

[Specification]

[Title of the Invention]

SURFACE-TREATED STEEL SHEET

[Technical Field of the Invention]

5 [0001]

The present invention relates to a surface-treated steel sheet.

Priority is claimed on Japanese Patent Application No. 2021-055665 filed March 29, 2021, the content of which is incorporated herein by reference.

[Related Art]

10 [0002]

Plated steel sheets (zinc-based plated steel sheets) in which a plated layer containing a zinc as a main component (zinc-based plated layer) is formed on a surface of a steel sheet have been heretofore used in a wide range of applications such as automobiles, building materials and household electric appliances. By forming a zinc-based plated layer, excellent corrosion resistance is imparted to a steel sheet.

In recent years, zinc-based plated steel sheets have also been used as design materials because a plated layer has a unique external appearance, and the exterior color changes from silvery-white to subdued grayish-brown due to oxidation of the plated layer. Of these, zinc-based plated steel sheets containing Sb in a plated layer are used as materials having higher designability because a bloomed blossom-like crystal pattern (spangle pattern) originating from crystals of a zinc is notably formed.

[0003]

However, zinc-based plated steel sheets have a problem that white rust which is zinc oxide is generated due to corrosion, and the white rust impairs the external appearance.

Heretofore, as a common technique for suppressing generation of such white rust, chemical conversion treatment mainly including a resin has been performed on a zinc-based plated layer as disclosed in Patent Documents 1 to 4.

[0004]

5 However, in chemical conversion treatment containing a resin as disclosed in Patent Documents 1 to 4, black refuse resistance during processing is insufficient because an organic resin component is used. The black refuse resistance during processing refers to resistance to a situation in which when a metal is subjected to processing such as press processing, a metal material surface receives heavy sliding movement from a press
10 die or the like, so that a black deposit substance is generated from a film covering the metal material surface, solidly stuck, and deposited, resulting in impairment of the external appearance. Generation of black refuse substance may be caused by an organic resin component for chemical conversion treatment.

[0005]

15 As chemical conversion treatment capable of suppressing generation of the black deposit, chemical conversion treatment mainly including an organosilicon compound having a cyclic siloxane bond as disclosed in Patent Document 5 is known. Patent Document 5 indicates that chemical conversion treatment mainly including an organosilicon compound having a cyclic siloxane bond enables suppression of generation
20 of black deposit even in severe processing due to the extremely small organic resin content, and exhibits high fingerprint resistance and white rust resistance.

[Citation List]

[Patent Document]

[0006]

25 [Patent Document 1]

Japanese Unexamined Patent Application, First Publication No. 2020-7606

[Patent Document 2]

PCT International Publication No. WO 2014/084371

[Patent Document 3]

5 PCT International Publication No. WO 2018/083784

[Patent Document 4]

PCT International Publication No. WO 2016/162422

[Patent Document 5]

PCT International Publication No. WO 2012/147860

10 [Summary of Invention]

[Problems to be Solved by the Invention]

[0007]

However, chemical conversion treatment mainly including an organosilicon compound having a cyclic siloxane bond as disclosed in Patent Document 5 has been
15 developed for conventional applications of zinc plating, that is, applications other than design applications. On the other hand, zinc-based plated steel sheets have been used as design materials in recent years as described above. In design applications, higher fingerprint resistance is required as compared to conventional applications, but there is a possibility that chemical conversion treatment mainly including an organosilicon
20 compound having a cyclic siloxane bond as shown in Patent Document 5 cannot sufficiently meet requirements in design applications.

[0008]

In view of such a background, an object of the present invention is to provide a surface-treated steel sheet including a zinc-based plated layer and a chemical conversion
25 treatment layer formed on a surface of the zinc-based plated layer, and having sufficient

corrosion resistance (white rust resistance), and excellent fingerprint resistance higher than before (sufficient performance even for design applications).

[Means for Solving the Problem]

[0009]

5 The present inventors have conducted studies on a method for improving fingerprint resistance in a surface-treated steel sheet including a zinc-based plated layer and a chemical conversion treatment layer. It is to be noted that in relation to black deposit resistance, the studies have been conducted on the premise that the chemical conversion treatment layer has no organic resin.

10 As a result, the following findings were obtained.

(a) A surface that is unlikely to be stained with fingerprints can be formed by segregating P in a surface layer area of the chemical conversion treatment layer to adjust surface free energy.

(b) Not only fingerprint resistance but also corrosion resistance (white rust
15 resistance) can be improved by further segregating F in the vicinity of an interface with a plated layer in the chemical conversion treatment layer.

(c) Blackening resistance can also be improved by further segregating Sb in the vicinity of an interface with the plated layer in the chemical conversion treatment layer.

[0010]

20 The present invention has been made on the basis of the above-described findings. The gist of the present invention is as follows.

[1] A surface-treated steel sheet according to an aspect of the present invention includes a steel sheet, a zinc-based plated layer formed on a surface of the steel sheet, and a chemical conversion treatment layer formed on a surface of the zinc-based plated
25 layer, in which the chemical conversion treatment layer contains Si, C, O and P, the

chemical conversion treatment layer has a C concentration of 20.0 mass% or more, an O concentration of 15.0 mass% or more, a Si concentration of 10.0 mass% or more, and a P concentration of 0.10 mass% or more, when t is a thickness of the chemical conversion treatment layer, an area starting from a surface of the chemical conversion treatment layer and ending at a position of $t/10$ from the surface of the chemical conversion treatment layer in a thickness direction is a surface layer region, an area starting from the position of $9t/10$ from the surface of the chemical conversion treatment layer in the thickness direction and ending at an interface between the chemical conversion treatment layer and the zinc-based plated layer is an interface side region, and a region sandwiched between the surface layer region and the interface side region is an intermediate region and a maximum value of a P concentration of the surface layer region is 1.5 times to 5.0 times an average P concentration of an intermediate region,.

[2] In the surface-treated steel sheet of [1], Al may be present in the interface side region, and an F content of the interface side region may be 20% or more of an F content of the entire chemical conversion treatment layer.

[3] In the surface-treated steel sheet of [1] or [2], Sb may be present in the interface side region.

[4] In the surface-treated steel sheet of any one of [1] to [3], a surface of the zinc-based plated layer may be regular spangle-finished.

[Effects of the Invention]

[0011]

According to the above-described aspect of the present invention, it is possible to provide a surface-treated steel sheet excellent in fingerprint resistance.

According to a preferred aspect of the present invention, it is possible to provide a surface-treated steel sheet excellent in corrosion resistance and/or blackening resistance

in addition to fingerprint resistance.

[Brief Description of the Drawings]

[0012]

FIG. 1 is a view showing an example of a cross section of a surface-treated steel
5 sheet according to the present embodiment.

FIG. 2 is a view illustrating a chemical conversion treatment layer of the
surface-treated steel sheet according to the present embodiment.

FIG. 3 is a diagram showing an example of a results of performing continuous
point analysis using EDS for the chemical conversion treatment layer of the surface-
10 treated steel sheet according to the present embodiment.

[Embodiment of the Invention]

[0013]

Hereinafter, a surface-treated steel sheet according to an embodiment of the
present invention (surface-treated steel sheet according to the present embodiment) will
15 be described.

As shown in FIG. 1, a surface-treated steel sheet 1 according to the present
embodiment includes a steel sheet 11, a zinc-based plated layer 12 formed on a surface of
the steel sheet 11, and a chemical conversion treatment layer 13 formed on a surface of
the zinc-based plated layer 12.

20 The chemical conversion treatment layer 13 contains Si, C, O and P, and has a C
concentration of 20.0 mass% or more, an O concentration of 15.0 mass% or more, a Si
concentration of 10.0 mass% or more, and a P concentration of 0.10 mass% or more.

As shown in FIG. 2, when t is a thickness of the chemical conversion treatment layer 13,
an area starting from a surface of the chemical conversion treatment layer 13 and ending
25 at a position of $t/10$ from the surface of the chemical conversion treatment layer 13 in a

thickness direction is a surface layer region 101, an area starting from the position of $9t/10$ from the surface of the chemical conversion treatment layer 13 in the thickness direction and ending at an interface between the chemical conversion treatment layer 13 and the zinc-based plated layer 12 (at a position of t from the surface in the thickness direction) is an interface side region 102, , and a region sandwiched between the surface layer region 101 and the interface side region 102 is the intermediate region 103, a maximum value of a P concentration of the surface layer region 101 is 1.5 to 5.0 times the average P concentration of an intermediate region 103.

In FIG. 1, the zinc-based plated layer 12 and the chemical conversion treatment layer 13 (surface layer region 101 + intermediate region 103 + interface side region 102) are formed on one surface of the steel sheet 11, but may be formed on both surfaces of the steel sheet 11.

[0014]

<Steel sheet (base steel sheet)>

The zinc-based plated layer 12 and the chemical conversion treatment layer 13 characterize the surface-treated steel sheet 1 according to the present embodiment. Therefore, the steel sheet 11 is not particularly limited. The steel sheet 11 may be determined according to a product to be applied, required strength, sheet thickness and the like, and for example, a hot-rolled steel sheet described in JIS G 3193: 2019 or a cold-rolled steel sheet described in JIS G 3141: 2017 may be used.

[0015]

<Zinc-based plated layer>

The zinc-based plated layer 12 of the surface-treated steel sheet 1 according to the present embodiment is a zinc-based plated layer formed on a surface of the steel sheet 11 and containing a zinc.

[0016]

[Chemical composition]

The chemical composition of the zinc-based plated layer 12 is not limited as long as it is a plated layer containing a zinc as a main component.

5 However, a chemical composition of Al: 4.0% or more and less than 25.0%, Mg: 0% or more and less than 12.5%, Sn: 0% to 20%, Bi: 0% or more and less than 5.0%, In: 0% or more and less than 2.0%, Ca: 0% to 3.0%, Y: 0% to 0.5%, La: 0% or more and less than 0.5%, Ce: 0% or more and less than 0.5%, Si: 0% or more and less than 2.5%, Cr: 0% or more and less than 0.25%, Ti: 0% or more and less than 0.25%, Ni: 0% or more and less than 0.25%, Co: 0% or more and less than 0.25%, V: 0% or more and less than 0.25%, Nb: 0% or more and less than 0.25%, Cu: 0% or more and less than 0.25%, Mn: 0% or more and less than 0.25%, Fe: 0% to 5.0%, Sb: 0% or more and less than 0.5%, Sr: 0% or more and less than 0.5%, Pb: 0% or more and less than 0.5%, B: 0% or more and less than 0.5%, and remainder: Zn and impurities is preferable because a more
10 significant effect of improving corrosion resistance is obtained.
15

[0017]

The reason why the above-mentioned chemical composition of the zinc-based plated layer (hereinafter, sometimes referred to simply as a plated layer) 12 is preferable will be described. Hereinafter, a numerical value range indicated by numerical values
20 with the term “to” interposed therebetween essentially includes the numerical values at both ends as a lower limit and an upper limit, respectively. That is, for example, “0% to 20%” represents 0% or more and 20% or less.

