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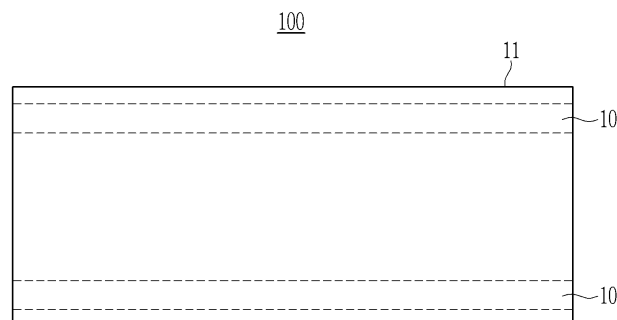
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(54) **NON-ORIENTED ELECTRICAL STEEL SHEET AND METHOD FOR MANUFACTURING SAME**

(57) A grain-oriented electrical steel sheet according to an embodiment of the present disclosure includes, in wt%, Si: 1.5 to 5.0%, Al: 0.1 to 2.0%, Mn: 0.1 to 2.0%, Sn: 0.001 to 0.08%, Sb: 0.001 to 0.08%, and B: 0.0002 to 0.0007% and includes the balance of Fe and an inevitable impurity. A weight ratio of a max-

imum Si content to a maximum Al content is 25 or less when an element content is measured in a direction of a thickness of the steel sheet in a surface portion within a range of 0.3 to 1 μm from a surface of the steel sheet toward the inside of the steel sheet.

FIG. 1



Description**[Technical Field]**

5 **[0001]** An embodiment of the present disclosure relates to a non-oriented electrical steel sheet and a method for manufacturing the same. Specifically, the embodiment of the present disclosure relates to the non-oriented electrical steel sheet using segregation of B, Sn, and Sb and densely concentrating Al and Si on a surface portion thereof by adjusting a condition in a cold-rolled sheet annealing process to simultaneously improve a mechanical strength and a magnetic characteristic, and the method for manufacturing the same.

[Background Art]

10 **[0002]** A non-oriented electrical steel sheet is mainly used in a motor that converts an electrical energy into a mechanical energy, and in order to achieve a high efficiency in the process, an excellent magnetic characteristic of the non-oriented electrical steel sheet is required. In particular, as an eco-friendly vehicle driven by a motor instead of an internal combustion engine has been gaining attention recently, demand for the non-oriented electrical steel sheet used as a core material of a driving motor is increasing, and for this purpose, the non-oriented electrical steel sheet with the excellent magnetic characteristic and an excellent strength is required.

20 **[0003]** A core of the motor may be divided into a stator core and a rotor core. In order to meet demand for miniaturization and a high output for a HEV driving motor or the like, the non-oriented electrical steel sheet used for the stator core is strongly required to have the excellent magnetic characteristic such as a high magnetic flux density and a low iron loss.

25 **[0004]** The number of revolutions of the motor that is a means of achieving the miniaturization and the high output of the HEV driving motor or the like tends to be increased, but because the HEV driving motor has a large outer diameter, a large centrifugal force acts on the rotor core and a very narrow portion called a bridge portion of the rotor core exists depending on a structure so that a mechanical strength is also required for the non-oriented electrical steel sheet used for the rotor core.

30 **[0005]** Thus, a characteristic of the non-oriented electrical steel sheet used in the motor core requires a high strength along with a magnetic characteristic for the rotor core and a high magnetic flux density and a low iron loss for the stator core. Even if the non-oriented electrical steel sheet is used for the same motor core, a characteristic required in the rotor core and a characteristic required in the stator core are significantly different. However, from a viewpoint of increasing a material yield or the like when the motor core is manufactured, it is preferable to simultaneously collect a rotor core material and a stator core material from the same material steel sheet and then stack each core material to assemble the stacked materials into the rotor core or the stator core.

[Disclosure]**[Technical Problem]**

40 **[0006]** An embodiment of the present disclosure provides a non-oriented electrical steel sheet and a method for manufacturing the same. Specifically, the embodiment of the present disclosure provides the non-oriented electrical steel sheet densely concentrating Al and Si on a surface portion thereof by using segregation of B, Sn, and Sb and adjusting a condition in a cold-rolled sheet annealing process to simultaneously improve a mechanical strength and a magnetic characteristic, and the method for manufacturing the same.

[Technical Solution]

50 **[0007]** A non-oriented electrical steel sheet according to an embodiment of the present disclosure includes, in wt%, Si: 1.5 to 5.0%, Al: 0.1 to 2.0%, Mn: 0.1 to 2.0%, Sn: 0.001 to 0.08%, Sb: 0.001 to 0.08%, and B: 0.0002 to 0.0007% and includes the balance of Fe and an inevitable impurity. A weight ratio of an Al content to Si at a point where the Al content is maximum is 25 or less when an element content is measured in a direction of a thickness of the steel sheet in a surface portion within a range of 0.3 to 1 μm from a surface of the steel sheet toward the inside of the steel sheet.

[0008] The maximum Al content may be 1.8 wt% or more when the element content is measured in the direction of the thickness of the steel sheet in the surface portion.

55 **[0009]** A Si content at the point where the Al content is maximum may be 0.5 wt% or more when the element content is measured in the direction of the thickness of the steel sheet in the surface portion.

[0010] The non-oriented electrical steel sheet may further include S: 0.005 wt% or less (excluding 0%). The non-oriented electrical steel sheet may satisfy Equation below.

[Equation]

$$0.7 \leq ([\text{Sn}] + [\text{Sb}] + [\text{S}] \times 10)/([\text{B}] \times 100) \leq 5.2.$$

[0011] In Equation above, [Sn], [Sb], [S], and [B] may represent a content (wt %) of Sn, a content (wt %) of Sb, a content (wt %) of S, and a content (wt %) of B, respectively.

[0012] The non-oriented electrical steel sheet may further include at least one of P: 0.1 wt% or less (excluding 0%), C: 0.005 wt% or less (excluding 0%), Ti: 0.005 wt% or less (excluding 0%), and N: 0.005 wt% or less (excluding 0%).

[0013] The non-oriented electrical steel sheet may further include 0.005 to 0.200 wt% of each or a combined amount of one or more of Bi, Pb, Ge, and As.

[0014] The non-oriented electrical steel sheet may further include at least one of Cu: 0.005 to 0.2 wt%, Cr: 0.01 to 0.5 wt%, Ni: 0.05 wt% or less (excluding 0%), Zn: 0.01 wt% or less (excluding 0%), and Co: 0.05 wt% or less (excluding 0%).

[0015] The non-oriented electrical steel sheet may further include at least one of Mo: 0.03 wt% or less (excluding 0%), B: 0.0050 wt% or less (excluding 0%), V: 0.0050 wt% or less (excluding 0%), Ca: 0.0050 wt% or less (excluding 0%), Nb: 0.0050 wt% or less (excluding 0%), Zr: 0.005 wt% or less (excluding 0%), Te: 0.01 wt% or less (excluding 0%), and Mg: 0.0050 wt% or less (excluding 0%).

[0016] A method for manufacturing a non-oriented electrical steel sheet according to an embodiment of the present disclosure includes: manufacturing a hot-rolled steel sheet by hot-rolling a slab including, in wt%, Si: 1.5 to 5.0%, Al: 0.1 to 2.0%, Mn: 0.1 to 2.0%, Sn: 0.001 to 0.08%, Sb: 0.001 to 0.08%, and B: 0.0002 to 0.0007% and including the balance of Fe and an inevitable impurity; manufacturing a cold-rolled sheet by cold-rolling the hot-rolled steel sheet; and annealing the cold-rolled sheet. In the annealing of the cold-rolled sheet, a cracking temperature is 900 to 1050°C, a hydrogen fraction within an atmosphere is 10 to 35 volume%, and a dew point of the atmosphere is -55 to -15°C.

