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APPARATUS AND METHOD FOR INSPECTING ELECTRODE ASSEMBLY

Abstract

Disclosed is an apparatus for inspecting an electrode assembly, which can perform inspection of an electrode assembly in a short period of time without destruction of the electrode assembly. The inspection apparatus can inspect an electrode assembly including an anode, a cathode and a separator interposed between the anode and the cathode, and may include: a laser irradiation unit irradiating the electrode assembly with a laser beam; an illumination unit irradiating the electrode assembly with light; an image acquisition unit obtaining an image of the electrode assembly irradiated with the laser beam or light; and a processor inspecting the electrode assembly based on the obtained image.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This present application claims priority to and the benefit under 35 U.S.C. § 119 (a)-(d) of Korean Patent Application No. 10-2024-0020556, filed on Feb. 13, 2024, in the Korean Intellectual Property Office, the entire disclosure of which is incorporated herein by reference.

FIELD

[0002] The present embodiments relate to an apparatus and method for inspecting an electrode assembly to check quality of the electrode assembly.

BACKGROUND

[0003] Secondary batteries can be charged and discharged unlike primary batteries that cannot be charged. Low-capacity secondary batteries are used in small, portable electronic devices, such as smartphones, feature phones, notebook computers, digital cameras, and camcorders, and high-capacity secondary batteries are widely used as power sources for motors in hybrid and electric vehicles and as power storage cells. Such a secondary battery can include an electrode assembly including a cathode and an anode, a case receiving the electrode assembly, and electrode terminals connected to the electrode assembly.

[0004] With recent advances in science and technology, secondary batteries are applied to a variety of devices. As a result, interest in safety of the secondary batteries has further increased.

[0005] This section is intended only to provide a better understanding of the background of the technology and thus may include information which is not necessarily prior art.

SUMMARY

[0006] It is at least one aspect of the present technology to provide an inspection apparatus and/or an inspection method capable of inspecting a secondary battery and/or an electrode assembly in the secondary battery through visual inspection.

[0007] It is at least another aspect of the present technology to provide an inspection apparatus and/or an inspection method capable of performing various inspections simultaneously for inspecting quality of a secondary battery and/or an electrode assembly in the secondary battery.

[0008] The above and other aspects and features of the present technology will become apparent from the following description of embodiments of the present technology.

[0009] In accordance with some aspects of the present technology, an apparatus for inspecting an electrode assembly including an anode, a cathode, and a separator interposed between the anode and the cathode includes: a laser irradiation unit configured to irradiate the electrode assembly with a beam; an illumination unit configured to irradiate the electrode assembly with light; an image acquisition unit configured to obtain an image of the electrode assembly irradiated with the beam and/or light; and a processor configured to inspect the electrode assembly based on the obtained image.

[0010] In accordance with other aspects of the present technology, a method for inspecting an electrode assembly includes: performing inspection of the electrode assembly with regard to at least one of miswinding, alignment, major diameter, volume, and folded state of the electrode assembly through the inspection apparatus.

[0011] According to some embodiments, it is possible to provide an inspection apparatus and/or an inspection method capable of performing inspection of a secondary battery without destruction of

the secondary battery.
[0012] According to some embodiments, it is possible to provide an inspection apparatus and/or an inspection method capable of performing a fully automated inspection of a secondary battery.
[0013] According to some embodiments, it is possible to perform multiple inspections on secondary batteries within a short period of time.
[0014] However, aspects and features of the technology described herein are not limited to those described above and other aspects and features not mentioned will be clearly understood by those skilled in the art from the detailed description given below.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
[0015] The following drawings accompanying this specification illustrate embodiments of the present technology, and further describe aspects and features of the present technology together with the detailed description. Thus, the present technology should not be construed as being limited to the drawings:
[0016] FIG. **1** is a perspective view of a cylindrical battery according to some embodiments;
[0017] FIG. **2** is a cross-sectional view of the cylindrical battery according to some embodiments;
[0018] FIG. **3** is a schematic diagram of an apparatus for inspecting an electrode assembly according to some embodiments;
[0019] FIG. **4** is a flowchart illustrating a method for inspecting an electrode assembly according to some embodiments;
[0020] FIG. **5** is a flowchart illustrating miswinding inspection according to some embodiments;
[0021] FIG. **6**A to FIG. **6**B are diagrams illustrating the miswinding inspection according to some embodiments;
[0022] FIG. **7** is a flowchart illustrating miswinding inspection according to some embodiments;
[0023] FIG. **8** is a diagram illustrating the miswinding inspection according to some embodiments;
[0024] FIG. **9** is a flowchart illustrating alignment inspection according to some embodiments;
[0025] FIG. **10** is a diagram illustrating the alignment inspection according to some embodiments;
[0026] FIG. **11** is a flowchart illustrating alignment inspection according to some embodiments;
[0027] FIG. **12** is a diagram illustrating the alignment inspection according to some embodiments; and
[0028] FIG. **13** is a flowchart illustrating major diameter inspection according to some embodiments.
DETAILED DESCRIPTION
[0029] Hereinafter, exemplary embodiments of the present technology will be described, in 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 having meanings and concepts consistent with the technical idea of the present technology based on the principle that the inventor(s) can be his/her own lexicographer to appropriately define the concept of the term to explain the technology in the most suitable way. The embodiments described in this specification and the configurations shown in the drawings are only some of the embodiments of the present technology and do not represent all of the technical ideas, aspects, and features of the present technology. Accordingly, it should be understood that there may be various equivalents and modifications that can replace or modify the embodiments described herein at the time of filing this application.
[0030] It will 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. Further, the use of “may” when describing embodiments of the present technology relates to “one or more embodiments of the present technology.”

[0031] In the figures, dimensions of the various elements, layers, and the like may be exaggerated for clarity of illustration. The same reference numerals designate the same elements.

