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

(72) Inventors:
- **KWON, Yunik**
  Pohang-si, Gyeongsangbuk-do 37859 (KR)
- **HAN, Minsoo**
  Pohang-si, Gyeongsangbuk-do 37859 (KR)
- **KO, Hyunseok**
  Pohang-si, Gyeongsangbuk-do 37859 (KR)
- **KIM, Jae Hyung**
  Pohang-si, Gyeongsangbuk-do 37859 (KR)

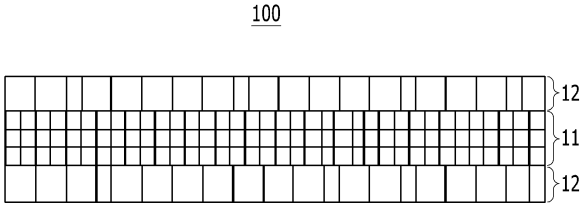
(74) Representative: **Meissner Bolte Partnerschaft mbB**
Patentanwälte Rechtsanwälte
Postfach 86 06 24
81633 München (DE)

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(54) ELECTRICAL STEEL SHEET FOR ELECTROMAGNETIC WAVE SHIELDING, AND MANUFACTURING METHOD THEREFOR

(57) An electrical steel sheet for electromagnetic shielding according to an embodiment of the present invention, may include grains of which a ratio (D2/D1) of a diameter (D1) of a circumscribed circle and a diameter (D2) of an inscribed circle is 0.5 or higher among the entire grains on the steel sheet surface are 70 area% or more, and an average grain size within a surface portion from the steel sheet surface to less than 2/5 of a steel sheet thickness in a thickness direction is 100 μm to 500 μm, and an average grain size within a central portion from 2/5 to 3/5 of the steel sheet thickness is 55 to 90 μm.

FIG. 1



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Description

[Technical Field]

[0001] An embodiment of the present invention relates to an electrical steel sheet for electromagnetic shielding and a manufacturing method thereof. Specifically, an embodiment of the present invention relates to an electrical steel sheet for electromagnetic shielding with excellent electromagnetic shielding effect and a manufacturing method thereof.

[Background Art]

[0002] The undergrounding of transmission towers involves burying high-voltage power lines directly in the ground or constructing underground tunnels, such as power conduits, to accommodate them, thereby improving urban aesthetics and preventing accidents that may be caused by natural disasters. Electromagnetic fields that can affect the human body are generated near these underground power lines, and aluminum is used to shield them. Aluminum is resistant to corrosion, making it advantageous for long-term use, but the material must be applied thickly to achieve a sufficient shielding rate. Such thick aluminum material has the disadvantage of making construction difficult and increasing the cost of shielding underground power lines due to the large amount of material used.

[0003] To solve the above problem, it was proposed to apply steel materials, which are relatively cheaper than aluminum. To ensure excellent magnetic field shielding properties in steel materials, the content of interstitial elements and precipitate-forming elements is limited. Since this significantly reduces permeability due to precipitates generated and strain caused by interstitial elements, a method to limit this has been proposed. In addition, excellent magnetic flux density was sought by limiting the constituent elements and restricting the size of the precipitates to a small size. However, when shielding electromagnetic waves generated in low magnetic fields, excellent shielding performance can be secured only by simultaneously applying the influence of constituent elements and grain size control, so additional microstructure control is required. In addition, since electromagnetic shielding steel is often used in environments that are buried underground, thereby being exposed to soil corrosion, and electromagnetic shielding needs to be ensured along power transmission and distribution lines, high processability and constructability of the material is required. Therefore, steel for electromagnetic shielding requires excellent processability to undergo a surface treatment with very strong corrosion resistance in environments such as soil, but currently, there are no shielding materials that meet these requirements.

[Disclosure]

[Technical Problem]

[0004] An embodiment of the present invention provides an electrical steel sheet for electromagnetic shielding and a manufacturing method thereof. Specifically, an embodiment of the present invention provides an electrical steel sheet for electromagnetic shielding with excellent electromagnetic shielding effect and a manufacturing method thereof.

[Technical Solution]

[0005] An electrical steel sheet for electromagnetic shielding according to an embodiment of the present invention, may include grains of which a ratio (D2/D1) of a diameter (D1) of a circumscribed circle and a diameter (D2) of an inscribed circle is 0.5 or higher among the entire grains on the steel sheet surface are 70 area% or more, and an average grain size within a surface portion from the steel sheet surface to less than 2/5 of a steel sheet thickness in a thickness direction is 100 μm to 500 μm, and an average grain size within a central portion from 2/5 to 3/5 of the steel sheet thickness is 55 to 90 μm.

[0006] A ratio of the area fraction of the area fraction of grains having a <110> direction parallel to the rolling direction of the steel sheet within 15° with respect to grains having a <111> direction within the steel sheet parallel to the rolling direction of the steel sheet within 15° is 3 or greater.

[0007] A ratio of the average grain size within the surface portion with respect to the average grain size within the central portion is 2.0 or greater.

[0008] An electrical steel sheet for electromagnetic shielding according to an embodiment of the present invention may include, in wt%, Si:0.3% to 7.0%, C:0.15% or less (excluding 0%) and balance including Fe and unavoidable impurities.

[0009] An electrical steel sheet for electromagnetic shielding according to an embodiment of the present invention may further include Mn: 0.1 wt% or less and S: 0.005 wt% or less.

