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Maeda et al.

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(54) **ENERGY STORAGE DEVICE**

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H01M 2/26	(2006.01)
H01M 10/04	(2006.01)
H01M 10/0525	(2010.01)
H01M 2/30	(2006.01)

(52) **U.S. Cl.**
CPC ***H01M 2/26*** (2013.01); ***H01M 2/22*** (2013.01); ***H01M 2/263*** (2013.01); ***H01M 2/30*** (2013.01); ***H01M 10/0431*** (2013.01); ***H01M 10/0525*** (2013.01)

(58) **Field of Classification Search**
CPC H01M 2/22; H01M 2/26; H01M 2/263; H01M 2/30; H01M 10/0431; H01M 10/0525
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,709,965	A	1/1998	Grivel et al.	
6,159,633	A	12/2000	Yang	
2007/0231684	A1 *	10/2007	Takano	H01M 2/0285 429/161
2012/0219845	A1	8/2012	Chiba	
2015/0236328	A1 *	8/2015	Shinohara	H01M 2/263 429/178

FOREIGN PATENT DOCUMENTS

JP	H 08-83598	A	3/1996
JP	3060540	U	9/1999
JP	2001-256950	A	9/2001
JP	2004-273178	A	9/2004
JP	2012-181941	A	9/2012
JP	2012-190636	A	10/2012
JP	2013-187077	A	9/2013
JP	2014-151570	A	8/2014
JP	2015-005456	A	1/2015
JP	2015-103318	A	6/2015
JP	2015-222631	A	12/2015

OTHER PUBLICATIONS

Machine translation of JP 2004-273178, published on Sep. 30, 2004 (Year: 2004).*

* cited by examiner

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(57) **ABSTRACT**

An energy storage device comprising: electrode terminals; an electrode assembly formed by stacking a positive electrode plate and a negative electrode plate; and current collectors which connect the electrode terminals and the electrode assembly to each other, wherein at least one of the positive electrode plate and the negative electrode plate has a plurality of tab groups which are joined to the current collector, each tab group being formed by stacking one or more tabs projecting toward the electrode terminal, and at least one tab group among the tab groups and the current collector has a swaged joint portion, the swaged joint portion projecting from either one of the tab group or the current collector to the other of the tab group or the current collector.

17 Claims, 14 Drawing Sheets

FIG. 1

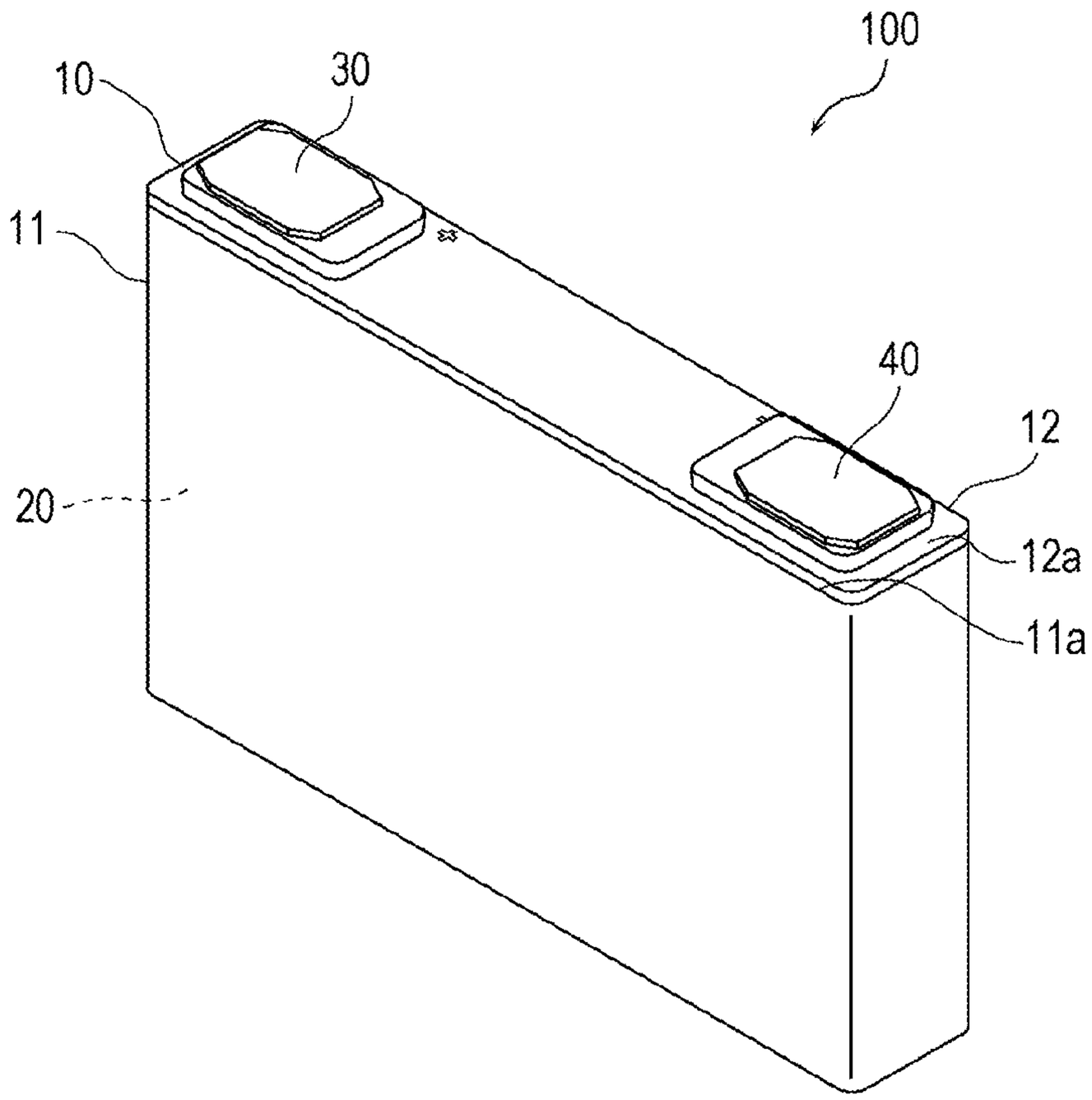


FIG. 2

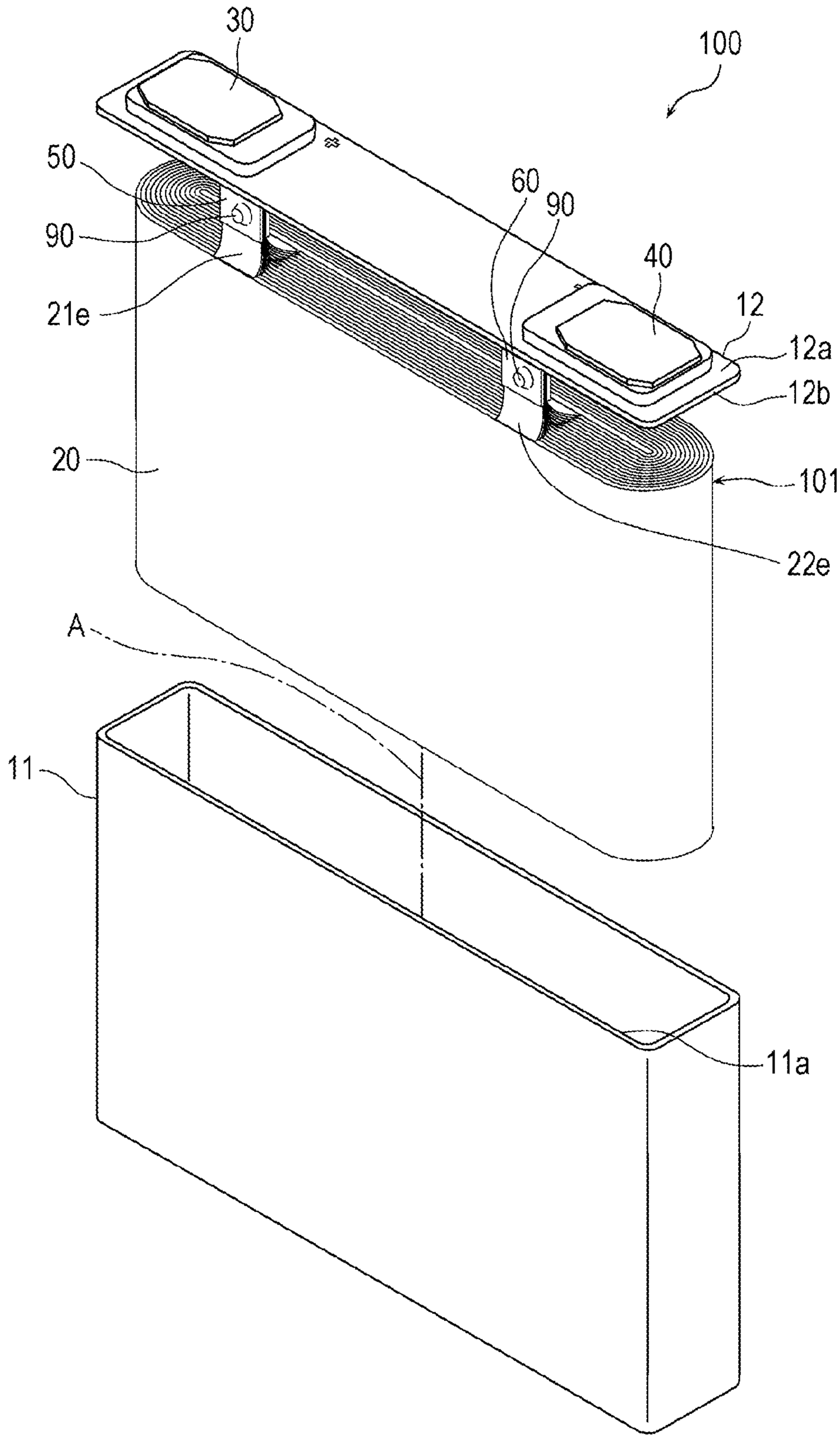


FIG. 3

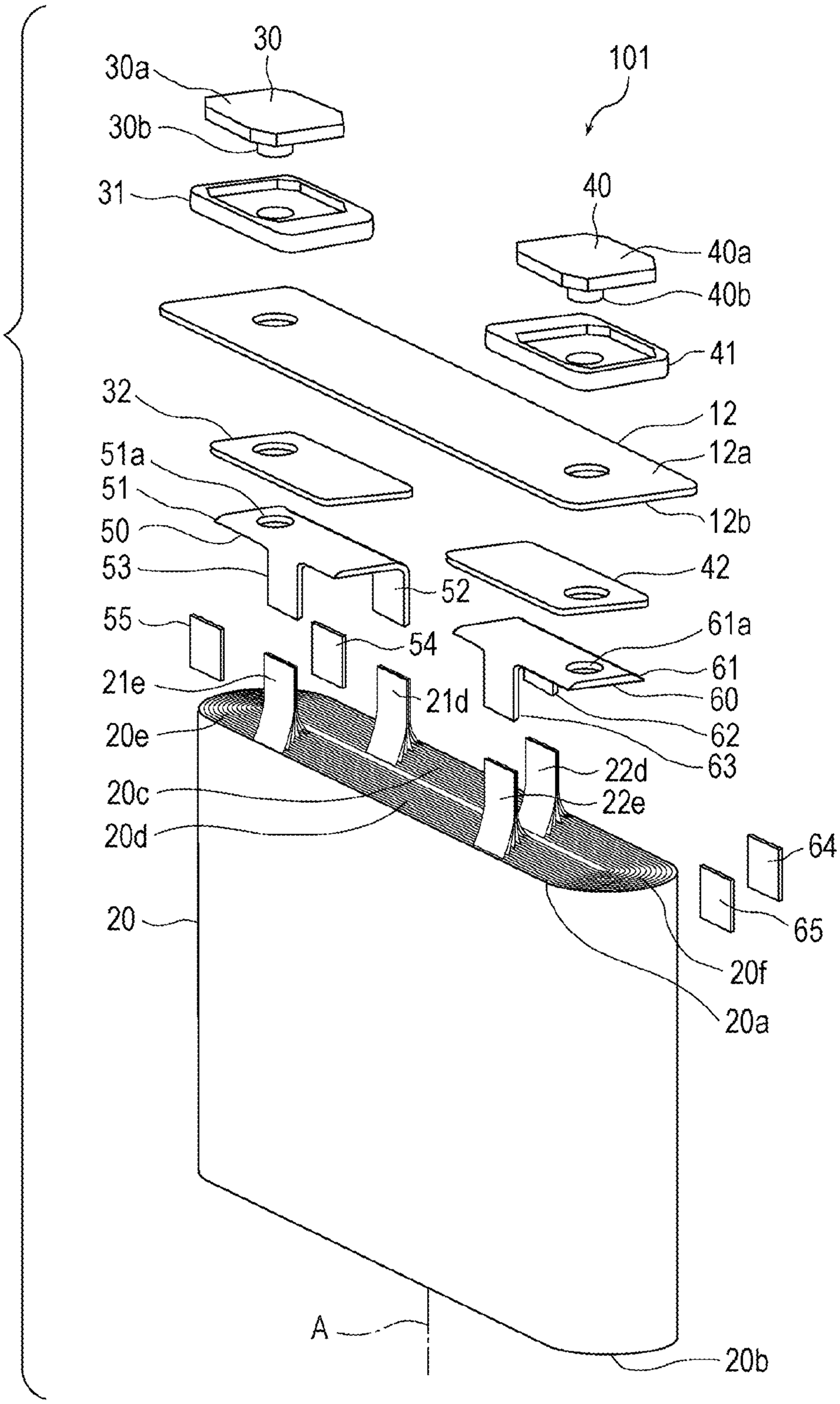

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30b
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40a
40b
41
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12
12a
12b
51a
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61a
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21e
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22e
20c
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20f
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FIG. 4

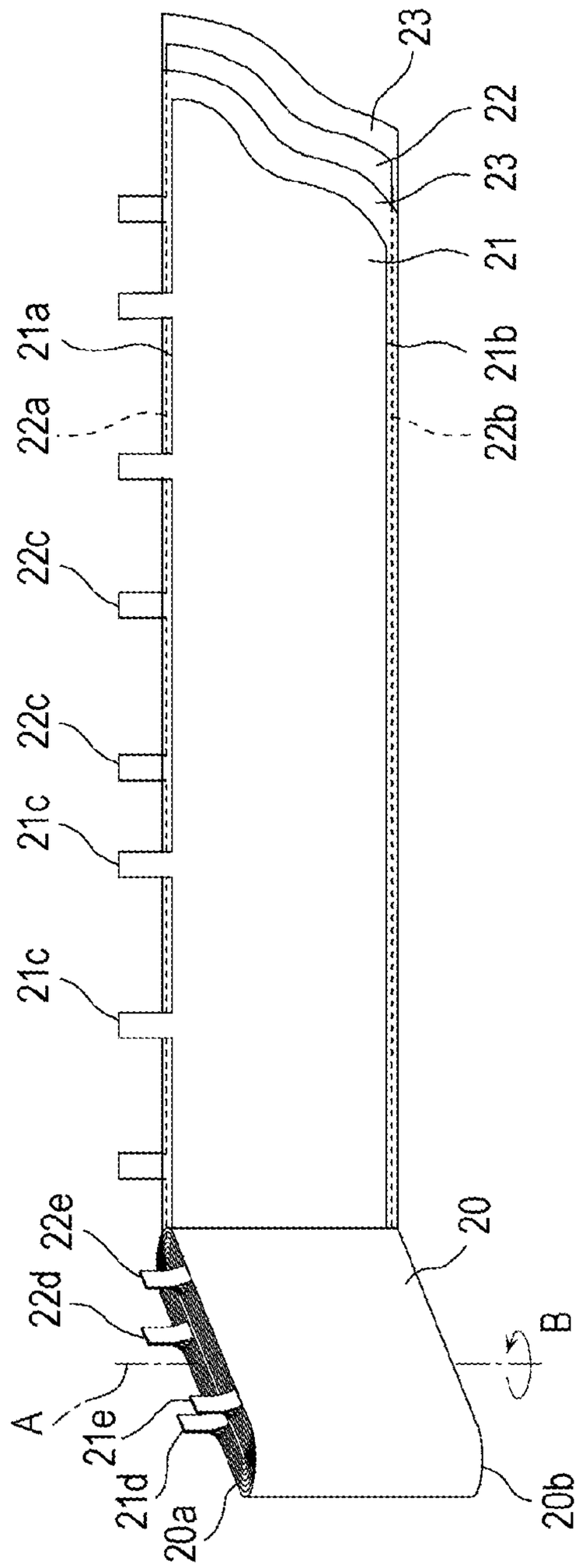

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FIG. 5

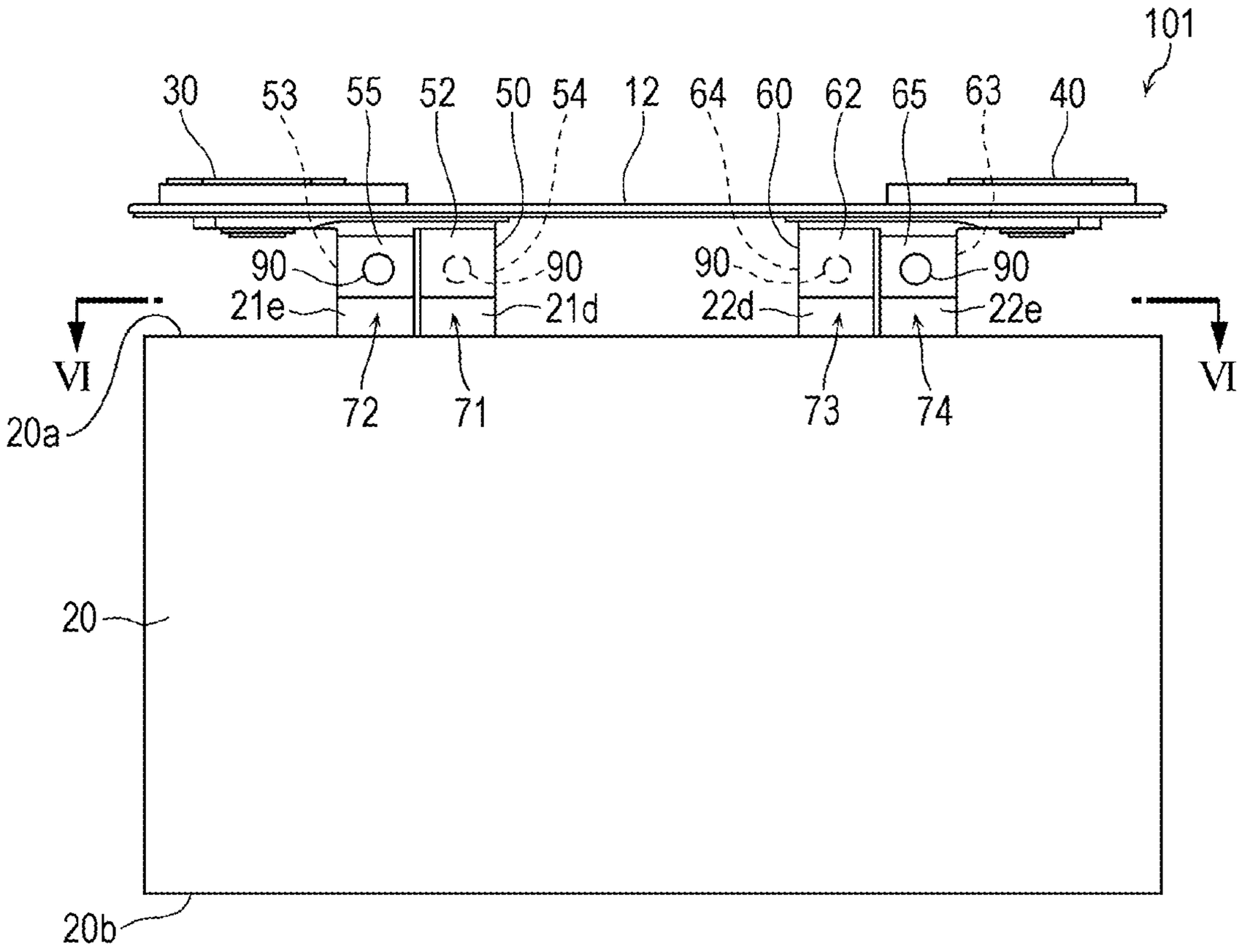

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20b

FIG. 6

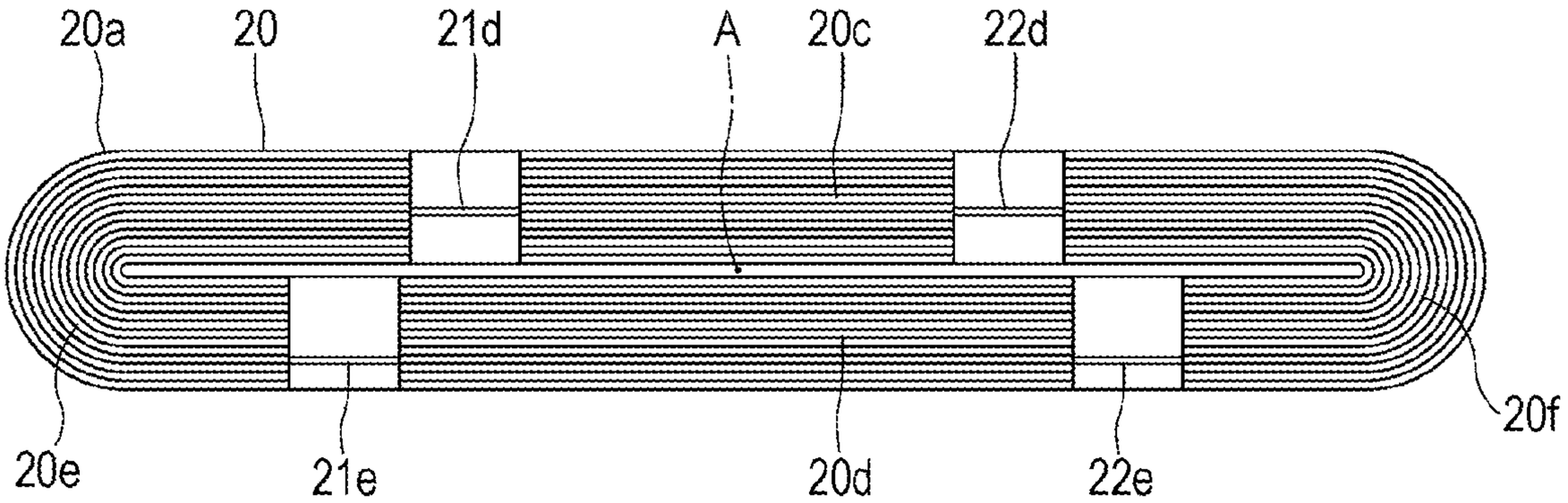

20a
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21d
A
20c
22d
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FIG. 7

