

[Document Type] Specification

[Title of the Invention]

HOT-DIP PLATED STEEL SHEET

[Technical Field]

5 [0001]

The present invention relates to a hot-dip plated steel sheet.

Priority is claimed on Japanese Patent Application No. 2019-216681, Japanese Patent Application No. 2019-216682, Japanese Patent Application No. 2019-216683 and Japanese Patent Application No. 2019-216684, filed in Japan on November 29, 2019, the  
10 content of which is incorporated herein by reference.

[Background Art]

[0002]

Hot-dip plated steel sheets are excellent in terms of corrosion resistance, and, particularly, Zn-Al-Mg-based hot-dip plated steel sheets have particularly excellent  
15 corrosion resistance. Zn-Al-Mg-based hot-dip plated steel sheets having higher corrosion resistance than hot-dip galvanized steel sheets are in wide use in a variety of manufacturing industries such as building materials, home appliances, and automobile fields, and the amount of Zn-Al-Mg-based hot-dip plated steel sheets used has been increasing in recent years.

20 [0003]

Incidentally, for the purpose of displaying letters, marks, design drawings or the like on the surface of a hot-dip plating layer of a hot-dip plated steel sheet, there are cases where a step such as printing or painting is carried out on the hot-dip plating layer to display the letters, the marks, the design drawings or the like on the surface of the hot-dip  
25 plating layer.

[0004]

However, the step such as printing or painting carried out on the hot-dip plating layer creates a problem of an increase in the cost or time for providing the letters, designs or the like. Furthermore, in the case of displaying letters, designs or the like on the surface of a plating layer by printing or painting, there is a concern that a metallic glossy external appearance, which is highly popular to consumers, may be lost and, due to a problem of deterioration of coating films themselves over time or deterioration of the adhesion of the coating films over time, durability may be poor and the letters, the designs or the like may disappear over time. In addition, in the case of displaying letters, designs or the like on the surface of a plating layer with pre-inked stamps, the costs or time can be kept relatively low, but there is a concern that the corrosion resistance of the hot-dip plating layer may deteriorate due to ink. Moreover, in the case of displaying design or the like by grinding a hot-dip plating layer, the durability of the design or the like is excellent, but a significant decrease in the thickness of the hot-dip plating layer at a ground site inevitably degrades the corrosion resistance, and there is a concern of deterioration of plating characteristics.

[0005]

As described in the following patent documents, a variety of techniques for Zn-Al-Mg-based hot-dip plated steel sheets have been developed, but there is no known technique for improving the durability in the case of displaying letters, designs or the like on the surface of a plating layer.

[0006]

Regarding Zn-Al-Mg-based hot-dip plated steel sheets, there is related art intended to make the pear skin-like external appearance of plating shown on the Zn-Al-Mg-based hot-dip plated steel sheets more beautiful.

[0007]

For example, Patent Document 1 describes a Zn-Al-Mg-based hot-dip plated steel sheet having a pear skin-like external appearance with a fine texture and a number of smooth glossy portions, that is, a Zn-Al-Mg-based hot-dip plated steel sheet having a favorable pear skin-like external appearance in which the number of white portions per unit area is large and the proportion of the area of the glossy portions is large. In addition, Patent Document 1 describes that an unfavorable pear skin state is a state in which a surface external appearance in which irregular white portions and circular glossy portions are present in a mixed manner and scattered on the surface is exhibited.

10 [0008]

In addition, Patent Document 2 describes a Zn-Al-Mg-based plated steel sheet in which, in a cross section of a plating layer in the thickness direction, a portion where no Al crystals are present between the interface between the plating layer and a base metal and a plating surface layer occupies 10% to 50% of the length of the cross section in the width direction, whereby the external appearance of the plating is improved.

[0009]

Furthermore, Patent Document 3 describes a hot-dip galvanized steel sheet having excellent formability in which a center line average roughness Ra of a surface of the plated steel sheet is 0.5 to 1.5  $\mu\text{m}$ , the number of 1.27  $\mu\text{m}$  or larger peaks per inch (2.54 cm) (PPI) is 150 to 300, and the number of 0.5  $\mu\text{m}$  or larger peaks per centimeter (Pc) satisfies  $Pc \geq PPI/2.54 + 10$ .

Moreover, Patent Document 4 describes a highly corrosion-resistant hot-dip galvanized steel sheet in which a ternary eutectic structure of Al/MgZn<sub>2</sub>/Zn is refined, whereby the glossiness of a plating layer increases as a whole and the external appearance evenness improves.

[0010]

However, no techniques for improving durability and preventing the deterioration of corrosion resistance in the case of displaying letters or the like on the surface of a plating layer have been thus far known in the related art.

5 [Citation List]

[Patent Document]

[0011]

[Patent Document 1]

Japanese Patent No. 5043234

10 [Patent Document 2]

Japanese Patent No. 5141899

[Patent Document 3]

Japanese Patent No. 3600804

[Patent Document 4]

15 PCT International Publication No. WO 2013/002358

[Summary of the invention]

[Problems to be Solved by the Invention]

[0012]

20 The present invention has been made in consideration of the above-described circumstances, and an objective of the present invention is to provide a hot-dip plated steel sheet capable of displaying letters, designs or the like on the surface of a plating layer and having excellent durability and excellent corrosion resistance.

[Means for Solving the Problem]

[0013]

25 The gist of the present invention is as described below.

[1] A hot-dip plated steel sheet including a steel sheet and a hot-dip plating layer formed on a surface of the steel sheet,

in which the hot-dip plating layer contains, in an average composition, 0 to 90 mass% of Al and 0 to 10 mass% of Mg with a remainder including Zn and impurities,

5 the hot-dip plating layer includes a pattern portion and a non-pattern portion disposed so as to form a predetermined shape,

in a case where a first region and a second region are specified by any one of the following determination methods 1 to 5,

the pattern portion and the non-pattern portion are each composed of one or both  
10 of the first region and the second region, and

an absolute value of a difference between an area ratio of the first region in the pattern portion and an area ratio of the first region in the non-pattern portion is 30% or more.

[Determination method 1]

15 Virtual grid lines are drawn at 0.5 mm intervals on a surface of the hot-dip plating layer, in each of a plurality of regions partitioned by the virtual grid lines, a circle having a centroid of each region at a center and having a diameter of 0.5 mm is defined as a measurement region A, and an  $L^*$  value in each measurement region A is measured. When 50 arbitrary points are selected from the obtained  $L^*$  values, and a 50-point  
20 average of the obtained  $L^*$  values is defined as a reference  $L^*$  value, regions where the  $L^*$  value is the reference  $L^*$  value or more are defined as the first regions, and regions where the  $L^*$  value is less than the reference  $L^*$  value are defined as the second regions.

[Determination method 2]

Virtual grid lines are drawn at 0.5 mm intervals on a surface of the hot-dip  
25 plating layer, in each of a plurality of regions partitioned by the virtual grid lines, a circle

having a centroid of each region at a center and having a diameter of 0.5 mm is defined as a measurement region A, an  $L^*$  value in each measurement region A is measured, regions where the  $L^*$  value is 45 or more are defined as the first regions, and regions where the  $L^*$  value is less than 45 are defined as the second regions.

5 [Determination method 3]

Virtual grid lines are drawn at 0.5 mm intervals on a surface of the hot-dip plating layer, and, in each of a plurality of regions partitioned by the virtual grid lines, an arithmetic average roughness  $S_a$  is measured. Regions where the obtained  $S_a$  is 1  $\mu\text{m}$  or more are defined as the first regions, and regions where the obtained  $S_a$  is less than 1  $\mu\text{m}$  are defined as the second regions.

[Determination method 4]

Virtual grid lines are drawn at 1 mm intervals or 10 mm intervals on a surface of the hot-dip plating layer, in each of a plurality of regions partitioned by the virtual grid lines, a diffraction peak intensity  $I_{0002}$  of a (0002) plane of a Zn phase and a diffraction peak intensity  $I_{10-11}$  of a (10-11) plane of the Zn phase are measured by an X-ray diffraction method in which an X-ray is incident on each region, and an intensity ratio thereof ( $I_{0002}/I_{10-11}$ ) is defined as an orientation ratio. Regions where the orientation ratio is 3.5 or higher are defined as the first regions, and regions where the orientation ratio is lower than 3.5 are defined as the second regions.

20 [Determination method 5]

Virtual grid lines are drawn at 1 mm intervals on a surface of the hot-dip plating layer, next, in each of a plurality of regions partitioned by the virtual grid lines, a circle S having a centroid G of each region at a center is drawn. A diameter R of the circle S is set such that a total length of surface boundary lines in the hot-dip plating layer that is included in the circle S reaches 10 mm. An average value of a maximum diameter  $R_{\text{max}}$

and a minimum diameter  $R_{min}$  of the diameters  $R$  of the circles in the plurality of regions is defined as a reference diameter  $R_{ave}$ , regions having a circle  $S$  with a diameter  $R$  of less than the reference diameter  $R_{ave}$  are defined as the first regions, and regions having a circle  $S$  with a diameter  $R$  of the reference diameter  $R_{ave}$  or more are defined as the second regions.

[2] The hot-dip plated steel sheet according to [1], in which the hot-dip plating layer contains, in the average composition, 4 to 22 mass% of Al and 1 to 10 mass% of Mg with the remainder including Zn and impurities.

[3] The hot-dip plated steel sheet according to [1] or [2], in which the hot-dip plating layer further contains, in the average composition, 0.0001 to 2 mass% of Si.

[4] The hot-dip plated steel sheet according to any one of [1] to [3], in which the hot-dip plating layer further contains, in the average composition, a total of 0.0001 to 2 mass% of one or more of the group consisting of Ni, Ti, Zr, Sr, Fe, Sb, Pb, Sn, Ca, Co, Mn, P, B, Bi, Cr, Sc, Y, REM, Hf and C.

[5] The hot-dip plated steel sheet according to any one of [1] to [4], in which the pattern portion is disposed so as to form a shape of any one of a straight-line portion, a curved line portion, a dot portion, a figure, a number, a symbol, a mark or a letter or a shape consisting of a combination of two or more thereof.

[6] The hot-dip plated steel sheet according to any one of [1] to [5], in which the pattern portion is intentionally formed.

[7] The hot-dip plated steel sheet according to any one of [1] to [6], in which a total amount of the hot-dip plating layer attached to both surfaces of the steel sheet is 30 to 600 g/m<sup>2</sup>.

[8] A hot-dip plated steel sheet including a steel sheet and a hot-dip plating layer formed on a surface of the steel sheet,

in which the hot-dip plating layer contains, in an average composition, 0 to 90 mass% of Al and 0 to 10 mass% of Mg with a remainder including Zn and impurities,

the hot-dip plating layer includes a pattern portion and a non-pattern portion disposed so as to form a predetermined shape,

5 the pattern portion and the non-pattern portion each include one or both of a first region and a second region that are determined by any of the following determination methods 1 to 5,

an absolute value of a difference between an area ratio of the first region in the pattern portion and an area ratio of the first region in the non-pattern portion is 30% or

10 more.

[Determination method 1]

Virtual grid lines are drawn at 0.5 mm intervals on a surface of the hot-dip plating layer, in each of a plurality of regions partitioned by the virtual grid lines, a circle having a centroid of each region at a center and having a diameter of 0.5 mm is defined

15 as a measurement region A, and an  $L^*$  value in each measurement region A is measured.

When 50 arbitrary points are selected from the obtained  $L^*$  values, and a 50-point average of the obtained  $L^*$  values is defined as a reference  $L^*$  value, regions where the  $L^*$  value is the reference  $L^*$  value or more are defined as the first regions, and regions where the  $L^*$  value is less than the reference  $L^*$  value are defined as the second regions.

20 [Determination method 2]

Virtual grid lines are drawn at 0.5 mm intervals on a surface of the hot-dip plating layer, in each of a plurality of regions partitioned by the virtual grid lines, a circle having a centroid of each region at a center and having a diameter of 0.5 mm is defined as a measurement region A, an  $L^*$  value in each measurement region A is measured,

25 regions where the  $L^*$  value is 45 or more are defined as the first regions, and regions

where the  $L^*$  value is less than 45 are defined as the second regions.

[Determination method 3]

Virtual grid lines are drawn at 0.5 mm intervals on a surface of the hot-dip plating layer, and, in each of a plurality of regions partitioned by the virtual grid lines, an arithmetic average roughness  $S_a$  is measured. Regions where the obtained  $S_a$  is 1  $\mu\text{m}$  or more are defined as the first regions, and regions where the obtained  $S_a$  is less than 1  $\mu\text{m}$  are defined as the second regions.

[Determination method 4]

Virtual grid lines are drawn at 1 mm intervals or 10 mm intervals on a surface of the hot-dip plating layer, in each of a plurality of regions partitioned by the virtual grid lines, a diffraction peak intensity  $I_{0002}$  of a (0002) plane of a Zn phase and a diffraction peak intensity  $I_{10-11}$  of a (10-11) plane of the Zn phase are measured by an X-ray diffraction method in which an X-ray is incident on each region, and an intensity ratio thereof ( $I_{0002}/I_{10-11}$ ) is defined as an orientation ratio. Regions where the orientation ratio is 3.5 or higher are defined as the first regions, and regions where the orientation ratio is lower than 3.5 are defined as the second regions.

[Determination method 5]

Virtual grid lines are drawn at 1 mm intervals on a surface of the hot-dip plating layer, next, in each of a plurality of regions partitioned by the virtual grid lines, a circle  $S$  having a centroid  $G$  of each region at a center is drawn. A diameter  $R$  of the circle  $S$  is set such that a total length of surface boundary lines in the hot-dip plating layer that is included in the circle  $S$  reaches 10 mm. An average value of a maximum diameter  $R_{\text{max}}$  and a minimum diameter  $R_{\text{min}}$  of the diameters  $R$  of the circles in the plurality of regions is defined as a reference diameter  $R_{\text{ave}}$ , regions having a circle  $S$  with a diameter  $R$  of less than the reference diameter  $R_{\text{ave}}$  are defined as the first regions, and regions

having a circle S with a diameter R of the reference diameter  $R_{ave}$  or more are defined as the second regions.

[Effects of the Invention]

[0014]

5           According to the hot-dip plated steel sheet of the present invention in which the first region and the second region are specified by the determination methods 1 to 4, the absolute value of the difference between the area ratio of the first region in the pattern portion and the area ratio of the first region in the non-pattern portion is set to 30% or more, which makes the pattern portion and the non-pattern portion distinguishable.

10          Therefore, it is possible to provide a hot-dip plated steel sheet having excellent durability and also having excellent corrosion resistance in the case of displaying letters, designs or the like on the surface of a hot-dip plating layer.

[0015]

            In addition, according to the hot-dip plated steel sheet of the present invention in  
15          which the first region and the second region are specified by the determination method 5, the surface of the hot-dip plating layer is divided into the first region that is included in a portion where the density of boundary lines appearing on the surface of the hot-dip plating layer is relatively high and the second region that is included in a portion where the density of the boundary lines appearing on the surface of the hot-dip plating layer is  
20          relatively low, and the absolute value of the difference between the area ratio of the first region in the pattern portion and the area ratio of the first region in the non-pattern portion is set to 30% or more, which makes the pattern portion and the non-pattern portion discriminable by a difference in the density of the boundary lines. Therefore, it is possible to provide a hot-dip plated steel sheet having excellent durability and also  
25          having excellent corrosion resistance in the case of displaying letters, designs or the like

on the surface of a hot-dip plating layer.

[Brief Description of Drawings]

[0016]

Fig. 1 is a schematic view for describing a determination method (determination  
5 method 5) of a first region and a second region in a hot-dip plated steel sheet, which is an  
example of the present embodiment.

Fig. 2 is a schematic view for describing a determination method of the first  
region and the second region in the hot-dip plated steel sheet, which is an example of the  
present embodiment.

10 Fig. 3 is an enlarged photograph of a first region in Example No. 1-1 captured  
with a scanning electron microscope.

Fig. 4 is an enlarged photograph of a second region in Example No. 1-1 captured  
with the scanning electron microscope.

15 Fig. 5 is an enlarged plan view showing the surface of a hot-dip plated steel  
sheet of Example 1.

Fig. 6 is an enlarged photograph of a first region in Example No. 2-1 captured  
with the scanning electron microscope.

Fig. 7 is an enlarged photograph of a second region in Example No. 2-1 captured  
with the scanning electron microscope.

20 Fig. 8 is an enlarged plan view showing the surface of a hot-dip plated steel  
sheet of Example 2.

Fig. 9 is an enlarged photograph of a pattern portion in Example No. 3-1  
captured with the scanning electron microscope.

25 Fig. 10 is an enlarged photograph of a non-pattern portion in Example No. 3-1  
captured with the scanning electron microscope.

Fig. 11 is an enlarged plan view showing the surface of a hot-dip plated steel sheet of Example 3.

Fig. 12 is a schematic view showing boundary lines obtained by carrying out a binarization treatment on the imaging data of the surface of a hot-dip plating layer in  
5 Example No. 4-1.

Fig. 13 is an enlarged photograph of a first region in Example No. 4-1 captured with the scanning electron microscope.

Fig. 14 is an enlarged photograph of a second region in Example No. 4-1 captured with the scanning electron microscope.

10 Fig. 15 is an enlarged plan view showing the surface of a hot-dip plated steel sheet of Example 4.

[Embodiment for implementing the Invention]

[0017]

Hereinafter, a hot-dip plated steel sheet that is an embodiment of the present  
15 invention will be described.

In the present specification, numerical ranges expressed using “to” include numerical values before and after “to” as the lower limit value and the upper limit value.

[0018]

(Overview of hot-dip plated steel sheet of present embodiment)

20 A hot-dip plated steel sheet of the present embodiment includes a steel sheet and a hot-dip plating layer formed on a surface of the steel sheet, the hot-dip plating layer contains, in the average composition, 0 to 90 mass% of Al and 0 to 10 mass% of Mg with the remainder including Zn and impurities, the hot-dip plating layer includes a pattern portion and a non-pattern portion disposed so as to form a predetermined shape, in a case  
25 where a first region and a second region are specified by any one of the following

determination methods 1 to 5, the pattern portion and the non-pattern portion are each composed of one or both of the first region and the second region, and the absolute value of a difference between the area ratio of the first region in the pattern portion and the area ratio of the first region in the non-pattern portion is 30% or more.

5            In the hot-dip plating layer of this hot-dip plated steel sheet, in a case where the first region and the second region are specified by any one of the following determination methods 1 to 5, the pattern portion and the non-pattern portion are each composed of one or both of the first region and the second region.

            That is, the first region and the second region in the pattern portion and the first  
10    region and the second region in the non-pattern portion are defined by the same determination method. For example, in a case where the first region and the second region in the pattern portion are defined by the determination method 1, the first region and the second region in the non-pattern portion are defined by the determination method 1.

15    [0019]

            The hot-dip plated steel sheet of the present embodiment may be a hot-dip plated steel sheet including a steel sheet and a hot-dip plating layer formed on a surface of the steel sheet, in which the hot-dip plating layer contains, in an average composition, 0 to 90 mass% of Al and 0 to 10 mass% of Mg with the remainder including Zn and impurities,  
20    the hot-dip plating layer includes a pattern portion and a non-pattern portion disposed so as to form a predetermined shape, the pattern portion and the non-pattern portion each include one or both of a first region and a second region that are determined by any one of the following determination methods 1 to 5, and the absolute value of a difference between the area ratio of the first region in the pattern portion and the area ratio of the  
25    first region in the non-pattern portion is 30% or more.

In this hot-dip plating layer, the pattern portion and the non-pattern portion each include one or both of the first region and the second region that are determined by any of the following determination methods 1 to 5.

That is, in the present invention, since there are five types of determination  
5 methods 1 to 5 as the determination method of the first region and the second region, in the hot-dip plating layer, the determination method of the first region in the pattern portion and the determination method of the second region in the pattern portion may be the same determination method or the determination method of the first region in the pattern portion and the determination method of the second region in the pattern portion  
10 may be different determination methods. Similarly, the determination method of the first region in the non-pattern portion and the determination method of the second region in the non-pattern portion may be the same determination method or different determination methods.

In addition, the determination method of the first region in the pattern portion  
15 and the determination method of the first region in the non-pattern portion may be the same determination method or may be different determination methods. Similarly, the determination method of the second region in the pattern portion and the determination method of the second region in the non-pattern portion may be the same determination method or may be different determination methods.

