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(54) **IRON-BASED METALLIC GLASS ALLOY POWDER**

(57) The present invention provides an iron-based metallic glass alloy powder comprising: an iron-based metal element group mainly comprising Fe; a semimetal element group comprising Si, B, P, and C; a small amount of at least one degree-of-supercooling improvement element group selected from the group consisting of Nb and Mo; and optionally a corrosion resistance modification component, wherein the total amount of the semimetal element group and the total amount of the corrosion resistance modification component are set within predetermined ranges, and the iron-based metallic glass alloy powder has a particle size of 30 μm or less.

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Description

Technical Field

5 **[0001]** The present invention relates to a flame-retardant iron-based metallic glass alloy powder which can be used as, for example, a magnetic material for electronic components such as inductors and choke coils.

Background Art

10 **[0002]** Metallic glass is a class of amorphous metals, and several hundreds of alloy compositions of metallic glass have been found such as iron-based alloy compositions and titanium-based alloy compositions. Among these, iron-based metallic glass alloys provide excellent magnetic properties, when subjected to powder compaction. Hence, iron-based metallic glass alloys are expected to have a wide range of uses such as the use as a magnetic material for producing electronic components such as inductors and choke coils, the use as a material for electromagnetic wave shields, such as noise suppression sheets for electronic components (Patent Literature 1).

15 **[0003]** In general, a noise suppression sheet is required to have flame retardancy, because it is used in the vicinity of an electronic device that generates heat. In this respect, a noise suppression sheet has been reported which is made flame retardant by incorporating a flat soft magnetic material powder at a high ratio (Patent Literature 2). Another noise suppression sheet has been reported which is made flame retardant by incorporating a nanocrystalline soft magnetic metal powder and an acrylic binder resin (Patent Literature 3). However, the flame retardancy evaluated in these patent Literatures is not the flame retardancy of powders, but the flame retardancy of sheets.

20 **[0004]** Ignitability causes some problem not particularly in finished products, but also in the states of materials, such as a powder, before the formation of finished products. This is because the materials may have a risk of ignition when being handled during and after production. Attention has to be paid when the materials are stored until the formation of finished products and when the materials are transferred for the production of finished products in other places.

25 **[0005]** As a powder excellent in flame retardancy, a flat iron-based alloy powder for a flame-retardant magnetic shield has been reported, wherein predetermined amounts of Al and/or Si, Cr, and O are contained, and D_{50} is 10 to 40 μm , and the aspect ratio (D_{50}/d) is 20 to 200 (Patent Literature 4). Another flat iron-based alloy powder for a flame-retardant magnetic shield has been reported, wherein predetermined amounts of Al and/or Si, Cr, O, and N are contained, D_{50} is 10 to 40 μm , and the aspect ratio (D_{50}/d) is 20 to 200 (Patent Literature 5). In these patent literatures, the flame retardancy of powders is evaluated, but these powders are not amorphous powders.

30 **[0006]** Meanwhile, inductors have been used for mobile devices such as smartphones and automotive electrical systems such as power steering and air-bags. Recently, the frequencies of circuits have been getting higher and higher for the purpose of high-speed arithmetic processing in CPUs. With the circuit frequencies getting higher, inductors have been required to handle higher currents. In general, the higher currents results in increase in size of inductors, but the sizes of the inductor can be reduced by using a material having a high saturation magnetization. Under such circumstances, saturation magnetization, which is a magnetic property, of a magnetic material constituting an inductor has been considered to be important.

35 **[0007]** One of the materials having high saturation magnetization is a metal material mainly composed of Fe. However, because of its high electrical conductivity, the metal material cannot be used in a bulk state in a high-frequency circuit. This is because when the metal material is used in a bulk state in a high-frequency circuit, a large eddy-current loss is produced. In general, the iron loss (a general term for energy loss due to a magnetic material in an inductor) of a soft magnetic material can be expressed by the following modified Steinmetz's equation:

$$\text{Iron Loss of Soft Magnetic Material} = \text{Hysteresis Loss} + \text{Eddy-Current Loss}$$

45 **[0008]** Since the eddy-current loss depends on the particle size, it is effective to reduce the particle size for the reduction of the iron loss by reducing the eddy-current loss.

50 **[0009]** On the other hand, amorphous materials are known to have excellent soft magnetic properties with a low iron loss, because of the lack of anisotropy due to crystal structure.

[0010] In order to reduce the sizes of inductors that are to be mounted on mobile devices and electrical systems, there is a need for an iron-based metallic glass alloy powder mainly composed of Fe and having a small particle size.

Citation List

Patent Literatures

[0011]

Patent Literature 1: Japanese Patent Application Publication No. 2014-169482
 Patent Literature 2: Japanese Patent Application Publication No. 2009-59753
 Patent Literature 3: Japanese Patent Application Publication No. 2004-288941
 Patent Literature 4: Japanese Patent Application Publication No. Hei 10-4004
 Patent Literature 5: Japanese Patent Application Publication No. Hei 10-121103

Summary of Invention

Technical Problems

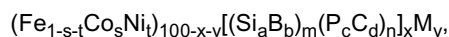
[0012] Several iron-based metallic glass alloy powders of amorphous compositions have been found so far, and the applicant of the present application has also reported such powders in Japanese Patent Application Publication No. 2005-290468, Japanese Patent Application Publication No. 2014-169482, etc. However, it is not known that iron-based metallic glass alloy powders are highly ignitable.

[0013] Accordingly, the present invention is aimed to solve the problem of the high ignitability of the iron-based metallic glass alloy powders, and an object of the present invention is to provide a flame-retardant iron-based metallic glass alloy powder.

Solution to Problems

[0014] The present inventors have conducted intensive studies, and consequently have succeeded in providing an iron-based metallic glass alloy powder with flame retardancy by adjusting the composition of the iron-based metallic glass alloy powder. Specifically, the present invention provides the following iron-based metallic glass alloy powders:

[1] An iron-based metallic glass alloy powder, wherein the iron-based metallic glass alloy is represented by the following compositional formula:



the compositional ratios of the iron-based metal element group Fe, Co, and Ni are such that $19 \leq x \leq 22$, $0 \leq y \leq 6.0$, $0 \leq s \leq 0.35$, $0 \leq t \leq 0.35$, and $s+t \leq 0.35$,
 the compositional ratios of the semimetal element group Si, B, P, and C are such that

$$(0.5:1) \leq (m:n) \leq (6:1),$$

$$(2.5:7.5) \leq (a:b) \leq (5.5:4.5),$$

and

$$(5.5:4.5) \leq (c:d) \leq (9.5:0.5),$$

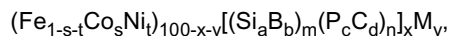
the degree-of-supercooling improvement element group M is at least one selected from the group consisting of Nb and Mo,

the iron-based metallic glass alloy further comprises at least one selected from the group consisting of Cr and Zr as a corrosion resistance modification component,

the content ratio of the corrosion resistance modification component is 2.8 to 5.5% by weight based on the total mass of the alloy components, and

the iron-based metallic glass alloy powder has a particle size of 0.5 μm or more and less than 3 μm .