[0010] A manufacturing method of an electrical steel sheet for electromagnetic shielding according to an embodiment of the present invention may include manufacturing a hot-rolled steel sheet by hot-rolling a slab, annealing the hot-rolled steel sheet, cold rolling the annealed hot-rolled steel sheet, decarburization annealing the cold-rolled steel sheet, and non-oxidizing annealing the decarburization annealed steel sheet, where τ defined in Equation 1 below is 0.23 to 0.5.

[Equation 1]

$$\tau = \left(\frac{finish\ rolling\ temperature + 273}{ROT\ cooling\ rate \times hot - rolled\ sheet\ thickness \times 10^4}\right) \cdot \left(\frac{2.54 \times (dew\ point\ temperature + 273) \times (annealing\ temperature + 273)}{cold - rolled\ sheet\ thickness \times 10^4}\right.$$

(in Equation 1, the finish rolling temperature is a hot-rolling finish rolling temperature (°C), the ROT cooling rate is a cooling rate (-°C/s) in a ROT section before winding a coil after hot-rolling finish rolling, the hot-rolled sheet thickness is a thickness (mm) of the hot-rolled sheet, the dew point temperature is the dew point temperature (°C) of the atmosphere in the decarburization annealing, the annealing temperature is an annealing temperature (°C) in the decarburization annealing, and the cold-rolled sheet thickness means a steel sheet thickness (mm) after cold rolling.)

[0011] The slab may include, in wt%, Si:0.3% to 7.0%, C:0.01% to 0.4% and balance including Fe and unavoidable impurities.

[0012] The slab may further include Mn: 0.1 wt% or less and S: 0.005 wt% or less.

[0013] The annealing of the hot-rolled steel sheet may include a decarburization process.

[0014] The annealing of the hot-rolled steel sheet may be performed at a temperature of 850 °C to 1,000 °C and a dew point temperature of 70 °C or less.

[0015] The decarburization annealing may be performed at a temperature of 600 °C to 1,000 °C and a dew point temperature of 0 °C to 70 °C.

[0016] The non-oxidizing annealing may be performed at a soaking temperature of 750 to 1,050 °C for 30 seconds to 5 minutes.

[0017] The non-oxidizing annealing may be performed in an atmosphere with a dew point temperature of -20 °C or below.

[Advantageous Effects]

[0018] According to an embodiment of the present invention, electromagnetic shielding properties are excellent.

[0019] According to an embodiment of the present invention, a steel sheet for electromagnetic shielding, which has excellent processability, can be provided.

[0020] Additionally, it may be manufactured through a continuous process so the manufacturing time may be relatively shortened and productivity may be improved.

[Description of the Drawings]

[0021]

FIG. 1 is a schematic diagram schematically representing a cross-section of a steel sheet for electromagnetic shielding according to an embodiment of the present invention.

FIG. 2 is a schematic diagram schematically showing an example of use of a steel sheet for electromagnetic shielding according to an embodiment of the present invention.

FIG. 3 is a photograph representing a surface of a steel sheet for electromagnetic shielding manufactured in Example 1 through an EBSD analysis.

FIG. 4 is a photograph observing a cross-section of a steel sheet for electromagnetic shielding manufactured in Example 1 through an optical microscope.

[Mode for Invention]

[0022] 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.

[0023] 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.

[0024] 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.

[0025] 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.

[0026] Unless otherwise stated, % means wt%, and 1 ppm is 0.0001 wt%.

[0027] 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.

[0028] 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 invention.

[0029] FIG. 1 schematically represents a cross-section of an electrical steel sheet for electromagnetic shielding according to an embodiment of the present invention.

[0030] As appears in FIG. 1, according to an electrical steel sheet 100 for electromagnetic shielding according to an embodiment of the present invention, grains of which a ratio (D2/D1) of a diameter D1 of a circumscribed circle and a diameter D2 of an inscribed circle is 0.5 or higher among the entire grains on the steel sheet surface are 70 area% or more, an average grain size within a surface portion 12 from the steel sheet surface to less than 2/5 of the steel sheet thickness in a thickness direction is 100 μm to 500 μm, and an average grain size within a central portion 11 from 2/5 to 3/5 of the steel sheet thickness is 55 to 90 μm.

[0031] Hereinafter, each configuration of an electrical steel sheet for electromagnetic shielding according to an embodiment of the present invention will be described in detail.

[0032] First, the electrical steel sheet 100 for electromagnetic shielding according to an embodiment of the present invention includes, in wt%, Si:0.3% to 7.0%, C:0.15% or less (excluding 0%) and balance including Fe and unavoidable impurities.

Si: 0.3 to 7.0 wt%

[0033] Silicon (Si) improves the electromagnetic shielding performance of materials in low-magnetic-field regions. If the Si content is excessively small, problems may arise with the material's ability to absorb external magnetic fields in low-magnetic-field regions. If the amount of Si is excessively high, the impurity content in the material increases, which can lead to a decrease in shielding ability due to a reduction in saturation magnetic flux density. More specifically, Si may be included in an amount of 0.5 to 4.0 wt%.

C: 0.15 wt% or less

[0034] The carbon (C) in a central portion needs to escape to a surface layer so as to allow Goss grains on the surface layer to be diffused to the central portion during intermediate decarburization annealing and final decarburization annealing, so the content of carbon (C) in the slab may be 0.010 to 0.400 wt%. More specifically, the content of C in the slab may be 0.100 to 0.300 wt%. In addition, the carbon content in the steel sheet whose manufacturing process is completed after the decarburization annealing may be 0.150 wt% or less. More specifically, it may be 0.100 wt% or less. More specifically, it may be 0.050 wt% or less.