[0017] The slab may further include S: 0.005 wt% or less (excluding 0%), and the slab may satisfy Equation below.

[Equation]

$$0.7 \leq ([\text{Sn}] + [\text{Sb}] + [\text{S}] \times 10)/([\text{B}] \times 100) \leq 5.2.$$

[0018] In Equation above, [Sn], [Sb], [S], and [B] may represent a content (wt %) of Sn, a content (wt %) of Sb, a content (wt %) of S, and a content (wt %) of B, respectively.

[0019] The slab may further include at least one of P: 0.1 wt% or less (excluding 0%), C: 0.005 wt% or less (excluding 0%), Ti: 0.005 wt% or less (excluding 0%), and N: 0.005 wt% or less (excluding 0%).

[0020] The slab may further include 0.005 to 0.200 wt% of each or a combined amount of one or more of Bi, Pb, Ge, and As.

[0021] The slab may further include at least one of Cu: 0.005 to 0.2 wt%, Cr: 0.01 to 0.5 wt%, Ni: 0.05 wt% or less (excluding 0%), Zn: 0.01 wt% or less (excluding 0%), and Co: 0.05 wt% or less (excluding 0%).

[0022] The slab may further include at least one of Mo: 0.03 wt% or less (excluding 0%), B: 0.0050 wt% or less (excluding 0%), V: 0.0050 wt% or less (excluding 0%), Ca: 0.0050 wt% or less (excluding 0%), Nb: 0.0050 wt% or less (excluding 0%), Zr: 0.005 wt% or less (excluding 0%), Te: 0.01 wt% or less (excluding 0%), and Mg: 0.0050 wt% or less (excluding 0%).

[Advantageous Effects]

[0023] A non-oriented electrical steel sheet according to an embodiment of the present disclosure may have an excellent mechanical strength after cold-rolled sheet annealing and an excellent high-frequency iron loss characteristic after stress relief annealing.

[Description of the Drawings]

[0024]

FIG. 1 is a schematic diagram showing a cross-section of a steel sheet according to an embodiment of the present disclosure.

FIG. 2 is a schematic diagram schematically showing an analysis graph of each of an Al concentration and a Si concentration by thickness of the steel sheet according to an embodiment of the present disclosure.

[Mode for Invention]

[0025] Terms such as "first", "second", and "third" are used herein to describe various portions, components, regions, layers, and/or sections, but are not limited thereto. The terms are used only to distinguish one portion, component, region, layer, or section from another portion, component, region, layer, or section. Accordingly, a first portion, component, region, layer, or section described below may be referred to as a second portion, component, region, layer, or section within a scope that does not depart from a scope of the present disclosure.

[0026] A technical term used herein is intended only to refer to a specific embodiment, and is not intended to limit the present disclosure. Singular forms used herein also include plural forms unless phrases clearly indicate an opposite meaning. A term "include" used in the specification specifies a specific characteristic, region, integer, step, operation, element, and/or component, and does not exclude presence or addition of another characteristic, region, integer, step, operation, element, and/or component.

[0027] When it is said that a portion is "on" or "above" another portion, the portion may be disposed directly on or above the other portion, or another portion may be interposed therebetween. In contrast, when a portion is said to be "directly above" another portion, no other portion is interposed therebetween.

[0028] Unless otherwise stated, % means wt%, and 1 ppm is 0.0001 wt%.

[0029] In an embodiment of the present disclosure, inclusion of an additional element means replacing the balance of iron (Fe) by an additional amount of the additional element.

[0030] Although not otherwise defined, all terms used herein, including a technical term and a scientific term, have the same meanings as those generally understood by a person of ordinary skill in the art to which the present disclosure belongs. Terms defined in a dictionary commonly used are additionally interpreted to have a meaning consistent with the relevant technical literature and the presently disclosed contents, and are not interpreted in an ideal or very formal sense unless otherwise defined.

[0031] Hereinafter, an embodiment of the present disclosure will be described in detail so that a person of ordinary skill in the art to which the present disclosure belongs may easily implement the present disclosure. The present disclosure may be modified in various ways, all without departing from the spirit or scope of the present disclosure.

[0032] A non-oriented electrical steel sheet according to an embodiment of the present disclosure may include, in wt%, Si: 1.5 to 5.0%, Al: 0.1 to 2.0%, Mn: 0.1 to 2.0%, Sn: 0.001 to 0.08%, Sb: 0.001 to 0.08%, and B: 0.0002 to 0.0007%, and may include the balance of Fe and an inevitable impurity.

[0033] Hereinafter, a reason for limiting the components of the non-oriented electrical steel sheet will be described.

Si: 1.5 to 5.0 wt%

[0034] Silicon (Si) may play a role in lowering an iron loss by increasing resistivity of a material and increasing a strength through solid solution strengthening. If too little Si is added, an effect of improving the iron loss and the strength may be insufficient. If too much Si is added, brittleness of the material may be increased. Thus, sheet breakage may occur during winding and cold rolling so that rolling productivity is rapidly reduced. Thus, the non-oriented electrical steel sheet may include 1.5 to 5.0 wt% of Si. For example, the non-oriented electrical steel sheet may include 2.0 to 4.5 wt% of Si. For example, the non-oriented electrical steel sheet may include 3.0 to 4.0 wt% of Si. For example, the non-oriented electrical steel sheet may include 3.0 to 3.8 wt% of Si.

Al: 0.1 to 2.0 wt%

[0035] Aluminum (Al) may play a role in lowering an iron loss and improving rollability by increasing resistivity of a material, and may play a role in improving workability during cold rolling. If too little Al is added, it may be difficult to obtain an effect of reducing a high-frequency iron loss, and a precipitation temperature of AlN may be lowered so that nitride is finely formed to lower a magnetic characteristic. If too much Al is added, nitride may be excessively formed to degrade a magnetic characteristic, and a problem may occur in all processes such as steelmaking and continuous casting so that productivity is significantly reduced. Thus, the non-oriented electrical steel sheet may include 0.1 to 2.0 wt% of Al. For example, the non-oriented electrical steel sheet may include 0.3 to 1.9 wt% of Al. For example, the non-oriented electrical steel sheet may include 0.5 to 1.5 wt% of Al.

Mn: 0.1 to 2.0 wt%

[0036] Manganese (Mn) may play a role in improving an iron loss by increasing resistivity of a material, and may play a role in forming sulfide. If too little Mn is added, sulfide may be finely formed to degrade a magnetic characteristic, and if too much Mn is added, fine MnS may be excessively precipitated and formation of {111} texture unfavorable to the magnetic characteristic may be encouraged so that a magnetic flux density is rapidly reduced. Thus, the

non-oriented electrical steel sheet may include 0.1 to 2.0 wt% of Mn. For example, the non-oriented electrical steel sheet may include 0.2 to 1.6 wt% of Mn. For example, the non-oriented electrical steel sheet may include 0.3 to 1.5 wt% of Mn.

5 Sn: 0.001 to 0.080 wt%

[0037] Tin (Sn) may be segregated on a grain boundary and a surface to play a role in improving a texture of a material and inhibiting surface oxidation so that it is added to improve a magnetic characteristic. If an amount of Sn added is too small, an effect thereof may not be sufficient. If too much Sn is added, segregation of a grain boundary may become severe so that a surface quality is degraded, and hardness may be increased to cause breakage of a cold-rolled sheet so that rollability is reduced. Thus, Sn may be added within the above-described range. For example, the non-oriented electrical steel sheet may include 0.01 to 0.08 wt% of Sn. For example, the non-oriented electrical steel sheet may include 0.03 to 0.05 wt% of Sn.

