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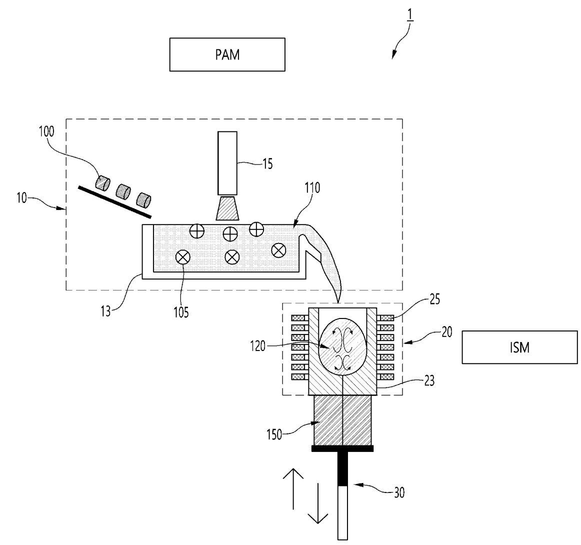
(54) **APPARATUS FOR MANUFACTURING TITANIUM INGOT AND METHOD FOR MANUFACTURING TITANIUM INGOT USING SAME**

(57) An apparatus for manufacturing a titanium ingot according to embodiments of the present invention may comprise: a plasma arc melting unit for melting metal scrap with a plasma arc; an induction skull melting unit for melting the molten metal melted by the plasma with an induced current; and an ingot drawing unit for withdrawing the metal ingot that is solidified after being melted by the induced current, wherein the plasma arc melting unit and the induction skull melting unit may be disposed in one chamber in the order named.

[FIG. 1]



Description

[Technical Field]

[0001] The present invention relates to an apparatus for manufacturing a titanium ingot and a method for manufacturing a titanium ingot using the same, and more particularly, to a method for manufacturing a high purity titanium ingot or a titanium alloy ingot, for example, a titanium alloy ingot for a bio material, by using an apparatus for manufacturing a titanium ingot that continuously applies plasma arc melting (PAM) and induction skull melting (ISM).

[Background Art]

[0002] A biomaterial for plastic surgery or dentistry requires excellent strength, toughness, wear resistance, and corrosion resistance, while being harmless to a human body and securing biocompatibility for the material to be coupled to a living bone. Representative biological metal materials that exhibit these features may include nickel-chromium (Ni-Cr) stainless steel (316L), a cobalt-chromium-molybdenum (Co-Cr-Mo) alloy developed under a trade name of vitalium, and a titanium (Ti) alloy. These metal materials currently account for 70% or more of implant materials for implantation in the body. The stainless steel and the Co-Cr-Mo alloy have been respectively used for biomedical purposes since the 1930s and 1940s. An osseointegration phenomenon, where a titanium (Ti) surface is coupled to a bone tissue, was announced by Per-Ingvar Brεnemark in Sweden in 1952. Afterwards, the titanium (Ti) alloy was first applied to a dental implant in 1965, and has been commercialized in earnest since the mid-1970s. The Ti alloy is lightweight and non-magnetic, and has excellent biocompatibility in addition to mechanical features such as corrosion resistance, strength, and toughness. Therefore, the Ti alloys are widely used today in dentistry for fillings (inlays), crowns, and tooth roots, in orthopedics for fracture fixators and artificial joints, and in circulatory surgery for pacemakers and stents. Although not bioactive, the Ti metal and the Ti alloy are evaluated to have better biocompatibility than another biometallic material (e.g., stainless steel or vitalium) or a polymer material (e.g., polymethyl metaacrylate (PMMA)) in terms of a bone formation pattern. A Ti-6Al4V alloy (composition: wt.%), which is currently most commonly used for the biomedical purpose, is an alloy having a ($\alpha + \beta$) type two-phase structure. The Ti-6Al4V alloy was originally developed for a structural part of an aircraft, and its suitability for biomedical purposes has also been proven. Therefore, there is a need for a technology for manufacturing a high-quality titanium alloy powder or ingot.

[0003] In South Korea, there is no infrastructure for manufacturing the titanium alloy powder or the titanium alloy ingot. Therefore, most of titanium bars and alloy powders depend on foreign countries, which results in not only their expensive prices, but also difficulties in their vitalization in the market.

[0004] As examples of attempts to solve the above problems, Korean Patent No. 10-1751794, which relates to a titanium refining furnace and a method for refining titanium by using the same, where molten titanium is formed by melting titanium scrap by using heating means including induction heating and plasma, the titanium scrap is refined by using the heating means to remove various metal impurities and oxygen included in the molten titanium, and the titanium ingot is manufactured by cooling the refined material, discloses a technology related to a titanium refining furnace including: a titanium melting part accommodating an object to be molten; a main chamber part including the titanium melting part therein; a heating source part having a first function of removing the metal impurities and a second function of removing oxygen; a scrap supply part supplying the titanium scrap to the titanium melting part; and an ingot extraction part withdrawing the molten titanium from the titanium melting part, wherein the heating source part includes an induction coil part performing the first function and a plasma generation part performing the first function and the second function. Korean Patent No. 10-1441654 discloses a dozen titanium bar manufacturing method of using a continuous non-consumable vacuum arc melting, the method including steps of: cleaning titanium alloy scrap, installing an end of a sharply machined tungsten electrode in a vacuum arc melting furnace to generate an arc in a predetermined direction; and inserting the scrap into a hearth installed in the vacuum arc melting furnace. Korean Patent No. 10-1370029 discloses titanium scrap refining method of removing oxygen included in a molten metal by supplying hydrogen plasma to a surface of the molten metal to refine titanium scrap.