[0032] References to two compared elements, features, and the like as being “the same,” may mean that they are “substantially the same.” Thus, the phrase “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.

[0033] It will be understood that, although the terms first, second, third, and the like may be used herein to describe various elements, components, regions, layers, and/or sections, these elements, components, regions, layers, and/or sections should not 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 could be termed a second element, component, region, layer, or section without departing from the teachings of example embodiments.

[0034] Throughout the specification, unless specified otherwise, each element may be singular or plural.

[0035] When an arbitrary element is referred to as being disposed (or located or disposed) “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 disposed) on (or under) the component.

[0036] In addition, it will 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 an intervening element 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 can be directly connected to another part or an intervening part may be present therebetween such that the part and another part are indirectly connected to each other.

[0037] Throughout the specification, when “A and/or B” is stated, it means A, B or A and B, unless specified otherwise. 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 specified otherwise.

[0038] The terminology used herein is for the purpose of describing embodiments of the present technology and is not intended to be limiting of the present technology.

[0039] In general, to check whether secondary batteries have been safely manufactured, quality inspection is performed on multiple secondary batteries. Quality inspection of the secondary batteries may include miswinding inspection, alignment inspection, major diameter inspection, volume inspection, and/or one-end folded state inspection.

[0040] Since there is no instrument capable of automatically inspecting secondary batteries, the secondary batteries are manually inspected by an operator. For example, inspection is carried out through destruction of the secondary battery. However, the inventors have recognized such inspection results in extensive waste of batteries, high time consumption, and inconvenience.

[0041] On the other hand, X-ray or CT instruments have been used to check the quality of secondary batteries to prevent destruction of the secondary batteries. However, these instruments have problems of high time consumption and low reliability. Moreover, this method has difficulty in securing a safe working environment due to use of radiation and/or requires excessive costs for inspection.

[0042] FIG. **1** is a perspective view of a cylindrical battery according to some embodiments.

[0043] FIG. **2** is a cross-sectional view of the cylindrical battery according to some embodiments.
[0044] Referring to FIG. **1** and FIG. **2**, a cylindrical lithium ion secondary battery **100** according to various embodiments may include a cylindrical can **110**, an electrode assembly **120**, and a cap assembly **140**. The cylindrical lithium ion secondary battery **100** may further include a center pin **130**. Furthermore, in the secondary battery **100** according to some embodiments, the cap assembly **140** also performs current interruption and is thus often referred to as a current interrupt device.
[0045] The cylindrical can **110** may include a substantially circular bottom **111** and a cylindrical sidewall **112** extending a certain length upwards from a circumference of the bottom **111**. During a manufacturing process of the secondary battery, an upper portion of the cylindrical can **110** is open. Thus, during an assembly process of the secondary battery, the electrode assembly **120** and the center pin **130** may be inserted into the cylindrical can **110** together with the electrolyte. The cylindrical can **110** may be formed of, for example, steel, stainless steel, aluminum, aluminum alloys, or an equivalent thereto, without being limited thereto.
[0046] In addition, the cylindrical can **110** may include a beading portion **113** recessed inwards at a lower portion thereof and a crimping portion **114** bent inwards at an upper portion thereof with respect to the cap assembly **140** to prevent the cap assembly **140** from being detached outwards.
[0047] The electrode assembly **120** may be received within the cylindrical can **110**. The electrode assembly **120** may include an anode plate **121** having an anode active material (for example, graphite, carbon, and the like) coated on an anode collector, a cathode plate **122** having a cathode active material (for example, transition metal oxide (LiCoO.sub.2, LiNiO.sub.2, LiMn.sub.2O.sub.4, and the like)) coated on a cathode collector, and a separator **123** interposed between the anode plate **121** and the cathode plate **122** to prevent short circuit while allowing only migration of lithium ions. Further, the anode plate **121**, the cathode plate **122**, and the separator **123** may be wound in a substantially cylindrical shape. By way of example, the anode collector may be formed of copper (Cu) foil, the cathode collector may be formed of aluminum (Al) foil, and the separator may be formed of polyethylene (PE) or polypropylene (PP) without being limited thereto.
[0048] In addition, an anode tab **124** may be welded to the anode plate **121** to protrude a certain length downwards and a cathode tab **125** may be welded to the cathode plate **122** to protrude a certain length upwards, or vice versa. By way of example, the anode tab **124** may be formed of copper (Cu) or nickel (Ni) and the cathode tab **125** may be formed of aluminum (Al), without being limited thereto.
[0049] In addition, the anode tab **124** of the electrode assembly **120** may be welded to the bottom **111** of the cylindrical can **110**. Accordingly, the cylindrical can **110** may act as an anode. It should be understood that the cathode tab **125** may be welded to the bottom **111** of the cylindrical can **110** to act as a cathode.
[0050] In addition, a first insulating plate **126** coupled to the cylindrical can **110** and formed with a first hole **126***a* at a center thereof and a second hole **126***b* at a periphery thereof may be interposed between the electrode assembly **120** and the bottom **111**. The first insulating plate **126** may serve to prevent the electrode assembly **120** from electrically contacting the bottom **111** of the cylindrical can **110**. In particular, the first insulating plate **126** may serve to prevent the cathode plate **122** of the electrode assembly **120** from electrically contacting the bottom **111**. Here, the first hole **126***a* serves to allow a gas to rapidly flow upwards through the center pin **130** in the event of generation of a large amount of gas due to an abnormality in the secondary battery, and the second hole **126***b* serves to allow the anode tab **124** to be welded to the bottom **111** therethrough.
[0051] In addition, a second insulating plate **127** coupled to the cylindrical can **110** and formed with a first hole **127***a* at a center thereof and a plurality of second holes **127***b* on a periphery thereof may be interposed between the electrode assembly **120** and the cap assembly **140**. The second insulating plate **127** may serve to prevent the electrode assembly **120** from electrically contacting the cap assembly **140**. In particular, the second insulating plate **127** may serve to prevent the anode plate **121** of the electrode assembly **120** from electrically contacting the cap assembly **140**. Here,

the first hole **127***a* can serve to allow a gas to rapidly flow into the cap assembly **140** in the event of generation of a large amount of gas due to an abnormality in the secondary battery, and one of the second holes **127***b* can serve to allow the cathode tab **125** to be welded to the cap assembly **140** therethrough. In addition, the remaining second holes **127***b* can serve to allow an electrolyte to rapidly flow into the electrode assembly **120** during an electrolyte injection process.

