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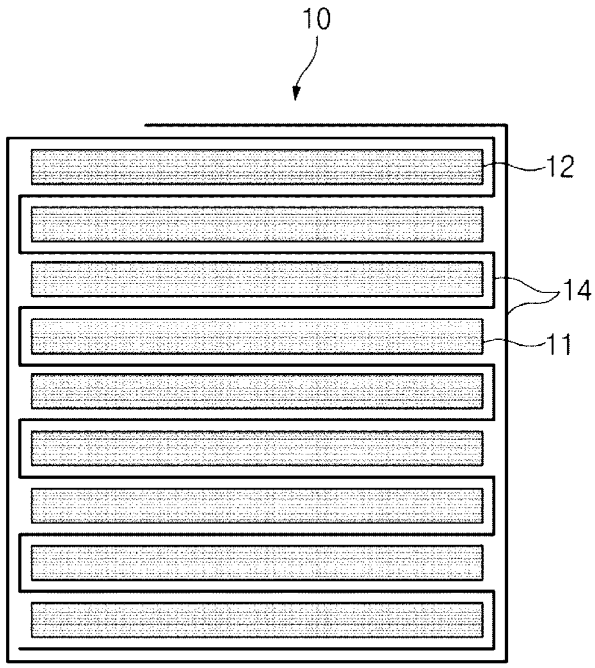

(57) Abstract: An electrode assembly includes a plurality of electrodes arranged in a stack along a stacking axis with a respective separator portion of an elongated separator sheet positioned between and winding around each of the electrodes in the stack along a serpentine path. An intermediate one of the separator portions may be adhered to an intermediate one of the electrodes such that it would take a peel force in a range from 5 gf to 35 gf per 20 mm width applied to an edge of the intermediate separator portion in order to peel it away from the intermediate electrode at a speed of 100 mm/min along the stacking axis. Moreover, top and bottom ones of the separator portions may each have a value of air permeability from 70 sec/100ml to 85 sec/100ml per square inch of the respective separator portion at a pressure of 0.05 MPa and at room temperature.

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Description

Title of Invention: ELECTRODE ASSEMBLY

Technical Field

[1] This application claims priority from Korean Patent Application No. 10-2021-0090600 filed on July 09, 2021, Korean Patent Application No. 10-2021-0090592 filed on July 09, and Korean Patent Application No. 10-2021-0090601 filed on July 09, 2021, the entire contents of all of which are incorporated herein by reference.

[2] The present invention relates to an electrode assembly.

Background Art

[3] Secondary batteries, unlike primary batteries, are rechargeable, and have been widely researched and developed in recent years due to their small size and large capacity. As technology development and demand for mobile devices increase, the demand for secondary batteries as an energy source is rapidly increasing.

[4] Secondary batteries can be classified into a coin-type battery, a cylindrical battery, a prismatic battery, and a pouch-type battery, according to the shape of the battery case. In a secondary battery, an electrode assembly mounted inside a battery case is a chargeable/dischargeable power generating element having a stacked structure comprising electrodes and separators.

[5] The electrode assembly may be generally classified into a jelly-roll type, a stack type, and a stack-and-folding type. In the jelly-roll type, a separator is interposed between a sheet type positive electrode and a sheet type negative electrode, each of which are coated with an active material, and the entire arrangement is wound. In the stack type, a plurality of positive and negative electrodes are sequentially stacked with a separator interposed therebetween. In a stack-and-folding type, stacked unit cells are wound with a long-length separation film.

[6] [Prior Art Literature]

[7] [Patent Document]

[8] Korean Patent Application Laid-Open No. 10-2013-0132230

Disclosure of Invention

Technical Problem

[9] The present invention provides, among other things, an electrode assembly which has reduced deviations in adhesive force and air permeability across each layer, while still maintaining adequate adhesive force and air permeability.

Solution to Problem

[10] An exemplary aspect of the present invention provides an electrode assembly. The

electrode assembly in accordance with such aspect of the invention preferably includes a plurality of electrodes arranged in a stack along a stacking axis with a respective separator portion positioned between each of the electrodes in the stack. The plurality of electrodes include a top electrode positioned at a top of the stack along the stacking axis, a bottom electrode positioned at a bottom of the stack along the stacking axis, and an intermediate electrode positioned between the top and bottom electrodes along the stacking axis. The separator portions including a top separator portion abutting the top electrode, a bottom separator portion abutting the bottom electrode, and an intermediate separator portion abutting the intermediate electrode. The intermediate separator portion may be adhered to the intermediate electrode to a degree that it would take a peel force in a range from 5 gf to 35 gf per 20 mm width of the intermediate separator portion applied to an edge of the intermediate separator portion in order to peel the intermediate separator portion away from the intermediate electrode at a speed of 100 mm/min along the stacking axis. Moreover, the top and bottom separator portions may each have a value of air permeability from 70 sec/100ml to 85 sec/100ml per square inch of the respective separator portion at a pressure of 0.05 MPa and at room temperature.

[11] In accordance with some aspects of the invention, the separator portions may be portions of an elongated separator sheet. Such elongated separator sheet may be folded between each separator portion such that the elongated separator sheet follows a serpentine path traversing back and forth along an orthogonal dimension orthogonal to the stacking axis to extend between each of the successive electrodes in the stack.

Advantageous Effects of Invention

[12] The electrode assembly according to exemplary aspects of the present invention is desirably capable of preventing side-effects, such as lithium (Li) precipitation in the electrode assembly and non-charging of the electrode assembly. The electrode assembly according to exemplary embodiments of the present invention may also have uniform performance.

Brief Description of Drawings

[13] FIG. 1 is a cross-sectional view illustrating an example of an electrode assembly according to an exemplary embodiment of the present invention.

[14] FIG. 2 is a cross-sectional view of the electrode assembly of FIG. 1, illustrating positions of an upper surface, a lower surface, and a middle portion of the electrode assembly.

[15] FIG. 3 is a top plan view illustrating an electrode assembly manufacturing apparatus for manufacturing the electrode assembly according to the present invention.

[16] FIG. 4 is a front elevation view conceptually illustrating the electrode assembly man-

ufacturing apparatus of FIG. 3.

[17] FIG. 5 is a diagram schematically illustrating an electrode assembly manufacturing method for manufacturing the electrode assembly according to the present invention.

[18] FIG. 6 is a perspective view of a separator heating unit of a separator supply unit according to the exemplary embodiment of the present invention.

