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(71) Applicant: **POSCO Co., Ltd**
Gyeongsangbuk-do 37859 (KR)

(72) Inventors:
• **Lee, Hunju**
Pohang-si, Gyeongsangbuk-do 37859 (KR)
• **Lee, Sangwoo**
Pohang-si, Gyeongsangbuk-do 37859 (KR)
• **Kim, Yun-Su**
Pohang-si, Gyeongsangbuk-do 37859 (KR)

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

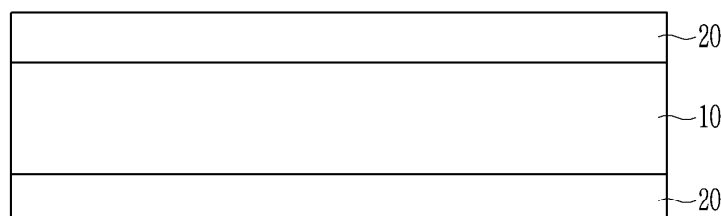
(54) **NON-ORIENTED ELECTRICAL STEEL SHEET AND METHOD FOR MANUFACTURING SAME**

(57) An exemplary embodiment of the present disclosure provides a non-oriented electrical steel sheet comprises, in weight %, Si: 1.5 to 5.0%, Al: 0.1 to 2.0%, Mn: 0.1 to 2.0%, with a remainder of Fe and unavoidable impurities, and having a {001}<100> orien-

tation intensity of 3.0 or more, expressed in terms of the orientation distribution function (ODF), and a {011}<100> orientation intensity is higher than the {001}<100> orientation intensity.

FIG. 1

100



EP 4 826 031 A1

Description**[Technical Field]**

5 **[0001]** An embodiment of the present invention relates to a non-oriented electrical steel sheet and a method for manufacturing the same. Specifically, an embodiment of the present invention pertains to a non-oriented electrical steel sheet and its manufacturing method, which maximizes magnetic anisotropy by developing a specific texture structure through adjusting the reduction rate in each pass during the processes of preliminary cold rolling and cold rolling.

[Background Art]

10 **[0002]** A non-oriented electrical steel sheets are primarily used in motors that convert electrical energy into mechanical energy, requiring excellent magnetic properties to achieve high efficiency in the process. Recently, as environmentally friendly vehicles powered by motors instead of internal combustion engines have gained attention, the demand for non-oriented electrical steel sheets used as core materials in drive motors has increased. Consequently, there is a need for non-oriented electrical steel sheets with excellent magnetic properties and strength.

15 **[0003]** The magnetic properties of non-oriented electrical steel sheets are mainly evaluated by iron loss and magnetic flux density. Iron loss refers to energy loss occurring at a specific magnetic flux density and frequency, while magnetic flux density indicates the degree of magnetization obtained under a specific magnetic field. Lower iron loss allows the manufacture of motors with higher energy efficiency under the same conditions, and higher magnetic flux density enables motor miniaturization or reduction of copper loss. Therefore, using non-oriented electrical steel sheets with low iron loss and high magnetic flux density can create drive motors with excellent efficiency and torque, thereby enhancing the driving range and output of environmentally friendly vehicles.

20 **[0004]** The characteristics of non-oriented electrical steel sheets to be considered vary depending on the operating conditions of the motor. A common criterion for evaluating the properties of non-oriented electrical steel sheets used in motors is the iron loss, $W_{15/50}$, measured when a 1.5T magnetic field is applied at a commercial frequency of 50Hz. However, for non-oriented electrical steel sheets with a thickness of 0.35mm or less used in environmentally friendly vehicle drive motors, magnetic properties are often important at low magnetic fields of 1.0T or less and high frequencies of 400Hz or more. Therefore, the characteristics of non-oriented electrical steel sheets are often evaluated by the $W_{10/400}$ iron loss.

25 **[0005]** Recently, as non-oriented electrical steel sheets are used for electric vehicle drive motors, attempts are being made to maximize magnetic anisotropy to increase motor output, rather than achieving uniform magnetic properties as generally intended. When magnetic anisotropy is maximized, motor output increases, enhancing overall efficiency. In this case, magnetic anisotropy refers to a significant difference in magnetic flux density measured in the rolling direction and at a 55° angle to the rolling direction.

[Disclosure]**[Technical Problem]**

30 **[0006]** An embodiment of the present invention provides a non-oriented electrical steel sheet and a method for manufacturing the same. Specifically, an embodiment of the present invention provides a non-oriented electrical steel sheet with maximized magnetic anisotropy and a method for manufacturing the same by developing a specific texture through controlling the reduction rate in each pass during the preliminary cold rolling and cold rolling processes.

[Technical Solution]

35 **[0007]** An exemplary embodiment of the present disclosure provides a non-oriented electrical steel sheet comprises, in weight %, Si: 1.5 to 5.0%, Al: 0.1 to 2.0%, Mn: 0.1 to 2.0%, with a remainder of Fe and unavoidable impurities, and having a {001}<100> orientation intensity of 3.0 or more, expressed in terms of the orientation distribution function (ODF), and a {011}<100> orientation intensity is higher than the {001}<100> orientation intensity.

40 **[0008]** The non-oriented electrical steel sheet according to an embodiment of the present invention may include a surface portion from the surface of the steel sheet to a depth of 50μm in the inward direction and a central portion, and the ratio of the average grain size in the surface portion to the average grain size in the central portion may be 0.6 to 0.8.

45 **[0009]** The non-oriented electrical steel sheet according to an embodiment of the present invention may further include one or more of P: 0.1 weight% or less (excluding 0%), C: 0.005 weight% or less (excluding 0%), S: 0.005

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

[0010] The non-oriented electrical steel sheet according to an embodiment of the present invention may further include 0.005 to 0.200 weight% of one or two or more of Sn, Sb, Bi, Pb, Ge, and As, individually or in total.

[0011] The non-oriented electrical steel sheet according to an embodiment of the present invention may further include one or more of Cu: 0.005 to 0.2 weight%, Cr: 0.01 to 0.5 weight%, Ni: 0.05 weight% or less (excluding 0%), Zn: 0.01 weight% or less (excluding 0%), and Co: 0.05 weight% or less (excluding 0%).

[0012] The non-oriented electrical steel sheet according to an embodiment of the present invention may further include one or more of Mo: 0.03 weight% or less (excluding 0%), B: 0.0050 weight% or less (excluding 0%), V: 0.0050 weight% or less (excluding 0%), Ca: 0.0050 weight% or less (excluding 0%), Nb: 0.0050 weight% or less (excluding 0%), Zr: 0.005 weight% or less (excluding 0%), Te: 0.01 weight% or less (excluding 0%), and Mg: 0.0050 weight% or less (excluding 0%).

[0013] The non-oriented electrical steel sheet according to an embodiment of the present invention may satisfy the following formula 1.

[Formula 1]

$$B_{50L} - B_{50(55^\circ)} \geq 0.11 T$$

[0014] (In Formula 1, B_{50L} represents the magnetic flux density B_{50} measured in the rolling direction, and $B_{50(55^\circ)}$ represents the magnetic flux density B_{50} measured in the direction at an angle of 55° to the rolling direction.)

[0015] Another exemplary embodiment of the present disclosure provides a method for manufacturing a non-oriented electrical steel sheet including: hot rolling a slab comprising, in weight%, Si: 1.5 to 5.0%, Al: 0.1 to 2.0%, Mn: 0.1 to 2.0%, with a remainder of Fe and unavoidable impurities, to produce a hot-rolled steel sheet; preliminarily cold rolling the hot-rolled steel sheet; first annealing the preliminarily cold-rolled steel sheet; cold rolling the annealed steel sheet to produce a cold-rolled sheet; and second annealing the cold-rolled sheet.

