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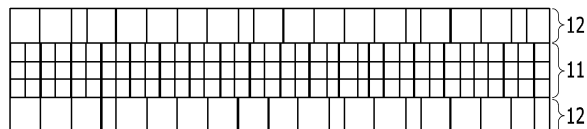
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(54) **ELECTRICAL STEEL SHEET FOR ELECTROMAGNETIC SHIELDING AND METHOD FOR MANUFACTURING SAME**

(57) An electrical steel sheet for electromagnetic wave shielding, wherein, on a surface of the steel sheet, grains having a ratio ($D2/D1$) of a diameter ($D2$) of an inscribed circle to a diameter ($D1$) of a circumscribed circle of 0.5 or more occupy 70 area% or more of total grains, an average grain size within a surface portion from the surface of the steel sheet to less than $1/4$ of a thickness of the steel sheet in a thickness direction is $80\text{ }\mu\text{m}$ to $500\text{ }\mu\text{m}$, and an average grain size within a center portion from $1/4$ to $1/2$ of the thickness of the steel sheet is $50\text{ }\mu\text{m}$ or less.

FIG. 1

100

Description**[Technical Field]**

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

[Background Art]

[0002] An undergrounding work of transmission towers involves directly burying high-voltage power lines in the ground or constructing underground tunnels, such as power tunnels, to accommodate the power lines. This improves urban aesthetics and prevents accidents that may be caused by natural disasters. In the vicinity of such underground power lines, electromagnetic fields that may affect the human body are generated, and aluminum is currently being used to shield them. Although aluminum materials are advantageous for long-term use due to their high corrosion resistance, they must be applied thickly to achieve a sufficient shielding rate. Such a thick aluminum material has disadvantages in that it makes construction difficult and increases the cost of shielding the underground transmission lines due to a large amount of material consumption.

[0003] To solve the above problems, it has been proposed to apply a steel material, which is relatively less expensive than aluminum. In order to secure excellent magnetic field shielding property in steel materials, the contents of interstitial elements and precipitate-forming elements are limited. This method has been proposed because strain caused by interstitial elements and generated precipitates significantly decrease magnetic permeability. In addition to limiting the constituent elements, attempts have been made to obtain an excellent magnetic flux density by limiting the size of precipitates to be small. However, when shielding electromagnetic waves generated in a low magnetic field, an excellent shielding property can be secured only when both the effect of constituent elements and grain size control are applied simultaneously, and thus additional microstructure control is required. Furthermore, because steel materials for electromagnetic wave shielding are frequently buried underground and thus exposed to soil corrosion environments, and must secure electromagnetic wave shielding properties along the periphery of transmission and distribution lines, high workability and constructability of the material are required. Therefore, although excellent workability of the material is necessary for the steel material for electromagnetic wave shielding to undergo a surface treatment having very high corrosion resistance in an environment such as soil, there is currently no shielding material that satisfies such performance requirements.

[Disclosure]**[Technical Problem]**

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

[Technical Solution]

[0005] According to an embodiment of the present disclosure, an electrical steel sheet for electromagnetic wave shielding is provided, wherein on a surface of the steel sheet, grains having a ratio ($D2/D1$) of a diameter ($D2$) of an inscribed circle to a diameter ($D1$) of a circumscribed circle of 0.5 or more occupy 70 area% or more of total grains, an average grain size within a surface portion from the surface of the steel sheet to less than 1/4 of a thickness of the steel sheet in a thickness direction is 80 μm to 500 μm , and an average grain size within a center portion from 1/4 to 1/2 of the thickness of the steel sheet is 50 μm or less.

[0006] A ratio of an area fraction of grains having a $\langle 110 \rangle$ direction parallel to a rolling direction of the steel sheet within 15° to an area fraction of grains having a $\langle 111 \rangle$ direction parallel to the rolling direction of the steel sheet within 15° may be 3 or more.

[0007] A ratio of the average grain size within the surface portion to the average grain size within the center portion may be 2.0 or more.

[0008] According to an embodiment of the present disclosure, the electrical steel sheet for electromagnetic wave shielding may include, by weight%, Si: 0.3% to 7.0%, C: 0.15% or less (excluding 0%), and the balance of Fe and

unavoidable impurities.

[0009] According to an embodiment of the present disclosure, the electrical steel sheet for electromagnetic wave shielding may include Mn: 0.1% or less, and S: 0.005% or less.

[0010] A method for manufacturing an electrical steel sheet for electromagnetic wave shielding includes hot-rolling a slab to manufacture a hot-rolled steel sheet, hot-rolled sheet annealing the hot-rolled steel sheet, cold-rolling the hot-rolled sheet annealed hot-rolled steel sheet, and decarburization-annealing the cold-rolled steel sheet.

