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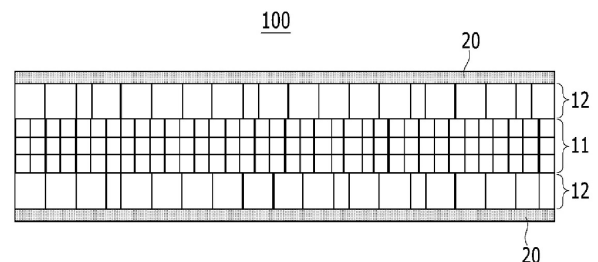
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(54) **ELECTRICAL STEEL SHEET FOR ELECTROMAGNETIC WAVE SHIELDING AND MANUFACTURING METHOD THEREFOR**

(57) An embodiment of the present invention provides an electrical steel sheet for electromagnetic wave shielding, including: a steel sheet substrate, and a coating positioned on a surface of the steel sheet substrate, wherein, on the surface of the steel sheet substrate, 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 are present in an amount of 70 area% or more of total grains, in a thickness direction, an average grain size within a surface portion from the surface of the steel sheet substrate to less than 1/4 of a thickness of the steel sheet substrate 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 substrate is 50 μm or less, and the coating includes a fluoroolefin-based resin.

FIG. 1



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Description**[Technical Field]**

5 **[0001]** An embodiment of the present invention relates to an electrical steel sheet for electromagnetic wave shielding and a manufacturing method therefor. Specifically, an embodiment of the present invention relates to an electrical steel sheet for electromagnetic wave shielding and a manufacturing method therefor that may have an excellent electromagnetic wave shielding effect and exhibits insulation, oil resistance, and chemical resistance characteristics.

[Background Art]

10 **[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. In the vicinity of such underground power lines, electromagnetic fields that may affect a human body are generated, and aluminum is being used to shield them. Aluminum materials are advantageous for long-term use due to their high corrosion resistance, but the materials must be applied thickly to obtain a sufficient shielding rate. Such a thick aluminum material has disadvantages in that it makes construction difficult and increases a cost of shielding an underground transmission line due to a large amount of material used.

20 **[0003]** To solve the above problem, it has been proposed to apply a steel material, which is relatively lower in cost than aluminum. In order to secure excellent magnetic field shielding properties in steel materials, contents of interstitial elements and precipitate-forming elements are restricted. Since the permeability is significantly reduced by strain caused by interstitial elements and by the generated precipitates, a method for restricting them has been proposed. In addition, in addition to restricting the component elements, it has been attempted to obtain an excellent magnetic flux density by restricting a size of the precipitates to be small. However, when shielding electromagnetic waves generated in a low magnetic field, an effect of component elements and grain size control must be simultaneously applied to secure excellent shielding properties, and thus additional microstructure control is required. In addition, since an environment in which a steel material for electromagnetic wave shielding is used is often buried underground, resulting in exposure to a soil corrosion environment, and electromagnetic wave shielding properties must be secured along a periphery of transmission and distribution lines, high workability and constructability of the material are required. Therefore, the steel material for electromagnetic wave shielding requires excellent workability of the material as well as a surface treatment having very high corrosion resistance in an environment such as soil, but there is currently no shielding material that satisfies these required levels.

[Disclosure]**[Technical Problem]**

40 **[0004]** An embodiment of the present invention provides an electrical steel sheet for electromagnetic wave shielding and a manufacturing method therefor. Specifically, an embodiment of the present invention provides an electrical steel sheet for electromagnetic wave shielding and a manufacturing method therefor that may have an excellent electromagnetic wave shielding effect and exhibits insulation, oil resistance, and chemical resistance characteristics.

[Technical Solution]

45 **[0005]** An embodiment of the present invention provides an electrical steel sheet for electromagnetic wave shielding, including: a steel sheet substrate, and a coating positioned on a surface of the steel sheet substrate, wherein, on the surface of the steel sheet substrate, 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 are present in an amount of 70 area% or more of total grains, in a thickness direction, an average grain size within a surface portion from the surface of the steel sheet substrate to less than 1/4 of a thickness of the steel sheet substrate 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 substrate is 50 μm or less, and the coating includes a fluoroolefin-based resin.

55 **[0006]** A ratio of an area fraction of grains in which a $\langle 110 \rangle$ direction is parallel to a rolling direction of the steel sheet within 15° to an area fraction of grains in which a $\langle 111 \rangle$ direction is parallel to the rolling direction of the steel sheet within 15° in the steel sheet substrate may be 3 or more.

[0007] A ratio (surface portion/center portion) 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] The steel sheet substrate may include, in wt%, Si: 0.3% to 7.0%, C: 0.15% or less (excluding 0%), and a balance of Fe and inevitable impurities.

[0009] The steel sheet substrate may further include: Mn: 0.1 wt% or less and S: 0.005 wt% or less.

