **9** is an enlarged cross-sectional view of a part of an electrode assembly according to another embodiment of the present disclosure wound in a jelly roll shape.

[0138] Referring to FIGS. **3** and **7** to **9**, an electrode tab **300** according to the present example may be included in the electrode assembly **100**, rather than the electrode tab **200** according to the example shown in FIGS. **3** and **4**. The electrode tab **300** includes a plurality of conductive wires **301** arranged side by side in a width direction thereof. Herein, a case in which the electrode tab **300** is bonded to the positive electrode plate **130** will be described as an example, but the electrode tab **300** may be similarly applied to the negative electrode plate **110**.

[0139] The conductive wire **301** may be formed of, for example, an aluminum or aluminum alloy material. However, the conductive wire **301** may be formed of another type of electrically conductive metal material, other than aluminum and an aluminum alloy.

[0140] In an embodiment, a cross-sectional shape of the conductive wire **301** may be a circular shape with a constant diameter. However, the cross-sectional shape of the conductive wire **301** may be a polygonal shape of a pentagon or more sides.
[0141] The plurality of conductive wires **301** may be arranged side by side in the width direction thereof. The plurality of conductive wires **301** may be arranged back-to-back such that outer circumferential surfaces thereof are in contact with each other, or may also be arranged to be spaced apart such that a fine gap is formed between the adjacent conductive wires **301**. A width direction of the conductive wire **301** may be the same as a longitudinal direction of the positive electrode plate **130** and the negative electrode plate **110**.
[0142] The conductive wire **301** includes an overlapping part **310** that overlaps the electrode plates **110** and **130** and is bonded to the electrode plates **110** and **130**, and a protruding part **330** connected to the overlapping part **310** and protruding outward at the boundary of the electrode plates **110** and **130**. The protruding part **330** may be bonded to the cap assembly **30** illustrated in FIGS. **1** and **2**. The protruding part **330** of the electrode tab **300** bonded to the negative electrode plate **110** may be bonded to the bottom part **14** of the can **12**.
[0143] The overlapping part **310** may be bonded to the positive electrode uncoated region **145** in the positive electrode plate **130**.
[0144] In an embodiment, the overlapping part **310** may be welded to the positive electrode uncoated region **145**. For example, ultrasonic welding may be applied to weld the conductive wire **301** to the positive electrode uncoated region **145** with energy of ultrasonic vibrations.
[0145] By placing an ultrasonic horn (not shown) to overlap the overlapping parts **310** of the plurality of conductive wires **301** that overlap the positive electrode uncoated region **145**, and applying pressure toward the positive electrode uncoated region **145** while operating the ultrasonic horn, the overlapping parts **310** of the conductive wires **301** may be melted and bonded to the positive electrode uncoated region **145** by energy of ultrasonic vibrations.
[0146] Ultrasonic welding using an ultrasonic horn may be advantageous in that the plurality of conductive wires **301** can be concurrently (e.g., simultaneously) welded to the positive electrode uncoated region **145**, thereby improving working speed and reducing working costs.
[0147] Each of the conductive wires **301** may extend along a path that is longer than a shortest distance between a first side end **303** and a second side end **304** thereof in the longitudinal direction. The conductive wire **301** of the electrode tab **300** illustrated in FIGS. **7** to **9** extends along a wave path.
[0148] However, the wave path is provided as an example, and in other examples, the conductive wire **301** may extend along another type of path such as, for example, a zigzag path. In an embodiment, the plurality of conductive wires **301** may have a same size and shape such that the plurality of conductive wires **301** may be arranged side by side with a decreasing gap therebetween.
[0149] In an embodiment, an end part of the ultrasonic horn applied to the welding operation of the electrode tab **300** may have a narrow and long rectangular cross-sectional shape. In FIG. **8**, a region indicated by a dash-double dotted line and designated by a reference numeral “H**2**” represents an ultrasonic horn region H**2** in which the ultrasonic horn overlaps the plurality of conductive wires **301**.
[0150] In the overlapping part **310**, a size of a maximum width WM**1** of the plurality of conductive wires **301** in the longitudinal direction of the positive electrode plate **130** is greater than a size of a width WH of the ultrasonic horn region H**2**.
[0151] However, as shown in FIG. **8**, when the ultrasonic horn is placed to overlap the overlapping part **310** such that the ultrasonic horn region H**2** is located at the center of the maximum width WM**1** of the plurality of conductive wires **301**, and when applying pressure toward the positive electrode uncoated region **145** while operating the ultrasonic horn, the plurality of wave-shaped conductive wires **301** may be concurrently (e.g., simultaneously) welded.
[0152] All of the conductive wires **301** can be concurrently (e.g., simultaneously) welded even