20 Furthermore, the first region and the second region in the pattern portion and the first region and the second region in the non-pattern portion may be defined by the same determination method. For example, in a case where the first region and the second region in the pattern portion are defined by the determination method 1, the first region and the second region in the non-pattern portion may be defined by the determination  
25 method 1.

[0020]

Regarding the surface of the hot-dip plating layer according to the present embodiment, the first region and the second region are preferably specified by the same determination method. Additionally, the determination methods of the first region and the second region are more preferably the same in the pattern portion and the non-pattern portion. That is, the first region and the second region in the pattern portion and the first region and the second region in the non-pattern portion are more preferably all differentiated by the same determination method. For example, in a case where the first region and the second region in the pattern portion are defined by the determination method 1, in the non-pattern portion as well, the first region and the second region are more preferably defined by the determination method 1.

[0021]

[Determination method 1]

Virtual grid lines are drawn at 0.5 mm intervals on the surface of the hot-dip plating layer, in each of a plurality of regions partitioned by the virtual grid lines, a circle having the centroid of each region at the center and having a diameter of 0.5 mm is defined as a measurement region A, and the  $L^*$  value in each measurement region A is measured. When 50 arbitrary points are selected from the obtained  $L^*$  values, and the 50-point average of the obtained  $L^*$  values is defined as the reference  $L^*$  value, regions where the  $L^*$  value is the reference  $L^*$  value or more are defined as the first regions, and regions where the  $L^*$  value is less than the reference  $L^*$  value are defined as the second regions.

[0022]

[Determination method 2]

Virtual grid lines are drawn at 0.5 mm intervals on the surface of the hot-dip

plating layer, in each of a plurality of regions partitioned by the virtual grid lines, a circle having the centroid of each region at the center and having a diameter of 0.5 mm is defined as a measurement region A, the  $L^*$  value in each measurement region A is measured, regions where the  $L^*$  value is 45 or more are defined as the first regions, and  
5 regions where the  $L^*$  value is less than 45 are defined as the second regions.

[0023]

[Determination method 3]

Virtual grid lines are drawn at 0.5 mm intervals on the surface of the hot-dip plating layer, and, in each of a plurality of regions partitioned by the virtual grid lines, the  
10 arithmetic average roughness  $S_a$  is measured. Regions where the obtained  $S_a$  is 1  $\mu\text{m}$  or more are defined as the first regions, and regions where the obtained  $S_a$  is less than 1  $\mu\text{m}$  are defined as the second regions.

[0024]

[Determination method 4]

15 Virtual grid lines are drawn at 1 mm intervals or 10 mm intervals on the surface of the hot-dip plating layer, in each of a plurality of regions partitioned by the virtual grid lines, the diffraction peak intensity  $I_{0002}$  of the (0002) plane of a Zn phase and the diffraction peak intensity  $I_{10-11}$  of the (10-11) plane of the Zn phase are measured by the X-ray diffraction method in which an X-ray is incident on each region, and the intensity  
20 ratio thereof ( $I_{0002}/I_{10-11}$ ) is defined as the orientation ratio. Regions where the orientation ratio is 3.5 or higher are defined as the first regions, and regions where the orientation ratio is lower than 3.5 are defined as the second regions.

[0025]

[Determination method 5]

25 Virtual grid lines are drawn at 1 mm intervals on the surface of the hot-dip

plating layer, next, in each of a plurality of regions partitioned by the virtual grid lines, a circle S having the centroid G of each region at the center is drawn. A diameter R of the circle S is set such that the total length of surface boundary lines in the hot-dip plating layer that is included in the circle S reaches 10 mm. The average value of the maximum diameter R<sub>max</sub> and the minimum diameter R<sub>min</sub> of the diameters R of the circles in the plurality of regions is defined as the reference diameter R<sub>ave</sub>, regions having a circle S with a diameter R of less than the reference diameter R<sub>ave</sub> are defined as the first regions, and regions having a circle S with a diameter R of the reference diameter R<sub>ave</sub> or more are defined as the second regions.

10 [0026]

(Description of determination methods 1 and 2)

The determination method 1 is as described below. Virtual grid lines are drawn at 0.5 mm intervals on the surface of the hot-dip plating layer, in each of a plurality of regions partitioned by the virtual grid lines, a circle having the centroid of each region at the center and having a diameter of 0.5 mm is defined as a measurement region A, and the L\* value in each measurement region A is measured. In addition, 50 arbitrary points are selected from the obtained L\* values, and the 50-point average is defined as the reference L\* value.

In the determination method 2, the reference L\* value in the determination method 1 is set to 45. Except the reference L\* value, the determination method 1 and the determination method 2 are the same as each other.

[0027]

In the hot-dip plated steel sheet of the present embodiment, in a case where virtual grid lines are drawn at 0.5 mm intervals on the surface of the hot-dip plating layer, the plurality of regions partitioned by the virtual grid lines are each classified into any of

the first region and the second region depending on the  $L^*$  value.

[0028]

The first region is a region where the  $L^*$  value is the reference  $L^*$  value or more.

On the other hand, the second region is a region where the  $L^*$  value is less than the

5 reference  $L^*$  value. Since the first region has a large  $L^*$  value, a site in the hot-dip plating layer where the first region is larger appears relatively white or nearly white compared with a site where the second region is larger when observed with the naked eye or under a microscope. In addition, since the second region has a small  $L^*$  value, a site in the hot-dip plating layer where the second region is larger and the first region is  
10 smaller appears relatively metallic glossy or dark compared with a site where the first region is larger. Furthermore, a site where the first region and the second region are present in a mixed manner and the area ratio of the first region is 30% to 70% has a relatively pear skin-like external appearance.

[0029]

15 (Description of determination method 3)

The determination method 3 is as described below. Virtual grid lines are drawn at 0.5 mm intervals on the surface of the hot-dip plating layer, and, in each of a plurality of regions partitioned by the virtual grid lines, the arithmetic average roughness  $S_a$  is measured.

20 [0030]

In the hot-dip plated steel sheet of the present embodiment, in a case where virtual grid lines are drawn at 0.5 mm intervals on the surface of the hot-dip plating layer, the plurality of regions partitioned by the virtual grid lines are each classified into any of the first region and the second region depending on the arithmetic average roughness  $S_a$ .

25 [0031]

The first region is a region where the arithmetic average roughness  $S_a$  is 1  $\mu\text{m}$  or more. On the other hand, the second region is a region where the arithmetic average surface roughness  $S_a$  is less than 1  $\mu\text{m}$ . Since the first region has a large arithmetic average roughness  $S_a$ , a site in the hot-dip plating layer where the first region is larger appears relatively white or nearly white compared with a site where the second region is larger when observed with the naked eye or under a microscope. Since the second region has a small arithmetic average roughness  $S_a$ , a site in the hot-dip plating layer where the second region is larger and the first region is smaller appears relatively metallic glossy compared with a site where the first region is larger when observed with the naked eye or under a microscope. Furthermore, a site where the first region and the second region are present in a mixed manner and the area ratio of the first region is 30% to 70% has a relatively pear skin-like external appearance.

[0032]

(Description of determination method 4)

The determination method 4 is as described below. Virtual grid lines are drawn at 1 mm intervals or 10 mm intervals on the surface of the hot-dip plating layer, in each of a plurality of regions partitioned by the virtual grid lines, the diffraction peak intensity  $I_{0002}$  of the (0002) plane of a Zn phase and the diffraction peak intensity  $I_{10-11}$  of the (10-11) plane of the Zn phase are measured by the X-ray diffraction method in which an X-ray is incident on each region, and the intensity ratio thereof ( $I_{0002}/I_{10-11}$ ) is defined as the orientation ratio. “-1” in (10-11) means that a bar is imparted above “1”.

[0033]

In the hot-dip plated steel sheet of the present embodiment, in a case where virtual grid lines are drawn at 1 mm intervals or 10 mm intervals on the surface of the hot-dip plating layer, the plurality of regions partitioned by the virtual grid lines are each

classified into any of the first region and the second region depending on the orientation ratio ( $I_{0002}/I_{10-11}$ ).

[0034]

As a result of measuring the orientation ratio by carrying out X-ray diffraction measurement on each of the regions partitioned by the virtual grid lines and investigating the relationship between the external appearance of each region and the orientation ratio, the present inventors found that the external appearance of the region is relatively white as the orientation ratio is higher and the external appearance of the region appears relatively metallic glossy as the orientation ratio is lower. The present inventors found that such a relationship between the orientation ratio and the external appearance is not confirmed in an Al phase or a  $MgZn_2$  phase, but can be confirmed in the case of a Zn phase.

[0035]

The first region is a region where the orientation ratio is 3.5 or higher. On the other hand, the second region is a region where the orientation ratio is lower than 3.5. Since the first region has a high orientation ratio, a site in the hot-dip plating layer where the first region is larger appears relatively white or nearly white compared with a site where the second region is larger when observed with the naked eye or under a microscope. Since the second region has a low orientation ratio, a site in the hot-dip plating layer where the second region is larger and the first region is smaller appears relatively metallic glossy compared with a site where the first region is larger to the naked eye or under a microscope. Furthermore, a site where the first region and the second region are present in a mixed manner and the area ratio of the first region is 30% to 70% has a relatively pear skin-like external appearance.

[0036]

(Description of determination method 5)

The determination method 5 is as described below. Virtual grid lines are drawn at 1 mm intervals on the surface of the hot-dip plating layer, next, in each of a plurality of regions partitioned by the virtual grid lines, a circle S having the centroid G of each  
5 region at the center is drawn. The diameter R of the circle S is set such that the total length of surface boundary lines in the hot-dip plating layer that is included in the circle S reaches 10 mm. The average value of the maximum diameter R<sub>max</sub> and the minimum diameter R<sub>min</sub> of the diameters R of the circles in the plurality of regions is defined as the reference diameter R<sub>ave</sub>, regions having a circle S with a diameter R of less than the  
10 reference diameter R<sub>ave</sub> are defined as the first regions, and regions having a circle S with a diameter R of the reference diameter R<sub>ave</sub> or more are defined as the second regions.

[0037]

As the boundary lines appearing on the hot-dip plating layer, for example,  
15 crystal grain boundaries appearing on the plating surface or boundaries between portions with high luminosity and portions with low luminosity on the plating surface are exemplary examples.

[0038]

When a region that is included in a portion where the density of crystal grain  
20 boundaries appearing on the plating surface is high or a region that is included in a portion where the density of the crystal grain boundaries is low is disposed so as to form a shape like a straight-line portion or a letter on the plating surface, the straight-line portion or the letter is recognized to be present on the plating surface.

[0039]

25 Similarly, when a region that is included in a portion where the density of

light/dark boundaries on the plating surface is high or a region that is included in a portion where the density of light/dark boundaries on the plating surface is low is disposed so as to form a shape like a straight-line portion or a letter on the plating surface, the straight-line portion or the letter is recognized to be present on the plating surface.

[0040]

Therefore, the present inventors attempted to divide the surface of the hot-dip plating layer into the first region and the second region with the density of the boundary lines appearing on the plating surface.

[0041]

In the hot-dip plated steel sheet of the present embodiment, in a case where virtual grid lines are drawn at 1 mm intervals on the surface of the hot-dip plating layer, the plurality of regions partitioned by the virtual grid lines are each classified into any of the first region or the second region depending on the density of surface boundary lines on the hot-dip plating layer in the vicinity of each partitioned region.

[0042]

The first region is a region that is included in a portion where the density of the boundary lines appearing on the surface of the hot-dip plating layer is high. In addition, the second region is a region that is included in a portion where the density of the boundary lines appearing on the surface of the hot-dip plating layer is low. Since the density of the boundary lines differs between a site where the first regions gather and a site where the second regions gather in the hot-dip plating layer, the first region and the second region appear to be relatively different.

[0043]

(Absolute value of difference between area ratio of first region in pattern portion and area

ratio of first region in non-pattern portion in hot-dip plated steel sheet of present embodiment being set to 30% or more)

As described above, in the determination methods 1 to 4, the surface of the hot-dip plating layer appears any of relatively white or nearly white, metallic glossy, with low luminosity, or pear skin-like depending on the area ratio of the first region.

In addition, in the determination method 5, since the first region is a region that is included in a portion where the density of the boundary lines appearing on the surface of the hot-dip plating layer is high and the second region is a region that is included in a portion where the density of the boundary lines appearing on the surface of the hot-dip plating layer is low, the density of the boundary lines differs between a site where the first regions gather and a site where the second regions gather in the hot-dip plating layer, and the first region and the second region appear to be relatively different.

[0044]

Here, in order to make a letter, a figure, a line, a dot, a mark and the like visible on the surface of the hot-dip plating layer, the pattern portion that configures this letter and the like and the other non-pattern portions need to be made distinguishable. Therefore, the area proportion of the first region in the pattern portion and the area proportion of the first region in the non-pattern portion need to be different from each other.

[0045]

Specifically, the absolute value of the difference between the area ratio of the first region in the pattern portion and the area ratio of the first region in the non-pattern portion needs to be 30% or more. In such a case, the pattern portion and the non-pattern portion are distinguishable.

[0046]

In the determination methods 1 to 4, for example, in a case where the area proportion of the first region in the pattern portion is 75%, the pattern portion appears relatively white or nearly white. In addition, in a case where the area proportion of the first region in the non-pattern portion is 45% or less, the non-pattern portion appears relatively pear skin-like or metallic glossy. Furthermore, in the case of the determination methods 1 and 2, there is also a case where the non-pattern portion appears in color with relatively low luminosity. In addition, in a case where the difference in the area ratio of the first region is 30% or more between the pattern portion and the non-pattern portion, the pattern portion and the non-pattern portion become distinguishable due to such a difference in the external appearance.

[0047]

In addition, in a case where the area proportion of the first region in the pattern portion is approximately 65% and the area proportion of the first region in the non-pattern portion is approximately 35%, both the pattern portion and the non-pattern portion appear relatively pear skin-like, but the area proportion of the first region in the pattern portion is large, and thus the pattern portion presents a relatively white external appearance compared with the non-pattern portion. In addition, in a case where the difference in the area ratio of the first region is 30% or more between the pattern portion and the non-pattern portion, the pattern portion and the non-pattern portion become distinguishable due to such a difference in the external appearance.

[0048]

Furthermore, in a case where the first region in the pattern portion is 50%, the pattern portion appears relatively pear skin-like. In addition, in a case where the area proportion of the first region in the non-pattern portion is 20% or less, the non-pattern portion appears relatively metallic glossy or in color with low luminosity. In addition, in

a case where the difference in the area ratio of the first region is 30% or more between the pattern portion and the non-pattern portion, the pattern portion and the non-pattern portion become distinguishable due to such a difference in the external appearance.

[0049]

5           In addition, in the determination method 5, for example, in a case where the first region is large in the pattern portion, a large number of boundary lines are shown in the pattern portion. In this case, the area proportion of the first region in the non-pattern portion is small. Since the area proportion of the first region is small in the non-pattern portion, the area proportion of the second region is relatively large, and thus a small  
10   number of boundary lines are shown in the non-pattern portion. Therefore, the pattern portion where a large number of boundary lines are shown and the non-pattern portion where a small number of boundary lines are shown are distinguishable to the naked eye, under a magnifying glass or under a microscope.

[0050]

15           In addition, in a case where the second region is large in the pattern portion, a small number of boundary lines are shown in the pattern portion. In this case, the area proportion of the second region in the non-pattern portion is decreased, and the area proportion of the first region is increased. Since the area proportion of the first region is large in the non-pattern portion, a large number of boundary lines are shown in the non-  
20   pattern portion. Therefore, the pattern portion where a small number of boundary lines are shown and the non-pattern portion where a large number of boundary lines are shown are distinguishable to the naked eye, under a magnifying glass or under a microscope.

[0051]

          As described above, in the determination methods 1 to 5, when the absolute  
25   value of the difference between the area ratio of the first region in the pattern portion and

the area ratio of the first region in the non-pattern portion is 30% or more, since the external appearances of the pattern portion and the non-pattern portion are relatively different, the pattern portion is clearly distinguishable. That is, in a visible light image of the surface of the plating layer, since the differences in relative hue, luminosity, saturation and the like between the pattern portion and the non-pattern portion are large, the pattern portion and the non-pattern portion are distinguishable.

[0052]

On the other hand, when the absolute value of the difference between the area ratio of the first region in the pattern portion and the area ratio of the first region in the non-pattern portion is less than 30%, since there is no relative difference in external appearance between the pattern portion and the non-pattern portion, it is impossible to clearly distinguish the pattern portion. That is, in a visible light image of the surface of the plating layer, since the differences in relative hue, luminosity, saturation and the like between the pattern portion and the non-pattern portion is small, it is impossible to distinguish the pattern portion and the non-pattern portion.

[0053]

As described above, an example of the abundance of the first region in the pattern portion and the non-pattern portion has been described, but there is no need to limit the abundance of the first region in each of the pattern portion and the non-pattern portion as long as the absolute value of the difference between the area ratio of the first region in the pattern portion and the area ratio of the first region in the non-pattern portion is 30% or more.

[0054]

Hereinafter, the hot-dip plated steel sheet of the embodiment of the present invention will be described.

[0055]

(Steel sheet)

The material of the steel sheet that serves as the base material of the hot-dip plating layer is not particularly limited. While described in detail below, as the material,  
5 ordinary steel or the like can be used with no particular limitations, Al killed steel or some of high alloy steel can also be applied, and the shapes are also not particularly limited. The hot-dip plating layer according to the present embodiment is formed by applying a hot-dip plating method described below to the steel sheet.

[0056]

10 (Chemical components of hot-dip plating layer)

Next, the chemical components of the hot-dip plating layer will be described. The hot-dip plating layer contains, in the average composition, 0 to 90 mass% of Al and 0 to 10 mass% of Mg with the remainder including Zn and impurities. The hot-dip plating layer more preferably contains, in the average composition, 4 to 22 mass% of Al  
15 and 1 to 10 mass% of Mg with the remainder including Zn and impurities. The hot-dip plating layer still more preferably contains, in the average composition, 4 to 22 mass% of Al and 1 to 10 mass% of Mg with the remainder consisting of Zn and impurities. In addition, the hot-dip plating layer may contain, in the average composition, 0.0001 to 2 mass% of Si. Furthermore, the hot-dip plating layer may also contain, in the average  
20 composition, one or more of the group consisting of Ni, Ti, Zr, Sr, Fe, Sb, Pb, Sn, Ca, Co, Mn, P, B, Bi, Cr, Sc, Y, REM, Hf and C in a total of 0.0001 to 2 mass%.

[0057]

The Al content is, in the average composition, within a range of 0 to 90 mass% and preferably 4 to 22 mass%. Al is preferably contained in order to ensure the corrosion  
25 resistance. When the Al content in the hot-dip plating layer is 4 mass% or more, an

effect on improvement of the corrosion resistance becomes stronger. When the Al content is 90% or less, it is possible to stably form the plating layer. In addition, when the Al content exceeds 90%, a long time is taken to impart design, and there is a case where manufacturing becomes realistically difficult. Furthermore, when the Al content exceeds 90%, the amount of Zn present becomes small, and it becomes impossible to clearly distinguish the first region and the second region. In addition, when the Al content exceeds 22 mass%, the effect on improvement of the corrosion resistance is saturated. From the viewpoint of the corrosion resistance, the Al content is preferably set to 5 to 18 mass%. The Al content is more preferably set to 6 to 16 mass%.

[0058]

The Mg content is, in the average composition, within a range of 0 to 10 mass% and preferably 1 to 10 mass%. Mg is preferably contained in order to improve the corrosion resistance. When the Mg content in the hot-dip plating layer is 1 mass% or more, an effect on improvement of the corrosion resistance becomes stronger. When the Mg content exceeds 10 mass%, the generation of dross in a plating bath becomes significant, and it becomes difficult to stably manufacture the hot-dip plated steel sheet. From the viewpoint of the balance between the corrosion resistance and the generation of dross, the Mg content is set to 1.5 to 6 mass%. The Mg content is more preferably set to be within a range of 2 to 5 mass%.

[0059]

Al and Mg may be each 0%. That is, the hot-dip plating layer in the hot-dip plated steel sheet of the present embodiment is not limited to a Zn-Al-Mg-based hot-dip plating layer and may be a Zn-Al-based hot-dip plating layer, may be a hot-dip galvanized layer or may be a hot-dip galvanized layer.

[0060]

In addition, the hot-dip plating layer may contain Si within a range of 0.0001 to 2 mass%.

