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(71) Applicant: **Mitsubishi Materials Corporation**
Chiyoda-ku
Tokyo 100-8117 (JP)

(72) Inventors:
• **KATO Jun**
Kitamoto-shi
Saitama 364-0022 (JP)
• **KITA Koichi**
Kitamoto-shi
Saitama 364-0022 (JP)
• **SAIWAI Toshihiko**
Kitamoto-shi
Saitama 364-0022 (JP)

(74) Representative: **Gille Hrabal**
Brucknerstrasse 20
40593 Düsseldorf (DE)

(54) **COPPER POROUS BODY, COPPER POROUS COMPOSITE MEMBER, METHOD FOR PRODUCING COPPER POROUS BODY, AND METHOD FOR PRODUCING COPPER POROUS COMPOSITE MEMBER**

(57) The porous copper body of the disclosure includes a skeleton having a three-dimensional network structure, in which a porosity is in a range of 50% to 90% and a porosity-normalized electrical conductivity σ_N

which is defined by dividing a electrical conductivity of the porous copper body, measured by a 4-terminal sensing, by an apparent density ratio of the porous copper body is 20% IACS or higher.

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Description

Technical Field

[0001] The present disclosure relates to a porous copper body formed from copper or a copper alloy, a porous copper composite member in which the porous copper body is bonded to a main member body, a method of manufacturing the porous copper body, and a method of manufacturing the porous copper composite member.

[0002] Priority is claimed on Japanese Patent Application No. 2016-089358, filed on April 27, 2016, the content of which is incorporated herein by reference.

Background Art

[0003] The porous copper body and the porous copper composite member are used, for example, as electrodes and current collectors in various batteries, heat exchanger components, heat pipes, and the like.

[0004] For example, PTL 1 discloses a method in which a pressure-sensitive adhesive is applied to a skeleton of a three-dimensional network structure (for example, synthetic resin foam having open cells such as urethane foam, polyethylene foam, natural fiber cloth, man-made fiber cloth, and the like) made of a material burned off by heating and a formed body on which a metal powdery material is adhered is used, or a method of using a sheet-like formed body which is made of a material burned off by heating and in which a metal powder material has been mixed to a material (for example, pulp or wool fiber) capable of forming a three-dimensional network structure, as a method of manufacturing a metal sintered body (porous copper sintered body) forming the three-dimensional network structure.

[0005] In addition, PTL 2 discloses a method of obtaining a porous material by electrically heating a copper fiber under pressure.

Citation List

Patent Literature

[0006]

[PTL 1] Japanese Unexamined Patent Application, First Publication No. H08-145592

[PTL 2] Japanese Patent No. 3735712

SUMMARY OF DISCLOSURE

Technical Problem

[0007] In the above-described porous copper body, in addition to having a high porosity and an open cell structure, in a case of being used as a conductive member such as an electrode and a current collector, excellent conductivity is required, and in a case of being used as a heat conduction member such as a heat exchanger component and heat pipe, excellent heat conductivity is required.

[0008] In the porous copper body described in PTL 1 and PTL 2, conductivity and heat conductivity are not considered, and in particular, in a case where the porosity is high, bonding between metal powders or the copper fibers is insufficient, resulting in a concern that conductivity and heat conductivity may be insufficient.

[0009] The disclosure has been made in consideration of the above-described circumstances, and an object thereof is to provide a porous copper body which has sufficient conductivity and heat conductivity, even in a case where a porosity is high, and is particularly suitable for a conductive member and a heat-transfer member, a porous copper composite member in which the porous copper body is bonded to a main member body, a method of manufacturing the porous copper body, and method of manufacturing the porous copper composite member.

Solution to Problem

[0010] To solve the above-described problem and to accomplish the above-described object, according to an aspect of the disclosure, a porous copper body is provided. The porous copper body is a porous copper body, including: a skeleton having a three-dimensional network structure, in which a porosity is in a range of 50% to 90%, and a porosity-normalized electrical conductivity σ_N which is defined by dividing a electrical conductivity of the porous copper body, measured by a 4-terminal sensing, by an apparent density ratio of the porous copper body is 20% IACS or higher.

[0011] According to the porous copper body having the above-described configuration, even in a case where a porosity

is in a range of 50% to 90%, a porosity-normalized electrical conductivity σ_N which is defined by dividing a electrical conductivity of the porous copper body, measured by a 4-terminal sensing, by an apparent density ratio of the porous copper body is 20% IACS or higher. Accordingly, the porous copper body is excellent in conductivity and particularly suitable for a conductive member. In addition, free electrons are responsible for thermal conduction as well as electrical conduction. Accordingly, when conductivity is ensured, heat conductivity is also ensured. Therefore, the porous copper body of the disclosure is also excellent in heat conductivity and particularly suitable for a heat-transfer member.

[0012] Here, in the porous copper body according to an aspect of the disclosure, it is preferable that an oxidation-reduction layer be formed on a surface of the skeleton.

[0013] In this case, since the oxidation-reduction layer is formed on the surface of the skeleton, unevenness is formed on the surface to increase a specific surface area. For example, it is possible to greatly improve various characteristics such as heat-exchange efficiency through a porous skeleton surface and the like. In addition, by performing an oxidation-reduction treatment, it is possible to further improve the porosity-normalized electrical conductivity σ_N .

[0014] In addition, in the porous copper body according to an aspect of the disclosure, the skeleton may be a sintered body of: at least one of copper powders and copper fibers; or both of copper powders and copper fibers, both of copper powders and copper fibers being made of copper or a copper alloy.

[0015] In this case, it is possible to obtain the porous copper body in which the porosity is in the range of 50% to 90% by adjusting a filling rate of copper powders and copper fibers which are formed from copper or a copper alloy.

[0016] Further, in the porous copper body according to an aspect of the disclosure, it is preferable that, in each of the copper fibers, a diameter R be in a range of 0.02 mm to 1.0 mm and a ratio L/R between a length L and the diameter R be in a range of 4 to 2500.

[0017] In this case, since in each of the copper fibers, the diameter R is set in a range of 0.02 mm to 1.0 mm, and the ratio L/R between the length L and the diameter R is set in a range of 4 to 2500, a sufficient void is secured between the copper fibers, and a shrinkage rate in the sintering can be suppressed. Accordingly, it is possible to raise the porosity, and it is possible to attain excellent dimensional accuracy.

[0018] In addition, in the porous copper body according to an aspect of the disclosure, in a bonding portion of: at least one of copper powders and copper fibers; or both of copper powders and copper fibers, it is preferable that the oxidation-reduction layers formed on surfaces of: at least one of copper powders and copper fibers; or both of copper powders and copper fibers, be integrally bonded to each other.

[0019] In this case, the oxidation-reduction layers are integrally bonded to each other in the bonding portion of: at least one of copper powders and copper fibers; or both of copper powders and copper fibers, accordingly, the porous copper body is excellent in bonding strength. In addition, since the copper fibers and the copper powders are strongly bonded to each other, it is also possible to improve conductivity and heat conductivity.

[0020] According to another aspect of the disclosure, a porous copper composite member is provided, including a bonded body of a main member body and the above-described porous copper body.

[0021] According to the porous copper composite member having the configuration, the porous copper composite member is formed from a bonded body of the porous copper body which is excellent in conductivity and heat conductivity and the main member body, accordingly, it is possible to exhibit excellent conductivity and heat conductivity as the porous copper composite member.

[0022] Here, in the porous copper composite member according to another aspect of the disclosure, it is preferable that a bonding surface in the main member body with the porous copper body be formed from copper or a copper alloy and a bonding portion of the porous copper body and the main member body be a sintered layer.

[0023] In this case, since the bonding portion of the porous copper body and the main member body is the sintered layer, the porous copper body and the main member body are strongly bonded to each other, and thus it is possible to obtain excellent strength, conductivity, and heat conductivity, as the porous copper composite member.

[0024] In addition, according to still another aspect of the disclosure, a method of manufacturing the above-described porous copper body is provided, the method including performing an oxidation treatment on a skeleton having a three-dimensional network structure under conditions of a holding temperature of 500°C to 1050°C in an oxidizing atmosphere; performing a reduction treatment on the skeleton having a three-dimensional network structure under conditions of a holding temperature of 500°C to 1050°C in a reducing atmosphere; and setting the porosity-normalized electrical conductivity σ_N to 20% IACS or higher by the oxidation treatment and the reduction treatment.

[0025] According to the method of manufacturing the porous copper body as described above, by performing the oxidation treatment and the reduction treatment on the skeleton having a three-dimensional network structure under the conditions, the conductivity is improved. Accordingly, it is possible to set the porosity-normalized electrical conductivity σ_N to 20% IACS or higher.

[0026] In addition, according to still another aspect of the disclosure, a method of manufacturing the above-described porous copper body is provided, the method including: performing an oxidation treatment on at least one of copper powders and copper fibers, or both of copper powders and copper fibers, under conditions of a holding temperature of 500°C to 1050°C in an oxidizing atmosphere; and performing a reduction treatment on at least one of copper powders

and copper fibers, or both of copper powders and copper fibers, under conditions of a holding temperature of 500°C to 1050°C in a reducing atmosphere, in which the skeleton including a sintered body of: at least one of copper powders and copper fibers; or both of copper powders and copper fibers, are formed and the porosity-normalized electrical conductivity σ_N is set to 20% IACS or higher by the oxidation treatment and the reduction treatment.

[0027] According to the method of manufacturing the porous copper body as described above, by performing the oxidation treatment and the reduction treatment on at least one of copper powders and copper fibers, or both of copper powders and copper fibers, under above-described conditions, it is possible to form the skeleton including a sintered body of: at least one of copper powders and copper fibers; or both of copper powders and copper fibers, and it is possible to obtain a porous copper body formed from the sintered body. In addition, the conductivity is improved. Accordingly, it is possible to set the porosity-normalized electrical conductivity σ_N to 20% IACS or higher.

