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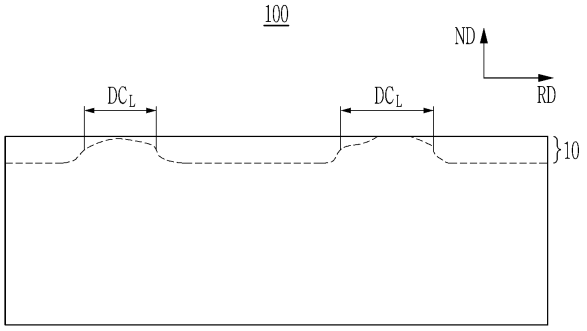
(54) **NON-ORIENTED ELECTRICAL STEEL SHEET AND METHOD FOR MANUFACTURING SAME**

(57) An embodiment of the present invention provides a non-oriented electrical steel sheet including: in wt%, Si: 1.5 to 4.5%, Al: 0.1 to 2.0%, Mn: 0.1 to 2.0%, with the balance being Fe and inevitable impurities, and an oxide layer existing from a surface toward the inside, wherein, in a cross-section including a rolling direction of the steel sheet, a length of an oxide layer disconnecting portion in which a thickness of the oxide layer is 2 nm or less is 5 to 500 nm per 200 μm in the rolling direction.

FIG. 1



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Description

[**Technical Field**]

[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 relates to a non-oriented electrical steel sheet and a method for manufacturing the same, which improves magnetism by forming an appropriate oxide layer on a surface of a steel sheet by controlling a dew point and tension in an annealing process before cold rolling.

[**Background Art**]

[0002] A non-oriented electrical steel sheet is mainly used in a motor that converts electrical energy to mechanical energy, and an excellent magnetic characteristic of the non-oriented electrical steel sheet is required to achieve high efficiency while the motor converts the electrical energy to the mechanical energy. In particular, recently, as environmentally-friendly vehicles driven by motors instead of internal combustion engines have been gaining attention, the demand for non-oriented electrical steel sheets used as driving motor core materials is increasing, and for this purpose, non-oriented electrical steel sheets with excellent magnetic properties and strength are required.

[0003] The magnetic properties of non-oriented electrical steel sheets are mainly evaluated by iron loss and magnetic flux density. The iron loss means energy loss occurring at a specific magnetic flux density and frequency, and the magnetic flux density means a degree of magnetization obtained in a specific magnetic field. Lower iron loss allows for more energy-efficient motors to be manufactured under the same conditions, and higher magnetic flux density allows for smaller motors or reduced copper loss. Therefore, by using non-oriented electrical steel sheets with low iron loss and high magnetic flux density, a driving motor with excellent efficiency and torque may be manufactured, thereby improving the driving range and output of environmentally-friendly vehicles.

[0004] Depending on operational conditions of the motor, the characteristics of the non-oriented electrical steel sheet that should be considered is also varied. The general standard for evaluating the characteristics of non-oriented electrical steel sheets used in motors is widely used as W15/50, which is the iron loss when a 1.5T magnetic field is applied at a commercial frequency of 50Hz. However, in the case of non-oriented electrical steel sheets with a thickness of 0.35 mm or less used in environmentally-friendly vehicle driving motors, magnetic properties are often important at low magnetic fields of 1.0 T or less and high frequencies of 400 Hz or higher, so the properties of non-oriented electrical steel sheets are often evaluated using the W10/400 iron loss.

[0005] A commonly used method to improve the magnetic properties of non-oriented electrical steel sheets is to add alloying elements such as Si, Al, and Mn. When the specific resistance of the steel increases through the addition of these alloying elements, the eddy current loss decreases lowering the overall iron loss. Additionally, these alloying elements may be dissolved in iron as substitutional elements to cause a strengthening effect, thereby increasing strength. On the contrary, as the amount of alloy elements such as Si, Al, and Mn added increases, the magnetic flux density is deteriorated and brittleness increases, and when more than a certain amount thereof is added, it may not be cold rolled and may not be able to be commercially produced. In particular, as the thickness of electrical steel sheets is reduced, high-frequency iron loss becomes better, but the reduction in rollability due to brittleness becomes a critical problem. The maximum total content of Si, Al, and Mn that may be commercially produced is known to be approximately 4.5 wt and by optimizing the content of trace elements, it is possible to produce the highest quality non-oriented electrical steel with excellent magnetism and strength.

[0006] However, when a large amount of high specific resistance alloying elements such as Si, Al, Mn, and Cr are added, the problem of a decrease in magnetic flux density occurs. Particularly, the use of materials with high magnetic flux density is essential for materials that continuously require weight reduction, such as environmentally-friendly electric vehicle driving motors.

[0007] To this end, a method of improving properties by thinning the hot-rolled sheet has been proposed, and a method of improving magnetism by including high Al and performing double annealing and double rolling has been proposed. In addition, a method of thinning a hot-rolled sheet through a thin slab manufacturing method has been proposed.

[0008] However, the method of reducing the thickness of the hot-rolled sheet is difficult to mass-produce due to the increase in rolling load in the general hot-rolling process, and although the addition of high Al and the double annealing and double rolling processes have some improvement in magnetism, the {110}<001> Goss texture also develops, so the circumferential characteristics of the motor deteriorate and surface defects due to the addition of high Al also increase significantly.

[**Disclosure**]

[Technical Problem]

[0009] 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 and a method for manufacturing the same, which improves magnetism by forming an appropriate oxide layer on a surface of a steel sheet by controlling a dew point and tension in an annealing process before cold rolling.

[Technical Solution]

[0010] An embodiment of the present invention provides a non-oriented electrical steel sheet including: in wt%, Si: 1.5 to 4.5%, Al: 0.1 to 2.0%, Mn: 0.1 to 2.0%, with the balance being Fe and inevitable impurities, and an oxide layer existing from a surface toward the inside, wherein, in a cross-section including a rolling direction of the steel sheet, a length of an oxide layer disconnecting portion in which a thickness of the oxide layer is 2 nm or less is 5 to 500 nm per 200 μm in the rolling direction..

[0011] A thickness of the oxide layer may be 15 to 50 nm.

[0012] The non-oriented electrical steel sheet according the embodiment of the present invention may further include one or more of P: 0.1 wt% or less (excluding 0%), C: 0.005 wt% or less (excluding 0%), S: 0.005 wt% or less (excluding 0%), Ti: 0.004 wt% or less (excluding 0%), and N: 0.005 wt% or less (excluding 0%). .