[0052] Furthermore, the first holes **126***a*, **127***a* of the first and second insulating plates **126**, **127** may have smaller diameters than the center pin **130** to prevent the center pin **130** from electrically contacting the bottom **111** of the cylindrical can **110** or the cap assembly **140** due to external impact.

[0053] The center pin **130** may be prepared in the form of a hollow circular pipe, which may be coupled substantially to the center of the electrode assembly **120**. Such a center pin **130** may be formed of, for example, steel, stainless steel, aluminum, aluminum alloys, or polybutylene terephthalate, without being limited thereto. The center pin **130** can serve to suppress deformation of the electrode assembly **120** during charging and discharging of the battery and can act as a flow conduit for gases generated within the secondary battery. Of course, in some embodiments, the center pin **130** may be omitted.

[0054] The cap assembly **140** may include a top plate **141**, a middle plate **142**, an insulating plate **143**, and a bottom plate **144**.

[0055] The middle plate **142** may be disposed under the top plate **141** and may have a substantially flat shape.

[0056] The insulating plate **143** may be formed in a circular ring shape having a constant width in bottom view. In addition, the insulating plate **143** can serve to insulate the middle plate **142** and the bottom plate **144** from each other. The insulating plate **143** may be, for example, interposed between the middle plate **142** and the bottom plate **144** and may be ultrasonically welded thereto, without being limited thereto.

[0057] The cap assembly **140** may be fixed to the inside of the can **110** by a gasket **145** to seal the case. The gasket **145** may electrically insulate between the can **110** and the cap assembly. The gasket **145** may prevent moisture or electrolyte from flowing in or out between the can and cap assembly.

[0058] However, it should be understood that the present technology is not limited thereto and the case may have various shapes, such as a circular shape, a pouch shape, and the like, and may be formed of metal, such as aluminum, aluminum alloys, and nickel-plated steel, a laminate film constituting a pouch, or plastics, without being limited thereto.

[0059] The lithium secondary battery **100**, according to some embodiments, has been described with reference to FIG. **1** and FIG. **2**. On the other hand, as described herein, safety concerns regarding the secondary battery **100** have been increasing in recent years. Accordingly, when manufacture of the secondary battery **100** is completed, the secondary battery **100** is subjected to quality inspection before application of the secondary battery **100** to products. Here, the quality inspection of the secondary battery **100** can be a process of checking the external appearance of the secondary battery **100** to ensure that the secondary battery **100** has been properly manufactured in accordance with design. The quality inspection of the secondary battery **100** can be performed through visual inspection of the electrode assembly **120** in the secondary battery.

[0060] Next, a method and/or apparatus for inspecting an electrode assembly in a secondary battery **100** will be described.

[0061] On the other hand, an object to be inspected by an apparatus for inspecting an electrode assembly according to some embodiments is not limited to the electrode assembly. The inspection apparatus may perform inspection not only of the electrode assembly, but also of the secondary battery in which the electrode assembly is embedded, a cell module including the secondary battery, a cell pack, and the like. Furthermore, the inspection apparatus may perform inspection of any object formed by stacking a plurality of layers, such as an electrode assembly. For simplicity of description, an electrode assembly will be described as a non-limiting example of an object to be inspected herein.

[0062] FIG. **3** is a schematic view of an apparatus for inspecting an electrode assembly according to some embodiments.

[0063] In FIG. **3**, electrode assembly **200** denotes an electrode assembly including, for example, the electrode assembly **120** illustrated in FIG. **1** and FIG. **2**. As described in relation to FIG. **1** and FIG. **2**, the electrode assembly **200** may include an anode, a cathode, and a separator interposed between the anode and the cathode. The electrode assembly **200** may include a laminate structure formed by stacking the anode, the cathode, and the separator. The electrode assembly **200** includes, for example, a jellyroll type electrode assembly, which is formed by winding such a laminate structure in one direction. The electrode assembly **200** to be inspected by the inspection apparatus according to some embodiments is not limited to the jellyroll type, and may include, for example, a pouch type, a prismatic type, a coil type, and the like. However, for simplicity of description, a jelly-roll type electrode assembly **200** will hereinafter be described as an object of inspection by way of example.

[0064] In FIG. **3**, inspection apparatus **300** denotes an apparatus for inspecting the electrode assembly **200**. The inspection apparatus **300** checks quality of the electrode assembly **200**. Specifically, the inspection apparatus **300** checks the quality of the electrode assembly **200** by checking the shape of the electrode assembly **200**, that is, an external appearance thereof. For example, the inspection apparatus **300** inspects the electrode assembly **200** with regard to at least one of miswinding, alignment, major diameter, volume, and folded states thereof.

[0065] To this end, the inspection apparatus **300** shown in FIG. **3** includes a laser irradiation unit **310**, an illumination unit **330**, an image acquisition unit **340**, and a processor **360**. The inspection apparatus **300** may further include a reflector **320** and a lens unit **350**. However, components of the inspection apparatus **300** are not limited to the components shown in FIG. **3**. The inspection apparatus **300** may include fewer components than shown in FIG. **3** and/or may include more components in addition to the components shown in FIG. **3**. For example, the inspection apparatus **300** may further include a memory (not shown) storing instructions and/or data required for operation of the inspection apparatus **300** (e.g., a non-transitory computer readable medium), and a communication unit (not shown) that enables the inspection apparatus **300** to communicate with external devices and/or external servers. The processor may be configured to execute instructions stored in the memory.

