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(71) Applicant: **Posco**
Pohang-si, Gyeongsangbuk-do 37859 (KR)

(72) Inventors:
• **KIM, Yeon-Ho**
Gwangyang-si
Jeollanam-do 57807 (KR)

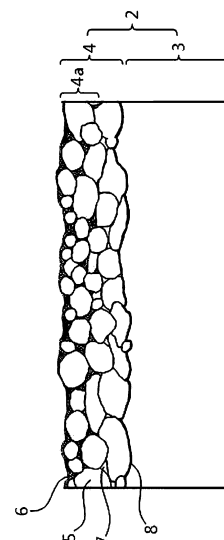
• **KANG, Ki-Cheol**
Gwangyang-si
Jeollanam-do 57807 (KR)
• **BYEON, Chang-Se**
Gwangyang-si
Jeollanam-do 57807 (KR)
• **SONG, Yon-Kyun**
Gwangyang-si
Jeollanam-do 57807 (KR)

(74) Representative: **Zech, Stefan Markus**
Meissner Bolte Patentanwälte
Rechtsanwälte Partnerschaft mbB
Postfach 86 06 24
81633 München (DE)

(54) **METHOD FOR COATING STEEL PLATE WITH METAL AND METAL-COATED STEEL PLATE MANUFACTURED USING SAME**

(57) The present invention relates to a method for coating a steel plate with a metal and a metal-coated steel plate manufactured using the same. The present invention provides a method for coating a steel plate with a metal and a metal-coated steel plate manufactured using the same, the method comprising the steps of: heating first metal powder below a softening point; heating a gas to a temperature of 200 to 600°C; vacuum-ejecting the heated metal powder together with the heated gas, thereby forming a metal coating layer; and forming a second metal plating layer on the metal coating layer.

【Figure 1】



Description

[Technical Field]

[0001] The present disclosure relates to a method for coating a steel plate with a metal and a metal-coated steel plate manufactured by the method, and more particularly, to a method of forming a pore-free coating layer by forming a porous coating layer through a vacuum ejection coating process and then forming a plating layer, and a steel plate on which the pore-free coating layer is formed.

[Background Art]

[0002] A method of coating with particles may be used as a surface treatment method for coating various materials with various powder materials, and an ejection velocity is guaranteed by a gas pressure difference between a powder carrier gas and a coating portion normally having a boundary at a nozzle. Particle coating refers to coating with particles, and since particle coating is performed as particles having a size of several tens to several hundreds of nanometers (nm) collide with a coating target material, a coating layer is formed at a much higher rate than in physical vapor deposition (PVD), chemical vapor deposition (CVD), or the like in which coating is performed on an atomic or molecular basis. In addition, the chemical composition of a raw material powder is not changed during the particle coating.

[0003] Examples of particle coating include a spraying method (such as a thermal spraying method or a cold spraying method) and a vacuum ejection method which are generally useful for coating with solid particles of metals, alloys, cermet, or the like, and in these methods, temperature and ejection velocity are key factors.

[0004] In the vacuum ejection method, a coating unit is maintained in a vacuum state (a low-pressure state) to create a pressure difference. That is, a coating target member is provided in a vacuum body, and coating is performed by ejecting powder onto the coating target member in a state in which the powder is carried by a carrier gas. This method does not require that the carrier gas has a high pressure, thereby consuming a smaller amount of gas than the spraying method and enabling room-temperature coating because it is not necessary to heat gas to a high pressure.

[0005] The possibility of mass production (coating efficiency) and economical aspects (the amount of gas consumption) are considered to apply such particle coating methods to the steel industry, for example, for steel plate surface treatment. In this regard, although the vacuum ejection method is economical because of a low amount of gas consumption, the vacuum ejection method results in low coating efficiency (stacking amount/total ejection amount) and is usable for limited coating materials because of a coating temperature substantially close to room temperature and a lower powder particle ejection velocity than that of the spraying method (such as a thermal spraying method or a cold spraying method).

[0006] As disclosed in Korean Patent Application No. 2008-0076019, the vacuum ejection method is generally used for coating with a brittle material such as a ceramic material which is pulverized into powder and recombined during coating and is not suitable for coating with a ductile material such as a metal requiring a large amount of energy for plastic deformation.

[0007] In addition, although a particle coating method using the spraying method (such as a thermal spraying method or a cold spraying method) has high efficiency in terms of metal powder, since a body in which a coating target member is provided is maintained at atmospheric pressure, high-pressure gas having a pressure of several megapascals (MPa) is used as a powder carrier gas to create a large pressure difference from atmospheric pressure, thereby resulting in a large amount of gas consumption. In addition, expensive low-density gas such as He or N₂ is commonly used to ensure a particle velocity for high-speed collisions with a coating target member maintained at atmospheric pressure. That is, the spraying method is generally used for coating a small area and requires particles having a size of several tens of micrometers (μm) for high-speed ejection due to air resistance at atmospheric pressure. Furthermore, according to the spraying method, it is necessary to form a thick coating layer having a thickness within the range of several tens to several hundreds of micrometers (μm) because of problems such as coating layer defects and residual stress, and thus it is practically difficult to form a dense thin coating layer having a thickness of several micrometers (μm) to several tens of micrometers (μm) by the spraying method. In general, according to such particle coating methods for coating with metal powder, pores are formed in a coating layer, and particularly, in the case of coating with a thin film having a thickness of several micrometers (μm) to several tens of micrometers (μm), corrosion factors permeate through such pores, thereby lowering the corrosion resistance of steel plates.

[0008] Therefore, if a coating method addressing the above-described problems with the spraying method and the vacuum coating method is provided for forming a metal coating layer having maximized functionality, such as corrosion resistance on a steel plate surface, the coating method will be widely used in related fields.

[Disclosure]

[Technical Problem]

- 5 **[0009]** An aspect of the present disclosure may provide a method for coating a steel plate with a metal without pores.
[0010] An aspect of the present disclosure may also provide a metal-coated steel plate having a pore-free coating layer manufactured by the metal coating method.

[Technical Solution]

- 10 **[0011]** According to an aspect of the present disclosure, a method for coating a steel plate with a metal may include: heating a first metal powder to a temperature equal to, or higher than, room temperature but lower than a softening temperature; heating a gas to a temperature of 200°C to 600°C; vacuum-ejecting the first metal powder, having been heated, together with the heated gas to form a porous first metal coating layer; and forming a plating layer of a second metal in gaps between powder particles of the first metal coating layer.

15 **[0012]** The first metal may include at least one metal selected from the group consisting of copper (Cu), aluminum (Al), zinc (Zn), iron (Fe), nickel (Ni), chromium (Cr), molybdenum (Mo), titanium (Ti), cobalt (Co), manganese (Mn), tungsten (W), zirconium (Zr), and tin (Sn).

