

DESCRIPTION

[Title of Invention] GALVANIZED STEEL SHEET

[Technical Field]

5 [0001]

The present invention relates to an environmentally friendly galvanized steel sheet that is used for automobiles, household electrical appliances, building materials, and the like and that is surface-treated such that a surface-
10 treatment film formed on a surface of the galvanized steel sheet is completely free from regulated substances causing pollution such as hexavalent chromium; in particular, to a galvanized steel sheet that is suitable for applications relating to electric and electronic devices and the like in
15 which electromagnetic interference (EMI) needs to be suppressed, that has excellent electromagnetic shielding characteristics, and that also has excellent corrosion resistance.

[Background Art]

20 [0002]

With recent trends toward digitization of household electrical appliances, an increase in the speed of CPUs, and the like, issues relating to hazard of electromagnetic radiation to devices and human bodies around such appliances
25 and CPUs have been attracting attention. To address the

issues, "The Voluntary Control Council for Interference by
Information Technology Equipment (VCCI)" was established in
Japan. To comply with the rules of VCCI, there has been an
increasingly strong trend in the industry toward voluntary
5 control in terms of the issues relating to hazard of
electromagnetic radiation. To address electromagnetic noise
from electronic boards and the like within electric and
electronic devices, for example, there is a technique of
surrounding the electronic boards and the like with shield
10 boxes composed of metal (electrically conductive) materials
to achieve electromagnetic shielding.

[0003]

In such a shield box, the electrically conductive
material forming the shield box reflects electromagnetic
15 waves to thereby achieve electromagnetic shielding. The
higher the electrical conductivity of a material forming a
shield box, the higher the electromagnetic wave reflectivity
becomes and the better the electromagnetic shielding
property becomes. Accordingly, to ensure the
20 electromagnetic shielding property of a shield box, it is
important that metal plates forming the shield box have high
electrical conductivity.

[0004]

Such a shield box is produced by forming metal plates
25 into the shape and hence has discontinuous portions (joints

and joining portions). Leakage or entry of electromagnetic waves tends to occur through such discontinuous portions. Accordingly, to suppress leakage and entry of electromagnetic waves, electrically conductive gaskets are generally inserted in the discontinuous portions of shield boxes.

[0005]

To enhance the shielding property of a shield box, the shield box needs to have a structure in which desired current can be passed through the entirety of the shield box. However, such portions where metal members and gaskets are in contact with each other generally have a low contact pressure and hence have poor electrical continuity (hereafter, simply referred to as "continuity") between the metal members and gaskets. Thus, the amount of current passing through the contact portions tends to become small. Accordingly, to further enhance the performance of a shield box, it is important to ensure electrical conductivity of metal plates forming the shield box and to ensure continuity between the metal plates and gaskets.

[0006]

Since electric and electronic devices are used in various environments, materials forming shield boxes are required not to corrode in usage in severe environments, that is, to have excellent corrosion resistance. Steel

sheets obtained by subjecting surfaces of galvanized steel sheets to a chromate treatment with a treatment solution mainly containing chromic acid, dichromic acid, or a salt of the foregoing for the purpose of enhancing corrosion resistance (white-rust resistance and red-rust resistance) are widely used as steel sheets for household electrical appliances, steel sheets for building materials, and steel sheets for automobiles.

[0007]

10 As described above, metal members (steel sheets) forming shield boxes need to have high electrical conductivity and to allow for continuity between the metal members and gaskets. Although films formed on surfaces of steel sheets by a chromate treatment have lower electrical
15 conductivity than the base steel sheets, films formed by a chromate treatment can exhibit rust resistance even when the films have a small thickness. Accordingly, in surface-treated steel sheets subjected to a chromate treatment, by forming films having low electrical conductivity so as to
20 have a minimum thickness, electrical conductivity equivalent to that of steel sheets (not surface-treated) is achieved. As a result, continuity between the sheets and the gaskets can be sufficiently ensured and hence both rust resistance and electromagnetic shielding can be achieved. However, due
25 to recent global environmental issues, there is an

increasing demand for employment of pollution-free surface-treated steel sheets provided without using a chromate treatment, that is, chromium-free treated steel sheets.

[0008]

5 A large number of techniques relating to chromium-free treated steel sheets have been developed: for example, techniques of using the passivation effect of molybdic acid and tungstic acid belonging to group IVA as with chromic acid; techniques of using metal salts of transition metals
10 such as Ti, Zr, V, Mn, Ni and Co and rare-earth elements such as La and Ce; techniques based on chelating agents such as polyhydric phenolcarboxylic acid such as tannic acid and S- or N-containing compounds; techniques of forming polysiloxane films with silane coupling agents; and
15 techniques in combination of the foregoing.

[0009]

Specific examples are as follows:

- (1) a technique of forming a film with a treatment solution containing a coating agent obtained by reaction between an
20 organic resin such as a polyvinylphenol derivative, an acid component, and an epoxy compound, a silane coupling agent, a vanadium compound, and the like (for example, Patent Literatures 1, 2, 3, and 4),
(2) a technique of forming a film containing an aqueous
25 resin, a thiocarbonyl group, a vanadate compound, and

phosphoric acid (for example, Patent Literature 5),

(3) a technique of forming a film with a treatment solution containing a compound of a metal such as Ti, an inorganic acid such as a fluoride or a phosphate compound, and an

5 organic acid (Patent Literatures 6, 7, 8, 9, 10, 11, and 12),

(4) a technique in which a composite film containing a rare-earth element such as Ce, La, or Y and the Ti or Zr element, a layer having a high oxide content is formed in a region of the film closer to the interface between the film and the

10 coated layer, and a layer having a high hydroxide content is formed in a region of the film closer to the front surface (Patent Literature 13); and a technique of forming a composite film composed of Ce and a Si oxide (Patent Literature 14),

15 (5) a technique of forming an organic composite coating constituted by a lower layer that is a phosphoric acid and/or phosphate compound film containing an oxide and an upper layer that is a resin film (for example, Patent Literatures 15 and 16), and

20 (6) a technique of forming a composite film composed of a specific inhibitor component and a silica/zirconium compound (for example, Patent Literature 17).

[0010]

The films formed by these techniques are intended to
25 suppress generation of white rust of zinc by composite

addition of organic components or inorganic components. For example, in the techniques (1) and (2), corrosion resistance is ensured by mainly adding organic resins. However, in a film containing such organic resins, the organic resins have an insulating property. Accordingly, a steel sheet having such a film does not have sufficient electrical conductivity and hence is not suitable as the material of a shield box.

[0011]

The techniques (3) and (4) provide films that are completely free from organic components and are composed of inorganic components only. However, such a composite film composed of a metal oxide and a metal hydroxide needs to have a large thickness to impart sufficient corrosion resistance to a galvanized steel sheet. In addition, a surface of a galvanized steel sheet is covered with a non-conductive film (insulating film) composed of zinc phosphate or the like. Accordingly, as in the techniques (1) and (2), high electrical conductivity is less likely to be achieved and it is difficult to achieve both corrosion resistance and electrical conductivity.

[0012]

In the technique (5), since the electrical conductivity of a surface of a surface-treated steel sheet depends on the thickness of an insulating film formed on the surface, the insulating film is formed so as to have a small thickness to

thereby achieve good electrical conductivity. However, a decrease in the film thickness results in degradation of corrosion resistance of the steel sheet. Accordingly, it is difficult to provide a surface-treated steel sheet that is
5 excellent in terms of both corrosion resistance and electrical conductivity.

[0013]

The technique (6) provides excellent corrosion resistance by using the passivation effect of a vanadate
10 compound serving as an inhibitor component and a sparingly soluble metal salt from a phosphate compound serving as an inhibitor component, and by forming a composite film containing a zirconium compound, silica fine particles, and a silane coupling agent that form the skeleton of the film.
15 However, to ensure electrical conductivity, the film thickness needs to be small. Accordingly, it is difficult to achieve both corrosion resistance and electrical conductivity.

[0014]

20 As described above, to make the chromium-free treated steel sheet having been developed so far have corrosion resistance equivalent to that of existing chromate films, films having a high insulating property need to be formed so as to have a large thickness. Accordingly, it is difficult
25 for such chromium-free treated steel sheets to have

sufficiently high electrical conductivity. Thus, these steel sheets do not sufficiently satisfy characteristics required for steel sheets forming shield box bodies. In addition, as described above, to enhance the shielding property of a shield box, sufficiently high continuity needs to be achieved between metal members (steel sheets) and gaskets that are in contact with each other at a low contact pressure. However, such continuity is not considered at all in any of the above-described techniques.

10 [Citation List]

[Patent Literature]

[0015]

PTL 1: Japanese Unexamined Patent Application
Publication No. 2003-13252

15 PTL 2: Japanese Unexamined Patent Application
Publication No. 2001-181860

PTL 3: Japanese Unexamined Patent Application
Publication No. 2004-263252

20 PTL 4: Japanese Unexamined Patent Application
Publication No. 2003-155452

PTL 5: Japanese Patent No. 3549455

PTL 6: Japanese Patent No. 3302677

PTL 7: Japanese Unexamined Patent Application
Publication No. 2002-105658

25 PTL 8: Japanese Unexamined Patent Application

Publication No. 2004-183015

PTL 9: Japanese Unexamined Patent Application

Publication No. 2003-171778

PTL 10: Japanese Unexamined Patent Application

5 Publication No. 2001-271175

PTL 11: Japanese Unexamined Patent Application

Publication No. 2006-213958

PTL 12: Japanese Unexamined Patent Application

Publication No. 2005-48199

10 PTL 13: Japanese Unexamined Patent Application

Publication No. 2001-234358

PTL 14: Japanese Patent No. 3596665

PTL 15: Japanese Unexamined Patent Application

Publication No. 2002-53980

15 PTL 16: Japanese Unexamined Patent Application

Publication No. 2002-53979

PTL 17: Japanese Unexamined Patent Application

Publication No. 2008-169470

[Summary of Invention]

20 [Technical Problem]

[0016]

An object of the present invention is to provide a
galvanized steel sheet having a surface-treatment film on a
galvanized surface, the surface-treatment film overcoming
25 the above-described problems, being completely free from

regulated substances causing pollution such as hexavalent chromium, having various properties such as corrosion resistance and adhesion, and allowing for excellent continuity without degrading corrosion resistance even under
5 a severe condition in which the steel sheet is in contact with a gasket or the like at a low contact pressure.

[Solution to Problem]

[0017]

The inventors of the present invention have performed
10 thorough studies on how to overcome the problems. As a result, the inventors have found that the problems can be overcome by using an alkaline surface-treatment agent containing a water-soluble zirconium compound, a tetraalkoxysilane, an epoxy-group-containing compound, a
15 chelating agent, a vanadate compound, a metal compound, and the like. Thus, the present invention has been accomplished.

