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(54) **VACUUM TUBE STEEL AND MANUFACTURING METHOD THEREFOR**

(57) A vacuum tube steel according to one aspect of the present invention comprises, by wt%, 0.1-0.2% of C, 0.05-0.5% of Si, 1.0-1.6% of Mn, 0.5-1.0% of Ni, 1.5-4.0% of Cr, and the balance of Fe and inevitable impurities, and can include, as a microstructure, a composite structure of ferrite and pearlite.

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Description

[Technical Field]

- 5 **[0001]** The present disclosure relates to a steel material having properties that are particularly suitable for a vacuum tube that is provided for a high-speed vacuum tube train, and a method of manufacturing the steel material.

[Background Art]

- 10 **[0002]** Recently, research into a high-speed vacuum tube train, also known as a hyperloop, as a next generation transportation system, has been actively conducted domestically and internationally. A high-speed vacuum tube train is a means of transportation that fundamentally moves a train within a vacuum tube. That is, it is a means of transportation utilizing a concept in which it is possible to operate a train at a super high speeds because air resistance is minimized by maintaining the inside of a tube in a vacuum state.

- 15 **[0003]** In a vacuum tube that is used for a high-speed vacuum tube train, not only the structure of the tube, but the material of the tube are factors that have a significant influence on maintaining the inside of the tube in a vacuum state, but studies and development of the tube material are insignificant at present.

- [0004]** A section of tubing for manufacturing a vacuum tube that may be used for a high-speed train vacuum tube is disclosed in Patent Document 1; however, the material of the tube is not specifically stated therein.

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[Related Art Document]

[Patent Document]

- 25 **[0005]** (Patent Document 1) US 2019/0170276 A1 (published on 2019.06.06)

[Disclosure]

[Technical Problem]

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- [0006]** According to an aspect of the present disclosure, a steel material having properties that are particularly suitable for a vacuum tube that is provided for a high-speed vacuum tube train, and a method of manufacturing the steel material, may be provided.

- 35 **[0007]** The objectives of the present disclosure are not limited to that described above. Those skilled in the art would be able to understand additional objectives of the present disclosure from the contents of the entire specification without difficulty.

[Technical Solution]

- 40 **[0008]** A steel material for a vacuum tube according to an aspect of the present disclosure may include C: 0.1~0.2%, Si: 0.05~0.5%, Mn: 1.0~1.6%, Ni: 0.5~1.0%, Cr: 1.5~4.0%, and the balance of Fe and unavoidable impurities in percentage by weight, and may have a complex structure of ferrite and pearlite as a microstructure, may have complex structure of ferrite and pearlite as a microstructure, and may have an outgassing rate of 1.0×10^{-10} mbar·l·s⁻¹·cm⁻² or less.

- 45 **[0009]** A total content of Ti, Nb, and V of the impurities included in the steel material may be less than 0.01% (including 0%).

- [0010]** A fraction of the ferrite may be 60~90 percent by area and a fraction of the pearlite may be 10~40 percent by area.

- [0011]** A fraction of martensite or bainite included in the steel material may less than 1 percent by area (including 0%).

- [0012]** The steel material may have yield strength (YS) of 400~600MPa, a yield ratio (YR) of 0.8 or less, and elongation (El) of 19~30%.

- 50 **[0013]** The steel material may have Charpy impact energy of 30~50J at -20°C.

- [0014]** A thickness of the steel material may be 15~30mm.

- [0015]** A method of controlling a steel material for a vacuum tube according to an aspect of the present disclosure may include: providing a steel material by reheating a slab including C: 0.1~0.2%, Si: 0.05~0.5%, Mn: 1.0~1.6%, Ni: 0.5~1.0%, Cr: 1.5~4.0%, and the balance of Fe and unavoidable impurities in percentage by weight, and then by hot-rolling the slab at a finishing rolling temperature of 900~1000°C; primarily cooling the hot-rolled steel material up to 550-650°C at a first cooling speed of 5~50°C/s; coiling the steel material into a coil at a primary cooling end temperature after the primary cooling; and secondarily cooling the coil to room temperature at a secondary cooling speed of 0.005~0.05°C/s.

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[0016] A total content of Ti, Nb, and V of the impurities included in the slab may be less than 0.01% (including 0%).

[0017] A thickness of the hot-rolled steel material may be 15~30mm.