[0066] The laser irradiation unit **310** may emit a laser beam towards the electrode assembly **200**. To this end, the laser irradiation unit **310** may be spaced apart from the electrode assembly **200** such that the electrode assembly **200** can be irradiated with the laser beam.

[0067] The laser irradiation unit **310** emits a laser beam toward the electrode assembly **200**. The laser irradiation unit **310** includes at least one of a gas laser, a solid-state laser, and an excimer laser. The gas laser includes, for example, a He—Ne laser, an Ar laser, and/or a CO.sub.2 laser. The solid-state laser includes, for example, any laser that is optically pumped by a flash lamp and/or an arc lamp. The excimer laser includes any laser that emits light in the ultraviolet band at high power. However, it should be understood that the present technology is not limited thereto and the laser irradiation unit **310** can include any device capable of emitting a laser beam amplified through inductive emission.

[0068] Alternatively, the laser irradiation unit **310** may emit a laser beam towards the electrode assembly **200** through the reflector **320**. In some embodiments, as shown in FIG. **3**, the reflector **320** may be realized by one or multiple reflectors that reflect the emitted laser beam received from the laser irradiation unit **310** towards the electrode assembly **200**. Specifically, the laser irradiation unit **310** emits a laser beam towards the reflector **320**. The reflector **320** reflects the laser beam towards the electrode assembly **200**. The reflector **320** may be spaced apart from the laser irradiation unit **310** to receive the laser beam emitted from the laser irradiation unit **310**. However, the reflector **320** may also be disposed within the laser irradiation unit **310** to directly contact the laser beam emitted from the laser irradiation unit **310**. Further, the reflector **320** (as shown) is spaced apart from the electrode assembly **200** such that the received laser beam can be reflected back to the electrode assembly **200**. With this structure, the reflector **320** (e.g., mirror) can ensure that the laser beam can be accurately delivered to the electrode assembly **200**.

[0069] The laser beam delivered to the electrode assembly **200** may be reflected from the electrode assembly **200** to be acquired by the image acquisition unit **340**. As a result, the inspection apparatus **300** according to some embodiments can inspect the electrode assembly **200** based on a laser phase difference.

[0070] The illumination unit **330** may emit light towards the electrode assembly **200**. The illumination unit **330** may be spaced apart from the electrode assembly **200** to emit light. For example, the illumination unit **330** is disposed such that light emitted from the illumination unit **330** is directed towards an upper surface of the electrode assembly **200**. The illumination unit may irradiate the electrode assembly with light. The illumination units **330** may be provided in plural, for example, to emit light towards upper, lower, left and/or right sides of the upper surface of the electrode assembly **200**. Alternatively, the illumination unit(s) **330** may be one light source that surrounds the upper, lower, left and/or right sides of the upper surface of the electrode assembly **200**. Alternatively, the illumination unit **330** may be implemented by the laser irradiation unit **310** or the laser irradiation unit **310** may be implemented by the illumination unit **330**. In this case, one of the laser irradiation unit **310** and the illumination unit **330** may be omitted.

[0071] Light delivered to the electrode assembly **330** may be reflected from the electrode assembly **200** to be acquired by the image acquisition unit **340**.

[0072] The image acquisition unit **340** can obtain an image of the electrode assembly **200** irradiated with the laser beam or light. For example, the image acquisition unit **340** may acquire an image of the electrode assembly **200** irradiated with the laser beam and/or light that is refracted by the lens unit **350**. To this end, the lens unit **350** may be spaced apart from the image acquisition unit **340** and/or the electrode assembly **200**. For example, the lens unit **350** may be disposed such that the laser beam and/or light reflected from the electrode assembly **200** is bent at 90 degrees to reach the image acquisition unit **340**. The lens unit may allow for the image acquisition unit to obtain the image of the electrode assembly.

[0073] The image acquisition unit **340**, in some embodiments, includes a sensor capable of obtaining an image, for example, a vision sensor (including, for example, a vision camera), a LiDAR sensor, and/or a laser sensor.

[0074] An image obtained by the image acquisition unit **340** can include any images that represent information regarding the electrode assembly **200**, such as photographic images, images representing distances or properties, and the like.

[0075] The image obtained by the image acquisition unit **340** includes, for example, an image of an upper surface of the electrode assembly **200**. Here, the image of the upper surface of the electrode assembly **200** includes an image of a laser beam incident on the upper surface of the electrode assembly **200**. Alternatively, the image of the upper surface of the electrode assembly **200** may include a photographic image of the upper surface of the electrode assembly **200**.

[0076] The upper surface of the electrode assembly **200** is a cross-section in a direction in which a stacked shape of the anode, the cathode, and the separator in the electrode assembly **200** can be viewed. For example, the upper surface of the electrode assembly **200** is a cross-section perpendicular to a winding core axis of the jellyroll and can be observed when a winding core of the jellyroll is observed in a winding axis direction of the jellyroll.

[0077] The processor **360** may control all or some components of the inspection apparatus **300**. The processor **360** may be embedded in the inspection apparatus **300**. Alternatively, the processor **360** may be placed outside the inspection apparatus **300** and may control each of the components in the inspection apparatus **300** through wired or wireless communication.