[0018]

Specifically, the present invention provides the following (1) to (5).

- 20 (1) A galvanized steel sheet including a surface-treatment film having a coating weight of 50 to 1200 mg/m² relative to a surface of the galvanized steel sheet, wherein the surface-treatment film is obtained by applying a surface-treatment agent to the surface of the galvanized steel sheet
25 and drying the surface-treatment agent by heating; and the

surface-treatment agent is prepared so as to contain a water-soluble zirconium compound (A), a tetraalkoxysilane (B), an epoxy-group-containing compound (C), a chelating agent (D), a vanadate compound (E), and a metal compound (F) containing one or more metals selected from the group consisting of Ti, Al, and Zn, to have a pH of 8 to 10, and to satisfy conditions (I) to (V) below,

Note

(I) a ratio (A/B) of a mass of the water-soluble zirconium compound (A) in terms of Zr to a mass of the tetraalkoxysilane (B) is 1.0 to 6.0;

(II) a ratio (B/C) of the mass of the tetraalkoxysilane (B) to a mass of the epoxy-group-containing compound (C) is 0.1 to 1.6;

(III) a ratio (B/D) of the mass of the tetraalkoxysilane (B) to a mass of the chelating agent (D) is 0.3 to 2.0;

(IV) a ratio (E/D) of a mass of the vanadate compound (E) in terms of V to the mass of the chelating agent (D) is 0.03 to 1.0; and

(V) a ratio (F/D) of a total metal mass of the metal compound (F) to the mass of the chelating agent (D) is 0.05 to 0.8.

Note that, in the formulae representing the mass ratios, A represents the mass of the water-soluble zirconium

compound (A) in terms of Zr; B represents the mass of the tetraalkoxysilane (B); C represents the mass of the epoxy-group-containing compound (C); D represents the mass of the chelating agent (D); E represents the mass of the vanadate
5 compound (E) in terms of V; and F represents the total metal mass of the metal compound (F). These definitions will also be used below.

[0019]

(2) The galvanized steel sheet according to (1), wherein the
10 coating weight relative to the surface is 50 to 500 mg/m².

[0020]

(3) The galvanized steel sheet according to (1) or (2), wherein the surface-treatment agent further contains a lubricant (G) and a content of the lubricant (G) is 1 to 10
15 mass% relative to a total solid content of the surface-treatment agent.

[0021]

(4) The galvanized steel sheet according to any one of (1) to (3), wherein the surface-treatment agent further contains
20 a nonionic acrylic resin emulsion (H) and a content of the nonionic acrylic resin emulsion (H) is 0.5 to 45.0 mass% relative to a total solid content of the surface-treatment agent.

[0022]

25 (5) The galvanized steel sheet according to (4), wherein the

content of the nonionic acrylic resin emulsion (H) is 0.5 to 4.5 mass% relative to the total solid content of the surface-treatment agent.

[Advantageous Effects of Invention]

5 [0023]

According to the present invention, a galvanized steel sheet can be provided that has various properties such as corrosion resistance and adhesion and allows for excellent continuity without degrading corrosion resistance even under
10 a severe condition in which the steel sheet is in contact with a gasket or the like at a low contact pressure.

[Description of Embodiments]

[0024]

Hereinafter, the present invention will be described in
15 detail.

A galvanized steel sheet according to the present invention will be first described.

[0025]

Non-limiting examples of a galvanized steel sheet
20 according to the present invention include a hot dip galvanized steel sheet (GI), a hot dip galvanized steel sheet (GI), a hot dip galvanized steel sheet (GI), a hot dip Zn-5 mass% Al alloy-coated steel sheet (GF), a hot dip Zn-55 mass% Al alloy-coated steel sheet (GL), an electrogalvanized steel sheet
25

(EG), and a Zn-Ni alloy electrogalvanized steel sheet (Zn-11 mass% Ni).

[0026]

A galvanized steel sheet according to the present
5 invention is excellent in terms of continuity and includes a film having a coating weight of 50 to 1200 mg/m² relative to a surface of the galvanized steel sheet, wherein the film is obtained by applying a surface-treatment agent to the surface of the galvanized steel sheet and drying the
10 surface-treatment agent by heating; and the surface-treatment agent is prepared so as to contain a water-soluble zirconium compound (A), a tetraalkoxysilane (B), an epoxy-group-containing compound (C), a chelating agent (D), a vanadate compound (E), and a metal compound (F) containing
15 one or more metals selected from the group consisting of Ti, Al, and Zn.

Hereinafter, a surface-treatment agent used in the present invention will be described.

[0027]

20 A surface-treatment agent used in the present invention contains a water-soluble zirconium compound (A). When a surface-treatment film is formed on a surface of a galvanized steel sheet with a surface-treatment agent containing a water-soluble zirconium compound, a galvanized
25 steel sheet is provided that is excellent in terms of

various properties such as corrosion resistance of the steel sheet, adhesion of the formed film, and corrosion resistance of the steel sheet after alkaline degreasing, and is excellent in terms of heat resistance and weldability, which are characteristics of inorganic films.

[0028]

A water-soluble zirconium compound (A) used in the present invention is not particularly limited and examples thereof include zirconium nitrate, zirconium oxynitrate, zirconyl acetate, zirconyl sulfate, zirconium carbonate, ammonium zirconyl carbonate, potassium zirconyl carbonate, sodium zirconyl carbonate, and zircon hydrofluoric acid. One or more of these examples may be used. In particular, ammonium zirconyl carbonate and sodium zirconyl carbonate are preferred because a galvanized steel sheet more excellent in terms of corrosion resistance and continuity is provided.

[0029]

A surface-treatment agent used in the present invention contains a tetraalkoxysilane (B). When a film is formed on a surface of a galvanized steel sheet with a surface-treatment agent containing the water-soluble zirconium and a tetraalkoxysilane, a galvanized steel sheet is provided that is excellent in terms of various properties such as corrosion resistance of the steel sheet, adhesion of the

formed film, and corrosion resistance of the steel sheet after alkaline degreasing, and is excellent in terms of heat resistance and weldability, which are characteristics of inorganic films. The reason why such excellent

5 characteristics are provided is not clear. But, the characteristics are probably provided because, when the tetraalkoxysilane (B) and the above-described water-soluble zirconium (A) are used in combination, the water-soluble zirconium (A) and the tetraalkoxysilane (B) form a film
10 having three-dimensional crosslinking.

[0030]

A tetraalkoxysilane (B) used in the present invention is not particularly limited as long as it has four alkoxy groups in a single molecule. Examples of the
15 tetraalkoxysilane (B) include tetramethoxysilane, tetraethoxysilane, tetrapropoxysilane, and tetrabutoxysilane. One or more of these examples may be used. Such an alkoxy group is not particularly limited and may be, for example, an alkoxy group having 1 to 4 carbon atoms, preferably 1 to
20 3 carbon atoms, more preferably 1 to 2 carbon atoms.

Specifically, in view of providing a galvanized steel sheet having more excellent corrosion resistance, tetraethoxysilane and tetramethoxysilane are preferable.

[0031]

25 A surface-treatment agent according to the present

invention contains the water-soluble zirconium (A) and the tetraalkoxysilane (B) such that a ratio (A/B) of the mass of the water-soluble zirconium (A) in terms of Zr to the mass of the tetraalkoxysilane (B) is 1.0 to 6.0, preferably 1.6 to 3.1. When the mass ratio is less than 1.0, a galvanized steel sheet having excellent corrosion resistance is not provided. When the mass ratio is more than 6.0, the galvanized steel sheet exhibits poor continuity.

[0032]

10 A surface-treatment agent used in the present invention contains an epoxy-group-containing compound (C). When a film is formed on a surface of a galvanized steel sheet with a surface-treatment agent containing the water-soluble zirconium, the tetraalkoxysilane, and the epoxy-group-
15 containing compound (C), a galvanized steel sheet is provided that is excellent in terms of various properties such as corrosion resistance of the steel sheet and corrosion resistance of the steel sheet after alkaline degreasing; and the film formed on the surface of the
20 galvanized steel sheet is excellent in terms of adhesion, resistance to scratching, and lubricity.

[0033]

An epoxy-group-containing compound (C) used in the present invention is not particularly limited and examples
25 thereof include an epoxy-group-containing silane coupling

agent such as γ -glycidoxypropyltrimethoxysilane, γ -glycidoxypropylmethyldiethoxysilane, or γ -glycidoxypropyltriethoxysilane; an epoxy-group-containing ester compound such as diglycidyl adipate, diglycidyl phthalate, and diglycidyl terephthalate; and an epoxy-containing ether compound such as sorbitol polyglycidyl ether, sorbitan polyglycidyl ether, polyglycerol polyglycidyl ether, pentaerythritol polyglycidyl ether, diglycerol polyglycidyl ether, glycerol polyglycidyl ether, trimethylpropane polyglycidyl ether, neopentylglycol diglycidyl ether, ethylene glycol diglycidyl ether, polyethylene glycol diglycidyl ether, propylene glycol diglycidyl ether, or polypropylene glycol diglycidyl ether. One or more of these examples may be used. In particular, in view of providing a galvanized steel sheet having more excellent corrosion resistance with a small film weight, an epoxy-group-containing silane coupling agent is preferred.

[0034]

The epoxy-group-containing compound (C) used in the present invention is contained such that the ratio (B/C) of the mass of the tetraalkoxysilane (B) to the total mass of the epoxy-group-containing compound (C) is 0.1 to 1.6, preferably 0.2 to 1.2. When the mass ratio is less than 0.1, a galvanized steel sheet having excellent corrosion resistance is not provided. When the mass ratio is more

than 1.6, adhesion of the film becomes poor.

[0035]

A surface-treatment agent used in the present invention contains a chelating agent (D). A surface-treatment agent
5 that contains the chelating agent (D) exhibits excellent storage stability. The reason for this is not clear. The chelating agent (D) probably has the effect of suppressing polymerization of the tetraalkoxysilane (B) in the surface-treatment agent. Probably as a result of this effect, even
10 when the surface-treatment agent is stored over a long period of time after the preparation thereof, it does not alter and maintains the quality thereof at the time of preparation. The chelating agent (D) is also necessary to stably dissolve the vanadate compound (E) and the metal
15 compound (F) in the surface-treatment agent. The chelating agent (D) is less likely to etch the surface of a zinc-coated layer than inorganic acids such as nitric acid, phosphoric acid, sulfuric acid, and hydrofluoric acid and does not form a passivation film of zinc phosphate or the
20 like. Probably for these reasons, a galvanized steel sheet having a film formed with a surface-treatment agent containing the chelating agent (D) allows for more excellent continuity.

