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Current collector for positive electrode

Abstract

A current collector for a positive electrode according to the present invention may include a base film, a conductive material provided on at least one of upper and lower surfaces of the base film, a metal piece provided on the upper or lower surface of the base film and electrically connected to the conductive material, and a lead tab joined to any one of the metal piece, the conductive material, and the base film and electrically connected to the conductive material, in which the conductive material is positioned between the metal piece and the base film or between the lead tab and the base film, and in which the lead tab is welded to one of the metal pieces provided on the upper and lower surfaces of the base film or welded to the metal piece provided on one surface of the base film that faces the lead tab.

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Background/Summary

TECHNICAL FIELD

(1) The present invention relates to a current collector for a positive electrode, and more particularly, to a current collector for an electrode, which can reduce a weight of the electrode without using metal foil, reduce a thickness of an electrode assembly, connect a lead tab securely and stably, and ensure safety of a battery.

BACKGROUND ART

(2) As technical research and demands for mobile devices increase, there are rapidly increasing demands for secondary batteries as energy sources. Among the secondary batteries, lithium secondary batteries have been commercially available and have high energy density and action potential and a low self-discharge rate.

(3) A lithium metal secondary battery is the first secondary battery that has been commercially available. The lithium metal secondary battery uses lithium metal as a negative electrode. However, the lithium metal secondary battery has a problem in that a lithium dendrite formed on a surface of a lithium metal negative electrode causes expansion of volume of a cell, gradual deterioration in capacity and energy density, a short circuit caused by consistent growth of the dendrite, a decrease in cycle lifespan, and deterioration in cell stability (explosion and ignition). For this reason, the production of the lithium metal secondary battery was stopped in a just few years after the secondary lithium metal battery was commercially available. Therefore, there has been used a carbon-based negative electrode that is more suitable than lithium metal and can store lithium in an ionic state in a lattice or vacant space. The use of the carbon-based negative electrode allows the lithium secondary battery to be properly commercially available and come into wide use.

(4) The lithium secondary battery is mainly made of carbon-based or non-carbon-based negative electrode materials up to now. The development of the negative electrode material is mostly focused on carbon-based materials (graphite, hard carbon, soft carbon, etc.) and non-carbon-based materials (silicon, tin, titanium oxide, etc.).

(5) Meanwhile, recently, as portable electronic devices and information communication devices are miniaturized, the lithium secondary battery is significantly expected to be used as an ultra-small power system for operating the devices.

(6) Moreover, recently, development and research have been actively conducted on polymer-based electronic devices and elements using advantages such as flexibility, low cost, and ease of manufacturing. Therefore, to use the miniaturized device, it is necessary to reduce a thickness or weight of the battery while maintaining energy density or performance of the lithium secondary battery.

(7) In addition, a current pass is blocked or destroyed in the event of an internal short circuit even though the thickness or weight of the lithium secondary battery is reduced. Therefore, it is necessary to improve safety of the lithium secondary battery.

(8) Furthermore, even in a case in which the thickness or weight of the lithium secondary battery is reduced, a lead tab configured to be connected to an external device needs to be stably connected to a current collector for an electrode and have sufficient tensile strength to allow the lithium secondary battery to serve as a battery.

(9) The present applicant proposes the present invention to solve the above-mentioned problems.

DISCLOSURE

Technical Problem

(10) The present invention has been made in an effort to solve the above-mentioned problems, and an object of the present invention is to provide a current collector for a positive electrode, which is capable of reducing a thickness in comparison with a current collector using metal foil.

(11) Another object of the present invention is to provide a current collector for a positive electrode, which is capable of reducing a weight in comparison with a current collector using metal foil.

(12) Still another object of the present invention is to provide a current collector for a positive electrode, which is capable of having a larger resistance value than resistance of a current collector using metal foil, thereby reducing short-circuit current in the event of an internal short circuit.

(13) Yet another object of the present invention is to provide a current collector for a positive electrode, which is capable of securely and stably connecting a lead tab to a current collector provided in the form of a film.

Technical Solution

(14) To achieve the above-mentioned objects, a current collector for a positive electrode according to the present invention may include a base film, a conductive material provided on at least one of upper and lower surfaces of the base film, a metal piece provided on the upper or lower surface of the base film and electrically connected to the conductive material, and a lead tab joined to any one of the metal piece, the conductive material, and the base film and electrically connected to the conductive material, in which the conductive material is positioned between the metal piece and the base film or between the lead tab and the base film, and in which the lead tab is welded to one of the metal pieces provided on the upper and lower surfaces of the base film or welded to the metal piece provided on one surface of the base film that faces the lead tab.

(15) The metal pieces may be respectively provided on the upper and lower surfaces of the base film, or the metal piece may be provided on any one of the upper and lower surfaces of the base film and the lead tab may be provided on the other of the upper and lower surfaces of the base film.

(16) An insulating polymeric layer may be provided between the conductive material and the metal piece or between the conductive material and the lead tab.

(17) The insulating polymeric layer may have bondability or adhesiveness.

(18) The insulating polymeric layer may be melted at the same temperature as the base film or melted at a lower temperature than the base film.

(19) A current pass may be formed only by a welded part or a welded point of the lead tab.

(20) The insulating polymeric layer positioned between the conductive material and the metal piece or the insulating polymeric layer positioned between the conductive material and the lead tab may block or insulate a short-circuit current by insulating a portion between the conductive material and the metal piece or a portion between the conductive material and the lead tab except for a welded part of the lead tab.

(21) The conductive material may be made of aluminum with a thickness of 2 μm or less based on a maximum cross-section.

(22) The metal piece may be configured as aluminum foil or SUS 316 L foil.

Advantageous Effects

(23) The current collector for a positive electrode according to the present invention uses the base film made of a nonconductor, instead of metal foil, thereby reducing weights of the electrode assembly and the battery.

(24) In addition, the current collector for a positive electrode according to the present invention forms the coating or plating layer made of a conductive material on the surface of the base film, instead of using metal foil, thereby further reducing the thickness in comparison with the current collector using metal foil.

(25) In addition, the current collector for a positive electrode according to the present invention may have a larger resistance value than resistance of the current collector using metal foil, and the flow of current may be hindered by damage to the base film or damage to the conductive material layer. Therefore, it is possible to reduce a short-circuit current and improve safety of the battery in the event of a short circuit.

(26) In addition, according to the current collector for a positive electrode according to the present

invention, the lead tab is welded to any one of the metal pieces in a state in which the metal pieces made of a metallic material are positioned on the two opposite upper and lower surfaces of the base film, or the lead tab is welded to the metal piece in a state in which the metal piece is positioned on any one of the two opposite upper and lower surfaces of the base film and the lead tab is positioned on the other of the two opposite upper and lower surfaces of the base film. Therefore, it is possible to securely and stably attach the lead tab to the base film and prevent deterioration in tensile strength of the part to which the lead tab is attached.

(27) In addition, in the current collector for a positive electrode according to the present invention, the insulating polymeric layer is provided between the conductive material and the metal piece or between the conductive material and the lead tab, thereby improving safety of the battery in the event of a short circuit.

Description

DESCRIPTION OF DRAWINGS

(1) FIG. 1 is a perspective view illustrating an electrode assembly including a current collector for a positive electrode according to the present invention.

(2) FIG. 2 is an exploded perspective view illustrating the electrode assembly according to the present invention.