15 Sb: 0.001 to 0.080 wt%

[0038] Antimony (Sb) may be segregated on a grain boundary and a surface to play a role in improving a texture of a material and inhibiting surface oxidation so that it is added to improve a magnetic characteristic. If an amount of Sb added is too small, an effect thereof may be minimal. If too much Sb is added, segregation of a grain boundary may become severe so that a surface quality is degraded, and hardness may be increased to cause breakage of a cold-rolled sheet so that rollability is reduced. Thus, Sb may be added within the above-described range. For example, the non-oriented electrical steel sheet may include 0.01 to 0.08 wt% of Sb. For example, the non-oriented electrical steel sheet may include 0.03 to 0.05 wt% of Sb.

25 B: 0.0002 to 0.0007 wt%

[0039] Boron (B) may be an element with a very strong segregation tendency within a steel, and may be segregated even with a small amount of content to greatly affect formation of an oxide layer on a surface. In particular, B may compete with segregation elements such as S, Sn, and Sb and may be segregated on the surface. Accordingly, a degree of formation of the oxide layer on the surface may vary to form nitrides directly below a surface layer. Thus, the non-oriented electrical steel sheet may include 0.0002 to 0.0007 wt% of B. For example, the non-oriented electrical steel sheet may include 0.0003 to 0.0006 wt% of B.

[0040] The non-oriented electrical steel sheet according to the embodiment of the present disclosure may further include S: 0.005 wt% or less (excluding 0%), and may satisfy Equation 1 below.

[Equation 1]

$$0.7 \leq ([\text{Sn}] + [\text{Sb}] + [\text{S}] \times 10)/([\text{B}] \times 100) \leq 5.2$$

[0041] In Equation 1, [Sn], [Sb], [S], and [B] may represent a content (wt %) of Sn, a content (wt %) of Sb, a content (wt %) of S, and a content (wt %) of B, respectively.

S: 0.0050 wt% or less

[0042] Sulfur (S) may form fine sulfide inside a base material to suppress growth of a grain so that it weakens an iron loss. Thus, it may be desirable that a content of sulfur (S) is low. If the content of sulfur (S) is too high, sulfur (S) may be combined with Mn or the like to suppress growth of the grain or increase a degree of deterioration of a magnetic characteristic after processing. For example, the non-oriented electrical steel sheet may include 0.0001 to 0.0050 wt% of S. For example, the non-oriented electrical steel sheet may include 0.0010 to 0.0035 wt% of S.

[0043] Sn, Sb, S, and B among the components of the non-oriented electrical steel sheet that are the components that may be segregated on a surface to change behavior of an oxide layer may tend to be competitively segregated on the surface, and S, Sn, and Sb may not be related to each other because they exist in different ways within a lattice of a steel, but B may have a competitive relationship with S, Sn, and Sb. Thus, in order to reduce nitride on the surface, it is necessary to satisfy Equation 1 that is a relationship between contents of elements of S, Sn, Sb, and B that may be segregated on the surface to control oxidation. For example, a value of Equation 1 may be between 1.0 and 5.0.

[0044] The non-oriented electrical steel sheet according to an embodiment of the present disclosure may further include at least one of P: 0.1 wt% or less (excluding 0%), C: 0.005 wt% or less (excluding 0%), Ti: 0.005 wt% or less

(excluding 0%), and N: 0.005 wt% or less (excluding 0%).

P: 0.1 wt% or less

[0045] Phosphorus (P) not only may play a role in increasing resistivity of a material but also may improve a magnetic flux density as a grain boundary segregation element. However, if too much P is added, brittleness of the steel sheet may be increased so that weldability is poor. For example, the non-oriented electrical steel sheet may include 0.0001 to 0.0500 wt% of P. For example, the non-oriented electrical steel sheet may include 0.0010 to 0.0200 wt% of P.

C: 0.005 wt% or less

[0046] Carbon (C) may cause magnetic aging and may be combined with another impurity element to form carbide so that it impedes a grain boundary or a movement of a magnetic wall to deteriorate a magnetic characteristic. For example, the non-oriented electrical steel sheet may include 0.0001 to 0.003 wt% of C.

Ti: 0.005 wt% or less

[0047] Titanium (Ti) may have a strong tendency in which a precipitate is formed within a steel, and may form fine carbide, fine nitride, or fine sulfide within a base material to suppress growth of a grain and a movement of a magnetic wall so that it deteriorates an iron loss. For example, the non-oriented electrical steel sheet may include 0.0001 to 0.0030 wt% of Ti.

N: 0.005 wt% or less

[0048] Nitrogen (N) not only may form a fine AlN precipitate inside a base material but also may be combined with another impurity to form a fine precipitate so that it inhibits growth of a grain and a movement of a magnetic wall to worsen an iron loss. For example, the non-oriented electrical steel sheet may include 0.0001 to 0.0030 wt% of N.

[0049] The non-oriented electrical steel sheet according to the embodiment of the present disclosure may further include 0.005 to 0.200 wt% of each or a combined amount of one or more of Bi, Pb, Ge, and As.

Bi, Pb, Ge, and As

[0050] When bismuth (Bi), lead (Pb), germanium (Ge), and arsenic (As) are additionally added, bismuth (Bi), lead (Pb), germanium (Ge), and arsenic (As) may be segregated at a grain boundary to relieve stress concentration at the grain boundary during cold rolling. Thus, bismuth (Bi), lead (Pb), germanium (Ge), and arsenic (As) may improve a magnetic flux density by suppressing a recrystallization of <111>ND orientation grain in annealing of the recrystallization that is a post-process. If bismuth (Bi), lead (Pb), germanium (Ge), and arsenic (As) are properly added, the above-described effect may be additionally obtained, but if too much of them is included, a large amount of segregation may be generated so that the magnetic flux density and an iron loss may be rather degraded by suppressing growth of the grain. For example, the non-oriented electrical steel sheet may further include 0.010 to 0.150 wt% of each or a combined amount of one or more of Bi, Pb, Ge, and As.

[0051] The non-oriented electrical steel sheet according to an embodiment of the present disclosure may further include at least one of Cu: 0.005 to 0.2 wt%, Cr: 0.01 to 0.5 wt%, Ni: 0.05 wt% or less (excluding 0%), Zn: 0.01 wt% or less (excluding 0%), and Co: 0.05 wt% or less (excluding 0%).

Cu: 0.005 to 0.200 wt%

[0052] Copper (Cu) may play a role in forming sulfide together with Mn. If too little Cu is added, (Cu·Mn)S may be finely precipitated so that a magnetic characteristic is deteriorated. If too much Cu is added, high-temperature brittleness may occur so that a crack is formed during continuous casting or hot rolling. For example, the non-oriented electrical steel sheet may include 0.01 to 0.10 wt% of Cu.

Cr: 0.01 to 0.50 wt%

[0053] Chromium (Cr) may play a role in improving an iron loss by increasing resistivity. If too little Cr is added, a resistivity-increasing effect may not be sufficient. If too much Cr is included, a magnetic flux density may be decreased. For example, the non-oriented electrical steel sheet may include 0.050 to 0.20 wt% of Cr.

Ni: 0.05 wt% or less

[0054] Nickel (Ni) may react with impurity elements to form fine sulfide, fine carbide, and fine nitride so that it has a harmful influence on a magnetic characteristic. For example, the non-oriented electrical steel sheet may include 0.001 to 0.030 wt% of Ni.

Zn: 0.01 wt% or less

[0055] If a content of zinc (Zn) is excessive, zinc (Zn) may act as an impurity to deteriorate a magnetic characteristic. Thus, Zn may be added within the above-described range. For example, the non-oriented electrical steel sheet may include 0.001 to 0.005 wt% of Zn.