[0036]

25 A chelating agent (D) used in the present invention is

not particularly limited and examples thereof include a hydroxy carboxylic acid such as tartaric acid or malic acid; a monocarboxylic acid; a polycarboxylic acid such as dicarboxylic acid or a tricarboxylic acid: oxalic acid, malonic acid, succinic acid, citric acid, or adipic acid; an aminocarboxylic acid such as glycine; phosphonic acid, and phosphonate. One or more of these chelating agents may be used. In particular, in view of storage stability of the surface-treatment agent and corrosion resistance and continuity of the galvanized steel sheet, a compound having two or more carboxyl groups or two or more phosphonic acid groups in a molecule is preferred.

[0037]

The chelating agent (D) used in the present invention is contained such that a ratio (B/D) of the mass of the tetraalkoxysilane (B) to the total mass of the chelating agent (D) is 0.3 to 2.0, preferably 0.5 to 1.8. When the mass ratio is less than 0.3 or more than 2.0, a galvanized steel sheet having excellent corrosion resistance is not obtained.

[0038]

A surface-treatment agent used in the present invention contains a vanadate compound (E). The vanadate compound (E) is uniformly dispersed in a film formed on a surface of a galvanized steel sheet, in the form of being readily soluble

in water and it exhibits the so-called inhibitor effect at the time of corrosion of zinc. Examples of the vanadate compound (E) used in the present invention include ammonium metavanadate and sodium metavanadate. One or more of these
5 examples may be used.

[0039]

The vanadate compound (E) used in the present invention is contained such that a ratio (E/D) of the total mass of the vanadate compound (E) in terms of V to the total mass of
10 the chelating agent (D) is 0.03 to 1.0, more preferably 0.05 to 0.71. When the mass ratio is less than 0.03, a galvanized steel sheet having excellent corrosion resistance is not obtained. When the mass ratio is more than 1.0, it becomes difficult for the vanadate compound to dissolve in
15 the surface-treatment agent.

[0040]

A surface-treatment agent used in the present invention contains a metal compound (F) containing at least one metal selected from the group consisting of Ti, Al, and Zn. When
20 such a metal component is contained, a galvanized steel sheet having excellent corrosion resistance (in particular, in processed portions) can be provided.

[0041]

A metal compound (F) used in the present invention is
25 not particularly limited as long as it is a metal compound

containing at least one metal selected from the group consisting of Ti, Al, and Zn.

[0042]

Examples of a Ti-containing metal compound include
5 titanyl sulfate, titanyl nitrate, titanium nitrate, titanyl
chloride, titanium chloride, titania sol, titanium oxide,
potassium oxalate titanate, fluorotitanic acid, ammonium
fluorotitanate, titanium lactate, titanium tetraisopropoxide,
titanium acetylacetonate, and diisopropyl titanium
10 bisacetylacetonate. The examples further include metatitanic
acid obtained by thermal hydrolysis of an aqueous solution
of titanyl sulfate, orthotitanic acid obtained by
neutralization of an aqueous solution of titanyl sulfate
with an alkali, and salts of the foregoing.

15 [0043]

Examples of an Al-containing metal compound include
aluminum oxide, aluminum hydroxide, aluminum sulfate,
aluminum nitrate, aluminum phosphate, and aluminum chloride.

[0044]

20 Examples of a Zn-containing metal compound include zinc
carbonate, zinc oxide, zinc hydroxide, zinc sulfate, zinc
nitrate, zinc chloride, and zinc phosphate; and, since zinc
is an amphoteric metal, the examples further include sodium
zincate and potassium zincate, which are generated with an
25 alkali. One or more of these examples may be used in

combination.

[0045]

The metal compound (F) used in the present invention is contained such that a ratio (F/D) of the total metal mass of the metal compound (F) to the total mass of the chelating agent (D) is 0.05 to 0.8, preferably 0.17 to 0.34. When the mass ratio is less than 0.05, a galvanized steel sheet having excellent corrosion resistance is not provided. When the mass ratio is more than 0.8, it becomes difficult for the metal compound (F) to dissolve in the surface-treatment agent.

[0046]

A surface-treatment agent used in the present invention has a pH of 8 to 10, preferably a pH of 8.2 to 9.5. When the treatment solution has a pH of less than 8, storage stability of the surface-treatment agent, corrosion resistance of the galvanized steel sheet, and adhesion of a film formed on a surface of the steel sheet are degraded. When the treatment solution has a pH of more than 10 or is acidic, zinc is considerably etched and corrosion resistance and continuity of the galvanized steel sheet are degraded. In the present invention, an alkali used for the pH adjustment is preferably ammonium, an amine, an amine derivative, or an aminopolycarboxylic acid; and an acid for the pH adjustment is preferably selected from the above-

described chelating agents (D).

[0047]

A film formed on the surface of a zinc-coated layer according to the present invention is adjusted such that the coating weight thereof is 50 to 1200 mg/m² relative to the surface, preferably 100 to 900 mg/m², more preferably 100 to 500 or less mg/m². When the coating weight is less than 50 mg/m², there are cases where the advantages of the present invention are not sufficiently achieved. When the coating weight is more than 1200 mg/m², the advantages become saturated, which results in economical disadvantage, and there are cases where continuity becomes poor.

[0048]

A surface-treatment agent used in the present invention may further contain a lubricant (G) for enhancing lubricity. Examples of the lubricant include solid lubricants such as polyethylene wax, polyethylene oxide wax, polypropylene oxide wax, carnauba wax, paraffin wax, montan wax, rice wax, Teflon (registered trademark) wax, carbon disulfide, and graphite. One or more of these solid lubricants may be used.

[0049]

The content of the lubricant (G) used in the present invention is preferably 1 to 10 mass% relative to the total solid content of the surface-treatment agent, more preferably 3 to 7 mass%. When the content is 1 mass% or

more, the lubricity is enhanced. When the content is 10 mass% or less, corrosion resistance of galvanized steel sheets is not degraded.

[0050]

5 A surface-treatment agent used in the present invention may further contain a nonionic acrylic resin emulsion (H) for the purpose of enhancing corrosion resistance of a film formed on a surface of a galvanized steel sheet. The nonionic acrylic resin emulsion (H) is not particularly
10 limited. An acrylic resin emulsified with a nonionic emulsifying agent may be used: for example, an aqueous emulsion obtained by emulsion polymerization of a vinyl monomer such as acrylic acid, methacrylic acid, acrylate, methacrylate, or styrene in water in the presence of a
15 nonionic surfactant (emulsifying agent) having a polyethylene oxide or polypropylene oxide in the structure.

[0051]

 The content of the nonionic acrylic resin emulsion (H) used in the present invention is 0.5 to 45.0 mass% relative
20 to the total solid content of the surface-treatment agent, preferably 1.0 to 40.0 mass%, more preferably 4.5 mass% or less. When the content is 0.5 mass% or more, the effect of enhancing wettability of the surface-treatment agent is provided. When the content is 45.0 mass% or less, the
25 continuity of galvanized steel sheets is not degraded.

[0052]

A surface-treatment agent used in the present invention is provided by mixing the above-described components in water such as deionized water or distilled water. The solid content of the surface-treatment agent may be appropriately determined. A surface-treatment agent used in the present invention may optionally contain a water-soluble solvent containing an alcohol, a ketone, cellosolve, or the like; a surfactant; a defoaming agent; a leveling agent; an antimicrobial-antifungal agent; a colorant; or the like. Addition of such agents enhances the drying property, coating appearance, processability, storage stability, and design property of the surface-treatment agent. However, it is important that the agents are added as long as qualities provided by the present invention are not degraded. The maximum amount of the agents added is less than 5 mass% relative to the total solid content of the surface-treatment agent.

[0053]

A method for coating a galvanized steel sheet with a surface-treatment agent according to the present invention is optimally selected in accordance with, for example, the shape of the galvanized steel sheet to be treated and may be roll coating, bar coating, dipping, spray coating, or the like. Specifically, for example, a galvanized steel sheet

having the shape of a sheet is coated by roll coating, bar coating, or spraying a surface-treatment agent and adjusting the adhesion amount by roll squeezing or blowing of gas at a high pressure; or a galvanized steel sheet having the shape of a formed product may be coated by dipping the galvanized steel sheet in a surface-treatment agent, withdrawing the galvanized steel sheet, and optionally adjusting the adhesion amount by blowing off excessive surface-treatment agent with compressed air.

10 [0054]

Before a galvanized steel sheet is coated with a surface-treatment agent, the galvanized steel sheet may be optionally subjected to a pretreatment performed for the purpose of removing oil or stains on a surface of the galvanized steel sheet. Galvanized steel sheets are often coated with rust-inhibiting oil for preventing rust. When galvanized steel sheets are not coated with rust-inhibiting oil, oil, stains, or the like adhere to the steel sheets during processes. By subjecting a galvanized steel sheet to the pretreatment, the surface of the galvanized steel sheet is cleaned and the surface of the metal material becomes uniformly wettable. When oil and stains are not present and uniform wetting with a surface-treatment agent can be achieved, the pretreatment step may be eliminated.

25 The method for performing the pretreatment is not

particularly limited and may be, for example, cleaning with hot water, cleaning with a solvent, or alkaline-degrease cleaning.

[0055]

5 The heating temperature (maximum sheet temperature) at the time of drying a film formed on a surface of a galvanized steel sheet according to the present invention is generally 60°C to 200°C, preferably 80°C to 180°C. When the heating temperature is 60°C or more, water serving as the
10 main solvent does not remain and, for example, the corrosion resistance of a galvanized steel sheet is not degraded. When the heating temperature is 200°C or less, degradation of corrosion resistance of a galvanized steel sheet due to cracking of a film is not caused. The method for performing
15 drying by heating is not particularly limited. For example, a surface-treatment agent may be dried by heating with hot air, an induction heater, infrared rays, near-infrared rays, or the like.

As for the time for which the heating is performed, an
20 optimal condition is appropriately selected in accordance with, for example, the type of a galvanized steel sheet used. In view of productivity and the like, the time is preferably 0.1 to 60 seconds, more preferably 1 to 30 seconds.

[0056]

25 The reasons why a galvanized steel sheet obtained by

the present invention has various properties such as corrosion resistance and adhesion of a film formed on a surface of the galvanized steel sheet and allows for desired continuity without degradation of the corrosion resistance
5 are not necessarily clear. However, such advantages are probably provided by the following effects.

