

DESCRIPTION

SPUTTERING TARGET FOR MAGNETIC RECORDING MEDIUM

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TECHNICAL FIELD

[0001] The present invention relates to a sputtering target that is used for forming a magnetic thin film in a magnetic recording medium.

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BACKGROUND ART

[0002] In the field of magnetic recording as represented with hard disk drives, a material based on Co, Fe or Ni as ferromagnetic metals is being used as the material of the magnetic thin film of a magnetic recording medium. For example, Co-Cr-based or Co-Cr-Pt-based ferromagnetic alloys having Co as its main component are used for the magnetic thin film of hard disks adopting the longitudinal magnetic recording system.

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Moreover, composite materials made of Co-Cr-Pt-based ferromagnetic alloys having Co as its main component and oxides are often used for the magnetic thin film of hard disks adopting the perpendicular magnetic recording system which was recently put into practical application. In addition, the foregoing magnetic thin film is often produced by sputtering a target having the foregoing materials as its components using a magnetron sputtering equipment in light of its high productivity.

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[0003] Meanwhile, the recording density of hard disks is rapidly increasing year by year, and is now on the verge of exceeding 1 Tbit/in². When the recording density reaches 1 Tbit/in², the size of the recording bit will fall below 10 nm. In such a case, it is anticipated that the super-paramagnetization caused by thermal fluctuation will become a problem, and it is further anticipated that the material currently used for a magnetic recording medium; for instance, a material with higher magnetic crystalline anisotropy obtained by adding Pt to a Co-based alloy, will no longer be sufficient.

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This is because, for grains to stably behave ferromagnetically at a size of 10 nm or less, the magnetic grains need to possess even higher magnetic crystalline anisotropy.

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[0004] Due to the foregoing reasons, an Fe-Pt alloy having an L1₀ structure is attracting attention as a material for use in an ultrahigh density recording medium. Since an Fe-Pt alloy having an L1₀ structure exhibits high magnetic crystalline anisotropy and yields superior corrosion resistance and oxidation resistance, it is expected to become a material that can be suitably applied for a magnetic recording medium.

Furthermore, in connection with using the Fe-Pt alloy having an L1₀ structure as a material for use in an ultrahigh density recording medium, demanded is the development of technology for dispersing the Fe-Pt magnetic grains ordered to the L1₀ structure, in a magnetically isolated state, while densely aligning the orientation thereof as much as possible.

[0005] In light of the foregoing circumstances, a magnetic thin film having a granular structure in which the Fe-Pt magnetic grains having an L1₀ structure are isolated through the interposition of nonmagnetic materials such as C (carbon) and oxides is being proposed for use in a magnetic recording medium of next-generation hard disks adopting the thermally assisted magnetic recording system. This magnetic thin film has a granular structure in which the magnetic grains are magnetically insulated from each other through the interposition of nonmagnetic materials encompassing the magnetic grains.

Documents related to magnetic recording mediums having a granular magnetic thin film and other related publications include, for example, Patent Document 1, Patent Document 2, Patent Document 3, Patent Document 4, and Patent Document 5 listed below.

[0006] As a magnetic thin film having a granular structure with the foregoing Fe-Pt magnetic grains having the L1₀ structure, a magnetic thin film containing C as a nonmagnetic material is particularly attracting attention from its high magnetic properties. However, when a sputtering target made from an Fe-Pt alloy and C is sputtered, there is a problem in that C becomes inadvertently detached during sputtering, and numerous particles (foreign particles that become adhered to the substrate) are generated.

In order to resolve this problem, it is necessary to provide a sputtering target in which the adhesion between the Fe-Pt alloy and C is increased. Moreover, while a superior magnetic thin film can be obtained even when a target containing a carbide or a nitride in substitute for C is used, even in this case there is a problem in that numerous particles are generated during sputtering.

[0007] Patent Document 6 below describes a sputtering target containing Fe, Pt and C, and additionally containing metal elements other than Fe and Pt, wherein the metal elements other than Fe and Pt are selected from Cu, Ag, Mn, Ni, Co, Pd, Cr, V, and B and contained in an amount that is more than 0 at% and 20 at% or less. Nevertheless, Patent Document 6 only includes one example where Cu is contained in an amount of 10 at%, and the type and content of additive elements are considerably different from those of the present invention described later.

[0008] Moreover, Patent Document 7 below discloses a technology of mixing an FePt alloy powder, a Pt powder and a carbon black powder, and subjecting the mixed powder to hot pressing in order to produce a sintered compact in which a C phase is dispersed in an FePt alloy phase. Nevertheless, in the foregoing case, Patent Document 7 fails to consider any solution for resolving the problem in which C becomes detached during sputtering and causes the generation of numerous particles (foreign particles that become adhered to the substrate).

Moreover, Patent Document 8 below describes an FePt (Au and/or Cu) C-based sputtering target for forming a magnetic recording medium thin film. Patent Document 8 discloses a technology in which a part of the Au and/or Cu may be substituted with Ag, and in which the generation of particles can be consequently inhibited.

Moreover, Patent Document 9 below describes an FePtAgC-based sputtering target for forming a magnetic recording medium thin film. Patent Document 9 discloses a technology in which a part of the Ag may be substituted with Au and/or Cu, and in which the generation of particles can be consequently inhibited.

[0009] Patent Document 8 and Patent Document 9 described above relate to similar technologies, and Patent Document 8 and Patent Document 9 describe that, since the melting points of Ag, Au and Cu, which are added in order to inhibit the generation of particles, are low, there is a problem in that these elements start melting first during the hot press process and, therefore, the sintering temperature needs to be lowered.

Patent Document 8 and Patent Document 9 further describe that, in order to prevent the foregoing problem, the powders of Ag, Au and Cu to become the raw materials need to be prepared in advance as an AgPt powder, an AuPt powder, and a CuPt powder, and then mixed with the other raw material powders and sintered. This method entails the problem of causing the production process to

become complicated, and there is also a problem in that the additive amount of these elements needs to be increased.

[0010] Patent Document 1: JP 2000-306228 A

Patent Document 2: JP 2000-311329 A

5 Patent Document 3: JP 2008-059733 A

Patent Document 4: JP 2008-169464 A

Patent Document 5: JP 2004-152471 A

Patent Document 6: JP 2012-214874 A

Patent Document 7: JP 2012-102387 A

10 Patent Document 8: JP 2012-178210 A (Japanese Patent No. 5041261)

Patent Document 9: JP 2012-178211 A (Japanese Patent No. 5041262)

SUMMARY OF INVENTION

15 [Technical Problem]

[0011] While the foregoing Fe-Pt alloy forms an $L1_0$ -type ordered lattice near the 1:1 composition, a material in which the crystal structure is of ordered lattice generally has poor ductility, and there is a problem in that, even if this kind of material is sintered using a pressure sintering device, it is difficult to increase the density of the sintered compact. In particular, with an Fe-Pt-C-based alloy containing C (carbon), which is a sintering-resistant material, it is extremely difficult to obtain a dense sintered compact. Thus, when this kind of sintered compact sputtering target with a low density is used for sputtering, there is a problem in that the nonmagnetic materials become inadvertently detached, and numerous particles (foreign particles that become adhered to the substrate) are generated.

[0012] Moreover, when the Fe-Pt alloy of a $L1_0$ ordered lattice is heated to 1300°C or higher, the state will make a transition from an ordered state to a disordered state and the ductility will increase, but depending on the type of nonmagnetic materials that are contained therein, some nonmagnetic materials may become decomposed at a temperature of 1300°C or higher. In addition, in a high temperature range of 1300°C or higher, there are cases where the sintered compact structure becomes coarse due to the growth of crystal grains, and there is a problem in that such coarse crystal grains become the origin of an abnormal discharge (arcing) during sputtering, and cause the generation of particles.

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In light of the foregoing circumstances, an object of the present invention is to provide a sintered compact sputtering target made from an Fe-Pt-based alloy and nonmagnetic material(s), which can considerably reduce the amount of particles to be generated during sputtering, and can be efficiently produced.

