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

(57) A non-oriented electrical steel sheet according to an embodiment of the present invention includes, in wt%, Si: 2.6 to 4.5%, Al: 0.0005 to 2.5%, Mn: 0.05 to

2.5%, S: 0.0051 to 0.0100%, and Ca: 0.0002 to 0.0100%, with the balance being Fe and inevitable impurities.

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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 relates to a non-oriented electrical steel sheet having excellent magnetism and a method for manufacturing the same, by manufacturing a slab using steel scrap, even if a steel composition contains a large amount of S.

10 **[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. 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. 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 $W_{10/400}$ iron loss. Meanwhile, the world is currently experiencing an extreme climate crisis due to global warming, and carbon neutrality activities aimed at reducing carbon emissions are being emphasized worldwide. The steel industry is developing technology to reduce carbon emissions during the manufacturing process by reducing the amount of molten iron used in conventional blast furnace operations, which emits large amounts of carbon, and replacing it with steel scrap, which does not emit carbon during the manufacturing process. However, steel scrap contains a large amount of impurities such as S that deteriorate magnetism, which causes the magnetic properties of electrical steel sheets to deteriorate. When the magnetism of electrical steel sheet deteriorates, the energy efficiency of motors and small transformers decreases, requiring more electric energy, and as a result, additional thermal power plants using fossil fuels are operated, which increases carbon emissions generated during the power generation process. In order to solve the problem of magnetic property deviation caused by non-uniform formation of precipitates due to temperature differences between the area in contact with the skid and the area not in contact with the skid during slab reheating heat treatment of non-oriented electrical steel sheets, a method is provided in which rare earth metals are added to form oxysulfides to render harmless the magnetic deterioration caused by S, and Ti precipitates are complexly precipitated with oxysulfides to solve the magnetic deterioration problem, however, no method is provided at all to solve the problem of magnetic deterioration caused by containing a large amount of S. In addition, a method has been proposed to control the components of Ti, C, N, Mn, and S to form Ti together with Mn as a spherical (Mn, Cu, Ti)S sulfide, thereby suppressing the formation of fine Ti inclusions and increasing coarse inclusions to solve the problem of magnetic deterioration, however, no solution has been provided at all to solve the problem of magnetic deterioration caused by the inclusion of a large amount of S. In addition, a method has been proposed to improve grain growth by controlling the content of Ca and S in the steel composition to precipitate CaS and to improve magnetic properties in the rolling direction by performing skin pass rolling after final annealing, however, no solution has been provided to solve the problem caused by a large amount of S, which has a negative effect on magnetism. Accordingly, research is needed on methods to improve magnetism in steel compositions containing a large amount of S.

55 **[Disclosure]**

[Technical Problem]

[0003] 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 having excellent magnetism and a method for manufacturing the same, by manufacturing a slab using steel scrap, even if a steel composition contains a large amount of S.

[Technical Solution]

[0004] A non-oriented electrical steel sheet according to an embodiment of the present invention includes, in wt%, Si: 2.6 to 4.5%, Al: 0.0005 to 2.5%, Mn: 0.05 to 2.5%, S: 0.0051 to 0.0100%, and Ca: 0.0002 to 0.0100%, with the balance being Fe and inevitable impurities.

[0005] The non-oriented electrical steel sheet according to the embodiment of the present invention may satisfy the following Formula 1.

[Formula 1]

$$0.09 \leq [\text{Ca}]/[\text{S}] \leq 0.50$$

(wherein, in Formula 1, [Ca] and [S] respectively represent the content (wt%) of Ca and S.)

[0006] An average particle size of sulfide in the steel sheet may be 1 to 10 μm .

[0007] The sulfide may include one or more of Ca, Mn, Al, and Cu.

[0008] The non-oriented electrical steel sheet according to the embodiment of the present invention may further include one or more of P: 0.002 to 0.02 wt%, C: 0.005 wt% (excluding 0%), Ti: 0.005 wt% or less (excluding 0%), and N: 0.005 wt% or less (excluding 0%).

[0009] The non-oriented electrical steel sheet according to 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.

[0010] 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%).

[0011] The non-oriented electrical steel sheet according to the embodiment of the present invention may further include one or more of Mo: 0.05 wt% or less (excluding 0%), B: 0.0050 wt% or less (excluding 0%), V: 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%).

[0012] In the non-oriented electrical steel sheet according to the embodiment of the present invention, an average size of grains in the steel sheet may be 50 to 80 μm .

[0013] In the non-oriented electrical steel sheet according to the embodiment of the present invention, a core loss ($W_{10/400}$) may be 10.5 W/Kg or less, and a magnetic flux density (B_{50}) may be 1.59 T or more.

