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(54) POWER STORAGE MODULE

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(57) ABSTRACT

A power storage module includes a first active material layer and a second active material layer, a separator disposed between the first active material layer and the second active material layer, and a gas discharge restricting portion. The second active material layer includes a main surface positioned toward the first active material layer. The main surface includes an opposite region that is opposite the first active material layer. The gas discharge restricting portion is provided on the main surface and is provided in a position being outside the opposite region and adjoining the opposite region.

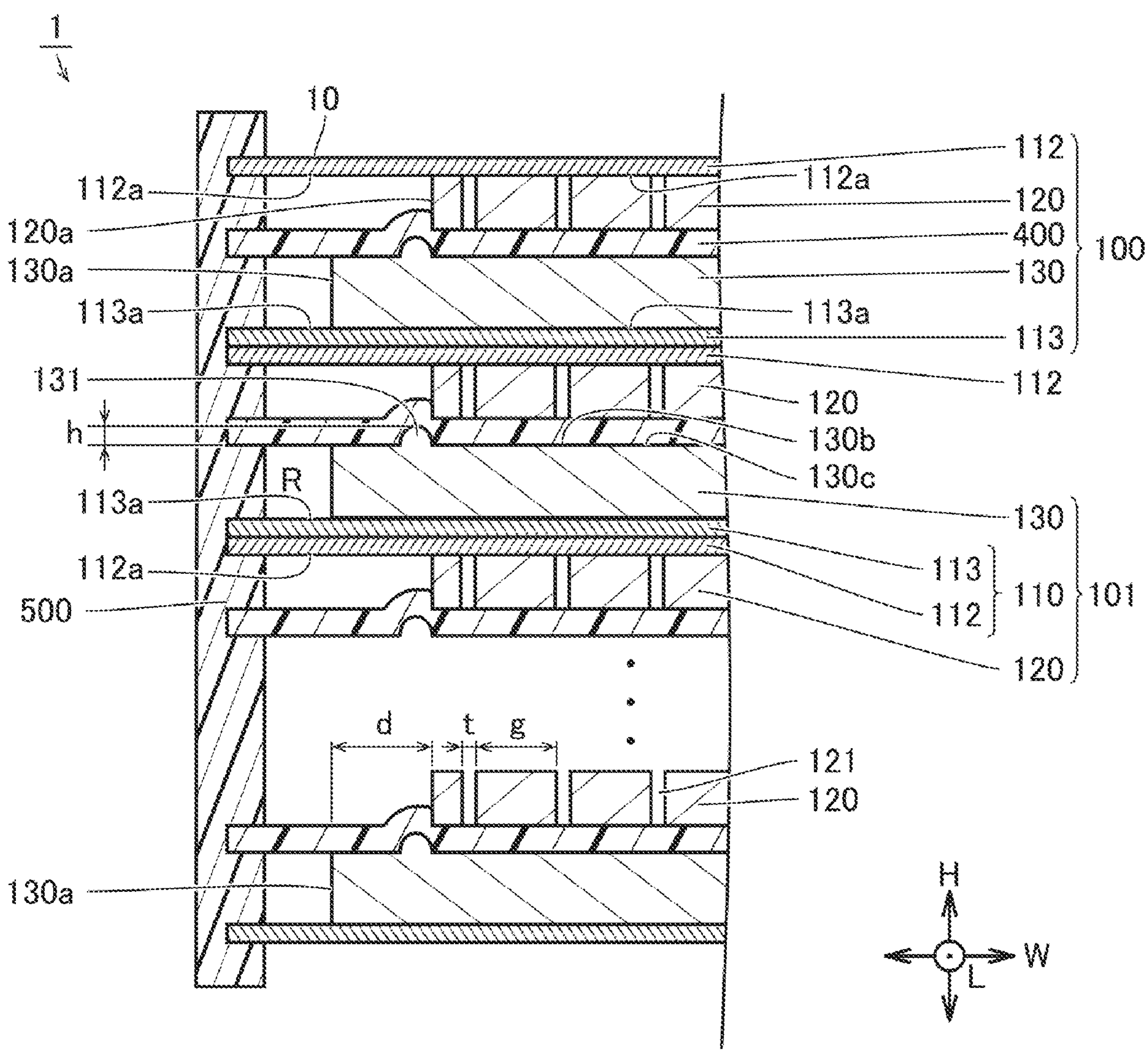

FIG.1

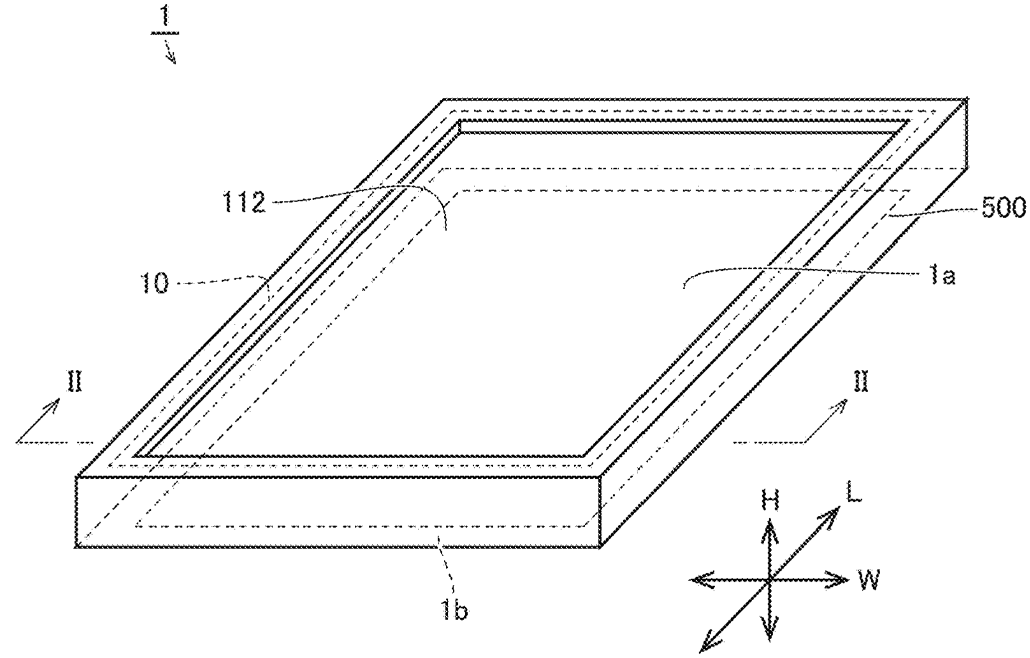
1
112
500
10
1a
II
II
H
L
W
1b

FIG.2

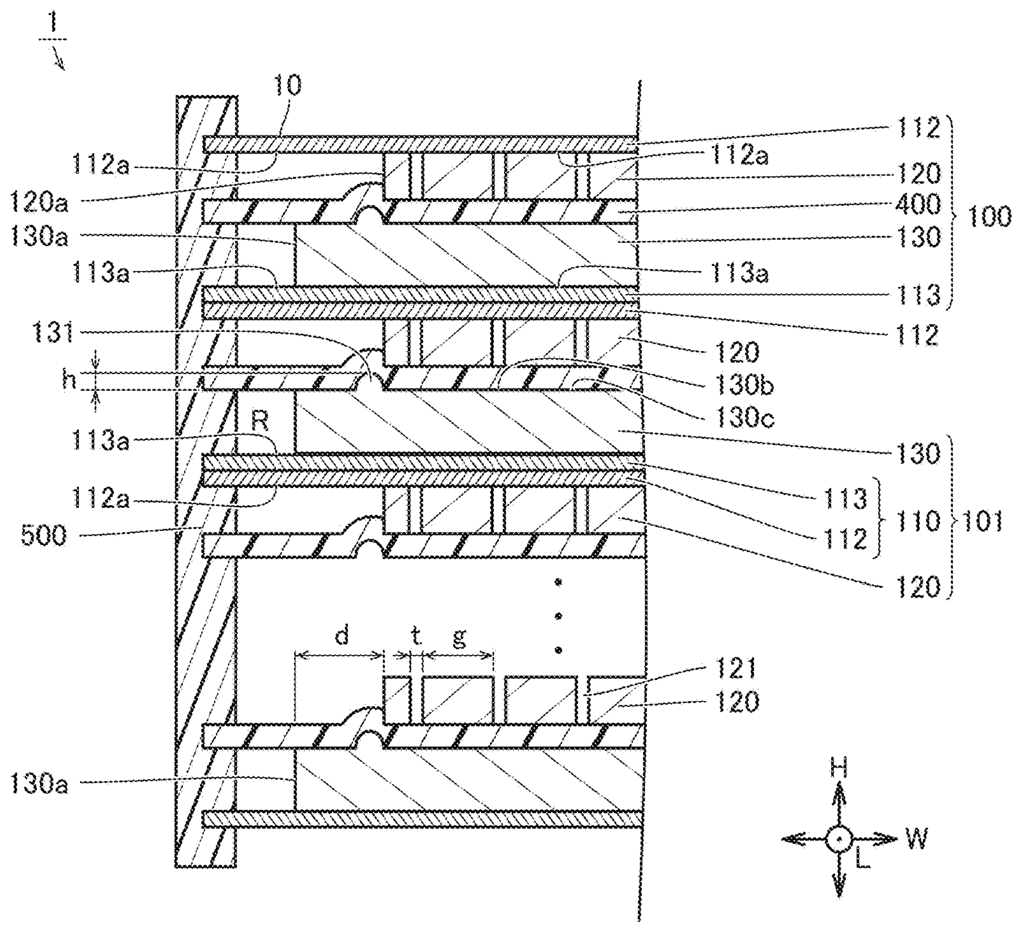
1
10
112
112a
112a
120
120a
400
100
130a
130
113a
113a
113
131
112
120
h
130b
130c
113a
R
130
113
112a
110
101
500
112
120
d
t
g
121
120
130a
H
W
L

