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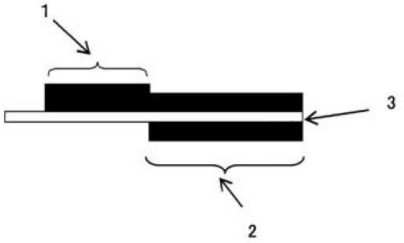
(54) [Title of Invention] ELECTRODE PLATE FOR NON-AQUEOUS ELECTROLYTE SECONDARY BATTERY AND METHOD FOR MANUFACTURING SUCH

(57) [Abstract]
[Problem] To provide a method for manufacturing an electrode plate for a non-aqueous electrolyte secondary battery having excellent productivity by suppressing peeling of the active material layer formed on the current collector and breakage of the electrode plate when winding.
[Resolution Means] By removing a portion of an active material layer on a single side of an electrode plate at the outermost circumference of a battery, and making the thickness of an active material layer applied on the opposite side thereof through a current collector thicker than that of the thickness of an active material layer applied on another electrode plate on the inner circumference, the packing density of the active material layer of the electrode plate at the outermost circumference is made greater than the packing density of the active material layer on the inner circumference, making it possible to provide a method for manufacturing an excellent electrode plate for a non-aqueous electrolyte secondary battery.
[Selected Drawing] FIG. 1



[Scope of Patent Claims]
[Claim 1]
A method for manufacturing an electrode plate for a non-aqueous electrolyte secondary battery, wherein a portion of an active material layer on a single side of an electrode plate at the outermost circumference of a battery is removed, and a packing density of an active material layer on an opposite side thereof through a current collector is larger than that of a packing density of an active material layer of another electrode plate at the inner circumference.
[Claim 2]
The method for manufacturing an electrode plate for a non-aqueous electrolyte secondary battery according to claim 1, wherein a portion of the active material layer on a single side of the electrode plate at the outermost circumference of the battery is removed, and with the packing density of the active material layer on the opposite side thereof through the current collector as M and the packing density of the active material layer of the other electrode plate at the inner circumference as N, the ratio of N to M is $0.7 < N / M < 1.0$.
[Claim 3]
A method for manufacturing an electrode plate for a non-aqueous electrolyte secondary battery, applying the configuration according to either of claims 1 or 2, wherein a lithium-containing composite oxide is used as a positive electrode active material and a carbonaceous material is used as a negative electrode active material.
[Detailed Description of Invention]
[Technical Field]
[0001]
The present invention relates to a method for manufacturing an electrode plate for a non-aqueous electrolyte secondary battery.
[Background Art]
[0002]
In recent years, progress in making consumer electronic devices portable and cordless has been rapidly advancing. Currently, nickel-cadmium batteries, nickel-hydrogen batteries, or sealed small lead-acid batteries serve as the power sources for such electronic devices. However, as progress and achievements are made in making batteries portable and cordless, there is a growing demand for secondary batteries that serve as power sources to have higher energy density and to be smaller and lighter.
[0003]
In addition, due to the rapid market expansion of devices represented by small computers and communication equipment, there is also a demand for non-aqueous electrolyte secondary batteries that enable high rate charging and discharging.
[0004]
To handle such non-aqueous electrolyte secondary batteries, efforts have been made to maximize the electrode area by adopting a spiral structure wherein the positive electrode plate and negative electrode plate are wound with a separator interposed therebetween, and this has been put into practical use.
[0005]
For example, exposing the surface of the current collector of the positive electrode plate on a portion corresponding to the outermost and innermost circumferences positive electrode plate wound in a spiral shape of the non-aqueous electrolyte secondary battery described above, on a portion that does not oppose the positive electrode plate makes it possible to increase the effective electrode area, thereby improving battery performance (see, for example, Patent Document 1).
[Patent Document 1] JP 2000-195556 A
[Disclosure of Invention]
[Problem to be Solved by Invention]
[0006]
However, in order to put such non-aqueous electrolyte secondary batteries into practical use, it is necessary to roll the electrodes that have been coated and dried in the manufacturing process at high density in the next process, which is the rolling process.
[0007]
In relation to the rolling method, there is a sized rolling method wherein the electrode passes through a fixed gap, or a fixed pressure rolling method wherein the electrode passes under a certain pressure. However, in either method, the single-sided active material layer portion, wherein the active material layer is formed only on a single side of the current collector, has a thinner electrode plate when compared to the two-sided active material portion because the active material layer is formed only on a single side of the current collector.
[0008]