when a sum of diameters of the plurality of conductive wires **301** is larger than the size of the width WH of the ultrasonic horn region H**2**.
[0153] Accordingly, compared to the electrode tab **200** according to the previous example, in the electrode tab **300** according to the present example, a larger number of conductive wires **301** can be welded concurrently (e.g., simultaneously), which increases an electrical capacity of the electrode tab **300** and allows charging and discharging to proceed more stably. In addition, the speed and productivity of the welding operation of the electrode tab **300** may be improved.
[0154] However, the ultrasonic welding is provided as an example of a method of bonding the conductive wires **301** to the positive electrode uncoated region **145**. In another embodiment, the conductive wires **301** may be bonded to the positive electrode uncoated region **145** by another method, such as attaching the plurality of conductive wires **301** one by one to the positive electrode uncoated region **145** by laser welding.
[0155] In an embodiment, any conductive wire **301** may not be bonded to another adjacent conductive wire **301**.
[0156] In an embodiment, the electrode tab **300** bonded to the positive electrode plate **130** may be bonded to the positive electrode inner side surface **136** of the positive electrode uncoated region **145**, and the electrode tab **300** bonded to the negative electrode plate **110** may be bonded to the negative electrode inner side surface **116** of the negative electrode uncoated region **125**.
[0157] When the electrode plates **110** and **130** are bent during winding of the electrode assembly **100**, or when the electrode plates **110** and **130** are expanded during charging and discharging of the secondary battery **10**, in the electrode tab **300** according to the present example, the conductive wires **301** are spaced apart from each other or a gap therebetween is reduced, thereby mitigating stress on the electrode plates **110** and **130** caused by the electrode tab **300**.
[0158] In an embodiment, the electrode plates **110** and **130** come into contact with and press the curved outer circumferential surface of the conductive wire **301** having a circular or circular-like cross-sectional shape, and the stress on the electrode plates **110** and **130** caused by the electrode tab **300** is mitigated. Accordingly, cracking of the electrode plates **110** and **130** due to close contact with the electrode tab **300** may be suppressed, and durability of the secondary battery **10** including the electrode assembly **100** may be improved.
[0159] The overlapping part **310** may include a welding part W**2** welded to the positive electrode uncoated region **145** of the positive electrode plate **130** by the above-described ultrasonic welding operation and a free part FR**1** not welded to the positive electrode uncoated region **145** by the above-described ultrasonic welding operation. Similarly, when the electrode tab **300** is bonded to the negative electrode plate **110**, the overlapping part **310** may include the welding part W**2** welded to the negative electrode uncoated region **125** of the negative electrode plate **110** and the free part FR**1** not welded to the negative electrode uncoated region **125**.
[0160] Since the free part FR**1** is not fixed to the electrode plates **110** and **130**, when the electrode plates **110** and **130** are wound or expanded, the free part FR**1** may move more freely than the welding part W**2** in a direction that avoids or mitigates a pressure causing the free part FR**1** to come into close contact with the electrode plates **110** and **130**. Accordingly, the pressure applied to the electrode plates **110** and **130** by the electrode tab **300** may be mitigated to a greater extent, and a phenomenon of cracking of the electrode plates **110** and **130** may be more reliably prevented.
[0161] In FIG. **9**, the electrode tab **300** is illustrated as being bonded to the positive electrode inner side surface **136**, but is not limited thereto, and may be bonded to the negative electrode inner side surface **116**, or may be bonded to the positive electrode outer side surface **138** or the negative electrode outer side surface **118**.
[0162] FIG. **10** is a perspective view illustrating another example of the electrode tab included in the electrode assembly of the present disclosure; FIG. **11** is an enlarged plan view of the electrode tab of FIG. **10** and a part of the electrode plate to which the electrode tab is attached; and FIG. **12** is an enlarged cross-sectional view of a part of an electrode assembly according to another