[19] <Reference Numeral>

[20] 10: ASSEMBLED ELECTRODE ASSEMBLY

[21] 11: FIRST ELECTRODE

[22] 12: SECOND ELECTRODE

[23] 14: SEPARATOR

[24] 100: APPARATUS FOR MANUFACTURING AN ELECTRODE ASSEMBLY

[25] 110: STACK TABLE

[26] 111: TABLE BODY

[27] 112: STACK TABLE HEATER

[28] 120: SEPARATOR SUPPLY UNIT

[29] 121: SEPARATOR HEATING UNIT

[30] 121a: BODY

[31] 121b: SEPARATOR HEATER

[32] 122: SEPARATOR ROLL

[33] 130: FIRST ELECTRODE SUPPLY UNIT

[34] 131: FIRST ELECTRODE SEATING TABLE

[35] 133: FIRST ELECTRODE ROLL

[36] 134: FIRST CUTTER

[37] 135: FIRST CONVEYOR BELT

[38] 136: FIRST ELECTRODE SUPPLY HEAD

[39] 140: SECOND ELECTRODE SUPPLY UNIT

[40] 141: SECOND ELECTRODE SEATING TABLE

[41] 143: SECOND ELECTRODE ROLL

[42] 144: SECOND CUTTER

[43] 145: SECOND CONVEYOR BELT

[44] 146: SECOND ELECTRODE SUPPLY HEAD

[45] 150: FIRST ELECTRODE STACK UNIT

[46] 151: FIRST SUCTION HEAD

[47] 151a: VACUUM SUCTION PORT

[48] 151b: BOTTOM SURFACE

[49] 153: FIRST MOVING UNIT

[50] 160: SECOND ELECTRODE STACK UNIT

[51] 161: SECOND SUCTION HEAD

[52] 163: SECOND MOVING UNIT
[53] 170: HOLDING MECHANISM
[54] 171: FIRST HOLDER
[55] 172: SECOND HOLDER
[56] 180: PRESS UNIT
[57] 181, 182: PRESSING BLOCK
[58] S: STACK

Best Mode for Carrying out the Invention

[59] The objects, specific advantages, and novel features of the present invention will become more apparent from the following detailed description taken in conjunction with the accompanying drawings and exemplary embodiments. In the present specification, in adding reference numbers to the constituent elements of each drawing, it should be noted that the same constituent elements are given the same number even though they are indicated on different drawings. In addition, the present invention may be implemented in several different forms and is not limited to the exemplary embodiments described herein. Further, in describing the present invention, detailed descriptions of related known technologies that may unnecessarily obscure the gist of the present invention will be omitted.

[60] FIG. 1 is a cross-sectional view illustrating an example of an electrode assembly according to an exemplary embodiment of the present invention. That is, referring to FIG. 1, an electrode assembly 10 according to the exemplary embodiment of the present invention includes a stack of electrodes in which one or more first electrodes 11 alternates with one or more second electrode 12s. Each of the electrodes in the stack are separated from one another by a separator 14 positioned therebetween, which may be a single elongated separator 14 repeatedly folded so as to follow a serpentine or zigzag path around each successive electrode.

[61] The electrode assembly 10 is a chargeable/dischargeable power generating element, where the first electrode may be a positive electrode, and the second electrode may be a negative electrode. However, alternatively, the first electrode may be a negative electrode, and the second electrode may be a positive electrode. Moreover, the electrode assembly 10 may be provided in a form in which the outermost portion is surrounded by the separator 14, e.g., by wrapping the separator around the assembled electrode assembly 10, as illustrated in FIG. 1. With respect to the electrodes and the separator comprising the electrode assembly, materials commonly used in the art may be used.

[62] As discussed further herein, an "upper surface" of the electrode assembly 10 refers to the uppermost position of the electrode assembly 10 in the stacking direction of the

electrode assembly, which is designated by reference numeral 2 in FIG. 2. Thus, subsequent references to "upper surface air permeability" relate to air permeability of the separator 14 abutting the uppermost electrode in the electrode assembly. Likewise, subsequent references to "upper surface adhesive force" refer the adhesive force between the uppermost electrode in the electrode assembly and the abutting portion of the separator 14.

[63] Further, as discussed herein, a "lower surface" of the electrode assembly 10 refers to the lowermost position of the electrode assembly 10 in the stacking direction of the electrode assembly, which is designated by reference numeral 3 in FIG. 2. Thus, subsequent references to "lower surface air permeability" relate to air permeability of the separator 14 abutting the lowermost electrode in the electrode assembly. Likewise, subsequent references to "lower surface adhesive force" refer the adhesive force between the lowermost electrode in the electrode assembly and the abutting portion of the separator 14.

[64] Finally, as discussed herein, the "middle" of the electrode assembly 10 refers to a middle position between the upper surface and the lower surface of the electrode assembly 10 in the stacking direction of the electrode assembly, as designated by reference numeral 1 in FIG. 2. For example, when an electrode assembly 10 formed of nine electrodes and viewed from the side, as in FIG. 2, the "middle" position relates to the position of the fifth electrode in the stack. Thus, subsequent references to "middle air permeability" relate to air permeability of the separator 14 abutting the middle electrode in the electrode assembly. Likewise, subsequent references to "middle adhesive force" refer the adhesive force between the middle electrode in the electrode assembly and the abutting portion of the separator 14.

[65] Referring to FIGS. 3 and 4, an apparatus 100 for manufacturing an electrode assembly according to an exemplary embodiment of the present invention includes a stack table 110; a separator supply unit 120 for supplying a separator 14; a first electrode supply unit 130 for supplying a first electrode 11; a second electrode supply unit 140 for supplying a second electrode 12; a first electrode stack unit 150 for stacking the first electrode 11 on the stack table 110; a second electrode stack unit 160 for stacking the second electrode 12 on the stack table 110; and a press unit 180 for bonding the first electrode 11, the separator 14, and the second electrode 12 to each other. Further, the apparatus 100 for manufacturing the electrode assembly according to the exemplary embodiment of the present invention may include a holding mechanism 170 for fixing the stack (comprising the first electrode(s) 11, the second electrode(s) 12, and the separator 14) to the stack table 110 as the stack is being assembled.

[66] The separator supply unit 120 may have a passage through which the separator 14

passes towards the stack table 110. In particular, the separator supply unit 120 may include a separator heating unit 121 defining the passage through which the separator 14 passes towards the stack table 110. As shown in FIG. 6, the separator heating unit 121 may include a pair of bodies 121a, each of which may be in the form of a square block, and the bodies 121a may be spaced apart by a distance defining one of the dimensions of the passage through which the separator 14 passes. At least one or both of the bodies 121a may further include a separator heater 121b for heating the respective body 121a, and thereby transferring heat to the separator 14.