[0057]

In the present invention, the skeleton of a film formed on a galvanized steel sheet is constituted by a water-
10 soluble zirconium compound, a tetraalkoxysilane, and an epoxy-group-containing compound. A dried film composed of water-soluble zirconium does not dissolve back into water and provides a barrier effect. Thus, a galvanized steel sheet is provided that is excellent in terms of various
15 properties such as corrosion resistance of the galvanized steel sheet, adhesion of a film, and corrosion resistance of the galvanized steel sheet after alkaline degreasing, and is excellent in terms of heat resistance and weldability, which are characteristics of inorganic films. In addition, the
20 presence of the tetraalkoxysilane probably results in three-dimensional crosslinking between silanol groups generated from the alkoxy groups and the water-soluble zirconium compound to thereby form a dense film. In addition, a surface-treatment agent according to the present invention
25 contains the epoxy-group-containing compound and, as a

result, crosslinking reaction of the epoxy groups with the silanol groups and the water-soluble zirconium probably occurs. Accordingly, the bonding strength of the film is probably further enhanced. By using the epoxy-group-

5 containing compound, a galvanized steel sheet is provided that is excellent in terms of resistance to scratching and lubricity, which are characteristics of organic films.

[0058]

The vanadate compound and the metal compound are
10 uniformly dispersed in a film in the form of being readily soluble in water and exhibit the so-called inhibitor effect at the time of corrosion of zinc. Specifically, portions of the vanadate compound and the metal compound are probably ionized in a corrosive environment and passivated to thereby
15 suppress corrosion of zinc. In particular, the metal compound is probably mainly released in defect portions of the film after the forming to thereby suppress corrosion of zinc. The chelating agent probably provides, in the surface-treatment agent, the effect of suppressing
20 polymerization of the tetraalkoxysilane and the effect of stably dissolving the vanadate compound and the metal compound. When the film is formed by drying, the chelating agent does not form an insulating film such as a zinc phosphate film and the carboxyl groups or phosphonic acid
25 groups in the chelating agent serve as a crosslinking agent

for forming the dense skeleton of the film together with the film-skeleton components. Accordingly, the chelating agent probably enhances the continuity.

[0059]

5 In summary, a galvanized steel sheet allowing for excellent continuity according to the present invention can maintain excellent continuity even when it is in contact under a low pressure with a gasket or the like probably because a film formed from a water-soluble zirconium
10 compound, a tetraalkoxysilane, and an epoxy-group-containing compound is highly corrosive resistant in spite of a small thickness, and a chelating agent, a vanadate compound, and a metal compound serving as corrosion inhibitors are made present in the film.

15 [0060]

 The present invention can provide a galvanized steel sheet having various properties such as corrosion resistance and adhesion and allowing for excellent continuity without degrading corrosion resistance even under a severe condition
20 in which the steel sheet is under a low contact pressure. Such galvanized steel sheets according to the present invention are applicable to various applications and are suitably used as, for example, materials used in various fields relating to construction, electricity, automobiles,
25 and the like.

[EXAMPLES]

[0061]

Hereinafter, advantages according to the present invention will be described with reference to Examples and Comparative examples. However, the Examples are mere examples for illustrating the present invention and do not limit the present invention.

[0062]

1. Method for preparing test sheets

10 (1) test sheets (materials)

The following commercially available materials were used as test sheets.

(i) electrogalvanized steel sheet (EG): sheet thickness of 0.8 mm and coating weight of 20/20 (g/m²)

15 (ii) hot dip galvanized steel sheet (GI): sheet thickness of 0.8 mm and coating weight of 60/60 (g/m²)

(iii) hot dip galvanized steel sheet (GA): sheet thickness of 0.8 mm and coating weight of 40/40 (g/m²)

Note that the coating weight represents a coating weight relative to a main surface of each steel sheet. For example, the electrogalvanized steel sheet has a coating weight of 20/20 (g/m²) and has a coated layer having a coating weight of 20 g/m² on each surface of the steel sheet.

[0063]

25 (2) Pretreatment (cleaning)

Test samples were prepared in the following manner. A surface of each test material was treated with PALKLIN N364S manufactured by Nihon Parkerizing Co., LTD. to remove oil and stains on the surface. The surface of the metal
5 material was then cleaned with tap water and it was demonstrated that the 100% area of the surface was wet with water. Pure water (deionized water) was further splashed onto the metal material. The metal material was dried in an oven having an atmosphere at 100°C and then used as a test
10 sample.

[0064]

(3) Preparation of treatment solutions according to the present invention

Surface-treatment agents were obtained by mixing the
15 components in deionized water so as to achieve the compositions (mass ratios) in Table 1. Note that the mixing amounts of the components (G) and (H) in Table 1 are the amounts (g) of the components (G) and (H) added to 1 kg of a surface-treatment agent.

20 [0065]

[Table 1 (No. 1)]

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(*1)-(*6) mixing ratios (mass ratios) (*1)A1:A2=1:1 (*2)C1:C2=1:1 (*3)D1:D2=9:1 (*4)E1:E2=1:1 (*5)F1:F2=1:1 (*6)F1:F3=1:1

[Table 1 (No. 2)]

Test condition		Surface-treatment agents for galvanized surfaces																	
		Composition																	
		Component (A)	Component (B)	Component (C)	Component (D)	Component (E)	Component (F)	Component (G)			Component (H)	(A/B)	(B/C)	(B/D)	(E/D)	(F/D)	(G)	(H)	pH
			Type	Type	Type	Type	Type	Type	Mixing amount	Type	Mixing amount	Mass ratio	Mass ratio	Mass ratio	Mass ratio	Mass ratio	Mass%	Mass%	
Example 11	A1	B2	C2	D1 +D2 (*3)	E1	F2	-	0	-	0	2.94	0.20	0.61	0.34	0.07	0.00	0.00	8.4	
Example 12	A1	B1	C2	D1 +D2 (*3)	E1	F2	-	0	-	0	2.94	0.20	0.61	0.34	0.07	0.00	0.00	8.4	
Example 13	A1	B1	C2	D1 +D2 (*3)	E1	F2	-	0	-	0	1.47	0.43	1.22	0.34	0.07	0.00	0.00	8.4	
Example 14	A1	B1	C2	D1 +D2 (*3)	E1	F2	-	0	-	0	1.47	0.43	1.22	0.34	0.07	0.00	0.00	8.4	
Example 15	A1	B1	C2	D1 +D2 (*3)	E1	F2	-	0	-	0	1.47	0.43	1.22	0.34	0.07	0.00	0.00	8.4	
Example 16	A1	B1	C2	D1 +D2 (*3)	E1	F2	-	0	-	0	1.49	0.95	1.69	0.22	0.05	0.00	0.00	8.4	
Example 17	A1	B1	C1	D1 +D2 (*3)	E1	F2	-	0	-	0	1.35	1.06	1.88	0.22	0.05	0.00	0.00	8.4	
Example 18	A1	B1	C1 +C2 (*2)	D1 +D2 (*3)	E1	F2	-	0	-	0	1.35	1.06	1.88	0.22	0.05	0.00	0.00	8.4	

(*1)-(*6) mixing ratios (mass ratios) (*1)A1:A2=1:1 (*2)C1:C2=1:1 (*3)D1:D2=9:1 (*4)E1:E2=1:1 (*5)F1:F2=1:1 (*6)F1:F3=1:1

[Table 1 (No. 3)]

Surface-treatment agents for galvanized surfaces																				
Test condition		Composition																		
		Component (A)		Component (B)		Component (C)		Component (D)		Component (E)		Component (F)		Component (G)		Component (H)		(A/B) (B/C) (B/D) (E/D) (F/D) (G) (H)		
		Type	Type	Type	Type	Type	Type	Type	Type	Type	Type	Type	Type	Type	Type	Type	Type	Mass ratio	Mass ratio	Mass ratio
Example	19	A1	B1	C2	D1 +D2 (*3)	E1	F2	-	0	-	0	1.35	1.06	1.88	0.22	0.05	0.00	0.00	8.4	
Example	20	A1	B1	C2	D1 +D2 (*3)	E1	F2	-	0	-	0	1.28	1.11	1.97	0.22	0.05	0.00	0.00	8.4	
Example	21	A1	B1	C2	D1 +D2 (*3)	E1	F2	-	0	-	0	1.47	1.05	1.22	0.34	0.07	0.00	0.00	8.4	
Example	22	A1	B1	C2	D1 +D2 (*3)	E1	F2	-	0	-	0	1.47	0.43	1.22	0.34	0.07	0.00	0.00	8.0	
Example	23	A1	B1	C2	D1 +D2 (*3)	E1	F2	-	0	-	0	1.47	0.43	1.22	0.34	0.07	0.00	0.00	8.2	
Example	24	A1	B1	C2	D1 +D2 (*3)	E1	F2	-	0	-	0	1.47	0.43	1.22	0.34	0.07	0.00	0.00	9.5	
Example	25	A1	B1	C2	D1 +D2 (*3)	E1	F2	-	0	-	0	1.47	0.43	1.22	0.34	0.07	0.00	0.00	10.0	
Example	26	A1	B1	C2	D1 +D2 (*3)	E1	F2	-	0	-	0	1.47	0.84	1.22	0.34	0.07	0.00	0.00	8.4	

(*1)-(*) mixing ratios (mass ratios) (*1)A1:A2=1:1 (*2)C1:C2=1:1 (*3)D1:D2=9:1 (*4)E1:E2=1:1 (*5)F1:F2=1:1 (*6)F1:F3=1:1

[Table 1 (No. 4)]