Co: 0.05 wt% or less

[0056] Cobalt (Co) may not form a fine-sized precipitate that degrades a magnetic characteristic of the steel sheet, but may increase a high-temperature strength to cause a defect in a shape of a coil after hot rolling.

[0057] The non-oriented electrical steel sheet according to an embodiment of the present disclosure may further include at least one of Mo: 0.03 wt% or less (excluding 0%), V: 0.0050 wt% or less (excluding 0%), Ca: 0.0050 wt% or less (excluding 0%), Nb: 0.0050 wt% or less (excluding 0%), Zr: 0.0050 wt% or less (excluding 0%), Te: 0.0100 wt% or less (excluding 0%), and Mg: 0.0050 wt% or less (excluding 0%).

Mo: 0.030 wt% or less

[0058] If an excessive amount of molybdenum (Mo) is added, segregation of a segregation element may be suppressed so that an effect of improving a texture is reduced. Thus, the non-oriented electrical steel sheet may include 0.03 wt% or less of Mo. A lower limit thereof is not particularly limited, but Mo may play a role in improving the texture by being segregated on a surface and a grain boundary so that the non-oriented electrical steel sheet includes 0.001 wt% or more of Mo. For example, the non-oriented electrical steel sheet may include 0.001 to 0.010 wt% of Mo. For example, the non-oriented electrical steel sheet may include 0.005 to 0.010 wt% of Mo.

V: 0.0050 wt% or less

[0059] Vanadium (V) may have a strong tendency in which a precipitate is formed within a steel, and may form fine carbide or fine nitride within a base material to suppress growth of a grain and a movement of a magnetic wall so that it deteriorates an iron loss. Thus, the non-oriented electrical steel sheet may include 0.0050 wt% or less of V. A lower limit thereof is not particularly limited, but the non-oriented electrical steel sheet may include 0.0003 wt% of V due to a steelmaking cost. That is, the non-oriented electrical steel sheet may include 0.0003 to 0.0050 wt% of V. For example, the non-oriented electrical steel sheet may include 0.0003 to 0.0030 wt% of V.

Ca: 0.0050 wt% or less

[0060] Calcium (Ca) may have a strong tendency in which a precipitate is formed within a steel, and may form fine sulfide within a base material to suppress growth of a grain and a movement of a magnetic wall so that it deteriorates an iron loss.

Nb: 0.0050 wt% or less

[0061] Niobium (Nb) may have a strong tendency in which a precipitate is formed within a steel, and may form fine carbide or fine nitride within a base material to suppress growth of a grain and a movement of a magnetic wall so that it deteriorates an iron loss. Thus, the non-oriented electrical steel sheet may include 0.0050 wt% or less of Nb. A lower limit thereof is not particularly limited, but the non-oriented electrical steel sheet may include 0.0003 wt% of Nb due to a steelmaking cost. That is, the non-oriented electrical steel sheet may include 0.0003 to 0.0050 wt% of Nb. For example, the non-oriented electrical steel sheet may include 0.0003 to 0.0030 wt% of Nb.

Zr: 0.0050 wt% or less

[0062] If an excessive amount of zirconium (Zr) is added, deterioration of a magnetic characteristic may be caused due to formation of an inclusion within a steel or the like. Thus, the non-oriented electrical steel sheet may include

0.005 wt% or less of Zr. A lower limit thereof is not particularly limited, but the non-oriented electrical steel sheet may include 0.0001 wt% of Zr due to a steelmaking cost. That is, the non-oriented electrical steel sheet may include 0.0001 to 0.0050 wt% of Zr. For example, the non-oriented electrical steel sheet may include 0.0005 to 0.0030 wt% of Zr.

Te: 0.0100 wt% or less

[0063] Because tellurium (Te) is diffused into an oxide layer on a surface of a hot-rolled coil to increase a coefficient of friction between the oxide layer and a rolling work roll and be concentrated at a lower portion of the oxide layer so it improves hardness, tellurium (Te) may be added to prevent the oxide layer crushed during rolling from being pressed into a base material and remove the oxide layer crushed during the rolling. If an amount of Te added is too small, an effect thereof may be minimal. If too much Te is added, the oxide layer may be easily removed so that the base material is in direct contact with the work roll and the effect is reduced, and a deformation band may be excessively generated within the steel sheet during cold rolling so that {111}/ND texture unfavorable to a magnetic characteristic is developed. For example, the non-oriented electrical steel sheet may include 0.0001 to 0.007 wt% of tellurium.

Mg: 0.0050 wt% or less

[0064] Magnesium (Mg) may be an element that is mainly combined with S to form sulfide, and may affect a surface oxide layer of a base iron. Thus, the non-oriented electrical steel sheet may include 0.0050 wt% or less of Mg. A lower limit thereof is not particularly limited, but the non-oriented electrical steel sheet may include 0.0001 wt% of Mg due to a steelmaking cost. That is, the non-oriented electrical steel sheet may include 0.0001 to 0.0050 wt% of Mg. For example, the non-oriented electrical steel sheet may include 0.0005 to 0.0030 wt% of Mg.

[0065] The balance (or the remainder) may include Fe and an inevitable impurity. The inevitable impurity may be an impurity mixed in a steelmaking step and a manufacturing process of the non-directional electrical steel sheet, and because this is widely known in the field, a detailed description thereof will be omitted. An embodiment of the present disclosure does not exclude addition of an element in addition to the above-described alloy component, and may be variously included within a range that does not impair the technical idea of the present disclosure. If the additional element is included, the additional element may replace the balance of iron (Fe).

[0066] As described above, the embodiment of the present disclosure may densely concentrate Al and Si on a surface portion thereof by appropriately adjusting alloy components of the steel sheet and adjusting a condition in a cold-rolled sheet annealing process to simultaneously improve a mechanical strength and a magnetic characteristic.

[0067] FIG. 1 schematically shows a cross-section of the steel sheet according to an embodiment of the present disclosure. As shown in FIG. 1, a surface portion 10 may exist in a range of 0.3 to 1 μm from a surface of a steel sheet 11 toward the inside thereof. In FIG. 1, an example in which the surface portion 10 exists on both sides of the steel sheet is described, but it is also possible that the surface portion 10 exists only on one surface of the steel sheet.

[0068] In an embodiment of the present disclosure, when an element content is measured in a thickness direction for the surface portion 10, a weight ratio of a maximum Si content to a maximum Al content may be 25 or less.

[0069] If an insulating film is present on a surface of an electrical steel sheet to be described later, the surface portion 10 except for the insulating film may be in a range of 0.3 to 1 μm in an inner direction based on a surface 11 of a steel sheet substrate.

[0070] The element content in the thickness direction may be measured through a glow discharge spectrometer (GDS). To reduce an error depending on a measurement position, measurement may be taken at intervals of at least 2 cm so that an average thereof is obtained from three surrounding points. FIG. 2 shows examples of Al and Si contents in the thickness direction.

[0071] The surface portion 10 may include a large amount of Al and Si compared with the inside of the steel sheet due to concentration of Al and Si. In this case, by adjusting a diffusion amount of each of Al and Si, a weight ratio ($\text{Al}_{\text{max}}/\text{Si}_{\text{maxAl}}$) of the Al content to Si at a point where the Al content is maximum may be adjusted to 25 or less. If the weight ratio ($\text{Al}_{\text{max}}/\text{Si}_{\text{maxAl}}$) of the Al content to Si at the point where the Al content is maximum is too large, an Al concentrated layer may develop too strongly so that delamination between a base material and a coating layer appears. For example, the weight ratio ($\text{Al}_{\text{max}}/\text{Si}_{\text{maxAl}}$) of the Al content to Si at the point where the Al content is maximum within the surface portion 10 may be 1.0 to 15.0.