A cooling type of the primary cooling may be water cooling and a cooling type of the secondary cooling may be discharge of cold.

[Advantageous Effects]

[0018] According to an aspect of the present disclosure, it is possible to provide a steel material having properties that are particularly suitable for a vacuum tube that is provided for a high-speed vacuum tube train because the steel material has low outgassing rate and yield ratio, and a method of manufacturing the steel material.

[Best Mode]

[0019] The present disclosure relates to a steel material for a vacuum tube and a method of manufacturing the steel material. Hereafter, preferred embodiments of the present disclosure are described. Embodiments of the present disclosure may be modified in various ways and the scope of the present disclosure should not be construed as being limited to the embodiments to be described below. The embodiments are provided to describe the present disclosure in detail to those skilled in the art.

[0020] Hereafter, a steel material for a vacuum tube according to an aspect of the present disclosure is described in detail.

[0021] A steel material for a vacuum tube according to an embodiment of the present disclosure may include, in percentage by weight, C: 0.1~0.2%, Si: 0.05~0.5%, Mn: 1.0~1.6%, Ni: 0.5~1.0%, Cr: 1.5~4.0%, and the balance of Fe and unavoidable impurities, may have a complex structure of ferrite and pearlite as a microstructure, and may have an outgassing rate of 1.0×10^{-10} mbar-l-s⁻¹·cm⁻² or less.

[0022] Hereafter, the alloy composition of the present disclosure is described in detail. Hereafter, unless specifically stated, % and ppm related to the content of an alloy composition is based on weight.

[0023] A steel material for a vacuum tube according to an embodiment of the present disclosure may include, in percentage by weight, C: 0.1~0.2%, Si: 0.05~0.5%, Mn: 1.0~1.6%, Ni: 0.5~1.0%, Cr: 1.5~4.0%, and the balance of Fe and unavoidable impurities, in which the total content of Ni, Nb, Nd, and V of the impurities can be suppressed under 0.01% (including 0%).

Carbon (C): 0.1~0.2%

[0024] Carbon (C), which is a representative hardenability improvement element, is an element that most effectively contributes to securing strength of a steel material. Accordingly, the present disclosure may include carbon (C) of 0.1% or more in order to secure strength of a vacuum tube structure. A preferred content of carbon (C) may exceed 0.1%, and a more preferable content of carbon (C) may be 0.12% or more. However, when the content of carbon (C) is excessive, toughness of a steel material decreases and weldability is deteriorated, and additionally, the yield ratio increase, so the upper limit of the content of carbon (C) may be limited at 2.0%. A preferred content of carbon (C) may be less than 0.2%, and a more preferable content of carbon (C) may be 0.18% or less.

Silicon (Si): 0.05~0.5%

[0025] Silicon (Si) is an element that contributes to deoxidization of steel. Accordingly, the present disclosure may include silicon (Si) of 0.05% or more to secure the degree of purity of steel. A preferred content of silicon (Si) may be 0.06% or more, and a more preferable content of silicon (Si) may be 0.08%. However, when silicon (Si) is excessively added, it may interfere with detachment of surface scale, so not only the surface quality of a product may be deteriorated, but extraction of carbides may be interfered with, whereby formation of a target microstructure may be interfered with. Accordingly, the present disclosure may limit the upper limit of the content of silicon (Si) at 0.5%. A preferred content of silicon (Si) may be 0.4% or less, and a more preferable content of silicon (Si) may be 0.3% or less.

Manganese (Mn): 1.0~1.6%

[0026] Manganese (Mn) is an element that contributes to improving hardenability of steel, so the present disclosure may include manganese (Mn) of 1.0% or more to secure strength of a steel material. A preferred content of manganese (Mn) may be 1.1% or more, and a more preferable content of silicon (Si) may be 1.2% or more. However, manganese (Mn) is excessively added, the roughness of steel decreases and crack resistance is deteriorated, and additionally, material deviation may be caused due to molding segregation, so the present disclosure may limit the upper limit of the content

of manganese (Mn) at 1.6%. A preferred content of manganese (Mn) may be 1.5% or less, and a more preferable content of silicon (Si) may be 1.4% or less.