Surface-treatment agents for galvanized surfaces																			pH
Test condition	Composition																		
	Component (A) Type	Component (B) Type	Component (C) Type	Component (D) Type	Component (E) Type	Component (F) Type	Component (G) Type	Mixing amount	Component (H) Type	Mixing amount	(A/B) Mass ratio	(B/C) Mass ratio	(B/D) Mass ratio	(E/D) Mass ratio	(F/D) Mass ratio	(G) Mass%	(H) Mass%		
Example 27	A1	B1	C2	D1 +D2 (*3)	E1	F2	-	0	-	0	1.47	0.63	1.22	0.34	0.07	0.00	0.00	8.4	
Example 28	A2	B2	C1	D1	E2	F3	-	0	-	0	1.47	0.43	0.31	0.09	0.06	0.00	0.00	8.4	
Example 29	A2	B2	C1	D1	E1	F3	-	0	-	0	1.47	0.43	0.57	0.16	0.11	0.00	0.00	8.4	
Example 30	A2	B2	C1	D1	+E2 (*4)	F3	-	0	-	0	1.47	0.43	0.57	0.16	0.11	0.00	0.00	8.4	
Example 31	A2	B2	C1	D1	E2	F3	-	0	-	0	1.47	0.43	0.57	0.16	0.11	0.00	0.00	8.4	
Example 32	A2	B2	C1	D1	E2	F3	-	0	-	0	1.47	0.43	0.47	0.14	0.09	0.00	0.00	8.4	
Example 33	A2	B2	C1	D1	E2	F3	-	0	-	0	1.47	0.43	0.93	0.27	0.06	0.00	0.00	8.4	
Example 34	A2	B2	C1	D1	E2	F3	-	0	-	0	1.47	0.43	1.01	0.29	0.06	0.00	0.00	8.4	
Example 35	A2	B2	C1	D1	E2	F1	-	0	-	0	1.47	0.43	1.69	0.48	0.10	0.00	0.00	8.4	
Example 36	A2	B2	C1	D1	E2	F1 +F2 (*5)	-	0	-	0	1.47	0.43	1.69	0.48	0.10	0.00	0.00	8.4	
Example 37	A2	B2	C1	D1	E2	F2	-	0	-	0	1.47	0.43	1.69	0.48	0.10	0.00	0.00	8.4	
Example 38	A2	B2	C1	D1	E2	F3	-	0	-	0	1.47	0.43	1.69	0.48	0.10	0.00	0.00	8.4	
Example 39	A2	B2	C1	D1	E2	F3	-	0	-	0	1.47	0.43	1.76	0.51	0.11	0.00	0.00	8.4	
Example 40	A2	B2	C1	D1	E2	F3	-	0	-	0	1.47	0.43	2.00	0.58	0.12	0.00	0.00	8.4	
Example 41	A2	B2	C1	D1	E2	F1 +F2 (*5)	-	0	-	0	1.47	0.43	1.22	0.05	0.07	0.00	0.00	8.4	

(*1)-(*6) mixing ratios (mass ratios) (*1)A1:A2=1:1 (*2)C1:C2=1:1 (*3)D1:D2=9:1 (*4)E1:E2=1:1 (*5)F1:F2=1:1 (*6)F1:F3=1:1

Surface-treatment agents for galvanized surfaces

Test condition		Surface treatment agents for galvanneal coatings																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																					
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		Component (A)		Component (B)		Component (C)		Component (D)		Component (E)		Component (F)		Component (G)		Component (H)		(A/B)		(B/C)		(B/D)		(E/D)		(F/D)		(G)		(H)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																									
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Example	50	A2	B2	C1	D1	E1	F1	F1	F2	F2	F3	F3	F4	F4	F5	F5	F6	F6	F7	F7	F8	F8	F9	F9	F10	F10	F11	F11	F12	F12	F13	F13	F14	F14	F15	F15	F16	F16	F17	F17	F18	F18	F19	F19	F20	F20	F21	F21	F22	F22	F23	F23	F24	F24	F25	F25	F26	F26	F27	F27	F28	F28	F29	F29	F30	F30	F31	F31	F32	F32	F33	F33	F34	F34	F35	F35	F36	F36	F37	F37	F38	F38	F39	F39	F40	F40	F41	F41	F42	F42	F43	F43	F44	F44	F45	F45	F46	F46	F47	F47	F48	F48	F49	F49	F50	F50	F51	F51	F52	F52	F53	F53	F54	F54	F55	F55	F56	F56	F57	F57	F58	F58	F59	F59	F60	F60	F61	F61	F62	F62	F63	F63	F64	F64	F65	F65	F66	F66	F67	F67	F68	F68	F69	F69	F70	F70	F71	F71	F72	F72	F73	F73	F74	F74	F75	F75	F76	F76	F77	F77	F78	F78	F79	F79	F80	F80	F81	F81	F82	F82	F83	F83	F84	F84	F85	F85	F86	F86	F87	F87	F88	F88	F89	F89	F90	F90	F91	F91	F92	F92	F93	F93	F94	F94	F95	F95	F96	F96	F97	F97	F98	F98	F99	F99	F100	F100	F101	F101	F102	F102	F103	F103	F104	F104	F105	F105	F106	F106	F107	F107	F108	F108	F109	F109	F110	F110	F111	F111	F112	F112	F113	F113	F114	F114	F115	F115	F116	F116	F117	F117	F118	F118	F119	F119	F120	F120	F121	F121	F122	F122	F123	F123	F124	F124	F125	F125	F126	F126	F127	F127	F128	F128	F129	F129	F130	F130	F131	F131	F132	F132	F133	F133	F134	F134	F135	F135	F136	F136	F137	F137	F138	F138	F139	F139	F140	F140	F141	F141	F142	F142	F143	F143	F144	F144	F145	F145	F146	F146	F147	F147	F148	F148	F149	F149	F150	F150	F151	F151	F152	F152	F153	F153	F154	F154	F155	F155	F156	F156	F157	F157	F158	F158	F159	F159	F160	F160	F161	F161	F162	F162	F163	F163	F164	F164	F165	F165	F166	F166	F167	F167	F168	F168	F169	F169	F170	F170	F171	F171	F172	F172	F173	F173	F174	F174	F175	F175	F176	F176	F177	F177	F178	F178	F179	F179	F180	F180	F181	F181	F182	F182	F183	F183	F184	F184	F185	F185	F186	F186	F187	F187	F188	F188	F189	F189	F190	F190	F191	F191	F192	F192	F193	F193	F194	F194	F195	F195	F196	F196	F197	F197	F198	F198	F199	F199	F200	F200	F201	F201	F202	F202	F203	F203	F204	F204	F205	F205	F206	F206	F207	F207	F208	F208	F209	F209	F210	F210	F211	F211	F212	F212	F213	F213	F214	F214	F215	F215	F216	F216	F217	F217	F218	F218	F219	F219	F220	F220	F221	F221	F222	F222	F223	F223	F224	F224	F225	F225	F226	F226	F227	F227	F228	F228	F229	F229	F230	F230	F231	F231	F232	F232	F233	F233	F234	F234	F235	F235	F236	F236	F237	F237	F238	F238	F239	F239	F240	F240	F241	F241	F242	F242	F243	F243	F244	F244	F245	F245	F246	F246	F247	F247	F248	F248	F249	F249	F250	F250	F251	F251	F252	F252	F253	F253	F254	F254	F255	F255	F256	F256	F257	F257	F258	F258	F259	F259	F260	F260	F261	F261	F262	F262	F263	F263	F264	F264	F265	F265	F266	F266	F267	F267	F268	F268	F269	F269	F270	F270	F271	F271	F272	F272	F273	F273	F274	F274	F275	F275	F276	F276	F277	F277	F278	F278	F279	F279	F280	F280	F281	F281	F282	F282	F283	F283	F284	F284	F285	F285	F286	F286	F287	F287	F288	F288	F289	F289	F290	F290	F291	F291	F292	F292	F293	F293	F294	F294	F295	F295	F296	F296	F297	F297	F298	F298	F299	F299	F300	F300	F301	F301	F302	F302	F303	F303	F304	F304	F305	F305	F306	F306	F307	F307	F308	F308	F309	F309	F310	F310	F311	F311	F312	F312	F313	F313	F314	F314	F315	F315	F316	F316	F317	F317	F318	F318	F319	F319	F320	F320	F321	F321	F322	F322	F323	F323	F324	F324	F325	F325	F326	F326	F327	F327	F328	F328	F329	F329	F330	F330	F331	F331	F332	F332	F333	F333	F334	F334	F335	F335	F336	F336	F337	F337	F338	F338	F339	F339	F340	F340	F341	F341	F342	F342	F343	F343	F344	F344	F345	F345	F346	F346	F347	F347	F348	F348	F349	F349	F350	F350	F351	F351	F352	F352	F353	F353	F354	F354	F355	F355	F356	F356	F357	F357	F358	F358	F359	F359	F360	F360	F361	F361	F362	F362	F363	F363	F364	F364	F365	F365	F366	F366	F367	F367	F368	F368	F369	F369	F370	F370	F371	F371	F372	F372	F373	F373	F374	F374	F375	F375	F376	F376	F377	F377	F378	F378	F379	F379	F380	F380	F381	F381	F382	F382	F383	F383	F384	F384	F385	F385	F386	F386	F387	F387	F388	F388	F389	F389	F390	F390	F391	F391	F392	F392	F393	F393	F394	F394	F395	F395	F396	F396	F397	F397	F398	F398	F399	F399	F400	F400	F401	F401	F402	F402	F403	F403	F404	F404	F405	F405	F406	F406	F407	F407	F408	F408	F409	F409	F410	F410	F411	F411	F412	F412	F413	F413	F414	F414	F415	F415	F416	F416	F417	F417	F418	F418	F419	F419	F420	F420	F421	F421	F422	F422	F423	F423	F424	F424	F425	F425	F426	F426	F427	F427	F428	F428	F429	F429	F430	F430	F431	F431	F432	F432	F433	F433	F434	F434	F435	F435	F436	F436	F437	F437	F438	F438	F439	F439	F440	F440	F441	F441	F442	F442	F443	F443	F444	F444	F445	F445	F446	F446	F447	F447	F448	F448	F449	F449	F450	F450	F451	F451	F452	F452	F453	F453	F454	F454	F455	F455	F456	F456	F457	F457	F458	F458	F459	F459	F460	F460	F461	F461	F462	F462	F463	F463	F464	F464	F465	F465	F466	F466	F467	F467	F468	F468	F469	F469	F470	F470	F471	F471	F472	F472	F473	F473	F474	F474	F475	F475	F476	F476	F477	F477	F478	F478	F479	F479	F480	F480	F481	F481	F482	F482	F483	F483	F484	F484	F485	F485	F486	F486	F487	F487	F488	F488	F489	F489	F490	F490	F491	F491	F492	F492	F493	F493	F494	F494	F495	F495	F496	F496	F497	F497	F498	F498	F499	F499	F500	F500	F501	F501	F502	F502	F503	F503	F504	F504	F505	F505	F506	F506	F507	F507	F508	F508	F509	F509	F510	F510	F511	F511	F512	F512	F513	F513	F514	F514	F515	F515	F516	F516	F517	F517	F518	F518	F519	F519	F520	F520	F521	F521	F522	F522	F523	F523	F524	F524	F525	F525	F526	F526	F527	F527	F528	F528	F529	F529	F530	F530	F531	F531	F532	F532	F533	F533	F534	F534	F535	F535	F536	F536	F537	F537	F538	F538	F539	F539	F540	F540	F541	F541	F542	F542	F543	F543	F544	F544	F545	F545	F546	F546	F547	F547	F548	F548	F549	F549	F550	F550	F551	F551	F552	F552	F553	F553	F554	F554	F555	F555	F556	F556	F557	F557	F558	F558	F559	F559	F560	F560	F561	F561	F562	F562	F563	F563	F564	F564	F565	F565	F566	F566	F567	F567	F568	F568	F569	F569	F570	F570	F571	F571	F572	F572	F573	F573	F574	F574	F575	F575	F576	F576	F577	F577	F578	F578	F579	F579	F580	F580	F581	F581	F582	F582	F583	F583	F584	F584	F585	F585	F586	F586	F587	F587	F588	F588	F589	F589	F590	F590	F591	F591	F592	F592	F593	F593	F594	F594	F595	F595	F596	F596	F597	F597	F598	F598	F599	F599	F600	F600	F601	F601	F602	F602	F603	F603	F604	F604	F605	F605	F606	F606	F607	F607	F608	F608	F609	F609	F610	F610	F611	F611	F612	F612	F613	F613	F614	F614	F615	F615	F616	F616	F617	F617	F618	F618	F619	F619	F620	F620	F621	F621	F622	F622	F623	F623	F624	F624	F625	F625	F626	F626	F627	F627	F628	F628	F629	F629	F630	F630	F631	F631	F632	F632	F633	F633	F634	F634	F635	F635	F636	F636	F637	F637	F638	F638	F639	F639	F640	F640	F641	F641	F642	F642	F643	F643	F644	F644	F645	F645	F646	F646	F647	F647	F648	F648	F649	F649	F650	F650	F651	F651	F652	F652	F653	F653	F654	F654	F655	F655	F656	F656	F657	F657	F658	F658	F659	F659	F660	F660	F661	F661	F662	F662	F663	F663	F664	F664	F665	F665	F666	F666	F667	F667	F668	F668	F669	F669	F670	F670	F671	F671	F672	F672	F673	F673	F674	F674	F675	F675	F676	F676	F677	F677	F678	F678	F679	F679	F680	F680	F681	F681	F682	F682	F683	F683	F684	F684	F685	F685	F686	F686	F687	F687	F688	F688	F689	F689	F690	F690	F691	F691	F692	F692	F693	F693	F694	F694	F695	F695	F696	F696	F697	F697	F698	F698	F699	F699	F700	F700	F701	F701	F702	F702	F703	F703	F704	F704	F705	F705	F706	F706	F707	F707	F708	F708	F709	F709	F710	F710	F711	F711	F712	F712	F713	F713	F714	F714	F715	F715	F716	F716	F717	F717	F718	F718	F719	F719	F720	F720	F721	F721	F722	F722	F723	F723	F724	F724	F725	F725	F726	F726	F727	F727	F728	F728	F729	F729	F730	F730	F731	F731	F732	F732	F733	F733	F734	F734	F735	F735	F736	F736	F737	F737	F738	F738	F739	F739	F740	F740	F741	F741	F742	F742	F743	F743	F744	F744	F745	F745	F746	F746	F747	F747	F748	F748	F749	F749	F750	F750	F751	F751	F752	F752	F753	F753	F754	F754	F755	F755	F756	F756	F757	F757	F758	F758	F759	F759	F760	F760	F76