[0011] τ defined by Equation 1 below is 0.23 to 0.5:

[Equation 1]

$$\tau = \left(\frac{FRT + 273}{CR_{ROT} \times t_{HR} \times 10^4} \right) \cdot \left(\frac{2.54 \times (DP + 273) \times (AT + 273)}{t_{CR} \times 10^4} \right)$$

(wherein, in Equation 1, the finish rolling temperature (FRT) is a finish rolling temperature in the hot rolling ($^{\circ}\text{C}$), a run-out table (ROT) cooling rate (CR_{ROT}) is a cooling rate ($^{\circ}\text{C/s}$) in the ROT section after the finish rolling in the hot rolling and before a coil is wound, the hot-rolled sheet thickness (t_{HR}) is a thickness (mm) of the hot-rolled sheet, the dew point temperature (DP) is a dew point temperature ($^{\circ}\text{C}$) of an atmosphere in the decarburization-annealing, the annealing temperature (AT) is an annealing temperature ($^{\circ}\text{C}$) in the decarburization-annealing, and the cold-rolled sheet thickness (t_{CR}) means a thickness (mm) of the steel sheet after the cold-rolling.)

[0012] The slab may include, by weight%, Si: 0.3% to 7.0%, C: 0.01% to 0.4%, and the balance of Fe and unavoidable impurities.

[0013] The slab may further include, by weight%, Mn: 0.1% or less; and S: 0.005% or less.

[0014] The hot-rolled sheet annealing may include a decarburization process.

[0015] The hot-rolled sheet annealing may be performed at a temperature of 850°C to 1000°C and a dew point temperature of 70°C or less.

[0016] The decarburization-annealing may be performed at a temperature of 600°C to 1000°C and a dew point temperature of 0°C to 70°C .

[Advantageous Effects]

[0017] According to an embodiment of the present disclosure, excellent electromagnetic wave shielding property is provided.

[0018] According to an embodiment of the present disclosure, it is possible to provide an electrical steel sheet for electromagnetic wave shielding having excellent workability.

[0019] In addition, since the steel sheet can be manufactured through a continuous process, the manufacturing time can be relatively shortened, and productivity can be improved.

[Description of the Drawings]

[0020]

FIG. 1 is a schematic view schematically illustrating a cross section of a steel sheet for electromagnetic wave shielding according to an embodiment of the present disclosure.

FIG. 2 is a schematic view schematically illustrating a usage example of a steel sheet for electromagnetic wave shielding according to an embodiment of the present disclosure.

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

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

[Mode for Invention]

[0021] It should 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 a second part, component, area, layer, or section within the range of the present disclosure.

[0022] The technical terms used herein are to simply mention a particular embodiment and are not meant to limit the present disclosure. 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 should be understood that 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.

[0023] When reference is made to a part 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 reference is made to a part being "directly above" another part, no other part is interposed therebetween.

[0024] Unless otherwise stated, all terms used herein, including technical or scientific terms, have the same meanings as those that would be generally understood by those with ordinary knowledge in the field of art to which the present disclosure belongs. Terms defined in commonly used dictionaries may be 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 stated otherwise.

[0025] Unless otherwise stated, % means weight %, and 1 ppm is 0.0001 wt%.

[0026] In an embodiment of the present disclosure, inclusion of an additional element means replacing the balance of iron (Fe) by an additional amount of the additional element.

[0027] The present disclosure 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.

[0028] FIG. 1 schematically illustrates a cross section of a steel sheet for electromagnetic wave shielding according to an embodiment of the present disclosure.

[0029] As shown in FIG. 1, an electrical steel sheet for electromagnetic wave shielding 100 is provided, wherein on a surface of the steel sheet, grains having a ratio ($D2/D1$) of a diameter ($D2$) of an inscribed circle to a diameter ($D1$) of a circumscribed circle of 0.5 or more occupy 70 area% or more of total grains, an average grain size within a surface portion from the surface of the steel sheet to less than 1/4 of a thickness of the steel sheet in a thickness direction is 80 μm to 500 μm , and an average grain size within a center portion from 1/4 to 1/2 of the thickness of the steel sheet is 50 μm or less.

[0030] Hereinafter, each component of the electrical steel sheet for electromagnetic wave shielding according to an embodiment of the present disclosure will be described in detail.

[0031] First, according to an embodiment of the present disclosure, the electrical steel sheet for electromagnetic wave shielding 100 may include, by weight%, Si: 0.3% to 7.0%, C: 0.15% or less (excluding 0%), and the balance of Fe and unavoidable impurities.

Si: 0.3 to 7.0 wt%

[0032] Silicon (Si) improves texture to improve magnetic flux density. It improves the electromagnetic wave shielding performance of the material in a low magnetic field region. If the Si content is too low, a problem may occur in the ability of the material to absorb an external magnetic field in the low magnetic field region. If the Si content is too high, the content of impurities in the material increases, which may cause a problem of reduced shielding ability due to a decrease in saturation magnetic flux density. More specifically, Si may be contained in an amount of 0.5 to 4.0 wt%.

