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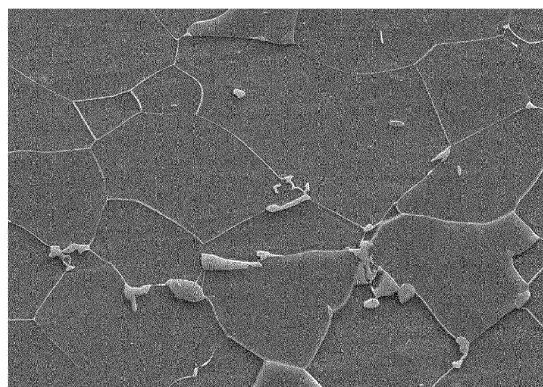
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(54) **COLD ROLLED STEEL SHEET AND PLATED STEEL SHEET WHICH HAVE EXCELLENT BAKE-HARDENABILITY AND ROOM-TEMPERATURE ANTIAGING PROPERTY, AND MANUFACTURING METHODS THEREFOR**

(57) A cold rolled steel sheet having excellent bake-hardening ability and room-temperature anti-aging property, according to one aspect of the present invention, comprises, by wt%, 0.002-0.015%, of C, 1.5-3.0% of Mn, 0.03% or less of P, 0.01% or less of S, 0.01% or less of N, 0.02-0.06% of sol. Al, 1.2% or less of Cr (excluding 0%), and the balance of Fe and inevitable impurities, comprises, as a microstructure, ferrite, which is a matrix structure, and the balance of hard tissue, and has a hard tissue occupancy ratio (V) that can be 70% or more in grain boundary triple points defined by the following relation 1. [Relation 1] $V(\%) = \{V_{tp} / (V_{gb} + V_{tp})\} \times 100$ In relation 1, V_{gb} means the number of hard tissues observed in ferrite grain boundaries within an observation region, and V_{tp} means the number of hard tissues observed in ferrite grain boundary triple points within the observation region.

【FIG. 1】



— 1 μm

Description

[Technical Field]

5 **[0001]** The present disclosure relates to a steel sheet having properties particularly suitable as a material of automotive external panels because bake hardenability and room-temperature aging resistance are excellent, and a method of manufacturing the steel sheet.

[Background Art]

10 **[0002]** The materials of automotive external panels are required to have bake hardenability and aging resistance at a predetermined level. Bake hardening is a phenomenon in which solute carbon and nitrogen activated in a baked finish adhere to dislocations formed in the process of machining the steel sheet, thereby increasing the yield strength of a steel sheet. Since a steel sheet having excellent bake hardenability has a characteristic that forming of the steel sheet is easy before bake finish and dent resistance of the resultant product is improved, such a steel sheet is evaluated as an ideal material as a material of automotive external panels.

15 **[0003]** However, there is a tendency that when the bake hardenability of a steel sheet increases, the aging resistance of the steel sheet is deteriorated on the contrary, so even if bake hardenability of a steel sheet is secured, aging occurs over a predetermined time, whereby the possibility of a surface defect, etc. in part machining may increase. Accordingly, materials of automotive external panels are required to secure bake hardenability over an appropriate level and also to have aging resistance over an appropriate level.

20 **[0004]** Patent Document 1 proposes a technique that improves bake hardenability by adding Sn, but does not propose a fundamental solution to the problem of deterioration of aging resistance due to an increase of bake hardenability.

25 **[0005]** Accordingly, it is required to supply a steel sheet having properties particularly suitable as a material of automotive external panels by having both bake hardenability and room-temperature aging resistance over an appropriate level.

[Related Art Document]

30 [Patent Document]

[0006] (Patent Document 1) Japanese Patent Laid-Open Publication No. 1994-306531 (published 1994.11.01)

[Disclosure]

35 [Technical Problem]

[0007] According to an aspect of the present disclosure, a cold-rolled steel sheet and a plated steel sheet having excellent bake hardenability and room-temperature aging resistance, and a method of manufacturing the cold-rolled steel sheet and the plated steel sheet.

40 **[0008]** The objectives of the present disclosure are not limited to that described above. Those skilled in the art would be able to understand additional objectives of the present disclosure from the contents of the entire specification without difficulties.

45 [Technical Solution]

[0009] A cold-rolled steel sheet having excellent bake hardenability and room-temperature aging resistance according to an aspect of the present disclosure includes, in percentage by weight, C: 0.002~0.015%, Mn: 1.5~3.0%, P: 0.03% or less, S: 0.01% or less, N: 0.01% or less, sol.Al: 0.02~0.06%, Cr: 1.2% or less (excluding 0%), and a balance of Fe and unavoidable impurities, and includes ferrite, which is a matrix structure, and a balance of a hard structure as a microstructure, in which a hard structure ratio V of a grain boundary triple point defined by the following Equation 1 may be 70% or more.

55 [Equation 1]

$$V(\%) = \{V_{tp} / (V_{gb} + V_{tp})\} \times 100$$

[0010] In Equation 1, V_{gb} is the number of hard structures observed at a ferrite grain boundary in an observation region and V_{tp} is the number of hard structures observed at a ferrite grain boundary triple point in the observation region.

[0011] A fraction of the ferrite may be 95% or more in area percentage, and the hard structure may include martensite.

[0012] In the cold-rolled steel sheet, H_{el} defined by the following Equation 2 may satisfy a range of 1.2~2.5,

[Equation 2]

$$H_{el} = [C] + 0.5*[Mn] + 0.75*[Cr]$$

[0013] In Equation 2, $[C]$, $[Mn]$, and $[Cr]$ are contents (percentages by weight) of C, Mn, and Cr, respectively.

[0014] The cold-rolled steel sheet may further include silicon (Si) of 0.1% or less (0% included) in percentage by weight.

[0015] In the cold-rolled steel sheet, a bake hardening amount may be 30MPa or more (BH, tension test after heat treatment at 170°C for 20 minutes) and yield point elongation may be 0.2% or less (YP-EI, tension test after heat treatment at 100°C for 1 hour).

[0016] A plated steel sheet having excellent bake hardenability and room-temperature aging resistance according to an aspect of the present disclosure may include: the cold-rolled steel sheet; and a plating layer or an alloying-plating layer on at least a side of the cold-rolled steel.