[2] An iron-based metallic glass alloy powder, wherein the iron-based metallic glass alloy is represented by the following compositional formula:



the compositional ratios of the iron-based metal element group Fe, Co, and Ni are such that $19 \leq x \leq 26$, $0 \leq y \leq 6.0$, $0 \leq s \leq 0.35$, $0 \leq t \leq 0.35$, and $s+t \leq 0.35$,

the compositional ratios of the semimetal element group Si, B, P, and C are such that

$$(0.5:1) \leq (m:n) \leq (6:1),$$

$$(2.5:7.5) \leq (a:b) \leq (5.5:4.5),$$

and

$$(5.5:4.5) \leq (c:d) \leq (9.5:0.5),$$

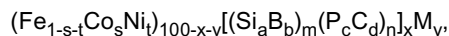
the degree-of-supercooling improvement element group M is at least one selected from the group consisting of Nb and Mo,

the iron-based metallic glass alloy further comprises at least one selected from the group consisting of Cr and Zr as a corrosion resistance modification component,

the content ratio of the corrosion resistance modification component is 2.3 to 5.5% by weight based on the total mass of the alloy components, and

the iron-based metallic glass alloy powder has a particle size of 3 μm or more and less than 10 μm .

[3] An iron-based metallic glass alloy powder, wherein the iron-based metallic glass alloy is represented by the following compositional formula:



the compositional ratios of the iron-based metal element group Fe, Co, and Ni are such that $19 \leq x \leq 26$, $0 \leq y \leq 6.0$, $0 \leq s \leq 0.35$, $0 \leq t \leq 0.35$, and $s+t \leq 0.35$,

the compositional ratios of the semimetal element group Si, B, P, and C are such that

$$(0.5:1) \leq (m:n) \leq (6:1),$$

$$(2.5:7.5) \leq (a:b) \leq (5.5:4.5),$$

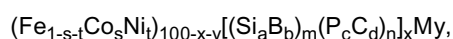
and

$$(5.5:4.5) \leq (c:d) \leq (9.5:0.5),$$

the degree-of-supercooling improvement element group M is at least one selected from the group consisting of Nb and Mo, and

the iron-based metallic glass alloy powder has a particle size of 10 to 30 μm .

[4] An iron-based metallic glass alloy powder, wherein the iron-based metallic glass alloy is represented by the following compositional formula:



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the compositional ratios of the iron-based metal element group Fe, Co, and Ni are such that $19 \leq x \leq 22$, $0 \leq y \leq 6.0$, $0 \leq s \leq 0.35$, $0 \leq t \leq 0.35$, and $s+t \leq 0.35$,
the compositional ratios of the semimetal element group Si, B, P, and C are such that

$$(0.5:1) \leq (m:n) \leq (6.1:1),$$

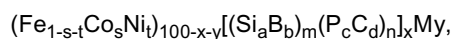
$$(2.5:7.5) \leq (a:b) \leq (5.6:4.4),$$

and

$$(4.2:5.8) \leq (c:d) \leq (9.5:0.5),$$

the degree-of-supercooling improvement element group M is at least one selected from the group consisting of Nb and Mo,
the iron-based metallic glass alloy further comprises at least one selected from the group consisting of Cr and Zr as a corrosion resistance modification component,
the content ratio of the corrosion resistance modification component is 2.8 to 5.5% by weight based on the total mass of the alloy components, and
the iron-based metallic glass alloy powder has a particle size of 0.5 μm or more and less than 3 μm .

[5] An iron-based metallic glass alloy powder, wherein the iron-based metallic glass alloy is represented by the following compositional formula:



the compositional ratios of the iron-based metal element group Fe, Co, and Ni are such that $19 \leq x \leq 26$, $0 \leq y \leq 6.0$, $0 \leq s \leq 0.35$, $0 \leq t \leq 0.35$, and $s+t \leq 0.35$,
the compositional ratios of the semimetal element group Si, B, P, and C are such that

$$(0.5:1) \leq (m:n) \leq (6.1:1),$$

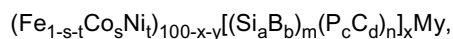
$$(2.5:7.5) \leq (a:b) \leq (5.6:4.4),$$

and

$$(4.2:5.8) \leq (c:d) \leq (9.5:0.5),$$

the degree-of-supercooling improvement element group M is at least one selected from the group consisting of Nb and Mo,
the iron-based metallic glass alloy further comprises at least one selected from the group consisting of Cr and Zr as a corrosion resistance modification component,
the content ratio of the corrosion resistance modification component is 2.3 to 5.5% by weight based on the total mass of the alloy components, and
the iron-based metallic glass alloy powder has a particle size of 3 μm or more and less than 10 μm .

[6] An iron-based metallic glass alloy powder, wherein the iron-based metallic glass alloy is represented by the following compositional formula:



the compositional ratios of the iron-based metal element group Fe, Co, and Ni are such that $19 \leq x \leq 26$, $0 \leq y \leq 6.0$,

$0 \leq s \leq 0.35$, $0 \leq t \leq 0.35$, and $s+t \leq 0.35$,

the compositional ratios of the semimetal element group Si, B, P, and C are such that

$$(0.5:1) \leq (m:n) \leq (6.1:1),$$

$$(2.5:7.5) \leq (a:b) \leq (5.6:4.4),$$

and

$$(4.2:5.8) \leq (c:d) \leq (9.5:0.5),$$

the degree-of-supercooling improvement element group M is at least one selected from the group consisting of Nb and Mo, and

the iron-based metallic glass alloy powder has a particle size of 10 to 30 μm .

[7] The iron-based metallic glass alloy powder according to [3] or [6], wherein the iron-based metallic glass alloy further comprises at least one selected from the group consisting of Cr and Zr as a corrosion resistance modification component in an amount of greater than 0% by weight and not higher than 5.5% by weight based on the total mass of the alloy components.

[8] The iron-based metallic glass alloy powder according to [1], [2], [4], [5], or [7], wherein the corrosion resistance modification component is Cr.

[9] A formed article produced by using the iron-based metallic glass alloy powder according to any one of claims [1] to [8].

Advantageous Effects of Invention

[0015] The present invention makes it possible to provide a flame-retardant iron-based metallic glass alloy powder. By eliminating the risk of ignition during handling of the material during or after production, storage until the formation of a finished product or a transfer method can be simplified. Hence, the material can be used safely at low costs.

[0016] In addition, the iron-based metallic glass alloy powder of the present invention retains high magnetic properties. For this reason, the iron-based metallic glass alloy powder of the present invention can be used as a material for powder compaction of various electronic components or as a material for coating materials for forming magnetic films on electronic circuit boards and the like.

Brief Description of Drawing

[0017] Fig. 1 is a cross-sectional view showing a concept of a water atomization device used to produce iron-based metallic glass alloy powders of the present invention.