[0005] These conventional titanium scrap refining technologies refine the titanium scrap by using the method of forming the molten titanium by applying the plasma and induction melting simultaneously to the titanium alloy to thus melt the titanium scrap and applying heat to the molten titanium at this stage to thus remove various metal impurities and oxygen included therein. In a case of melting a metal by using the plasma, the shorter a distance between a metal material and a plasma torch, the greater meltability of the metal. However, the distance between the metal material and the plasma torch may be relatively long, which leads to difficulty in complete melting and a failure in removal of high-density impurities. Therefore, the conventional method is not suitable for refining and manufacturing the titanium alloy applied to a field requiring its high quality, for example, the biomaterial.

[Disclosure]

[Technical Problem]

[0006] An object of the present invention is to provide an apparatus for manufacturing a titanium ingot that may significantly improve purity of the titanium ingot while increasing its meltability.

[0007] An object of the present invention is to provide a method for manufacturing a titanium ingot by using the apparatus for manufacturing a titanium ingot.

[0008] An object of the present invention is to provide a method for manufacturing a titanium alloy ingot for a biomaterial, which may shorten a distance between a plasma arc and a titanium alloy to thus completely melt a metal material and completely remove impurities therein, thereby refining the titanium alloy, and manufacture the titanium alloy ingot through an induction skull melting process.

[Technical Solution]

[0009] According to embodiments, provided is an apparatus for manufacturing a titanium ingot, the apparatus including: a plasma arc melting unit for melting metal scrap by using a plasma arc; an induction skull melting unit for melting the molten metal, molten by the plasma, by using an induced current; and an ingot drawing unit for withdrawing the metal ingot that is solidified after being molten by the induced current, wherein the plasma arc melting unit and the induction skull melting unit are disposed in one chamber in the order named.

[0010] A placement height of the plasma arc melting unit may be greater than a placement height of the induction skull melting unit.

[0011] The plasma arc melting unit may include a cold hearth and a plasma torch, the induction skull melting unit may include a cold crucible and an induction coil, and one end of the cold hearth may be disposed above the cold crucible.

[0012] According to embodiments, provided is a method for manufacturing a titanium ingot, the method including: a step of melting titanium scrap by using a plasma arc; a step of melting the molten titanium scrap by an induction skull method; and a step of casting a titanium ingot from titanium molten sequentially by means of the plasma arc and the induction skull method.

[0013] The titanium scrap may have a shape of a bar, a lump, a chip, a clip, or a sponge.

[0014] The plasma arc melting step may include a step of inputting the titanium scrap into a plasma arc melting unit, a step of melting the titanium scrap into a primary molten titanium by driving a plasma torch, and a step of separating inclusions from the primary molten titanium by flowing the primary molten titanium on a cold hearth and precipitating the inclusions or evaporating the inclusions into vapor.

[0015] The cold hearth may be made of a water-cooled copper vessel.

[0016] The induction skull melting step may include a step of inputting the primary molten titanium into an induction skull melting unit, a step of melting the primary molten titanium into a secondary molten titanium by driving an induction coil, and a step of purifying the secondary molten titanium on a cold crucible.

[0017] The plasma arc melting step and the induction skull melting step may be performed independently of each other.

[0018] The plasma arc melting step and the induction skull melting step may be performed sequentially.

[Advantageous effect]

[0019] The method for manufacturing a titanium ingot according to the embodiments of the present invention may use the titanium scrap to achieve economic effects and simultaneously solve environmental problems, use copper melting furnaces instead of ceramic refractories to also reduce production costs and improve productivity, and use two independent heating processes to increase the meltability of the metal material and manufacture the high-purity titanium ingot.

[Description of Drawings]

[0020]

FIG. 1 is a diagram for explaining an apparatus for manufacturing a titanium ingot according to embodiments of the present invention.

FIG. 2 is a flowchart for explaining a method for manufacturing a titanium ingot according to embodiments of the present invention.

FIG. 3 is a diagram illustrating a step of melting titanium by using a plasma arc melting unit according to embodiments of the present invention.

FIG. 4 is a diagram illustrating a step of melting titanium by using an induction skull melting unit according to embodiments of the present invention.

[Best Mode]

[0021] Hereinafter, specific embodiments of the present invention are described. A detailed description below is provided to facilitate a comprehensive understanding of a method, an apparatus and/or a system, described in the specification. However, the embodiments are only described by way of examples and the present invention is not limited thereto.