[0017] A method of manufacturing a cold-rolled steel sheet having excellent bake hardenability and room-temperature aging resistance according to an aspect of the present disclosure includes: heating a slab including, in percentage by weight, C: 0.002~0.015%, Mn: 1.5~3.0%, P: 0.03% or less, S: 0.01% or less, N: 0.01% or less, sol.Al: 0.02~0.06%, Cr: 1.2% or less (excluding 0%), and a balance of Fe and unavoidable impurities; providing a hot-rolled steel sheet by hot-rolling the slab; coiling the hot-rolled steel sheet; providing a cold-rolled steel sheet by cold-rolling the hot-rolled steel sheet; and continuously annealing the cold-rolled steel sheet, in which the continuous annealing increases temperature up to a range of $(Ac_1+5^{\circ}C)$ ~ $(Ac_3-20^{\circ}C)$ at a temperature increasing speed of 1~10°C/s and then maintains the temperature for 30~240 seconds.

[0018] The slab may be configured such that H_{el} defined by the following Equation 2 satisfies a range of 1.25~2.42.

[Equation 2]

$$H_{el} = [C] + 0.5*[Mn] + 0.75*[Cr]$$

[0019] The slab may further include silicon (Si) of 0.1% or less (0% included) in percentage by weight.

[0020] In Equation 2, $[C]$, $[Mn]$, and $[Cr]$ are contents (percentages by weight) of C, Mn, and Cr, respectively.

[0021] Heating temperature of the slab may be 1100~1300°C, finish rolling temperature of the hot rolling may be 880°C or more, the coiling temperature may be 400~700°C, and a reduction ratio of the cold rolling may be 50~90%.

[0022] A method of manufacturing a plated steel sheet having excellent bake hardenability and room-temperature aging resistance according to an aspect of the present disclosure may further include: performing hot-dip galvanizing by dipping the cold-rolled steel sheet manufactured by the method described above in a hot-dip galvanizing bath at 440~480°C; and selectively performing alloying by maintaining at a temperature range of 460~610°C for 20 seconds or more after the hot-dip galvanizing.

[0023] The subject matters do not include all of characteristics of the present disclosure, and various characteristics and corresponding advantages and effects of the present disclosure may be understood in more detail with reference to the following detailed description.

[Advantageous Effects]

[0024] According to a preferred aspect of the present disclosure, it is possible to provide a steel sheet that has properties particularly suitable for materials of automotive external panels because bake hardenability and room-temperature aging resistance are excellent, and a method of manufacturing the steel sheet.

[BRIEF DESCRIPTION OF THE DRAWINGS]

[0025] FIG. 1 is a picture showing the microstructure of a specimen 1-1.

[Best Mode]

[0026] The present disclosure relates to a cold-rolled steel sheet and a plated steel sheet having excellent bake hardenability and room-temperature aging resistance, and a method of manufacturing the cold-rolled steel sheet and the plated steel sheet, and preferred embodiments of the present disclosure are described hereafter. Embodiments of the present disclosure may be modified in various ways and the scope of the present disclosure should not be construed as being limited to the embodiments to be described below. The embodiments are provided to describe the present disclosure in detail to those skilled in the art.

[0027] Hereafter, a cold-rolled steel sheet and a plated steel sheet having excellent bake hardenability and room-temperature aging resistance according to an aspect of the present disclosure are described in more detail hereafter.

[0028] A cold-rolled steel sheet having excellent bake hardenability and room-temperature aging resistance according to an aspect of the present disclosure includes, in percentage by weight, C: 0.002~0.015%, Mn: 1.5~3.0%, P: 0.03% or less, S: 0.01% or less, N: 0.01% or less, sol.Al: 0.02~0.06%, Cr: 1.2% or less (excluding 0%), and a balance of Fe and unavoidable impurities, and includes ferrite, which is a matrix structure, and a balance of a hard structure as a micro-structure, in which a hard structure ratio V of a grain boundary triple point defined by the following Equation 1 may be 70% or more.

[Equation 1]

$$V(\%) = \{V_{tp} / (V_{gb} + V_{tp})\} \times 100$$

[0029] In Equation 1, V_{gb} is the number of hard structures observed at a ferrite grain boundary in an observation region and V_{tp} is the number of hard structures observed at a ferrite grain boundary triple point in the observation region.

[0030] Hereafter, the alloy composition of the present disclosure is described in more detail. Hereafter, unless specifically stated, % and ppm related to the content of an alloy composition is based on weight.

[0031] A cold-rolled steel sheet having excellent bake hardenability and room-temperature aging resistance according to an aspect of the present disclosure may include, in percentage by weight, C: 0.002~0.015%, Mn: 1.5~3.0%, P: 0.03% or less, S: 0.01% or less, N: 0.01% or less, sol.Al: 0.02~0.06%, Cr: 1.2% or less (excluding 0%), and a balance of Fe and unavoidable impurities.

Carbon (C): 0.002~0.015%

[0032] Carbon (C), which is a constituent that effectively contributes to forming martensite, should be added over a predetermined level to manufacture complex phase steel intended by the present disclosure. Accordingly, the lower limit of the content of carbon (C) may be limited at 0.02% to secure bake hardenability and room-temperature aging resistance for implementing complex phase steel in the present disclosure. A preferred lower limit of the content of carbon (C) may be 0.003%, and a more preferable lower limit of the content of carbon (C) may be 0.004%. However, when carbon (C) is excessively added, it is advantageous in terms of forming complex phase steel, but the strength of the material increases and the elongation decreases, so there is a problem that the possibility of a rugged defect that is generated on the surface of a product when parts are machined by customers. Accordingly, the present disclosure may limit the upper limit of the content of carbon (C) at 0.015%. A preferred upper limit of the content of carbon (C) may be 0.013%, and a more preferable upper limit of the content of carbon (C) may be 0.01%.

Manganese (Mn): 1.5~3.0%

[0033] Manganese (Mn) is a constituent that not only contributes to improving hardenability, but effectively contributes to forming martensite like carbon (C). Accordingly, the lower limit of the content of manganese (Mn) may be limited at 1.5% to secure bake hardenability and room-temperature aging resistance for implementing complex phase steel in the present disclosure. A preferred lower limit of the content of manganese (Mn) may be 1.6%, and a more preferable lower limit of the content of manganese (Mn) may be 1.8%. However, when manganese (Mn) is excessively added, elongation decreases, so machinability is deteriorated and manganese (Mn) oxides are formed in a band shape in a structure. Accordingly, there is a problem that the possibility of cracks and coil break increases. Further, when manganese (Mn) is excessively added, there is a problem that manganese (Mn) oxides are extracted on the surface of a steel sheet in annealing, so plating ability is greatly decreased. Accordingly, the present disclosure may limit the upper limit of the content of manganese (Mn) at 3.0%. A preferred upper limit of the content of manganese (Mn) may be 2.6%, and a more preferable upper limit of the content of manganese (Mn) may be 2.3%.