[Solution to Problem]

[0013] Upon producing a sintered compact sputtering target having an Fe-Pt alloy and nonmagnetic material(s) containing at least C (carbon) as its main components, trace additive element(s) is/are added in an amount of 50 massppm to 5000 massppm in the present invention. The present inventors discovered that it is possible to: form a carbide having better wettability than C as an independent element by adding trace additive element(s), in which a standard free energy ΔG° for the formation of a carbide is -5000 [cal/mol] or less per 1 mol of carbon in the carbide; that is, by adding element(s) being prone to form a carbide; and improve the adhesion between the Fe-Pt-based alloy and C through the formed carbide.

This is the basis of the present invention, and the present inventors consequently discovered that the thus obtained sintered compact sputtering target can considerably reduce the amount of particles that are generated during sputtering. Note that powder raw materials are used for all sintering raw materials explained below.

[0014] Based on the foregoing discovery, the present invention provides:

- 1) A sintered compact sputtering target having an Fe-Pt alloy and one or more nonmagnetic materials as its main components, wherein the sintered compact sputtering target contains at least C (carbon) as the nonmagnetic material and additionally contains one or more trace additive elements other than the main components in an amount of 50 massppm to 5000 massppm, and a standard free energy ΔG° for the formation of a carbide of each trace additive element is -5000 [cal/mol] or less per 1 mol of carbon in the carbide;
- 2) The sintered compact sputtering target according to 1) above, wherein the trace additive elements are one or more elements selected from W and Cr;
- 3) The sintered compact sputtering target according to 1) or 2) above, wherein the sintered compact sputtering target additionally contains, as the nonmagnetic materials, one or more materials selected from an oxide, a nitride, and a carbide in addition to the C (carbon); and
- 4) The sintered compact sputtering target according to any one of 1) to 3)

above, wherein the sintered compact sputtering target additionally contains, as metal components, one or more elements selected from Ag, Au, Co, Cu, Ga, Ge, Ir, Ni, Pd, Re, Rh, Ru, Sn, and Zn in addition to the main components and the trace additive elements.

5 [0015] The present invention additionally provides:

5) A method of producing a sintered compact sputtering target having an Fe-Pt alloy and one or more nonmagnetic materials as its main components, wherein, as raw material powders, an Fe powder, a Pt powder, a C powder (graphite powder) and one or more trace additive element powders in which a standard
10 free energy of formation ΔG° , in a case of forming a carbide, per 1 mol of carbon is -5000 [cal/mol] or less are prepared, these powders are mixed and pulverized in an Ar atmosphere, the mixed and pulverized powder is filled in a carbon mold, and hot pressed using a hot press device under the following conditions; specifically, a vacuum atmosphere, a rate of temperature increase of 200 to
15 600°C/hour, holding temperature of 800 to 1400°C, and holding time of 0 to 4 hours, and a pressure of 20 to 50 MPa is applied from the start of temperature increase to the end of holding, to produce a sintered compact;

6) The method of producing a sintered compact sputtering target according to
20 4) above, wherein the trace additive elements are one or more elements selected from W and Cr;

7) The method of producing a sintered compact sputtering target according to
25 5) or 6) above, wherein sintering is performed to the raw materials, in which one or more materials selected from an oxide, a nitride, and a carbide are additionally contained as raw material powders of nonmagnetic materials in addition to the C (carbon); and

8) The method of producing a sintered compact sputtering target according to
30 any one of 5) to 7) above, wherein sintering is performed to the raw materials, in which one or more elements selected from Ag, Au, Co, Cu, Ga, Ge, Ir, Ni, Pd, Re, Rh, Ru, Sn, and Zn are additionally contained as raw materials of metal components.

[Advantageous Effects of Invention]

[0016] According to the present invention, it is possible to provide a sputtering target,
35 which can considerably reduce the amount of particles to be generated during sputtering. Consequently, the present invention yields a superior effect of being able to considerably improve the yield during deposition, and improve the

productivity.

DESCRIPTION OF EMBODIMENTS

5 [0017] The sintered compact sputtering target of the present invention is a sintered compact sputtering target having an Fe-Pt alloy and nonmagnetic material(s) as its main components, wherein the sintered compact sputtering target contains at least C (carbon) as the nonmagnetic material, additionally contains trace additive
10 element(s) other than the main components in an amount of 50 massppm to 5000 massppm, and a standard free energy ΔG° for the formation of a carbide of each trace additive element is -5000 [cal/mol] or less per 1 mol of carbon in the carbide.

Representative materials of the trace additive elements are W and Cr, and it is effective to add W and/or Cr. Nevertheless, there is no particular problem in
15 using other elements so as long as they satisfy the following condition within the sintering temperature range; namely, a standard free energy ΔG° for the formation of a carbide of a trace additive element is -5000 [cal/mol] or less per 1 mol of carbon in the carbide.

[0018] As the Fe-Pt alloy composition, a composition in which Pt is blended at an
20 atomic ratio of 35% or more and 55% or less and the remainder being Fe, may be generally used, but there is no particular limitation so as long as the composition is within a range that is capable of maintaining the properties as an effective magnetic recording medium. The Fe-Pt alloy in the sputtering target is generally configured from an $L1_0$ -type ordered lattice, but there is also no
25 particular limitation.

What is particularly important in the present invention is that, as the trace additive element in the sputtering target, used (added) is an additive element in which a standard free energy of formation ΔG° , in a case of forming a carbide, per 1 mol of carbon is -5000 [cal/mol] or less. Moreover, while there is no
30 particular limitation in the C content so as long as it is within a range that is capable of maintaining the properties as an effective magnetic recording medium, the C content is desirably set to be within a range of 20 to 45%, expressed as a volume ratio in the sputtering target.

[0019] In other words, by adding element(s) being prone to form a carbide, it is
35 possible to form a carbide having better wettability than C as an independent

element, and improve the adhesion between the Fe-Pt-based alloy and C through the formed carbide.

Consequently, the sintered compact sputtering target of the present invention can inhibit the detachment of C during sputtering and considerably reduce the amount of particles to be generated.

As described above, W and Cr are effective as trace additive elements, and it is desirable to add W and/or Cr. In the ensuing explanation, a case of using W and/or Cr as the representative trace additive elements is described.

[0020] The content of W and/or Cr is set to be 50 massppm to 5000 massppm. If the content of W and/or Cr is less than 50 massppm, formation of a carbide with favorable wettability becomes insufficient, and improvement in the adhesion between the Fe-Pt alloy and C cannot be expected. Meanwhile, if the content of W and/or Cr exceeds 5000 massppm, it may not be possible to obtain sufficient magnetic properties as a magnetic thin film.

Similar effects can be yielded when one or both of W and Cr are added. When both W and Cr are added, the total content thereof should be 50 massppm to 5000 massppm, expressed as a content ratio in the overall sputtering target.

[0021] Moreover, the sputtering target of the present invention may additionally contain, as nonmagnetic materials, one or more materials selected from an oxide, a nitride, and a carbide in addition to the C (carbon). In the foregoing case, as preferred oxides, considered may be the oxides of one or more elements selected from Al, B, Ba, Be, Ca, Ce, Cr, Dy, Er, Eu, Ga, Gd, Ho, Li, Mg, Mn, Nb, Nd, Pr, Sc, Sm, Sr, Ta, Tb, Ti, V, Y, Zn, and Zr. Moreover, as preferred nitrides, considered may be the nitrides of one or more elements selected from Al, B, Ca, Nb, Si, Ta, Ti, and Zr. Moreover, as preferred carbides, considered may be the carbides of one or more elements selected from B, Ca, Nb, Si, Ta, Ti, W, and Zr. A magnetic film formed from the foregoing sputtering target is expected to yield favorable magnetic properties since the carbon, carbide, nitride, and oxide take on a structure of insulating the magnetic interaction of the magnetic grains.

[0022] Moreover, the sputtering target of the present invention may additionally contain, as metal components, one or more elements selected from Ag, Au, Co, Cu, Ga, Ge, Ir, Ni, Pd, Re, Rh, Ru, Sn, and Zn in addition to the main components and the trace additive element(s).