(3) FIG. 3 is a perspective view illustrating the current collector for a positive electrode according to the present invention.

(4) FIG. 4 is a cross-sectional view illustrating a current collector for a positive electrode according to a first embodiment of the present invention.

(5) FIG. 5 is a cross-sectional view illustrating a current collector for a positive electrode according to a second embodiment of the present invention.

(6) FIG. 6 is a cross-sectional view illustrating a current collector for a positive electrode according to a third embodiment of the present invention.

(7) FIG. 7 is a cross-sectional view illustrating a current collector for a positive electrode according to a fourth embodiment of the present invention.

(8) FIG. 8 is a top plan view illustrating the current collector for a positive electrode illustrated in FIG. 4.

(9) FIGS. 9A and 9B are graphs illustrating results of external short circuit tests performed on lead tab connection parts of secondary batteries including the electrode assemblies having the current collector for a positive electrode illustrated in FIG. 4 and the current collector for a positive electrode illustrated in FIG. 6.

(10) FIGS. 10A and 10B are graphs illustrating results of external short circuit experiments performed on the battery using the current collector for a positive electrode having no insulating polymeric layer.

BEST MODE

(11) Hereinafter, embodiments according to the present invention will be described in detail with reference to the accompanying drawings. However, the present invention is not restricted or limited by the embodiments. Like reference numerals indicated in the respective drawings refer to like members.

(12) FIG. 1 is a perspective view illustrating an electrode assembly including a current collector for a positive electrode according to the present invention, FIG. 2 is an exploded perspective view illustrating the electrode assembly according to the present invention, FIG. 3 is a perspective view illustrating the current collector for a positive electrode according to the present invention, FIG. 4 is a cross-sectional view illustrating a current collector for a positive electrode according to a first embodiment of the present invention, FIG. 5 is a cross-sectional view illustrating a current

collector for a positive electrode according to a second embodiment of the present invention, FIG. 6 is a cross-sectional view illustrating a current collector for a positive electrode according to a third embodiment of the present invention, FIG. 7 is a cross-sectional view illustrating a current collector for a positive electrode according to a fourth embodiment of the present invention, FIG. 8 is a top plan view illustrating the current collector for a positive electrode illustrated in FIG. 4, and FIGS. 9A and 9B are graphs illustrating results of external short circuit tests performed on lead tab connection parts of secondary batteries including the electrode assemblies having the current collector for a positive electrode illustrated in FIG. 4 and the current collector for a positive electrode illustrated in FIG. 6.

(13) FIGS. 1 and 2 illustrate an electrode assembly **10** including a current collector **100** for a positive electrode (a cathode) according to the present invention. The current collector **100** for a positive electrode according to the present invention illustrated in FIGS. 1 and 2 is a positive electrode current collector. A surface of the current collector **100** for a positive electrode needs to be coated with a positive electrode active material **103** so that the current collector **100** for a positive electrode is used for the electrode assembly **10**.

(14) Meanwhile, a current collector **200** for a negative electrode (an anode) may have negative electrode metal foil **201** coated with a negative electrode active material **203**, and a negative electrode lead tab **290** may be connected to one end of the current collector **200** for a negative electrode based on a longitudinal direction of the current collector **200** for a negative electrode.

(15) A separator **300** is disposed between the current collector **200** for a negative electrode and the current collector **100** for a positive electrode according to the present invention. In a state illustrated in FIG. 2, as the current collector **200** for a negative electrode and the current collector **100** for a positive electrode are sequentially stacked with the separator **300** interposed therebetween, the electrode assembly **10** illustrated in FIG. 1 is made.

(16) FIG. 3 illustrates the current collector **100** for a positive electrode according to the present invention. The current collector **100** for a positive electrode does not use metal foil unlike the current collector **200** for a negative electrode described above.

(17) The current collector **100** for a positive electrode (current collector for cathode electrodes) according to the present invention illustrated in FIG. 3 has a larger resistance value than resistance of the current collector using the metal foil, such that the current collector **100** may adjust a limit current value of the current flowing in the current collector. Because the flow of current may be hindered by damage to a base film, the current collector **100** may reduce short-circuit current or prevent heat generation in the event of an internal short circuit of the secondary battery.

(18) The lithium secondary battery having the current collector **100** for a positive electrode according to the present invention may have properties or concept of a max current limited battery (MCLB). Hereinafter, the current collector for a positive electrode according to the present invention, which enables implementation of the MCLB, will be described.

(19) Since the current collector **100** for a positive electrode according to the present invention has a higher resistance value than the resistance of the positive electrode current collector of the battery in the related art using the metal foil, the current collector **100** may adjust the limit current and reduce the short-circuit current and heat generation occurring in the event of a short circuit by destroying a current pass in the event of the internal short circuit, thereby improving safety of the battery.

(20) The current collector **100** for a positive electrode according to the present invention does not use the metal foil but uses a base film **101** made of a polymeric material as a basic material, and metal with a thin thickness may be applied onto the base film **101**, or the base film **101** may be coated with metal.

(21) Hereinafter, various shapes of the current collector **100** for a positive electrode according to the present invention will be described with reference to the drawings.

(22) First, referring to FIGS. 4 to 7, a current collector **100**, **400**, **500**, or **600** for a positive

electrode according to the present invention includes: the base film **101**; a conductive material **102** provided on at least one of upper and lower surfaces of the base film **101**; a metal piece (metal element) **120** provided on the upper or lower surface of the base film **101** and electrically connected to the conductive material **102**; and a lead tab **190** joined to any one of the metal piece **120**, the conductive material **102**, and the base film **101** and electrically connected to the conductive material **102**. The conductive material **102** may be positioned between the metal piece **120** and the base film **101** or positioned between the lead tab **190** and the base film **101**. The lead tab **190** may be welded to one of the metal pieces **120** provided on the upper and lower surfaces of the base film **101** or welded to the metal piece **120** provided on one surface of the base film **101** that faces the lead tab **190**.

(23) In this case, the conductive material **102** may be positioned between the metal piece **120** and the base film **101** or positioned between the base film **101** and the lead tab **190**.

(24) In this case, in the event of a short circuit, the conductive material **102** may serve as an electrochemical fuse through a reaction with an electrolyte, such that the conductive material **102** may have a function of preventing a short circuit. The electrochemical characteristics of the conductive material **102** will be described below.

(25) The base film **101** may be provided in the form of a band having a predetermined length. In this case, the electrode assembly **10** to be described below may be formed as the base film **101** is supplied or transferred by a roll-to-roll method along a longitudinal direction thereof (i.e., a direction of a relatively long length).

(26) The base film **101** may be made of a polymeric nonconductive material such as polyethylene (PE), polypropylene (PP), polybutylene terephthalate (PBT), polyimide (PI), or polyethylene terephthalate (PET).

(27) The base film **101** may have a thickness of 50 μm or less, particularly, a thickness of 1.4 μm or more and 50 μm or less. The current collector **100** for a positive electrode according to the first embodiment of the present invention may reduce a thickness or weight of the battery in comparison with a case in which the current collector using the metal foil in the related art is used. The current collector **100** uses, as the base film **101**, a polymeric film having a thickness of 1.4 μm or more and 50 μm or less and made of a nonconductive material, which makes it possible to an overall thickness or weight of the lithium secondary battery having the current collector **100**, **400**, **500**, or **600** for a positive electrode according to the present invention.