[0035] An electrical steel sheet for electromagnetic shielding according to an embodiment of the present invention may further include Mn: 0.1 wt% or less and S: 0.005 wt% or less.

[0036] Mn and S form MnS precipitates, which hinder the growth of Goss grains that diffuse into the center during the decarburization process. Therefore, it is preferable that Mn and S are not added. However, in consideration of the amount that is inevitably mixed during the steelmaking process, Mn and S in the slab and the steel sheet after the non-oxidizing annealing can be controlled so that Mn is 0.1 wt% or less, and S is 0.005 wt% or less, respectively.

[0037] The balance includes Fe and unavoidable impurities. The unavoidable impurities are mixed in during the steelmaking process and the process for manufacturing electrical steel sheets, which is widely known in the field, and a detailed description thereof will be omitted. In detail, components such as Al, N, Ti, Mg, and Ca react with oxygen in the steel to form oxides, so strong suppression is required, and the respective components may be managed to be 0.005 wt% or less. In the embodiment of the present invention, the addition of elements other than the above-described alloy compositions 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.

[0038] Among the entire grains on the steel sheet surface, grains having a value of 0.5 or higher for the ratio (D2/D1) of the diameter D1 of the circumscribed circle and the diameter D2 of the inscribed circle may be 70 area% or more. This is because, as will be described later regarding the manufacturing process, decarburization annealing and non-oxidation annealing were performed for a short period of time. If the annealing is performed for a long time of 30 minutes or more through batch annealing after decarburization annealing, the diameter D1 of the circumscribed circle becomes significantly larger than that of the inscribed circle D2, so the ratio cannot be greater than 0.5. Here, the circumscribed circle refers to the smallest imaginary circle surrounding the outside of the grain, and the inscribed circle refers to the largest imaginary circle contained within the grain. More specifically, among entire grains, grains having a value of 0.5 or higher for the ratio (D2/D1) of the diameter D1 of the circumscribed circle and the diameter D2 of the inscribed circle may be 75 area% or more. More specifically, among entire grain, grains having a value of 0.5 or higher for the ratio (D2/D1) of the diameter D1 of the circumscribed circle and the diameter D2 of the inscribed circle may be 75 to 97 area%. Grains of this shape respond to external magnetic fields, particularly in low-magnetic-field regions, and contribute to electromagnetic shielding by the material absorbing the magnetic field. Among entire grain, grains having a value of 0.5 or higher for the ratio (D2/D1) of the diameter D1 of the circumscribed circle and the diameter D2 of the inscribed circle can be analyzed the observed photograph, by using a computer program, after observing the surface (ND surface) of the steel sheet by an optical microscope.

[0039] In an embodiment of the present invention, the average grain size within the surface portion 12 from the steel sheet surface to less than 2/5 of the steel sheet thickness in the thickness direction is 100 μm to 500 μm, and the average grain size within the central portion 11 from 2/5 to 3/5 of the steel sheet thickness is 55 to 90 μm. In this way, by forming the grain sizes of the surface portion 12 and the central portion 11 differently, the grains of the surface portion can react to and absorb an external magnetic field, thereby contributing to electromagnetic shielding. If the average grain size within the surface portion 12 is excessively small, the ability of the material to absorb an external magnetic field is reduced, and the electromagnetic shielding performance may be reduced. If the average grain size within the surface portion 12 is excessively large, the ductility of the material is greatly reduced, and problems such as the material breaking during cold rolling or plate breaking in the continuous line may occur. If an average grain size of the central portion 11 is excessively large, the ability of the material to react to and absorb external magnetic fields decreases, and thus the electromagnetic shielding performance may be reduced. More specifically, the average grain size within the surface portion 12 is 150 μm to 450 μm, and the average grain size within the central portion 11 may be 58 to 88 μm. The average grain size can be obtained by measuring the number of grains in the measurement area for a cross-section including the thickness direction of the steel sheet, and dividing the measurement area by the number of grains to obtain the average grain area. The grain size can be obtained as a diameter of a circle having the same area.

[0040] A ratio of the average grain size within the surface portion with respect to the average grain size within the central portion (surface portion/central portion) may be 2.0 or higher. If this ratio is excessively small, the material's ability to respond to an external magnetic field decreases, which may result in inferior electromagnetic shielding properties. More specifically, a ratio of the average grain size within the surface portion with respect to the average grain size within the central portion (surface portion/central portion) may be 3.0 to 20.0.

[0041] A ratio (<110>//ND / <111>//ND) of the area fraction of grains having a <110> direction parallel to the rolling direction of the steel sheet within 15° with respect to the area fraction of grains having a <111> direction parallel to the rolling direction of the steel sheet within 15° may be 3.0 or more. When this ratio is high, it can increase permeability in low-magnetic-field environments and contribute to electromagnetic shielding. More specifically, <110>//ND / <111>//ND may be 3.3 to 6.5. This may be measured by a backscattered electron diffraction pattern analyzer (EBSD).

[0042] In this way, by appropriately adjusting the steel composition of the steel sheet and properly forming the texture, the electromagnetic shielding performance is excellent. Specifically, the shielding rate in a 60Hz, 100mG

magnetic field may be 50% or more, and the shielding rate in a 60Hz, 1G magnetic field may be 65% or more. More specifically, the shielding rate in a 60Hz, 100mG magnetic field may be 50.0% to 75.0%, and the shielding rate in a 60Hz, 1G magnetic field may be 65.0% to 85.0%.