Nickel (Ni): 0.5~1.0%

[0027] Nickel (Ni) is not only an element that contributes to increasing the strength of a steel material, but an element that effectively contributes to increasing the shock toughness of a steel material. Accordingly, the present disclosure may include nickel (Ni) of 0.5% or more for this effect. A preferred content of nickel (Ni) may exceed 0.5%, and a more preferable content of nickel (Ni) may be 0.6% or more. However, the content of nickel (Ni) exceeds a predetermined level, the effects described above are saturated, but it is not preferable in terms of economical efficiency, so the present disclosure may limit the upper limit of the content of nickel (Ni) at 1.0%. A preferred content of nickel (Ni) may be less 1.0%, and a more preferable content of nickel (Ni) may be 0.9% or less.

Chrome (Cr): 1.5~4.0%

[0028] Chrome (Cr) is an element that effectively contributes to reducing an outgassing rate intended in the present disclosure. Chrome (Cr) has reduction potential (-0.73V) lower than that of iron (-0.44V), so it is possible to form a very thin and dense chrome oxide film on the surface of a steel material. A dense oxide film acts as a barrier against gas that is discharged from a material, so it is possible to effectively reduce the outgassing rate of a material. Accordingly, the present disclosure may include chrome (Cr) of 1.5% or more for this effect. A preferred content of chrome (Cr) may exceed 1.5%, and a more preferable content of chrome (Cr) may be 1.7% or more. The higher the content of chrome (Cr), the more the effect of reducing an outgassing rate is improved. However, considering that chrome (Cr) is an expensive element, it is not preferable in terms of economic that chrome (Cr) is added at a predetermined level or more. Further, when chrome (Cr) is excessively added, hardenability is excessively increased, so it may cause low-temperature microstructure formation in a surface layer, which is not preferable in terms of property material deviation. Accordingly, the present disclosure may limit the upper limit of the content of chrome (Cr) at 4.0%. A preferred content of chrome (Cr) may be 3.6% or less, and a more preferable content of chrome (Cr) may be 3.3% or less.

[0029] The steel material for a vacuum tube according to an aspect of the present disclosure may include the balance of Fe and other unavoidable impurities other than the components described above. However, since unintended impurities may be unavoidably mixed from a raw material or a surrounding environment in a common manufacturing process, such impurities cannot be completely excluded. Since anyone of those skilled in the art can know such impurities, all impurities are not specifically stated in the specification. Further, addition of effective components other than the composition described above is not excluded.

[0030] Further, it is possible to actively limit the total content of titanium (Ti), niobium (Nb), and vanadium (V), which are included as impurities, less than 0.01% (including 0%) in the steel material of the present disclosure. Titanium (Ti), niobium (Nb), and vanadium (V), which are representative precipitation strengthening elements, are elements that effectively contribute to improving the strength of a steel material by forming micro carbonitrides even though only a small amount of them is added. Since the target to which the steel material of the present disclosure is applied is a vacuum tube for a high-speed vacuum tube train that is a large structure, an increase of a yield ratio is not advantageous in terms of constructability. Accordingly, the present disclosure, in order to achieve a target yield ratio, actively restricts intentional addition of titanium (Ti), niobium (Nb), and vanadium (V), and even if these components are unavoidably mixed, it is possible to limit the total content less than 0.01% (including 0%).

[0031] The steel material for a vacuum tube according to an aspect of the present disclosure may have a complex structure of ferrite and pearlite as a microstructure and can actively suppress formation of a hard phase. The fraction of ferrite may be 60~90 percent by area, the fraction of pearlite may be 10~40 percent by area, and the total fraction of martensite or bainite that is a hard phase may be less than 1 percent by area (including 0%).

[0032] Since low-temperature microstructures such as martensite or bainite have high strength and a low yield ratio, they show excellent characteristics as a material for structures. However, since the thickness of the steel material for a vacuum tube of the present disclosure is about 5~30mm, there is a high possibility that a hard phase is introduced only on the surface of the steel material even through control under a cooling condition. That is, a hard phase is not formed at the center portion of the steel material, but a hard phase is intensively formed only at the surface portion of the steel material, so there is a high possibility of material deviation in the thickness direction of the steel material. Accordingly, the present disclosure can actively control the total fraction of martensite or bainite to reduce such material deviation.