Phosphorous: 0.03% or less

[0034] Phosphorous (P) in steel is an element that does not greatly decrease formability and is the most advantageous in security of strength. However, when phosphorous (P) is excessively added, the possibility of brittle fracture increases, which not only may cause coil break of a slab during hot rolling, but may remarkably deteriorate the surface characteristic of a plated steel sheet. Accordingly, the present disclosure may limit the upper limit of the content of phosphorous (P) at 0.03%. However, 0% may be excluded from the lower limit of the content of phosphorous (P) in consideration of the unavoidably included level.

Sulfur (S): 0.01% or less

[0035] Sulfur (S) is an impurity element that is unavoidably included in steel and it is preferable to manage the content as low as possible. In particular, sulfur (S) in steel may cause hot shortness, so the present disclosure may limit the upper limit of the content of sulfur (S) at 0.01%. However, 0% may be excluded from the lower limit of the content of sulfur (S) in consideration of the unavoidably included level.

Nitrogen (N); 0.01% or less

[0036] Nitrogen (N) is also an impurity element that is unavoidably included in steel. Accordingly, it is preferable to manage the content as low as possible, but the present disclosure may limit the upper limit of the content of nitrogen (N) at 0.01% in consideration of steelmaking load and work conditions. However, 0% may be excluded from the lower limit of the content of nitrogen (N) in consideration of the unavoidably included level.

Soluble aluminum (sol.Al): 0.02~0.06%

[0037] Aluminum (Al) is a constituent that is added to grain refinement and decarburization of steel. The present disclosure may limit the lower limit of the content of soluble aluminum (sol.Al) at 0.02% to manufacture Al-killed steel in a stable state. A preferable lower limit of soluble aluminum (sol.Al) may be 0.025%. However, when aluminum (Al) is excessively added, strength is increased by grain refinement, but inclusions are excessively formed in steelmaking and continuous casting, so not only the surface quality of steel may be deteriorated, but the manufacturing cost may be increased. Accordingly, the present disclosure may limit the upper limit of the content of soluble aluminum (sol.Al) at 0.06% and a more preferable upper limit of the content of soluble aluminum (sol.Al) may be 0.07%.

Chrome (Cr): 1.2% or less (excluding 0%)

[0038] Since chrome (Cr) has similar characteristics to manganese (Mn) described above, it is a constituent that not only improves hardenability of steel, but effectively contributes to forming martensite. When chrome (Cr) is added in steel, coarse chrome (Cr)-based carbides such as Cr_{23}C_6 are produced in hot rolling, so yield point elongation (YP-EI) is suppressed by controlling the amount of solute carbon (C) at a predetermined level or less in steel, whereby it is possible to provide complex phase steel having a low yield ratio. Chrome (Cr) is also an element that effectively contributes securing elongation of complex phase steel by minimizing a drop of elongation with respect to an increase of strength. Accordingly, the present disclosure may necessarily add chrome (Cr) to achieve this effect. However, when chrome (Cr) is excessively added, the generation ratio of martensite is excessively increased, so not only elongation is deteriorated, but corrosion resistance may be deteriorated. Accordingly, the present disclosure may limit the upper limit of the content of chrome (Cr) at 1.2% and a more preferable upper limit of the content of chrome (Cr) may be 0.95%.

[0039] The cold-rolled steel sheet having excellent bake hardenability and room-temperature aging resistance according to an embodiment of the present disclosure may further include silicon (Si) of 0.1% or less in percentage by weight.

Silicon (Si): 0.1% or less

[0040] Silicon (Si) is a constituent that contributes to increasing strength of steel through solid solution strengthening, but silicon is not intentionally added in the present disclosure. According to the present disclosure, it is possible to secure desired properties even without adding silicon (Si). When the content of silicon (Si) exceeds a predetermined level, there is a problem the surface characteristic of a resultant plating material is deteriorated by Si oxides produced from a hot-rolling step, so the present disclosure may limit the upper limit of the content of silicon (Si) at 0.1%. A preferable upper limit of the content of silicon (Si) may be 0.08%. However, 0% may be excluded from the lower limit of the content of silicon (Si) in consideration of the unavoidable inflow level.

[0041] The cold-rolled steel sheet having excellent bake hardenability and room-temperature aging resistance accord-

ing to an aspect of the present disclosure may include the balance of Fe and other unavoidable impurities other than the constituents described above. However, since unintended impurities may be unavoidably mixed from a raw material or a surrounding environment in a common manufacturing process, it cannot be completely excluded. Since anyone of those skilled in the art can know such impurities, all impurities are not specifically stated in the specification. Further,

[0042] In the cold-rolled steel sheet having excellent bake hardenability and room-temperature aging resistance according to an aspect of the present disclosure, H_{el} defined by the following Equation 2 can satisfy the range of 1.2~2.5.

[Equation 2]

$$H_{el} = [C] + 0.5 * [Mn] + 0.75 * [Cr]$$

[0043] In Equation 2, $[C]$, $[Mn]$, and $[Cr]$ are the contents (percentages by weight) of C, Mn, and Cr, respectively.

[0044] Since the content of carbon (C) is limited within the range of 0.002~0.015% in the present disclosure, it is necessary to add Mn and Cr that are elements improving hardenability in order to achieve the intended complex phase and Equation 2 defines the optimal contents of Mn and Cr that are elements improving hardenability. The present disclosure may limit the lower limit of H_{el} defined by Equation 2 at 1.2 to form an intended complex phase. When the H_{el} value is less than 1.2 in Equation 2, martensite is not formed even by rapid cooling after annealing due to lower hardenability, so an intended complex phase cannot be formed. A preferable lower limit of the H_{el} value may be 1.25 and a more preferable lower limit of the H_{el} value may be 1.5. However, when the H_{el} value exceeds a predetermined level, a complex phase can be formed, but yield strength and tensile strength are increased and elongation is decreased by addition of a large amount of alloy elements, so the present disclosure may limit the upper limit of the H_{el} value at 2.5. A preferable upper limit of the H_{el} value may be 2.42 and a more preferable upper limit of the H_{el} value may be 2.0.

