DESCRIPTION

SURFACE-TREATED STEEL SHEET AND PRODUCTION METHOD THEREFOR

TECHNICAL FIELD

[0001] The present invention relates to a surface-treated steel sheet and a production method therefor.

BACKGROUND ART

[0002] In recent years, portable devices, such as audio devices and cell phones, have been used in many fields, and as their operating power sources, alkaline batteries, which are primary batteries, and nickel hydrogen batteries, lithium ion batteries and the like, which are secondary batteries, are widely used. These batteries are required to have improved performance including an increased output and a prolonged life, and as an important constitutional element thereof, the battery cases for packing power generating elements including a positive electrode active substance, a negative electrode active substance and the like are also required to have improved performance.

[0003] For example, Patent Document 1 discloses a battery case having a specific nickel-cobalt alloy layer formed as the outermost surface which is to be the inner surface of a battery case when used in view of improving the battery characteristics.

RELATED ART

PATENT DOCUMENT

[0004] Patent Document 1: International Publication No. WO 2012/147843

SUMMARY

PROBLEM TO BE SOLVED

[0005] However, if the battery case disclosed in Patent Document 1 is used as a battery case of a battery containing a strongly alkaline electrolyte solution, such as an alkaline battery, a nickel hydrogen battery or the like, the contact resistance value of the inner surface of the battery case in contact with the electrolyte solution undesirably rises along with a lapse of time to impair the battery characteristics. With regard to this problem, further improvements of battery characteristics have been demanded, including suppression of impairing the battery characteristics after a lapse of time.

[0006] An object of the present disclosure is to provide a surface-treated steel sheet which ensures excellent battery characteristics when used in a battery case for a battery containing a strongly alkaline electrolyte solution, and can suppress a reduction in battery characteristics even after a lapse of time. Another object of the present disclosure is to provide a method for producing such a surface-treated steel sheet.

MEANS FOR SOLVING THE PROBLEM

[0007] The present inventors, who have conducted extensive research to achieve the above objects, have found that these objects can be achieved by a surface-treated steel sheet including a nickel-cobalt-iron diffusion layer formed on a steel sheet as an outermost surface layer thereof, wherein the Co concentration gradient ΔP_{Co} as a Co concentration change rate is controlled to fall within a specific range, the concentration of Co in the nickel-cobalt-iron diffusion layer being determined by performing measurement by radio frequency glow discharge optical emission spectrometry on the surface-treated steel sheet, and have completed the present disclosure.

[0007a] In an aspect of the present disclosure, there is provided a surface-treated steel sheet, comprising:

a steel sheet; and

a nickel-cobalt-iron diffusion layer formed on the steel sheet as an outermost layer,

wherein when the intensities for Ni, Co, and Fe are consecutively measured from a surface of the nickel-cobalt-iron diffusion layer in the depth direction by radio frequency glow discharge optical emission spectrometry, and the concentration of Ni, the concentration of Co, and the concentration of Fe at each of depth positions of the nickel-cobalt-iron diffusion layer are determined based on the intensities for Ni, Co, and Fe,

a Co concentration gradient ΔP_{Co} ranging from a depth position D_{Co_MAX} to a depth position $D_{Co_15\%}$ is 33% by mass/0.1 μm or less, where a depth position at which the concentration of Co is maximum is defined as D_{Co_MAX} and a depth position which is located closer to the steel sheet than the depth position D_{Co_MAX} and at which the concentration of Co is 15% of the maximum value is defined as $D_{Co_15\%}$,

a Ni concentration gradient ΔP_{Ni} ranging from a depth position D_{Ni_MAX} to a depth position $D_{Ni_15\%}$ is 15% by mass/μm or more, where a depth position at which the concentration of Ni is maximum is defined as D_{Ni_MAX} and a depth position which is located closer to the steel sheet than the depth position D_{Ni_MAX} and at which the concentration of Ni is 15% of the maximum value is defined as $D_{Ni_15\%}$.

[0007b] In another aspect, there is provided a battery case, comprising the surface-treated steel sheet as defined above.

[0007c] In another aspect, there is provided a battery including the battery case as defined above.