FIG.3

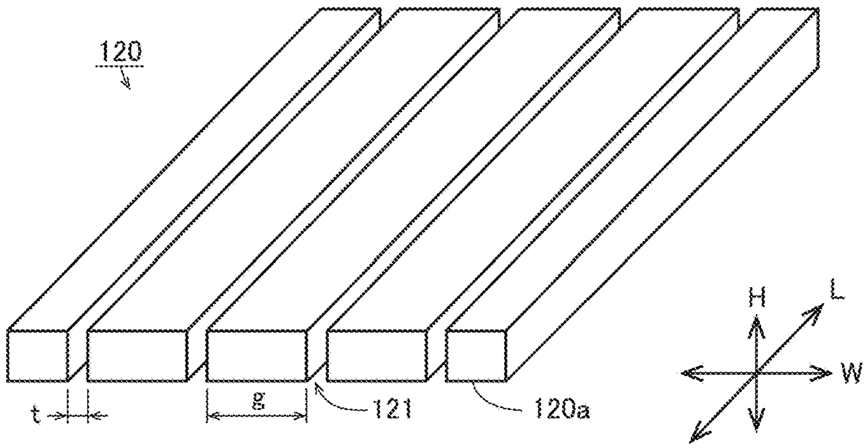

FIG.4

EXAMPLES	GROOVE PORTION(S)		GAS DISCHARGE RESTRICTING PORTION		DEGREE OF TEMPERATURE RISE
	WIDTH	QUANTITY	PHASE DIFFERENCE	HEIGHT	5-GRADE EVALUATION
FIRST EXAMPLE GROUP	none	0	0.5mm	50 μm	3
				100 μm	3
				200 μm	3
			1.0mm	50 μm	3
				100 μm	3
				200 μm	3
			2.0mm	50 μm	3
				100 μm	3
				200 μm	3
SECOND EXAMPLE GROUP	0.5mm	2	2.0mm	50 μm	3
	0.8mm				3
	1.2mm				3
	2.5mm				3
	10.0mm				4
	0.5mm	4			3
	0.5mm	6			3
	0.5mm	8			4
	2.5mm	10			5
	20.0mm	10			5

FIG.5

DEGREE OF TEMPERATURE RISE	5-GRADE EVALUATION
CATEGORY 1: COMPLETE TEMPERATURE RISE WITH LARGE AMOUNT OF GAS BURSTING OUT OF BATTERY	1
CATEGORY 2: COMPLETE TEMPERATURE RISE WITH GAS BURSTING OUT OF BATTERY	2
CATEGORY 3: STOP DUE TO LOCAL TEMPERATURE RISE WITH GAS BURSTING OUT OF BATTERY	3
CATEGORY 4: STOP DUE TO LOCAL TEMPERATURE RISE WITH SMALL AMOUNT OF GAS BURSTING OUT OF BATTERY	4
CATEGORY 5: STOP DUE TO LOCAL TEMPERATURE RISE WITH NO GAS BURSTING OUT OF BATTERY	5

POWER STORAGE MODULE

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This nonprovisional application is based on Japanese Patent Application No. 2024-020175 filed on Feb. 14, 2024, and Japanese Patent Application No. 2024-209539 filed on Dec. 2, 2024, with the Japan Patent Office, the entire contents of which are hereby incorporated by reference.

BACKGROUND

Field

[0002] The present disclosure relates to a power storage module.

Description of the Background Art

[0003] For example, Japanese Patent Laying-Open No. 2020-177761 discloses a power storage module that includes an electrode stack constituted of a plurality of unit cells and a resin material provided so as to surround a side surface of the electrode stack.

SUMMARY

[0004] A power storage module includes a resin frame and an electrode stack disposed in the resin frame. The electrode stack includes a plurality of unit cells.

[0005] The plurality of unit cells include a first current collector plate, a first active material layer, a separator, a second active material layer, and a second current collector plate. The separator is disposed between the first active material layer and the second active material layer. In the unit cells adjoining each other in a stack direction, the first current collector plate of one of the unit cells and the second current collector plate of the other unit cell are in contact with each other, and the first current collector plate and the second current collector plate in contact with each other form a stacked current collector plate.

[0006] The power storage module is sealed with the resin frame, the first current collector plate, and the second current collector plate. An electrolyte solution is housed in the power storage module. The first active material layer, the second active material layer, and the separator are soaked in the electrolyte solution.

[0007] When the electrical insulation function of the separator is lost in the power storage module configured as described above, the first active material layer and the second active material layer that are opposite each other with the separator interposed therebetween are short-circuited and a short-circuit current is caused. The short-circuit current induces Joule heat, which heats the electrolyte solution. The electrolyte solution raised in temperature through the heating gasifies. The gas increases the internal pressure of the power storage module and causes the power storage module to expand. After that, the power storage module cannot retain the gas therein, and the gas may break the resin frame of the power storage module and burst to the outside.

[0008] The present disclosure has been made in view of the above-described problem, and an object of the present disclosure is to provide a power storage module that enables it to hinder an adverse effect due to expansion of gas caused by vaporization of an electrolyte solution raised in temperature.

[0009] A power storage module according to a first aspect of the present disclosure includes a first active material layer and a second active material layer, a separator disposed between the first active material layer and the second active material layer, and a projecting portion. The second active material layer includes a main surface positioned toward the first active material layer. The main surface includes an opposite region that is opposite the first active material layer. The projecting portion is provided on the main surface and is provided in a position being outside the opposite region and adjoining the opposite region.

[0010] In the power storage module according to the first aspect of the present disclosure, the projecting portion is provided so as to extend in an annular manner along an outer peripheral edge portion of the opposite region.

[0011] In the power storage module according to the first aspect of the present disclosure, the projecting portion has a height of 50 μm or more from the main surface.

[0012] The power storage module according to the first aspect of the present disclosure further includes a current collector plate on which the first active material layer is provided. The current collector plate is positioned opposite the separator in relation to the first active material layer. At least one groove portion is provided in the first active material layer. The current collector plate is exposed from the first active material layer in the at least one groove portion.

[0013] In the power storage module according to the first aspect of the present disclosure, the first active material layer and the second active material layer each have a dimension of at least 1 m or more in a length direction or a width direction.

[0014] In the power storage module according to the first aspect of the present disclosure, a width of the at least one groove portion is 0.5 mm or more and 20 mm or less.

[0015] In the power storage module according to the first aspect of the present disclosure, an interval of the at least one groove portion is 40 mm or more and 350 mm or less.