[0022] In describing the embodiments of the present invention, omitted is a detailed description of a case where it is decided that the detailed description of the known functions or configurations related to the present invention may unnecessarily obscure the gist of the present invention. In addition, terms described below are those defined in consideration of functions in the present invention, and may be construed in different ways by the intentions of users or operators, or practices. Therefore, the terms should be defined on the basis of the contents throughout the specification. Terms used in the detailed description are merely to describe the embodiments of the present invention, and should not be construed to be restrictive. A term of a single number may include its plural number unless explicitly indicated otherwise. It is to be understood that terms "include", "have", or the like, used in the specification specify certain features, numerals, steps, operations, elements, or portions or combinations thereof, and it should not be construed to exclude the presence or possibility of one or more other features, numbers, steps, operations, elements, or portions or combinations thereof other than those described.

[0023] In addition, terms "first", "second", A, B, (a), (b), and the like, may be used in describing components of an embodiment of the present invention. These terms are only used to distinguish any components from other components, and the essences, sequences, order, or the like of the corresponding components are not limited by these terms.

[0024] Meanwhile, hereinafter, a term "Titanium" may be used as "titanium", and vice versa, the term "titanium" may be used as "Titanium". "Titanium" and "titanium" may both be interpreted to indicate a metal corresponding to an element symbol Ti (Titanium/titanium) . In addition, both "dissolution" and "melting" may indicate that a solid material absorbs heat energy and is changed into a liquid material.

[0025] FIG. 1 is a diagram for explaining an apparatus for manufacturing a titanium ingot according to embodiments of the present invention.

[0026] Referring to FIG. 1, an apparatus 1 for manufacturing a titanium ingot according to embodiments of the present invention may include a plasma arc melting unit 10, an induction skull melting unit 20, and an ingot drawing unit 30.

[0027] The plasma arc melting unit 10 may be a plasma arc melting (PAM) furnace, and may include a cold hearth 13 and a plasma torch 15.

[0028] A metal input into the plasma arc melting unit 10 may be titanium scrap 100, and the titanium scrap 100 may be made of a raw material having various shapes such as a bar, a lump, a chip, a clip, and a sponge.

[0029] The cold hearth 13 may be made of, for example, a water-cooled copper vessel, and remove high density inclusions (HDIs) or low density inclusions (LDIs) from a molten metal by precipitating the inclusions or evaporating the inclusions into vapor, thereby functioning to increase purity of a metal cast. For example, the water-cooled copper vessel may be a reusable copper crucible, and here, the copper crucible, which may be destroyed or lost due to a high melting temperature, may be controlled by a metal skull generated on an inner wall of the crucible. Therefore, it is possible to prevent reaction with the molten metal, caused by use of a conventional ceramic crucible.

[0030] The high density inclusions (HDI) may be, for example, a metal compound such as tungsten carbide (WC) or tantalum carbide (TaC), the low density inclusions (LDI) may be, for example, a metal compound such as titanium nitride (TiN) or titanium carbide (TiC), the high density inclusions (HDI) may be precipitated on a bottom surface of the cold hearth 13, and the low density inclusions (LDI) may be evaporated into vapor.

[0031] Meanwhile, FIG. 1 shows that the cold hearth 13 has a flat bottom surface, and the present invention is not necessarily limited to this concept. The cold hearth 13 may have a bottom surface inclined rather than flat, or have a bottom surface having steps of different heights. That is, the bottom surface of the cold hearth 13 may have a different shape to more efficiently remove the high density inclusions (HDI) and/or the low density inclusions (LDI).

[0032] The plasma torch 15 may be configured to generate a plasma arc to melt metal scrap, and thus be referred to as a plasma arc generation unit. Meanwhile, the plasma arc may be replaced by an electron beam. Although not shown, the plasma torch 15 may be controlled to be moved above the cold hearth 13 in a vertical direction and/or a horizontal direction, and a rotation of the plasma torch 15 may be controlled to adjust a spray direction of the plasma arc.

[0033] In the embodiments, the titanium scrap 100 input into the plasma arc melting unit 10 may be molten into a primary molten titanium 110 by the plasma arc generated and sprayed from the plasma torch 15, and the inclusions 105 included in the primary molten titanium 110 may be precipitated and then removed as the primary molten titanium 110 flows on the cold hearth 13.

[0034] The induction skull melting unit 20 may be an induction skull melting (ISM) furnace, and may include a cold crucible 23 and an induction coil 25.

[0035] The cold crucible 23 may provide a space for accommodating the metal primarily molten by the plasma arc melting unit 10, and may be, for example, a water-cooled copper crucible.

[0036] The induction coil 25 may be configured to inductively heat the molten metal by generating a current and forming a magnetic field, and may have, for example, a shape of a wound high-frequency coil made of copper. The induction coil 25 may also be referred to as a high frequency coil. The magnetic field generated by the induction coil 25 may be adjusted by controlling a frequency of a power supply (not shown), and the molten metal may be secondarily melted by the magnetic field.

[0037] In the embodiments, the primary molten titanium 110 input into the induction skull melting unit 20 may be re-melted into a secondary molten titanium 120 by the magnetic field formed by the induction coil 25. The secondary molten titanium 120 may then be solidified on the cold crucible 23 and cast into a titanium ingot 150. Here, the secondary molten titanium 120 may be formed by additionally removing the impurities or gases included in the primary molten titanium 110, thus greatly improving the purity and quality of the finally cast titanium ingot 150.