[0013] The first metal powder may have an average particle size of 1 μm to 20 μm.

20 **[0014]** The gas may include at least one gas having a density equal to or lower than the density of air which is selected from the group consisting of nitrogen (N₂), helium (He), and air.

[0015] The vacuum-ejecting may be performed at a pressure of 0.01 Torr to 20 Torr.

[0016] The vacuum-ejecting may be performed at a temperature of 10°C to 200°C.

25 **[0017]** The second metal may include at least one metal selected from the group consisting of zinc (Zn), nickel (Ni), tin (Sn), copper (Cu), and chromium (Cr).

[0018] The forming of the plating layer of the second metal may be performed by an electroplating method or an electroless plating method.

[0019] The method may further include polishing the plating layer of the second metal.

30 **[0020]** The method may further include performing a heat treatment process at a temperature of 200°C to 1000°C after the forming of the plating layer of the second metal.

[0021] According to another aspect of the present disclosure, a metal-coated steel plate may be manufactured by the method of the aspect of the present disclosure.

35 **[0022]** According to another aspect of the present disclosure, a metal-coated steel plate may include: a steel plate; a porous first metal coating layer formed on at least one surface of the steel plate using a first metal powder; and a plating layer of a second metal formed in gaps between particles of the first metal powder of the first metal coating layer.

[0023] The second metal plating layer may be formed on a surface region of the first metal coating layer and in pores of the first metal coating layer.

[0024] An anchoring layer may be formed on an interface between the steel plate and the first metal coating layer.

40 **[0025]** The first metal may include at least one metal selected from the group consisting of copper (Cu), aluminum (Al), zinc (Zn), iron (Fe), nickel (Ni), chromium (Cr), molybdenum (Mo), titanium (Ti), cobalt (Co), manganese (Mn), tungsten (W), zirconium (Zr), and tin (Sn).

[0026] The first metal powder may have an average particle size of 1 μm to 20 μm.

45 **[0027]** The second metal may include at least one metal selected from the group consisting of zinc (Zn), nickel (Ni), tin (Sn), copper (Cu), and chromium (Cr).

[Advantageous Effects]

50 **[0028]** According to the present disclosure, since heated gas is used, high-pressure gas for ejecting metal powder can be provided without increasing the amount of gas consumption, and the efficiency of coating may be increased using plastic deformation of the metal powder heated to a temperature lower than a softening point thereof. The metal-coated steel plate of the present disclosure may have a coating layer not having pores owing to a plating layer formed between metal powder particles, and thus the corrosion resistance of the metal-coated steel plate may be improved while guaranteeing functionality of the coating powder.

55 [Description of Drawings]

[0029]

FIG. 1 is a schematic view illustrating an example structure of a coating layer formed according to the present disclosure.

FIG. 2 is a schematic view illustrating an example of an ejection device usable for performing a coating method of the present disclosure.

FIG. 3 is a schematic view illustrating another example of an ejection device usable for performing the coating method of the present disclosure.

[Best Mode]

[0030] Exemplary embodiments of the present disclosure will now be described in detail with reference to the accompanying drawings. The disclosure may, however, be exemplified in many different forms and should not be construed as being limited to the specific embodiments set forth herein.

[0031] The present disclosure provides a coating technique for maximizing the functionality of a metal coating layer by forming the metal coating layer on a steel plate without pores using a metal plating layer formed in the metal coating layer and/or between surface metal powder particles of the metal coating layer, and a steel plate surface-treated using the coating technique.

[0032] Steel plates to which a method for coating a steel plate with a metal is applicable according to the present disclosure are not particularly limited. However, the metal coating method of the present disclosure may be applied to steel plates selected from the group consisting of hot-rolled steel plates, cold-rolled steel plates, cold-rolled annealed steel plates, galvanized steel plates, zinc-based alloy plated steel plates, and aluminum-based plated steel plates.

[0033] According to the present disclosure, the method for coating a steel plate with a metal includes: heating a first metal powder to a temperature equal to higher than room temperature but lower than a softening point; heating a gas to a temperature of 200°C to 600°C; vacuum-ejecting the heated metal powder together with the heated gas to form a porous first metal coating layer; and forming a plating layer of a second metal in gaps between powder particles of the first metal coating layer.

[0034] That is, in the metal coating method of the present disclosure, a coating structure is formed by mixing a metal powder and a gas heated to proper temperatures, and ejecting the metal powder carried by the gas in a low-temperature, low-pressure atmosphere. According to the present disclosure, since the first metal powder is vacuum-ejected to the steel plate, an anchoring layer 8 may be formed on an interface with the steel plate as shown in FIG. 1.

[0035] Here, room temperature refers to a temperature ranging from about 15°C to about 25°C.

[0036] In addition, according to the present disclosure, since the inside of a vacuum body 100 into which the powder carried by the gas is ejected is maintained in a low-temperature, low-pressure state, the gas may be ejected by a high pressure difference between the carrier gas and a coating portion having a boundary at a nozzle ejection hole without increasing the consumption of gas. Furthermore, since the vacuum body 100 is maintained at a low temperature, even in the case that the gas carrying the powder is ejected, an increase in the internal pressure of the vacuum body 100 is prevented, and thus the powder may be stably ejected.

[0037] In the process of heating the powder of the first metal to a temperature equal to or higher than room temperature but lower than the softening point, the first metal may include at least one metal selected from the group consisting of copper (Cu), aluminum (Al), zinc (Zn), iron (Fe), nickel (Ni), chromium (Cr), molybdenum (Mo), titanium (Ti), cobalt (Co), manganese (Mn), tungsten (W), zirconium (Zr), and tin (Sn). However, the first metal is not limited thereto. The first metal may be at least one of the listed metals, an alloy of at least two of the listed metals, or an alloy including at least one of the listed metals. For example, powder of stainless steel may be used. Powder of an Fe-based metal such as 200 series, 300 series, or 400 series stainless steels may be used. In addition, powder of a high-strength alloy may also be used. Therefore, the softening point may vary according to the first metal.

[0038] In addition, according to the present disclosure, preferably, the first metal powder may have an aspect ratio (long-axis length/short-axis length) of less than 2.

[0039] For example, the temperature at which the process of heating the first metal powder is performed may range from room temperature to 900°C if the first metal powder is stainless steel powder.

[0040] If the temperature at which the process of heating the first metal powder is performed is lower than room temperature, plastic deformation coating may not smoothly occur. However, this may be overcome by additionally heating the carrier gas. If the temperature at which the process of heating the first metal powder is performed is higher than the softening point, and the first metal powder has a high melting point, the steel plate may be damaged, and manufacturing costs may increase.