[67] The separator supply unit 120 may further include a separator roll 122 on which the separator 14 is wound. Thus, the separator 14 wound on the separator roll 122 may be gradually unwound and pass through the formed passage to be supplied to the stack table 110.

[68] The first electrode supply unit 130 may include a first electrode roll 133 on which the first electrode 11 is wound in the form of a sheet, a first cutter 134 for cutting the first electrode 11 at regular intervals to form the first electrodes 11 having a predetermined size when the first electrode 11 is unwound and supplied from the first electrode roll 133, a first conveyor belt 135 for moving the first electrode 11 cut by the first cutter 134, and a first electrode supply head 136 for picking up (e.g., via vacuum suction) the first electrode 11 transferred by the first conveyor belt 135 and seating the first electrode 11 on a first electrode seating table 131.

[69] The second electrode supply unit 140 may include a second electrode seating table 141 on which the second electrode 12 is seated before being stacked on the stack table 110 by the second electrode stack unit 160. The second electrode supply unit 140 may further include a second electrode roll 143 on which the second electrode 12 is wound in the form of a sheet, a second cutter 144 for cutting the second electrode 12 at regular intervals to form the second electrode 12 of a predetermined size when the second electrode 12 is unwound and supplied from the second electrode roll 143, a second conveyor belt 145 for moving the second electrode 121 cut by the second cutter 144, and a second electrode supply head 146 for picking up (e.g., via vacuum suction) the second electrode 12 transferred by the second conveyor belt 145 and seating the second electrode on the second electrode seating table 141.

[70] The first electrode stack unit 150 may be structured to stack the first electrode 11 on the stack table 110. The first electrode stack unit 150 may include a first suction head 151 and a first moving unit 153. The first suction head 151 may pick up the first electrode 11 seated on the first electrode seating table 131 via vacuum suction through one or more vacuum suction ports (not shown) formed on a bottom surface of the first suction head 150, and then the first moving unit 153 may move the first suction head 151 to the stack table 110 so as to allow the first suction head 151 to stack the first

electrode 11 on the stack table 110.

[71] The second electrode stack unit 160 may also be structured to stack the second electrode 12 on the stack table 110. The second electrode stack unit 160 may have the same structure as that of the foregoing first electrode stack unit 150. In such case, the second electrode stack unit 160 may include a second suction head 161 and a second moving unit 163. The second suction head 161 may pick up the second electrode 12 seated on the second electrode seating table 141 via vacuum suction. The second moving unit 163 may then move the second suction head 161 to the stack table 110 so as to allow the second suction head 161 to stack the second electrode 12 on the stack table 110.

[72] The stack table 110 may be rotatable so as to rotate between positions facing the first electrode stack unit 150 and the second electrode stack unit 160. As the stack table 110 rotates, the holding mechanism 170 may hold the stack being assembled (comprising the first electrode 11, the second electrode 12, and the separator 14) in order to secure the position of the stack relative to the stack table 110. For example, the holding mechanism 170 may apply downward pressure to the upper surface of the stack to press it towards the stack table 110. The holding mechanism 170 may include, for example, a first holder 171 and a second holder 172 to fix opposing sides of the first electrode 11 or the second electrode 12. The holders 171, 172 may each be in the form of one or more clamps or other clamping mechanisms.

[73] Thus, in operation, the first electrode 11 is supplied from the first electrode supply unit 130 to the first electrode stack unit 150, the first electrode stack unit 150 stacks the first electrode 11 on the upper surface of the separator 14 stacked on the stack table 110. The holding mechanism 170 then presses down on the upper surface of the first electrode 11 to secure the position of the first electrode 11 on the stack table 110. Thereafter, the stack table 110 is rotated in the direction of the second electrode stack unit 160 while the separator 14 is continuously supplied so as to cover the upper surface of the first electrode 11. Meanwhile, the second electrode 12 is supplied from the second electrode supply unit 140 and is stacked by the second electrode stack unit 160 on a portion of the separator 14 where the separator 14 covers the upper surface of the first electrode 11. Then the holding mechanism 170 releases the upper surface of the first electrode 11 and then presses down on the upper surface of the second electrode 12 to secure the position of the stack S being built vis-a-vis the stack table 110. Thereafter, by repeating the process of stacking the first electrode 11 and the second electrode 12, the stack S in which the separator 14 is zig-zag-folded and positioned between each of the successive first and second electrodes 11, 12 may be formed.

[74] After the components of the electrode assembly are stacked, the electrode assembly

may undergo one or more heat press operations. In particular, the electrode assembly may be moved to the press unit 180, which applies heat and pressure to the stack by advancing heated pressing blocks 181 and 182 towards one another with the stack positioned therebetween. As a result, the components of the stack (i.e., the electrodes and separator) are thermally bonded to one another, so as to desirably prevent the completed electrode assembly from falling apart or the components of the electrode assembly from shifting their positions within the stack.

[75] The heat press operations applied to the electrode assembly may include a primary heat press operation, a preheating operation, and a secondary heat press operation. The primary heat press relates to an operation after the first electrode(s) and the second electrode(s) are alternately stacked between the folded separators to define a stack, where the stack is gripped with a gripper, and then the stack is heated and pressed. The secondary heat press operation relates to an operation after the primary heat press operation, in which the gripping of the stack by the gripper is ceased and the stack is once more heated and pressed. The preheating operation relates to a process of heating the stack for a specific time with a constant pressure between the primary and secondary heat press operations.

[76] Referring to FIG. 5, the method may first include a stack process of assembling a stack (stack cell) on a stack table by alternately stacking the first electrode and the second electrode on the separator, where the separator is continuously supplied and sequentially folded over a previously-stacked one of the first and second electrodes before a subsequent one of the first and second electrodes is stacked. After the stack process, the stack may be moved away from the stack table. During such time, the separator is pulled, and, after the separator is pulled for a predetermined length, the separator is cut. Thereafter, the predetermined length of he cut end of the separator is wound around the stack cell. The movement of the stack away from the stack table may be accomplished by the gripper, which is desirably a movable component that can grip the stack on the stack table and then move the stack to the press unit 180, where the heat press operations are performed. The primary heat press operation is then performed in a state in which the wound stack cell is gripped with the gripper. After the primary heat press operation is completed, the grip of the stack cell by the gripper is released. After the gripper is removed, the preheating operation is performed. After the preheating operation, the secondary heat press operation is performed. When the secondary heat press operation is completed, the finished electrode assembly may be complete.