[0013] The non-oriented electrical steel sheet according the embodiment of the present invention may further include 0.005 to 0.200 wt% in each or a combined amount of one or two or more of Sn, Sb, Bi, Pb, Ge, and As.

[0014] The non-oriented electrical steel sheet according the embodiment of the present invention may further include one or more 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 according the embodiment of the present invention may further include one or more 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 nitride density with a grain size of 10 to 200 nm in a cross-section up to a depth of 100 nm from the surface may be $4/\mu m^2$ or less.

[0017] Another embodiment of the present invention provides a method for manufacturing a non-oriented electrical steel sheet, including: a step of hot rolling a slab including, in wt%, Si: 1.5 to 4.5%, Al: 0.1 to 2.0%, and Mn: 0.1 to 2.0%, with a balance being Fe and inevitable impurities, to manufacture a hot-rolled sheet; a pre-cold rolling annealing step of annealing the steel sheet while applying a dew point of -70 to -40°C and a tension of 3.0 to 5.0 kgf/mm^2; a step of cold rolling the annealed steel sheet to manufacture a cold-rolled steel sheet; and a cold-rolled sheet annealing step of annealing the cold-rolled sheet.

[0018] The slab may further include one or more of P: 0.1 wt% or less (excluding 0%), C: 0.005 wt% or less (excluding 0%), S: 0.005 wt% or less (excluding 0%), Ti: 0.004 wt% or less (excluding 0%), and N: 0.005 wt% or less (excluding 0%).

[0019] The slab may further include 0.005 to 0.200 wt% in each or a combined amount of one or two or more of Sn, Sb, Bi, Pb, Ge, and As.

[0020] The slab may further include one or more 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%).

[0021] The slab may further include one or more 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%).

[0022] After manufacturing the hot-rolled steel sheet, a subsequent step may be performed while a scale remaining on the hot-rolled steel sheet remains.

[0023] A step of preliminary cold rolling a hot-rolled sheet prior to the pre-cold rolling annealing step may be further included.

[0024] A reduction ratio in the step of preliminary cold rolling may be 25 to 65%.

[0025] A soaking temperature of the pre-cold rolling annealing step may be 800 to 1100°C.

[0026] A reduction ratio in the step of manufacturing the cold-rolled sheet may be 55 to 70%.

[0027] The cold-rolled sheet annealing step may be performed at a soaking temperature of 850 to 1100°C in an atmosphere with a dew point of 0°C or less.

[Advantageous Effects]

[0028] A non-oriented electrical steel sheet according to an embodiment of the present invention has further improved magnetic properties without causing surface layer deterioration.

[0029] Ultimately, the non-oriented electrical steel sheet according to the embodiment of the present invention contributes to the manufacture of environmentally-friendly automobile motors, high-efficiency home appliance motors, and super premium-grade electric motors.

[**Description of the Drawing**]

[0030] FIG. 1 illustrates a schematic cross-sectional view of a non-oriented electrical steel sheet according to an embodiment of the present invention.

[**Mode for Invention**]

[0031] It will be understood that, although the terms first, second, third, etc. may be used herein to describe various elements, components, regions, layers, and/or sections, they are not limited thereto. These terms are only used to distinguish one element, component, region, layer, or section from another element, component, region, layer, or section. Therefore, a first part, component, area, layer, or section to be described below may be referred to as second part, component, area, layer, or section within the range of the present invention.

[0032] The technical terms used herein are to simply mention a particular embodiment and are not meant to limit the present invention. An expression used in the singular encompasses an expression of the plural, unless it has a clearly different meaning in the context. In the specification, it is to be understood that the terms such as "including", "having", etc., are intended to indicate the existence of specific features, regions, numbers, stages, operations, elements, components, and/or combinations thereof disclosed in the specification, and are not intended to preclude the possibility that one or more other features, regions, numbers, stages, operations, elements, components, and/or combinations thereof may exist or may be added.

[0033] When referring to a part as being "on" or "above" another part, it may be positioned directly on or above the other part, or another part may be interposed therebetween. In contrast, when referring to a part being "directly above" another part, no other part is interposed therebetween.

[0034] Unless otherwise stated, % means wt%, and 1 ppm is 0.0001 wt%.

[0035] In embodiments of the present invention, inclusion of an additional element means replacing the balance of iron (Fe) by an additional amount of the additional elements.

[0036] Unless otherwise defined, all terms used herein, including technical or scientific terms, have the same meanings as those generally understood by those with ordinary knowledge in the field of art to which the present invention belongs. Terms defined in commonly used dictionaries are further interpreted as having meanings consistent with the relevant technical literature and the present disclosure, and are not to be construed as having idealized or very formal meanings unless defined otherwise.

[0037] The present invention will be described more fully hereinafter with reference to the accompanying drawings, in which embodiments of the invention are shown. 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.

[0038] A non-oriented electrical steel sheet according to an embodiment of the present invention includes, in wt%, Si: 1.5 to 4.5%, Al: 0.1 to 2.0%, and Mn: 0.1 to 2.0%, with the balance being Fe and inevitable impurities.

[0039] Hereinafter, the reason for limiting the components of the non-oriented electrical steel sheet will be described.

Si: 1.5 to 4.5 wt%

[0040] Silicon (Si) increases the specific resistance of the material, lowers iron loss, and increases strength through solid solution strengthening. if too little Si is added, an effect of improving the iron loss and strength may be insufficient. If too much Si is added, brittleness of the material increases, and rolling productivity is rapidly deteriorated, and an oxide layer and an oxide on a surface that are harmful to magnetism may be formed. Accordingly, Si may be included in an amount of 1.5 to 4.5 wt%. More specifically, it may be included in an amount of 2.0 wt% to 4.3 wt%. More specifically, it may be included in an amount of 2.5 wt% to 4.2 wt%.

Al: 0.1 to 2.0 wt%

[0041] Aluminum (Al) increases the specific resistance of the material, lowers iron loss, and increases strength

through solid solution strengthening. If too little Al is added, fine nitrides may be formed, making it difficult to obtain the effect of improving magnetism. If too much Al is added, the nitride is excessively formed, deteriorating the magnetism, and causing problems in all processes such as steel making and continuous casting, which may considerably reduce productivity. Accordingly, Al may be included in an amount of 0.1 to 2.0 wt%. More specifically, it may be included in an amount of 0.2 wt% to 1.6 wt%. More specifically, it may be included in an amount of 0.3 wt% to 1.5 wt%.