[0045] The cold-rolled steel sheet having excellent bake hardenability and room-temperature aging resistance according to an aspect of the present disclosure may have a complex phase in which ferrite is a matrix structure and a balance structure that is a hard structure. Since the lower the fraction of ferrite, the more the fraction of a hard phase relatively increases, it is slightly advantageous in terms of implementing a complex phase, but yield strength and a yield ratio are necessarily increased, so there is a problem that the possibility of a rugged defect of a surface increases in part machining. Accordingly, the present disclosure may limit the fraction of ferrite at 95 area percentage on the basis of the thickness t of the entire steel sheet.

[0046] The hard structure included as the balance structure may be martensite, and may partially include bainite and pearlite. However, it is preferable to decrease the production amount of bainite and pearlite as small as possible. In the present disclosure, the martensite may be fine martensite of which the average diameter is $1\mu m$ or less. Since the more the martensite is fine, the more the sites (mobile dislocations) to which solute carbon (C) and nitrogen (N) adhere are formed, it is possible to more effectively secure bake hardenability and room-temperature aging resistance intended in the present disclosure. However, when a large amount of martensite is formed, there is a possibility that elongation decreases and a rugged defect of surface is generated in part machining, so it is preferable to limit the fraction of martensite at a predetermined level or less. Accordingly, the fraction of martensite may be 2 percentage by area or less (excluding 0%) in the present disclosure.

[0047] In the cold-rolled steel sheet having excellent bake hardenability and room-temperature aging resistance according to an aspect of the present disclosure, hard structure ratio V of a grain boundary triple point defined by the following Equation 1 may be 70% or more.

[Equation 1]

$$V(\%) = \{V_{tp} / (V_{gb} + V_{tp})\} \times 100$$

[0048] In Equation 1, V_{gb} is the number of hard structures observed at a ferrite grain boundary in an observation region and V_{tp} is the number of hard structures observed at a ferrite grain boundary triple point in the observation region.

[0049] For example, when a microstructure is observed using an optical or electron microscope, an observation region of $10,000\mu m^2$ is defined and the microstructure in the observation region is observed, in which the number of all martensite observed at a ferrite grain boundary in the observation region is defined as V_{gb} , the number of martensite observed at a ferrite grain boundary triple point in the same observation region is defined as V_{tp} , and the hard structure ratio V of a grain boundary triple point can be calculated.

[0050] The number V_{gb} of all martensite is the total number of martensite that can be observed at all ferrite in the

observation region using a microscope and the number V_{tp} of martensite at the grain boundary triple point may be the number of martensite that occupy even a portion of a region set within a diameter of 50nm around a point at which three or more ferrite grain boundaries meet in the observation region.

[0051] The inventor(s) of the present disclosure performed a deep study of securing both bake hardenability and room-temperature aging resistance of a steel sheet and, as a result, could find out that not only the fraction of all martensite, but distribution of martensite have great influence on bake hardenability. That is, the inventor(s) of the present disclosure could find out that it is possible to control the frequency of interaction between mobile dislocations and solute carbon C around martensite by controlling distribution of the martensite, and derived the present disclosure by the observation that distribution of martensite is controlled under optimal conditions to secure both bake hardenability and room-temperature aging resistance.

[0052] Martensite is formed during cooling of a steel sheet and a large amount of mobile dislocations are formed around the martensite due to expansion. Increasing the fraction of martensite is one method of improving bake hardenability, but in this case, deterioration of room-temperature aging resistance necessarily accompanies, so it is very difficult to achieve the object of securing both bake hardenability and room-temperature aging resistance.

[0053] A large amount of carbon (C) is concentrated at the ferrite grain boundary in comparison to the inside of the ferrite grains, and a grain boundary triple point of ferrite shows high concentration of carbon (C) even among ferrite grain boundaries. When a common bake heat treatment condition (170°C and 20 minutes) is applied to a steel sheet, carbon (C) most actively diffuses from the grain boundary triple point of ferrite, which means that carbon (C) can more easily adhere to mobile dislocations existing at the grain boundary triple point of ferrite. However, under an artificial aging condition (100°C and 1 hour), temperature is relatively low, so the diffusion of carbon (C) from a grain boundary and the martensite is limited, so there is no large difference according to distribution of martensite. That is, it means that when a large amount of martensite is distributed at a grain boundary triple point of ferrite, it is possible to further improve bake hardenability while maintaining room-temperature aging resistance of a steel sheet.

[0054] Accordingly, since the hard structure ratio V of a grain boundary triple point defined by Equation 2 is limited at 70% or more in the present disclosure, it is possible to effectively improve bake hardenability while maintaining room-temperature aging resistance at a predetermined level.

[0055] In the cold-rolled steel sheet having excellent bake hardenability and room-temperature aging resistance according to an aspect of the present disclosure, a bake hardening amount may be 30MPa or more (BH, tension test after heat treatment at 170°C for 20 minutes) and yield point elongation may be 0.2% or less (YP-EI, tension test after heat treatment at 100°C for 1 hour).

[0056] A plated steel sheet having excellent bake hardenability and room-temperature aging resistance according to another aspect of the present disclosure may include a plating layer or an alloying-plating layer on at least a side of the cold-rolled steel described above. The plating layer and the alloying-plating layer may be a hot-dip galvanized layer and a galvanized layer, but they are not necessarily limited thereto and may be construed as a concept including all plating layers or alloying-plating layers suitable for materials of automotive external panels.

[0057] Hereafter, a method of manufacturing the cold-rolled steel sheet having excellent bake hardenability and room-temperature aging resistance according to an aspect of the present disclosure is described in more detail hereafter.

[0058] The method of manufacturing the cold-rolled steel sheet having excellent bake hardenability and room-temperature aging resistance according to an aspect of the present disclosure includes: heating a slab having a predetermined alloy composition; providing a hot-rolled steel sheet by hot-rolling the slab; coiling the hot-rolled steel sheet; providing a cold-rolled steel sheet by cold-rolling the hot-rolled steel sheet; and continuously annealing the cold-rolled steel sheet, in which the continuous annealing may increase temperature up to a range of $(Ac1+5^{\circ}C) \sim (Ac3-20^{\circ}C)$ at a temperature increasing speed of $1 \sim 10^{\circ}C/s$ and then maintain the temperature for 30~240 seconds.