[77] According to exemplary embodiments of the present invention, the primary heat pressing operation may include applying heat and pressure to the stack for a time period from 5 seconds to 20 seconds under a temperature condition from 45°C to 75°C

and under a pressure condition from 1 Mpa to 2.5 Mpa. Preferably, the primary heat pressing operation may include applying heat and pressure to the stack for a time period from 10 seconds to 20 seconds under a temperature condition from 45°C to 65°C and under a pressure condition of 1 Mpa to 2 Mpa. More preferably still, the primary heat pressing operation may include applying heat and pressure to the stack for a time period from 10 seconds to 20 seconds under a temperature condition from 45°C to 60°C and under a pressure condition from 1 Mpa to 1.5 Mpa.

[78] According to exemplary embodiments of the present invention, the preheating operation may include applying heat and pressure to stack for a time period from 10 seconds to 40 seconds under pressure condition from 0.5 MPa to 2 MPa and under a temperature condition from 50°C to 85°C. Preferably, the preheating operation may include applying heat and pressure to the stack for a time period from 10 seconds to 35 seconds under a pressure condition from 0.5 MPa to 1.5 MPa and under a temperature condition from 55°C to 85°C.

[79] According to exemplary embodiments of the present invention, the secondary heat press operation may include applying heat and pressure to the stack for a time period from 5 seconds to 10 seconds under a temperature condition from 50°C to 85°C and under a pressure condition from 1 Mpa to 2.5 Mpa. Preferably, the secondary heat press operation may include applying heat and pressure to the stack for a time period from 5 seconds to 10 seconds under a temperature condition from 55°C to 85°C and under a pressure condition from 1.5 Mpa to 2.5 Mpa. More preferably, the secondary heat press operation may include applying heat and pressure to the stack for a time period from 5 seconds to 10 seconds under a temperature condition from 50°C to 85°C and under a pressure condition from 1.5 Mpa to 2 Mpa.

[80] When the temperature, pressure, and time conditions disclosed herein are not satisfied, the components of the electrode assembly may not be properly adhered together, which can result in the electrode assembly falling apart or the components of the electrode assembly shifting their positions within the assembly, particularly when the electrode assembly is moved before being inserted into a battery case. A problem may also occur in which the air permeability of the separator is excessively high.

[81] On the other hand, when the heat press operations disclosed herein are performed (including satisfying the respective pressure, temperature, and time conditions), an electrode assembly may be manufactured without the need to individually heat and/or press each level of the electrode assembly (i.e., heating and/or pressing each electrode and separator pair at each step of the process) in order to bond the components together. Such individual heat pressing at each level can detrimentally cause the effects of the heat and/or pressure to accumulate in the lower separators in the stack, since the already-stacked layers will experience the heat and/or pressure of each application.

That can negatively impact such portions of separator by, for example, reducing porosity (and air permeability). In contrast, the present invention allows the entire electrode assembly to be simultaneously bonded, which improves uniformity, among other things. It is thus possible to simultaneously achieve both an appropriate level of adhesive force between the electrodes and also achieve a separator having an appropriate amount of air permeability, all while minimizing damage to the unit electrode.

[82] In the present application, the "air permeability" of the electrode assembly refers to the air permeability of the separator component of the electrode assembly. In addition, unless specifically stated, the "air permeability" means air permeability of all separators comprising the electrode assembly, where the air permeability of each separator may be independently the same or different.

[83] When the air permeability ranges disclosed herein are satisfied, the movement speed of lithium ions in the separator in the electrode assembly may be increased while maintaining the safety of the electrode assembly. As a result, providing a separator with the air permeability values disclosed herein greatly improves safety, efficiency, and performance of charging and discharging cycles of the electrode assembly.

[84] In accordance with the present invention, the method for measuring the air permeability of the separator is not particularly limited, and the air permeability may be measured by using a method commonly used in the art. For example, a Gurley type Densometer (No. 158) manufactured by Toyoseiki may be used according to the JIS Gurley measurement method of the Japanese industrial standard. That is, the air permeability of the separator may be obtained by measuring the time it takes for 100 ml (or 100 cc) of air to pass through the separator of 1 square inch under a pressure of 0.05 MPa at room temperature (i.e., 20°C to 25°C).

[85] According to exemplary embodiments of the present invention, the middle air permeability of the electrode assembly may be in a range from 75 sec/100 ml to 85 sec/100 ml.

[86] According to exemplary embodiments of the present invention, the upper surface air permeability of the electrode assembly may be in a range from 80 sec/100 ml to 85 sec/100 ml.

[87] According to exemplary embodiments of the present invention, the lower surface air permeability of the electrode assembly may be in a range from 80 sec/100 ml to 85 sec/100 ml.

[88] According to exemplary embodiments of the present invention, the lower surface air permeability may be less than or equal to the upper surface air permeability. In addition, the middle air permeability may be less than or equal to the lower surface air permeability.

[89] That is, the magnitude of the upper surface air permeability, the lower surface air permeability, and the middle air permeability may satisfy Equation 1 below.

[90] [Equation 1]

[91] Upper surface air permeability ≥ Lower surface air permeability ≥ Middle air permeability

[92] The values of air permeability in Equation 1 relate to the air permeability of the separators in the electrode assembly after the completion of the heating and pressing steps.

[93] According to exemplary embodiments of the present invention, the adhesive force between the separator and the electrodes at any of the positions in the electrode assembly (i.e., upper surface, middle, and lower surface) may be in a range from 5 gf/20 mm to 30 gf/20 mm.

[94] In the present invention, a method for measuring adhesive force of the separator is not particularly limited. For example, samples of the lower portion, the middle portion, and the upper portion of the electrode assembly may be separated from the stack. Such samples may include a positive electrode and a separator or a negative electrode and a separator. The samples, which may have a width of 55 mm and a length of 20 mm, are each adhered to a respective slide glass with the electrode being positioned on the adhesive surface of the slide glass. The samples are then each tested by performing a 90° peel test at a speed of 100 mm/min pursuant to the testing method set forth in ASTM-D6862. That is, an edge of the separator is pulled upwardly at 90° relative to the slide glass at a speed of 100 mm/min so as to peel the separator away from the electrode along the width direction of the sample (i.e., peeling from 0 mm to 55 mm).

[95] According to exemplary embodiments of the present invention, the middle adhesive force of the electrode assembly may be in a range from 5 gf/20 mm to 10 gf/20 mm.

[96] According to exemplary embodiments of the present invention, the upper surface adhesive force of the electrode assembly may be in a range from 5 gf/20 mm to 30 gf/20 mm.