Unless otherwise specified, “%” related to the chemical composition of the zinc-based plated layer represents mass%.

25 [0018]

[Al: 4.0% or more and less than 25.0%]

Al is an element effective for improving corrosion resistance in the zinc-based plated layer. When Al is made to be contained in the chemical conversion treatment layer, it is preferable that the plated layer contains Al. For obtaining the above-

5 described effect to a sufficient extent, the Al concentration is preferably 4.0% or more.

On the other hand, if the Al concentration is 25.0% or more, the corrosion resistance of a cut end surface of the zinc-based plated layer decreases. For this reason, the Al concentration is preferably less than 25.0%.

[0019]

10 The zinc-based plated layer 12 may contain Al, with the remainder consisting of Zn and impurities. However, the following elements may be further contained.

[0020]

[Mg: 0% or more and less than 12.5%]

Mg is an element having an effect of enhancing the corrosion resistance of the plated layer. For obtaining the above-described effect to a sufficient extent, the Mg

15 concentration is preferably more than 1.0%.

On the other hand, a Mg concentration of 12.5% or more does not lead to further enhancement of the corrosion resistance improving effect, and may deteriorate the workability of the plated layer. In addition, there is a manufacture-related problem such

20 as an increase in amount of dross generated in a plating bath. For this reason, the Mg concentration is preferably less than 12.5%.

[0021]

[Sn: 0% to 20.0%]

[Bi: 0% or more and less than 5.0%]

25 [In: 0% or more and less than 2.0%]

These elements contribute to improvement of corrosion resistance and sacrificial corrosion resistance. Therefore, one or more of these elements may be contained. For obtaining the above-described effect to a sufficient extent, the concentration of each of the elements is preferably 0.05% or more, or 0.1% or more.

5 Of these, Sn is preferable because it is a low-melting-point metal and can be easily incorporated without impairing the properties of the plating bath.

On the other hand, if the Sn concentration is more than 20.0%, the Bi concentration is 5.0% or more, or the In concentration is 2.0% or more, corrosion resistance decreases. For this reason, it is preferable that the Sn concentration is 20.0%
10 or less, the Bi concentration is less than 5.0%, and the In concentration is less than 2.0%.
[0022]

[Ca: 0% to 3.0%]

Ca is an element which reduces the amount of formation of dross likely to be formed during operation, and contributes to improvement of plating manufacturability.
15 Therefore, Ca may be contained. For obtaining this effect, the Ca concentration is preferably 0.1% or more.

On the other hand, if the Ca concentration is high, the corrosion resistance of a flat portion itself of the plated layer tends to be deteriorated, and the corrosion resistance of the periphery of the weld may also be deteriorated. For this reason, the Ca
20 concentration is preferably 3.0% or less.

[0023]

[Y: 0% to 0.5%]

[La: 0% or more and less than 0.5%]

[Ce: 0% or more and less than 0.5%]

25 Y, La and Ce are elements that contribute to improvement of corrosion

resistance. For obtaining this effect, it is preferable that one or more of these elements are each contained at 0.05% or more, or 0.1% or more.

On the other hand, if the concentration of these elements is excessively high, there is a concern that the viscosity of the plating bath increases, and thus the initial
5 make-up of the plating bath itself is often difficult, and a steel having good plating properties cannot be manufactured. For this reason, it is preferable that the Y concentration is 0.5% or less, the La concentration is less than 0.5%, and the Ce concentration is less than 0.5%.

[0024]

10 [Si: 0% or more and less than 2.5%]

Si is an element that contributes to improvement of corrosion resistance. In addition, Si is an element having an effect of enhancing adhesion between the steel sheet and the plated layer by suppressing a situation in which an alloy layer formed between a steel sheet surface and the plated layer in formation of the plated layer on the steel sheet
15 has an excessively large thickness. For obtaining these effects, the Si concentration is preferably 0.1% or more. The Si concentration is more preferably 0.2% or more.

On the other hand, if the Si concentration is 2.5% or more, an excessive amount of Si is precipitated in the plated layer, so that not only corrosion resistance decreases but also the workability of the plated layer is deteriorated. Therefore, the Si concentration
20 is preferably less than 2.5%. The Si concentration is more preferably 1.5% or less.

[0025]

[Cr: 0% or more and less than 0.25%]

[Ti: 0% or more and less than 0.25%]

[Ni: 0% or more and less than 0.25%]

25 [Co: 0% or more and less than 0.25%]

[V: 0% or more and less than 0.25%]

[Nb: 0% or more and less than 0.25%]

[Cu: 0% or more and less than 0.25%]

[Mn: 0% or more and less than 0.25%]

5 These elements contribute to improvement of corrosion resistance. For obtaining this effect, it is preferable that the concentration of at least one of the elements is 0.05% or more.

 On the other hand, if the concentration of these elements is excessively high, there is a concern that the viscosity of the plating bath increases, and thus the initial
10 make-up of the plating bath itself is often difficult, and a steel having good plating properties cannot be manufactured. For this reason, the concentration of each of the elements is preferably less than 0.25%.

[0026]

[Fe: 0% to 5.0%]

15 Fe is mixed in the plated layer as an impurity in manufacture of the plated layer. Fe may be contained at up to about 5.0%, and as long as the content of Fe is in this range, there is little adverse impact on the effect of the surface-treated steel sheet according to the present embodiment. For this reason, the Fe concentration is preferably 5.0% or less.

20 [0027]

[B: 0% or more and less than 0.5%]

 B is an element that bonds to Zn, Al, Mg or the like to form various intermetallic compounds when contained in the plated layer. Such intermetallic compounds have an effect of improving LME. For obtaining this effect, the B concentration is preferably
25 0.05% or more.

On the other hand, if the B concentration is excessively high, there is a concern that the melting point of plating significantly increases, and this plating operability is deteriorated, so that a surface-treated steel sheet having good plating properties cannot be obtained. For this reason, the B concentration is preferably less than 0.5%.

5 [0028]

[Sb: 0% or more and less than 0.5%]

When the plated layer contains Sb, the external appearance of the plated layer changes, a spangle is formed, and improvement in metallic gloss is observed. For obtaining this effect, the Sb concentration is preferably 0.03% or more.

10 On the other hand, if the Sb concentration is excessively high, there is a concern that the viscosity of the plating bath increases, and thus the initial make-up of the plating bath itself is often difficult, and a steel having good plating properties cannot be manufactured. For this reason, the Sb concentration is preferably less than 0.5%.

[0029]

15 [Sr: 0% or more and less than 0.5%]

[Pb: 0% or more and less than 0.5%]

Like Sb, Sr and Pb are elements that contribute to formation of a spangle. For obtaining this effect, it is preferable that the concentration of at least one of Sr and Pb is 0.05% or more.

20 On the other hand, if the concentration of these elements is excessively high, there is a concern that the viscosity of the plating bath increases, and thus the initial make-up of the plating bath itself is often difficult, and a steel having good plating properties cannot be manufactured. For this reason, the concentration of each of the elements is preferably less than 0.5%.

25 [0030]

The thickness of the zinc-based plated layer 12 is not limited, and is preferably 10 g/m² or more per one surface for improving corrosion resistance. On the other hand, a thickness of more than 200 g/m² does not lead to further enhancement of corrosion resistance, and causes an economic disadvantage. For this reason, the thickness is preferably 200 g/m² or less.

[0031]

[Spangle]

From the viewpoint of designability, it is preferable that a spangle pattern is formed on a surface of the zinc-based plated layer 12 in the surface-treated steel sheet 1 according to the present embodiment.

The spangle pattern generally includes a regular spangle and a minimized spangle, and from the viewpoint of designability, a regular spangle is more preferable. That is, it is preferable that surface of the zinc-based plated layer 12 in the surface-treated steel sheet 1 according to the present embodiment is regular spangle-finished.

[0032]

<Chemical conversion treatment layer>

The chemical conversion treatment layer 13 of the surface-treated steel sheet 1 according to the present embodiment contains Si, C, O and P, and has a C concentration of 20.0 mass% or more, an O concentration of 15.0 mass% or more, and a Si concentration of 10.0 mass% or more. That is, since the chemical conversion treatment layer 13 contains an inorganic component as a main component, excellent black deposit resistance is obtained. The upper limit of each of the C concentration, the O concentration and the Si concentration is not specified, and the C concentration is more than 40.0 mass% mainly when the main component is an organic component. For this reason, the C concentration is preferably 40.0 mass% or less. From the viewpoint of the

powdering property of the chemical conversion treatment layer 13, it is preferable that the O concentration is 40.0 mass% or less, and the Si concentration is 25.0 mass% or less.

The chemical conversion treatment layer 13 of the surface-treated steel sheet according to the present embodiment is obtained by applying a treatment solution containing an organosilicon compound such as a silane coupling agent and a P compound such as a phosphate on a plated layer containing a zinc under predetermined conditions and performing drying. Therefore, the chemical conversion treatment layer 13 of the surface-treated steel sheet according to the present embodiment contains Si, C, O and P.

If P is not contained at 0.10 mass% or more, generally required corrosion resistance cannot be obtained. For this reason, the P concentration is 0.10 mass% or more. On the other hand, an excessively high P concentration is not preferable because powdering is likely to occur. If the P concentration of the treatment liquid is high, the amount of soluble components tends to be large, leading a decrease in corrosion resistance. For this reason, the P concentration of the chemical conversion treatment layer is preferably 5.0 mass% or less.

A F compound (fluorine compound), a Zr compound (zirconium compound) and/or a V compound (vanadium compound) may be contained in the treatment solution so that the chemical conversion treatment layer 13 of the surface-treated steel sheet according to the present embodiment further contains F, Zr and/or V derived from these compounds. The chemical conversion treatment layer 13 may contain Al, Zn, Sb or the like eluted from the zinc-based plated layer.