Mn: 0.1 to 2.0 wt%

[0042] Manganese (Mn) improves the iron loss by increasing the specific resistance of the material and serves to form a sulfide. If too little Mn is added, the sulphide is finely formed, causing magnetic deterioration, and when too much Mn is added, fine MnS is excessively precipitated and the formation of a {111} texture unfavorable to magnetism is promoted, resulting in a rapid decrease in magnetic flux density. Accordingly, Mn may be included in an amount of 0.1 to 2.0 wt%. More specifically, it may be included in an amount of 0.2 wt% to 1.6 wt%. More specifically, it may be included in an amount of 0.3 wt% to 1.5 wt%.

[0043] The non-oriented electrical steel sheet according to the embodiment of the present invention may further include one or more of P: 0.1 wt% or less (excluding 0%), C: 0.005 wt% or less (excluding 0%), S: 0.005 wt% or less (excluding 0%), Ti: 0.004 wt% or less (excluding 0%), and N: 0.005 wt% or less (excluding 0%).

P at 0.1 wt% or less

[0044] Phosphorus (P) is a grain boundary segregation element that may improve the magnetic flux density, but if too much is added, it increases the brittleness of the steel sheet, resulting in poor weldability. More specifically, P may be included in an amount of 0.0001 to 0.0500 wt%.

C: 0.005 wt% or less

[0045] Carbon (C) may cause magnetic aging and combine with other impurity elements to form carbides, which may impede grain boundary or domain wall movement and deteriorate magnetic properties. More specifically, C may be included in an amount of 0.0001 to 0.003 wt%.

S: 0.005 wt% or leas

[0046] Sulfur (S) may form fine precipitates, MnS and CuS, which may worsen magnetic properties and hot workability. More specifically, S may be included in an amount of 0.0001 to 0.0030 wt%.

Ti: 0.004 wt% or leas

[0047] Titanium (Ti) has a strong tendency to form precipitates inside the steel, and may deteriorate the iron loss by forming fine carbides, nitrides, or sulfides inside the base material, thereby suppressing grain growth and domain wall movement. Specifically, Ti may be included in an amount of 0.0001 to 0.003 wt%.

N: 0.005 wt% or less

[0048] Nitrogen (N) not only forms fine AlN precipitates inside the base material, but also combines with other impurities to form fine precipitates, which may supress grain growth and domain wall movement, thereby worsening iron loss. Specifically, N may be included in an amount of 0.0001 to 0.0030 wt%.

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

Sn and Sb

[0050] Tin (Sn) and antimony (Sb) segregate at the initial grain boundaries during final recrystallization annealing and serve to suppress the development of the {111} orientation, which worsens magnetism. If Sn and Sb are added too much, they may hinder the recovery and growth of coarse elongated grain structures and deteriorate surface quality. Therefore, one or more of Sn and Sb may be further added within the aforementioned range. More specifically, Sn may be included in an amount of 0.005 to 0.200 wt%, or Sb may be included in an amount of 0.005 to 0.200 wt%.

Bi, Pb, Ge, and As

[0051] When additionally added, bismuth (Bi), lead (Pb), germanium (Ge), and arsenic (As) segregate at grain boundaries, thereby alleviating stress concentration at grain boundaries during cold rolling, thereby suppressing recrystallization of <111>//ND orientation grains in the subsequent recrystallization annealing process, thereby improving magnetic flux density. If these are added appropriately, the aforementioned effects may be additionally obtained, but if they are included in too much, a large amount of segregation may occur, inhibiting grain growth and resulting in lower magnetic flux density and iron loss.

[0052] The non-oriented electrical steel sheet according to the embodiment of the present invention may further include one or more 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%

[0053] Copper (Cu) serves to form sulfides together with Mn. When Cu is further added, if too little Cu is added, (Cu·Mn)S may be finely precipitated and magnetism may be degraded. If too much Cu is added, high temperature brittleness occurs, which may form cracks during casting or hot rolling. More specifically, Cu may be included in an amount of 0.01 to 0.10 wt%.

Cr: 0.01 to 0.50 wt%

[0054] Chromium (Cr) serves to improve iron loss by increasing specific resistance. If too little Cr is added, the effect of increasing specific resistance may not be sufficient. If too much Cr is included, the magnetic flux density may deteriorate. Specifically, Cr may be contained in an amount of 0.050 to 0.20 wt%.

Ni: 0.05 wt% or less

[0055] Nickel (Ni) may react with impurity elements to form fine sulfides, carbides, and nitrides, which may have a detrimental effect on magnetism. More specifically, Ni may be included in an amount of 0.001 to 0.03 wt%.

Zn: 0.01 wt% or less

[0056] If the content of zinc (Zn) is excessive, it may act as an impurity and deteriorate magnetism. Therefore, Zn may be further added within the above-mentioned range. More specifically, Zn may be included in an amount of 0.001 to 0.005 wt%.

Co: 0.05 wt% or less

[0057] Cobalt (Co), while not forming fine precipitates that degrade the magnetism of the steel sheet, may increase high-temperature strength, leading to poor coil shape after hot rolling.

[0058] The non-oriented electrical steel sheet according to the embodiment of the present invention one or more 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: 0.0050 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

[0059] If molybdenum (Mo) is added in excessive amounts, the effect of improving the texture may be reduced by suppressing the segregation of segregation elements. Therefore, Mo may be included in an amount of 0.03 wt% or less. The lower limit thereof is not particularly limited, but it may be included in an amount of 0.001 wt% or more because it serves to improve the texture by segregating on the surface and grain boundaries. More specifically, Mo may be included in an amount of 0.001 to 0.010 wt%. More specifically, Mo may be included in an amount of 0.005 to 0.010 wt%.

B: 0.0050 wt% or less

[0060] If boron (B) is added in excessive amounts, it may cause deterioration of magnetism through the formation of inclusions in the steel. Therefore, B may be included in an amount of 0.005 wt% or less. The lower limit thereof is not

particularly limited, but it may be set at 0.0001 wt% due to steelmaking costs. More specifically, B may be included in an amount of 0.0001 to 0.0030 wt%.

V: 0.0050 wt% or less

[0061] Vanadium (V) has a strong tendency to form precipitates inside the steel, and they deteriorate the iron loss by forming fine carbides or nitrides inside the base material, thereby suppressing grain growth and domain wall movement. Therefore, the content of V may each be 0.0050 wt% or less. The lower limit thereof is not particularly limited, but it may be set at 0.0003 wt% due to steelmaking costs. That is, V may be included in an amount of 0.0003 to 0.0050 wt%. More specifically, V may be included in an amount of 0.0003 to 0.0030 wt%.