[0016] In the step of producing the cold-rolled sheet, cold rolling may be performed through three or more passes, with a reduction rate of 23 to 33% in each of the first, second, and third passes.

[0017] The slab may further include one or more of P: 0.1 weight% or less (excluding 0%), C: 0.005 weight% or less (excluding 0%), S: 0.005 weight% or less (excluding 0%), Ti: 0.005 weight% or less (excluding 0%), and N: 0.005 weight% or less (excluding 0%).

[0018] The slab may further include 0.005 to 0.200 weight% of one or two or more of Sn, Sb, Bi, Pb, Ge, and As, individually or in total.

[0019] The slab may further include one or more of Cu: 0.005 to 0.2 weight%, Cr: 0.01 to 0.5 weight%, Ni: 0.05 weight% or less (excluding 0%), and Zn: 0.01 weight% or less (excluding 0%).

[0020] The slab may further include one or more of Mo: 0.03 weight% or less (excluding 0%), B: 0.0050 weight% or less (excluding 0%), V: 0.0050 weight% or less (excluding 0%), Ca: 0.0050 weight% or less (excluding 0%), Nb: 0.0050 weight% or less (excluding 0%), Zr: 0.005 weight% or less (excluding 0%), Te: 0.01 weight% or less (excluding 0%), Co: 0.05 weight% or less (excluding 0%), and Mg: 0.0050 weight% or less (excluding 0%).

[0021] After manufacturing the hot-rolled steel sheet, subsequent steps may be performed while the scale present on the hot-rolled steel sheet.

[0022] The first annealing step may be performed while applying a tension of 0.1 to 1.0 kgf/mm².

[0023] In the first annealing step, the steel sheet may be soaked at a temperature of 800 to 1100°C for 5 to 20 seconds.

[0024] In the step of producing the cold-rolled sheet, the product of the diameter (mm) of the work roll and the friction coefficient (μ) between the work roll and the material may be 1.5 to 9.0.

[Advantageous Effects]

[0025] An exemplary embodiment of the present disclosure provides a non-oriented electrical steel sheet has an improved texture, resulting in greater magnetic anisotropy, which allows for high torque when manufactured into a motor for automobiles.

[Brief Description of the Drawings]

[0026]

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

FIG. 2 is a graph of the orientation distribution function (ODF) results of the non-oriented electrical steel sheet manufactured in Example B6.

[Mode for Invention]

[0027] The terms such as first, second, and third are used for describing various parts, components, areas, layers, and/or sections, but are not limited thereto. These terms are used only for distinguishing one part, component, area, layer, or section from other parts, components, areas, layers, or sections. Therefore, a first part, component, area, layer, or section described below may be mentioned as a second part, component, area, layer, or section without departing from the scope of the present disclosure.

[0028] The terminology used herein is only for mentioning a certain example, and is not intended to limit the present disclosure. Singular forms used herein also include plural forms unless otherwise stated clearly to the contrary. The meaning of "comprising" used in the specification is embodying certain characteristics, areas, integers, steps, operations, elements, and/or components, but is not excluding the presence or addition of other characteristics, areas, integers, steps, operations, elements, and/or components.

[0029] In the present specification, when it is mentioned that a part is "on" or "above" the other part, it means that the part is directly on or above the other part or another part may be interposed therebetween. In contrast, when it is mentioned that a part is "directly on" the other part, it means that nothing is interposed therebetween.

[0030] In addition, unless otherwise particularly described, % refers to wt%, and 1 ppm refers to 0.0001 wt%.

[0031] In an exemplary embodiment of the present disclosure, the meaning of further inclusion of an additional element is replacing iron (Fe) as a remainder by the addition amount.

[0032] Though not defined otherwise, all terms including technical terms and scientific terms used herein have the same meaning as commonly understood by a person with ordinary skill in the art to which the present disclosure pertains. Terms defined in commonly used dictionaries are further interpreted as having a meaning consistent with the related technical literatures and the currently disclosed description, and unless otherwise defined, they are not interpreted as having an ideal or very formal meaning.

[0033] Hereinafter, an exemplary embodiment of the present disclosure will be described in detail so that a person with ordinary skill in the art to which the present disclosure pertains may easily carry out the present disclosure. As those skilled in the art would realize, the described embodiments may be modified in various different ways, all without departing from the spirit or scope of the present disclosure.

[0034] An exemplary embodiment of the present disclosure provides a non-oriented electrical steel sheet comprises, in weight %, Si: 1.5 to 5.0%, Al: 0.1 to 2.0%, Mn: 0.1 to 2.0%, with a remainder of Fe and unavoidable impurities.

[0035] Hereinafter, the reason for limiting steel sheet alloy components will be described first.

Si: 1.5 to 5.0 weight%

[0036] Silicon (Si) serves to lower iron loss by increasing the resistivity of a material, and enhance strength through high ductility. If too little Si is added, the effects of reducing iron loss and improving strength may be insufficient. If too much Si is added, the brittleness of the material increases, significantly reducing rolling productivity and forming surface oxide layers and oxides on the surface that are detrimental to magnetic properties. Therefore, Si can be included in the range of 1.5 to 5.0% weight%. More specifically, it can be included in an amount of 2.0 to 4.5 weight%, and even more specifically, 2.5 to 4.0 weight%.

Al: 0.1 to 2.0 weight%

[0037] Aluminum (Al) serves to lower iron loss by increasing the resistivity of a material, and improve rollability by enhancing workability during cold rolling. If too little Al is added, it may be difficult to achieve high-frequency iron loss reduction effects, and the precipitation temperature of AlN is lowered, leading to the fine formation of nitrides that can degrade magnetic properties. If too much Al is added, excessive formation of nitrides can degrade magnetic properties and cause problems in all processes such as steelmaking and continuous casting, greatly reducing productivity. Therefore, Al can be included in an amount of 0.1 to 2.0 weight%. More specifically, it can be included in an amount of 0.15 to 1.7 weight%, and even more specifically, 0.2 to 1.6 weight%.

Mn: 0.1 to 2.0 weight%

[0038] Manganese (Mn) serves to improve iron loss by increasing the resistivity of a material, and form sulfides. If

too little Mn is added, fine sulfides can form, causing degradation of magnetic properties, and if too much Mn is added, excessive precipitation of fine MnS can promote the formation of {111} texture unfavorable to magnetic properties, causing significantly decrease in magnetic flux density. Therefore, Mn can be included in an amount of 0.1 to 2.0 weight%. More specifically, it can be included in an amount of 0.15 to 1.7 weight%, and even more specifically, 0.2 to 1.6 weight%.

[0039] The non-oriented electrical steel sheet according to an embodiment of the present invention may further include one or more of P: 0.1 weight% or less (excluding 0%), C: 0.005 weight% or less (excluding 0%), S: 0.005 weight% or less (excluding 0%), Ti: 0.005 weight% or less (excluding 0%), and N: 0.005 weight% or less (excluding 0%).

P: 0.1 weight% or less

[0040] Phosphorus (P) not only increases the resistivity of the material but also, as a grain boundary segregating element, can enhance magnetic flux density. However, if too much P is added, it increases the brittleness of the steel sheet, deteriorating weldability. More specifically, P can be included in an amount of 0.0001 to 0.0500 weight%. Even more specifically, P can be included in an amount of 0.0010 to 0.0200 weight%.

C: 0.005 weight% or less

[0041] Carbon (C) can cause magnetic aging and degrade magnetic properties by forming carbides in combination with other impurity elements, hindering grain boundary or magnetic domain movement. More specifically, C can be included in an amount of 0.0001 to 0.0035 weight%.