Si improves the adhesion of the hot-dip plating layer in some cases and thus may be contained. When 0.0001 mass% or more of Si is contained, since an effect on improvement of the adhesion is developed, 0.0001 mass% or more of Si is preferably contained. On the other hand, even when more than 2 mass% of Si is contained, an effect on improvement of the plating adhesion is saturated, and thus the Si content is set to 2 mass% or less. From the viewpoint of the plating adhesion, the Si content may be set to be within a range of 0.001 to 1 mass% or may be set to be within a range of 0.01 to 0.8 mass%.

[0061]

The hot-dip plating layer may also contain, in the average composition, one or more of the group consisting of Ni, Ti, Zr, Sr, Fe, Sb, Pb, Sn, Ca, Co, Mn, P, B, Bi, Cr, Sc, Y, REM, Hf and C in a total of 0.001 to 2 mass%. When these elements are contained, it is possible to further improve the corrosion resistance. REM refers to one or more of rare earth elements having atomic numbers of 57 to 71 in the periodic table. In addition, the amount of these elements may be contained in a total of 0.0001 to 2 mass%.

[0062]

The remainder of the chemical components of the hot-dip plating layer is zinc and impurities. Zn is always contained in the hot-dip plating layer. Examples of the impurity include an impurity that is inevitably contained in ground metals other than zinc and impurities that is contained due to the melting of steel in a plating bath.

[0063]

The average composition of the hot-dip plating layer can be measured by the following method. First, a surface layer coating film is removed with a coating film-

exfoliating agent that does not erode the plating (for example, NEO REVER SP-751 manufactured by Sansai Kako Co., Ltd.), then, the hot-dip plating layer is melted in hydrochloric acid containing an inhibitor (for example, HIBIRON manufactured by Sugimura Chemical Industrial Co., Ltd.), and an inductively coupled plasma (ICP) emission spectroscopic analysis is carried out on the obtained solution, whereby the average composition can be obtained. In addition, in a case where no surface layer coating film is present, operation for removing the surface layer coating film can be skipped.

[0064]

#### 10 (Metallographic structure of hot-dip plating layer)

Next, the structure of the hot-dip plating layer will be described. The structure to be described below is a structure in a case where the hot-dip plating layer contains, in the average composition, 4 to 22 mass% of Al, 1 to 10 mass% of Mg and 0 to 2 mass% of Si.

#### 15 [0065]

The hot-dip plating layer containing Al, Mg and Zn includes [Al phase] and [ternary eutectic structure of Al/Zn/MgZn<sub>2</sub>]. The hot-dip plating layer has a form in which the [Al phase] is included in the parent material of the [ternary eutectic structure of Al/Zn/MgZn<sub>2</sub>]. Furthermore, [MgZn<sub>2</sub> phase] or [Zn phase] may be included in the parent material of the [ternary eutectic structure of Al/Zn/MgZn<sub>2</sub>]. In addition, in a case where Si has been added, [Mg<sub>2</sub>Si phase] may be included in the parent material of the [ternary eutectic structure of Al/Zn/MgZn<sub>2</sub>].

[0066]

Here, the [ternary eutectic structure of Al/Zn/MgZn<sub>2</sub>] refers to a ternary eutectic structure of an Al phase, a Zn phase and an intermetallic compound MgZn<sub>2</sub> phase, and

the Al phase that forms the [ternary eutectic structure of Al/Zn/MgZn<sub>2</sub>] corresponds to, for example, an “Al” phase” (which is a solid solution of Al that forms a solid solution of Zn and contains a small amount of Mg) at a high temperature in the Al-Zn-Mg ternary equilibrium diagram. At normal temperature, the Al” phase at a high temperature

5 normally appears as a fine Al phase and a fine Zn phase separately. In addition, the Zn phase in the [ternary eutectic structure of Al/Zn/MgZn<sub>2</sub>] is a solid solution of Zn that forms a solid solution of a small amount of Al and, in some cases, further forms a solid solution of a small amount of Mg. The MgZn<sub>2</sub> phase in the [ternary eutectic structure of Al/Zn/MgZn<sub>2</sub>] is an intermetallic compound phase present in the vicinity of

10 approximately 84 mass% of Zn in the Zn-Mg binary equilibrium diagram. According to the phase diagram, it is considered that, in each phase, other elements added form no solid solutions or only an extremely small amount of solid solutions even when forming solid solutions and the amount thereof cannot be clearly differentiated by a normal analysis, and thus, in the present specification, a ternary eutectic structure including these

15 three phases will be expressed as the [ternary eutectic structure of Al/Zn/MgZn<sub>2</sub>].

[0067]

In addition, the [Al phase] is a phase that looks like islands with clear boundaries in the parent material of the [ternary eutectic structure of Al/Zn/MgZn<sub>2</sub>] and corresponds to, for example, “Al” phase” (which is a solid solution of Al that forms a

20 solid solution of Zn and contains a small amount of Mg) at a high temperature in the Al-Zn-Mg ternary equilibrium diagram.

In the Al” phase at a high temperature, the amount of Zn or Mg that forms a solid solution differs depending on the concentration of Al or Mg in a plating bath. This Al” phase at a high temperature is normally separated into a fine Al phase and a fine Zn

25 phase at normal temperature, and an island-like shape shown at normal temperature may

be considered as a shape in which the skeleton of the Al'' phase at a high temperature is fastened. According to the phase diagram, it is considered that, in this phase, other elements added form no solid solutions or only an extremely small amount of solid solutions even when forming solid solutions and the amount thereof cannot be clearly differentiated by a normal analysis, and thus, in the present specification, a phase that is derived from the Al'' phase at a high temperature and has the skeleton of the Al'' phase fastened in terms of the shape will be referred to as the [Al phase]. This [Al phase] can be clearly differentiated from the Al phase that forms the [ternary eutectic structure of Al/Zn/MgZn<sub>2</sub>] in microscopic observation.

10 [0068]

In addition, the [Zn phase] is a phase that looks like islands with clear boundaries in the parent material of the [ternary eutectic structure of Al/Zn/MgZn<sub>2</sub>], and, in actual cases, there is also a case where a solid solution of a small amount of Al and, furthermore, a solid solution of a small amount of Mg are formed. According to the phase diagram, it is considered that, in this phase, other elements added form no solid solutions or solid solutions only in an extremely small amount even when forming solid solutions. This [Zn phase] can be clearly differentiated from the Zn phase that forms the [ternary eutectic structure of Al/Zn/MgZn<sub>2</sub>] in microscopic observation. There is also a case where the [Zn phase] is included in the plating layer of the present invention depending on manufacturing conditions; however, in experiments, the [Zn phase] shows almost no influence on improvement of the corrosion resistance in worked portions, and thus there is no particular problem with the [Zn phase] being included in the plating layer.

20 [0069]

25 In addition, the [MgZn<sub>2</sub> phase] is a phase that looks like islands with clear

boundaries in the parent material of the [ternary eutectic structure of Al/Zn/MgZn<sub>2</sub>], and, in actual cases, there is a case where a solid solution of a small amount of Al is formed. According to the phase diagram, it is considered that, in this phase, other elements added form no solid solutions or solid solutions only in an extremely small amount even when forming solid solutions. This [MgZn<sub>2</sub> phase] can be clearly differentiated from the MgZn<sub>2</sub> phase that forms the [ternary eutectic structure of Al/Zn/MgZn<sub>2</sub>] in microscopic observation. There is a case where the [MgZn<sub>2</sub> phase] is not included in the plating layer of the present invention depending on manufacturing conditions, but the [MgZn<sub>2</sub> phase] is included in the plating layer under almost all manufacturing conditions.

10 [0070]

In addition, the [Mg<sub>2</sub>Si phase] is a phase that looks like islands with clear boundaries in the solidification structure of the plating layer in a case where Si has been added thereto. According to the phase diagram, it is considered that Zn, Al and other elements added form no solid solutions or solid solutions only in an extremely small amount even when forming solid solutions. This [Mg<sub>2</sub>Si phase] can be clearly differentiated during plating in microscopic observation.

15

[0071]

(Regarding pattern portion and non-pattern portion)

Next, the pattern portion and the non-pattern portion on the surface of the hot-dip plating layer will be described.

20

[0072]

A pattern portion and a non-pattern portion disposed so as to form a predetermined shape are included on the surface of the hot-dip plating layer of the present embodiment. The pattern portion is preferably disposed so as to form a shape of any one of a straight-line portion, a curved line portion, a dot portion, a figure, a number,

25

a symbol, a mark or a letter or a shape consisting of a combination of two or more thereof. In addition, the non-pattern portion is a region other than the pattern portion. In addition, the shape of the pattern portion is acceptable as long as the shape can be recognized as a whole even when a part is missing such as a dead pixel. In addition, the non-pattern portion may have a shape that fringes the boundary of the pattern portion. The area rate between the pattern portion and the non-pattern portion in the hot-dip plating layer is not particularly limited.

[0073]

In a case where a shape of any one of a straight-line portion, a curved line portion, a dot portion, a figure, a number, a symbol, a mark or a letter or a shape consisting of a combination of two or more thereof is disposed on the surface of the hot-dip plating layer, it is possible to define a region where the shape is disposed as the pattern portion and to define the other regions as the non-pattern portion. The boundary between the pattern portion and the non-pattern portion can be perceived with the naked eye. The boundary between the pattern portion and the non-pattern portion may also be perceived from an enlarged image produced with an optical microscope, a magnifying glass or the like.

[0074]

The pattern portion needs to be formed so large that the presence of the pattern portion can be discriminated with the naked eye, under a magnifying glass or under a microscope. In addition, the non-pattern portion is a region that occupies the majority of the hot-dip plating layer (the surface of the hot-dip plating layer), and there is a case where the pattern portion is disposed in the non-pattern portion.

The pattern portion is disposed in a predetermined shape in the non-pattern portion. Specifically, the pattern portion is disposed so as to form a shape of any one of a

straight-line portion, a curved line portion, a figure, a dot portion, a figure, a number, a symbol, a mark or a letter or a shape consisting of a combination of two or more thereof in the non-pattern portion. A shape of any one of a straight-line portion, a curved line portion, a figure, a dot portion, a figure, a number, a symbol, a mark or a letter or a shape consisting of a combination of two or more thereof is displayed on the surface of the hot-dip plating layer by adjusting the shape of the pattern portion. For example, on the surface of the hot-dip plating layer, a letter string, a number string, a symbol, a mark, a linear drawing, a design image, a combination thereof, or the like, which are formed of the pattern portion, is shown. This shape is a shape formed intentionally or artificially by a manufacturing method to be described below and is not a naturally-formed shape.

[0075]

As described above, the pattern portion and the non-pattern portion are regions formed on the surface of the hot-dip plating layer. In addition, in each of the pattern portion and the non-pattern portion, one or both of the first region and the second region are included. The pattern portion and the non-pattern portion may be each composed of one or both of the first region and the second region.

[0076]

(Regarding first region and second region)

Next, the first region and the second region in the determination methods 1 to 5 will be each described.

[0077]

(First region and second region in determination methods 1 and 2)

The first region in the determination method 1 is a region including the measurement region A where the  $L^*$  value that is obtained by the following determination method 1 is the reference  $L^*$  value or more. In addition, the second region

is a region including the measurement region A where the  $L^*$  value that is obtained by the determination method 1 is less than the reference  $L^*$  value.

[0078]

A site in the hot-dip plating layer where the first region is larger appears  
5 relatively white or nearly white. On the other hand, a site in the hot-dip plating layer where the second region is larger appears relatively metallic glossy or dark. In addition, a site where the first region and the second region each disperse and gather and the area ratio of the first region is 30% to 70% has a relatively pear skin-like external appearance.

[0079]

10 The first region and the second region may be specified by the determination method 2 to be described below.

[0080]

Next, the determination methods 1 and 2 will be described.

[0081]

15 In the determination method 1, virtual grid lines are drawn at 0.5 mm intervals on the surface of the hot-dip plating layer, in each of a plurality of regions partitioned by the virtual grid lines, a circle having the centroid of each region at the center and having a diameter of 0.5 mm is defined as the measurement region A, and the  $L^*$  value in each measurement region A is measured.

20 [0082]

In the determination method 1, virtual grid lines are drawn at 0.5 mm intervals on the surface of the hot-dip plating layer, and a plurality of regions partitioned by these virtual grid lines is set. The shape of each region is a square in which each side is 0.5 mm. The region set here becomes either the first region or the second region. A circle  
25 having the centroid of each region partitioned by the virtual grid lines at the center and

having a diameter of 0.5 mm is defined as the measurement region A, and the  $L^*$  value in each measurement region A is measured.

[0083]

Next, the reference  $L^*$  value is obtained. The reference  $L^*$  value is the average  
5 value of the  $L^*$  values of 50 regions arbitrarily selected from the plurality of regions  
partitioned by the virtual grid lines. The 50 arbitrary measurement points for measuring  
the reference  $L^*$  value are selected, for example, as described below. First, out of the  
plurality of regions partitioned by the virtual grid lines, one region is selected. Next, a  
total of 50 regions in 10 vertical regions and five horizontal regions (50 mm x 25 mm)  
10 that include the above-selected region as the starting point and are arranged at intervals  
of 10 regions are selected. A total of the 50 regions selected as described above are  
regarded as the 50 arbitrary measurement points for measuring the reference  $L^*$  value.

[0084]

In addition, among the regions partitioned by the virtual grid lines, regions  
15 including the measurement region A where the  $L^*$  value is the reference  $L^*$  value or  
more are regarded as the first regions, and regions including the measurement region A  
where the  $L^*$  value is less than the reference  $L^*$  value are regarded as the second regions.

[0085]

In addition, in the determination method 2, the first region and the second region  
20 are specified using  $L^* = 45$  instead of the reference  $L^*$  value. That is, virtual grid lines  
are drawn at 0.5 mm intervals on the surface of the hot-dip plating layer, and a plurality  
of regions partitioned by the virtual grid lines is set. The shape of each region is a square  
in which each side is 0.5 mm. The region set here is the first region or the second region.  
Centroids partitioned by the virtual grid lines are selected. In addition, circles having the  
25 centroid at the center and having a diameter of 0.5 mm are regarded as the measurement

regions A, and the  $L^*$  value in each measurement region A is measured.

[0086]

In addition, among the regions, regions including the measurement region A where the  $L^*$  value is 45 or more are regarded as the first regions, and regions including the measurement region A where the  $L^*$  value is less than 45 are regarded as the second regions.

[0087]

In the determination methods 1 and 2, the  $L^*$  values are measured according to JIS K 5600-4-5. In the present embodiment, among the parameters that indicate the color space represented by the  $L^*a^*b^*$  color system, the  $L^*$  value indicating luminosity is used. The  $L^*$  value is measured by irradiating the surface of the hot-dip plating layer with light that is radiated from a halogen lamp as a light source at an angle of  $45^\circ$  with respect to the vertical direction ( $90^\circ$  direction) to the surface of the hot-dip plating layer and receiving the reflected light that is reflected in the vertical direction ( $90^\circ$  direction) to the surface of the hot-dip plating layer with a light receiver. As the  $L^*$  value measuring instrument, a micro spectrophotometer (VSS 7700 manufactured by Nippon Denshoku Industries Co., Ltd.) can be used. The measurement wavelength range is set to 380 nm to 780 nm, and the intensities within this wavelength range need to be measured at 5 nm intervals and converted into  $L^*$  values.

[0088]

(First region and second region in determination method 3)

Since the first region in the determination method 3 is a region where the arithmetic average surface roughness  $S_a$  is  $1\text{ }\mu\text{m}$  or more, a site in the hot-dip plating layer where the first region is larger appears relatively white or nearly white. On the other hand, a site in the hot-dip plating layer where the second region is larger appears

relatively metallic glossy. In addition, a site where the first region and the second region each disperse and gather and the area ratio of the first region is 30% to 70% has a relatively pear skin-like external appearance.

[0089]

5            Since the first region is a region where the arithmetic average surface roughness  $S_a$  is 1  $\mu\text{m}$  or more, a site in the hot-dip plating layer where the first region is larger appears relatively white or nearly white. On the other hand, a site in the hot-dip plating layer where the second region is larger appears relatively metallic glossy. In addition, a site where the first region and the second region each disperse and gather and the area  
10 ratio of the first region is 30% to 70% has a relatively pear skin-like external appearance.

[0090]

Next, a method for measuring the arithmetic average surface roughness  $S_a$  will be described.

First, virtual grid lines are drawn at 0.5 mm intervals on the surface of the hot-  
15 dip plating layer, and, in each of a plurality of regions partitioned by the virtual grid lines, the arithmetic average roughness  $S_a$  of each region is measured.

Regions where the arithmetic average surface roughness  $S_a$  is 1  $\mu\text{m}$  or more is the first regions, and regions where the arithmetic average surface roughness  $S_a$  is less than 1  $\mu\text{m}$  is the second regions.

20 [0091]

In the determination method 3, the arithmetic average surface roughness  $S_a$  is measured using a 3D laser microscope (manufactured by Keyence Corporation). In the present embodiment, in each of the plurality of regions partitioned by the virtual grid lines, the heights  $Z$  in the region are measured using a standard lens of 20 times at  
25 measurement interval of 50  $\mu\text{m}$ . In the case of measuring the heights on a grid, 100

measurement points can be obtained in the region. When the obtained 100 heights Z are indicated as height Z1 to height Z100, Sa is calculated using the following formula. Zave indicates the average of the 100 heights Z.

$$Sa = 1/100 \times \Sigma[x = 1 \rightarrow 100] (\text{height } Zx - Zave)$$

5 [0092]

(First region and second region in determination method 4)

The first region in the determination method 4 is a region where the orientation ratio is 3.5 or higher. A site in the hot-dip plating layer where the first region is larger appears relatively white or nearly white. On the other hand, the second region is a region  
10 where the orientation ratio is lower than 3.5. A site in the hot-dip plating layer where the second region is larger appears relatively metallic glossy to the naked eye. In addition, a site where the first region and the second region disperse and gather and the area ratio of the first region is 30% to 70% has a relatively pear skin-like external appearance.

[0093]

15 Next, a method for measuring the orientation ratio will be described.

First, virtual grid lines are drawn at 1 mm intervals or 10 mm intervals on the surface of the hot-dip plating layer. Next, in each of a plurality of regions partitioned by the virtual grid lines, the diffraction peak intensity  $I_{0002}$  of the (0002) plane of a Zn phase and the diffraction peak intensity  $I_{10-11}$  of the (10-11) plane of the Zn phase are measured  
20 by the X-ray diffraction method in which an X-ray is incident toward the centroid of each region as the center. In addition, the intensity ratio thereof ( $I_{0002}/I_{10-11}$ ) is regarded as the orientation ratio.

[0094]

The intensities of the Zn phase that are measured by the X-ray diffraction  
25 method are the sum of the intensities of a Zn phase that configures the [ternary eutectic

structure of Al/Zn/MgZn<sub>2</sub>], a Zn phase that configures the [Zn phase] and a fine Zn phase that configures the [Al phase]. Among these, phases that dominantly contribute to the orientation ratio are the Zn phase that configures the [ternary eutectic structure of Al/Zn/MgZn<sub>2</sub>] and the Zn phase that configures the [Zn phase].

5 [0095]

In the X-ray diffraction measurement, a Co tube is used as the X-ray light source. As the diffraction peak intensity  $I_{0002}$  of the (0002) plane of the Zn phase, the intensity of the diffraction peak of the (0002) plane of the Zn phase that appears within a range of  $42.41^\circ \pm 0.5^\circ$  in the  $2\theta$  range is used. As the diffraction peak intensity  $I_{10-11}$  of the (10-11) plane of the Zn phase, the intensity of the diffraction peak of the (10-11) plane of the Zn phase that appears within a range of  $50.66^\circ \pm 0.5^\circ$  in the  $2\theta$  range is used. The step is preferably  $0.02^\circ$ , the scanning speed is preferably  $5^\circ/\text{min}$ , and a high-speed semiconductor two-dimensional detector is preferably used as the detector.

[0096]

15 In a case where the intervals between the virtual grid lines are set to 1 mm, X-rays that are emitted from the X-ray light source are preferably focused with a polycapillary. The irradiation range with the focused X-rays is preferably set to be within an elliptical range having a major axis of 1 mm and a minor axis of 0.75 mm. Each region partitioned by the virtual grid lines at 1 mm intervals is irradiated with the X-rays having the irradiation range narrowed as described above, whereby the X-ray diffraction measurement can be carried out on each region. For the X-ray diffraction measurement in this case, an X-ray diffractometer for micro region measurement is preferably used.