[0028] According to still another aspect of the disclosure, a method of manufacturing a porous copper composite member including a bonded body of a main member body and a porous copper body is provided, the method including a bonding process of bonding the porous copper body that is manufactured by the above-described method of manufacturing the porous copper body, and the main member body.

[0029] According to the method of manufacturing a porous copper composite member as described above, the porous copper body, which is manufactured by the above-described method of manufacturing the porous copper body, is provided, and thus it is possible to manufacture a porous copper composite member excellent in heat conductivity and conductivity. Examples of a shape of the main member body include a plate, a rod, a pipe, and the like.

[0030] Here, in the method of manufacturing a porous copper composite member of an aspect of the disclosure, in the main member body, a bonding surface to which the porous copper body is bonded may be constituted by copper or a copper alloy, and the porous copper body and the main member body may be bonded to each other through sintering.

[0031] In this case, the main member body and the porous copper body can be integrated with each other through sintering, and thus it is possible to manufacture a porous copper composite member excellent in stability of characteristics.

Advantageous Effects of Disclosure

[0032] According to the disclosure, it is possible to provide a porous copper body which has sufficient conductivity and heat conductivity, even in a case where a porosity is high, and is particularly suitable for a conductive member and a heat-transfer member, a porous copper composite member in which the porous copper body is bonded to a main member body, a method of manufacturing the porous copper body, and method of manufacturing the porous copper composite member.

Brief Description of Drawings

[0033]

FIG. 1 is an enlarged schematic view of a porous copper body according to a first embodiment of the disclosure.
 FIG. 2 is a flowchart illustrating an example of a method of manufacturing the porous copper body illustrated in FIG. 1.
 FIG. 3 is a view illustrating a manufacturing process of manufacturing the porous copper body illustrated in FIG. 1.
 FIG. 4 is a view illustrating an external appearance of a porous copper composite member according to a second embodiment of the disclosure.
 FIG. 5 is a flowchart illustrating an example of a method of manufacturing the porous copper composite member illustrated in FIG. 4.
 FIG. 6 is an external view of a porous copper composite member according to another embodiment of the disclosure.
 FIG. 7 is an external view of a porous copper composite member according to still another embodiment of the disclosure.
 FIG. 8 is an external view of a porous copper composite member according to still another embodiment of the disclosure.
 FIG. 9 is an external view of a porous copper composite member according to still another embodiment of the disclosure.
 FIG. 10 is an external view of a porous copper composite member according to still another embodiment of the disclosure.
 FIG. 11 is an external view of a porous copper composite member according to still another embodiment of the disclosure.

Description of Embodiments

[0034] Hereinafter, description will be given of a porous copper body, a porous copper composite member, a method

of manufacturing the porous copper body, and a method of manufacturing the porous copper composite member according to embodiments of the disclosure with reference to the accompanying drawings.

(First Embodiment)

[0035] First, description will be given of a porous copper body 10 according to a first embodiment of the disclosure with reference to FIG. 1 to FIG. 3.

[0036] As illustrated in FIG. 1, the porous copper body 10 according to this embodiment includes a skeleton 12 in which a plurality of copper fibers 11 are sintered.

[0037] Here, the copper fibers 11 are formed from copper or a copper alloy, a diameter R is set in a range of 0.02 mm to 1.0 mm, and a ratio L/R between a length L and the diameter R is set in a range of 4 to 2500. In this embodiment, the copper fibers 11 are formed from, for example, C1020 (oxygen-free copper).

[0038] Furthermore, in this embodiment, the copper fiber 11 is subjected to shape imparting such as twisting and bending. In addition, in the porous copper body 10 according to this embodiment, an apparent density ratio D_A is set to 51% or less of a true density D_T of the copper fiber 11. A shape of the copper fiber 11 is an arbitrary shape such as a linear shape and a curved shape as long as the apparent density ratio D_A is 51% or less of the true density D_T of the copper fiber 11. However, when using the copper fiber 11 in which at least a part thereof is subjected to predetermined shape-imparting processing such as twisting processing and bending processing, it is possible to form a void between fibers in a three-dimensional and isotropic shape. As a result, it is possible to improve isotropy in various characteristics such as heat-transfer characteristics and conductivity of the porous copper body 10.

[0039] Furthermore, the copper fiber 11 is manufactured through adjustment into a predetermined circle-converted diameter R by a drawing method, a coil cutting method, a wire cutting method, a melting spraying method, and the like, length adjustment for satisfying predetermined L/R, and cutting.

[0040] Here, the circle-converted diameter R is a value that is calculated on the basis of a cross-sectional area A of each fiber, and is defined by the following expression on the assumption of a perfect circle regardless of a cross-sectional shape.

$$R=(A/\pi)^{1/2}\times 2$$

[0041] In addition, in the porous copper body 10 according to this embodiment, an oxidation-reduction layer is formed on a surface of the skeleton 12 (copper fiber 11). In addition, in a bonding portion between the plurality of copper fibers 11, oxidation-reduction layers formed on surfaces of the plurality of copper fibers 11 are integrally bonded to each other.

[0042] Furthermore, each of the oxidation-reduction layers has a porous structure, which causes minute unevenness on the surface of skeleton 12 (copper fiber 11). According to this, a specific surface area of the entirety of the porous copper body 10 is set to 0.01 m²/g or greater. The specific surface area of the entirety of the porous copper body 10 is preferably 0.03 m²/g or greater. However, there is no limitation thereto.

[0043] In addition, in the porous copper body 10 according to the embodiment, a porosity P is in a range of 50% to 90% and a porosity-normalized electrical conductivity σ_N (% IACS) which is defined by dividing a electrical conductivity σ_P of the porous copper body 10, measured by a 4-terminal sensing, by an apparent density ratio D_A of the porous copper body 10 is 20% IACS or higher. The porosity-normalized electrical conductivity σ_N , the apparent density ratio D_A , and the porosity P are respectively calculated by the following expressions.

$$\sigma_N=\sigma_P\times(1/D_A)$$

$$D_A=m/(V\times D_T)$$

$$P(\%)=(1-(m/(V\times D_T)))\times 100$$

[0044] Here, m is the mass (g) of the porous copper body 10. V is the volume (cm³) of the porous copper body 10. D_T is the true density (g/cm³) of the copper fibers 11 constituting the porous copper body 10.

[0045] The porosity P is preferably in a range of 70% to 90%. However, there is no limitation thereto.

[0046] Next, description will be given of a method of manufacturing the porous copper body 10 according to this embodiment with reference to a flowchart in FIG. 2, a process diagram of FIG. 3, and the like.

[0047] First, as illustrated in FIG. 3, the copper fiber 11 is distributed from a distributor 31 toward the inside of a stainless steel container 32 to volumetrically fill the stainless steel container 32. According to this, lamination of the copper fibers 11 is performed (copper fiber lamination process S01).

[0048] Here, in the copper fiber lamination process S01, a plurality of the copper fibers 11 are laminated so that a volume density D_p after the filling becomes 50% or less of the true density D_T of the copper fibers 11. Furthermore, in this embodiment, shape-imparting processing such as twisting processing and bending processing is carried out with respect to the copper fibers 11, and thus it is possible to secure a three-dimensional and isotropic void between the copper fibers 11 during lamination.

[0049] Next, the copper fibers 11, which volumetrically fill the stainless steel container 32, are subjected to an oxidation-reduction treatment (oxidation-reduction treatment process S02).

[0050] As illustrated in FIG. 2 and FIG. 3, the oxidation-reduction treatment process S02 includes an oxidation treatment process S21 of performing an oxidation treatment of the copper fibers 11, and a reduction treatment process S22 of reducing and sintering the copper fibers 11 which are subjected to the oxidation treatment.

[0051] In this embodiment, as illustrated in FIG. 3, the stainless steel container 32, which is filled with the copper fibers 11, is put in a heating furnace 33 and is heated in an oxidizing atmosphere to perform an oxidation treatment of the copper fiber 11 (oxidation treatment process S21). For example, an oxide layer having a thickness of 1 μm to 100 μm is formed on a surface of each of the copper fibers 11 through the oxidation treatment process S21.

[0052] Conditions of the oxidation treatment process S21 in this embodiment are as follows. Specifically, an atmosphere is set to an atmospheric atmosphere (atmospheric atmosphere (a)), a holding temperature is set to 500°C to 1050°C, and a holding time is set in a range of 5 minutes to 300 minutes.

[0053] Here, in a case where the holding temperature in the oxidation treatment process S21 is lower than 500°C, there is a concern that the oxide layer is not sufficiently formed on the surface of the copper fiber 11. On the other hand, in a case where the holding temperature in the oxidation treatment process S21 is higher than 1050°C, there is a concern that oxidation may progress to the inside of the copper fiber 11.

[0054] In this regard, in this embodiment, the holding temperature in the oxidation treatment process S21 is set to 500°C to 1050°C. Furthermore, in the oxidation treatment process S21, it is preferable that the lower limit of the holding temperature be set to 600°C or higher, and the upper limit of the holding temperature be set to 1000°C or lower so as to reliably form the oxide layer on the surface of the copper fiber 11.

[0055] In addition, in a case where the holding time in the oxidation treatment process S21 is shorter than 5 minutes, there is a concern that the oxide layer may not be sufficiently formed on the surface of the copper fiber 11. On the other hand, in a case where the holding time in the oxidation treatment process S21 is longer than 300 minutes, there is a concern that oxidation may progress to the inside of the copper fiber 11.