[97] According to exemplary embodiments of the present invention, the lower surface adhesive force of the electrode assembly may be in a range from 5 gf/20 mm to 30 gf/20 mm.

[98] According to exemplary embodiments of the present invention, the adhesive force between the positive electrode and the separator and the adhesive force between the negative electrode and the separator may be the same as or different from each other.

[99] According to exemplary embodiments of the present invention, a deviation between the middle adhesive force of the electrode assembly and either the upper surface adhesive force or the lower surface adhesive force of the electrode assembly may be in a range from 3 gf/20 mm to 20 gf/20 mm.

[100] According to exemplary embodiments of the present invention, a deviation between the middle air permeability of the electrode assembly and either the upper surface air permeability or the lower surface air permeability of the electrode assembly may be in a range from 3 sec/100 ml to 20 sec/100 ml.

[101] When the air permeability and adhesive force conditions described above are satisfied, it may preferably make cleaning and process handling easy, and it may also make wetting of the separator by the electrolyte easier, so that an electrode assembly having uniform performance may be manufactured. In addition, side-effects, such as lithium (Li) precipitation in the electrode assembly and non-charging of the electrode assembly, may be prevented.

[102] A withstand voltage of the electrode assembly of the present invention may be in a range from 1.5 kV to 1.8 kV. The electrode assembly of the present invention is manufactured by the electrode assembly manufacturing method including the primary heat press operation, the preheating operation, and the secondary heat press operation, which may result in both excellent adhesive force and excellent withstand voltage compared to the case where only the primary heat press operation is performed.

Mode for the Invention

[103] While the present invention has been described in detail through specific exemplary embodiments, the present invention is not limited thereto. Various different implementations may be made by those of ordinary skill in the art within the technical spirit of the present invention.

[104] **1) Example 1**

[105] 19 positive electrode sheets, 20 negative electrode sheets, and an elongated separator were supplied to the stack table from the respective positive electrode supply unit, negative electrode supply unit, and separator supply unit.

[106] More specifically, the positive electrode and the negative electrode were supplied after being cut from a positive electrode sheet and a negative electrode sheet, respectively, and the separator was supplied in the form of an elongated separator sheet. Thereafter, the supplied separator was folded while rotating the stack table and stacking the positive electrodes and the negative electrode as described above. A holding mechanism was used to press down on and stabilize the stack, which resulted in a stack including 39 electrodes.

[107] After assembling the stack, a primary heat press operation was performed by gripping the stack with the gripper and pressing for 15 seconds while heating the stack under a temperature condition of 50°C and a pressure condition of 1.46 MPa.

[108] After the primary heat press operation, the gripper was released from the stack and a preheating operation was performed, in which the temperature of the pressing block

was maintained at 60° C (temperature condition) and a pressure of 1 MPa (pressure condition) was applied to the stack for 15 seconds (press time) was performed.

[109] After the preheating operation, the secondary heat press operation was performed, in which a pressing block was maintained at 60° C (temperature condition) and a pressure of 1.8 MPa (pressure condition) was applied to the stack for 7 seconds (press time).

[110] **2) Examples 2 to 12 and Comparative Examples 1 to 6**

[111] Electrode assemblies of Examples 2 to 6 were manufactured in the same manner as the electrode assembly manufacturing method in Example 1, except that the method was performed under the temperature conditions, pressure conditions, and press time represented in Table 1 below.

[112] Electrode assemblies of Comparative Examples 1 to 15 were manufactured by performing the primary and secondary heat press operations in the same manner as the electrode assembly manufacturing method in Example 1, except that the method was performed under the temperature conditions, pressure conditions, and press time represented in Tables 2 and 3 below. That is, in the case of Comparative Examples 1 to 12, the preheating operation was not performed.

[113] [Table 1]

	Primary heat press			Preheating			Secondary heat press		
	Temperature condition (°C)	Pressure condition (MPa)	Press time (s)	Temperature condition (°C)	Pressure condition (MPa)	Press time (s)	Temperature condition (°C)	Pressure condition (MPa)	Press time (s)
Example 1	50	1.46	15	60	1	15	60	1.8	7
Example 2						35			
Example 3				70		15	70		
Example 4						35			
Example 5				80		35	80		

[114] [Table 2]

	Primary heat press			Preheating			Secondary heat press		
	Temperature condition (°C)	Pressure condition (MPa)	Press time (s)	Temperature condition (°C)	Pressure condition (MPa)	Press time (s)	Temperature condition (°C)	Pressure condition (MPa)	Press time (s)

Comparative Example 1	50	1.46	15	-	-	-	60	1.8	25
Comparative Example 2				-	-	-			42
Comparative Example 3				-	-	-		3	25
Comparative Example 4				-	-	-			42
Comparative Example 5				-	-	-	70	1.8	25
Comparative Example 6				-	-	-			42
Comparative Example 7				-	-	-		3	25
Comparative Example 8				-	-	-			42
Comparative Example 9				-	-	-	80	1.8	25

Comparative Example 10	-	-	-		42
Comparative Example 11	-	-	-	3	25
Comparative Example 12	-	-	-		42

[115] [Table 3]

	Primary heat press			Preheating			Secondary heat press		
	Temperature condition (°C)	Pressure condition (MPa)	Press time (s)	Temperature condition (°C)	Pressure condition (MPa)	Press time (s)	Temperature condition (°C)	Pressure condition (MPa)	Press time (s)
Comparative Example 13	50	1.46	15	70	1	15	70	3	7
Comparative Example 14						35			
Comparative Example 15				80	1	15	80	3	7
Comparative Example 16									
Comparative Example 17				90	4	45	90	3	7

[116] **3) Experimental Example 1 - Evaluation of adhesive force**

[117] The electrode assemblies of Examples 1 to 6 and Comparative Examples 4, 8, and 11 to 17 were disassembled and analyzed to measure upper surface, lower surface, and middle adhesive force. Specifically, adhesive force between the negative electrode and the separator located at the lowermost end of the stack was measured. Additionally, adhesive force between the negative electrode and the separator located at the uppermost end of the stack was measured. Finally, adhesive force between the negative electrode and the separator located at the middle location along the stacking direction

of the stack was measured.

[118] In each of the separated electrode assemblies, the negative electrode and the separator sampled had a width of 55 mm and a length of 20 mm. The sampled sample was adhered to the slide glass with the electrode being positioned on the adhesive surface of the slide glass. After that, the slide glass with the sample was mounted to an adhesive force measuring device and tested by performing a 90° peel test at a speed of 100 mm/min pursuant to the testing method set forth in ASTM-D6862. That is, an edge of the separator was pulled upwardly at 90° relative to the slide glass at a speed of 100 mm/min so as to peel the separator away from the electrode along the width direction of the sample (i.e., peeling from 0 mm to 55 mm). After discounting any initial significant fluctuations, the values for applied force per sample width (in grams/mm) were measured while the separator is peeled away from the electrode.