[0014] Another embodiment of the present invention provides a method for manufacturing a non-oriented electrical steel sheet, including: hot-rolling a slab including, in wt%, Si: 2.6 to 4.5%; Al: 0.0005 to 2.5%; Mn: 0.05 to 2.5%; S: 0.0051 to 0.0100%; and Ca: 0.0002 to 0.0100%, with the balance being Fe and inevitable impurities, to manufacture a hot-rolled steel sheet; cold rolling the hot-rolled steel sheet to manufacture a cold-rolled sheet; and a cold-rolled sheet annealing step of annealing the cold-rolled sheet.

[0015] The slab may satisfy the following Formula 1.

[Formula 1]

$$0.09 \leq [\text{Ca}]/[\text{S}] \leq 0.50$$

(wherein, in Formula 1, [Ca] and [S] respectively represent the content (wt%) of Ca and S.)

[0016] The slab may further include one or more of P: 0.002 to 0.02 wt%, C: 0.005 wt% (excluding 0%), Ti: 0.005 wt% or less (excluding 0%), and N: 0.005 wt% or less (excluding 0%).

[0017] 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.

[0018] 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%).

[0019] The slab may further include one or more of Mo: 0.05 wt% or less (excluding 0%), B: 0.0050 wt% or less

(excluding 0%), V: 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%).

[0020] The slab may be manufactured using 80 wt% or less of blast furnace hot metal and 20 wt% or more of steel scrap.

[0021] A soaking temperature in the cold-rolled sheet annealing step may be 900 to 1100°C.

[Advantageous Effects]

[0022] According to an embodiment of the present invention, it is possible to reduce carbon generated during the manufacturing process by manufacturing using steel scrap.

[0023] A non-oriented electrical steel sheet according to an embodiment of the present invention simultaneously has excellent magnetic flux density and high-frequency iron loss.

[0024] 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 motor cores.

[Mode for Invention]

[0025] 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.

[0026] 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.

[0027] 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.

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

[0029] In embodiments of the present invention, inclusion of an additional element means replacing the remaining iron (Fe) by an additional amount of the additional elements.

[0030] 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.

[0031] 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.

[0032] A non-oriented electrical steel sheet according to an embodiment of the present invention includes, in wt%, Si: 2.6 to 4.5%, Al: 0.0005 to 2.5%, Mn: 0.05 to 2.5%, S: 0.0051 to 0.0100%, and Ca: 0.0002 to 0.0100%, with the balance being Fe and inevitable impurities.

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

Si: 2.6 to 4.5 wt%

[0034] Silicon (Si) serves to increase specific resistance of a material to decrease iron loss. When too little Si is added, an effect of improving the iron loss may be insufficient. If too much Si is added, the material's brittleness increases, which may lead to a sharp decrease in rolling productivity and a severe deterioration in magnetic flux density. Accordingly, Si may be included in an amount of 2.6 to 4.5 wt%. More specifically, it may be included in an amount of 2.8 wt% to 4.3 wt%. More specifically, it may be included in an amount of 3.0 wt% to 4.0 wt%.

Al: 0.0005 to 2.5 wt%

[0035] Aluminum (Al) serves as an element to reduce magnetic deviation in the rolling direction and the direction perpendicular to the rolling direction by increasing the resistivity of the material to lower iron loss and reduce magnetic anisotropy. If too little Al is added, it may be difficult to secure sufficient resistivity and obtain the sufficient iron loss improvement effect. If too much Al is added, the magnetic flux density deteriorates, causing problems in all processes such as steelmaking and continuous casting, which may significantly reduce productivity. Accordingly, Al may be included in an amount of 0.0005 to 2.5 wt%. More specifically, it may be included in an amount of 0.5 wt% to 2.3 wt%. More specifically, it may be included in an amount of 0.7 wt% to 2.1 wt%.

Mn: 0.05 to 2.5 wt%

[0036] Manganese (Mn) serves to improve the iron loss by increasing the resistivity of the material. In addition, it reacts with S to form Mn sulfide and reacts with nitrogen, Al, and Si at high temperatures to form (Al, Si, Mn) nitride, which has the effect of inhibiting grain growth. It is difficult for Mn to sufficiently improve the iron loss, and if too much Mn is added, the magnetic flux density decreases, and fine MnS is excessively precipitated, which hinders the movement of magnetic domains, thereby deteriorating the magnetic flux density and iron loss. Accordingly, Mn may be included in an amount of 0.05 to 2.5 wt%. More specifically, it may be included in an amount of 0.5 wt% to 2.0 wt%. More specifically, it may be included in an amount of 0.8 wt% to 1.8 wt%.