S: 0.005 weight% or less

[0042] Sulfur (S) can form fine precipitates such as MnS and CuS, deteriorating magnetic properties and hot workability. More specifically, S can be included in an amount of 0.0001 to 0.0050 weight%. More specifically, S can be included in an amount of 0.0005 to 0.0045 weight%.

Ti: 0.005 weight% or less

[0043] Titanium (Ti) has a strong tendency to form precipitates in steel, and Ti can degrade iron loss by forming fine carbides, nitrides, or sulfides within the base metal, thereby inhibiting grain growth and magnetic domain movement. More specifically, Ti can be included in an amount of 0.0001 to 0.0050 weight%. More specifically, Ti can be included in an amount of 0.0005 to 0.0030 weight%.

N: 0.005 weight% or less

[0044] Nitrogen (N) not only forms fine AlN precipitates within the base metal but also forms fine precipitates by combining with other impurities, inhibiting grain growth and magnetic domain movement, which can degrade iron loss. More specifically, N can be included in an amount of 0.0001 to 0.0050 weight%. More specifically, N can be included in an amount of 0.0005 to 0.0030 weight%.

[0045] The non-oriented electrical steel sheet according to an embodiment of the present invention may further include 0.005 to 0.200 weight% of one or two or more of Sn, Sb, Bi, Pb, Ge, and As, individually or in total.

Sn

[0046] Tin (Sn) serves to segregate to grain boundaries and surfaces to improve the material's microstructure and suppresses surface oxidation, and can be added to enhance magnetic properties. If too much Sn is added, grain boundary segregation becomes severe, degrading surface quality, increasing hardness, causing fractures in cold-rolled sheets, and reducing rollability. Specifically, Sn can be further included in an amount of 0.005 to 0.200 weight%. More specifically, in an amount of 0.010 to 0.080 weight%.

Sb

[0047] Antimony (Sb) serves to segregate to grain boundaries and surfaces to improve the material's microstructure and suppress surface oxidation, and can be additionally added to enhance magnetic properties. If too much Sb is added, grain boundary segregation becomes severe, degrading surface quality, increasing hardness, causing frac-

tures in cold-rolled sheets, and reducing rollability. Specifically, Sb can be further included in an amount of 0.005 to 0.200 weight%. More specifically, in an amount of 0.010 to 0.080 weight%.

Bi, Pb, Ge, and As

[0048] Bismuth (Bi), Lead (Pb), Germanium (Ge), and Arsenic (As), when additionally added, segregate to grain boundaries to alleviate stress concentration at grain boundaries during cold rolling, thereby suppressing the recrystallization of <111>ND oriented grains during subsequent annealing, thereby enhancing magnetic flux density. When these elements are appropriately added, additional effects as mentioned above can be obtained. However, if included in too large an amount, excessive segregation can inhibit grain growth, thereby worsening magnetic flux density and iron loss.

[0049] The non-oriented electrical steel sheet according to an embodiment of the present invention may further include one or more of Cu: 0.005 to 0.2 weight%, Cr: 0.01 to 0.5 weight%, Ni: 0.05 weight% or less (excluding 0%), Zn: 0.01 weight% or less (excluding 0%), and Co: 0.05 weight% or less (excluding 0%).

Cu: 0.005 to 0.200 weight%

[0050] Copper (Cu) serves to form sulfides together with Mn. If too little Cu is added, it can result in fine precipitation of (Cu·Mn)S, degrading magnetic properties. If too much Cu is added, hot brittleness occurs, potentially causing soaks during annealing or hot rolling. More specifically, Cu can be included in an amount of 0.01 to 0.10 weight%.

Cr: 0.01 to 0.50 weight%

[0051] Chromium (Cr) serves to increase resistivity, improving iron loss. If too little Cr is added, the resistivity enhancement effect may be insufficient. If too much Cr is included, it can decrease magnetic flux density. More specifically, Cr can be included in an amount of 0.050 to 0.20 weight%.

Ni: 0.05 weight% or less

[0052] Nickel (Ni) can react with impurity elements to form fine sulfides, carbides, and nitrides that can negatively affect magnetic properties. More specifically, Ni can be included in an amount of 0.001 to 0.03 weight%.

Zn: 0.01 weight% or less

[0053] Zinc (Zn), if excessively contained, can act as an impurity and deteriorate magnetic properties. Therefore, Zn can be further added within the aforementioned range. More specifically, Zn can be included in an amount of 0.001 to 0.005 weight%.

Co: 0.05 mass% or less

[0054] Cobalt (Co) does not form fine precipitates that reduce magnetic properties but increases high-temperature strength, potentially causing defects in coil shape after hot rolling.

[0055] The non-oriented electrical steel sheet according to an embodiment of the present invention may further include one or more of Mo: 0.03 weight% or less (excluding 0%), B: 0.0050 weight% or less (excluding 0%), V: 0.0050 weight% or less (excluding 0%), Ca: 0.0050 weight% or less (excluding 0%), Nb: 0.0050 weight% or less (excluding 0%), Zr: 0.005 weight% or less (excluding 0%), Te: 0.01 weight% or less (excluding 0%), and Mg: 0.0050 weight% or less (excluding 0%).

Mo: 0.030 weight% or less

[0056] Molybdenum (Mo), if added in excess, can suppress the segregation of element segregating elements, reducing the effect of improving microstructure. Therefore, Mo can be included in an amount of 0.03 weight% or less. The lower limit is not particularly limited, but since it segregates to surfaces and grain boundaries to improve microstructure, it can be included in an amount of 0.001 weight% or more. More specifically, Mo can be included in an amount of 0.001 to 0.010 weight%, and even more specifically, 0.005 to 0.010 weight%.

B: 0.0050 weight% or less

[0057] Boron (B), if added in excess, can cause degradation of magnetic properties through the formation of inclusions in steel. Therefore, B can be included in an amount of 0.005 weight% or less. The lower limit is not particularly limited, but due to steelmaking costs, it can be set to 0.0001 weight%. More specifically, B can be included in an amount of 0.0001 to 0.0030 weight%.

V: 0.0050 weight% or less

[0058] Vanadium (V) has a very strong tendency to form precipitates in steel, forming fine carbides or nitrides within the base metal, thereby inhibiting grain growth and magnetic domain movement, which can degrade iron loss. Therefore, the V content can be 0.0050 weight% or less. The lower limit is not particularly limited, but due to steelmaking costs, it can be set to 0.0003 weight%. Specifically, V can be included in an amount of 0.0003 to 0.0050 weight%, and even more specifically, 0.0003 to 0.0030 weight%.

Ca: 0.0050 weight% or less

[0059] Calcium (Ca) has a very strong tendency to form precipitates in steel, forming fine sulfides within the base metal, thereby inhibiting grain growth and magnetic domain movement, which can degrade iron loss.

Nb: 0.0050 weight% or less

[0060] Niobium (Nb) has a very strong tendency to form precipitates in steel, forming fine carbides or nitrides within the base metal, thereby inhibiting grain growth and magnetic domain movement, which can degrade iron loss. Therefore, Nb content can be 0.0050 weight% or less. The lower limit is not particularly limited, but due to steelmaking costs, it can be set to 0.0003 weight%. Specifically, Nb can be included in an amount of 0.0003 to 0.0050 weight%, and even more specifically, 0.0003 to 0.0030 weight%.