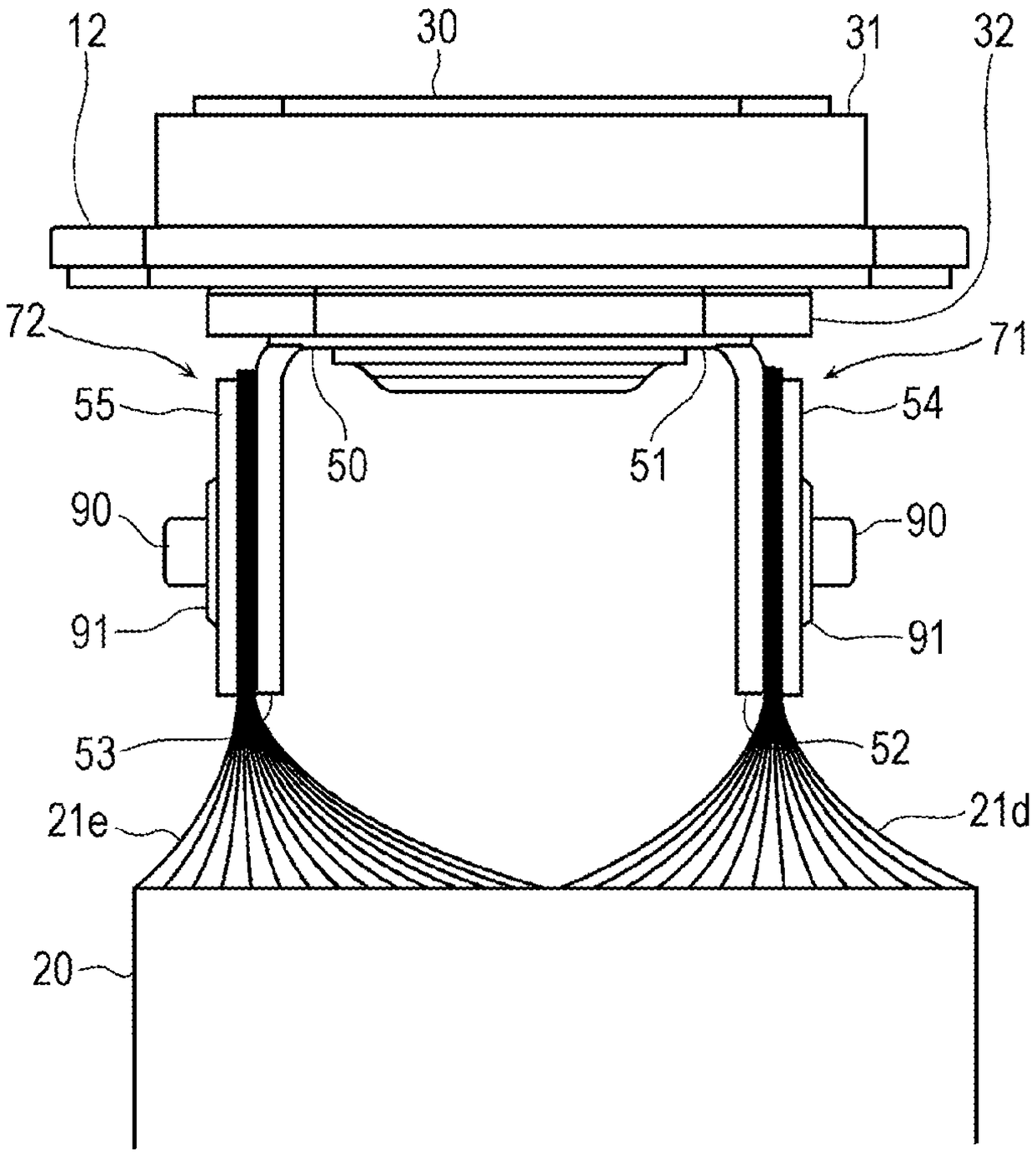

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FIG. 8

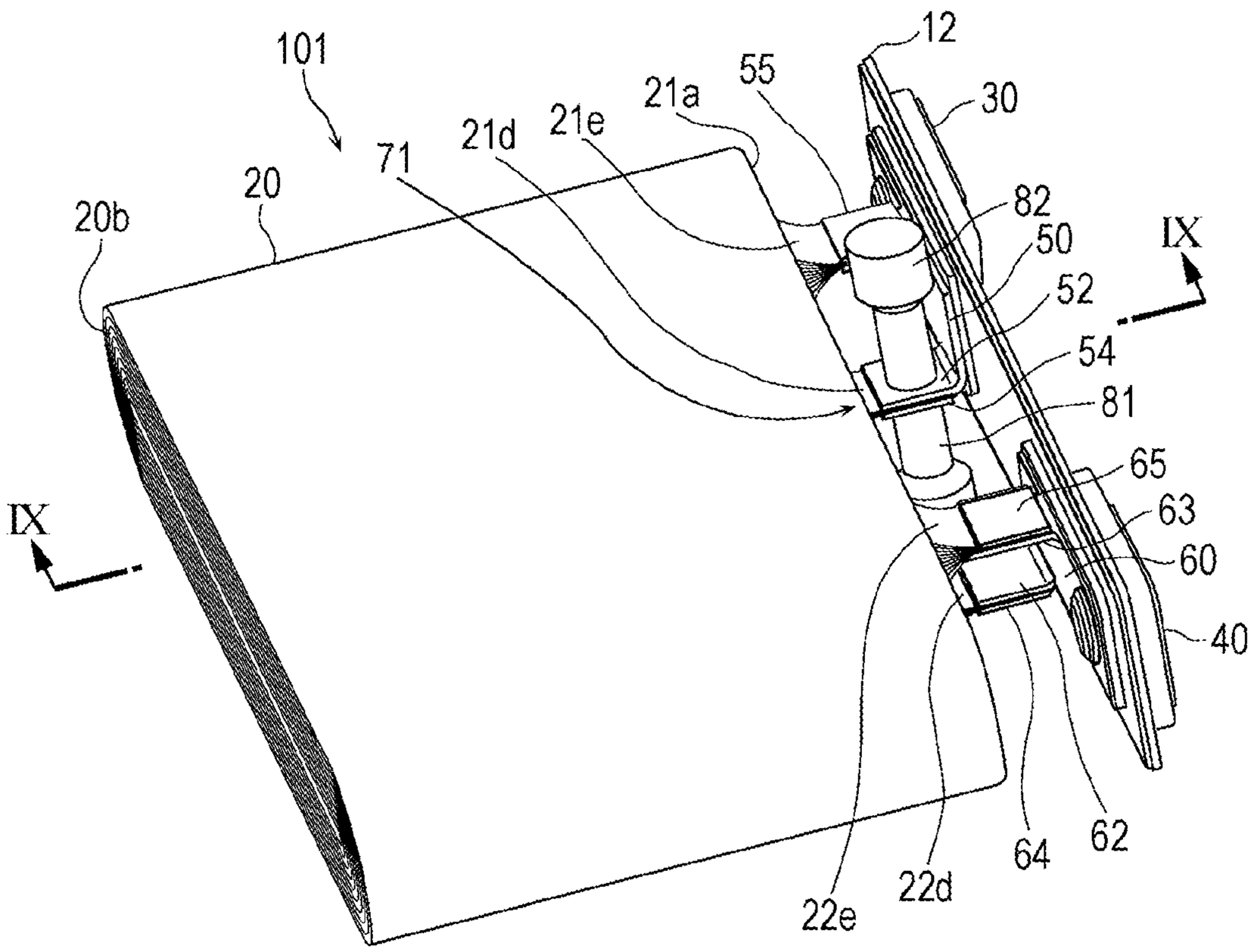

101
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FIG. 9

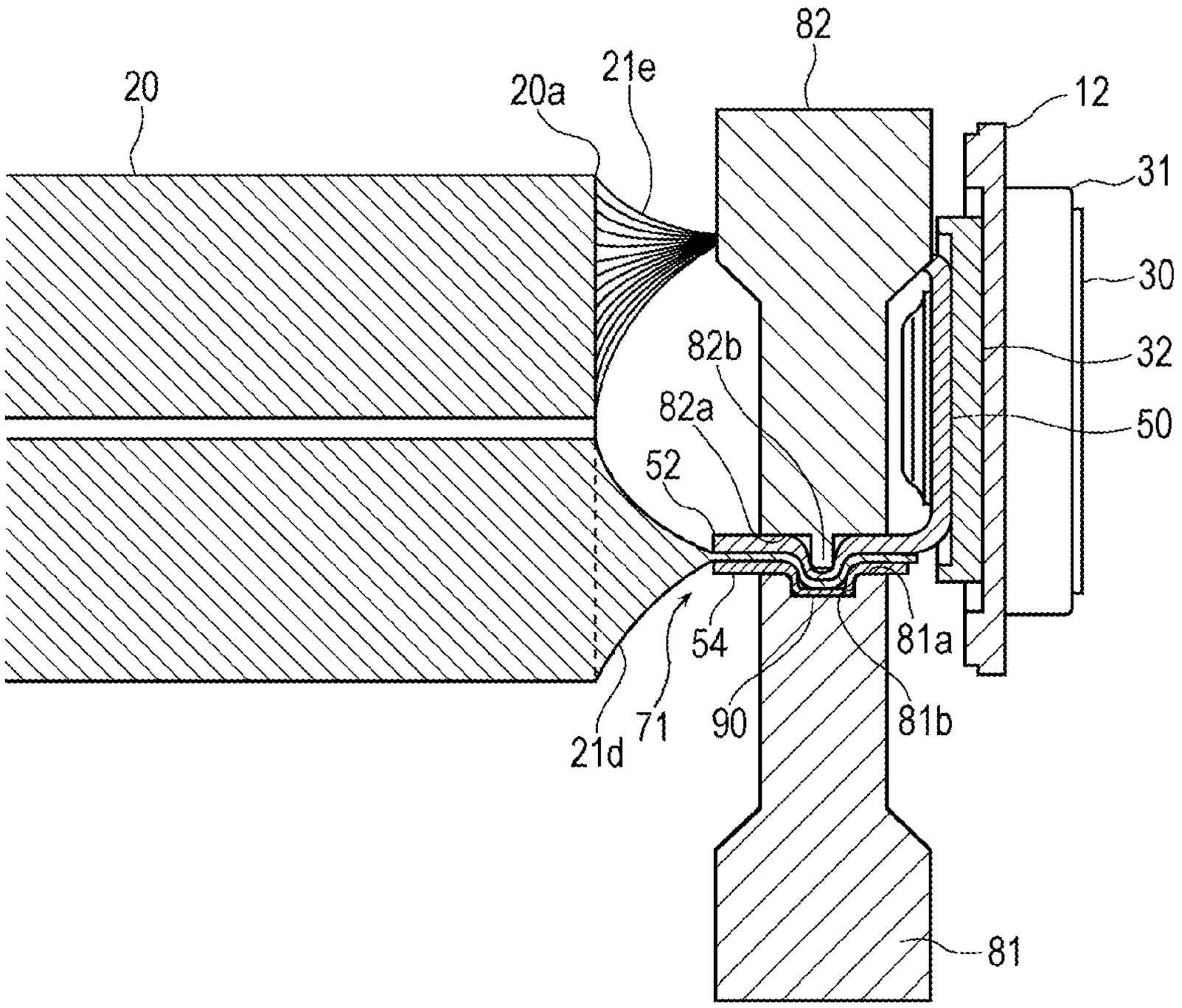


FIG. 10

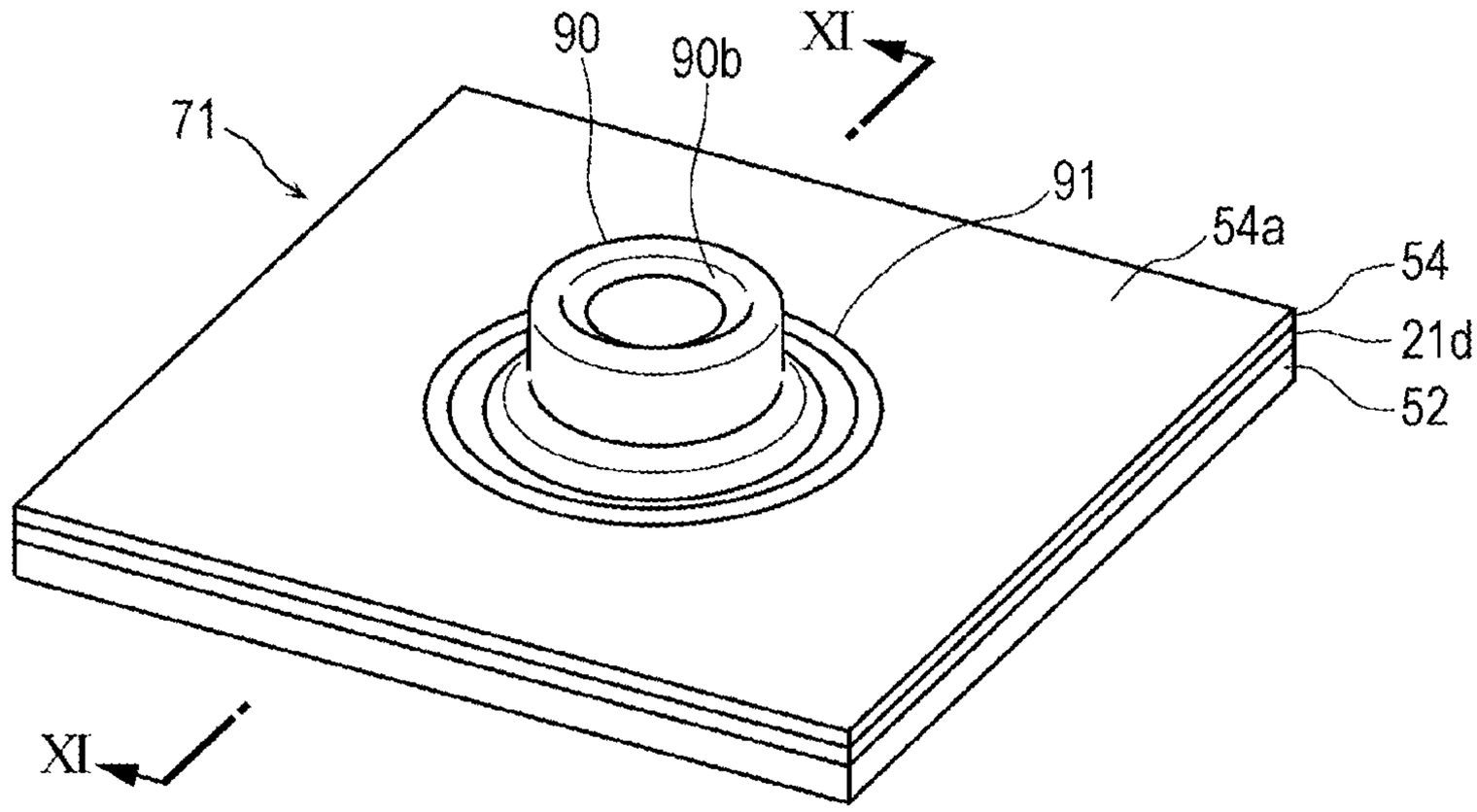


FIG. 11

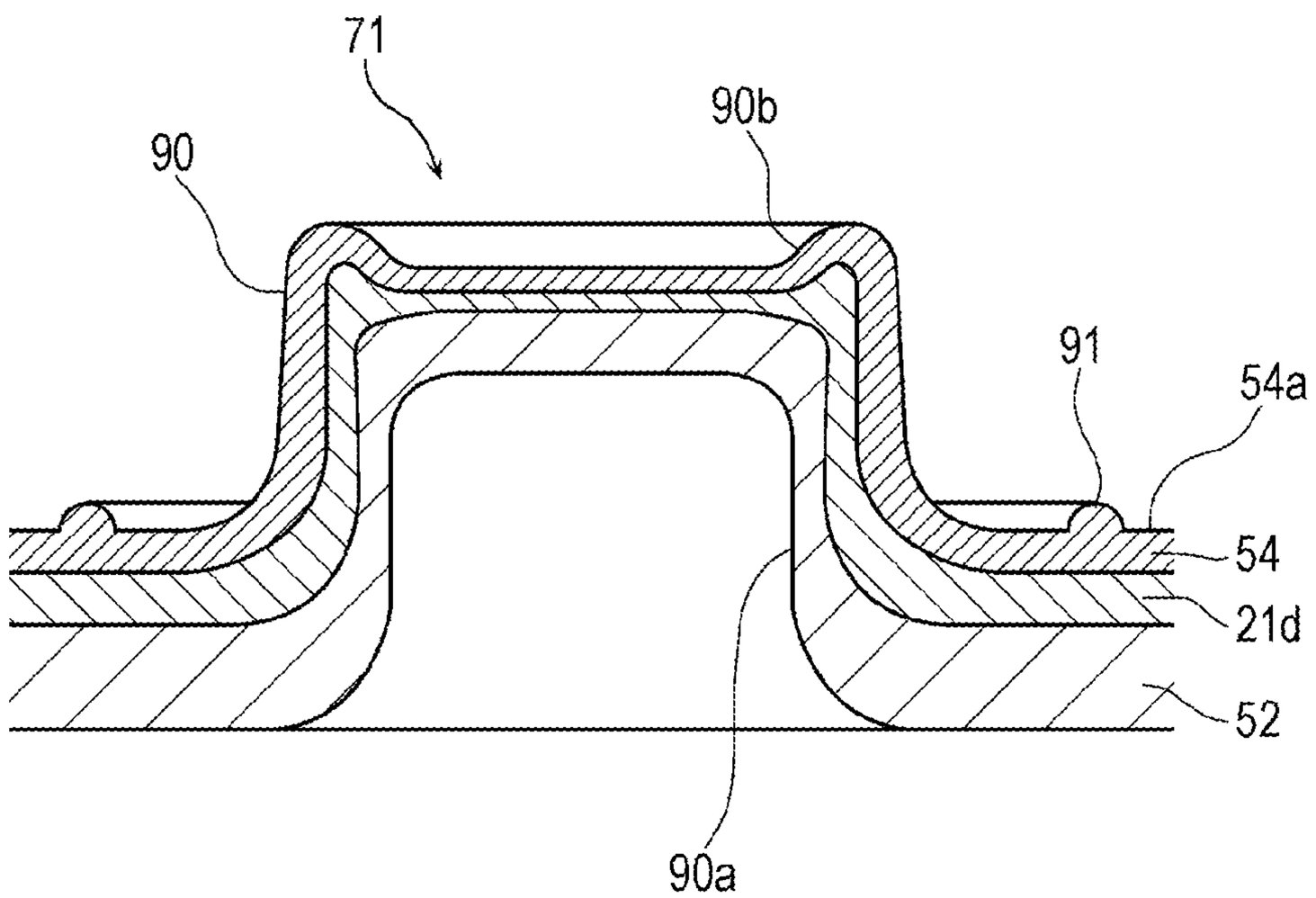


FIG. 12

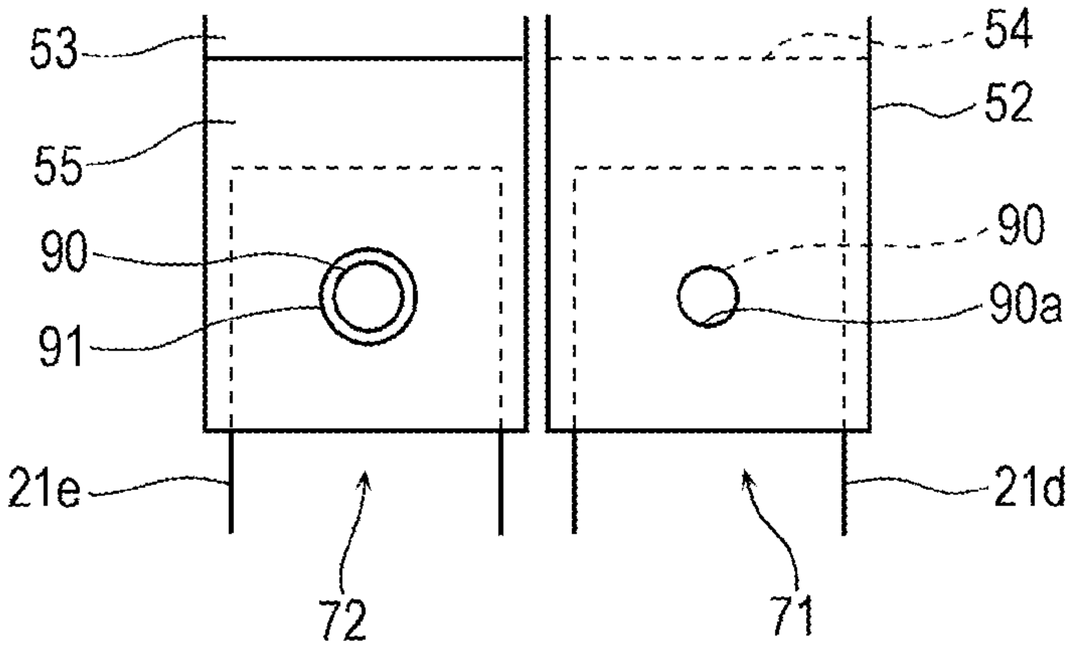

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FIG. 13

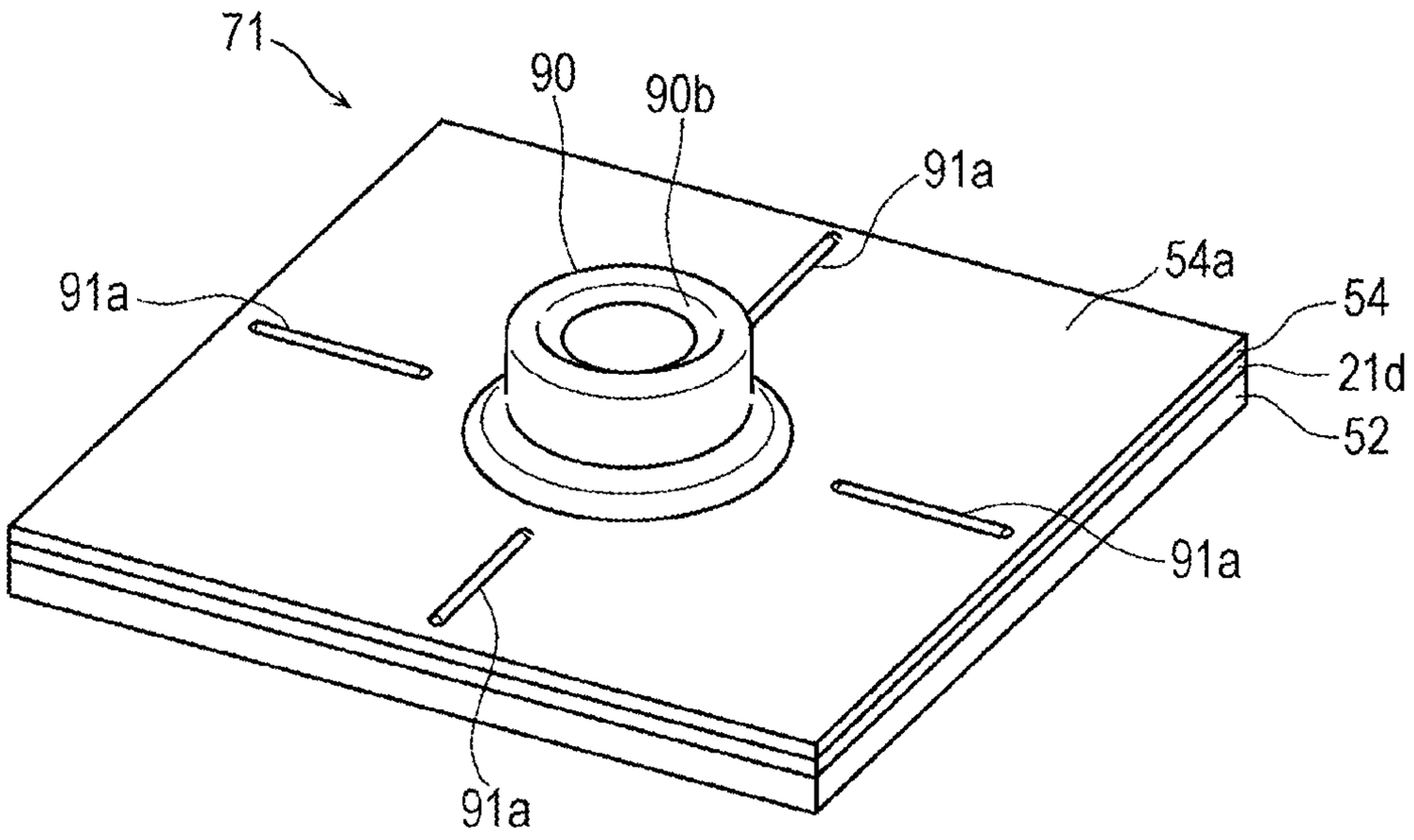

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FIG. 14

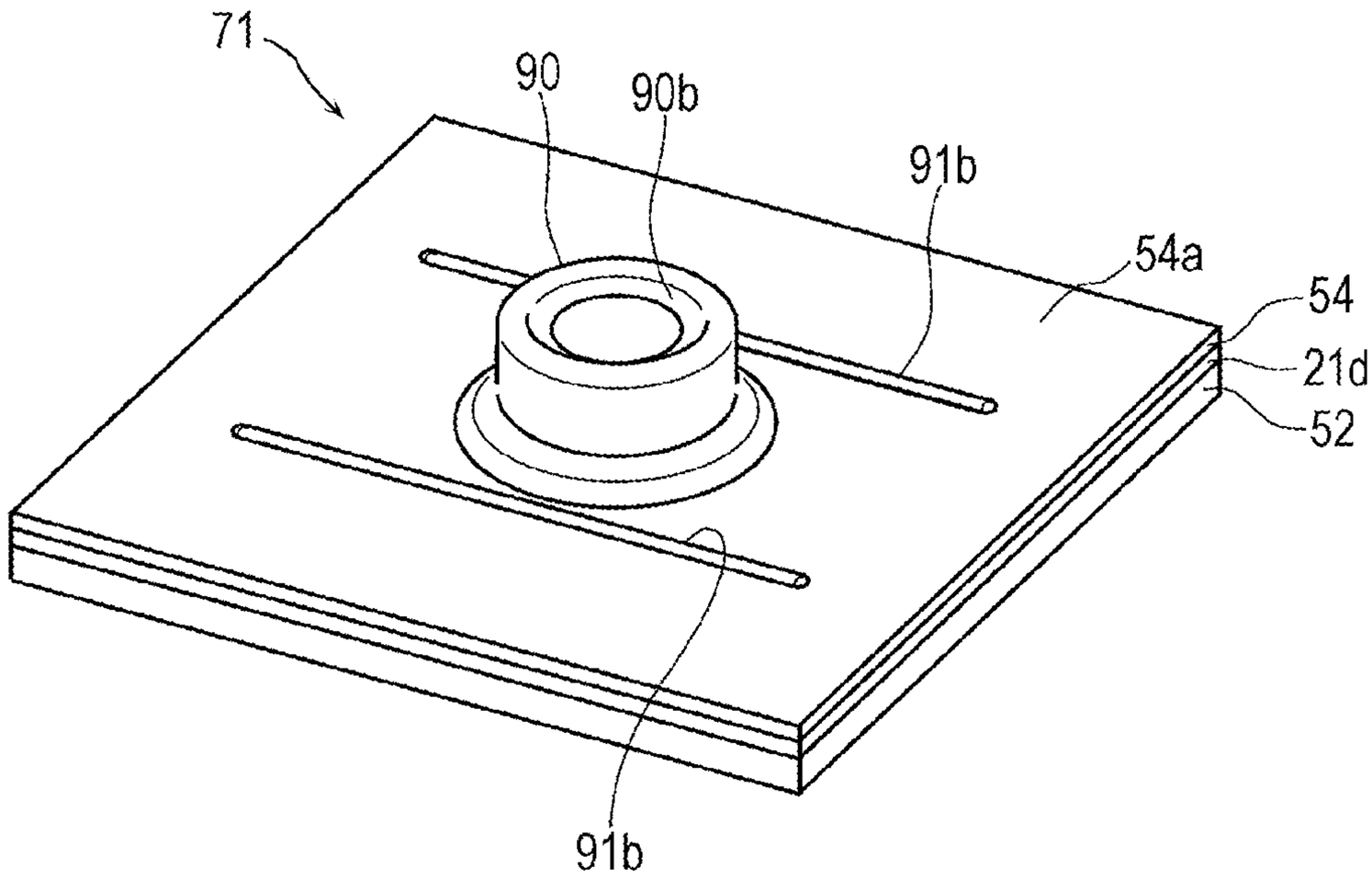


FIG. 15

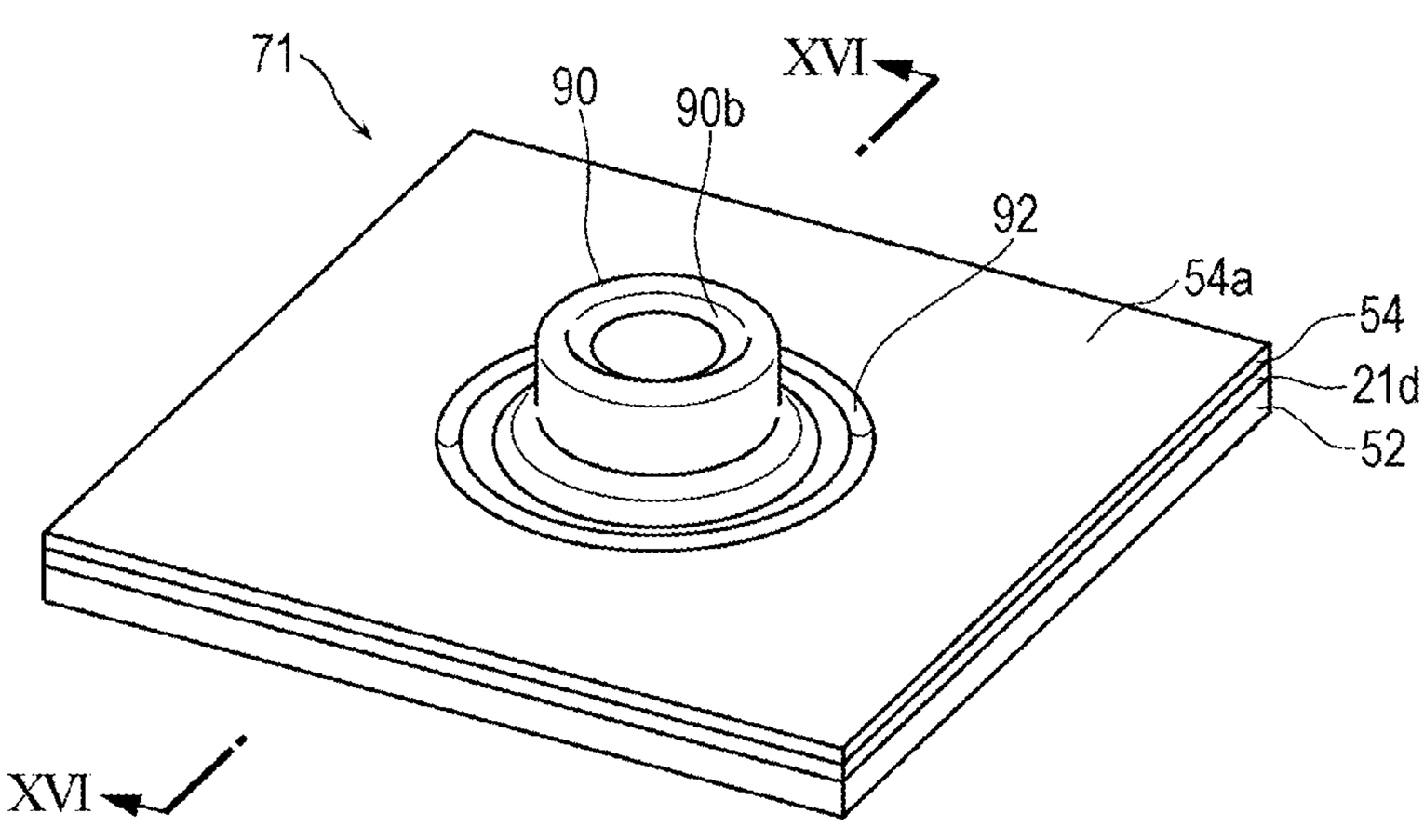


FIG. 16

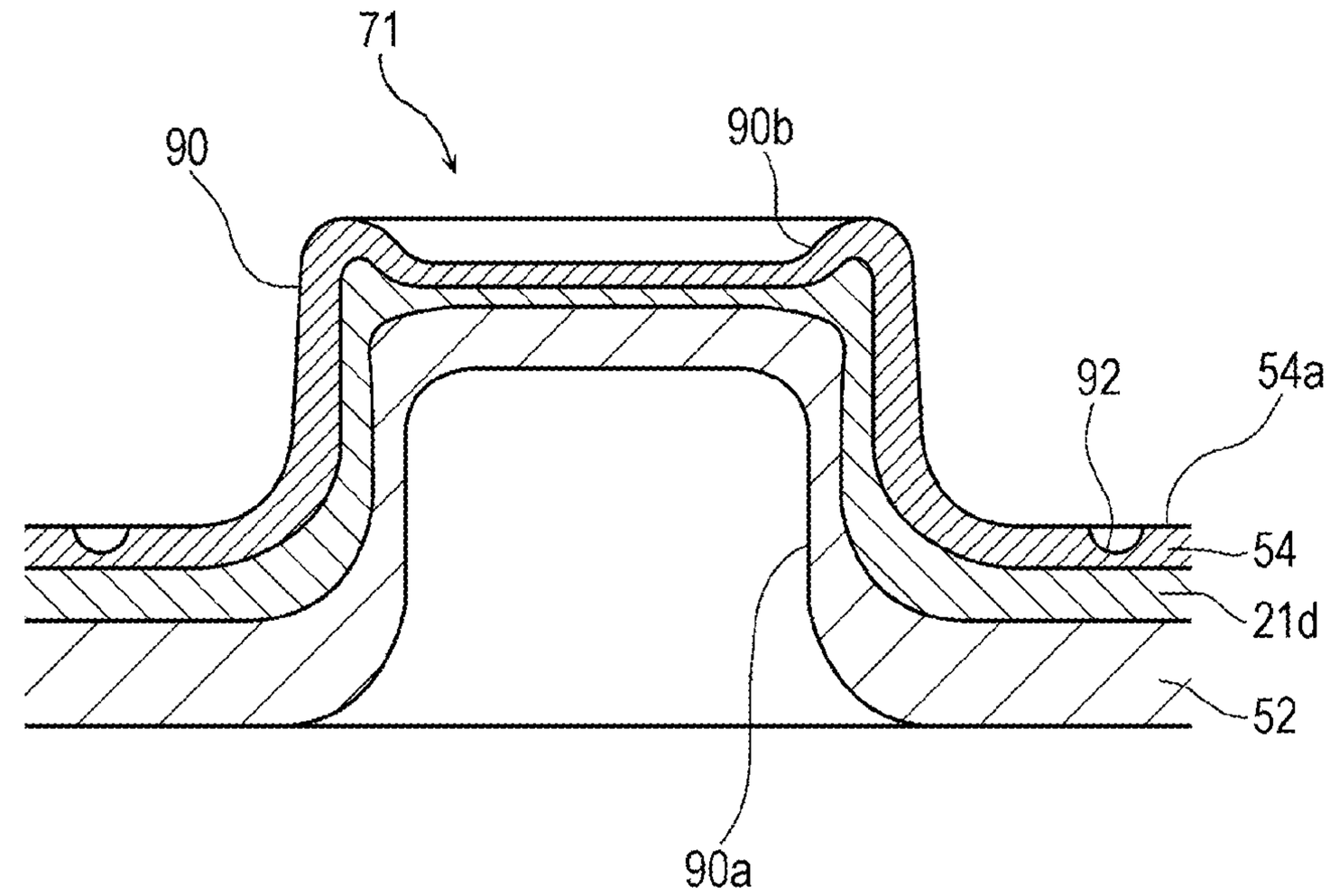


FIG. 17

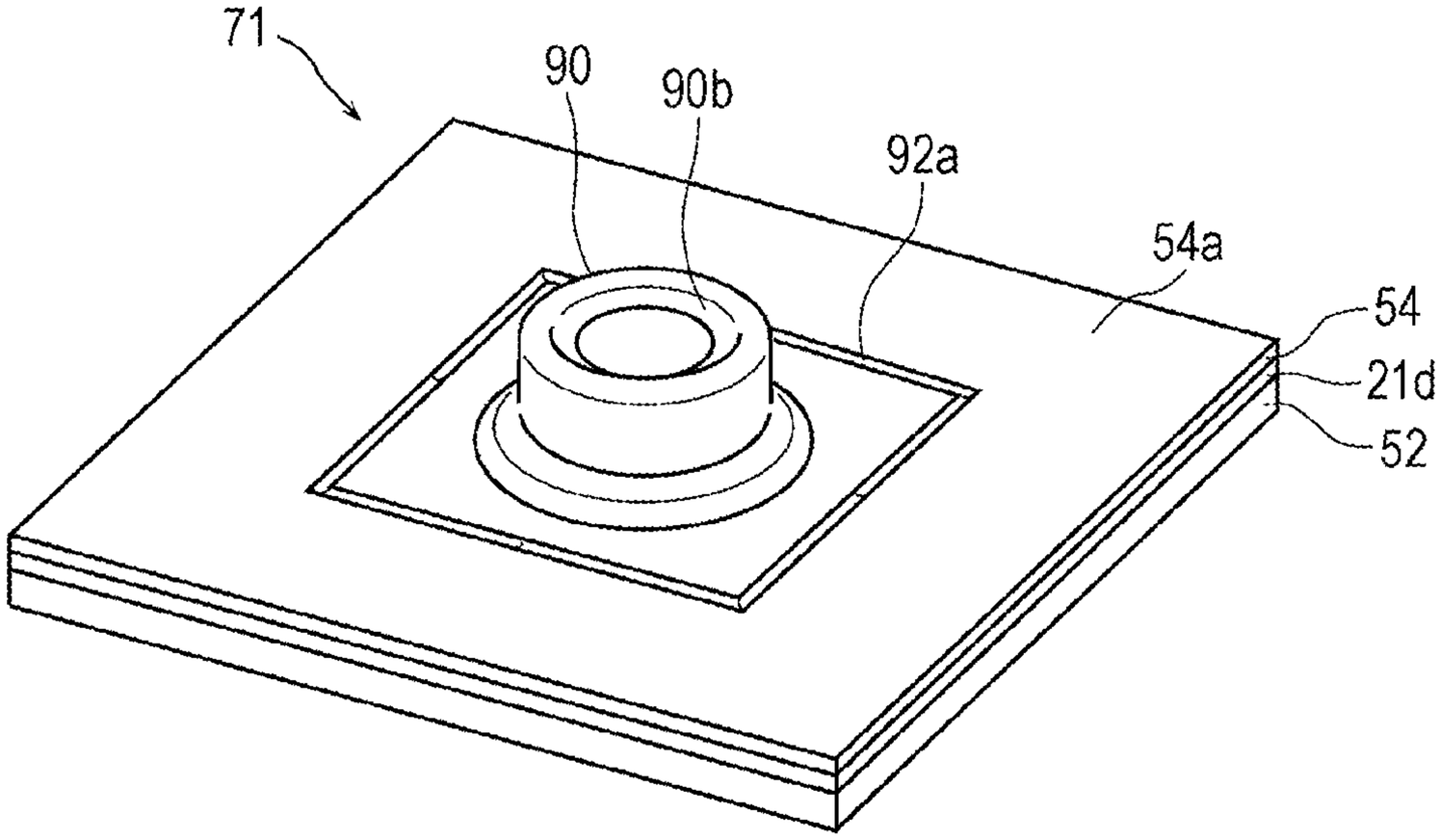


FIG. 18

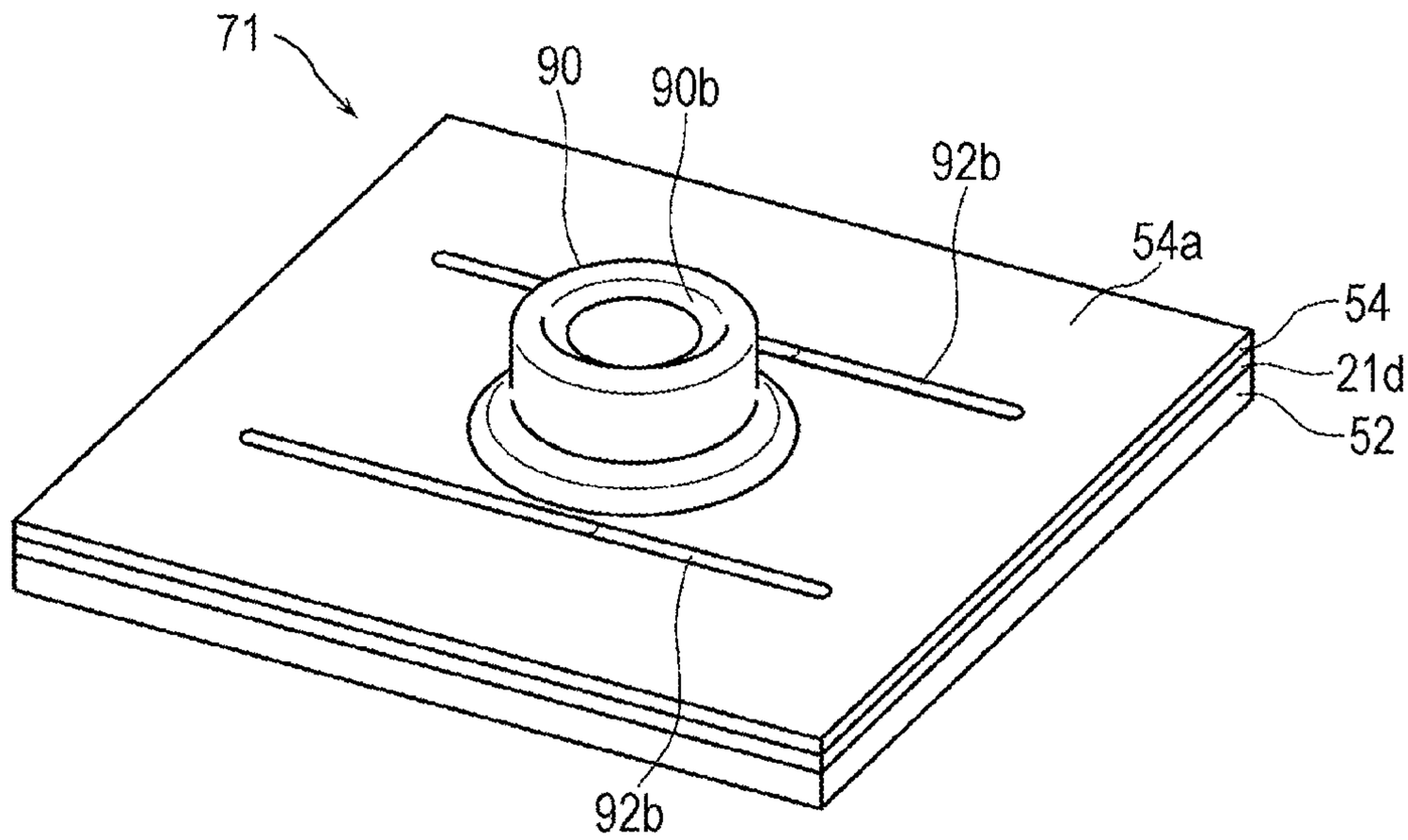

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FIG. 19

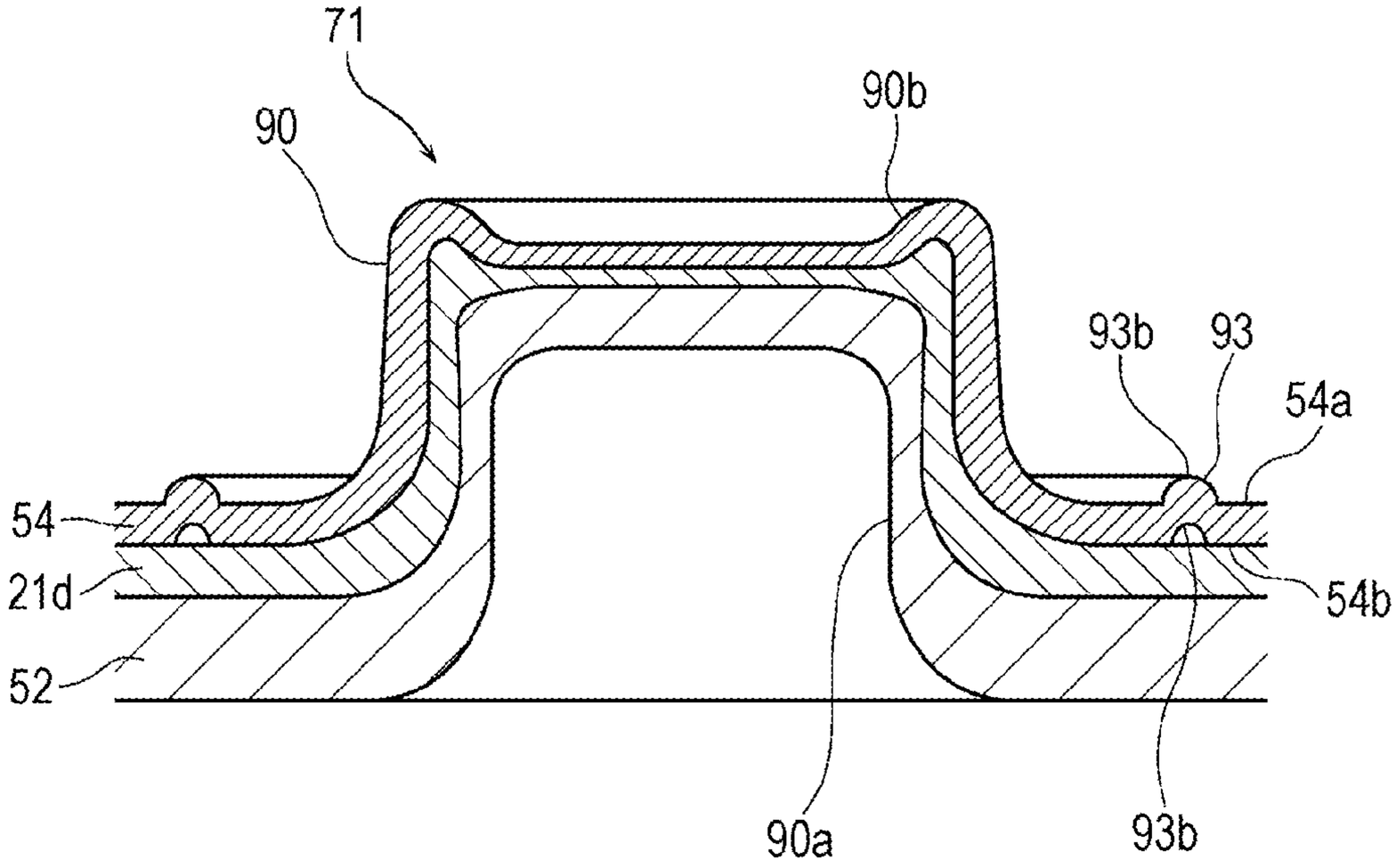
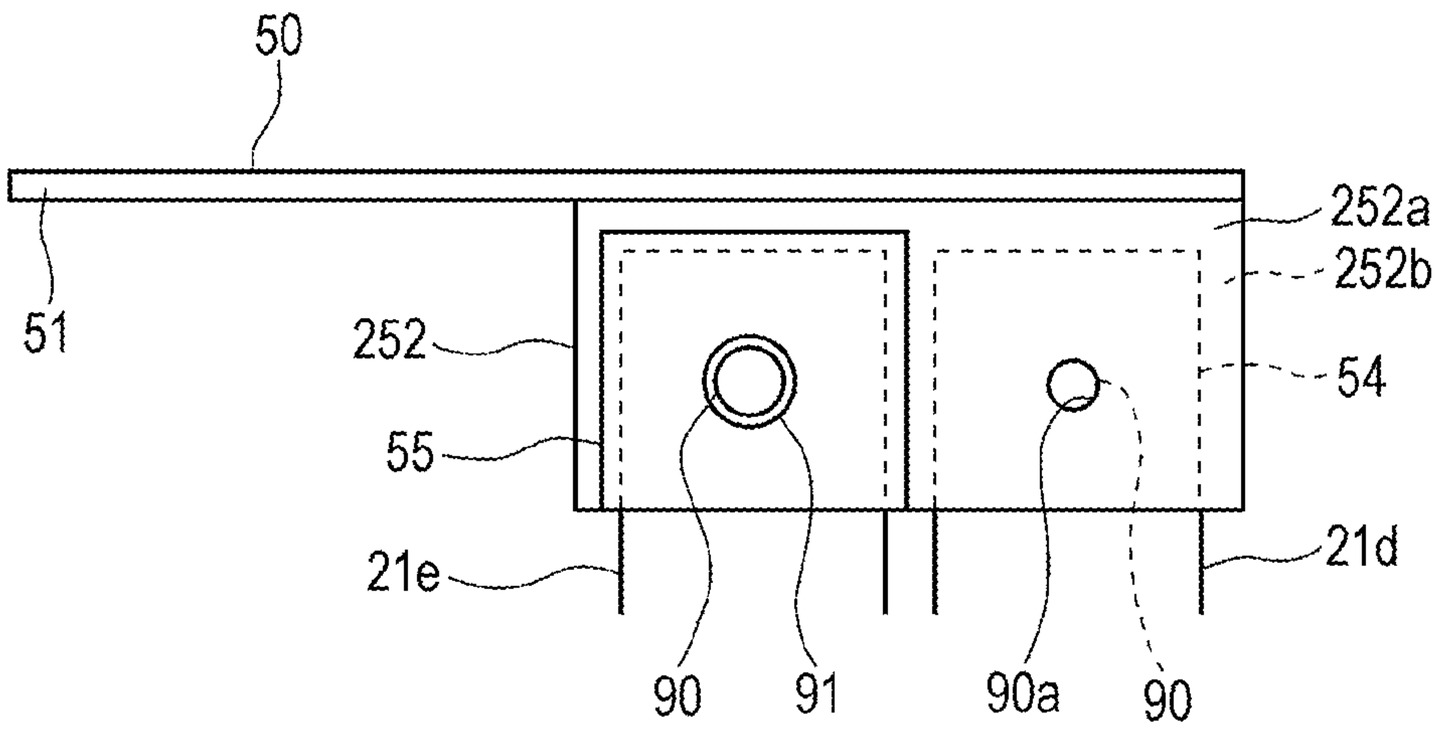

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FIG. 20



ENERGY STORAGE DEVICE

CROSS-REFERENCE TO RELATED APPLICATION

This application claims the benefit of Japanese patent applications No. 2016-087547 filed on Apr. 25, 2016 and No. 2017-039452 filed on Mar. 2, 2017, which are incorporated by reference.

FIELD

The present invention relates to an energy storage device which includes an electrode assembly.

BACKGROUND

As an energy storage device such as a lithium ion secondary battery, there has been known an energy storage device which includes an electrode assembly formed by overlapping a positive electrode plate, a negative electrode plate, and a sheet-like separator having an electric insulation property. For example, JP 2004-273178 A (patent literature 1) describes an energy storage device which includes an electrode assembly formed of a winding electrode. The winding electrode is formed by stacking and winding a set formed of an elongated insulation sheet, an elongated positive electrode sheet, an elongated insulation sheet and an elongated negative electrode sheet. In the winding electrode, a positive electrode foil of the positive electrode sheet, which projects from one long side of the insulation sheet, is stacked, and a negative electrode foil of the negative electrode sheet, which projects from the other long side of the insulation sheet, is stacked. The stacked positive electrode foil is joined to plate portions of a positive electrode terminal which sandwich the stacked positive electrode foil from both sides. The stacked negative electrode foil is joined to plate portions of a negative electrode terminal which sandwich the stacked negative electrode foil from both sides. In performing the joining, two plate portions which sandwich the electrode foil therebetween are plastically deformed such that one plate portion and the positive electrode foil or the negative electrode foil are sunk into the other plate portion.

SUMMARY

The following presents a simplified summary of the invention disclosed herein in order to provide a basic understanding of some aspects of the invention. This summary is not an extensive overview of the invention. It is intended to neither identify key or critical elements of the invention nor delineate the scope of the invention. Its sole purpose is to present some concepts of the invention in a simplified form as a prelude to the more detailed description that is presented later.

In recent years, an energy storage device (like one described in patent literature 1) is mounted on a movable body such as an automobile. During the movement of the movable body, the energy storage device and the winding electrode receive vibrations from the movable body. Accordingly, connecting portions between the winding electrode and the positive electrode terminal and the negative electrode terminal also receive vibrations. Since the connecting portions between the winding electrode and the positive electrode terminal and the negative electrode terminal are electrically conductive portions, the connecting portions are required to ensure reliability of the connection such that the connection can be maintained even after the connecting portions receive vibrations or the like. That is, improvement of quality of the connecting portions is required.

An object of the present invention is to provide an energy storage device which can realize the enhancement of quality of a connecting portion between electrically conductive members.

An energy storage device according to an aspect of the present invention includes: electrode terminals; an electrode assembly formed by stacking a positive electrode plate and a negative electrode plate; and current collectors which connect the electrode terminals and the electrode assembly to each other, wherein at least one of the positive electrode plate and the negative electrode plate has a plurality of tab groups which are joined to the current collector, each tab group being formed by stacking one or more tabs projecting toward the electrode terminal, and at least one tab group among the tab groups and the current collector has a swaged joint portion, the swaged joint portion projecting from either one of the tab group or the current collector to the other of the tab group or the current collector.

BRIEF DESCRIPTION OF DRAWINGS

The foregoing and other features of the present invention will become apparent from the following description and drawings of an illustrative embodiment of the invention in which:

FIG. **1** is a perspective view schematically showing an external appearance of an energy storage device according to an embodiment of the present invention.

FIG. **2** is an exploded perspective view of the energy storage device shown in FIG. **1** and showing a state where an assembly formed of a lid body of a container and an electrode assembly is separated from a container body of the container.

FIG. **3** is an exploded perspective view showing the assembly formed of the lid body and the electrode assembly shown in FIG. **2** in an exploded manner.

FIG. **4** is a perspective view of the electrode assembly showing a portion of the electrode assembly shown in FIG. **3** in a developed manner.

FIG. **5** is a side view of the assembly formed of the lid body and the electrode assembly shown in FIG. **2** as viewed from a side.

FIG. **6** is a plan view of the electrode assembly when the electrode assembly is viewed from a plane taken along line VI-VI shown in FIG. **5**.

FIG. **7** is a view showing joint portions between positive electrode current collecting tab groups of the electrode assembly and the positive electrode current collector shown in FIG. **5** in an enlarged manner and is also a view of the joint portions as viewed in a direction from a negative electrode terminal toward a positive electrode terminal.

FIG. **8** is a perspective view showing a state at the time of connecting the positive electrode current collecting tab group of the electrode assembly and the positive electrode current collector in the assembly shown in FIG. **2**.

FIG. **9** is a cross-sectional side view taken along a cross section which passes the joint portion between the positive electrode current collecting tab group of the electrode assembly shown in FIG. **8** and the positive electrode current collector, and a die tool and a punching tool for connection as viewed in a direction IX.

FIG. **10** is a perspective view of the joint portion after being caulked shown in FIG. **8** as viewed from a projecting side of a swaged joint portion of the joint portion.

FIG. **11** is a cross-sectional view of the joint portion shown in FIG. **10** as viewed in a direction XI in a cross section taken along a radial direction of the swaged joint portion of the joint portion.

FIG. **12** is a side view showing the joint portion between the positive electrode current collecting tab group of the electrode assembly and the positive electrode current collector shown in FIG. **5** in an enlarged manner.

FIG. **13** is a perspective view showing another example of a strip-shaped projection of the joint portion shown in FIG. **10**.

FIG. **14** is a perspective view showing still another example of the strip-shaped projection of the joint portion shown in FIG. **10**.

FIG. **15** is a view showing a modification 1 of the energy storage device according to the embodiment, and is a perspective view showing a modification of the joint portion shown in FIG. **10**.

FIG. **16** is a cross-sectional view of the joint portion shown in FIG. **15** when a cross section of the joint portion taken along a radial direction of the swaged joint portion of the joint portion is viewed in a direction XVI.

FIG. **17** is a perspective view showing another example of a groove-shaped recessed portion of the joint portion shown in FIG. **15**.

FIG. **18** is a perspective view showing still another example of the groove-shaped recessed portion of the joint portion shown in FIG. **15**.

FIG. **19** is a view showing a modification 2 of the energy storage device according to the embodiment, and is a cross-sectional view showing another modification of the joint portion shown in FIG. **11**.

FIG. **20** is a view showing a modification 3 of the energy storage device according to the embodiment, and is a side view showing a modification of the positive electrode current collector shown in FIG. **12**.