(28) Meanwhile, the base film **101** may be made of a material which is melted at a temperature lower than 300° C. The lead tab **190** is fixed to the base film **101** by welding. Unless the base film **101** is melted at a temperature lower than a welding temperature of the lead tab **190**, the lead tab **190** cannot be coupled to the base film **101**. Therefore, the base film **101** needs to have a melting point at which the base film **101** may be melted during the process of welding the lead tab **190**. The base film **101** may have a melting point lower than 300° C.

(29) Meanwhile, the current collector **100**, **400**, **500**, or **600** for a positive electrode according to the present invention may include the conductive material **102** disposed on at least one of the upper and lower surfaces of the base film **101**.

(30) The conductive material **102** may be aluminum (Al), and the surface of the base film **101** may be plated or coated with the conductive material **102**. Therefore, the conductive material **102** may be referred to as a conductive layer that defines an outermost surface of the current collector **100** for a positive electrode.

(31) The conductive material **102** may be formed to adjust or reduce limit current or maximum current of the current collector **100**, **400**, **500**, or **600** for a positive electrode. In other words, the conductive material **102** may be aluminum with which at least one of the upper and lower surfaces of the base film **101** is plated or coated to control conductivity of the current collector **100**, **400**, **500**, or **600** for a positive electrode. When the description is focused on the state in which the surface of the base film **101** is plated or coated with the conductive material **102**, the conductive

material **102** may be referred to as the conductive layer. Hereinafter, it is noted that the conductive material **102** has the concept including the conductive layer.

(32) It is possible to control or reduce the maximum amount of current flowing in the current collector **100**, **400**, **500**, or **600** for a positive electrode by adjusting the amount of coating or a coating thickness of the conductive material **102** with which at least one of the upper and lower surfaces of the base film **101** is plated or coated. Therefore, it is possible to improve the safety of the lithium secondary battery and ensure safety of the battery in the event of a short circuit.

(33) In other words, the limit current or the maximum current flowing in the current collector **100** for a positive electrode may be adjusted depending on the thickness or the amount of the conductive material **102** formed on the surface of the base film **101**. As described above, the conductive material **102** of the current collector **100**, **400**, **500**, or **600** for an electrode according to the present invention may implement properties or concept of the max current limited battery (MCLB) of the lithium secondary battery.

(34) In addition, in the event of a physical internal short circuit or an external short circuit, the base film **101** may be melted and hinder rapid current generation, thereby improving safety of the battery. Further, when the conductive material **102** has a small thickness, electric potential of the aluminum layer constituting the conductive material **102** is reduced in the event of an internal short circuit or an external short circuit, which induces an electrochemical reaction between the aluminum layer and the electrolyte. Therefore, it possible to reduce the conductivity or block the current, thereby improving safety of the battery.

(35) The conductive material **102** may be formed on the surface of the base film **101** in various ways. For example, when the conductive material **102** is made of metal, the conductive material **102** may be formed on the surface of the base film **101** by sputtering or evaporation coating.

(36) It is possible to control the conductivity of the current collector **100** for a positive electrode or ensure safety of the battery depending on the amount (weight) or thickness of the conductive material **102** with which the surface of the base film is plated or coated. Therefore, it is necessary to use a method capable of controlling or adjusting the thickness or weight of the conductive material **102**.

(37) The thickness of the conductive material **102** with which the surface of the base film **101** is plated or coated may be determined depending on a length of the lead tab **190** and a length of the electrode (current collector). For example, when the length of the electrode (current collector) increases, a plating thickness of the conductive material **102** may also increase.

(38) The conductive material **102** may be formed on only one surface of the base film **101** or both of the two opposite surfaces of the base film **101**. In this case, the conductive material **102** may have a thickness of 2 μm or less based on a maximum cross-section.

(39) In the current collector **100**, **400**, **500**, or **600** for a positive electrode according to the present invention, the flow of current may be implemented by the conductive material **102**. Therefore, the state in which the surface of the base film **101** is plated or coated with the conductive material **102** needs to be properly maintained. To this end, the base film **101** may be subjected to surface treatment, thereby increasing a binding force between the conductive material **102** and the base film **101**.

(40) If the binding force between the conductive material **102** and the base film **101** is low, the conductive material **102** may be detached or separated from the surface of the base film **101** in a state in which the electrolyte is injected. Therefore, it is important to increase the binding force between the conductive material **102** and the base film **101**.

(41) The surface treatment may be performed on the surface of the base film **101** to increase a bonding force or binding force with the conductive material **102**.

(42) The surface of the base film **101** may be subjected to corona treatment to increase the binding force between the conductive material **102** and the base film **101**.

(43) Meanwhile, the current collector **100**, **400**, **500**, or **600** for a positive electrode according to

the present invention may have the lead tab **190** configured to be connected to the external device.

(44) In the case of the electrode current collector using the metal foil in the related art, the lead tab may be welded directly to the metal foil. In contrast, in the case of the current collector **100**, **400**, **500**, or **600** for a positive electrode according to the present invention, the thin base film **101** corresponds to the metal foil in the related art. For this reason, the lead tab cannot be welded directly to the base film **101**. That is, the lead tab **190** needs to be welded to the conductive material **102** formed on the upper or lower surface of the base film **101**, but since the base film **101** is thin, sufficient tensile strength of a welded part cannot be ensured, which makes it difficult to attach the lead tab **190** to the base film **101**. According to the current collector **100**, **400**, **500**, or **600** for a positive electrode according to the present invention, the lead tab **190** is welded to the metal piece **120** made of a metallic material in the state in which the metal pieces **120** are attached to the upper and lower surfaces of the base film **101**, or the lead tab **190** is welded to the metal piece **120** in the state in which the metal piece **120** is attached to one surface of the base film **101** and the lead tab **190** is attached to the other surface of the base film **101**, which makes it possible to solve the above-mentioned problem.

(45) According to the current collector **100**, **400**, **500**, or **600** for a positive electrode according to the present invention, the lead tab **190** may be welded to the metal piece **120**, the conductive material **102**, or the base film **101** by ultrasonic welding, laser welding, or spot welding.

(46) According to the current collectors **100**, **400**, **500**, and **600** for a positive electrode according to the present invention illustrated in FIGS. **4** to **7**, the metal piece **120** and the lead tab **190**, which are made of metal, are positioned on the upper and lower surfaces of the base film **101**, respectively.

(47) Hereinafter, the current collectors **100**, **400**, **500**, and **600** for a positive electrode will be described in more detail with reference to FIGS. **4** to **7**.

(48) First, in the current collector **100** for a positive electrode according to the first embodiment of the present invention illustrated in FIG. **4**, the conductive materials **102** are provided on the upper and lower surfaces of the base film **101**. The metal pieces **120** are respectively provided on the upper and lower surfaces of the base film **101** and respectively joined or connected to the upper and lower conductive materials **102**. That is, the metal pieces **120** may be respectively joined or connected to the conductive materials **102** on the upper and lower surfaces of the base film **101**. The lead tab **190** is welded to any one of the metal pieces **120** provided on the upper and lower surfaces of the base film **101**, such that the lead tab **190** may be electrically connected to the metal piece **120** and the conductive material **102**.

(49) In this case, the metal piece **120** may serve to ensure a position on the base film **101** at which the lead tab **190** is welded. That is, the metal piece **120** may serve as a connection part of the lead tab **190**.