[0033] The outgassing rate of the steel material for a vacuum tube according to an aspect of the present disclosure may be 1.0×10^{-10} mbar·ls⁻¹·cm⁻² or less. The outgassing rate means the amount of gas per time and area that is discharged from a material to a vacuum when a vacuum chamber is configured using the material. That is, when a chamber is configured using a material, the chamber is evacuated, and then the pump is separated from the chamber, a phenomenon in which the pressure in the chamber increases after a predetermined time passes. It is possible to calculate an outgassing

rate by measuring a pressure increase value in such a chamber and then substituting the value into the following [Equation 1].

[Equation 1]

$$q = (V/A) \cdot (\Delta P/t)$$

[0034] In Equation 1, q is an outgassing rate ($\text{mbar} \cdot \text{l} \cdot \text{s}^{-1} \cdot \text{cm}^{-2}$), V is the volume (liter) of a chamber, A is the surface area (cm^2) of the chamber, P is internal pressure (mbar) of the chamber, and t is time (s).

[0035] Further, the steel material for a vacuum tube according to an aspect of the present disclosure may have yield strength (YS) of 400~600MPa, a yield ratio (YR) of 0.8 or less, elongation (EI) of 19~30%, and Charpy impact energy at -20°C can satisfy the range of 30-50J.

[0036] Since the steel material according to an aspect of the present disclosure has the characteristics of a low outgassing rate and a low yield ratio, the steel material can provide properties specifically appropriate as a vacuum tube for a high-speed vacuum train that is a large vacuum structure. In particular, since a vacuum tube manufactured using the steel material according to an embodiment of the present disclosure has a low outgassing rate, it is possible not only to effectively maintain the vacuum state in the vacuum tube, but to have an excellent earthquake-proof characteristic because it has a low yield ratio.

[0037] The steel material for a vacuum tube according to an aspect of the present disclosure may have a thickness of 5-30mm, and thickness of the steel material that is applied to a vacuum tube to be applied may be selectively determined in accordance with the diameter of the vacuum tube. As a non-limiting example, when the diameter of a vacuum tube is about 1~3m, a steel material having a thickness of 5~15mm may be applied, and when the diameter of a vacuum tube is about 3~5m, a steel material having a thickness of 15~30mm may be applied.

[0038] Hereafter, a method of manufacturing the steel material for a vacuum tube according to an aspect of the present disclosure is described in detail.

[0039] The method of manufacturing the steel material for a vacuum tube according to an aspect of the present disclosure may include: providing a steel material by reheating a slab including, in percentage by weight, C: 0.1~0.2%, Si: 0.05~0.5%, Mn: 1.0~1.6%, Ni: 0.5~1.0%, Cr: 1.5~4.0%, and the balance of Fe and unavoidable impurities and then by hot-rolling the slab at a finishing hot-rolling temperature of 900~1000°C; primarily cooling the hot-rolled steel material up to 550~650°C at a primary cooling speed of 5~50°C/s; coiling the steel material into a coil at a primary cooling stop temperature after finishing the primary cooling; and secondarily cooling the coil to room temperature at a secondary cooling speed of 0.005~0.05°C/s.

Reheating of slab

[0040] A slab having predetermined components can be prepared and reheated. Since the alloy composition of the slab of the present disclosure correspond to the alloy composition of the steel material described above, the description of the alloy composition of the slab of the present disclosure refers to the description of the alloy composition of the steel material described above. The common slab heating condition may be applied as the slab heating condition of the present disclosure, but, as a non-limiting example, reheating of the slab may be performed in a temperature range of 1200~1350°C.

Hot rolling

[0041] A hot-rolled steel material can be provided by hot-rolling the reheated slab. Finishing hot-rolling may be performed in a temperature range of 900~1000°C. Finishing hot-rolling may be performed in a temperature range of 900°C or more to prevent deterioration of the low yield ratio characteristic due to structure refinement. Further, it is preferable that finishing hot-rolling is performed in a temperature range of 1000°C or less to prevent an excessive scale.

Primary cooling and coiling

[0042] The hot-rolled steel material after hot rolling is finished is cooled up to 550~650°C at a primary cooling speed of 5~50°C/s and then can be wound into a hot-rolled coil.

[0043] When the primary cooling speed is excessively low, transformation occurs after winding, so formation of a scale due to recuperative heat may be a matter. Accordingly, the present disclosure may perform primary cooling at a cooling speed of 5°C/s or more. However, when the primary cooling speed is excessively high, there is a possibility that the

shape of a product is deteriorated or a low-temperature microstructure is generated, so the present disclosure may limit the upper limit of the primary cooling speed at 50°C/s.