[0056] In this regard, in this embodiment, the holding time in the oxidation treatment process S21 is set in a range of 5 minutes to 300 minutes. Furthermore, it is preferable that the lower limit of the holding time in the oxidation treatment process S21 be set to 10 minutes or longer so as to reliably form the oxide layer on the surface of the copper fiber 11. In addition, it is preferable that the upper limit of the holding time in the oxidation treatment process S21 be set to 100 minutes or shorter so as to reliably suppress oxidation to the inside of the copper fiber 11.

[0057] Next, in this embodiment, as illustrated in FIG. 3, after performing the oxidation treatment process S21, the stainless steel container 32, which is filled with the copper fiber 11, is put in the heating furnace 34 and is heated in a reduction atmosphere. According to this, the oxidized copper fiber 11 is subjected to a reduction treatment to form an oxidation-reduction layer, and the copper fibers 11 are bonded to each other to form the skeleton 12 (reduction treatment process S22).

[0058] Conditions of the reduction treatment process S22 in this embodiment are as follows. Specifically, an atmosphere is set to a mixed gas atmosphere of argon and hydrogen ($\text{Ar}+\text{H}_2$ atmosphere (b)), a holding temperature is set to 500°C to 1050°C, and a holding time is set in a range of 5 minutes to 300 minutes.

[0059] Here, in a case where the holding temperature in the reduction treatment process S22 is lower than 500°C, there is a concern that the oxide layer formed on the surface of the copper fiber 11 may not be sufficiently reduced. On the other hand, in a case where the holding temperature in the reduction treatment process S22 is higher than 1050°C, there is a concern that heating may be performed to near the melting point of copper, and thus a decrease in strength and porosity may occur.

[0060] In this regard, in this embodiment, the holding temperature in the reduction treatment process S22 is set to 500°C to 1050°C. Furthermore, it is preferable that the lower limit of the holding temperature in the reduction treatment process S22 be set to 600°C or higher so as to reliably reduce the oxide layer formed on the surface of the copper fiber 11. In addition, it is preferable that the upper limit of the holding temperature in the reduction treatment process S22 be set to 1000°C or lower so as to reliably suppress the decrease in strength and the porosity.

[0061] In addition, in a case where the holding time in the reduction treatment process S22 is shorter than 5 minutes, there is a concern that the oxide layer formed on the surface of the copper fiber 11 may not be sufficiently reduced, and sintering may become insufficient. On the other hand, in a case where the holding time in the reduction treatment process

S22 is longer than 300 minutes, there is a concern that thermal shrinkage may increase and strength may decrease due to the sintering.

[0062] In this regard, in this embodiment, the holding time in the reduction treatment process S22 is set in a range of 5 minutes to 300 minutes. Furthermore, it is preferable that the lower limit of the holding time in the reduction treatment process S22 be set to 10 minutes or longer so as to reliably reduce the oxide layer formed on the surface of the copper fiber 11 and to allow sintering to sufficiently progress. In addition, it is preferable that the upper limit of the holding time in the reduction treatment process S22 be set to 100 minutes or shorter so as to reliably suppress the thermal shrinkage or the decrease in strength due to the sintering.

[0063] An oxidation-reduction layer is formed on the surface of the copper fiber 11 (skeleton 12) by the oxidation treatment process S21 and the reduction treatment process S22, and thus minute unevenness having a unique microporous structure occurs. That is, the oxidation-reduction layers has a porous structure, which causes minute unevenness on the surface of the copper fiber 11. According to this, a specific surface area of the entirety of the porous copper body 20 is set to 0.01 m²/g or greater.

[0064] In addition, the oxide layer is formed on the surface of the copper fiber 11 by the oxidation treatment process S21, and a plurality of the copper fibers 11 are cross-linked by the oxide layer. Then, when the reduction treatment process S22 is performed, the oxide layer formed on the surface of the copper fiber 11 is reduced, and thus the above-described oxidation-reduction layer is formed. In addition, a plurality of the oxidation-reduction layers are bonded to each other, and the copper fibers 11 are sintered, and thus the skeleton 12 is formed.

[0065] According to the manufacturing method as described above, the copper fibers 11 are sintered, and thus the skeleton 12 is formed, and the oxidation-reduction layer is formed on the surface of the skeleton 12 (copper fiber 11). Further, the above-described porosity-normalized electrical conductivity σ_N is set to 20% IACS or higher. Accordingly, the porous copper body 10 according to this embodiment is manufactured.

[0066] According to the porous copper body 10 according to this embodiment having the above-described configuration, the porosity P is as high as in a range of 50% to 90% and the porosity-normalized electrical conductivity σ_N is 20% IACS or higher. Accordingly, the porous copper body is excellent in conductivity and heat conductivity, and has excellent characteristics as a conductive member and a heat-transfer member.

[0067] In addition, according to the porous copper body 10 according to this embodiment, since the oxidation-reduction layer is formed on the surface of the skeleton 12, unevenness having a unique microporous structure is formed on the surface to increase a specific surface area. For example, it is possible to greatly improve various characteristics such as heat-exchange efficiency through a porous skeleton surface and the like. In addition, by performing an oxidation-reduction treatment, it is possible to further improve the porosity-normalized electrical conductivity σ_N .

[0068] Further, in this embodiment, in the bonding portion between the copper fibers 11, oxidation-reduction layers formed on surfaces of the copper fibers 11 are integrally bonded to each other. Accordingly, the porous copper body 10 is excellent in bonding strength.

[0069] In addition, according to the porous copper body 10 according to this embodiment, since the copper fibers 11, in which the diameter R is set in a range of 0.02 mm to 1.0 mm and the ratio L/R between the length L and the diameter R is set in a range of 4 to 2500, are sintered to form the skeleton 12, a sufficient void is secured between the copper fibers 11, and a shrinkage rate in the sintering can be suppressed. Accordingly, it is possible to raise the porosity, and it is possible to attain excellent dimensional accuracy.

[0070] In addition, this embodiment includes the copper fiber lamination process S01 in which the copper fibers 11 of which the diameter R is set in a range of 0.02 mm to 1.0 mm and the ratio L/R between the length L and the diameter R is set in a range of 4 to 2500 are laminated so that the volume density D_p becomes 50% or less of the true density D_T of the copper fibers 11. Accordingly, it is possible to secure a void between the copper fibers 11, and thus it is possible to suppress shrinkage. According to this, it is possible to manufacture the porous copper body 10 in which the porosity is high and the dimensional accuracy is excellent.

[0071] Here, in a case where the diameter R of the copper fibers 11 is less than 0.02 mm, a bonding area between the copper fibers 11 is small, and thus there is a concern that sintering strength may be deficient. On the other hand, in a case where the diameter R of the copper fibers 11 is greater than 1.0 mm, the number of contact points at which the copper fibers 11 come into contact with each other is deficient, and thus there is a concern that the sintering strength also becomes deficient.

[0072] In this regard, in this embodiment, the diameter R of the copper fibers 11 is set in a range of 0.02 mm to 1.0 mm. Furthermore, it is preferable that the lower limit of the diameter R of the copper fibers 11 be set to 0.05 mm or greater, and the upper limit of the diameter R of the copper fibers 11 be set to 0.5 mm or less so as to attain an additional improvement in strength.

[0073] In addition, in a case where the ratio L/R between the length L and the diameter R of the copper fibers 11 is less than 4, when laminating the copper fibers 11, it is difficult for the volume density D_p to be 50% or less of the true density D_T of the copper fibers 11, and thus there is a concern that it is difficult to obtain the porous copper body 10 having a high porosity P. On the other hand, in a case where the ratio L/R between the length L and the diameter R of

the copper fibers 11 is greater than 2500, it is difficult to uniformly disperse the copper fibers 11, and thus there is a concern that it is difficult to obtain the porous copper body 10 having a uniform porosity P.

[0074] In this regard, in this embodiment, the ratio L/R between the length L and the diameter R of the copper fibers 11 is set in a range of 4 to 2500. Furthermore, it is preferable that the lower limit of the ratio L/R between the length L and the diameter R of the copper fibers 11 be set to 10 or greater so as to attain an additional improvement in porosity. In addition, it is preferable that the upper limit of the ratio L/R between the length L and the diameter R of the copper fibers 11 be set to 500 or less so as to reliably obtain the porous copper body 10 having a uniform porosity P.

[0075] In addition, according to the method of manufacturing the porous copper body according to this embodiment, the oxidation treatment process S21 of oxidizing the copper fibers 11 and the reduction treatment process S22 of reducing the oxidized copper fibers 11 are provided, and thus it is possible to form the oxidation-reduction layer on the surface of the copper fibers 11 (skeleton 12). In addition, it is possible to set the porosity-normalized electrical conductivity σ_N to 20% IACS or higher by the oxidation treatment process S21 and the reduction treatment process S22.

(Second Embodiment)

[0076] Next, description will be given of a porous copper composite member 100 according to a second embodiment of the disclosure with reference to the accompanying drawings.

[0077] FIG. 4 illustrates the porous copper composite member 100 according to this embodiment. The porous copper composite member 100 includes a copper plate 120 (main member body) formed from copper or a copper alloy, and a porous copper body 110 that is bonded to a surface of the copper plate 120.

[0078] Here, in the porous copper body 110 according to this embodiment, a plurality of copper fibers are sintered and a skeleton is formed in the same manner as in the first embodiment. Here, the copper fibers are formed from copper or a copper alloy, and a diameter R is set in a range of 0.02 mm to 1.0 mm, and a ratio L/R between a length L and the diameter R is set in a range of 4 to 2500. In this embodiment, the copper fibers are formed from, for example, C1020 (oxygen-free copper).