Zr: 0.0050 weight% or less

[0061] Zirconium (Zr), if added in excess, can cause degradation of magnetic properties through the formation of inclusions in steel. Therefore, Zr can be included in an amount of 0.005 weight% or less. The lower limit is not particularly limited, but due to steelmaking costs, it can be set to 0.0001 weight%. Specifically, Zr can be included in an amount of 0.0001 to 0.0050 weight%, and even more specifically, 0.0005 to 0.0030 weight%.

Te: 0.0100 weight% or less

[0062] Tellurium (Te) diffuses into the oxide layer on the surface of hot-rolled coils, increasing the friction coefficient between the oxide layer and rolling work rolls by accumulating beneath the oxide layer, thereby improving hardness. Therefore, it can be added to prevent the crushed oxide layer from being pressed into the base metal and ensuring its detachment during rolling. If the amount of Te added is too small, the effect may be negligible. If too much Te is added, the oxide layer can easily detach, causing the base metal to directly contact the work rolls, reducing the aforementioned effect, and excessive deformation bands can be generated in the steel sheet during cold rolling, leading to the development of {111}//ND oriented grain structures unfavorable to magnetic properties. Specifically, Tellurium can be included in an amount of 0.0001 to 0.007 weight%.

Mg: 0.0050 weight% or less

[0063] Magnesium (Mg) primarily combines with S to form sulfides and can affect the surface oxide layer of hot-rolled steel. Therefore, Mg can be included in an amount of 0.0050 weight% or less. The lower limit is not particularly limited, but due to steelmaking costs, it can be set to 0.0001 weight%. Specifically, Mg can be included in an amount of 0.0001 to 0.0050 weight%, and even more specifically, 0.0005 to 0.0030 weight%.

[0064] The balance comprises Fe and unavoidable impurities. Unavoidable impurities are impurities mixed during the steelmaking step and the manufacturing processes of non-oriented electrical steel sheets, which are widely known in the field, thus specific descriptions are omitted. In one embodiment of the present invention, adding elements in addition to the aforementioned alloy components is not excluded and can be variously included within the range that does not impair the technical spirit of the present invention. When the additional element is further included, it replaces Fe as the remainder.

[0065] As described above, in one embodiment of the present invention, by appropriately adjusting the alloy components of the steel sheet and controlling the reduction rate in each pass during the processes of preliminary cold rolling and cold rolling, a specific texture can be developed to maximize magnetic anisotropy.

[0066] Specifically, the non-oriented electrical steel sheet according to one embodiment of the present invention has an orientation intensity of $\{001\}<100>$ of 3.0 or more, expressed in terms of the orientation distribution function (ODF), and the orientation intensity of $\{011\}<100>$ is higher than the $\{001\}<100>$ orientation intensity.

[0067] The orientation distribution function (ODF) is a method for quantitatively analyzing the texture distribution within a steel sheet, allowing the quantification of how much a specific texture orientation is distributed within the steel sheet. Orientation intensity refers to how strongly a specific texture orientation has developed compared to a random texture.

[0068] In one embodiment of the present invention, the measurement plane of the orientation distribution function (ODF) targets the transverse direction plane (TD plane), and the measurement area is at least $5\text{mm} \times 5\text{mm}$. To reduce errors according to the measurement location, data over a sufficiently wide area should be measured, and more than 20 specimens can be measured and the data combined for calculation at once.

[0069] The measurement method uses EBSD mounted on an SEM, and analysis can be performed using OIM analysis software, with an error angle for orientation set to 15° .

[0070] The $\{001\}<100>$ orientation has a crystal direction that is easy to magnetize in the $<100>$ direction both in the rolling direction and transverse direction, and the circumferential magnetism corresponding to the average in all directions is also excellent. If the $\{001\}<100>$ orientation intensity is suppressed, orientations like $<111>$, which are difficult to magnetize, may develop in-plane, leading to deterioration in magnetic properties. More specifically, the $\{001\}<100>$ orientation intensity can be 3.0 to 4.5, or more specifically, 3.1 to 4.0.

[0071] The grains of the $\{011\}<100>$ orientation have an easy magnetization $<100>$ direction in-plane, with $\{001\}<100>$, thus favorably affecting magnetism. In one embodiment of the present invention, by making the $\{011\}<100>$ orientation intensity higher than that of $\{001\}<100>$, not only magnetism but also magnetic anisotropy is maximized. More specifically, the $\{011\}<100>$ orientation intensity can be 3.3 to 5.5, or more specifically, 3.5 to 5.0. The $\{011\}<100>$ orientation intensity can be 0.3 to 2.0 higher than the $\{001\}<100>$ orientation intensity.

[0072] Fig. 1 schematically shows a cross-section of the non-oriented electrical steel sheet (100) according to one embodiment of the present invention. As shown in Fig. 1, the non-oriented electrical steel sheet (100) according to one embodiment of the present invention includes a surface portion (20) from the steel sheet surface to a depth of $50\mu\text{m}$ inward, and a central portion (10), and the ratio (surface/central) of the average grain diameter in the surface portion (20) to that in the central portion (10) can be 0.60 to 0.80.

[0073] If the grains in the surface portion (20) are smaller than those in the central portion (10), hysteresis loss increases and permeability decreases in the surface portion, leading to deterioration in magnetic properties. If the grains in the surface portion (20) are larger than those in the central portion (10), eddy current loss in the surface portion increases, and a texture unfavorable for magnetization develops. More specifically, the ratio (surface/central) of the average grain size in the surface portion (20) to that in the central portion (10) can be 0.63 to 0.77.

[0074] The grain diameter can be determined by assuming a virtual circle with the same area as the grain and calculating its diameter. Measurements are based on the transverse direction plane (TD plane), and by counting the number of grains within the surface portion (20) and the central portion (10), the average area of each grain can be calculated and determined as a circle with that area. The surface portion (20) exists both on the top and bottom of the steel sheet, and in this case, the average of the grain sizes of the top and bottom surface portions can be calculated.

[0075] As described above, in one embodiment of the present invention, a specific texture can be developed to maximize magnetic anisotropy. Specifically, the non-oriented electrical steel sheet according to one embodiment of the present invention can satisfy the following formula 1.

[Formula 1]

$$B_{50L} - B_{50(55^\circ)} \geq 0.11 \text{ T}$$

[0076] (In formula 1, B_{50L} represents the flux density B_{50} measured in the rolling direction, and $B_{50(55^\circ)}$ represents the flux density B_{50} measured in the direction forming an angle of 55° with the rolling direction.)

[0077] Formula 1 represents the difference in flux density between the rolling direction (RD direction) and the direction forming an angle of 55° with the rolling direction, and the larger this difference, the higher the magnetic anisotropy. Specifically, the value on the left side of formula 1 can be 0.12 to 0.20 T.

[0078] In one embodiment of the present invention, the iron loss ($W_{10/400}$) of the non-oriented electrical steel sheet can be 12.5W/Kg or less. Iron loss ($W_{10/400}$) is the iron loss when a flux density of 1.0T is induced at a frequency of 400HZ. More specifically, the iron loss ($W_{10/400}$) of the non-oriented electrical steel sheet can be 10.0 to 12.0W/kg . In

one embodiment of the present invention, iron loss can be expressed based on a thickness of 0.25mm.

[0079] A method for manufacturing non-oriented electrical steel sheet according to an embodiment of the present invention includes hot rolling a slab to produce a hot-rolled steel sheet; preliminarily cold rolling the hot-rolled steel sheet; first annealing the preliminarily cold-rolled steel sheet; cold rolling the annealed steel sheet to produce a cold-rolled sheet; and second annealing the cold-rolled sheet.

[0080] Below is a detailed description of each step.

[0081] First, the slab is hot rolled.