[0033]

In the chemical conversion treatment layer 13, the solid content mass ratio between P derived from the phosphorus compound (W) and Si derived from the

organosilicon compound (V) [(Ws)/(Vs)], is preferably 0.15 to 0.31. A solid content mass ratio [(Ws)/(Vs)] of less than 0.15 is not preferable because an effect of the phosphorus compound (W) as an elutability inhibitor cannot be obtained.

On the other hand, a solid content mass ratio [(Ws)/(Vs)] of more than 0.31 is not preferable because the chemical conversion treatment layer is significantly dissolved in water. The solid content mass ratio [(Ws)/(Vs)] is more preferably 0.16 to 0.28, still more preferably 0.18 to 0.25.

[0034]

In the chemical conversion treatment layer 13 of the surface-treated steel sheet 1 according to the present embodiment, when t is a thickness of the chemical conversion treatment layer, an area starting from a surface of the chemical conversion treatment layer 13 and ending at a position of t/10 from the surface of the chemical conversion treatment layer 13 in a thickness direction is a surface layer region 101, an area starting from the position of 9t/10 from the surface of the chemical conversion treatment layer 13 in the thickness direction and ending at an interface between the chemical conversion treatment layer 13 and the zinc-based plated layer 12 is an interface side region 102, and a region sandwiched between the surface layer region and the interface side region is the intermediate region 103, a maximum value of a P concentration of the surface layer region 101 is 1.5 times to 5.0 times the average P concentration of an intermediate region 103.

A surface that is unlikely to be stained with fingerprints can be formed by segregating P in a surface layer region of the chemical conversion treatment layer 13 to adjust surface free energy. (Fingerprint resistance is improved.)

If the maximum value of the P concentration in the surface layer region 101 is less than 1.5 times the average P concentration of the intermediate region 103, fingerprint

resistance becomes insufficient. Preferably, the maximum value of the P concentration in the surface layer region 101 is not less than 2.0 times the average P concentration in the intermediate region 103. In this case, fingerprint resistance can be further improved.

On the other hand, if the maximum value of the P concentration in the surface layer region is more than 5.0 times the average P concentration in the intermediate region, a brittle phosphorus compound is formed on the surface, so that powdering occurs during press processing, which is not preferable as a steel sheet including a zinc-based plated layer.

[0035]

Further, in the chemical conversion treatment layer 13 of the surface-treated steel sheet 1 according to the present embodiment, it is preferable that Al is present in the interface side region 102, and the F content (concentration) of the interface side region 102 is 20% or more of the F content (concentration) of the entire chemical conversion treatment layer 13.

The fact that Al is present in the interface side region 102 of the chemical conversion treatment layer 13 and F is concentrated in the above-described range indicates that Al and F form a complex salt. The complex salt is hardly soluble, and hardly permeable to corrosive factors from the outside. Thus, when such a complex salt is formed, the flat sheet corrosion resistance of the surface-treated steel sheet is improved, so that the generation of white rust is suppressed.

When Al is not present in the interface side region 102 or the F content of the interface side region 102 is less than 20% of the F content of the entire chemical conversion treatment layer 13, the above-described effect cannot be obtained to a sufficient extent. The upper limit is not limited, but even if the F content of the interface region 102 is increased over a certain level, further enhancement of the effect is

not obtained and economic efficiency is deteriorated because F that does not form a complex salt with Al increases in a case where the content of F becomes excessively high with respect to Al. Therefore, the content of F may be, for example, 60% or less.

[0036]

5 In addition, it is preferable that Sb is present (contained) in the interface side region 102 in the chemical conversion treatment layer 13 of the surface-treated steel sheet 1 according to the present embodiment. In this case, blackening of the surface-treated steel sheet can be suppressed (blackening resistance is improved). The mechanism thereof is unknown, but may be similar to a mechanism in which flush
10 treatment with Co or the like contributes to prevention of blackening of the surface-treated steel sheet.

[0037]

For the surface-treated steel sheet according to the present embodiment, whether the chemical conversion treatment layer contains the elements of Si, C, O, P and F, the
15 ratio of the maximum value of the P concentration of the surface layer region to the average P concentration of the intermediate region, the ratio of the F content of the surface layer region to the F content of the entire chemical conversion treatment layer, and the presence or absence of Al and Sb in the interface side region are determined by EDS linear analysis.

20 Specifically, by a cryogenic focused ion beam (FIB) method, a test piece is cut out from a zinc-based plated steel sheet on which a chemical conversion treatment layer is formed, and a cross section structure of the obtained test piece is observed with a transmission electron microscope (TEM) at a magnification which allows the entire chemical conversion treatment layer to fall within the observed visual field. For
25 identifying the constituent elements of each layer, line analysis is performed along the

thickness direction by TEM-EDS (energy dispersive X-ray spectroscopy), and quantitative analysis of the chemical composition at each site is performed. The method of the line analysis is not particularly limited, and continuous point analysis with an interval of several nm between points may be performed, or an element map in an arbitrary region may be measured to determine the thickness-direction distribution of the element in terms of the average in a plane direction.

The values of the C concentration, the O concentration, the Si concentration and the P concentration in the chemical conversion treatment layer are each determined as the average of the line analysis results for the entire chemical conversion treatment layer.

As the maximum value of the P concentration of the surface layer region, the largest value among the concentrations obtained by performing line analysis of the surface layer region in the thickness direction is adopted.

Each of the F content of the interface side region and the F content of the entire chemical conversion treatment layer is “average F concentration of observed region (layer)” $\times$ “volume of the region (layer)”, respectively. (The volume of the interface side region is 1/10 of that of the entire chemical conversion treatment layer.)

In the interface side region, line analysis is performed in the thickness direction. It is determined that Al is present if the average Al concentration is 0.10 mass% or more, and it is determined that Sb is present if the maximum value of the Sb concentration is 0.01 mass% or more.

The apparatus used for the analysis is not particularly limited, and for example, TEM (electrolysis emission transmission electron microscope: JEM-2100F manufactured by JEOL Ltd.) or EDS (JED-2300T manufactured by JEOL Ltd.) may be used.

[0038]

The thickness of the chemical conversion treatment layer 13 of the surface-

treated steel sheet 1 according to the present embodiment is preferably 10 to 2000 nm.

A thickness of less than 10 nm is not preferable because there is a possibility that a

surface of the steel cannot be covered, and thus sufficient corrosion resistance cannot be

obtained. On the other hand, a thickness of more than 2000 nm is not preferable

5 because black deposit resistance during processing decreases. The thickness is more preferably 200 to 800 nm.

[0039]

The thickness of the chemical conversion treatment layer can be measured by observing a cross section using TEM.

10 The interface between the plated layer and the chemical conversion treatment layer is identified by observation of the cross sectional with the TEM, and the thickness from this interface to the surface of the chemical conversion treatment layer is defined as a thickness of the chemical conversion treatment layer.

[0040]

15 <Manufacturing Method>

Next, a preferred manufacturing method for the surface-treated steel sheet according to the present embodiment will be described.

As long as the surface-treated steel sheet according to the present embodiment has the above-described characteristics, the effects thereof can be obtained regardless of a
20 manufacturing method, the manufacturing method described below is preferable because it enables stable manufacture.

That is, the surface-treated steel sheet according to the present embodiment can be manufactured by a manufacturing method including the following steps.

(I) a plating step of forming a zinc-based plated layer on a surface of a steel
25 (steel sheet) by immersing the steel in a plating bath containing Zn;

(II) a step of applying a surface treatment metal agent (treatment solution) to a steel including a zinc-based plated layer;

(III) a heating step of heating the steel sheet, to which the surface treatment metal agent is applied, to form a chemical conversion treatment layer containing Si, C, O
5 and P; and

(IV) a cooling step of cooling the steel sheet after the heating step.

Hereinafter, preferred conditions for each step will be described.

[0041]

[Plating step]

10 There is no particular limitation on the plating step. The plating may be performed by a normal hot-dip galvanizing method so as to obtain sufficient plating adhesion.

In addition, there is no particular limitation on the manufacturing method for the steel that is subjected to the plating step.

15 The manufacturing method may be a manufacturing method for a zinc-plated steel sheet as specified in JIS G 3302: 2019 or a manufacturing method for a plated steel sheet as specified in JIS G 3323: 2019.

Since the composition of the plating bath is substantially equal to the composition of the plated layer, the composition of the plating bath may be adjusted
20 according to the composition of a desired zinc-based plated layer. For regular spangle-finishing a surface of the plated layer, it is preferable that the plating bath contains Sb at 0.03 to 0.15 mass%.

[0042]

[Application step]

25 In the application step, a surface treatment metal agent (treatment solution) is

applied to the steel sheet after the plating step (steel sheet including a zinc-based plated layer) using a roll coater or the like.

[0043]

The surface treatment metal agent contains an organosilicon compound (V),
5 which is a compound containing Si, C and O, as a film-forming component. The organosilicon compound is not particularly limited, and is obtained by, for example, blending a silane coupling agent (A) containing one amino group in the molecule and a silane coupling agent (B) containing one glycidyl group in the molecule at a solid content mass ratio [(A)/(B)] of 0.5 to 1.7.

10 The blending ratio between the silane coupling agent (A) and the silane coupling agent (B) is preferably 0.5 to 1.7 in terms of a solid content ratio [(A)/(B)]. A solid content ratio [(A)/(B)] of less than 0.5 is not preferable because bath stability and black deposit resistance may be significantly deteriorated. On the other hand, a solid content ratio [(A)/(B)] of more than 1.7 is not preferable because water resistance may
15 significantly decrease.

[0044]

The surface treatment metal agent contains a P compound (phosphorus compound) (W) as an inhibitor component. The phosphorus compound (W) is not particularly limited, and examples thereof include phosphoric acid, ammonium
20 phosphate, potassium phosphate, and sodium phosphate.

[0045]

For the blending amount of the phosphorus compound (W), the solid content mass ratio between Si derived from the organosilicon compound (V) and P derived from the phosphorus compound (W), [(Ws)/(Vs)], is preferably 0.15 to 0.31. It is not
25 preferable that the solid content mass ratio between Si derived from the organosilicon

compound (V) and P derived from the phosphorus compound (W), $[(W_s)/(V_s)]$, is less than 0.15 because good corrosion resistance cannot be obtained due to the shortage of the inhibitor component. On the other hand, a solid content mass ratio $[(W_s)/(V_s)]$ of more than 0.31 is not preferable because the film (chemical conversion treatment layer) is significantly dissolved in water, so that good corrosion resistance cannot be obtained.