[0016] A power storage module according to a second aspect of the present disclosure includes a plurality of bipolar electrodes stacked in a stack direction, and a separator disposed between the plurality of bipolar electrodes. Each of the plurality of bipolar electrodes includes a current collector plate, a first active material layer, a second active material layer, and a projecting portion. The current collector plate includes a first application surface and a second application surface in the stack direction. The first active material layer is applied to the first application surface of the current collector plate. The second active material layer is applied to the second application surface of the current collector plate and includes a main surface. The main surface is covered with the separator. The main surface includes an opposite region being opposite the first active material layer included in one of the plurality of bipolar electrodes adjacent to each other with interposition of the separator. The projecting portion is provided on the main surface and is provided in a position being outside the opposite region and adjoining the opposite region.

[0017] In the power storage module according to the second aspect of the present disclosure, the projecting portion is provided so as to extend in an annular manner along an outer peripheral edge portion of the opposite region.

[0018] In the power storage module according to the second aspect of the present disclosure, at least one groove portion is provided in the first active material layer. The current collector plate is exposed from the first active material layer in the at least one groove portion.

[0019] The foregoing and other objects, features, aspects, and advantages of the present disclosure will become apparent from the following detailed description of the present disclosure, which will be understood in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] FIG. **1** is a diagram schematically showing a power storage module according to an embodiment of the present disclosure.

[0021] FIG. **2** is an end surface view of the power storage module along line II-II in FIG. **1**, which is seen in the arrow direction.

[0022] FIG. **3** is a diagram schematically showing a first active material layer in FIG. **2**.

[0023] FIG. **4** is a table showing conditions of a comparison test and evaluation results under respective conditions.

[0024] FIG. **5** is a table showing categorization on the degree of a temperature rise.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0025] Embodiments of the present disclosure are described with reference to the drawings. In the drawings referred to below, the same reference numerals are given to identical or equivalent members.

<Configuration of Power Storage Module>

[0026] FIG. **1** is a schematic diagram of a power storage module **1** according to an embodiment of the present disclosure. In FIG. **1** and the like, a stack direction H represents a stack direction of power storage module **1**. In FIG. **1**, a width direction W and a length direction L represent a width direction and a length direction of power storage module **1**, respectively.

[0027] As shown in FIG. **1**, power storage module **1** is formed so as to have a rectangular parallelepiped shape. Power storage module **1** includes a first main surface **1***a* and a second main surface **1***b* lying at a distance from each other in stack direction H. Power storage module **1** includes an electrode stack **10** and a resin portion **500**.

[0028] FIG. **2** is an end surface view of the power storage module along line II-II in FIG. **1**, which is seen in the arrow direction. Electrode stack **10** includes a plurality of unit cells **100**. The plurality of unit cells **100** are stacked in stack direction H.

[0029] Each unit cell **100** includes a first current collector plate **112**, a first active material layer **120**, a separator **400**, a second active material layer **130**, and a second current collector plate **113**.

[0030] First active material layer **120** is, for example, a positive electrode active material layer. First active material layer **120** is formed on a first application surface **112***a* of first current collector plate **112**. First application surface **112***a* is a lower surface of first current collector plate **112**.

[0031] Second active material layer **130** is, for example, a negative electrode active material layer. Second active material layer **130** is formed on a second application surface **113***a* of second current collector plate **113**. Second application surface **113***a* is an upper surface of second current collector plate **113**.

[0032] Separator **400** is disposed between first active material layer **120** and second active material layer **130**.

[0033] In unit cells **100** adjoining each other in stack direction H, first current collector plate **112** of one of unit cells **100** and second current collector plate **113** of the other unit cell **100** are in contact with each other. First current collector plate **112** and second current collector plate **113** in contact with each other form a stacked current collector plate **110**.

[0034] Although an example in which first current collector plate **112** and second current collector plate **113** are in contact with each other is shown, the present disclosure is not limited thereto. First current collector plate **112** and second current collector plate **113** are just required to be at least electrically connected to each other. For example, first current collector plate **112** and second current collector plate **113** may be electrically connected to each other by being stacked with interposition of a conductive adhesive, a conductive material, a conductive resin, or a combination of these. The first current collector plate and the second current collector plate may be electrically connected to each other via a conductive wire or a terminal.

[0035] Stacked current collector plate **110** is formed so as to have a rectangular shape when stacked current collector plate **110** is seen in a plan view from a position at a distance from stacked current collector plate **110** in stack direction H. Stacked current collector plate **110** includes first current collector plate **112** and second current collector plate **113**. First current collector plate **112** is made of aluminum for example. Second current collector plate **113** is made of copper for example. In stack direction H, stacked current collector plate **110** includes first application surface **112***a*, which is a surface of first current collector plate **112**, and second application surface **113***a*, which is a surface of second current collector plate **113**.

[0036] FIG. **3** is a diagram schematically showing first active material layer **120**. For example, first active material layer **120** is formed so as to have a rectangular shape when first active material layer **120** is seen in a plan view from a position at a distance from first active material layer **120** in stack direction H. First active material layer **120** is formed so that its dimension in length direction L or width direction W is at least 1.0 m or more. At least one groove portion **121** is formed in first active material layer **120**.

[0037] Groove portion **121** is formed so as to extend in length direction L. Both ends of groove portion **121** reach an outer peripheral edge portion **120***a* of first active material layer **120** and first active material layer **120** is partitioned into a plurality of portions by the plurality of groove portions **121**. A groove width t of groove portion **121** is, for example, 0.5 mm or more and, for example, 20.0 mm or less. Groove portions **121** and their respective adjacent groove portions **121** are arranged at intervals g in width direction W. Interval g is, for example, 40 mm or more and, for example, 350 mm or less.