[0010] Another embodiment of the present invention provides a manufacturing method for an electrical steel sheet for electromagnetic wave shielding, including: 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 steel sheet; decarburization annealing the cold-rolled steel sheet; and forming a coating including a fluoroolefin-based resin on a surface of the decarburization annealed steel sheet.

[0011] τ defined by the following Equation 1 is 0.23 to 0.5.

[Equation 1]

$$\tau = \left(\frac{\text{Finishing rolling temperature} + 273}{\text{ROT cooling rate} \times \text{Hot-rolled sheet thickness} \times 10^4} \right) \cdot \frac{(2.54 \times \text{Dew point temperature} + 273) \times (\text{Annealing temperature} + 273)}{\text{Cold-rolled plate thickness} \times 10^4}$$

(in Equation 1, the finishing rolling temperature refers to a hot rolling finishing rolling temperature (°C), the ROT cooling rate refers to a cooling rate (-°C/s) in an ROT section from after the hot rolling finishing rolling until a coil is wound, the hot-rolled sheet thickness refers to a thickness (mm) of the hot-rolled sheet, the dew point temperature refers to a dew point temperature (°C) of an atmosphere in the decarburization annealing, the annealing temperature refers to an annealing temperature (°C) in the decarburization annealing, and the cold-rolled sheet thickness refers to a thickness (mm) of the steel sheet after cold rolling.)

[0012] The slab may include, in wt%, Si: 0.3% to 7.0%, C: 0.01% to 0.4%, and a balance of Fe and inevitable impurities.

[0013] The slab may further include: Mn: 0.1 wt% or less and S: 0.005 wt% 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.

[0017] The forming of the coating may be performed by lamination coating.

[Advantageous Effects]

[0018] According to an embodiment of the present invention, electromagnetic wave shielding and corrosion resistance are simultaneously excellent.

[0019] According to an embodiment of the present invention, a steel sheet for electromagnetic wave shielding having excellent workability may be provided.

[0020] In addition, since the steel sheet may be manufactured through a continuous process, a manufacturing time may be relatively shortened, and productivity may be improved.

[Description of the Drawings]

[0021]

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

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

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

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

[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 terminologies used herein are used just to illustrate a specific exemplary embodiment, but are not intended 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. It will be further understood that the term "comprises" or "includes", used in this specification, specifies stated properties, regions, integers, steps, operations, elements, and/or components, but does not preclude the presence or addition of other properties, regions, integers, steps, operations, elements, components, and/or groups.

[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, % represents wt%, and 1 ppm is 0.0001 wt%.

[0027] In an embodiment of the present invention, inclusion of an additional element means replacing the balance of iron (Fe) by an additional amount of the additional elements.

[0028] Hereinafter, embodiments of the present invention will be described in detail so that those skilled in the art to which the present invention pertains may easily carry out the invention. 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.

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

[0030] As illustrated in FIG. 1, an electrical steel sheet 100 for electromagnetic wave shielding according to an embodiment of the present invention includes a steel sheet substrate 10 and a coating 20 positioned on a surface of the steel sheet substrate 10, wherein the surface of the steel sheet substrate, 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 among total grains are present in an amount of 70 area% or more, and in a thickness direction, an average grain size within a surface portion 12 from the surface of the steel sheet substrate to less than 1/4 of a thickness of the steel sheet substrate 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 substrate is 50 μm or less.

[0031] The coating 20 includes a fluoroolefin-based resin.

[0032] Hereinafter, each component of the electrical steel sheet for electromagnetic wave shielding according to an embodiment of the present invention will be described in detail.

[0033] First, the steel sheet substrate 10 includes, in wt%, Si: 0.3% to 7.0%, C: 0.15% or less (excluding 0%), and a balance of Fe and inevitable impurities.

Si: 0.3 to 7.0 wt%

[0034] Silicon (Si) improves electromagnetic wave shielding performance of a material in a low magnetic field region. If a Si content is too low, a problem may occur in an ability of the material to absorb an external magnetic field in the low magnetic field region. If the Si content is too high, a content of impurities in the material increases, which may cause a problem of deterioration in shielding ability due to a decrease 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

[0035] A content of C of the slab may be 0.010 to 0.400 wt% because carbon (C) needs a process in which C in a center is discharged to a surface layer in order for Goss grains in a surface layer to diffuse to the center during intermediate decarburization-annealing and final decarburization-annealing. More specifically, the C content of the slab may be 0.100 to 0.300 wt%. In addition, after a decarburization annealing step in which manufacturing is completed, a carbon amount in the steel sheet 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.

[0036] The steel sheet substrate 10 may further include Mn: 0.1 wt% or less and S: 0.005 wt% or less.

[0037] Mn and S form a precipitate of MnS, so that they hinder growth of the Goss grains that diffuse to the center

during the decarburization process. Therefore, it is preferable that Mn and S are not added. However, in the slab and in the steel sheet after the non-oxidation annealing step in consideration of an amount inevitably mixed during the steel-making process, Mn may be controlled to 0.1 wt% or less, and S may be controlled to 0.005 wt% or less.