embodiment of the present disclosure wound in a jelly roll shape.
[0163] Referring to FIGS. **3** and **10** to **12**, an electrode tab **400** according to the present example may be included in the electrode assembly **100**, rather than the electrode tab **200** according to the example shown in FIGS. **3** and **4**. The electrode tab **400** includes a plurality of conductive wires **401** arranged side by side in a width direction thereof and a reinforcing thin plate **450**. Herein, a case in which the electrode tab **400** is bonded to the positive electrode plate **130** will be described as an example, but the electrode tab **400** may be similarly applied to the negative electrode plate **110**.
[0164] A conductive wire **401** may be formed of, for example, an aluminum or aluminum alloy material. However, the conductive wire **401** may be formed of another type of electrically conductive metal materials other than aluminum and an aluminum alloy.
[0165] In an embodiment, a cross-sectional shape of the conductive wire **401** may be a circular shape with a constant diameter. However, the cross-sectional shape of the conductive wire **401** may be a polygonal shape of a pentagon or more sides.
[0166] The plurality of conductive wires **401** may be arranged side by side in the width direction perpendicular to a longitudinal direction thereof. The plurality of conductive wires **401** may be arranged back-to-back such that outer circumferential surfaces thereof are in contact with each other, or may be arranged to be spaced apart such that a fine gap is formed between the adjacent conductive wires **401**. The width direction of the conductive wire **401** may be the same as the longitudinal direction of the positive electrode plate **130** and the negative electrode plate **110**.
[0167] The conductive wire **401** includes an overlapping part **410** that overlaps the electrode plates **110** and **130** to be bonded to the electrode plates **110** and **130**, and a protruding part **430** connected to the overlapping part **410** and protruding outward at the boundary of the electrode plates **110** and **130**.
[0168] The protruding part **430** may be bonded to the cap assembly **30** illustrated in FIGS. **1** and **2**, and the protruding part **430** of the electrode tab **400** bonded to the negative electrode plate **110** may be bonded to the bottom part **14** of the can **12**.
[0169] The overlapping part **410** may be bonded to the positive electrode uncoated region **145** in the positive electrode plate **130**.
[0170] In an embodiment, the overlapping part **410** may be welded to the positive electrode uncoated region **145**. For example, ultrasonic welding may be applied to weld the conductive wire **401** to the positive electrode uncoated region **145** with energy of ultrasonic vibrations.
[0171] The reinforcing thin plate **450** is bonded to the plurality of conductive wires **401** and is not bonded to the electrode plates **110** and **130**. The reinforcing thin plate **450** may be formed of, for example, an aluminum or aluminum alloy material similar to the conductive wire **401**. However, the reinforcing thin plate **450** may be formed of another type of electrically conductive metal material other than aluminum and an aluminum alloy. A thickness of the reinforcing thin plate **450** may be of a similar size to a thickness of each of the substrates **111** and **113** of the electrode plates **110** and **130**.
[0172] All of the conductive wires **401** may be bonded to the reinforcing thin plate **450**. In an embodiment, the conductive wires **401** may be bonded to the reinforcing thin plate **450** by welding. In FIG. **12**, a region indicated by a dash-double dotted line and designated by a reference designator "WP" represents a reinforcing thin plate welding part WP in which the reinforcing thin plate **450** and the plurality of conductive wires **401** are welded.
[0173] The overlapping parts **410** of some conductive wires **401** of the plurality of conductive wires **401** may not be bonded to the electrode plates **110** and **130**. For example, the overlapping parts **410** of the plurality of conductive wires **401** face the positive electrode uncoated region **145** of the positive electrode plate **130**, and the electrode tab **400** may be placed on the positive electrode uncoated region **145** such that the plurality of conductive wires **401** are interposed between the reinforcing thin plate **450** and the positive electrode uncoated region **145**.