S: 0.0051 to 0.0100 wt%

[0037] Sulfur (S) is an element that reacts with Cu, Mn, and the like in steel to precipitate sulfides, and as fine sulfides precipitate in larger quantities, the effect of hindering magnetic domain movement becomes stronger, which has the effect of worsening magnetism. It is generally known that the effect of deteriorating magnetism becomes stronger when it is contained at 0.005 wt% or more. In an embodiment of the present invention, a non-oriented electrical steel sheet is intended to be manufactured using steel scrap, and since steel scrap inevitably contains a large amount of S, the lower limit is set at 0.0051 wt%, and even if a large amount of S is contained, a non-oriented electrical steel sheet is manufactured without deterioration of iron loss and magnetic flux density. On the other hand, if the S content is too high, excessive precipitation of sulfides may occur, weakening the effect of reducing the interference with magnetic domain movement due to sulfide coarsening. Therefore, the S content may be 0.0051 to 0.0100 wt%. More specifically, it may be 0.0060 to 0.0100 wt%.

Ca: 0.0002 to 0.0100 wt%

[0038] In the embodiment of the present invention, when Ca is appropriately included in a non-oriented electrical steel sheet containing a large amount of S, the size of sulfides becomes coarse, thereby promoting grain growth and also improving magnetic quality. However, if too much Ca is added, the sulfide becomes coarse and the residual stress in the matrix structure increases, which hinders the movement of magnetic domains and may deteriorate the magnetism. More specifically, it may be included in an amount of 0.0005 wt% to 0.0075 wt%. More specifically, it may be included in an amount of 0.0010 wt% to 0.0050 wt%.

[0039] The non-oriented electrical steel sheet according to the embodiment of the present invention may satisfy the following Formula 1.

[Formula 1]

$$0.09 \leq [\text{Ca}]/[\text{S}] \leq 0.50$$

(wherein, in Formula 1, [Ca] and [S] respectively represent the content (wt%) of Ca and S.)

[0040] In the embodiment of the present invention, Ca is intended to improve magnetism by coarsely forming sulfides in a steel composition containing a large amount of S. Therefore, it is necessary to include Ca in the river in proportion to S. If the value of Formula 1 is included too small, it means that the Ca content is low compared to S, and the coarsening of sulfide is insufficient, which may result in poor magnetism. If the value of Formula 1 is included too large, it means that Ca is included in excess compared to S, and the sulfide becomes coarser, which increases the residual stress in the matrix structure, which hinders the movement of magnetic domains and may deteriorate the magnetism. More specifically, the value of Formula 1 may be 0.10 to 0.47.

[0041] The non-oriented electrical steel sheet according to the embodiment of the present invention may further

include one or more of P: 0.002 to 0.02 wt%, C: 0.005 wt% (excluding 0%), Ti: 0.005 wt% or less (excluding 0%), and N: 0.005 wt% or less (excluding 0%).

P: 0.002 to 0.02 wt%

[0042] Phosphorus (P) may improve the magnetic flux density as a grain boundary segregation element. If the amount added is too small, the effect is not sufficient, and if added too much, it may suppress grain growth, resulting in poor iron loss, and grain boundary segregation may cause poor rolling properties, which may also reduce productivity. More specifically, P may be included in an amount of 0.003 to 0.015 wt%.

C: 0.005 wt% or less

[0043] 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%.

Ti: 0.005 wt% or less

[0044] Titanium (Ti) may be limited because it forms carbonitrides, which hinders the movement of magnetic domains. More specifically, Ti may be included in an amount of 0.0001 to 0.005 wt%. More specifically, Ti may be included in an amount of 0.0001 to 0.003 wt%.

N: 0.005 wt% or less

[0045] Nitrogen (N) has the characteristic of forming nitrides by reacting with Al, Si, and Cr. These nitrides may deteriorate hysteresis loss by hindering grain growth and increasing the grain boundary fraction, and may deteriorate eddy current loss by hindering the movement and rotation of magnetic domains. More specifically, N may be included in an amount of 0.0001 to 0.0030 wt%.

[0046] 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

[0047] 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

[0048] 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.

[0049] 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%

[0050] Copper (Cu) serves to form sulfides together with Mn. If too much Cu is added, the grains may not grow beyond an appropriate size, which may result in poor magnetism. More specifically, Cu may be included in an amount of 0.007 to 0.050 wt%. More specifically, it may be included in an amount of 0.008 wt% to 0.030 wt%.

Cr: 0.01 to 0.50 wt%

[0051] 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. More specifically, Cr may be contained in an amount of 0.050 to 0.20 wt%.

Ni: 0.05 wt% or less

[0052] 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

[0053] 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

[0054] 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.

[0055] The non-oriented electrical steel sheet according to the embodiment of the present invention may further include one or more of Mo: 0.05 wt% or less (excluding 0%), B: 0.0050 wt% or less (excluding 0%), V: 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: 0.050 wt% or less

[0056] 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

[0057] 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

[0058] 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%.