DESCRIPTION OF EMBODIMENTS

An energy storage device according to an aspect of the present invention includes: electrode terminals; an electrode assembly formed by stacking a positive electrode plate and a negative electrode plate; and current collectors which connect the electrode terminals and the electrode assembly to each other, wherein at least one of the positive electrode plate and the negative electrode plate has a plurality of tab groups which are joined to the current collector, each tab group being formed by stacking one or more tabs projecting toward the electrode terminal, and at least one tab group among the tab groups and the current collector has a swaged joint portion, the swaged joint portion projecting from either one of the tab group or the current collector to the other of the tab group or the current collector.

The tab groups may be disposed at different positions when viewed in a stacking direction of the tabs.

The current collector may have a plurality of plate portions joined to the tab groups, and among the tab groups and the plate portions, the tab group and the plate portion which correspond to each other may have the swaged joint portion, the swaged joint portion projecting from either one of the tab group or the plate portion to the other of the tab group or the plate portion.

The current collector may have plate portions disposed between two tab groups among the tab groups, and the plate portions and the two tab groups may have the swaged joint portions, respectively, projecting from either one of the plate portion or the tab group to the other of the plate portion or the tab group.

Two swaged joint portions, which the current collector and two tab groups have, may project in directions opposite to each other.

According to the energy storage device, quality of the connecting portion between the electrically conductive members can be enhanced.

Hereinafter, an energy storage device according to an embodiment of the present invention is described with reference to drawings. The embodiment described hereinafter relates to a comprehensive and specific example of the present invention. However, numerical values, shapes, materials, constitutional elements, arrangement positions and connections modes of the constitutional elements and the like described in the embodiment hereinafter are only examples and are not intended to be used for limiting the present invention. Among the constitutional elements in the embodiments described hereinafter, the constitutional elements which are not described in independent claims which describe uppermost concepts are described as arbitrary constitutional elements. The respective views in the attached drawings are schematic views and are not necessarily strictly described in an actual scale. In the respective drawings, the identical or the substantially identical constitutional elements are given the same symbols. Further, in the description of the embodiments made hereinafter, there may be a case where the expression which is affixed with "substantially" such as "substantially parallel" or "substantially orthogonal" is used. For example, "substantially parallel" means not only "completely parallel" but also "substantially parallel". That is, "substantially" includes a difference of several percentage, for example. The same goes for other expressions which are affixed with "substantially".

Embodiment

A configuration of an energy storage device **100** according to an embodiment is described. FIG. **1** is a perspective view schematically showing an external appearance of the energy storage device **100** according to the embodiment. As shown in FIG. **1**, the energy storage device **100** has a flat rectangular parallelepiped external shape. The energy storage device **100** is a chargeable and dischargeable secondary battery. For example, the energy storage device **100** is a non-aqueous electrolyte secondary battery such as a lithium ion secondary battery. However, the energy storage device **100** is not limited to the non-aqueous electrolyte secondary battery and may be a secondary battery other than the non-aqueous electrolyte secondary battery, may be a primary battery which can provide stored electricity even when a user does not charge, or may be a capacitor.

With reference to FIG. **1**, FIG. **2** and FIG. **3**, the energy storage device **100** includes: a flat rectangular parallelepiped container **10**; an electrode assembly **20** housed in the container **10**; and a positive electrode terminal **30** and a negative electrode terminal **40**. FIG. **2** is an exploded perspective view of the energy storage device **100** in FIG. **1**, and is a view showing a state where an assembly **101** formed of a lid body **12** of the container **10** and the electrode assembly **20** is separated from a container body **11** of the container **10**. FIG. **3** is an exploded perspective view showing the assembly **101** formed of the lid body **12** and the electrode assembly **20** shown in FIG. **2** in an exploded manner. In this

embodiment, the positive electrode terminal **30** and the negative electrode terminal **40** are one example of electrode terminals.

The container **10** includes: the container body **11** having a bottomed square cylindrical shape; and the lid body **12** having an elongated rectangular plate shape which can close an opening portion **11***a* of the container body **11**, the opening portion **11***a* having an elongated rectangular shape. The container body **11** has a flat rectangular parallelepiped external shape. The positive electrode terminal **30** and the negative electrode terminal **40** are disposed on an outer surface **12***a* of the lid body **12**. In the container **10**, an electrolyte such as an electrolytic solution (in this embodiment, non-aqueous electrolytic solution) is sealed together with the electrode assembly **20**. However, the illustration of the electrolyte is omitted. A kind of the electrolyte is not particularly limited and various kinds of electrolytes can be selected as the electrolyte to be sealed in the container **10** provided that the electrolyte does not deteriorate the performance of the energy storage device **100**.

The container body **11** and the lid body **12** are fixed to each other such that a joint portion therebetween is brought into an air-tightly sealed state by a joining method such as welding. With such a configuration, a sealed space is formed in the container **10**. The container body **11** and the lid body **12** may be respectively made of weldable metal such as stainless steel, aluminum or an aluminum alloy, for example, although not limited to such materials. In the energy storage device **100**, a constitutional element which houses the electrode assembly **20** therein may not have high rigidity and strength as the container **10** has. For example, the electrode assembly **20** may be housed in a film-like or a sheet-like exterior body having flexibility. The energy storage device may include such an exterior body as the container, and such an energy storage device is also referred to as a laminate-type energy storage device.

The positive electrode terminal **30** and the negative electrode terminal **40** which have conductivity penetrate the lid body **12**, project from an inner surface **12***b* of the lid body **12** on a side opposite to the outer surface **12***a* of the lid body **12**, and are connected to a positive electrode current collector **50** and a negative electrode current collector **60** on the above-mentioned opposite side and having conductivity. The positive electrode current collector **50** and the negative electrode current collector **60** are further connected to the electrode assembly **20**.

A plate-like upper insulating member **31** is disposed between the positive electrode terminal **30** and the lid body **12** so as to electrically insulate the positive electrode terminal **30** and the lid body **12** from each other, and a plate-like lower insulating member **32** is disposed between the lid body **12** and the positive electrode current collector **50** so as to electrically insulate the lid body **12** and the positive electrode current collector **50** from each other. A plate-like upper insulating member **41** is disposed between the negative electrode terminal **40** and the lid body **12** so as to insulate the negative electrode terminal **40** and the lid body **12** from each other, and a plate-like lower insulating member **42** is disposed between the lid body **12** and the negative electrode current collector **60** so as to insulate the lid body **12** and the negative electrode current collector **60** from each other. The insulating members **31**, **32**, **41** and **42** are made of a material having an electrically insulating property such as a resin, and are formed of a gasket made of polyphenylene sulfide (PPS), polyether ether ketone (PEEK), polypropylene (PP), tetrafluoroethylene-perfluoroalkyl vinyl ether copolymer (PFA) or the like, for example.