(50) The metal piece **120** may have a thickness of 5 μm or more. In this case, it is enough that the metal piece **120** is provided on only a part of the base film **101**. The number of metal pieces **120** or the position of the metal piece **120** provided on the base film **101** is not limited. However, in the case in which the lead tab **190** is welded to the metal piece **120**, the position on the metal piece **120** at which the lead tab **190** is welded may be determined in consideration of the shape of the electrode assembly.

(51) As described above, the metal piece **120** may be provided in the form of a thin metal film or metal foil having a thickness of 5 μm or more, but the shape of the metal piece **120** is not necessarily limited thereto. That is, the metal piece **120** may be provided in the form of a thin film, foil, or a mesh.

(52) The metal piece **120** may be configured as aluminum foil or SUS 316 L foil.

(53) As described above, the metal piece **120** of the current collector **100** for a positive electrode according to the first embodiment of the present invention may ensure the welding position of the lead tab **190**.

(54) As illustrated in FIG. **4**, the conductive materials **102** may be respectively formed on the two

opposite upper and lower surfaces of base film **101** and the metal pieces **120** may be respectively provided on the two opposite upper and lower surfaces of the base film **101** and in contact with the upper and lower conductive materials **102**. The lead tab **190** may be welded to any one of the upper and lower metal pieces **120**. When the welding is performed, the base film **101** may be melted, such that the conductive material **102**, the metal piece **120**, and the lead tab **190** may be electrically connected.

(55) In addition, referring to the current collector **100** for a positive electrode according to the first embodiment of the present invention illustrated in FIG. 4, insulating polymeric layers **130** may each be provided between the conductive material **102** and one surface of the metal piece **120** that faces the conductive material **102**. The insulating polymeric layer **130** serves to attach the metal piece **120** to the surface of the base film **101** or the surface of the conductive material **102** or insulate the conductive material **102** and the metal piece **120**. Referring to FIG. 4, the insulating polymeric layer **130** may be provided between the conductive material **102** and the metal piece **120**.

(56) The insulating polymeric layer **130** may be made of a material having bondability or adhesiveness. In addition, the insulating polymeric layer **130** may be made of a polymeric material or provided in the form of a polymeric film.

(57) In the case in which the insulating polymeric layer **130** is provided in the form of a polymeric film, the insulating polymeric layer **130** may have a thickness smaller than 50 μm . If the thickness of the insulating polymeric layer **130** is larger than 50 μm , there is a problem in that welding is not properly performed and resistance increases (see Tables 1 and 2).

(58) TABLE-US-00001 TABLE 1 Experimental Result Resistance Resistance Structure: Al foil/KMG + Tensile (Ω) (Ω) Al/Pet/Al + KMG/Al foil Strength (Front (Rear No. Al-coated PET Al foil Weldability (Kgf/mm.sup.2) Surface) Surface) 1-1 1 μm Al + 7 μm 12 μm Al/ OK 0.12 0.068 0.060 PET + 1 μm Al KMG 5 μm 1-2 1 μm Al + 7 μm 12 μm Al/ OK 0.17 0.096 0.069 PET + 1 μm Al KMG 10 μm 1-3 1 μm Al + 7 μm 12 μm Al/ OK 0.21 0.103 0.097 PET + 1 μm Al KMG 20 μm 1-4 1 μm Al + 7 μm 12 μm Al/ OK 0.32 0.070 0.080 PET + 1 μm Al KMG 30 μm 1-5 1 μm Al + 7 μm 12 μm Al/ NG — — — PET + 1 μm Al KMG 50 μm 1-6 1 μm Al + 7 μm 12 μm Al/ NG — — — PET + 1 μm Al KMG 100 μm

(59) TABLE-US-00002 TABLE 2 Experimental Result Structure: Al foil/EVA + Resistance Resistance Al/PET/Al + EVA/Al foil Tensile (Ω) (Ω) Al-coated Strength (Front (Rear No. PET Al foil Weldability (Kgf/mm.sup.2) Surface) Surface) 2-1 1 μm Al + 7 μm 12 μm Al/ OK 0.15 0.068 0.060 PET + 1 μm Al EVA 5 μm 2-2 1 μm Al + 7 μm 12 μm Al/ OK 0.16 0.096 0.095 PET + 1 μm Al EVA 10 μm 2-3 1 μm Al + 7 μm 12 μm Al/ OK 0.2 0.123 0.110 PET + 1 μm Al EVA 20 μm 2-4 1 μm Al + 7 μm 12 μm Al/ OK 0.21 0.050 0.050 PET + 1 μm Al EVA 30 μm 2-5 1 μm Al + 7 μm 12 μm Al/ NG — — — PET + 1 μm Al EVA 50 μm 2-6 1 μm Al + 7 μm 12 μm Al/ NG — — — PET + 1 μm Al EVA 100 μm

(60) The insulating polymeric layer **130** may be melted at the same temperature as the base film **101** or melted at a lower temperature than the base film **101**. That is, the insulating polymeric layer **130** may have the same melting point as the base film **101** or a melting point lower in temperature than a melting point of the base film **101**.

(61) The insulating polymeric layer **130** may not only be made of a polymeric material such as polyethylene (PE), polypropylene (PP), polyvinylidene difluoride (PVDF), polyethylene terephthalate (PET), or polyimide (PI), but also be made of a polymeric material such as ethylene vinyl acetate (EVA) or acrylate-based compound having adhesive components.

(62) The insulating polymeric layer **130** may not only serve to attach the metal piece **120** to the surface of the base film **101** or the conductive material **102** but also serve as an insulating layer. The insulating polymeric layer **130** is electrically connected to the conductive material **102** while being melted at the time of welding the lead tab **190**, and a part of the lead tab **190**, except for the welded part, is insulated by the insulating polymeric layer **130**. In the case in which the electrically

connected part is limited to the welded part, the conductive material **102** corresponding to the welded part reacts to reduce or block current in the event of an external short circuit. If the electrically connected part is large, a large amount of reaction is required, which makes it difficult to block the current. Therefore, in the case in which the metal piece **120** is attached to the conductive material **102**, the insulating polymeric layer **130** having insulation may be provided between the conductive material **102** and the metal piece **120**.

(63) In this case, the insulating polymeric layers **130** and the metal pieces **120** respectively attached to the conductive materials **102** respectively provided on the two opposite surfaces of the base film **101** may be provided at the same position based on the base film **101**.

(64) The following Table 3 shows results of experiments performed on tensile strength, electrical conductivity, and the like of the base film **101** at the time of welding the lead tab **190** to the current collector **100** for an electrode illustrated in FIG. 4.