C: 0.15 wt% or less

[0033] Carbon (C) may be contained in the slab in an amount of 0.010 to 0.400 wt% because a process in which C in the center portion escapes to the surface layer portion is required for Goss grains in the surface layer portion to diffuse to the center portion during intermediate decarburization-annealing and final decarburization-annealing. More specifically, the C content in the slab may be 0.100 to 0.300 wt%. In addition, the carbon content in the steel sheet after the decarburization-annealing, in which manufacturing is completed, may be 0.150 wt% or less. More specifically, it may be 0.100 wt% or less. Even more specifically, it may be 0.050 wt% or less.

[0034] According to an embodiment of the present disclosure, the electrical steel sheet for electromagnetic wave shielding may include Mn: 0.1% or less, and S: 0.005% or less.

[0035] Mn and S form MnS precipitates to hinder the growth of Goss grains diffusing to the center portion during the decarburization process. Therefore, it is preferable that Mn and S are not added. However, considering the amounts unavoidably introduced during the steelmaking process, Mn and S in the slab and the steel sheet after the decarburization-annealing may be controlled to Mn: 0.1 wt% or less and S: 0.005 wt% or less, respectively.

[0036] The balance includes Fe and unavoidable impurities. The unavoidable impurities are impurities introduced

during the steelmaking and the manufacturing process of the electrical steel sheet, and since they are widely known in the art, detailed descriptions thereof will be omitted. Specifically, since components such as Al, N, Ti, Mg, and Ca react with oxygen in the steel to form oxides, it is necessary to strongly suppress them, and thus they may be controlled to 0.005 wt% or less for each component. In an embodiment of the present disclosure, the addition of elements other than the aforementioned alloy components is not excluded, and various elements may be included within a range that does not impair the technical spirit of the present disclosure. When additional elements are further included, they are included by replacing Fe, which is the balance.

[0037] On the surface of the steel sheet, grains having the ratio ($D2/D1$) of the diameter ($D2$) of the inscribed circle to the diameter ($D1$) of the circumscribed circle of 0.5 or more may occupy 70 area% or more of total grains. This is because decarburization-annealing is performed for a short period of time, as will be described later in connection with the manufacturing process. When annealing is performed for a long period of time for 1 hour or more through batch annealing after the decarburization-annealing, the diameter ($D1$) of the circumscribed circle becomes significantly larger than that of the inscribed circle ($D2$), so that the ratio cannot be 0.5 or more. Here, the circumscribed circle means the smallest circle among imaginary circles surrounding the outside of the grain, and the inscribed circle means the largest circle among imaginary circles included inside the grain. More specifically, grains having the ratio ($D2/D1$) of the diameter ($D2$) of the inscribed circle to the diameter ($D1$) of the circumscribed circle of 0.5 or more may occupy 75 to 95 area% of total grains. Grains having such a shape react to an external magnetic field, particularly in a low magnetic field region, and serve to absorb the magnetic field, thereby contributing to electromagnetic wave shielding. The grains having the ratio ($D2/D1$) of the diameter ($D2$) of the inscribed circle to the diameter ($D1$) of the circumscribed circle of 0.5 or more can be analyzed by observing the surface (ND plane) of the steel sheet with an optical microscope and then analyzing the observed photograph using a computer program.

[0038] In an embodiment of the present disclosure, an average grain size within a surface portion 12 from the surface of the steel sheet to less than 1/4 of a thickness of the steel sheet in a thickness direction is 80 μm to 500 μm , and an average grain size within a center portion 11 from 1/4 to 1/2 of the thickness of the steel sheet is 50 μm or less. As described above, by forming the grain sizes of the surface portion 12 and the center portion 11 to be different from each other, the grains in the surface portion may cause the material to react to and absorb an external magnetic field, thereby contributing to electromagnetic wave shielding. If the average grain size within the surface portion 12 is too small, the ability of the material to absorb an external magnetic field is reduced, which may lead to a decrease in electromagnetic wave shielding performance. If the average grain size within the surface portion 12 is too large, a decrease in adhesion due to a reduction in an interfacial contact surface during coating may become a problem. If the average grain size of the center portion 11 is too large, the ability of the material to react to and absorb an external magnetic field is reduced, which may lead to a decrease in electromagnetic wave shielding performance. More specifically, the average grain size in the surface portion 12 may be 100 μm to 400 μm , and the average grain size in the center portion 11 may be 10 μm to 48 μm . The average grain size may be determined by measuring the number of grains relative to a measurement area on a cross section including a steel sheet thickness direction, and dividing the measurement area by the number of grains to obtain an average grain area. The grain size can be determined as a diameter of a circle having the same area.

[0039] A ratio of the average grain size in the surface portion to the average grain size in the center portion (surface portion/center portion) may be 2.0 or more. If this ratio is too small, the ability of the material to respond to an external magnetic field decreases, which may result in poor electromagnetic wave shielding characteristics. More specifically, a ratio of the average grain size in the surface portion to the average grain size in the center portion (surface portion/center portion) may be 3.0 to 20.0.