[0174] In an embodiment, the overlapping part **410** of at least one conductive wire **401** of the plurality of conductive wires **401** may be welded to the positive electrode uncoated region **145** while the reinforcing thin plate **450** is spaced apart from the positive electrode plate **130**.

[0175] By placing an ultrasonic horn (not shown) to overlap a part of the reinforcing thin plate **450**, which overlaps the positive electrode plate **130**, and applying pressure toward the positive electrode uncoated region **145** while operating the ultrasonic horn, the overlapping parts **410** of the conductive wires **401** may be melted and bonded to the positive electrode uncoated region **145** by energy of ultrasonic vibrations passing through the reinforcing thin plate **450**.

[0176] Ultrasonic welding using an ultrasonic horn may be advantageous in that the plurality of conductive wires **401** can be concurrently (e.g., simultaneously) welded to the positive electrode uncoated region **145**, thereby improving working speed and reducing working costs.

[0177] In an embodiment, the plurality of conductive wires **401** may have a same size and shape such that the plurality of conductive wires **401** may be arranged side by side with a decreasing gap therebetween. In an embodiment, each of the conductive wires **401** may extend along a straight path parallel to the others.

[0178] In an embodiment, an end part of the ultrasonic horn applied to the welding operation of the electrode tab **400** may have a narrow and long rectangular cross-sectional shape. In FIG. **11**, a region indicated by a dash-double dotted line and designated by a reference numeral "H**3**" represents an ultrasonic horn region H**3** in which the ultrasonic horn overlaps the plurality of conductive wires **401**.

[0179] As shown in FIG. **12**, in the overlapping part **410**, when a size of a maximum width WM**2** of the plurality of conductive wires **401** in the longitudinal direction of the positive electrode plate **130** is greater than a size of a width WH of the ultrasonic horn region H**3**, only some conductive wires **401** of the plurality of conductive wires **401** may be welded to the positive electrode plate **130**, and the remaining conductive wires **401** may not be welded to the positive electrode plate **130**.

[0180] However, since all of the conductive wires **401** are welded to the reinforcing thin plate **450**, the electrode tab **400** may be reliably welded to the positive electrode plate **130**. In other words, even when a sum of diameters of the plurality of conductive wires **401** is larger than the width WH of the ultrasonic horn region H**3**, the electrode tab **400** may be firmly welded to the positive electrode uncoated region **145** of the positive electrode plate **130**.

[0181] Accordingly, compared to the electrode tab **200** according to the example of FIGS. **4** to **6**, the electrode tab **400** according to the present example can have a larger number of conductive wires **401**, which increases an electrical capacity of the electrode tab **400** and allows charging and discharging to proceed more stably.

[0182] In an embodiment, any conductive wire **401** may not be bonded to another adjacent conductive wire **401**.

[0183] In an embodiment, the electrode tab **400** bonded to the positive electrode plate **130** may be bonded to the positive electrode inner side surface **136** of the positive electrode uncoated region **145**, and the electrode tab **400** bonded to the negative electrode plate **110** may be bonded to the negative electrode inner side surface **116** of the negative electrode uncoated region **125**.

[0184] When the electrode plates **110** and **130** are bent during winding of the electrode assembly **100**, or when the electrode plates **110** and **130** are expanded during charging and discharging of the secondary battery **10**, in the electrode tab **400** according to the present example, the conductive wires **401** are spaced apart from each other or a gap therebetween is reduced, thereby mitigating stress on the electrode plates **110** and **130** caused by the electrode tab **400**.