The electrode assembly **20** is provided in a suspended manner from the lid body **12** by way of the positive electrode current collector **50** and the negative electrode current collector **60**. The electrode assembly **20** is housed in the container body **11** together with the positive electrode current collector **50** and the negative electrode current collector **60**. There may be a case where the electrode assembly **20** is covered by an insulation film for electrically insulating the electrode assembly **20** and the container body **11** from each other. There may be also a case where a buffer member such as a spacer is provided between the electrode assembly **20** and the container body **11**.

The configuration of the electrode assembly **20** is described with reference to FIG. **3** and FIG. **4**. FIG. **4** is a perspective view of the electrode assembly **20** showing a portion of the electrode assembly **20** shown in FIG. **3** in a developed manner. The electrode assembly **20** is an energy storage element (also referred to as a power generation element) which can store electricity therein. The electrode assembly **20** includes: a sheet-like positive electrode plate **21** having an elongated rectangular strip-shaped planar shape; a sheet-like negative electrode plate **22** having an elongated rectangular strip-shaped planar shape; and two sheet-like separators **23** each having an elongated rectangular strip-shaped planar shape, wherein the positive electrode plate **21**, the negative electrode plate **22** and the separators **23** are stacked with each other in a layered manner.

The electrode assembly **20** is configured such that one separator **23**, the negative electrode plate **22**, the other separator **23**, and the positive electrode plate **21** are made to overlap with each other in a layered manner in this order, and are wound together in a multi-layered spiral shape in a winding direction B shown in FIG. **4** about a winding axis A. The winding axis A is an imaginary axis indicated by a chain line in FIG. **3** and FIG. **4**, and the electrode assembly **20** has a configuration substantially symmetrical with respect to the winding axis A. In this embodiment, the electrode assembly **20**, having a cross section perpendicular to the winding axis A of a flat elongated circular shape, has a flat elongated circular external shape although not limited to such a shape. However, a cross-sectional shape of the electrode assembly **20** may be a shape other than an elongated circular shape, that is, may be a circular shape, an elliptical shape, a rectangular shape, and other polygonal shape.

The positive electrode plate **21** includes: a positive electrode base material which is an elongated rectangular strip-shaped metal foil made of metal such as aluminum or an aluminum alloy; and positive active material layers which are formed on the substantially whole wide main surfaces on both sides of the positive electrode base material by a coating method or the like. The negative electrode plate **22** includes: a negative electrode base material which is an elongated rectangular strip-shaped metal foil made of metal such as copper or a copper alloy; and negative active material layers which are formed on the substantially whole wide main surfaces on both sides of the negative electrode base material by a coating method or the like. As the positive active material used for forming the positive active material layer or the negative active material used for forming the negative active material layer, a known material can be used provided that the positive active material or the negative active material can occlude and discharge lithium ions. In this embodiment, the positive active material layer and the negative active material layer are formed on the main surfaces on both sides of the positive electrode base material and the negative electrode base material. However, the

positive active material layer and the negative active material layer may be formed on the main surface on only one side of the positive electrode base material and the negative electrode base material. The separator **23** is formed using a microporous sheet made of a material having an electrically insulating property such as a resin.

Among two edges **21***a* and **21***b* extending along a longitudinal direction of the positive electrode plate **21**, on one edge **21***a*, a plurality of positive electrode current collecting tabs **21***c* each having a rectangular foil shape are formed in a projecting manner. The positive electrode current collecting tabs **21***c* extend integrally and continuously from the positive electrode base material and form portions of the positive electrode base material. The positive electrode current collecting tab **21***c* is made of the same material as the positive electrode base material, and a positive active material layer is not formed on the positive electrode current collecting tab **21***c*. In this embodiment, two positive electrode current collecting tabs **21***c* are disposed per one winding of the positive electrode plate **21** in the electrode assembly **20**. In the electrode assembly **20**, after being wound, the plurality of positive electrode current collecting tabs **21***c* are positioned collectively at two places thus forming positive electrode current collecting tab groups **21***d*, **21***e* at respective places. In each of the positive electrode current collecting tab groups **21***d*, **21***e*, the positive electrode current collecting tabs **21***c* are positioned in substantially one row in a stacking direction of the multi-layered structure formed by the positive electrode plate **21**, the negative electrode plate **22** and the separators **23** which are wound around each other.

In each of the positive electrode current collecting tab groups **21***d*, **21***e*, the plurality of positive electrode current collecting tabs **21***c* may be disposed such that peripheral edges of the positive electrode current collecting tabs **21***c* are aligned with each other in a direction perpendicular to the stacking direction, or may be disposed such that the peripheral edges of the positive electrode current collecting tabs **21***c* are displaced from each other in the direction perpendicular to the stacking direction. For example, in each of the positive electrode current collecting tab groups **21***d*, **21***e*, the plurality of positive electrode current collecting tabs **21***c* may be disposed such that at least the positive electrode current collecting tabs **21***c* partially overlap with each other in the stacking direction. Such an assembly formed of the positive electrode current collecting tabs **21***c* can form the positive electrode current collecting tab groups **21***d*, **21***e*.

Among two edges **22***a* and **22***b* extending along a longitudinal direction of the negative electrode plate **22**, on one edge **22***a*, a plurality of negative electrode current collecting tabs **22***c* each having a rectangular foil shape are formed in a projecting manner. The negative electrode current collecting tab **22***c* extends integrally and continuously from the negative electrode base material and forms a portion of the negative electrode base material. The negative electrode current collecting tab **22***c* is made of the same material as the negative electrode base material, and a negative active material layer is not formed on the negative electrode current collecting tab **22***c*. In this embodiment, two negative electrode current collecting tabs **22***c* are disposed per one winding of the negative electrode plate **22** in the electrode assembly **20**. In the electrode assembly **20**, after being wound, the plurality of negative electrode current collecting tabs **22***c* are positioned collectively at two places thus forming negative electrode current collecting tab groups **22***d*, **22***e* at respective places. In each of the negative electrode current collecting tab groups **22***d*, **22***e*, the negative electrode current collecting tabs **22***c* are positioned in substantially one row in the stacking direction of the positive electrode plate **21**, the negative electrode plate **22** and the separators **23** which are wound around each other.

In each of the negative electrode current collecting tab groups **22***d*, **22***e*, the plurality of negative electrode current collecting tabs **22***c* may be disposed such that peripheral edges of the negative electrode current collecting tabs **22***c* are aligned with each other in a direction perpendicular to the stacking direction, or may be disposed such that the peripheral edges of the negative electrode current collecting tabs **22***c* are displaced from each other in the direction. For example, in each of the negative electrode current collecting tab groups **22***d*, **22***e*, the plurality of negative electrode current collecting tabs **22***c* may be disposed such that the negative electrode current collecting tabs **22***c* at least partially overlap with each other in the stacking direction. Such an assembly formed of the negative electrode current collecting tabs **22***c* can form the negative electrode current collecting tab groups **22***d*, **22***e*. In this embodiment, the positive electrode current collecting tab groups **21***d*, **21***e* and the negative electrode current collecting tab groups **22***d*, **22***e* are one example of the tab groups.