20 [0097]

In a case where the intervals between the virtual grid lines are set to 10 mm, X-rays that are emitted from the X-ray light source are preferably focused with a normal

method. The irradiation range with the focused X-rays is preferably set to be within a rectangular range having a height of 10 mm and a width of 10 mm. Each region partitioned by the virtual grid lines at 10 mm intervals is irradiated with the X-rays having the irradiation range narrowed as described above, whereby the X-ray diffraction measurement can be carried out on each region. For the X-ray diffraction measurement in this case, a normal X-ray diffractometer is preferably used.

[0098]

The intervals between the virtual grid lines may be appropriately set depending on the size of the pattern portion and the size of the hot-dip plating layer. In a case where the pattern portion displaying a straight-line portion, a letter or the like is relatively small, when the intervals between the virtual grid lines is set to 10 mm, a region partitioned by the virtual grid lines may be positioned astride both the pattern portion and the non-pattern portion. Therefore, in a case where the minimum width of the pattern portions is less than 10 mm, the intervals between the virtual grid lines are preferably set to 1 mm or less. On the other hand, in a case where the minimum width of the pattern portions exceeds 10 mm, the intervals between the virtual grid lines may be set to 10 mm or may be set to 1 mm.

[0099]

(First region and second region in determination method 5)

The first region in the determination method 5 is a region that is included in a portion where the density of the boundary lines appearing on the surface of the hot-dip plating layer is high. In addition, the second region is a region that is included in a portion where the density of the boundary lines appearing on the surface of the hot-dip plating layer is low. Since the density of the boundary lines differs between a site where the first regions gather and a site where the second regions gather in the hot-dip plating

layer, both sites can be distinguished from each other.

[0100]

Next, a determination method of the first region and the second region will be described with reference to Fig. 1.

5           As shown in Fig. 1, virtual grid lines K are drawn at 1 mm intervals on the surface of the hot-dip plating layer. In Fig. 1, the virtual grid lines are indicated by dash-dotted lines. In Fig. 1, boundary lines appearing on the hot-dip plating layer are not shown. Next, a plurality of regions M partitioned by virtual grid lines K is set. The shape of each region M is a square in which each side is 1 mm. The region set here is  
10 either the first region or the second region. Next, in each of the plurality of regions M partitioned by the virtual grid lines K, the centroid G of each region is set. Next, a circle S having the centroid G at the center is drawn. The diameter R of the circle S is set such that the total length of surface boundary lines in the hot-dip plating layer that is included in the circle S reaches 10 mm.

15   [0101]

Fig. 2(a) and Fig. 2(b) show circles S corresponding to arbitrary regions M. In Fig. 2(a) and Fig. 2(b), boundary lines appearing on the surface of the hot-dip plating layer are shown. The boundary lines shown in Fig. 2(a) and Fig. 2(b) each have a total length of 10 mm. In the present embodiment, the diameter of the circle S is adjusted  
20 such that the total length of the boundary lines L that are included in the circle S reaches 10 mm. Therefore, in a case where a large number of the boundary lines L are present in the region M and the vicinity thereof as shown in Fig. 2(a), the diameter R of the circle S becomes relatively small. On the other hand, in a case where a relatively small number of the boundary lines L are present in the region M and the vicinity thereof as shown in  
25 Fig. 2(b), the diameter R of the circle S becomes relatively large. Circles S are drawn for

all of the regions and the diameters  $R$  of the individual circles  $S$  are determined.

[0102]

In addition, the average value of the maximum diameter  $R_{\max}$  and the minimum diameter  $R_{\min}$  of the diameters  $R$  of the circles  $S$  in the plurality of regions  $M$  is defined as the reference diameter  $R_{\text{ave}}$ , regions having a circle  $S$  with a diameter  $R$  of less than the reference diameter  $R_{\text{ave}}$  are defined as the first regions, and regions having a circle  $S$  with a diameter  $R$  of the reference diameter  $R_{\text{ave}}$  or more are defined as the second regions. The first region is a region that is included in a portion where a large number of the boundary lines  $L$  are present as shown in Fig. 2(a). On the other hand, the second region is a region that is included in a portion where a small number of the boundary lines  $L$  are present as shown in Fig. 2(b).

[0103]

As the boundary lines appearing on the hot-dip plating layer, for example, crystal grain boundaries appearing on the plating surface or boundaries between portions with high luminosity and portions with low luminosity on the plating surface are exemplary examples. As the boundaries between portions with high luminosity and portions with low luminosity, boundary lines that are obtained by binarizing the imaging of the plating surface may be used.

[0104]

(Regarding first region and second region in pattern portion and non-pattern portion in determination methods 1 to 5)

A plurality of the regions partitioned by the virtual grid lines is included in the pattern portion, and each region is classified into any of the first region or the second region. In addition, a plurality of the regions partitioned by the virtual grid lines is also included in the non-pattern portion, and each region is classified into any of the first

region or the second region. That is, the pattern portion may include only any one of the first region and the second region or may include both of the first region and the second region. Similarly, the non-pattern portion may include only any one of the first region and the second region or may include both of the first region and the second region.

5 [0105]

Here, in the pattern portion, it is possible to obtain the area proportion of each of the first region and the second region.

In addition, in the determination methods 1 to 4, in a case where the area fraction of the first region exceeds 70%, the pattern portion appears relatively white or  
10 nearly white. In a case where the area fraction of the first region is 30% or more and 70% or less, the pattern portion appears relatively pear skin-like. In addition, in a case where the surface fraction of the first region is less than 30%, the pattern portion appears relatively metallic glossy or dark.

In addition, in the determination method 5, a relatively large number of  
15 boundary lines are included in the pattern portion. On the other hand, when the area fraction of the second region in the pattern portion is high, a relatively small number of boundary lines are included in the pattern portion.

As described above, the external appearance of the pattern portion depends on the area fraction of the first region.

20 [0106]

On the other hand, in the non-pattern portion as well, it is possible to obtain the area proportion of each of the first region and the second region. Similar to the pattern portion, the external appearance of the non-pattern portion depends on the area fraction of the first region.

25 [0107]

In addition, in a case where the absolute value of the difference between the area proportion of the first region in the pattern portion and the area proportion of the first region in the non-pattern portion is 30% or more, the pattern portion and the non-pattern portion become distinguishable. When the difference in the area proportion is less than 5 30%, the difference between the area proportion of the first region in the pattern portion and the area proportion of the first region in the non-pattern portion is small, the external appearances of the pattern portion and the non-pattern portion become similar to each other, and it becomes difficult to distinguish the pattern portion. The difference in the area proportion is preferably as large as possible, more preferably 40% or more, and still 10 more preferably 60% or more.

[0108]

The pattern portion and the non-pattern portion may be distinguishable with the naked eye or may be distinguishable under a magnifying glass or under a microscope. Being distinguishable under a magnifying glass or under a microscope means that, for 15 example, a shape composed of the pattern portion needs to be distinguishable in a visual field of 50 times or less. In the visual field of 50 times or less, the pattern portion and the non-pattern portion can be distinguished due to the relative difference in the external appearance. The pattern portion and the non-pattern portion can be distinguished at a magnification of preferably 20 times or less, more preferably 10 times or less and still 20 more preferably 5 times or less.

[0109]

(Chemical conversion layer and coating film layer)

The hot-dip plated steel sheet according to the present embodiment may have a chemical conversion film layer or a coating film layer on the surface of the hot-dip 25 plating layer. Here, the type of the chemical conversion film layer or coating film layer

is not particularly limited, and a well-known chemical conversion film layer or coating film layer can be used.

[0110]

(Manufacturing method of hot-dip plated steel sheet)

5           Next, a manufacturing method of the hot-dip plated steel sheet of the present embodiment will be described.

[0111]

For the hot-dip plated steel sheet of the present embodiment, hot-dip plating is carried out on a steel sheet manufactured through steelmaking, casting, and hot rolling.

10       At the time of manufacturing the steel sheet, pickling, hot-rolled sheet annealing, cold rolling, and cold-rolled sheet annealing may be further carried out. Hot-dip plating may be a continuous hot-dip plating method in which the steel sheet is continuously threaded through a hot-dip plating bath or may be a hot-dip galvanizing method in which steel obtained by working the steel sheet into a predetermined shape or the steel sheet itself is  
15       immersed in a hot-dip plating bath and then lifted.

[0112]

The hot-dip plating bath preferably contains 0 to 90 mass% of Al and 0 to 10 mass% of Mg with the remainder including Zn and impurities. In addition, the hot-dip plating bath may contain 4 to 22 mass% of Al and 1 to 10 mass% of Mg with the  
20       remainder including Zn and impurities. Furthermore, the hot-dip plating bath may contain 0.0001 to 2 mass% of Si. Still furthermore, the hot-dip plating bath may contain one or more of the group consisting of Ni, Ti, Zr, Sr, Fe, Sb, Pb, Sn, Ca, Co, Mn, P, B, Bi, Cr, Sc, Y, REM, Hf and C in a total of 0.0001 to 2 mass%. The average composition of the hot-dip plating layer of the present embodiment is almost the same as the  
25       composition of the hot-dip plating bath.

[0113]

The temperature of the hot-dip plating bath differs depending on the composition, but is preferably, for example, within a range of 400°C to 500°C. This is because, when the temperature of the hot-dip plating bath is within this range, a desired hot-dip plating layer can be formed.

[0114]

In addition, the amount of the hot-dip plating layer attached needs to be adjusted with a method such as gas wiping carried out on the steel sheet lifted from the hot-dip plating bath. The total amount of the hot-dip plating layer attached to both surfaces of the steel sheet is preferably adjusted so as to be within a range of 30 to 600 g/m<sup>2</sup>. In a case where the amount attached is less than 30 g/m<sup>2</sup>, the corrosion resistance of the hot-dip plated steel sheet deteriorates, which is not preferable. In a case where the amount attached is more than 600 g/m<sup>2</sup>, the molten metal attached to the steel sheet sags, which makes it impossible to smoothen the surface of the hot-dip plating layer, which is not preferable.

[0115]

After the amount of the hot-dip plating layer attached is adjusted, the steel sheet is cooled. In the case of the hot-dip plated steel sheet in which the first region and the second region are determined by the determination methods 1 to 3, there is no need to particularly limit the cooling conditions. On the other hand, in the case of the hot-dip plated steel sheet in which the first region and the second region are determined by the determination method 4 or 5, there is a need to limit the cooling conditions. Hereinafter, the cases of the determination methods 1 to 5 will be described separately.

[0116]

(Manufacturing method of hot-dip plated steel sheet in which first region and second

region are determined by determination methods 1 and 2)

In the case of the determination methods 1 and 2, as described above, after the amount of the hot-dip plating layer attached is adjusted, the steel sheet is cooled. There is no need to particularly limit the cooling conditions.

5 [0117]

After the formation of the hot-dip plating layer, the pattern portion and the non-pattern portion are formed. The pattern portion and the non-pattern portion are formed by attaching an acidic solution to the surface of the hot-dip plating layer of the hot-dip plated steel sheet (60°C to 200°C). More specifically, it is preferable to prepare an acidic  
10 solution and attach the acidic solution to the surface of the hot-dip plating layer by a printing method. As the printing method, it is possible to apply a normal printing method such as a printing method in which a variety of sheets are used (gravure printing, flexographic printing, offset printing, silk printing or the like) or an inkjet method.

[0118]

15 As an example of the printing method in which a sheet is used, the acidic solution can be attached by attaching the acidic solution to a rubber roll or rubber stamp having a printing pattern formed on the circumferential surface and pressing the rubber roll or the rubber stamp against the surface of the hot-dip plating layer to transfer the acidic solution. According to this method, it is possible to efficiently attach the acidic  
20 solution to the steel sheet that is continuously threaded.

[0119]

At a site to which the acidic solution has been attached, the top surface of the hot-dip plating layer dissolves (that is, the outermost layer in the upper portion of the hot-dip plating layer dissolves extremely thinly), and the surface of the hot-dip plating layer  
25 changes from the plated state. Therefore, the external appearance of the site to which the

acidic solution has been attached changes compared with sites to which the acidic solution is not attached. It is presumed that this makes the difference between the area ratio of the first region in the pattern portion and the area ratio of the first region in the non-pattern portion large and makes the pattern portion and the non-pattern portion distinguishable. In the present method, while the reason is not clear, unlike grinding, there is no influence on the corrosion resistance. As the reason, an extremely small decrease in the thickness of the hot-dip plating layer or a change in the structure of the plating layer resulting from the attachment of the acid is conceivable.

[0120]

10           The attachment range of the acidic solution may be a region corresponding to the pattern portion or may be a region corresponding to the non-pattern portion.

[0121]

              As the acidic solution, an inorganic acid such as hydrochloric acid, nitric acid or sulfuric acid is preferably used. In addition, the concentration of the acid in the acidic solution is desirably 0.1 to 10 mass%. The temperature of the steel sheet at the time of attaching the acidic solution is 60°C to 200°C and desirably 50°C to 80°C. The adjustment of the type or concentration of the acidic solution makes it possible to adjust the area fractions of the first region and the second region on the surface of the hot-dip plating layer in the site to which the acidic solution has been attached.

20   [0122]

              When the surface temperature of the hot-dip plating layer at the time of attaching the acidic solution is lower than 60°C, a long time is required to form the pattern portion or the non-pattern portion, which is not preferable. When the surface temperature of the hot-dip plating layer exceeds 200°C, the acidic solution volatilizes immediately, and it becomes impossible to form the pattern portion and the non-pattern

portion, which is not preferable.

[0123]

After the attachment of the acidic solution, there is a need to wash the surface of the hot-dip plating layer with water within 1 to 10 seconds.

5 [0124]

(Manufacturing method of hot-dip plated steel sheet in which first region and second region are determined by determination method 3)

In the case of the determination method 3, as described above, after the amount of the hot-dip plating layer attached is adjusted, the steel sheet is cooled. There is no  
10 need to particularly limit the cooling conditions.

[0125]

After the formation of the hot-dip plating layer, the pattern portion and the non-pattern portion are formed. The pattern portion and the non-pattern portion are formed by pressing a roll having a partially increased surface roughness against the surface of the  
15 hot-dip plating layer and transferring the surface shape of the roll to the hot-dip plating layer. For example, when the roughness of a site on the surface of the roll corresponding to the pattern portion is increased compared with that of other sites in order to form the pattern portion on the surface of the hot-dip plating layer, it is possible to form the pattern portion where the first region having large surface roughness is larger. In  
20 addition, conversely, a roll that decreases the roughness of a site corresponding to the pattern portion compared with that of other sites may also be used. Regarding the roughness (arithmetic average roughness,  $S_a$  ( $\mu\text{m}$ )) of the roll surface, the range of the roughness at a site where the roughness is increased is set to 0.6 to 3.0  $\mu\text{m}$  and preferably set to 1.2 to 3.0  $\mu\text{m}$ . The range of roughness at a site where the roughness is decreased is  
25 set to 0.05 to 1.0  $\mu\text{m}$  and preferably set to 0.05 to 0.8  $\mu\text{m}$ . The surface shape of the roll is

preferably transferred when the surface temperature of the hot-dip plating layer is within a range of 100°C to 300°C. In addition, the difference between the roughness at the site where the roughness is increased and the roughness at the site where the roughness is decreased is set to more than 0.2 μm and preferably set to 0.3 μm or more in terms of the arithmetic average surface roughness Sa. When the difference in roughness becomes small, it becomes difficult to discriminate the pattern portion and the non-pattern portion.

[0126]

When the surface temperature of the hot-dip plating layer during roll transfer is lower than 100°C, the hot-dip plating layer does not soften and it becomes difficult to form a clear pattern portion, which is not preferable. In addition, when the surface temperature of the hot-dip plating layer exceeds 300°C, the roll is transferred in a state where the hot-dip plating layer is significantly softened, and there is a concern that it may not be possible to clearly distinguish the pattern portion and the non-pattern portion, which is not preferable.

[0127]

(Manufacturing method of hot-dip plated steel sheet in which first region and second region are determined by determination method 4)

In the case of the determination method 4, a non-oxidizing gas is locally sprayed with a gas nozzle to metal in a molten state in a steel sheet or steel immediately after lifting the steel sheet or steel from a hot-dip plating bath and adjusting the amount attached after. As the non-oxidizing gas, nitrogen or argon is preferably used.

[0128]

In addition, while the optimum temperature range differs with the composition, the non-oxidizing gas is preferably sprayed when the temperature of the molten metal is within a range of (final solidification temperature - 5)°C to (final solidification

temperature + 5)°C. Furthermore, the temperature of the non-oxidizing gas is set to lower than the final solidification temperature.

[0129]

In a site to which the non-oxidizing gas is sprayed when the hot-dip plating layer is within the above-described temperature range, the cooling rate of the molten metal increases, which increases the orientation ratio of the hot-dip plating layer after solidification. On the other hand, in a site to which the non-oxidizing gas is not sprayed, the cooling rate of the molten metal decreases, which decreases the orientation ratio of the hot-dip plating layer after solidification. Therefore, the adjustment of the spraying range of the non-oxidizing gas makes it possible to intentionally or arbitrarily adjust sites where a region with a high orientation ratio and a region with a low orientation ratio each appear.

Therefore, it is possible to arbitrarily adjust the shapes of the pattern portion and the non-pattern portion, and the pattern portion and the non-pattern portion becomes distinguishable. Since the orientation ratio increases as the temperature of the gas to be sprayed decreases, the orientation ratio can be adjusted with the temperature of the gas to be sprayed. The gas temperature is preferably set to lower than the final solidification temperature and may be adjusted to, for example, 25°C to 250°C.

[0130]

(Manufacturing method of hot-dip plated steel sheet in which first region and second region are determined by determination method 5)

In the case of the determination method 5, a non-oxidizing gas at the final solidification temperature of plating or higher is locally sprayed with a gas nozzle to metal in a molten state in a steel sheet or steel immediately after lifting the steel sheet or steel from a hot-dip plating bath and adjusting the amount attached. As the non-

oxidizing gas, nitrogen or argon is preferably used.

[0131]

In addition, while the optimum temperature range differs with the composition, the non-oxidizing gas is preferably sprayed when the temperature of the molten metal is within a range of (final solidification temperature - 5)°C to (final solidification temperature + 5)°C.

[0132]

Furthermore, the temperature of the non-oxidizing gas is preferably set to the final solidification temperature or higher. For example, in a plating composition of 11% of Al and 3% of Mg, it is preferable to spray a non-oxidizing gas having a gas temperature of the final solidification temperature or higher when the temperature of the molten metal is 330°C to 340°C.

In the periphery to which the non-oxidizing gas has been sprayed, the cooling rate of the molten metal decreases, which makes boundaries or crystal grain boundaries appearing on the surface coarse. Therefore, the adjustment of the spraying amount and range of the non-oxidizing gas makes it possible to arbitrarily adjust the sizes of the boundaries or crystal grain boundaries appearing on the surface.

Therefore, it is possible to arbitrarily adjust the shapes of the pattern portion and the non-pattern portion, and the pattern portion and the non-pattern portion becomes distinguishable to the naked eye, under a magnifying glass or under a microscope.

[0133]

The pattern portion or the non-pattern portion may be formed by combining the above-described manufacturing methods. When the manufacturing method is different, the surface external appearance of the hot-dip plating layer is different, and, in the determination methods 1 to 4, a site where the first region is larger appears relatively

white or nearly white, and the second region appears relatively metallic glossy to the naked eye. Therefore, for example, even when “the manufacturing method of the hot-dip plated steel sheet in which the first region and the second region are determined by the determination methods 1 and 2” is used for the pattern portion and “the manufacturing method of the hot-dip plated steel sheet in which the first region and the second region are determined by the determination method 3” is used for the non-pattern portion, as long as the absolute value of the difference in the area ratio specified as the first region between the pattern portion and the non-pattern portion is 30% or more, the pattern portion and the non-pattern portion can be discriminated.

10 [0134]

(Chemical conversion layer and coating film layer)

In a case where a chemical conversion layer is formed on the surface of the hot-dip plating layer, a chemical conversion treatment is carried out on the hot-dip plated steel sheet in which the hot-dip plating layer has been formed. The type of the chemical conversion treatment is not particularly limited, and a well-known chemical conversion treatment can be used.

[0135]

In addition, in a case where a coating film layer is formed on the surface of the hot-dip plating layer or on the surface of the chemical conversion layer, a painting treatment is carried out on the hot-dip plated steel sheet in which the hot-dip plating layer has been formed or the chemical conversion layer has been formed. The type of the painting treatment is not particularly limited, and a well-known painting treatment can be used.