[0079] Furthermore, in this embodiment, the copper fibers are subjected to shape imparting such as twisting and bending. In addition, in the porous copper body 110 according to this embodiment, an apparent density ratio D_A is set to 51% or less of a true density D_T of the copper fiber.

[0080] In addition, in this embodiment, an oxidation-reduction treatment (an oxidation treatment and a reduction treatment) is performed as described later. According to this, an oxidation-reduction layer is formed on the surface of the copper fibers (skeleton) which constitute the porous copper body 110 and the copper plate 120, and minute unevenness occurs on the surface of copper fibers (skeleton) and the copper plate 120. According to this, a specific surface area of the entirety of the porous copper body 110 is set to 0.01 m²/g or greater. The specific surface area of the entirety of the porous copper body 110 is preferably 0.03 m²/g or greater. However, there is no limitation thereto.

[0081] In addition, an oxidation-reduction layer formed on the surface of the copper fibers and an oxidation-reduction layer formed on the surface of the copper plate are integrally bonded to each other at a bonding portion between the copper fibers which constitute the porous copper body 110 and the surface of the copper plate 120.

[0082] In addition, in the porous copper body 110 according to the embodiment, a porosity P is in a range of 50% to 90% and a porosity-normalized electrical conductivity σ_N which is defined by dividing a electrical conductivity σ_P of the porous copper body 110, measured by a 4-terminal sensing, by an apparent density ratio D_A of the porous copper body 110 is 20% IACS or higher.

[0083] The porosity P is preferably in a range of 70% to 90%. However, there is no limitation thereto.

[0084] Next, description will be given of a method of manufacturing the porous copper composite member 100 according to this embodiment with reference to a flowchart in FIG. 5.

[0085] First, the copper plate 120 that is a main member body is prepared (copper plate-disposing process S100). Next, copper fibers are dispersed and laminated on a surface of the copper plate 120 (copper fiber lamination process S101). Here, in the copper fiber lamination process S101, a plurality of the copper fibers are laminated so that a volume density D_P becomes 50% or less of the true density D_T of the copper fibers.

[0086] Next, the copper fibers laminated on the surface of the copper plate 120 are sintered to shape the porous copper body 110, and the porous copper body 110 and the copper plate 120 are bonded to each other (a sintering process S102 and a bonding process S103). As illustrated in FIG. 5, the sintering process S102 and the bonding process S103 include an oxidation treatment process S121 of performing an oxidation treatment of the copper fibers and the copper plate 120, and a reduction treatment process S122 of reducing and sintering the copper fibers and the copper plate 120 which are subjected to the oxidation treatment.

[0087] In this embodiment, the copper plate 120 on which the copper fibers are laminated is put in a heating furnace, and is heated in an oxidizing atmosphere to perform an oxidation treatment of the copper fibers (oxidation treatment process S121). According to the oxidation treatment process S121, for example, an oxide layer having a thickness of 1 μ m to 100 μ m is formed on the surface of the copper fibers and the copper plate 120.

[0088] Here, conditions of the oxidation treatment process S121 in this embodiment are as follows. Specifically, a holding temperature is set to 500°C to 1050°C and preferably 600°C to 1000°C, and a holding time is set in a range of 5 minutes to 300 minutes and preferably in a range of 10 minutes to 100 minutes.

[0089] Next, in this embodiment, after performing the oxidation treatment process S121, the copper plate 120 on which the copper fibers are laminated is put in a sintering furnace, and is heated in a reduction atmosphere to perform a reduction treatment of the copper fibers and the copper plate 120 which are oxidized. According to this, the copper fibers are bonded to each other, and the copper fibers and the copper plate 120 are bonded to each other (reduction treatment process S122).

[0090] Here, conditions of the reduction treatment process S122 in this embodiment are as follows. An atmosphere is set to a mixed gas atmosphere of nitrogen and hydrogen, a holding temperature is set to 500°C to 1050°C and preferably 600°C to 1000°C, and a holding time is set in a range of 5 minutes to 300 minutes and preferably in a range of 10 minutes to 100 minutes.

[0091] An oxidation-reduction layer is formed on the surface of the copper fibers (skeleton) and the copper plate 120 by the oxidation treatment process S121 and the reduction treatment process S122, and minute unevenness occurs.

[0092] In addition, the oxide layer is formed on the copper fibers (skeleton) and the surface of the copper plate 120 by the oxidation treatment process S121. Due to the oxide layer, a plurality of the copper fibers are cross-linked to each other, and the copper fibers and the copper plate 120 are cross-linked to each other. Then, when the reduction treatment process S122 is performed, the oxide layer formed on the surface of the copper fibers (skeleton) and the copper plate 120 is reduced, and the copper fibers are sintered through the oxidation-reduction layer. According to this, the skeleton is formed, and the porous copper body 110 and the copper plate 120 are bonded to each other. Further, the above-described porosity-normalized electrical conductivity σ_N of the porous copper body 110 is set to 20% IACS or higher.

[0093] According to the manufacturing method as described above, the porous copper composite member 100 according to this embodiment is manufactured.

[0094] According to the porous copper composite member 100 according to this embodiment having the above-described configuration, the porosity-normalized electrical conductivity σ_N of the porous copper body 110 is set to 20% IACS or higher. Accordingly, the porous copper composite member 100 is excellent in conductivity and heat conductivity, and it is possible to improve conductivity and heat conductivity of the entirety of the porous copper composite member 100.

[0095] In addition, in this embodiment, the oxidation-reduction layer is formed on the surface of the copper fibers which constitute the porous copper body 110 and the copper plate 120, the specific surface area of the entirety of the porous copper body 110 is set to 0.01 m²/g or greater, and the porosity P is set in a range of 50% to 90%. Accordingly, it is possible to greatly improve heat-exchange efficiency, water retention and the like.

[0096] In addition, in this embodiment, an oxidation-reduction layer formed on the surface of the copper fibers and an oxidation-reduction layer formed on the surface of the copper plate 120 are integrally bonded to each other at a bonding portion between the copper fibers which constitute the porous copper body 110 and the surface of the copper plate 120. Accordingly, the porous copper body 110 and the copper plate 120 are strongly bonded to each other, and thus strength of a bonding interface, conductivity, and heat conductivity are excellent.

[0097] According to the method of manufacturing the porous copper composite member 100 according to this embodiment, the copper fibers are laminated on the surface of the copper plate 120 formed from copper or a copper alloy, and the sintering process S102 and the bonding process S103 are simultaneously performed, and thus it is possible to simplify a manufacturing process.

[0098] In addition, it is possible to set the porosity-normalized electrical conductivity σ_N to 20% IACS or higher by carrying out the oxidation treatment process S121 and the reduction treatment process S122.

[0099] Hereinbefore, description has been given of the embodiments of the disclosure, but approximate modifications can be made in a range not departing from the scope of the disclosure without limitation thereto.

[0100] For example, description has been given of manufacturing of the porous copper body by using a manufacturing facility illustrated in FIG. 3. However, there is no limitation thereto, and the porous copper body can be manufactured by using another manufacturing facility.

[0101] With regard to the atmosphere of the oxidation treatment processes S21 and S121, an oxidation atmosphere in which copper or a copper alloy is oxidized at a predetermined temperature may be used. Specifically, the atmosphere is not limited to the atmospheric atmosphere, and may be an atmosphere in which 0.5 vol% or greater of oxygen is contained in an inert gas (for example, nitrogen). In addition, with regard to the atmosphere of the reduction treatment processes S22 and S122, it is possible to use a reduction atmosphere in which a copper oxide is reduced into metal copper or the copper oxide is decomposed at a predetermined temperature. Specifically, it is possible to appropriately use a nitrogen-hydrogen mixed gas containing several vol% or greater of hydrogen, an argon-hydrogen mixed gas, a pure hydrogen gas, an ammonia decomposed gas which is industrially used in many cases, and the like and a propane decomposed gas which is industrially used in many cases, and the like.

[0102] In addition, in this embodiment, description has been given of an example in which the skeleton of the porous copper body is formed by sintering the copper fibers. However, there is no limitation thereto. For example, a porous

copper body such as a fiber nonwoven fabric or a metal filter is prepared, and by performing the oxidation treatment on the porous copper body under conditions of a holding temperature of 500°C to 1050°C in an oxidizing atmosphere and performing the reduction treatment on the porous copper body under conditions of a holding temperature of 500°C to 1050°C in a reducing atmosphere, the porosity-normalized electrical conductivity σ_N may be set to 20% IACS or higher.

[0103] Further, in this embodiment, description has been given of an example in which the oxidation-reduction layer is formed on the surface of the skeleton. However, there is no limitation thereto. The oxidation-reduction layer may not be sufficiently formed as long as the porosity-normalized electrical conductivity σ_N is 20% IACS or higher.

[0104] In addition, in this embodiment, description has been given of an example in which copper fibers formed from oxygen-free copper (JIS C1020), phosphorous-deoxidized copper (JIS C1201 and C1220), or tough pitch copper (JIS C1100) are used. However, there is no limitation thereto, and as a material of the copper fibers 11, other high conductivity copper alloys such as Cr-copper (C18200) or Cr-Zr copper (C18150) may be used. In this embodiment, the copper fibers are used, however, copper powders may be used and both the copper powders and the copper fibers may also be used. An average particle diameter of the copper powders is preferably 0.005 mm to 0.3 mm and more preferably 0.01 mm to 0.1 mm. However, there is no limitation thereto. In addition, in a case where both the copper fibers and the copper powders are used, the copper powder content is preferably 5% to 20% based on the copper fiber content. However, there is no limitation thereto.