[119] The results are represented in Table 4 below.

[120] [Table 4]

	Negative electrode adhesive force (gf/20 mm)			
	Upper surface	Middle	Lower surface	Deviation
Example 1	10.2	3.8	19	10.8
Example 2	11	5.9	17.1	8.15
Example 3	14.3	5.7	8.4	5.65
Example 4	15.1	8.1	16.2	7.55
Example 5	21.1	8.2	23.4	14.05
Comparative Example 4	37.7	18.4	40.9	20.9
Comparative Example 8	55	34.7	56.3	20.95
Comparative Example 11	63.4	18.9	54	39.8
Comparative Example 12	65.9	39.4	73.3	30.2
Comparative Example 13	24.4	8.7	26.1	16.55
Comparative Example 14	33.6	14.3	33.8	19.4
Comparative Example 15	28.7	12.9	40.1	21.5
Comparative Example 16	49.2	18.4	45.5	28.95
Comparative Example 17	104.8	90.3	100.5	12.35

[121] From the results of Table 4, in Comparative Examples 4, 8, 11, and 12, in which the secondary heat press was performed at 3 MPa (which is a pressure condition higher than 2.5 MPa), without preheating, it was confirmed that the adhesive force at at least one of the positions in the electrode assembly exceeded 35 gf/20 mm.

[122] In addition, it was confirmed through Comparative Examples 12 to 17 that, even when the secondary heat press was performed at 3 MPa (which is a pressure condition higher than 2.5 MPa), and even when preheating was performed, the adhesive force at

at least one of the positions in the electrode assembly exceeded 35 gf/20 mm.

[123] In particular, in the case of Comparative Examples 14 and 16, in which the preheating time exceeded 30 seconds, while the preheating pressure and temperature conditions of the electrode assembly manufacturing method of the present invention were satisfied, and in the case of Comparative Example 17, in which the preheating was performed, but all of the preheating pressure, temperature, and time conditions of the electrode assembly of the present invention were not satisfied, it was confirmed that the adhesive forces at at least one of the positions in the electrode assembly greatly exceeded 35 gf/20 mm.

[124] When the adhesive force of the electrode assembly exceeds 35 gf/20 mm, in may make cleaning and process handling difficult, and thus the processing costs may increase. Moreover, it may be difficult to manufacture an electrode assembly having uniform performance, due to poor wetting of the separator by the electrolyte.

[125] In contrast, when utilizing the heat press methodologies of the present invention, including the associated pressure, temperature, and time conditions, it was confirmed that cleaning and process handling were much easier, and performance of the electrode assembly was much more uniform.

[126] In addition, in the case of Examples 1 to 4, since the deviations between the adhesive forces at different locations within the stack were also small, it was confirmed that the electrode assembly had more uniform performance.

[127] **4) Experimental Example 1 - Withstand voltage evaluation**

[128] Withstand voltages of the electrode assembles of Examples 1 to 5, as well as of the electrode assemblies of Comparative Examples 2, 5, 6, 9, and 10 (in which the pressure conditions of the secondary heat press were the same as those of Examples 1 to 5 and the total press time was the same as or similar to those of Examples 1 to 5) were measured.

[129] In particular, the voltage applied to the electrode assemblies of Examples 1 to 5 and Comparative Examples 2, 5, 6, 9, and 10 was increased from 9 V to 4000 V, and the voltage value at the point in time when the leakage current became 0.6 mA or more was measured and determined to be the withstand voltage values.

[130] The results are represented in Table 5 below.

[131] [Table 5]

	Withstand voltage (kV)	Pressure condition of secondary heat press (MPa)	Total press time (s)
Example 1	1.72	1.8	37
Example 2	1.53	1.8	57
Example 3	1.57	1.8	37
Example 4	1.57	1.8	57
Example 5	1.66	1.8	57
Comparative Example 2	1.42	1.8	57
Comparative Example 5	1.4	1.8	40
Comparative Example 6	1.33	1.8	57
Comparative Example 9	1.8	1.8	40
Comparative Example 10	1.13	1.8	57

[132] In general, the main factor that causes damage to the electrode assembly is a pressure condition.

[133] From the results of Table 5, it was confirmed that Examples 1 to 5 (which are the electrode assemblies of the present invention) had better withstand voltage performance as compared to Comparative Examples 2, 5, 6, 9 and 10 (in which the pressure conditions of the secondary heat press were the same and the total time (total press time) of heating and pressing was the same across the entire process, but in which the preheating operation was omitted).

Claims

[Claim 1] An electrode assembly, comprising
a plurality of electrodes arranged in a stack along a stacking axis with a respective separator portion positioned between each of the electrodes in the stack, the plurality of electrodes including a top one of the plurality of electrodes positioned at a top of the stack along the stacking axis, a bottom one of the plurality of electrodes positioned at a bottom of the stack along the stacking axis, and an intermediate one of the plurality of electrodes positioned between the top electrode and the bottom electrode along the stacking axis, and the separator portions including a top one of the separator portions abutting the top electrode, a bottom one of the separator portions abutting the bottom electrode, and an intermediate one of the separator portions abutting the intermediate one of the plurality of electrodes,
wherein the intermediate separator portion is adhered to the intermediate electrode to a degree that it would take a peel force in a range from 5 gf to 35 gf per 20 mm width of the intermediate separator portion applied to an edge of the intermediate separator portion in order to peel the intermediate separator portion away from the intermediate electrode at a speed of 100 mm/min along the stacking axis, and
wherein the top separator portion and the bottom separator portion each have a value of air permeability from 70 sec/100ml to 85 sec/100ml per square inch of the respective separator portion at a pressure of 0.05 MPa and at room temperature.

[Claim 2] The electrode assembly of claim 1, wherein the separator portions are portions of an elongated separator sheet, the elongated separator sheet being folded between each separator portion such that the elongated separator sheet follows a serpentine path traversing back and forth along an orthogonal dimension orthogonal to the stacking axis to extend between each of the successive electrodes in the stack.

[Claim 3] The electrode assembly of claim 1, wherein the intermediate separator portion has a value of air permeability from 75 sec/100ml to 85 sec/100ml per square inch of the respective separator portion and at a pressure of 0.05 MPa and at room temperature.