Ca: 0.0050 wt% or less

[0062] Calcium (Ca) has a strong tendency to form precipitates inside the steel, and they deteriorate the iron loss by forming fine sulfides inside the base material, thereby suppressing grain growth and domain wall movement.

Nb: 0.0050 wt% or less

[0063] Niobium (Nb) has a strong tendency to form precipitates inside the steel, and they deteriorate the iron loss by forming fine carbides or nitrides inside the base material, thereby suppressing grain growth and domain wall movement. Therefore, the Nb content may be 0.0050 wt% or less. The lower limit thereof is not particularly limited, but it may be set at 0.0003 wt% due to steelmaking costs. That is, Nb may be included in an amount of 0.0003 to 0.0050 wt%. More specifically, Nb may be included in an amount of 0.0003 to 0.0030 wt%.

Zr: 0.0050 wt% or less

[0064] If zirconium (Zr) is added in excessive amounts, it may cause deterioration of magnetism through the formation of inclusions in the steel. Therefore, Zr may be included in an amount of 0.005 wt% or less. The lower limit thereof is not particularly limited, but it may be set at 0.0001 wt% due to steelmaking costs. That is, Zr may be included in an amount of 0.0001 to 0.0050 wt%. More specifically, it may be included in an amount of 0.0005 wt% to 0.0030 wt%.

Te: 0.0100 wt% or less

[0065] Tellurium (Te) diffuses into the oxide layer on the surface of a hot-rolled coil, increases the coefficient of friction between the oxide layer and the rolling work roll, and improves hardness by concentrating under the oxide layer, so that it may be added to prevent the oxide layer that is broken during rolling from being pressed into the base metal and to be removed. If the amount of Te added is too small, the effect may be insignificant. If too much Te is added, the oxide layer is easily removed, causing the base material to come into direct contact with the work roll, thereby reducing the above effect, and excessive deformation bands may be generated within the steel sheet during cold rolling, which may lead to the development of {111}//ND texture, which is unfavorable for magnetism

[0066] More specifically, tellurium may be included in an amount of 0.0001 to 0.007 wt%.

Mg: 0.0050 wt% or less

[0067] Magnesium (Mg) is an element that mainly combines with sulfur to form sulfides, and may affect the surface oxide layer of iron. Therefore, Mg may be included in an amount of 0.0050 wt% or less. The lower limit thereof is not particularly limited, but it may be set at 0.0001 wt% due to steelmaking costs. That is, Mg may be included in an amount of 0.0001 to 0.0050 wt%. More specifically, it may be included in an amount of 0.0005 wt% to 0.0030 wt%.

[0068] The balance includes Fe and inevitable impurities. The inevitable impurities are impurities mixed in the steelmaking and the manufacturing process of the non-oriented electrical steel sheet, which are widely known in the field, and thus a detailed description thereof will be omitted. In the embodiment of the present invention, the addition of elements other than the above-described alloy components is not excluded, and various elements may be included within a range that does not hinder the technical concept of the present invention. When the additional elements are further included, they replace the balance of Fe.

[0069] As described above, in the embodiment of the present invention, by appropriately controlling the alloy composition of the steel sheet and appropriately forming an oxide layer on the surface of the steel sheet, magnetism may be improved.

[0070] FIG. 1 illustrates a schematic view of a cross-section of a non-oriented electrical steel sheet according to an

embodiment of the present invention.

[0071] As shown in FIG. 1, an oxide layer 10 is included that exists from the surface of a non-oriented electrical steel sheet (100) toward the inside.

[0072] The oxide layer 10 may be formed when oxygen penetrates into the steel sheet during the manufacturing process of the electrical steel sheet.

[0073] The oxide layer 10 is defined as a portion of the steel sheet surface where oxygen is present at 20 wt% or more. When the detection and thickness of the oxide layer 10 are analyzed by EDS after processing the TD surface of the specimen with FIB and observing it with TEM, the portion with oxygen of 20 wt% or more may be determined as the oxide layer. In this case, the steel sheet sample may be used as a sample without an insulating film formed, or as a sample with an insulating film formed and removed. In order to reduce the measurement error according to the position, the specimen may be measured at a minimum length of 200 μm in the RD direction and measured as the average value.

[0074] As shown in FIG. 1, in a cross-section including the rolling direction of the steel , there is an oxide layer disconnecting portion having an oxide layer thickness of 2 nm or less, and the length (DC_L) of this disconnecting portion may be 5 to 500 nm per 200 μm in the rolling direction. As shown in FIG. 1, a plurality of oxide layer disconnecting portions may exist within the specimen, in which case the sum of the lengths of all oxide layer disconnecting portions may be included in the range described above. If the length of the oxide layer disconnecting portion is too short, the thickness of the oxide layer increases overall, and an uneven shape may be formed at the interface between the oxide layer and the base material, which may cause problems in magnetic properties. If the length of the oxide layer disconnection is too long, fine nitride formation is promoted in the region 100 nm or less from the center of the base material in the oxide layer, which may cause problems with the magnetic properties. More specifically, the length of the disconnecting portion (DC_L) may be 50 to 400 nm per 200 μm in the rolling direction. The measurement and determination of the disconnecting portion may be performed in the same manner as the measurement and determination of the oxide layer described above.

[0075] The oxide layer 10 and the oxide layer disconnecting portion may be appropriately formed by adjusting the dew point and tension in the annealing process before cold rolling. A more specific method will be described later in relation to the method of manufacturing the non-oriented electrical steel sheet.

[0076] The thickness of the oxide layer 10 may be 15 to 50 nm. If the thickness of the oxide layer 10 is too thin, Al concentration within the oxide layer 10 may not be properly achieved, and the AlN suppression effect described above may not be sufficiently achieved. If the thickness of the oxide layer 10 is too thick, a large amount of oxygen may penetrate into the steel sheet, which may deteriorate magnetic properties. More specifically, the thickness of the oxide layer 10 may be 20 to 30 nm.

[0077] Due to the surface concentration of Al, the oxide layer 10 may include 20 wt% or more of Al. More specifically, Al may be included in an amount of 20 to 60 wt%. The remaining alloy components other than Al and O are the same as the alloy components of the non-oriented electrical steel sheet described above. Since the thickness of the oxide layer 10 is very thin compared to the thickness of the entire non-oriented electrical steel sheet 100, it does not substantially affect the alloy composition of the non-oriented electrical steel sheet 100.