[0041] The first metal powder may preferably have an average particle size within the range of 1 μm to 20 μm, and more preferably within the range of 1 μm to 10 μm. If the average particle size of the first metal powder is less than 1 μm, manufacturing costs may increase because of high powdering costs. Conversely, if the average particle size of the first metal powder is greater than 20 μm, it is difficult to form a dense powder coating layer because the size of pores between particles of the powder coating layer is large, and gas consumption increases because impact energy necessary

for coating the steel plate with the first metal powder increases and thus it is necessary to use the gas at a higher pressure.

[0042] In addition, the process of heating the gas is performed separately from the process of heating the first metal powder, and more particularly, the gas may preferably be heated to a temperature of 200°C to 600°C and more preferably, to a temperature of 200° to 500°C. If the temperature is less than 200°C, a sufficient gas pressure is not guaranteed. Conversely, if the temperature is greater than 600°C, the steel plate may be damaged because the ejection velocity of the powder may increase, or material bending and high manufacturing costs may be caused because of a high temperature.

[0043] Herein, the gas may have a density equal to or lower than that of air, and the gas may be at least one selected from the group consisting of nitrogen (N₂), helium (He), and air. However, the gas is not limited thereto. That is, although a low-density gas such as nitrogen (N₂) or helium (He) may be used as the gas, dry air having relatively high density may also be used as the gas by considering factors such as the consumption amount or price of the gas.

[0044] A higher powder temperature may be effective in increasing the efficiency of coating with metal powder by plastic deformation. However, in the present disclosure, the metal powder is heated to the above-mentioned temperature, and the metal powder is mixed with the gas heated to a relative lower temperature and supplied at a large flow rate. Then, the mixture is ejected, thereby maximizing the plastic strain of the powder and realizing ejection at an optimized velocity.

[0045] Thereafter, the porous first metal coating layer is formed by vacuum-ejecting the heated metal powder together with the heated gas.

[0046] With reference to FIGS. 2 and 3, the metal coating method of the present disclosure will now be described in more detail together with a device that may be used to perform the method.

[0047] For example, the present disclosure may be implemented using a powder ejection device 1 in which a steel plate being a coating target member 3 may be provided in the vacuum body 100, and the powder may be ejected together with the heated high-pressure gas carrying the powder onto the coating target member 3 using a heating ejection unit 200 such that the powder may be stacked on the coating target member 3 while undergoing plastic deformation.

[0048] The coating target member 3 is mounted on a member transfer device 3a in the vacuum body 100 so as to be coated. Thereafter, the gas is provided by a gas supply unit 220 and is heated by a gas heating unit 230, and the powder is provided by a powder supply unit 210 and heated by a powder heating unit 240. Then, the powder and the gas heated to high pressure are provided to a nozzle unit 250 and are ejected at a high velocity into the vacuum body 100 maintained at a vacuum state, and thus the powder may form a coating layer while being plastically deformed and stacked on the coating target member 3 provided in the vacuum body 100.

[0049] That is, according to the present disclosure, the gas and the powder are individually heated before being ejected, and thus existing vacuum ejection methods in which a high-pressure gas is provided by increasing the flow rate of the gas and is then ejected may be improved so as to provide a high-pressure gas for high-speed ejection of powder without increasing the amount of gas consumption. In addition, the metal powder used as a coating material is heated to a particular temperature or higher according to the kind of the metal powder, so as to increase the plastic strain of the metal powder and thus to facilitate stacking of the metal powder when the metal powder collides with the steel plate.

[0050] For example, the powder heating unit 240 may be provided to the powder supply unit 210 for heating the powder. The powder is heated to facilitate plastic deformation of the powder, and the powder heating unit 240 may be controlled to have an operating temperature higher than that of the gas heating unit 230 so as to improve coating efficiency. That is, the powder heating unit 240 may be provided separately from the gas heating unit 230 to separately heat the gas and the powder and thus to obtain a powder temperature higher than a gas temperature. In addition, the powder heating unit 240 may also include a sensor S for temperature measurement, and the sensor S may be connected to a control unit C for heating temperature control.

[0051] To form a vacuum, the vacuum body 100 may include a chamber unit 110 in which the steel plate 3 is provided, and a vacuum unit 130 provided at the chamber unit 110.

[0052] Here, the chamber unit 110 may be hermetically sealed to maintain a vacuum formed by the vacuum unit 130. The transfer device 3a on which the steel plate 3 is provided may also be provided in the chamber unit 110.

[0053] Furthermore, in the present disclosure, the vacuum ejection may preferably be performed at a pressure of 0.01 Torr to 20 Torr, and more preferably at a pressure of 0.1 Torr to 15 Torr.

[0054] If the vacuum ejection is performed at a pressure less than 0.01 Torr, manufacturing costs increase to form a high-degree vacuum, and if the vacuum ejection is performed at a pressure greater than 20 Torr, a sufficient powder ejection velocity may not be obtained because of an increase in the pressure of a vacuum chamber.

[0055] For example, as illustrated in FIGS. 2 and 3, the vacuum unit 130 may have a function of forming a vacuum in the chamber unit 110, and to this end, the vacuum unit 130 may include a vacuum pump 131, a powder filter 132, and a cooler 133. That is, the vacuum unit 130 may have a function of maintaining the inside of the chamber unit 110 in a low-degree vacuum state ranging from 0.01 Torr to 20 Torr.

[0056] The vacuum body 100 may further include a cooling unit 120 to enable high-speed ejection by increasing a temperature difference between the vacuum body 100 and the heating ejection unit 200 to create a higher pressure

difference.

[0057] That is, preferably, the vacuum ejection may be performed at a temperature of 10°C to 200°C, and more preferably at a temperature of 25°C to 100°C. If the vacuum ejection is performed at a temperature less than 10°C, costs for maintaining the temperature increases, and if the vacuum ejection is performed at a temperature greater than 200°C,

a sufficient pressure difference may not be obtained because of an increase in the pressure of the vacuum chamber. [0058] That is, the cooling unit 120 may maintain the entire internal area of the chamber unit 110 at a low temperature, thereby increasing the pressure difference between the inside of the chamber unit 110 and supplied gas for powder ejection at a higher velocity, and maintaining stable powder ejection by preventing an increase in the internal pressure of the chamber unit 110 even when the heating ejection unit 200 (described later) ejects the gas and powder.

[0059] Therefore, according to the present disclosure, the vacuum body 100 of the powder ejection device 1 may include the chamber unit 110 and the cooling unit 120 provided on the chamber unit 110 to maintain the inside of the chamber unit 110 at a low temperature. The cooling unit 120 may surround outer surfaces of the chamber unit 110 in a dual structure as shown in the powder ejection device 1 shown in FIG. 2 to cool the entire surface of the chamber unit 110, or may be provided as a cooling coil or cooling fins as shown in an ejection device 1, shown in FIG. 3.