[0007d] In another aspect, there is provided a method for producing the surface-treated steel sheet as defined above, the method comprising the steps of:

forming a nickel plating layer containing 0.2 to 12.5 g/m^2 of nickel on a steel sheet;

forming a cobalt plating layer containing 0.2 to 5.0 g/m^2 of cobalt on the nickel plating layer; and

performing a heat treatment at a temperature of 450 to 900°C on the steel sheet having the nickel plating layer and the cobalt plating layer to form a nickel-cobalt-iron diffusion layer as an outermost layer thereof, the nickel-cobalt-iron diffusion layer having a Co concentration gradient ΔP_{Co} of 33% by mass/0.1 μm or less.

[0008] Namely, the present disclosure provides a surface-treated steel sheet comprising: a steel sheet; and a nickel-cobalt-iron diffusion layer

formed on the steel sheet as an outermost layer, wherein when the intensities for Ni, Co, and Fe are consecutively measured from a surface of the nickel-cobalt-iron diffusion layer in the depth direction by radio frequency glow discharge optical emission spectrometry, and the concentration of Ni, the concentration of Co, and the concentration of Fe at each of depth positions of the nickel-cobalt-iron diffusion layer are determined based on the intensities for Ni, Co, and Fe, a Co concentration gradient ΔP_{Co} ranging from a depth position D_{Co_MAX} to a depth position $D_{Co_15\%}$ is 33% by mass/0.1 μm or less, where a depth position at which the concentration of Co is maximum is defined as D_{Co_MAX} and a depth position which is located closer to the steel sheet than the depth position D_{Co_MAX} and at which the concentration of Co is 15% of the maximum value is defined as $D_{Co_15\%}$.

[0009] In the surface-treated steel sheet according to the present disclosure, when the intensities for Ni, Co, and Fe are consecutively measured from the surface of the nickel-cobalt-iron diffusion layer in the depth direction by radio frequency glow discharge optical emission spectrometry, and the concentration of Ni, the concentration of Co, and the concentration of Fe at each of depth positions of the nickel-cobalt-iron diffusion layer are determined based on the intensities for Ni, Co, and Fe, a Ni concentration gradient ΔP_{Ni} ranging from a depth position D_{Ni_MAX} to a depth position $D_{Ni_15\%}$ is preferably 15% by mass/μm or more, where a depth position at which the concentration of Ni is maximum is defined as D_{Ni_MAX}, and a depth position which is located closer to the steel sheet than the depth position D_{Ni_MAX} and at which the concentration of Ni is 15% of the maximum value is defined as $D_{Ni_15\%}$.

[0010] In the surface-treated steel sheet according to the present disclosure, when the intensities for Ni, Co, and Fe are consecutively measured from the surface of the nickel-cobalt-iron diffusion layer in the depth direction by radio frequency glow discharge optical emission

spectrometry, and the concentration of Ni, the concentration of Co, and the concentration of Fe at each of depth positions of the nickel-cobalt-iron diffusion layer are determined based on the intensities for Ni, Co, and Fe, preferably, the Ni concentration $P_{Ni}(D_{Ni_0.5\%})$ at a depth position $D_{Ni_0.5\%}$ is 70% by mass or less, the Co concentration $P_{Co}(D_{Ni_0.5\%})$ at the depth position $D_{Ni_0.5\%}$ is 5% by mass or more, and the Fe concentration $P_{Fe}(D_{Ni_0.5\%})$ at the depth position $D_{Ni_0.5\%}$ is 15% by mass or more, where among depth positions at which the intensity for Ni in the nickel-cobalt-iron diffusion layer is 0.5% of the maximum value, the depth position located closest to the surface is defined as $D_{Ni_0.5\%}$.

In the surface-treated steel sheet according to the present disclosure, the Fe concentration $P_{Fe}(D_{Ni_0.5\%})$ at the depth position $D_{Ni_0.5\%}$ is preferably 30% by mass or more.

In the surface-treated steel sheet according to the present disclosure, the Co concentration $P_{Co}(D_{Ni_0.5\%})$ at the depth position $D_{Ni_0.5\%}$ is preferably 12% by mass or more.

[0011] In the surface-treated steel sheet according to the present disclosure, the Co content in the nickel-cobalt-iron diffusion layer is preferably 0.2 g/m^2 or more.

In the surface-treated steel sheet according to the present disclosure, the Ni content in the nickel-cobalt-iron diffusion layer is preferably 0.2 to 12.5 g/m^2.