(65) TABLE-US-00003 TABLE 3 Structure: Al foil (12 μm) + KMG (10 μm) + (Al/PET/Al) + Experimental Result Al foil (12 μm) + Resistance Resistance KMG (10 μm) + Al tab Tensile (Ω) (Ω) Al-coated Strength (Front (Rear No. PET Al tab Weldability (Kgf/mm.sup.2) Surface) Surface) 3-1 1 μm Al + 7 μm 80 μm OK 0.5 0.135 0.124 PET + 1 μm Al 3-2 1 μm Al + 7 μm 100 μm OK 0.49 0.166 0.150 PET + 1 μm Al

(66) In Table 3, “Structure: Al foil (12 μm)+KMG (10 μm)+(Al/PET/Al)+Al foil (12 μm)+KMG (10 μm)+Al tab” means the current collector **100** for a positive electrode having a cross-sectional structure illustrated in FIG. 4. In this case, “Al foil” means the aluminum metal piece **120** having a thickness of 12 μm , and “KMG” means the insulating polymeric layer **130** which is a bonding agent from KMG made of acrylate-based compound having bondability and a thickness of 10 μm . “Al/PET/Al” means the base film **101** made of polymeric PET and having the two opposite upper and lower surfaces coated with the aluminum conductive materials **102**, and “Al tab” means the lead tab **190** made of aluminum. In addition, “Resistance (Ω) (Front Surface)” means a value of resistance between the Al tab and a side of the conductive material layer to which the Al tab is attached, and “Resistance (Ω) (Rear Surface)” means a value of resistance between the Al tab and a side of the conductive material layer to which the Al tab is not attached. The resistance was measured by using Hioki 3555. The same also applied to the other experiments. Table 3 shows results of measuring weldability, tensile strength, and resistance in a state in which the aluminum conductive material **102** with a thickness of 1 μm is applied onto each of the two opposite upper and lower surfaces of the base film **101** made of PET and having a thickness of 7 μm and the lead tab **190** with a thickness of 80 μm (1-1) and 100 μm (1-2) is welded to any one of the metal pieces **120**.

(67) Meanwhile, in the experiment, the welding was performed by using an ultrasonic welder.

(68) Referring to the results shown in Table 3, it can be ascertained that there is no problem during the process of welding the lead tab **190** to any one of the metal pieces **120** because the metal pieces **120** made of a metallic material are positioned on the two opposite upper and lower surfaces of the base film **101**. In addition, it can be ascertained that tensile strength of the welded part of the lead tab **190** is ensured because the lead tab **190** is attached in the state in which the metal pieces **120** are provided on the two opposite upper and lower surfaces of the base film **101**.

(69) It can be ascertained that the experimental result similar to that shown in Table 3 is obtained even in a case in which EVA having bondability and a thickness or 10 μm is used, instead of KMG, as the insulating polymeric layer **130**. In addition, it can be ascertained that the different conductive material layers are electrically connected through the welded parts.

(70) Table 4 shows results of experiments performed on the current collector for a positive electrode in which the insulating polymeric layer **130** is removed from the current collector **100** illustrated in FIG. 4. Table 4 shows results of experiments performed on the current collector for a positive electrode having a structure in which the metal pieces **120** are respectively attached to the upper and lower conductive materials **102** and the lead tab **190** is welded to any one of the metal

pieces **120**.

(71) TABLE-US-00004 TABLE 4 Structure: Al foil (12 μm) + Experimental Result (Al/PET/Al) + Al foil Resistance Resistance (12 μm) + Al tab Tensile (Ω) (Ω) Al-coated Strength (Front (Rear No. PET Al tab Weldability (Kgf/mm.sup.2) Surface) Surface) 4-1 1 μm Al + 7 μm 80 μm OK 0.6 0.098 0.065 PET + 1 μm Al 4-2 1 μm Al + 7 μm 100 μm OK 0.61 0.12 0.095 PET + 1 μm Al

(72) In Table 4, "Structure: Al foil (12 μm)+(Al/PET/Al)+Al foil (12 μm)+Al tab" means a cross-sectional shape of the current collector **100** for an electrode. In this case, "Al foil" means the aluminum metal piece **120** having a thickness of 12 μm , "Al/PET/Al" means the base film **101** made of polymeric PET and having the two opposite surfaces coated with the aluminum conductive materials **102**, and "Al tab" means the lead tab **190** made of aluminum. Table 4 shows results of measuring weldability, tensile strength, and resistance in a state in which the aluminum conductive material **102** with a thickness of 1 μm is applied onto each of the two opposite upper and lower surfaces of the base film **101** made of PET and having a thickness of 7 μm and the lead tab **190** with a thickness of 80 μm (2-1) and 100 μm (2-2) is welded to any one of the metal pieces **120**.
(73) Referring to the results shown in Table 4, it can be ascertained that there is no problem with the welding of the lead tab **190** to any one of the metal pieces **120** because the metal pieces **120** made of a metallic material are positioned on the two opposite upper and lower surfaces of the base film **101**. In addition, it can be ascertained that tensile strength of the welded part of the lead tab **190** is ensured because the metal pieces **120** are attached to the two opposite upper and lower surfaces of the base film **101** or the lead tab **190** is attached each of the two opposite upper and lower surfaces of the base film **101**.

(74) In this case, the metal pieces **120** respectively provided on the two opposite surfaces of the base film **101** may be provided at the same position.

(75) Meanwhile, it is difficult to ensure tensile strength of the welded part in a case in which the metal piece **120** or the lead tab **190** is attached to only any one of the two opposite upper and lower surfaces of the base film **101**. Table 5 shows results of experiments performed in the case in which both the metal piece **120** and the lead tab **190** are positioned on one surface of the base film **101**.

(76) TABLE-US-00005 TABLE 5 Experimental Result Resistance Resistance Structure: Al tab + Al foil Tensile (Ω) (Ω) (12 μm) + (Al/PET/Al) Strength (Front (Rear No. Al-coated PET Al tab Weldability (Kgf/mm.sup.2) Surface) Surface) 5-1 1 μm Al + 7 μm 80 μm OK 0.03 0.103 0.053 PET + 1 μm Al 5-2 1 μm Al + 7 μm 100 μm OK 0.02 0.131 0.058 PET + 1 μm Al

(77) Table 5 shows results of experiments performed on the current collector for a positive electrode in which the metal piece **120** provided in the form of Al foil is positioned only any one of the upper and lower surfaces of the base film **101** and the lead tab **190** is welded to the metal piece **120**. That is, Table 5 shows results of experiments performed on the current collector for a positive electrode in which metal is concentrated only one surface of the base film **101**. It can be ascertained that tensile strength is very low in the results shown in Table 5 compared to Tables 3 and 4. If the tensile strength is low, it is impossible to weld the lead tab to the base film. FIG. illustrates the current collector **400** for a positive electrode according to the second embodiment of the present invention. Referring to FIG. 5, the current collector **400** for a positive electrode may include conductive materials **102** applied onto two opposite upper and lower surfaces of a base film **101**, a metal piece **120** provided on a surface of one of the conductive materials **102**, a lead tab **190** provided on a surface of the other of the conductive materials **102**, an insulating polymeric layer **130** provided between the conductive material **102** and the metal piece **120**, and an insulating polymeric layer **130** provided between the conductive material **102** and the lead tab **190**.

(78) In comparison with the current collector **100** for a positive electrode illustrated in FIG. 4, there is a difference in that the metal piece **120** is provided at one side of the base film **101**, the lead tab **190** is provided at the other side of the base film **101**, and the insulating polymeric layer **130** is provided between the metal piece **120** and the conductive material **102**, but no metal piece **120** is provided between the insulating polymeric layer **130** and the lead tab **190**. However, the current

collector **400** for a positive electrode illustrated in FIG. 5 is similar to the current collector **100** for a positive electrode illustrated in FIG. 4 in that the members made of metal, i.e., the metal piece **120** and the lead tab **190** are respectively positioned on both the upper and lower surfaces of the base film **101**.

(79) The metal piece **120** and the lead tab **190** respectively provided on the two opposite upper and lower surfaces of the base film **101** may be provided at the same position.

(80) The following Table 6 shows results of experiments performed on tensile strength, electrical conductivity, and the like of the base film **101** at the time of welding the lead tab **190** to the current collector **400** for a positive electrode illustrated in FIG. 5.