[0043] At this time, the shielding rate can be measured by generating a magnetic field of 1G or less using the Helmholtz coil method and installing a pickup coil capable of measuring the magnetic field in the center of the generated magnetic field. The pickup coil is shielded with a shielding material, the magnetic field strength measured before and after shielding is determined, and the shielding rate is calculated as follows. Pickup coil shielding is achieved by wrapping the coil in a cylindrical shape or shielding all four sides in a box shape.

$$\text{Shielding rate}(\%) = (1 - B_{\text{Shielding Applied}} / B_{\text{Shielding Not Applied}}) \times 100$$

[0044] Although not shown in FIG. 1, a film located on the surface of the electrical steel sheet 100 for electromagnetic shielding may be additionally included.

[0045] In FIG. 2, one embodiment of the present invention is shown for one use example of an electrical steel sheet for electromagnetic shielding. As appears in FIG. 2, the electrical steel sheet 100 for electromagnetic shielding can be installed to surround the underground conduit (power conduit), or the electrical steel sheet 100 for electromagnetic shielding can be inserted between the transmission line and the underground conduit (power conduit) for use. Alternatively, the electrical steel sheet 100 for electromagnetic shielding can be rolled into a cylindrical tube shape and installed to wrap around the transmission line 200.

[0046] A manufacturing method of an electrical steel sheet for electromagnetic shielding according to an embodiment of the present invention includes manufacturing a hot-rolled steel sheet by hot-rolling a slab; annealing the hot-rolled steel sheet; cold rolling the annealed hot-rolled steel sheet; decarburization annealing the cold-rolled steel sheet; and non-oxidizing annealing the decarburization annealed steel sheet.

[0047] Hereinafter, each step will be described in detail.

[0048] First, the slab is hot-rolled.

[0049] The slab may include Si:0.3% to 7.0%, C:0.01% to 0.4%, in wt%, and balance including Fe and unavoidable impurities.

[0050] The slab may further include Mn: 0.1 wt% or less and S: 0.005 wt% or less.

[0051] The description of the steel composition of the slab is the same as the description of the electrical steel sheet for electromagnetic shielding mentioned above, so the redundant description is omitted. Except for C, the steel composition of the steel sheet can be substantially the same as the steel composition of the slab.

[0052] The slab may be heated before hot-rolling the slab. The slab heating temperature may be 1,050 °C to 1,350 °C, which is higher than a normal heating temperature. When the temperature is high during slab reheating, there is a problem in that the hot-rolled structure becomes coarse, which has an adverse effect on magnetism. However, a manufacturing method of an electrical steel sheet according to an embodiment of the present invention has a higher carbon content than the conventional art, so the hot-rolled structure is not coarsened even if the slab re-heating temperature is high, and it is advantageous in hot rolling by re-heating at a higher temperature than usual. However, when the reheating temperature is high, the solubility of the deposition such as TiN, AlN, or the like increases, and a large number of micro depositions are distributed during cooling, which hinders the growth of grains on the surface.

[0053] Hot rolling may be used to manufacture a hot-rolled sheet with the thickness of 1.3 to 4.3 mm by applying an appropriate rolling rate in the final cold rolling so that the final product with the thickness may be manufactured. More specifically, it may be manufacture at a thickness of 1.5 to 4.0 mm.

[0054] The hot-rolling finish rolling temperature may be 750 °C to 1,050 °C. If the finish rolling temperature of hot rolling is excessively high, surface defects occur, thereby degrading quality. In addition, if the finish rolling temperature is excessively low, the rolling load increases, which reduces sheet throughput and lowers productivity. More specifically, it may be 800 to 1,030 °C. In an embodiment of the present invention, the cooling speed in the ROT section can be controlled until the coil is wound after hot-rolling finish rolling. More specifically, the cooling rate in the ROT section can be controlled to -50 to -5°C/s. If the cooling rate is excessively high, it inhibits the growth of surface grains, making it difficult to obtain coarse grains. More specifically, the cooling rate can be controlled to -30 to -7°C/s.

[0055] After the hot rolling, the hot-rolled steel sheet is annealed. At this time, the hot-rolled sheet annealing may include a decarburization process. Specifically, hot-rolled sheets can be annealed at a temperature of 850°C to 1,000 °C and a dew point temperature of 70°C or lower. In detail, annealing may be performed at the dew point temperature of -70 °C to 70 °C. After the annealing described above, further annealing may be performed at the temperature of 1,000 to 1,200 °C and the dew point temperature of 0 °C or lower. After performing the hot-rolled sheet annealing, pickling may be performed.

[0056] Subsequently, a cold-rolled steel sheet is manufactured by performing cold rolling.

[0057] Therefore, cold rolling may be performed at a reduction ratio of 50% to 80%. More specifically, it may be 55% to 75%. Through this, a cold-rolled steel sheet having a final thickness of 0.3 to 2.0 mm can be manufactured.

[0058] Subsequently, the cold-rolled steel sheet is decarburization annealed. At this time, the decarburization annealing may be performed in an austenite single-phase area or a region where a composite phase of ferrite and austenite exists. Specifically, it may be annealed at the temperature of 800 °C to 970 °C and the dew point temperature of 3 °C to 65 °C. In addition, the atmosphere may be a mixed gas atmosphere of hydrogen and nitrogen. In addition, after the decarburization annealing, the amount of carbon in the steel sheet may be 0.15 wt%. or less.