[0078] As described above, the formation of nitride near the surface is suppressed due to the presence of the oxide layer 10. Specifically, the nitride density with a grain size of 10 to 200 nm in a cross-section up to a depth of 100 nm from the surface may be $4/\mu m^2$ or less. The grain size and number density of nitride may be measured based on a cross-section perpendicular to the rolling vertical direction (TD direction) of the steel sheet (TD plane). As a measurement method, a specimen may be prepared using the replica method and observed using TEM. The grain size is assumed to be the diameter of an imaginary circle having the same area as the area occupied by the nitride.

[0079] As described above, in the embodiment of the present invention, magnetism may be improved by appropriately controlling the steel composition and appropriately forming the oxide layer. Specifically, the core loss ($W_{10/400}$) of non-oriented electrical steel sheet may be 12.5 W/Kg or less based on a thickness of 0.25 mm. In addition, the magnetic flux density (B50) may be 1.67 T or more. The iron loss ($W_{10/400}$) is iron loss when a magnetic flux density of 1.0 T is induced at a frequency of 400 Hz. The magnetic flux density (B_{50}) means the magnetic flux density induced in a magnetic field of 5000 A/m. More specifically, the core loss ($W_{10/400}$) of the non-oriented electrical steel sheet may be 10.0 to 12.0 W/kg. More specifically, it may be 10.5 to 11.5W/kg. The magnetic flux density (B50) may be 1.68 to 1.75 T.

[0080] A method for manufacturing a non-oriented electrical steel sheet according to an embodiment of the present invention includes a step of hot-rolling a slab to manufacture a hot-rolled steel sheet; a pre-cold rolling annealing step of annealing the steel sheet; a step of cold-rolling the annealed steel sheet to manufacture a cold-rolled sheet; and a cold-rolled sheet annealing step of annealing the cold-rolled sheet.

[0081] Hereinafter, respective steps will be specifically described.

[0082] First, the slab is hot-rolled.

[0083] The alloy composition of the slab has been described in the alloy composition of the non-oriented electrical

steel sheet described above, so duplicate descriptions will be 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 are substantially the same.

[0084] Specifically, the slab includes, in wt%, Si: 1.5 to 4.5%, Al: 0.1 to 2.0%, Mn: 0.1 to 2.0%, with the balance being Fe and inevitable impurities.

[0085] Other additional elements have been described in the alloy composition of the non-oriented electrical steel sheet, so duplicate descriptions will be omitted.

[0086] The slab may be heated before hot-rolling. The heating temperature of the slab is not limited, but the slab may be heated at 1,200 °C or less. When the slab heating temperature is too high, precipitates such as AlN and MnS present in the slab are re-dissolved and then finely precipitated during hot-rolling and annealing, thereby inhibiting grain growth and reducing magnetism.

[0087] Next, the slab is hot-rolled to manufacture the hot-rolled sheet. A thickness of the hot-rolled sheet may be 0.8 to 2.0 mm. In the manufacturing of the hot-rolled sheet, a finish rolling temperature may be 800 °C or higher. Specifically, it may be 800 to 1,000 °C. The hot-rolled sheet may be wound at temperatures of 600°C or more. More specifically, the thickness of the hot-rolled sheet may be 0.9 to 1.8 mm.

[0088] After manufacturing the hot-rolled steel sheet, the subsequent steps may be performed while the scale remaining on the hot-rolled steel sheet remains. That is, after hot rolling, the subsequent steps may be performed without removing the scale, such as pickling, shot blasting, or surface grinding. By performing cold rolling in a state in which the pickling process is omitted, the friction between the rolling work roll and the steel sheet increases, so that shear deformation is simultaneously applied in addition to plane deformation during rolling, and a specific orientation develops during recrystallization annealing. In the embodiment of the present invention, scale refers to a portion where elements such as Fe, Al, and Si combine with oxygen with oxygen on the surface of the steel sheet to form a phase different from that of the base material. The meaning that scale remains signifies that at least a 1 μm thick scale remains on the hot-rolled sheet. In this case, the scale thickness means the sum of the scale thicknesses formed on both surfaces of the steel sheet. If the remaining scale thickness is too thin, the effect due to the remaining scale may not be sufficiently achieved. Even if the scale thickness is thicker, the effect is not improved, and there is a problem that the yield of the steel sheet decreases. More specifically, a scale with a thickness of 0.1 to 1 μm may remain.

[0089] In the embodiment of the present invention, after manufacturing the hot-rolled steel sheet, a pre-cold rolling annealing step of immediately annealing the hot-rolled steel sheet may be performed. Alternatively, after performing preliminary cold rolling on the hot-rolled steel sheet, a pre-cold rolling annealing step of annealing the preliminary cold-rolled sheet may be performed.

[0090] The preliminary cold rolling is distinguished from cold rolling, which will be described later, in that it is the first rolling step of the process of rolling to an intermediate thickness rather than the final product thickness, then performing intermediate annealing, and then cold rolling to the final product thickness.

[0091] The preliminary cold rolling may be performed in a reduction ratio range of 25 to 65% to improve the final cold rolling productivity and the grain size of the final product sheet. In addition, in the case in which rolling productivity is not considered, performing preliminary cold rolling in a Reverse Mill is also possible in the present invention. The preliminary cold-rolled sheet may have a thickness of 0.5 to 1.5 mm. More specifically, the reduction ratio may be 30 to 60% and the thickness may be 0.8 to 1.3 mm.

[0092] The preliminary cold reduction ratio may be calculated by (steel sheet thickness before rolling - steel sheet thickness after rolling) / steel sheet thickness before rolling. If the reduction ratio is too low in the preliminary cold rolling step, the rolling load increases during the final cold rolling, which reduces productivity, and the final reduction ratio increases, which may cause problems such as promoting fine <111>//ND orientation recrystallization. Conversely, if the reduction ratio is too high, the cold rolling load increases, and the possibility of sheet breakage also increases.

[0093] The preliminary cold rolling step may be performed at a temperature ranging from 60 to 300°C. This temperature may be raised naturally by the temperature of the steel sheet rising due to friction between the steel sheet and the rolling rolls, or by applying heat from the outside. If the temperature is too low, the rolling load significantly increases, and the steel sheet may slip between the rolling rolls instead of being rolled, which may cause problems such as twisting. If the temperature is too high, a thick oxide layer may occur on the surface of the steel sheet, which may deteriorate magnetism, and issues such as ignition of rolling oil may occur. More specifically, it is preferably performed at a temperature of 70 to 250°C. The aforementioned temperature refers to the temperature of the steel sheet.