(*)1)-(*)6) mixing ratios (mass ratios) (*1)A1:A2=1:1 (*2)C1:C2=1:1 (*3)D1:D2=9:1 (*4)E1:E2=1:1 (*5)F1:F2=1:1 (*6)F1:F3=1:1

[Table 1 (No. 7)]

Test condition		Surface treatment agents for galvanized surfaces																			
		Composition																			
		Component (A)		Component (B)		Component (C)		Component (D)		Component (E)		Component (F)		Component (G)		Component (H)		Component (I)		Component (J)	
		Type	Mass%	Type	Mass%	Type	Mass%	Type	Mass%	Type	Mass%	Type	Mass%	Type	Mass%	Type	Mass%	Type	Mass%	Type	Mass%
Example 58	A2	B2	C1	D1	E2	F1 + F3 (*6)	-	0	-	0	1.47	0.43	1.22	0.34	0.80	0.00	0.00	0.00	0.00	0.00	8.4
Example 59	A2	B2	C1	D1 + D2 (*3)	E2	F1	-	0	H1	1.3	1.47	0.43	1.22	0.34	0.07	0.00	0.5	0.00	0.00	0.00	8.4
Example 60	A2	B2	C1	D1 + D2 (*3)	E2	F1	-	0	-	0	1.47	0.43	1.22	0.34	0.07	0.00	0.00	0.00	0.00	0.00	8.4
Example 61	A2	B2	C1	D1 + D2 (*3)	E2	F1	-	0	H1	3.3	1.47	0.43	1.22	0.34	0.07	0.00	1.0	0.00	0.00	0.00	8.4
Example 62	A2	B2	C1	D1 + D2 (*3)	E2	F1	-	0	-	0	1.47	0.43	1.22	0.34	0.07	0.00	0.00	0.00	0.00	0.00	8.4
Example 63	A2	B2	C1	D1 + D2 (*3)	E2	F1	-	0	-	0	1.47	0.43	1.22	0.34	0.07	0.00	0.00	0.00	0.00	0.00	8.4
Example 64	A2	B2	C1	D1 + D2 (*3)	E2	F1	-	0	-	0	1.47	0.43	1.22	0.34	0.07	0.00	0.00	0.00	0.00	0.00	8.4
Example 65	A2	B2	C1	D1 + D2 (*3)	E2	F1	-	0	-	0	1.47	0.43	1.22	0.34	0.07	0.00	0.00	0.00	0.00	0.00	8.4

(*1)-(*6) mixing ratios (mass ratios) (*1)A1:A2=1:1 (*2)C1:C2=1:1 (*3)D1:D2=9:1 (*4)E1:E2=1:1 (*5)F1:F2=1:1 (*6)F1:F3=1:1

[Table 1 (No. 8)]

Test condition		Surface-treatment agents for galvanized surfaces																													
		Composition																													
		Component (A)		Component (B)		Component (C)		Component (D)		Component (E)		Component (F)		Component (G)		Component (H)		(A/B)		(B/C)		(B/D)		(E/D)		(F/D)		(G)		(H)	
		Type	Type	Type	Type	Type	Type	Type	Type	Type	Type	Mixing amount	Type	Mixing amount	Mass ratio	Mass ratio	Mass ratio	Mass ratio	Mass ratio	Mass ratio	Mass ratio	Mass ratio	Mass ratio	Mass ratio	Mass ratio	Mass ratio	Mass ratio	Mass ratio	Mass ratio	Mass ratio	Mass ratio
Example	66	A2	B2	C1	D1 +D2 (*3)	E2	F1	-	0	-	0	1.47	0.43	1.22	0.34	0.07	0.00	0.00	8.4												
Example	67	A2	B1	C1	D1 +D2 (*3)	E1	F1	-	0	-	0	1.47	0.43	1.22	0.34	0.07	0.00	0.00	8.4												
Example	68	A2	B2	C1	D1 +D2 (*3)	E2	F1	-	0	-	0	1.47	0.43	1.22	0.34	0.07	0.00	0.00	8.4												
Example	69	A2	B2	C1	D1 +D2 (*3)	E2	F1	-	0	H1 30	1.47	0.43	1.22	0.34	0.07	0.00	8.6	8.4													
Example	70	A2	B2	C1	D1 +D2 (*3)	E2	F1	-	0	H1 300	1.47	0.43	1.22	0.34	0.07	0.00	48.6	8.4													
Example	71	A2	B2	C1	D1 +D2 (*3)	E2	F1 +F2 (*5)	G1	2.5	-	0	1.47	0.43	1.22	0.34	0.07	1	0.00	8.4												
Example	72	A2	B2	C1	D1 +D2 (*3)	E2	F1 +F2 (*5)	G1	10.0	-	0	1.47	0.43	1.22	0.34	0.07	3	0.00	8.4												
Example	73	A2	B2	C1	D1 +D2 (*3)	E2	F1 +F2 (*5)	G1	25.0	-	0	1.47	0.43	1.22	0.34	0.07	7	0.00	8.4												

(*1)-(*6) mixing ratios (mass ratios) (*1)A1:A2=1:1 (*2)C1:C2=1:1 (*3)D1:D2=9:1 (*4)E1:E2=1:1 (*5)F1:F2=1:1 (*6)F1:F3=1:1

Surface-treatment agents for galvanized surfaces

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(*1)A1:A2=1:1 (*2)C1:C2=1:1 (*3)D1:D2=9:1 (*4)E1:E2=1:1 (*5)F1:F2=1:1 (*6)F1:F3=1:1
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[Table 1 (No. 12)]

Surface-treatment agents for galvanized surfaces															
Test condition		Composition													
		Component (A)		Component (B)		Component (C)		Component (D)		Component (E)		Component (F)		Component (G)	
		Type	Amount	Type	Amount	Type	Amount	Type	Amount	Type	Amount	Type	Amount	Type	Amount
		(A/B)		(B/C)		(B/D)		(E/D)		(F/D)		(G)		(H)	
		Mass ratio	Mass ratio	Mass ratio	Mass ratio	Mass ratio	Mass ratio	Mass ratio	Mass ratio	Mass ratio	Mass ratio	Mass ratio	Mass ratio	Mass ratio	Mass ratio
Comparative example	99	A2	-	C1	D1 +D2 (*3)	E1	F1	-	0	-	0	0.00	0.00	0.14	0.00
Comparative example	100	A2	B1	-	D1 +D2 (*3)	E1	F1	-	0	1.47	-	2.37	0.00	0.14	0.00
Comparative example	101	A2	B1	C1	D1 +D2 (*3)	-	-	-	0	1.47	0.43	2.37	-	-	0.00
Comparative example	102	A2	B1	C1	D1 +D2 (*3)	E1	-	-	0	1.47	0.43	2.37	0.00	0.14	0.00
Comparative example	103	A2	B1	C1	-	E1	F1	-	0	1.47	0.43	2.37	0.00	0.00	0.00

(*1)-(*6) mixing ratios (mass ratios) (*1)A1:A2=1:1 (*2)C1:C2=1:1 (*3)D1:D2=9:1 (*4)E1:E2=1:1 (*5)F1:F2=1:1 (*6)F1:F3=1:1

[0066]

Hereinafter, the compounds used in Table 1 will be described.