(81) TABLE-US-00006 TABLE 6 Structure: Al foil (12 μm) + Experimental Result KMG (10 μm) + Resistance Resistance (Al/PET/Al) + Tensile (Ω) (Ω) KMG (10 μm) + Al tab Strength (Front (Rear No. Al-coated PET Al tab Weldability (Kgf/mm.sup.2) Surface) Surface) 6-1 1 μm Al + 7 μm 80 μm OK 0.43 0.112 0.115 PET + 1 μm Al 6-2 1 μm Al + 7 μm 100 μm OK 0.45 0.12 0.13 PET + 1 μm Al

(82) In Table 6, "Structure: Al foil (12 μm)+KMG (10 μm)+(Al/PET/Al)+KMG (10 μm)+Al tab" means the current collector for an electrode **400** having a cross-sectional structure illustrated in FIG. 5. In this case, "Al foil" means the aluminum metal piece **120** having a thickness of 12 μm , and "KMG" means the insulating polymeric layer **130** which is a bonding agent from KMG made of acrylate-based compound having bondability and a thickness of 10 μm . "Al/PET/Al" means the base film **101** made of polymeric PET and having the two opposite upper and lower surfaces coated with the aluminum conductive materials **102**, and "Al tab" means the lead tab **190** made of aluminum. Table 6 shows results of measuring weldability, tensile strength, and resistance in a state in which the aluminum conductive material **102** with a thickness of 1 is applied onto each of the two opposite upper and lower surfaces of the base film **101** made of PET and having a thickness of 7 μm and the lead tab **190** with a thickness of 80 μm (4-1) and 100 μm (4-2) is welded directly to the conductive material **102**.

(83) Referring to the results shown in Table 6, it can be ascertained that there is no problem with the welding of the lead tab **190** because the metal piece **120** and the lead tab **190**, which are made of a metallic material, are respectively positioned on the two opposite upper and lower surfaces of the base film **101**. In addition, it can be ascertained that tensile strength of the welded part of the lead tab **190** is ensured because the lead tab **190** is welded in the state in which the metal piece **120** and the lead tab **190** are respectively provided on the two opposite upper and lower surfaces of the base film **101**.

(84) It can be ascertained that the experimental result similar to that shown in Table 6 is obtained even in a case in which EVA having bondability and a thickness or 10 μm is used, instead of KMG, as the insulating polymeric layer **130** provided between the conductive material **102** and the metal piece **120**.

(85) FIG. 6 illustrates the current collector **500** for a positive electrode according to the third embodiment of the present invention. Referring to FIG. 6, the current collector **500** for a positive electrode may include a conductive material **102** applied only onto any one of two opposite upper and lower surfaces of a base film **101**, a metal piece **120** provided on a surface of the conductive material **102**, a lead tab **190** provided on a surface of the base film **101** on which no conductive material **102** is provided, and an insulating polymeric layer **130** provided between the conductive material **102** and the metal piece **120**.

(86) In comparison with the current collector **400** for a positive electrode illustrated in FIG. 5, there is a difference in that the conductive material **102** and the metal piece **120** are provided only on one surface of the base film **101**, only the lead tab **190** is provided on the other surface of the base film **101**, and the insulating polymeric layer **130** is provided between the metal piece **120** and the conductive material **102**, but no insulating polymeric layer **130** is provided between the base film **101** and the lead tab **190**. However, the current collector **500** for a positive electrode illustrated in

FIG. 6 is similar to the current collector **100** illustrated in FIG. 4 and the current collector **400** for a positive electrode illustrated in FIG. 4 in that the members made of metal, i.e., the metal piece **120** and the lead tab **190** are respectively positioned on both the upper and lower surfaces of the base film **101**.

(87) The metal piece **120** and the lead tab **190** respectively provided on the two opposite upper and lower surfaces of the base film **101** may be provided at the same position.

(88) The following Table 7 shows results of experiments performed on tensile strength, electrical conductivity, and the like of the base film **101** at the time of welding the lead tab **190** to the current collector **500** for a positive electrode illustrated in FIG. 6.

(89) TABLE-US-00007 TABLE 7 Structure: Al foil (12 μm) + KMG (10 μm) + Experimental Result (Al/PET) + Al tab Tensile (80 μm) Strength Resistance Resistance Resistance No. Al-coated PET Weldability (Kgf/mm.sup.2) 1 (Ω) 2 (Ω) 3 (Ω) 7-1 1 μm Al + 7 μm OK 0.36 0.087 0.050 0.047 PET

(90) In Table 7, “Structure: Al foil (12 μm)+KMG (10 μm)+(Al/PET)+Al tab (80 μm)” means the current collector **500** for an electrode having a cross-sectional structure illustrated in FIG. 6. In this case, “Al foil” means the aluminum metal piece **120** having a thickness of 12 μm , and “KMG” means the insulating polymeric layer **130** which is a bonding agent from KMG made of acrylate-based compound having bondability and a thickness of 10 μm . “Al/PET” means the base film **101** made of polymeric PET and having an upper surface coated with the aluminum conductive material **102**, and “Al tab” means the lead tab **190** made of aluminum and having a thickness of 80 μm . In addition, Resistance 1 means resistance measured between the metal piece **120** and the conductive material **102**, Resistance 2 means resistance measured between the metal piece **120** and the lead tab **190**, and Resistance 3 means resistance measured between the conductive material **102** and the lead tab **190**. Table 7 shows results of measuring weldability, tensile strength, and resistance in a state in which the aluminum conductive material **102** with a thickness of 1 μm is applied onto the upper surface of the base film **101** made of PET and having a thickness of 7 μm and the lead tab **190** with a thickness of 80 μm is welded to a lower surface of the base film **101**.

(91) Referring to the results shown in Table 7, it can be ascertained that there is no problem with the welding of the lead tab **190** because the metal piece **120** and the lead tab **190**, which are made of a metallic material, are respectively positioned on the two opposite upper and lower surfaces of the base film **101**. In addition, it can be ascertained that tensile strength of the welded part of the lead tab **190** is ensured because the lead tab **190** is welded in the state in which the metal piece **120** and the lead tab **190** are respectively provided on the two opposite upper and lower surfaces of the base film **101**. In addition, according to a result of analyzing measured values of Resistance 1 to 3, it can be ascertained that electrical conductivity is also good.

(92) In the current collector **500** for a positive electrode according to the third embodiment of the present invention illustrated in FIG. 6, the lead tab **190** is attached to one surface of the base film **101** onto which no aluminum conductive material **102** is applied. Therefore, the lead tab **190** does not meet the separator and the negative electrode at the time of forming the electrode assembly by folding inward the surface on which no conductive material **102** is provided. Therefore, there is an advantage in that no separate protective film is required to prevent a short circuit of the lead tab **190**.

(93) FIG. 7 illustrates the current collector **600** for a positive electrode according to the fourth embodiment of the present invention. Referring to FIG. 7, the current collector **600** for a positive electrode may include a conductive material **102** applied only onto any one of the two opposite upper and lower surfaces of the base film **101**, a lead tab **190** provided on a surface of the conductive material **102**, a metal piece **120** provided on a surface of the base film **101** on which no conductive material **102** is provided, and an insulating polymeric layer **130** provided between the conductive material **102** and the lead tab **190**.