Nb: 0.0050 wt% or less

[0059] 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

[0060] 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

[0061] 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

[0062] More specifically, tellurium may be included in an amount of 0.0001 to 0.007 wt%.

Mg: 0.0050 wt% or less

[0063] 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%.

[0064] The balance includes Fe and inevitable impurities. The inevitable impurities are impurities mixed in the steel-making 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.

[0065] In the embodiment of the present invention, the steel contains a large amount of S, while coarsely precipitating sulfides to minimize magnetic deterioration due to S. Specifically, the average particle size of sulfides in the steel sheet may be 1 to 10 μm . A sulfide refers to S elements agglomerated into a particulate form. That is, it refers to a portion where sulfur is contained in a larger amount than the content of the substrate of the steel sheet. In the embodiment of the present invention, the sulfide is a particle having an aggregate particle size of at least 1 nm as measured by a scanning electron microscope (SEM) and containing S in excess of the content in the matrix steel sheet. The reference cross-section for measuring sulfides is not particularly limited, but may be a normal plane (TD plane) in the rolling vertical direction (TD direction) of the steel sheet. The particle size of a sulfide refers to the diameter of an imaginary circle having the same area as the area occupied by the sulfide. The average particle size of sulfides may be analyzed by an image analysis program using images obtained through TEM or SEM and EDS. To reduce variations depending on the measurement position, measurements may be performed at 10 $\mu\text{m} \times 10 \mu\text{m}$ intervals on a specimen having an area of 5 mm $\times$ 5 mm or more, and may be obtained as an average value for the total number of sulfides.

[0066] Sulfides may include one or more of Ca, Mn, Al, and Cu in addition to S. It is also possible for them to co-precipitate with C, N, and O in addition to the aforementioned elements. That is, sulfides may include precipitates represented by (Ca, Mn, Al, Cu)(S, C, N, O). In this case, (A, B) means single or combined precipitation of A and B. More specifically, sulfides may include one or more of CaS, MnS, and CuS.

[0067] If the average particle size of the sulfides is too small, it not only hinders magnetic domain movement, deteriorating magnetic quality, but also suppresses grain growth, which may lower magnetism. If the average particle size of the sulfides is too large, grain growth is promoted, but magnetic domain movement is hindered due to stress fields formed at the interface between the sulfides and the matrix metal, which may result in deterioration of magnetism. More specifically, the average particle size of the sulfides may be 1.1 to 8.0 μm . More specifically, the average particle size of the sulfides may be 2.0 to 7.5 μm .

[0068] In the embodiment of the present invention, the non-oriented electrical steel sheet may have an average grain size of 50 to 80 μm in the steel sheet. If the average grain size is too small, the iron loss may be deteriorated due to excessive increase in hysteresis loss. If the average grain size is too large, the iron loss may be deteriorated due to an excessive increase in eddy current loss. More specifically, the average grain size of grains in the steel sheet may be 50 to 80 μm . It may be 50 to 75 μm .

[0069] The non-oriented electrical steel sheet according to the embodiment of the present invention has excellent magnetic flux density and excellent highfrequency iron loss. Specifically, the non-oriented electrical steel sheet according to the embodiment of the present invention may have an iron loss ($W_{10/400}$) of 10.5 W/Kg or less and a magnetic flux density (B_{50}) of 1.59 T or more.

[0070] B_{50} refers to the magnetic flux density induced in a magnetic field of 5000 A/m.

[0071] $W_{10/400}$ is the iron loss when a magnetic flux density of 1.0 T is induced at a frequency of 400 Hz.

[0072] In the embodiment of the present invention, B_{50} and $W_{10/400}$ are represented by averaging the measured values in the rolling direction (RD direction) and the rolling vertical direction (TD direction). More specifically, in the embodiment of the present invention, the non-oriented electrical steel sheet may have an iron loss ($W_{10/400}$) of 9.0 to 10.5 W/Kg and a magnetic flux density (B_{50}) of 1.59 T to 1.65 T.

[0073] A method for manufacturing a non-oriented electrical steel sheet according to an embodiment of the present invention includes the steps of: hot rolling a slab to produce a hot-rolled steel sheet; cold rolling the hot-rolled steel sheet to produce a cold-rolled sheet; and a cold-rolled sheet annealing step of annealing the cold-rolled sheet.

[0074] Hereinafter, respective steps will be specifically described.

[0075] First, the slab is hot-rolled.

[0076] 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.

[0077] Specifically, the slab includes, in wt%, Si: 2.6 to 4.5%, Al: 0.0005 to 2.5%, Mn: 0.05 to 2.5%, S: 0.0051 to 0.0100%, and Ca: 0.0002 to 0.0100%, with the balance being Fe and inevitable impurities.

[0078] Other additional elements have been described in the alloy composition of the non-oriented electrical steel sheet, so duplicate descriptions will be omitted.