Description of Embodiments

[0018] In the present specification, elements constituting the "iron-based metal element group" are Fe, Co, and Ni.

[0019] In the present specification, elements constituting the "semimetal element group" are Si, B, P, and C.

[0020] In the present specification, elements constituting the "degree-of-supercooling improvement element group" are Nb and Mo.

[0021] In the present specification, the "content ratio" of each component element of an alloy represents the content ratio (% by weight) of the component element based on the total mass of the iron-based glass alloy powder obtained by adding additive elements (the corrosion resistance modification component and the corrosion resistance modification secondary component) to the above-described compositional formula. In addition, each compositional ratio in the above-described compositional formula is expressed by % by atom (at%) or the atomic ratio, unless otherwise specified.

[0022] In the present specification, the term "particle size" refers to an average particle size (median size, D_{50}), unless otherwise specified.

[0023] An iron-based metallic glass alloy that is flame retardant even though having a smaller particle size than conventional ones can be obtained by adjusting the compositional ratios in the above-described compositional formula (base composition). The present invention includes first to third embodiments which are classified depending on the compositional ratio and the particle size. Note that "the present invention" herein refers to all the embodiments, unless

otherwise specified.

[0024] The first embodiment relates to an iron-based metallic glass alloy powder mainly characterized in that $19 \leq x \leq 22$, the corrosion resistance modification component is 2.8 to 5.5% by weight based on the total mass of the alloy components, and the particle size is 0.5 μm or more and less than 3 μm .

[0025] The second embodiment relates to an iron-based metallic glass alloy powder mainly characterized in that $19 \leq x \leq 26$, the corrosion resistance modification component is 2.3 to 5.5% by weight based on the total mass of the alloy components, and the particle size is 3 μm or more and less than 10 μm .

[0026] The third embodiment relates to an iron-based metallic glass alloy powder mainly characterized in that $19 \leq x \leq 26$, the corrosion resistance modification component is 0 to 5.5% by weight based on the total mass of the alloy components, and the particle size is 10 to 30 μm .

[0027] Hereinafter, matters common among all the embodiments are described first, and matters specific to each embodiment are described next.

1. Compositional Ratios relating to All Embodiments

1-1. Compositional Ratios (s, t, s+t) of Iron-Based Metal Element Group

[0028] In the base composition, the compositional ratios of the iron-based metal element group are such that $0 \leq s \leq 0.35$, $0 \leq t \leq 0.35$, and $s+t \leq 0.35$.

[0029] s and t may be zero. In other words, an iron-based metal element other than Fe such as Co or Ni does not necessarily have to be contained. Even when Co and Ni, which are expensive, are not contained, it is possible to provide excellent magnetic properties and excellent corrosion resistance, and further it is possible to obtain a degree of supercooling of 40 K or more. Hence, an iron-based metallic glass alloy powder can be obtained at lower costs.

[0030] When $s+t > 0.35$, not only the increase in Co or Ni content results in increase in raw material costs, but also the degree of supercooling decreases to an unmeasurable level. As a result, it is not possible to obtain a degree of supercooling of 40 K or more, which is a requirement for the formation of an amorphous composition.

1-2. Compositional Ratios (a, b, m, c, d, and n) of Semimetal Element Group

[0031] The compositional ratios (a, b, m, c, d, and n) of all the elements constituting the semimetal element group are in the ranges of

$$(0.5:1) \leq (m:n) \leq (6.1:1),$$

$$(2.5:7.5) \leq (a:b) \leq (5.6:4.4),$$

and

$$(4.2:5.8) \leq (c:d) \leq (9.5:0.5),$$

within the range of the compositional ratio (x) of the total sum. Preferably, the compositional ratios (a, b, m, c, d, and n) are in the ranges of

$$(0.5:1) \leq (m:n) \leq (6:1),$$

$$(2.5:7.5) \leq (a:b) \leq (5.5:4.5),$$

and

$$(5.5:4.5) \leq (c:d) \leq (9.5:0.5).$$

[0032] When the compositional ratios of the semimetal element group are out of the above-described ranges, a degree of supercooling $\Delta T_x \geq 40$ K is difficult to obtain.

[0033] Preferably, the compositional ratios of the semimetal element group are such that

$$(1.5:1) \leq (m:n) \leq (5.5:1),$$

$$(3.5:6.5) \leq (a:b) \leq (6.5:3.5),$$

and

$$(6.0:4.0) \leq (c:d) \leq (8.5:1.5).$$

[0034] More preferably, the compositional ratios of the semimetal element group are such that

$$(2.5:1) \leq (m:n) \leq (3.5:1),$$

$$(4.3:5.7) \leq (a:b) \leq (5.2:4.8),$$

and

$$(6.5:3.5) \leq (c:d) \leq (7.0:3.0).$$

[0035] By setting the ratios of the semimetal element group within such ranges, the magnetic properties and corrosion resistance of the iron-based metallic glass alloy powder can be further improved.

1-3. Compositional Ratio (y) of Degree-of-Supercooling Improvement Element Group

[0036] The compositional ratio of the degree-of-supercooling improvement element group is such that $0 \leq y \leq 6.0$, preferably such that $0.05 \leq y \leq 2.4$, and more preferably such that $0.15 \leq y \leq 1.3$. By setting the compositional ratio of the degree-of-supercooling improvement element group in such a range, the magnetic properties can be improved. However, since Nb or Mo is an expensive rare metal, the compositional ratio of the Nb or Mo is preferably as low as possible within a range where necessary magnetic properties can be obtained. When the compositional ratio of the degree-of-supercooling improvement element group is excessive, the degree-of-supercooling improvement effect tends to reach the saturated value, and the magnetic properties tend to be lowered relatively.

[0037] Note that the compositional ratio of one of Nb and Mo is set equal to the compositional ratio of the total of the both, because the two elements have similar chemical properties, and also have similar atomic radii and similar atomic weights.

2. Compositional Ratios and Particle Size relating to Each Embodiment

2-1. First Embodiment

2-1-1. Compositional Ratio (x) of Semimetal Element Group

[0038] In the first embodiment, the compositional ratio (x) of the total sum of the semimetal element group is such that $19 \leq x \leq 22$. From the viewpoints of the flame retardancy, the degree of supercooling, and the magnetic properties, the range of $21 \leq x \leq 22$ is preferable.

[0039] Note that the lower limit of x is set from the viewpoints of obtaining a degree of supercooling $\Delta T_x \geq 40$ K and of

obtaining a single amorphous phase. The upper limit of x is set firstly from the viewpoint of the flame retardancy, and secondary by giving consideration to prevention of deterioration of magnetic properties due to the decrease in the amount of Fe and to the reduction of raw material costs.

2-1-2. Corrosion Resistance Modification Component

[0040] In the first embodiment, the content ratio of the corrosion resistance modification component is 2.8 to 5.5% by weight, and preferably 2.8 to 4.0% by weight based on the total mass of the alloy components. Since Cr and Zr contained in the iron-based metallic glass alloy powder form oxide coating on the surface of the iron-based metallic glass alloy powder, the corrosion resistance is improved. The corrosion resistance modification component is preferably Cr for an economical reason.