[0136]

25 As described above, in the hot-dip plated steel sheet of the present embodiment,

in the first region and the second region, the absolute value of the difference between the area ratio of the first region in the pattern portion and the area ratio of the first region in the non-pattern portion is set to 30% or more, which makes the pattern portion and the non-pattern portion distinguishable. The formed pattern portion and non-pattern portion are not formed by printing or painting and thus have high durability. In addition, the pattern portion and the non-pattern portion are not formed by printing or painting and thus have no influence on the corrosion resistance of the hot-dip plating layer.

Furthermore, the pattern portion and the non-pattern portion are not formed by the grinding or the like of the surface of the hot-dip plating layer. Therefore, the thickness of the hot-dip plating layer in the pattern portion does not decrease to a thickness of the plating layer at which the corrosion resistance deteriorates compared with the thickness of the hot-dip plating layer in the non-pattern portion. Therefore, the hot-dip plated steel sheet of the present embodiment has excellent corrosion resistance.

[0137]

According to the present embodiment, it is possible to provide a hot-dip plated steel sheet having high durability in the pattern portion formed in a predetermined shape and having favorable plating characteristics such as corrosion resistance.

[0138]

Particularly, in the case of a hot-dip plated steel sheet in which the first region and the second region are determined by the determination methods 1 and 2, the acidic solution is attached to the surface of the hot-dip plating layer so as to form an arbitrary pattern, whereby it is possible to form the range of the pattern portion or the non-pattern portion in an intentional or artificial shape and to dispose the pattern portion so as to form a shape of any one of a straight-line portion, a curved line portion, a dot portion, a figure, a number, a symbol, a mark or a letter or a shape consisting of a combination of

two or more thereof.

[0139]

In addition, in the case of a hot-dip plated steel sheet in which the first region and the second region are determined by the determination method 3, a roll having a partially different roughness is pressed against the surface of the hot-dip plating layer to transfer the surface shape of the roll to the hot-dip plating layer, whereby it is possible to form the range of the pattern portion or the non-pattern portion in an intentional or artificial shape and to dispose the pattern portion so as to form a shape of any one of a straight-line portion, a curved line portion, a dot portion, a figure, a number, a symbol, a mark or a letter or a shape consisting of a combination of two or more thereof.

[0140]

In addition, in the case of a hot-dip plated steel sheet in which the first region and the second region are determined by the determination method 4, a non-oxidizing gas is locally sprayed with a gas nozzle to the surface of the hot-dip plating layer when the temperature of molten metal after lifted from a plating bath is within a range of (final solidification temperature - 5)°C to (final solidification temperature + 5)°C, thereby increasing the orientation ratio of the solidified hot-dip plating layer, which makes it possible to form the range of the pattern portion or the non-pattern portion in an intentional or artificial shape and to dispose the pattern portion so as to form a shape of any one of a straight-line portion, a curved line portion, a dot portion, a figure, a number, a symbol, a mark or a letter or a shape consisting of a combination of two or more thereof.

[0141]

Furthermore, in the case of a hot-dip plated steel sheet in which the first region and the second region are determined by the determination method 5, a non-oxidizing gas

is locally sprayed with a gas nozzle to the surface of the hot-dip plating layer when the temperature of molten metal after lifted from a plating bath is within a range of (final solidification temperature - 5)°C to (final solidification temperature + 5)°C, thereby arbitrarily adjusting the sizes of boundaries or crystal grain boundaries appearing on the surface of the hot-dip plating layer after solidification, which makes it possible to form the range of the pattern portion or the non-pattern portion in an intentional or artificial shape and to dispose the pattern portion so as to form a shape of any one of a straight-line portion, a curved line portion, a dot portion, a figure, a number, a symbol, a mark or a letter or a shape consisting of a combination of two or more thereof.

10 [0142]

In addition, in the hot-dip plated steel sheet of the present embodiment, it is possible to display a variety of design, trademarks and other identification marks on the surface of the hot-dip plating layer without carrying out printing or painting and to enhance the distinguishability, design properties or the like of the origin of the steel sheet. In addition, it is also possible to impart information necessary for process control, inventory control or the like or any information required by consumers to the hot-dip plated steel sheet with the pattern portion. This also makes it possible to contribute to improvement in the productivity of the hot-dip plated steel sheet.

[Examples]

20 [0143]

Next, examples of the present invention will be described.

[0144]

(Example 1)

Steel sheets were degreased and washed with water, and then reduction annealing, immersion in a plating bath, control of the amount attached and cooling were

carried out, thereby manufacturing hot-dip plated steel sheets No. 1-1 to No. 1-32 shown in Table 2. Next, acidic solutions containing a component shown in Table 1 were attached to rubber sheets having a protrusion or recessed part in a 50 mm x 50 mm square pattern, and these rubber sheets were pressed against the surfaces of hot-dip plating layers to attach the acidic solutions to the steel sheets, thereby forming square pattern portions. The surface temperatures of the hot-dip plating layers of the hot-dip plated steel sheets at the time of attaching the acidic solutions were set to be within a range of 60°C to 200°C. In addition, sites other than the square pattern portions were regarded as non-pattern portions. However, in No. 1-30, the acidic solution was attached when the surface temperature of the hot-dip plating layer was higher than 200°C.

[0145]

In addition, a Zn-Al-Mg-based hot-dip plated steel sheet was manufactured in the same manner as described above. After that, a 50 mm x 50 mm square pattern was printed on the surface of a hot-dip plating layer by an inkjet method. This result is shown in Table 2 as No. 1-33.

[0146]

In addition, a Zn-Al-Mg-based hot-dip plated steel sheet was manufactured in the same manner as described above. After that, a 50 mm x 50 mm square pattern was produced on the surface of a hot-dip plating layer with a pre-inked stamp. This result is shown in Table 2 as No. 1-34.

[0147]

For the obtained hot-dip plated steel sheets, the area ratios of first regions and second regions that were included in the pattern portions and the non-pattern portions were obtained. First, the boundaries between the pattern portion and the non-pattern portion were specified by observing the surfaces of the hot-dip plating layers with the

naked eye. In a case it was difficult to specify the boundary with the naked eye, an enlarged image captured with a magnifying glass or an optical microscope was used. In examples where the discrimination of the boundary was difficult, the pattern portion and the non-pattern portion were determined based on the attachment range of the acidic solution, and the area ratios of the first region and the second region were evaluated.

[0148]

Next, the area ratios of the first regions that were included in the pattern portion and the non-pattern portion were obtained by the determination method 1 for the hot-dip plated steel sheets except No. 1-7. That is, virtual grid lines were drawn at 0.5 mm intervals on the surface of the hot-dip plating layer, in each of a plurality of regions partitioned by the virtual grid lines, a circle having the centroid of each region at the center and having a diameter of 0.5 mm was defined as a measurement region A, and the  $L^*$  value in each measurement region A was measured. In addition, 50 arbitrary points were selected from the obtained  $L^*$  values, and the 50-point average was defined as the reference  $L^*$  value.

[0149]

Specifically, the 50 arbitrary measurement points for measuring the reference  $L^*$  value were selected as described below. First, out of the plurality of regions partitioned by the virtual grid lines, one region was selected. Next, a total of 50 regions in 10 vertical regions and five horizontal regions (50 mm x 25 mm) that included the above-selected region as the starting point and were arranged at intervals of 10 regions were selected. A total of these 50 regions was regarded as the 50 arbitrary measurement points for measuring the reference  $L^*$  value.

[0150]

In addition, among the regions including the measurement region A, regions

where the  $L^*$  value was the reference  $L^*$  value or more were discriminated as the first regions, and regions where the  $L^*$  value was less than the reference  $L^*$  value were discriminated as the second regions.

[0151]

5           In addition, the area ratios of the first regions in the pattern portion and the non-pattern portion were each obtained. In addition, the difference between the area ratio of the first region in the pattern portion and the area ratio of the second region in the non-pattern portion were obtained.

[0152]

10           In the hot-dip plated steel sheet No. 1-7, the area ratios of the first regions that were included in the pattern portion and the non-pattern portion were obtained by the determination method 2, and the difference in the area ratio of the first region between the pattern portion and the non-pattern portion was obtained from the results.

[0153]

15           The  $L^*$  value was measured by irradiating the surface of the hot-dip plating layer with light that was radiated from a halogen lamp (12 V, 20 W) as a light source at an angle of  $45^\circ$  with respect to the vertical direction ( $90^\circ$  direction) to the surface of the hot-dip plating layer and receiving the reflected light that was reflected in the vertical direction ( $90^\circ$  direction) to the surface of the hot-dip plating layer with a light receiver.

20           As the  $L^*$  value measuring instrument, a micro spectrophotometer (VSS 7700 manufactured by Nippon Denshoku Industries Co., Ltd.) was used, the measurement wavelength range was set to 380 nm to 780 nm, and the intensities within this wavelength range were measured at 5 nm intervals and converted into  $L^*$  values.

[0154]

25           [Distinguishability]

On test sheets provided with the square pattern portion in an initial state where the test sheet was just manufactured and in an aged state where the test sheet had been exposed outdoors for six months, visual evaluation was carried out based on the following determination criteria. A to C were regarded as a pass for both the initial state and the aged state.

[0155]

A: The pattern portion is visible at a distance of 5 meters.

B: The pattern portion is not visible at a distance of 5 meters, but is highly visible at a distance of 3 meters.

10 B: The pattern portion is not visible at a distance of 3 meters, but is highly visible at a distance of 1 meter.

D: The pattern portion is not visible at a distance of 1 meter.

[0156]

[Corrosion resistance]

15 The test sheet was cut to 150 × 70 mm, 30 cycles of a copper corrosion test CCT according to JASO-M609 was carried out, and then a rust generation status was investigated and evaluated based on the following determination criteria. A to C were regarded as pass.

[0157]

20 A: No rust is generated, and both the pattern portion and the non-pattern portion maintain a beautiful design external appearance.

B: No rust is generated, but an extremely slight change in the design external appearance change is admitted in both the pattern portion and the non-pattern portion.

C: The design external appearance is slightly impaired, but the pattern portion and the non-pattern portion can be visually differentiated.

D: Both the pattern portion and the non-pattern portion significantly deteriorate in the external appearance quality and cannot be visually differentiated.

[0158]

As shown in Table 2, the hot-dip plated steel sheets of Present Invention  
5 Examples No. 1-1 to No. 1-29 were excellent in terms of both the distinguishability and the corrosion resistance. Fig. 3 shows the observation result of the first region that mainly configured the pattern portion in No. 1-1 with a scanning electron microscope, and Fig. 4 shows the observation result of the second region that configured the non-pattern portion in No. 1-1 with the scanning electron microscope. It is found that a  
10 relatively metallic glossy region is large in the pattern portion compared with the non-pattern portion and the pattern portion and the non-pattern portion are distinguishable.

[0159]

In No. 1-30, since the temperature of the hot-dip plating layer at the time of attaching the acidic solution was too high, the difference between the area ratio of the  
15 first region in the pattern portion and the area ratio of the first region in the non-pattern portion was less than 30%, and the distinguishability of the pattern portion deteriorated.

In addition, in No. 1-31 and No. 1-32, the compositions of the hot-dip plating layers were outside the scope of the present invention, and the distinguishability after six months of outdoor exposure deteriorated.

20 [0160]

In No. 1-33 where the square pattern portion was printed by the inkjet method, the pattern portion was thinned by six-month outdoor exposure, and the distinguishability deteriorated. In addition, in No. 1-34 where the square pattern portion was produced with a pre-inked stamp, the corrosion resistance significantly deteriorated, and it was  
25 difficult to visually differentiate the pattern portion and the non-pattern portion.

The hot-dip plating layers in No. 1-1 to No. 1-6, No. 1-10 to No. 1-30 and No. 1-32 to No. 1-34 included the [Al phase] and the [ternary eutectic structure of Al/Zn/MgZn<sub>2</sub>].

[0161]

5            Fig. 5 shows the surface of a hot-dip plated steel sheet displaying a letter string (alphabet) with a pattern portion by attaching an acidic solution to a Zn-Al-Mg-based hot-dip plating layer.

According to the present invention, it becomes possible to intentionally display a pattern portion composed of a letter, a mark or the like on the surface of a hot-dip plated steel sheet.

[0162]

[Table 1]

| Sign | Acidic solution   | Concentration of acid<br>(mass)% |
|------|-------------------|----------------------------------|
| A    | Hydrochloric acid | 10                               |
| B    | Nitric acid       | 1                                |
| C    | Sulfuric acid     | 1                                |

[0163]

[Table 2]

| Manufacturing method |                               |                 | Hot-dip plating layer                                       |     |      |           |                                                                                 |                            |                             |                            |                             |                                        | Evaluation            |                    |               | Note |                         |
|----------------------|-------------------------------|-----------------|-------------------------------------------------------------|-----|------|-----------|---------------------------------------------------------------------------------|----------------------------|-----------------------------|----------------------------|-----------------------------|----------------------------------------|-----------------------|--------------------|---------------|------|-------------------------|
| No.                  | Production method             | Acidic solution | Average composition (mass%)<br>remainder: Zn and impurities |     |      |           | Amount of<br>plating<br>attached per<br>both<br>surfaces<br>(g/m <sup>2</sup> ) | Pattern portion            |                             | Non-pattern portion        |                             | Difference in<br>area ratio<br>(area%) | Reference<br>L* value | Distinguishability |               |      | Corrosion<br>resistance |
|                      |                               |                 | Al                                                          | Mg  | Si   | Other     |                                                                                 | First<br>region<br>(area%) | Second<br>region<br>(area%) | First<br>region<br>(area%) | Second<br>region<br>(area%) |                                        |                       | Initial<br>state   | Aged<br>state |      |                         |
| 1-1                  | Attachment of acidic solution | A               | 11                                                          | 3   | 0.2  | Ti: 0.005 | 100                                                                             | 85                         | 15                          | 40                         | 60                          | 45                                     | 55                    | A                  | A             | A    | Invention Example       |
| 1-2                  | Attachment of acidic solution | A               | 11                                                          | 3   | 0.2  | Ni: 0.01  | 180                                                                             | 10                         | 90                          | 60                         | 40                          | 50                                     | 50                    | A                  | A             | A    | Invention Example       |
| 1-3                  | Attachment of acidic solution | B               | 11                                                          | 3   | 0.2  | Ti: 0.005 | 80                                                                              | 50                         | 50                          | 10                         | 90                          | 40                                     | 40                    | A                  | A             | A    | Invention Example       |
| 1-4                  | Attachment of acidic solution | A               | 11                                                          | 3   | 0.2  | Ti: 0.005 | 80                                                                              | 100                        | 0                           | 10                         | 90                          | 90                                     | 45                    | A                  | A             | A    | Invention Example       |
| 1-5                  | Attachment of acidic solution | C               | 11                                                          | 3   | 0.2  | Ti: 0.005 | 100                                                                             | 0                          | 100                         | 80                         | 20                          | 80                                     | 30                    | A                  | A             | A    | Invention Example       |
| 1-6                  | Attachment of acidic solution | B               | 11                                                          | 3   | 0.2  | Ti: 0.005 | 100                                                                             | 40                         | 60                          | 80                         | 20                          | 40                                     | 40                    | A                  | A             | A    | Invention Example       |
| 1-7                  | Attachment of acidic solution | A               | 0.2                                                         | -   | -    | -         | 90                                                                              | 10                         | 90                          | 50                         | 50                          | 40                                     | (45)                  | B                  | C             | B    | Invention Example       |
| 1-8                  | Attachment of acidic solution | A               | 3.5                                                         | 1   | -    | -         | 100                                                                             | 70                         | 30                          | 20                         | 80                          | 50                                     | 70                    | B                  | B             | B    | Invention Example       |
| 1-9                  | Attachment of acidic solution | A               | 4                                                           | 3   | -    | -         | 100                                                                             | 40                         | 60                          | 80                         | 20                          | 40                                     | 60                    | A                  | B             | B    | Invention Example       |
| 1-10                 | Attachment of acidic solution | A               | 22                                                          | 1   | -    | -         | 100                                                                             | 80                         | 20                          | 40                         | 60                          | 40                                     | 30                    | A                  | B             | B    | Invention Example       |
| 1-11                 | Attachment of acidic solution | B               | 23                                                          | 1   | -    | -         | 90                                                                              | 60                         | 40                          | 100                        | 0                           | 40                                     | 55                    | B                  | B             | B    | Invention Example       |
| 1-12                 | Attachment of acidic solution | A               | 20                                                          | 10  | -    | -         | 80                                                                              | 80                         | 20                          | 20                         | 80                          | 60                                     | 75                    | A                  | B             | B    | Invention Example       |
| 1-13                 | Attachment of acidic solution | A               | 11                                                          | 3   | 0.01 | -         | 130                                                                             | 90                         | 10                          | 30                         | 70                          | 60                                     | 65                    | A                  | B             | A    | Invention Example       |
| 1-14                 | Attachment of acidic solution | A               | 11                                                          | 3   | 2    | -         | 120                                                                             | 80                         | 20                          | 30                         | 70                          | 50                                     | 70                    | A                  | B             | A    | Invention Example       |
| 1-15                 | Attachment of acidic solution | A               | 5                                                           | 0.5 | -    | Ni: 0.1   | 80                                                                              | 70                         | 30                          | 30                         | 70                          | 40                                     | 35                    | A                  | B             | B    | Invention Example       |
| 1-16                 | Attachment of acidic solution | C               | 11                                                          | 3   | 0.2  | Zr: 0.02  | 40                                                                              | 60                         | 40                          | 100                        | 0                           | 40                                     | 40                    | A                  | A             | A    | Invention Example       |
| 1-17                 | Attachment of acidic solution | A               | 11                                                          | 3   | 0.2  | Sr: 0.02  | 90                                                                              | 50                         | 50                          | 90                         | 10                          | 40                                     | 40                    | A                  | A             | A    | Invention Example       |
| 1-18                 | Attachment of acidic solution | A               | 11                                                          | 3   | 0.2  | Sb: 0.1   | 100                                                                             | 20                         | 80                          | 60                         | 40                          | 40                                     | 65                    | A                  | A             | A    | Invention Example       |
| 1-19                 | Attachment of acidic solution | A               | 11                                                          | 3   | 0.2  | Pb: 0.1   | 110                                                                             | 70                         | 30                          | 20                         | 80                          | 50                                     | 55                    | A                  | A             | A    | Invention Example       |
| 1-20                 | Attachment of acidic solution | B               | 11                                                          | 3   | 0.2  | Sn: 0.2   | 80                                                                              | 20                         | 80                          | 70                         | 30                          | 50                                     | 60                    | A                  | A             | A    | Invention Example       |
| 1-21                 | Attachment of acidic solution | A               | 11                                                          | 3   | 0.2  | Ca: 0.01  | 100                                                                             | 30                         | 70                          | 70                         | 30                          | 40                                     | 25                    | A                  | A             | A    | Invention Example       |
| 1-22                 | Attachment of acidic solution | B               | 11                                                          | 3   | 0.2  | Co: 0.05  | 90                                                                              | 10                         | 90                          | 90                         | 10                          | 80                                     | 45                    | A                  | A             | A    | Invention Example       |
| 1-23                 | Attachment of acidic solution | A               | 11                                                          | 3   | 0.2  | Mn: 0.01  | 150                                                                             | 50                         | 50                          | 90                         | 10                          | 40                                     | 30                    | A                  | A             | A    | Invention Example       |
| 1-24                 | Attachment of acidic solution | A               | 11                                                          | 3   | 0.2  | Pb: 0.01  | 60                                                                              | 60                         | 40                          | 30                         | 70                          | 30                                     | 35                    | C                  | C             | A    | Invention Example       |
| 1-25                 | Attachment of acidic solution | A               | 11                                                          | 3   | 0.2  | Bi: 0.01  | 80                                                                              | 30                         | 70                          | 70                         | 30                          | 40                                     | 55                    | A                  | A             | A    | Invention Example       |
| 1-26                 | Attachment of acidic solution | A               | 11                                                          | 3   | 0.2  | Bi: 0.01  | 100                                                                             | 20                         | 80                          | 90                         | 10                          | 70                                     | 40                    | A                  | A             | A    | Invention Example       |
| 1-27                 | Attachment of acidic solution | A               | 11                                                          | 3   | 0.2  | Cr: 0.1   | 110                                                                             | 90                         | 10                          | 0                          | 100                         | 90                                     | 30                    | A                  | A             | A    | Invention Example       |
| 1-28                 | Attachment of acidic solution | A               | 11                                                          | 3   | 0.2  | Se: 0.1   | 90                                                                              | 40                         | 60                          | 80                         | 20                          | 40                                     | 30                    | A                  | A             | A    | Invention Example       |
| 1-29                 | Attachment of acidic solution | A               | 11                                                          | 3   | 0.2  | C: 0.1    | 230                                                                             | 30                         | 70                          | 80                         | 20                          | 50                                     | 25                    | A                  | A             | A    | Invention Example       |
| 1-30                 | Attachment of acidic solution | A               | 11                                                          | 3   | 0.2  | Ti: 0.005 | 160                                                                             | 40                         | 60                          | 65                         | 35                          | 25                                     | 30                    | D                  | D             | B    | Comparative Example     |
| 1-31                 | Attachment of acidic solution | A               | 95                                                          | 0   | 0.2  | Ti: 0.005 | 80                                                                              | 20                         | 80                          | 90                         | 10                          | 70                                     | 70                    | B                  | D             | B    | Comparative Example     |
| 1-32                 | Attachment of acidic solution | A               | 11                                                          | 11  | 0.2  | Ti: 0.005 | 70                                                                              | 80                         | 20                          | 20                         | 80                          | 60                                     | 30                    | B                  | D             | B    | Comparative Example     |
| 1-33                 | Printing after plating        | -               | 11                                                          | 3   | 0.2  | Ti: 0.005 | 120                                                                             | -                          | -                           | -                          | -                           | -                                      | -                     | A                  | D             | B    | Comparative Example     |
| 1-34                 | Stamping after plating        | -               | 11                                                          | 3   | 0.2  | Ti: 0.005 | 110                                                                             | -                          | -                           | -                          | -                           | -                                      | -                     | A                  | C             | D    | Comparative Example     |

\* The reference L\* value in No. 1-7 was obtained by the determination method 2.