[0038] The balance includes Fe and inevitable impurities. The inevitable impurities are impurities mixed in the steel-making and the manufacturing process of the electrical steel sheet, which are widely known in the field, and thus a detailed description thereof will be omitted. Specifically, components such as Al, N, Ti, Mg, and Ca react with oxygen in the steel to form oxides, so it is necessary to strongly suppress them, thus each component may be managed to 0.005 wt% or less. 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.

[0039] On the surface of the steel sheet substrate 10, 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 among the total grains may be 70 area% or more. This is because the decarburization annealing is performed for a short period of time, as will be described later in relation to the manufacturing process. When annealing is performed for a long period of time through batch annealing after the decarburization annealing, the diameter (D1) of the circumscribed circle becomes significantly larger than the diameter (D2) of the inscribed circle, so that the ratio cannot be 0.5 or more. Here, the circumscribed circle refers to a smallest circle among imaginary circles surrounding an outer side of a grain, and the inscribed circle refers to a largest circle among imaginary circles included inside the grain. More specifically, 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 among the total grains may be 75 to 95 area%. More specifically, 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 among the total grains may be 97% to 99.9 area%. The grains having this shape react to external magnetic fields, particularly in a low magnetic field region, and contribute to electromagnetic wave shielding by serving to absorb the magnetic field by the material. 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 among the total grains may be analyzed using a computer program after observing the surface (ND plane) of the substrate 10 of the steel sheet with an optical microscope. If the coating 20 is present on the steel sheet substrate 10, the surface of the steel sheet substrate 10 may be analyzed after appropriately removing the coating 20.

[0040] In an embodiment of the present invention, in the thickness direction, the average grain size within the surface portion 12 from the surface of the steel sheet substrate 10 to less than 1/4 of the thickness of the steel sheet substrate is 80 μm to 500 μm , and the average grain size within the center portion 11 from 1/4 to 1/2 of the thickness of the steel sheet substrate is 50 μm or less. As such, by forming the grain sizes of the surface portion 12 and the center portion 11 differently in the steel sheet substrate 10, the grains in the surface portion 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, an ability of the material to absorb an external magnetic field is deteriorated, so that electromagnetic wave shielding performance may be decreased. If the average grain size within the surface portion 12 is too large, adhesion may be decreased due to a reduction in an interfacial contact surface during coating. 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 decreases, so that the electromagnetic wave shielding performance may be decreased. More specifically, the average grain size within the surface portion 12 may be 100 μm to 400 μm , and the average grain size within the center portion 11 may be 15 μm to 47 μm . The average grain size may be obtained by measuring the number of grains with respect to a measurement area on a cross section including the thickness direction of the steel sheet, and dividing the measurement area by the number of grains to obtain an average grain area. The grain size may be obtained as a diameter of a circle having the same area.

[0041] A ratio (surface portion/center portion) of the average grain size within the surface portion to the average grain size within the center portion may be 2.0 or more. If this ratio is too small, the ability of the material to react to an external magnetic field decreases, so that electromagnetic wave shielding characteristics may be inferior. More specifically, the ratio (surface portion/center portion) of the average grain size within the surface portion to the average grain size within the center portion may be 3.0 to 20.0.

[0042] A ratio ($\langle 110 \rangle // \text{ND} / \langle 111 \rangle // \text{ND}$) of an area fraction of grains in which a $\langle 110 \rangle$ direction is parallel to a rolling direction of the steel sheet within 15° to an area fraction of grains in which a $\langle 111 \rangle$ direction is parallel to the rolling direction of the steel sheet within 15° in the steel sheet substrate may be 3.0 or more. If this ratio is high, permeability in a low magnetic field region is increased, thereby contributing to electromagnetic wave shielding. More specifically, the ratio $\langle 110 \rangle // \text{ND} / \langle 111 \rangle // \text{ND}$ in the steel sheet substrate may be 3.3 to 6.5. This can be measured with an electron backscatter diffraction analyzer.

[0043] As described above, by appropriately controlling the steel composition of the steel sheet substrate 10 and appropriately forming the texture, the electromagnetic wave shielding performance is excellent. 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, the shielding rate in the 60 Hz, 100 mG magnetic field may be 50.0% to 75.0%, and the shielding rate in the 60 Hz, 1 G magnetic field may be 70.0% to 85.0%.

[0044] In this case, the shielding rate may be measured by a method of 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 at the center of the generated magnetic field. The shielding rate is calculated by shielding the pickup coil with a shielding material, obtaining magnetic field intensities measured before and after shielding, and performing a calculation as follows. The shielding of the pickup coil is performed by wrapping the coil in a cylindrical shape or shielding four sides in a box shape.