(94) The metal piece **120** and the lead tab **190** respectively provided on the two opposite upper and

lower surfaces of the base film **101** may be provided at the same position.

(95) The current collector **600** for a positive electrode illustrated in FIG. **7** differs from the current collector **400** for a positive electrode illustrated in FIG. **6** in that the positions of the metal piece **120** and the lead tab **190** are reversed. However, the current collector **600** for a positive electrode illustrated in FIG. **7** is similar to the current collector **100** for a positive electrode illustrated in FIG. **4**, the current collector **400** for a positive electrode illustrated in FIG. **4**, and the current collector **500** for a positive electrode illustrated in FIG. **6** in that the members made of metal, i.e., the metal piece **120** and the lead tab **190** are respectively positioned on both the upper and lower surfaces of the base film **101**. Therefore, it can be seen that the current collector **600** for a positive electrode according to the fourth embodiment of the present invention illustrated in FIG. **7** may also ensure sufficient tensile strength of the welded part of the lead tab **190** and have excellent electrical conductivity.

(96) According to the current collector **100**, **400**, **500**, or **600** for a positive electrode according to the present invention, tensile strength of the welded part of the base film **101** or the lead tab **190** is good even in the case in which the insulating polymeric layer **130** made of a polymer is provided on at least one of the upper or lower surface of the base film **101** because the member made of metal, i.e., the metal piece **120** or the lead tab **190** is positioned on each of the two opposite surfaces of the base film **101**.

(97) When the lead tab **190** is welded, the lead tab **190** is joined as the insulating polymeric layer **130** and the base film **101** are melted at the welded part, such that the lead tab **190** may be electrically connected to the conductive material **102**.

(98) TABLE-US-00008 TABLE 8 Structure: Al foil (12 μm) + PE (16 Experimental Result μm) + (Al/PET) + PE (16 μm) + Al Tensile Resistance Resistance foil (12 μm) Strength (Ω) (Front (Ω) (Rear No. Al-coated PET Weldability (Kgf/mm.sup.2) Surface) Surface) 8-1 1 μm Al + 7 μm PET + 1 μm Al OK 0.40 0.155 0.125

(99) TABLE-US-00009 TABLE 9 Structure: Al foil (12 μm) + PI (12 Experimental Result μm) + (Al/PET) + PI (12 μm) + Al Tensile Resistance Resistance foil (12 μm) Strength (Ω) (Front (Ω) (Rear No. Al-coated PET Weldability (Kgf/mm.sup.2) Surface) Surface) 9-1 1 μm Al + 7 μm PET + 1 μm Al NG — — —

(100) Tables 8 and 9 show results of experiments performed on weldability in a case in which the insulating polymeric layer is made of PE or PI higher in melting point than KMG or EVA. It can be ascertained that PE having a lower melting point than PET may be welded and have similar tensile strength and resistance values to KMG or EVA applied to the insulating polymeric layer. In contrast, it can be ascertained that PI having a high melting point is not welded well. FIG. **8** is a top plan view illustrating the current collector **100** for a positive electrode according to the first embodiment of the present invention. Referring to FIG. **8**, the metal piece **120** is positioned on the conductive material **102**, and the lead tab **190** is positioned on the metal piece **120**. In this case, the insulating polymeric layer **130** is present between the metal piece **120** and the conductive material **102**. During the process of welding the lead tab **190**, a welded point is formed as the insulating polymeric layer **130** and the base film **101** are melted. That is, as illustrated in FIG. **8**, the lead tab **190** is welded as the insulating polymeric layer **130** positioned between the metal piece **120** and the conductive material **102** is melted. The electrical connection is implemented only by the welded point connected as the insulating polymeric layer **130** is melted. In the case in which the insulating polymeric layer **130** is present as described above, the electrical connection forms a current pass at a very small portion only on the welded point at the time of welding the lead tab **190**. As a result, it is possible to insulate a portion between the lead tab **190** and the conductive material **102** or between the metal piece **120** and the conductive material **102**. In addition, the remaining part, except for the welded point, is exposed to the electrolyte or is in a state in which the electrolyte easily permeates into the remaining part.

(101) If no insulating polymeric layer is provided between the lead tab or metal piece and the

conductive material, the conductive material is in direct contact with the lead tab or the metal piece. In this case, the lead tab or the metal piece is in physical contact with the conductive material in an area corresponding to a size of the lead tab or the metal piece. In the case of the current collector for a positive electrode in which the lead tab or the metal piece is in physical contact with the conductive material on the welded part of the lead tab as described above, no insulating polymeric layer is provided between the metal piece and the conductive material. Therefore, a surface contact corresponding to an area of the metal piece is provided, and a reaction area is inevitably large. For this reason, it is difficult to allow all the conductive materials applied onto the surface of the base film to react. When an external short circuit occurs on the battery using the current collector for a positive electrode, the current pass is maintained, which may cause an increase in temperature of the battery without blocking current (see FIG. 10A).

(102) FIGS. 9A and 9B are graphs illustrating results of external short circuit tests performed on lead tab connection parts of secondary batteries including the electrode assemblies having the current collector **100** for a positive electrode according to the first embodiment of the present invention and the current collector **500** for a positive electrode according to the third embodiment of the present invention.

(103) FIG. 9A illustrates the result of the test performed in a case in which a capacity of the battery including the current collector **100** for a positive electrode is 400 mAh. The current collector **500** for a positive electrode may include the base film **101** made of PET and having the two opposite surfaces on which the aluminum conductive materials **102** are formed, the metal pieces **120** made of aluminum and being in contact with the conductive materials **102** on the two opposite surfaces of the base film **101**, the insulating polymeric layers **130** made of KMG and provided between the conductive materials **102** and the metal pieces **120**, and the lead tab **190** welded to any one of the metal pieces **120**.

(104) FIG. 9B illustrates the result of the test performed in a direction in which a capacity of the battery including the current collector **500** for a positive electrode is 1000 mAh. The current collector **300** for a positive electrode may include the base film **101** made of PET and having a cross-section on which the aluminum conductive material **102** is formed, the metal piece **120** made of aluminum and being in contact with the conductive material **102** on the base film **101**, the conductive insulating polymeric layer **130** provided between the conductive material **102** and the metal piece **120**, and the lead tab **190** joined to one surface of the base film **101** on which no conductive material **102** is provided.

(105) In the current collector **100** or **500** for a positive electrode used for the test, a composition consisting of lithium cobalt oxide (LCO, Umicore) of 95%, conductive material (Super-P, Timcal) of 2.5%, binder (5130, Solef) of 2.5% was used for the positive electrode, and a composition consisting of graphite (BGF-L, BTR) of 97.1%, conductive material (Super-P, Timcal) of 0.3%, binder SBR (BM-400B, Zeon) of 1.3%, CMC (BSH12, Nippon Paper) of 1.3% was used for the negative electrode. In addition, a PE separator (SETELA FO7BC, Toray Tonen) was used as the separator, and EC/EMC=1/2, 1M LiPF₆ (Panaxetec) was used for the electrolyte. A product of 88 μm from DNP was used as a pouch, and a product from Shinhwa Itek, made of Al (with thickness of 0.1 mm and width of 3 mm) and Cu (with thickness of 0.1 mm and width of 3 mm), was used as the lead tab.

(106) The battery was charged up to 4.35 V, and then an external short circuit test was performed. In this case, an acrylate-based compound product from KMG was used for the insulating polymeric layer **130**.