[0059] In a manufacturing method of an electrical steel sheet for electromagnetic shielding according to an embodiment of the present invention, τ defined by Equation 1 below is 0.230 to 0.500 .

[Equation 1]

$$\tau = \left(\frac{finish\ rolling\ temperature + 273}{ROT\ cooling\ rate \times hot - rolled\ sheet\ thickness \times 10^4}\right) \cdot \left(\frac{2.54 \times (dew\ point\ temperature + 273) \times (annealing\ temperature + 273)}{cold - rolled\ sheet\ thickness \times 10^4}\right)$$

(in Equation 1, the finish rolling temperature is the hot-rolling finish rolling temperature (°C), the ROT cooling rate is a cooling rate (-°C/s) in the ROT section before winding the coil after hot-rolling finish rolling, the hot-rolled sheet thickness is a thickness (mm) of the hot-rolled sheet, dew point temperature is the dew point temperature (°C) of the atmosphere in decarburization annealing, the annealing temperature is an annealing temperature (°C) in the decarburization annealing, the cold-rolled sheet thickness means a steel sheet thickness (mm) after primary cold rolling.)

[0060] If τ is excessively small, grain growth of the surface portion 12 may not be sufficient. If τ is excessively large, the grain growth of the central portion 11 may occur significantly, which may have an adverse effect on the electromagnetic shielding performance. More specifically, τ may be 0.240 to 0.450.

[0061] After decarburization annealing, second cold rolling may be further included. Through this, a cold-rolled steel sheet having a final thickness of 0.1 to 1.0 mm can be manufactured.

[0062] Subsequently, the decarburization annealed steel sheet is subject to non-oxidizing annealing.

[0063] The non-oxidizing annealing may be performed for 30 seconds to 5 minutes at a crack temperature of 750 to 1,050 °C.

[0064] The object of the non-oxidizing annealing is to grow the grains of the surface portion 12 and the central portion 11 to a preset size or larger. This allows for the growth of surface grains, which can further improve electromagnetic shielding performance in low-magnetic-field regions. If the soaking temperature is excessively low or time is short, grain growth of the surface portion 12 and the central portion 11 may not be sufficient, and the improvement of electromagnetic shielding performance may not be sufficient. If the crack temperature is excessively high or the time is excessively long, the grain size on the surface and inside becomes uniform, making it impossible to obtain excellent shielding efficiency at 100 mG and 1 G magnetic fields simultaneously. More specifically, the soaking temperature of non-oxidizing annealing may be 800 to 1,000 °C may. More specifically, it may be 900 to 970 °C.

[0065] The secondary non-oxidizing annealing may be performed at the dew point temperature of -20 °C or lower. If the dew point temperature is excessively high, an oxide layer may be formed on the surface, which may adversely affect magnetism. More specifically, it may be performed at the atmosphere of 99 volume% or more of hydrogen at the dew point temperature of -50 to -30 °C.

[0066] After cold rolling, it may be performed as a continuous process up to the non-oxidizing annealing. The continuous process means that there is no batch process for coiling a steel sheet into a coil and annealing it. As described above, the continuous process is possible because the decarburization annealing or the non-oxidizing annealing is completed in less than a few minutes.

[0067] Hereinafter, a specific Example of the present invention will be described. However, the Example below is merely a specific example of the present invention, and the present invention is not limited to the Example below.

Example

[0068] A slab containing Si:2.0% and C:0.101% in wt% and balance of Fe and unavoidable impurities is heated at a temperature of 1,270 °C, and then hot rolling, hot-rolled sheet annealing, cold rolling, decarburization annealing, and

non-oxidizing annealing are sequentially performed under the manufacture condition of Table 1. After the decarburization annealing, C was 0.05 wt% or less. Non-oxidizing annealing was performed for 30 seconds at the temperatures in Table 1 below and the dew point temperature of -20°C.

[0069] Manufacturing condition 11 was subsequently non-oxidizing annealed for 30 minutes.

[0070] The average grain size, magnetic flux density, and electromagnetic shielding rate of the fabricated specimens were measured for the surface and central portions and are shown in Table 2.

[0071] The average grain size was measured by using an optical microscope.

[0072] The grain morphology on the surface was measured by using a backscattered electron diffraction pattern analyzer (EBSD).

[0073] <110>//ND / <111>//ND was measured by a backscattered electron diffraction pattern analyzer (EBSD).

[0074] Magnetic flux density was measured by using single strip magnetic field measurement, and the average values were shown in Table 3 after measuring the magnetic flux density in the rolling direction and the direction perpendicular to the rolling direction. The magnetic flux density measured at 50 Hz and 100 A/m was denoted as B_1, and the magnetic flux density measured at 50 Hz and 5000 A/m was denoted as B_{50}.