Therefore, when rolling the coated and dried electrodes to a prescribed density, the pressure applied to the single-sided active material layer portion is smaller than the pressure applied to the two-sided active material layer portion, which poses a challenge wherein the single-sided active material layer portion is not sufficiently rolled during the rolling process.

[0009]

Furthermore, the single-sided active material layer portion did not have sufficient adhesion to the current collector, resulting in issues such as the active material layer detaching from the current collector.

[0010]

If an attempt is made to set a prescribed density for the single-sided active material layer portion to prevent the active material layer of the single-sided active material layer portion from detaching, excessive pressure will be applied to the two-sided active material layer portion, and at the same time, excessive load will be applied to the current collector. As a result, breakage of the electrode plate due to the decreased strength of the current collector is more likely to occur, making the winding operation of the electrode plate in the winding process difficult, resulting in not being possible to increase the winding speed, which significantly reduces productivity.

[Means For Solving Problem]

[0011]

In light of the above, the present invention is a battery configured by winding a positive electrode plate and a negative electrode plate in a spiral with a separator therebetween, wherein a portion of an active material layer on a single side of an electrode plate at the outermost circumference of the battery is removed, and the thickness of an active material layer applied on the opposite side thereof through a current collector is made thicker than that of the thickness of an active material layer applied on another electrode plate on the inner circumference, thereby causing the packing density of the active material layer of the electrode plate at the outermost circumference to be greater than the packing density of the active material layer on the inner circumference.

[0012]

Here, with the packing density of the single-sided active material portion as M and the packing density of the two-sided active material layer portion is denoted as N, when the ratio of the active material density is 0.7 or less, the thickness of the single-sided active material layer portion becomes larger than the thickness of the two-sided active material portion, resulting in increased pressure on the single-sided active material portion during rolling, which causes the single-sided active material layer portion to break.

[0013]

In addition, when the ratio of the active material density is 1.0 or more, the thickness of the two-sided active material layer portion becomes larger than the thickness of the single-sided active material layer portion, resulting in a smaller pressure applied to the single-sided active material layer during rolling, which prevents the single-sided active material layer portion from being sufficiently rolled, leading to peeling of the single-sided active material layer portion.

[0014]

In light of the above, it is preferable for the ratio of the density of active material to be $0.7 < N / M < 1.0$.

[0015]

When changing the density of the active material, it is difficult to intermittently change the thickness with a rolling machine to achieve a prescribed active material density, because rolling machines press at a fixed size. In a fixed pressure press, when a single-sided portion is set to a prescribed density, the density of the two-sided coated portion becomes excessive, making it difficult to achieve the prescribed density for both the single-sided and two-sided portions simultaneously.

[0016]

Therefore, by varying the thickness of the single-sided active material portion and the thickness of the two-sided active material portion during the application of the active material, and performing a fixed-size press using a rolling machine, the prescribed active material density ratio is obtained.

[Effect of Invention]

[0017]

A non-aqueous electrolyte secondary battery configured by winding in a spiral through a separator, a portion of the active material layer on a single side of the electrode plate at the outermost periphery is removed, and with the packing density on the opposite side through a current collector as M and the packing density of the active material layer on another electrode plate on the inner circumference as N, the thickness of the packing density M when applying the active material layer is made larger than the packing density N when applying the active material layer, so when the ratio of the packing density M of the single-sided active material layer of the electrode plate and the packing density N of the two-sided active material of the electrode plate is $0.7 < N / M < 1.0$, the thickness of the single-sided active material layer portion is larger than the two-sided active material layer, and the pressure applied to the single-sided active material portion during rolling increases, thereby increasing the adhesion.