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

[0045] The coating 20 includes a fluoroolefin-based resin. This resin is a material with excellent insulation, oil resistance, and chemical resistance properties, and particularly exhibits excellent corrosion resistance even when exposed to a soil corrosion environment. The fluoroolefin-based resin may include not only fluoroolefins such as vinyl fluoride, vinylidene fluoride, tetrafluoroethylene, hexafluoropropylene, 1,1,3,3,3-pentafluoropropylene, 2,2,3,3-tetrafluoropropylene, 1,1,2-trifluoroethylene, and 3,3,3-trifluoropropylene, but also fluoroolefins in a broad sense containing a halogen atom other than a fluorine atom, such as chlorotrifluoroethylene, bromotrifluoroethylene, 1-chloro-1,2-difluoroethylene, and 1,1-dichloro-2,2-difluoroethylene. More specifically, it may include tetrafluoroethylene.

[0046] The coating 20 may further include an additional resin in addition thereto. Specifically, it may further include one or more of polyurethane, polyvinyl chloride, acrylonitrile-butadiene-styrene resin, polyacetal, polyethylene, polypropylene, polyphenylene oxide, polybutylene terephthalate, polyethylene terephthalate, a phenolic resin, an epoxy resin, unsaturated polyester, polyimide, polymethyl methacrylate resin, polyether ether ketone resin, polyphenylene sulfide, polyamide, and polycarbonate.

[0047] A thickness of the coating 20 may be 1 to 50 μm . If the thickness of the coating 20 is too thin, it is difficult to sufficiently obtain target corrosion resistance. Even if the thickness of the coating 20 is thicker, the corrosion resistance is not further enhanced, but rather, an excessive coating thickness may cause a problem of hindering adhesion between the coating and the material. More specifically, the thickness of the coating 20 may be 3 to 30 μm .

[0048] The coating 20 may be composed of a single layer or a plurality of layers. The plurality of layers means forming a coating by combining the coatings presented above. The thickness of the aforementioned coating 20 is a thickness for a single layer, and if the plurality of layers are present, a total thickness of the coating 20 may be 10 to 50 μm .

[0049] FIG. 2 illustrates a use example of an electrical steel sheet for electromagnetic wave shielding according to an embodiment of the present invention. As shown in FIG. 2, the electrical steel sheet 100 for electromagnetic wave shielding may be rolled into a cylindrical tube shape and installed to surround a power transmission line 200. Alternatively, in a cylindrical underground conduit surrounding the power transmission line 200, it is also possible to insert the electrical steel sheet 100 for electromagnetic wave shielding between the power transmission line and the underground conduit, or install the electrical steel sheet 100 for electromagnetic wave shielding to surround the underground conduit.

[0050] A manufacturing method for an electrical steel sheet for electromagnetic wave shielding according to an embodiment of the present invention 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 steel sheet; decarburization annealing the cold-rolled steel sheet; and forming a coating including a fluoroolefin-based resin on a surface of the decarburization annealed steel sheet.

[0051] Hereinafter, respective steps will be specifically described.

[0052] First, the slab is hot-rolled.

[0053] The slab may include, in wt%, Si: 0.3% to 7.0%, C: 0.01% to 0.4%, and a balance of Fe and inevitable impurities.

[0054] The slab may further include: Mn: 0.1 wt% or less and S: 0.005 wt% or less.

[0055] The description of the steel composition of the slab is the same as the description of the electrical steel sheet for electromagnetic wave shielding described above, so redundant descriptions thereof will be omitted. Except for C, the steel composition of the steel sheet may be substantially the same as the steel composition of the slab.

[0056] Before hot-rolling the slab, the slab may be heated. A slab heating temperature may be 1050°C to 1350°C, which is higher than a typical heating temperature. When the temperature is high during slab reheating, there is a problem that the hot-rolled structure is coarsening, which adversely affects magnetism. However, since the manufacturing method for the electrical steel sheet according to the embodiment of the present invention has a higher carbon content than a conventional method, the hot-rolled structure is not coarsened even if the slab reheating temperature is high, and reheating at a temperature higher than a typical case is advantageous during hot rolling. However, when the

reheating temperature is high, solid solubility of precipitates such as TiN and AlN increases, so that a large number of fine precipitates are distributed during cooling, thereby serving to hinder growth of grains on the surface.

[0057] The hot-rolling may be performed to manufacture a hot-rolled sheet having a thickness of 1.3 to 4.3 mm by applying an appropriate reduction rate in a final cold-rolling step so as to manufacture a final product thickness. More specifically, it may be manufactured to a thickness of 1.5 to 4.0 mm.

[0058] A hot-rolling finishing rolling temperature may be 750°C to 1050°C. If the hot-rolling finishing rolling temperature is too high, surface defects occur to deteriorate quality. In addition, if the finishing rolling temperature is too low, a rolling load increases to lower sheet throughability and decrease productivity. More specifically, it may be 800°C to 1030°C. In an embodiment of the present invention, a cooling rate in the ROT section after the hot-rolling finishing rolling and before a coil is wound may be controlled. 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, growth of surface grains is suppressed, making it difficult to obtain coarse grains. More specifically, the cooling rate may be controlled to -30 to -7°C/s.