[0060] As the gas and the first metal powder are heated and ejected into the vacuum body 100 at a higher velocity, the steel plate 3 being a coating target member provided inside the vacuum body 100 may be coated with the first metal powder undergoing plastic deformation. To this end, the heating ejection unit 200 may include the powder supply unit 210, the gas supply unit 220, the gas heating unit 230, the powder heating unit 240, the nozzle unit 250, etc.

[0061] The powder supply unit 210 supplies the powder to be ejected for coating the steel plate 3, and the powder may be heated by the powder heating unit 240 and then may be supplied. In addition, the powder supply unit 210 may adjust the supply amount of the powder and may receive some gas from a connection tube 223a connected to a gas distributor 223 of the gas supply unit 220 such that powder stored in the powder supply unit 210 may float in the gas and may receive driving force from the gas while the floating powder being transferred.

[0062] In addition, the gas supply unit 220 supplies high-pressure gas for ejecting the powder at a high velocity. That is, since the powder is ejected into the vacuum body 100 in a state in which the powder is carried by the high-pressure gas ejected into the vacuum body 100, if the high-pressure gas is ejected at a high velocity, the powder may also be ejected at a high velocity. In addition, for high-speed ejection of the gas, the gas supply unit 220 may be maintained in a high-pressure state, and in addition to this, the gas may be provided in a high-temperature, high-pressure state owing to heating by the gas heating unit 230. To this end, the gas supply unit 220 may include a gas storage chamber 221, a gas transfer tube 222, the gas distributor 223, a dehumidifier 224, etc., and a sensor S for measuring temperature may be provided in connection with the control unit C so as to control the temperature of heating by the gas heating unit 230.

[0063] The temperatures and velocities of gas and powder are key factors determining the velocity of ejection and may be properly set according to the material of the metal powder. If the temperature or velocity of the gas is excessively low, when the metal powder collides with the steel plate, sufficient impact energy for coating may not be obtained. Conversely, if the temperature or velocity of the gas is excessively high, etching rather than coating may occur, or the powder may not be stacked but may bounce off the steel plate after collision with the steel plate.

[0064] That is, proper impact energy is necessary for coating the steel plate with the metal powder, and to this end, the temperature and velocity conditions of the gas and the powder are key factors. Under optimized conditions, high impact energy may induce metallic bonding between interfaces of the steel plate and the metal coating layer; an inter-metallic layer may be formed of components of the steel plate and the coating powder material; initial collision particles may dig into the steel plate and form an anchoring layer owing to high impact energy; or at least two or all of these structures may be formed. In more detail, if impact energy is low, the formation of an anchoring layer and stacking may occur even in the case that metallic bonding or the formation of an intermetallic layer does not occur. As impact energy increases, metallic bonding occurs together with the formation of an anchoring layer, and an intermetallic layer may be formed if the steel plate and the powder have different components. In addition, if impact energy is low, adhesion may be somewhat low. However, a heat treatment process (described later) may be performed to induce metallic bonding which guarantees adhesion.

[0065] As described above, owing to the metallic bonding, the intermetallic layer, and the anchoring layer between the steel plate and the first metal coating layer, strong adhesion may be obtained between the steel plate and the first metal coating layer. In addition, metallic bonding or an intermetallic layer involving plastic deformation may be present even between particles of the coating layer.

[0066] Through these processes, the metal powder may be ejected to the steel plate to form the metal coating layer with high coating efficiency. Although coating efficiency is high in this case, most powder particles may participate in coating the steel plate while colliding with the steel plate in a state in which the powder particles maintain their shapes with slight deformation, and due to this, pores may be formed in the coating layer, thereby causing problems such as low corrosion resistance.

[0067] According to the present disclosure, preferably, the first metal powder may have an aspect ratio (long-axis length/short-axis length) of less than 2.

[0068] Therefore, according to the present disclosure, the process of forming the second metal plating layer is performed.

[0069] That is, according to the present disclosure, an additional metal layer is formed between the metal powder particles by plating a surface region, an inner region, or both regions of the metal coating layer to provide a final pore-free coating layer, thereby preventing permeation of corrosion factors and maximizing the functionality of the coating material.

[0070] In this case, the second metal may include at least one selected from the group consisting of zinc (Zn), nickel (Ni), tin (Sn), copper (Cu), and chromium (Cr). However, the second metal is not limited thereto. For example, the second metal may be one of the listed metals, an alloy of at least two of the listed metals, or an alloy including at least one of the listed metals.

[0071] In addition, the process of forming the plating layer may be performed by an electroplating method or an electroless plating method.

[0072] The is, the steel plate on which the metal coating layer is formed may be plated with an additional plating layer by an electroplating method or an electroless plating method to fill pores between powder particles of the metal coating layer, thereby removing pores of the metal coating layer.

[0073] FIG. 1 is a schematic view illustrating a structure in which an additional metal layer is formed by plating gaps between metal powder particles of a metal coating layer and a surface region of the metal coating layer. In another example, a plating layer may be formed mainly on pores between metal powder particles inside the coating layer while suppressing the surface region of the coating layer from being plated. In the latter case, an inhibitor may be included in a plating solution, and the metal layer may additionally only be formed in the pores of the metal coating layer.

[0074] In this case, the inhibitor is not particularly limited. An inhibitor generally used in an electroplating method or an electroless plating method may be used as long as the inhibitor optimizes characteristics of the metal coating layer determined by the kind of metal and the size of powder of the metal coating layer of the present disclosure. For example, a surfactant such as a polyol-based or amine-based organic compound surfactant may be used.

[0075] In addition, according to the present disclosure, a process of polishing the second metal plating layer may be additionally included.

[0076] If the polishing process is performed, pores in a surface region may be minimized, and hair lines or metallic texture may be imparted to the surface of the metal coating layer to improve appearance. Owing to friction during the polishing process, surface pores may be closed, and owing to metal texture such as hair lines formed through the polishing process, the value of products may also be improved.

[0077] In addition, in the coating method of the present disclosure, a heat treatment process may be additionally performed at a temperature of 200°C to 1000°C, and it may be more preferable that the heat treatment temperature be within the range of 300°C to 850°C.

[0078] The temperature of the additional heat treatment process may be lower than the melting point of the metal or alloy of the metal coating layer, and if the steel plate is a plated steel plate, the heat treatment process may be performed at a low temperature for a long period of time by considering the melting point of a plating layer and the alloying temperature of the plating layer.

[0079] In addition, a heat treatment method such as a laser or plasma heating method may be used to have heat treatment effects only on the coating layer while minimizing the influence of heat on the steel plate.