[0079] The slab may be manufactured using 80 wt% or less of blast furnace molten metal and 20 wt% or more of steel scrap. Compared to the blast furnace molten metal, a large amount of S exists in the steel scrap, which may cause a large amount of precipitates such as sulfides to be precipitated. In the embodiment of the present invention, by adding an appropriate amount of Ca, the particle size of the precipitate may be appropriately adjusted to reduce the adverse effect on magnetism, and the grain size may be uniformly grown to improve magnetism.

[0080] 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.

[0081] Next, the slab is hot-rolled to manufacture the hot-rolled sheet. A thickness of the hot-rolled sheet may be 1.0 to 4.5 mm. In the embodiment of the present invention, a step of preliminary cold rolling before cold rolling may be additionally included, so that even if the thickness of the hot-rolled sheet is relatively thick, a non-oriented electrical steel sheet of an appropriate thickness may be manufactured. More specifically, the thickness of the hot-rolled sheet may be 1.5 to 3.5 mm.

[0082] The step of manufacturing the hot-rolled sheet may include a step of finish-rolling at a temperature of 850°C or higher.

[0083] If the hot rolling finish-rolling temperature is too low, the rolling load increases and the hot rolling workability deteriorates. In addition, a lot of deformation structures remain in the hot-rolled steel sheet, which may cause an increase in the rolling load during the subsequent preliminary cold rolling process. In addition, during intermediate annealing, recrystallization of <111>//ND orientation grains from the deformation structure is promoted, resulting in a lower magnetic flux density. Therefore, the higher the hot rolling finish-rolling temperature, the better, and more specifically, it is preferable to perform finish-rolling at a temperature of 860 to 1000°C.

[0084] The step of manufacturing the hot-rolled plate may include a step of performing water cooling after 0.1 seconds or more after the finish-rolling.

[0085] After the finish-rolling, cooling is performed for coiling, and when performing water cooling, if water cooling is performed immediately after the finish-rolling (that is, in less than 0.1 seconds), the steel sheet may be rapidly cooled, causing deformation and residual stress in the steel sheet, making coiling difficult. In addition, in terms of microstructure, the deformation stress after the finish-rolling is not released and remains as it is, which may cause an increase in the rolling load in the subsequent cold rolling step and recrystallization of the fine <111>//ND orientation. Therefore, maintaining the hot-rolled deformation structure for more than 0.1 seconds immediately after the hot-rolled finish-rolling so that recovery and recrystallization may occur reduces the rolling load during the subsequent preliminary cold rolling and suppresses the formation of <111>//ND orientation recrystallized grains. More specifically, water cooling may be performed after 0.3 to 5.0 seconds, and even more specifically, water cooling may be performed after 0.5 to 3.0 seconds.

[0086] The step of manufacturing the hot-rolled sheet may include a step of coiling at a temperature of 600 to 800°C.

A step of rough rolling may also be included before the step of finish-rolling.

[0087] If the temperature is controlled too low during the step of the winding, recovery and recrystallization of the hot-rolled deformation structure will not occur well, and the cooling load will increase to quickly cool the steel sheet to a low temperature, which may make it difficult to wind the supercooled coil. Conversely, if the temperature is too high, recovery and recrystallization may be promoted, but additional oxidation by atmospheric oxygen may occur while wound, which may cause thicker scale formation and grain boundary oxidation problems. The grain boundary oxidation of the hot rolled sheet promotes grain boundary corrosion during the subsequent pickling process, which increases the possibility of surface stripe defects and severe wear of the rolling roll. Therefore, it is recommended that the coiling temperature be 600 to 800°C, and more specifically, it may be coiled at 600 to 750°C.

[0088] After manufacturing the hot-rolled steel sheet, hot-rolled sheet annealing may be performed before cold rolling. The soaking temperature during hot-rolled sheet annealing may be 800 to 1200°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 1170°C. The soaking time may be 15 to 180 seconds. The hot-rolled sheet annealing may be omitted as needed.

[0089] Returning to the description of the method for manufacturing the non-oriented electrical steel sheet, a cold-rolled sheet is manufactured by cold rolling a hot-rolled steel sheet. In this case, cold rolling may be performed at a reduction ratio of 30 to 80%. 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 40 to 70%. The thickness may be 0.1 mm to 0.5 mm. More specifically, it may be 0.15 to 0.35 mm. 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.

[0090] Next, the cold-rolled sheet is annealed.

[0091] The cold-rolled sheet annealing step may be performed in an atmosphere having a mixed gas and atmosphere of hydrogen (H₂) and nitrogen (N₂). The mixed gas may contain 40 vol% or less of hydrogen and 60 vol% or more of nitrogen.