Slab heating

[0059] A slab having a predetermined alloy composition may be prepared and then slab reheating may be performed. The slab of the present disclosure has an alloy composition corresponding to the cold-rolled steel sheet described above, so a description of the alloy composition of the slab refers to the alloy composition of the cold-rolled steel sheet described above.

[0060] Since slab reheating is performed to smoothly perform following hot rolling and sufficiently achieve intended properties of a steel sheet, conditions for such slab reheating are not specifically limited in the present disclosure. Accordingly, slab reheating can be performed under common conditions in the present disclosure, and for example, slab reheating may be performed in a temperature range of 1100~1300°C.

Hot rolling and coiling

[0061] A reheated slab may be finish-rolled within a temperature range of 880°C or more and then coiled in a temperature

range of 400~700°C.

[0062] It is preferable to perform finish hot rolling in a single phase region of austenite. When finish hot rolling is performed in a single phase region of austenite, pancakeshaped austenite and a deformation band are formed, so it is more advantageous in the refinement of the resultant structure. Further, when finish hot rolling is performed in a two phase region of austenite and ferrite, a non-uniform material quality is caused and excessive rolling load may be caused. Accordingly, the present disclosure may limit the temperature range of finish hot rolling at 880°C or more such that finish hot rolling is performed in a single phase region of austenite. The present disclosure does not specifically limit the upper limit of the finish hot rolling temperature. However, it is possible to limit the upper limit of the temperature range of finish hot rolling at 950°C in order to prevent a non-uniform material quality due to production of abnormal coarse grains.

[0063] Thereafter, the steel plate that has undergone hot roller may be coiled into a hot-rolled coil. When a coiling temperature does not reach a predetermined level, a large amount of hard phases such as martensite or bainite are formed, so the strength of the steel may be excessively increased. Accordingly, the present disclosure may limit the coiling temperature at 400°C or more in order to reduce rolling load and prevent poor shaping in following cold rolling after coiling. However, when the coiling temperature exceeds a predetermined range, there is a problem that surface concentration of oxidative elements in steel increases. Accordingly, the present disclosure may limit the upper limit of the coiling temperature at 700°C to secure a surface quality and a plating quality of a steel sheet.

Cold rolling

[0064] The coiled hot-rolled steel sheet may be pickled under common conditions and then cold rolling is applied, whereby a cold-rolled steel sheet can be provided. It is preferable to perform cold rolling at a reduction ratio of 50~90% in the present disclosure. If the reduction ratio of cold rolling is less than a predetermined level, there is a problem that it is difficult to secure an intended thickness of a steel sheet and it is difficult to correct the shape of the steel sheet, so the present disclosure may limit the lower limit of the reduction ratio at 50% in cold rolling. However, when the reduction ratio of cold rolling exceeds a predetermined level, the possibility that cracks are formed at the edge of the steel sheet is high and excessive rolling load may become a problem, so the present disclosure may limit the upper limit of the reduction ratio at 90% in cold rolling.

Continuous annealing

[0065] In order to control an intended microstructure, particularly, the fractions of ferrite and martensite and distribution of martensite in the present disclosure, it is necessary to severely manage continuous annealing conditions. In order to secure the intended microstructure of the present disclosure, it is possible to perform continuous annealing of increasing the temperature of the cold-rolled steel sheet that has undergone cold rolling up to a temperature range of (Ac1+5°C)~(Ac3-20°C) at a temperature increasing speed of 1~10°C/s and then maintaining the temperature for 30~240 seconds.

[0066] When the temperature increasing speed is lower than a predetermined level in continuous annealing, non-uniformity of a size between structures increases and the size of initial ferrite unnecessarily increases due to an increase of temperature which is too slow, so the strength of the steel sheet may decrease. That is, as the size of grains of ferrite increases, the area ratio of the ferrite grain boundary triple point of ferrite grain boundaries decreases, and the content of entire martensite decreases even if an intended martensite ratio V in a ferrite grain boundary triple point is secured, so it may be difficult to secure intended properties. Accordingly, the present disclosure may limit the lower limit of the temperature increasing speed at 1°C/s and a more preferable upper limit of the temperature increasing speed may be 2°C/s. However, the present disclosure does not specifically limit the upper limit of the temperature increasing speed in continuous annealing. However, when the temperature increasing speed is excessively high, excessive load may be applied to the on-site facilities, so the present disclosure may limit the upper limit of the temperature increasing speed at 10°C/s.

[0067] It is preferable that the annealing temperature is the range of (Ac1+5°C) ~ (Ac3-20°C). Since the present disclosure intends to control the fractions of ferrite and martensite and distribution of martensite in a resultant steel sheet, it is possible to perform continuous annealing of maintaining a two-phase region temperature range for a predetermined time. When the annealing temperature is excessively low, an austenite fraction at a two-phase region temperature is excessively low, so there is a problem that it is impossible to achieve a martensite fraction at an intended level in the resultant steel sheet. Accordingly, the present disclosure may limit the lower limit of annealing temperature at (Ac1+5°C) in order to achieve the intended martensite fraction. A preferable lower limit of the annealing temperature may be (Ac1+10°C) and a more preferable lower limit of the annealing temperature may be (Ac1+15°C).

[0068] However, in common dual phase steel (DP) over 590MPa, when annealing temperature increases, an austenite fraction at a two-phase region temperature increases, and accordingly, there may be a problem that a large amount of coarse martensite is formed in the resultant steel sheet. However, in low-strength dual phase and complex phase steel

under 490MPa, when annealing temperature increases, an austenite fraction at a two-phase region temperature increases, but it does not mean that a martensite fraction is high in the resultant steel sheet. The fact that the austenite fraction increases at the two-phase region temperature means that hardenability elements (representatively C and Mn) existing in the steel sheet diffuse to more austenite regions, and means that the concentration of hardenability elements in austenite is low in comparison to low two-phase region temperature (which means a lower two-phase region austenite fraction). That is, when the annealing temperature increases, transformation into ferrite becomes easy during cooling after annealing by decreasing stability of austenite, so the content of martensite finally produced decreases on the contrary, whereby it is difficult to secure an intended content of martensite. That is, in low-strength complex phase steel under 490Mpa intended in the present disclosure, when annealing temperature is excessively high, stability of two-phase region austenite excessively decreases, so the final martensite fraction decreases, whereby there is a problem that it is impossible to secure bake hardenability at an intended level.