[0059] After hot rolling, the hot-rolled steel sheet is subjected to hot-rolled sheet annealing. 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, additional annealing may be performed at a temperature of 1000°C to 1200°C and a dew point temperature of 0°C or less. Pickling may be performed after the hot-rolled sheet annealing is performed.

[0060] Next, cold rolling is performed to manufacture a cold-rolled steel sheet.

[0061] Accordingly, the cold rolling may be performed at a reduction ratio of 50% to 80% during the cold rolling. More specifically, it may be 55 % to 75%. Through this, a cold-rolled steel sheet having a final thickness of 0.3 mm to 2.0 mm may be manufactured.

[0062] Next, the cold-rolled steel sheet is subjected to decarburization annealing. In this case, the step of decarburization annealing may be performed in an austenite single-phase region or a region in which a composite 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. In addition, after the decarburization annealing, the amount of carbon in the steel sheet may be 0.15 wt% or less.

[0063] In the manufacturing method for the electrical steel sheet for electromagnetic wave shielding according to the embodiment of the present invention, τ defined by Equation 1 below is 0.230 to 0.500.

[Equation 1]

$$\tau = \left(\frac{\text{Finishing rolling temperature} + 273}{\text{ROT cooling rate} \times \text{Hot-rolled sheet thickness} \times 10^4} \right) \cdot \frac{(2.54 \times \text{Dew point temperature} + 273) \times (\text{Annealing temperature} + 273)}{\text{Cold-rolled plate thickness} \times 10^4}$$

(In Equation 1, the finishing rolling temperature refers to a hot rolling finishing rolling temperature (°C), the ROT cooling rate refers to a cooling rate (-°C/s) in an ROT section from after the hot rolling finishing rolling until a coil is wound, the hot-rolled sheet thickness refers to a thickness (mm) of the hot-rolled sheet, the dew point temperature refers to a dew point temperature (°C) of an atmosphere in the step of decarburization annealing, the annealing temperature refers to an annealing temperature (°C) in the step of decarburization annealing, and the cold-rolled sheet thickness refers to a thickness (mm) of the steel sheet after primary cold rolling.)

[0064] 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 significantly occurs, which may adversely affect electromagnetic wave shielding performance. More specifically, τ may be 0.240 to 0.450.

[0065] Next, a coating including a fluoroolefin-based resin is formed on a surface of the decarburization-annealed steel sheet. The coating is the same as described above, so a redundant description thereof will be omitted. In the embodiment of the present invention, the coating may be formed by manufacturing a film including a fluoroolefin-based resin and then adhering the film to the surface of the steel sheet substrate, rather than by a method of applying a composition. That is, it may be formed by lamination coating. The lamination coating refers to a process of overlying the film-type coating presented in the present invention on a steel sheet, wherein appropriate heat and pressure are applied to increase adhesion between the film and the material. In addition, it refers to a process in which a film into which a curing agent is introduced is overlaid on a material at room temperature under an appropriate pressure, and then the film is cured with ultraviolet (UV) light to complete the coating, and the present invention does not impose specific limitations on the lamination process.

[0066] Hereinafter, specific examples of the present invention will be described. However, the following examples are merely specific examples of the present invention, and the present invention is not limited to the following

examples.

Example

[0067] A slab containing, in wt%, Si: 2.0%, C: 0.101%, and a balance of Fe and inevitable impurities was heated at a temperature of 1270°C, and then processes were performed in the order of hot rolling, hot-rolled sheet annealing, cold rolling, and decarburization annealing under the manufacturing conditions of Table 1. After the decarburization annealing, the content of C was 0.005 wt%.

[0068] Manufacturing Condition 11 subsequently added a step of high-temperature annealing from -20°C dew point to 1200°C for 30 minutes.

[0069] Thereafter, a coating was formed by laminating tetrafluoroethylene to a thickness of 10 μm. Invention Examples 2 and 3 were formed by forming multiple layers to a total thickness of 20 μm, and Comparative Examples 6 and 7 were formed by applying a phosphate composition and drying the same.

[0070] For the manufactured specimens, the average grain size of the surface portion and the center portion, the magnetic flux density, and the electromagnetic wave shielding rate were measured, and the results are shown in Table 2 and Table 3.

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

[0072] The grain morphology at the surface was measured using an electron backscatter diffraction analyzer.

[0073] <110>//ND / <111>//ND were measured using an electron backscatter diffraction analyzer.

[0074] The magnetic flux density was measured by Single Strip Magnetic Field Measurement.

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

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

[0076] Insulation properties were measured as Franklin insulation properties, and were measured as a received current value when an input current of 0.5V and 1.0A was passed under a pressure of 300 PSI.

[0077] Salt spray corrosion resistance was evaluated by repeating a test with a 5 wt% NaCl solution at 35°C for 8 hours as 1 cycle to determine the order at which rust formation on the specimen began.

[0078] Soil corrosion resistance was tested under test conditions (salinity, pH control agent), Fog (35°C, 24hr), and a test solution was 1% NaCl + 0.01% Na₂SO₄ + 0.01% Na₂CO₃, and a time until rust occurred after burying the material to a depth of 10 cm (moisture content controlled) was measured.