[0072] When the element content is measured in the thickness direction of the steel sheet in the surface portion 10, the maximum Al content may be 1.8 wt% or more. When the maximum Al content (Al_{max}) is too small, Al concentration (or Al enrichment) may not occur densely within the surface portion 10, and as a result, a large number of fine inclusions may be formed inside the steel sheet due to N_2 , O_2 , or the like introduced from an outside air to have a bad influence on the magnetic characteristic. For example, when the element content is measured in the thickness direction of the steel sheet at the surface portion 10, the maximum Al content (Al_{max}) may be 1.8 to 15 wt%.

[0073] In addition, when the element content is measured in the thickness direction of the steel sheet at the surface

portion 10, a Si content ($Si_{\max Al}$) at the point where the Al content is maximum may be 0.5 wt% or more. When the Si content ($Si_{\max Al}$) is too small, Si concentration may not occur densely within the surface portion 10, and as a result, a large number of fine inclusions or precipitates may be formed inside the steel sheet due to N_2 , O_2 , or the like introduced from an outside air to have a bad influence on the magnetic characteristic. For example, when the element content is measured in the thickness direction of the steel sheet at the surface portion 10, the Si content ($Si_{\max Al}$) may be 0.5 to 4 wt%.

[0074] As described above, the embodiment of the present disclosure may appropriately concentrate Si and Al on the surface portion 10 to improve the magnetic characteristic. For example, the non-oriented electrical steel sheet according to the embodiment of the present disclosure may have a B50 of 1.64 or more. For example, the non-oriented electrical steel sheet according to the embodiment of the present disclosure may have a B50 of 1.64 to 1.70 T.

[0075] Additionally, in an embodiment of the present disclosure, an iron loss ($W_{10/400}$) of the non-oriented electrical steel sheet may be 12.5 W/Kg or less based on a thickness of 0.25 mm. The iron loss ($W_{10/400}$) may be an iron loss when a magnetic flux density of 1.0 T is induced at a frequency of 400 Hz. For example, the iron loss ($W_{10/400}$) of the non-oriented electrical steel sheet may be 10.0 to 12.3 W/kg. An iron loss ($W_{10/800}$) may be less than 34.5 W/Kg or less. For example, the iron loss ($W_{10/800}$) may be 30.0 to 34.5 W/Kg. The iron loss ($W_{10/800}$) may be an iron loss when a magnetic flux density of 1.0 T is induced at a frequency of 800 Hz.

[0076] A method for manufacturing the non-oriented electrical steel sheet according to an embodiment of the present disclosure may include a step of hot-rolling a slab to manufacture a hot-rolled steel sheet; a step of cold-rolling the hot-rolled steel sheet to manufacture a cold-rolled steel sheet; and a cold-rolled steel sheet annealing step of annealing the cold-rolled steel sheet.

[0077] Hereinafter, each step will be described in detail.

[0078] First, the slab may be hot rolled.

[0079] Because an alloy component of the slab is described in the alloy component of the above-described non-oriented electrical steel sheet, a redundant description thereof will be omitted. Because the alloy component is not substantially changed during a manufacturing process of the non-oriented electrical steel sheet, the alloy component of the non-oriented electrical steel sheet and the alloy component of the slab may be substantially the same.

[0080] For example, the slab may include, in wt%, Si: 1.5 to 5.0%, Al: 0.1 to 2.0%, Mn: 0.1 to 2.0%, Sn: 0.001 to 0.08%, Sb: 0.001 to 0.08%, and B: 0.0002 to 0.0007%, and may include the balance of Fe and an inevitable impurity.

[0081] Because another additional element is described in the alloy component of the non-oriented electrical steel sheet, a redundant description thereof will be omitted.

[0082] The slab may be heated before the hot rolling. A heating temperature of the slab is not limited, but the slab may be heated to 1200°C or less. If the heating temperature of the slab is too high, a precipitate such as AlN or MnS present within the slab may be re-dissolved and then may be finely precipitated during the hot rolling and the annealing to inhibit growth of a grain and reduce a magnetic characteristic.

[0083] Next, the slab may be hot rolled to manufacture the hot-rolled sheet. A thickness of the hot-rolled sheet may be 1.0 to 4.5 mm. In a process of manufacturing the hot-rolled sheet, a finishing rolling temperature may be 800°C or higher. For example, the finishing rolling temperature may be 850 to 950°C. The hot-rolled sheet may be wound at a temperature of 600°C or higher. For example, the thickness of the hot-rolled sheet may be 1.5 to 4.3 mm.

[0084] After the hot-rolled steel sheet is manufactured, a subsequent step may be performed in a state in which a scale existing on the hot-rolled steel sheet remains. That is, after the hot rolling, removal of the scale such as pickling, shot blasting, or surface grinding may be omitted, and the subsequent step may be performed. Friction between the rolling work roll and the steel sheet may be increased by cold rolling without a pickling process, so that shear deformation is applied simultaneously in addition to plane deformation during the rolling and a specific orientation develops during annealing of a recrystallization. In an embodiment of the present disclosure, the scale may refer to a portion in which an element such as Fe, Al, or Si is combined with oxygen to form a phase different from that of a base material. That the scale remains may mean that a scale having a thickness of at least 1 μm remains on the hot-rolled sheet. In this case, a thickness of the scale may mean a sum of thicknesses of scales generated on both surfaces of the steel sheet. If the remaining scale thickness is too thin, an effect of the remaining scale may not be fully realized. Even if the scale thickness is thicker, the effect may not be improved, and there may be a problem in which a yield of the steel sheet is reduced. For example, the scale with a thickness of 0.1 to 1 μm may remain.

[0085] After the hot-rolled sheet is manufactured, a step of annealing the hot-rolled sheet may be additionally included. An annealing temperature of the hot-rolled sheet may be 950 to 1150°C. An annealing time of the hot-rolled sheet may be 10 to 300 seconds. The annealing of the hot-rolled sheet may be omitted if necessary.

[0086] Next, the hot-rolled steel sheet may be cold rolled to manufacture the cold-rolled sheet. In this case, the cold rolling may be performed at a reduction ratio of 70 to 90%. If the reduction ratio is too low, deformation energy accumulated in the rolled steel sheet may be small so that recrystallization becomes difficult in a subsequent annealing process. Thus, a rolling structure may remain so that a problem occurs in improving a magnetic flux density and an

iron loss. Conversely, if the reduction ratio is too high, a recrystallization of <111>/ND orientation grain may be promoted in a subsequent annealing process and a grain may be fine so that a problem in which the magnetic flux density is inferior and the iron loss is increased occurs. For example, the reduction ratio may be 58 to 67%. In the cold rolling step, a tandem cold rolling mill that continuously cold-rolls the steel sheet using a plurality of rolling stands or a reverse rolling mill that discontinuously cold-rolls the steel sheet using 12 or more rolling rolls may be used. One cold rolling or two or more cold rollings with intermediate annealing interposed therebetween may be performed. A final thickness of the rolling may be 0.1 to 0.35 mm.

[0087] Next, the cold-rolled sheet may be annealed.

[0088] In the cold-rolled sheet annealing step, a cracking temperature may be 900 to 1050°C, a hydrogen fraction within an atmosphere may be 10 to 35 volume%, and a dew point of the atmosphere may be -55 to -15°C.

[0089] If the cracking temperature is too low, a diameter of a grain may not grow sufficiently so that a problem in which a magnetic characteristic is deteriorated occurs. If the cracking temperature is too high, the diameter of the grain may grow too much so that a problem in which the magnetic characteristic is deteriorated occurs. For example, the cracking temperature may be 930 to 1020°C.