[0018]

As a result, peeling of the active material layer from the current collector is suppressed, and there is no breakage on the two-sided active material layer portion during the winding of the electrode plates, and no detachment of the single-sided active material layer portion from the current collector, leading to a dramatic improvement in productivity.

[Best Mode for Carrying Out Invention]

[0019]

The best mode for carrying out the present invention will be described below with reference to drawings.

[Embodiment 1]

[0020]

The present invention is not limited to the examples below.

[0021]

In the present invention, in a battery configured by a positive electrode plate and a negative electrode plate being wound in a spiral through a separator, a portion of the active material layer on a single side of the electrode plate at the outermost periphery of the battery is removed, and with the packing density of the active material layer on which coating has been applied and dried on the opposite side through a current collector as M and the packing density of the active material layer on which coating has been applied and dried on another electrode plate on the inner circumference as N, the ratio of the packing density M and the packing density N is made to be $0.7 < N / M < 1.0$, the thickness of the single-sided active material layer portion that has been coated is larger than the two-sided active material layer that has been coated, the pressure applied to the single-sided active material portion during rolling increases, thereby increasing the adhesion. Breakage of the electrode plate during battery winding and detachment of the active material layer from the current collector can be eliminated, thereby improving productivity.

[0022]

When the ratio of the active material density is 0.7 or less, the thickness of the single-sided active material layer portion becomes larger than the thickness of the two-sided active material portion, resulting in increased pressure on the single-sided active material portion during rolling, which causes the single-sided active material layer portion to break.

[0023]

In addition, when the ratio of the active material density is 1.0 or more, the thickness of the two-sided active material layer portion becomes larger than the thickness of the single-sided active material layer portion, resulting in a smaller pressure applied to the single-sided active material layer during rolling, which prevents the single-sided active material layer portion from being sufficiently rolled, leading to peeling of the single-sided active material layer portion.

FIG. 1 is a cross-sectional diagram describing a positive electrode active material formed structure of the electrode plate for a positive electrode of the present invention. FIG. 2 is a cross-sectional diagram describing an electrode plate for the positive electrode wherein the positive electrode active material layer is rolled formed in the present invention.

[0024]

The positive electrode is produced by applying a positive electrode coating to a positive electrode current collector made of a strip of aluminum foil using a coating device, drying, and then forming a positive electrode active material layer on a single side of the positive electrode current collector. Then, a positive electrode coating is similarly applied to a predetermined portion on the opposite side of the positive electrode current collector, creating a positive electrode on which a portion where the positive electrode active material is present on both sides of the current collector, a portion where the positive electrode active material is present only on a single side of the current collector, and a portion where the positive electrode active material is not present on either side of the current collector on only the current collector.

[0025]

Then, as in FIG. 1, the positive electrode active material layer portion that exists only on a single side of the current collector is thickened by applying multiple layers of positive electrode coating using a coating device and drying.

[0026]

Any well-known method can be applied to change the density of the positive electrode active material layer portion. The methods for changing the density of the positive electrode active material portion are illustrated below.

[0027]

Methods for applying multiple layers of the positive electrode active material portion include, for example, methods for stripe coating or screen printing on electrodes with uniform thickness, methods for increasing the extrusion flow rate of a delivery pump, or the like.

[0028]

As in FIG. 1, the electrode plate created by thickening the positive electrode active material layer portion that exists only on a single side of the current collector by applying multiple layers of positive electrode coating using a coating device and drying is roll-pressed from both sides using a press roller. At this time, as illustrated in FIG. 2, the thickness of the single-sided active material layer on the current collector is larger, resulting in greater pressure applied on the single-

sided active material layer compared to when multiple layers are not applied, and the single-sided active material layer is rolled more uniformly.

[0029]

(Embodiment 1)

To the positive electrode current collector 4 made of strip-shaped aluminum foil, 100 parts by weight of powder of LiCoO2 produced by Nichia Chemical, which is an active material, is mixed with 5 parts by weight of Denka Black, 4 parts by weight of a binder such as polyvinylidene fluoride (PVDF) is added thereto, and this was used as a thickening agent. This is then diluted with 7 parts by weight of a solvent of N-methyl-2-pyrrolidone produced by Mitsubishi Chemical, dispersion mixing was performed, and the prepared positive electrode coating is applied using a coating device at a speed of 15 m/min at a drying temperature of 200°C, and after applying a coating of 60 cm on the surface with an active material layer weight of 200 g/cm$^2$, the 10 cm coating is stopped. This process is repeated to create an electrode plate wherein portions that have the active material on the current collector and portions that have only the current collector intermittently exist.