[0094] As described above, the preliminary cold rolling step may be omitted if necessary.

[0095] Subsequently, in the pre-cold rolling annealing step, the hot-rolled steel sheet or the preliminary cold-rolled sheet is annealed. In the embodiment of the present invention, the oxide layer 10 may be appropriately formed by controlling the dew point and tension in the pre-cold rolling annealing step.

[0096] Specifically, the dew point may be in the range of -70 to -40°C. If the dew point is too low, the disconnecting portion of the oxide layer in the final product may excessively increase, or a large amount of fine nitrides may be

generated near the surface, which may cause problems with the magnetic properties. If the dew point is too high, an excessively thick oxide layer may be formed, or fine oxide particles may be formed near the surface, which may cause problems with the magnetic properties. More specifically, the dew point may be in the range of -65 to -45°C. More specifically, the dew point may be the dew point of the atmosphere during the soaking process.

[0097] In addition, a tension of 3.0 to 5.0 kgf/mm^2 may be applied. If the tension is too low, the shape of the steel sheet may not be sufficiently corrected, resulting in a partially excessive formation of the oxide layer on the final product sheet, which may cause problems with the magnetic properties. If the tension is too high, excessive disconnecting portions of the oxide layer may be formed on the final product sheet, which may cause problems with the magnetic properties. More specifically, the tension may be in the range of 3.3 to 4.7 kgf/mm^2. The tension may be the tension measured between the Bridle Rolls at the entry and exit sides of the annealing furnace and may be measured using a load cell.

[0098] In the pre-cold rolling annealing step, the soaking temperature may be in the range of 800 to 1100°C. If the annealing temperature is too low, the recrystallized structure is not formed or grows finely, so the effect of increasing the magnetic flux density is small, while if the annealing temperature is too high, the magnetic properties may deteriorate, and the rolling workability may deteriorate due to deformation of the sheet shape. More specifically, the temperature range may be 830 to 1080°C. The soaking time may be 30 to 300 seconds.

[0099] The annealing before cold rolling mentioned above may be performed in vertical continuous annealing equipment or horizontal continuous annealing equipment. If scale removal is omitted after hot rolling, scale removal may be performed after pre-cold rolling annealing. If scale remains in the final manufactured non-oriented electrical steel sheet, it will harm the magnetism. In addition, when cold rolling is performed while the scale remains, the marks of the scale being pressed into or removed from the surface may form unevenness, which may deteriorate the operational stability and magnetic characteristics of the motor. After pickling, the scale may be completely removed or may be present at a thickness of 0.01 μm or less. Pickling refers to all physical and chemical descaling methods, not just acid immersion. The pickling methods may include acid immersion, shot blasting, or surface grinding.

[0100] Next, the annealed steel sheet is cold-rolled to manufacture a cold-rolled sheet. In this case, cold rolling may be performed at a reduction ratio of 55 to 70%. If the reduction ratio is too low, the strain energy accumulated in the rolled steel sheet is small, making it difficult to recrystallize in the subsequent annealing process, so the rolled structure remains, which may cause problems in improving the magnetic flux density and iron loss. Conversely, if the reduction ratio is too high, the recrystallization of <111>//ND orientation grains may be promoted during the subsequent annealing process, and the grains may become finer, resulting in a lower magnetic flux density and an increase in iron loss. More specifically, the reduction ratio may be 58 to 67%. The cold rolling step may be performed using 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. The final rolled thickness may be from 0.1 mm to 0.35 mm.

[0101] Next, the cold-rolled sheet is annealed. The cold-rolled sheet annealing step may be annealed in an atmosphere with a dew point temperature of 0°C or lower. More specifically, it may be annealed in an atmosphere with a dew point temperature of -50 to -10°C.

[0102] The cold-rolled sheet annealing step may be annealed at a soaking temperature of 850 to 1100°C. If the soaking temperature is too low, the grains may not grow sufficiently, which may cause the hysteresis loss to increase and the iron loss to deteriorate. If the soaking temperature is too high, problems such as increased eddy current loss and rapid decrease in magnetic flux density may occur. More specifically, it may be annealed at a temperature ranging from 900 to 1050°C. It may be soaked for 10 to 300 seconds.

[0103] In the cold-rolled sheet annealing process, the processed texture formed in the cold-rolling step may be entirely (that is, 99 % or more) recrystallized.

[0104] After the cold-rolled sheet annealing, an insulating film may be formed. The insulating film may be formed as an organic, inorganic, and organic/inorganic composite film, and it may be formed with other insulating coating materials.

[0105] Hereinafter, the present invention will be described in more detail through examples. However, the examples are only for illustrating the present invention, and the present invention is not limited thereto.

Example 1

[0106] A slab was manufactured with components containing the following Table 1 and the balance Fe and other inevitable impurities. This was heated at 1150°C and hot-rolled at a finishing temperature of 950°C to manufacture a hot-rolled sheet having the thickness of Table 2. Specimen number A1 was pickled to completely remove scale on the hot-rolled sheet, and the scale removal was omitted for the remaining specimens.

[0107] Thereafter, the hot-rolled sheet was subjected to preliminary cold rolling under the conditions of Table 2 without annealing, and annealed before cold rolling, and then cold-rolled to obtain a final thickness of 0.25 mm. The

cold-rolled steel sheet was annealed at a soaking temperature of 1000°C for 100 seconds.

[0108] The magnetic flux density and iron loss were measured in the rolling direction and the direction perpendicular to the rolling using a single sheet tester by cutting 60 mm width × 60 mm length × 5 sheets for each specimen, and the average values were shown.

[0109] In this case, $W_{10/400}$ is iron loss when a magnetic flux density of 1.0 T is induced at a frequency of 400 Hz. $B5_0$ refers to the magnetic flux density induced in a magnetic field of 5000 A/m.

[0110] The characteristics of the oxide layer and nitride were analyzed by TEM images taken of the TD surface of the FIB-processed specimen along the RD direction for a length of 300 μm or more, and the chemical composition was analyzed by EDS. In the cross-section from the surface to a depth of 100 nm, if the nitride density exceeded 4/μm^2 with a particle size of 10 to 200 nm, it was marked as ◦, and if it was 4/μm^2 or less, it was marked as X.