[0038] In an embodiment, a placement height of the plasma arc melting unit 10 may be greater than a placement height of the induction skull melting unit 20, and one end of the cold hearth 13 may be disposed above the cold crucible 23.

[0039] In the embodiments, the molten metal, i.e., primary molten titanium 110, inserted into the induction skull melting unit 20 may be completely melted into a uniform phase by convection in the cold crucible 23 through induction heating, thereby forming the secondary molten titanium 120. Here, the secondary molten titanium 120 in contact with the cold crucible 23 may be solidified by a water-cooled segment (not shown). The skull generated later may generate a thin metal boundary layer between the cold crucible 23 and the secondary molten titanium 120. This boundary layer may act as a thermal resistance to thus reduce heat transferred from the secondary molten titanium 120 to the cold crucible 23, thereby functioning to extend a life of the cold crucible 23.

[0040] In addition, a melting method used by the induction skull melting unit 20 may be performed by melting the metal metal-to-metal at the cold crucible 23, i.e., water-cooled copper crucible, without a refractory material in a vacuum state. Here, the reaction between the molten metal, i.e., secondary molten titanium 120, and oxygen may be inhibited due to the absence of the refractory material.

[0041] In addition, a side portion of the secondary molten titanium 120 may be pushed inward from an inner side wall of the cold crucible 23. Accordingly, the side portion of the secondary molten titanium 120 may have no physical contact with the inner side wall of the cold crucible 23, thereby preventing the water-cooled segment from being electrically short-circuited and reducing heat loss to the cold crucible 23.

[0042] The ingot drawing unit 30 may be configured to withdraw a metal ingot, i.e., titanium ingot 150 formed by ingotting the molten metal through primary melting and secondary melting. In an embodiment, the ingot drawing unit 30 may be controlled to withdraw the metal ingot by its movement in the vertical direction.

[0043] In the embodiments, the plasma arc melting unit 10 and the induction skull melting unit 20 may be disposed in one chamber in the order named. Accordingly, a plasma arc melting (PAM) process and an induction skull melting (ISM) process may be performed sequentially and continuously.

[0044] As described above, the apparatus 1 for manufacturing a titanium ingot according to the embodiments of the present invention may include the sequentially-disposed plasma arc melting unit 10 and induction skull melting unit 20, and the metal scrap may be cast into the metal ingot through the plasma arc melting (PAM) process and the induction skull melting (ISM) process, which are performed continuously by the apparatus 1 for manufacturing a titanium ingot, thereby improving the meltability of the metal scrap and increasing the purity of the finally cast metal ingot.

[0045] FIG. 2 is a flowchart for explaining a method for manufacturing a titanium ingot according to embodiments of the present invention.

[0046] Referring to FIG. 2, the method for manufacturing a titanium ingot according to the embodiments of the present invention may include: a step (S-1) of melting titanium scrap 100 by using a plasma arc; a step (S-2) of melting the molten titanium scrap by an induction skull method; and a step (S-3) of casting a titanium ingot from titanium molten sequentially by means of the plasma arc and the induction skull method.

[0047] Referring to FIGS. 1 and 2 together, the titanium scrap 100 may be melted into a primary molten titanium 110 through the plasma arc melting step (S-1), and the primary molten titanium 110 may be re-melted into a secondary molten titanium 120 through the induction skull melting step (S-2). Next, the secondary molten titanium 120 may be solidified and cast into the titanium ingot 150.

[0048] FIG. 3 is a diagram illustrating the step of melting titanium by using a plasma arc melting unit 10 according to the embodiments of the present invention.

[0049] Referring to FIG. 3, the plasma arc melting step (S-1) may include a step (S11) of inputting the titanium scrap 100 into the plasma arc melting unit 10, a step (S12) of melting the titanium scrap 100 into the primary molten titanium 110 by driving a plasma torch 15, and a step (S13) of separating inclusions 105 from the primary molten titanium 110 by flowing the primary molten titanium 110 on a cold hearth 13 and precipitating the inclusions or evaporating the inclusions into vapor.

[0050] FIG. 4 is a diagram illustrating the step of melting titanium by using an induction skull melting unit 20 according to the embodiments of the present invention.

[0051] Referring to FIG. 4, the induction skull melting step (S-2) may include a step (S21) of inputting the primary molten titanium 110 into the induction skull melting unit 20, a step (S22) of melting the primary molten titanium 110 into the secondary molten titanium 120 by driving an induction coil 25, and a step (S23) of purifying the secondary molten titanium 120 on the cold crucible 23.

[0052] In the embodiments, the plasma arc melting step (S-1) and the induction skull melting step (S-2) may be performed independently of each other, and the plasma arc melting step (S-1) and induction skull melting step (S-2) may be performed sequentially.

[0053] As described above, the method for manufacturing a titanium ingot according to the present invention may be performed by applying two different melting processes independently and sequentially to improve meltability of the titanium scrap 100 and minimize the inclusions 105.