In the surface-treated steel sheet according to the present disclosure, the Ni content in the nickel-cobalt-iron diffusion layer is preferably 0.2 to 7.0 g/m^2.

In the surface-treated steel sheet according to the present disclosure, the total content of Ni and Co contained in the nickel-cobalt-iron diffusion layer is preferably 1.6 to 14.0 g/m^2.

In the surface-treated steel sheet according to the present disclosure, the total content of Ni and Co contained in the nickel-cobalt-iron diffusion layer is preferably 1.6 to 7.5 g/m^2.

[0012] Preferably, the surface-treated steel sheet according to the present disclosure further comprises an iron-nickel diffusion layer between the steel sheet and the nickel-cobalt-iron diffusion layer.

In the surface-treated steel sheet according to the present disclosure, the total content of Ni contained in the nickel-cobalt-iron diffusion layer and the iron-nickel diffusion layer is preferably 1.0 to 12.5 g/m^2.

In the surface-treated steel sheet according to the present disclosure, the total content of Ni and Co contained in the nickel-cobalt-iron diffusion layer and the iron-nickel diffusion layer is preferably 1.6 to 14.0 g/m^2.

[0013] Moreover, the present disclosure provides a battery case comprising any one of the surface-treated steel sheets above.

The present disclosure provides a battery including the battery case.

[0014] Furthermore, the present disclosure provides a method for producing a surface-treated steel sheet, comprising the steps of: forming a nickel plating layer containing 0.2 to 12.5 g/m^2 of nickel on a steel sheet; forming a cobalt plating layer containing 0.2 to 5.0 g/m^2 of cobalt on the nickel plating layer; and performing a heat treatment at a temperature of 450 to 900°C on the steel sheet having the nickel plating layer and the cobalt plating layer to form a nickel-cobalt-iron diffusion layer as an outermost layer thereof, the nickel-cobalt-iron diffusion layer having a Co concentration gradient ΔP_{Co} of 33% by mass/0.1 μm or less.

EFFECTS

[0015] The present disclosure can provide a surface-treated steel sheet which ensures excellent battery characteristics when used in a battery case for a battery containing a strongly alkaline electrolyte solution, and can suppress a reduction in battery characteristics even after a lapse of time. The present disclosure can also provide a method for producing such a surface-treated steel sheet.

BRIEF DESCRIPTION OF DRAWINGS

[0016] Figure 1 is a perspective view showing one embodiment of a battery including the surface-treated steel sheet according to the present invention.

Figure 2 is a cross-sectional view taken along the line II-II in Figure 1.

Figure 3 is an enlarged cross-sectional view of a portion III in Figure 2 in one embodiment of the surface-treated steel sheet according to the present invention.

Figure 4 is a diagram for illustrating a method for producing the surface-treated steel sheet shown in Figure 3.

Figure 5 shows graphs for illustrating measurement by radio frequency glow discharge optical emission spectrometry.

Figure 6 shows graphs for illustrating a method of determining the Co concentration gradient ΔP_{Co} and the Ni concentration gradient ΔP_{Ni}.

Figure 7 is a cross-sectional view showing a second embodiment of the surface-treated steel sheet according to the present invention.

Figure 8 shows graphs showing the results obtained by measuring the surface-treated steel sheet in Example 2 by radio frequency glow discharge optical emission spectrometer.

DESCRIPTION OF EMBODIMENTS

CLAIMS

1. A surface-treated steel sheet, comprising:

a steel sheet; and

a nickel-cobalt-iron diffusion layer formed on the steel sheet as an outermost layer,

wherein when the intensities for Ni, Co, and Fe are consecutively measured from a surface of the nickel-cobalt-iron diffusion layer in the depth direction by radio frequency glow discharge optical emission spectrometry, and the concentration of Ni, the concentration of Co, and the concentration of Fe at each of depth positions of the nickel-cobalt-iron diffusion layer are determined based on the intensities for Ni, Co, and Fe,

a Co concentration gradient ΔP_{Co} ranging from a depth position D_{Co_MAX} to a depth position $D_{Co_15\%}$ is 33% by mass/0.1 μm or less, where a depth position at which the concentration of Co is maximum is defined as D_{Co_MAX} and a depth position which is located closer to the steel sheet than the depth position D_{Co_MAX} and at which the concentration of Co is 15% of the maximum value is defined as $D_{Co_15\%}$,

a Ni concentration gradient ΔP_{Ni} ranging from a depth position D_{Ni_MAX} to a depth position $D_{Ni_15\%}$ is 15% by mass/μm or more, where a depth position at which the concentration of Ni is maximum is defined as D_{Ni_MAX} and a depth position which is located closer to the steel sheet than the depth position D_{Ni_MAX} and at which the concentration of Ni is 15% of the maximum value is defined as $D_{Ni_15\%}$.