[0041] The iron-based metallic glass alloy powder of the first embodiment of the present invention may further comprise Al as a corrosion resistance modification component. Al also forms oxide coating on the surface of the iron-based metallic glass alloy powder, and has an effect of increasing the hardness of the oxide coating formed from Cr and/or Zr. With the increase in hardness of the oxide coating, the corrosion resistance is further improved. In addition, when an iron-based metallic glass alloy powder is produced by an atomization method described later, Al contributes to the sphere formation of the powder.

[0042] When Al is contained, it is preferable that the content ratio of Al be 0.01 to 0.75% by weight based on the total mass of the iron-based metallic glass alloy powder of the first embodiment of the present invention, and the content ratio of the corrosion resistance modification components including Al be 1.0 to 5.0% by weight. Moreover, it is desirable that the content ratio of Al be 0.03 to 0.50% by weight, and the content ratio of the corrosion resistance modification components including Al be 1.5 to 1.9% by weight. When the latter composition is employed, not only the corrosion resistance, but also the magnetic properties are further improved.

[0043] The iron-based metallic glass alloy powder of the first embodiment of the present invention may further comprise at least one selected from the group consisting of V, Ti, Ta, Cu, and Mn as a corrosion resistance modification secondary component. This makes it possible to obtain excellent magnetic properties, while reducing the content of the corrosion resistance modification component. The total content ratio of the corrosion resistance modification secondary components is desirably 0.03 to 0.70% by weight, further desirably 0.05 to 0.50% by weight, and still further desirably 0.10 to 0.30% by weight based on the total mass of the iron-based metallic glass alloy powder of the first embodiment of the present invention. As in the case of Al, the corrosion resistance modification secondary component can also form oxide coating on the surface of the iron-based metallic glass alloy powder to improve the corrosion resistance. Moreover, by a synergistic effect with the above-described corrosion resistance modification component, the specific resistance of the iron-based metallic glass alloy powder can be improved.

2-1-3. Particle Size

[0044] The iron-based metallic glass alloy powder of the first embodiment of the present invention has a particle size of 0.5 μm or more and less than 3 μm . In general, a smaller particle size is more advantageous in that the eddy-current loss in the iron loss can be reduced and excellent magnetic properties are achieved. However, a smaller particle size is more disadvantageous in that the increased specific surface area leads to increased reactivity, which results in lowered reliability of the material. However, the iron-based metallic glass alloy powder having the composition of the first embodiment of the present invention overcomes such disadvantages. In addition, an iron-based metallic glass alloy powder with a smaller particle size is more corrosion-susceptible, in general. However, the iron-based metallic glass alloy powder of the first embodiment of the present invention have a good corrosion resistance, even though the particle size is as small as, for example, 0.5 μm or more and less than 3 μm .

2-2. Second Embodiment

2-2-1. Compositional Ratio (x) of Semimetal Element Group

[0045] In the second embodiment, the compositional ratio (x) of the total sum of the semimetal element group is such that $19 \leq x \leq 26$. From the viewpoints of the flame retardancy, the degree of supercooling, and the magnetic properties, the range of $21 \leq x \leq 26$ is preferable.

[0046] Note that the lower limit of x is set from the viewpoints of obtaining a degree of supercooling $\Delta T_x \geq 40$ K and of obtaining a single amorphous phase. The upper limit of x is set firstly from the viewpoint of the flame retardancy, and secondary by giving consideration to prevention of deterioration of magnetic properties due to the decrease in the amount of Fe and to the reduction of raw material costs.

2-2-2. Corrosion Resistance Modification Component

[0047] In the second embodiment, the content ratio of the corrosion resistance modification component is 2.3 to 5.5% by weight, and preferably 2.3 to 4.0% by weight based on the total mass of the alloy components. Since Cr and Zr contained in the iron-based metallic glass alloy powder form oxide coating on the surface of the iron-based metallic glass alloy powder, the corrosion resistance is improved. The corrosion resistance modification component is preferably Cr for an economical reason.

[0048] The further corrosion resistance modification component (Al) and the corrosion resistance modification secondary component (at least one selected from the group consisting of V, Ti, Ta, Cu, and Mn) are as described in the first embodiment.

2-2-3. Particle Size

[0049] The iron-based metallic glass alloy powder of the second embodiment of the present invention has a particle size of 3 μm or more and less than 10 μm . In general, a smaller particle size is more advantageous in that the eddy-current loss in the iron loss can be reduced and excellent magnetic properties are achieved. However, a smaller particle size is more disadvantageous in that the increased specific surface area leads to increased reactivity, which results in lowered reliability of the material. However, the iron-based metallic glass alloy powder having the composition of the second embodiment of the present invention overcomes such disadvantages. In addition, an iron-based metallic glass alloy powder with a smaller particle size is more corrosion-susceptible, in general. However, the iron-based metallic glass alloy powder of the second embodiment of the present invention have a good corrosion resistance, even though the particle size is as small as 3 μm or more and less than 10 μm .

2-3. Third Embodiment

2-3-1. Compositional Ratio (x) of Semimetal Element Group

[0050] In the third embodiment, the compositional ratio (x) of the total sum of the semimetal element group is such that $19 \leq x \leq 26$. From the viewpoints of the flame retardancy, the degree of supercooling, and the magnetic properties, the range of $21 \leq x \leq 26$ is preferable.

[0051] Note that the lower limit of x is set from the viewpoints of obtaining a degree of supercooling $\Delta T_x \geq 40$ K and of obtaining a single amorphous phase. The upper limit of x is set firstly from the viewpoint of the flame retardancy, and secondary by giving consideration to prevention of deterioration of magnetic properties due to the decrease in the amount of Fe and to the reduction of raw material costs.

2-3-2. Corrosion Resistance Modification Component

[0052] In the third embodiment, the content ratio of the corrosion resistance modification component is 0 to 5.5% by weight, and preferably 3.0 to 4.0% by weight based on the total mass of the alloy components. Since Cr and Zr contained in the iron-based metallic glass alloy powder form oxide coating on the surface of the iron-based metallic glass alloy powder, the corrosion resistance is improved. The corrosion resistance modification component is preferably Cr for an economical reason.

[0053] The further corrosion resistance modification component (Al) and the corrosion resistance modification secondary component (at least one selected from the group consisting of V, Ti, Ta, Cu, and Mn) are as described in the first embodiment.

2-3-3. Particle Size

[0054] The iron-based metallic glass alloy powder of the third embodiment of the present invention has a particle size of 10 to 30 μm . In general, a smaller particle size is more advantageous in that the eddy-current loss in the iron loss can be reduced and excellent magnetic properties are achieved. However, a smaller particle size is more disadvantageous in that the increased specific surface area leads to increased reactivity, which results in lowered reliability of the material. However, the iron-based metallic glass alloy powder of the composition of the third embodiment of the present invention overcomes such disadvantages. In addition, an iron-based metallic glass alloy powder with a smaller particle size is more corrosion-susceptible, in general. However, the iron-based metallic glass alloy powder of the third embodiment of the present invention has a good corrosion resistance, even though the particle size is as small as 10 to 30 μm .