[0185] In an embodiment, the electrode plates **110** and **130** come into contact with and press a curved outer circumferential surface of the conductive wire **401** having a circular or circular-like cross-sectional shape, and the stress on the electrode plates **110** and **130** caused by the electrode tab **400** is mitigated. Accordingly, cracking of the electrode plates **110** and **130** due to close contact with the electrode tab **400** may be suppressed, and durability of the secondary battery **10** including

the electrode assembly **100** may be improved.
[0186] The overlapping part **410** may include a welding part W**3** welded to the positive electrode uncoated region **145** of the positive electrode plate **130** by the above-described ultrasonic welding operation and a free part FR**2** not welded to the positive electrode uncoated region **145** by the above-described ultrasonic welding operation. Similarly, when the electrode tab **400** is bonded to the negative electrode plate **110**, the overlapping part **410** may include the welding part W**3** welded to the negative electrode uncoated region **125** of the negative electrode plate **110** and the free part FR**2** not welded to the negative electrode uncoated region **125**.
[0187] Since the free part FR**2** is not fixed to the electrode plates **110** and **130**, when the electrode plates **110** and **130** are wound or expanded, the free part FR**2** may move more freely than the welding part W**3** in a direction that avoids or mitigates a pressure causing the free part FR**2** to come into close contact with the electrode plates **110** and **130**. Accordingly, the pressure applied to the electrode plates **110** and **130** by the electrode tab **400** may be mitigated to a greater extent, and a phenomenon of cracking of the electrode plates **110** and **130** may be more reliably prevented.
[0188] In FIGS. **10** and **12**, the electrode tab **400** is illustrated as being bonded to the positive electrode inner side surface **136**, but is not limited thereto, and may be bonded to the negative electrode inner side surface **116**, or may be bonded to the positive electrode outer side surface **138** or the negative electrode outer side surface **118**.
[0189] FIG. **13** is a flowchart illustrating a method for fabricating the electrode assembly according to an embodiment of the present disclosure. Referring to FIGS. **3**, **5**, and **8**, the method for fabricating the electrode assembly according to the present embodiment of the present disclosure may include preparing an electrode tab (S**110**), overlapping the electrode tab (S**120**), and welding the electrode tab (S**130**).
[0190] The preparing of the electrode tab (S**110**) is an operation of preparing electrode tabs **200** and **300** respectively including a plurality of conductive wires **201** and a plurality of conductive wires **301** arranged side by side in a width direction. The overlapping of the electrode tab (S**120**) is an operation of placing some of the electrode tabs **200** and **300** in a longitudinal direction, i.e., overlapping parts **210** and **310** to overlap the electrode plates **110** and **130**.
[0191] The welding of the electrode tab (S**130**) is an operation of welding some of the electrode tabs **200** and **300**, i.e., the overlapping parts **210** and **310** to the electrode plates **110** and **130**. The welding of the electrode tab (S**130**) may include welding the conductive wires **201** and **301** to the electrode plates **110** and **130** with energy of ultrasonic vibrations.
[0192] Further detailed configurations of the preparing of the electrode tab (S**110**), the overlapping of the electrode tab (S**120**), and the welding of the electrode tab (S**130**) have been already described in the disclosure for the configurations of the electrode tab **200** according to the example of FIGS. **4** to **6** and the configuration of the electrode tab **300** according to the example of FIGS. **7** to **9**, and, thus, repeated descriptions will be omitted.
[0193] The method for fabricating the electrode assembly according to an embodiment of the present disclosure may further include overlapping the positive electrode plate **130** and the negative electrode plate **110**, to which the electrode tab **200** or **300** is bonded, such that the separator **101** is interposed therebetween and winding the overlapping positive electrode plate **130**, negative electrode plate **110**, and separator **101**, after the welding of the electrode tab (S**130**).
[0194] FIG. **14** is a flowchart illustrating a method for fabricating the electrode assembly according to another embodiment of the present disclosure. Referring to FIGS. **3** and **11**, the method for fabricating the electrode assembly according to the present embodiment of the present disclosure may include preparing an electrode tab (S**210**), overlapping the electrode tab (S**220**), and welding the electrode tab (S**230**).
[0195] The preparing of the electrode tab (S**210**) is an operation of preparing an electrode tab **400** including a plurality of conductive wires **401** arranged side by side in a width direction. The preparing of the electrode tab (S**210**) may include overlapping the conductive wire (S**211**) and

welding the conductive wire (S**212**).