[0038] Referring again to FIG. **2**, in groove portion **121**, first application surface **112***a* of first current collector plate **112** is exposed from first active material layer **120**.

[0039] For example, when second active material layer **130** is seen in a plan view from a position at a distance from second active material layer **130** in stack direction H, second active material layer **130** is formed so as to have a rectangular shape, and further, is formed so as to protrude from first active material layer **120**. Specifically, an outer peripheral edge portion **130***a* of second active material layer **130** protrudes outward by a phase difference d from outer peripheral edge portion **120***a* of first active material layer **120**. Phase difference d is, for example, 0.5 mm or more. Second active material layer **130** is formed so that its dimension in length direction L or width direction W is at least 1.0 m or more.

[0040] In unit cell **100**, second active material layer **130** includes a main surface **130***b* positioned toward first active material layer **120**.

[0041] Main surface **130***b* includes an opposite region **130***c* being a region that is opposite first active material layer **120**. When second active material layer **130** and first active material layer **120** are seen in a plan view from a position at a distance in stack direction H, outer peripheral edge portion **120***a* is positioned inside outer peripheral edge portion **130***a*. Thus, opposite region **130***c* is part of main surface **130***b*.

[0042] Second active material layer **130** includes a gas discharge restricting portion **131**. Gas discharge restricting portion **131** is a projecting portion formed integrally with second active material layer **130**. Gas discharge restricting portion **131** is provided on main surface **130***b*. More specifically, gas discharge restricting portion **131** is formed in a position being outside opposite region **130***c* and adjoining opposite region **130***c*. Gas discharge restricting portion **131** is formed so as to extend in an annular manner along an outer peripheral edge portion of opposite region **130***c*. Gas discharge restricting portion **131** is formed so as to project from main surface **130***b* by a height h. Height h is 50 μm or more. The cross-sectional shape of gas discharge restricting portion **131** is semicircular but may be rectangular, trapezoidal, or elliptical.

[0043] Gas discharge restricting portion **131** is an example of the projecting portion according to the present disclosure.

[0044] Separator **400** is formed so as to have a rectangular shape when seen from a position at a distance from separator **400** in stack direction H. Separator **400** is formed so as to protrude from outer peripheral edge portion **130***a*.

[0045] Separator **400** is formed like a sheet for example. Separator **400** may be a porous sheet or a nonwoven fabric. For example, separator **400** contains polymer that absorbs and retains an electrolyte. Examples of the material from which separator **400** is formed include polypropylene (PP), polyethylene (PE), polyolefin, and polyester.

[0046] Separator **400** may have a single-layer structure or a multilayer structure. For example, in order to enhance heat resistance and electrical insulation properties, a multilayer structure constituted of a porous resin layer and a ceramic layer may be employed as separator **400**.

[0047] A resin portion **500** is formed in an annular manner so as to surround electrode stack **10**. An outer peripheral end portion of stacked current collector plate **110** and an outer peripheral end portion of separator **400** are embedded in resin portion **500**. Resin portion **500** and stacked current collector plate **110** embedded in resin portion **500** form a space R, which is sealed. An electrolyte solution is provided in space R sealed.

[0048] In both end portions of power storage module **1** in stack direction H, first current collector plate **112** and second current collector plate **113** are exposed. By disposing a member with conductivity (such as a current collector plate) on the portion exposed, it is enabled to electrically connect a plurality of power storage modules **1** in series.

[0049] The configuration of power storage module **1** is described above, focusing on unit cell **100**. On the other hand, power storage module **1** is a bipolar battery and includes a plurality of bipolar electrodes **101**. The details are described below.

[0050] Power storage module **1** includes the plurality of bipolar electrodes **101**, which are stacked in stack direction H, and separator **400**. Separator **400** is disposed between bipolar electrodes **101**.

[0051] Bipolar electrode **101** includes second active material layer **130**, stacked current collector plate **110**, and first active material layer **120**. Stacked current collector plate **110** includes first current collector plate **112** and second current collector plate **113**. Stacked current collector plate **110** includes first application surface **112***a* and second application surface **113***a*. First application surface **112***a* and second application surface **113***a* lie at a distance from each other in stack direction H. Second active material layer **130** is applied to second application surface **113***a*. First active material layer **120** is applied to first application surface **112***a*. Thus, stacked current collector plate **110** is positioned opposite separator **400** in relation to first active material layer **120**.

[0052] Second active material layer **130** includes main surface **130***b*. In bipolar electrode **101**, main surface **130***b* is a surface of second active material layer **130** and is covered with separator **400**. Main surface **130***b* includes opposite region **130***c*.

[0053] In bipolar electrode **101**, opposite region **130***c* is a region that is opposite first active material layer **120** of bipolar electrode **101** adjacent in stack direction H with separator **400** interposed therebetween.

<Comparison Test>

[0054] FIG. **4** is a table showing conditions for each power storage module to undergo a comparison test and evaluation results on the degree of a temperature rise in each power storage module. FIG. **5** is a table showing categorization on the degree of the temperature rise. Referring to FIGS. **4** and **5**, the comparison test is described.

[0055] In the comparison test, power storage modules according to a first example group and a second example group, shown in FIG. **4**, were prepared. Whether gas discharge restricting portion **131** and groove portion **121** each have an effect of inhibiting a temperature rise was confirmed by comparing, in terms of the degree of the temperature rise, the respective evaluations of the power storage modules according to the first example group and the second example group and the evaluation of the power storage module according to the comparative reference, which is not shown in FIG. **4**. Unless otherwise specified, the power storage module according to the comparative reference, the power storage modules according to the first example group, and the power storage modules according to the second example group have common configurations and each had a configuration identical to that of power storage module **1** according to the embodiment of the present disclosure.