[0082] The alloy composition of the slab has been described in the alloy composition of the non-oriented electrical steel sheet mentioned above, so redundant explanations are omitted. Since the alloy composition does not substantially change during the manufacturing process of the non-oriented electrical steel sheet, the alloy composition of the non-oriented electrical steel sheet and the slab is substantially the same.

[0083] Specifically, the slab comprises, by weight%, Si: 1.5 to 5.0%, Al: 0.1 to 2.0%, Mn: 0.1 to 2.0%, with a remainder of Fe and unavoidable impurities.

[0084] Additional elements have been described in the alloy composition of the non-oriented electrical steel sheet, and therefore redundant descriptions are omitted.

[0085] The slab may be heated before hot rolling. The heating temperature of the slab is not limited, but it can be heated to 1200°C or less. If the heating temperature of the slab is too high, precipitates such as AlN and MnS existing in the slab may be re-dissolved and then finely precipitated during hot rolling and annealing, which may inhibit grain growth and deteriorate magnetic properties.

[0086] Next, the slab is hot rolled to produce a hot-rolled sheet. The thickness of the hot-rolled sheet may be 1.0 to 4.5mm. In the step of producing the hot-rolled sheet, the finishing rolling temperature may be 800°C or higher. Specifically, it may be 870 to 950°C.

[0087] The hot-rolled sheet can be coiled at a temperature of 600°C or higher. More specifically, the thickness of the hot-rolled sheet may be 1.4 to 3.0mm.

[0088] After producing the hot-rolled steel sheet, the subsequent steps can be performed with the scale remaining on the hot-rolled steel sheet. That is, after hot rolling, scale removal processes such as pickling, shot blasting, or surface grinding may be omitted, and the subsequent steps may be performed. By omitting the pickling process and performing cold rolling, friction between the rolling work roll and the steel sheet increases, and shear deformation is applied simultaneously with planar deformation during rolling, resulting in the development of a specific orientation during recrystallization annealing.

[0089] In one embodiment of the present invention, scale refers to portions where elements such as Fe, Al, and Si on the steel sheet surface combine with oxygen to form a phase different from the base material. The term "scale remains" means that at least 1μm thick scale remains on the hot-rolled sheet. At this time, the scale thickness refers to the sum of the scale thickness generated on both surfaces of the steel sheet. If the remaining scale thickness is too thin, the effect of scale retention may not be sufficiently exerted. Even if the scale thickness is thicker, the effect does not improve, and there is a problem of reduced yield of the steel sheet. More specifically, scale with a thickness of 0.1 to 1μm may remain. Also, after hot rolling, the steel sheet can be preliminarily cold rolled without applying heat from the outside. That is, hot-rolled sheet annealing can be omitted.

[0090] Next, the hot-rolled steel sheet is preliminarily cold rolled. Preliminary cold rolling is distinguished from the cold rolling described later in that it is a primary rolling step in the process of rolling to an intermediate thickness rather than the final product thickness, followed by intermediate annealing, and then cold rolling to the final product thickness.

[0091] Preliminary cold rolling can be carried out in a reduction rate range of 40 to 79% to improve the productivity of final cold rolling and the grain refinement of the final product sheet. Additionally, if productivity is not considered, preliminary cold rolling may be performed in a reverse mill in the present invention. The thickness of the preliminary cold-rolled sheet may be 0.3 to 1.5mm. More specifically, the reduction rate may be 50 to 75% and the thickness may be 0.5 to 1.0mm.

[0092] The preliminary cold rolling reduction rate can be calculated as (thickness before rolling - thickness after rolling) / thickness before rolling. If the reduction rate is too low in the preliminary cold rolling step, the rolling load increases during final cold rolling, reducing productivity, and the final reduction rate increases, promoting the recrystallization of fine <111> orientations. Conversely, if the reduction rate is too high, the cold rolling load increases, and the possibility of sheet breakage also increases.

[0093] Next, in the first annealing step, the preliminarily cold-rolled steel sheet is annealed.

[0094] In one embodiment of the present invention, by appropriately adjusting the tension in the first annealing step, the grain diameters at the surface and center of the steel sheet may be appropriately controlled. If the tension is too small, fine grains develop at the surface, reducing the average grain diameters at the surface and suppressing the development of the {011}<100> orientation, which may have some adverse effects on magnetism. If the tension is too large, grain growth at the surface and center may occur similarly, increasing the average grain diameter at the surface.

In this case, random orientations develop, which may have some adverse effects on magnetism. More specifically, annealing can be performed while applying a tension of 0.10 to 1.00 kgf/mm². At this time, the tension is measured at the entry side of the annealing furnace and can be measured by passing the coil through a roll equipped with a load cell. More specifically, annealing may be performed while applying a tension of 0.25 to 0.75 kgf/mm².

[0095] In the first annealing step, the steel sheet may be soaked at a temperature of 800 to 1100°C for 5 to 20 seconds. If the annealing temperature is too low, the coarse microstructure at the center does not sufficiently recover, so the {001}<100> orientation of the final product does not sufficiently develop, and magnetism may be inferior. If the annealing temperature is too high, fine precipitates form at the surface, preventing the sufficient development of the {011}<100> orientation of the final product, which may degrade magnetism. More specifically, the first annealing step may be performed at a temperature of 850 to 1050°C.

[0096] If the annealing time is too short, the fine microstructure at the surface may not sufficiently recrystallize, causing the surface grains of the final product to become excessively small compared to the center grains. If the annealing time is too long, the surface grains may grow excessively. More specifically, annealing can be performed for 7 to 17 seconds.

[0097] Returning to the description of the method for manufacturing non-oriented electrical steel sheet, after the first annealing step, the annealed steel sheet is cold rolled to produce a cold-rolled sheet.

[0098] In one embodiment of the present invention, cold rolling is performed through three or more passes, and the reduction rates of 23 to 33% in each of the first, second, and third passes. In one embodiment of the present invention, a "pass" refers to the number of times the steel sheet passes through the work rolls of the rolling mill. Cold rolling can be performed by tandem rolling or reverse rolling, and combining these is also possible.

[0099] If the reduction rate is high, not only is planar deformation applied to the material, but shear deformation also increases. If the number of passes is the same, more shear deformation occurs with a higher reduction rate, making it easier to develop the {011}<100> orientation in the material. If the reduction rate per pass is too low, it is difficult to expect an improvement in magnetism because the {011}<100> orientation does not sufficiently develop. If the reduction rate per pass is too high, the development of the {001}<100> orientation can be suppressed. More specifically, the reduction rates in the first, second, and third passes may be 24 to 30%.

[0100] Also, during the step of producing the cold-rolled sheet, the product of the diameter (mm) of the work roll and the friction coefficient (μ) between the work roll and the material can be 1.5 to 9.0. If the work roll diameter is large, the contact area between the work roll and the material increases at a given reduction rate, allowing for greater shear deformation, and if the work roll diameter is small, the amount of shear deformation decreases. The friction coefficient is determined by the roughness of the work roll and the material, the type of rolling oil, etc., and a larger friction coefficient under given conditions allows for greater shear deformation. The friction coefficient may be measured by the method of disclosed patent KR1996-0021206.

[0101] If the product of the work roll diameter and the friction coefficient is large, the amount of shear deformation applied to the material increases, promoting the development of the {011}<100> orientation. If the value is too small, it is difficult to achieve sufficient improvement in magnetic properties because the {011}<100> orientation does not sufficiently develop, and if the value is too large, the development of the {001}<100> orientation can be suppressed. More specifically, the product of the work roll diameter (mm) and the friction coefficient (μ) may be 1.8 to 8.8. Specifically, the work roll diameter may be 50 to 150mm. More specifically, the work roll diameter may be 55 to 100mm. The friction coefficient may be 0.02 to 0.13 μ . More specifically, the friction coefficient may be 0.03 to 0.12 μ . The work roll diameter and friction coefficient may be values from the last pass of cold rolling.