[0030]

The coating on the rear side is the same as that of the front side, that is, 50 cm is applied at a drying temperature of 200°C, at a speed of 15 m/min, so that the weight of the active material layer on both sides of the applied portion reaches 400 g/cm$^2$, then the application is stopped at 20 cm. On the single-side coated portion 1, the coating device was used again to apply the positive electrode coating at a drying temperature of 200°C, at a speed of 15 m/min, so that the weight of the active material layer 120 g/cm$^2$.

[0031]

In relation to the obtained coated electrode plates, rolling was performed using a roll press machine to obtain a density of the active material layer on the two-side coated portion of 4.0 g/cc, and a density of the active material layer on the single-side coated portion of 5.7 g/cc, and cutting was then performed to the prescribed dimensions to produce a sheet-like positive electrode plate. This was used as the electrode plate in Embodiment 1.

[0032]

(Embodiment 2)

Next, the positive electrode plate of embodiment 2 was created by rolling after changing the coating amount of the single-side coated portion 1 while keeping the same active material density of the two-side coated portion 2, and creating a positive electrode plate by changing so that the active material density of the single-side coated portion 1 is 5.0 g/cc.

[0033]

(Embodiment 3)

Next, the positive electrode plate of embodiment 3 was created by rolling after changing the coating amount of the single-side coated portion 1 while keeping the same active material density of the two-side coated portion 2, and creating a positive electrode plate by changing so that the active material density of the single-side coated portion 1 is 4.4 g/cc.

[0034]

(Embodiment 4)

Additionally, the positive electrode plate of embodiment 4 was created by rolling after changing the coating amount of the single-side coated portion 1 while keeping the same active material density of the two-side coated portion 2, and creating a positive electrode plate by changing so that the active material density of the single-side coated portion 1 is 4.0 g/cc.

[0035]

(Comparative Example 1)

The positive electrode plate of comparative example 1 was created by rolling without changing the coating amount of the single-side coated portion 1 while keeping the same active material density of the two-side coated portion 2, and creating a positive electrode plate by changing so that the active material density of the single-side coated portion 1 is 2.0 g/cc.

[0036]

(Comparative Example 2)

The positive electrode plate of comparative example 2 was created by rolling after changing the coating amount of the single-side coated portion 1 while keeping the same active material density of the two-side coated portion 2, and creating a positive electrode plate by changing so that the active material density of the single-side coated portion 1 is 6.5 g/cc.

[0037]

(Comparative Example 3)

The positive electrode plate of comparative example 3 was created by rolling after changing the coating amount of the single-side coated portion 1 while keeping the same active material density of the two-side coated portion 2, and creating a positive electrode plate by changing so that the active material density of the single-side coated portion 1 is 8.0 g/cc.

[0038]

The positive electrode plates of comparative examples 1 to 4 and the positive electrode plates of comparative examples 1 and 2 obtained in this manner were subjected to a bending test.

[0039]

The method for the bending test is as follows.

[0040]

In the test, a positive electrode plate single-side coated portion having a width of 30 mm and a height of 100 mm was used. A round bar having a diameter of 2 mm was arranged along the width direction of the positive electrode plate single-side coated portion. A bending process was repeated 100 times in the length direction of the positive electrode plate single-side coated portion. Then, the length of the cracks that occurred in the width direction of the positive electrode plate single-side coated portion in contact with the round bar was visually observed.

The crack rate was calculated from the following formula.

Crack rate [%] = (length with cracks [mm] ÷ length of total width of the electrode plate [mm] ) × 100

The positive electrode plate in comparative example 3 could not undergo a bending test due to breakage of the active material layer occurring on the single-side active material portion when rolling using a roll press machine.

The results of the bending test are shown in Table 1.