(Table 1)

Manufacturing condition	Hot rolling			Hot - rolled sheet	Cold rolling		Decarburization annealing		Parameter (τ)
	Finishing rolling temperature ($^{\circ}\text{C}$)	ROT cooling rate ($^{\circ}\text{C/s}$)	Thickness (mm)		Reduction ratio (%)	Thickness (mm)	Dew point temperature ($^{\circ}\text{C}$)	Annealing temperature ($^{\circ}\text{C}$)	
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

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(Table 2)

Manufacturing condition	Average grain size (μm)		D2/D1 0.5 or larger fraction (area%)	(Surface portion/Center portion grain size)	<110>//ND / <111>//ND
	Surface portion	Central 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
			100mG (%)	1G (%)
1	0.879	1.887	51.2	72.8
2	1.345	1.853	66.5	75.6
3	1.295	1.825	64.0	74.4
4	1.270	1.781	61.4	71.2
5	1.360	1.867	64.2	75.1
6	0.555	1.835	30.5	67.8
7	0.298	1.700	18.3	61.8
8	0.605	1.846	31.8	68.7
9	0.482	1.832	25.2	67.5
10	0.921	1.702	60.2	62.8
11	1.458	1.710	72.5	63.5

(Table 4)

Manufacturing condition	Coating	Number of layers	Insulation (mA)	Corrosion resistance (salt spray, cycle)	Corrosion resistance (soil corrosion, hr)	Classification
1	tetrafluoroethylene	1	38	4	998	Inventive Example 1
2	tetrafluoroethylene	2	25	5	1254	Inventive Example 2
3	tetrafluoroethylene	3	5	6	1540	Inventive Example 3
4	tetrafluoroethylene	1	49	4	912	Inventive Example 4

(continued)

Manufacturing condition	Coating	Number of layers	Insulation (mA)	Corrosion resistance (salt spray, cycle)	Corrosion resistance (soil corrosion , hr)	Classification
5	tetrafluoroethylene	1	51	4	907	Inventive Ex-ample 5
6	tetrafluoroethylene	1	50	4	950	Comparative Example 1
7	tetrafluoroethylene	1	35	4	942	Comparative Example 2
8	tetrafluoroethylene	1	39	4	955	Comparative Example 3
9	tetrafluoroethylene	1	43	4	932	Comparative Example 4
10	tetrafluoroethylene	1	40	4	978	Comparative Example 5
11	tetrafluoroethylene	1	43	4	955	Comparative Example 6
1	phosphate	1	395	1	138	Comparative Example7
2	phosphate	1	322	1	129	Comparative Example8

[0079] As shown in Table 1 to Table 4, when process conditions are appropriately controlled, it can be confirmed that a texture of a steel sheet substrate is appropriately formed and a shielding rate is excellent. In addition, when a fluoroolefin-based resin is used as the coating, it can be confirmed that insulation and corrosion resistance are excellent.

[0080] On the other hand, when the process conditions are not appropriately controlled, it can be confirmed that the texture of the steel sheet substrate is not appropriately formed and the shielding rate is inferior.

[0081] Even if the steel sheet substrate is appropriately manufactured, when a phosphate coating is used as the coating, it can be confirmed that the insulation and the corrosion resistance are inferior.

[0082] 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]

[0083]

100: electrical steel sheet for electromagnetic wave shielding,

10: electrical steel sheet substrate,

11: center portion,

20: coating,

12:

200:

surface portion,

transmission line

Claims

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

a steel sheet substrate, and a coating positioned on a surface of the steel sheet substrate, wherein, on the surface of the steel sheet substrate, 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 are present in an amount of 70 area% or more of total grains,

in a thickness direction, an average grain size within a surface portion from the surface of the steel sheet substrate to less than 1/4 of a thickness of the steel sheet substrate 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 substrate is 50 μm or less, and

the coating includes a fluoroolefin-based resin.

2. The electrical steel sheet for electromagnetic wave shielding of claim 1, wherein a ratio of an area fraction of grains in which a <110> direction is parallel to a rolling direction of the steel sheet within 15° to an area fraction of grains in which a <111> direction is parallel to the rolling direction of the steel sheet within 15° in the steel sheet substrate 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, wherein the steel sheet substrate includes, in wt%, Si: 0.3% to 7.0%, C: 0.15% or less (excluding 0%), and a balance of Fe and inevitable impurities.

5. The electrical steel sheet for electromagnetic wave shielding of claim 1, wherein the steel sheet substrate further includes: Mn: 0.1 wt% or less and S: 0.005 wt% or less.