3. Production Method

[0055] The iron-based metallic glass alloy powder of the present invention can be produced by a water atomization method. The water atomization method is a method which allows the production of an iron-based metallic glass alloy powder in the air, and which allows the production at low facility costs and low production costs.

[0056] As shown in Fig. 1, an atomization apparatus for the water atomization method comprises: a melting crucible 1 in which a bottom plate having a melt orifice 5 formed by making a hole in the downward direction is integrally formed with a side plate provided to stand in a cylindrical shape; an induction-heating coil 2 spirally arranged on the entire outer periphery of the side plate of the melting crucible 1; a melt stopper 3 which is inserted in the melting crucible 1 and which opens or closes the melting crucible 1; and atomization nozzles 6 arranged below the melt orifice 5.

[0057] A to-be-melt/molten raw material 4 (a base composition, a corrosion resistance modification component, and, if necessary, a corrosion resistance modification secondary component) corresponding to the iron-based metallic glass alloy powder of the present invention is introduced into the melting crucible 1, while adjusting their ratios so that the iron-based metallic glass alloy powder can have a predetermined composition. Subsequently, the to-be-melt/molten raw material 4 is melted to form a melt by heating to the melting point or higher with the induction-heating coil 2. Subsequently, the melt stopper 3 is caused to open the melt orifice 5 to allow the melt (to-be-melt/molten raw material 4) to fall down through the melt orifice 5. The atomization nozzles 6 jet water to form water films below the melt orifice 5. The melt falling down through the melt orifice 5 is broken up by collision with the water film and is rapidly cooled to be solidified. The melt now solidified into a powder falls down into water 8 in a water tank (not-illustrated) arranged below the atomization nozzle, and is further cooled. The powder is collected, and subjected to a drying step and a classification step. Thus, an iron-based metallic glass alloy powder can be obtained with an intended composition and an intended grain size.

[0058] The iron-based metallic glass alloy powder of the present invention does not crystallize, even when the iron-based metallic glass alloy powder is produced at a lower cooling speed than conventional iron-based metallic glass alloys. In other words, it is possible to easily produce an iron-based metallic glass alloy powder in a single amorphous phase containing no crystal phase even in general-purpose mass production facilities in which the cooling speed is low. This is because the degree of supercooling ΔT_x represented by the difference between the crystallization start temperature T_x and the glass transition temperature T_g is so large that the amorphous-forming ability is improved.

[0059] The iron-based metallic glass alloy powder obtained through the above-described steps has a high sphericity. Hence, for example, when a product such as an electronic component is formed from the iron-based metallic glass alloy powder by packing and molding the iron-based metallic glass alloy powder in a mold to obtain a magnetic core, the packing density of the iron-based metallic glass alloy powder can be increased. Hence, products such as electronic components can be produced with excellent magnetic properties.

[0060] In the present invention, the particle size of the iron-based metallic glass alloy powder can be controlled by changing the production conditions in the water atomization method, or a powder having a desired particle size can be obtained by classification using a sieve or the like.

[Examples]

[0061] The base composition and the corrosion resistance modification component were adjusted to achieve the content ratios of the corrosion resistance modification component as shown in the tables below. The obtained material mixtures were melted in a high-frequency induction furnace. Then, powders having intended compositions were obtained by a water atomization method under the following conditions:

<Water Atomization Conditions>

[0062]

- Water pressure: 100 MPa
- Water quantity: 100 L/min
- Water temperature: 20°C
- Orifice size: 4 mm in diameter
- Molten raw material temperature: 1,500°C

[0063] The obtained iron-based metallic glass alloy powder was classified to have $D_{50}=2\pm 0.3\ \mu\text{m}$ by using an air-flow classifier (manufactured by Nisshin Engineering Inc.: TUURBO CLASSIFIER). The particle size was measured with a laser diffraction-type particle size distribution measuring apparatus (manufactured by NIKKISO CO., LTD.: Microtrac MT3300EX II (wet type)). The content ratios of the semimetal elements and the degree-of-supercooling improvement elements were measured with an ICP emission spectrometer (manufactured by Hitachi High-Tech Science Corporation:

SPS3500DD).

<Evaluation of Flame-Retardancy>

5 **[0064]** The ignitability of the obtained iron-based metallic glass alloy powders of the first to third embodiments were investigated by the small gas flame ignition test according to the Category II hazardous material testing method under the Japanese Fire Service Act. Specifically, a test powder is spread into a semi-spherical shape of 30 mm in width × 15 mm in height. By using a simple ignition apparatus (portable simple gas lighter) with a flame length adjusted to 70 mm, the flame is brought into contact with the sample at a contact angle of 30 degrees for 10 seconds. When the combustion does not last, this operation is repeated 10 times. Among samples which are ignited at least once and which continue combustion with a flame or smokeless combustion after the flame is taken away, samples ignited in 3 seconds or less are regarded as highly ignitable (type-1 combustible solid) and samples ignited in a period exceeding 3 seconds but not longer than 10 seconds are regarded as ignitable (second combustible solid). In this evaluation, however, samples ignited in 10 seconds or less were regarded as ignitable, because such samples fall within hazardous materials. Samples ignited after 10 seconds or samples which did not continue combustion were regarded as non-ignitable. The occurrence of the ignition was evaluated on the basis of the following evaluation criteria. The tables below also show the results.