[Claim 4] The electrode assembly of claim 1, the top separator portion is adhered to the top electrode to a degree that it would take a peel force in a range from 5 gf to 30 gf per 20 mm width of the top separator portion applied to an edge of the top separator portion in order to peel the top separator portion away from the top electrode at a speed of 100 mm/min along the stacking axis.

[Claim 5] The electrode assembly of claim 1, wherein the top separator portion has a value of air permeability from 80 sec/100 ml to 85 sec/100 ml per square inch of the respective separator portion at a pressure of 0.05 MPa and at room temperature.

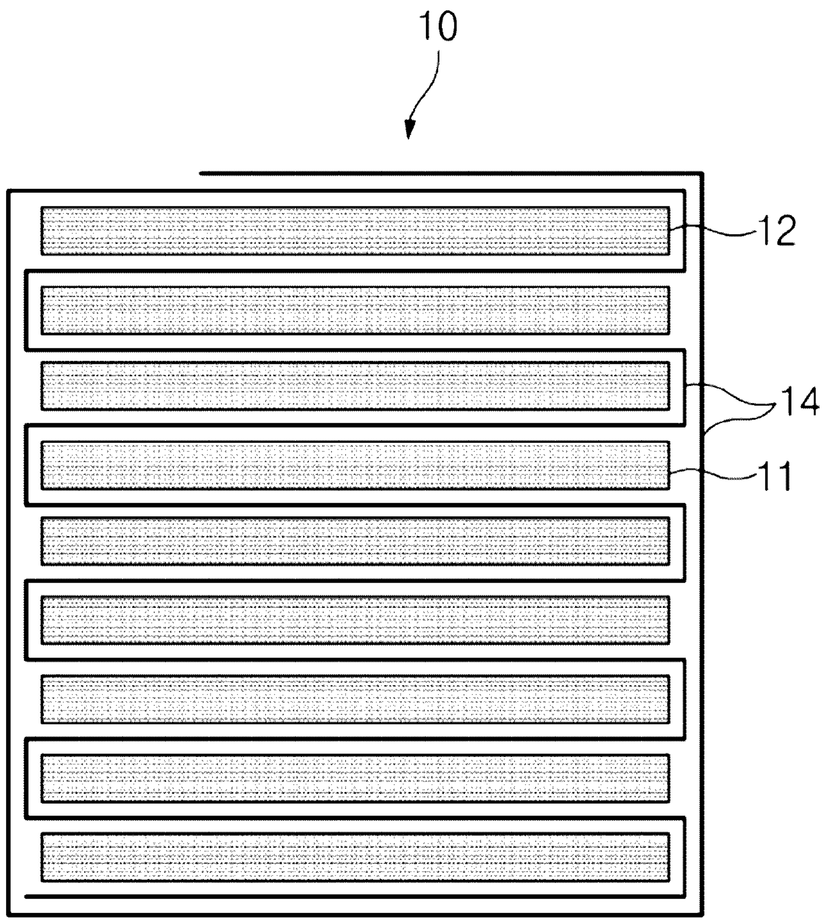
[Claim 6] The electrode assembly of claim 1, wherein the bottom separator portion is adhered to the bottom electrode to a degree that it would take a peel force in a range from 5 gf to 30 gf per 20 mm width of the bottom separator portion applied to an edge of the bottom separator portion in order to peel the bottom separator portion away from the bottom electrode at a speed of 100 mm/min along the stacking axis.

[Claim 7] The electrode assembly of claim 1, wherein the bottom separator portion has a value of air permeability from 80 sec/100ml to 85 sec/100ml per square inch of the respective separator portion at a pressure from 0.05 MPa and at room temperature.

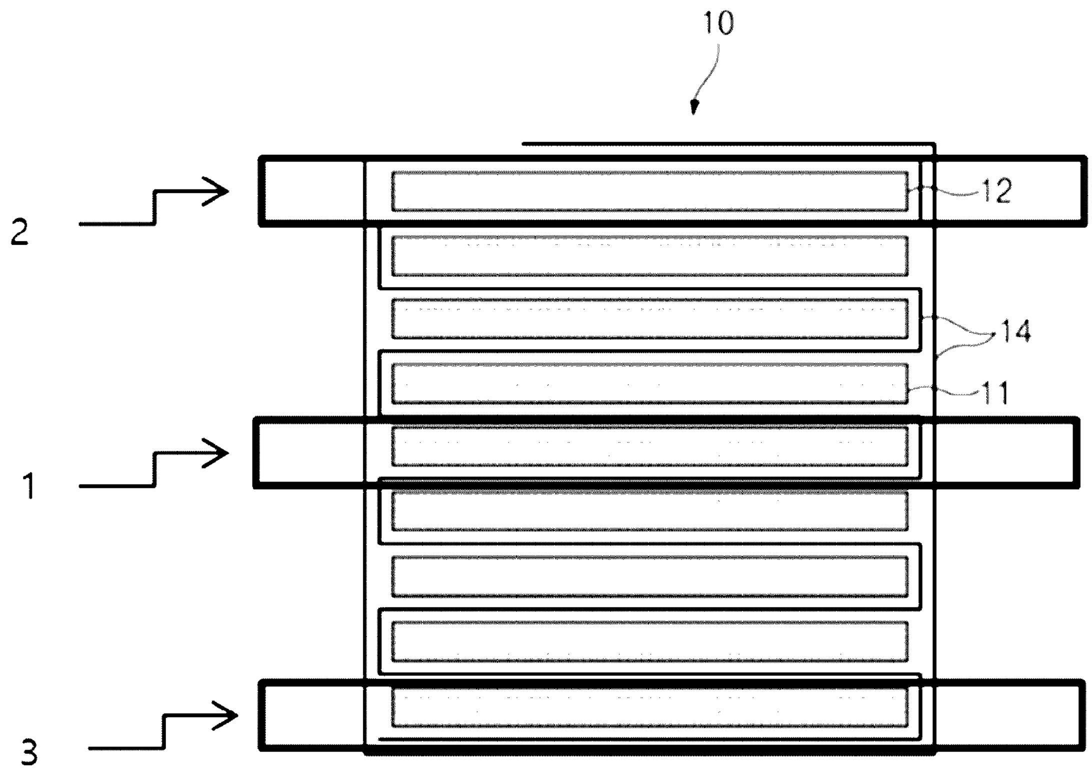
[Claim 8] The electrode assembly of claim 1, wherein the top and bottom separator portions are adhered to the respective top and bottom electrodes to a degree that it would take a second peel force per 20 mm width of the respective top and bottom separator portions applied to an edge of the respective top and bottom separator portion in order to peel the respective top and bottom separator portion away from the respective top and bottom electrode at a speed of 100 mm/min along the stacking axis, wherein a difference between the second peel force and the peel force of the intermediate separator portion is from 3 gf/20 mm to 20 gf/20 mm.