6. A manufacturing method for an electrical steel sheet for electromagnetic wave shielding, including:

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 steel sheet;

decarburization annealing the cold-rolled steel sheet; and

forming a coating including a fluoroolefin-based resin on a surface of the decarburization annealed steel sheet,

wherein τ defined by the following Equation 1 is 0.23 to 0.5:

[Equation 1]

$$\tau = \left(\frac{\text{Finishing rolling temperature} + 273}{\text{ROT cooling rate} \times \text{Hot-rolled sheet thickness} \times 10^4} \right) \cdot \frac{(2.54 \times \text{Dew point temperature} + 273) \times (\text{Annealing temperature} + 273)}{\text{Cold-rolled plate thickness} \times 10^4}$$

(in Equation 1, the finishing rolling temperature refers to a hot rolling finishing rolling temperature (°C), the ROT cooling rate refers to a cooling rate (°C/s) in an ROT section from after the hot rolling finishing rolling until a coil is wound, the hot-rolled sheet thickness refers to a thickness (mm) of the hot-rolled sheet, the dew point temperature refers to a dew point temperature (°C) of an atmosphere in the decarburization annealing, the annealing temperature refers to an annealing temperature (°C) in the decarburization annealing, and the cold-rolled sheet thickness refers to a thickness (mm) of the steel sheet after cold rolling).

7. The manufacturing method for the electrical steel sheet for electromagnetic wave shielding of claim 6, wherein the slab includes, in wt%, Si: 0.3% to 7.0%, C: 0.01% to 0.4%, and a balance of Fe and inevitable impurities.

8. The manufacturing method for the electrical steel sheet for electromagnetic wave shielding of claim 7, wherein the slab further includes: Mn: 0.1 wt% or less and S: 0.005 wt% or less.

9. The manufacturing method for the electrical steel sheet for electromagnetic wave shielding of claim 6, wherein the hot-rolled sheet annealing includes a decarburization process.

10. The manufacturing method for the 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.

5 11. The manufacturing method for the 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.

10 12. The manufacturing method for the electrical steel sheet for electromagnetic wave shielding of claim 6, wherein the forming of the coating is performed by lamination coating.