[0078] The processor **360** includes at least one of, for example, a central processing unit (CPU), a microprocessor unit (MPU), a microcontroller unit (MCU), a graphics processing unit (GPU), a digital signal processor (DSP), a floating-point unit (FPU), an application specific integrated circuit (ASIC), and a field programmable gate array (FPGA).
[0079] The processor **360** may inspect the electrode assembly **200** based on the obtained image.
[0080] As such, the inspection apparatus **300** according to some embodiments can acquire an image of the electrode assembly **200** and check the quality of the electrode assembly **200** without destruction of the electrode assembly **200**. In addition, the inspection apparatus **300** can perform two or more inspections on the electrode assembly **200** at the same time. Further, the inspection apparatus **300** allows the inspections on the electrode assembly **200** to be automatically performed. Accordingly, the inspection apparatus **300** improves an operator load factor while minimizing the number of electrode assemblies **200** that will be destroyed by inspection and then discarded.
[0081] FIG. **4** is a flowchart illustrating a method for inspecting an electrode assembly according to some embodiments. FIG. **4** illustrates a method for inspecting the electrode assembly **200** through the inspection apparatus **300** shown in FIG. **3**, as a non-limiting example.
[0082] The method for inspecting an electrode assembly according to some embodiments includes a step of irradiating the electrode assembly **200** with a laser beam and/or light (step S**101**). As illustrated in FIG. **3**, the laser irradiation unit **310** may emit a laser beam towards the electrode assembly **200** and the illumination unit **330** may emit light towards the electrode assembly **200**. Here, the laser irradiation unit **310** may emit the laser beam while the illumination unit **330** emits light, may emit the laser beam before the illumination unit **330** emits light, or may emit the laser beam after the illumination unit **330** emits light.
[0083] The method for inspecting an electrode assembly according to some embodiments includes a step of obtaining an image of the electrode assembly **200** irradiated with the laser beam and/or light (step S**102**). Referring to FIG. **3**, the image acquisition unit **340** may obtain an image of the electrode assembly **200**.
[0084] The method for inspecting an electrode assembly according to some embodiments includes a step of inspecting the electrode assembly **200** based on the obtained image (step S**103**). As illustrated in FIG. **3**, the processor **360** may check the quality of the electrode assembly **200** based on the obtained image. For example, based on the obtained image, the processor **360** inspects the electrode assembly **200** with regard to at least one of miswinding, alignment, major diameter, volume, and one-end folded state of the electrode assembly **200**.
[0085] The following description will focus on one or more inspections performed by the inspection apparatus **300**.
[0086] FIG. **5** is a flowchart illustrating miswinding inspection according to some embodiments.
[0087] FIG. **6**A and FIG. **6**B are diagrams illustrating the miswinding inspection according to some embodiments.
[0088] FIG. **5**, FIG. **6**A and FIG. **6**B illustrate miswinding inspection of the electrode assembly **200** as one example of checking the quality of the electrode assembly **200** illustrated in FIG. **3** and FIG. **4**.
[0089] Referring to FIG. **5**, the inspection apparatus **300** according to some embodiments calculates a phase difference between two of the anode, the cathode, and the separator based on the obtained image (step S**201**).
[0090] For example, as shown in FIG. **6**A, a laser beam b emitted from the laser irradiation unit **310** is directed toward the electrode assembly **200**. Here, as illustrated in FIG. **3** and FIG. **4**, the laser beam b may be reflected towards the electrode assembly **200** by the reflector **320**.
[0091] FIG. **6**B shows an image of an upper surface **200***t* of the electrode assembly. The image acquisition unit **340** may obtain an image caused by the laser beam b on the upper surface **200***t* of the electrode assembly.
[0092] Based on the obtained image, the processor **360** calculates a phase difference between at

least two of the anode, the cathode, and the separator. The phase difference may be generated by, for example, a thickness of at least one of the anode, the cathode, and the separator.

[0093] Specifically, the processor **360** determines zones where the laser beam b has different phases. For example, the processor **360** determines that a laser beam image b**1** created in a first zone and a laser beam image b**2** created in a second zone have different phases. For example, the processor **360** determines, based on the phases of the laser beam image b**1** created in the first zone and the laser beam image b**2** created in the second zone, that the first zone is placed 5 mm further inwards than the second zone. As such, the processor **360** calculates a phase difference between materials based on images of the laser beam b formed on the electrode assembly **200**.

[0094] Referring to FIG. **5**, the inspection apparatus **300** according to some embodiments performs miswinding inspection of the electrode assembly **200** based on the calculated phase difference (step S**202**).

[0095] Here, the miswinding inspection is performed to check a wound state between the materials of the electrode assembly **200**. The materials of the electrode assembly **200** include at least one of the anode, the cathode, and the separator. Specifically, the miswinding inspection may include measuring a height difference between the materials.

[0096] The processor **360** performs the miswinding inspection of the electrode assembly **200** based on the calculated phase difference. The miswinding inspection performed by the processor **360** based on the calculated phase difference will be described in more detail with reference to FIG. **7** and FIG. **8**.

[0097] As such, the inspection apparatus **300** according to some embodiments can rapidly check miswinding of the electrode assembly **200** using a laser beam in real time without destruction of the electrode assembly **200**.

[0098] FIG. **7** is a flowchart of the miswinding inspection according to some embodiments.

[0099] FIG. **8** is a diagram illustrating the miswinding inspection according to some embodiments.

[0100] Referring now to FIG. **7** and FIG. **8**, at least one example of the miswinding inspection of the electrode assembly **200** illustrated in FIG. **3** to FIG. **6**B will be described in more detail. Referring to FIG. **8**, the electrode assembly **200** is formed by stacking an anode **210**, a cathode **220** and a separator **230** such that the separator **230** is interposed between the anode **210** and the cathode **220**.

[0101] Referring to FIG. **7**, the inspection apparatus **300** according to some embodiments calculates a thickness based on the phase difference (step S**301**).