[0046]

The solid content of the surface treatment metal agent is 3.0 to 15.0 mass%. If the solid content of the surface treatment metal agent is less than 3.0 mass%, corrosion resistance decreases. The reason for this is unknown, but may be that water remains in the chemical conversion treatment layer (film), so that the barrier property of the film is deteriorated. On the other hand, if the solid content of the surface treatment metal agent is more than 15.0 mass%, it is difficult to segregate P of the surface layer region. The reason for this is unknown, but may be that a compound contained in the surface treatment metal agent and containing Si, C and O suppresses movement of P in the surface treatment metal agent.

[0047]

It is preferable to use the surface treatment metal agent within 72 hours after the organosilicon compound (V), which is a compound containing Si, C and O, and the P compound (phosphorus compound) (W) are mixed. After more than 72 hours, the effect of segregating P in the surface layer region decreases. The reason for this is unknown, but may be that the organosilicon compound (V) and the P compound (phosphorus compound) (W) contained in the surface treatment metal agent react with each other, so that movement of P in the surface-treated metal agent is suppressed.

[0048]

For performing control so that a complex salt of Al and F is formed in the

interface side region of the chemical conversion treatment layer, it is preferable that Al is contained in the zinc-based plated layer, and a fluorine compound (X) is contained in the surface treatment metal agent. When the fluorine compound is contained, Al on the plated surface is dissolved, and Al and F react with each other, so that a hardly soluble salt is formed in the interface side region of the chemical conversion treatment layer.

Examples of the fluorine compound include hydrogen fluoride.

[0049]

For the blending amount of the fluorine compound (X), the concentration of F derived from the fluorine compound (X) contained in the surface treatment agent is preferably 0.03 to 4.50 mass%. If the blending amount of the fluorine compound (X) is less than 0.03 mass%, the amount of dissolution of Al on the plating surface is insufficient, so that a hardly soluble salt obtained by reaction between Al and F is not formed, and thus it is difficult to obtain the effect of improving corrosion resistance. If the blending amount of the fluorine compound (X) is more than 4.50 mass%, Al is excessively dissolved on the plated surface, so that the external appearance is deteriorated.

[0050]

For the blending amount of the fluorine compound (X), the solid content mass ratio between Si derived from the organosilicon compound (V) and F derived from the fluorine compound (X), $[(X_s)/(V_s)]$, is preferably 0.01 to 0.30. If the solid content mass ratio between Si derived from the organosilicon compound (V) and F derived from the fluorine compound (X), $[(X_s)/(V_s)]$, is less than 0.01, the effect of improving corrosion resistance cannot be obtained to a sufficient extent. On the other hand, a solid content mass ratio $[(X_s)/(V_s)]$ of more than 0.30 is not preferable because the chemical conversion treatment layer is significantly dissolved in water.

[0051]

The surface treatment metal agent may contain a Zr compound (Y). The Zr compound (Y) is not particularly limited, and examples thereof include ammonium zirconium carbonate, hexafluorozirconium hydroacid, and ammonium zirconium
5 hexafluoride.

[0052]

For the blending amount of the Zr compound (Y), the solid content mass ratio between Si derived from the organosilicon compound (V) and Zr derived from the Zr compound (Y), $[(Ys)/(Vs)]$, is preferably 0.06 to 0.15. If the solid content mass ratio
10 between Si derived from the organosilicon compound (V) and the Zr derived from the Zr compound (Y), $[(Ys)/(Vs)]$, is less than 0.06, the effect of improving corrosion resistance is insufficient. On the other hand, a solid content mass ratio $[(Ys)/(Vs)]$ of more than 0.15 does not lead to further enhancement of the effect of improving corrosion resistance.

[0053]

15 The surface treatment metal agent may contain a V compound (Z). The V compound (Z) is not particularly limited, and examples thereof include vanadium pentoxide V_2O_5 , metavanadate HVO_3 , ammonium metavanadate, sodium metavanadate, vanadium oxytrichloride $VOCl_3$, vanadium trioxide V_2O_3 , vanadium dioxide VO_2 , vanadium oxysulfate $VOSO_4$, vanadium oxyacetylacetonate
20 $VO(OC(=CH_2)CH_2COCH_3)_2$, vanadium acetylacetonate $V(OC(=CH_2)CH_2COCH_3)_3$, vanadium trichloride VCl_3 , and linvanadomolybdic acid. It is also possible to use compounds obtained by reducing a pentavalent vanadium compound to tetravalence to divalence with an organic compound having at least one functional group selected from the group consisting of a hydroxyl group, a carbonyl group, carboxylic acid, a primary to
25 tertiary amino group, an amide group, a phosphoric acid group and a phosphonic acid

group.

[0054]

For the blending amount of the V compound (Z), the solid content mass ratio between Si derived from the organosilicon compound (V) and V derived from the V compound (Z), $[(Zs)/(Vs)]$, is preferably 0.05 to 0.17. If the solid content mass ratio between Si derived from the organosilicon compound (V) and V derived from the V compound (Z), $[(Zs)/(Vs)]$, is less than 0.05, the effect of improving corrosion resistance cannot be obtained to a sufficient extent. On the other hand, a solid content mass ratio $[(Zs)/(Vs)]$ of more than 0.17 is not preferable because bath stability is deteriorated.

10 [0055]

For performing control so that Sb is present in the interface side region of the chemical conversion treatment layer, it is preferable that Sb is contained in the zinc-based plated layer, hydrogen fluoride is contained in the surface treatment metal agent, and the pH of the surface treatment metal agent is set to 1 to 5. When hydrogen fluoride is contained in the surface treatment agent to set the pH of the surface treatment metal agent to 1 to 5, Sb in the zinc-based plated layer is eluted in the surface treatment metal agent, and moves to the interface side region of the chemical conversion treatment layer.

For setting the pH to 1 to 5, a pH adjuster may be incorporated in the surface treatment metal agent. The pH adjuster is not particularly limited, and organic acids such as formic acid, acetic acid and lactic acid, ammonium salts, amines, and the like may be used.

20 [0056]

[Heating step and cooling step]

In the heating step, the steel sheet, to which a surface treatment metal agent is applied is heated and dried with a drying furnace or the like to form a chemical

conversion treatment layer on a surface thereof.

[0057]

5 In the heating step, P can be segregated in the surface layer region of the chemical conversion treatment layer by heating the surface treatment metal agent at an appropriate temperature rising rate. The reason for this is unknown, but may be that in the process of forming the chemical conversion treatment layer, P moves to a chemical conversion treatment layer-non-formed portion due to poor compatibility between a film containing Si, O and C and P in the process of forming the chemical conversion treatment layer.

10 [0058]

For segregating P, it is necessary that the temperature rising rate be 10 to 150°C/sec until the temperature reaches 55°C, which is a temperature at which the surface treatment metal agent is dried to form the chemical conversion treatment layer, after application at room temperature. If the temperature rising rate is more than 15 150°C/sec, the movement of P becomes insufficient, so that the P concentration in the surface layer region cannot be sufficiently increased. On the other hand, if the temperature rising rate is less than 10 °C/sec, the amount of movement of P increases, so that the P concentration of the surface layer region becomes excessive.

[0059]

20 In the heating step, a layer including a complex salt of Al and F can be formed by controlling the time until formation of the chemical conversion treatment layer immediately after application of the surface treatment metal agent to concentrate F in a region on the interface side with the plated layer in the chemical conversion treatment layer if the surface treatment metal agent contains hydrogen fluoride.

25 [0060]

The time from application of the surface treatment metal agent to formation of the chemical conversion treatment layer immediately is preferably 1.0 to 10.0 seconds.

If the time until formation of the chemical conversion treatment layer is less than 1.0 seconds, a complex salt of Al and F is hardly formed, so that it is not possible to obtain

5 F-concentrated layer sufficient for improving corrosion resistance. On the other hand, if the time until formation of the chemical conversion treatment layer is more than 10.0 seconds, the surface layer of the plated layer is excessively etched by hydrogen fluoride, resulting in deterioration of the external appearance of the steel sheet after chemical conversion treatment.

10 [Examples]

[0061]

A cold-rolled steel sheet having a sheet thickness of 0.8 mm and satisfying the provision of JIS G 3141: 2017 was immersed in a plating bath having a composition shown in Table 1, thereby obtaining a plated steel sheet whose thickness is shown in

15 Table 8. In Table 1, for example, “Zn-0.2% Al” indicates a composition having Al of 0.2 mass% with the remainder of Zn and impurities. For a to g, a hot-dip plating method was applied, and for h, an electro plating method was applied.

In addition, a silicon compound (silane coupling agent), a phosphorus compound (P compound), a fluorine compound (F compound), a zirconium compound (Zr compound) and a vanadium compound (V compound) shown in Tables 2 to 6 were mixed in proportions shown in Table 7, thereby preparing aqueous surface treatment metal agents.

20 [0062]

The surface treatment metal agent was applied to the plated steel sheet by a roll coater, and dried to by heating to 55°C to form a chemical conversion treatment layer.

25

Here, the combinations of the plated steel sheet, the surface treatment metal agent and the application and drying conditions were as shown in Tables 10-1 to 10-12.

In this way, surface-treated steel sheets Nos. 1 to 171 were manufactured.

[0063]

5 For the obtained surface-treated steel sheet, fingerprint resistance, powdering resistance, corrosion resistance, the external appearance and blackening resistance were evaluated in the following manner.

[0064]

<Fingerprint resistance>

10 Vaseline (registered trademark) was applied to a surface of the flat sheet test piece, and left standing for 10 minutes, the Vaseline (registered trademark) was then removed, and a color difference (ΔE) before and after the application of the Vaseline (registered trademark) was measured using a spectrophotometric colorimeter (SC-T45 manufactured by Suga Test Instruments Co., Ltd.). Here, the evaluation criteria are as
15 follows. A sample meeting $\odot+$, $\odot$ or $\circ$ was rated as being excellent in fingerprint resistance.