[0044] Since the steel material having the alloy composition of the present disclosure shows the highest transformation speed at around 600°C, it is preferable to finish cooling in a temperature range of 550~650°C and then perform coiling in the temperature range in order to introduce all microstructures of the final steel material into a complex structure of ferrite and pearlite.

Secondary cooling

[0045] The wound coil can be cooled up to room temperature at a secondary cooling speed of 0.005~0.05°C/s. The steel material of the present disclosure finishes ferrite and pearlite transformation at around 600°C, but it is preferable to perform secondary cooling under a low cooling condition in order to prevent some non-transformed structures from changing into low-temperature microstructures. Further, when the wound coil is cooled at a high cooling speed, poor shapes such as twisting and bending of a product may be generated, so the present disclosure may limit the upper limit of the secondary cooling speed at 0.05°C/s. However, although the present disclosure does not specifically limit the lower limit of the secondary cooling speed, it is possible to limit the lower limit of the secondary cooling speed at 0.005°C/s in a meaning of excluding a cooling speed of 0°C/s. The cooling condition of the secondary cooling may be discharge of cold.

[0046] The steel material manufactured through the manufacturing method described above not only have a complex structure of ferrite and pearlite, but can actively suppress formation of a hard phase such as martensite and bainite. Preferably, the fraction of ferrite may be 60~90%, the fraction of pearlite may be 10~40 percent by area, and the fraction of a hard phase may be less than 1 percentage by weight (including 0%).

[0047] Further, the steel material manufactured through the manufacturing method may have an outgassing rate of 1.0×10^{-10} mbar·l·s⁻¹·cm⁻² or less, a yield strength (YS) of 400~600MPa, a yield ratio (YR) of 0.8 or less, elongation (EI) of 19-30%, and Charpy impact energy of 30~50J at -20°C.

[Mode for Invention]

[0048] Hereafter, the present disclosure is described in more detail through embodiments. However, it should be noted that the following embodiments are provided only to concrete the present disclosure through exemplification rather than limiting the right range of the present disclosure.

(Embodiment)

[0049] A hot-rolled steel material having a thickness of 25mm was manufactured by heating a slab having the composition of Table 1 in a temperature range of 1250°C and then performing finishing hot rolling in a temperature range of 950°C. Thereafter, the hot-rolled steel material was cooled up to 600°C at a cooling speed of 25°C/s, and after cooling, the hot-rolled steel material was coiled at the cooling end temperature. Thereafter, the hot-rolled steel material was cooled up to room temperature at a cooling speed of 0.03°C/s, and then a microstructure, a yield ratio, and an outgassing rate were measured for each sample and described in Table 1.

[0050] The microstructure was measured by etching each sample through Nital etching and using an optical microscope having a magnification of 500. In the microstructure of Table 1, F is ferrite and P is pearlite. Samples of JIS5 were taken and a tension test was performed on the samples in the rolling direction, and a yield ratio was obtained by dividing a 0.2% off-set yield strength by tensile strength. An outgassing rate was measured through [Equation 1] described above after configuring a vacuum chamber having a 500mm length, a 150mm diameter, and a 20mm thickness.

[Table 1]

Sample No.	Alloy composition (wt%)						Micro structure	Yield ratio (%)	Outgassing rate (mbar·l·s ⁻¹ ·cm ⁻²)
	C	Si	Mn	Ni	Cr	Nb			
1	0.15	0.1	1.3	0.8	1.5	-	F+P	0.74	8.6×10^{-11}
2	0.15	0.1	1.3	0.8	2.5	-	F+P	0.75	6.0×10^{-11}
3	0.15	0.1	1.3	0.8	2.5	0.02	F+P	0.82	5.1×10^{-11}
4	0.15	0.1	1.3	0.8	0.8	-	F+P	0.71	5.7×10^{-10}

[0051] It could be seen that the samples 1 and 2 that satisfy the conditions limited in the present disclosure satisfy both an outgassing ratio of 1.0×10^{-10} mbar-l-s⁻¹·cm⁻² or less and a yield ratio of 0.8 or less. However, it could be seen that the samples 3 and 4 that did not satisfy the conditions limited in the present disclosure did not satisfy both the yield ratio and the outgassing rate intended in the present disclosure.