[0164]

(Example 2)

Steel sheets were degreased and washed with water, and then reduction annealing, immersion in a plating bath, control of the amount attached and cooling were carried out, thereby manufacturing hot-dip plated steel sheets No. 2-1 to No. 2-32 shown in Table 4 and Table 5. Next, rolls having a 50 mm x 50 mm square pattern were pressed against the surfaces of hot-dip plating layers in a state where the surface temperatures of the hot-dip plating layers were set to 100°C to 300°C, thereby forming pattern portions. The roughness of the square patterns and the roughness (arithmetic average surface roughness, Sa (μm)) of the roll surfaces excluding the square patterns are as shown in Table 3. Sites of the square patterns were regarded as pattern portions, and sites other than the square patterns were regarded as non-pattern portions.

[0165]

In addition, a Zn-Al-Mg-based hot-dip plated steel sheet was manufactured in the same manner as described above. After that, a 50 mm x 50 mm square pattern was printed on the surface of a hot-dip plating layer by an inkjet method. This result is shown in Table 4 and Table 5 as No. 2-33.

[0166]

Furthermore, a Zn-Al-Mg-based hot-dip plated steel sheet was manufactured in the same manner as described above. After that, a 50 mm x 50 mm square pattern was formed by grinding the surface of a hot-dip plating layer. This result is shown in Table 4 and Table 5 as No. 2-34.

[0167]

For the obtained hot-dip plated steel sheets, the area ratios of first regions and second regions that were included in the pattern portions and the non-pattern portions

were obtained. First, the boundaries between the pattern portion and the non-pattern portion were specified by observing the surfaces of the hot-dip plating layers with the naked eye. In a case it was difficult to specify the boundary with the naked eye, an enlarged image captured with a magnifying glass or an optical microscope was used. In  
5 examples where the discrimination of the boundary was difficult, sites corresponding to the square patterns on the roll surfaces were regarded as the pattern portions, and the area ratios of the first region and the second region were evaluated.

[0168]

Next, the area ratios of individual regions that were included in the pattern  
10 portion and the non-pattern portion were obtained by a measurement method to be subsequently described. That is, virtual grid lines were drawn at 0.5 mm intervals on the surface of the hot-dip plating layer, a plurality of regions partitioned by the virtual grid lines was set, and the arithmetic average roughness Sa was calculated.

In addition, regions where the arithmetic average surface roughness Sa was 1  
15  $\mu\text{m}$  or more were discriminated as the first regions, and regions where the arithmetic average surface roughness Sa was less than 1  $\mu\text{m}$  were discriminated as the second regions.

[0169]

In addition, the area ratios of the first regions in the pattern portion and the non-  
20 pattern portion were each obtained. In addition, the difference between the area ratio of the first region in the pattern portion and the area ratio of the first region in the non-pattern portion were obtained.

[0170]

In the measurement method, the arithmetic average surface roughness Sa was  
25 measured using a 3D laser microscope (manufactured by Keyence Corporation, VK-

9710). In each of the plurality of regions partitioned by the virtual grid lines, the heights Z in the region were measured using a standard lens of 20 times at measurement interval of 50 μm. The obtained 100 heights Z were indicated as height Z1 to height Z100, and Sa was calculated using the following formula. Zave indicated the average of the 100 heights Z.

$$Sa = 1/100 \times \Sigma[x = 1 \rightarrow 100] (\text{height } Zx - Zave)$$

[0171]

[Distinguishability]

On test sheets provided with the square pattern portion in an initial state where the test sheet was just manufactured and in an aged state where the test sheet had been exposed outdoors for six months, visual evaluation was carried out based on the determination criteria. A to C were regarded as pass for both the initial state and the aged state. The determination criteria were the same as those in Example 1.

[0172]

[Corrosion resistance]

A corrosion resistance test was carried out on a test sheet under the same conditions as in Example 1, and then a rust generation status was investigated and evaluated based on the following determination criteria. A to C were regarded as pass. The determination criteria were the same as those in Example 1.

[0173]

As shown in Table 4 and Table 5, the Zn-Al-Mg-based hot-dip plated steel sheets of Present Invention Examples No. 2-1 to No. 2-29 were excellent in terms of both the distinguishability and the corrosion resistance. Fig. 6 shows the observation result of the first region in No. 2-1 with a scanning electron microscope, and Fig. 7 shows the observation result of the second region in No. 2-1 with the scanning electron microscope.

It is found that the arithmetic average surface roughness was clearly large in the first region shown in Fig. 6 compared with the second region shown in Fig. 7.

[0174]

In No. 2-30, since the difference between the roughness of the square pattern  
5 and the roughness of the other portions on the roll was not sufficient, the difference between the area ratio of the first region in the pattern portion and the area ratio of the first region in the non-pattern portion was less than 30%, and the distinguishability of the pattern portion deteriorated.

In addition, in No. 2-31 and No. 2-32, the compositions of the hot-dip plating  
10 layers were outside the scope of the present invention, and the distinguishability after six months of outdoor exposure deteriorated.

[0175]

In No. 2-33 where the square pattern portion was printed by the inkjet method,  
the pattern portion was thinned by six-month outdoor exposure, and the distinguishability  
15 deteriorated.

In addition, in No. 2-34 where the square pattern was formed by grinding, the thickness of the plating layer at the ground site decreased, and the corrosion resistance in the ground site deteriorated.

The plating layers in No. 2-1 to No. 2-6, No. 2-10 to No. 2-30 and No. 2-32 to  
20 No. 2-34 included the [Al phase] and the [ternary eutectic structure of Al/Zn/MgZn<sub>2</sub>].

[0176]

Fig. 8 shows the surface of a hot-dip plated steel sheet displaying a letter string (alphabet) with a pattern portion by transferring the surface shape of a roll to a Zn-Al-Mg-based hot-dip plating layer to a hot-dip plating layer.

25 According to the present invention, it is possible to intentionally display a

pattern portion composed of a letter, a mark or the like on the surface of a hot-dip plated steel sheet.

[0177]

[Table 3]

| Roll | Roughness of square pattern<br>(arithmetic average roughness, Sa (μm)) | Roughness of region other than square<br>pattern<br>(arithmetic average roughness, Sa (μm)) |
|------|------------------------------------------------------------------------|---------------------------------------------------------------------------------------------|
| A    | 0.5                                                                    | 1                                                                                           |
| B    | 2                                                                      | 1                                                                                           |
| C    | 1                                                                      | 2                                                                                           |
| D    | 0.5                                                                    | 2                                                                                           |
| E    | 2                                                                      | 0.5                                                                                         |
| F    | 1                                                                      | 0.5                                                                                         |
| G    | 0.5                                                                    | 0.8                                                                                         |
| H    | 0.5                                                                    | 0.7                                                                                         |

5 [0178]

[Table 4]

| No.  | Manufacturing method |           | Hot-dip plating layer                                     |     |      |        |       |                                                                 |
|------|----------------------|-----------|-----------------------------------------------------------|-----|------|--------|-------|-----------------------------------------------------------------|
|      | Production method    | Roll used | Average composition (mass%), remainder: Zn and impurities |     |      |        |       | Amount of plating attached to both surfaces (g/m <sup>2</sup> ) |
|      |                      |           | Al                                                        | Mg  | Si   | Others |       |                                                                 |
| 2-1  | Roll transfer        | A         | 11                                                        | 3   | 0.2  | Ti     | 0.005 | 100                                                             |
| 2-2  | Roll transfer        | B         | 11                                                        | 3   | 0.2  | Ni     | 0.01  | 180                                                             |
| 2-3  | Roll transfer        | C         | 11                                                        | 3   | 0.2  | Ti     | 0.005 | 80                                                              |
| 2-4  | Roll transfer        | D         | 11                                                        | 3   | 0.2  | Ti     | 0.005 | 80                                                              |
| 2-5  | Roll transfer        | E         | 11                                                        | 3   | 0.2  | Ti     | 0.005 | 100                                                             |
| 2-6  | Roll transfer        | F         | 11                                                        | 3   | 0.2  | Ti     | 0.005 | 100                                                             |
| 2-7  | Roll transfer        | A         | 0.2                                                       | -   | -    | -      |       | 90                                                              |
| 2-8  | Roll transfer        | A         | 3.5                                                       | 1   | -    | -      |       | 100                                                             |
| 2-9  | Roll transfer        | A         | 4                                                         | 3   | -    | -      |       | 100                                                             |
| 2-10 | Roll transfer        | A         | 22                                                        | 1   | -    | -      |       | 100                                                             |
| 2-11 | Roll transfer        | A         | 23                                                        | 1   | -    | -      |       | 90                                                              |
| 2-12 | Roll transfer        | A         | 20                                                        | 10  | -    | -      |       | 80                                                              |
| 2-13 | Roll transfer        | A         | 11                                                        | 3   | 0.01 | -      |       | 130                                                             |
| 2-14 | Roll transfer        | A         | 11                                                        | 3   | 2    | -      |       | 120                                                             |
| 2-15 | Roll transfer        | A         | 5                                                         | 0.5 | -    | Ni     | 0.1   | 80                                                              |
| 2-16 | Roll transfer        | A         | 11                                                        | 3   | 0.2  | Zr     | 0.02  | 40                                                              |
| 2-17 | Roll transfer        | A         | 11                                                        | 3   | 0.2  | Sr     | 0.02  | 90                                                              |
| 2-18 | Roll transfer        | A         | 11                                                        | 3   | 0.2  | Sb     | 0.1   | 100                                                             |
| 2-19 | Roll transfer        | A         | 11                                                        | 3   | 0.2  | Pb     | 0.1   | 110                                                             |
| 2-20 | Roll transfer        | A         | 11                                                        | 3   | 0.2  | Sn     | 0.2   | 80                                                              |
| 2-21 | Roll transfer        | A         | 11                                                        | 3   | 0.2  | Ca     | 0.01  | 100                                                             |
| 2-22 | Roll transfer        | A         | 11                                                        | 3   | 0.2  | Co     | 0.05  | 90                                                              |
| 2-23 | Roll transfer        | A         | 11                                                        | 3   | 0.2  | Mn     | 0.01  | 150                                                             |
| 2-24 | Roll transfer        | G         | 11                                                        | 3   | 0.2  | Pb     | 0.01  | 60                                                              |
| 2-25 | Roll transfer        | A         | 11                                                        | 3   | 0.2  | B      | 0.01  | 80                                                              |

|      |                        |   |    |    |     |    |       |     |
|------|------------------------|---|----|----|-----|----|-------|-----|
| 2-26 | Roll transfer          | A | 11 | 3  | 0.2 | Bi | 0.01  | 100 |
| 2-27 | Roll transfer          | A | 11 | 3  | 0.2 | Cr | 0.1   | 110 |
| 2-28 | Roll transfer          | A | 11 | 3  | 0.2 | Sc | 0.1   | 90  |
| 2-29 | Roll transfer          | A | 11 | 3  | 0.2 | C  | 0.1   | 230 |
| 2-30 | Roll transfer          | H | 11 | 3  | 0.2 | Ti | 0.005 | 160 |
| 2-31 | Roll transfer          | A | 95 | 0  | 0.2 | Ti | 0.005 | 80  |
| 2-32 | Roll transfer          | A | 11 | 11 | 0.2 | Ti | 0.005 | 70  |
| 2-33 | Printing after plating | - | 11 | 3  | 0.2 | Ti | 0.005 | 120 |
| 2-34 | Grinding after plating | - | 11 | 3  | 0.2 | Ti | 0.005 | 90  |

[0179]

[Table 5]

| No.  | Hot-dip plating layer |                       |                      |                       |                                  | Evaluation         |            |                      | Note              |
|------|-----------------------|-----------------------|----------------------|-----------------------|----------------------------------|--------------------|------------|----------------------|-------------------|
|      | Pattern portion       |                       | Non-pattern portion  |                       | Difference in area ratio (area%) | Distinguishability |            | Corrosion resistance |                   |
|      | First region (area%)  | Second region (area%) | First region (area%) | Second region (area%) |                                  | Initial state      | Aged state |                      |                   |
| 2-1  | 10                    | 90                    | 50                   | 50                    | 40                               | A                  | A          | A                    | Invention Example |
| 2-2  | 90                    | 10                    | 50                   | 50                    | 40                               | A                  | A          | A                    | Invention Example |
| 2-3  | 50                    | 50                    | 100                  | 0                     | 50                               | A                  | A          | A                    | Invention Example |
| 2-4  | 0                     | 100                   | 90                   | 10                    | 90                               | A                  | A          | A                    | Invention Example |
| 2-5  | 90                    | 10                    | 10                   | 90                    | 80                               | A                  | A          | A                    | Invention Example |
| 2-6  | 50                    | 50                    | 10                   | 90                    | 40                               | A                  | A          | A                    | Invention Example |
| 2-7  | 10                    | 90                    | 50                   | 50                    | 40                               | B                  | C          | B                    | Invention Example |
| 2-8  | 10                    | 90                    | 50                   | 50                    | 40                               | B                  | B          | B                    | Invention Example |
| 2-9  | 10                    | 90                    | 50                   | 50                    | 40                               | A                  | B          | B                    | Invention Example |
| 2-10 | 10                    | 90                    | 50                   | 50                    | 40                               | A                  | B          | B                    | Invention Example |
| 2-11 | 10                    | 90                    | 50                   | 50                    | 40                               | B                  | B          | B                    | Invention Example |
| 2-12 | 10                    | 90                    | 50                   | 50                    | 40                               | A                  | B          | B                    | Invention Example |
| 2-13 | 10                    | 90                    | 50                   | 50                    | 40                               | A                  | B          | A                    | Invention Example |
| 2-14 | 10                    | 90                    | 50                   | 50                    | 40                               | A                  | B          | A                    | Invention Example |
| 2-15 | 10                    | 90                    | 50                   | 50                    | 40                               | A                  | B          | B                    | Invention Example |
| 2-16 | 10                    | 90                    | 50                   | 50                    | 40                               | A                  | A          | A                    | Invention Example |
| 2-17 | 10                    | 90                    | 50                   | 50                    | 40                               | A                  | A          | A                    | Invention Example |
| 2-18 | 10                    | 90                    | 50                   | 50                    | 40                               | A                  | A          | A                    | Invention Example |
| 2-19 | 10                    | 90                    | 50                   | 50                    | 40                               | A                  | A          | A                    | Invention Example |
| 2-20 | 10                    | 90                    | 50                   | 50                    | 40                               | A                  | A          | A                    | Invention Example |
| 2-21 | 10                    | 90                    | 50                   | 50                    | 40                               | A                  | A          | A                    | Invention Example |
| 2-22 | 10                    | 90                    | 50                   | 50                    | 40                               | A                  | A          | A                    | Invention Example |
| 2-23 | 10                    | 90                    | 50                   | 50                    | 40                               | A                  | A          | A                    | Invention Example |
| 2-24 | 10                    | 90                    | 40                   | 60                    | 30                               | C                  | C          | A                    | Invention Example |
| 2-25 | 10                    | 90                    | 50                   | 50                    | 40                               | A                  | A          | A                    | Invention Example |
| 2-26 | 10                    | 90                    | 50                   | 50                    | 40                               | A                  | A          | A                    | Invention Example |
| 2-27 | 10                    | 90                    | 50                   | 50                    | 40                               | A                  | A          | A                    | Invention Example |
| 2-28 | 10                    | 90                    | 50                   | 50                    | 40                               | A                  | A          | A                    | Invention Example |

|          |    |    |    |    |           |   |   |   |                        |
|----------|----|----|----|----|-----------|---|---|---|------------------------|
| 2-<br>29 | 10 | 90 | 50 | 50 | 40        | A | A | A | Invention<br>Example   |
| 2-<br>30 | 10 | 90 | 35 | 65 | <u>25</u> | D | D | B | Comparative<br>Example |
| 2-<br>31 | 10 | 90 | 50 | 50 | 40        | B | D | B | Comparative<br>Example |
| 2-<br>32 | 10 | 90 | 50 | 50 | 40        | B | D | B | Comparative<br>Example |
| 2-<br>33 | -  | -  | -  | -  | -         | A | D | B | Comparative<br>Example |
| 2-<br>34 | -  | -  | -  | -  | -         | B | B | D | Comparative<br>Example |

[0180]

(Example 3)

Steel sheets were degreased and washed with water, and then reduction annealing, immersion in a plating bath, control of the amount attached and cooling were carried out, thereby manufacturing hot-dip plated steel sheets No. 3-1 to No. 3-32 shown in Table 7 and Table 8. Nitrogen gas, which is one type of non-oxidizing gas, was sprayed with a gas nozzle to molten metal on the surfaces of the steel sheets while the temperatures of the molten metal were within a range of (final solidification temperature - 5)°C to (final solidification temperature + 5)°C at the time of lifting the steel sheets from the plating bath. The spraying conditions of the nitrogen gas were set as shown in Table 6. The gas temperatures shown in Table 6 were all lower than the final solidification temperature. After that, the steel sheets were cooled to completely solidify the molten metal. The spraying of the nitrogen gas controlled such that 50 mm x 50 mm square patterns to appear. However, in No. 3-30, the nitrogen gas was sprayed with the gas nozzle when the temperature of the molten metal was lower than the range of (final solidification temperature - 5)°C to (final solidification temperature + 5)°C.

[0181]

In addition, a Zn-Al-Mg-based hot-dip plated steel sheet was manufactured in the same manner as described above. After that, a 50 mm x 50 mm square pattern was printed on the surface of a hot-dip plating layer by an inkjet method. This result is shown in Table 7 and Table 8 as No. 3-33.

[0182]

Furthermore, a Zn-Al-Mg-based hot-dip plated steel sheet was manufactured in the same manner as described above. After that, a 50 mm x 50 mm square pattern was formed by grinding the surface of a hot-dip plating layer. This result is shown in Table 7 and Table 8 as No. 3-34.

[0183]

For the obtained hot-dip plated steel sheets, the area ratios of first regions and second regions that were included in the pattern portions and the non-pattern portions were obtained. First, the boundaries between the pattern portion and the non-pattern portion were specified by observing the surfaces of the hot-dip plating layers with the naked eye. In a case it was difficult to specify the boundary with the naked eye, an enlarged image captured with a magnifying glass or an optical microscope was used. In examples where the discrimination of the boundary was difficult, the boundary was set based on the spraying range of the nitrogen gas, and the area ratios of the first region and the second region were evaluated.