$\odot+$: $\Delta E \leq 0.5$

$\odot$: $0.5 < \Delta E \leq 1$

$\circ$: $1 < \Delta E \leq 2$

20 $\times$: $\Delta E > 2$

[0065]

<Powdering resistance>

A flat sheet test piece was prepared, and subjected to contact bending in accordance with JIS Z 2248: 2014, and a cellophane tape peeling test was conducted on
25 the contact bending part. Thereafter, the cellophane tape-peeled part was observed with

a scanning electron microscope to evaluate the residual state of the chemical conversion treatment film. A sample meeting ○ was rated as being excellent in powdering resistance, and a sample meeting △ was rated as being acceptable in practical use.

<Evaluation criteria>

5 ○: Either cracking or peeling is not observed in the chemical conversion treatment film.

△: Cracking is observed, but peeling is not observed in the chemical conversion treatment film.

×: Peeling of chemical conversion treatment film is recognized.

10 [0066]

<Corrosion resistance (white rust resistance)>

A flat sheet test piece was prepared, and a salt water spray test conforming to JIS Z 2371: 2015 was conducted on each test piece to evaluate the state of generation of white rust on the surface after 144 hours (ratio of the white rust generation area to the area of the test piece). A sample meeting △ was rated as having corrosion resistance sufficient for practical use, a sample meeting ○ was rated as being excellent in corrosion resistance, and a sample meeting ◎ was rated as being further excellent in corrosion resistance.

<Evaluation criteria>

20 ◎ = Rust is generated over less than 5% of the total area.

○ = Rust is generated over 5% or more and less than 10% of the total area.

△ = Rust is generated over 10% or more and less than 30% of the total area.

× = Rust is generated over 30% or more of the total area.

[0067]

25 <External appearance>

The external appearance of the flat sheet test piece was visually evaluated on the basis of the following criteria. A sample meeting ○ was rated as being excellent in external appearance.

<Evaluation criteria>

5 ○: Whitening is not observed.

△: Local whitening is recognized.

[0068]

<Blackening resistance>

The test sheet was held in a wet box at a temperature of 70°C and a relative humidity of 80% for 6 days, and then taken out, and a blackening state of the test sheet was visually evaluated.

The evaluation criteria are as follows. A sample meeting ○ was rated as being acceptable, and a sample meeting ⊙ was rated as being particularly excellent in blackening resistance.

15 ⊙ = The area fraction of blackened portions is less than 1%.

○ = The area fraction of blackened portions is 1% or more and less than 25%.

△ = The area fraction of blackened portions is 25% or more and less than 50%.

× = The area fraction of blackened portions is 50% or more.

[0069]

20 [Table 1]

	Plating composition	Spangle
a	Zn-0.2%Al	Minimized spangle
b	Zn-0.2%Al-0.08%Sb	Regular spangle
c	Zn-6.0%Al-3.0%Mg	None
d	Zn-11.0%Al-3.0%Mg-0.2%Si	None
e	Zn-16.0%Al-6.0%Mg-0.2%Si	None
f	Zn-19.0%Al-6.0%Mg-1.5%Sn-0.5%Ca-0.2%Si	None
g	Zn-24.0%Al-12.0%Mg-0.5%Ca-1.2%Si	None

h	Zn	None
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[0070]

[Table 2]

	Name
A1	3-Aminopropyltrimethoxysilane
A2	3-Aminopropyltriethoxysilane
B1	3-Glycidoxypropyltrimethoxysilane
B2	3-Glycidoxypropyltriethoxysilane

5 [0071]

[Table 3]

	Name
W1	Phosphoric acid
W2	Ammonium phosphate

[0072]

[Table 4]

	Name
X1	Hydrogen fluoride

10

[0073]

[Table 5]

	Name
Y1	Ammonium zirconium carbonate
Y2	Hexafluorozirconium hydroacid

[0074]

15 [Table 6]

	Name
Z1	Vanadium oxysulfate VO SO_4
Z2	Vanadium oxyacetylacetonate $\text{VO}(\text{OC}(=\text{CH}_2)\text{CH}_2\text{COCH}_3)$

[0075]

[Table 7]

No.	Organosilicon compound (V)			P compound (W)		F compound (X)			Zr compound (Y)		V Compound (Z)		Solid content (mass%)	pH
	Silane coupling agent		Proportion	Type	Proportion	Type	Proportion	F concentration in treatment solution mass%	Type	Proportion	Type	Proportion		
	A	B												
ST1	A1	B1	1.0	W1	0.17	-	-	-	-	-	-	-	3.0	5.5
ST2	A1	B2	0.7	W2	0.20	-	-	-	-	-	-	-	6.7	8.5
ST3	A2	B1	1.3	W1	0.30	-	-	-	-	-	-	-	8.3	5.5
ST4	A2	B2	1.5	W2	0.16	-	-	-	-	-	-	-	11.5	7.8
ST5	A1	B1	1.3	W1	0.16	X1	0.02	0.11	-	-	-	-	5.6	5.2
ST6	A1	B2	1.4	W2	0.20	X1	0.28	1.90	-	-	-	-	6.8	8.2
ST7	A2	B1	0.6	W1	0.20	X1	0.25	1.97	-	-	-	-	7.9	5.3
ST8	A2	B2	0.7	W2	0.20	X1	0.15	1.53	-	-	-	-	10.2	8.0
ST9	A1	B1	0.8	W2	0.18	-	-	-	-	-	-	-	11.5	3.5
ST10	A1	B2	1.1	W1	0.27	-	-	-	-	-	-	-	12.8	3.4
ST11	A2	B1	1.3	W2	0.16	-	-	-	-	-	-	-	4.5	2.4
ST12	A2	B2	1.5	W1	0.16	-	-	-	-	-	-	-	4.5	4.5
ST13	A1	B1	1.0	W1	0.18	X1	0.04	0.14	-	-	-	-	3.6	2.3
ST14	A1	B2	1.0	W2	0.27	X1	0.04	0.22	-	-	-	-	5.5	1.5
ST15	A2	B1	0.9	W1	0.27	X1	0.05	0.43	-	-	-	-	8.6	4.8
ST16	A2	B2	0.9	W2	0.27	X1	0.28	1.87	-	-	-	-	6.7	3.5
ST17	A1	B1	0.8	W1	0.20	X1	0.04	0.30	Y1	0.10	-	-	7.7	1.3
ST18	A1	B2	0.6	W2	0.21	X1	0.04	0.29	-	-	Z2	0.07	7.3	2.8
ST19	A2	B1	1.6	W1	0.23	X1	0.05	0.50	Y1	0.14	Z1	0.06	10.1	4.9
ST20	A2	B2	1.3	W2	0.24	X1	0.28	3.38	Y2	0.07	Z2	0.16	12.1	3.4
ST21	A1	B1	1.5	W2	0.27	-	-	-	-	-	-	-	1.5	7.5
ST22	A2	B2	0.6	W2	0.25	-	-	-	-	-	-	-	1.8	7.7
ST23	A2	B1	1.1	W2	0.16	-	-	-	-	-	-	-	18.0	7.8
ST24	A2	B2	1.3	W1	0.28	-	-	-	-	-	-	-	23.0	5.3
ST25	A2	B1	1.2	W2	0.02	X1	0.02	0.14	-	-	-	-	3.1	6.3
ST26	A1	B2	1.3	W1	0.45	X1	0.28	2.30	-	-	-	-	14.0	6.4
ST27	A2	B1	1.2	W2	0.15	X1	0.02	0.01	-	-	-	-	3.1	6.3
ST28	A1	B2	1.3	W1	0.17	X1	0.28	4.80	-	-	-	-	14.0	6.4
ST29	A1	B1	1.1	W1	0.03	-	-	-	-	-	-	-	3.6	2.3
ST30	A2	B2	0.7	W2	0.12	-	-	-	-	-	-	-	6.7	3.5

[0076]

5 [Table 8]

No.	Sheet thickness	Plating		Spangle
		Type	Thickness	
	(mm)		(g/m ²)	
O1	0.8	a	90	Minimized spangle
O2	0.8	b	90	Regular spangle
O3	0.8	c	90	None
O4	0.8	d	90	None
O5	0.8	e	90	None
O6	0.8	f	90	None
O7	0.8	g	90	None

O8	0.8	h	30	None
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[0077]

[Table 9]

No.	Application conditions	Drying step	Time until formation of chemical conversion treatment layer after application
	Film adhesion amount	Temperature rising rate	
	(nm)	(°C/sec)	
C1	20	30	2.1
C2	50	100	5.2
C3	80	140	8.5
C4	300	15	9.3
C5	450	50	7.1
C6	600	120	4.2
C7	750	145	1.5
C8	1000	20	7.8
C9	1500	80	5.0
C10	1800	130	2.5
C11	300	1	2.3
C12	450	3	4.5
C13	800	5	7.2
C14	900	7	8.1
C15	50	180	1.5
C16	250	200	2.8
C17	500	220	5.0
C18	750	250	9.7
C19	70	140	0.1
C20	400	100	0.8
C21	850	60	0.2
C22	1850	20	0.9
C23	70	140	11.0
C24	400	100	18.9
C25	850	60	13.8
C26	1850	20	25.5

5 [0078]

[Table 10-1]