The number of positive electrode current collecting tabs **21***c* disposed per one winding of the positive electrode plate **21** and the number of negative electrode current collecting tab **22***c* disposed per one winding of the negative electrode plate **22** are not limited to two. In this embodiment, the positive electrode current collecting tab **21***c* and the negative electrode current collecting tab **22***c* each has a rectangular planar shape. However, the positive electrode current collecting tab **21***c* and the negative electrode current collecting tab **22***c* may have any shape.

The positive electrode plate **21** and the negative electrode plate **22** are made to overlap with each other for winding in a state where longitudinal direction of the positive electrode plate **21** and the longitudinal direction of the negative electrode plate **22** are equal. In such a configuration, the positive electrode current collecting tabs **21***c* and the negative electrode current collecting tabs **22***c* are disposed on the same side with respect to overlapping portions of the positive electrode plate **21** and the negative electrode plate **22**. That is, the edge **21***a* of the positive electrode plate **21** and the edge **22***a* of the negative electrode plate **22** are positioned adjacently to each other, and an edge **21***b* of the positive electrode plate **21** and an edge **22***b* of the negative electrode plate **22** are positioned adjacently to each other.

Two separators **23** are disposed on the flat main surfaces on both sides of one negative electrode plate **22**. One separator **23** is disposed adjacently to the negative electrode plate **22** at the outer side of the negative electrode plate **22** at the time of winding, and the other separator **23** is disposed adjacently to the negative electrode plate **22** at the inner side of the negative electrode plate **22** at the time of winding. The whole negative electrode plate **22** except for the negative electrode current collecting tabs **22***c* is covered by two separators **23**. In such a configuration, the negative electrode current collecting tabs **22***c* pass through between two separators **23** and project from the separators **23**.

One positive electrode plate **21** is disposed on the separator **23** in an overlapping manner so as to be at the inner side of the separator **23** which is disposed adjacently to the negative electrode plate **22** at the inner side of the negative electrode plate **22** at the time of winding. In such a configuration, except for the positive electrode current collecting tabs **21***c*, the whole positive electrode plate **21** is covered by the negative electrode plate **22** and two separators **23**, and

faces the negative electrode plate **22**. The positive electrode current collecting tabs **21***c* project from two separators **23**.

In a state where one positive electrode plate **21**, one negative electrode plate **22** and two separators **23** which are stacked each other as described above are made to overlap with each other, these constitutional elements are wound around in a spiral shape in the winding direction B about the winding axis A thus forming the electrode assembly **20**. In the electrode assembly **20** after being wound, the edge **21***a* of the stacked positive electrode plate **21** and the edge **22***a* of the stacked negative electrode plate **22** are disposed in a coplanar shape thus forming an end portion **20***a* of the electrode assembly **20** in the direction of the winding axis A. The edge **21***b* of the stacked positive electrode plate **21** and the edge **22***b* of the stacked negative electrode plate **22** are disposed in a coplanar shape thus forming an end portion **20***b* of the electrode assembly **20** in the direction of the winding axis A. The end portions **20***a*, **20***b* extend substantially orthogonal to the winding axis A.

Further, in the electrode assembly **20** after being wound, the positive electrode plate **21**, the negative electrode plate **22**, and the separators **23** which are stacked with each other form a wall-like body extending along the winding direction B. To be more specific, the wall-like body is formed of two flat-wall-like portions **20***c*, **20***d* which are disposed to face each other with the winding axis A sandwiched therebetween and are flat and wide; and two bent-wall-like portions **20***e*, **20***f* which are disposed to face each other with the winding axis A sandwiched therebetween and are bent in a semicircular shape respectively. The flat-wall-like portions **20***c*, **20***d* extend substantially parallel to each other. The bent-wall-like portions **20***e*, **20***f* connect the flat-wall-like portions **20***c*, **20***d* to each other at both ends of the flat-wall-like portions **20***c*, **20***d* respectively.

With reference to FIG. **3**, FIG. **4**, FIG. **5** and FIG. **6**, in this embodiment, the positive electrode current collecting tab group **21***d* and the negative electrode current collecting tab group **22***d* are disposed on the end portion **20***a* of the flat-wall-like portion **20***c*, and the positive electrode current collecting tab group **21***e* and the negative electrode current collecting tab group **22***e* are disposed on the end portion **20***a* of the flat-wall-like portion **20***d*. FIG. **5** is a side view of the assembly **101** formed of the lid body **12** and the electrode assembly **20** shown in FIG. **2** as viewed from the side of the assembly **101**. FIG. **6** is a plan view of the electrode assembly **20** when the electrode assembly **20** is viewed from a plane taken along line VI-VI in FIG. **5**.

The positive electrode current collecting tab groups **21***d*, **21***e* are disposed between the winding axis A positioned at the center of the electrode assembly **20** and the bent-wall-like portion **20***e* in a direction along the flat-wall-like portions **20***c*, **20***d*. The positive electrode current collecting tab group **21***d* is disposed closer to the winding axis A in the direction along the flat-wall-like portions **20***c*, **20***d* than the positive electrode current collecting tab group **21***e* is. That is, the positive electrode current collecting tab group **21***d* is disposed away from the bent-wall-like portion **20***e*. Accordingly, the positive electrode current collecting tab groups **21***d*, **21***e* are disposed at positions displaced from each other in the direction along the flat-wall-like portions **20***c*, **20***d* which is also a direction along the winding direction of the electrode assembly **20**. In this embodiment, the positive electrode current collecting tab groups **21***d*, **21***e* are disposed such that, when the electrode assembly **20** is viewed in a direction from the flat-wall-like portion **20***d* toward the flat-wall-like portion **20***c*, that is, in a stacking direction of the positive electrode current collecting tabs **21***c* in the positive electrode current collecting tab groups **21***d*, **21***e*, the positive electrode current collecting tab groups **21***d*, **21***e* do not overlap with each other. The positive electrode current collecting tab groups **21***d*, **21***e* may be disposed in a partially overlapping manner. The positive electrode current collecting tab groups **21***d*, **21***e* may be positioned at the bent-wall-like portion **20***e*, and may be positioned between the winding axis A and the bent-wall-like portion **20***f*.

The negative electrode current collecting tab groups **22***d*, **22***e* are disposed between the winding axis A and the bent-wall-like portion **20***f* in a direction along the flat-wall-like portions **20***c*, **20***d*. The negative electrode current collecting tab group **22***d* is disposed closer to the winding axis A in the direction along the flat-wall-like portions **20***c*, **20***d* than the negative electrode current collecting tab group **22***e* is. That is, the negative electrode current collecting tab group **22***d* is disposed away from the bent-wall-like portion **20***f*. Accordingly, the negative electrode current collecting tab groups **22***d*, **22***e* are disposed at positions displaced from each other in the direction along the flat-wall-like portions **20***c*, **20***d*. In this embodiment, the negative electrode current collecting tab groups **22***d*, **22***e* are disposed such that, when the electrode assembly **20** is viewed in a direction from the flat-wall-like portion **20***d* toward the flat-wall-like portion **20***c*, that is, in a stacking direction of the negative electrode current collecting tabs **22***c* in the negative electrode current collecting tab groups **22***d*, **22***e*, the negative electrode current collecting tab groups **22***d*, **22***e* do not overlap with each other. The negative electrode current collecting tab groups **22***d*, **22***e* may be disposed in a partially overlapping manner. Further, the negative electrode current collecting tab groups **22***d*, **22***e* may be positioned at the bent-wall-like portion **20***f*, and may be positioned between the winding axis A and the bent-wall-like portion **20***f*. That is, the arrangement of the positive electrode current collecting tab groups **21***d*, **21***e* and the arrangement of the negative electrode current collecting tab groups **22***d*, **22***e* are not limited to the above-mentioned arrangement.

With reference to FIG. **2** and FIG. **3**, the positive electrode current collecting tab groups **21***d*, **21***e* are connected to the positive electrode current collector **50**, and the negative electrode current collecting tab groups **22***d*, **22***e* are connected to the negative electrode current collector **60**. The positive electrode current collector **50** may be made of substantially the same material as the positive electrode base material of the positive electrode plate **21** of the electrode assembly **20**. The negative electrode current collector **60** may be made of substantially the same material as the negative electrode base material of the negative electrode plate **22** of the electrode assembly **20**.

With reference to FIG. **3**, FIG. **5** and FIG. **7**, the positive electrode current collector **50** is an integral body which is integrally formed by a first connecting portion **51** having a rectangular plate shape, and a second connecting portion **52** and a third connecting portion **53** which respectively project from the first connecting portion **51** in the substantially same directions which are substantially orthogonal to the first connection portion **51**, for example. The second connecting portion **52** and the third connecting portion **53** extend continuously from the first connecting portion **51**. However, the second connecting portion **52** and the third connecting portion **53** may be separable from the first connecting portion **51**. The negative electrode current collector **60** is an integral body which is integrally formed by a first connecting portion **61** having a rectangular plate shape, and a second connecting portion **62** and a third connecting portion **63** which respectively project from the first connecting portion

61 in the substantially same directions which are substantially orthogonal to the first connecting portion **61**, for example. The second connecting portion **62** and the third connecting portion **63** extend continuously from the first connecting portion **61**. However, the second connecting portion **62** and the third connecting portion **63** may be separable from the first connecting portion **61**. FIG. **7** is a view showing joint portions **71**, **72** between the positive electrode current collecting tab groups **21***d*, **21***e* of the electrode assembly **20** and the positive electrode current collector **50** in FIG. **5** in an enlarged manner. FIG. **7** is also a view when the joint portions **71**, **72** are viewed in a direction from the negative electrode terminal **40** toward the positive electrode terminal **30**. In this embodiment, the connecting portions **52**, **53** and the connecting portions **62**, **63** are one example of a plate portions of the current collector.

In this embodiment, the second connecting portion **52** and the third connecting portion **53** of the positive electrode current collector **50** respectively have a rectangular plate-like shape, and respectively extend continuously from two edges of the first connecting portion **51** positioned opposite to each other. The second connecting portion **52** is connected to the positive electrode current collecting tab group **21***d*, and the third connecting portion **53** is connected to the positive electrode current collecting tab group **21***e*. The second connecting portion **52** and the third connecting portion **53** have positions thereof in a longitudinal direction and in a lateral direction of the rectangular plate-like first connecting portion **51** displaced from each other such that the second connecting portion **52** and the third connecting portion **53** agree with the positive electrode current collecting tab groups **21***d*, **21***e* in position respectively. The second connecting portion **52** has a size and a shape which enable the second connecting portion **52** to overlap with the whole positive electrode current collecting tab group **21***d* in a stacking direction of the positive electrode current collecting tab group **21***d*. The third connecting portion **53** also has a size and a shape which enable the third connecting portion **53** to overlap with the whole positive electrode current collecting tab group **21***e* in a stacking direction of the positive electrode current collecting tab group **21***e*.

The first connecting portion **51** of the positive electrode current collector **50** is connected to a shaft portion **30***b* having a circular cylindrical shape which is formed on a plate-like terminal body **30***a* of the positive electrode terminal **30**. The shaft portion **30***b* of the positive electrode terminal **30** extends in a penetrating manner through respective through holes formed in the upper insulating member **31**, the lid body **12** and the lower insulating member **32** and a through hole **51***a* formed in the first connecting portion **51**. In this embodiment, the shaft portion **30***b* of the positive electrode terminal **30** is connected to the first connecting portion **51** by swaging. That is, a diameter of a distal end of the shaft portion **30***b* which projects from the through hole **51***a* is plastically deformed by pressing. With such a configuration, the positive electrode terminal **30** and the positive electrode current collector **50** are fixed to the lid body **12** in a state where the upper insulating member **31**, the lid body **12** and the lower insulating member **32** are clamped by the terminal body **30***a* and the first connecting portion **51**. Accordingly, the positive electrode terminal **30** and the positive electrode current collector **50** are physically and electrically connected to each other.

The second connecting portion **62** of the negative electrode current collector **60** is connected to the negative electrode current collecting tab group **22***d* and the third connecting portion **63** of the negative electrode current collector **60** is connected to the negative electrode current collecting tab group **22***e*. In this embodiment, the second connecting portion **62** and the third connecting portion **63** respectively have a rectangular plate-like shape, and extend continuously from two edges of the first connecting portion **61** positioned opposite to each other. The second connecting portion **62** and the third connecting portion **63** have positions thereof in a longitudinal direction and in a lateral direction of the first connecting portion **61** displaced from each other such that the second connecting portion **62** and the third connecting portion **63** agree with the negative electrode current collecting tab groups **22***d*, **22***e* in position respectively. The second connecting portion **62** has a size and a shape which enable the second connecting portion **62** to overlap with the whole negative electrode current collecting tab group **22***d* in a stacking direction of the negative electrode current collecting tab group **22***d*. The third connecting portion **63** has a size and a shape which enable the third connecting portion **63** to overlap with the whole negative electrode current collecting tab group **22***e* in a stacking direction of the negative electrode current collecting tab group **22***e*.

The first connecting portion **61** of the negative electrode current collector **60** is connected to a shaft portion **40***b* having a circular cylindrical shape which is formed on a plate-like terminal body **40***a* of the negative electrode terminal **40**. The shaft portion **40***b* of the negative electrode terminal **40** extends in a penetrating manner through respective through holes formed in the upper insulating member **41**, the lid body **12**, the lower insulating member **42** and a through hole **61***a* formed in the first connecting portion **61**. In this embodiment, the shaft portion **40***b* of the negative electrode terminal **40** is connected to the first connecting portion **61** by swaging a distal end of the shaft portion **40***b* which projects from the through hole **61***a*. With such a configuration, the negative electrode terminal **40** and the negative electrode current collector **60** are fixed to the lid body **12** in a state where the upper insulating member **41**, the lid body **12** and the lower insulating member **42** are clamped by the terminal body **40***a* and the first connecting portion **61**. With such a configuration, the negative electrode terminal **40** and the negative electrode current collector **60** are physically and electrically connected to each other. In this embodiment, the connection between the shaft portion **30***b* of the positive electrode terminal **30** and the first connecting portion **51**, and the connection between the shaft portion **40***b* of the negative electrode terminal **40** and the first connecting portion **61** are not limited to the connection by swaging, and various connection methods such as welding, screwing are applicable.

The electrode assembly **20** which is connected to the positive electrode terminal **30** and the negative electrode terminal **40** via the positive electrode current collecting tab groups **21***d*, **21***e* and the negative electrode current collecting tab groups **22***d*, **22***e* is disposed on and is fixed to the lid body **12** with the winding axis A thereof directed in a direction substantially orthogonal to the lid body **12**. The electrode assembly **20** disposed in such an arrangement is also referred to as a horizontally-winding-type electrode assembly. Further, in the electrode assembly **20**, the positive electrode current collecting tab groups **21***d*, **21***e* and the negative electrode current collecting tab groups **22***d*, **22***e* are respectively positioned in a direction that the positive electrode current collecting tab groups **21***d*, **21***e* and the negative electrode current collecting tab groups **22***d*, **22***e* project toward the positive electrode terminal **30** and the negative

electrode terminal **40** from the end portion **20***a* of the electrode assembly **20** respectively.

A connection by swaging, that is, swaging joining (plastic working) is applied to the joint portion **71** which is a connecting portion between the second connecting portion **52** of the positive electrode current collector **50** and the positive electrode current collecting tab group **21***d* and to the joint portion **72** which is a connecting portion between the third connecting portion **53** and the positive electrode current collecting tab group **21***e*. In the same manner, swaging joining is applied to the joint portion **73** between the second connecting portion **62** of the negative electrode current collector **60** and the negative electrode current collecting tab group **22***d* and to the joint portion **74** between the third connecting portion **63** and the negative electrode current collecting tab group **22***e*.

The positive electrode current collector **50** includes cover members **54**, **55** which respectively form rectangular plate-like contact plates provided in addition to the connecting portions **51**, **52** and **53**. The cover members **54**, **55** are made of a material having conductivity, and may be made of substantially the same material as the positive electrode current collector **50**. The cover members **54**, **55** have thicknesses smaller than thicknesses of the second connecting portion **52** and the third connecting portion **53** respectively. The second connecting portion **52** and the cover member **54** are disposed so as to sandwich the positive electrode current collecting tab group **21***d* therebetween. The second connecting portion **52**, the positive electrode current collecting tab group **21***d*, and the cover member **54** are fixed to each other by being swaged together in a state where the second connecting portion **52**, the positive electrode current collecting tab group **21***d*, and the cover member **54** are made to overlap with each other. The second connecting portion **52**, the positive electrode current collecting tab group **21***d*, and the cover member **54** form the joint portion **71**. In this embodiment, the positive electrode current collecting tab group **21***d* and the cover member **54** are disposed on an outer side surface of the second connecting portion **52**. That is, the positive electrode current collecting tab group **21***d* and the cover member **54** are disposed on a surface of the second connecting portion **52** positioned on a side opposite to a direction from the second connecting portion **52** to the third connecting portion **53**.

Further, the third connecting portion **53** and the cover member **55** are disposed such that the third connecting portion **53** and the cover member **55** sandwich the positive electrode current collecting tab group **21***e* therebetween. The third connecting portion **53**, the positive electrode current collecting tab group **21***e*, and the cover member **55** are fixed to each other by being caulked together in a state where the third connecting portion **53**, the positive electrode current collecting tab group **21***e*, and the cover member **55** are made to overlap with each other. With such a configuration, the third connecting portion **53**, the positive electrode current collecting tab group **21***e*, and the cover member **55** form the joint portion **72**. In this embodiment, the positive electrode current collecting tab group **21***e* and the cover member **55** are disposed on an outer side surface of the third connecting portion **53**. That is, the positive electrode current collecting tab group **21***e* and the cover member **55** are disposed on a surface of the third connecting portion **53** positioned on a side opposite to a direction from the third connecting portion **53** to the second connecting portion **52**.

In the same manner, the negative electrode current collector **60** includes rectangular plate-like cover members **64**, **65** provided in addition to the connecting portions **61**, **62** and **63**. The cover members **64**, **65** are made of a material having conductivity, and may be made of substantially the same material as the negative electrode current collector **60**. The cover members **64**, **65** have thicknesses smaller than thicknesses of the second connecting portion **62** and the third connecting portion **63** respectively. The second connecting portion **62** and the cover member **64** are disposed so as to sandwich the negative electrode current collecting tab group **22***d* therebetween. The second connecting portion **62**, the negative electrode current collecting tab group **22***d*, and the cover member **64** are fixed to each other by being swaged together in a state where the second connecting portion **62**, the negative electrode current collecting tab group **22***d*, and the cover member **64** are made to overlap with each other. The second connecting portion **62**, the negative electrode current collecting tab group **22***d*, and the cover member **64** form the joint portion **73**. In this embodiment, the negative electrode current collecting tab group **22***d* and the cover member **64** are disposed on an outer side surface of the second connecting portion **62**. That is, the negative electrode current collecting tab group **22***d* and the cover member **64** are disposed on a surface of the second connecting portion **62** positioned on a side opposite to a direction from the second connecting portion **62** to the third connecting portion **63**.

Further, the third connecting portion **63** and the cover member **65** are disposed such that the third connecting portion **63** and the cover member **65** sandwich the negative electrode current collecting tab group **22***e* therebetween. The third connecting portion **63**, the negative electrode current collecting tab group **22***e*, and the cover member **65** are fixed to each other by being swaged together in a state where the third connecting portion **63**, the negative electrode current collecting tab group **22***e*, and the cover member **65** are made to overlap with each other. The third connecting portion **63**, the negative electrode current collecting tab group **22***e*, and the cover member **65** form the joint portion **74**. In this embodiment, the negative electrode current collecting tab group **22***e* and the cover member **65** are disposed on an outer side surface of the third connecting portion **63**. That is, the negative electrode current collecting tab group **22***e* and the cover member **65** are disposed on a surface of the third connecting portion **63** positioned on a side opposite to a direction from the third connecting portion **63** to the second connecting portion **62**.

In both of the positive electrode current collector **50** and the negative electrode current collector **60**, the arrangement configuration of the second connecting portion, the third connecting portion, the cover member and the current collecting tab group is not limited to the above-mentioned arrangement configuration. Any arrangement configuration may be adopted provided that the current collecting tab group is sandwiched by the second connecting portion, the third connecting portion and the cover member. For example, the cover member and the current collecting tab group may be disposed on the inner side of the second connecting portion and the third connecting portion in a sideward direction.

Configurations of the joint portions **71**, **72**, **73** and **74** are described hereinafter. Since all of the joint portions **71**, **72**, **73** and **74** have substantially the same configuration, only the configuration of the joint portion **71** is described. With reference to FIG. **8** and FIG. **9**, at the time of performing swaging joining, a die tool **81** and a punching tool **82** for connection by swaging are mounted on the second connecting portion **52**, the positive electrode current collecting tab group **21***d* and the cover member **54** which are made to

overlap with each other such that the positive electrode current collecting tab group **21***d* is sandwiched between the second connecting portion **52** of the positive electrode current collector **50** and the cover member **54**. FIG. **8** is a perspective view showing a state of the assembly **101** in FIG. **2** when the positive electrode current collecting tab group **21***d* of the electrode assembly **20** and the positive electrode current collector **50** are connected to each other. FIG. **9** is a cross-sectional side view taken along a cross section which passes the joint portion **71** between the positive electrode current collecting tab group **21***d* of the electrode assembly **20** and the positive electrode current collector **50** shown in FIG. **8**, and the die tool **81** and the punching tool **82** for connection as viewed in a direction IX.

The die tool **81** has a receiving surface **81***a* formed on an end portion thereof, and a recessed portion **81***b* which is recessed from the receiving surface **81***a* and has a circular cylindrical shape. The punching tool **82** has a pressing surface **82***a* formed on an end portion thereof, and a punch **82***b* which is a circular columnar projection projecting from the pressing surface **82***a*. At the time of performing swaging joining, the second connecting portion **52**, the positive electrode current collecting tab group **21***d*, and the cover member **54** are made to overlap with each other in this order. The die tool **81** is disposed on the cover member **54** with the receiving surface **81***a* thereof directed toward the cover member **54**, and the punching tool **82** is disposed on the second connecting portion **52** with the pressing surface **82***a* thereof directed toward the second connecting portion **52**. At this stage of operation, the receiving surface **81***a* and the recessed portion **81***b* of the die tool **81** and the pressing surface **82***a* and the punch **82***b* of the punching tool **82** are positioned so as to face each other with the cover member **54**, the positive electrode current collecting tab group **21***d* and the second connecting portion **52** interposed therebetween. Further, the die tool **81** is positioned below the punching tool **82**.

When the punching tool **82** is pressed downward toward the die tool **81**, the punch **82***b* presses the second connecting portion **52**, the positive electrode current collecting tab group **21***d* and the cover member **54** together thus plastically deforming these members such that these members project into the recesses portion **81***b* of the die tool **81**. Theses members may be further plastically deformed by pressing the cover member **54** in a direction that another punch having a circular columnar shape (not shown in the drawing) which is embedded in a bottom portion of the recessed portion **81***b* of the die tool **81** and is slidable in the axial direction projects from the bottom portion of the recessed portion **81***b*, that is, by pressing the cover member **54** upward.