[0040] A ratio of an area fraction of grains having a $\langle 110 \rangle$ direction parallel to a rolling direction of the steel sheet within 15° to an area fraction of grains having a $\langle 111 \rangle$ direction parallel to the rolling direction of the steel sheet within 15° ($\langle 110 \rangle // \text{ND} / \langle 111 \rangle // \text{ND}$) may be 3.0 or more. When this ratio is high, the magnetic permeability in a low magnetic field region is increased, thereby contributing to electromagnetic wave shielding. More specifically, $\langle 110 \rangle // \text{ND} / \langle 111 \rangle // \text{ND}$ may be 3.3 to 6.5. This can be measured using an electron backscatter diffraction (EBSD) system.

[0041] As described above, by appropriately adjusting the steel composition of the steel sheet and appropriately forming the texture, excellent electromagnetic wave shielding performance can be achieved. Specifically, a shielding rate in a 60 Hz, 100 mG magnetic field may be 50% or more, and a shielding rate in a 60 Hz, 1 G magnetic field may be 65% or more. More specifically, a shielding rate in a 60 Hz, 100 mG magnetic field may be from 50.0% to 75.0%, and a shielding rate in a 60 Hz, 1 G magnetic field may be from 70.0% to 85.0%.

[0042] In this case, the shielding rate may be measured by generating a magnetic field of 1 G or less using a Helmholtz coil method, and installing a pickup coil capable of measuring the magnetic field in the center of the generated magnetic field. The shielding rate is calculated according to the following equation by shielding the pickup coil with a shielding material to obtain the intensities of the magnetic field measured before and after the shielding. In shielding the pickup coil, the coil is wrapped in a cylindrical shape, or four sides thereof are shielded in a box shape.

$$\text{Shielding Rate (\%)} = (1 - B_{\text{shielded}}/B_{\text{unshielded}}) \times 100$$

[0043] Although omitted in FIG. 1, a coating layer positioned on a surface of the electrical steel sheet for electromagnetic wave shielding 100 may be additionally included.

[0044] FIG. 2 illustrates a usage example of an electrical steel sheet for electromagnetic wave shielding according to an embodiment of the present disclosure. As shown in FIG. 2, the electrical steel sheet for electromagnetic wave shielding 100 may be installed to surround an underground conduit (power cable tunnel), or may be used by being inserted between a transmission line and the underground conduit (power cable tunnel). Alternatively, the electrical steel sheet for electromagnetic wave shielding 100 may be rolled into a cylindrical tube shape to surround a transmission line 200.

[0045] A method for manufacturing an electrical steel sheet for electromagnetic wave shielding includes hot-rolling a slab to manufacture a hot-rolled steel sheet, hot-rolled sheet annealing the hot-rolled steel sheet, cold-rolling the hot-rolled sheet annealed hot-rolled steel sheet, and decarburization-annealing the cold-rolled steel sheet.

[0046] Hereinafter, each step will be described in detail.

[0047] First, a slab is hot-rolled.

[0048] The slab may include, by weight%, Si: 0.3% to 7.0%, C: 0.01% to 0.4%, and the balance of Fe and unavoidable impurities.

[0049] The slab may further include, by weight%, Mn: 0.1% or less; and S: 0.005% or less.

[0050] Since the description of the steel composition of the slab is the same as the description of the electric steel sheet for electromagnetic wave shielding described above, redundant descriptions thereof will be omitted. Except for C, the steel composition of the steel sheet may be substantially identical to the steel composition of the slab.

[0051] Before hot-rolling the slab, the slab may be heated. The slab heating temperature may be 1050°C to 1350°C, which is higher than a conventional heating temperature. When the temperature during slab reheating is high, there is a problem in that a hot-rolled structure becomes coarsened, thereby adversely affecting magnetic properties. However, in the method for manufacturing an electrical steel sheet according to an embodiment of the present disclosure, since the carbon content is higher than conventional ones, the hot-rolled structure is not coarsened even if the slab reheating temperature is high, and reheating at a temperature higher than a conventional case is advantageous during hot rolling. However, when the reheating temperature is high, the solid solubility of precipitates such as TiN and AlN increases, and thus a large number of fine precipitates are distributed during cooling, thereby serving to hinder the growth of grains on the surface.

[0052] The hot-rolling may produce a hot-rolled sheet having a thickness of 1.3 to 4.3 mm by hot rolling so that a final product thickness can be manufactured by applying an appropriate rolling reduction ratio in a final cold rolling. More specifically, it may be manufactured to a thickness of 1.5 to 4.0 mm.

[0053] A finish rolling temperature in the hot rolling may be 750°C to 1050°C. When the finish rolling temperature in the hot rolling is too high, surface defects occur, thereby degrading quality. In addition, when the finish rolling temperature is too low, a rolling load increases, which deteriorates strip passability and lowers productivity. More specifically, it may be 800°C to 1030°C. In an embodiment of the present disclosure, the cooling rate in the ROT section can be controlled after finishing rolling in the hot rolling and before the coil is coiled. More specifically, the cooling rate in the ROT section may be controlled to -50 to -5°C/s. If the cooling rate is too high, it suppresses the growth of surface grains, making it difficult to obtain coarse grains. More specifically, the cooling rate may be controlled to -30 to -7°C/s.