<Evaluation Criteria>

20 **[0065]**

○: no ignition

×: ignition

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Table 1

First Embodiment																	
	(1-s-t)x (100-x-y)	1-s-t	s	t	a:b		c:d		m:n		m:n	x	y	Cr (wt%)	Particle Size (μm)	Flame Retardancy	
1-1*	73.85	1	0	0	4.3	5.7	8.1	1.9	7.4	2.6	2.8	1	22.5	0.86	3	1.69	x
1-2*	75.09	1	0	0	4.2	5.8	8.1	1.9	7.3	2.7	2.7	1	21.9	0.9	2.26	1.87	x
1-3	74.88	1	0	0	4.3	5.7	8	2	7.2	2.8	2.6	1	20.5	0.86	3.97	1.87	○
1-4	75.25	1	0	0	4	6	8	2	7.3	2.7	2.7	1	21.1	0.83	3.06	1.88	○
1-5*	73.55	1	0	0	4.2	5.8	8.1	1.9	7.4	2.6	2.8	1	22.9	0.87	2.92	1.96	x
1-6*	73.66	1	0	0	4.3	5.7	8.1	1.9	7.4	2.6	2.8	1	22.8	0.86	2.88	1.92	x
1-7*	72.7	1	0	0	4.1	5.9	8.1	1.9	7.5	2.5	3.0	1	23.5	0.98	3.11	1.96	x
1-8	74.98	1	0	0	4.2	5.8	8.2	1.8	7.1	2.9	2.4	1	21.3	0.86	1 3.08	1.96	○
1-9	76.56	1	0	0	4.2	5.8	8	2	7.3	2.7	2.7	1	20.6	0	3	1.99	○
1-10	74.98	1	0	0	4.3	5.7	8.1	1.9	7.1	2.9	2.4	1	21.2	0.9	3.17	1.99	○
1-11	74.67	1	0	0	4.5	5.5	8.1	1.9	7.2	2.8	2.6	1	21.1	0.88	3.57	2	○
1-12*	73.58	1	0	0	4.1	5.9	8.1	1.9	7.4	2.6	2.8	1	23.1	0.86	2.68	2.03	x
1-13	76.09	1	0	0	4.6	5.4	7.9	2.1	7.3	2.7	2.7	1	20.2	0.84	3	2.12	○
1-14	76.62	1	0	0	4.4	5.6	8	2	7.3	2.7	2.7	1	20.6	0	2.96	2.1	○
1-15*	76.11	1	0	0	4.2	5.8	8	2	7.5	2.5	3.0	1	22.9	0.97	0	2.11	x
1-16	75.37	1	0	0	4.2	5.8	8	2	7.2	2.8	2.6	1	20.9	0.88	3.03	2.11	○
1-17	74.79	1	0	0	4.3	5.7	8.1	1.9	7.2	2.8	2.6	1	21	0.86	3.56	2.15	○
1-18	75.96	1	0	0	4.1	5.9	8	2	7.2	2.8	2.6	1	20.4	0.85	2.98	2.21	○
1-19	75.44	1	0	0	4.5	5.5	8.1	1.9	7.1	2.9	2.4	1	20.2	1.01	3.54	2.27	○
1-20	76.21	1	0	0	4.7	5.3	7.9	2.1	7.4	2.6	2.8	1	21.1	0	2.91	2.3	○
1-21	75.34	1	0	0	4.3	5.7	8.1	1.9	7.2	2.8	2.6	1	20.9	0.87	3.07	2.66	○
1-8	74.98	1	0	0	4.2	5.8	8.2	1.8	7.1	2.9	2.4	1	21.3	0.86	3.08	1.51	○
1-9	76.56	1	0	0	4.2	5.8	8	2	7.3	2.7	2.7	1	20.6	0	3	1.47	○
1-10	74.98	1	0	0	4.3	5.7	8.1	1.9	7.1	2.9	2.4	1	21.2	0.9	3.17	1.36	○

First Embodiment

First Embodiment																	
	(1-s-t)x (100-x-y)	1-s-t	s	t	a:b		c:d		m:n		m:n		x	y	Cr (wt%)	Particle Size (μm)	Flame Retardancy
1-11	74.67	1	0	0	4.5	5.5	8.1	1.9	7.2	2.8	2.6	1	21.1	0.88	3.57	1.41	○
1-8	74.98	1	0	0	4.2	5.8	8.2	1.8	7.1	2.9	2.4	1	21.3	0.86	3.08	0.61	○
1-9	76.56	1	0	0	4.2	5.8	8	2	7.3	2.7	2.7	1	20.6	0	3	0.55	○
1-10	74.98	1	0	0	4.3	5.7	8.1	1.9	7.1	2.9	2.4	1	21.2	0.9	3.17	0.49	○
1-11	74.67	1	0	0	4.5	5.5	8.1	1.9	7.2	2.8	2.6	1	21.1	0.88	3.57	0.48	○
01-1	74.48	1	0	0	2.5	7.5	7.1	2.9	8.6	1.4	6.1	1	21.8	0.87	2.93	2.09	○
01-2*	73.09	1	0	0	2.6	7.4	8	2	6.6	3.4	1.9	1	23.1	0.87	2.84	1.98	×
01-4	73.31	1	0	0	5.5	4.5	5.6	4.4	8.6	1.4	6.1	1	21.0	0.86	2.78	1.77	○
01-6*	71.36	1	0	0	5.6	4.4	6.4	3.6	3.3	6.7	0.5		23.6	0.86	2.85	1.66	×
01-7	73.87	1	0	0	5.6	4.4	7.6	2.4	8.6	1.4	6.1	1	18.9	0.87	2.78	2.15	○
01-8	75.26	1	0	0	2.5	7.5	7.7	2.3	8.6	1.4	6.1	1	19.2	0.87	2.84	2.04	○
01-9	74.6	1	0	0	2.5	7.5	8.5	1.5	6.9	3.1	2.2	1	19.0	0.87	2.76	1.89	○
01-10	74.25	1	0	0	5.5	4.5	4.2	5.8	3.4	6.6	0.5	1	19.1	0.87	2.77	1.96	○
01-14	74.48	1	0	0	2.5	7.5	7.1	2.9	8.6	1.4	6.1	1	21.8	0.87	2.93	1.74	○
01-15*	73.09	1	0	0	2.6	7.4	8	2	6.6	3.4	1.9	1	23.1	0.87	2.84	0.71	×
01-16*	71.75	1	0	0	2.5	7.5	8.7	1.3	3.3	6.7	0.5	1	21.9	0.86	2.71	0.61	×
01-17	73.31	1	0	0	5.5	4.5	5.6	4.4	8.6	1.4	6.1	1	21.0	0.86	2.78	0.46	○
01-18*	71.35	1	0	0	5.6	4.4	8.8	1.2	6.6	3.4	1.9	1	23.4	0.86	2.8	0.55	×
01-19*	71.36	1	0	0	5.6	4.4	6.4	3.6	3.3	6.7	0.5	1	23.6	0.86	2.85	0.54	×
01-20	73.87	1	0	0	5.6	4.4	7.6	2.4	8.6	1.4	6.1	1	18.9	0.87	2.78	0.51	○
01-21	75.26	1	0	0	2.5	7.5	7.7	2.3	8.6	1.4	6.1	1	19.2	0.87	2.84	0.63	○
01-22	74.6	1	0	0	2.5	7.5	8.5	1.5	6.9	3.1	2.2	1	19.0	0.87	2.76	0.57	○
01-23*	74.25	1	0	0	5.5	4.5	4.2	5.8	3.4	6.6	0.5	1	19.1	0.87	2.77	0.44	×