[0102] The final rolling thickness may be 0.1mm to 0.35mm.

[0103] Next, in the second annealing step, the cold-rolled sheet is annealed. The second annealing step may be performed at a temperature of 900°C or higher. If the annealing temperature is too low, the grains do not sufficiently grow, increasing hysteresis loss and deteriorating iron loss. More specifically, annealing may be performed at a temperature of 900 to 1050°C. The second annealing step may be performed for 50 to 120 seconds. The dew point may be -10°C or lower.

[0104] During the annealing process of the cold-rolled sheet, the work structure formed in the cold rolling step may be completely (i.e., 99% or more) recrystallized.

[0105] After annealing the cold-rolled sheet, an insulating coating may be formed. The insulating coating may be treated with organic, inorganic, and organic-inorganic composite coatings, and it is also possible to treat with other insulating coating agents.

[0106] Hereinafter, the present disclosure will be described in more detail by the examples. However, the examples are only for illustrating the present disclosure, and the present disclosure is not limited thereto.

Example 1

[0107] The slab was manufactured with the steel alloys shown in Table 1, with a remainder of Fe and other unavoid-

EP 4 826 031 A1

able impurities. It was heated to 1150°C and hot rolled to a finishing temperature of 950°C to produce a hot-rolled sheet with the thickness specified in Table 3.

[0108] Subsequently, the hot-rolled sheet was subjected to preliminary cold rolling to the thickness specified in Table 2 without annealing, annealed under the conditions specified in Table 2, and then cold rolled under the conditions specified in Table 2 to achieve a final thickness of 0.25mm. The cold-rolled steel sheet was subjected to a second annealing at a dew point of -20°C and a soaking temperature of 1000°C for 100 seconds.

[0109] To analyze the texture of the manufactured non-oriented electrical steel sheet, 30 specimens of 10mm × 20mm were cut for each sample, mounted in three sets of 10 each with the observation surface being the TD surface, and polished to a mirror finish without scratches. EBSD measurements were conducted with a height of 5000μm, a width of approximately 2500μm (covering all 10 sheets of the 0.25mm specimen), and a step size of 1μm. The measurement data from the three sets were merged using the merging function of the OIM software, and the ODF was calculated at once, with the results shown in Table 4.

[0110] The magnetic properties, such as magnetic flux density and iron loss, were measured by cutting specimens of 60mm width × 60mm length × 5 sheets for each sample and using a single sheet tester. The magnetic flux density was measured in the rolling direction and at 55°, and the results were analyzed. Iron loss was measured in the rolling direction and perpendicular to the rolling direction, and the average was analyzed. Here, $W_{10/400}$ refers to the iron loss when a magnetic flux density of 1.0T is induced at a frequency of 400Hz, and B50 refers to the magnetic flux density induced in a magnetic field of 5000A/m.

[Table 1]

Steel No.	Si [%]	Al [%]	Mn [%]	C [ppm]	S [ppm]	N [ppm]	Ti [ppm]	Nb [ppm]	V [ppm]
A1	2.70	1.6	0.7	28	14	16	11	19	15
A2	2.70	1.6	0.7	28	13	13	23	17	21
A3	2.70	1.6	0.7	20	18	18	24	8	19
A4	2.70	1.6	0.7	13	18	17	17	18	10
A5	2.70	1.6	0.7	17	16	14	14	16	16
A6	2.70	1.6	0.7	24	43	17	17	17	14
A7	2.70	1.6	0.7	26	13	13	11	13	13
A8	2.70	1.6	0.7	14	14	16	14	14	18
B1	3.30	0.6	1.6	13	73	14	12	11	23
B2	3.30	0.6	1.6	35	13	15	9	13	9
B3	3.30	0.6	1.6	16	32	9	24	19	10
B4	3.30	0.6	1.6	17	20	12	14	20	21
B5	3.30	0.6	1.6	13	13	13	17	13	18
B6	3.30	0.6	1.6	28	17	16	14	17	15
B7	3.30	0.6	1.6	29	42	14	13	18	17
B8	3.30	0.6	1.6	31	13	18	18	13	13
C1	3.75	0.2	1.6	68	19	9	24	19	20
C2	3.75	0.2	1.6	21	16	11	21	23	16
C3	3.75	0.2	1.6	29	17	12	23	14	12
C4	3.75	0.2	1.6	21	8	8	17	18	18
C5	3.75	0.2	1.6	31	45	13	9	14	11
C6	3.75	0.2	1.6	28	15	16	13	15	12
C7	3.75	0.2	1.6	25	17	16	7	17	15
C8	3.75	0.2	1.6	27	42	17	14	14	18
D1	4.20	0.5	0.2	22	9	81	18	9	23
D2	4.20	0.5	0.2	17	16	11	12	16	11

EP 4 826 031 A1

(continued)

Steel No.	Si [%]	Al [%]	Mn [%]	C [ppm]	S [ppm]	N [ppm]	Ti [ppm]	Nb [ppm]	V [ppm]
D3	4.20	0.5	0.2	14	35	10	12	21	13
D4	4.20	0.5	0.2	9	16	14	14	16	14
D5	4.20	0.5	0.2	16	17	16	16	17	17
D6	4.20	0.5	0.2	21	33	20	15	18	21
D7	4.20	0.5	0.2	16	17	20	10	17	24
D8	4.20	0.5	0.2	31	13	12	13	13	13

[Table 2]

Steel No.	Thickness of hot-rolled sheet [mm]	Thickness after preliminarily cold rolling [mm]	Soak temperature of first annealing [°C]	Soak time of first annealing [sec]	Tension of first annealing [kgf/mm ²]
A1	2.08	0.73	850	30	0.70
A2	2.08	0.73	950	7	0.70
A3	2.08	0.73	1000	7	0.70
A4	2.72	0.95	1050	7	0.70
A5	2.08	0.73	850	7	0.30
A6	2.08	0.73	950	7	0.30
A7	2.08	0.73	1000	7	0.30
A8	2.08	0.73	1050	7	0.30
B1	1.84	0.64	850	17	0.30
B2	1.84	0.64	950	17	1.20
B3	1.40	0.49	1000	17	0.30
B4	1.84	0.64	1150	17	0.30
B5	1.84	0.64	850	17	0.50
B6	1.84	0.64	950	17	0.50
B7	1.84	0.64	1000	17	0.50
B8	1.84	0.64	1050	17	0.50
C1	1.63	0.57	850	12	0.30
C2	1.63	0.57	750	12	0.30
C3	1.63	0.57	850	12	0.05
C4	1.63	0.57	850	3	0.30
C5	1.63	0.57	850	12	0.70
C6	1.63	0.57	850	12	0.70
C7	1.63	0.57	850	12	0.70
C8	1.63	0.57	850	12	0.70
D1	2.08	0.73	950	10	0.80
D2	2.08	0.73	950	10	0.80
D3	2.08	0.73	950	10	0.80
D4	2.08	0.73	950	10	0.80

EP 4 826 031 A1

(continued)

Steel No.	Thickness of hot-rolled sheet	Thickness after preliminarily cold rolling	Soak temperature of first annealing	Soak time of first annealing	Tension of first annealing
	[mm]	[mm]	[°C]	[sec]	[kgf/mm ²]
D5	2.08	0.73	950	10	0.50
D6	2.08	0.73	950	10	0.50
D7	2.08	0.73	950	10	0.50
D8	2.08	0.73	950	10	0.50