These metal elements are added mainly for the purpose of lowering the temperature of heat treatment that is performed for realizing the L1₀ structure in

the sputtered thin film. There is no particular limitation in the blending ratio thereof so as long as it is within a range where the properties as an effective magnetic recording medium can be maintained.

[0023] The sputtering target of the present invention can be produced, for example, using the powder sintering method in the manner described below.

Foremost, an Fe powder, a Pt powder, a Cr powder, a Cu powder, a W powder and the like are prepared as the metal powders. Other than metal powders of independent elements, alloy powders may also be used as the metal powders. The grain size of these metal powders is desirably within a range of 1 to 10 μm . When the grain size is 1 to 10 μm , the metal powders can be mixed uniformly, and segregation and crystal grain coarsening can be prevented.

[0024] If the grain size of the metal powders is larger than 10 μm , there are cases where the nonmagnetic materials do not disperse uniformly. Moreover, if the grain size of the metal powders is smaller than 1 μm , there is a problem in that the composition of the target may deviate from the intended composition due to the influence of the oxidation of the metal powders. Note that the foregoing grain size range is a preferred range, and it should be naturally understood that the deviation from such grain size range is not a condition that denies the present invention.

[0025] Moreover, an oxide powder, a nitride powder, a carbide powder and the like are prepared in addition to the foregoing C (carbon) powder as the nonmagnetic material powders. Desirably, the grain size of these nonmagnetic material powders is within a range of 1 to 30 μm . When the grain size is 1 to 30 μm , the nonmagnetic material powders will not agglomerate easily when mixed with the foregoing metal powders, and can be uniformly dispersed therein.

With regard to the C powder among the nonmagnetic materials, there are types that have a crystal structure such as graphite and nano tubes and types that are amorphous as represented with carbon black, but either C powder may be used.

[0026] Upon producing the sintered compact sputtering target of the present invention, an Fe powder, a Pt powder, a C powder (graphite powder) and trace additive element powder(s) in which a standard free energy of formation ΔG° , in a case of forming a carbide, per 1 mol of carbon is -5000 [cal/mol] or less are weighed to attain a predetermined composition, and these powders are mixed and pulverized in an Ar atmosphere using a known means such as a ball mill.

The mixed and pulverized powder is filled in a carbon mold, and hot pressed using a hot press device under the following condition; specifically, a vacuum atmosphere or an inert atmosphere, a rate of temperature increase of 200 to 600°C/hour, holding temperature of 800 to 1400°C, and holding time of 0 to 4 hours, and a pressure of 20 to 50 MPa is applied from the start of temperature increase to the end of holding, to produce a sintered compact.

[0027] The plasma discharge sintering method and various other pressure sintering methods may be adopted in addition to the hot press method. The hot isostatic sintering method is particularly effective for increasing the density of the sintered compact. While this will depend on the constituents of the target, the holding temperature during the sintering process is often set to a temperature range of 800 to 1400°C. The sputtering target of the present invention can be produced by processing the thus obtained sintered compact into an intended shape using a lathe.

[0028] The sputtering target of the present invention can be produced in the manner described above. The thus produced sputtering target yields a superior effect of being able to reduce the amount of particles that are generated during sputtering, and improve the yield during deposition.

[Examples]

[0029] The present invention is now explained in detail with reference to the Examples and Comparative Examples. Note that these Examples are merely illustrative, and the present invention shall in no way be limited thereby. In other words, various modifications and other embodiments are covered by the present invention, and the present invention is limited only by the scope of its claims.

[0030] (Example 1)

As the raw material powders, prepared were an Fe powder having an average grain size of 3 μm , a Pt powder having an average grain size of 3 μm , a W powder having an average grain size of 3 μm , and a C powder (graphite powder) having an average grain size of 10 μm .

The basic components were weighed at a weighed composition (molar ratio) of 30Fe-30Pt-40C to attain a total weight of 2600 g.

Furthermore, 5.2 g of W was weighed as a trace additive component.

[0031] Subsequently, all of the weighed powders were placed in a ball mill pot having a capacity of 10 liters together with SUS balls as the pulverizing medium, and mixed and pulverized by agitation therein for 16 hours in an Ar atmosphere.

The powder removed from the pot was thereafter filled in a carbon mold and molded and sintered using a hot press device. The hot press conditions were as follows; namely, vacuum atmosphere, rate of temperature increase of 300°C/hour, holding temperature of 1400°C, and holding time of 2 hours, and a pressure of 30 MPa was applied from the start of temperature increase to the end of holding. After the end of holding, the resultant product was naturally cooled as is in the chamber.

[0032] Subsequently, a small piece extracted from the thus produced sintered compact was subject to composition analysis. Fe, Pt, and W were measured using an ICP-AES device, and C was measured using a carbon analyzer adopting an infrared absorption method after combustion in a high-frequency induction furnace. Consequently, the W content in the sputtering target was 1990 massppm. Moreover, as a result of calculating the molar ratio of the basic components from the weight ratio obtained via analysis, the composition of this sputtering target was an analyzed composition (molar ratio) of 30.09Fe-30.04Pt-39.87C.

[0033] In addition, a lathe was used to machine the sintered compact into a shape having a diameter of 180.0 mm and a thickness of 5.0 mm to obtain a disk-shaped target. This target was mounted on a magnetron sputtering equipment (C-3010 sputtering system manufactured by Canon Anelva), and then sputtered. The sputtering conditions were as follows; namely, input power of 1 kW, Ar gas pressure of 1.7 Pa, and after performing pre-sputtering at 2 kW/hr, film deposition was performed onto a silicon substrate having a 4-inch diameter for 20 seconds. Subsequently, the number of particles that adhered to the substrate was measured with a particle counter. The number of particles in this case was 185 particles.

[0034] (Comparative Example 1)

As the raw material powders, prepared were an Fe powder having an average grain size of 3 μm , a Pt powder having an average grain size of 3 μm , a W powder having an average grain size of 3 μm , and a C powder (graphite powder) having an average grain size of 10 μm .

The basic components were weighed at a weighed composition (molar ratio) of 30Fe-30Pt-40C to attain a total weight of 2600 g.

Furthermore, 0.13 g of W was weighed as a trace additive component.

[0035] Subsequently, all of the weighed powders were placed in a ball mill pot

having a capacity of 10 liters together with SUS balls as the pulverizing medium, and mixed and pulverized by agitation therein for 16 hours in an Ar atmosphere. The powder removed from the pot was thereafter filled in a carbon mold and molded and sintered using a hot press device. The hot press conditions were as follows; namely, vacuum atmosphere, rate of temperature increase of 300°C/hour, holding temperature of 1400°C, and holding time of 2 hours, and a pressure of 30 MPa was applied from the start of temperature increase to the end of holding. After the end of holding, the resultant product was naturally cooled as is in the chamber.

[0036] Subsequently, a small piece extracted from the thus produced sintered compact was subject to composition analysis. Fe, Pt, and W were measured using an ICP-AES device, and C was measured using a carbon analyzer adopting an infrared absorption method after combustion in a high-frequency induction furnace. Consequently, the W content in the sputtering target was 40 massppm. Moreover, as a result of calculating the molar ratio of the basic components from the weight ratio obtained via analysis, the composition of this sputtering target was an analyzed composition (molar ratio) of 30.20Fe-30.08Pt-39.72C.

[0037] In addition, a lathe was used to machine the sintered compact into a shape having a diameter of 180.0 mm and a thickness of 5.0 mm to obtain a disk-shaped target. This target was sputtered under the same conditions as Example 1, and the number of particles that adhered to the substrate was measured with a particle counter. The number of particles in this case was 498 particles, and increased in comparison to Example 1.

[0038] (Comparative Example 2)

As the raw material powders, prepared were an Fe powder having an average grain size of 3 μm , a Pt powder having an average grain size of 3 μm , a W powder having an average grain size of 3 μm , and a C powder (graphite powder) having an average grain size of 10 μm .

The basic components were weighed at a weighed composition (molar ratio) of 30Fe-30Pt-40C to attain a total weight of 2600 g.

Furthermore, 52.0 g of W was weighed as a trace additive component.

[0039] Subsequently, all of the weighed powders were placed in a ball mill pot having a capacity of 10 liters together with SUS balls as the pulverizing medium, and mixed and pulverized by agitation therein for 16 hours in an Ar atmosphere.