[0054] After the hot rolling, hot-rolled sheet annealing is performed on the hot-rolled steel sheet. In this case, the hot-rolled sheet annealing may include a decarburization process. Specifically, the hot-rolled sheet annealing may be performed at a temperature of 850°C to 1000°C and a dew point temperature of 70°C or less. More specifically, the annealing may be performed at a dew point temperature of -70°C to 70°C. After the aforementioned annealing, further annealing may be performed at a temperature of 1000 to 1200°C and a dew point temperature of 0°C or less. Pickling may be performed after the hot-rolled sheet annealing.

[0055] Next, cold rolling is performed to manufacture a cold-rolled steel sheet.

[0056] Accordingly, during the cold rolling, the cold rolling may be performed at a reduction rate 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 may be manufactured.

[0057] Next, the cold-rolled steel sheet is decarburization-annealed. In this case, the decarburization annealing may be performed in an austenite singlephase region or a region where a mixed phase of ferrite and austenite exists. Specifically, the annealing may be performed at a temperature of 800°C to 970°C and a dew point temperature of 3°C to 65°C. In addition, the atmosphere may be a mixed gas atmosphere of hydrogen and nitrogen. Further, after the decarburization annealing, the carbon content in the steel sheet may be 0.15 wt% or less.

[0058] In the method for manufacturing an electrical steel sheet for electromagnetic shielding according to an embodiment of the present disclosure, τ defined by Equation 1 below is 0.230 to 0.500.

[Equation 1]

$$\tau = \left(\frac{FRT + 273}{CR_{ROT} \times t_{HR} \times 10^4} \right) \cdot \left(\frac{2.54 \times (DP + 273) \times (AT + 273)}{t_{CR} \times 10^4} \right)$$

(wherein, in Equation 1, the finish rolling temperature (FRT) is a finish rolling temperature in the hot rolling ($^{\circ}\text{C}$), a run-out table (ROT) cooling rate (CR_{ROT}) is a cooling rate ($^{\circ}\text{C/s}$) in the ROT section after the finish rolling in the hot rolling and before a coil is wound, the hot-rolled sheet thickness (t_{HR}) is a thickness (mm) of the hot-rolled sheet, the dew point temperature (DP) is a dew point temperature ($^{\circ}\text{C}$) of an atmosphere in the decarburization-annealing, the annealing temperature (AT) is an annealing temperature ($^{\circ}\text{C}$) in the decarburization-annealing, and the cold-rolled sheet thickness (t_{CR}) means a thickness (mm) of the steel sheet after the cold-rolling.)

[0059] If τ is too small, grain growth in the surface portion 12 may be insufficient. If τ is too large, grain growth in the center portion 11 occurs significantly, which may adversely affect electromagnetic shielding performance. More specifically, τ may be 0.240 to 0.450.

[0060] Hereinafter, specific examples of the present disclosure will be described. However, the following examples are merely specific examples of the present disclosure, and the present disclosure is not limited to the following example.

Examples

[0061] A slab containing, by weight%, Si: 2.0% and C: 0.101%, with the balance being Fe and unavoidable impurities, is heated at a temperature of 1270°C , and then processes are performed in the order of hot rolling, hot-rolled sheet annealing, cold rolling, and decarburization annealing under the manufacturing conditions in Table 1. After the decarburization annealing, C was 0.05 wt% or less.

[0062] For manufacturing condition 11, performing high-temperature annealing at 1200°C for 30 minutes at a dew point of -20°C was subsequently added.

[0063] The average grain size of the surface portion and the center portion, magnetic flux density, and electromagnetic shielding rate of the manufactured specimens were measured and are shown in Table 2.

[0064] The average grain size was measured using an optical microscope.

[0065] The grain shape at the surface was measured using the EBSD analyzer.

[0066] $\langle 110 \rangle // \text{ND}$ / $\langle 111 \rangle // \text{ND}$ was measured using the EBSD analyzer.

[0067] The magnetic flux density was measured by a single strip magnetic field measurement, and the magnetic flux density was measured in a rolling direction and a direction perpendicular to the rolling direction, and the average value thereof is shown in Table 3. The magnetic flux density measured at 50 Hz and 100 A/m was denoted as B1, and the magnetic flux density measured at 50 Hz and 5000 A/m was denoted as B50.