[0092] The cold-rolled sheet annealing step may be performed at a temperature of 900°C to 1100°C for 60 to 300 seconds. In the embodiment of the present invention, annealing is performed at a relatively high temperature; however, due to the appropriate precipitation of sulfides, excessive growth of grain size may be prevented, thereby preventing magnetic deterioration caused by this. In addition, by annealing at high temperature in a state in which sulfides are properly precipitated, the grains may be grown uniformly. If the annealing temperature is too low or the time is too short, grain growth may not be sufficient, and core loss may deteriorate due to an excessive increase in hysteresis loss. If the annealing temperature is too high or the time is too long, the grains may grow too large, and core loss may deteriorate due to an excessive increase in eddy current loss. More specifically, the cold-rolled sheet annealing step may be performed at a temperature of 950°C to 1050°C for 120 to 240 seconds.

[0093] After the cold rolled sheet annealing step, a step of forming an insulating film may be further included to secure insulation and corrosion resistance to the steel sheet. Since the insulating film is widely known, a detailed description thereof will be omitted.

[0094] 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

[0095] Slats containing the alloy components and residual Fe and unavoidable impurities summarized in Table 1 and Table 2 were manufactured, heated to 1180°C, and hot-rolled to a thickness of 2.3 mm. The hot-rolled sheet was heated to a temperature of 1000°C and then water-cooled, and the steel thus subjected to hot-rolled sheet annealing was pickled, then rolled once to a thickness of 0.2 mm, and the cold-rolled sheet was annealed as a cold-rolled sheet by maintaining it at a temperature of 1000°C for 180 seconds.

[0096] After processing magnetic measurement specimens, the iron loss $W_{10/400}$ and magnetic flux density B_{50} were measured, and the results are shown in Table 2 below.

[0097] The magnetic properties were measured by Epstein tester by preparing Epstein specimens at each angle, and the average results in the rolling direction and the direction perpendicular to the rolling are summarized in Table 3.

[0098] The sulfides were measured in 5 mm × 5 mm areas at 10 μm × 10 μm intervals using a scanning electron

microscope (SEM), and are summarized in Table 3.

[0099] The average grain size was measured using a scanning electron microscope (SEM), and is summarized in Table 3.

(Table 1)

(wt%)	Si	Mn	Al	S	Ca	Ca/S
Inventive Material 1	3.68	1.167	1.201	0.0051	0.0006	0.12
Inventive Material 2	3.09	1.327	1.715	0.0053	0.0008	0.15
Inventive Material 3	3.95	1.254	0.890	0.0062	0.0012	0.19
Inventive Material 4	3.32	1.493	1.398	0.0066	0.0017	0.26
Inventive Material 5	3.81	1.042	1.133	0.0073	0.0022	0.30
Inventive Material 6	3.41	1.184	1.465	0.0075	0.0026	0.35
Inventive Material 7	3.90	1.459	0.835	0.0085	0.0034	0.40
Inventive Material 8	4.14	0.910	0.867	0.0088	0.0040	0.45
Inventive Material 9	2.66	1.467	2.071	0.0092	0.0042	0.46
Inventive Material 10	3.69	0.984	1.278	0.0098	0.0045	0.46
Comparative Material 1	2.82	1.045	2.126	0.0050	0.0001	0.02
Comparative Material 2	3.53	0.827	1.520	0.0061	0.0003	0.05
Comparative Material 3	3.73	1.037	1.213	0.0075	0.0006	0.08
Comparative Material 4	3.51	0.818	1.541	0.0083	0.0005	0.06
Comparative Material 5	3.09	1.319	1.713	0.0091	0.0006	0.07
Comparative Material 6	3.08	1.067	1.854	0.0099	0.0008	0.08
Comparative Material 7	2.78	1.375	1.995	0.0050	0.0024	0.48
Comparative Material 8	3.61	1.041	1.336	0.0061	0.0032	0.52
Comparative Material 9	2.81	1.098	2.107	0.0075	0.0045	0.60
Comparative Material 10	3.85	1.398	0.917	0.0083	0.0066	0.80
Comparative Material 11	3.59	1.033	1.357	0.0091	0.0073	0.80
Comparative Material 12	3.82	1.144	1.075	0.0099	0.0079	0.80
Comparative Material 13	2.50	0.910	0.867	0.0088	0.0040	0.45
Comparative Material 14	3.41	1.184	1.465	0.0248	0.0117	0.47

(Table 2)