[0054] That is, a process of removing impurities in a raw material by using plasma arc melting (PAM) may be used first, and only a pure molten metal, from which low density inclusions (LDIs) and high density inclusions (HDIs) are removed, may be inserted into an induction skull melting (ISM) cold crucible, and the pure molten metal may then be further re-melted, thereby further improving the purity of the finally manufactured metal ingot.

[0055] However, the present invention is not necessarily limited to this concept. The apparatus for manufacturing a titanium ingot and the method for manufacturing a titanium ingot according to the embodiments of the present invention may be applied to various technical fields in addition to the above-mentioned technical field, for example, a method for manufacturing a titanium alloy ingot.

[0056] In an embodiment, in the method for manufacturing a titanium alloy ingot, the titanium scrap 100 may be replaced by the titanium alloy scrap. Accordingly, the primary molten titanium 110 and the secondary molten titanium 120 may also be referred to as the primary titanium alloy molten metal and the secondary titanium alloy molten metal, respectively.

[0057] However, the method for manufacturing a titanium alloy ingot may be performed through steps that are substantially the same as or similar to steps of the method for manufacturing a titanium ingot described above in that the titanium scrap 100 is molten into the primary molten titanium 110 and the secondary molten titanium 120 by the plasma arc melting unit 10 and the induction skull melting unit 20. The method for manufacturing a titanium alloy ingot may further include a step of inputting an alloy component into the primary molten titanium 110 or the secondary molten titanium 120.

[0058] Although the various embodiments of the present invention have been specifically described above, those skilled in the art to which the present invention pertains may appreciate that the embodiments described above may be changed in various ways without departing from the scope of the present invention. Accordingly, the scope of the present invention is not construed as being limited to the described embodiments, and defined by the appended claims as well as equivalents thereto.

Claims

1. An apparatus for manufacturing a titanium ingot, the apparatus comprising:

a plasma arc melting unit for melting metal scrap by using a plasma arc;
an induction skull melting unit for melting the molten metal, molten by the plasma, by using an induced current; and
an ingot drawing unit for withdrawing the metal ingot that is solidified after being molten by the induced current,
wherein the plasma arc melting unit and the induction skull melting unit are disposed in one chamber in the order named.

2. The apparatus of claim 1, wherein a placement height of the plasma arc melting unit is greater than a placement height of the induction skull melting unit.

3. The apparatus of claim 1, wherein the plasma arc melting unit includes a cold hearth and a plasma torch,

the induction skull melting unit includes a cold crucible and an induction coil, and
one end of the cold hearth is disposed above the cold crucible.

4. A method for manufacturing a titanium ingot, the method comprising:

a step of melting titanium scrap by using a plasma arc;
a step of melting the molten titanium scrap by an induction skull method; and
a step of casting a titanium ingot from titanium molten sequentially by means of the plasma arc and the induction skull method.

5. The method of claim 4, wherein the titanium scrap has a shape of a bar, a lump, a chip, a clip, or a sponge.

6. The method of claim 4, wherein the plasma arc melting step includes

a step of inputting the titanium scrap into a plasma arc melting unit,
a step of melting the titanium scrap into a primary molten titanium by driving a plasma torch, and
a step of separating inclusions from the primary molten titanium by flowing the primary molten titanium on a cold hearth and precipitating the inclusions or evaporating the inclusions into vapor.