The powder removed from the pot was thereafter filled in a carbon mold and molded and sintered using a hot press device. The hot press conditions were as follows; namely, vacuum atmosphere, rate of temperature increase of 300°C/hour, holding temperature of 1400°C, and holding time of 2 hours, and a pressure of 30 MPa was applied from the start of temperature increase to the end of holding. After the end of holding, the resultant product was naturally cooled as is in the chamber.

[0040] Subsequently, a small piece extracted from the thus produced sintered compact was subject to composition analysis. Fe, Pt, and W were measured using an ICP-AES device, and C was measured using a carbon analyzer adopting an infrared absorption method after combustion in a high-frequency induction furnace. Consequently, the W content in the sputtering target was 20100 massppm. Moreover, as a result of calculating the molar ratio of the basic components from the weight ratio obtained via analysis, the composition of this sputtering target was an analyzed composition (molar ratio) of 30.07Fe-30.01Pt-39.92C.

[0041] In addition, a lathe was used to machine the sintered compact into a shape having a diameter of 180.0 mm and a thickness of 5.0 mm to obtain a disk-shaped target. This target was sputtered under the same conditions as Example 1, and the number of particles that adhered to the substrate was measured with a particle counter. The number of particles in this case was 354 particles, and increased in comparison to Example 1.

Meanwhile, sufficient magnetic properties could not be obtained in comparison to Example 1. This is considered to be because the saturation magnetization and magnetic crystalline anisotropy energy consequently deteriorated due to a high W content.

[0042] (Example 2)

As the raw material powders, prepared were an Fe powder having an average grain size of 3 μm , a Pt powder having an average grain size of 3 μm , a C powder (graphite powder) having an average grain size of 10 μm , and a Cr powder having an average grain size of 3 μm .

The basic components were weighed at a weighed composition (molar ratio) of 30Fe-30Pt-40C to attain a total weight of 2600 g.

Furthermore, 2.6 g of Cr was weighed as a trace additive component.

[0043] Subsequently, all of the weighed powders were placed in a ball mill pot

having a capacity of 10 liters together with SUS balls as the pulverizing medium, and mixed and pulverized by agitation therein for 16 hours in an Ar atmosphere. The powder removed from the pot was thereafter filled in a carbon mold and molded and sintered using a hot press device. The hot press conditions were as follows; namely, vacuum atmosphere, rate of temperature increase of 300°C/hour, holding temperature of 1300°C, and holding time of 2 hours, and a pressure of 30 MPa was applied from the start of temperature increase to the end of holding. After the end of holding, the resultant product was naturally cooled as is in the chamber.

[0044] Subsequently, a small piece extracted from the thus produced sintered compact was subject to composition analysis. Fe, Pt, and Cr were measured using an ICP-AES device, and C was measured using a carbon analyzer adopting an infrared absorption method after combustion in a high-frequency induction furnace. Consequently, the Cr content in the sputtering target was 990 massppm. Moreover, as a result of calculating the molar ratio of the basic components from the weight ratio obtained via analysis, the composition of this sputtering target was an analyzed composition (molar ratio) of 29.85Fe-30.10Pt-40.05C.

[0045] In addition, a lathe was used to machine the sintered compact into a shape having a diameter of 180.0 mm and a thickness of 5.0 mm to obtain a disk-shaped target. This target was sputtered under the same conditions as Example 1, and the number of particles that adhered to the substrate was measured with a particle counter. The number of particles in this case was 255 particles.

[0046] (Comparative Example 3)

As the raw material powders, prepared were an Fe powder having an average grain size of 3 μm , a Pt powder having an average grain size of 3 μm , a C powder (graphite powder) having an average grain size of 10 μm , and a Cr powder having an average grain size of 3 μm .

The basic components were weighed at a weighed composition (molar ratio) of 30Fe-30Pt-40C to attain a total weight of 2600 g.

Furthermore, 0.13 g of Cr was weighed as a trace additive component.

[0047] Subsequently, all of the weighed powders were placed in a ball mill pot having a capacity of 10 liters together with SUS balls as the pulverizing medium, and mixed and pulverized by agitation therein for 16 hours in an Ar atmosphere.

The powder removed from the pot was thereafter filled in a carbon mold and molded and sintered using a hot press device. The hot press conditions were as follows; namely, vacuum atmosphere, rate of temperature increase of 300°C/hour, holding temperature of 1300°C, and holding time of 2 hours, and a pressure of 30 MPa was applied from the start of temperature increase to the end of holding. After the end of holding, the resultant product was naturally cooled as is in the chamber.

[0048] Subsequently, a small piece extracted from the thus produced sintered compact was subject to composition analysis. Fe, Pt, and Cr were measured using an ICP-AES device, and C was measured using a carbon analyzer adopting an infrared absorption method after combustion in a high-frequency induction furnace. Consequently, the Cr content in the sputtering target was 30 massppm. Moreover, as a result of calculating the molar ratio of the basic components from the weight ratio obtained via analysis, the composition of this sputtering target was an analyzed composition (molar ratio) of 30.23Fe-29.85Pt-39.92C.

[0049] In addition, a lathe was used to machine the sintered compact into a shape having a diameter of 180.0 mm and a thickness of 5.0 mm to obtain a disk-shaped target. This target was mounted on a magnetron sputtering equipment and sputtered under the same conditions as Example 1, and the number of particles that adhered to the substrate was measured with a particle counter. The number of particles in this case was 658 particles, and increased in comparison to Example 2.

[0050] (Comparative Example 4)

As the raw material powders, prepared were an Fe powder having an average grain size of 3 μm , a Pt powder having an average grain size of 3 μm , a C powder (graphite powder) having an average grain size of 10 μm , and a Cr powder having an average grain size of 3 μm .

The basic components were weighed at a weighed composition (molar ratio) of 30Fe-30Pt-40C to attain a total weight of 2600 g.

Furthermore, 26 g of Cr was weighed as a trace additive component.

[0051] Subsequently, all of the weighed powders were placed in a ball mill pot having a capacity of 10 liters together with SUS balls as the pulverizing medium, and mixed and pulverized by agitation therein for 16 hours in an Ar atmosphere. The powder removed from the pot was thereafter filled in a carbon mold and

molded and sintered using a hot press device. The hot press conditions were as follows; namely, vacuum atmosphere, rate of temperature increase of 300°C/hour, holding temperature of 1300°C, and holding time of 2 hours, and a pressure of 30 MPa was applied from the start of temperature increase to the end of holding. After the end of holding, the resultant product was naturally cooled as is in the chamber.

[0052] Subsequently, a small piece extracted from the thus produced sintered compact was subject to composition analysis. Fe, Pt, and Cr were measured using an ICP-AES device, and C was measured using a carbon analyzer adopting an infrared absorption method after combustion in a high-frequency induction furnace. Consequently, the Cr content in the sputtering target was 10200 massppm. Moreover, as a result of calculating the molar ratio of the basic components from the weight ratio obtained via analysis, the composition of this sputtering target was an analyzed composition (molar ratio) of 30.05Fe-30.10Pt-39.85C.

[0053] In addition, a lathe was used to machine the sintered compact into a shape having a diameter of 180.0 mm and a thickness of 5.0 mm to obtain a disk-shaped target. This target was sputtered under the same conditions as Example 1, and the number of particles that adhered to the substrate was measured with a particle counter. The number of particles in this case was 325 particles, and was roughly of the same level as Example 2. Meanwhile, sufficient magnetic properties could not be obtained in comparison to Example 2. This is considered to be because the saturation magnetization and magnetic crystalline anisotropy energy consequently deteriorated due to a high Cr content.

[0054] (Example 3)

As the raw material powders, prepared were an Fe powder having an average grain size of 3 μm, a Pt powder having an average grain size of 3 μm, a W powder having an average grain size of 3 μm, a Cr powder having an average grain size of 3 μm, a C powder (graphite powder) having an average grain size of 10 μm, and a BN powder having an average grain size of 10 μm.

The basic components were weighed at a weighed composition (molar ratio) of 35Fe-35Pt-20C-10BN to attain a total weight of 2600 g.