[0056] The common configurations among the power storage modules are described in detail. Each power storage module included 30 unit cells **100**, and had an outer shape of 1535 mm in length direction L and 1210 mm in width direction W.

[0057] Unique configurations of the power storage modules are described.

[0058] First active material layer **120** and second active material layer **130** of the power storage module according to the comparative reference were not provided with groove portion **121** and gas discharge restricting portion **131**, respectively.

[0059] In first active material layer **120** of the power storage module according to the first example group, groove portion **121** was not formed. On the other hand, there were nine types of second active material layer **130** of the power storage module according to the first example group. Specifically, second active material layer **130** had phase difference d of 0.5 mm, 1.0 mm, or 2.0 mm and included gas discharge restricting portion **131** with height h of 50 μm, 100 μm, or 200 μm.

[0060] The power storage module according to the second example group included second active material layer **130** having phase difference d of 2.0 mm and including gas discharge restricting portion **131** with height h of 50 μm. There were ten types of first active material layer **120** of the power storage module according to the second example group. Specifically, firstly, in first active material layer **120**, two groove portions **121** were formed, which each had groove width t of 0.5 mm, 0.8 mm, 1.2 mm, 2.5 mm, or 10.0 mm. Secondly, in first active material layer **120**, four, six, or eight groove portions **121** were formed, which each had groove width t of 0.5 mm. Thirdly, in first active material layer **120**, ten groove portions **121** were formed, which each had groove width t of 2.5 mm or 20.0 mm.

[0061] The power storage module according to the comparative reference, the power storage modules according to the first example group, and the power storage modules according to the second example group were each evaluated through the comparison test in terms of the degree of the temperature rise. A specific method of the comparison test is described. First, first main surface **1***a* of the power storage module was heated with a heater, and the heating was ended when the temperature of second main surface **1***b* of the power storage module reached 300° C. After the end of the heating, how self-heating of the power storage module due to the temperature rise stopped and the inside of the power storage module after the stop of the self-heating were observed. From the observation results, the degree of the temperature rise of each power storage module was evaluated on a scale of one to five.

[0062] FIG. **5** shows the categorization on the degree of the temperature rise. As shown in FIG. **5**, the degree of the temperature rise was put into one of five categories: Category 1, which indicates a complete temperature rise with a large amount of gas bursting out of the battery; Category 2, which indicates a complete temperature rise with gas bursting out of the battery; Category 3, which indicates stop due to a local temperature rise with gas bursting out of the battery; Category 4, which indicates stop due to a local temperature rise with a small amount of gas bursting out of the battery; and Category 5, which indicates stop due to a local temperature rise with no gas bursting out of the battery. The complete temperature rise relating to the degree of the temperature rise means that all of the cells in the power storage module reached a high temperature. The local temperature rise means that only part of the cells in the power storage module reached a high temperature.

[0063] In addition, each category was evaluated on a scale of one to five, and Grade 1 was given when the degree of the temperature rise was the highest and the evaluation was the lowest while Grade 5 was given when the degree of the temperature rise was the lowest and the evaluation was the highest. Categories 1 to 5 were evaluated as Grades 1 to 5, respectively.

[0064] After evaluating each power storage module in terms of the degree of the temperature rise, the evaluation of the power storage module according to the comparative reference, the evaluation of each power storage module according to the first example group, and the evaluation of each power storage module according to the second example group were compared in terms of the degree of the temperature rise. The configuration of the power storage module that gained an evaluation higher than the evaluation of the power storage module according to the comparative reference in terms of the degree of the temperature rise was determined as a configuration in which the effect of inhibiting a temperature rise was obtained.

[0065] The results of the comparison test are described below. First, the evaluation results on the degree of the temperature rise of each power storage module are described with reference to FIG. **4**.

[0066] The present inventor found that when the power storage module according to the comparative reference was heated by the heating method described above, a large amount of gas burst out of the power storage module and a complete temperature rise was caused. Thus, the power storage module according to the comparative reference was evaluated as Grade 1 in terms of the degree of the temperature rise.

[0067] The power storage modules according to the first example group were all evaluated as Grade 3 in terms of the degree of the temperature rise.

[0068] The power storage modules according to the second example group were each evaluated as one of Grades 3 to 5 in terms of the degree of the temperature rise. More specifically, the power storage module including first active material layer **120** in which two groove portions **121** each having groove width t of 10.0 mm were formed was evaluated as Grade 4 in terms of the degree of the temperature rise. Further, the power storage module including first active material layer **120** in which eight groove portions **121** each having groove width t of 0.5 mm were formed was evaluated as Grade 4 in terms of the degree of the temperature rise. Moreover, the power storage module according to the second example group including first active material layer **120** in which ten groove portions **121** each having groove width t of 2.5 mm or 20.0 mm were formed was evaluated as Grade 5 in terms of the degree of the temperature rise. The other power storage modules according to the second example group were each evaluated as Grade 3 in terms of the degree of the temperature rise.

[0069] Next, the results of comparing the respective evaluations of the power storage modules in terms of the degree of the temperature rise are described.

[0070] Firstly, the evaluation of the power storage module according to the comparative reference and the respective evaluations of the power storage modules according to the first example group were compared in terms of the degree of the temperature rise.