[Table 3]

Steel No.	Reduction rate in first pass of cold rolling [%]	Reduction rate in second pass of cold rolling [%]	Reduction rate in third pass of cold rolling [%]	Diameter of work roll [mm]	Friction coefficient	Diameter of work roll × Friction coefficient
A1	30	30	30	60	0.03	1.8
A2	30	30	30	80	0.14	11.2
A3	30	30	30	45	0.03	1.4
A4	36	36	36	80	0.03	2.4
A5	30	30	30	60	0.07	4.2
A6	30	30	30	80	0.07	5.6
A7	30	30	30	60	0.07	4.2
A8	30	30	30	80	0.07	5.6
B1	27	27	27	60	0.05	3.0
B2	27	27	27	80	0.05	4.0
B3	20	20	20	60	0.05	3.0
B4	27	27	27	80	0.05	4.0
B5	27	27	27	60	0.11	6.6
B6	27	27	27	80	0.11	8.8
B7	27	27	27	60	0.11	6.6
B8	27	27	27	80	0.11	8.8
C1	24	24	24	80	0.03	2.4
C2	24	24	24	60	0.03	1.8
C3	24	24	24	80	0.03	2.4
C4	24	24	24	60	0.03	1.8
C5	24	24	24	80	0.07	5.6
C6	24	24	24	60	0.07	4.2
C7	24	24	24	80	0.07	5.6
C8	24	24	24	60	0.07	4.2
D1	30	30	30	80	0.05	4.0
D2	30	30	30	210	0.05	10.5
D3	30	30	30	80	0.01	0.8
D4	30	30	30	60	0.05	3.0

EP 4 826 031 A1

(continued)

5	Steel No.	Reduction rate in first pass of cold rolling [%]	Reduction rate in second pass of cold rolling [%]	Reduction rate in third pass of cold rolling [%]	Diameter of work roll [mm]	Friction coefficient	Diameter of work roll × Friction coefficient
	D5	30	30	30	80	0.11	8.8
	D6	30	30	30	60	0.11	6.6
10	D7	30	30	30	80	0.11	8.8
	D8	30	30	30	60	0.11	6.6

[Table 4]

15	Steel No.	{001}<100> orientation intensity	{011}<100> orientation intensity	Grain diameter in surface portion [μm]	Grain diameter in central portion [μm]	Surface / Central
	A1	3.5	2.2	72	78	0.92
20	A2	2.1	3.7	52	72	0.72
	A3	3.2	2.2	56	83	0.67
	A4	2.2	3.5	55	84	0.65
25	A5	3.3	3.7	61	79	0.77
	A6	3.3	3.7	53	82	0.65
	A7	3.1	4.0	64	84	0.76
	A8	3.4	3.6	58	77	0.75
30	B1	3.6	2.2	77	81	0.95
	B2	3.6	2.3	76	85	0.89
	B3	3.5	2.0	53	77	0.69
	B4	3.3	2.1	60	79	0.76
35	B5	3.7	4.2	58	77	0.75
	B6	3.5	4.8	55	82	0.67
	B7	3.4	4.3	56	79	0.71
40	B8	3.2	4.2	60	83	0.72
	C1	3.3	2.4	76	81	0.94
	C2	2.0	3.7	61	84	0.73
45	C3	3.7	2.1	41	83	0.49
	C4	3.6	1.9	39	78	0.50
	C5	3.7	4.0	58	76	0.76
	C6	3.2	4.2	52	80	0.65
50	C7	3.2	3.7	56	81	0.69
	C8	3.4	3.8	53	83	0.64
	D1	3.2	2.5	71	76	0.93
	D2	2.2	3.6	54	76	0.71
55	D3	3.4	2.3	60	79	0.76
	D4	3.5	3.9	53	81	0.65
	D5	3.2	4.2	55	77	0.71

EP 4 826 031 A1

(continued)

Steel No.	{001}<100> orientation intensity	{011}<100> orientation intensity	Grain diameter in surface portion [μm]	Grain diameter in central portion [μm]	Surface / Central
D6	3.4	4.6	52	75	0.69
D7	3.3	4.2	56	79	0.71
D8	3.5	4.5	52	76	0.68

[Table 5]

Steel No.	W10/400(W/kg)	B50(RD) [T]	B50(55°) [T]	ΔB50 [T]
A1	12.8	1.69	1.59	0.10
A2	12.6	1.69	1.59	0.10
A3	12.9	1.69	1.60	0.09
A4	12.5	1.69	1.59	0.10
A5	11.5	1.72	1.59	0.13
A6	11.4	1.72	1.58	0.14
A7	11.5	1.72	1.59	0.13
A8	11.6	1.72	1.59	0.13
B1	12.6	1.69	1.60	0.09
B2	12.6	1.69	1.59	0.10
B3	12.5	1.69	1.59	0.10
B4	12.7	1.69	1.59	0.10
B5	11.6	1.72	1.59	0.13
B6	11.4	1.72	1.59	0.13
B7	11.4	1.72	1.59	0.13
B8	11.5	1.72	1.58	0.14
C1	12.6	1.69	1.59	0.10
C2	12.7	1.69	1.59	0.10
C3	12.5	1.69	1.59	0.10
C4	12.7	1.69	1.59	0.10
C5	11.5	1.72	1.59	0.13
C6	11.6	1.72	1.59	0.13
C7	11.4	1.72	1.59	0.13
C8	11.7	1.72	1.59	0.13
D1	12.6	1.69	1.59	0.10
D2	12.8	1.69	1.59	0.10
D3	12.8	1.69	1.60	0.09
D4	11.7	1.72	1.58	0.14
D5	11.5	1.72	1.59	0.13
D6	11.4	1.72	1.59	0.13
D7	11.4	1.72	1.59	0.13
D8	11.6	1.72	1.59	0.13

[0111] As shown in Table 1 to Table 5, when the steel alloy is appropriately controlled and the process conditions are suitably adjusted, resulting in an optimally controlled texture, the invention example exhibits excellent iron loss and magnetic flux density while simultaneously maximizing magnetic anisotropy. On the other hand, if the steel alloy is not properly controlled or the process conditions are not suitably adjusted, leading to an inadequately formed texture, it can be confirmed that the iron loss and magnetic flux density are inferior, or sufficient magnetic anisotropy cannot be achieved.

[0112] The present disclosure is not limited by the above exemplary embodiments and may be manufactured in various forms different from each other, and it may be understood that a person with ordinary skill in the art to which the present disclosure pertains may carry out the present disclosure in another specific form without modifying the technical idea or essential feature of the present disclosure. Therefore, it should be understood that the exemplary embodiments described above are illustrative and are not restrictive in all aspects.

[Description of symbols]

[0113]

100 : Non-oriented electrical steel sheet 10 : Central portion

Claims

1. A non-oriented electrical steel sheet comprising, in weight %, Si: 1.5 to 5.0%, Al: 0.1 to 2.0%, Mn: 0.1 to 2.0%, with a remainder of Fe and unavoidable impurities, having a {001}<100> orientation intensity of 3.0 or more, expressed in terms of the orientation distribution function (ODF), and a {011}<100> orientation intensity is higher than the {001}<100> orientation intensity.

2. The non-oriented electrical steel sheet of claim 1, wherein:

the non-oriented electrical steel sheet includes a surface portion from the surface of the steel sheet to a depth of 50 μ m in the inward direction and a central portion, wherein the ratio of the average grain diameter in the surface portion to the average grain diameter in the central portion is 0.6 to 0.8.