[0105] In addition, in the second embodiment, description has been given of the porous copper composite member having a structure illustrated in FIG. 4 as an example. However, there is no limitation thereto, and a porous copper composite member having a structure as illustrated in FIG. 6 to FIG. 11 is also possible.

[0106] Further, in the second embodiment, the bonding method in which the sintered layer including oxidation-reduction layer is formed on the bonding portion of the porous copper body and the main member body is exemplified as a desirable method, but there is no limitation thereto. Various welding methods (laser welding method and resistance welding process) or a bonding method by a brazing method using brazing material melting at low temperature may also be used as long as the porosity-normalized electrical conductivity σ_N of the porous copper body is 20% IACS or higher.

[0107] For example, as illustrated in FIG. 6, it may be a porous copper composite member 200 having a structure in which, as a main member body, a plurality of copper tubes 220 are inserted into a porous copper body 210.

[0108] Alternatively, as illustrated in FIG. 7, it may be a porous copper composite member 300 having a structure in which, as a main member body, a copper tube 320 curved in a U-shape is inserted into a porous copper body 310.

[0109] In addition, as illustrated in FIG. 8, it may be a porous copper composite member 400 having a structure in which a porous copper body 410 is bonded to an inner peripheral surface of a copper tube 420 that is a main member body.

[0110] In addition, as illustrated in FIG. 9, it may be a porous copper composite member 500 having a structure in which a porous copper body 510 is bonded to an outer peripheral surface of a copper tube 520 that is a main member body.

[0111] In addition, as illustrated in FIG. 10, it may be a porous copper composite member 600 having a structure in which a porous copper body 610 is bonded to an inner peripheral surface and an outer peripheral surface of a copper tube 620 that is a main member body.

[0112] In addition, as illustrated in FIG. 11, it may be a porous copper composite member 700 having a structure in which a porous copper body 710 is bonded to both surfaces of a copper plate 720 that is a main member body.

Examples

[0113] Hereinafter, description will be given of the results of a confirmation experiment carried out to confirm the effect of the disclosure.

[Example 1]

[0114] Various porous bodies manufactured by the materials and manufacturing method shown in Table 1 were prepared. First, the porosity and the porosity-normalized electrical conductivity before the heat treatment were measured. Thereafter, an oxidation treatment and reduction treatment were performed under the conditions described in Table 1, and the porosity and the porosity-normalized electrical conductivity after the oxidation treatment and reduction treatment were measured. The porosity and the porosity-normalized electrical conductivity were measured in the following manner. Evaluation results are illustrated in Table 1.

(Porosity)

[0115] The true density D_T (g/cm³) was measured by a precision balance to calculate the porosity P by the following expression. The mass of the porous copper body was represented as $m(g)$, and a volume of the porous copper body was V (cm³).

$$\text{Porosity } P = (1 - (m / (V \times D_T))) \times 100$$

(Porosity-normalized electrical conductivity)

[0116] Using a sample cut into a plate having dimensions of 30 mm (width)×200 mm (length)×5 mm (thickness), the electrical conductivity σ_P (% IACS) was measured by the 4-terminal sensing under conditions of a voltage terminal interval of 150 mm and measuring current of 0.5 A with a microohm high tester 3227 manufactured by HIOKI E.E. CORPORATION, in accordance with JIS C 2525. In addition, the porosity-normalized electrical conductivity σ_N was calculated by the following expression.

$$\text{Porosity-normalized electrical conductivity } \sigma_N (\% \text{ IACS}) = \sigma_P \times (1/D_A)$$

[0117] The apparent density ratio D_A (%) was calculated according to the following expression.

$$\text{Apparent density ratio } D_A = 100 \times m / (V \times D_T)$$

[0118] Here, m is the mass (g) of the porous copper body. V is the volume (cm³) of the porous copper body. D_T is the true density (g/cm³) of copper or copper alloy constituting the porous copper body.

[Table 1]

	Porous copper body before treatment				Oxidation treatment process			Reduction treatment process			Porous copper body after treatment	
	Material	Manufacturing method	Porosity (%)	Porosity -normalized electrical conductivity (% IACS)	Atmosphere	Temperature (°C)	Time (min)	Atmosphere	Temperature (°C)	Time (min)	Porosity (%)	Porosity -normalized electrical conductivity (%IACS)
Example	1 C1100	Nonwoven fabric	55	17.5	Atmospheric	500	60	N ₂ -10%H ₂	1050	10	51	24.6
	2 C1100	Foaming method	85	16.3	N ₂ -1%O ₂	700	120	N ₂ -10%H ₂	500	90	77	26.3
	3 C1100	Spacer method	70	19.1	Atmospheric	900	30	H ₂	700	30	63	30.0
	4 C1100	Precision casting method	85	18.8	Atmospheric	1050	10	H ₂	900	60	81	29.1
Comparative Example	1 C1100	Foaming method	85	16.3	Atmospheric	450	60	N ₂ -10%H ₂	600	120	83	17.9
	2 C1100	Spacer method	70	19.1	N ₂ -10%O ₂	700	30	H ₂	450	60	69	18.8

[0119] In Examples 1 to 4 in which the oxidation treatment and the reduction treatment were performed under the conditions specified in the disclosure, the porosity P was in a range of 50% to 90% and all the porosity-normalized electrical conductivity was higher than 20% IACS.

[0120] In contrast, in Comparative Example 1 in which a temperature condition of the oxidation treatment was low and Comparative Example 2 in which a temperature condition of the reduction treatment was low, even after the oxidation treatment and the reduction treatment, the electrical conductivity was not sufficiently improved, and the porosity-normalized electrical conductivity σ_N was lower than 20% IACS.

(Example 2)

[0121] In addition, an oxidation-reduction treatment was performed using copper powders illustrated in Table 2 under conditions illustrated in Table 2 to manufacture a porous copper body. The porosity and the porosity-normalized electrical conductivity were measured with respect to the porous copper body that was obtained. The porosity and the porosity-normalized electrical conductivity were measured by the same method as in Example 1, except that, in Example 2, D_T at the time of calculating the porosity-normalized electrical conductivity was set to a true density (g/cm^3) of the copper powders constituting the porous copper body. Evaluation results are illustrated in Table 2.

[Table 2]

		Copper raw material (powder)		Oxidation treatment process			Reduction treatment process			Porous copper body	
		Material	Average particle diameter (mm)	Atmosphere	Temperature (°C)	Time (min)	Atmosphere	Temperature (°C)	Time (min)	Porosity (%)	Porosity -normalized electrical conductivity (% IACS)
Example	11	C1020	0.07	Atmospheric	1050	30	H ₂	600	90	70	24.5
	12	C1100	0.06	N ₂ -10%O ₂	500	60	H ₂	800	30	53	30.3
	13	C1201	0.07	N ₂ -1%O ₂	700	10	N ₂ -10%H ₂	1050	10	61	28.2
	14	C1220	0.06	Atmospheric	900	90	N ₂ -10%H ₂	500	60	51	29.2
Comparative Example	11	C1201	0.07	Atmospheric	450	60	N ₂ -10%H ₂	600	120	74	19.7
	12	C1100	0.06	Atmospheric	700	30	H ₂	450	120	62	11.5

[0122] In Examples 11 to 14 in which the oxidation treatment and the reduction treatment were performed under the conditions specified in the disclosure, the porosity P was in a range of 50% to 90% and all the porosity-normalized electrical conductivity was higher than 20% IACS.

[0123] In contrast, in Comparative Example 11 in which a temperature condition of the oxidation treatment was low and Comparative Example 12 in which a temperature condition of the reduction treatment was low, the porosity-normalized electrical conductivity σ_N was lower than 20% IACS.

(Example 3)

[0124] In addition, an oxidation-reduction treatment was performed using copper fibers illustrated in Table 3 under conditions illustrated in Table 3 to manufacture a porous copper body. The fiber diameter R and the fiber length L of the copper fiber were measured by the following method.

(Fiber Diameter R)

[0125] As the fiber diameter R (mm), an average value of an equivalent circle diameter (Heywood diameter) $R=(A/\pi)^{1/2} \times 2$, which was calculated through image analysis on the basis of JIS Z 8827-1 by using a particle analyzer "Morphologi G3" manufactured by Malvern Instruments Ltd., was used.

(Fiber Length L)

[0126] As the fiber length L (mm) of the copper fibers, a simple average value, which was calculated through image analysis by using the particle analyzer "Morphologi G3" manufactured by Malvern Instruments Ltd., was used.

[0127] First, with respect to the porous copper body that was obtained, the porosity and the porosity-normalized electrical conductivity were measured. The porosity and the porosity-normalized electrical conductivity were measured by the same method as in Example 1, except that, in Example 3, D_T at the time of calculating the porosity-normalized electrical conductivity was set to a true density (g/cm^3) of the copper fibers constituting the porous copper body. Evaluation results are illustrated in Table 3.

[Table 3]

	Copper raw material (fiber)			Oxidation treatment process			Reduction treatment process			Porous copper body		
	Material	Diameter R (mm)	Ratio L/R between length L and diameter R	Atmosphere	Temperature (°C)	Time (min)	Atmosphere	Temperature (°C)	Time (min)	Porosity (%)	Porosity-normalized electrical conductivity (% IACS)	
Example	21	C1020	0.10	30	Atmospheric	1000	30	N ₂ -10%H ₂	550	120	77	28.1
	22	C1020	0.10	30	N ₂ -10%O ₂	550	150	AX gas	900	60	71	24.3
	23	C1100	0.03	1000	Atmospheric	900	10	H ₂	1050	10	87	27.3
	24	C1201	1.00	5	Atmospheric	1050	60	H ₂	700	30	53	31.2
	25	C1220	0.30	100	N ₂ -1%O ₂	600	90	N ₂ -10%H ₂	800	60	79	25.9
Comparative Example	26	C1220	0.30	100	Atmospheric	850	120	RX gas	1000	90	83	26.5
	21	C1220	0.30	100	Atmospheric	450	60	N ₂ -10%H ₂	600	120	85	18.1
	22	C1020	0.10	30	N ₂ -10%O ₂	700	30	H ₂	450	120	84	12.5

[0128] In Examples 21 to 26 in which the oxidation treatment and the reduction treatment were performed under the conditions specified in the disclosure, the porosity P was in a range of 50% to 90% and all the porosity-normalized electrical conductivity was higher than 20% IACS.