[0090] If the hydrogen fraction within the atmosphere is too low, an atmosphere inside an annealing furnace may be changed to an oxidation atmosphere, and an oxidation problem may occur. If the hydrogen fraction is too high, there may be risk of explosion in the annealing furnace. For example, the hydrogen fraction within the atmosphere may be 15 to 30 volume%. The rest other than hydrogen may be oxygen and nitrogen. For example, 65 to 90 volume% of nitrogen may be included.

[0091] If the dew point of the atmosphere is too low, an appropriate Si/Al concentration layer may not be formed so that a problem in which nitrogen is permeated to form fine nitride occurs. If the dew point of the atmosphere is too high, there may be a problem in which a surface is strongly oxidized. For example, the dew point of the atmosphere may be -50 to -30°C.

[0092] The annealing time may be 40 to 100 seconds. For example, the annealing time may be 50 to 90 seconds.

[0093] After the annealing of the cold-rolled sheet, an insulating film may be formed. The insulating film may be treated with an organic film, an inorganic film, or an organic-inorganic composite film, and may also be treated with another insulating film agent.

[0094] Additionally, after the cold-rolled sheet annealing step, a stress relief annealing step of annealing the cold-rolled sheet at 700 to 800°C may be further included. The annealing time may be 40 to 120 minutes.

[0095] Hereinafter, the present disclosure will be described in more detail through an embodiment. However, the embodiment is only intended to illustrate the present disclosure, and the present disclosure is not limited thereto.

Embodiment 1

[0096] A slab is manufactured with components including Table 1, Table 2, and the balance of Fe and an inevitable impurity. The slab is heated to 1150°C and is hot rolled to a finishing temperature of 950°C to manufacture a hot-rolled sheet having a thickness of 1.8 mm.

[0097] Thereafter, the hot-rolled sheet is annealed at 1030°C for 100 seconds and is cold rolled to make a final thickness of 0.25 mm. The cold-rolled steel sheet is annealed for 60 seconds under a condition listed in Table 2 below.

[0098] A surface of the manufactured non-oriented electrical steel sheet is analyzed by a GDS so that a result thereof is shown in Table 3.

[0099] A magnetic flux density and an iron loss are measured using a single sheet tester by cutting five specimens with a width of 60mm × a length of 60mm so that the manufactured values are shown.

[0100] In this case, $W_{10/400}$ is an iron loss when a magnetic flux density of 1.0 T is induced at a frequency of 400 Hz, and $W_{10/800}$ is an iron loss when a magnetic flux density of 1.0 T is induced at a frequency of 800 Hz. B_{50} refers to a magnetic flux density induced in a magnetic field of 5000 A/m.

(Table 1)

Classification (wt%)	Si	Mn	Al	Sn	Sb	B	S	Equation 1
1	3.5	0.69	1.26	0.0014	0.0003	0.0003	0.0045	1.6
2	3.6	1.02	0.68	0.0057	0.0065	0.0005	0.0036	1.0
3	3.3	0.92	0.98	0.0019	0.0031	0.0003	0.0030	1.2
4	3.0	1.16	1.50	0.0035	0.0028	0.0002	0.0040	2.3
5	3.3	1.20	0.79	0.0050	0.0005	0.0003	0.0027	1.1
6	2.9	1.48	0.91	0.0037	0.0027	0.0003	0.0034	1.3

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(continued)

Classification (wt%)	Si	Mn	Al	Sn	Sb	B	S	Equation 1
7	3.6	0.68	0.53	0.0055	0.0010	0.0005	0.0036	0.9
8	3.1	1.23	0.79	0.0032	0.0041	0.0006	0.0034	0.7
9	3.2	1.39	1.50	0.0031	0.0047	0.0005	0.0037	0.9
10	3.5	0.44	1.14	0.0059	0.0075	0.0006	0.0037	0.8
11	3.4	0.76	1.01	0.0023	0.0062	0.0006	0.0035	0.7
12	3.1	1.10	1.44	0.0062	0.0033	0.0003	0.0021	1.0
13	3.5	0.34	1.17	0.0021	0.0068	0.0004	0.0044	1.3
14	3.4	1.04	0.95	0.0047	0.0071	0.0006	0.0049	1.0
15	3.7	1.03	0.58	0.0077	0.0039	0.0006	0.0040	0.9
16	3.6	0.52	1.18	0.0013	0.0067	0.0003	0.0039	1.6
17	3.5	1.41	0.78	0.0071	0.0033	0.0003	0.0047	1.9
18	3.7	0.91	0.89	0.0015	0.0038	0.0006	0.0050	0.9
19	1.3	0.69	0.75	0.0023	0.0035	0.0003	0.0047	1.8
20	5.3	1.45	0.98	0.0057	0.0063	0.0006	0.0026	0.6
21	3.6	0.05	0.66	0.0036	0.0045	0.0002	0.0040	2.4
22	3.2	2.20	1.37	0.0014	0.0064	0.0007	0.0036	0.6
23	3.2	1.37	0.05	0.0043	0.0021	0.0005	0.0049	1.1
24	3.4	1.23	2.20	0.0016	0.0072	0.0005	0.0046	1.1
25	3.3	1.21	0.72	0.0005	0.0050	0.0003	0.0017	0.8
26	3.3	0.45	1.20	0.0790	0.0058	0.0003	0.0016	3.4
27	3.7	0.66	0.62	0.0079	0.0005	0.0002	0.0045	2.7
28	3.2	0.70	1.04	0.0004	0.0850	0.0006	0.0033	2.0
29	3.5	1.35	1.47	0.0068	0.0058	0.0001	0.0020	3.3
30	3.1	0.76	1.27	0.0740	0.0740	0.0010	0.0014	1.6
31	3.2	0.30	1.29	0.0028	0.0012	0.0004	0.0075	2.0
32	3.0	0.64	1.27	0.0071	0.0055	0.0007	0.0023	0.5
33	3.4	1.24	0.67	0.0750	0.0750	0.0003	0.0022	5.7
34	3.2	1.03	0.67	0.0062	0.0010	0.0006	0.0034	0.7
35	3.4	1.11	1.32	0.0045	0.0068	0.0005	0.0032	0.9
36	4.0	0.47	1.29	0.0047	0.0066	0.0003	0.0018	1.0
37	3.8	0.64	0.80	0.0016	0.0065	0.0003	0.0035	1.4
38	3.2	0.54	0.50	0.0019	0.0003	0.0006	0.0047	0.8
39	3.7	0.99	1.37	0.0043	0.0014	0.0005	0.0028	0.7

(Table 2)

Classification	Cracking temperature (°C)	Hydrogen fraction (volume%)	Dew point (°C)	Al _{max} (wt%)	Si _{maxAl} (wt%)	Al _{max} /Si _{maxAl}
1	940	23	-37	2.8	0.5	5.6
2	950	18	-40	4.2	0.6	7.0

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(continued)