(Table 1)

Specimen number	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
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

(continued)

Specimen number	Si (%)	Al (%)	Mn (%)	C (ppm)	S (ppm)	N (ppm)	Ti (ppm)	Nb (ppm)	V (ppm)
D8	4.20	0.5	0.2	31	13	12	13	13	13
D9	4.20	0.5	0.2	21	8	8	17	18	18

(Table 2)

Specimen number	Hot-rolled sheet thickness (mm)	Thickness after preliminary cold rolling (mm)	Preliminary cold rolling reduction ratio (%)	Annealing temperature before cold rolling (°C)	Annealing dew point before cold rolling (°C)	Annealing tension before cold rolling (kgf/mm^2)	Cold reduction ratio (%)
A1	0.96	0.63	35	750	-55	3.5	60
A2	2.08	0.63	70	950	-55	4.5	60
A3	1.56	0.63	60	1000	-80	3.5	60
A4	1.54	1.00	35	1050	-55	4.5	75
A5	1.56	0.63	60	850	-55	3.5	60
A6	0.96	0.63	35	950	-55	4.5	60
A7	0.96	0.63	35	1000	-55	3.5	60
A8	1.56	0.63	60	1050	-55	4.5	60
B1	1.14	0.63	45	850	-55	4.5	60
B2	1.14	0.63	45	950	-55	6.0	60
B3	0.91	0.50	45	1000	-55	4.5	50
B4	1.14	0.63	45	1150	-55	3.5	60
B5	1.14	0.63	45	850	-55	4.5	60
B6	1.14	0.63	45	950	-55	3.5	60
B7	1.14	0.63	45	1000	-55	4.5	60
B8	1.14	0.63	45	1050	-55	3.5	60
C1	1.59	0.71	55	850	-55	3.5	65
C2	1.10	0.71	35	750	-55	4.5	65
C3	1.10	0.71	35	1000	-55	2.0	65
C4	1.59	0.71	55	1050	-55	4.5	65
C5	1.10	0.71	35	850	-55	3.5	65
C6	1.59	0.71	55	950	-55	4.5	65
C7	1.59	0.71	55	1000	-55	3.5	65
C8	1.10	0.71	35	1050	-55	4.5	65
D1	1.59	0.71	55	850	-55	4.5	65
D2	0.89	0.71	20	950	-55	3.5	65
D3	1.59	0.71	55	1000	-30	4.5	65
D4	1.59	0.71	55	1050	-55	3.5	65
D5	1.59	0.71	55	850	-55	4.5	65
D6	1.59	0.71	55	950	-55	3.5	65
D7	1.59	0.71	55	1000	-55	4.5	65
D8	1.59	0.71	55	1050	-55	3.5	65

(continued)

Specimen number	Hot-rolled sheet thickness (mm)	Thickness after preliminary cold rolling (mm)	Preliminary cold rolling reduction ratio (%)	Annealing temperature before cold rolling (°C)	Annealing dew point before cold rolling (°C)	Annealing tension before cold rolling (kgf/mm^2)	Cold reduction ratio (%)
D9	1.59	0.71	55	950	0	0.3	65

(Table 3)

Specimen number	Oxide layer thickness (nm)	Oxide layer disconnecting portion length (nm)	Nitride density (number/μm^2)	W10/400 (W/kg)	B50 (Tesla)
A1	5	200	○	12.8	1.66
A2	30	800	○	13.0	1.64
A3	5	200	○	13.0	1.64
A4	40	1300	○	12.8	1.65
A5	40	100	×	11.2	1.68
A6	30	200	×	11.2	1.68
A7	30	200	×	11.1	1.68
A8	40	200	×	11.3	1.68
B1	5	300	○	13.0	1.66
B2	40	1300	○	13.1	1.66
B3	70	200	○	13.0	1.64
B4	80	200	○	13.2	1.65
B5	40	100	×	11.3	1.68
B6	30	100	×	11.3	1.68
B7	40	200	×	11.1	1.68
B8	40	200	×	11.2	1.68
C1	5	300	○	13.2	1.66
C2	5	300	○	13.2	1.64
C3	70	100	○	13.1	1.66
C4	40	300	×	11.3	1.68
C5	30	200	×	11.2	1.68
C6	30	200	×	11.2	1.68
C7	30	300	×	11.3	1.68
C8	40	300	×	11.2	1.68
D1	5	100	○	12.9	1.66
D2	80	100	○	12.9	1.64
D3	80	300	○	12.8	1.65
D4	40	200	×	11.1	1.68
D5	40	200	×	11.3	1.68
D6	40	200	×	11.1	1.68
D7	30	100	×	11.1	1.68

(continued)

Specimen number	Oxide layer thickness (nm)	Oxide layer disconnecting portion length (nm)	Nitride density (number/μm^2)	W10/400 (W/kg)	B50 (Tesla)
D8	40	300	×	11.2	1.68
D9	150	0	×	12.9	1.64

[0111] As shown in Table 1 to Table 3, it can be confirmed that the remaining inventive examples in which the steel component is properly controlled, the process conditions are properly controlled, and the oxide layer characteristics are properly formed have excellent iron loss and magnetic flux density.

[0112] On the other hand, in cases in which the steel component is not properly controlled, the process conditions are not properly controlled, and the oxide layer is not properly formed, it can be confirmed that the iron loss and magnetic flux density are inferior.

[0113] The present invention may be embodied in many different forms, and should not be construed as being limited to the disclosed embodiments. In addition, it will be understood by those skilled in the art that various changes in form and details may be made thereto without departing from the technical spirit and essential features of the present invention. Therefore, it is to be understood that the above-described embodiments are for illustrative purposes only, and the scope of the present invention is not limited thereto.

[Description of symbols]

[0114]

100: non-oriented electrical steel sheet, 10: oxide layer

Claims

1. A non-oriented electrical steel sheet comprising:

in wt%, Si: 1.5 to 4.5%, Al: 0.1 to 2.0%, Mn: 0.1 to 2.0%, with the balance being Fe and inevitable impurities, and
an oxide layer existing from a surface toward the inside,
wherein, in a cross-section including a rolling direction of the steel sheet, a length of an oxide layer disconnecting portion in which a thickness of the oxide layer is 2 nm or less is 5 to 500 nm per 200 μm in the rolling direction.

2. The non-oriented electrical steel sheet of claim 1, wherein
the thickness of the oxide layer is 15 to 50 nm.

3. The non-oriented electrical steel sheet of claim 1, further comprising
one or more of P: 0.1 wt% or less (excluding 0%), C: 0.005 wt% or less (excluding 0%), S: 0.005 wt% or less (excluding 0%), Ti: 0.004 wt% or less (excluding 0%), and N: 0.005 wt% or less (excluding 0%).