7. The method of claim 6, wherein the cold hearth is made of a water-cooled copper vessel.

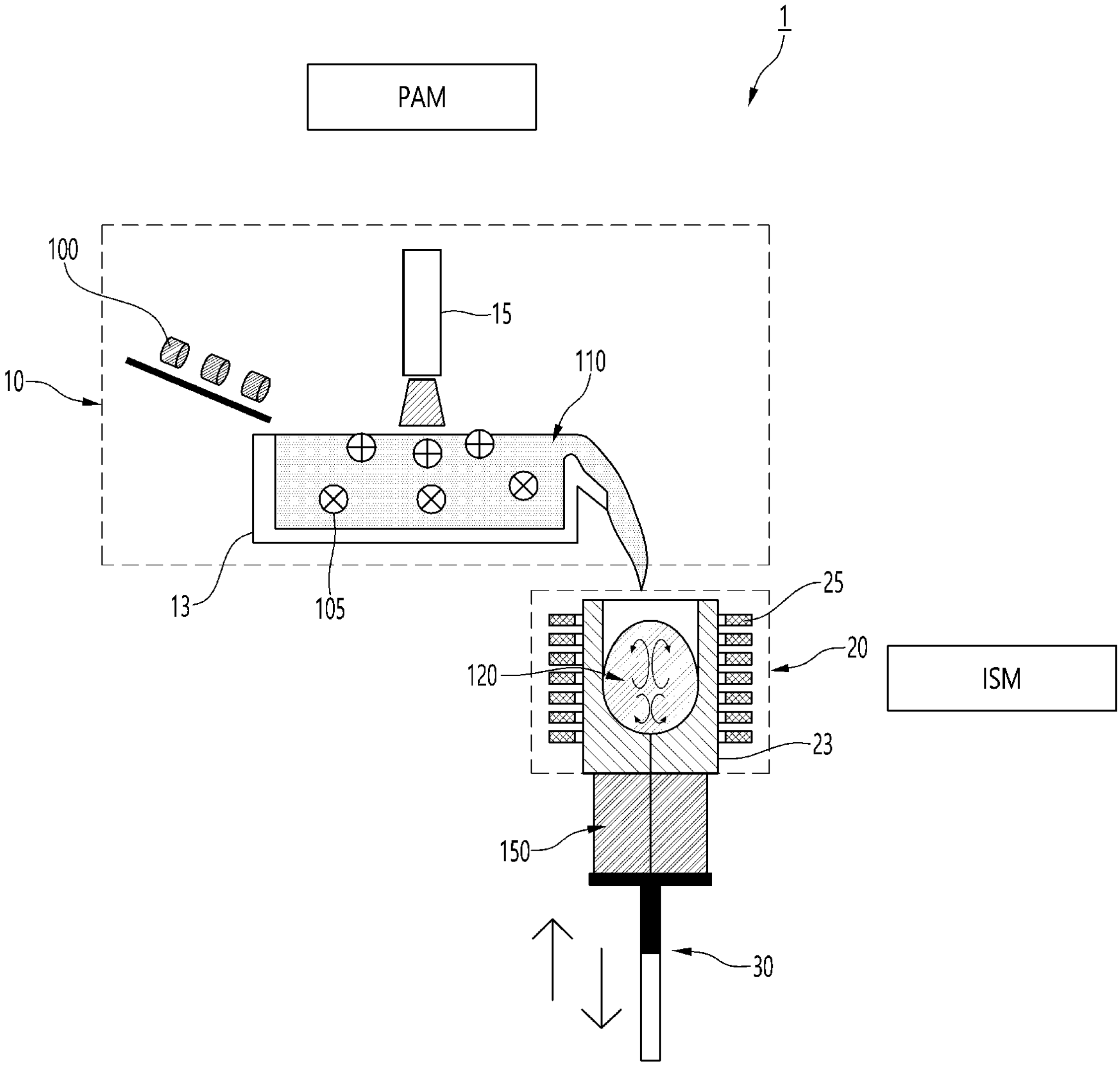
8. The method of claim 6, wherein the induction skull melting step includes

a step of inputting the primary molten titanium into an induction skull melting unit,
a step of melting the primary molten titanium into a secondary molten titanium by driving an induction coil, and
a step of purifying the secondary molten titanium on a cold crucible.

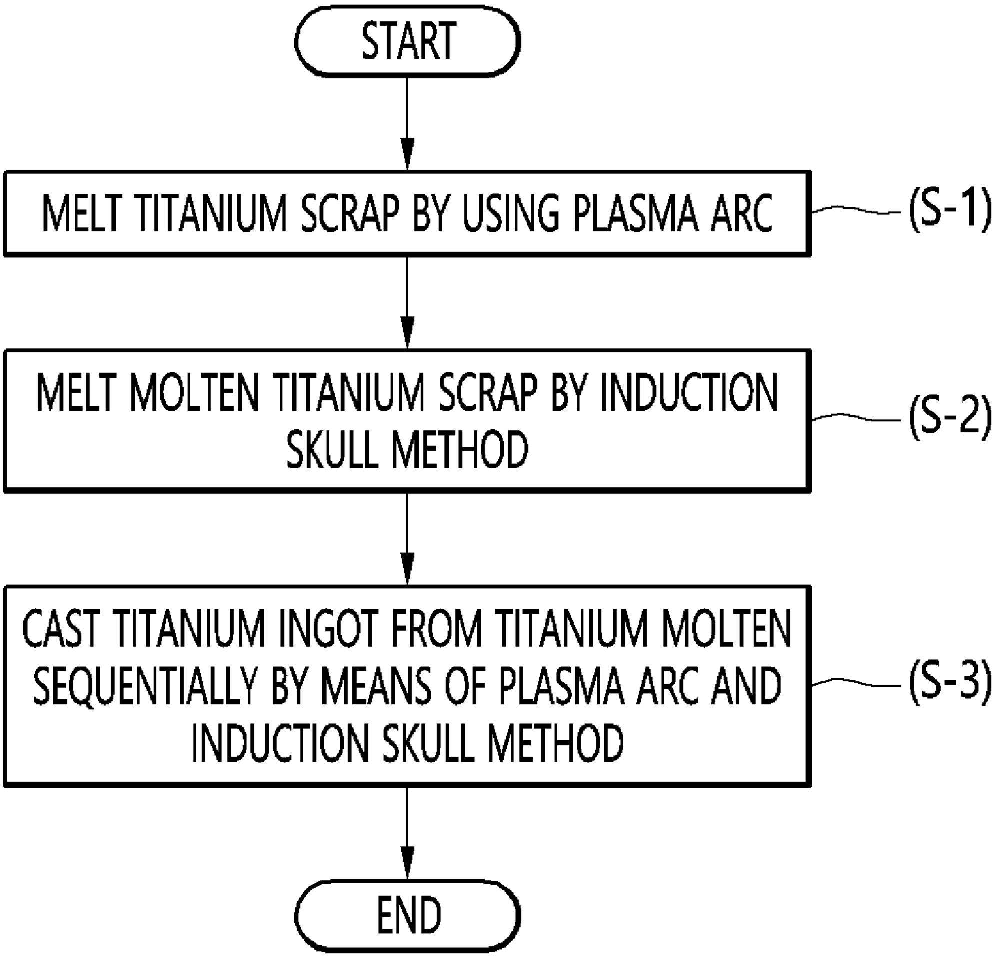
9. The method of claim 8, wherein the plasma arc melting step and the induction skull melting step are performed independently of each other.