[0080] As described above, owing to the additional heat treatment process, pores in the metal coating layer may be further minimized, and adhesion may be secured between the steel plate and the metal coating layer, between powder particles of the metal coating layer, and between metal powder particles and the plating layer, thereby improving workability together with corrosion resistance.

[0081] The reason for this is that sintering occurs at interfaces during the additional heat treatment. In addition, although dislocations occur in crystal grains due to plastic deformation of powder particles during the coating process, the heat treatment removes the dislocations, and crystal grains of the powder particles recrystallize to a size less than the original average size D50 of the powder particles. Thus, workability improves compared to the case in which the metal coating layer is not heat treated.

[0082] In this case, different metals may form intermetallic layers at an interface between the metal power particles and at an interface between the base steel plate and the metal coating layer.

[0083] The additional heat treatment process may be performed before or after the polishing process. That is, the order of the processes is not limited.

[0084] The present disclosure provides a metal-coated steel plate manufactured by the above-described method for coating a steel plate of the present disclosure.

[0085] In more detail, the metal-coated steel plate of the present disclosure includes: a steel plate; a porous first metal coating layer formed on at least one surface of the steel plate using a first metal powder; and a plating layer of a second metal formed in gaps between metal powder particles of the first metal coating layer.

[0086] Referring to FIG. 1, a metal-coated steel plate 2 includes: a first metal coating layer 4 formed on a steel plate

or a plated steel plate 3 by ejecting a first metal powder onto the steel plate 3; and a second metal plating layer 6 formed in gaps between metal powder particles 5 of the first metal coating layer 4. That is, the metal-coated steel plate 2 has a pore-free coating layer 4a.

[0087] In this case, the second metal plating layer may be formed in pores of the first metal coating layer and/or on a surface region of the first metal coating layer. Therefore, a coating layer free of pores is finally provided, thereby guaranteeing corrosion resistance because corrosion factors are prevented from reaching the steel plate, and maximizing the functionality of the metal of the coating layer.

[0088] In addition, according to the present disclosure, the porous first metal coating layer is formed through a vacuum ejection process, and thus the size of crystal grains of the first metal powder is less than the average size D50 of original powder particles.

[0089] In addition, an intermetallic layer is present at interface between the first metal powder particles and the second metal plating layer formed between the first metal powder particles, and metallic bonding, an anchoring layer 8, and an intermetallic layer may be formed on an interface between the steel plate and the first metal coating layer.

[0090] The first metal may include at least one metal selected from the group consisting of copper (Cu), aluminum (Al), zinc (Zn), iron (Fe), nickel (Ni), chromium (Cr), molybdenum (Mo), titanium (Ti), cobalt (Co), manganese (Mn), tungsten (W), zirconium (Zr), and tin (Sn). However, the first metal is not limited thereto. The first metal may be at least one of the listed metals, an alloy of at least two of the listed metals, or an alloy including at least one of the listed metals. For example, powder of stainless steel may be used. Powder of an Fe-based metal such as 200 series, 300 series, or 400 series stainless steels may be used. In addition, powder of a high-strength alloy may also be used. Therefore, the softening point may vary according to the first metal.

[0091] The first metal powder may be powder of a single metal having an average particle size preferably within the range of 1 μm to 20 μm , more preferably within the range of 3 μm to 10 μm , and even more preferably within the range of 5 μm to 10 μm . If the average particle size of the first metal powder is less than 1 μm , manufacturing costs may increase because of high powdering costs. Conversely, if the average particle size of the first metal powder is greater than 20 μm , it is difficult to form a dense powder coating layer because the size of pores between particles of the powder coating layer is large, and gas consumption increases because impact energy necessary for coating the steel plate with the first metal powder increases and thus it is necessary to use gas at a higher pressure.

[0092] In this case, the second metal may include at least one selected from the group consisting of zinc (Zn), nickel (Ni), tin (Sn), copper (Cu), and chromium (Cr). However, the second metal is not limited thereto. For example, the second metal may be one of the listed metals, an alloy of at least two of the listed metals, or an alloy including at least one of the listed metals.

[0093] Hereinafter, the present disclosure will be described more specifically through examples. The following examples are for illustrative purposes only and are not intended to limit the scope of the present invention.

[Mode for Invention]

EXAMPLES

1. Experiment for checking temperature-dependent variations in coating layer during coating process

[0094] A cold-rolled steel plate was used as a coating target object to be coated, and stainless steel powder was used as a coating material. The average particle size D50 of the powder was 5 μm , and the particle size of the powder followed a normal distribution within the range of 1 μm to 10 μm .

[0095] A coating experiment was performed using the coating device shown in FIG. 2 by filling the powder supply unit 210 with the powder and setting coating conditions as follows: an initial pressure of the vacuum body 100 was set to 5 x 0.01 Torr, and a gas pressure before ejection through a nozzle was set to 800 Torr. At that time, dry air was used as gas, and the flow rate was set to be 30 L/min at a powder transfer tube 211 and 200 L/min at the gas transfer tube 222. In addition, a cylinder nozzle having a throat size of 0.8 mm x 100 mm was used as the nozzle unit 250 in such a manner that the nozzle unit 250 was fixed at a distance of 10 mm away from the coating target material, and coating was performed while moving the coating target material left and right twice at a velocity of 10 mm/sec.

[0096] The powder heating unit 240 and the gas heating unit 230 were operated to adjust the temperatures of the powder transfer tube 211 and the gas transfer tube 222 to values shown in Table 1 below during the coating experiment.

[0097] The thickness of a coating layer of the cold-rolled steel plate being a coating target member was measured by cross-sectional element analysis of chromium (Cr) using a scanning electron microscope (SEM), and average values of the measured values are shown in Table 1 below according to coating conditions.

[Table 1]

No	Temperature of powder transfer tube (°C)	Temperature of gas transfer tube (°C)	Thickness of coating layer (μm)
Comparative Example 1	Room temperature	Room temperature	less than 0.2 coating
Comparative Example 2	Room temperature	150	2.5
Example 1	Room temperature	200	10
Example 2	Room temperature	600	29
Example 3	300	600	34
Example 4	600	600	53
Example 5	800	600	86

[0098] As shown in Table 1 above, coating scarcely occurred in Comparative Example 1 performed under room temperature conditions, and the thickness of a coating layer increased as the temperature of the gas increased as shown in Comparative Example 2 (the size of particles followed a normal distribution within the range of 1 μm to 10 μm), Example 1, and Example 2. However, in Comparative Example 2, a structure not having pores was obtained with low coating efficiency, and thus Comparative Example 2 is not useful. In Examples 1 to 5, pores were formed.

[0099] The reason for these results is that the pressure of the gas increases as the temperature of the gas increases, and the ejection velocity of powder increases as the pressure difference between the high-pressure gas and the inside of the vacuum body 100 increases.