[0071] As a result, all of the power storage modules according to the first example group were each evaluated as a grade higher than that of the power storage module according to the comparative reference in terms of the degree of the temperature rise. Accordingly, it could be confirmed that the effect of inhibiting a temperature rise was obtained by causing gas discharge restricting portion **131** formed so as to extend in an annular manner to adjoin opposite region **130***c* of second active material layer **130**.

[0072] Secondly, the respective evaluations of the power storage modules in the first example group were mutually compared in terms of the degree of the temperature rise.

[0073] As a result, all of the power storage modules according to the first example group were each evaluated as the same grade in terms of the degree of the temperature rise. Accordingly, it could be confirmed that the effect of inhibiting a temperature rise brought by forming gas discharge restricting portion **131** on second active material layer **130** was the same within the range of a combination of phase difference d and height h of gas discharge restricting portion **131** shown as to the first example group in FIG. **4**.

[0074] Thirdly, the evaluation of the power storage module according to the comparative reference and the respective evaluations of the power storage modules according to the second example group were compared in terms of the degree of the temperature rise.

[0075] As a result, all of the power storage modules according to the second example group were each evaluated as a grade higher than that of the power storage module according to the comparative reference in terms of the degree of the temperature rise. Accordingly, it was confirmed that the effect of inhibiting a temperature rise was obtained by forming groove portion **121** in first active material layer **120** and forming gas discharge restricting portion **131** on second active material layer **130**.

[0076] Fourthly, the respective evaluations of the power storage modules according to the first example group and the respective evaluations of the power storage modules according to the second example group were compared in terms of the degree of the temperature rise. More specifically, comparison was performed between the power storage module according to the first example group including second active material layer **130** on which gas discharge restricting portion **131** having phase difference d of 2.0 mm and height h of 50 μm was formed, and the power storage modules according to the second example group each including second active material layer **130** on which gas discharge restricting portion **131** having phase difference d of 2.0 mm and height h of 50 μm was formed and including first active material layer **120** in which groove portions **121** each having groove width t of 0.5 mm were formed.

[0077] As a result, in terms of the degree of the temperature rise, each power storage module including first active material layer **120** in which no groove portion **121** was formed was evaluated as the same grade as that of the power storage module including first active material layer **120** in which two, four, or six groove portions **121** each having groove width t of 0.5 mm were formed.

[0078] On the other hand, in terms of the degree of the temperature rise, the power storage module including first active material layer **120** in which eight groove portions **121** each having groove width t of 0.5 mm were formed was evaluated as a grade higher than that of the power storage module including first active material layer **120** in which six groove portions **121** each having groove width t of 0.5 mm were formed.

[0079] Accordingly, it was confirmed that first active material layer **120** in which a predetermined quantity of groove portions were formed had a higher effect of inhibiting a temperature rise in comparison with first active material layer **120** in which no groove portion **121** was formed. Here, the predetermined quantity denotes the number of groove portions **121** that is eight or more, groove portions **121** each having groove width t of 0.5 mm.

[0080] Fifthly, the respective evaluations of the power storage modules in the second example group were mutually compared in terms of the degree of the temperature rise.

[0081] As a result, in terms of the degree of the temperature rise, the power storage module including first active material layer **120** in which two groove portions **121** each having groove width t of 10.0 mm were formed was evaluated as a grade higher than that of the power storage module including first active material layer **120** in which two groove portions **121** each having groove width t of 2.5 mm were formed. Accordingly, it was confirmed that by widening groove width t, a higher effect of inhibiting a temperature rise was obtained.

[0082] On the other hand, in terms of the degree of the temperature rise, the power storage module in which ten groove portions **121** each having groove width t of 20.0 mm were formed was evaluated as the same grade as that of the power storage module in which ten groove portions **121** each having groove width t of 2.5 mm were formed. Accordingly, it was confirmed that the effect of inhibiting a temperature rise by widening groove width t was limited.

[0083] Sixthly, in terms of the degree of the temperature rise, the evaluation of the power storage module according to the comparative reference, the respective evaluations of the power storage modules according to the first example group, and the respective evaluations of the power storage modules according to the second example group were compared.

[0084] As a result, the power storage module according to the second example group including first active material layer **120** in which ten groove portions **121** each having groove width t of 2.5 mm or 20.0 mm were formed was evaluated as the highest grade in terms of the degree of the temperature rise. Accordingly, it was confirmed that within the range of the test conditions of this comparison test, the power storage module including second active material layer **130** on which gas discharge restricting portion **131** having phase difference d of 2.0 mm and height h of 50 μm was formed and first active material layer **120** in which ten groove portions **121** each having groove width t of 2.5 mm or 20.0 mm were formed had the highest effect of inhibiting a temperature rise under the conditions of this test. In view of reservation of an application area for first active material layer **120**, it may be determined that the most preferable condition was presented by the power storage module including second active material layer **130** on which gas discharge restricting portion **131** having phase difference d of 2.0 mm and height h of 50 μm was formed and first active material layer **120** in which ten groove portions **121** each having groove width t of 2.5 mm were formed.

[0085] In this test, the effect of inhibiting a temperature rise was obtained when interval g was 40 mm or more and 350 mm or less.

[0086] In the embodiment of the present disclosure, separator **400** is, for example, a porous body formed of a porous sheet. Gas discharge restricting portion **131** is formed so as to adjoin opposite region **130***c*. Because of such a configuration, separator **400** follows the shape of gas discharge restricting portion **131** and a bent portion is formed in separator **400**.