10. The method of claim 9, wherein the plasma arc melting step and the induction skull melting step are performed sequentially.

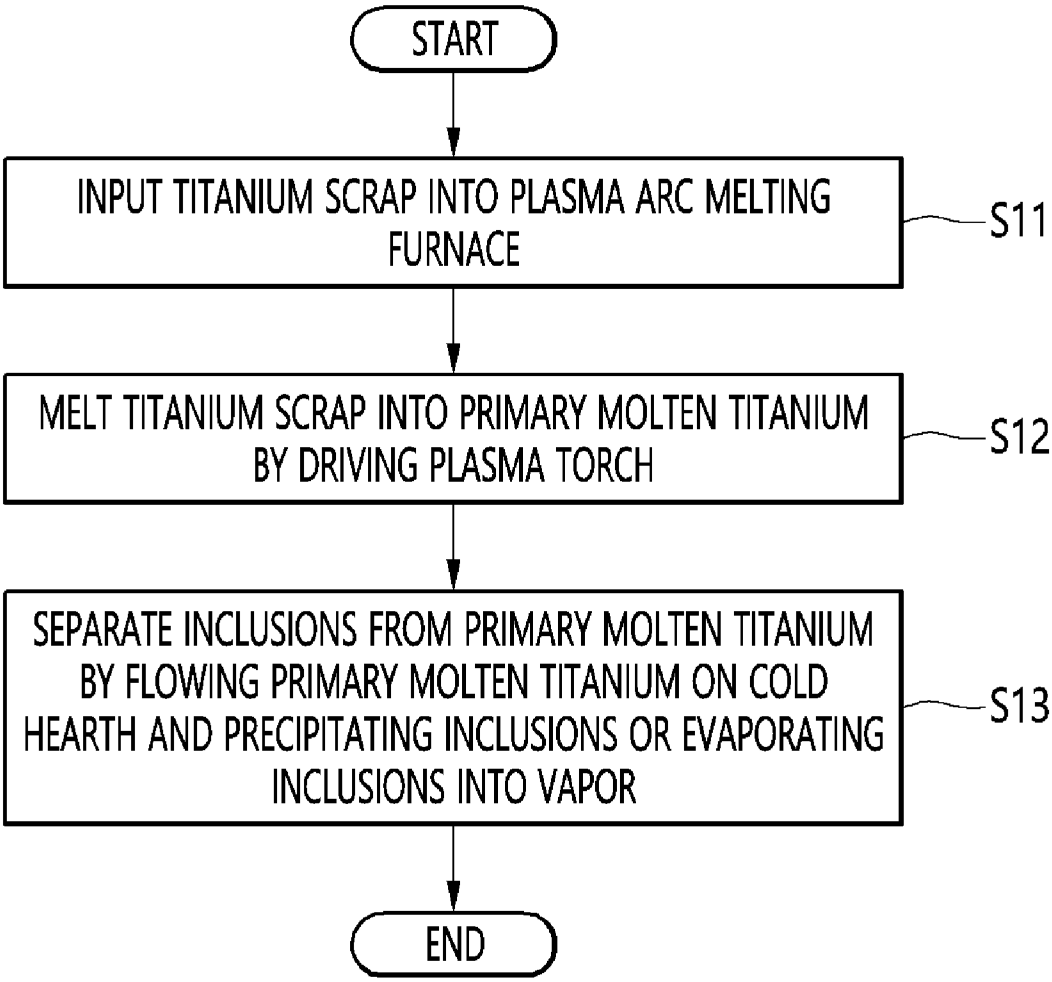
[FIG. 1]