[0100] In addition, it could be understood that the thickness of the coating layer increased owing to heating of the powder. Therefore, the plastic strain of the metal powder could be maximized by heating the metal powder, and thus the efficiency of coating could be markedly increased when compared to Comparative Example 1.

2. Experiment for checking properties of coating layer according to coating processes

[0101] The same base steel plate and coating conditions as those used in Experiment 1 were used. In detail, the same temperature conditions as those in Example 4 shown in Table 1 were used, but samples were prepared by setting the average particle size of powder to be 5 μm and the coating thickness to be about 25 μm.

[0102] The samples prepared in this manner were additionally subjected to processes such as an electroplating process, a heat treatment process, or a polishing process as shown in Table 2 below, and when a plurality of subsequent processes were performed, the processes were performed in the order of an electroplating process, a heat treatment process, and a polishing process.

[0103] The electroplating process was performed to plate a metal powder coating layer with nickel (Ni) using a plating solution to which an inhibitor was added in a very small amount under the conditions of a current density of 20 A/dm², a plating solution temperature of 50°C, and a plating weight of 2 g/m².

[0104] The heat treatment process was performed at 850°C for 5 minutes under a reducing atmosphere, and the polishing process was performed using general sand paper until a surface region was removed by about 2 μm to 5 μm.

[0105] The corrosion resistance and workability of the samples prepared as described above were measured, and results thereof are shown in Table 2 below.

[0106] Corrosion resistance was measured through a salt spray test by measuring the time taken until an area of red rust reached 5% of the total area, 75 mm X 150 mm, of each sample.

[0107] Workability was measured through a bending test by checking the formation of cracks in a portion bent to 90°C with a radius of curvature of 3 mm by using an optical microscope. In Table 2 below, "X" denotes that cracking occurred, and "O" denotes that cracking did not occur.

[Table 2]

No	Electroplating	Heat treatment	Polishing	Salt spray test (red rust 5% occurrence time)	Bending test
Comparative Example 3	not performed	not performed	not performed	less than 24 hours	×

(continued)

No	Electroplating	Heat treatment	Polishing	Salt spray test (red rust 5% occurrence time)	Bending test
Comparative Example 4	not performed	performed	not performed	24 to 48 hours	○
Comparative Example 5	not performed	not performed	performed	96 to 120 hours	×
Comparative Example 6	not performed	performed	performed	96 to 120 hours	○
Example 6	performed	not performed	not performed	120 to 168 hours	×
Example 7	performed	performed	not performed	240 hours or longer	○
Example 8	performed	not performed	performed	240 hours or longer	×
Example 9	performed	performed	performed	240 hours or longer	○

[0108] In the case of Comparative Examples 3 to 6 having pores in metal coating layers, corrosion resistance could be increased to some degree through the heat treatment process or polishing process even in the case that the metal coating layers did not include a metal in addition to the metal powder. However, the corrosion resistance and functionality of the STS powder coating layer were not sufficient.

[0109] In addition, as shown in Example 6, the functionality of the coating layer was more effectively shown when an additional metal is included between coating powder particles, and as shown in Examples 7 to 9, the characteristics of the coating layer could be further improved by additionally performing heat treatment and polishing.

[0110] While exemplary embodiments have been shown and described above, the scope of the present disclosure is not limited thereto, and it will be apparent to those skilled in the art that modifications and variations could be made without departing from the scope of the present invention as defined by the appended claims.

[Reference numerals]

- | | |
|--|-----------------------------|
| 1: POWDER EJECTION DEVICE | 2: METAL-COATED STEEL PLATE |
| 3: COATING TARGET MATERIAL (SUPPLY PIPE OR PLATED STEEL PLATE) | |
| 4: METAL COATING LAYER | 4A: PORE-FREE COATING LAYER |
| 5: FIRST METAL POWDER PARTICLES | |
| 6: SECOND METAL | 7: PORES |
| 8: ANCHORING LAYER | 100: VACUUM BODY |
| 110: CHAMBER UNIT | 120: COOLING UNIT |
| 130: VACUUM UNIT | 131: VACUUM PUMP |
| 132: POWDER FILTER | 133: COOLER |
| 200: HEATING EJECTION UNIT | 210: POWDER SUPPLY UNIT |
| 211: POWDER TRANSFER TUBE | 220: GAS SUPPLY UNIT |
| 221: GAS STORAGE CHAMBER | 222: GAS TRANSFER TUBE |
| 223: GAS DISTRIBUTOR | 223A: CONNECTION TUBE |
| 224: DEHUMIDIFIER | 230: GAS HEATING UNIT |
| 240: POWDER HEATING UNIT | 250: NOZZLE UNIT |

Claims

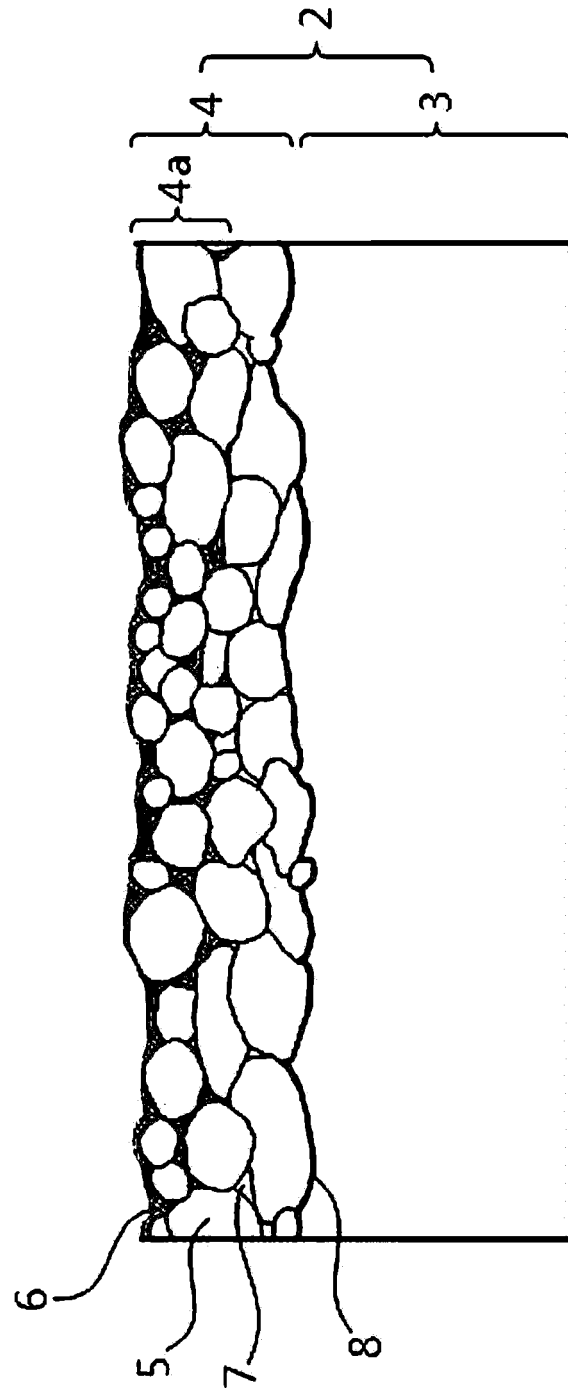
1. A method for coating a steel plate with a metal, the method comprising:

heating a first metal powder to a temperature equal to, or higher than, room temperature but lower than a softening temperature;
 heating a gas to a temperature of 200°C to 600°C;
 vacuum-ejecting the first metal powder, having been heated, together with the heated gas to form a porous first metal coating layer; and