No.	Manufacture conditions				Analysis			
	Base sheet under test	Surface treatment metal agent	Time (h) until application/drying after preparation of surface	Conditions for application/drying of surface treatment metal	Si content (mass%)	C content (mass%)	O content (mass%)	P content (mass%)

			treatment metal agent	agent				
1	O2	ST1	58	C1	12.3	36.0	22.1	2.1
2	O2	ST2	48	C2	11.5	29.9	19.0	2.0
3	O2	ST3	68	C3	17.2	22.8	22.9	2.6
4	O2	ST4	131	C4	15.7	29.8	18.7	3.2
5	O2	ST1	34	C5	14.1	21.8	21.9	2.9
6	O2	ST2	147	C6	13.0	26.0	29.5	2.3
7	O2	ST3	84	C7	11.4	29.6	24.1	2.8
8	O2	ST4	46	C8	11.3	26.6	27.6	2.0
9	O2	ST1	6	C9	12.4	27.1	33.7	2.4
10	O2	ST2	20	C10	16.6	35.8	19.4	3.1
11	O1	ST3	21	C1	11.3	34.1	29.9	2.4
12	O3	ST4	21	C2	11.7	26.5	34.8	2.5
13	O4	ST1	22	C3	13.7	34.1	27.1	2.5
14	O5	ST2	55	C4	11.0	25.4	26.4	2.6
15	O6	ST3	65	C5	12.4	27.5	30.0	1.9
16	O7	ST4	31	C6	13.8	28.4	25.2	3.0
17	O1	ST1	41	C11	17.2	30.2	25.7	4.1
18	O2	ST2	5	C12	10.1	20.5	22.1	2.1
19	O3	ST3	59	C13	11.7	27.2	18.8	2.8
20	O4	ST4	69	C14	10.6	23.2	20.2	2.0
21	O5	ST1	37	C11	14.1	27.1	25.0	2.3
22	O6	ST2	35	C12	15.9	25.5	22.4	2.9
23	O7	ST3	14	C13	16.3	32.4	30.0	2.9
24	O2	ST4	60	C14	15.8	20.7	27.3	2.8
25	O1	ST1	218	C15	17.1	25.5	18.5	4.2
26	O2	ST2	215	C16	12.2	22.1	33.7	2.4
27	O3	ST3	229	C17	19.8	32.3	31.1	3.2
28	O4	ST4	215	C18	12.7	25.5	19.0	2.6
29	O5	ST1	75	C15	11.5	33.3	32.7	1.9
30	O6	ST2	178	C16	14.5	29.3	31.9	3.5
31	O7	ST3	147	C17	19.3	24.1	27.5	3.6
32	O2	ST4	110	C18	17.2	26.7	18.3	4.0
33	O2	ST5	7	C1	12.2	21.9	23.7	2.7
34	O2	ST6	19	C2	12.0	21.1	18.5	2.2
35	O2	ST7	67	C3	11.3	28.3	27.8	2.1
36	O2	ST8	158	C4	17.5	29.9	26.9	3.5
37	O2	ST5	27	C5	12.4	23.5	28.7	1.9
38	O2	ST6	43	C6	13.6	32.2	21.1	2.3
39	O2	ST7	43	C7	10.9	24.1	33.6	2.3
40	O2	ST8	29	C8	10.9	30.2	33.4	2.4
41	O2	ST5	61	C9	13.8	24.5	28.7	3.3
42	O2	ST6	33	C10	11.8	25.8	23.0	2.3
43	O1	ST7	67	C1	19.9	33.8	20.1	4.0
44	O3	ST8	8	C2	17.9	25.6	25.5	2.8
45	O4	ST5	65	C3	17.3	28.7	19.2	3.3
46	O5	ST6	4	C4	10.3	22.7	30.8	1.7
47	O6	ST7	48	C5	17.4	20.9	19.4	3.0
48	O7	ST8	29	C6	12.5	23.5	20.6	2.0

[0079]

[Table 10-2]

No.	Manufacture conditions				Analysis			
	Base sheet under test	Surface treatment metal agent	Time (h) until application/drying after preparation of surface treatment metal agent	Conditions for application/drying of surface treatment metal agent	Si content (mass%)	C content (mass%)	O content (mass%)	P content (mass%)
49	O1	ST5	70	C19	10.0	35.5	22.6	2.3
50	O2	ST6	12	C20	11.2	27.1	32.5	2.4
51	O3	ST7	118	C21	11.2	24.5	25.8	2.7
52	O4	ST8	24	C22	18.6	26.1	26.3	2.8
53	O5	ST5	31	C19	15.5	30.9	20.6	3.0
54	O6	ST6	71	C20	13.3	34.4	30.5	2.3
55	O7	ST7	202	C21	17.6	25.0	30.6	3.3
56	O2	ST8	69	C22	11.1	28.3	24.3	2.0
57	O1	ST5	34	C23	16.6	24.5	24.4	3.3
58	O2	ST6	20	C24	19.6	22.3	23.3	3.5
59	O3	ST7	38	C25	11.2	33.9	23.9	1.9
60	O4	ST8	52	C26	14.0	25.6	30.7	2.4
61	O5	ST5	65	C23	15.9	36.8	18.9	3.8
62	O6	ST6	29	C24	15.6	23.1	17.6	2.7
63	O7	ST7	149	C25	17.9	25.9	20.9	4.3
64	O2	ST8	45	C26	10.9	34.8	24.4	1.7
65	O2	ST9	180	C1	12.3	32.8	30.1	2.8
66	O2	ST10	26	C2	19.9	35.0	32.8	4.3
67	O2	ST11	45	C3	11.6	22.5	27.3	2.8
68	O2	ST12	5	C4	15.5	36.5	25.6	2.9
69	O2	ST9	20	C5	11.7	20.8	30.8	1.9
70	O2	ST10	209	C6	19.2	33.2	30.4	3.8
71	O2	ST11	37	C7	15.4	31.4	22.5	2.7
72	O2	ST12	27	C8	17.9	24.3	20.7	4.2
73	O2	ST9	57	C9	15.6	28.3	23.9	2.4
74	O2	ST10	113	C10	16.6	36.0	25.0	2.6
75	O2	ST11	39	C1	10.7	31.2	25.1	2.4
76	O2	ST12	52	C2	19.0	22.1	21.5	3.4
77	O2	ST9	47	C3	18.3	20.1	21.8	3.0
78	O2	ST10	40	C4	14.0	24.0	19.6	2.5
79	O2	ST11	20	C5	13.2	32.9	23.9	2.4
80	O2	ST12	29	C6	11.5	25.8	24.5	2.1
81	O2	ST13	111	C1	12.2	25.7	20.7	2.4
82	O2	ST14	47	C2	19.1	28.3	22.8	3.4
83	O2	ST15	38	C3	18.7	22.2	27.6	4.6
84	O2	ST16	223	C4	11.7	27.2	30.7	2.6
85	O2	ST13	12	C5	12.0	22.9	28.7	2.5
86	O2	ST14	67	C6	13.7	29.0	26.3	2.3
87	O2	ST15	202	C7	17.8	31.2	32.0	4.2
88	O2	ST16	1	C8	15.6	26.9	21.6	3.2
89	O2	ST13	67	C9	14.4	35.6	34.2	3.2
90	O2	ST14	31	C10	14.4	22.1	33.2	2.4
91	O2	ST15	51	C1	11.1	27.4	29.0	1.9
92	O2	ST16	61	C2	13.1	20.3	30.3	2.0
93	O2	ST13	48	C3	15.9	32.3	33.9	2.7
94	O2	ST14	3	C4	19.4	35.3	19.3	4.6
95	O2	ST15	16	C5	15.0	32.6	30.1	2.8
96	O2	ST16	28	C6	16.2	29.3	34.5	3.2

[0080]

[Table 10-3]

No.	Manufacture conditions				Analysis			
	Base sheet under test	Surface treatment metal agent	Time (h) until application/drying after preparation of surface treatment metal agent	Conditions for application/drying of surface treatment metal agent	Si content (mass%)	C content (mass%)	O content (mass%)	P content (mass%)
97	O1	ST9	29	C1	18.0	21.1	32.2	2.7
98	O3	ST10	76	C2	19.5	25.3	25.3	4.1
99	O4	ST11	211	C3	19.6	25.9	21.3	4.1
100	O5	ST12	35	C4	12.3	21.3	33.4	2.7
101	O6	ST9	36	C5	10.3	28.9	24.4	1.7
102	O7	ST10	9	C6	14.4	24.2	31.8	3.5
103	O1	ST11	33	C7	15.7	22.4	29.1	3.5
104	O3	ST12	41	C8	11.7	22.0	19.1	2.5
105	O4	ST13	60	C9	10.0	29.0	19.0	2.4
106	O5	ST14	92	C10	16.1	20.9	33.1	3.2
107	O6	ST15	16	C1	10.2	33.9	32.7	1.9
108	O7	ST16	12	C2	18.9	36.9	23.9	4.1
109	O1	ST13	64	C3	18.5	21.9	30.3	3.4
110	O3	ST14	0	C4	14.7	35.9	20.8	2.9
111	O4	ST15	149	C5	14.3	26.0	28.9	2.7
112	O5	ST16	57	C6	15.2	31.3	33.2	3.4
113	O2	ST17	25	C1	15.5	36.5	30.4	3.1
114	O2	ST18	62	C2	11.0	22.2	30.8	2.5
115	O2	ST19	64	C3	10.8	26.1	27.8	2.0
116	O2	ST20	51	C4	13.8	36.5	28.1	3.1
117	O2	ST17	22	C5	19.6	20.5	23.8	4.1
118	O2	ST18	11	C6	10.7	34.1	23.7	1.9
119	O2	ST19	64	C7	18.6	28.5	32.7	3.0
120	O2	ST20	41	C8	11.3	27.2	30.7	2.3
121	O2	ST17	26	C1	11.5	26.2	22.4	2.5
122	O2	ST18	57	C2	18.3	24.8	23.1	3.5

[0081]

5 [Table 10-4]

No.	Manufacture conditions				Analysis			
	Base sheet under test	Surface treatment metal agent	Time (h) until application/drying after preparation of surface treatment metal agent	Conditions for application/drying of surface treatment metal agent	Si content (mass%)	C content (mass%)	O content (mass%)	P content (mass%)
129	O1	ST21	93	C1	14.2	20.5	25.2	2.1
130	O2	ST22	39	C2	19.6	21.3	27.2	3.7
131	O3	ST21	218	C3	18.0	26.1	29.1	3.0
132	O4	ST22	48	C4	19.1	30.6	26.3	4.6
133	O5	ST21	170	C5	18.8	29.3	26.8	3.7
134	O6	ST22	62	C6	18.4	31.8	29.9	3.8
135	O7	ST21	18	C7	19.5	21.2	26.5	3.3
136	O2	ST22	41	C8	12.7	20.3	18.2	2.5
137	O1	ST23	90	C9	14.0	31.0	21.2	3.2
138	O2	ST24	103	C10	10.2	30.0	32.1	1.9