As a result, the plastically deformed second connecting portion **52**, positive electrode current collecting tab group **21***d* and the cover member **54** form a bottomed circular cylindrical swaged joint portion **90** which projects from a flat surface **54***a* of the cover member **54** as shown in FIG. **10** and FIG. **11**. A shape of the swaged joint portion **90** is not limited to the above-mentioned shape. FIG. **10** is a perspective view when the joint portion **71** after caulking joining in FIG. **8** is viewed from a projecting side of the swaged joint portion **90** of the joint portion **71**. FIG. **11** is a cross-sectional view of the joint portion **71** shown in FIG. **10** as viewed in a direction XI in a cross section taken along a radial direction of the swaged joint portion **90** of the joint portion **71**. The swaged joint portion **90** shown in FIG. **10** and FIG. **11** is formed by receiving pressing of the punch embedded in the bottom portion of the recessed portion **81***b* of the die tool **81**.

In the swaged joint portion **90**, the second connecting portion **52** of the positive electrode current collector **50**, the positive electrode current collecting tab group **21***d*, and the cover member **54** are brought into close contact with each other and are integrally deformed thus forming a bottomed circular cylindrical shape in a state where the cover member **54** is positioned at an outermost side. In the swaged joint portion **90**, a circular cylindrical inner recessed portion **90***a* is formed on an inner side of the second connecting portion **52** which is positioned on an innermost side. Such a swaged joint portion **90** has a stereoscopic structure where the second connecting portion **52** and the positive electrode current collecting tab group **21***d* are plastically deformed so as to enter the inner side of the cover member **54** which is plastically deformed in a projecting manner and to follow an inner shape of the cover member **54**. In this stereoscopic structure, the second connecting portion **52**, the positive electrode current collecting tab group **21***d*, and the cover member **54** are deformed so as to follow the shape of the punch **82***b* of the punching tool **82** and shapes of the respective members. Further, on a cover member **54** side, both the second connecting portion **52** and the cover member **54** project in a direction extending from the second connecting portion **52** toward the cover member **54**, and on a second connecting portion **52** side, both the second connecting portion **52** and the cover member **54** are recessed in a direction extending from the second connecting portion **52** toward the cover member **54**.

In the swaged joint portion **90** described above, a joint between the second connecting portion **52**, the positive electrode current collecting tab group **21***d*, and the cover member **54** is formed. Further, by pressing the cover member **54** using another punch from the bottom portion of the recessed portion **81***b* of the die tool **81**, an outer recessed portion **90***b* having a flat frustoconical shape is formed on a bottom portion which is a projection end of the swaged joint portion **90**. In and around the outer recessed portion **90***b*, deformed shapes of the positive electrode current collecting tab group **21***d* and the cover member **54** become complicated and hence, a joining strength between the second connecting portion **52**, the positive electrode current collecting tab group **21***d*, and the cover member **54** is enhanced.

A thickness of the cover member **54** is smaller than a thickness of the second connecting portion **52**. Accordingly, the cover member **54** which is more deformable than the second connecting portion **52** is deformed more easily than the second connecting portion **52** which is less deformable than the cover member **54**. Accordingly, the second connecting portion **52**, the positive electrode current collecting tab group **21***d*, and the cover member **54** can form a bottomed cylindrical shape of the swaged joint portion **90** in a state where the second connecting portion **52**, the positive electrode current collecting tab group **21***d*, and the cover member **54** are brought into close contact with each other and are formed into an integral body. With such a configuration, a joining strength at the swaged joint portion **90** is enhanced.

A swaging method for forming the swaged joint portion **90** as described above may be referred to as clinching caulking. A method of performing clinching caulking applied to the swaged joint portion **90** is not limited to the above-mentioned method and, various methods are conceivable. Further, the swaged joint portion **90** may be formed such that the swaged joint portion **90** does not project in a

direction from the second connecting portion **52** toward the cover member **54** as described above but projects in a direction from the cover member **54** toward the second connecting portion **52**.

Further, on the outer surface **54***a* of the cover member **54**, a rigidity changing part **91** is formed around the swaged joint portion **90**. The outer surface **54***a* of the cover member **54** is a surface positioned on a projecting direction side of the swaged joint portion **90** out of two wide flat surfaces of the cover member **54** opposite to each other. The rigidity changing part **91** is an element which changes rigidity of the cover member **54** in or in the vicinity of the rigidity changing part **91**. The rigidity changing part **91** forms the joint portion **71** together with the swaged joint portion **90**.

In this embodiment, the rigidity changing part **91** is a strip-shaped projection projecting from the outer surface **54***a* of the cover member **54**. The rigidity changing part (hereinafter also referred to as a strip-shaped projection) **91** is an annular continuous strip-shaped projection which surrounds the swaged joint portion **90** on the flat outer surface **54***a* of the cover member **54**. The strip-shaped projection **91** is integrally formed with the cover member **54**. That is, the strip-shaped projection **91** is made of the same material as the cover member **54**, and extends continuously from the cover member **54**. The strip-shaped projection **91** is disposed at a position away from the swaged joint portion **90**. To be more specific, the strip-shaped projection **91** is disposed away from a base portion of the swaged joint portion **90** on the outer surface **54***a* radially outward. Alternatively, the strip-shaped projection **91** may be disposed at the base portion of the swaged joint portion **90**. That is, the strip-shaped projection **91** is disposed on the side of the swaged joint portion **90** on the outer surface **54***a* of the cover member **54**.

The strip-shaped projection **91** may be formed simultaneously at the time of manufacturing the cover member **54**, may be formed by applying working such as press working after manufacturing the cover member **54**, or may be formed at the time of swaging by using the die tool **81** and the punching tool **82**. When the strip-shaped projection **91** is formed at the time of swaging, unevenness for forming the strip-shaped projection **91** by deforming the cover member **54** may be formed on the receiving surface **81***a* of the die tool **81** which is brought into contact with the cover member **54**. Alternatively, the strip-shaped projection **91** may be formed after swaging by using the die tool **81** and the punching tool **82**.

In the cover member **54**, a portion where the strip-shaped projection **91** is formed has a larger cross section than a portion disposed adjacently to the strip-shaped projection **91** on an outer side and hence, the portion where the strip-shaped projection **91** is formed has a higher rigidity than the portion disposed adjacently to the strip-shaped projection **91** on an outer side. The portion on an outer side of the strip-shaped projection **91** means a portion on a side opposite to a portion disposed on the inner side of the strip-shaped projection **91** where the swaged joint portion **90** is formed with the strip-shaped projection **91** interposed between the portions in a direction along the outer surface **54***a* of the cover member **54**. Accordingly, when a bending load which intends to peel off the cover member **54** from the second connecting portion **52** is applied to the cover member **54** on an outer side of the strip-shaped projection **91**, the cover member **54** is bent at a position in the vicinity of an outer side of the strip-shaped projection **91** at first thus suppressing deformation of the cover member **54** on the inner side of the strip-shaped projection **91**. Particularly, the strip-shaped projection **91** extends continuously so as to surround the swaged joint portion **90** over the whole circumference and hence, even when a bending load described above is applied to the cover member **54** from any direction, the deformation of the cover member **54** at the inner side of the strip-shaped projection **91** can be suppressed.

On the other hand, when a bending load described above is applied to the cover member **54** in a state where the strip-shaped projection **91** is not formed, a possibility that the cover member **54** is deformed so as to increase a diameter of the base portion of the swaged joint portion **90** radially outward becomes high. When the cover member **54** is deformed in this manner, joining at the swaged joint portion **90** is loosened or the swaged joint portion **90** is broken. Accordingly, the strip-shaped projection **91** enhances durability of the swaged joint portion **90**. Also in the joint portions **72**, **73** and **74**, the swaged joint portion **90** and the strip-shaped projection **91** are formed in the same manner as the joint portion **71**.

In FIG. **7**, FIG. **8**, FIG. **9** and FIG. **12**, the joint portions **71**, **72** between the positive electrode current collector **50** and the positive electrode current collecting tab groups **21***d*, **21***e* of the electrode assembly **20** are shown. FIG. **12** is a side view showing the joint portions **71**, **72** between the positive electrode current collecting tab groups **21***d*, **21***e* of the electrode assembly **20** and the positive electrode current collector **50** shown in FIG. **5** in an enlarged manner. The swaged joint portion **90** of the joint portion **71** and the swaged joint portion **90** of the joint portion **72** project in directions opposite to each other with respect to the positive electrode current collector **50**. With such a configuration, as shown particularly in FIG. **8** and FIG. **9**, at the time of connecting the positive electrode current collector **50** and the positive electrode current collecting tab groups **21***d*, **21***e* of the electrode assembly **20** to each other, in a state where one joint portion to be joined is disposed below the other joint portion out of the joint portions **71** and **72**, the joint portion to be joined is set to the die tool **81**. Accordingly, setting and fixing of the joint portion to be joined to the die tool **81** can be easily performed from the beginning of the swaging to the completion of the swaging.

Further, the joint portions **71**, **72** are disposed at different positions in a direction from the third connecting portion **53** toward the second connecting portion **52** of the positive electrode current collector **50** which is a pressing direction of the punching tool **82** to the die tool **81**, that is, in a stacking direction of the positive electrode current collecting tab groups **21***d*, **21***e*. Accordingly, swaging by using the die tool **81** and the punching tool **82** can be individually performed at the respective joint portions **71**, **72**. Further, unlike the case where the positive electrode current collecting tabs **21***c* included in the positive electrode current collecting tab groups **21***d*, **21***e* are connected to the positive electrode current collector **50** at one joint portion, the positive electrode current collecting tabs **21***c* are connected to the positive electrode current collector **50** at two joint portions **71**, **72** and hence, the number of positive electrode current collecting tabs **21***c* which are connected to the positive electrode current collector **50** by swaging in each of the joint portions **71**, **72** is reduced. With such a configuration, it is possible to increase a joining strength at the swaged joint portion **90** without increasing the swaged joint portion **90** in size. Although the description has been made with respect to the joint portions **71**, **72** between the positive electrode current collector **50** and the positive electrode current collecting tab groups **21***d*, **21***e* heretofore, the joint portions **73**, **74** between the negative electrode current

collector **60** and the negative electrode current collecting tab groups **22***d*, **22***e* also have substantially the same configuration and can acquire substantially the same manner of operation and advantageous effects as the above-mentioned configuration, manner of operation and advantageous effects.

As described above, the energy storage device **100** according to this embodiment includes the positive electrode current collector **50** and the negative electrode current collector **60** which respectively have conductivity and are joined to each other, and the cover members **54**, **55**, **64** and **65**. The energy storage device **100** includes the swaged joint portions **90** which join the positive electrode current collector **50** and the cover members **54**, **55** to each other respectively and, at the same time, project in the direction from the positive electrode current collector **50** toward the cover members **54**, **55** respectively, and the joint portions **90** which join the negative electrode current collector **60** and the cover members **64**, **65** to each other respectively and, at the same time, project in the direction from the negative electrode current collector **60** toward the cover members **64**, **65**. The cover members **54**, **55**, **64** and **65** respectively include the strip-shaped projection **91** which forms the rigidity changing part on the side of the swaged joint portion **90**.

In the above-mentioned configuration, rigidities of the cover members **54**, **55**, **64** and **65** which includes the swaged joint portion **90** respectively change at the strip-shaped projection **91** disposed on the side of the swaged joint portion **90**. Accordingly, when the cover member **54**, **55**, **64** or **65** receives a bending load at a portion outside the strip-shaped projection **91** on a side opposite to the swaged joint portion **90**, the cover member **54**, **55**, **64** and **65** can be deformed at or in the vicinity of the strip-shaped projection **91** or at a portion in the vicinity of the strip-shaped projection **91** at first. Accordingly, the disengagement of the swaged joint portion brought about by the deformation of the swaged joint portion **90** can be suppressed.

In the energy storage device **100** according to the embodiment, the strip-shaped projection **91** projects from each surface of the cover member **54**, **55**, **64**, and **65** on the side of the swaged joint portion **90**. For example, the strip-shaped projection **91** projects from the outer surface **54***a* of the cover member **54**. In the above-mentioned configuration, rigidity of the cover member **54**, **55**, **64** and **65** is enhanced at a portion where the strip-shaped projection **91** is formed. Accordingly, when the cover member **54**, **55**, **64** or **65** receives a bending load at a portion outside the strip-shaped projection **91**, the cover member **54**, **55**, **64** or **65** may deform at a portion in the vicinity of an outer side of the strip-shaped projection **91** at first.

In the energy storage device **100** according to the embodiment, in the swaged joint portion **90**, both the positive electrode current collector **50** and the cover member **54** or **55** project in a direction from the positive electrode current collector **50** toward the cover member **54** or **55** on a side of the cover member **54** or **55** and, at the same time, are recessed in a direction from the positive electrode current collector **50** toward the cover member **54** or **55** on a side of the positive electrode current collector **50**. In the above-mentioned configuration, the positive electrode current collector **50** and the cover member **54** or **55** are integrally deformed thus forming the swaged joint portion **90**. Such a swaged joint portion **90** can join the positive electrode current collector **50** and the cover member **54** or **55** to each other with certainty. Also the negative electrode current collector **60** and the cover members **64** and **65** have substantially the same configuration, and can acquire substantially the same advantageous effects as the above-mentioned configuration and advantageous effects.

In the energy storage device **100** according to the embodiment, the positive electrode plate **21** is sandwiched between the positive electrode current collector **50** and the cover members **54**, **55**. To be more specific, the positive electrode current collecting tab groups **21***d*, **21***e* of the positive electrode plate **21** are sandwiched. In the above-mentioned configuration, in the swaged joint portion **90**, the plurality of positive electrode current collecting tabs **21***c* of the positive electrode current collecting tab groups **21***d*, **21***e* are deformed integrally with the positive electrode current collector **50** and the cover members **54**, **55**. Accordingly, the positive electrode current collecting tab groups **21***d*, **21***e* are firmly connected with the positive electrode current collector **50** due to joining by swaging. Also the negative electrode current collector **60**, the negative electrode current collecting tab group **22***d*, **22***e*, and the cover members **64** and **65** have substantially the same configuration, and can acquire substantially the same advantageous effects as the above-mentioned configuration and advantageous effects.

In the energy storage device **100** according to the embodiment, the cover members **54**, **55** on a side where the swaged joint portion **90** projects respectively have a thickness smaller than a thickness of the positive electrode current collector **50**. To be more specific, the cover members **54**, **55** respectively have a thickness smaller than a thickness of the second connecting portion **52** and a thickness of the third connecting portion **53** of the positive electrode current collector **50**. In the above-mentioned configuration, in the swaged joint portion **90**, the cover members **54**, **55** are deformed more largely than the second connecting portion **52** and the third connecting portion **53** of the positive electrode current collector **50** so that the cover members **54**, **55** are deformed more easily than the second connecting portion **52** and the third connecting portion **53** of the positive electrode current collector **50**. Accordingly, the cover member **54** or **55** and the second connecting portion **52** or the third connecting portion **53** are integrally deformable so as to follow the shape of the punch **82***b* of the punching tool **82** used in joining by swaging and the shapes of these members. Accordingly, strong and reliable swaged joint portion **90** can be formed. The negative electrode current collector **60** and the cover members **64** and **65** also have substantially the same configuration, and can acquire substantially the same advantageous effects as the above-mentioned configuration and advantageous effects.

Further, the energy storage device **100** according to this embodiment includes: the positive electrode terminal **30** and the negative electrode terminal **40**; the electrode assembly **20** formed by stacking the positive electrode plate **21** and the negative electrode plate **22** to each other; and the positive electrode current collector **50** and the negative electrode current collector **60** which connect the positive electrode terminal **30** and the negative electrode terminal **40** to the electrode assembly **20** respectively. In the energy storage device **100**, the positive electrode plate **21** includes the positive electrode current collecting tab groups **21***d*, **21***e* which are respectively formed by stacking at least one or more positive electrode current collecting tabs **21***c* projecting toward the positive electrode terminal **30**, and the positive electrode current collecting tab groups **21***d*, **21***e* are respectively connected to the positive electrode current collector **50**. The negative electrode plate **22** includes the negative electrode current collecting tab groups **22***d*, **22***e* which are respectively formed by stacking at least one or more negative electrode current collecting tabs **22***c* project-

ing toward the negative electrode terminal **40**, and the negative electrode current collecting tab groups **22***d*, **22***e* are respectively connected to the negative electrode current collector **60**. Further, a set of the positive electrode current collecting tab group **21***d* and the positive electrode current collector **50**, and a set of the positive electrode current collecting tab group **21***e* and the positive electrode current collector **50** respectively have the swaged joint portion **90** which projects from either one of the positive electrode current collecting tab group **21***d*, **21***e* or the positive electrode current collector **50** to the other of the positive electrode current collecting tab group **21***d*, **21***e* or the positive electrode current collector **50**. In the same manner, a set of the negative electrode current collecting tab group **22***d* and the negative electrode current collector **60** and a set of the negative electrode current collecting tab group **22***e* and the negative electrode current collector **60** respectively have the swaged joint portion **90** which projects from either one of the negative electrode current collecting tab group **22***d*, **22***e* or the negative electrode current collector **60** to the other of the negative electrode current collecting tab group **22***d*, **22***e* or the negative electrode current collector **60**.

In the above-mentioned configuration, the positive electrode current collecting tabs **21***c* are stacked to each other in a divided manner into a plurality of, for example, two positive electrode current collecting tab groups **21***d*, **21***e*, and the negative electrode current collecting tabs **22***c* are stacked to each other in a divided manner into a plurality of, for example, two negative electrode current collecting tab groups **22***d*, **22***e*. With such a configuration, a thickness in a stacking direction of the current collecting tabs per one current collecting tab group is reduced and hence, joining by swaging between the positive electrode current collecting tab group **21***d* and the positive electrode current collector **50**, joining by swaging between the positive electrode current collecting tab group **21***e* and the positive electrode current collector **50**, joining by swaging between the negative electrode current collecting tab group **22***d* and the negative electrode current collector **60**, and joining by swaging between the negative electrode current collecting tab group **22***e* and the negative electrode current collector **60** can be facilitated. Further, a diameter of the punch **82***b* of the punching tool **82** used for joining by caulking can be made small and hence, a projecting diameter of the swaged joint portion **90** can be made small and, at the same time, projecting lengths of the positive electrode current collecting tab groups **21***d*, **21***e* and projecting lengths of the negative electrode current collecting tab groups **22***d*, **22***e* from the end portion **20***a* of the electrode assembly **20** can be made small.

Still further, the joining is performed by swaging and hence, at the time of joining, the generation of metal particles and metal powders from the positive electrode base material of the positive electrode current collecting tab groups **21***d*, **21***e* and from the negative electrode base material of the negative electrode current collecting tab groups **22***d*, **22***e* can be suppressed to a low level. Accordingly, the occurrence of short-circuiting between the positive electrode plate **21** and the negative electrode plate **22** attributed to generated metal particles and metal powders can be suppressed. For example, there is a possibility that, when metal particles and metal powders generated from the negative electrode base material reach the positive electrode plate **21**, the metal particles and metal powders are ionized and flow in the positive electrode plate **21** and, further, reach the negative electrode plate **22** through the separator **23** and are deposited on the negative electrode plate **22**. When the deposit on the negative electrode plate **22** grows and is accumulated, there is a possibility that the accumulated deposit causes internal short-circuiting between the positive electrode plate **21** and the negative electrode plate **22**. The horizontally-winding-type electrode assembly **20** is configured such that when the energy storage device **100** is disposed with the lid body **12** facing upward, the positive electrode current collecting tab groups **21***d*, **21***e* and the negative electrode current collecting tab groups **22***d*, **22***e* are positioned on an upper portion of the electrode assembly **20**. The suppression of the generation of metal particles and metal powders is effective for the suppression of intrusion of metal particles and metal powders into the electrode assembly **20** from the respective current collecting tab groups.

In the energy storage device **100** according to the embodiment, the positive electrode current collecting tab groups **21***d*, **21***e* are disposed at positions which differ from each other in the stacking direction of the positive electrode current collecting tabs **21***c*. That is, when the positive electrode current collecting tab groups **21***d*, **21***e* are viewed in the stacking direction of the positive electrode current collecting tabs **21***c*, the positive electrode current collecting tab groups **21***d*, **21***e* are disposed at different positions. In the same manner, the negative electrode current collecting tab groups **22***d*, **22***e* are disposed at positions which differ from each other in the stacking direction of the negative electrode current collecting tabs **22***c*. That is, when the negative electrode current collecting tab groups **22***d*, **22***e* are viewed in the stacking direction of the negative electrode current collecting tabs **22***c*, the negative electrode current collecting tab groups **22***d*, **22***e* are disposed at different positions.

In the above-mentioned configuration, the plurality of positive electrode current collecting tabs **21***c* are divided into a plurality of bundles at positions different from each other in the stacking direction thus forming the positive electrode current collecting tab groups **21***d*, **21***e*. The plurality of negative electrode current collecting tabs **22***c* are divided into a plurality of bundles at positions different from each other in the stacking direction thus forming the negative electrode current collecting tab groups **22***d*, **22***e*. Accordingly, at the time of joining the positive electrode current collecting tab groups **21***d*, **21***e* by swaging respectively, the die tool **81** and the punching tool **82** can perform joining of the respective positive electrode current collecting tab groups **21***d*, **21***e* while displacing positions of the respective positive electrode current collecting tab groups **21***d*, **21***e* in the winding direction of the electrode assembly **20**. In the same manner, at the time of joining the negative electrode current collecting tab groups **22***d*, **22***e* by swaging respectively, the die tool **81** and the punching tool **82** can perform joining of the respective negative electrode current collecting tab groups **22***d*, **22***e* while displacing positions of the respective negative electrode current collecting tab groups **22***d*, **22***e* in the winding direction of the electrode assembly **20**. Accordingly, projection lengths of the plurality of positive electrode current collecting tabs **21***c* can be made equal to each other, and projection lengths of the plurality of negative electrode current collecting tabs **22***c* can be made equal to each other. Therefore, the positive electrode current collecting tab groups **21***d*, **21***e* where projection lengths of the positive electrode current collecting tabs **21***c* are suppressed can be formed, and the negative electrode current collecting tab groups **22***d*, **22***e* where projection lengths of the negative electrode current collecting tabs **22***c* are suppressed can be formed.

In the energy storage device **100** according to the embodiment, the positive electrode current collector **50** includes the plurality of connecting portions **52**, **53** connected to the

positive electrode current collecting tab groups **21***d*, **21***e* respectively, and the negative electrode current collector **60** includes the plurality of connecting portions **62**, **63** connected to the negative electrode current collecting tab groups **22***d*, **22***e* respectively. Further, among the positive electrode current collecting tab groups **21***d*, **21***e* and the connecting portions **52**, **53**, the positive electrode current collecting tab group and the connecting portion which correspond to each other have the swaged joint portion **90** which projects from either one of the positive electrode current collecting tab group or the connecting portion to the other of the positive electrode current collecting tab group or the connecting portion. In the same manner, among the negative electrode current collecting tab groups **22***d*, **22***e* and the connecting portions **62**, **63**, the negative electrode current collecting tab group and the connecting portion which correspond to each other have the swaged joint portion **90** which projects from one of the negative electrode current collecting tab group or the connecting portion to the other of the negative electrode current collecting tab group or the connecting portion. In the above-mentioned configuration, the current collecting tab groups **21***d*, **21***e*, **22***d* and **22***e* are respectively joined to the corresponding connecting portions **52**, **53**, **62** and **63** by swaging and hence, joining by swaging can be easily performed.