[0069] Further, the present disclosure intends to perform continuous annealing in a two-phase region temperature range, but it is preferable to perform continuous annealing in a temperature range in which ferrite formation is as advantageous as possible. This is because when continuous annealing is performed in a temperature range in which ferrite formation is advantageous, initial ferrite formation is promoted, so an environment that is more advantageous for grain growth can be provided. Further, when continuous annealing is performed in a temperature range in which ferrite formation is advantageous, the concentration of carbon (C) and manganese (Mn) in austenite is increased, so it is possible to decrease martensite transformation start temperature M_s . Further, it is possible to induce fine and uniform martensite to be distributed and formed in a large quantity in ferrite grains in a following cooling process or a cooling process after plating. Accordingly, the present disclosure may limit the upper limit of annealing temperature at ($Ac_3-20^\circ C$) to secure an intended martensite ratio V of a ferrite grain boundary triple point. A preferable upper limit of the annealing temperature may be ($Ac_3-25^\circ C$) and a more preferable upper limit of the annealing temperature may be ($Ac_3-30^\circ C$).

[0070] A maintenance time after temperature is increased is an important process variable for securing the microstructure intended in the present disclosure. When the maintenance time after temperature is increased is less than a predetermined level, carbon (C) and manganese (Mn) do not sufficiently diffuse to austenite formed in the two-phase region period, so stability of the austenite decreases, whereby the possibility that austenite transforms into another microstructure rather than the intended martensite during cooling after annealing is increased. Accordingly, the present disclosure may limit the lower limit of the maintenance time after temperature is increased at 30 seconds and a more preferable lower limit of the maintenance time after temperature is increased may be 60 seconds. However, when the maintenance time after temperature is increased exceeds a predetermined level, the ferrite formed in the early stage unnecessarily coarsens, so non-uniformity may be caused in structure size of ferrite and other structures formed after final cooling. As described above, non-uniformity in structure sizes is a factor that deteriorates bake hardenability and aging resistance, so the present disclosure may limit the upper limit of the maintenance time after temperature is increased at 240 seconds. A more preferable upper limit of the maintenance time after temperature is increased may be 180 seconds.

[0071] The cold-rolled steel sheet manufactured through the manufacturing process described above may include ferrite of 95 area percentage or more and the balance of martensite as a microstructure and a hard structure ratio V of a grain boundary triple point defined by the following Equation 1 may satisfy 70% or more.

[Equation 1]

$$V(\%) = \{V_{tp} / (V_{gb} + V_{tp})\} \times 100$$

[0072] In Equation 1, V_{gb} is the number of hard structures observed at a ferrite grain boundary in an observation region and V_{tp} is the number of hard structures observed at a ferrite grain boundary triple point in the observation region.

[0073] Further, the cold-rolled steel sheet manufactured through the manufacturing method described above may satisfy a bake hardening amount of 30MPa or more (BH, tension test after heat treatment at $170^\circ C$ for 20 minutes) and yield point elongation of 0.2% or less (YP-El, tension test after heat treatment at $100^\circ C$ for 1 hour).

[0074] The plated steel sheet having excellent bake hardenability and room-temperature aging resistance according to an aspect of the present disclosure can be provided by applying a plating process to the cold-rolled steel sheet manufactured through the manufacturing method described above. The plating process may be a hot-dip galvanizing process or a galvannealing process, but is not necessarily limited thereto, and all plating processes that are applied to the materials of common automotive external panels may be applied.

[0075] As a non-limiting example of the plating process, a hot-dip galvanizing process that dips the cold-rolled steel sheet described above into a hot-dip galvanizing bath (Pot) at $440\sim 480^\circ C$ that is a common temperature range may be applied. Further, as another non-limiting example of the plating process, a galvannealing process that performs alloying by dipping the cold-rolled steel sheet described above into a hot-dip galvanizing bath (Pot) at $440\sim 480^\circ C$ that is a

common temperature range and then maintaining the cold-rolled steel sheet for 20 seconds or more at a temperature range of 460~610°C may be applied.

[Mode for Invention]

[0076] Hereafter, the present disclosure is described in more detail through embodiments. However, it should be noted that the following embodiments are provided only to concrete the present disclosure through exemplification rather than limiting the right range of the present disclosure.

(Embodiment)

[0077] A slab having the alloy composition shown in Table 1 was prepared and the process conditions shown in Table 2 were applied, whereby a hot-dip galvanized steel sheet was manufactured. A slab reheating temperature condition of 1200°C and a cold-cooling reduction ratio of 70% were commonly applied to each specimen. The results of observing the microstructure and measuring properties of the specimens were shown in Table 2.

[0078] A hard structure ratio V of a grain boundary triple point was measured using a scanning microscope (SEM, JEOL JSN-7001F, resolution: 1nm). In detail, an observation region 10,000 μm^2 was defined at a 1/4t point in the thickness direction of each of the specimens and the number of martensite existing a ferrite grain boundary in the observation region was measured, whereby a hard structure ratio V of a grain boundary triple point was calculated. The number of all martensite is the total number of martensite that can be observed at all ferrite grain boundaries in the observation region using a scanning microscope. Further, the number of martensite of a grain boundary triple point is the number of martensite occupying even a portion of a region set within a diameter of 50nm around a point at which three or more ferrite grain boundaries meet in the observation region.

[0079] Bake hardenability (BH₂) was measured by measuring flow-stress at 2% by pre-straining each specimen by 2% and performing a tension test after performing heat treatment on the same specimen at 170°C for 20 seconds. Yield point elongation (YP-EI) was measured by performing a tension test after heat treatment at 100°C for 1 hour. In this case, ASTM-e8/e8m-16a was applied as a tension test condition.