	Classification	Cracking temperature (°C)	Hydrogen fraction (volume%)	Dew point (°C)	Al _{max} (wt%)	Si _{maxAl} (wt%)	Al _{max} /Si _{maxAl}
5	3	1020	20	-40	2.6	0.8	3.3
	4	950	18	-37	4.1	1.1	3.7
	5	980	14	-30	6.2	2.8	2.2
10	6	1020	17	-53	6.6	0.6	11.0
	7	960	24	-45	4.1	1.6	2.6
	8	950	15	-28	2.4	1.7	1.4
15	9	950	20	-47	2.2	0.6	3.7
	10	950	25	-41	4.4	0.6	7.3
	11	970	30	-31	6.3	1.4	4.5
	12	1030	20	-20	9.2	2.0	4.6
20	13	940	11	-39	4.9	1.1	4.5
	14	1000	34	-50	1.8	1.3	1.4
	15	1030	35	-48	5.1	1.2	4.3
25	16	1020	10	-32	5.0	1.2	4.2
	17	940	32	-33	8.8	0.6	14.7
	18	940	10	-41	7.2	0.8	9.0
	19	1010	26	-46	6.3	0.7	9.0
30	20	Impossibility of cold rolling	Impossibility of cold rolling	Impossibility of cold rolling	Impossibility of cold rolling	Impossibility of cold rolling	Impossibility of cold rolling
	21	980	22	-33	16.2	0.6	27.0
	22	980	22	-42	20.3	0.8	25.4
35	23	930	11	-47	14.5	0.4	36.3
	24	960	14	-38	22.1	0.7	31.6
	25	960	14	-52	4.4	0.5	8.8
40	26	920	10	-17	4.3	0.1	43.0
	27	940	35	-24	13.2	0.4	33.0
	28	960	27	-36	24.5	0.6	40.8
	29	940	17	-46	22.9	3.8	6.0
45	30	1010	26	-49	8.4	2.9	2.9
	31	1010	30	-38	8.8	0.3	29.3
	32	960	22	-51	7.4	0.2	37.0
50	33	940	16	-44	8.4	0.3	28.0
	34	880	19	-32	1.6	0.7	2.3
	35	1070	16	-43	27.5	0.9	30.6
	36	980	5	-34	33.8	1.2	28.2
55	37	940	40	-49	1.2	0.4	3.0
	38	1020	31	-65	1.7	0.3	5.7
	39	1020	14	8	25.2	0.4	63.0

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(Table 3)

	Classification	B ₅₀ (Tesla)	Iron loss W _{10/400} (W/kg)	W _{10/800} (W/kg)	Note
5	1	1.65	12.1	34.2	Embodiment
	2	1.65	11.8	33.1	Embodiment
	3	1.65	11.6	32.9	Embodiment
10	4	1.65	11.2	31.8	Embodiment
	5	1.66	12.1	33.5	Embodiment
	6	1.66	11.5	33.0	Embodiment
	7	1.67	11.8	32.7	Embodiment
15	8	1.66	11.7	33.2	Embodiment
	9	1.66	11.0	32.0	Embodiment
	10	1.68	11.9	32.1	Embodiment
20	11	1.65	12.2	34.5	Embodiment
	12	1.64	12.1	33.0	Embodiment
	13	1.65	11.6	31.8	Embodiment
	14	1.65	12.1	34.1	Embodiment
25	15	1.65	11.8	33.8	Embodiment
	16	1.65	11.8	33.2	Embodiment
	17	1.66	11.1	32.9	Embodiment
	18	1.65	11.0	32.3	Embodiment
30	19	1.69	19.5	62.7	Comparative Example
	20	Impossibility of cold rolling	Impossibility of cold rolling	Impossibility of cold rolling	Comparative Example
35	21	1.62	13.6	35.1	Comparative Example
	22	1.60	13.5	36.4	Comparative Example
	23	1.61	13.9	35.2	Comparative Example
	24	1.61	12.7	34.8	Comparative Example
40	25	1.62	12.9	36.2	Comparative Example
	26	1.63	16.1	37.0	Comparative Example
	27	1.64	12.8	35.5	Comparative Example
	28	1.64	16.5	38.1	Comparative Example
45	29	1.63	12.5	34.7	Comparative Example
	30	1.60	14.3	36.2	Comparative Example
	31	1.65	12.3	34.2	Embodiment
50	32	1.63	13.2	37.8	Comparative Example
	33	1.62	14.7	37.2	Comparative Example
	34	1.63	13.8	36.5	Comparative Example
	35	1.63	12.7	34.6	Comparative Example
55	36	1.60	14.5	37.2	Comparative Example
	37	1.61	12.7	35.0	Comparative Example
	38	1.62	14.1	35.7	Comparative Example

(continued)

Classification	B ₅₀ (Tesla)	Iron loss W _{10/400} (W/kg)	W _{10/800} (W/kg)	Note
39	1.60	15.0	35.8	Comparative Example

[0101] As shown in Tables 1 to 3, if components of the steel are appropriately adjusted and a condition of the annealing of the cold-rolled sheet is appropriately adjusted, it may be confirmed that Si and Al are densely concentrated on a surface layer so that the embodiment has an excellent iron loss and an excellent magnetic flux density.

[0102] If the components of the steel are not appropriately adjusted or the condition of the annealing of the cold-rolled sheet is not appropriately adjusted so that the surface layer is not appropriately formed, it may be confirmed that the iron loss and the magnetic flux density are inferior.

[0103] The present disclosure is not limited to the embodiments, may be manufactured in various different forms, and a person of ordinary skill in the art to which the present disclosure belongs will be able to understand that the present disclosure may be implemented in other specific forms without changing the technical idea or essential feature of the present disclosure. Therefore, it should be understood that the embodiments described above are illustrative and not limited in all respects.

<Description of symbols>

[0104]

100: non-oriented electrical steel sheet 10: surface portion
11: steel sheet surface

Claims

1. A non-oriented electrical steel sheet, comprising, in wt%, Si: 1.5 to 5.0%, Al: 0.1 to 2.0%, Mn: 0.1 to 2.0%, Sn: 0.001 to 0.08%, Sb: 0.001 to 0.08%, and B: 0.0002 to 0.0007% and comprising the balance of Fe and an inevitable impurity, wherein a weight ratio of a maximum Si content to a maximum Al content is 25 or less when an element content is measured in a direction of a thickness of the steel sheet in a surface portion within a range of 0.3 to 1 μm from a surface of the steel sheet toward the inside of the steel sheet.
2. The non-oriented electrical steel sheet of claim 1, wherein the maximum Al content is 1.8 wt% or more when the element content is measured in the direction of the thickness of the steel sheet in the surface portion.
3. The non-oriented electrical steel sheet of claim 1, wherein a Si content at a point where the Al content is maximum is 0.5 wt% or more when the element content is measured in the direction of the thickness of the steel sheet in the surface portion.
4. The non-oriented electrical steel sheet of claim 1, further comprising S: 0.005 wt% or less (excluding 0%),

wherein the non-oriented electrical steel sheet satisfies Equation below:

[Equation]

$$0.7 \leq ([\text{Sn}] + [\text{Sb}] + [\text{S}] \times 10)/([\text{B}] \times 100) \leq 5.2,$$

wherein in Equation above, [Sn], [Sb], [S], and [B] represent a content (wt %) of Sn, a content (wt %) of Sb, a content (wt %) of S, and a content (wt %) of B, respectively.

5. The non-oriented electrical steel sheet of claim 1, further comprising at least one of P: 0.1 wt% or less (excluding 0%), C: 0.005 wt% or less (excluding 0%), Ti: 0.005 wt% or less (excluding 0%), and N: 0.005 wt% or less (excluding 0%).