[0087] The first active material layer and the second active material layer are short-circuited and a short-circuit current is caused. The electrolyte solution is raised in temperature by Joule heat induced by the short-circuit current and gasifies, and the volume thereof expands and accordingly, a slight space is formed between the first active material layer and the second active material layer. The gas moves in the space in the horizontal direction. The projecting portion serves as a physical barrier against the gas moving in the horizontal direction and can inhibit discharge of the gas to the outside of the gas discharge restricting portion.

[0088] Thus, it is enabled to inhibit increase in the internal pressure of space R and inhibit a partial rupture of resin portion **500**. If resin portion **500** partially ruptures, stacked current collector plates **110** adjacent to each other in stack direction H may come into contact with each other and a short circuit may be caused.

[0089] In contrast, in power storage module **1** according to the embodiment of the present disclosure, it is enabled to inhibit a rupture of resin portion **500** as described above and thus, occurrence of the above-described adverse effect can be hindered.

[0090] In the embodiment of the present disclosure, groove portion **121** is formed in first active material layer **120**. With such a configuration, the gas caused by vaporization of the electrolyte solution in separator **400** climbs through groove portion **121** and reaches stacked current collector plate **110**. The gas that has reached stacked current collector plate **110** dissipates heat to stacked current collector plate **110**, and the gas temperature is lowered accordingly. Thus, by lowering the gas temperature, melting of separator **400** can be hindered and short-circuiting of first active material layer **120** and second active material layer **130** can be inhibited. As the gas temperature is lowered, the volume of the gas decreases and the pressure in space R can be reduced.

[0091] In particular, in bipolar electrode **101** including stacked current collector plate **110** in which first current collector plate **112** and second current collector plate **113** are formed in direct contact with each other, the heat of the gas that has reached the current collector plate through groove portion **121** is dissipated through the current collector plate more easily in comparison with a battery in which first current collector plate **112** and second current collector plate **113** are electrically connected to each other via a conductive wire, a terminal, or the like. Accordingly, the temperature of the gas is lowered, the volume of the gas decreases, and the pressure in space R can be further reduced.

[0092] Although the above-described embodiment shows an example in which gas discharge restricting portion **131** is formed integrally with second active material layer **130**, the present disclosure is not limited thereto. For example, gas discharge restricting portion **131** may be formed separately from second active material layer **130** and may be disposed in a position being outside opposite region **130***c* in main surface **130***b* and adjoining opposite region **130***c*.

[0093] Gas discharge restricting portion **131** may be formed of a material different from that of second active material layer **130**. For example, gas discharge restricting portion **131** may be formed by shaping a resin or the like in an annular manner on main surface **130***b* along the outer periphery of opposite region **130***c*.

[0094] Although the above-described embodiment shows an example in which groove portion **121** is formed so as to extend in length direction L, the present disclosure is not limited thereto. For example, when seen in stack direction H, groove portions **121** may be formed in a lattice manner or be partially formed. Groove portion **121** is not necessarily required to be linear.

[0095] Although embodiments of the present disclosure have been described, it should be understood that the herein-disclosed embodiments are presented by way of illustration and example in all respects and are not to be taken by way of limitation. The scope of the present disclosure is defined by the claims and intended to include all changes within the purport and scope equivalent to the claims.

What is claimed is:

1. A power storage module comprising:

a first active material layer and a second active material layer;

a separator disposed between the first active material layer and the second active material layer; and

a projecting portion, wherein

the second active material layer includes a main surface positioned toward the first active material layer,

the main surface includes an opposite region that is opposite the first active material layer, and

the projecting portion is provided on the main surface and is provided in a position being outside the opposite region and adjoining the opposite region.

2. The power storage module according to claim **1**, wherein the projecting portion is provided so as to extend in an annular manner along an outer peripheral edge portion of the opposite region.

3. The power storage module according to claim **1**, wherein the projecting portion has a height of 50 μm or more from the main surface.

4. The power storage module according to claim **1**, further comprising

a current collector plate on which the first active material layer is provided, wherein

the current collector plate is positioned opposite the separator in relation to the first active material layer,

at least one groove portion is provided in the first active material layer, and

the current collector plate is exposed from the first active material layer in the at least one groove portion.

5. The power storage module according to claim **4**, wherein the first active material layer and the second active material layer each have a dimension of at least 1 m or more in a length direction or a width direction.

6. The power storage module according to claim **4**, wherein a width of the at least one groove portion is 0.5 mm or more and 20 mm or less.

7. The power storage module according to claim **4**, wherein an interval of the at least one groove portion is 40 mm or more and 350 mm or less.

8. A power storage module comprising:

a plurality of bipolar electrodes stacked in a stack direction; and

a separator disposed between the plurality of bipolar electrodes, wherein

each of the plurality of bipolar electrodes includes a current collector plate, a first active material layer, a second active material layer, and a projecting portion,

the current collector plate includes a first application surface and a second application surface in the stack direction,

the first active material layer is applied to the first application surface of the current collector plate,

the second active material layer is applied to the second application surface of the current collector plate and includes a main surface,

the main surface is covered with the separator,

the main surface includes an opposite region being opposite the first active material layer included in one of the plurality of bipolar electrodes adjacent to each other with interposition of the separator, and

the projecting portion is provided on the main surface and is provided in a position being outside the opposite region and adjoining the opposite region.

9. The power storage module according to claim **8**, wherein the projecting portion is provided so as to extend in an annular manner along an outer peripheral edge portion of the opposite region.

10. The power storage module according to claim **8**, wherein

at least one groove portion is provided in the first active material layer, and

the current collector plate is exposed from the first active material layer in the at least one groove portion.

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