[0075] The electromagnetic shielding rate was measured by generating a magnetic field of less than 1G by using the Helmholtz coil method and installing a cylindrical pickup coil capable of measuring the magnetic field in the center of the generated magnetic field. The pickup coil was shielded with a steel sheet, the magnetic field strength measured before and after shielding was determined, and the shielding rate was calculated as follows.

$$\text{Shielding rate}(\%) = (1 - B_{\text{Shielding Applied}} / B_{\text{Shielding Not Applied}}) \times 100$$

[Table 1]

Manufacture condition	Hot rolling			Hot-rolled sheet	Cold rolling		Decarburization-annealing		Parameter (τ)	Nonoxidation annealing
	Finish rolling temperature (°C)	ROT cooling rate (-°C/s)	Thickness (mm)	Annealing temperature (°C)	Reduction ratio (%)	Thickness (mm)	Dew point temperature (°C)	Annealing temperature (°C)		Annealing temperature (°C)
1	1002	8	4.0	920	60	1.60	60	950	0.258	985
2	975	10	3.0	920	65	1.05	43	923	0.380	970
3	950	13	2.5	920	70	0.75	23	873	0.432	947
4	925	25	2.0	920	62	0.76	5	820	0.243	945
5	900	28	1.5	920	63	0.56	10	815	0.390	920
6	880	32	5.0	920	61	1.95	15	895	0.032	1032
7	911	55	2.8	920	80	0.56	0	857	0.108	952
8	843	35	2.7	920	70	0.81	-20	920	0.112	912
9	863	30	2.5	920	80	0.50	7	745	0.219	875
10	965	32	1.2	920	67	0.40	55	812	0.729	902
11	780	20	3.8	920	67	1.25	60	815	0.102	1200

[Table 2]

Category	Manufacture condition	Average grain size (μm)		D2/D1 fraction of 0.5 or more (area%)	(surface portion/ central portion grain size)	<110>//ND / <111>//IND
		Surface portion	Central portion			
Inventive Example 1	1	184	87	82	2.1	3.8
Inventive Example 2	2	401	59	92	6.8	4.8
Inventive Example 3	3	344	64	81	5.4	4.4
Inventive Example 4	4	316	66	78	4.8	4.2
Inventive Example 5	5	422	68	96	6.2	5.0
Comparative Example 1	6	54	48	77	1.1	3.4
Comparative Example 2	7	28	29	76	1.0	3.2
Comparative Example 3	8	58	50	78	1.2	3.3
Comparative Example 4	9	42	48	86	0.9	3.3
Comparative Example 5	10	166	102	74	1.5	3.5
Comparative Example 6	11	1102	1095	63	1.0	6.2

[Table 3]

Manufacture condition	B_1 (T)	B_{50} (T)	Shielding rate 100mG (%)	Shielding rate 1G (%)	Category
1	1.021	1.812	61.3	73.2	Inventive Example 1
2	1.385	1.803	67.2	72.3	Inventive Example 2
3	1.340	1.784	66.0	71.0	Inventive Example 3
4	1.301	1.711	64.1	67.4	Inventive Example 4
5	1.410	1.705	69.8	66.0	Inventive Example 5
6	0.623	1.815	33.5	74.0	Comparative Example 1
7	0.307	1.830	21.2	75.5	Comparative Example 2
8	0.642	1.811	38.1	73.1	Comparative Example 3
9	0.511	1.819	30.4	74.2	Comparative Example 4
10	0.986	1.692	62.2	59.8	Comparative Example 5
11	1.502	1.613	88.7	57.5	Comparative Example 6

[0076] As shown in Table 1 to Table 3, it can be confirmed that when process conditions are properly controlled, the texture of the steel sheet is properly formed and the shielding rate is excellent.

[0077] On the other hand, it can be confirmed that if process conditions are not properly controlled, the texture of the steel sheet is not properly formed and the shielding rate is inferior.

[0078] In particular, in the case of the manufacture condition 11, long-term annealing for 30 minutes reduces the difference in size between the surface and internal grains, resulting in the production of uniform grains. As a result, the shielding rate at 100 mG is excellent, but the shielding rate at 1 G is inferior, so it can be confirmed that not all characteristics due to the difference in crystal grains between the surface and the interior are obtained.

[0079] The present invention may be embodied in many different forms, and should not be construed as being limited to the disclosed embodiments and/or examples. 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 and/or examples are for illustrative purposes only, and the scope of the present invention is not limited thereto.

[Description of Symbols]

100: an electrical steel sheet for electromagnetic shielding
11: central portion,
12: surface portion, 200: transmission line

Claims

1. An electrical steel sheet for electromagnetic shielding, comprising:

   grains of which a ratio (D2/D1) of a diameter (D1) of a circumscribed circle and a diameter (D2) of an inscribed circle is 0.5 or higher among the entire grains on the steel sheet surface are 70 area% or more; and an average grain size within a surface portion from the steel sheet surface to less than 2/5 of a steel sheet thickness in a thickness direction is 100 μm to 500 μm, and an average grain size within a central portion from 2/5 to 3/5 of the steel sheet thickness is 55 to 90 μm.

2. The electrical steel sheet of claim 1, wherein a ratio of the area fraction of the area fraction of grains having a <110> direction parallel to the rolling direction of the steel sheet within 15° with respect to grains having a <111> direction within the steel sheet parallel to the rolling direction of the steel sheet within 15° is 3 or greater.

3. The electrical steel sheet of claim 1, wherein a ratio of the average grain size within the surface portion with respect to the average grain size within the central portion is 2.0 or greater.

4. The electrical steel sheet of claim 1, comprising, in wt%, Si:0.3% to 7.0%, C:0.15% or less (excluding 0%) and balance comprising Fe and unavoidable impurities.

5. The electrical steel sheet of claim 1, further comprises Mn: 0.1 wt% or less and S: 0.005 wt% or less.

6. A manufacturing method of an electrical steel sheet for electromagnetic shielding, comprising:

   manufacturing a hot-rolled steel sheet by hot-rolling a slab;
   annealing the hot-rolled steel sheet;
   cold rolling the annealed hot-rolled steel sheet;
   decarburization annealing the cold-rolled steel sheet; and
   non-oxidizing annealing the decarburization annealed steel sheet,
   wherein τ defined in Equation 1 below is 0.23 to 0.5.