[0129] In contrast, in Comparative Example 21 in which a temperature condition of the oxidation treatment was low and Comparative Example 22 in which a temperature condition of the reduction treatment was low, the porosity-normalized electrical conductivity σ_N was lower than 20% IACS.

[0130] As described above, it was confirmed that it is possible to provide a porous copper body which has sufficient conductivity and heat conductivity, even in a case where porosity is high, and is particularly suitable for a conductive member and a heat-transfer member, according to examples.

Industrial Applicability

[0131] According to the porous copper body, a porous copper composite member in which the porous copper body is bonded to a main member body, a method of manufacturing the porous copper body, and method of manufacturing the porous copper composite member of the disclosure, it is possible to obtain a porous copper body which has sufficient conductivity and heat conductivity, even in a case where a porosity is high. The porous copper body is suitable for a conductive member and a heat-transfer member.

Reference Signs List

[0132]

10, 110: Porous copper body

11: Copper fiber

12: Skeleton

100: Porous copper composite member

120: Copper plate (Main member body)

Claims

1. A porous copper body, comprising: a skeleton having a three-dimensional network structure, wherein a porosity is in a range of 50% to 90%, and a porosity-normalized electrical conductivity σ_N which is defined by dividing an electrical conductivity of the porous copper body, measured by a 4-terminal sensing, by an apparent density ratio of the porous copper body is 20% IACS or higher.
2. The porous copper body according to Claim 1, wherein an oxidation-reduction layer is formed on a surface of the skeleton.
3. The porous copper body according to Claim 1 or 2, wherein the skeleton is a sintered body of: at least one of copper powders and copper fibers; or both of copper powders and copper fibers, both of copper powders and copper fibers being made of copper or a copper alloy.
4. The porous copper body according to Claim 3, wherein each of the copper fibers has a diameter R in a range of 0.02 mm to 1.0 mm, and a ratio L/R between a length L and the diameter R in a range of 4 to 2500.
5. The porous copper body according to Claim 3 or 4, wherein, in a bonding portion of: at least one of copper powders and copper fibers; or both of copper powders and copper fibers, the oxidation-reduction layers formed on surfaces of: at least one of copper powders and copper fibers; or both of copper powders and copper fibers, are integrally bonded to each other.
6. A porous copper composite member, comprising a bonded body of a main member body and the porous copper body according to any one of Claims 1 to 5.
7. The porous copper composite member according to Claim 6, wherein in the main member body, a bonding surface with the porous copper body is formed from copper or a copper alloy, and

a bonding portion of the porous copper body and the main member body is a sintered layer.

8. A method of manufacturing the porous copper body according to any one of Claims 1 to 2, the method comprising:

5 performing an oxidation treatment on a skeleton having a three-dimensional network structure under conditions of a holding temperature of 500°C to 1050°C in an oxidizing atmosphere; and
performing a reduction treatment on the skeleton having a three-dimensional network structure under conditions of a holding temperature of 500°C to 1050°C in a reducing atmosphere,

10 wherein the porosity-normalized electrical conductivity σ_N is set to 20% IACS or higher by the oxidation treatment and the reduction treatment.

9. A method of manufacturing the porous copper body according to any one of Claims 3 to 5, the method comprising:

15 performing an oxidation treatment on at least one of copper powders and copper fibers, or both of copper powders and copper fibers, under conditions of a holding temperature of 500°C to 1050°C in an oxidizing atmosphere; and
performing a reduction treatment on at least one of copper powders and copper fibers, or both of copper powders and copper fibers, under conditions of a holding temperature of 500°C to 1050°C in a reducing atmosphere,

20 wherein, by the oxidation treatment and the reduction treatment, the skeleton including a sintered body of: at least one of copper powders and copper fibers; or both of copper powders and copper fibers, are formed and the porosity-normalized electrical conductivity σ_N is set to 20% IACS or higher.

- 25 10. A method of manufacturing a porous copper composite member including a bonded body of a main member body and the porous copper body according to any one of Claims 1 to 5, the method comprising a bonding process of bonding the porous copper body according to any one of Claims 1 to 5 and the main member body to each other.

- 30 11. The method of manufacturing a porous copper composite member according to Claim 10,
wherein in the main member body, a bonding surface to which the porous copper body is bonded is constituted by copper or a copper alloy, and
in the bonding process, the porous copper body and the main member body are bonded to each other through sintering.