[0184]

Next, the orientation ratio of each region that was included in the square pattern (expressed as the pattern portion in Table 7) and the other regions (expressed as the non-pattern portion in Table 7) was obtained by a measurement method to be subsequently described. That is, virtual grid lines were drawn at 1 mm intervals on the surface of the hot-dip plating layer. Next, in each of a plurality of regions partitioned by the virtual grid lines, the diffraction peak intensity  $I_{0002}$  of the (0002) plane of a Zn phase and the diffraction peak intensity  $I_{10-11}$  of the (10-11) plane of the Zn phase were measured by the X-ray diffraction method in which an X-ray was incident on each region. In addition, the intensity ratio thereof ( $I_{0002}/I_{10-11}$ ) was obtained and regarded as the orientation ratio.

[0185]

In the X-ray diffraction measurement, a Co tube was used as the X-ray light source. As the diffraction peak intensity  $I_{0002}$  of the (0002) plane of the Zn phase, the intensity of the diffraction peak of the (0002) plane of the Zn phase that appeared within a range of  $42.41^\circ \pm 0.5^\circ$  in the  $2\theta$  range was used. As the diffraction peak intensity  $I_{10-11}$  of the (10-11) plane of the Zn phase, the intensity of the diffraction peak of the (10-11) plane of the Zn phase that appeared within a range of  $50.66^\circ \pm 0.5^\circ$  in the  $2\theta$  range was used. The step was set to  $0.02^\circ$ , the scanning speed was set to  $5^\circ/\text{min}$ , and a high-speed semiconductor two-dimensional detector was used as the detector.

10 [0186]

In the present embodiment, the size of one side of the square pattern was 10 mm or more, but the intervals between the virtual grid lines were set to 1 mm. Therefore, X-rays that were emitted from the X-ray light source were focused with a polycapillary. The irradiation range with the focused X-rays was set to a circle having a diameter of 1 mm. The X-ray diffraction measurement in which each region partitioned by the virtual grid lines at 1 mm intervals was irradiated with the X-rays having the irradiation range narrowed as described above, an X-ray diffractometer for micro region measurement was used.

[0187]

20 In addition, regions where the orientation ratio was 3.5 or higher were discriminated as the first regions, and regions where the orientation ratio is lower than 3.5 were discriminated as the second regions.

[0188]

In addition, the area ratios of the first regions in the square pattern and the other portions were each obtained, and the absolute value of the difference in the area ratio of

25

the first region was obtained.

[0189]

[Distinguishability]

On test sheets provided with the square pattern portion in an initial state where  
5 the test sheet was just manufactured and in an aged state where the test sheet had been  
exposed outdoors for six months, visual evaluation was carried out based on the  
determination criteria. A to C were regarded as pass for both the initial state and the aged  
state. The determination criteria were the same as those in Example 1.

[0190]

10 [Corrosion resistance]

A corrosion resistance test was carried out on a test sheet under the same  
conditions as in Example 1, and then a rust generation status was investigated and  
evaluated based on the following determination criteria. A to C were regarded as pass.  
The determination criteria were the same as those in Example 1.

15 [0191]

As shown in Table 7 and Table 8, the Zn-Al-Mg-based hot-dip plated steel  
sheets of Present Invention Examples No. 3-1 to No. 3-29 were excellent in terms of both  
the distinguishability and the corrosion resistance. Fig. 9 shows the observation result of  
the pattern portion in No. 3-1 with a scanning electron microscope, and Fig. 10 shows the  
20 observation result of the non-pattern portion in No. 3-1 with the scanning electron  
microscope. It is found that the area ratio of the first region significantly differs in the  
pattern portion compared with the non-pattern portion and the pattern portion and the  
non-pattern portion are distinguishable.

[0192]

25 In No. 3-30, since the nitrogen gas was sprayed with the gas nozzle when the

temperature of the molten metal was lower than the range of (final solidification temperature - 5)°C to (final solidification temperature + 5)°C, the difference between the area ratio of the first region in the pattern portion and the area ratio of the first region in the non-pattern portion was less than 30%, and the distinguishability of the pattern portion deteriorated.

In addition, in No. 3-31 and No. 3-32, the compositions of the hot-dip plating layers were outside the scope of the present invention, and the distinguishability after six months of outdoor exposure deteriorated.

[0193]

In No. 3-33 where the square pattern portion was printed by the inkjet method, the pattern portion was thinned in an elapsed state after six months of outdoor exposure, and the distinguishability deteriorated.

In addition, in No. 3-34 where the square pattern portion was formed by grinding, the thickness of the plating layer at the ground site decreased, and the corrosion resistance in the ground site deteriorated.

The plating layers in No. 3-1 to No. 3-6, No. 3-10 to No. 3-30 and No. 3-32 to No. 3-34 included the [Al phase] and the [ternary eutectic structure of Al/Zn/MgZn<sub>2</sub>].

[0194]

Fig. 11 shows the surface of a hot-dip plated steel sheet displaying a letter string (alphabet) with a pattern portion by spraying nitrogen gas to a Zn-Al-Mg-based hot-dip plating layer.

According to the present invention, it is possible to intentionally display a pattern portion composed of a letter or a mark on the surface of a hot-dip plated steel sheet.

[0195]

[Table 6]

| Sign | Spraying condition of nitrogen gas |
|------|------------------------------------|
| A    | Gas temperature: 25°C              |
| B    | Gas temperature: 150°C             |
| C    | Gas temperature: 250°C             |

[0196]

[Table 7]

| No.  | Manufacturing method     |                    | Hot-dip plating layer                                     |     |      |        |       |                                                |
|------|--------------------------|--------------------|-----------------------------------------------------------|-----|------|--------|-------|------------------------------------------------|
|      | Production method        | Spraying condition | Average composition (mass%), remainder: Zn and impurities |     |      |        |       | Amount of plating attached (g/m <sup>2</sup> ) |
|      |                          |                    | Al                                                        | Mg  | Si   | Others |       |                                                |
| 3-1  | Spraying of nitrogen gas | C                  | 11                                                        | 3   | 0.2  | Ti     | 0.005 | 90                                             |
| 3-2  | Spraying of nitrogen gas | A                  | 11                                                        | 3   | 0.2  | Ni     | 0.01  | 160                                            |
| 3-3  | Spraying of nitrogen gas | B                  | 11                                                        | 3   | 0.2  | Ti     | 0.005 | 90                                             |
| 3-4  | Spraying of nitrogen gas | C                  | 11                                                        | 3   | 0.2  | Ti     | 0.005 | 100                                            |
| 3-5  | Spraying of nitrogen gas | A                  | 11                                                        | 3   | 0.2  | Ti     | 0.005 | 80                                             |
| 3-6  | Spraying of nitrogen gas | B                  | 11                                                        | 3   | 0.2  | Ti     | 0.005 | 90                                             |
| 3-7  | Spraying of nitrogen gas | A                  | 0.2                                                       | -   | -    | -      |       | 80                                             |
| 3-8  | Spraying of nitrogen gas | C                  | 3.5                                                       | 1   | -    | -      |       | 90                                             |
| 3-9  | Spraying of nitrogen gas | B                  | 4                                                         | 3   | -    | -      |       | 130                                            |
| 3-10 | Spraying of nitrogen gas | A                  | 22                                                        | 1   | -    | -      |       | 110                                            |
| 3-11 | Spraying of nitrogen gas | A                  | 23                                                        | 1   | -    | -      |       | 100                                            |
| 3-12 | Spraying of nitrogen gas | B                  | 20                                                        | 10  | -    | -      |       | 100                                            |
| 3-13 | Spraying of nitrogen gas | A                  | 11                                                        | 3   | 0.01 | -      |       | 90                                             |
| 3-14 | Spraying of nitrogen gas | C                  | 11                                                        | 3   | 2    | -      |       | 110                                            |
| 3-15 | Spraying of nitrogen gas | B                  | 5                                                         | 0.5 | -    | Ni     | 0.1   | 60                                             |
| 3-16 | Spraying of nitrogen gas | B                  | 11                                                        | 3   | 0.2  | Zr     | 0.02  | 80                                             |
| 3-17 | Spraying of nitrogen gas | A                  | 11                                                        | 3   | 0.2  | Sr     | 0.02  | 60                                             |
| 3-18 | Spraying of nitrogen gas | C                  | 11                                                        | 3   | 0.2  | Sb     | 0.1   | 140                                            |
| 3-19 | Spraying of nitrogen gas | A                  | 11                                                        | 3   | 0.2  | Pb     | 0.1   | 100                                            |
| 3-20 | Spraying of nitrogen gas | A                  | 11                                                        | 3   | 0.2  | Sn     | 0.2   | 100                                            |
| 3-21 | Spraying of nitrogen gas | A                  | 11                                                        | 3   | 0.2  | Ca     | 0.01  | 90                                             |
| 3-22 | Spraying of nitrogen gas | A                  | 11                                                        | 3   | 0.2  | Co     | 0.05  | 80                                             |

|      |                          |   |           |           |     |    |       |     |
|------|--------------------------|---|-----------|-----------|-----|----|-------|-----|
| 3-23 | Spraying of nitrogen gas | C | 11        | 3         | 0.2 | Mn | 0.01  | 100 |
| 3-24 | Spraying of nitrogen gas | A | 11        | 3         | 0.2 | Pb | 0.01  | 140 |
| 3-25 | Spraying of nitrogen gas | C | 11        | 3         | 0.2 | B  | 0.01  | 130 |
| 3-26 | Spraying of nitrogen gas | C | 11        | 3         | 0.2 | Bi | 0.01  | 130 |
| 3-27 | Spraying of nitrogen gas | C | 11        | 3         | 0.2 | Cr | 0.1   | 150 |
| 3-28 | Spraying of nitrogen gas | C | 11        | 3         | 0.2 | Sc | 0.1   | 100 |
| 3-29 | Spraying of nitrogen gas | C | 11        | 3         | 0.2 | C  | 0.1   | 220 |
| 3-30 | Spraying of nitrogen gas | C | 11        | 3         | 0.2 | Ti | 0.005 | 100 |
| 3-31 | Spraying of nitrogen gas | C | <u>95</u> | 0         | 0.2 | Ti | 0.005 | 90  |
| 3-32 | Spraying of nitrogen gas | B | 11        | <u>11</u> | 0.2 | Ti | 0.005 | 100 |
| 3-33 | Printing after plating   | - | 11        | 3         | 0.2 | Ti | 0.005 | 110 |
| 3-34 | Grinding after plating   | - | 11        | 3         | 0.2 | Ti | 0.005 | 110 |

[0197]

[Table 8]

| No.  | Hot-dip plating layer |                       |                      |                       |                                  | Evaluation         |            |                      | Note              |
|------|-----------------------|-----------------------|----------------------|-----------------------|----------------------------------|--------------------|------------|----------------------|-------------------|
|      | Pattern portion       |                       | Non-pattern portion  |                       | Difference in area ratio (area%) | Distinguishability |            | Corrosion resistance |                   |
|      | First region (area%)  | Second region (area%) | First region (area%) | Second region (area%) |                                  | Initial state      | Aged state |                      |                   |
| 3-1  | 10                    | 90                    | 50                   | 50                    | 40                               | A                  | A          | A                    | Invention Example |
| 3-2  | 90                    | 10                    | 40                   | 60                    | 50                               | A                  | A          | A                    | Invention Example |
| 3-3  | 50                    | 50                    | 90                   | 10                    | 40                               | A                  | A          | A                    | Invention Example |
| 3-4  | 20                    | 80                    | 80                   | 20                    | 60                               | A                  | A          | A                    | Invention Example |
| 3-5  | 80                    | 20                    | 10                   | 90                    | 70                               | A                  | A          | A                    | Invention Example |
| 3-6  | 60                    | 40                    | 10                   | 90                    | 50                               | A                  | A          | A                    | Invention Example |
| 3-7  | 80                    | 20                    | 20                   | 80                    | 60                               | B                  | C          | B                    | Invention Example |
| 3-8  | 30                    | 70                    | 90                   | 10                    | 60                               | B                  | B          | B                    | Invention Example |
| 3-9  | 40                    | 60                    | 90                   | 10                    | 50                               | A                  | B          | B                    | Invention Example |
| 3-10 | 90                    | 10                    | 30                   | 70                    | 60                               | A                  | B          | B                    | Invention Example |
| 3-11 | 80                    | 20                    | 40                   | 60                    | 40                               | B                  | B          | B                    | Invention Example |
| 3-12 | 60                    | 40                    | 20                   | 80                    | 40                               | A                  | B          | B                    | Invention Example |
| 3-13 | 80                    | 20                    | 40                   | 60                    | 40                               | A                  | B          | A                    | Invention Example |
| 3-14 | 20                    | 80                    | 90                   | 10                    | 70                               | A                  | B          | A                    | Invention Example |
| 3-15 | 60                    | 40                    | 20                   | 80                    | 40                               | A                  | B          | B                    | Invention Example |
| 3-16 | 40                    | 60                    | 90                   | 10                    | 50                               | A                  | A          | A                    | Invention Example |
| 3-17 | 80                    | 20                    | 30                   | 70                    | 50                               | A                  | A          | A                    | Invention Example |
| 3-18 | 10                    | 90                    | 60                   | 40                    | 50                               | A                  | A          | A                    | Invention Example |
| 3-19 | 80                    | 20                    | 20                   | 80                    | 60                               | A                  | A          | A                    | Invention Example |
| 3-20 | 90                    | 10                    | 30                   | 70                    | 60                               | A                  | A          | A                    | Invention Example |
| 3-21 | 100                   | 0                     | 30                   | 70                    | 70                               | A                  | A          | A                    | Invention Example |
| 3-22 | 70                    | 30                    | 10                   | 90                    | 60                               | A                  | A          | A                    | Invention Example |
| 3-23 | 10                    | 90                    | 60                   | 40                    | 50                               | A                  | A          | A                    | Invention Example |
| 3-24 | 70                    | 30                    | 40                   | 60                    | 30                               | C                  | C          | A                    | Invention Example |

|      |    |     |    |    |           |   |   |   |                     |
|------|----|-----|----|----|-----------|---|---|---|---------------------|
| 3-25 | 20 | 80  | 80 | 20 | 60        | A | A | A | Invention Example   |
| 3-26 | 20 | 80  | 70 | 30 | 50        | A | A | A | Invention Example   |
| 3-27 | 30 | 70  | 80 | 20 | 50        | A | A | A | Invention Example   |
| 3-28 | 20 | 80  | 60 | 40 | 40        | A | A | A | Invention Example   |
| 3-29 | 10 | 90  | 60 | 40 | 50        | A | A | A | Invention Example   |
| 3-30 | 0  | 100 | 20 | 80 | <u>20</u> | D | D | B | Comparative Example |
| 3-31 | 10 | 90  | 50 | 50 | 40        | B | D | B | Comparative Example |
| 3-32 | 50 | 50  | 90 | 10 | 40        | B | D | B | Comparative Example |
| 3-33 | -  | -   | -  | -  | -         | A | D | B | Comparative Example |
| 3-34 | -  | -   | -  | -  | -         | B | B | D | Comparative Example |

[0198]

(Example 4)

Steel sheets were degreased and washed with water, and then reduction annealing, immersion in a plating bath, control of the amount attached and cooling were carried out, thereby manufacturing Zn-Al-Mg-based hot-dip plated steel sheets No. 4-1 to No. 4-32 shown in Table 10. Nitrogen gas, which is one type of non-oxidizing gas, was sprayed in a heated state from a gas nozzle to molten metal on the surfaces of the steel sheets while the temperatures of the molten metal were within a range of (final solidification temperature - 5)°C to (final solidification temperature + 5)°C at the time of lifting the steel sheets from the plating bath. The spraying conditions of the nitrogen gas were set as shown in Table 9. The gas temperatures shown in Table 9 were all the final solidification temperature or higher. After that, the steel sheets were cooled to completely solidify the molten metal. The spraying of the nitrogen gas controlled such that 50 mm x 50 mm square patterns to appear. However, in No. 4-30, the nitrogen gas was sprayed with the gas nozzle when the temperature of the molten metal was higher than the range of (final solidification temperature - 5)°C to (final solidification temperature + 5)°C.

[0199]

In addition, a Zn-Al-Mg-based hot-dip plated steel sheet was manufactured in

the same manner as described above. After that, a 50 mm x 50 mm square pattern was printed on the surface of a hot-dip plating layer by an inkjet method. This result is shown in Table 10 as No. 4-33.

[0200]

5                Furthermore, a Zn-Al-Mg-based hot-dip plated steel sheet was manufactured in the same manner as described above. After that, a 50 mm x 50 mm square pattern was formed by grinding the surface of a hot-dip plating layer. This result is shown in Table 10 as No. 4-34.

[0201]

10              For the obtained hot-dip plated steel sheets, the area ratios of first regions and second regions that were included in the pattern portions and the non-pattern portions were obtained. First, the boundaries between the pattern portion and the non-pattern portion were specified by observing the surfaces of the hot-dip plating layers with the naked eye. In a case it was difficult to specify the boundary with the naked eye, an  
15              enlarged image captured with a magnifying glass or an optical microscope was used. In examples where the discrimination of the boundary was difficult, the boundary was set based on the spraying range of the nitrogen gas, and the area ratios of the first region and the second region were evaluated.

[0202]

20              Next, the area ratio of each region that was included in the square pattern (expressed as the pattern portion in Table 10) and the other regions (expressed as the non-pattern portion in Table 10) was obtained by the following determination method.

                As shown in Fig. 1, virtual grid lines K were drawn at 1 mm intervals on the surface of the hot-dip plating layer. In Fig. 1, boundary lines appearing on the hot-dip  
25              plating layer are not shown. Next, a plurality of regions M partitioned by the virtual grid

line K were set. The shape of each region M was a square in which each side was 1 mm. Next, in each of the plurality of regions M partitioned by the virtual grid lines K, the centroid G of each region was set. Next, a circle S having the centroid G at the center was drawn. The diameter R of the circle S was adjusted such that the total length of boundary lines that appeared on the surface of the hot-dip plating layer reached 10 mm.

[0203]

In addition, the average value of the maximum diameter  $R_{max}$  and the minimum diameter  $R_{min}$  of the diameters R of the circles S in the plurality of regions M was regarded as the reference diameter  $R_{ave}$ , regions having a circle S with a diameter R of less than the reference diameter  $R_{ave}$  were regarded as the first regions, and regions having a circle S with a diameter R of the reference diameter  $R_{ave}$  or more were regarded as the second regions.

[0204]

As the boundary lines appearing on the hot-dip plating layer, boundaries between portions with high luminosity and portions with low luminosity on the plating surface were used. These boundaries were converted into boundary lines obtained by binarizing the values of luminosity in the imaging data of the plating surface. An example of the boundary lines after the binarization treatment of the surface of the hot-dip plating layer is shown in Fig. 12.

[0205]

In addition, the area ratios of the first regions and the second regions in the square pattern and the other portions were each obtained, and the absolute value of the difference in the area ratio of the first region was obtained.

[0206]

[Distinguishability]

On test sheets provided with the square pattern portion in an initial state where the test sheet was just manufactured and in an aged state where the test sheet had been exposed outdoors for six months, visual evaluation was carried out based on the determination criteria. A to C were regarded as pass for both the initial state and the aged state. The determination criteria were the same as those in Example 1.

[0207]

[Corrosion resistance]

A corrosion resistance test was carried out on a test sheet under the same conditions as in Example 1, and then a rust generation status was investigated and evaluated based on the following determination criteria. A to C were regarded as pass. The determination criteria were the same as those in Example 1.

[0208]

As shown in Table 10, the Zn-Al-Mg-based hot-dip plated steel sheets of Present Invention Examples No. 4-1 to No. 4-29 were excellent in terms of both the distinguishability and the corrosion resistance. Fig. 13 shows the observation result of the pattern portion in No. 4-1 with a scanning electron microscope, and Fig. 14 shows the observation result of the non-pattern portion in No. 4-1 with the scanning electron microscope. It is found that the area ratio of the first region significantly differs in the pattern portion compared with the non-pattern portion and the pattern portion and the non-pattern portion are distinguishable.

[0209]

In No. 4-30, since the nitrogen gas was sprayed with the gas nozzle when the temperature of the molten metal was higher than the range of (final solidification temperature - 5)°C to (final solidification temperature + 5)°C, the difference between the area ratio of the first region in the pattern portion and the area ratio of the first region in

the non-pattern portion became less than 30%, and the distinguishability of the pattern portion deteriorated.

In addition, in No. 4-31 and No. 4-32, the compositions of the hot-dip plating layers were outside the scope of the present invention, and the distinguishability after six months of outdoor exposure deteriorated.