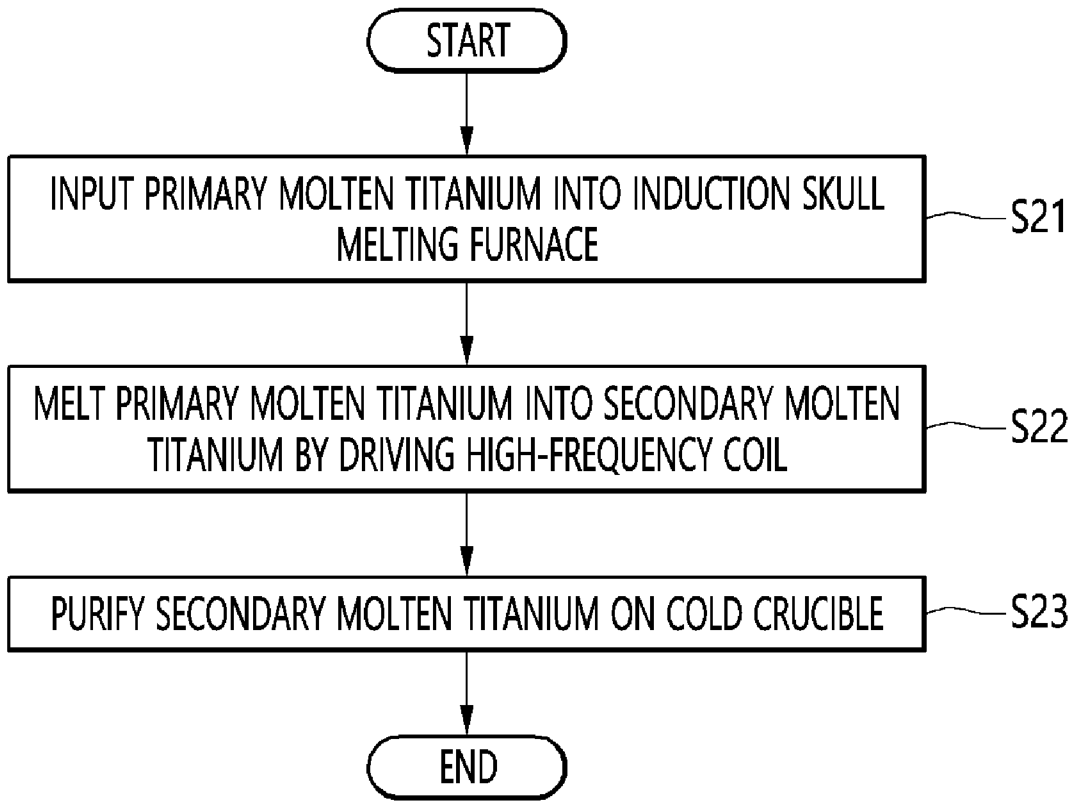
[FIG. 2]


START
MELT TITANIUM SCRAP BY USING PLASMA ARC
(S-1)
MELT MOLTEN TITANIUM SCRAP BY INDUCTION SKULL METHOD
(S-2)
CAST TITANIUM INGOT FROM TITANIUM MOLTEN SEQUENTIALLY BY MEANS OF PLASMA ARC AND INDUCTION SKULL METHOD
(S-3)
END

[FIG. 3]


START
INPUT TITANIUM SCRAP INTO PLASMA ARC MELTING FURNACE
S11
MELT TITANIUM SCRAP INTO PRIMARY MOLTEN TITANIUM BY DRIVING PLASMA TORCH
S12
SEPARATE INCLUSIONS FROM PRIMARY MOLTEN TITANIUM BY FLOWING PRIMARY MOLTEN TITANIUM ON COLD HEARTH AND PRECIPITATING INCLUSIONS OR EVAPORATING INCLUSIONS INTO VAPOR
S13
END

[FIG. 4]


START
INPUT PRIMARY MOLTEN TITANIUM INTO INDUCTION SKULL MELTING FURNACE
S21
MELT PRIMARY MOLTEN TITANIUM INTO SECONDARY MOLTEN TITANIUM BY DRIVING HIGH-FREQUENCY COIL
S22
PURIFY SECONDARY MOLTEN TITANIUM ON COLD CRUCIBLE
S23
END

INTERNATIONAL SEARCH REPORT

International application No. **PCT/KR2022/019755**

A. CLASSIFICATION OF SUBJECT MATTER

B22D 7/00(2006.01)i; **C22B 34/12**(2006.01)i; **C22B 7/00**(2006.01)i; **C22B 9/20**(2006.01)i; **C22B 9/16**(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)

B22D 7/00(2006.01); B22D 11/00(2006.01); B22D 11/04(2006.01); B22D 11/041(2006.01); B22D 11/055(2006.01); B22D 11/059(2006.01); B22D 11/11(2006.01); C22B 34/12(2006.01); C22B 7/00(2006.01); C22B 9/22(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: 유도코일(induction coil), 플라즈마(plasma), 잉곳(ingot), 티타늄(titanium), 금속(metal), 용융(melt), 주조(cast)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2014-217890 A (RTI INTERNAT METALS INC.) 20 November 2014 (2014-11-20) See paragraphs [0008]-[0009] and [0016]-[0017], claim 1 and figures 2 and 6.	1-2,4-5
Y		3,6-10
Y	JP 2013-043999 A (KOBE STEEL LTD.) 04 March 2013 (2013-03-04) See paragraphs [0024]-[0025] and figure 1.	3,6-10
A	JP 2005-508758 A (ALD VACUUM TECHNOLOGIES G.M.B.H. et al.) 07 April 2005 (2005-04-07) See claims 1 and 4-5 and figure 3.	1-10
A	JP 2018-134675 A (KOBE STEEL LTD.) 30 August 2018 (2018-08-30) See claims 1-4 and figure 1.	1-10

☑ 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
- "E" earlier application or patent but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
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Date of the actual completion of the international search	Date of mailing of the international search report
24 March 2023	**24 March 2023**
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2022/019755

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