(107) It can be seen from FIG. 9A that a small amount of current is formed and an increase in temperature of the battery is small. In addition, it can be seen from FIG. 9B that the current is blocked well, and there is no increase in temperature of the battery. In the current collector **500** for a positive electrode which is a subject for the experiments illustrated in FIGS. 9A and 9B, the conductive material **102** is formed only on the cross-section of the base film **101**, and the insulating

polymeric layer **130** is positioned between the conductive material **102** and the metal piece **120**. Therefore, the current pass may be formed only in a narrow part by the insulating polymeric layer **130** melted during welding, and the electrolyte may easily permeate or impregnate into one surface of the base film **101** on which no insulating polymeric layer **130** is provided. Therefore, it can be seen that it is possible to effectively prevent an increase in temperature of the battery and ensure very high safety against the external short circuit.

(108) FIGS. **10A** and **10B** are graphs illustrating results of external short circuit experiments performed on the battery using the current collector for a positive electrode having no insulating polymeric layer.

(109) In the current collector for a positive electrode which is a subject for the experiments illustrated in FIGS. **10A** and **10B**, the aluminum conductive materials are applied onto the two opposite surfaces of the base film, the metal pieces are positioned on the two opposite upper and lower surfaces of the base film, and the lead tab is welded to any one of the metal pieces by ultrasonic welding. A capacity of the battery was 400 mAh (see FIG. **10A**) and 1000 mAh (see FIG. **10B**) and a short circuit test was performed after the battery was fully charged.

(110) The experimental result illustrated in FIG. **10B** indicates that as the short circuit occurs, a large amount of current flows, a temperature of the battery increases, and the battery ignites. Unlike the current collector **500** for a positive electrode used for the experiment illustrated in FIG. **9**, the metal piece is in direct contact with the conductive material without the insulating polymeric layer in the current collector for a positive electrode used for the experiment illustrated in FIG. which causes surface contact with the current pass. For this reason, the current pass cannot be perfectly blocked and the battery ignites in the event of a short circuit.

(111) The result of the experiment on the external short circuit illustrated in FIGS. **9A** and **9B**, and **10A** and **10B** indicates that when the insulating polymeric layer **130** made of an insulating material is provided at boundaries between the conductive material **102**, the metal piece **120**, and the lead tab **190**, the electrical connection of the lead tab **190** is formed only on the welded point (welded part) connected when the insulating polymeric layer **130** is melted. Therefore, it can be seen that the configuration is advantageous in blocking the current pass and improving safety of the battery in the event of a short circuit.

(112) In addition, at least one of the two opposite upper and lower surfaces of the base film **101** may have a structure in which there is a portion where the insulating polymeric layer **130** is not attached, thereby allowing the electrolyte to easily permeate (impregnate). That is, the surface of the base film has a porous structure advantageous in electrolyte impregnation. Alternatively, the surface of the base film may have a structure in which the insulating polymeric layer **130** is provided on any one of the metal piece **120** and the conductive material **102** only at one side of the base film **101**, such that the electrolyte may permeate through a portion where no insulating polymeric layer is provided. In addition, the gelling properties of the electrolyte may be advantageous in the permeation of the electrolyte.

(113) In the case of the current collector **100**, **400**, **500**, or **600** for a positive electrode according to the present invention described above, the metal piece **120** or the lead tab **190** needs to be provided on the two opposite upper and lower surfaces of the base film **101** to make electric conduction and attach the metal piece **120** and the lead tab **190** to the two opposite upper and lower surfaces of the base film **101** onto which the conductive materials **102** are applied. For example, the metal pieces need to be provided on the two opposite upper and lower surfaces of the base film. Alternatively, the metal piece needs to be provided on one surface of the base film, and the lead tab needs to be provided on the other surface of the base film. If the metal piece or the lead tab is provided only on one surface of the base film, bonding strength or tensile strength of the welded part of the lead tab is low, which makes it difficult to use the lead tab.

(114) In addition, the insulating polymeric layer **130** made of a polymer capable of being melted while making insulation needs to be provided between the metal piece **120** and the conductive

material **102** or between the lead tab **190** and the conductive material **102** in order to ensure performance in blocking the current pass and improve safety of the battery in the event of an external short circuit. In this case, the electrical connection is made only by the welded point (welded part) of the lead tab **190** because of the insulating polymeric layer **130**.

(115) While the exemplary embodiments of the present invention have been described above with reference to particular contents such as specific constituent elements, the limited exemplary embodiments, and the drawings, but the exemplary embodiments are provided merely for the purpose of helping understand the present invention overall, and the present invention is not limited to the exemplary embodiment, and may be variously modified and altered from the disclosure by those skilled in the art to which the present invention pertains. Accordingly, the spirit of the present invention should not be limited to the described embodiment, and all of the equivalents or equivalent modifications of the claims as well as the appended claims belong to the scope of the spirit of the present invention.

Claims

1. A current collector for a positive electrode, the current collector comprising: a base film; a conductive material provided on at least one of upper and lower surfaces of the base film; a metal piece provided on the upper or lower surface of the base film and electrically connected to the conductive material; a lead tab joined to any one of the metal piece, the conductive material, and the base film and electrically connected to the conductive material, and an insulating polymeric layer provided between the conductive material and the metal piece or between the conductive material and the lead tab, wherein the conductive material is positioned between the metal piece and the base film or between the lead tab and the base film, wherein the lead tab is welded to the metal piece provided on the upper or lower surface of the base film, and wherein during the processing of welding the lead tab, the insulating polymeric layer positioned between the conductive material and the metal piece or between the conductive material and the lead tab is melted together with the base film, so that the lead tab is welded to the metal piece, an electrical connection between the lead tab and the conductive material is established only at a welded point formed by melting the insulating polymeric layer, and a current pass is formed only in a narrow part of the welded point, and wherein insulation is provided between the lead tab and the conductive material or between the metal piece and the conductive material by the insulating polymeric layer present in a remaining part of the insulating polymeric layer excluding the welded point.

2. The current collector of claim 1, the metal piece is provided on any one of the upper and lower surfaces of the base film and the lead tab is provided on the other of the upper and lower surfaces of the base film, or the metal piece is provided on the upper surface of the base film and another metal piece having the same structure as the metal piece is provided on the lower surface of the base film.

3. The current collector of claim 2, wherein the insulating polymeric layer is formed to have a thickness less than 50 μm , which allows welding of the lead tab to the metal piece and prevents increased resistance of the current collector.

4. The current collector of claim 3, wherein the insulating polymeric layer has bondability or adhesiveness.

5. The current collector of claim 4, wherein the insulating polymeric layer is melted at the same temperature as the base film or melted at a lower temperature than the base film.

6. The current collector of claim 1, wherein a current pass is at least one of the upper and lower surfaces of the base film has a structure in which there is a portion where the insulating polymeric layer is not provided so that the electrolyte permeates or impregnates the base film through the at least one of the upper and lower surfaces of the base film.

7. The current collector of claim 6, wherein the insulating polymeric layer positioned between the conductive material and the metal piece or the insulating polymeric layer positioned between the conductive material and the lead tab blocks or insulates a short-circuit current.
 8. The current collector of claim 6, wherein the conductive material is made of aluminum with a thickness of 2 μm or less based on a maximum cross-section.
 9. The current collector of claim 8, wherein the metal piece is configured as aluminum foil or SUS 316 L foil.
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