[0052] Accordingly, it could be seen that since the steel material according to an aspect of the present disclosure has the characteristics of both a low outgassing rate and a low yield ratio, the steel material has properties specifically appropriate as a vacuum tube for a high-speed vacuum train that is a large vacuum structure.

[0053] Although the present disclosure was described in detail above through embodiments, other embodiments may be possible. Therefore, the spirit and scope of the following claims are not limited to the embodiments.

Claims

1. A steel material for a vacuum tube, the steel material comprising

C: 0.1~0.2%, Si: 0.05~0.5%, Mn: 1.0~1.6%, Ni: 0.5~1.0%, Cr: 1.5~4.0%, and the balance of Fe and unavoidable impurities in percentage by weight, wherein the steel material has a complex structure of ferrite and pearlite as a microstructure, and an outgassing rate of the steel material is 1.0×10^{-10} mbar-l-s⁻¹·cm⁻² or less.

2. The steel material of claim 1, wherein a total content of Ti, Nb, and V of the impurities included in the steel material is less than 0.01% (including 0%).

3. The steel material of claim 1, wherein a fraction of the ferrite is 60~90 percent by area, and a fraction of the pearlite is 10~40 percent by area.

4. The steel material of claim 1, wherein a fraction of martensite or bainite included in the steel material is less than 1 percent by area (including 0%).

5. The steel material of claim 1, wherein the steel material has yield strength (YS) of 400~600MPa, a yield ratio (YR) of 0.8 or less, and elongation (EI) of 19~30%.

6. The steel material of claim 1, wherein the steel material has Charpy impact energy of 30~50J at -20°C.

7. The steel material of claim 1, wherein a thickness of the steel material is 5~30mm.

8. A method of manufacturing a steel material for a vacuum tube, the method comprising:

providing a steel material by reheating a slab including C: 0.1~0.2%, Si: 0.05~0.5%, Mn: 1.0~1.6%, Ni: 0.5~1.0%, Cr: 1.5~4.0%, and the balance of Fe and unavoidable impurities in percentage by weight, and then by hot-rolling the slab at a finishing rolling temperature of 900~1000°C; primarily cooling the hot-rolled steel material up to a temperature range of 550-650°C at a primary cooling speed of 5-50°C/s; coiling the steel material into a coil at a primary cooling end temperature after the primary cooling; and secondary cooling the coil to room temperature at a secondary cooling speed of 0.005~0.05°C/s.

9. The method of claim 8, wherein a total content of Ti, Nb, and V of the impurities included in the slab is less than 0.01% (including 0%).

10. The method of claim 8, wherein a thickness of the hot-rolled steel material is 5~30mm.

11. The method of claim 8, wherein a cooling type of the primary cooling is water cooling, and a cooling type of the secondary cooling is discharge of cold.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/KR2020/017828

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/58(2006.01)i; C22C 38/48(2006.01)i; C22C 38/50(2006.01)i; C21D 8/02(2006.01)i; B21B 3/00(2006.01)i; B21B 1/24(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 38/58(2006.01); C21D 8/02(2006.01); C22C 38/00(2006.01); C22C 38/04(2006.01); C22C 38/06(2006.01); C22C 38/14(2006.01); C22C 38/60(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: 진공튜브(vacuum tube), 페라이트(ferrite), 펄라이트(pearlite), 저항복비(low yield ratio), 내진특성(earthquake resistance)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2015-127447 A (JFE STEEL CORP.) 09 July 2015 (2015-07-09) See paragraphs [0063]-[0064] and [0074]-[0075], claims 1-2 and 4 and tables 2-3.	1-11
A	KR 10-0351791 B1 (JFE STEEL CORPORATION) 18 November 2002 (2002-11-18) See claims 1, 4, 9-10 and 13.	1-11
A	KR 10-2016-0082602 A (POSCO) 08 July 2016 (2016-07-08) See claims 1 and 3-4.	1-11
A	EP 2832889 B1 (JFE STEEL CORPORATION) 10 October 2018 (2018-10-10) See claims 1 and 3.	1-11
A	US 5454883 A (YOSHIE et al.) 03 October 1995 (1995-10-03) See claims 1-2.	1-11

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:

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

“D” document cited by the applicant in the international application

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