[0068] The electromagnetic shielding rate was measured by generating a magnetic field of 1G or less 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 to obtain the intensity of the magnetic field measured before and after shielding, and the shielding rate was calculated as follows:

$$\text{Shielding Rate (\%)} = (1 - B_{\text{shielded}} / B_{\text{unshielded}}) \times 100$$

(Table 1)

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

(Table 2)

Manufacturing condition	Average grain size (μm)		Fraction with D2/D1 of 0.5 or more (area%)	(Grain size of surface portion/center portion)	<110>//ND / <111>//ND
	Surface portion	Center portion			
1	153	46	75	3.4	3.5
2	334	31	88	10.6	4.5
3	287	23	78	12.5	4.2
4	263	19	75	13.6	3.8
5	352	25	95	14.1	4.8
6	45	32	72	1.4	3.3
7	23	19	70	1.2	3.1
8	48	33	73	1.5	3.1
9	35	32	85	1.1	3.2
10	138	102	72	1.4	3.1
11	826	815	52	1.0	5.2

(Table 3)

Manufacturing condition	B1 (T)	B50 (T)	Shielding rate	Shielding rate	Type
			100mG (%)	1G (%)	
1	0.879	1.887	51.2	72.8	Inventive 1
2	1.345	1.853	66.5	75.6	Inventive 2
3	1.295	1.825	64.0	74.4	Inventive 3
4	1.270	1.781	61.4	71.2	Inventive 4
5	1.360	1.867	64.2	75.1	Inventive 5
6	0.555	1.835	30.5	67.8	Comparative Example1
7	0.298	1.700	18.3	61.8	Comparative Example2
8	0.605	1.846	31.8	68.7	Comparative Example3
9	0.482	1.832	25.2	67.5	Comparative Example4
10	0.921	1.702	60.2	62.8	Comparative Example5
11	1.458	1.710	72.5	63.5	Comparative Example6

[0069] As shown in Tables 1 to 3, when the process conditions are appropriately controlled, it can be confirmed that the texture of the steel sheet is appropriately formed and the shielding rate is excellent.

[0070] On the other hand, when the process conditions are not appropriately controlled, the texture of the steel sheet is not appropriately formed, and it can be confirmed that the shielding rate is inferior.

[0071] Particularly, in the case of manufacturing condition 11, annealing is performed for a long period of time for 30 minutes to reduce the difference in grain size between the surface and the inside, thereby resulting in uniform grains. Due to this, the shielding rate at 100mG is excellent, but the shielding rate at 1G is inferior, and thus it can be confirmed that both of the respective characteristics due to the difference in grain size between the surface and the inside cannot be obtained.

[0072] The present disclosure may be embodied in many different forms, and should not be construed as being limited to the disclosed embodiments. In addition, it should 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 disclosure. Therefore, it is to be understood that the above-described embodiments are for illustrative purposes only, and the scope of the present disclosure is not limited thereto.

<Description of symbols>

100:	Electrical steel sheet for electromagnetic wave shielding		
11:	Center portion		
12:	Surface portion	200:	Transmission line

Claims

1. An electrical steel sheet for electromagnetic wave shielding, wherein,
on a surface of the steel sheet, grains having a ratio (D2/D1) of a diameter (D2) of an inscribed circle to a diameter (D1) of a circumscribed circle of 0.5 or more occupy 70 area% or more of total grains,
an average grain size within a surface portion from the surface of the steel sheet to less than 1/4 of a thickness of the steel sheet in a thickness direction is 80 μm to 500 μm, and an average grain size within a center portion from 1/4 to 1/2 of the thickness of the steel sheet is 50 μm or less.
2. The electrical steel sheet for electromagnetic wave shielding of claim 1, wherein
a ratio of an area fraction of grains having a <110> direction parallel to a rolling direction of the steel sheet within 15° to an area fraction of grains having a <111> direction parallel to the rolling direction of the steel sheet within 15° is 3 or more.
3. The electrical steel sheet for electromagnetic wave shielding of claim 1, wherein
a ratio of the average grain size within the surface portion to the average grain size within the center portion is 2.0 or more.
4. The electrical steel sheet for electromagnetic wave shielding of claim 1, comprising:
by weight%, Si: 0.3% to 7.0%; C: 0.15% or less (excluding 0%); and the balance of Fe and unavoidable impurities.
5. The electrical steel sheet for electromagnetic wave shielding of claim 1, further comprising:
Mn: 0.1% or less; and S: 0.005% or less.
6. A method for manufacturing an electrical steel sheet for electromagnetic wave shielding, comprising:
hot-rolling a slab to manufacture a hot-rolled steel sheet;
hot-rolled sheet annealing the hot-rolled steel sheet;
cold-rolling the hot-rolled sheet annealed hot-rolled steel sheet; and
decarburization-annealing the cold-rolled steel sheet,
wherein τ defined by Equation 1 below is 0.23 to 0.5:

[Equation 1]

$$\tau = \left(\frac{FRT + 273}{CR_{ROT} \times t_{HR} \times 10^4} \right) \cdot \left(\frac{2.54 \times (DP + 273) \times (AT + 273)}{t_{CR} \times 10^4} \right)$$

(wherein, in Equation 1, the finish rolling temperature (FRT) is a finish rolling temperature in the hot rolling (°C), a run-out table (ROT) cooling rate (CR_{ROT}) is a cooling rate (°C/s) in the ROT section after the finish rolling in the hot rolling and before a coil is wound, the hot-rolled sheet thickness (t_{HR}) is a thickness (mm) of the hot-rolled sheet, the dew point temperature (DP) is a dew point temperature (°C) of an atmosphere in the decarburization-annealing, the annealing temperature (AT) is an annealing temperature (°C) in the decarburization-annealing, and the cold-rolled sheet thickness (t_{CR}) means a thickness (mm) of the steel sheet after the cold-rolling.)