In the energy storage device **100** according to the embodiment, two swaged joint portions **90** which the positive electrode current collector **50** and two positive electrode current collecting tab groups **21***d*, **21***e* have in common project in directions opposite to each other. In the same manner, two swaged joint portions **90** which the negative electrode current collector **60** and two negative electrode current collecting tab groups **22***d*, **22***e* have in common project in directions opposite to each other. In the above-mentioned configuration, at the time of connecting two positive electrode current collecting tab groups **21***d*, **21***e* to the connecting portions **52**, **53** of the positive electrode current collector **50** so as to sandwich the positive electrode current collector **50** therebetween, in the respective joint portions **71**, **72**, two swaged joint portions **90** are formed by swaging from different sides. Accordingly, joining of two positive electrode current collecting tab groups **21***d*, **21***e* and the positive electrode current collector **50** can be easily performed. Also two negative electrode current collecting tab groups **22***d*, **22***e* and the negative electrode current collector **60** can acquire substantially the same advantageous effects as the above-mentioned advantageous effects.

In the energy storage device **100** according to the embodiment, the strip-shaped projection **91** which forms the rigidity changing part is formed on the outer surfaces of the cover members **54**, **55**, **64** and **65**. However, the present invention is not limited to such a configuration. The strip-shaped projection **91** may be formed on inner surfaces of the cover members **54**, **55**, **64** and **65** on a side opposite to the outer surfaces of the cover members **54**, **55**, **64** and **65**, or the strip-shaped projection **91** may be formed on the outer surfaces and the inner surfaces of the cover members **54**, **55**, **64** and **65** respectively. Further, the strip-shaped projection **91** may be formed on the second connecting portion **52** and the third connecting portion **53** of the positive electrode current collector **50** and on the second connecting portion **62** and the third connecting portion **63** of the negative electrode current collector **60** without being formed on the cover members **54**, **55**, **64** and **65**, or in addition to the cover members **54**, **55**, **64** and **65**. In this case, the strip-shaped projection **91** may be formed on one surface of the second connecting portion and one surface of the third connecting portion. Alternatively, the strip-shaped projection **91** may be formed on two surfaces of the second connecting portion and two surfaces of the third connecting portion at positions opposite to each other. Further, when the strip-shaped projection **91** is formed on the cover members, the second connecting portion and the third connecting portion, the positions of the strip-shaped projections **91** may be aligned with each other or may differ from each other in the stacking direction of the cover member and the second connecting portion and in the stacking direction of the cover member and the third connecting portion.

In the energy storage device **100** according to the embodiment, the strip-shaped projection **91** which is formed as the rigidity changing part on the outer surfaces of the cover members **54**, **55**, **64** and **65** respectively has a continuous annular planar shape. However, the strip-shaped projection **91** is not limited to such a configuration, and the strip-shaped projection **91** may have any shape. The planar shape is a shape of the strip-shaped projection **91** when the swaged joint portion **90** is viewed from a direction perpendicular to the outer surface **54***a* of the cover member **54**, for example. The rigidity changing part formed of a projection may be formed of a plurality of projections which are arranged in a divided annular shape. In this case, each of the plurality of projections may be formed of a strip-shaped projection and/or a dot-like projection. The planar shape of the rigidity changing part formed of a projection may be any shape such as a linear line segment, a curved line segment, an elliptical shape, an elongated circular shape, a polygonal shape, or a combination of these shapes.

In the energy storage device **100** according to the embodiment, it is sufficient for the rigidity changing part formed of a projection that the rigidity changing part be merely disposed between a portion of the cover member **54**, **55**, **64** or **65** to which a bending load is expected to be applied and the swaged joint portion **90**. With such a configuration, the rigidity changing part can suppress the transmission of a bending load to the cover member **54**, **55**, **64** or **65** of the swaged joint portion **90**.

For example, as show in FIG. **13** which shows another example of the strip-shaped projection **91** of the joint portion **71** shown in FIG. **10**, the rigidity changing part formed of a projection may be formed of a plurality of linear strip-shaped projections **91***a* extending in a radial direction toward radially outer sides from the circular cylindrical swaged joint portion **90**. In FIG. **13**, four strip-shaped projections **91***a* are formed. The strip-shaped projection **91***a* enhances bending rigidity of a portion of the cover member **54** where the strip-shaped projection **91***a* is formed in a longitudinal direction of the strip-shaped projection **91***a*.

Alternatively, as shown in FIG. **14** which shows still another example of the strip-shaped projection **91** of the joint portion **71** shown in FIG. **10**, the rigidity changing parts respectively formed of a projection may be linear strip-shaped projections **91***b* which are disposed adjacently to the swaged joint portion **90** and extend so as not to intersect with the swaged joint portion **90**. In FIG. **14**, two strip-shaped projections **91***b* are formed on both sides of the swaged joint portion **90** in such a manner that the strip-shaped projections **91***b* are disposed substantially parallel to each other along the swaged joint portion **90**. Further, each strip-shaped projection **91***b* has a length larger than a diameter of a base portion of the swaged joint portion **90**. When the swaged joint portion **90** is projected in a direction perpendicular to the longitudinal direction of the strip-shaped projection **91***b*, both ends of each strip-shaped projection **91***b* project from a projection image of the swaged joint portion **90**. When a

cover member **54** having such a configuration receives a bending load at a portion on a side opposite to the swaged joint portion **90** with respect to the strip-shaped projection **91***b*, that is, a portion outside the strip-shaped projection **91***b*, for example, the cover member **54** is bent at a portion in the vicinity of the strip-shaped projection **91***b* on an outer side of the strip-shaped projection **91***b* at first. With such a configuration, the occurrence of deformation of the cover member **54** at the swaged joint portion **90** can be suppressed. With the use of the strip-shaped projection **91***b* having a linear shape, the cover member **54** is easily bendable compared to the strip-shaped projection **91** having an annular shape. Further, with the use of the strip-shaped projections **91***b* which extend in a largely projecting manner from both sides of the swaged joint portion **90**, an influence which the deformation of the cover member **54** exerts on the swaged joint portion **90** can be suppressed to a low level.

[Modification 1]

As a modification 1 of the energy storage device **100** according to the embodiment, the following configuration can be exemplified. To be more specific, as shown in FIG. **15** and FIG. **16**, in an energy storage device according to the modification 1, on a joint portion of a cover member, a positive electrode current collecting tab group or a negative electrode current collecting tab group, and a positive electrode current collector or a negative electrode current collector, as a rigidity changing part, an annular strip-shaped recessed portion is formed around a swaged joint portion **90** in place of the strip-shaped projection. FIG. **15** is a view showing the modification 1 of the energy storage device **100** according to the embodiment, and is a perspective view showing a modification of the joint portion **71** shown in FIG. **10**. FIG. **16** is a cross-sectional view of the joint portion **71** shown in FIG. **15** when a cross section of the joint portion **71** taken along a radial direction of the swaged joint portion **90** of the joint portion **71** is viewed in a direction XVI. The joint portion of the positive electrode current collector and the joint portion of the negative electrode current collector have substantially the same configuration and hence, hereinafter, only the configuration of the joint portion **71** of the second connecting portion **52** of the positive electrode current collector **50**, the positive electrode current collecting tab group **21***d*, and the cover member **54** is described. Further, in the description of the modification made hereinafter, constitutional elements indicated by the same symbols as the reference symbols in the previously described drawings are identical or substantially identical to the corresponding constitutional elements in the previously descried drawings and hence, the detailed description of such constitutional elements is omitted.

With reference to FIG. **15** and FIG. **16**, in the joint portion **71**, on an outer surface **54***a* of the cover member **54**, a groove-shaped recessed portion **92** which forms an annular strip-shaped recessed portion and is recessed from the outer surface **54***a* is formed. The groove-shaped recessed portion **92** is a continuous annular groove which surrounds the swaged joint portion **90** on the flat outer surface **54***a* of the cover member **54**. The groove-shaped recessed portion **92** is made of a material for forming the cover member **54**. That is, the groove-shaped recessed portion **92** is a part of the cover member **54**. The groove-shaped recessed portion **92** is disposed on the side of the swaged joint portion **90** on the outer surface **54***a* of the cover member **54**. In this modification, although the groove-shaped recessed portion **92** is disposed at a position away from the swaged joint portion **90**, the groove-shaped recessed portion **92** may be disposed on a base portion of the swaged joint portion **90**.

The groove-shaped recessed portion **92** may be formed simultaneously at the time of manufacturing the cover member **54**, may be formed by applying working such as press working after manufacturing the cover member **54**, or may be formed at the time of swaging by using the die tool **81** and the punching tool **82**. When the groove-shaped recessed portion **92** is formed at the time of swaging, a projection for forming the groove-shaped recessed portion **92** by deforming the cover member **54** may be formed on the receiving surface **81***a* of the die tool **81** which is brought into contact with the cover member **54**. Alternatively, the groove-shaped recessed portion **92** may be formed after swaging by using the die tool **81** and the punching tool **82**.

In the cover member **54**, a portion where the groove-shaped recessed portion **92** is formed has the smaller cross section than a portion disposed adjacently to the groove-shaped recessed portion **92** on an outer side and hence, the portion where the groove-shaped recessed portion **92** is formed has a lower rigidity than the portion disposed adjacently to the groove-shaped recessed portion **92** on an outer side. Accordingly, when a bending load which intends to peel off the cover member **54** from the second connecting portion **52** is applied to the cover member **54** on an outer side of the groove-shaped recessed portion **92**, the cover member **54** is bent at a position of the groove-shaped recessed portion **92** at first thus suppressing occurrence of deformation of the cover member **54** at the inner side of the groove-shaped recessed portion **92**. Particularly, the groove-shaped recessed portion **92** extends continuously so as to surround the swaged joint portion **90** over the whole circumference of the swaged joint portion **90** and hence, even when a bending load described above is applied to the cover member **54** from any direction, the deformation of the cover member **54** at the inner side of the groove-shaped recessed portion **92** can be suppressed. Further, also on joint portions **72**, **73** and **74**, in the same manner as the joint portion **71**, the swaged joint portion **90** and the groove-shaped recessed portion **92** are formed.

Further, other configurations of the energy storage device according to the modification 1 are substantially equal to the corresponding configurations of the energy storage device **100** according to the embodiment and hence, the description of other configurations is omitted. The energy storage device according to the modification 1 can acquire substantially the same advantageous effects as the energy storage device **100** according to the embodiment. In the energy storage device according to the modification 1, the cover member **54** includes the groove-shaped recessed portion **92** as a strip-shaped recessed portion which is recessed from the outer surface **54***a* of the cover member **54** on a side of the swaged joint portion **90** as the rigidity changing part. With the above-mentioned configuration, at a portion of the cover member **54** where the groove-shaped recessed portion **92** is formed, rigidity of the cover member **54** is lowered. Accordingly, when the cover member **54** receives a bending load at a portion on a side opposite to the swaged joint portion **90** with respect to the groove-shaped recessed portion **92**, that is, outside the groove-shaped recessed portion **92**, the cover member **54** may be deformed at the groove-shaped recessed portion **92** at first. Therefore, it is possible to suppress the occurrence of deformation on the swaged joint portion **90** due to an action of the bending load. The groove-shaped recessed portion **92** may be formed also on the cover members **55**, **64** and **65** in the same manner as the cover member **54**, and these groove-shaped recessed portions **92**

also can acquire substantially the same advantageous effects as the groove-shaped recessed portion **92** formed on the cover member **54**.

In the energy storage device according to the modification 1, the groove-shaped recessed portion **92** is formed on the outer surfaces of the cover members **54**, **55**, **64** and **65** respectively. However, the present invention is not limited to such a configuration. The groove-shaped recessed portion **92** may be disposed at substantially the same place as the place where the above-mentioned strip-shaped projection **91** is disposed.

In the energy storage device according to the modification 1, the groove-shaped recessed portion **92** which forms the rigidity changing part has a continuous annular planar shape. However, the groove-shaped recessed portion **92** is not limited to such a shape, and may have any shape. The rigidity changing part formed of a recessed portion may be formed of a plurality of recessed portions which are arranged in a divided annular shape. In this case, each of the plurality of recessed portions may be formed of a groove-shaped recessed portion and/or a dot-like recessed portion. Further, a planar shape of the rigidity changing part formed of a recessed portion may be any shape such as a linear line segment, a curved line segment, an elliptical shape, an elongated circular shape, a polygonal shape, or a combination of these shapes. For example, as shown in FIG. **17** which shows another example of the groove-shaped recessed portion **92** of the joint portion **71** shown in FIG. **15**, the groove-shaped recessed portion may be a groove-shaped recessed portion **92***a* having a rectangular planar shape which surrounds the swaged joint portion **90** on the outer surface **54***a* of the cover member **54**. Such a groove-shaped recessed portion **92***a* can also acquire substantially the same advantageous effects as the advantageous effects of the annular groove-shaped recessed portion **92**.

In the energy storage device according to the modification 1, it is sufficient for the rigidity changing part formed of a recessed portion that the rigidity changing part be merely disposed between a portion of the cover member **54**, **55**, **64** and **65** to which a bending load is expected to be applied and the swaged joint portion **90**. With such a configuration, the rigidity changing part can suppress transmission of the bending load to the cover member **54**, **55**, **64** or **65** of the swaged joint portion **90**. For example, as show in FIG. **18** which shows still another example of the groove-shaped recessed portion **92** of the joint portion **71** shown in FIG. **15**, the rigidity changing parts respectively formed of a groove-shaped recessed portion may be formed of two linear groove-shaped recessed portions **92***b*. The groove-shaped recessed portions **92***b* can be disposed in the same manner as the strip-shaped projections **91***b* shown in FIG. **14**. When a cover member **54** receives a bending load at a portion outside the groove-shaped recessed portion **92***b*, the cover member **54** is bent at the groove-shaped recessed portion **92***b* at first. With such a configuration, occurrence of deformation of the cover member **54** at the swaged joint portion **90** can be suppressed. With the use of the groove-shaped recessed portions **92***b* having a linear shape, the cover member **54** is easily bendable compared to the case where the groove-shaped recessed portion **92** having an annular shape is used. Further, with the use of the groove-shaped recessed portions **92***b* which extend in a largely projecting manner from both sides of the swaged joint portion **90**, an influence which the deformation of the cover member **54** exerts on the swaged joint portion **90** can be suppressed to a low level.

[Modification 2]

As a modification 2 of the energy storage device **100** according to the embodiment, following configuration can be exemplified. To be more specific, as shown in FIG. **19**, in an energy storage device according to the modification 2, on a joint portion of a cover member, a positive electrode current collecting tab group or a negative electrode current collecting tab group, and a positive electrode current collector or a negative electrode current collector, as a rigidity changing part, an annular strip-shaped projection and an annular strip-shaped recessed portion are formed at a position where the annular strip-shaped projection and the annular strip-shaped recessed portion face each other around the swaged joint portion **90**. FIG. **19** is a view showing the modification 2 of the energy storage device **100** according to the embodiment, and is a cross-sectional view showing another modification of the joint portion **71** shown in FIG. **11**.

With reference to FIG. **19**, in the joint portion **71**, on an outer surface **54***a* of a cover member **54**, a strip-shaped projection **93***a* which projects from the outer surface **54***a* is formed, and on an inner surface **54***b* of the cover member **54** on a side opposite to the outer surface **54***a*, a groove-shaped recessed portion **93***b* which is recessed from the inner surface **54***b* is formed. The strip-shaped projection **93***a* and the groove-shaped recessed portion **93***b* respectively have a continuous annular shape so as to surround a base portion of the swaged joint portion **90**. The strip-shaped projection **93***a* and the groove-shaped recessed portion **93***b* are disposed at the position where the strip-shaped projection **93***a* and the groove-shaped recessed portion **93***b* face each other with the cover member **54** sandwiched therebetween. That is, the groove-shaped recessed portion **93***b* is positioned on a back side of the strip-shaped projection **93***a*. The groove-shaped recessed portion **93***b* has a planar shape which follows a planar shape of the strip-shaped projection **93***a*, and has a recessed cross-sectional shape which follows a projecting cross-sectional shape of the strip-shaped projection **93***a*.

The strip-shaped projection **93***a* and the groove-shaped recessed portion **93***b* are made of a material for forming the cover member **54**. The strip-shaped projection **93***a* and the groove-shaped recessed portion **93***b* can be formed by partially bending the cover member **54** so as to have a U shape or an S shape in cross section. Accordingly, the strip-shaped projection **93***a* and the groove-shaped recessed portion **93***b* form an annular bent portion **93** of the cover member **54**. In this embodiment, the strip-shaped projection **93***a* and the groove-shaped recessed portion **93***b* are disposed at a position away from the swaged joint portion **90**. However, the strip-shaped projection **93***a* and the groove-shaped recessed portion **93***b* may be disposed on the base portion of the swaged joint portion **90**. The strip-shaped projection **93***a* and the groove-shaped recessed portion **93***b* may be formed simultaneously at the time of manufacturing the cover member **54**, or may be formed by applying working such as press working after manufacturing of the cover member **54**.

In the cover member **54**, a portion where the strip-shaped projection **93***a* and the groove-shaped recessed portion **93***b* are formed or a portion in the vicinity of the portion where the strip-shaped projection **93***a* and the groove-shaped recessed portion **93***b* are formed have the lower rigidity than a flat portion around the above-mentioned portions. Accordingly, when a bending load which intends to peel off the cover member **54** from the second connecting portion **52** is applied to the cover member **54** outside the strip-shaped projection **93***a* and the groove-shaped recessed portion **93***b*,

the cover member **54** is bent at the portion where the strip-shaped projection **93***a* and the groove-shaped recessed portion **93***b* are formed or at the portion in the vicinity of the portion where the strip-shaped projection **93***a* and the groove-shaped recessed portion **93***b* are formed at first thus suppressing the occurrence of deformation at the inner side of the strip-shaped projection **93***a* and the groove-shaped recessed portion **93***b*. Further, also on the joint portions **72**, **73** and **74**, in the same manner as the joint portion **71**, the swaged joint portion **90**, the strip-shaped projection **93***a*, and the groove-shaped recessed portion **93***b* are formed.

Other configurations of the energy storage device according to the modification 2 are substantially equal to the corresponding configurations of the energy storage device **100** according to the embodiment and hence, the description of other configurations is omitted. Further, the energy storage device according to the modification 2 can acquire substantially the same advantageous effects as the energy storage device **100** according to the embodiment. In the energy storage device according to the modification 2, the groove-shaped recessed portion **93***b* of the cover member **54** is positioned on the cover member **54** at the position opposite to the strip-shaped projection **93***a*, and extends along the strip-shaped projection **93***a*. In the above-mentioned configuration, the strip-shaped projection **93***a* and the groove-shaped recessed portion **93***b* can be formed by bending the cover member **54** and hence, the strip-shaped projection **93***a* and the groove-shaped recessed portion **93***b* can be easily formed. Further, also on the cover members **55**, **64** and **65**, the strip-shaped projection **93***a* and the groove-shaped recessed portion **93***b* may be formed in the same manner as the cover member **54**. The strip-shaped projection **93***a* and the groove-shaped recessed portion **93***b* formed on each of the respective cover members **55**, **64** and **65** also can acquire substantially the same advantageous effects as the strip-shaped projection **93***a* and the groove-shaped recessed portion **93***b* formed on the cover member **54**.

In the energy storage device according to the modification 2, the groove-shaped recessed portion **93***b* formed on the cover member **54**, **55**, **64** and **65** is disposed on a back side of the strip-shaped projection **93***a*. However, the present invention is not limited to such a configuration, and the groove-shaped recessed portion **93***b* may be disposed at a position displaced from the back side of the strip-shaped projection **93***a*.

In the energy storage device according to the modification 2, the strip-shaped projection **93***a* is formed on the outer surface of the cover member **54**, **55**, **64** or **65**, and the groove-shaped recessed portion **93***b* is formed on the inner surface of the cover member **54**, **55**, **64** or **65**. However, the present invention is not limited to such a configuration. The strip-shaped projection **93***a* may be formed on the inner surface of the cover member **54**, **55**, **64** or **65**, and the groove-shaped recessed portion **93***b* may be formed on the outer surface of the cover member **54**, **55**, **64** or **65**. The strip-shaped projection **93***a* and the groove-shaped recessed portion **93***b* may be formed on the second connecting portion **52** and the third connecting portion **53** of the positive electrode current collector **50** and on the second connecting portion **62** and the third connecting portion **63** of the negative electrode current collector **60** without being formed on the cover members **54**, **55**, **64** and **65**, or in addition to the cover members **54**, **55**, **64** and **65**. In this case, the strip-shaped projection **93***a* and the groove-shaped recessed portion **93***b* may be formed on either one of a surface facing the cover member and a surface opposite to the cover member in the second connecting portion and the third connecting portion. Further, when the strip-shaped projection **93***a* and the groove-shaped recessed portion **93***b* are formed on the cover members, the second connecting portion and the third connecting portion, the positions of the strip-shaped projection **93***a* and the groove-shaped recessed portion **93***b* may be aligned with each other or may differ from each other in the stacking direction of the cover member and the second connecting portion and the stacking direction of the cover member and the third connecting portion.

The arrangement and the shapes of the strip-shaped projection **93***a* and the groove-shaped recessed portion **93***b* are not limited to the arrangement and the shapes described in this modification. The arrangement and the shapes of the strip-shaped projection **93***a* and the groove-shaped recessed portion **93***b* may be substantially equal to the arrangement and the shapes of the strip-shaped projection and the groove-shaped recessed portion described in the embodiment and the modification 1.

[Modification 3]

As a modification 3 of the energy storage device **100** according to the embodiment, following configuration can be exemplified. To be more specific, as shown in FIG. **20**, an energy storage device according to the modification 3 is configured such that one connecting portion of each of the positive electrode current collector **50** and the negative electrode current collector **60** is connected to two positive electrode current collecting tab groups **21***d*, **21***e* or two negative electrode current collecting tab groups **22***d*, **22***e* of an electrode assembly **20**. FIG. **20** is a view showing the modification 3 of the energy storage device **100** according to the embodiment, and is a side view showing a modification of the positive electrode current collector **50** shown in FIG. **12**. The positive electrode current collector **50** and the negative electrode current collector **60** have substantially the same configuration and hence, only the positive electrode current collector **50** is described hereinafter.

With reference to FIG. **3** and FIG. **20**, a positive electrode current collector **50** includes a plate-like first connecting portion **51** connected to a shaft portion **30***b* of a positive electrode terminal **30**, and a plate-like fourth connecting portion **252** projecting from the first connecting portion **51** as integral parts thereof. The positive electrode current collector **50** of this modification does not include the second connecting portion **52** and the third connecting portion **53**. Here, the fourth connecting portion **252** is one example of a plate portion of a current collector.

The fourth connecting portion **252** extends continuously from the first connecting portion **51** in a direction intersecting the first connecting portion **51**. The fourth connecting portion **252** has two flat wide surfaces **252***a*, **252***b* disposed at positions opposite to each other. The fourth connecting portion **252** extends between the positive electrode current collecting tab group **21***d* and the positive electrode current collecting tab group **21***e*. A surface **252***a* of the fourth connecting portion **252** faces the positive electrode current collecting tab group **21***e* and, at the same time, is disposed adjacently to the positive electrode current collecting tab group **21***e*. A surface **252***b* of the fourth connecting portion **252** faces the positive electrode current collecting tab group **21***d* and, at the same time, is disposed adjacently to the positive electrode current collecting tab group **21***d*.