Furthermore, 5.2 g of W and 5.2 g of Cr were weighed as trace additive components.

[0055] Subsequently, all of the weighed powders were placed in a ball mill pot

having a capacity of 10 liters together with SUS balls as the pulverizing medium, and mixed and pulverized by agitation therein for 16 hours in an Ar atmosphere. The powder removed from the pot was thereafter filled in a carbon mold and molded and sintered using a hot press device. The hot press conditions were as follows; namely, vacuum atmosphere, rate of temperature increase of 300°C/hour, holding temperature of 1200°C, and holding time of 2 hours, and a pressure of 30 MPa was applied from the start of temperature increase to the end of holding. After the end of holding, the resultant product was naturally cooled as is in the chamber.

[0056] Subsequently, a small piece extracted from the thus produced sintered compact was subject to composition analysis. Fe, Pt, B, W, and Cr were measured using an ICP-AES device. The BN content was calculated using a stoichiometric ratio from the measured value of B. Moreover, C was measured using a carbon analyzer adopting an infrared absorption method after combustion in a high-frequency induction furnace. Consequently, the W content in the sputtering target was 2000 massppm, and the Cr content in the sputtering target was 2050 massppm. Moreover, as a result of calculating the molar ratio of the basic components from the weight ratio obtained via analysis, the composition of this sputtering target was an analyzed composition (molar ratio) of 34.91Fe-35.35Pt-20.04C-9.70BN.

[0057] In addition, a lathe was used to machine the sintered compact into a shape having a diameter of 180.0 mm and a thickness of 5.0 mm to obtain a disk-shaped target. This target was mounted on a magnetron sputtering equipment and sputtered, and the number of particles that adhered to the substrate was measured with a particle counter. The number of particles in this case was 211 particles.

[0058] (Comparative Example 5)

As the raw material powders, prepared were an Fe powder having an average grain size of 3 μm , a Pt powder having an average grain size of 3 μm , a W powder having an average grain size of 3 μm , a Cr powder having an average grain size of 3 μm , a C powder (graphite powder) having an average grain size of 10 μm , and a BN powder having an average grain size of 10 μm .

The basic components were weighed at a weighed composition (molar ratio) of 35Fe-35Pt-20C-10BN to attain a total weight of 2600 g.

Furthermore, 0.06 g of W and 0.06 g of Cr were weighed as trace additive

components.

[0059] Subsequently, all of the weighed powders were placed in a ball mill pot having a capacity of 10 liters together with SUS balls as the pulverizing medium, and mixed and pulverized by agitation therein for 16 hours in an Ar atmosphere. The powder removed from the pot was thereafter filled in a carbon mold and molded and sintered using a hot press device. The hot press conditions were as follows; namely, vacuum atmosphere, rate of temperature increase of 300°C/hour, holding temperature of 1200°C, and holding time of 2 hours, and a pressure of 30 MPa was applied from the start of temperature increase to the end of holding. After the end of holding, the resultant product was naturally cooled as is in the chamber.

[0060] Subsequently, a small piece extracted from the thus produced sintered compact was subject to composition analysis. Fe, Pt, B, W, and Cr were measured using an ICP-AES device. The BN content was calculated using a stoichiometric ratio from the measured value of B. Moreover, C was measured using a carbon analyzer adopting an infrared absorption method after combustion in a high-frequency induction furnace. Consequently, the W content in the sputtering target was 20 massppm, and the Cr content in the sputtering target was 20 massppm. Moreover, as a result of calculating the molar ratio of the basic components from the weight ratio obtained via analysis, the composition of this sputtering target was an analyzed composition (molar ratio) of 35.09Fe-35.11Pt-19.87C-9.93BN.

[0061] In addition, a lathe was used to machine the sintered compact into a shape having a diameter of 180.0 mm and a thickness of 5.0 mm to obtain a disk-shaped target. This target was mounted on a magnetron sputtering equipment and sputtered under the same conditions as Example 1, and the number of particles that adhered to the substrate was measured with a particle counter. The number of particles in this case was 375 particles, and increased in comparison to Example 3.

[0062] (Comparative Example 6)

As the raw material powders, prepared were an Fe powder having an average grain size of 3 μm , a Pt powder having an average grain size of 3 μm , a W powder having an average grain size of 3 μm , a Cr powder having an average grain size of 3 μm , a C powder (graphite powder) having an average grain size of 10 μm , and a BN powder having an average grain size of 10 μm .

The basic components were weighed at a weighed composition (molar ratio) of 35Fe-35Pt-20C-10BN to attain a total weight of 2600 g.

Furthermore, 5.2 g of W and 13.0 g were weighed as trace additive components.

5 [0063] Subsequently, all of the weighed powders were placed in a ball mill pot having a capacity of 10 liters together with SUS balls as the pulverizing medium, and mixed and pulverized by agitation therein for 16 hours in an Ar atmosphere. The powder removed from the pot was thereafter filled in a carbon mold and molded and sintered using a hot press device. The hot press conditions were
10 as follows; namely, vacuum atmosphere, rate of temperature increase of 300°C/hour, holding temperature of 1200°C, and holding time of 2 hours, and a pressure of 30 MPa was applied from the start of temperature increase to the end of holding. After the end of holding, the resultant product was naturally cooled as is in the chamber.

15 [0064] Subsequently, a small piece extracted from the thus produced sintered compact was subject to composition analysis. Fe, Pt, B, W, and Cr were measured using an ICP-AES device. The BN content was calculated using a stoichiometric ratio from the measured value of B. Moreover, C was measured using a carbon analyzer adopting an infrared absorption method after
20 combustion in a high-frequency induction furnace. Consequently, the W content in the sputtering target was 1980 massppm, and the Cr content in the sputtering target was 5030 massppm. Moreover, as a result of calculating the molar ratio of the basic components from the weight ratio obtained via analysis, the composition of this sputtering target was an analyzed composition (molar ratio) of
25 34.94Fe-35.26Pt-19.97C-9.83BN.

[0065] In addition, a lathe was used to machine the sintered compact into a shape having a diameter of 180.0 mm and a thickness of 5.0 mm to obtain a disk-shaped target. This target was mounted on a magnetron sputtering equipment and sputtered, and the number of particles that adhered to the
30 substrate was measured with a particle counter. The number of particles in this case was 208 particles, and was roughly of the same level as Example 3. Meanwhile, sufficient magnetic properties could not be obtained in comparison to Example 3. This is considered to be because the saturation magnetization and magnetic crystalline anisotropy energy consequently deteriorated due to a high
35 W content and a high Cr content.

[0066] (Example 4)

As the raw material powders, prepared were an Fe powder having an average grain size of 3 μm , a Pt powder having an average grain size of 3 μm , a B powder having an average grain size of 10 μm , a C powder (graphite powder) having an average grain size of 10 μm , and a SiO_2 powder having an average grain size of 5 μm .

The basic components were weighed at a weighed composition (molar ratio) of 35Fe-35Pt-25C-5 SiO_2 to attain a total weight of 2500 g.

Furthermore, 0.25 g of B was weighed as a trace additive component.

Subsequently, all of the weighed powders were placed in a ball mill pot having a capacity of 10 liters together with SUS balls as the pulverizing medium, and mixed and pulverized by agitation therein for 16 hours in an Ar atmosphere. The powder removed from the pot was thereafter filled in a carbon mold and molded and sintered using a hot press device. The hot press conditions were as follows; namely, vacuum atmosphere, rate of temperature increase of 300°C/hour, holding temperature of 1150°C, and holding time of 2 hours, and a pressure of 30 MPa was applied from the start of temperature increase to the end of holding. After the end of holding, the resultant product was naturally cooled as is in the chamber.

Subsequently, a small piece extracted from the thus produced sintered compact was subject to composition analysis. Fe, Pt, Si, and B were measured using an ICP-AES device, and C was measured using a carbon analyzer adopting an infrared absorption method after combustion in a high-frequency induction furnace. The SiO_2 content was calculated using a stoichiometric ratio from the measured value of Si. Consequently, the B content in the sputtering target was 110 massppm. Moreover, as a result of calculating the molar ratio of the basic components from the weight ratio obtained via analysis, the composition of this sputtering target was an analyzed composition (molar ratio) of 34.95Fe-35.02Pt-24.90C-5.13 SiO_2 .