4. The non-oriented electrical steel sheet of claim 1, further comprising
0.005 to 0.200 wt% in each or a combined amount of one or two or more of Sn, Sb, Bi, Pb, Ge, and As.

5. The non-oriented electrical steel sheet of claim 1, further comprising
one or more 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%).

6. The non-oriented electrical steel sheet of claim 1, further comprising
one or more 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%).

7. The non-oriented electrical steel sheet of claim 1, wherein
a nitride density with a grain size of 10 to 200 nm in a cross-section up to a depth of 100 nm from the surface is $4/\mu m^2$ or less.

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

a step of hot rolling a slab including, in wt%, Si: 1.5 to 4.5%, Al: 0.1 to 2.0%, and Mn: 0.1 to 2.0%, with a balance being Fe and inevitable impurities, to manufacture a hot-rolled sheet;
a pre-cold rolling annealing step of annealing the steel sheet while applying a dew point of -70 to -40°C and a tension of 3.0 to 5.0 kgf/mm^2;
a step of cold rolling the annealed steel sheet to manufacture a cold-rolled steel sheet; and
a cold-rolled sheet annealing step of annealing the cold-rolled sheet.

9. The method for manufacturing the non-oriented electrical steel sheet of claim 8, wherein
the slab further includes one or more of P: 0.1 wt% or less (excluding 0%), C: 0.005 wt% or less (excluding 0%), S: 0.005 wt% or less (excluding 0%), Ti: 0.004 wt% or less (excluding 0%), and N: 0.005 wt% or less (excluding 0%).

10. The method for manufacturing the non-oriented electrical steel sheet of claim 8, wherein
the slab further includes 0.005 to 0.200 wt% in each or a combined amount of one or two or more of Sn, Sb, Bi, Pb, Ge, and As.

11. The method for manufacturing the non-oriented electrical steel sheet of claim 8, wherein
the slab further includes one or more 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%).

12. The method for manufacturing the non-oriented electrical steel sheet of claim 8, wherein
the slab further includes one or more 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%).

13. The method for manufacturing the non-oriented electrical steel sheet of claim 8, wherein
after manufacturing the hot-rolled steel sheet, a subsequent step is performed while a scale remaining on the hot-rolled steel sheet remains.

14. The method for manufacturing the non-oriented electrical steel sheet of claim 8, further comprising
a step of preliminary cold rolling a hot-rolled sheet prior to the pre-cold rolling annealing step.

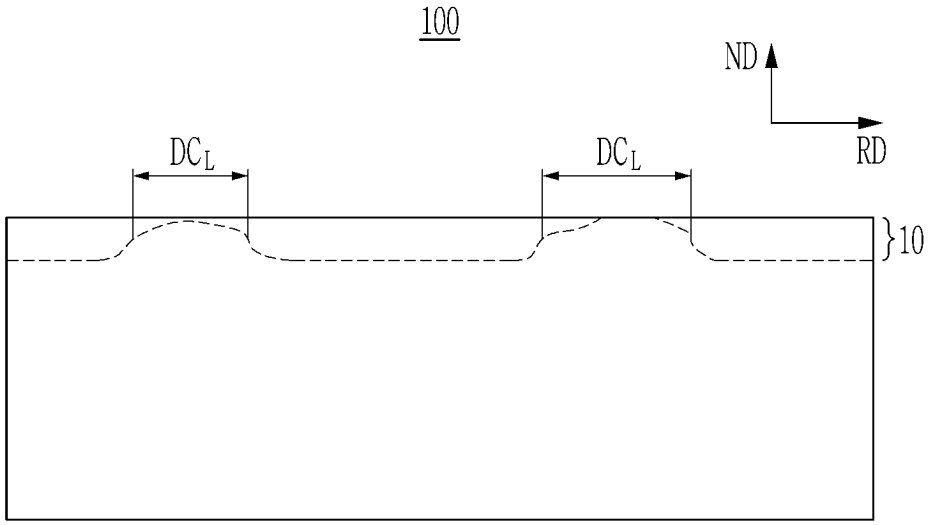
15. The method for manufacturing the non-oriented electrical steel sheet of claim 14, wherein
a reduction ratio in the step of preliminary cold rolling is 25 to 65%.

16. The method for manufacturing the non-oriented electrical steel sheet of claim 8, wherein
a soaking temperature of the pre-cold rolling annealing step is 800 to 1100°C.

17. The method for manufacturing the non-oriented electrical steel sheet of claim 8, wherein
a reduction ratio in the step of manufacturing the cold-rolled sheet is 55 to 70%.

18. The method for manufacturing the non-oriented electrical steel sheet of claim 8, wherein
the cold-rolled sheet annealing step is performed at a soaking temperature of 850 to 1100°C in an atmosphere with a dew point of 0°C or less.

FIG. 1



INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2024/020069

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 38/58**(2006.01)i; **C22C 38/52**(2006.01)i; **C22C 38/42**(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); C21D 8/12(2006.01); C21D 9/46(2006.01); C22C 38/00(2006.01); C22C 38/06(2006.01); H01F 1/147(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: 무방향성(non-oriented), 전기강판(electrical steel sheet), 이슬점(dew point), 장력(tension), 산화층(oxide layer)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2018-154853 A (NIPPON STEEL & SUMITOMO METAL) 04 October 2018 (2018-10-04) See paragraphs [0024] and [0045], claim 1 and figures 1-2.	1-18
A	KR 10-2325008 B1 (POSCO) 10 November 2021 (2021-11-10) See claims 12-13.	1-18
A	KR 10-2080174 B1 (POSCO) 21 February 2020 (2020-02-21) See claims 1-2 and 10.	1-18
A	US 2023-0045797 A1 (POSCO) 16 February 2023 (2023-02-16) See claims 1, 8, 11 and 13 and figure 1.	1-18
A	KR 10-2019-0078385 A (POSCO) 04 July 2019 (2019-07-04) See claims 1-2 and 10 and figure 1.	1-18

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"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	Date of mailing of the international search report
11 March 2025	**11 March 2025**
Name and mailing address of the ISA/KR **Korean Intellectual Property Office** **Government Complex-Daejeon Building 4, 189 Cheongsa-ro, 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/KR2024/020069

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
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		JP 2023-507436 A	22 February 2023
		JP 7583813 B2	14 November 2024
		KR 10-2021-0079545 A	30 June 2021
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		WO 2021-125683 A2	24 June 2021
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		JP 7142094 B2	26 September 2022
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		WO 2019-132132 A1	04 July 2019

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