[0210]

In No. 4-33 where the square pattern portion was printed by the inkjet method, the pattern portion was thinned by six-month outdoor exposure, and the designability deteriorated.

In addition, in No. 4-34 where the grid-like pattern was formed by grinding, the thickness of the plating layer at the ground site decreased, and the corrosion resistance in the ground site deteriorated.

The plating layers in No. 4-1 to No. 4-6, No. 4-10 to No. 4-30 and No. 4-32 to No. 4-34 included the [Al phase] and the [ternary eutectic structure of Al/Zn/MgZn<sub>2</sub>].

[0211]

Fig. 15 shows the surface of a hot-dip plated steel sheet displaying a letter string (alphabet) with a pattern portion.

According to the present invention, it is possible to arbitrarily display a pattern portion composed of a letter or a mark on the surface of a hot-dip plated steel sheet.

[0212]

[Table 9]

| Sign | Spraying condition of nitrogen gas |
|------|------------------------------------|
| A    | Gas temperature: 380°C             |
| B    | Gas temperature: 350°C             |
| C    | Gas temperature: 450°C             |

[0213]

[Table 10]

| No.  | Manufacturing method     |                    | Hot-dip plating layer                                    |     |     |       |                                                |                                   |                                   |                              |                      |                       |                      |                       |                                  | Evaluation         |              |                      |      |
|------|--------------------------|--------------------|----------------------------------------------------------|-----|-----|-------|------------------------------------------------|-----------------------------------|-----------------------------------|------------------------------|----------------------|-----------------------|----------------------|-----------------------|----------------------------------|--------------------|--------------|----------------------|------|
|      | Production method        | Spraying condition | Average composition (mass%) remainder: Zn and impurities |     |     |       | Amount of plating attached (g/m <sup>2</sup> ) | Minimum diameter of circle S (mm) | Maximum diameter of circle S (mm) | Reference diameter Rave (mm) | Pattern portion      |                       | Non-pattern portion  |                       | Difference in area ratio (area%) | Distinguishability |              | Corrosion resistance | Note |
|      |                          |                    | Al                                                       | Mg  | Si  | Other |                                                |                                   |                                   |                              | First region (area%) | Second region (area%) | First region (area%) | Second region (area%) |                                  | Initial state      | Ageing state |                      |      |
| 4-1  | Spraying of nitrogen gas | A                  | 11                                                       | 3   | 0.2 | Ti    | 0.005                                          | 2.1                               | 3.0                               | 2.55                         | 20                   | 80                    | 60                   | 40                    | 40                               | A                  | A            | Invention Example    |      |
| 4-2  | Spraying of nitrogen gas | A                  | 11                                                       | 3   | 0.2 | Ni    | 0.01                                           | 1.9                               | 3.5                               | 2.7                          | 90                   | 10                    | 40                   | 60                    | 50                               | A                  | A            | Invention Example    |      |
| 4-3  | Spraying of nitrogen gas | A                  | 11                                                       | 3   | 0.2 | Ti    | 0.005                                          | 1.5                               | 3.4                               | 2.45                         | 40                   | 60                    | 80                   | 20                    | 40                               | A                  | A            | Invention Example    |      |
| 4-4  | Spraying of nitrogen gas | A                  | 11                                                       | 3   | 0.2 | Ti    | 0.005                                          | 2.2                               | 3.3                               | 2.75                         | 10                   | 90                    | 90                   | 10                    | 80                               | A                  | A            | Invention Example    |      |
| 4-5  | Spraying of nitrogen gas | B                  | 11                                                       | 3   | 0.2 | Ti    | 0.005                                          | 3.0                               | 5.2                               | 4.1                          | 90                   | 10                    | 20                   | 80                    | 70                               | A                  | A            | Invention Example    |      |
| 4-6  | Spraying of nitrogen gas | A                  | 11                                                       | 3   | 0.2 | Ti    | 0.005                                          | 3.2                               | 4.3                               | 3.75                         | 60                   | 40                    | 20                   | 80                    | 40                               | A                  | A            | Invention Example    |      |
| 4-7  | Spraying of nitrogen gas | C                  | 0.2                                                      | -   | -   | Sb    | 0.1                                            | 5.5                               | 10.1                              | 7.8                          | 0                    | 100                   | 60                   | 40                    | 60                               | B                  | C            | Invention Example    |      |
| 4-8  | Spraying of nitrogen gas | C                  | 3.5                                                      | 1   | -   | -     | -                                              | 1.8                               | 3.3                               | 2.55                         | 60                   | 40                    | 20                   | 80                    | 40                               | B                  | B            | Invention Example    |      |
| 4-9  | Spraying of nitrogen gas | A                  | 4                                                        | 3   | -   | -     | -                                              | 1.9                               | 3.5                               | 2.7                          | 80                   | 20                    | 30                   | 70                    | 50                               | A                  | B            | Invention Example    |      |
| 4-10 | Spraying of nitrogen gas | C                  | 22                                                       | 1   | -   | -     | -                                              | 1.5                               | 3.3                               | 2.4                          | 40                   | 60                    | 80                   | 20                    | 40                               | A                  | B            | Invention Example    |      |
| 4-11 | Spraying of nitrogen gas | C                  | 23                                                       | 1   | -   | -     | -                                              | 2.1                               | 3.5                               | 2.8                          | 80                   | 20                    | 40                   | 60                    | 40                               | B                  | B            | Invention Example    |      |
| 4-12 | Spraying of nitrogen gas | A                  | 20                                                       | 10  | -   | -     | -                                              | 1.8                               | 3.0                               | 2.4                          | 20                   | 80                    | 60                   | 40                    | 40                               | A                  | B            | Invention Example    |      |
| 4-13 | Spraying of nitrogen gas | A                  | 11                                                       | 3   | 0.0 | -     | -                                              | 2.0                               | 3.5                               | 2.75                         | 10                   | 90                    | 60                   | 40                    | 50                               | A                  | B            | Invention Example    |      |
| 4-14 | Spraying of nitrogen gas | A                  | 11                                                       | 3   | 2   | -     | -                                              | 1.7                               | 2.8                               | 2.75                         | 90                   | 10                    | 20                   | 80                    | 70                               | A                  | B            | Invention Example    |      |
| 4-15 | Spraying of nitrogen gas | A                  | 5                                                        | 0.5 | -   | Ni    | 0.1                                            | 1.3                               | 3.5                               | 2.4                          | 60                   | 40                    | 20                   | 80                    | 40                               | A                  | B            | Invention Example    |      |
| 4-16 | Spraying of nitrogen gas | A                  | 11                                                       | 3   | 0.2 | Zr    | 0.02                                           | 2.2                               | 3.6                               | 2.9                          | 80                   | 20                    | 20                   | 80                    | 60                               | A                  | A            | Invention Example    |      |
| 4-17 | Spraying of nitrogen gas | A                  | 11                                                       | 3   | 0.2 | Sr    | 0.02                                           | 2.3                               | 4.0                               | 3.15                         | 50                   | 50                    | 10                   | 90                    | 40                               | A                  | A            | Invention Example    |      |
| 4-18 | Spraying of nitrogen gas | B                  | 11                                                       | 3   | 0.2 | Sb    | 0.1                                            | 2.2                               | 3.6                               | 2.9                          | 60                   | 40                    | 20                   | 80                    | 40                               | A                  | A            | Invention Example    |      |
| 4-19 | Spraying of nitrogen gas | A                  | 11                                                       | 3   | 0.2 | Pb    | 0.1                                            | 2.6                               | 3.8                               | 3.2                          | 30                   | 70                    | 80                   | 20                    | 50                               | A                  | A            | Invention Example    |      |

|      |                          |   |    |    |     |    |       |     |     |     |      |    |    |    |    |    |   |   |                     |
|------|--------------------------|---|----|----|-----|----|-------|-----|-----|-----|------|----|----|----|----|----|---|---|---------------------|
| 4-20 | Spraying of nitrogen gas | A | 11 | 3  | 0.2 | Sn | 0.2   | 100 | 2.2 | 4.3 | 3.25 | 70 | 30 | 30 | 70 | 40 | A | A | Invention Example   |
| 4-21 | Spraying of nitrogen gas | A | 11 | 3  | 0.2 | Ca | 0.01  | 160 | 2.0 | 3.2 | 2.6  | 70 | 30 | 30 | 70 | 40 | A | A | Invention Example   |
| 4-22 | Spraying of nitrogen gas | B | 11 | 3  | 0.2 | Co | 0.05  | 120 | 1.8 | 3.4 | 2.6  | 30 | 70 | 80 | 20 | 50 | A | A | Invention Example   |
| 4-23 | Spraying of nitrogen gas | A | 11 | 3  | 0.2 | Mn | 0.01  | 160 | 1.9 | 3.3 | 2.6  | 30 | 70 | 90 | 10 | 60 | A | A | Invention Example   |
| 4-24 | Spraying of nitrogen gas | A | 11 | 3  | 0.2 | Pb | 0.01  | 130 | 1.6 | 3.4 | 2.5  | 40 | 60 | 70 | 30 | 30 | C | A | Invention Example   |
| 4-25 | Spraying of nitrogen gas | A | 11 | 3  | 0.2 | B  | 0.01  | 110 | 2.3 | 3.5 | 2.9  | 20 | 80 | 90 | 10 | 70 | A | A | Invention Example   |
| 4-26 | Spraying of nitrogen gas | A | 11 | 3  | 0.2 | Bi | 0.01  | 150 | 1.9 | 3.4 | 2.65 | 10 | 90 | 80 | 20 | 70 | A | A | Invention Example   |
| 4-27 | Spraying of nitrogen gas | A | 11 | 3  | 0.2 | Cr | 0.1   | 100 | 1.9 | 3.5 | 2.7  | 10 | 90 | 50 | 50 | 40 | A | A | Invention Example   |
| 4-28 | Spraying of nitrogen gas | A | 11 | 3  | 0.2 | Sc | 0.1   | 90  | 1.7 | 2.8 | 2.25 | 20 | 80 | 80 | 20 | 60 | A | A | Invention Example   |
| 4-29 | Spraying of nitrogen gas | A | 11 | 3  | 0.2 | C  | 0.1   | 150 | 2.3 | 3.2 | 2.75 | 10 | 90 | 60 | 40 | 50 | A | A | Invention Example   |
| 4-30 | Spraying of nitrogen gas | A | 11 | 3  | 0.2 | Ti | 0.005 | 80  | 2.0 | 4.5 | 2.25 | 80 | 20 | 60 | 40 | 20 | D | B | Comparative Example |
| 4-31 | Spraying of nitrogen gas | A | 95 | 0  | 0.2 | Ti | 0.005 | 80  | 2.3 | 4.1 | 3.2  | 90 | 10 | 20 | 80 | 70 | B | B | Comparative Example |
| 4-32 | Spraying of nitrogen gas | A | 11 | 11 | 0.2 | Ti | 0.005 | 70  | 1.5 | 3.2 | 2.35 | 20 | 80 | 80 | 20 | 60 | B | B | Comparative Example |
| 4-33 | Printing after plating   | - | 11 | 3  | 0.2 | Ti | 0.005 | 120 | -   | -   | -    | -  | -  | -  | -  | -  | A | B | Comparative Example |
| 4-34 | Grinding after plating   | - | 11 | 3  | 0.2 | Ti | 0.005 | 120 | -   | -   | -    | -  | -  | -  | -  | -  | A | D | Comparative Example |

[Industrial Applicability]

[0214]

According to the present invention, it is possible to display a variety of design, trademarks and other identification marks on the surface of the hot-dip plating layer

5 without carrying out printing or painting and to enhance the distinguishability, design properties or the like of the origin of the steel sheet. In addition, it is also possible to impart information necessary for process control, inventory control or the like or any information required by consumers to the hot-dip plated steel sheet with the pattern

10 portion. This also makes it possible to contribute to improvement in the productivity of the hot-dip plated steel sheet. Therefore, the present invention has sufficient industrial applicability.

[What is claimed is]

1. A hot-dip plated steel sheet comprising:

a steel sheet; and

5 a hot-dip plating layer formed on a surface of the steel sheet,

wherein the hot-dip plated layer contains, in an average composition, 0 to 90 mass% of Al and 0 to 10 mass% of Mg with a remainder including Zn and impurities,

the hot-dip plating layer includes a pattern portion and a non-pattern portion disposed so as to form a predetermined shape,

10 in a case where a first region and a second region are specified by any one of the following determination methods 1 to 5,

the pattern portion and the non-pattern portion are each composed of one or both of the first region and the second region, and

an absolute value of a difference between an area ratio of the first region in the pattern portion and an area ratio of the first region in the non-pattern portion is 30% or more,

(determination method 1)

virtual grid lines are drawn at 0.5 mm intervals on a surface of the hot-dip plating layer, in each of a plurality of regions partitioned by the virtual grid lines, a circle having a centroid of each region at a center and having a diameter of 0.5 mm is defined as a measurement region A, an  $L^*$  value in each measurement region A is measured, when 50 arbitrary points are selected from the obtained  $L^*$  values, and a 50-point average of the obtained  $L^*$  values is defined as a reference  $L^*$  value, regions where the  $L^*$  value is the reference  $L^*$  value or more are defined as the first regions, and regions where the  $L^*$  value is less than the reference  $L^*$  value are defined as the second regions,

(determination method 2)

virtual grid lines are drawn at 0.5 mm intervals on a surface of the hot-dip plating layer, in each of a plurality of regions partitioned by the virtual grid lines, a circle having a centroid of each region at a center and having a diameter of 0.5 mm is defined  
5 as a measurement region A, an  $L^*$  value in each measurement region A is measured, regions where the  $L^*$  value is 45 or more are defined as the first regions, and regions where the  $L^*$  value is less than 45 are defined as the second regions,

(determination method 3)

virtual grid lines are drawn at 0.5 mm intervals on a surface of the hot-dip  
10 plating layer, and, in each of a plurality of regions partitioned by the virtual grid lines, an arithmetic average roughness  $S_a$  is measured, regions where the obtained  $S_a$  is 1  $\mu\text{m}$  or more are defined as the first regions, and regions where the obtained  $S_a$  is less than 1  $\mu\text{m}$  are defined as the second regions,

(determination method 4)

15 virtual grid lines are drawn at 1 mm intervals or 10 mm intervals on a surface of the hot-dip plating layer, in each of a plurality of regions partitioned by the virtual grid lines, a diffraction peak intensity  $I_{0002}$  of a (0002) plane of a Zn phase and a diffraction peak intensity  $I_{10-11}$  of a (10-11) plane of the Zn phase are measured by an X-ray diffraction method in which an X-ray is incident on each region, an intensity ratio thereof  
20 ( $I_{0002}/I_{10-11}$ ) is defined as an orientation ratio, regions where the orientation ratio is 3.5 or higher are defined as the first regions, and regions where the orientation ratio is lower than 3.5 are defined as the second regions,

(determination method 5)

virtual grid lines are drawn at 1 mm intervals on a surface of the hot-dip plating  
25 layer, next, in each of a plurality of regions partitioned by the virtual grid lines, a circle S

having a centroid G of each region at a center is drawn, a diameter R of the circle S is set such that a total length of surface boundary lines in the hot-dip plating layer that is included in the circle S reaches 10 mm, an average value of a maximum diameter R<sub>max</sub> and a minimum diameter R<sub>min</sub> of the diameters R of the circles in the plurality of regions is defined as a reference diameter R<sub>ave</sub>, regions having a circle S with a diameter R of less than the reference diameter R<sub>ave</sub> are defined as the first regions, and regions having a circle S with a diameter R of the reference diameter R<sub>ave</sub> or more are defined as the second regions.

10 2. The hot-dip plated steel sheet according to claim 1,

wherein the hot-dip plating layer contains, in the average composition, 4 to 22 mass% of Al and 1 to 10 mass% of Mg with the remainder including Zn and impurities.

3. The hot-dip plated steel sheet according to claim 1 or 2,

15 wherein the hot-dip plating layer further contains, in the average composition, 0.0001 to 2 mass% of Si.

4. The hot-dip plated steel sheet according to any one of claims 1 to 3,

20 wherein the hot-dip plating layer further contains, in the average composition, a total of 0.0001 to 2 mass% of one or more of the group consisting of Ni, Ti, Zr, Sr, Fe, Sb, Pb, Sn, Ca, Co, Mn, P, B, Bi, Cr, Sc, Y, REM, Hf and C.

5. The hot-dip plated steel sheet according to any one of claims 1 to 4,

25 wherein the pattern portion is disposed so as to form a shape of any one of a straight-line portion, a curved line portion, a dot portion, a figure, a number, a symbol, a

mark or a letter or a shape consisting of a combination of two or more thereof.

6. The hot-dip plated steel sheet according to any one of claims 1 to 5,

wherein the pattern portion is intentionally formed.

5

7. The hot-dip plated steel sheet according to any one of claims 1 to 6,

wherein a total amount of the hot-dip plating layer attached to both surfaces of the steel sheet is 30 to 600 g/m<sup>2</sup>.

10 8. A hot-dip plated steel sheet comprising:

a steel sheet; and

a hot-dip plating layer formed on a surface of the steel sheet,

wherein the hot-dip plating layer contains, in an average composition, 0 to 90 mass% of Al and 0 to 10 mass% of Mg with a remainder including Zn and impurities,

15 the hot-dip plating layer includes a pattern portion and a non-pattern portion disposed so as to form a predetermined shape,

the pattern portion and the non-pattern portion each include one or both of a first region and a second region that are determined by any of the following determination methods 1 to 5, and

20 an absolute value of a difference between an area ratio of the first region in the pattern portion and an area ratio of the first region in the non-pattern portion is 30% or more,

(determination method 1)

25 virtual grid lines are drawn at 0.5 mm intervals on a surface of the hot-dip plating layer, in each of a plurality of regions partitioned by the virtual grid lines, a circle

having a centroid of each region at a center and having a diameter of 0.5 mm is defined as a measurement region A, an  $L^*$  value in each measurement region A is measured, when 50 arbitrary points are selected from the obtained  $L^*$  values, and a 50-point average of the obtained  $L^*$  values is defined as a reference  $L^*$  value, regions where the  $L^*$  value is the reference  $L^*$  value or more are defined as the first regions, and regions where the  $L^*$  value is less than the reference  $L^*$  value are defined as the second regions,

(determination method 2)

virtual grid lines are drawn at 0.5 mm intervals on a surface of the hot-dip plating layer, in each of a plurality of regions partitioned by the virtual grid lines, a circle having a centroid of each region at a center and having a diameter of 0.5 mm is defined as a measurement region A, an  $L^*$  value in each measurement region A is measured, regions where the  $L^*$  value is 45 or more are defined as the first regions, and regions where the  $L^*$  value is less than 45 are defined as the second regions,

(determination method 3)

virtual grid lines are drawn at 0.5 mm intervals on a surface of the hot-dip plating layer, and, in each of a plurality of regions partitioned by the virtual grid lines, an arithmetic average roughness  $S_a$  is measured, regions where the obtained  $S_a$  is 1  $\mu\text{m}$  or more are defined as the first regions, and regions where the obtained  $S_a$  is less than 1  $\mu\text{m}$  are defined as the second regions,

(determination method 4)

virtual grid lines are drawn at 1 mm intervals or 10 mm intervals on a surface of the hot-dip plating layer, in each of a plurality of regions partitioned by the virtual grid lines, a diffraction peak intensity  $I_{0002}$  of a (0002) plane of a Zn phase and a diffraction peak intensity  $I_{10-11}$  of a (10-11) plane of the Zn phase are measured by an X-ray diffraction method in which an X-ray is incident on each region, an intensity ratio thereof

( $I_{0002}/I_{10-11}$ ) is defined as an orientation ratio, regions where the orientation ratio is 3.5 or higher are defined as the first regions, and regions where the orientation ratio is lower than 3.5 are defined as the second regions,

(determination method 5)

5            virtual grid lines are drawn at 1 mm intervals on a surface of the hot-dip plating layer, next, in each of a plurality of regions partitioned by the virtual grid lines, a circle S having a centroid G of each region at a center is drawn, a diameter R of the circle S is set such that a total length of surface boundary lines in the hot-dip plating layer that is included in the circle S reaches 10 mm, an average value of a maximum diameter Rmax  
10          and a minimum diameter Rmin of the diameters R of the circles in the plurality of regions is defined as a reference diameter Rave, regions having a circle S with a diameter R of less than the reference diameter Rave are defined as the first regions, and regions having a circle S with a diameter R of the reference diameter Rave or more are defined as the second regions.

15