In addition, a lathe was used to machine the sintered compact into a shape having a diameter of 180.0 mm and a thickness of 5.0 mm to obtain a disk-shaped target. This target was sputtered under the same conditions as Example 1, and the number of particles that adhered to the substrate was measured with a particle counter. The number of particles in this case was 108 particles.

[0070] (Comparative Example 7)

As the raw material powders, prepared were an Fe powder having an average grain size of 3 μm , a Pt powder having an average grain size of 3 μm , a B powder having an average grain size of 10 μm , a C powder (graphite powder) having an average grain size of 10 μm , and a SiO_2 powder having an average grain size of 5 μm .

The basic components were weighed at a weighed composition (molar ratio) of 35Fe-35Pt-25C-5 SiO_2 to attain a total weight of 2500 g.

Furthermore, 0.07 g of B was weighed as a trace additive component.

Subsequently, all of the weighed powders were placed in a ball mill pot having a capacity of 10 liters together with SUS balls as the pulverizing medium, and mixed and pulverized by agitation therein for 16 hours in an Ar atmosphere. The powder removed from the pot was thereafter filled in a carbon mold and molded and sintered using a hot press device. The hot press conditions were as follows; namely, vacuum atmosphere, rate of temperature increase of 300°C/hour, holding temperature of 1150°C, and holding time of 2 hours, and a pressure of 30 MPa was applied from the start of temperature increase to the end of holding. After the end of holding, the resultant product was naturally cooled as is in the chamber.

Subsequently, a small piece extracted from the thus produced sintered compact was subject to composition analysis. Fe, Pt, B, and Si were measured using an ICP-AES device, and C was measured using a carbon analyzer adopting an infrared absorption method after combustion in a high-frequency induction furnace. The SiO_2 content was calculated using a stoichiometric ratio from the measured value of Si. Consequently, the B content in the sputtering target was 20 massppm. Moreover, as a result of calculating the molar ratio of the basic components from the weight ratio obtained via analysis, the composition of this sputtering target was an analyzed composition (molar ratio) of 34.77Fe-35.02Pt-25.07C-5.14 SiO_2 .

In addition, a lathe was used to machine the sintered compact into a shape having a diameter of 180.0 mm and a thickness of 5.0 mm to obtain a disk-shaped target. This target was mounted on a magnetron sputtering equipment and sputtered under the same conditions as Example 1, and the number of particles that adhered to the substrate was measured with a particle counter. The number of particles in this case was 245 particles, and increased

in comparison to Example 4.

[0074] (Comparative Example 8)

As the raw material powders, prepared were an Fe powder having an average grain size of 3 μm , a Pt powder having an average grain size of 3 μm , a B powder having an average grain size of 10 μm , a C powder (graphite powder) having an average grain size of 10 μm , and a SiO_2 powder having an average grain size of 5 μm .

The basic components were weighed at a weighed composition (molar ratio) of 35Fe-35Pt-25C-5 SiO_2 to attain a total weight of 2500 g.

Furthermore, 17.5 g of B was weighed as a trace additive component.

[0075] Subsequently, all of the weighed powders were placed in a ball mill pot having a capacity of 10 liters together with SUS balls as the pulverizing medium, and mixed and pulverized by agitation therein for 16 hours in an Ar atmosphere. The powder removed from the pot was thereafter filled in a carbon mold and molded and sintered using a hot press device. The hot press conditions were as follows; namely, vacuum atmosphere, rate of temperature increase of 300°C/hour, holding temperature of 1150°C, and holding time of 2 hours, and a pressure of 30 MPa was applied from the start of temperature increase to the end of holding. After the end of holding, the resultant product was naturally cooled as is in the chamber.

[0076] Subsequently, a small piece extracted from the thus produced sintered compact was subject to composition analysis. Fe, Pt, Si, and B were measured using an ICP-AES device, and C was measured using a carbon analyzer adopting an infrared absorption method after combustion in a high-frequency induction furnace. The SiO_2 content was calculated using a stoichiometric ratio from the measured value of Si. Consequently, the B content in the sputtering target was 6950 massppm. Moreover, as a result of calculating the molar ratio of the basic components from the weight ratio obtained via analysis, the composition of this sputtering target was an analyzed composition (molar ratio) of 35.03Fe-34.87Pt-25.05C-5.05 SiO_2 .

[0077] In addition, a lathe was used to machine the sintered compact into a shape having a diameter of 180.0 mm and a thickness of 5.0 mm to obtain a disk-shaped target. This target was sputtered under the same conditions as Example 1, and the number of particles that adhered to the substrate was measured with a particle counter. The number of particles in this case was 117

particles, and was roughly of the same level as Example 4. Meanwhile, sufficient magnetic properties could not be obtained in comparison to Example 4. This is considered to be because the saturation magnetization and magnetic crystalline anisotropy energy consequently deteriorated due to a high B content.

5 [0078] (Example 5)

As the raw material powders, prepared were an Fe powder having an average grain size of 3 μm , a Pt powder having an average grain size of 3 μm , a Cu powder having an average grain size of 3 μm , a W powder having an average grain size of 3 μm , a C powder (graphite powder) having an average grain size of 10 μm , and a TaC powder having an average grain size of 1 μm . The basic components were weighed at a weighed composition (molar ratio) of 30Fe-30Pt-5Cu-20C-15TaC to attain a total weight of 3000 g.

Furthermore, 12.0 g of W was weighed as a trace additive component.

15 [0079] Subsequently, all of the weighed powders were placed in a ball mill pot having a capacity of 10 liters together with SUS balls as the pulverizing medium, and mixed and pulverized by agitation therein for 16 hours in an Ar atmosphere. The powder removed from the pot was thereafter filled in a carbon mold and molded and sintered using a hot press device. The hot press conditions were as follows; namely, nitrogen atmosphere, rate of temperature increase of 300°C/hour, holding temperature of 1100°C, and holding time of 2 hours, and a pressure of 30 MPa was applied from the start of temperature increase to the end of holding. After the end of holding, the resultant product was naturally cooled as is in the chamber.

25 [0080] Subsequently, a small piece extracted from the thus produced sintered compact was subject to composition analysis. Fe, Pt, Cu, Ta, and W were measured using an ICP-AES device, and C was measured using a carbon analyzer adopting an infrared absorption method after combustion in a high-frequency induction furnace. The TaC content was calculated using a stoichiometric ratio from the measured value of Ta. Consequently, the W content in the sputtering target was 4000 massppm. Moreover, as a result of calculating the molar ratio of the basic components from the weight ratio obtained via analysis, the composition of this sputtering target was an analyzed composition (molar ratio) of 29.92Fe-30.09Pt-5.04Cu-19.92C-15.03TaC.

35 [0081] In addition, a lathe was used to machine the sintered compact into a shape having a diameter of 180.0 mm and a thickness of 5.0 mm to obtain a

disk-shaped target. This target was sputtered under the same conditions as Example 1, and the number of particles that adhered to the substrate was measured with a particle counter. The number of particles in this case was 278 particles.

5 [0082] (Comparative Example 9)

As the raw material powders, prepared were an Fe powder having an average grain size of 3 μm , a Pt powder having an average grain size of 3 μm , a Cu powder having an average grain size of 3 μm , a W powder having an average grain size of 3 μm , a C powder (graphite powder) having an average grain size of 10 μm , and a TaC powder having an average grain size of 1 μm . The basic components were weighed at a weighed composition (molar ratio) of 30Fe-30Pt-5Cu-20C-15TaC to attain a total weight of 3000 g.

Furthermore, 0.1 g of W was weighed as a trace additive component.

15 [0083] Subsequently, all of the weighed powders were placed in a ball mill pot having a capacity of 10 liters together with SUS balls as the pulverizing medium, and mixed and pulverized by agitation therein for 16 hours in an Ar atmosphere. The powder removed from the pot was thereafter filled in a carbon mold and molded and sintered using a hot press device. The hot press conditions were as follows; namely, nitrogen atmosphere, rate of temperature increase of 300°C/hour, holding temperature of 1100°C, and holding time of 2 hours, and a pressure of 30 MPa was applied from the start of temperature increase to the end of holding. After the end of holding, the resultant product was naturally cooled as is in the chamber.