[0196] The overlapping of the conductive wire (S**211**) is an operation of arranging the plurality of conductive wires **401** side by side in the width direction and placing the plurality of conductive wires **401** to overlap a reinforcing thin plate **450**. The welding of the conductive wire (S**212**) is an operation of welding the conductive wires **401** to the reinforcing thin plate **450**. In an embodiment, in the welding of the conductive wire (S**212**), all of the conductive wires **401** may be welded to the reinforcing thin plate **450**.

[0197] The overlapping of the electrode tab (S**220**) is an operation of placing a portion

[0198] of the electrode tab in a longitudinal direction of the electrode tab **400**, i.e., some of the plurality of conductive wires **401** including the overlapping parts **410** to overlap the electrode plates **110** and **130**.

[0199] In the overlapping of the electrode tab (S**220**), the electrode tab **400** is placed on the electrode plates **110** and **130** such that the plurality of conductive wires **401** face the electrode plates **110** and **130** and the plurality of conductive wires **401** are interposed between the reinforcing thin plate **450** and the electrode plates **110** and **130**.

[0200] The welding of the electrode tab (S**230**) is an operation of welding a part of the electrode tab **400**, that is, the overlapping parts **410** to the electrode plates **110** and **130**.

[0201] In an embodiment, the welding of the electrode tab (S**230**) may include welding the conductive wires **401** to the electrode plates **110** and **130** with energy of ultrasonic vibrations.

[0202] In the welding of the electrode tab (S**230**), the conductive wires **401** may be welded to the electrode plates **110** and **130** while the reinforcing thin plate **450** is spaced apart from the electrode plates **110** and **130**. In an embodiment, in the welding of the electrode tab (S**230**), some conductive wires **401** of the plurality of conductive wires **401** may not be bonded to the electrode plates **110** and **130**.

[0203] Further detailed configurations of the preparing of the electrode tab (S**210**), the overlapping of the electrode tab (S**220**), and the welding of the electrode tab (S**230**) have been already described in the disclosure for the configurations of the electrode tab **400** according to the example of FIGS. **10** to **12**, and, thus, repeated descriptions will be omitted.

[0204] The method for fabricating the electrode assembly according to the second embodiment of the present disclosure may further include overlapping the positive electrode plate **130** and the negative electrode plate **110**, to which the electrode tab **400** is bonded, such that the separator **101** is interposed therebetween and winding the overlapping positive electrode plate **130**, negative electrode plate **110**, and separator **101**, after the welding of the electrode tab (S**230**).

[0205] According to one or more embodiments of the present disclosure, when an electrode plate is bent during winding of an electrode assembly, or when the electrode plate is expanded during charging and discharging, a plurality of conductive wires are spaced apart from each other or a gap therebetween is reduced, such that stress on the electrode plate caused by an electrode tab can be mitigated.

[0206] Further, in one or more embodiments, the electrode plate comes into contact with and presses a curved outer circumferential surface of the conductive wire, such that stress on the electrode plate caused by the electrode tab can be mitigated. Accordingly, cracking of the electrode plate due to close contact with the electrode tab can be suppressed, and durability of a secondary battery including the electrode assembly can be improved.

[0207] Although the present disclosure has been described with reference to some example embodiments and drawings illustrating aspects thereof, the present disclosure is not limited thereto. Various modifications and variations can be made by a person skilled in the art to which the present disclosure belongs within the scope of the technical spirit of the present disclosure and the claims and equivalents thereto.