139	O3	ST23	100	C1	15.4	22.1	23.9	2.7
140	O4	ST24	168	C2	15.3	22.9	18.4	3.0
141	O5	ST23	173	C3	16.6	24.6	30.8	3.2
142	O6	ST24	125	C4	16.0	22.8	17.7	3.7
143	O7	ST23	193	C5	12.4	25.0	31.8	2.1
144	O2	ST24	208	C6	10.9	35.8	17.6	2.3
145	O1	ST25	192	C7	11.5	20.5	17.8	<u>0.05</u>
146	O2	ST25	27	C8	10.2	35.7	25.5	<u>0.04</u>
147	O3	ST25	22	C9	10.7	28.5	22.3	<u>0.08</u>
148	O4	ST25	27	C10	15.5	27.2	31.7	<u>0.02</u>
149	O5	ST26	63	C1	19.6	22.4	28.7	10.3
150	O6	ST26	83	C2	11.3	26.5	15.5	10.9
151	O7	ST26	39	C3	10.7	25.2	16.7	11.5
152	O1	ST26	47	C4	12.3	31.9	28.8	9.8
153	O1	ST27	29	C5	16.0	25.2	22.7	3.3
154	O2	ST27	24	C6	13.2	26.5	31.8	3.1
155	O3	ST27	27	C7	19.5	28.9	27.7	4.5
156	O4	ST27	70	C8	17.4	21.6	34.8	2.8
157	O5	ST28	53	C9	19.0	32.5	26.1	3.3
158	O6	ST28	27	C10	12.7	28.5	26.0	2.7
159	O7	ST28	49	C1	10.4	25.0	20.4	2.1
160	O1	ST28	34	C2	16.9	25.8	24.7	3.7
161	O8	ST5	67	C4	17.3	30.2	27.2	2.3
162	O8	ST6	41	C3	16.9	33.5	34.5	3.5
163	O8	ST7	22	C2	10.5	25.0	26.3	3.5
164	O8	ST8	163	C1	21.3	25.7	18.7	4.7
165	O1	ST29	150	C1	11.5	25.7	29.1	<u>0.08</u>
166	O2	ST30	190	C2	12.3	23.2	29.9	<u>0.09</u>
167	O3	ST29	204	C3	11.1	20.8	26.5	<u>0.07</u>
168	O4	ST30	96	C4	13.2	31.5	18.2	<u>0.08</u>
169	O5	ST29	88	C1	13.3	30.7	32.1	<u>0.09</u>
170	O6	ST30	178	C2	10.5	29.3	17.3	<u>0.07</u>
171	O7	ST29	156	C3	10.3	30.8	26.0	<u>0.09</u>

[0082]

[Table 10-5]

No.	Analysis			
	Maximum value of P concentration of surface layer region/average P concentration of intermediate region	Presence or absence of Al in interface side region	Proportion of F content of interface side region (interface side region/total)	Presence or absence of Sb in interface side region
1	4.8	Present	0	None
2	3.8	Present	0	None
3	4.4	Present	0	None
4	1.5	Present	0	None
5	3.3	Present	0	None
6	1.6	Present	0	None
7	1.9	Present	0	None
8	3.0	Present	0	None
9	2.4	Present	0	None
10	3.4	Present	0	None
11	2.3	Present	0	None
12	4.5	Present	0	None
13	3.0	Present	0	None
14	4.7	Present	0	None

15	2.1	Present	0	None
16	4.5	Present	0	None
17	<u>8.3</u>	Present	0	None
18	<u>6.4</u>	Present	0	None
19	<u>5.1</u>	Present	0	None
20	<u>8.1</u>	Present	0	None
21	<u>9.9</u>	Present	0	None
22	<u>9.7</u>	Present	0	None
23	<u>9.7</u>	Present	0	None
24	<u>7.9</u>	Present	0	None
25	<u>0.9</u>	Present	0	None
26	<u>0.6</u>	Present	0	None
27	<u>1.2</u>	Present	0	None
28	<u>1.3</u>	Present	0	None
29	<u>1.1</u>	Present	0	None
30	<u>1.0</u>	Present	0	None
31	<u>1.2</u>	Present	0	None
32	<u>0.5</u>	Present	0	None
33	4.8	Present	25	None
34	3.5	Present	22	None
35	3.2	Present	28	None
36	1.7	Present	30	None
37	4.6	Present	21	None
38	2.6	Present	38	None
39	4.7	Present	45	None
40	3.6	Present	25	None
41	2.6	Present	30	None
42	4.1	Present	37	None
43	2.1	Present	39	None
44	2.4	Present	40	None
45	3.3	Present	25	None
46	3.2	Present	28	None
47	2.3	Present	30	None
48	2.8	Present	23	None

[0083]

[Table 10-6]

No.	Analysis			
	Maximum value of P concentration of surface layer region/average P concentration of intermediate region	Presence or absence of Al in interface side region	Proportion of F content of interface side region (interface side region/total)	Presence or absence of Sb in interface side region
49	3.0	Present	5	None
50	4.7	Present	7	None
51	1.8	Present	1	None
52	3.0	Present	15	None
53	4.7	Present	13	None
54	2.3	Present	8	None
55	1.6	Present	9	None
56	2.2	Present	2	None
57	4.6	Present	35	None
58	4.2	Present	38	None
59	3.6	Present	28	None
60	2.1	Present	25	None

61	3.4	Present	47	None
62	3.3	Present	23	None
63	2.0	Present	40	None
64	2.9	Present	27	None
65	1.6	Present	0	None
66	2.1	Present	0	None
67	4.5	Present	0	None
68	2.7	Present	0	None
69	2.5	Present	0	None
70	1.7	Present	0	None
71	4.1	Present	0	Present
72	2.5	Present	0	Present
73	2.8	Present	0	Present
74	1.6	Present	0	Present
75	4.6	Present	0	Present
76	3.5	Present	0	Present
77	4.1	Present	0	Present
78	2.9	Present	0	Present
79	2.8	Present	0	Present
80	4.1	Present	0	Present
81	1.9	Present	25	Present
82	4.0	Present	29	Present
83	4.5	Present	37	Present
84	1.7	Present	43	Present
85	3.5	Present	50	Present
86	4.6	Present	25	Present
87	1.6	Present	25	Present
88	3.7	Present	26	Present
89	3.2	Present	40	Present
90	3.8	Present	38	Present
91	2.4	Present	38	Present
92	4.1	Present	31	Present
93	4.6	Present	37	Present
94	4.1	Present	42	Present
95	3.3	Present	41	Present
96	2.1	Present	40	Present

[0084]

[Table 10-7]

No.	Analysis			
	Maximum value of P concentration of surface layer region/average P concentration of intermediate region	Presence or absence of Al in interface side region	Proportion of F content of interface side region (interface side region/total)	Presence or absence of Sb in interface side region
97	3.6	Present	0	None
98	1.8	Present	0	None
99	1.6	Present	0	None
100	4.3	Present	0	None
101	3.8	Present	0	None
102	4.4	Present	0	None
103	4.6	Present	0	None
104	3.1	Present	0	None

105	2.4	Present	0	None
106	1.9	Present	0	None
107	3.9	Present	0	None
108	2.5	Present	0	None
109	3.7	Present	0	None
110	2.8	Present	0	None
111	1.9	Present	0	None
112	4.1	Present	0	None
113	2.5	Present	28	Present
114	2.1	Present	30	Present
115	4.5	Present	33	Present
116	4.3	Present	33	Present
117	3.7	Present	37	Present
118	3.4	Present	21	Present
119	3.3	Present	28	Present
120	2.8	Present	40	Present
121	3.1	Present	45	Present
122	4.6	Present	30	Present

[0085]

[Table 10-8]

No.	Analysis			
	Maximum value of P concentration of surface layer region/average P concentration of intermediate region	Presence or absence of Al in interface side region	Proportion of F content of interface side region (interface side region/total)	Presence or absence of Sb in interface side region
129	1.9	Present	0	None
130	2.9	Present	0	None
131	1.8	Present	0	None
132	2.3	Present	0	None
133	1.5	Present	0	None
134	4.3	Present	0	None
135	4.2	Present	0	None
136	4.1	Present	0	None
137	<u>0.8</u>	Present	0	None
138	<u>0.7</u>	Present	0	None
139	<u>1.3</u>	Present	0	None
140	<u>1.1</u>	Present	0	None
141	<u>1.1</u>	Present	0	None
142	<u>1.2</u>	Present	0	None
143	<u>0.5</u>	Present	0	None
144	<u>0.4</u>	Present	0	None
145	1.8	Present	0	None
146	2.5	Present	0	None
147	3.5	Present	0	None
148	3.5	Present	0	None
149	4.8	Present	0	None
150	1.6	Present	0	None
151	2.4	Present	0	None
152	4.9	Present	0	None
153	2.4	Present	11	None
154	2.1	Present	7	None

155	3.1	Present	5	None
156	2.2	Present	8	None
157	4.6	Present	50	None
158	3.0	Present	45	None
159	3.2	Present	48	None
160	3.0	Present	38	None
161	4.7	None	11	None
162	3.4	None	5	None
163	3.3	None	5	None
164	1.8	None	8	None
165	1.5	Present	0	None
166	<u>1.7</u>	Present	0.0	None
167	1.6	Present	0	None
168	1.5	Present	0	None
169	1.5	Present	0	None
170	1.7	Present	0	None
171	1.5	Present	0	None

[0086]

[Table 10-9]

No.	Quality characteristics					Category
	Fingerprint resistance	Powdering resistance	Corrosion resistance	External appearance	Blackening resistance	
1	⊙	○	○	○	○	Inventive Example
2	⊙	○	○	○	○	Inventive Example
3	⊙	○	○	○	○	Inventive Example
4	○	○	○	○	○	Inventive Example
5	⊙	○	○	○	○	Inventive Example
6	○	○	○	○	○	Inventive Example
7	○	○	○	○	○	Inventive Example
8	⊙	○	○	○	○	Inventive Example
9	⊙	○	○	○	○	Inventive Example
10	⊙	○	○	○	○	Inventive Example
11	⊙	○	○	○	○	Inventive Example
12	⊙	○	○	○	○	Inventive Example
13	⊙	○	○	○	○	Inventive Example
14	⊙	○	○	○	○	Inventive Example
15	⊙	○	○	○	○	Inventive Example
16	⊙	○	○	○	○	Inventive Example
17	⊙+	×	○	○	○	Comparative Example
18	⊙+	×	○	○	○	Comparative Example
19	⊙+	×	○	○	○	Comparative Example
20	⊙+	×	○	○	○	Comparative Example
21	⊙+	×	○	○	○	Comparative Example
22	⊙+	×	○	○	○	Comparative Example
23	⊙+	×	○	○	○	Comparative Example
24	⊙+	×	○	○	○	Comparative Example