25 [0084] Subsequently, a small piece extracted from the thus produced sintered compact was subject to composition analysis. Fe, Pt, Cu, Ta, and W were measured using an ICP-AES device, and C was measured using a carbon analyzer adopting an infrared absorption method after combustion in a high-frequency induction furnace. The TaC content was calculated using a stoichiometric ratio from the measured value of Ta. Consequently, the W content in the sputtering target was 30 massppm. Moreover, as a result of calculating the molar ratio of the basic components from the weight ratio obtained via analysis, the composition of this sputtering target was an analyzed composition (molar ratio) of 29.92Fe-30.38Pt-5.18Cu-19.72C-14.80TaC.

35 [0085] In addition, a lathe was used to machine the sintered compact into a shape having a diameter of 180.0 mm and a thickness of 5.0 mm to obtain a

disk-shaped target. This target was sputtered under the same conditions as Example 1, and the number of particles that adhered to the substrate was measured with a particle counter. The number of particles in this case was 590 particles, and increased in comparison to Example 5.

5 [0086] (Comparative Example 10)

As the raw material powders, prepared were an Fe powder having an average grain size of 3 μm , a Pt powder having an average grain size of 3 μm , a Cu powder having an average grain size of 3 μm , a W powder having an average grain size of 3 μm , a C powder (graphite powder) having an average grain size of 10 μm , and a TaC powder having an average grain size of 1 μm . The basic components were weighed at a weighed composition (molar ratio) of 30Fe-30Pt-5Cu-20C-15TaC to attain a total weight of 3000 g.

Furthermore, 24.0 g of W was weighed as a trace additive component.

[0087] Subsequently, all of the weighed powders were placed in a ball mill pot having a capacity of 10 liters together with SUS balls as the pulverizing medium, and mixed and pulverized by agitation therein for 16 hours in an Ar atmosphere. The powder removed from the pot was thereafter filled in a carbon mold and molded and sintered using a hot press device. The hot press conditions were as follows; namely, nitrogen atmosphere, rate of temperature increase of 300°C/hour, holding temperature of 1100°C, and holding time of 2 hours, and a pressure of 30 MPa was applied from the start of temperature increase to the end of holding. After the end of holding, the resultant product was naturally cooled as is in the chamber.

[0088] Subsequently, a small piece extracted from the thus produced sintered compact was subject to composition analysis. Fe, Pt, Cu, Ta, and W were measured using an ICP-AES device, and C was measured using a carbon analyzer adopting an infrared absorption method after combustion in a high-frequency induction furnace. The TaC content was calculated using a stoichiometric ratio from the measured value of Ta. Consequently, the W content in the sputtering target was 7980 massppm. Moreover, as a result of calculating the molar ratio of the basic components from the weight ratio obtained via analysis, the composition of this sputtering target was an analyzed composition (molar ratio) of 30.03Fe-30.00Pt-5.06Cu-19.98C-14.93TaC.

[0089] In addition, a lathe was used to machine the sintered compact into a shape having a diameter of 180.0 mm and a thickness of 5.0 mm to obtain a

disk-shaped target. This target was sputtered under the same conditions as Example 1, and the number of particles that adhered to the substrate was measured with a particle counter. The number of particles in this case was 290 particles, and was roughly of the same level as Example 5. Meanwhile, sufficient magnetic properties could not be obtained in comparison to Example 5. This is considered to be because the saturation magnetization and magnetic crystalline anisotropy energy consequently deteriorated due to a high W content.

[0090] (Example 6)

As the raw material powders, prepared were an Fe powder having an average grain size of 3 μm , a Pt powder having an average grain size of 3 μm , a W powder having an average grain size of 3 μm , and a C powder (graphite powder) having an average grain size of 10 μm .

The basic components were weighed at a weighed composition (molar ratio) of 45.5Fe-24.5Pt-30C to attain a total weight of 2470 g.

Furthermore, 5.0 g of W was weighed as a trace additive component.

Subsequently, all of the weighed powders were placed in a ball mill pot having a capacity of 10 liters together with SUS balls as the pulverizing medium, and mixed and pulverized by agitation therein for 16 hours in an Ar atmosphere. The powder removed from the pot was thereafter filled in a carbon mold and molded and sintered using a hot press device. The hot press conditions were as follows; namely, vacuum atmosphere, rate of temperature increase of 300°C/hour, holding temperature of 1300°C, and holding time of 2 hours, and a pressure of 30 MPa was applied from the start of temperature increase to the end of holding. After the end of holding, the resultant product was naturally cooled as is in the chamber.

Subsequently, a small piece extracted from the thus produced sintered compact was subject to composition analysis. Fe, Pt, and W were measured using an ICP-AES device, and C was measured using a carbon analyzer adopting an infrared absorption method after combustion in a high-frequency induction furnace. Consequently, the W content in the sputtering target was 2010 massppm. Moreover, as a result of calculating the molar ratio of the basic components from the weight ratio obtained via analysis, the composition of this sputtering target was an analyzed composition (molar ratio) of 45.53Fe-24.50Pt-29.97C.

In addition, a lathe was used to machine the sintered compact into a shape

having a diameter of 180.0 mm and a thickness of 5.0 mm to obtain a disk-shaped target. This target was mounted on a magnetron sputtering equipment (C-3010 sputtering system manufactured by Canon Anelva), and then sputtered. The sputtering conditions were as follows; namely, input power of 1 kW, Ar gas pressure of 1.7 Pa, and after performing pre-sputtering at 2 kWhr, film deposition was performed onto a silicon substrate having a 4-inch diameter for 20 seconds. Subsequently, the number of particles that adhered to the substrate was measured with a particle counter. The number of particles in this case was 124 particles.

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10 [0094] (Comparative Example 11)

As the raw material powders, prepared were an Fe powder having an average grain size of 3 μm , a Pt powder having an average grain size of 3 μm , a W powder having an average grain size of 3 μm , and a C powder (graphite powder) having an average grain size of 10 μm .

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The basic components were weighed at a weighed composition (molar ratio) of 45.5Fe-24.5Pt-30C to attain a total weight of 2470 g.

Furthermore, 0.25 g of W was weighed as a trace additive component.

[0095]

Subsequently, all of the weighed powders were placed in a ball mill pot having a capacity of 10 liters together with SUS balls as the pulverizing medium, and mixed and pulverized by agitation therein for 16 hours in an Ar atmosphere. The powder removed from the pot was thereafter filled in a carbon mold and molded and sintered using a hot press device. The hot press conditions were as follows; namely, vacuum atmosphere, rate of temperature increase of 300°C/hour, holding temperature of 1300°C, and holding time of 2 hours, and a pressure of 30 MPa was applied from the start of temperature increase to the end of holding. After the end of holding, the resultant product was naturally cooled as is in the chamber.

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[0096]

Subsequently, a small piece extracted from the thus produced sintered compact was subject to composition analysis. Fe, Pt, and W were measured using an ICP-AES device, and C was measured using a carbon analyzer adopting an infrared absorption method after combustion in a high-frequency induction furnace. Consequently, the W content in the sputtering target was 80 massppm. Moreover, as a result of calculating the molar ratio of the basic components from the weight ratio obtained via analysis, the composition of this sputtering target was an analyzed composition (molar ratio) of

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45.40Fe-24.52Pt-30.08C.

[0097] In addition, a lathe was used to machine the sintered compact into a shape having a diameter of 180.0 mm and a thickness of 5.0 mm to obtain a disk-shaped target. This target was sputtered under the same conditions as Example 1, and the number of particles that adhered to the substrate was measured with a particle counter. The number of particles in this case was 354 particles, and increased in comparison to Example 6.

[0098] (Comparative Example 12)

As the raw material powders, prepared were an Fe powder having an average grain size of 3 μm , a Pt powder having an average grain size of 3 μm , a W powder having an average grain size of 3 μm , and a C powder (graphite powder) having an average grain size of 10 μm .