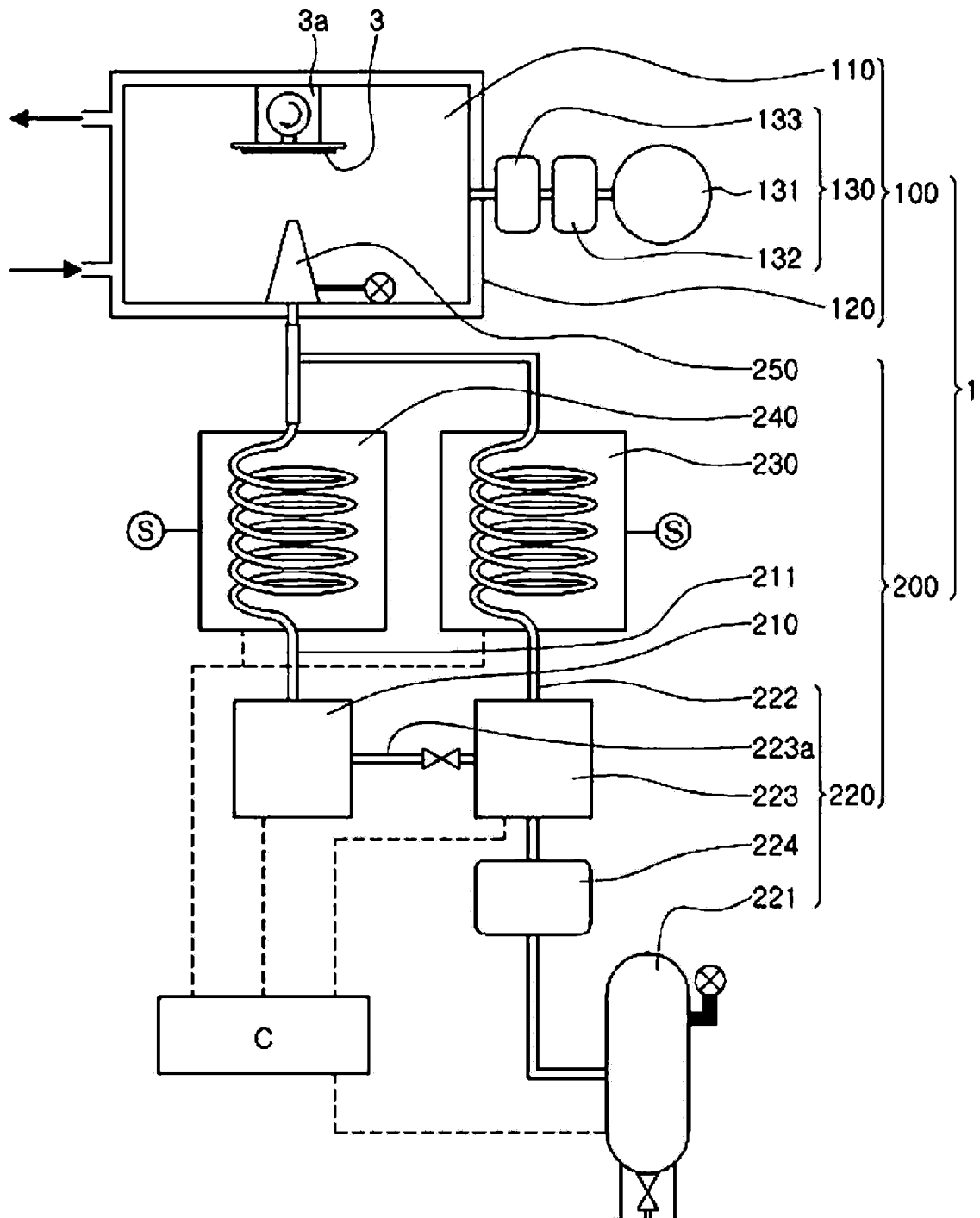
forming a plating layer of a second metal in gaps between powder particles of the first metal coating layer.

2. The method of claim 1, wherein the first metal comprises at least one metal selected from the group consisting of copper (Cu), aluminum (Al), zinc (Zn), iron (Fe), nickel (Ni), chromium (Cr), molybdenum (Mo), titanium (Ti), cobalt (Co), manganese (Mn), tungsten (W), zirconium (Zr), and tin (Sn).
3. The method of claim 1, wherein the first metal powder has an average particle size of 1 μm to 20 μm .
4. The method of claim 1, wherein the gas comprises at least one gas having a density equal to, or lower than the density of air which is selected from the group consisting of nitrogen (N_2), helium (He), and air.
5. The method of claim 1, wherein the vacuum-ejecting is performed at a pressure of 0.01 Torr to 20 Torr.
6. The method of claim 1, wherein the vacuum-ejecting is performed at a temperature of 10°C to 200°C.
7. The method of claim 1, wherein the second metal comprises at least one metal selected from the group consisting of zinc (Zn), nickel (Ni), tin (Sn), copper (Cu), and chromium (Cr).
8. The method of claim 1, wherein the forming of the plating layer of the second metal is performed by an electroplating method or an electroless plating method.
9. The method of claim 1, further comprising polishing the plating layer of the second metal.
10. The method of claim 1, further comprising performing a heat treatment process at a temperature of 200°C to 1000°C after the forming of the plating layer of the second metal.
11. A metal-coated steel plate manufactured by the method of any one of claims 1 to 10.
12. A metal-coated steel plate comprising:
 - a steel plate;
 - a porous first metal coating layer formed on at least one surface of the steel plate using a first metal powder; and
 - a plating layer of a second metal formed in gaps between particles of the first metal powder of the first metal coating layer.
13. The metal-coated steel plate of claim 12, wherein the second metal plating layer is formed on a surface region of the first metal coating layer and in pores of the first metal coating layer.
14. The metal-coated steel plate of claim 12, wherein an anchoring layer is formed on an interface between the steel plate and the first metal coating layer.
15. The metal-coated steel plate of claim 12, wherein the first metal comprises at least one metal selected from the group consisting of copper (Cu), aluminum (Al), zinc (Zn), iron (Fe), nickel (Ni), chromium (Cr), molybdenum (Mo), titanium (Ti), cobalt (Co), manganese (Mn), tungsten (W), zirconium (Zr), and tin (Sn).
16. The metal-coated steel plate of claim 12, wherein the first metal powder has an average particle size of 1 μm to 20 μm .
17. The metal-coated steel plate of claim 12, wherein the second metal comprises at least one metal selected from the group consisting of zinc (Zn), nickel (Ni), tin (Sn), copper (Cu), and chromium (Cr).