[0102] The processor **360** calculates the thickness of at least one of the anode **210**, the cathode **220**, and the separator **230** based on the phase difference. For example, in a structure in which the anode **210** is interposed between two separators **230**, the two separators **230** may have a different phase than the anode **210** interposed therebetween. Alternatively, for example, in a structure in which the cathode **220** is interposed between the two separators **230**, the two separators **230** may have a different phase than the cathode **220** interposed therebetween. Accordingly, the phase difference is, for example, a difference in phase between the anode **210** and the separator **230** or between the cathode **220** and the separator **230**. Based on such a phase difference between at least two materials, the processor **360** can calculate the thickness of each material. That is, the processor **360** can calculate the thickness of at least one of the anode **210**, the cathode **220**, and the separator **230**.

[0103] Referring to FIG. **7**, the inspection apparatus **300** according to some embodiments calculates a miswinding distance based on the thickness (step S**302**).

[0104] Based on the calculated thickness, the processor **360** may calculate the miswinding distance between at least two of the anode **210**, the cathode **220**, and the separator **230**. Here, the miswinding distance corresponds to a height difference between two materials. Here, a direction representing the height difference between the two materials is perpendicular to a direction representing the thickness of one material.

[0105] The miswinding distance represents, for example, a height difference h**1** between the anode

210 and the cathode **220**, a height difference h**2** between the separator **230** and the anode **210**, and/or a height difference between the separator **230** and the cathode **220**.

[0106] The processor **360** calculates the miswinding distance based on the thickness. For example, the processor **360** may calculate the miswinding distance using trigonometry based on the calculated thickness. For example, the processor **360** may calculate the miswinding distance according to Equation 1:

[00001] $h = \frac{d}{\tan}$ (Equation1)

[0107] Here, h denotes the miswinding distance between at least two of the anode **210**, the cathode **220** and the separator **230**; d denotes the thickness of at least one of the anode **210**, the cathode **220**, and the separator **230**; and θ denotes an angle between a straight line of the shortest distance connecting a corner of one material to a corner of another material adjacent thereto and a longitudinal direction of the one material. Here, the corner of the one material is placed in a direction of the upper surface of the electrode assembly **200** to be close to the adjacent material. In addition, the corner of the adjacent material is placed in the direction of the upper surface of the electrode assembly **200** to be away from the one material. The straight line of the shortest distance is the shortest line among straight lines connecting the corner of the one material to the corner of the adjacent material.

[0108] For example, referring to FIG. **8**, the separator **230** is placed adjacent the anode **210**. A corner of the separator **230** is, for example, corner e**1**. A corner of the anode **210** is, for example, corner e**2**. The straight line of the shortest distance is a straight line connecting corner e**1** to corner e**2**. d is the thickness of the adjacent material, that is, the thickness of the anode **210**. θ is an angle between the straight line connecting corner e**1** to corner e**2** and the longitudinal direction of the separator **230**. With these values, the processor **360** can calculate a miswinding value (height difference h**2**) between the separator **230** and the anode **210**.

[0109] Referring to FIG. **7**, the inspection apparatus **300** according to some embodiments performs the miswinding inspection based on the miswinding distance (step S**303**).

[0110] The processor **360** may compare the miswinding distance with a range of miswinding distances stored in a memory (for example, in the memory described in relation to FIG. **3**). Upon determining that the calculated miswinding distance falls within the range of miswinding distances, the processor **360** determines that miswinding of the electrode assembly **200** is properly performed. Upon determining that the calculated miswinding distance does not fall within the range of miswinding distances, the processor **360** determines that winding of the electrode assembly **200** is not properly performed (that is, the electrode assembly **200** is miswinding).

[0111] As such, the inspection apparatus **300** according to some embodiments can rapidly check miswinding of the electrode assembly **200** using a laser beam in real time without destruction of the electrode assembly **200**

[0112] FIG. **9** is a flowchart of alignment inspection according to some embodiments.

[0113] FIG. **10** is a diagram illustrating the alignment inspection according to some embodiments.

[0114] FIG. **9** and FIG. **10** illustrate alignment inspection of the electrode assembly **200** as an example of checking the quality of the electrode assembly **200** illustrated in FIG. **3** to FIG. **4**.

[0115] Referring to FIG. **9**, the inspection apparatus **300** according to some embodiments detects one end of the anode and/or one end of the cathode based on the obtained image (step S**401**).

[0116] The obtained image includes, for example, an image of an upper surface of a jellyroll in a wound state, as described above. The obtained image may further include an image of a side surface of the jellyroll in an unwound state. Here, the image of the side surface of the jellyroll in the unwound state includes, for example, an image in which the jellyroll is unwound to expose one end of the anode **210** and/or one end of the cathode **220**, as shown in FIG. **10**.

[0117] One end of the anode **210** and/or one end of the cathode **220** includes a start point (leading end) of the anode **210** and/or the cathode **220**. Here, the start point is an end of each layer located at a center of the jellyroll when the electrode assembly **200** is wound. Alternatively, the one end of the anode **210** and/or the cathode **220** includes a distal end (tip) of the anode **210** and/or the cathode **220**. The distal end is an end of each layer located at an outer periphery of the jellyroll when the electrode assembly **200** is wound. In other words, the one end of the anode **210** and/or the cathode **220** may include an end of each layer included in the electrode assembly **200**. For simplicity of description, FIG. **9** and FIG. **10** show “leading end” as an example of “one end”.

[0118] The processor **360** may detect one end p**1** of the anode and one end p**2** of the cathode based on the obtained image. For example, the processor **360** checks a zone of each material using the laser beam and detects one end of each material based on the image of the upper surface of the jellyroll in the wound state. As an additional example, the processor **360** detects one end of each material from an image of the side surface of the jellyroll in the unwound state.

[0119] Here, the one end p**1** of the anode indicates at least one point between an uncoated portion **211** and a coated portion **212**. The uncoated portion **211** is an uncoated portion of a base material of the anode. The coated portion **212** is a coated portion on the base material of the anode, which is coated with, for example, an anode active material.

[0120] The one end p**2** of the cathode **220** may be an end of one side of the cathode **220** in the longitudinal direction of the cathode **220**.