[Equation 1]

$$\tau = \left(\frac{finish\ rolling\ temperature + 273}{ROT\ cooling\ rate \times hot-rolled\ sheet\ thickness \times 10^4}\right) \cdot \left(\frac{2.54 \times (dew\ point\ temperature + 273) \times (annealing\ temperature + 273)}{cold-rolled\ sheet\ thickness \times 10^4}\right)$$

   (in Equation 1, the finish rolling temperature is a hot-rolling finish rolling temperature (°C), the ROT cooling rate is a cooling rate (-°C/s) in a ROT section before winding a coil after hot-rolling finish rolling, the hot-rolled sheet thickness is a thickness (mm) of the hot-rolled sheet, the dew point temperature is the dew point temperature (°C) of the atmosphere in the decarburization annealing, the annealing temperature is an annealing temperature (°C) in the decarburization annealing, and the cold-rolled sheet thickness means a steel sheet thickness (mm) after cold rolling.).

7. The manufacturing method of an electrical steel sheet of claim 6, wherein the slab comprises, in wt%, Si:0.3% to 7.0%, C:0.01% to 0.4% and balance comprising Fe and unavoidable impurities.

8. The manufacturing method of an electrical steel sheet of claim 7, wherein the slab further comprises Mn: 0.1 wt% or less and S: 0.005 wt% or less.

9. The manufacturing method of an electrical steel sheet of claim 6, wherein the annealing of the hot-rolled steel sheet comprises a decarburization process.

10. The manufacturing method of an electrical steel sheet of claim 6, wherein, the annealing of the hot-rolled steel sheet is performed at a temperature of 850 °C to 1,000 °C and a dew point temperature of 70 °C or less.

11. The manufacturing method of an electrical steel sheet of claim 6, wherein the decarburization annealing is performed at a temperature of 600 °C to 1,000 °C and a dew point temperature of 0 °C to 70 °C.

12. The manufacturing method of an electrical steel sheet of claim 6, wherein the non-oxidizing annealing is performed at a soaking temperature of 750 to 1,050 °C for 30 seconds to 5 minutes.

13. The manufacturing method of an electrical steel sheet of claim 6, wherein the non-oxidizing annealing is performed in an atmosphere with a dew point temperature of -20 °C or below.