(wt%)	C	N	P	Cu	Sn	Ni	Mo
Inventive Material 1	0.0036	0.0022	0.01	0.01	0.058	-	-
Inventive Material 2	0.0036	0.0018	0.01	0.01	0.056	-	0.01
Inventive Material 3	0.0031	0.0050	0.01	0.02	0.063	-	-
Inventive Material 4	0.0034	0.0026	0.01	0.01	0.056	-	-
Inventive Material 5	0.0036	0.0040	0.01	0.02	0.063	0.05	-
Inventive Material 6	0.0039	0.0014	0.01	0.02	0.062	-	0.04
Inventive Material 7	0.0037	0.0032	0.01	0.01	0.057	-	-
Inventive Material 8	0.0047	0.0040	0.01	0.02	0.065	-	-
Inventive Material 9	0.003	0.0042	0.01	0.01	0.058	-	-
Inventive Material 10	0.0041	0.0046	0.01	0.01	0.065	-	-

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(continued)

(wt%)	C	N	P	Cu	Sn	Ni	Mo
Comparative Material 1	0.0046	0.0038	0.01	0.01	0.059	-	-
Comparative Material 2	0.0036	0.0014	0.01	0.01	0.064	-	-
Comparative Material 3	0.0042	0.0040	0.01	0.02	0.064	-	-
Comparative Material 4	0.0037	0.0016	0.01	0.02	0.059	-	-
Comparative Material 5	0.0042	0.0050	0.01	0.02	0.062	-	-
Comparative Material 6	0.0035	0.0045	0.01	0.02	0.064	-	-
Comparative Material 7	0.0036	0.0027	0.01	0.02	0.059	-	-
Comparative Material 8	0.0037	0.0050	0.01	0.01	0.063	-	-
Comparative Material 9	0.0038	0.0019	0.01	0.01	0.065	-	-
Comparative Material 10	0.0035	0.0037	0.01	0.01	0.064	-	-
Comparative Material 11	0.0049	0.0026	0.01	0.02	0.058	-	-
Comparative Material 12	0.0041	0.0019	0.01	0.01	0.058	-	-
Comparative Material 13	0.003	0.0042	0.01	0.01	0.058	-	-
Comparative Material 14	0.0039	0.0014	0.01	0.02	0.062	-	0.04

(Table 3)

	Sulfide average particle size (μm)	Average grain size (μm)	$W_{10/400}$ (W/kg)	B50 (Tesla)
Inventive Material 1	1.1	68	9.8	1.60
Inventive Material 2	2.1	67	9.9	1.60
Inventive Material 3	3.8	56	9.2	1.64
Inventive Material 4	4.0	73	10.0	1.62
Inventive Material 5	3.6	68	10.4	1.62
Inventive Material 6	4.2	54	9.1	1.61
Inventive Material 7	6.8	53	10.4	1.61
Inventive Material 8	6.9	51	9.2	1.64
Inventive Material 9	6.0	52	9.2	1.62
Inventive Material 10	5.5	58	9.6	1.62
Comparative Material 1	0.0	48	10.0	1.56
Comparative Material 2	0.1	22	12.9	1.55
Comparative Material 3	0.0	45	12.4	1.57
Comparative Material 4	0.0	24	12.6	1.59
Comparative Material 5	0.0	48	12.9	1.55
Comparative Material 6	0.0	42	12.5	1.57
Comparative Material 7	13.5	78	11.9	1.58
Comparative Material 8	13.6	80	11.4	1.59
Comparative Material 9	11.5	80	12.1	1.55
Comparative Material 10	12.2	77	11.6	1.57
Comparative Material 11	12.6	90	12.0	1.57
Comparative Material 12	10.7	83	11.6	1.57

(continued)

	Sulfide average particle size (μm)	Average grain size (μm)	$W_{10/400}$ (W/kg)	B ₅₀ (Tesla)
Comparative Material 13	6.9	57	13.1	1.52
Comparative Material 14	16.4	63	12.9	1.53

[0100] As shown in Table 1 to Table 3, it can be confirmed that the examples in which the steel component is appropriately adjusted and the grain size of sulfide and grains is appropriately formed have excellent iron loss and magnetic flux density.

[0101] On the other hand, Comparative Materials 1 to 12 and Comparative Material 14 do not contain Ca or S appropriately, so that sulfide is too fine or is generated in too much amount, and as a result, the grains do not grow appropriately, resulting in poor iron loss $W_{10/400}$ and magnetic flux density B_{50} .

[0102] Comparative Material 13 has too little Si added, resulting in poor iron loss $W_{10/400}$ and magnetic flux density B_{50} .

[0103] 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.

Claims

1. A non-oriented electrical steel sheet comprising, in wt%:
Si: 2.6 to 4.5%; Al: 0.0005 to 2.5%; Mn: 0.05 to 2.5%; S: 0.0051 to 0.0100%; and Ca: 0.0002 to 0.0100%, with the balance being Fe and inevitable impurities.

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

the non-oriented electrical steel sheet satisfies the following Formula 1:

[Formula 1]

$$0.09 \leq [\text{Ca}]/[\text{S}] \leq 0.50$$

(wherein, in Formula 1, [Ca] and [S] respectively represent the content (wt%) of Ca and S.)