[0121] For example, the one end p**1** of the anode and the one end p**2** of the cathode are located at a winding core of the electrode assembly **200** in an unwound state of the electrode assembly **200**.

[0122] The processor **360** may calculate a distance between the one end p**1** of the anode and the one end p**2** of the cathode from the one end p**1** of the anode and the one end p**2** of the cathode detected thereby. This process will be described in more detail with reference to FIG. **11** to FIG. **12**. However, it should be understood that this process is provided by way of example and the processor **360** may calculate the distances between the anode **210** and the cathode **220**, between the anode **210** and the separator **230**, and between the cathode **220** and the separator **230** in any of the ways described above.

[0123] Referring to FIG. **9**, the inspection apparatus **300** according to some embodiments performs alignment inspection of the electrode assembly **200** based on one end of the anode and/or one end of the cathode (step S**402**).

[0124] The alignment inspection may be a process of checking a winding start point of each material in a process of winding a secondary battery. For example, in the alignment inspection, the winding start point of each of the anode **210**, the cathode **220** and/or the separator **230** in the electrode assembly **200** is checked.

[0125] The processor **360** may check the winding start point of each of the materials included in the electrode assembly **200** through the one end p**1** of the anode, the one end p**2** of the cathode **220** and/or one end of the separator **230** (not shown). In addition, the processor **360** checks alignment between at least two materials in the electrode assembly **200** through the one end p**1** of the anode, the one end p**2** of the cathode **220** and/or the one end of the separator **230** (not shown).

[0126] As such, the inspection apparatus **300** according to some embodiments may check the winding start point of each of the materials and may automatically calculate alignment quality therebetween by detecting one end of the anode **210**, one end of the cathode **220** and/or one end of the separator **230**, followed by calculating the distance therebetween.

[0127] FIG. **11** is a flowchart illustrating the alignment inspection according to some embodiments.

[0128] FIG. **12** is a diagram illustrating the alignment inspection according to some embodiments.

[0129] Referring to FIG. **11** and FIG. **12**, an example of performing alignment inspection of the electrode assembly **200** shown in FIGS. **3**, **4**, **9** and **10** is described in more detail. FIG. **12** shows the upper surface of the electrode assembly **200**.

[0130] Referring to FIG. **11**, the inspection apparatus **300** according to some embodiments determines a central point of the jellyroll (step S**501**).

[0131] The processor **360** may determine the central point c of the electrode assembly **200** forming the jellyroll. Here, the central point c is placed at the winding core of the electrode assembly **200**. For example, the central point c corresponds to a central axis about which the electrode assembly **200** is wound. The processor **360** may determine the central point c of the jellyroll based on the obtained image showing the upper surface of the wound electrode assembly **200**.

[0132] Referring to FIG. **11**, the inspection apparatus **300** according to some embodiments calculates a length of an arc corresponding to the distance between the one end of the anode and the one end of the cathode based on the central point (step S**502**).

[0133] The processor **360** may calculate the length of the arc, which corresponds to the distance between the materials in the electrode assembly, based on the central point c and one end of each material. For example, the processor **360** determines a first straight line **11** connecting the one end p**1** of the anode to the central point c and a second straight line **12** connecting the one end p**2** of the cathode to the central point c. The processor **360** may calculate an angle between the first straight line **11** and the second straight line **12**. Based on the angle a between the first straight line **11** and the second straight line **12**, the processor **360** calculates the length of the arc between the one end p**1** of the anode and the one end p**2** of the cathode. For example, the processor **360** calculates the length of the arc according to Equation 2:

[00002] $s = t$ .Math. $\frac{a}{360}$ (Equation2)

[0134] Here, s is the length of the arc, which corresponds to the distance between the materials in the electrode assembly. For example, s is the length of the arc between the one end p**1** of the anode and the one end p**2** of the cathode. Here, t is the length of the entire arc of the jellyroll, which corresponds to the circumference of the jellyroll. In addition, a is an angle (e.g., in degrees °) between the materials in the electrode assembly. The angle (°) has a value between 0° and 360°.

[0135] In this way, the processor **360** can calculate the arc length, which corresponds to the distance between the materials in the electrode assembly. For example, the processor **360** may calculate the length of the arc between the one end of the cathode and the one end of the anode.

[0136] Referring to FIG. **11**, the inspection apparatus **300** according to some embodiments performs alignment inspection based on the length of the arc (step S**503**).

[0137] The processor **360** may perform the alignment inspection of the electrode assembly **200** by comparing at least one of one end of each material and the length of the arc between the materials with data stored in the memory.

[0138] As such, the inspection apparatus **300** according to some embodiments can check the winding start point of each material and can automatically check alignment between the materials by detecting one end of the anode **210**, the cathode **220** and/or the separator **230** and calculating the distance therebetween.

[0139] FIG. **13** is a flowchart illustrating major diameter inspection according to some embodiments.

[0140] FIG. **13** illustrates the major diameter inspection of the electrode assembly **200** as an example of checking the quality of the electrode assembly **200** illustrated in FIG. **3** and FIG. **4**.

[0141] Referring to FIG. **13**, the inspection apparatus **300** according to some embodiments determines a major diameter of the electrode assembly **200** based on the obtained image (step S**601**).

[0142] As described above, the obtained image may include an image of the upper surface of the electrode assembly **200**.

[0143] The processor **360** may extract a certain pair of first points on the upper surface of the electrode assembly **200** (e.g., from the image of the upper surface). The processor **360** may calculate a first length corresponding to a distance between the first points. The processor **360** may calculate a second length corresponding to a distance between a certain pair of second points (extracted by the processor from the image). Here, one point of the pair of first points may overlap one point of the pair of second points. However, it should be noted that the pair of first points does not overlap the pair of second points. In other words, each of the pair of first points may be different from each of the pair of second points. The processor **360** may calculate the second length corresponding to the distance between the pair of second points. The processor **360** may compare the first length with the second length and determine a longer length among the first length and the second length to be a major diameter of the electrode assembly **200**. For example, the processor **360** may determine the major diameter, which is the longest length of the electrode assembly **200**, by repeating this process.