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FIG. 1

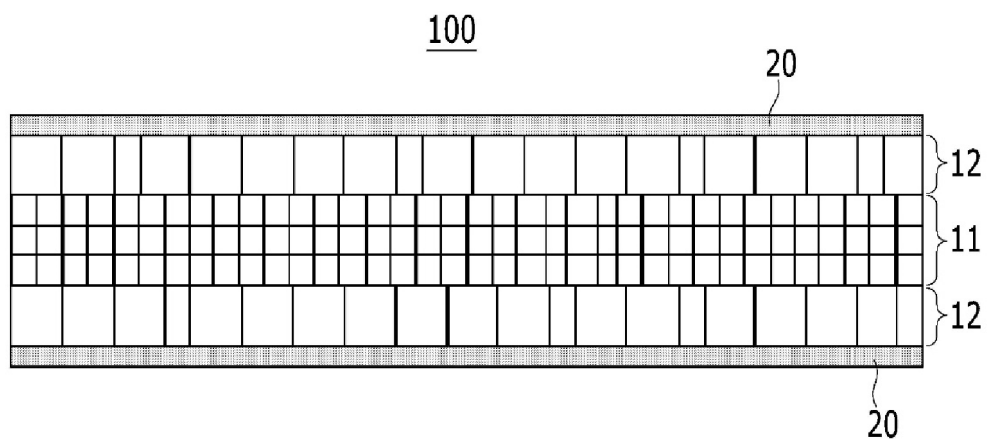


FIG. 2

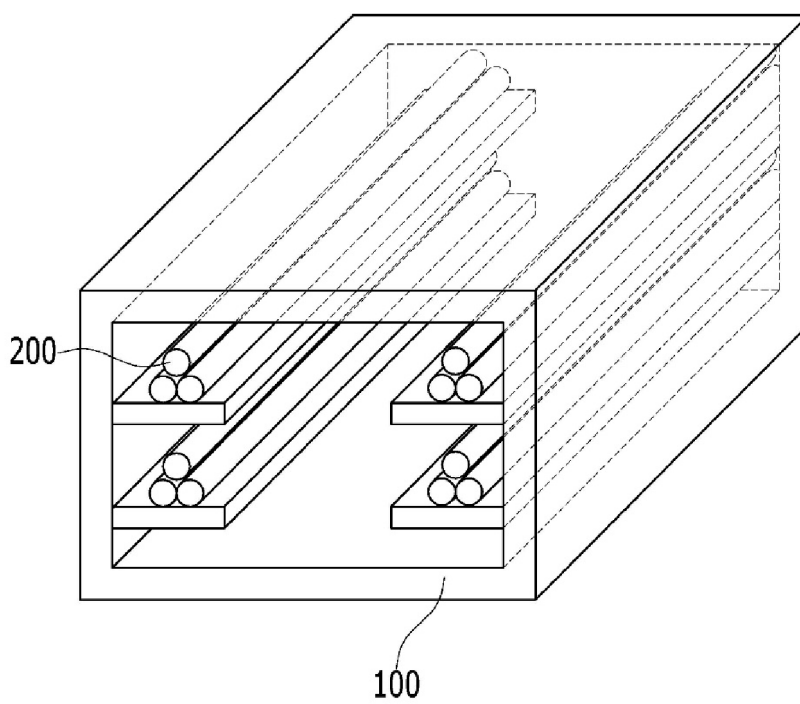


FIG. 3

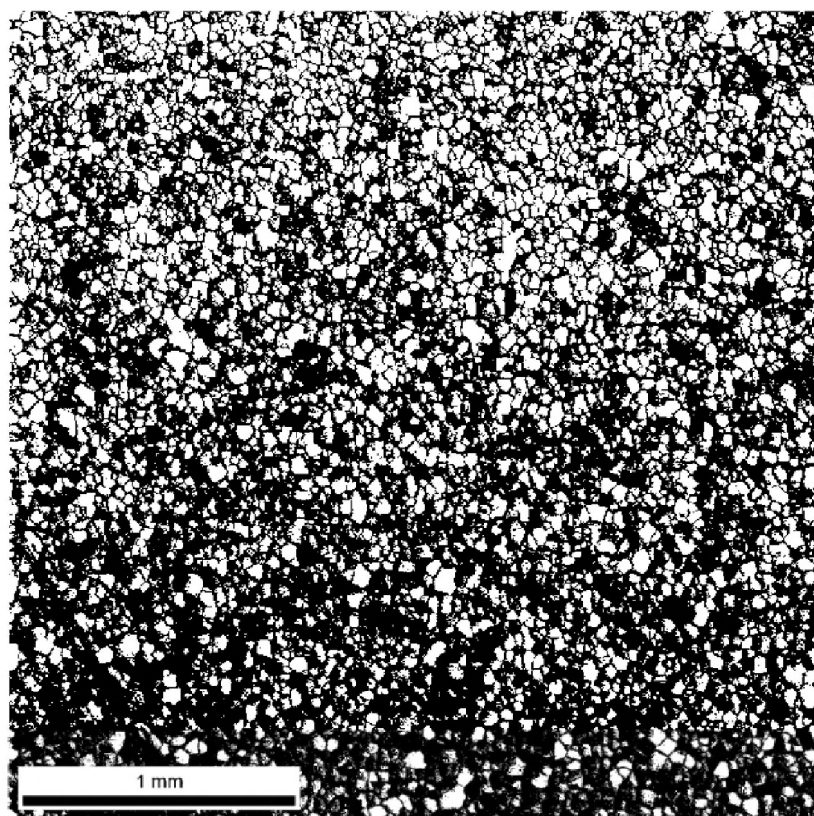
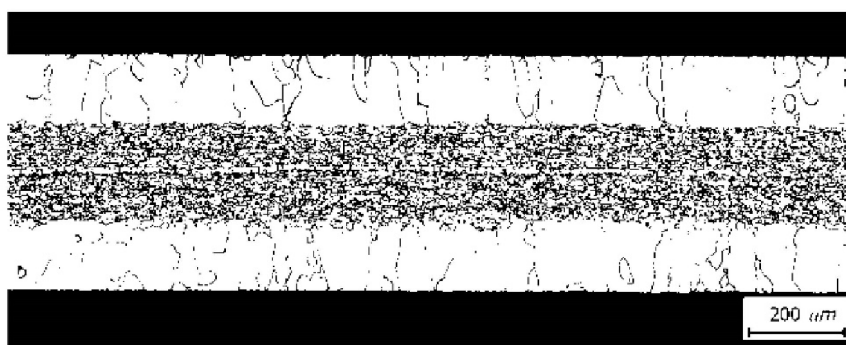


FIG. 4



INTERNATIONAL SEARCH REPORT

International application No.

PCT/IB2024/063308

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/02(2006.01)i; C22C 38/04(2006.01)i; C21D 8/12(2006.01)i; C23C 22/07(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); B05D 5/12(2006.01); B32B 15/08(2006.01); C21D 8/12(2006.01); C23C 22/00(2006.01); H01F 1/18(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), 피막(film), 결정립(grain), 플루오로올레핀 (fluoroolefin), 규소(Si), 열간압연(hot rolling), 냉간압연(cold rolling), 소둔(annealing), 탈탄(decarburization)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	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.	1-12
Y	JP 6733665 B2 (ASAHI GLASS COMPANY) 05 August 2020 (2020-08-05) See paragraphs [0019]-[0020] and [0034] and claim 1.	1-12
A	JP 5005844 B2 (NIPPON STEEL & SUMITOMO METAL CORP.) 22 August 2012 (2012-08-22) See paragraphs [0035]-[0036] and claims 1 and 3.	1-12
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A	KR 10-2022-0158843 A (NIPPON STEEL CORPORATION) 01 December 2022 (2022-12-01) See paragraph [0131] and claims 1-2 and 5-6.	1-12

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

* Special categories of cited documents:

“A” document defining the general state of the art which is not considered to be of particular relevance

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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

09 April 2025

Date of mailing of the international search report

09 April 2025

Name and mailing address of the ISA/KR

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Authorized officer

Telephone No.

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

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