25	×	○	○	○	○	Comparative Example
26	×	○	○	○	○	Comparative Example
27	×	○	○	○	○	Comparative Example
28	×	○	○	○	○	Comparative Example
29	×	○	○	○	○	Comparative Example
30	×	○	○	○	○	Comparative Example
31	×	○	○	○	○	Comparative Example
32	×	○	○	○	○	Comparative Example
33	⊙	○	⊙	○	○	Inventive Example
34	⊙	○	⊙	○	○	Inventive Example
35	⊙	○	⊙	○	○	Inventive Example
36	○	○	⊙	○	○	Inventive Example
37	⊙	○	⊙	○	○	Inventive Example
38	⊙	○	⊙	○	○	Inventive Example
39	⊙	○	⊙	○	○	Inventive Example
40	⊙	○	⊙	○	○	Inventive Example
41	⊙	○	⊙	○	○	Inventive Example
42	⊙	○	⊙	○	○	Inventive Example
43	⊙	○	⊙	○	○	Inventive Example
44	⊙	○	⊙	○	○	Inventive Example
45	⊙	○	⊙	○	○	Inventive Example
46	⊙	○	⊙	○	○	Inventive Example
47	⊙	○	⊙	○	○	Inventive Example
48	⊙	○	⊙	○	○	Inventive Example

[0087]

[Table 10-10]

No.	Quality characteristics					Category
	Fingerprint resistance	Powdering resistance	Corrosion resistance	External appearance	Blackening resistance	
49	⊙	○	○	○	○	Inventive Example
50	⊙	○	○	○	○	Inventive Example
51	○	○	○	○	○	Inventive Example
52	⊙	○	○	○	○	Inventive Example
53	⊙	○	○	○	○	Inventive Example
54	⊙	○	○	○	○	Inventive Example
55	○	○	○	○	○	Inventive Example
56	⊙	○	○	○	○	Inventive Example
57	⊙	○	⊙	△	○	Inventive Example
58	⊙	○	⊙	△	○	Inventive Example
59	⊙	○	⊙	△	○	Inventive Example
60	⊙	○	⊙	△	○	Inventive Example
61	⊙	○	⊙	△	○	Inventive Example
62	⊙	○	⊙	△	○	Inventive Example
63	⊙	○	⊙	△	○	Inventive Example
64	⊙	○	⊙	△	○	Inventive Example

65	○	○	○	○	○	Inventive Example
66	◎	○	○	○	○	Inventive Example
67	◎	○	○	○	○	Inventive Example
68	◎	○	○	○	○	Inventive Example
69	◎	○	○	○	○	Inventive Example
70	○	○	○	○	○	Inventive Example
71	◎	○	○	○	◎	Inventive Example
72	◎	○	○	○	◎	Inventive Example
73	◎	○	○	○	◎	Inventive Example
74	○	○	○	○	◎	Inventive Example
75	◎	○	○	○	◎	Inventive Example
76	◎	○	○	○	◎	Inventive Example
77	◎	○	○	○	◎	Inventive Example
78	◎	○	○	○	◎	Inventive Example
79	◎	○	○	○	◎	Inventive Example
80	◎	○	○	○	◎	Inventive Example
81	○	○	◎	○	◎	Inventive Example
82	◎	○	◎	○	◎	Inventive Example
83	◎	○	◎	○	◎	Inventive Example
84	○	○	◎	○	◎	Inventive Example
85	◎	○	◎	○	◎	Inventive Example
86	◎	○	◎	○	◎	Inventive Example
87	○	○	◎	○	◎	Inventive Example
88	◎	○	◎	○	◎	Inventive Example
89	◎	○	◎	○	◎	Inventive Example
90	◎	○	◎	○	◎	Inventive Example
91	◎	○	◎	○	◎	Inventive Example
92	◎	○	◎	○	◎	Inventive Example
93	◎	○	◎	○	◎	Inventive Example
94	◎	○	◎	○	◎	Inventive Example
95	◎	○	◎	○	◎	Inventive Example
96	◎	○	◎	○	◎	Inventive Example

[0088]

[Table 10-11]

No.	Quality characteristics					Category
	Fingerprint resistance	Powdering resistance	Corrosion resistance	External appearance	Blackening resistance	
97	◎	○	○	○	○	Inventive Example
98	○	○	○	○	○	Inventive Example
99	○	○	○	○	○	Inventive Example
100	◎	○	○	○	○	Inventive Example
101	◎	○	○	○	○	Inventive Example
102	◎	○	○	○	○	Inventive Example
103	◎	○	○	○	○	Inventive Example
104	◎	○	○	○	○	Inventive Example
105	◎	○	○	○	○	Inventive Example
106	○	○	○	○	○	Inventive Example
107	◎	○	○	○	○	Inventive Example
108	◎	○	○	○	○	Inventive Example
109	◎	○	○	○	○	Inventive Example
110	◎	○	○	○	○	Inventive Example

111	○	○	○	○	○	Inventive Example
112	◎	○	○	○	○	Inventive Example
113	◎	○	◎	○	◎	Inventive Example
114	◎	○	◎	○	◎	Inventive Example
115	◎	○	◎	○	◎	Inventive Example
116	◎	○	◎	○	◎	Inventive Example
117	◎	○	◎	○	◎	Inventive Example
118	◎	○	◎	○	◎	Inventive Example
119	◎	○	◎	○	◎	Inventive Example
120	◎	○	◎	○	◎	Inventive Example
121	◎	○	◎	○	◎	Inventive Example
122	◎	○	◎	○	◎	Inventive Example

[0089]

[Table 10-12]

No.	Quality characteristics					Category
	Fingerprint resistance	Powdering resistance	Corrosion resistance	External appearance	Blackening resistance	
129	○	○	△	○	○	Inventive Example
130	◎	○	△	○	○	Inventive Example
131	○	○	△	○	○	Inventive Example
132	◎	○	△	○	○	Inventive Example
133	○	○	△	○	○	Inventive Example
134	◎	○	△	○	○	Inventive Example
135	◎	○	△	○	○	Inventive Example
136	◎	○	△	○	○	Inventive Example
137	×	○	○	○	○	Comparative Example
138	×	○	○	○	○	Comparative Example
139	×	○	○	○	○	Comparative Example
140	×	○	○	○	○	Comparative Example
141	×	○	○	○	○	Comparative Example
142	×	○	○	○	○	Comparative Example
143	×	○	○	○	○	Comparative Example
144	×	○	○	○	○	Comparative Example
145	○	○	×	○	○	Comparative Example
146	◎	○	×	○	○	Comparative Example
147	◎	○	×	○	○	Comparative Example
148	◎	○	×	○	○	Comparative Example
149	◎	△	△	○	○	Inventive Example
150	○	△	△	○	○	Inventive Example
151	◎	△	△	○	○	Inventive Example

152	⊙	△	△	○	○	Inventive Example
153	⊙	○	○	○	○	Inventive Example
154	⊙	○	○	○	○	Inventive Example
155	⊙	○	○	○	○	Inventive Example
156	⊙	○	○	○	○	Inventive Example
157	⊙	○	⊙	△	○	Inventive Example
158	⊙	○	⊙	△	○	Inventive Example
159	⊙	○	⊙	△	○	Inventive Example
160	⊙	○	⊙	△	○	Inventive Example
161	⊙	○	○	○	○	Inventive Example
162	⊙	○	○	○	○	Inventive Example
163	⊙	○	○	○	○	Inventive Example
164	○	○	○	○	○	Inventive Example
165	○	○	×	○	○	Comparative Example
166	○	○	×	○	○	Comparative Example
167	○	○	×	○	○	Comparative Example
168	○	○	×	○	○	Comparative Example
169	○	○	×	○	○	Comparative Example
170	○	○	×	○	○	Comparative Example
171	○	○	×	○	○	Comparative Example

[0090]

As is apparent from Tables 1 to 10 to 12, Invention Examples Nos. 1 to 16, 33 to 122, 129 to 136 and 149 to 164 in which the chemical conversion treatment layer contains predetermined amounts of Si, C, O and P and the maximum value of the P concentration of the surface layer region is 1.5 times to 5.0 times the average P concentration of the intermediate region were excellent in the fingerprint resistance while having sufficient powdering resistance and corrosion resistance.

On the other hand, Comparative Examples Nos. 17 to 32, 137 to 148 and 165 to 171 were poor in any of fingerprint resistance, powdering resistance and corrosion resistance.

Among the inventive examples, those in which Al is present in the interface side region and the F content of the interface side region is 20% or more of the F content of

the entire chemical conversion treatment layer were further excellent in corrosion resistance.

When Sb was present in the interface side region, further excellent blackening resistance was exhibited.

5 [Brief Description of the Reference Symbols]

[0091]

1 Surface-treated steel sheet

11 Steel sheet

12 Plated layer

10 13 Chemical conversion treatment layer

101 Surface layer region

102 Interface side region

103 Intermediate region

[What is claimed is]

1. A surface-treated steel sheet comprising:

a steel sheet;

a zinc-based plated layer formed on a surface of the steel sheet; and

5 a chemical conversion treatment layer formed on a surface of the zinc-based plated layer,

wherein the chemical conversion treatment layer contains Si, C, O and P,

the chemical conversion treatment layer has a C concentration of 20.0 mass% or more, an O concentration of 15.0 mass% or more, a Si concentration of 10.0 mass% or

10 more, and a P concentration of 0.10 mass% or more,

when t is a thickness of the chemical conversion treatment layer, an area starting from a surface of the chemical conversion treatment layer and ending at a position of $t/10$ from the surface of the chemical conversion treatment layer in a thickness direction is a surface layer region, an area starting from the position of $9t/10$ from the surface of the chemical conversion treatment layer in the thickness direction and ending at an interface between the chemical conversion treatment layer and the zinc-based plated layer is an interface side region, and a region sandwiched between the surface layer region and the interface side region is an intermediate region,

15 a maximum value of a P concentration of the surface layer region is 1.5 times to 5.0 times an average P concentration of an intermediate region.

2. The surface-treated steel sheet according to claim 1, wherein Al is present in the interface side region, and

an F content of the interface side region is 20% or more of an F content of the entire chemical conversion treatment layer.

25 3. The surface-treated steel sheet according to claim 1 or 2, wherein

Sb is present in the interface side region.

4. The surface-treated steel sheet according to any one of claims 1 to 3, wherein
a surface of the zinc-based plated layer is regular spangle-finished.