[0144] Referring to FIG. **13**, the inspection apparatus **300** according to some embodiments performs the major diameter inspection (check) of the electrode assembly **200** based on the determined major diameter (step S**602**).

[0145] The major diameter inspection is a process of determining the major diameter, which is the maximum length at each angle, by connecting two points on the upper surface of the secondary battery **100** with a line.

[0146] The processor **360** may compare the determined major diameter with a range of major diameters stored in the memory to determine whether the electrode assembly **200** is properly manufactured.

[0147] Additionally or alternatively, the inspection apparatus **300** according to some embodiments may perform a volume inspection. The volume inspection is a process of photographing the upper surface of the secondary battery with a camera and measuring an area of the secondary battery based on the photographed image. For example, the processor **360** measures and/or checks the volume of the electrode assembly **200** based on the obtained image.

[0148] Additionally or alternatively, the inspection apparatus **300** according to some embodiments may perform one-end folded state inspection. The one-end folded state inspection is a process of checking a rolled state of each material and checking whether there is an overlapping portion between the materials. For example, the processor **360** checks a folded state of at least one of the anode, the cathode and the separator based on the obtained image showing the upper surface of the electrode assembly **200**. However, the inspection apparatus **300** may also perform the one-end folded state inspection of the electrode assembly **200**, with each material unfolded.

[0149] As such, the inspection apparatus **300** according to some embodiments can perform various quality inspections on the electrode assembly **200**. Further, the inspection apparatus **300** can perform these inspections simultaneously or sequentially within a short period of time. Furthermore, the inspection apparatus **300** can perform these inspections without destruction of the electrode assembly **200**.

[0150] Although the present technology has been described with reference to some embodiments and drawings illustrating aspects thereof, the present technology is not limited thereto. Various modifications and variations can be made by those skilled in the art within the technical spirit of the disclosure and the scope of the claims and equivalents thereto.

Claims

1. An apparatus for inspecting an electrode assembly including an anode, a cathode, and a separator interposed between the anode and the cathode, the apparatus comprising: a laser irradiation unit configured to irradiate the electrode assembly with a beam; an illumination unit configured to irradiate the electrode assembly with light; an image acquisition unit configured to obtain an image of the electrode assembly when irradiated with the beam and/or light; and a processor configured to inspect the electrode assembly based on the obtained image.

2. The apparatus according to claim 1, wherein the processor is configured to calculate a phase difference between at least two of the anode, the cathode and the separator based on the obtained image and is configured to perform miswinding inspection of the electrode assembly based on the calculated phase difference.

3. The apparatus according to claim 2, wherein the processor is configured to: calculate a thickness of at least one of the anode, the cathode and the separator based on the calculated phase difference; calculate a miswinding distance between at least two of the anode, the cathode and the separator based on the calculated thickness; and perform the miswinding inspection based on the calculated miswinding distance.
4. The apparatus according to claim 3, wherein the processor is configured to calculate the miswinding distance using trigonometry based on the calculated thickness.
5. The apparatus according to claim 1, wherein the processor is configured to: detect one end of the anode and one end of the cathode based on the obtained image and perform alignment inspection of the electrode assembly based on the one end of the anode and the one end of the cathode.
6. The apparatus according to claim 5, wherein the electrode assembly is wound in one direction to form a jellyroll.
7. The apparatus according to claim 6, wherein the processor is configured to: determine a central point of the jellyroll based on the obtained image, calculate a length of an arc between the one end of the anode and the one end of the cathode based on the central point, and perform the alignment inspection based on the arc length.
8. The apparatus according to claim 6, wherein the obtained image comprises at least one of an image of an upper surface of the jellyroll in a wound state and an image of a side surface of the jellyroll in an unwound state.
9. The apparatus according to claim 1, wherein the processor is configured to: determine a major diameter of the electrode assembly based on the obtained image including an image of an upper surface of the electrode assembly and check the major diameter of the electrode assembly based on the determined major diameter.
10. The apparatus according to claim 9, wherein the processor is configured to: extract a pair of first points from the image of the upper surface of the electrode assembly, calculate a first length corresponding to a distance between the pair of first points, extract a pair of second points from the image of the upper surface of the electrode assembly, calculate a second length corresponding to a distance between the pair of second points, and determine a longer length among the first length and the second length to be the major diameter of the electrode assembly by comparing the first length with the second length.
11. The apparatus according to claim 1, wherein the processor is configured to check a volume of the electrode assembly based on the obtained image.
12. The apparatus according to claim 1, wherein the processor is configured to check a folded state of at least one of the anode, the cathode and the separator based on the obtained image including an image of an upper surface of the electrode assembly.
13. The apparatus according to claim 1, wherein the image acquisition unit comprises a vision camera.
14. The apparatus according to claim 1, wherein the processor further comprises: a lens unit allowing the image acquisition unit to obtain the image of the electrode assembly when irradiated with the beam and/or light.
15. The apparatus according to claim 1, further comprising: at least one reflector reflecting the beam received from the laser irradiation unit towards the electrode assembly.
16. A method for inspecting an electrode assembly, comprising: performing inspection of the electrode assembly with regard to at least one of miswinding, alignment, major diameter, volume, and folded state of the electrode assembly through an apparatus for inspecting an electrode assembly including an anode, a cathode, and a separator interposed between the anode and the cathode, the apparatus comprising: a laser irradiation unit configured to irradiate the electrode assembly with a beam; an illumination unit configured to irradiate the electrode assembly with light; an image acquisition unit configured to obtain an image of the electrode assembly irradiated

with the beam and/or light; and a processor configured to inspect the electrode assembly based on the obtained image.