2. The surface-treated steel sheet according to claim 1,

wherein when the intensities for Ni, Co, and Fe are consecutively measured from the surface of the nickel-cobalt-iron diffusion layer in the

depth direction by radio frequency glow discharge optical emission spectrometry, and the concentration of Ni, the concentration of Co, and the concentration of Fe at each of depth positions of the nickel-cobalt-iron diffusion layer are determined based on the intensities for Ni, Co, and Fe,

the Ni concentration $P_{Ni}(D_{Ni_0.5\%})$ at a depth position $D_{Ni_0.5\%}$ is 70% by mass or less, the Co concentration $P_{Co}(D_{Ni_0.5\%})$ at the depth position $D_{Ni_0.5\%}$ is 5% by mass or more, and the Fe concentration $P_{Fe}(D_{Ni_0.5\%})$ at the depth position $D_{Ni_0.5\%}$ is 15% by mass or more, where among depth positions at which the intensity for Ni in the nickel-cobalt-iron diffusion layer is 0.5% of the maximum value, the depth position located closest to the surface is defined as $D_{Ni_0.5\%}$.

3. The surface-treated steel sheet according to claim 2, wherein the Fe concentration $P_{Fe}(D_{Ni_0.5\%})$ at the depth position $D_{Ni_0.5\%}$ is 30% by mass or more.

4. The surface-treated steel sheet according to claim 2 or 3, wherein the Co concentration $P_{Co}(D_{Ni_0.5\%})$ at the depth position $D_{Ni_0.5\%}$ is 12% by mass or more.

5. The surface-treated steel sheet according to any one of claims 1 to 4, wherein the Co content in the nickel-cobalt-iron diffusion layer is 0.2 g/m^2 or more.

6. The surface-treated steel sheet according to any one of claims 1 to 5, wherein the Ni content in the nickel-cobalt-iron diffusion layer is 0.2 to 12.5 g/m^2.

7. The surface-treated steel sheet according to claim 6, wherein the Ni content in the nickel-cobalt-iron diffusion layer is 0.2 to 7.0 g/m^2.

8. The surface-treated steel sheet according to any one of claims 1 to 7, wherein the total content of Ni and Co contained in the nickel-cobalt-iron diffusion layer is 1.6 to 14.0 g/m^2.

9. The surface-treated steel sheet according to claim 8, wherein the total content of Ni and Co contained in the nickel-cobalt-iron diffusion layer is 1.6 to 7.5 g/m^2.

10. The surface-treated steel sheet according to any one of claims 1 to 9, further comprising an iron-nickel diffusion layer between the steel sheet and the nickel-cobalt-iron diffusion layer.

11. The surface-treated steel sheet according to claim 10, wherein the total content of Ni contained in the nickel-cobalt-iron diffusion layer and the iron-nickel diffusion layer is 1.0 to 12.5 g/m^2.

12. The surface-treated steel sheet according to claim 10 or 11, wherein the total content of Ni and Co contained in the nickel-cobalt-iron diffusion layer and the iron-nickel diffusion layer is 1.6 to 14.0 g/m^2.

13. A battery case, comprising the surface-treated steel sheet according to any one of claims 1 to 12.

14. A battery including the battery case according to claim 13.

15. A method for producing the surface-treated steel sheet according to any one of claims 1 to 8, the method comprising the steps of:

forming a nickel plating layer containing 0.2 to 12.5 g/m^2 of nickel on a steel sheet;

forming a cobalt plating layer containing 0.2 to 5.0 g/m^2 of cobalt on the nickel plating layer; and

performing a heat treatment at a temperature of 450 to 900°C on the steel sheet having the nickel plating layer and the cobalt plating layer to form a nickel-cobalt-iron diffusion layer as an outermost layer thereof, the nickel-cobalt-iron diffusion layer having a Co concentration gradient ΔP_{Co} of 33% by mass/0.1 μm or less.