[Claim 9] The electrode assembly of claim 1, wherein the intermediate separator portion has a second value of air permeability per square inch at a pressure of 0.05 MPa and at room temperature, and wherein the difference between the second value of air permeability and the value of air permeability of the top separator portion and the bottom separator portion is from 3 sec/100 ml to 20 sec/100 ml per square inch of the respective separator portion at a pressure of 0.05 MPa and at room temperature.

[Fig. 1]



[Fig. 2]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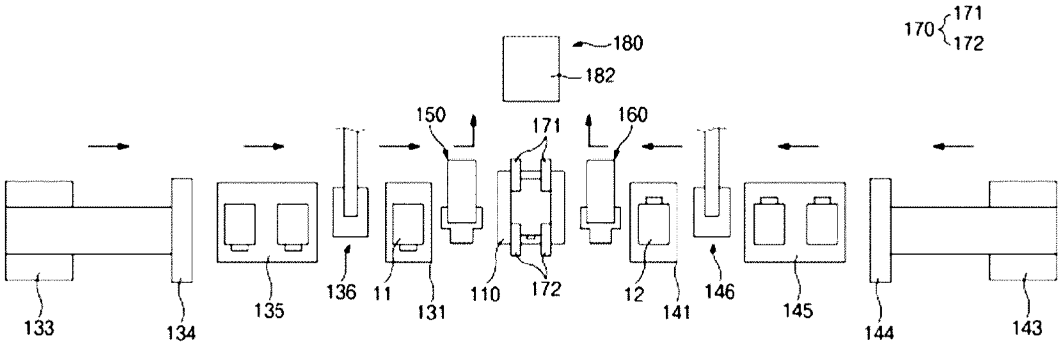
[Fig. 3]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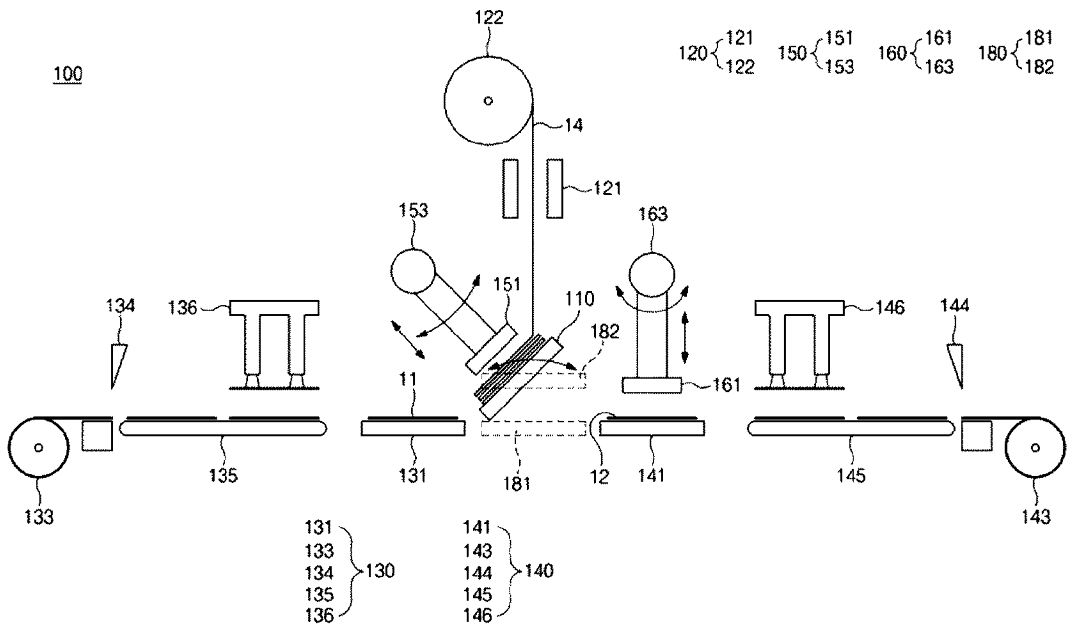
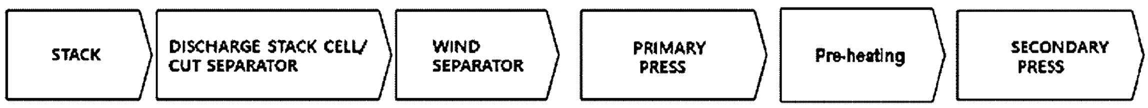
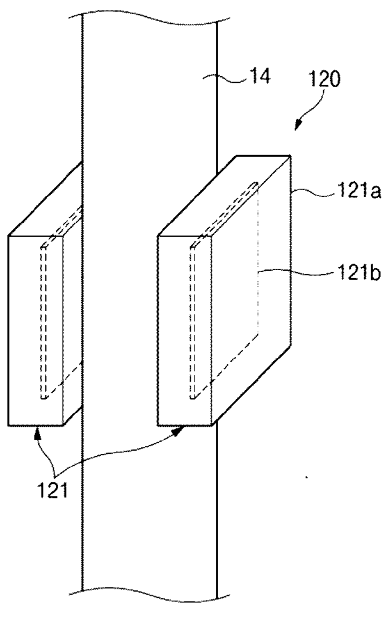
[Fig. 4]



[Fig. 5]



[Fig. 6]



INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2022/010000

A. CLASSIFICATION OF SUBJECT MATTER

H01M 10/04(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H01M 10/04(2006.01); H01M 10/38(2006.01); H01M 2/16(2006.01); H01M 2/20(2006.01); H01M 4/66(2006.01); H01M 50/409(2021.01)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: electrode, assembly, stack, fold, air, permeability, peel, force

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	KR 10-2008-0063523 A (NISSAN MOTOR CO., LTD.) 04 July 2008 (2008-07-04) the entire document	1-9
A	JP 2018-181843 A (NANO AND ADVANCED MATERIALS INSTITUTE LIMITED) 15 November 2018 (2018-11-15) the entire document	1-9
A	KR 10-2014-0064405 A (LG CHEM. LTD.) 28 May 2014 (2014-05-28) the entire document	1-9
A	KR 10-2256438 B1 (LG CHEM, LTD.) 03 June 2021 (2021-06-03) the entire document	1-9

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Date of the actual completion of the international search	Date of mailing of the international search report
26 October 2022	**26 October 2022**

Name and mailing address of the ISA/KR	Authorized officer
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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
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