7. The method for manufacturing an electrical steel sheet for electromagnetic wave shielding of claim 6, wherein the slab comprises, by weight%: Si: 0.3% to 7.0%; C: 0.01% to 0.4%; and the balance of Fe and unavoidable impurities.

8. The method for manufacturing an electrical steel sheet for electromagnetic wave shielding of claim 7, wherein the slab further comprises, by weight%: Mn: 0.1% or less; and S: 0.005% or less.
- 5 9. The method for manufacturing an electrical steel sheet for electromagnetic wave shielding of claim 6, wherein the hot-rolled sheet annealing comprises a decarburization process.
- 10 10. The method for manufacturing an electrical steel sheet for electromagnetic wave shielding of claim 6, wherein the hot-rolled sheet annealing is performed at a temperature of 850°C to 1000°C and a dew point temperature of 70°C or less.
11. The method for manufacturing an electrical steel sheet for electromagnetic wave shielding of claim 6, wherein the decarburization-annealing is performed at a temperature of 600°C to 1000°C and a dew point temperature of 0°C to 70°C.

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FIG. 1

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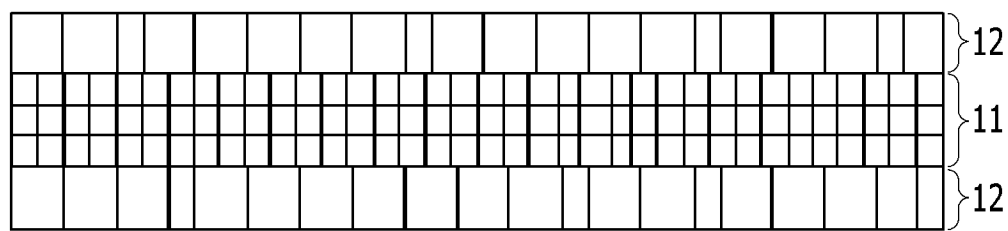