The positive electrode current collecting tab group **21***d* is sandwiched between the surface **252***b* of the fourth connecting portion **252** and the cover member **54**, and is swaged together with the fourth connecting portion **252** and the cover member **54**. With such a configuration, the positive electrode current collecting tab group **21***d* is connected to

the fourth connecting portion **252**. The positive electrode current collecting tab group **21***e* is sandwiched between the surface **252***a* of the fourth connecting portion **252** and the cover member **55**, and is swaged together with the fourth connecting portion **252** and the cover member **55**. With such a configuration, the positive electrode current collecting tab group **21***e* is connected to the fourth connecting portion **252**. That is, two positive electrode current collecting tab groups **21***d*, **21***e* are connected to one fourth connecting portion **252**. The swaged joint portion **90** which is formed on the cover member **54** accompanied with the strip-shaped projection **91** disposed around the cover member **54** and the swaged joint portion **90** which is formed on the cover member **55** accompanied with the strip-shaped projection **91** disposed around the cover member **55** project in directions opposite to each other with respect to the fourth connecting portion **252**. That is, the swaged joint portion **90** of the cover member **54** projects from the positive electrode current collecting tab group **21***d* toward the cover member **54**, and the swaged joint portion **90** of the cover member **55** projects from the positive electrode current collecting tab group **21***e* toward the cover member **55**. Further, in the same manner as the positive electrode current collector **50**, also the negative electrode current collector **60** includes a fourth connecting portion to which two negative electrode current collecting tab groups **22***d*, **22***e* are connected.

Other configurations of the energy storage device according to the modification 3 are substantially equal to the corresponding configurations of the energy storage device **100** according to the embodiment and hence, the description of other configurations is omitted. The energy storage device according to the modification 3 can acquire substantially the same advantageous effects as the energy storage device **100** according to the embodiment. In the energy storage device according to the modification 3, the positive electrode current collector **50** includes the fourth connecting portion **252** disposed between two positive electrode current collecting tab groups **21***d*, **21***e*, and the negative electrode current collector **60** includes the fourth connecting portion disposed between two negative electrode current collecting tab groups **22***d*, **22***e*. Further, a set of the fourth connecting portion **252** of the positive electrode current collector **50** and the positive electrode current collecting tab group **21***d* and a set of the fourth connecting portion **252** of the positive electrode current collector **50** and the positive electrode current collecting tab group **21***e* respectively have the swaged joint portion **90** which projects from one of the fourth connecting portion **252** or the positive electrode collecting tab group **21***d*, **21***e* to the other of the fourth connecting portion **252** or the positive electrode collecting tab group **21***d*, **21***e*.

In the same manner, a set of the fourth connecting portion of the negative electrode current collector **60** and the negative electrode current collecting tab group **22***d* and a set of the fourth connecting portion of the negative electrode current collector **60** and the negative electrode current collecting tab group **22***e* respectively have the swaged joint portion **90** which projects from one of the fourth connecting portion or the positive electrode collecting tab group **22***d*, **22***e* to the other of the fourth connecting portion or the positive electrode collecting tab group **22***d*, **22***e*. In the above-mentioned configuration, in the case where the plurality of positive electrode current collecting tabs **21***c* are divided into two positive electrode current collecting tab groups **21***d*, **21***e* which are disposed on both sides of the fourth connecting portion **252** of the positive electrode current collector **50** respectively, the positive electrode current collecting tab groups **21***d*, **21***e* can be joined to the fourth connecting portion **252** by swaging from both sides in a state where the positive electrode current collecting tab groups **21***d*, **21***e* sandwich the fourth connecting portion **252** therebetween. Accordingly, the positive electrode current collecting tab groups **21***d*, **21***e* can be easily joined to each other by swaging. Also the fourth connecting portion of the negative electrode current collector **60** and the negative electrode current collecting tab groups **22***d*, **22***e* can acquire substantially the same advantageous effects as the above-mentioned advantageous effects.

In the energy storage device according to the modification 3, the strip-shaped projection **91** is formed around the swaged joint portion **90**. However, the present invention is not limited to such a configuration, and the groove-shaped recessed portion **92** may be formed around the swaged joint portion **90**, or both the strip-shaped projection **93***a* and the groove-shaped recessed portion **93***b* may be formed around the swaged joint portion **90**.

In the energy storage device according to the modification 3, two positive electrode current collecting tab groups or two negative electrode current collecting tab groups are connected to one fourth connecting portion of the positive electrode current collector **50** or the negative electrode current collector **60**. However, three or more positive electrode current collecting tab groups or three or more negative electrode current collecting tab groups may be connected to one fourth connecting portion.

[Other Modification]

The energy storage devices according to the embodiment and the modifications of the present invention have been described heretofore. However, the present invention is not limited to such embodiment and modifications. That is, it should be construed that the embodiment and the modifications disclosed in this specification are provided for an exemplifying purpose and are not limitative in all aspects. The scope of the present invention is not defined by the above-mentioned description and is defined by the scope of claims, and it is intended that all alternations which are equivalent to the scope of claim in meaning and range are included in the scope of the present invention.

In the energy storage devices according to the embodiment and the modifications, two positive electrode current collecting tab groups **21***d*, **21***e* and two negative electrode current collecting tab groups **22***d*, **22***e* are disposed at the end portion **20***a* of the electrode assembly **20**. However, the arrangement of these current collecting tab groups is not limited to such an arrangement. One positive electrode current collecting tab group may be disposed on the end portion **20***a* of the electrode assembly **20** or three or more positive electrode current collecting tab groups may be disposed on the end portion **20***a* of the electrode assembly **20**. In the same manner, one negative electrode current collecting tab group may be disposed on the end portion **20***a* or three or more negative electrode current collecting tab groups may be disposed on the end portion **20***a*. Further, the positive electrode current collecting tab group and the negative electrode current collecting tab group may be disposed on both end portions **20***a* and **20***b* of the electrode assembly **20**. In this case, the positive electrode current collecting tab group may be disposed on only one or both of the end portions **20***a* and **20***b* of the electrode assembly **20**, and the negative electrode current collecting tab group may be disposed on only the other or both of the end portions **20***a* and **20***b* of the electrode assembly **20**.

In the above-mentioned configuration, the positive electrode current collector and the negative electrode current collector have connecting portions the number of which

corresponds to the number of positive electrode current collecting tab groups and the number of negative electrode current collecting tab groups. One positive electrode current collecting tab group or one negative electrode current collecting tab group may be connected to one connecting portion. Alternatively, two or more positive electrode current collecting tab groups or two or more negative electrode current collecting tab groups may be connected to one connecting portion. Further, all positive electrode current collecting tab groups or negative electrode current collecting tab groups may be connected to one connecting portion.

In the energy storage devices according to the embodiment and the modifications, the swaged joint portion **90** connects the positive electrode current collector **50** and the positive electrode current collecting tab groups **21***d*, **21***e* of the electrode assembly **20**, and connects the negative electrode current collector **60** and the negative electrode current collecting tab groups **22***d* and **22***e* of the electrode assembly **20**. However, the swaged joint portion **90** is not limited to such a configuration. The positive electrode current collector **50** and the negative electrode current collector **60** may include a conductive lead plate which forms an additional member as a constitutional element thereof, and the swaged joint portion **90** may connect the lead plate which is connected to the positive electrode current collector **50** and the positive electrode current collecting tab groups **21***d*, **21***e* to each other. The swaged joint portion **90** may connect a lead plate which is connected to the negative electrode current collector **60** and the negative electrode current collecting tab groups **22***d*, **22***e* to each other. Further, the positive electrode current collector **50** and the negative electrode current collector **60** may be joined to the lead plates by a joining method such as welding.

In the energy storage devices according to the embodiment and the modifications, the positive electrode current collecting tab groups **21***d*, **21***e* and the negative electrode current collecting tab groups **22***d*, **22***e* project from the end portion **20***a* of the electrode assembly **20** in an upright manner. Further, the positive electrode current collecting tab groups **21***d*, **21***e* are joined to the second connecting portion **52** and the third connecting portion **53** of the positive electrode current collector **50** in an upright state. The negative electrode current collecting tab groups **22***d*, **22***e* are also joined to the second connecting portion **62** and the third connecting portion **63** of the negative electrode current collector **60** in an upright manner. However, a state of the positive electrode current collecting tab groups **21***d*, **21***e* at the time of joining and a state of the negative electrode current collecting tab groups **22***d*, **22***e* at the time of joining are not limited to such a state. For example, the second connecting portion **52** and the third connecting portion **53** may be bendable to the first connecting portion **51** in the positive electrode current collector **50** or the second connecting portion **62** and the third connecting portion **63** may be bendable to the first connecting portion **61** in the positive electrode current collector **60**. In this case, the positive electrode current collecting tab groups **21***d*, **21***e* and the negative electrode current collecting tab groups **22***d*, **22***e* disposed in an upright state are bent together with the second connecting portion and the third connecting portion after the positive electrode current collecting tab groups **21***d*, **21***e* and the negative electrode current collecting tab groups **22***d*, **22***e* are respectively joined to the second connecting portion and the third connecting portion by swaging, and the positive electrode current collecting tabs **21***c* and the negative electrode current collecting tabs **22***c* extend along the lid body **12**. At the time of bending, the swaged joint portion in a projection shape may be deformed in a collapsed manner. Since the respective members which form the swaged joint portion are deformed such that the respective members entangle with each other, it is possible to increase a joining strength between the members.

The positive electrode current collecting tab groups **21***d*, **21***e*, the negative electrode current collecting tab groups **22***d*, **22***e* and the second connecting portion and the third connecting portion are bent in a short side direction of the lid body **12**, that is, in a direction perpendicular to a direction along which the positive electrode terminal **30** and the negative electrode terminal **40** are arranged. The positive electrode current collecting tab groups **21***d*, **21***e*, and the negative electrode current collecting tab groups **22***d*, **22***e* are disposed in a displaced manner from each other as viewed in a stacking direction of the electrode assembly **20** which is also a bending direction. Accordingly, at the time of bending, the positive electrode current collecting tab groups **21***d*, **21***e* and the negative electrode current collecting tab groups **22***d*, **22***e* do not interfere with each other thus facilitating bending.

In the electrode assemblies **20** of the energy storage devices according to the embodiment and the modifications, two positive electrode current collecting tabs **21***c* and two negative electrode current collecting tabs **22***c* are disposed per one winding. However, one positive electrode current collecting tab **21***c* and one negative electrode current collecting tab **22***c* may be disposed per one winding. In this case, the positive electrode current collecting tab groups **21***d*, **21***e* and the negative electrode current collecting tab groups **22***d*, **22***e* can reduce a stacking thickness by reducing the number of stacking of the positive electrode current collecting tabs **21***c* and the negative electrode current collecting tabs **22***c*. With such a configuration, the positive electrode current collecting tab groups **21***d*, **21***e* and the negative electrode current collecting tab groups **22***d*, **22***e* can increase a bending angle at the time of bending thus facilitating bending. Further, joining by swaging is also facilitated.

In the positive electrode current collector **50** and the negative electrode current collector **60**, the second connecting portions **52**, **62** and the third connecting portions **53**, **63** extend substantially perpendicular to the first connecting portions **51**, **61**. However, the direction that the second connecting portions **52**, **62** and the third connecting portions **53**, **63** extend is not limited to such a direction. In the same manner, the fourth connecting portion extends substantially perpendicular to the first connecting portion. However, the extending direction of the fourth connecting portion is not limited to such a direction. For example, the second connecting portions **52**, **62** and the third connecting portions **53**, **63** may extend along the first connecting portions **51**, **61**, and the fourth connecting portion may extend along the first connecting portion. In this case, the second connecting portion, the third connecting portion and the fourth connecting portion which extend substantially perpendicular to the first connecting portion may be bent so as to extend along the first connecting portion after the formation of swaged joint portions **90**. The swaged joint portions **90** of the bent second connecting portion, third connecting portion and fourth connecting portion may project toward the positive electrode terminal **30** or the negative electrode terminal **40** but not projecting toward the electrode assembly **20**. With such a configuration, it is possible to suppress the occurrence of a phenomenon that the swaged joint portion **90** is brought into contact with the electrode assembly **20** so that the positive electrode plate **21** and the negative electrode plate

22 are deformed and the separator **23** is broken whereby the positive electrode plate **21** and the negative electrode plate **22** are short-circuited with each other. In the case where the swaged joint portions **90** project as described above, two swaged joint portions **90** in the fourth connecting portion may project in the similar directions.

In the energy storage devices according to the embodiment and the modifications, the swaged joint portion **90** is formed into a bottomed circular cylindrical shape by a die tool **81** and a punching tool **82**. However, the swaged joint portion **90** is not limited to such a shape. The swaged joint portion **90** may be formed such that swaging is performed by using the die tool **81** and the punching tool **82** and, thereafter, the swaged joint portion **90** may be deformed in a collapsed manner by receiving a pressing pressure of the bottom portion which forms a projecting end of the die tool **81**. With such a configuration, the respective members which form the swaged joint portion **90** are deformed such that the respective members entangle with each other and hence, a joining strength between the members is enhanced. Further, the swaged joint portion **90** may not be completely collapsed and may project from the cover member. With such a configuration, the swaged joint portion **90** can maintain the stereoscopic structure and hence, a joining strength at the swaged joint portion **90** is further enhanced.

In the energy storage devices according to the embodiment and the modifications, the electrode assembly **20** includes the positive electrode current collecting tab groups **21***d*, **21***e* and the negative electrode current collecting tab groups **22***d*, **22***e*. However, the electrode assembly **20** may include neither the positive electrode current collecting tab groups **21***d*, **21***e* nor the negative electrode current collecting tab groups **22***d*, **22***e*. For example, the electrode assembly **20** may include a positive electrode active material layer non-forming portion where a positive electrode base material is exposed because of non-forming of a positive electrode active material layer on an edge **21***a* of the positive electrode plate **21**, and the electrode assembly **20** may include a negative electrode active material layer non-forming portion where a negative electrode base material is exposed because of non-forming of a negative electrode active material layer on an edge **22***b* of the negative electrode plate **22**. In this case, the swaged joint portion may connect the positive electrode active material layer non-forming potion and the positive electrode current collector to each other, and the swaged joint portion may connect the negative electrode active material layer non-forming portion and the negative electrode current collector to each other.

In the energy storage devices according to the embodiment and the modifications, the swaged joint portion **90** is applied to the connections between the electrode assembly **20** and the positive electrode current collector **50** and the negative electrode current collector **60**. However, the swaged joint portion **90** is not limited to such an application, and may be applied to the connection of two or more members having electrical conductivity.

In the energy storage devices according to the embodiment and the modifications, the electrode assembly **20** is a winding type electrode assembly which is formed by winding the positive electrode plate, the negative electrode plate and the separators overlapped with each other. However, the electrode assembly **20** is not limited to such a winding-type electrode assembly. The electrode assembly may be a stack-type electrode assembly formed by making a large number of positive electrode plates, negative electrode plates and separators overlapped with each other or a z-type electrode assembly formed by bending plural times one set or two or more sets of a positive electrode plate, a negative electrode plate and separators overlapped with each other.

Each of the energy storage devices according to the embodiment and the modifications includes one electrode assembly **20**. However, the energy storage device may include two or more electrode assemblies.

Each of the energy storage devices according to the embodiment and the modifications includes the horizontally-winding-type electrode assembly **20**. However, the energy storage device may include a vertically-winding-type electrode assembly where the electrode assembly is disposed in a direction where a winding axis A extends along a lid body **12** of the container **10**.

In the energy storage devices according to the embodiment and the modifications, the positive electrode terminal **30** and the positive electrode current collector **50** are formed as separate bodies from each other, and the negatives electrode terminal **40** and the negative electrode current collector **60** are formed as separate bodies from each other. However, the electrode terminal and the electrode current collector are not limited to such a configuration. The positive electrode terminal **30** and the positive electrode current collector **50** may be formed as an integral body, and the negative electrode terminal **40** and the negatives electrode current collector **60** may be formed as an integral body. In this case, the upper insulating member **31** and the lower insulating member **32** may be integrally formed with the lid body **12**, the positive electrode terminal **30** and the positive electrode current collector **50** by an integrally forming method such as insert molding. In the same manner, the upper insulating member **41** and the lower insulating member **42** may be integrally formed with the lid body **12**, the negative electrode terminal **40** and the negative electrode current collector **60** by an integrally forming method such as insert molding.

The energy storage devices according to the present invention which are exemplified in the embodiment and the modifications may be used as relatively large secondary batteries. A discharge capacity of such a relatively large secondary battery is preferably 3 Ah (ampere hour) or more, is more preferably 10 Ah or more, is further more preferably 20 Ah or more, and is still further more preferably 30 Ah or more. Such an energy storage device is applicable to, for example, a vehicle-use power source for an electric vehicle (EV), a hybrid electric vehicle (HEV) or a plug-in hybrid electric vehicle (PHEV), an electric storage power source such as an uninterruptible power supply device as a back-up device or a photovoltaic power system and the like.

The present invention also includes the configuration which is formed by arbitrarily combining the embodiment and the modifications. Further, the present invention can be realized not only as the above-mentioned energy storage device but also in an energy storage apparatus which includes at least one energy storage device. For example, the present invention can be realized as the energy storage apparatus which includes the plurality of energy storage devices **100**. The energy storage apparatus includes a plurality of energy storage units arranged parallel to each other, and each energy storage unit is formed of a plurality of energy storage devices **100** which are arranged in a row and are electrically connected to each other, for example. With such a configuration, the plurality of energy storage devices **100** are used as a single unit, and the number and the arrangement of the energy storage units can be selected corresponding to an electric capacity necessary for the energy storage apparatus, a shape and a size of the energy storage apparatus and the like. The energy storage apparatus

which includes the plurality of energy storage devices **100** and generates a high output can be also mounted as a vehicle-use power source as described previously. Further, the energy storage apparatus which includes the plurality of energy storage devices **100** and generates a high output may be used not only as a power source for an automobile but also as a power source for an automated guided vehicle (AGV) or an electrically-driven movable body such as an electric train.

The present invention is applicable to an energy storage device such as a lithium ion secondary battery.

What is claimed is:

1. An energy storage device, comprising:

electrode terminals;

an electrode assembly formed by stacking a positive electrode plate and a negative electrode plate;

current collectors which connect the electrode terminals and the electrode assembly to each other,

wherein at least one of the positive electrode plate and the negative electrode plate includes a plurality of tab groups which are joined to one of the current collectors, each tab group being formed by stacking one or more tabs projecting toward the electrode terminals, and

wherein at least one tab group among the tab groups and one current collector among the current collectors include a swaged joint portion, the swaged joint portion projecting from one tab group among the tab groups or one current collector among the current collectors to an other one of the one tab group among the tab groups or the one current collector among the current collectors; and

a cover material which overlaps with the at least one tab group among the tab groups and is fixed with the at least one tab group among the tab groups, and

wherein, in a stacking direction of the cover material on the at least one tab group, a projection portion or a recessed portion extends on a surface of the cover material, and the projection portion or the recessed portion is disposed at a position away from the swaged joint portion.

2. The energy storage device according to claim **1**, wherein the tab groups are disposed at different positions when viewed in a stacking direction of the tabs.

3. The energy storage device according to claim **1**, wherein the current collectors include a plurality of plate portions joined to the tab groups, and among the tab groups and the plate portions, a tab group and a plate portion which correspond to each other include the swaged joint portion, the swaged joint portion projecting from one of the tab group or the plate portion to an other one of the tab group or the plate portion.

4. The energy storage device according to claim **1**, wherein the current collectors include plate portions disposed between two tab groups among the tab groups, and the plate portions and the two tab groups include the swaged joint portion, respectively, the swaged joint portion projecting from one of a plate portion of the plate portions or a tab group of the two tab groups to an other one of the plate portion of the plate portions or the tab group of the two tab groups.

5. The energy storage device according to claim **4**, wherein two swaged joint portions, which the current collectors and two tab groups have, project in directions opposite to each other.

6. The energy storage device according to claim **1**, wherein the swaged joint portion projects from one tab group among the tab groups to one current collector among the current collectors.

7. The energy storage device according to claim **1**, wherein the swaged joint portion projects from one current collector among the current collectors to one tab group among the tab groups.

8. The energy storage device according to claim **1**, wherein the cover material overlaps with the at least one tab group in a stacking direction of the at least one tab group on one current collector among the current collectors.

9. The energy storage device according to claim **1**, wherein the cover material is disposed on a surface of the at least one tab group.

10. The energy storage device according to claim **1**, wherein the cover material is disposed on an entirety of a surface of the at least one tab group.

11. The energy storage device according to claim **1**, wherein the cover material includes the projection portion.

12. The energy storage device according to claim **1**, wherein the cover material includes the recessed portion.

13. The energy storage device according to claim **1**, wherein the current collector include:

a first connecting portion which has a plate shape; and

a second connecting portion and a third connecting portion which project from the first connecting portion toward the electrode assembly.

14. An energy storage device, comprising:

an electrode terminal;

an electrode assembly formed by stacking a positive electrode plate and a negative electrode plate; and

a current collector which connects the electrode terminal and the electrode assembly to each other,

wherein one of the positive electrode plate and the negative electrode plate includes a plurality of tab groups which are joined to the current collector, each tab group being formed by stacking one or more tabs projecting toward the electrode terminal,

wherein at least one tab group among the tab groups and the current collector includes a swaged joint portion, the swaged joint portion projecting from one of the tab group or the current collector to an other one of the tab group or the current collector, and

wherein the current collector includes:

a first connecting portion which has a plate shape; and

a second connecting portion and a third connecting portion which project from the first connecting portion toward the electrode assembly.

15. The energy storage device according to claim **14**, further comprising:

a cover material disposed on a surface of the at least one tab group,

wherein a projection portion extends on a surface of the cover material, and

wherein, in a stacking direction of the cover material on the at least one tab group, the projection portion projects from the surface of the cover material away from the at least one tab group.

16. The energy storage device according to claim **14**, further comprising:

a cover material disposed on a surface of the at least one tab group,

wherein a recessed portion extends on a surface of the cover material, and

wherein, in a stacking direction of the cover material on the at least one tab group, the recessed portion extends from the surface of the cover material towards the at least one tab group.

17. An energy storage device, comprising:

electrode terminals;

an electrode assembly formed by stacking and winding a positive electrode plate and a negative electrode plate and;

current collectors which connect the electrode terminals and the electrode assembly to each other,

wherein at least one of the positive electrode plate and the negative electrode plate includes a plurality of tab groups which are joined to one of the current collectors, each tab group being formed by stacking one or more tabs projecting toward the electrode terminals, and

wherein at least one tab group among the tab groups and one current collector among the current collectors include a swaged joint portion, the swaged joint portion projecting from one tab group among the tab groups or one current collector among the current collectors to an other one of the one tab group among the tab groups or the one current collector among the current collectors; and

a cover material disposed on a surface of the at least one tab group,

wherein, in a stacking direction of the cover material on the at least one tab group, a projection portion or a recessed portion extends on a surface of the cover material, and the projection portion or the recessed portion is disposed at a position away from the swaged joint portion.

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