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FIG. 1

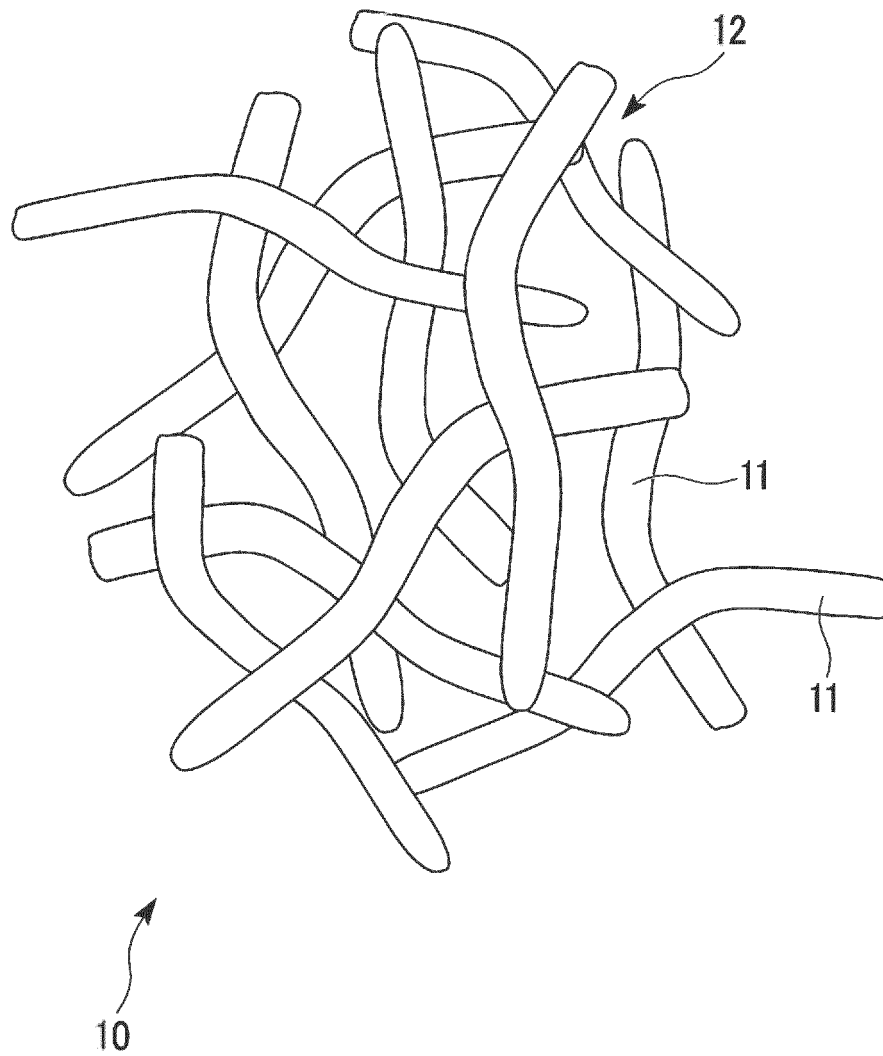


FIG. 2

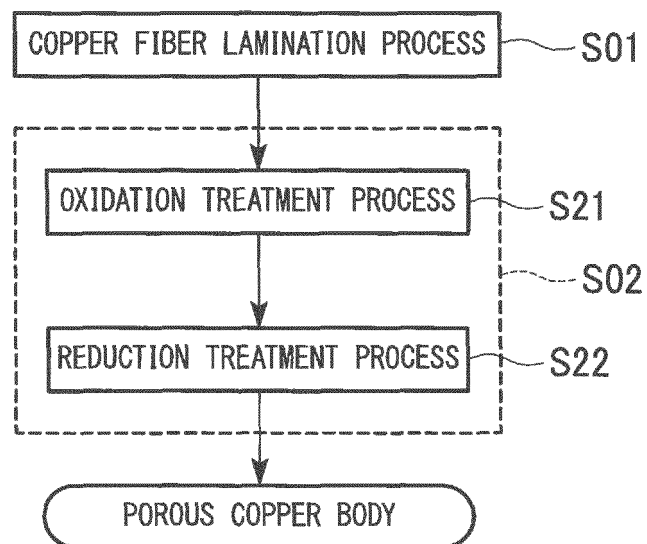


FIG. 3

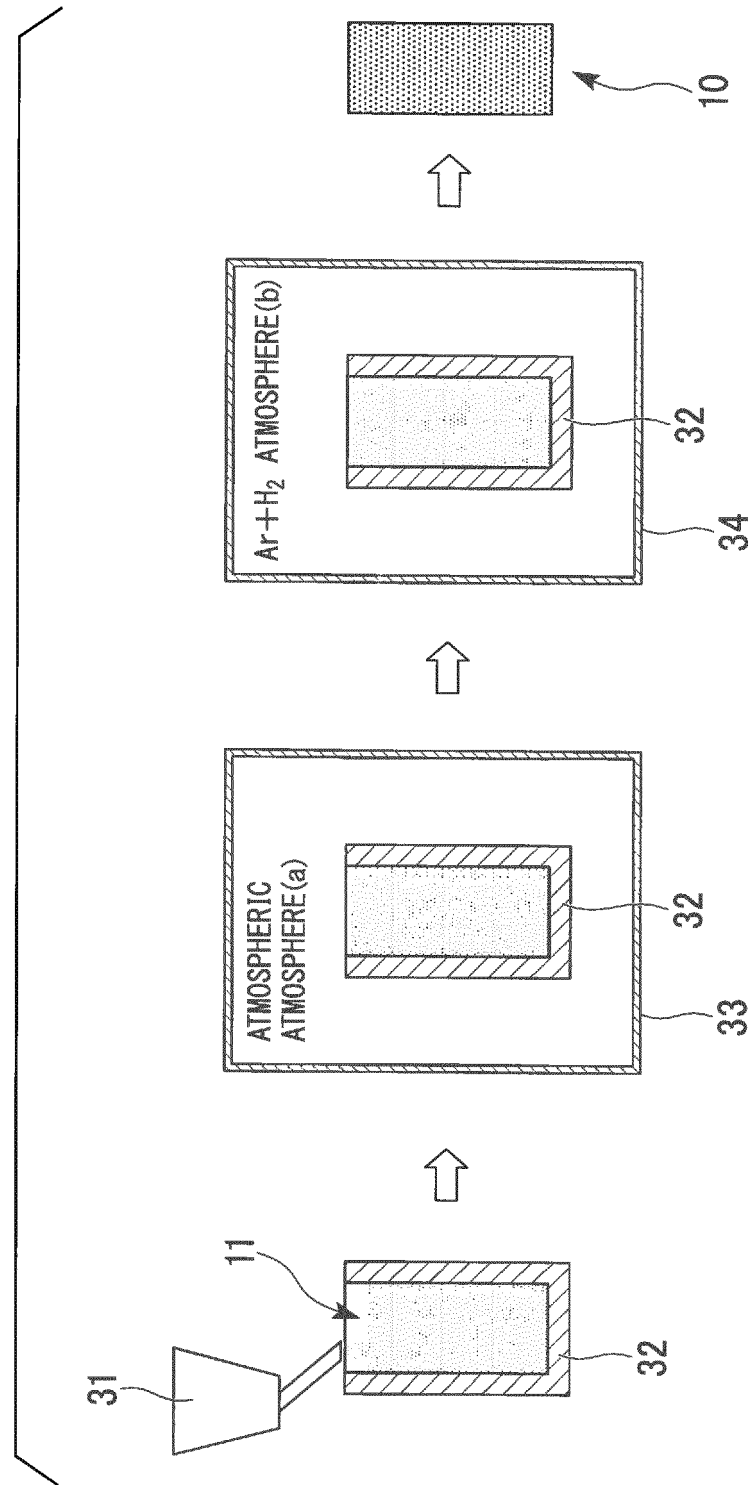


FIG. 4

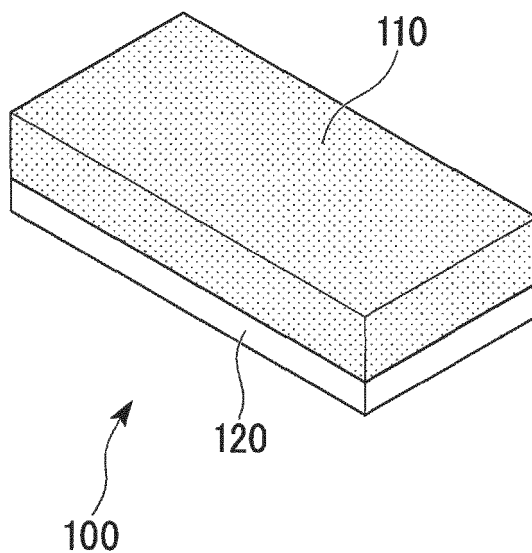


FIG. 5

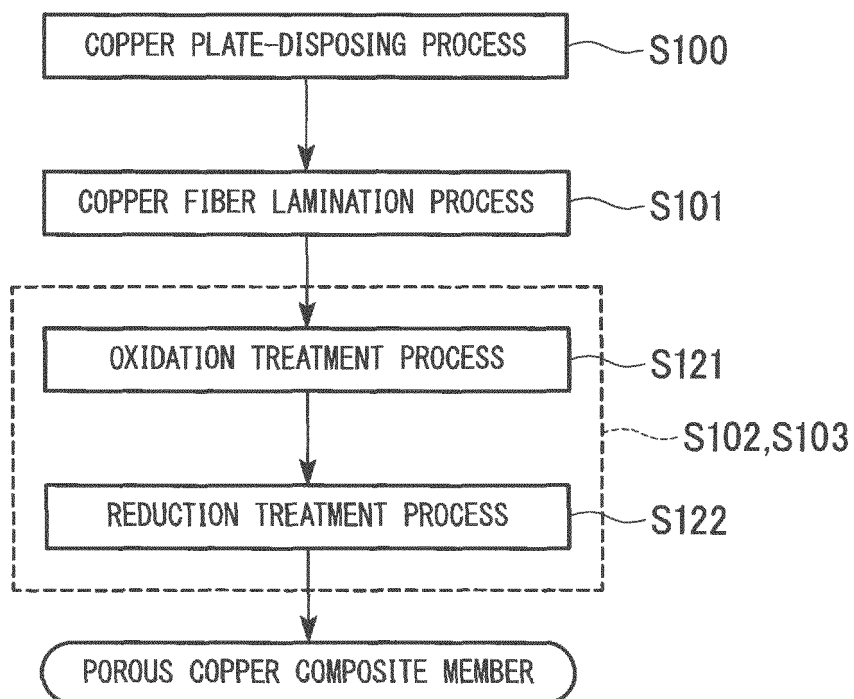


FIG. 6

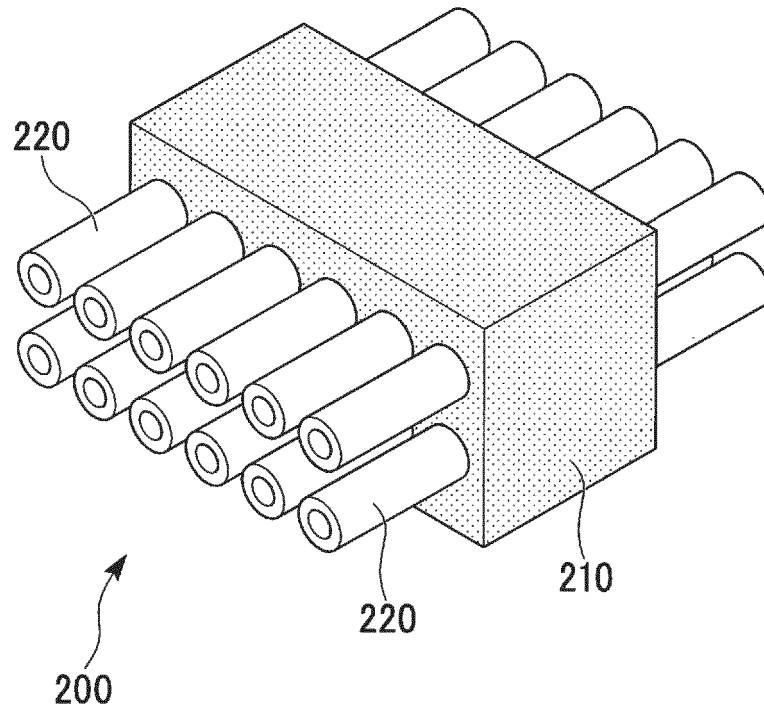


FIG. 7

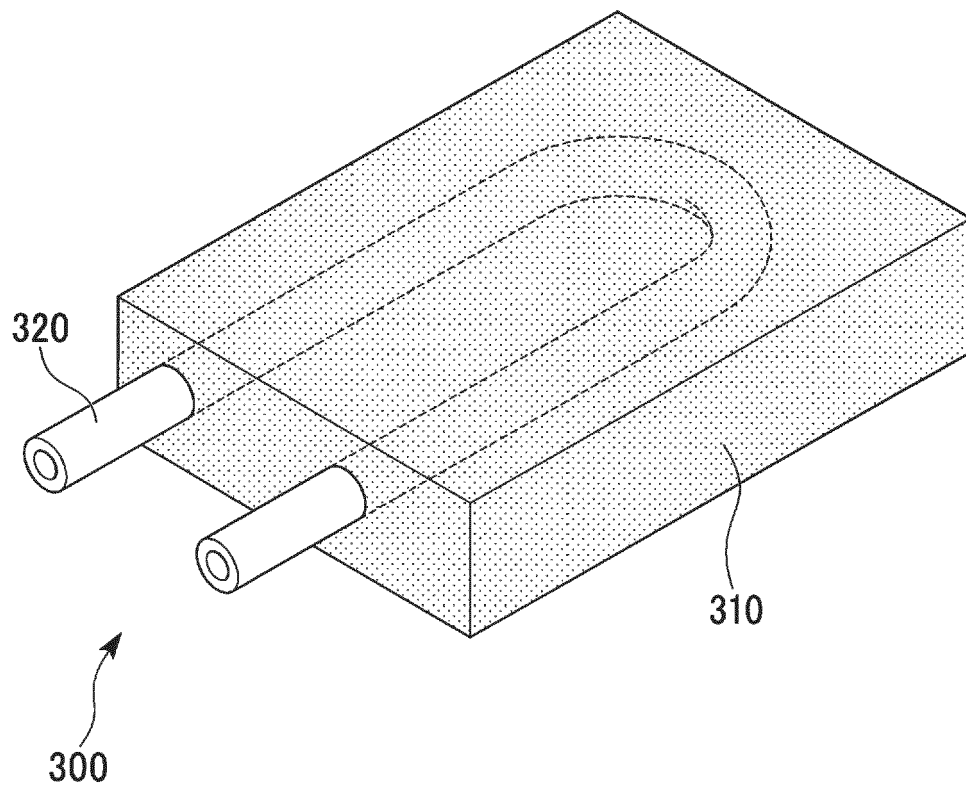


FIG. 8

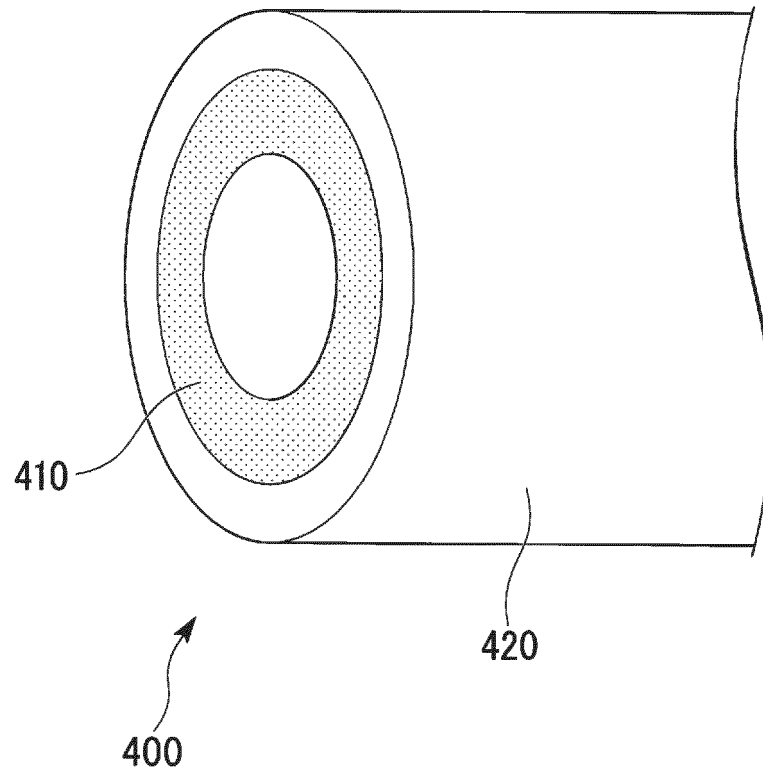


FIG. 9

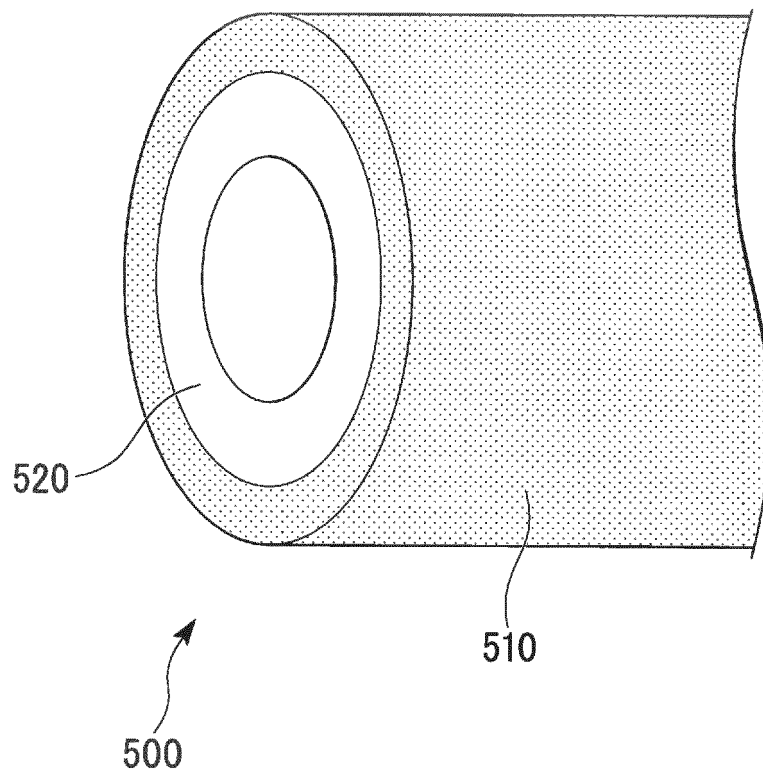


FIG. 10

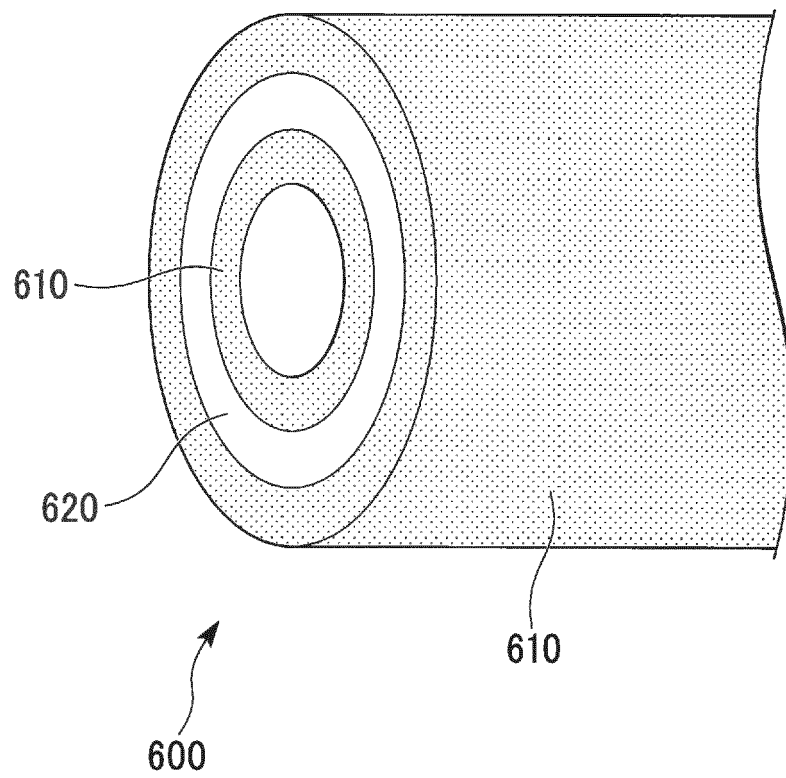
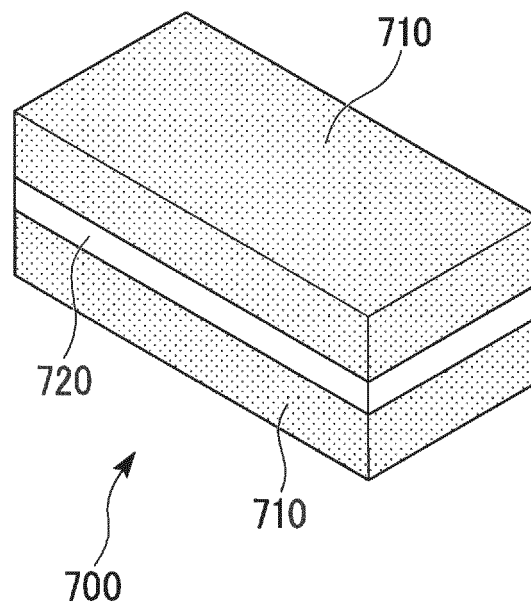


FIG. 11



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2017/014522

A. CLASSIFICATION OF SUBJECT MATTER

B22F3/11 (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)

B22F3/11

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2017

Kokai Jitsuyo Shinan Koho 1971-2017 Toroku Jitsuyo Shinan Koho 1994-2017

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	JP 2003-268410 A (National Institute of Advanced Industrial Science and Technology), 25 September 2003 (25.09.2003), claims; paragraphs [0001], [0011], [0017] (Family: none)	1-7 8-11
Y A	JP 07-006758 A (Yuasa Corp.), 10 January 1995 (10.01.1995), claims; paragraph [0014] (Family: none)	1-7 8-11
Y A	JP 07-150270 A (Sumitomo Electric Industries, Ltd.), 13 June 1995 (13.06.1995), claims; paragraph [0010] (Family: none)	1-7 8-11

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

* Special categories of cited documents:

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Name and mailing address of the ISA/

Japan Patent Office

3-4-3, Kasumigaseki, Chiyoda-ku,

Tokyo 100-8915, Japan

Authorized officer

Telephone No.

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International application No.

PCT/JP2017/014522

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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Y A	JP 2010-500771 A (H.C. Starck GmbH), 07 January 2010 (07.01.2010), claims; paragraphs [0023], [0037] & US 2010/0068510 A1 claims; paragraphs [0023], [0038] & WO 2008/019992 A1 page 8, lines 1 to 6; page 12, lines 1 to 10 & CA 2658690 A1 page 9, lines 1 to 6; page 13, lines 1 to 10 & EP 2054901 A0 & KR 10-2009-0040301 A & CN 101501797 A & IL 195932 A & ZA 900660 A & RU 2009109161 A & AU 2007286284 A & MX 2009001523 A & TW 834622 A & CN 102832048 A & BR PI0715961 A	2-7 8-11

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REFERENCES CITED IN THE DESCRIPTION

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