Table 2

Second Embodiment													
	(1-s-t)x (100-x-y)	1-s-t	s	t	a:b	c:d	m:n	m:n	x	y	Cr (wt%)	Particle Size (μm)	Flame Retardancy
2-1	74.98	1	0	0	4.3	5.7	8.1	1.9	21.2	0.9	3.17	3.09	○
2-2*	65.99	0.92	0	0.08	3.9	6.1	7.9	2.1	25	1.02*	0	4.71	×
2-3	72.15	1	0	0	4.0	6.0	8.0	2.0	24.4	0.98	2.74	4.75	○
2-4*	68.23	0.92	0	0.06	4.0	6.0	8.0	2.0	24.7	0.99*	0	4.78	×
2-5	71.78	1	0	0	4.0	6.0	8.0	2.0	24.3	0.97	3.29	4.78	○
2-6	75.44	1	0	0	4.5	5.5	8.1	1.9	20.2	1.01	3.54	5.61	○
2-7	72.7	1	0	0	4.1	5.9	8.1	1.9	23.5	0.98	3.11	5.87	○
2-8	74.57	1	0	0	4.1	5.9	7.9	2.1	21.7	0.9	3.08	6.16	○
02-2	73.09	1	0	0	2.6	7.4	8	2	23.1	0.87	2.84	3.02	○
02-3	71.75	1	0	0	2.5	7.5	8.7	1.3	21.9	0.86	2.71	2.98	○
02-6	71.36	1	0	0	5.6	4.4	6.4	3.6	23.6	0.86	2.85	3.15	○
02-11	45.38	0.64	0	0.36	5.5	4.5	6.8	3.2	23.2	0.88	2.77	3.06	○
02-12	46.2	0.65	0.35	0	5.5	4.5	5.6	4.4	22.8	0.88	2.81	3.14	○
02-13	46.03	0.64	0.18	0.18	5.6	4.4	5.6	4.4	22.7	0.89	2.79	2.91	○

Table 3

Third Embodiment														
Example	1-s-t	s	t	a:b		c:d		m:n		x	y	Cr (wt%)	Particle Size (μm)	Flame Retardancy
3-1	76.11	0	0	4.2	5.8	8.0	2.0	7.5	2.5	22.9	0.97	0	12.11	○
3-2	75.52	0	0	4.3	5.7	8.0	2.0	7.2	2.8	20.7	0.87	3.07	13.02	○
3-3	74.70	0	0	4.2	5.8	8.1	1.9	7.2	2.8	21.2	0.89	3.41	28.33	○
3-4	73.89	0	0	4.0	6.0	8.9	2.0	7.5	2.5	22.3	0.99	3.03	30.83	○

[0066] Table 4 shows compositions of iron-based metallic glass alloy powders of the second embodiment, and the particle sizes are 3 μm or more and less than 10 μm . These powders were not subjected to the flame retardancy test, because it can be expected from the results in Tables 1 to 3 that powders with larger particle sizes will not undergo ignition, when powders with smaller particle sizes did not undergo ignition.

Table 4

Second Embodiment															
	(1-s-t)x (100-x-y)	1-s-t	s	t	a:b		c:d		m:n		m:n		x	y	Cr (wt%)
02-1	74.48	1	0	0	2.5	7.5	7.1	2.9	8.6	1.4	6.1	1	21.8	0.87	2.93
02-4	73.31	1	0	0	5.5	4.5	5.6	4.4	8.6	1.4	6.1	1	21.0	0.86	2.78
02-5	71.35	1	0	0	5.6	4.4	8.8	1.2	6.6	3.4	1.9	1	23.4	0.86	2.8
02-7	73.87	1	0	0	5.6	4.4	7.6	2.4	8.6	1.4	6.1	1	18.9	0.87	2.78
02-8	75.26	1	0	0	2.5	7.5	7.7	2.3	8.6	1.4	6.1	1	19.2	0.87	2.84
02-9	74.6	1	0	0	2.5	7.5	8.5	1.5	6.9	3.1	2.2	1	19.0	0.87	2.76
02-10	74.25	1	0	0	5.5	4.5	4.2	5.8	3.4	6.6	0.5	1	19.1	0.87	2.77

[0067] Note that each sign "***" placed on the right shoulder of the numeral in the column "Example" indicates that the example is a comparative example. Meanwhile, each sign "***" placed on the right shoulder of the numeral in the column y indicates that M is Mo.

Industrial Applicability

[0068] The iron-based metallic glass alloy powder of the present invention can be suitably used as a magnetic material for producing electronic components such as inductors and choke coils, and also as a material for electromagnetic wave shields, noise suppression sheets, noise suppression filters, and the like. The iron-based metallic glass alloy powder of the present invention can also be used for a blasting material or an abrasive.

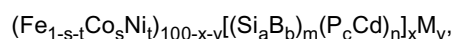
Reference Signs List

[0069]

- 1 melting crucible
- 2 induction-heating coil
- 3 melt stopper
- 4 to-be-melt/molten raw material
- 5 orifice
- 6 atomization nozzle
- 7 water film
- 8 water

Claims

1. An iron-based metallic glass alloy powder, wherein the iron-based metallic glass alloy is represented by the following compositional formula:



the compositional ratios of the iron-based metal element group Fe, Co, and Ni are such that $19 \leq x \leq 22$, $0 \leq y \leq 6.0$, $0 \leq s \leq 0.35$, $0 \leq t \leq 0.35$, and $s+t \leq 0.35$,

the compositional ratios of the semimetal element group Si, B, P, and C are such that

$$(0.5:1) \leq (m:n) \leq (6:1),$$

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$$(2.5:7.5) \leq (a:b) \leq (5.5:4.5),$$

and

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$$(5.5:4.5) \leq (c:d) \leq (9.5:0.5),$$

the degree-of-supercooling improvement element group M is at least one selected from the group consisting of Nb and Mo,

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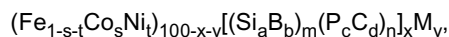
the iron-based metallic glass alloy further comprises at least one selected from the group consisting of Cr and Zr as a corrosion resistance modification component,

the content ratio of the corrosion resistance modification component is 2.8 to 5.5% by weight based on the total mass of the alloy components, and

the iron-based metallic glass alloy powder has a particle size of 0.5 μm or more and less than 3 μm .

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2. An iron-based metallic glass alloy powder, wherein the iron-based metallic glass alloy is represented by the following compositional formula:



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the compositional ratios of the iron-based metal element group Fe, Co, and Ni are such that $19 \leq x \leq 26$, $0 \leq y \leq 6.0$, $0 \leq s \leq 0.35$, $0 \leq t \leq 0.35$, and $s+t \leq 0.35$,

the compositional ratios of the semimetal element group Si, B, P, and C are such that

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$$(0.5:1) \leq (m:n) \leq (6:1),$$

$$(2.5:7.5) \leq (a:b) \leq (5.5:4.5),$$

35

and

$$(5.5:4.5) \leq (c:d) \leq (9.5:0.5),$$

40

the degree-of-supercooling improvement element group M is at least one selected from the group consisting of Nb and Mo,

the iron-based metallic glass alloy further comprises at least one selected from the group consisting of Cr and Zr as a corrosion resistance modification component,

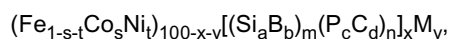
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the content ratio of the corrosion resistance modification component is 2.3 to 5.5% by weight based on the total mass of the alloy components, and

the iron-based metallic glass alloy powder has a particle size of 3 μm or more and less than 10 μm .