[Table 1]

steel type s	Alloy composition (wt%)								[Equation 2] Hel	A _{c1} * (°C)	A _{c3} ** (°C)
	c	Mn	P	S	N	Cr	S-Al	Si			
1	0.0035	2.21	0.013	0.005	0.003	0.74	0.028	0.003	1.66	734	873
2	0.0071	2.49	0.011	0.004	0.003	0.91	0.032	0.004	1.93	734	868
3	0.0024	2.05	0.008	0.006	0.004	0.48	0.033	0.001	1.39	731	876
4	0.011	1.65	0.091	0.007	0.003	0.25	0.024	0.002	1.02	731	880
5	0.0097	1.98	0.013	0.003	0.002	0.62	0.031	0.003	1.46	734	875
6	0.0068	2.34	0.021	0.004	0.003	0.53	0.045	0.001	1.64	729	856
7	0.0014	2.45	0.018	0.005	0.004	0.63	0.033	0.002	1.70	731	872
8	0.0085	1.31	0.021	0.004	0.004	0.35	0.039	0.005	0.93	735	884
9	0.0021	4.15	0.016	0.006	0.002	0.65	0.033	0.002	2.56	719	853
10	0.0017	0.88	0.015	0.005	0.005	0.87	0.043	0.001	1.09	745	888
[00110] * A _{c1} =739-22*[C]-7*[Mn]+2*[Si]+14*[Cr]+13*[Mo]-13*[Ni] [00111] ** A _{c3} =902-255*[C]-11*[Mn]+19*[Si]-5*[Cr]+13*[Mo]-20*[Ni]+55*[V]											

[Table 2]

Steel types	Specimen No	Hot rolling		Continuous annealing			[Equation 1] V (%)	BH ₂ (MPa)	YPEI (%)
		FDT (°C)	CT (°C)	Annealing temperature (°C)	Temperature increasing speed (°C/s)	Maintenance time (s)			
1	1-1	927	642	785	2.8	124	78	42	0
	1-2	931	613	805	7.6	68	81	38	0
2	2-1	915	519	718	3.5	52	0	39	0.65
	2-2	941	581	820	5.2	49	90	51	0
3	3-1	921	667	797	6.2	168	85	47	0
	3-2	916	629	822	0.3	205	62	28	0.11
4	4-1	909	558	815	8.1	187	57	28	0
	4-2	935	228	864	4.9	109	76	32	0.28
5	5-1	924	670	825	5.7	39	83	43	0
	5-2	921	561	895	3.3	64	54	38	0.34
6	6-1	932	553	828	9.2	384	38	27	0.41
	6-2	911	605	782	6.8	221	73	57	0
7	7-1	908	646	785	1.5	194	77	25	0.08
8	8-1	910	635	824	6.0	143	83	42	0.75
9	9-1	915	579	835	2.5	89	87	38	0.51
10	10-1	922	622	831	3.4	75	92	22	0.81

[0080] It could be seen that specimens that satisfy all of the alloy compositions and the process conditions limited by the present disclosure satisfied both bake hardenability and room-temperature aging resistance intended in the present disclosure, but specimens that did not satisfy any one or more of the alloy compositions and the process conditions limited by the present disclosure did not satisfy both bake hardenability and room-temperature aging resistance intended in the present disclosure.

[0081] Although the present disclosure was described in detail above through embodiments, other embodiments may be possible. Therefore, the spirit and scope of the following claims are not limited to the embodiments.

Claims

1. A cold-rolled steel sheet having excellent bake hardenability and room-temperature aging resistance, the cold-rolled steel sheet comprising, in percentage by weight,

C: 0.002~0.015%, Mn: 1.5~3.0%, P: 0.03% or less, S: 0.01% or less, N: 0.01% or less, sol.Al: 0.02~0.06%, Cr: 1.2% or less (excluding 0%), and a balance of Fe and unavoidable impurities, and comprising ferrite, which is a matrix structure, and a balance of a hard structure as a microstructure, wherein a hard structure ratio V of a grain boundary triple point defined by the following Equation 1 is 70% or more,

[Equation 1]

$$V(\%) = \{V_{tp} / (V_{gb} + V_{tp})\} \times 100$$

in Equation 1, V_{gb} is the number of hard structures observed at a ferrite grain boundary in an observation region and V_{tp} is the number of hard structures observed at a ferrite grain boundary triple point in the observation region.

2. The cold-rolled steel sheet of claim 1, wherein a fraction of the ferrite is 95% or more in area percentage, and the hard structure includes martensite.
3. The cold-rolled steel sheet of claim 1, wherein H_{el} defined by the following Equation 2 satisfies a range of 1.2~2.5,

[Equation 2]

$$H_{el} = [C] + 0.5*[Mn] + 0.75*[Cr]$$

in Equation 2, $[C]$, $[Mn]$, and $[Cr]$ are contents (percentages by weight) of C, Mn, and Cr, respectively.

4. The cold-rolled steel sheet of claim 1, further comprising silicon (Si) of 0.1% or less (0% included) in percentage by weight.
5. The cold-rolled steel sheet of claim 1, wherein a bake hardening amount is 30MPa or more (BH, tension test after heat treatment at 170°C for 20 minutes) and yield point elongation is 0.2% or less (YP-EI, tension test after heat treatment at 100°C for 1 hour).
6. A plated steel sheet having excellent bake hardenability and room-temperature aging resistance, the plated steel sheet comprising:

the cold-rolled steel sheet of any one of claims 1 to 5; and
a plating layer or an alloying-plating layer on at least a side of the cold-rolled steel sheet.

7. A method of manufacturing a cold-rolled steel sheet having excellent bake hardenability and room-temperature aging resistance, the method comprising:

heating a slab including, in percentage by weight, C: 0.002~0.015%, Mn: 1.5~3.0%, P: 0.03% or less, S: 0.01% or less, N: 0.01% or less, sol.Al: 0.02~0.06%, Cr: 1.2% or less (excluding 0%), and a balance of Fe and unavoidable impurities;
providing a hot-rolled steel sheet by hot-rolling the slab;
coiling the hot-rolled steel sheet;
providing a cold-rolled steel sheet by cold-rolling the hot-rolled steel sheet; and
continuously annealing the cold-rolled steel sheet,
wherein the continuous annealing increases temperature up to a range of $(Ac1+5^{\circ}C) \sim (Ac3-20^{\circ}C)$ at a temperature increasing speed of 1~10°C/s and then maintains the temperature for 30~240 seconds.

8. The method of claim 7, wherein the slab is configured such that H_{el} defined by the following Equation 2 satisfies a range of 1.2~2.5,

[Equation 2]

$$H_{el} = [C] + 0.5*[Mn] + 0.75*[Cr]$$

in Equation 2, $[C]$, $[Mn]$, and $[Cr]$ are contents (percentages by weight) of C, Mn, and Cr, respectively.

9. The method of claim 7, wherein the slab further includes silicon (Si) of 0.1% or less (0% included) in percentage by weight.
10. The method of claim 7, wherein heating temperature of the slab is 1100~1300°C,
finish rolling temperature of the hot rolling is 880°C or more,
the coiling temperature is 400~700°C, and
a reduction ratio of the cold rolling is 50~90%.