FIG. 1

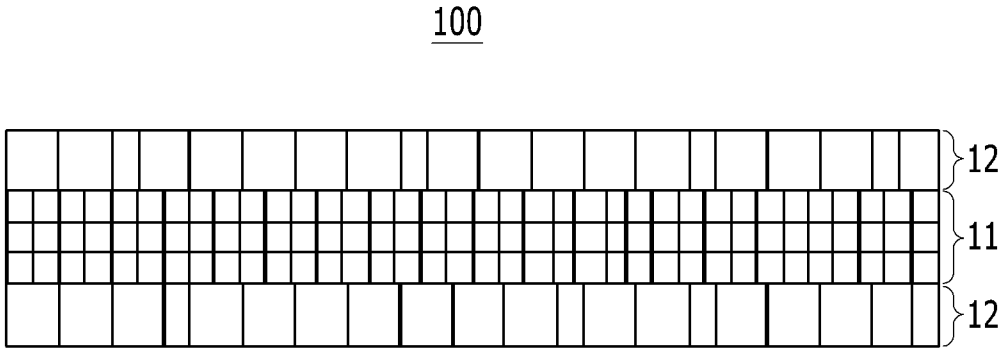


FIG. 2

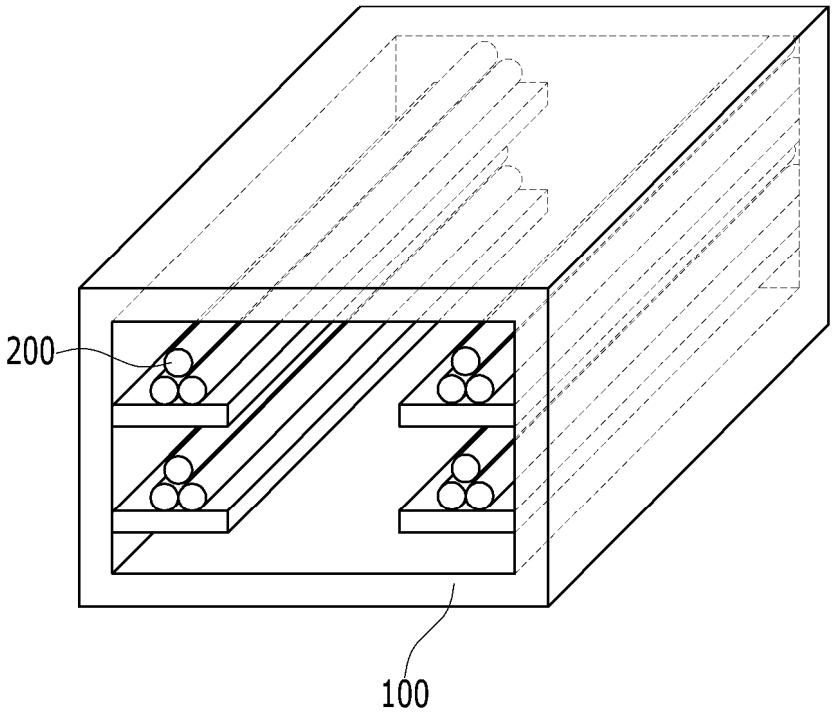


FIG. 3

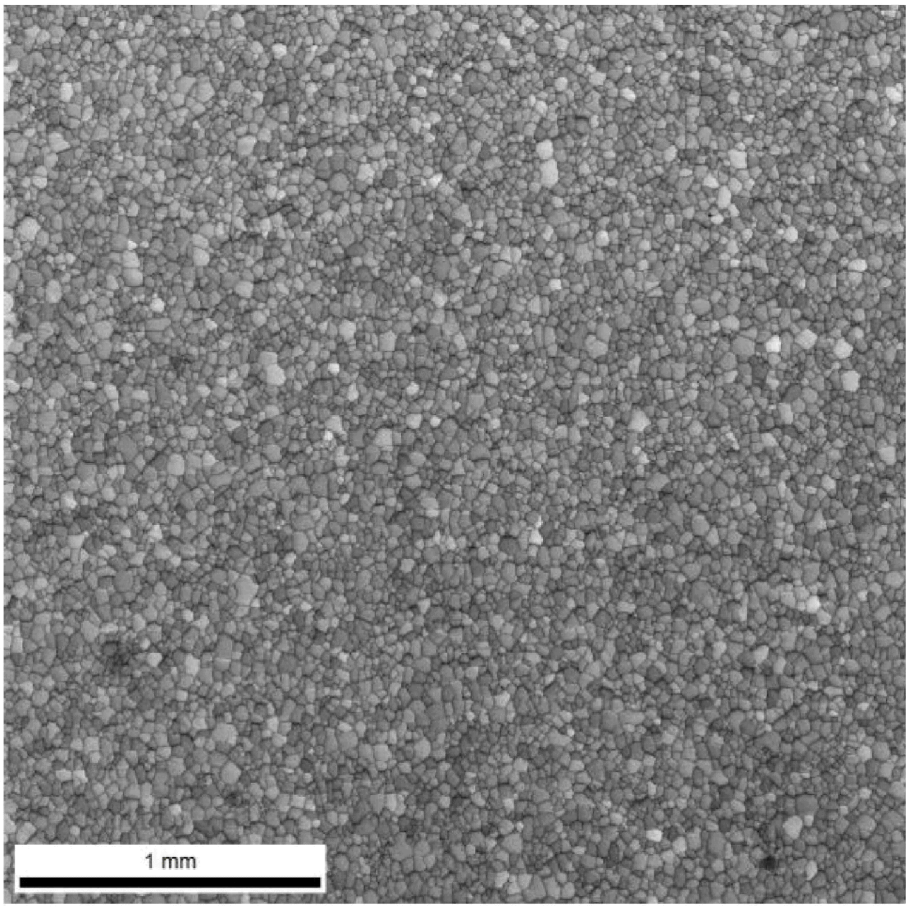
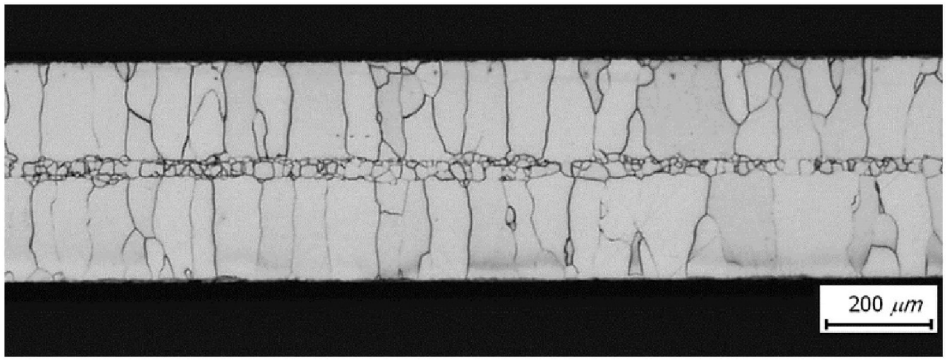


FIG. 4



INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB2024/063307

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/02(2006.01)i; **C22C 38/04**(2006.01)i; **C21D 8/12**(2006.01)i; **H01F 1/147**(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 38/00(2006.01); C22C 38/06(2006.01); H05K 9/00(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: 전기강판(electrical steel sheet), 결정립(grain), 규소(Si), 열간압연(hot rolling), 냉간압연(cold rolling), 소둔(annealing), 탈탄(decarburization), 이슬점(dew point)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	KR 10-0119557 B1 (POHANG IRON & STEEL CO., LTD.) 22 October 1997 (1997-10-22) See paragraphs [0007], [0011]-[0013], [0026] and [0030] and claim 1.	1-13
A	JP 2017-216341 A (NIPPON STEEL & SUMITOMO METAL) 07 December 2017 (2017-12-07) See paragraph [0124] and claims 1 and 9-10.	1-13
A	KR 10-1999-0039201 A (POHANG IRON & STEEL CO., LTD.) 05 June 1999 (1999-06-05) See claims 1-2.	1-13
A	JP 2016-003371 A (NIPPON STEEL & SUMITOMO METAL) 12 January 2016 (2016-01-12) See paragraphs [0040]-[0041] and claims 1-2.	1-13
A	KR 10-2013-0101092 A (JFE STEEL CORPORATION) 12 September 2013 (2013-09-12) See paragraph [0055] and claims 1 and 3.	1-13

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

* Special categories of cited documents:
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"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
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
14 April 2025	**14 April 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/IB2024/063307

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