FIG. 2

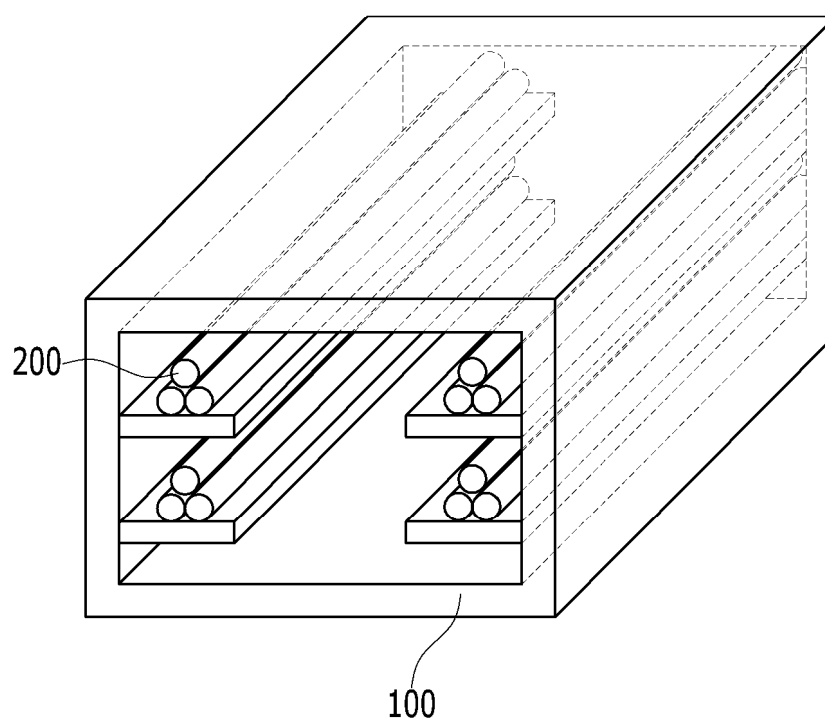


FIG. 3

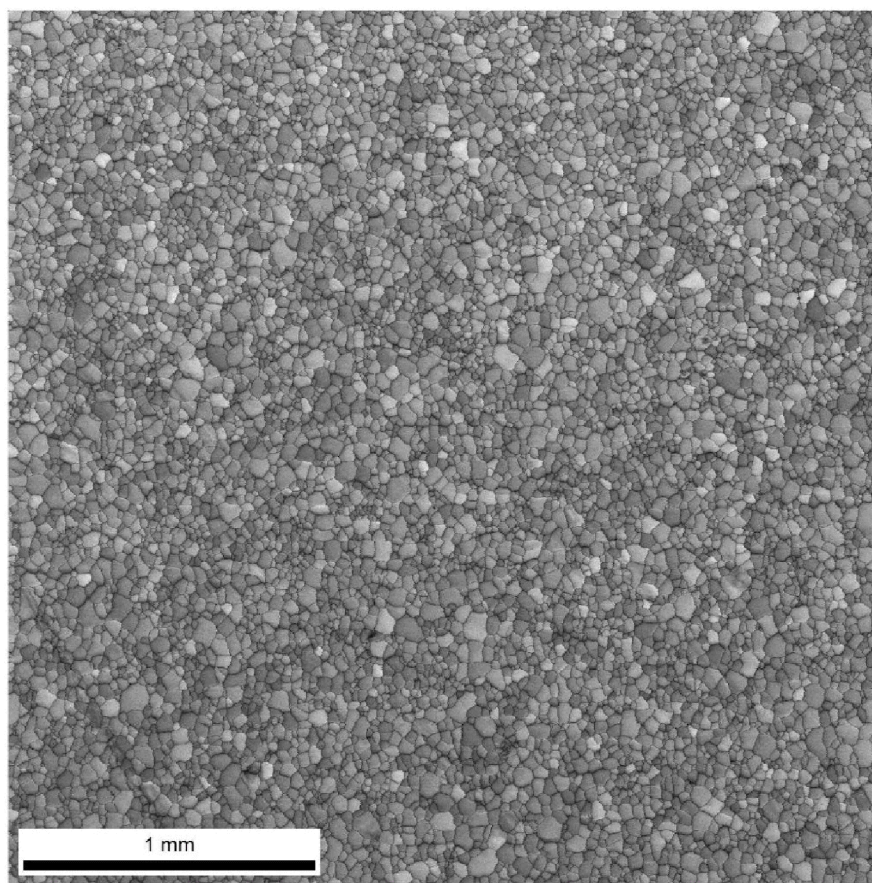
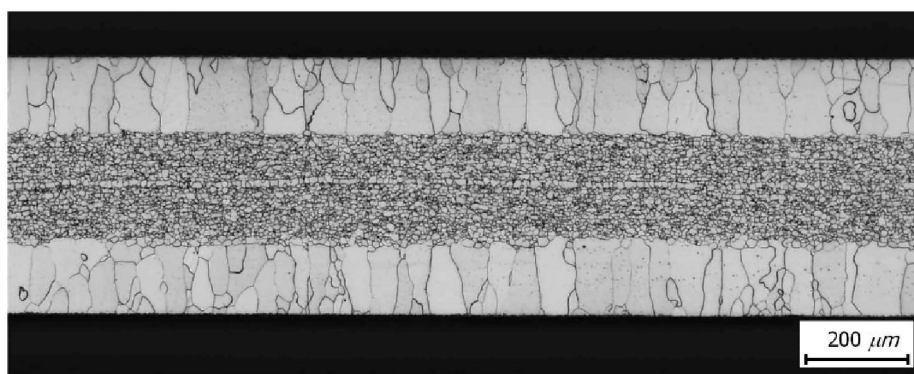


FIG. 4



INTERNATIONAL SEARCH REPORT

International application No.

PCT/IB2024/063306

A. CLASSIFICATION OF SUBJECT MATTER**C22C 38/02**(2006.01)i; **C22C 38/04**(2006.01)i; **C21D 8/12**(2006.01)i; **C21D 9/46**(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: 전자파 차폐(electromagnetic shield), 결정립크기(grain size), 탈탄소둔(decarburizing annealing), 이슬점(dew point), 전기강판(electrical steel sheet)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2017-216341 A (NIPPON STEEL & SUMITOMO METAL) 07 December 2017 (2017-12-07) See paragraph [0119] and claims 1 and 8-9.	1-11
A	JP 2017-214616 A (NIPPON STEEL & SUMITOMO METAL) 07 December 2017 (2017-12-07) See paragraphs [0077], [0079] and [0141] and claims 1 and 6.	1-11
A	JP 11-106876 A (NIPPON STEEL CORP.) 20 April 1999 (1999-04-20) See claim 1.	1-11
A	JP 2000-290759 A (NIPPON STEEL CORP.) 17 October 2000 (2000-10-17) See claims 1 and 4.	1-11
A	JP 2005-298968 A (JFE STEEL K.K.) 27 October 2005 (2005-10-27) See claims 1 and 4.	1-11

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

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“T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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“&” document member of the same patent family

Date of the actual completion of the international search

02 April 2025

Date of mailing of the international search report

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Name and mailing address of the ISA/KR

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Authorized officer

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/IB2024/063306

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Form PCT/ISA/210 (patent family annex) (July 2022)