3. The non-oriented electrical steel sheet of claim 1, wherein
an average particle size of sulfide in the steel sheet is 1 to 10 μm .

4. The non-oriented electrical steel sheet of claim 3, wherein
the sulfide includes one or more of Ca, Mn, Al, and Cu.

5. The non-oriented electrical steel sheet of claim 1, further comprising
one or more of P: 0.002 to 0.02 wt%, C: 0.005 wt% (excluding 0%), Ti: 0.005 wt% or less (excluding 0%), and N: 0.005 wt% or less (excluding 0%).

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

7. 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%).

8. The non-oriented electrical steel sheet of claim 1, further comprising

one or more of Mo: 0.05 wt% or less (excluding 0%), B: 0.0050 wt% or less (excluding 0%), V: 0.0050 wt% or less (excluding 0%), Nb: 0.0050 wt% or less (excluding 0%), Zr: 0.005 wt% or less (excluding 0%), Te: 0.01 wt% or less (excluding 0%), and Mg: 0.0050 wt% or less (excluding 0%).

9. The non-oriented electrical steel sheet of claim 1, wherein an average size of grains in the steel sheet is 50 to 80 μm .

10. The non-oriented electrical steel sheet of claim 1, wherein a core loss ($W_{10/400}$) is 10.5 W/Kg or less, and a magnetic flux density (B_{50}) is 1.59 T or more.

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

hot-rolling a slab including, in wt%, Si: 2.6 to 4.5%; Al: 0.0005 to 2.5%; Mn: 0.05 to 2.5%; S: 0.0051 to 0.0100%; and Ca: 0.0002 to 0.0100%, with the balance being Fe and inevitable impurities, to manufacture a hot-rolled steel sheet;

cold rolling the hot-rolled steel sheet to manufacture a cold-rolled sheet; and
a cold-rolled sheet annealing step of annealing the cold-rolled sheet.

12. The method for manufacturing the non-oriented electrical steel sheet of claim 11, wherein

the slab satisfies the following Formula 1. [Formula 1]

$$0.09 \leq [\text{Ca}]/[\text{S}] \leq 0.50$$

(wherein, in Formula 1, [Ca] and [S] respectively represent the content (wt%) of Ca and S.)

13. The method for manufacturing the non-oriented electrical steel sheet of claim 11, wherein the slab further includes one or more of P: 0.002 to 0.02 wt%, C: 0.005 wt% (excluding 0%), Ti: 0.005 wt% or less (excluding 0%), and N: 0.005 wt% or less (excluding 0%).

14. The method for manufacturing the non-oriented electrical steel sheet of claim 11, 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.

15. The method for manufacturing the non-oriented electrical steel sheet of claim 11, 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%).

16. The method for manufacturing the non-oriented electrical steel sheet of claim 11, wherein the slab further includes one or more of Mo: 0.05 wt% or less (excluding 0%), B: 0.0050 wt% or less (excluding 0%), V: 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%).

17. The method for manufacturing the non-oriented electrical steel sheet of claim 11, wherein the slab is manufactured using 80 wt% or less of blast furnace hot metal and 20 wt% or more of steel scrap.

18. The method for manufacturing the non-oriented electrical steel sheet of claim 11, wherein a soaking temperature in the cold-rolled sheet annealing step is 900 to 1100°C.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/KR2024/020322

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/02(2006.01)i; **C22C 38/04**(2006.01)i; **C22C 38/06**(2006.01)i; **C22C 38/12**(2006.01)i; **C22C 38/14**(2006.01)i;
C22C 38/00(2006.01)i; **C22C 38/58**(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); C21D 8/12(2006.01); C22C 38/04(2006.01); C22C 38/06(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), 황(S), 칼슘(Ca), 스크랩 (scrap), 황화물(sulfide)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 55-024942 A (KAWASAKI STEEL CORP.) 22 February 1980 (1980-02-22) See page 2, claim 1 and table 1.	1-3,5,10-13,17-18
Y		4,6-9,14-16
Y	KR 10-1918720 B1 (POSCO) 14 November 2018 (2018-11-14) See paragraph [0049], claims 1 and 6-9 and table 3.	4,6-9,14-16
A	KR 10-2000-0026557 A (POHANG IRON & STEEL CO., LTD.) 15 May 2000 (2000-05-15) See claims 1-2.	1-18
A	KR 10-2014-0113739 A (JFE STEEL CORPORATION) 24 September 2014 (2014-09-24) See claims 1-2.	1-18
A	CN 101358317 B (SHOUGANG CO., LTD.) 22 September 2010 (2010-09-22) See claim 1.	1-18

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

* Special categories of cited documents:

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“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 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.

Form PCT/ISA/210 (second sheet) (July 2022)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/KR2024/020322

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