<Water-soluble zirconium compound (A)>

5 A1: sodium zirconium carbonate

A2: ammonium zirconium carbonate

[0067]

<Tetraalkoxysilane (B)>

B1: tetraethoxysilane

10 B2: tetramethoxysilane

[0068]

<Epoxy-group-containing compound (C)>

C1: γ -glycidoxypropyltriethoxysilane

C2: polyethylene glycol diglycidyl ether

15 [0069]

<Chelating agent (D)>

D1: 1-hydroxymethane-1,1-diphosphonic acid

D2: tartaric acid

[0070]

20 <Vanadate compound (E)>

E1: ammonium metavanadate

E2: sodium metavanadate

[0071]

<Metal compound (F)>

25 F1: ammonium fluorotitanate

F2: aluminum nitrate hexahydrate

F3: zinc carbonate

[0072]

<Lubricant (G)>

5 G1: polyethylene wax (CHEMIPEARL (registered trademark) W900
manufactured by Mitsui Chemicals, Inc.)

[0073]

<Nonionic acrylic resin emulsion (H)>

H1: styrene-ethylmethacrylate-n-butylacrylate-acrylic acid
10 copolymer

[0074]

(4) Treatment method

A single surface of each test sample was coated with
such a surface-treatment agent by bar coating. After that,
15 the test sample was not washed with water and was placed in
an oven, and dried at a drying temperature in Table 2 to
form a film having a coating weight (mg/m²) in Table 2.

The drying temperature was adjusted by changing the
atmosphere temperature in the oven and the time for which a
20 test sample was placed in the oven. The drying temperature
is the maximum temperature of a single surface of a test
sample. The bar coating was specifically performed in the
following manner.

[0075]

25 Bar coating: the surface-treatment agents were dropped

onto the test samples and applied over the test samples with #3-5 bar coaters. A coating weight in Table 2 was achieved by changing the number of a bar coater used and the concentration of a surface-treatment agent.

5 [0076]

[Table 2 (No. 1)]

Test condition		Test sheet	Treatment method		
			Coating method	Coating weight	Drying temperature
			Type	mg/m ²	°C
Example	1	(i)	Bar coating	300	140
Example	2	(i)	Bar coating	300	140
Example	3	(i)	Bar coating	300	140
Example	4	(i)	Bar coating	300	140
Example	5	(i)	Bar coating	300	140
Example	6	(i)	Bar coating	300	140
Example	7	(i)	Bar coating	300	140
Example	8	(i)	Bar coating	300	140
Example	9	(i)	Bar coating	300	140
Example	10	(i)	Bar coating	300	140
Example	11	(i)	Bar coating	300	140
Example	12	(i)	Bar coating	300	140
Example	13	(i)	Bar coating	300	140
Example	14	(ii)	Bar coating	300	140
Example	15	(iii)	Bar coating	300	140
Example	16	(i)	Bar coating	300	140
Example	17	(i)	Bar coating	300	140
Example	18	(i)	Bar coating	300	140
Example	19	(i)	Bar coating	300	140
Example	20	(i)	Bar coating	300	140
Example	21	(i)	Bar coating	300	140
Example	22	(i)	Bar coating	300	140
Example	23	(i)	Bar coating	300	140
Example	24	(i)	Bar coating	300	140
Example	25	(i)	Bar coating	300	140
Example	26	(i)	Bar coating	300	140
Example	27	(i)	Bar coating	300	140
Example	28	(i)	Bar coating	300	140
Example	29	(i)	Bar coating	300	140
Example	30	(i)	Bar coating	300	140
Example	31	(i)	Bar coating	300	140
Example	32	(i)	Bar coating	300	140
Example	33	(i)	Bar coating	300	140
Example	34	(i)	Bar coating	300	140
Example	35	(i)	Bar coating	300	140
Example	36	(i)	Bar coating	300	140
Example	37	(i)	Bar coating	300	140
Example	38	(i)	Bar coating	300	140
Example	39	(i)	Bar coating	300	140
Example	40	(i)	Bar coating	300	140
Example	41	(i)	Bar coating	300	140
Example	42	(i)	Bar coating	50	140
Example	43	(i)	Bar coating	100	140
Example	44	(i)	Bar coating	200	140
Example	45	(i)	Bar coating	400	140

[Table 2 (No. 2)]

Test condition		Test sheet	Treatment method		
			Coating method	Coating weight	Drying temperature
			Type	mg/m ²	°C
Example	46	(i)	Bar coating	450	140
Example	47	(i)	Bar coating	500	140
Example	48	(i)	Bar coating	600	140
Example	49	(i)	Bar coating	800	140
Example	50	(i)	Bar coating	1000	140
Example	51	(i)	Bar coating	300	140
Example	52	(i)	Bar coating	300	140
Example	53	(i)	Bar coating	300	140
Example	54	(i)	Bar coating	300	140
Example	55	(i)	Bar coating	300	140
Example	56	(i)	Bar coating	300	140
Example	57	(i)	Bar coating	300	140
Example	58	(i)	Bar coating	300	140
Example	59	(i)	Bar coating	300	140
Example	60	(i)	Bar coating	300	40
Example	61	(i)	Bar coating	300	60
Example	62	(i)	Bar coating	300	60
Example	63	(i)	Bar coating	300	80
Example	64	(i)	Bar coating	300	180
Example	65	(i)	Bar coating	300	200
Example	66	(i)	Bar coating	300	250
Example	67	(i)	Bar coating	300	140
Example	68	(i)	Bar coating	300	140
Example	69	(i)	Bar coating	300	140
Example	70	(i)	Bar coating	300	140
Example	71	(i)	Bar coating	300	140
Example	72	(i)	Bar coating	300	140
Example	73	(i)	Bar coating	300	140
Example	74	(i)	Bar coating	300	140
Example	75	(i)	Bar coating	300	140
Example	76	(i)	Bar coating	300	140
Example	77	(i)	Bar coating	300	140
Example	78	(i)	Bar coating	600	140
Example	79	(i)	Bar coating	900	140
Example	80	(i)	Bar coating	1200	140
Example	81	(i)	Bar coating	300	140
Comparative example	82	(i)	Bar coating	300	140
Comparative example	83	(i)	Bar coating	300	140
Comparative example	84	(i)	Bar coating	300	140
Comparative example	85	(i)	Bar coating	300	140
Comparative example	86	(i)	Bar coating	300	140
Comparative example	87	(i)	Bar coating	300	140
Comparative example	88	(i)	Bar coating	300	140
Comparative example	89	(i)	Bar coating	300	140
Comparative example	90	(i)	Bar coating	300	140

[Table 2 (No. 3)]

Test condition		Test sheet	Treatment method		
			Coating method	Coating weight	Drying temperature
			Type	mg/m ²	°C
Comparative example	91	(i)	Bar coating	300	140
Comparative example	92	(i)	Bar coating	300	140
Comparative example	93	(i)	Bar coating	300	140
Comparative example	94	(i)	Bar coating	10	140
Comparative example	95	(i)	Bar coating	1500	140
Comparative example	96	(i)	Bar coating	10	140
Comparative example	97	(i)	Bar coating	1500	140
Comparative example	98	(i)	Bar coating	300	140
Comparative example	99	(i)	Bar coating	300	140
Comparative example	100	(i)	Bar coating	300	140
Comparative example	101	(i)	Bar coating	300	140
Comparative example	102	(i)	Bar coating	300	140
Comparative example	103	(i)	Bar coating	300	140

[0077]

(5) Evaluation test methods

(5-1) Evaluation of corrosion resistance

- 5 Specimens having a size of 70 mm × 150 mm were cut from test sheets and the back surfaces and end surfaces of the specimens were sealed with vinyl tapes. These specimens were tested in a manner described below. The evaluation was performed by visually determining area percentage of rust.
- 10 Salt spray testing (SST: in compliance with JIS-Z-2371-2000): The evaluation was performed with the following evaluation criteria on the basis of the area percentage of white rust after a lapse of 120 hours from SST by visual inspection.

15 Evaluation criteria:

Excellent: white-rust area percentage of less than 5%

Good: white-rust area percentage of 5% or more and less than 20%

Fair: white-rust area percentage of 20% or more and less than 40%

5 Poor: white-rust area percentage of 40% or more
[0078]

(5-2) Evaluation of overpaintability (adhesion)

Specimens having the same size as that of the above-described specimens were painted with a commercially
10 available melamine alkyd paint and baked at 140°C for 30 minutes such that the resultant painted film had a thickness of 30 µm. After that, the specimens were immersed in boiling water for 2 hours and a surface of each specimen was then cut in a pattern of 100 squares having 1 mm sides with
15 an NT cutter to such a depth as to reach the base steel. The specimen was subjected to cupping by 5 mm with an Erichsen tester such that the cut portion was on the outer (front) side. A tape was removed from the painted film and the remaining state of the painted film was evaluated in a
20 manner below. The Erichsen cupping conditions were compliance with JIS-Z-2247-2006 (Erichsen value symbol: IE) and the punch diameter was 20 mm, the die diameter was 27 mm, and the drawing width was 27 mm.

Evaluation criteria:

25 Excellent: delamination area of less than 5% and no

delamination

Good: delamination area of less than 10% and 5% or more

Fair: delamination area of less than 20% or more and 10% or more

5 Poor: delamination area of 20% or more

[0079]

(5-3) Evaluation of continuity

Each test sheet was evaluated by measuring surface resistivity thereof with an ESP probe of a Loresta GP

10 manufactured by Mitsubishi Chemical Analytech Co., Ltd.

Surface resistivity was measured every time when the load on the probe was increased by 50 g and the evaluation was performed on the basis of the minimum load under which $10^{-4} \Omega$ or less was achieved.

15 Excellent: average load of 10-point measurement was less than 250 g

Very good: average load of 10-point measurement was 250 g or more and less than 500 g

20 Good: average load of 10-point measurement was 500 g or more and less than 750 g

Fair: average load of 10-point measurement was 750 g or more and less than 950 g

Poor: average load of 10-point measurement was 950 g or more
[0080]

25 (5-4) Evaluation of storage stability

The surface-treatment agents having compositions described in Table 1 were stored in a constant temperature chamber at 40°C for 30 days. The appearance of the surface-treatment agents was evaluated by visual inspection.

5 Excellent: no change

Good: very small amount of precipitation

Fair: small amount of precipitation or an increase in viscosity to some extent

Poor: large amount of precipitation or gelation

10 [0081]

(5-5) Evaluation of lubricity

A disc-shaped specimen having a diameter of 100 mm was cut from each surface-treated test sheet and formed into a cup under conditions: a punch diameter of 50 mm, a die diameter of 51.91 mm, and a blank holding force of 1 ton. The appearance of the drawn surface of the formed product (side surface of the cup) was visually inspected and was evaluated in terms of how scratched it was and how blackened it was. The following evaluation criteria were used.

20 Excellent: almost no change over the entire surface, uniform appearance

Good: slightly scratched and blackened and clearly nonuniform appearance

Fair: severely scratched and blackened mainly in corner portions

25

Poor: cracked and the forming was not achieved

[0082]

The results of the evaluations (5-1) to (5-4) in terms
of the galvanized steel sheets obtained with the surface-
5 treatment agents described in Examples 1 to 81 and
Comparative examples 82 to 103 are described in Table 3.