3. The non-oriented electrical steel sheet of claim 1, wherein:

the non-oriented electrical steel sheet further comprises one or more of P: 0.1 weight% or less (excluding 0%), C: 0.005 weight% or less (excluding 0%), S: 0.005 weight% or less (excluding 0%), Ti: 0.005 weight% or less (excluding 0%), and N: 0.005 weight% or less (excluding 0%).

4. The non-oriented electrical steel sheet of claim 1, wherein:

the non-oriented electrical steel sheet further comprises 0.005 to 0.200 weight% of one or 2 or more of Sn, Sb, Bi, Pb, Ge, and As, individually or in total.

5. The non-oriented electrical steel sheet of claim 1, wherein:

the non-oriented electrical steel sheet further comprises one or more of Cu: 0.005 to 0.2 weight%, Cr: 0.01 to 0.5 weight%, Ni: 0.05 weight% or less (excluding 0%), Zn: 0.01 weight% or less (excluding 0%), and Co: 0.05 weight% or less (excluding 0%).

6. The non-oriented electrical steel sheet of claim 1, wherein:

the non-oriented electrical steel sheet further comprises one or more of Mo: 0.03 weight% or less (excluding 0%), B: 0.0050 weight% or less (excluding 0%), V: 0.0050 weight% or less (excluding 0%), Ca: 0.0050 weight% or less (excluding 0%), Nb: 0.0050 weight% or less (excluding 0%), Zr: 0.005 weight% or less (excluding 0%), Te: 0.01 weight% or less (excluding 0%), and Mg: 0.0050 weight% or less (excluding 0%).

7. The non-oriented electrical steel sheet of claim 1, wherein:

the non-oriented electrical steel sheet satisfies the following formula 1.

[Formula 1]

$$B_{50L} - B_{50(55^\circ)} \geq 0.11 \text{ T}$$

(In Formula 1, B_{50L} represents the magnetic flux density B_{50} measured in the rolling direction, and $B_{50(55^\circ)}$ represents the magnetic flux density B_{50} measured in the direction at an angle of 55° to the rolling direction.)

8. A method for manufacturing a non-oriented electrical steel sheet, the method including:

hot rolling a slab comprising, in weight%, Si: 1.5 to 5.0%, Al: 0.1 to 2.0%, Mn: 0.1 to 2.0%, with a remainder of Fe and unavoidable impurities, to produce a hot-rolled steel sheet;
 preliminarily cold rolling the hot-rolled steel sheet;
 first annealing preliminarily cold-rolled steel sheet;
 cold rolling annealed steel sheet to produce a cold-rolled sheet; and
 second annealing the cold-rolled sheet;
 wherein in the step of producing the cold-rolled sheet, cold rolling is performed through three or more passes, and reduction rates of 23 to 33% in each of the first, second, and third passes.

9. The method for manufacturing the non-oriented electrical steel sheet of claim 8, wherein:
 the slab further comprises one or more of P: 0.1 weight% or less (excluding 0%), C: 0.005 weight% or less (excluding 0%), S: 0.005 weight% or less (excluding 0%), Ti: 0.005 weight% or less (excluding 0%), and N: 0.005 weight% or less (excluding 0%).

10. The method for manufacturing the non-oriented electrical steel sheet of claim 8, wherein:
 the slab further comprises 0.005 to 0.200 weight% of one or two or more of Sn, Sb, Bi, Pb, Ge, and As, individually or in total.

11. The method for manufacturing the non-oriented electrical steel sheet of claim 8, wherein:
 the slab further comprises one or more of Cu: 0.005 to 0.2 weight%, Cr: 0.01 to 0.5 weight%, Ni: 0.05 weight% or less (excluding 0%), Zn: 0.01 weight% or less (excluding 0%), and Co: 0.05 weight% or less (excluding 0%).

12. The method for manufacturing the non-oriented electrical steel sheet of claim 8, wherein:
 the slab further comprises one or more of Mo: 0.03 weight% or less (excluding 0%), B: 0.0050 weight% or less (excluding 0%), V: 0.0050 weight% or less (excluding 0%), Ca: 0.0050 weight% or less (excluding 0%), Nb: 0.0050 weight% or less (excluding 0%), Zr: 0.005 weight% or less (excluding 0%), Te: 0.01 weight% or less (excluding 0%), Co: 0.05 weight% or less (excluding 0%), and Mg: 0.0050 weight% or less (excluding 0%).

13. The method for manufacturing the non-oriented electrical steel sheet of claim 8, wherein:
 after manufacturing the hot-rolled steel sheet, subsequent steps are performed while the scale present on the hot-rolled steel sheet.

14. The method for manufacturing the non-oriented electrical steel sheet of claim 8, wherein:
 the first annealing step is performed while applying a tension of 0.1 to 1.0 kgf/mm².

15. The method for manufacturing the non-oriented electrical steel sheet of claim 8, wherein:
 in the first annealing step the steel sheet is soaked at a temperature of 800 to 1100°C for 5 to 20 seconds.

16. The method for manufacturing the non-oriented electrical steel sheet of claim 8, wherein:
 in the step of producing the cold-rolled sheet, the product of the diameter (mm) of the work roll and the friction coefficient (μ) between the work roll and the material is 1.5 to 9.0.

FIG. 1

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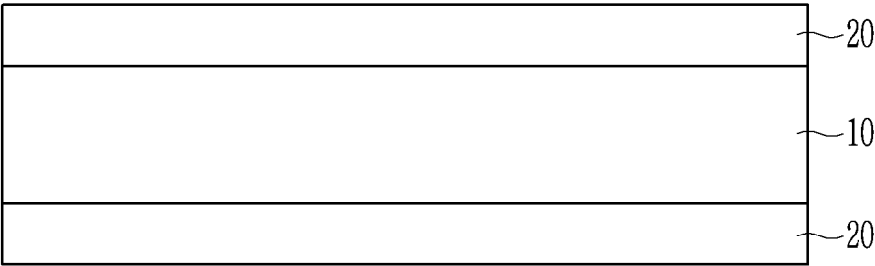


FIG. 2



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INTERNATIONAL SEARCH REPORT

International application No.

PCT/KR2024/020332

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/02(2006.01)i; C22C 38/04(2006.01)i; C22C 38/06(2006.01)i; C22C 38/14(2006.01)i; C22C 38/00(2006.01)i;
C22C 38/58(2006.01)i; C22C 38/52(2006.01)i; C22C 38/12(2006.01)i; C21D 8/12(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); B21B 1/24(2006.01); B21B 3/00(2006.01); C21D 8/12(2006.01); C22C 38/00(2006.01);
C22C 38/34(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), 집합조직(texture, aggregate structure), 방위(crystal orientation), 고스(goss), 방향성(oriented), 큐브(cube)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	KR 10-2015-0075255 A (POSCO) 03 July 2015 (2015-07-03) See claims 1, 7 and 10 and table 2.	1-16
A	KR 10-2015-0073787 A (POSCO) 01 July 2015 (2015-07-01) See claim 1.	1-16
A	KR 10-2023-0094463 A (POSCO) 28 June 2023 (2023-06-28) See claim 5.	1-16
A	KR 10-2023-0095256 A (POSCO) 29 June 2023 (2023-06-29) See claim 6.	1-16
A	KR 10-2241985 B1 (POSCO) 19 April 2021 (2021-04-19) See claims 1-2 and 12.	1-16

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

* Special categories of cited documents:

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“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 14 March 2025	Date of mailing of the international search report 14 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/KR2024/020332

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						EP	4455341	A1	30 October 2024
						JP	2024-519776	A	21 May 2024
						MX	2023010389	A	22 November 2023
						US	2024-0200175	A1	20 June 2024
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REFERENCES CITED IN THE DESCRIPTION

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