50

3. An iron-based metallic glass alloy powder, wherein the iron-based metallic glass alloy is represented by the following compositional formula:



55

the compositional ratios of the iron-based metal element group Fe, Co, and Ni are such that $19 \leq x \leq 26$, $0 \leq y \leq 6.0$, $0 \leq s \leq 0.35$, $0 \leq t \leq 0.35$, and $s+t \leq 0.35$,

the compositional ratios of the semimetal element group Si, B, P, and C are such that

$$(0.5:1) \leq (m:n) \leq (6:1),$$

$$(2.5:7.5) \leq (a:b) \leq (5.5:4.5),$$

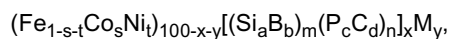
and

$$(5.5:4.5) \leq (c:d) \leq (9.5:0.5),$$

the degree-of-supercooling improvement element group M is at least one selected from the group consisting of Nb and Mo, and

the iron-based metallic glass alloy powder has a particle size of 10 to 30 μm .

4. An iron-based metallic glass alloy powder, wherein the iron-based metallic glass alloy is represented by the following compositional formula:



the compositional ratios of the iron-based metal element group Fe, Co, and Ni are such that $19 \leq x \leq 22$, $0 \leq y \leq 6.0$, $0 \leq s \leq 0.35$, $0 \leq t \leq 0.35$, and $s+t \leq 0.35$,

the compositional ratios of the semimetal element group Si, B, P, and C are such that

$$(0.5:1) \leq (m:n) \leq (6.1:1),$$

$$(2.5:7.5) \leq (a:b) \leq (5.6:4.4),$$

and

$$(4.2:5.8) \leq (c:d) \leq (9.5:0.5),$$

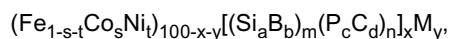
the degree-of-supercooling improvement element group M is at least one selected from the group consisting of Nb and Mo,

the iron-based metallic glass alloy further comprises at least one selected from the group consisting of Cr and Zr as a corrosion resistance modification component,

the content ratio of the corrosion resistance modification component is 2.8 to 5.5% by weight based on the total mass of the alloy components, and

the iron-based metallic glass alloy powder has a particle size of 0.5 μm or more and less than 3 μm .

5. An iron-based metallic glass alloy powder, wherein the iron-based metallic glass alloy is represented by the following compositional formula:



the compositional ratios of the iron-based metal element group Fe, Co, and Ni are such that $19 \leq x \leq 26$, $0 \leq y \leq 6.0$, $0 \leq s \leq 0.35$, $0 \leq t \leq 0.35$, and $s+t \leq 0.35$,

the compositional ratios of the semimetal element group Si, B, P, and C are such that

$$(0.5:1) \leq (m:n) \leq (6.1:1),$$

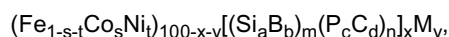
$$(2.5:7.5) \leq (a:b) \leq (5.6:4.4),$$

and

$$(4.2:5.8) \leq (c:d) \leq (9.5:0.5),$$

the degree-of-supercooling improvement element group M is at least one selected from the group consisting of Nb and Mo,
the iron-based metallic glass alloy further comprises at least one selected from the group consisting of Cr and Zr as a corrosion resistance modification component,
the content ratio of the corrosion resistance modification component is 2.3 to 5.5% by weight based on the total mass of the alloy components, and
the iron-based metallic glass alloy powder has a particle size of 3 μm or more and less than 10 μm .

6. An iron-based metallic glass alloy powder, wherein the iron-based metallic glass alloy is represented by the following compositional formula:



the compositional ratios of the iron-based metal element group Fe, Co, and Ni are such that $19 \leq x \leq 26$, $0 \leq y \leq 6.0$, $0 \leq s \leq 0.35$, $0 \leq t \leq 0.35$, and $s+t \leq 0.35$,
the compositional ratios of the semimetal element group Si, B, P, and C are such that

$$(0.5:1) \leq (m:n) \leq (6.1:1),$$

$$(2.5:7.5) \leq (a:b) \leq (5.6:4.4),$$

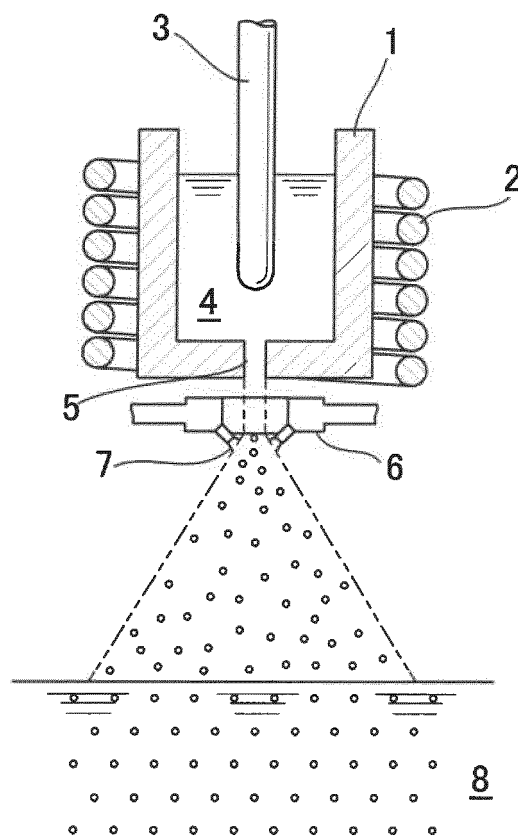
and

$$(4.2:5.8) \leq (c:d) \leq (9.5:0.5),$$

the degree-of-supercooling improvement element group M is at least one selected from the group consisting of Nb and Mo, and
the iron-based metallic glass alloy powder has a particle size of 10 to 30 μm .

7. The iron-based metallic glass alloy powder according to claim 3 or 6, wherein the iron-based metallic glass alloy further comprises at least one selected from the group consisting of Cr and Zr as a corrosion resistance modification component in an amount of greater than 0% by weight and not higher than 5.5% by weight based on the total mass of the alloy components.
8. The iron-based metallic glass alloy powder according to claim 1, 2, 4, 5, or 7, wherein the corrosion resistance modification component is Cr.
9. A formed article produced by using the iron-based metallic glass alloy powder according to any one of claims 1 to 8.

FIG.1



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2017/014380

A. CLASSIFICATION OF SUBJECT MATTER

B22F1/00(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)

B22F1/00

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.
X Y	JP 2005-290468 A (Akihisa INOUE), 20 October 2005 (20.10.2005), claims; paragraph [0069] (Family: none)	3, 6, 9 2, 5, 7-9
Y A	JP 2014-169482 A (Sinto Kogyo Ltd.), 18 September 2014 (18.09.2014), claims; paragraph [0009] & US 2016/0298216 A1 claims; paragraph [0009] & WO 2014/136148 A1 claims; paragraph [0008] & CN 104136147 A & TW 1435099 A & KR 10-2015-0123217 A	2, 5, 7-9 1, 4

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

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"P" document published prior to the international filing date but later than the priority date claimed

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

19 June 2017 (19.06.17)

Date of mailing of the international search report

27 June 2017 (27.06.17)

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REFERENCES CITED IN THE DESCRIPTION

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