6. The non-oriented electrical steel sheet of claim 1, further comprising 0.005 to 0.200 wt% of each or a combined amount of one or more of Bi, Pb, Ge, and As.
7. The non-oriented electrical steel sheet of claim 1, further comprising at least one of Cu: 0.005 to 0.2 wt%, Cr: 0.01 to 0.5 wt%, Ni: 0.05 wt% or less (excluding 0%), Zn: 0.01 wt% or less (excluding 0%), and Co: 0.05 wt% or less (excluding 0%).
8. The non-oriented electrical steel sheet of claim 1, further comprising at least one of Mo: 0.03 wt% or less (excluding 0%), B: 0.0050 wt% or less (excluding 0%), V: 0.0050 wt% or less (excluding 0%), Ca: 0.0050 wt% or less (excluding 0%), Nb: 0.0050 wt% or less (excluding 0%), Zr: 0.005 wt% or less (excluding 0%), Te: 0.01 wt% or less (excluding 0%), and Mg: 0.0050 wt% or less (excluding 0%).
9. A method for manufacturing a non-oriented electrical steel sheet, comprising:
- manufacturing a hot-rolled steel sheet by hot-rolling a slab including, in wt%, Si: 1.5 to 5.0%, Al: 0.1 to 2.0%, Mn: 0.1 to 2.0%, Sn: 0.001 to 0.08%, Sb: 0.001 to 0.08%, and B: 0.0002 to 0.0007% and including the balance of Fe and an inevitable impurity;
- manufacturing a cold-rolled sheet by cold-rolling the hot-rolled steel sheet; and
- annealing the cold-rolled sheet,
- wherein in the annealing of the cold-rolled sheet, a cracking temperature is 900 to 1050°C, a hydrogen fraction within an atmosphere is 10 to 35 volume%, and a dew point of the atmosphere is -55 to -15°C.
10. The method of claim 9, wherein the slab further includes S: 0.005 wt% or less (excluding 0%), and the slab satisfies Equation below:

[Equation]

$$0.7 \leq ([\text{Sn}] + [\text{Sb}] + [\text{S}] \times 10)/([\text{B}] \times 100) \leq 5.2,$$

wherein in Equation above, [Sn], [Sb], [S], and [B] represent a content (wt %) of Sn, a content (wt %) of Sb, a content (wt %) of S, and a content (wt %) of B, respectively.

11. The method of claim 9, wherein the slab further includes at least one of P: 0.1 wt% or less (excluding 0%), C: 0.005 wt% or less (excluding 0%), Ti: 0.005 wt% or less (excluding 0%), and N: 0.005 wt% or less (excluding 0%).
12. The method of claim 9, wherein the slab further includes 0.005 to 0.200 wt% of each or a combined amount of one or more of Bi, Pb, Ge, and As.
13. The method of claim 9, wherein the slab further includes at least one of Cu: 0.005 to 0.2 wt%, Cr: 0.01 to 0.5 wt%, Ni: 0.05 wt% or less (excluding 0%), Zn: 0.01 wt% or less (excluding 0%), and Co: 0.05 wt% or less (excluding 0%).
14. The method of claim 9, wherein the slab further includes at least one of Mo: 0.03 wt% or less (excluding 0%), B: 0.0050 wt% or less (excluding 0%), V: 0.0050 wt% or less (excluding 0%), Ca: 0.0050 wt% or less (excluding 0%), Nb: 0.0050 wt% or less (excluding 0%), Zr: 0.005 wt% or less (excluding 0%), Te: 0.01 wt% or less (excluding 0%), and Mg: 0.0050 wt% or less (excluding 0%).

FIG. 1

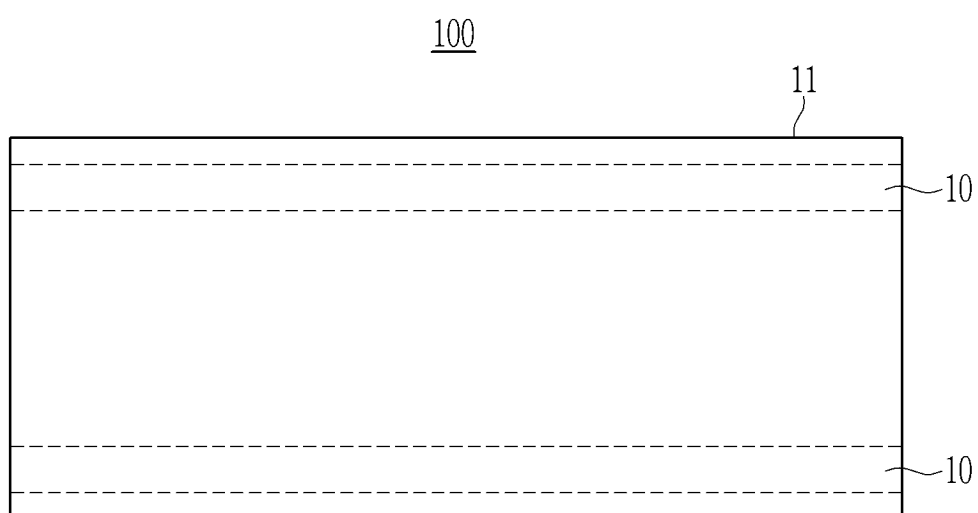
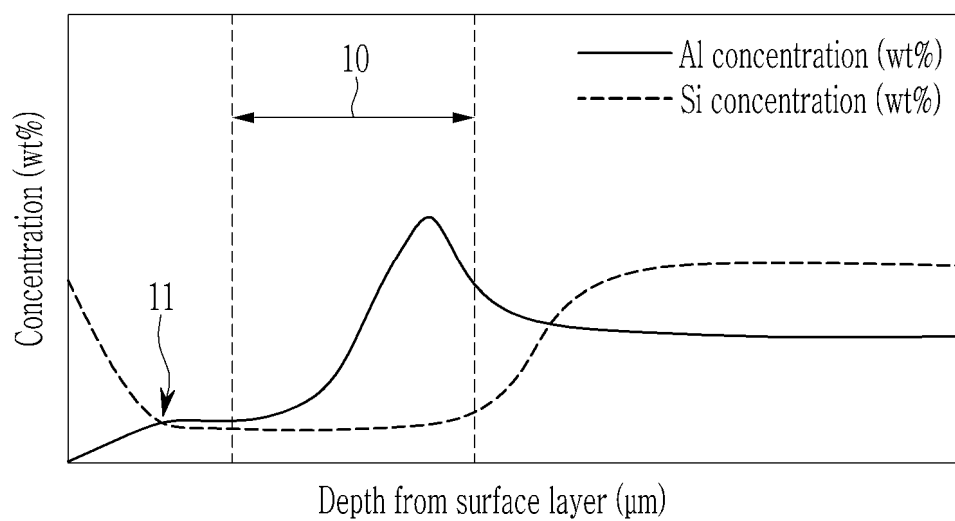


FIG. 2



INTERNATIONAL SEARCH REPORT

International application No.

PCT/KR2024/020331

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/02(2006.01)i; C22C 38/04(2006.01)i; C22C 38/06(2006.01)i; C22C 38/00(2006.01)i; C22C 38/14(2006.01)i;
C22C 38/42(2006.01)i; C22C 38/58(2006.01)i; C22C 38/52(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 38/02(2006.01); C21D 8/12(2006.01); C21D 9/00(2006.01); C22C 38/00(2006.01); C22C 38/14(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: 무방향(non-oriented), 전기강판(electrical steel sheet), 주석(Sn), 안티몬(Sb), 붕소(B), 이슬점(dew point)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	KR 10-2010-0084643 A (NIPPON STEEL CORPORATION) 27 July 2010 (2010-07-27) See paragraph [0111], claims 1, 3 and 9, table 1 and figure 1a.	1-8
Y		9-14
Y	KR 10-2530719 B1 (JFE STEEL CORPORATION) 09 May 2023 (2023-05-09) See paragraph [0023].	9-14
A	KR 10-2023-0095257 A (POSCO) 29 June 2023 (2023-06-29) See claims 7 and 10.	1-14
A	JP 6738056 B1 (JFE STEEL CORP.) 12 August 2020 (2020-08-12) See paragraph [0047] and claims 1-3 and 5.	1-14
A	KR 10-2164113 B1 (POSCO CO., LTD.) 13 October 2020 (2020-10-13) See claims 1-2.	1-14

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

* Special categories of cited documents:

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“D” document cited by the applicant in the international application

“E” earlier application or patent but published on or after the international filing date

“L” document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

“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 18 March 2025	Date of mailing of the international search report 18 March 2025
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.

PCT/KR2024/020331

5	Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
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