11. A method of manufacturing a plated steel sheet having excellent bake hardenability and room-temperature aging

resistance, the method further comprising:

performing hot-dip galvanizing by dipping the cold-rolled steel sheet of any one of claims 7 to 10 in a hot-dip galvanizing bath at 440~480°C; and
selectively performing alloying by maintaining at a temperature range of 460~610°C for 20 seconds or more after the hot-dip galvanizing.

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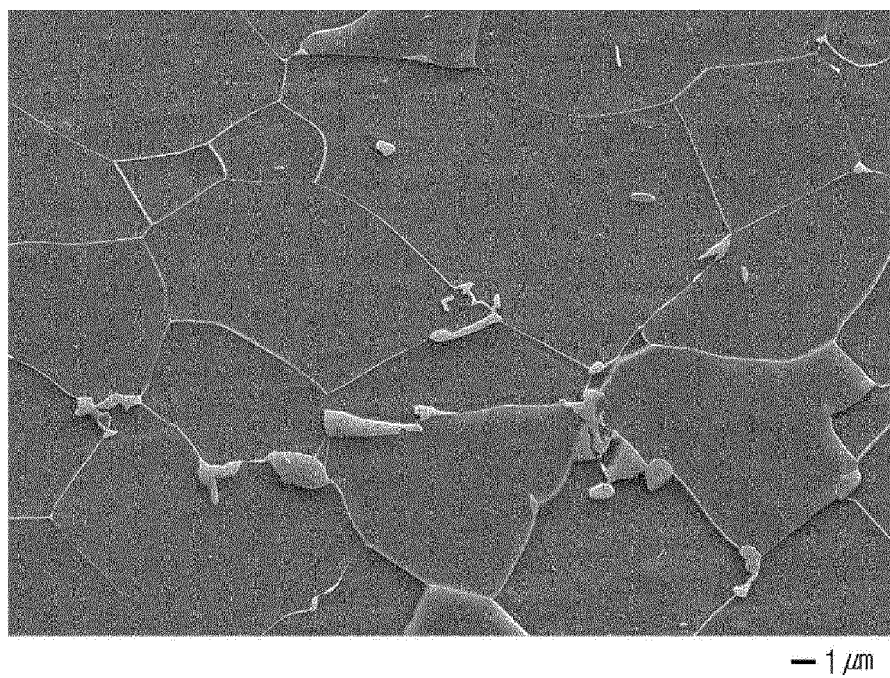
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【FIG. 1】



INTERNATIONAL SEARCH REPORT

International application No.

PCT/KR2020/017650

A. CLASSIFICATION OF SUBJECT MATTER C22C 38/38(2006.01)i; C21D 8/02(2006.01)i; C21D 8/12(2006.01)i; B21B 3/00(2006.01)i; B21B 1/24(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) C22C 38/38(2006.01); C21D 8/02(2006.01); C21D 8/04(2006.01); C21D 9/46(2006.01); C22C 38/00(2006.01); C22C 38/02(2006.01); C22C 38/04(2006.01); C22C 38/18(2006.01)																		
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: 소부경화성(bake hardenability), 연속소둔(continuous annealing), 냉연강판(cold rolling), 내식효성(aging resistance), 망간(Mn)																		
C. DOCUMENTS CONSIDERED TO BE RELEVANT																		
<table border="1"> <thead> <tr> <th>Category*</th> <th>Citation of document, with indication, where appropriate, of the relevant passages</th> <th>Relevant to claim No.</th> </tr> </thead> <tbody> <tr> <td>Y</td> <td>KR 10-2017-0012865 A (POSCO) 03 February 2017 (2017-02-03) See paragraphs [0103], [0110], [0121]-[0122] and [0126], claims 1 and 5-6 and table 2.</td> <td>1-11</td> </tr> <tr> <td>Y</td> <td>US 4496400 A (IRIE et al.) 29 January 1985 (1985-01-29) See column 9, lines 13-19 and figure 1a.</td> <td>1-11</td> </tr> <tr> <td>A</td> <td>JP 07-300623 A (KAWASAKI STEEL CORP.) 14 November 1995 (1995-11-14) See claims 1-4.</td> <td>1-11</td> </tr> <tr> <td>A</td> <td>KR 10-2005-0068358 A (POSCO) 05 July 2005 (2005-07-05) See claims 1-3.</td> <td>1-11</td> </tr> <tr> <td>A</td> <td>CN 106244923 A (BAOSHAN IRON & STEEL CO., LTD.) 21 December 2016 (2016-12-21) See claims 1 and 7.</td> <td>1-11</td> </tr> </tbody> </table>	Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.	Y	KR 10-2017-0012865 A (POSCO) 03 February 2017 (2017-02-03) See paragraphs [0103], [0110], [0121]-[0122] and [0126], claims 1 and 5-6 and table 2.	1-11	Y	US 4496400 A (IRIE et al.) 29 January 1985 (1985-01-29) See column 9, lines 13-19 and figure 1a.	1-11	A	JP 07-300623 A (KAWASAKI STEEL CORP.) 14 November 1995 (1995-11-14) See claims 1-4.	1-11	A	KR 10-2005-0068358 A (POSCO) 05 July 2005 (2005-07-05) See claims 1-3.	1-11	A	CN 106244923 A (BAOSHAN IRON & STEEL CO., LTD.) 21 December 2016 (2016-12-21) See claims 1 and 7.	1-11
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<table border="1"> <tr> <td>Date of the actual completion of the international search 02 March 2021</td> <td>Date of mailing of the international search report 03 March 2021</td> </tr> </table>	Date of the actual completion of the international search 02 March 2021	Date of mailing of the international search report 03 March 2021																
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<table border="1"> <tr> <td> Name and mailing address of the ISA/KR Korean Intellectual Property Office Government Complex-Daejeon Building 4, 189 Cheongsaro, Seo-gu, Daejeon 35208 Facsimile No. +82-42-481-8578 </td> <td> Authorized officer Telephone No. </td> </tr> </table>	Name and mailing address of the ISA/KR Korean Intellectual Property Office Government Complex-Daejeon Building 4, 189 Cheongsaro, Seo-gu, Daejeon 35208 Facsimile No. +82-42-481-8578	Authorized officer Telephone No.																
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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

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