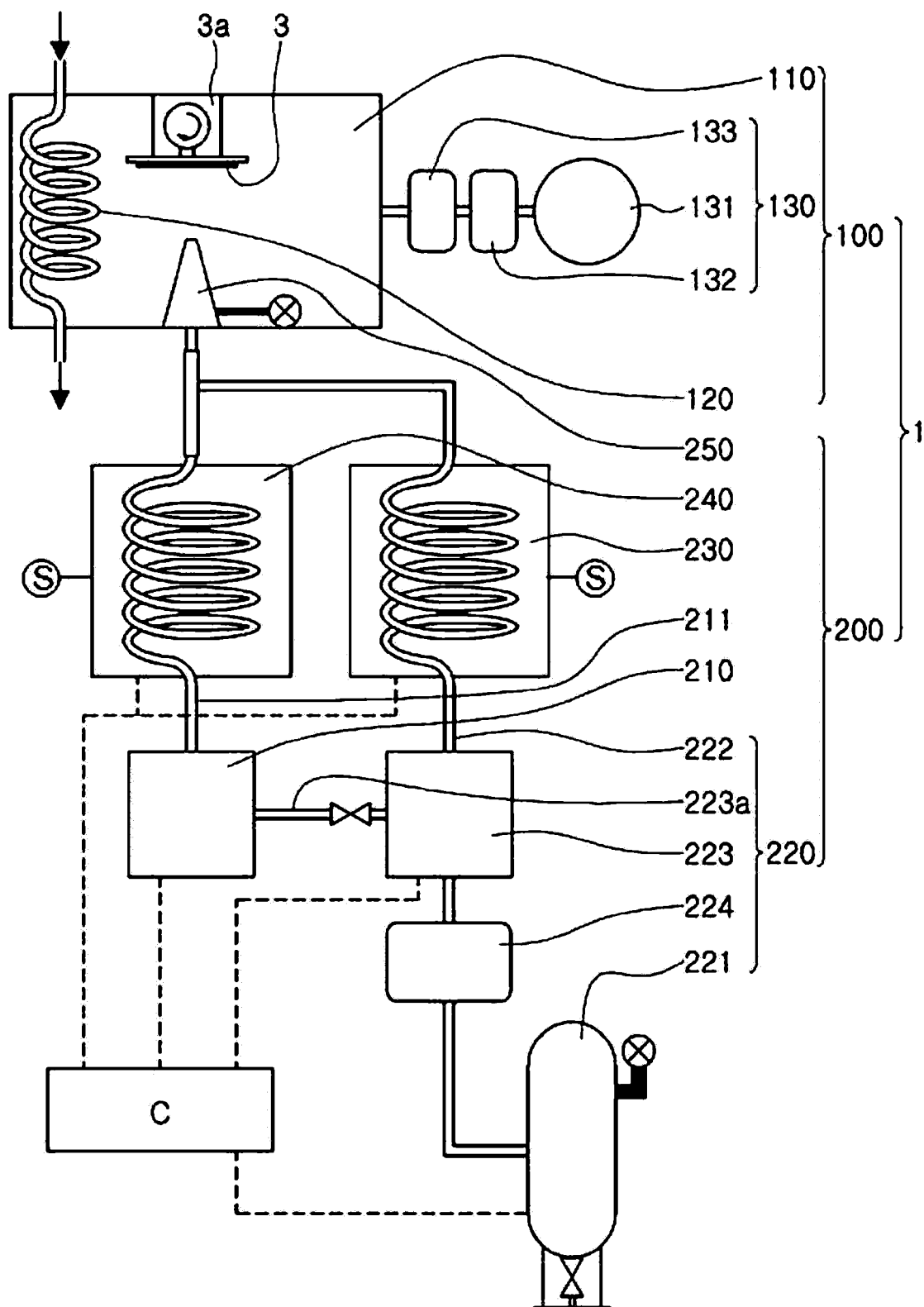
【Figure 1】



【Figure 2】



【Figure 3】



INTERNATIONAL SEARCH REPORT

International application No.

PCT/KR2016/014689

A. CLASSIFICATION OF SUBJECT MATTER

C23C 28/02(2006.01)i, C23C 4/06(2006.01)i, C23C 4/08(2006.01)i, C23C 4/12(2006.01)i, C23C 4/137(2016.01)i,
C25D 3/00(2006.01)i, C25D 3/12(2006.01)i, C25D 3/22(2006.01)i, C23C 18/16(2006.01)i
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

C23C 28/02; B24C 11/00; H01J 9/02; C23C 24/04; C23C 24/06; C23C 4/02; C23C 28/00; C23C 4/06; C23C 4/08; C23C 4/12;
C23C 4/137; C25D 3/00; C25D 3/12; C25D 3/22; C23C 18/16

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean Utility models and applications for Utility models: IPC as above
Japanese Utility models and applications for Utility models: IPC as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS (KIPO internal) & Keywords: steel plate, porous first metal coating layer, gap, second metal plating layer, vacuum
spray, electroplating method, electroless plating method

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2001-158974 A (FUJI SEISAKUSHO K.K.) 12 June 2001 See paragraphs [0011], [0028], [0055]-[0062], claims 1, 3 and figure 2.	12-17
A		1-11
A	KR 10-2015-0074999 A (POSCO) 02 July 2015 See paragraphs [0088], [0129].	1-17
A	KR 10-2015-0074899 A (POSCO) 02 July 2015 See abstract, claim 1 and figure 1.	1-17
A	JP 2000-265286 A (FUJI SEISAKUSHO K.K.) 26 September 2000 See abstract and claim 1.	1-17
A	JP 2013-067825 A (NHK SPRING CO., LTD.) 18 April 2013 See abstract and claim 1.	1-17

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

06 MARCH 2017 (06.03.2017)

Date of mailing of the international search report

07 MARCH 2017 (07.03.2017)

Name and mailing address of the ISA/KR

Korean Intellectual Property Office
Government Complex-Daejeon, 189 Seonsa-ro, Daejeon 302-701,
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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/KR2016/014689

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		WO 2013-042635 A1	28/03/2013

Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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- KR 20080076019 [0006]