Note that, in Comparative examples 89 and 101, the
treatment solutions were unstable and films were not formed.
Thus, the evaluations were not performed.

10 [0083]

[Table 3 (No. 1)]

Test condition		Corrosion resistance	Adhesion	Continuity	Storage stability	Lubricity
Example	1	Good	Excellent	Excellent	Excellent	Good
Example	2	Excellent	Excellent	Excellent	Excellent	Good
Example	3	Excellent	Excellent	Excellent	Excellent	Good
Example	4	Excellent	Excellent	Excellent	Excellent	Good
Example	5	Excellent	Excellent	Excellent	Excellent	Good
Example	6	Excellent	Excellent	Excellent	Excellent	Good
Example	7	Excellent	Excellent	Excellent	Excellent	Good
Example	8	Excellent	Excellent	Very good	Excellent	Good
Example	9	Good	Excellent	Excellent	Excellent	Good
Example	10	Excellent	Excellent	Excellent	Excellent	Good
Example	11	Excellent	Excellent	Excellent	Excellent	Good
Example	12	Excellent	Excellent	Excellent	Excellent	Good
Example	13	Excellent	Excellent	Excellent	Excellent	Good
Example	14	Excellent	Excellent	Excellent	Excellent	Good
Example	15	Excellent	Excellent	Excellent	Excellent	Good
Example	16	Excellent	Excellent	Excellent	Excellent	Good
Example	17	Excellent	Excellent	Excellent	Excellent	Good
Example	18	Excellent	Excellent	Excellent	Excellent	Good
Example	19	Excellent	Excellent	Excellent	Excellent	Good
Example	20	Excellent	Excellent	Excellent	Excellent	Good
Example	21	Excellent	Excellent	Excellent	Excellent	Good
Example	22	Good	Good	Excellent	Excellent	Good
Example	23	Excellent	Excellent	Excellent	Excellent	Good
Example	24	Excellent	Excellent	Excellent	Excellent	Good
Example	25	Good	Excellent	Very good	Excellent	Good
Example	26	Excellent	Excellent	Excellent	Excellent	Good
Example	27	Excellent	Good	Excellent	Excellent	Good
Example	28	Good	Excellent	Excellent	Excellent	Good
Example	29	Excellent	Excellent	Excellent	Excellent	Good
Example	30	Excellent	Excellent	Excellent	Excellent	Good
Example	31	Excellent	Excellent	Excellent	Excellent	Good
Example	32	Excellent	Excellent	Excellent	Excellent	Good
Example	33	Excellent	Excellent	Excellent	Excellent	Good
Example	34	Excellent	Excellent	Excellent	Excellent	Good
Example	35	Excellent	Excellent	Excellent	Excellent	Good
Example	36	Excellent	Excellent	Excellent	Excellent	Good
Example	37	Excellent	Excellent	Excellent	Excellent	Good
Example	38	Excellent	Excellent	Excellent	Excellent	Good
Example	39	Excellent	Excellent	Excellent	Excellent	Good
Example	40	Good	Excellent	Excellent	Excellent	Good
Example	41	Excellent	Excellent	Excellent	Excellent	Good
Example	42	Good	Excellent	Excellent	Excellent	Good
Example	43	Excellent	Excellent	Excellent	Excellent	Good
Example	44	Excellent	Excellent	Excellent	Excellent	Good
Example	45	Excellent	Excellent	Excellent	Excellent	Good

[Table 3 (No. 2)]

Test condition		Corrosion resistance	Adhesion	Continuity	Storage stability	Lubricity
Example	46	Excellent	Excellent	Excellent	Excellent	Good
Example	47	Excellent	Excellent	Excellent	Excellent	Good
Example	48	Excellent	Excellent	Very good	Excellent	Good
Example	49	Excellent	Good	Very good	Excellent	Good
Example	50	Excellent	Good	Good	Excellent	Good
Example	51	Good	Excellent	Excellent	Excellent	Good
Example	52	Excellent	Excellent	Excellent	Excellent	Good
Example	53	Excellent	Excellent	Excellent	Excellent	Good
Example	54	Excellent	Excellent	Excellent	Excellent	Good
Example	55	Good	Excellent	Excellent	Excellent	Good
Example	56	Excellent	Excellent	Excellent	Excellent	Good
Example	57	Excellent	Excellent	Excellent	Excellent	Good
Example	58	Excellent	Excellent	Very good	Excellent	Good
Example	59	Excellent	Excellent	Excellent	Excellent	Good
Example	60	Fair	Excellent	Excellent	Excellent	Good
Example	61	Excellent	Excellent	Excellent	Excellent	Good
Example	62	Good	Excellent	Excellent	Excellent	Good
Example	63	Excellent	Excellent	Excellent	Excellent	Good
Example	64	Excellent	Excellent	Excellent	Excellent	Good
Example	65	Good	Excellent	Excellent	Excellent	Good
Example	66	Fair	Excellent	Good	Excellent	Good
Example	67	Excellent	Excellent	Excellent	Excellent	Good
Example	68	Excellent	Excellent	Excellent	Excellent	Good
Example	69	Good	Excellent	Excellent	Excellent	Good
Example	70	Good	Excellent	Fair	Excellent	Excellent
Example	71	Excellent	Excellent	Excellent	Excellent	Good
Example	72	Excellent	Excellent	Excellent	Excellent	Good
Example	73	Excellent	Excellent	Excellent	Excellent	Good
Example	74	Good	Excellent	Excellent	Excellent	Good
Example	75	Fair	Excellent	Very good	Excellent	Excellent
Example	76	Excellent	Excellent	Excellent	Excellent	Excellent
Example	77	Excellent	Excellent	Excellent	Excellent	Excellent
Example	78	Excellent	Excellent	Very good	Excellent	Excellent
Example	79	Excellent	Good	Good	Excellent	Excellent
Example	80	Excellent	Good	Fair	Excellent	Excellent
Example	81	Good	Excellent	Very good	Good	Excellent
Comparative example	82	Poor	Fair	Very good	Good	Good
Comparative example	83	Good	Fair	Poor	Good	Fair
Comparative example	84	Poor	Fair	Poor	Excellent	Poor
Comparative example	85	Fair	Poor	Very good	Fair	Fair
Comparative example	86	Poor	Fair	Very good	Fair	Good
Comparative example	87	Poor	Fair	Very good	Fair	Good
Comparative example	88	Poor	Fair	Very good	Excellent	Poor
Comparative example	89	-	-	-	Poor	-
Comparative example	90	Poor	Fair	Very good	Excellent	Good

[Table 3 (No. 3)]

Test condition		Corrosion resistance	Adhesion	Continuity	Storage stability	Lubricity
Comparative example	91	Good	Fair	Poor	Fair	Good
Comparative example	92	Poor	Poor	Poor	Excellent	Good
Comparative example	93	Poor	Poor	Poor	Excellent	Good
Comparative example	94	Poor	Good	Excellent	Excellent	Poor
Comparative example	95	Excellent	Fair	Poor	Excellent	Good
Comparative example	96	Poor	Good	Excellent	Excellent	Fair
Comparative example	97	Excellent	Fair	Poor	Excellent	Excellent
Comparative example	98	Poor	Fair	Fair	Fair	Good
Comparative example	99	Poor	Fair	Fair	Excellent	Good
Comparative example	100	Poor	Poor	Good	Fair	Poor
Comparative example	101	-	-	-	Poor	-
Comparative example	102	Poor	Fair	Fair	Excellent	Good
Comparative example	103	Poor	Fair	Fair	Good	Good

[0084]

As described in Table 3, galvanized steel sheets according to the present invention can be provided, the galvanized steel sheets having various properties such as corrosion resistance and adhesion and allowing for excellent continuity under a condition in which the steel sheets are in contact with gaskets or the like at a low contact pressure. Galvanized steel sheets allowing for excellent continuity according to the present invention have films completely free from regulated substances causing pollution such as hexavalent chromium and hence are optimal as galvanized steel sheets used for parts of automobiles, household electrical appliances, and OA equipment.

[Industrial Applicability]

[0085]

A galvanized steel sheet can be provided that has a

film completely free from regulated substances causing pollution such as hexavalent chromium, has various properties such as corrosion resistance and adhesion, and allows for excellent continuity without degrading corrosion
5 resistance even under a severe condition in which the steel sheet is in contact with a gasket or the like at a low contact pressure.

CLAIMS

[Claim 1]

A galvanized steel sheet comprising a surface-treatment film having a coating weight of 50 to 1200 mg/m² relative to
5 a surface of the galvanized steel sheet, wherein the surface-treatment film is obtained by applying a surface-treatment agent to the surface of the galvanized steel sheet and drying the surface-treatment agent by heating; and the surface-treatment agent is prepared so as to contain a
10 water-soluble zirconium compound (A), a tetraalkoxysilane (B), an epoxy-group-containing compound (C), a chelating agent (D), a vanadate compound (E), and a metal compound (F) containing one or more metals selected from the group consisting of Ti, Al, and Zn, to have a pH of 8 to 10, and
15 to satisfy conditions (I) to (V) below,

Note

(I) a ratio (A/B) of a mass of the water-soluble zirconium compound (A) in terms of Zr to a mass of the tetraalkoxysilane (B) is 1.0 to 6.0;

20 (II) a ratio (B/C) of the mass of the tetraalkoxysilane (B) to a mass of the epoxy-group-containing compound (C) is 0.1 to 1.6;

(III) a ratio (B/D) of the mass of the tetraalkoxysilane (B) to a mass of the chelating agent (D)
25 is 0.3 to 2.0;

(IV) a ratio (E/D) of a mass of the vanadate compound (E) in terms of V to the mass of the chelating agent (D) is 0.03 to 1.0; and

(V) a ratio (F/D) of a total metal mass of the metal compound (F) to the mass of the chelating agent (D) is 0.05 to 0.8.

[Claim 2]

The galvanized steel sheet according to Claim 1, wherein the coating weight relative to the surface is 50 to 500 mg/m².

[Claim 3]

The galvanized steel sheet according to Claim 1 or 2, wherein the surface-treatment agent further contains a lubricant (G) and a content of the lubricant (G) is 1 to 10 mass% relative to a total solid content of the surface-treatment agent.

[Claim 4]

The galvanized steel sheet according to any one of Claims 1 to 3, wherein the surface-treatment agent further contains a nonionic acrylic resin emulsion (H) and a content of the nonionic acrylic resin emulsion (H) is 0.5 to 45.0 mass% relative to a total solid content of the surface-treatment agent.

[Claim 5]

The galvanized steel sheet according to Claim 4,

wherein the content of the nonionic acrylic resin emulsion (H) is 0.5 to 4.5 mass% relative to the total solid content of the surface-treatment agent.