Claims

1 what is claimed is:
1. An electrode assembly comprising: a pair of electrode plates; a separator between the pair of electrode plates; and an electrode tab comprising a plurality of conductive wires arranged side by side in a width direction, wherein each of the plurality of conductive wires comprises an overlapping part that overlaps an electrode plate of the pair of electrode plates to be bonded to an electrode plate of the pair of electrode plates, and a protruding part connected to the overlapping part and protruding to an outside at a boundary of the electrode plates.
2. The electrode assembly as claimed in claim 1, wherein the pair of electrode plates comprises a positive electrode plate and a negative electrode plate having opposite polarities, and the overlapping part is bonded to the positive electrode plate.
3. The electrode assembly as claimed in claim 1, wherein each of the electrode plates comprises a substrate and an active material applied to the substrate, and the overlapping part is bonded to an uncoated region of the electrode plate, to which the active material is not applied.
4. The electrode assembly as claimed in claim 1, wherein the pair of electrode plates and the separator are wound around a winding axis, each of the electrode plates comprises an inner side surface facing the winding axis, and an outer side surface opposite to the winding axis, and the electrode tab is bonded to the inner side surface.
5. The electrode assembly as claimed in claim 1, wherein the conductive wires extend along a path that is longer than a shortest distance between a first side end and a second side end in a longitudinal direction.
6. The electrode assembly as claimed in claim 5, wherein the conductive wires extend along a wave path.
7. The electrode assembly as claimed in claim 1, wherein the overlapping part comprises a welding part welded to the electrode plate, and a free part not welded to the electrode plate.
8. The electrode assembly as claimed in claim 1, wherein the electrode tab further comprises a reinforcing thin plate bonded to the plurality of conductive wires and not bonded to the electrode plate.
9. The electrode assembly as claimed in claim 8, wherein all of the conductive wires are bonded to the reinforcing thin plate.
10. The electrode assembly as claimed in claim 9, wherein some of the plurality of conductive wires are not bonded to the electrode plate.
11. The electrode assembly as claimed in claim 1, wherein a cross-sectional shape of the conductive wires is a circular shape.
12. The electrode assembly as claimed in claim 1, wherein the conductive wires are made of aluminum or an aluminum alloy.
13. A method for fabricating an electrode assembly, the method comprising: preparing an electrode tab, in which the electrode tab comprising a plurality of conductive wires arranged side by side in a width direction is prepared; overlapping the electrode tab, in which a part of the electrode tab in a longitudinal direction is placed to overlap an electrode plate; and welding the electrode tab, in which the part of the electrode tab is welded to the electrode plate.
14. The method as claimed in claim 13, wherein the preparing of the electrode tab comprises: overlapping the conductive wires, in which the plurality of conductive wires are arranged side by side in the width direction and placed to overlap a reinforcing thin plate; and welding the conductive wires, in which the conductive wires are welded to the reinforcing thin plate.
15. The method as claimed in claim 14, wherein the overlapping of the electrode tab comprises placing the electrode tab on the electrode plate such that the plurality of conductive wires face the electrode plate and the plurality of conductive wires are arranged between the reinforcing thin plate

and the electrode plate, and the welding of the electrode tab comprises welding the conductive wires to the electrode plate while the reinforcing thin plate is spaced apart from the electrode plate.

16. The method as claimed in claim 14, wherein, in the welding of the conductive wires, all of the conductive wires are bonded to the reinforcing thin plate, and in the welding of the electrode tab, some of the plurality of conductive wires are not bonded to the electrode plate.

17. The method as claimed in claim 13, wherein the welding of the electrode tab comprises welding the conductive wires to the electrode plate with energy of ultrasonic vibrations.

18. A secondary battery comprising: a case; and wherein the electrode assembly comprises: a pair of electrode plates; a separator between the pair of electrode plates; and an electrode tab comprising a plurality of conductive wires arranged side by side in a width direction, wherein each of the plurality of conductive wires comprises an overlapping part that overlaps the electrode plate to be bonded to the electrode plate, and a protruding part connected to the overlapping part and protruding to an outside at a boundary of the electrode plates.

19. The secondary battery as claimed in claim 18, wherein the case comprises: a cylindrical can having a side open and the electrode assembly inserted therein; and a cap assembly arranged to face the open side of the can.

20. The secondary battery as claimed in claim 18, wherein the electrode assembly is wound in a jelly roll shape and accommodated inside the case.