[0041]

[Table 1]

| | Active Material Density N of Two-Side Coated Portion g/cc | Active Material Density M of Single-Side Coated Portion g/cc | Active Material Density Ratio N/M | Crack Rate % |
|---|---|---|---|---|
| Embodiment 1 | 4 | 5.7 | 0.7 | 0 |
| Embodiment 2 | 4 | 5 | 0.8 | 0 |
| Embodiment 3 | 4 | 4.4 | 0.9 | 0 |
| Embodiment 4 | 4 | 4 | 1 | 0 |
| Comparative Example 1 | 4 | 2 | 2 | 62 |
| Comparative Example 2 | 4 | 6.5 | 0.6 | 84 |
| Comparative Example 3 | 4 | 8 | 0.5 | Single-Side Coated Portion Breakage |

[0042]

According to the results of comparative example 1 in table 1, when the ratio of the active material density of the two-side coated portion and the active material density of the single-side coated portion is 1.0 or greater, the thickness of the two-sided active material layer portion becomes larger than the thickness of the single-sided active material layer portion, resulting in a smaller pressure applied to the single-sided active material layer during rolling, which prevents the single-sided active material layer portion from being sufficiently rolled, leading to peeling of the single-sided active material layer.

[0043]

According to the results of comparative examples 2 and 3, when the ratio of the active material density is 0.7 or less, the thickness of the single-sided active material layer portion becomes larger than the thickness of the two-sided active material portion, resulting in increased pressure on the single-sided active material portion during rolling, which increases the crack rate of the single-sided active material layer portion, causing breakage.

[0044]

According to the results of embodiments 1 to 4, when the ratio of the active material density N of the two-sided coated portion and the active material density M of the single-sided coating portion is $0.7 < N / M < 1.0$, there will be no peeling or breaking of the active material layer in the single-side coated portion.

[Industrial Applicability]

[0045]

The method for manufacturing an electrode plate for a non-aqueous electrolyte secondary battery according to the present invention is useful as a portable power source or the like having excellent battery characteristics, practicality, and productivity.

[Brief Description of Drawings]

[0046]

[FIG. 1] A schematic diagram illustrating a state of aluminum foil, which is a current collector, coated with positive electrode paint

[FIG. 2] A schematic diagram illustrating a state of a positive electrode coating plate after rolling

[Description of Reference Numerals]

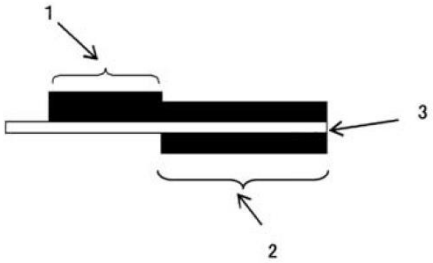
[0047]

1 Single-side coated portion

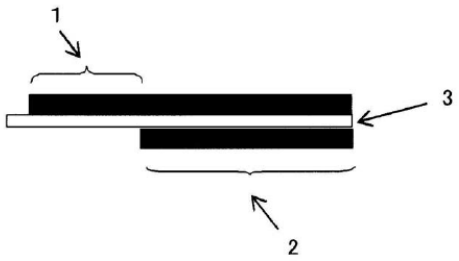
2 Two-side coated portion

3 Current collector

[FIG. 1]



[FIG. 2]



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# DECLARATION OF TRANSLATOR

I, Travis Huntsman, hereby declare as follows:

1. I personally performed the attached translation from Japanese into English of the patent number JP2009252349A that is entitled "非水電解液二次電池用電極板とその製造方法" in Japanese and "ELECTRODE PLATE FOR NON-AQUEOUS ELECTROLYTE SECONDARY BATTERY AND METHOD FOR MANUFACTURING SUCH " in English (also attached).

2. The attached translation is, to the best of my knowledge, a true, full and accurate translation of the attached Japanese document.

3. I am competent to perform this translation, because I have a ***Bachelor's Degree in Japanese and 10 years of translation experience.***.

4. I declare under the penalty of perjury under the laws of the United States that the foregoing is true and correct; and further declare that I am aware that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 1001 of Title 18 of the United States Code.

Dated: 1/16/2025

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