The basic components were weighed at a weighed composition (molar ratio) of 45.5Fe-24.5Pt-30C to attain a total weight of 2470 g.

Furthermore, 50.0 g of W was weighed as a trace additive component.

[0099] Subsequently, all of the weighed powders were placed in a ball mill pot having a capacity of 10 liters together with SUS balls as the pulverizing medium, and mixed and pulverized by agitation therein for 16 hours in an Ar atmosphere. The powder removed from the pot was thereafter filled in a carbon mold and molded and sintered using a hot press device. The hot press conditions were as follows; namely, vacuum atmosphere, rate of temperature increase of 300°C/hour, holding temperature of 1300°C, and holding time of 2 hours, and a pressure of 30 MPa was applied from the start of temperature increase to the end of holding. After the end of holding, the resultant product was naturally cooled as is in the chamber.

[0100] Subsequently, a small piece extracted from the thus produced sintered compact was subject to composition analysis. Fe, Pt, and W were measured using an ICP-AES device, and C was measured using a carbon analyzer adopting an infrared absorption method after combustion in a high-frequency induction furnace. Consequently, the W content in the sputtering target was 20100 massppm. Moreover, as a result of calculating the molar ratio of the basic components from the weight ratio obtained via analysis, the composition of this sputtering target was an analyzed composition (molar ratio) of 45.47Fe-24.58Pt-29.95C.

[0101] In addition, a lathe was used to machine the sintered compact into a shape

having a diameter of 180.0 mm and a thickness of 5.0 mm to obtain a disk-shaped target. This target was sputtered under the same conditions as Example 1, and the number of particles that adhered to the substrate was measured with a particle counter. The number of particles in this case was 163 particles, and increased in comparison to Example 6.

Meanwhile, sufficient magnetic properties could not be obtained in comparison to Example 6. This is considered to be because the saturation magnetization and magnetic crystalline anisotropy energy consequently deteriorated due to a high W content.

[0102] (Example 7)

As the raw material powders, prepared were an Fe powder having an average grain size of 3 μm , a Pt powder having an average grain size of 3 μm , a C powder (graphite powder) having an average grain size of 10 μm , and a Cr powder having an average grain size of 3 μm .

The basic components were weighed at a weighed composition (molar ratio) of 20.25Fe-24.75Pt-55C to attain a total weight of 2200 g.

Furthermore, 2.2 g of Cr was weighed as a trace additive component.

[0103] Subsequently, all of the weighed powders were placed in a ball mill pot having a capacity of 10 liters together with SUS balls as the pulverizing medium, and mixed and pulverized by agitation therein for 16 hours in an Ar atmosphere. The powder removed from the pot was thereafter filled in a carbon mold and molded and sintered using a hot press device. The hot press conditions were as follows; namely, vacuum atmosphere, rate of temperature increase of 300°C/hour, holding temperature of 1400°C, and holding time of 2 hours, and a pressure of 30 MPa was applied from the start of temperature increase to the end of holding. After the end of holding, the resultant product was naturally cooled as is in the chamber.

[0104] Subsequently, a small piece extracted from the thus produced sintered compact was subject to composition analysis. Fe, Pt, and Cr were measured using an ICP-AES device, and C was measured using a carbon analyzer adopting an infrared absorption method after combustion in a high-frequency induction furnace. Consequently, the Cr content in the sputtering target was 990 massppm. Moreover, as a result of calculating the molar ratio of the basic components from the weight ratio obtained via analysis, the composition of this sputtering target was an analyzed composition (molar ratio) of

20.35Fe-24.78Pt-54.87C.

[0105] In addition, a lathe was used to machine the sintered compact into a shape having a diameter of 180.0 mm and a thickness of 5.0 mm to obtain a disk-shaped target. This target was sputtered under the same conditions as Example 1, and the number of particles that adhered to the substrate was measured with a particle counter. The number of particles in this case was 356 particles.

[0106] (Comparative Example 13)

As the raw material powders, prepared were an Fe powder having an average grain size of 3 μm , a Pt powder having an average grain size of 3 μm , a C powder (graphite powder) having an average grain size of 10 μm , and a Cr powder having an average grain size of 3 μm .

The basic components were weighed at a weighed composition (molar ratio) of 20.25Fe-24.75Pt-55C to attain a total weight of 2200 g.

Furthermore, 0.1 g of Cr was weighed as a trace additive component.

[0107] Subsequently, all of the weighed powders were placed in a ball mill pot having a capacity of 10 liters together with SUS balls as the pulverizing medium, and mixed and pulverized by agitation therein for 16 hours in an Ar atmosphere. The powder removed from the pot was thereafter filled in a carbon mold and molded and sintered using a hot press device. The hot press conditions were as follows; namely, vacuum atmosphere, rate of temperature increase of 300°C/hour, holding temperature of 1400°C, and holding time of 2 hours, and a pressure of 30 MPa was applied from the start of temperature increase to the end of holding. After the end of holding, the resultant product was naturally cooled as is in the chamber.

[0108] Subsequently, a small piece extracted from the thus produced sintered compact was subject to composition analysis. Fe, Pt, and Cr were measured using an ICP-AES device, and C was measured using a carbon analyzer adopting an infrared absorption method after combustion in a high-frequency induction furnace. Consequently, the Cr content in the sputtering target was 30 massppm. Moreover, as a result of calculating the molar ratio of the basic components from the weight ratio obtained via analysis, the composition of this sputtering target was an analyzed composition (molar ratio) of 20.23Fe-24.80Pt-54.97C.

[0109] In addition, a lathe was used to machine the sintered compact into a shape

having a diameter of 180.0 mm and a thickness of 5.0 mm to obtain a disk-shaped target. This target was mounted on a magnetron sputtering equipment and sputtered under the same conditions as Example 1, and the number of particles that adhered to the substrate was measured with a particle counter. The number of particles in this case was 486 particles, and increased in comparison to Example 7.

[0110] (Comparative Example 14)

As the raw material powders, prepared were an Fe powder having an average grain size of 3 μm , a Pt powder having an average grain size of 3 μm , a C powder (graphite powder) having an average grain size of 10 μm , and a Cr powder having an average grain size of 3 μm .

The basic components were weighed at a weighed composition (molar ratio) of 20.25Fe-24.75Pt-55C to attain a total weight of 2200 g.

Furthermore, 20 g of Cr was weighed as a trace additive component.

Subsequently, all of the weighed powders were placed in a ball mill pot having a capacity of 10 liters together with SUS balls as the pulverizing medium, and mixed and pulverized by agitation therein for 16 hours in an Ar atmosphere. The powder removed from the pot was thereafter filled in a carbon mold and molded and sintered using a hot press device. The hot press conditions were as follows; namely, vacuum atmosphere, rate of temperature increase of 300°C/hour, holding temperature of 1400°C, and holding time of 2 hours, and a pressure of 30 MPa was applied from the start of temperature increase to the end of holding. After the end of holding, the resultant product was naturally cooled as is in the chamber.

Subsequently, a small piece extracted from the thus produced sintered compact was subject to composition analysis. Fe, Pt, and Cr were measured using an ICP-AES device, and C was measured using a carbon analyzer adopting an infrared absorption method after combustion in a high-frequency induction furnace. Consequently, the Cr content in the sputtering target was 10600 massppm. Moreover, as a result of calculating the molar ratio of the basic components from the weight ratio obtained via analysis, the composition of this sputtering target was an analyzed composition (molar ratio) of 20.24Fe-24.78Pt-54.98C.

In addition, a lathe was used to machine the sintered compact into a shape having a diameter of 180.0 mm and a thickness of 5.0 mm to obtain a

disk-shaped target. This target was sputtered under the same conditions as Example 1, and the number of particles that adhered to the substrate was measured with a particle counter. The number of particles in this case was 345 particles, and was roughly of the same level as Example 7. Meanwhile, sufficient magnetic properties could not be obtained in comparison to Example 7. This is considered to be because the saturation magnetization and magnetic crystalline anisotropy energy consequently deteriorated due to a high Cr content.

[0114] As described above, all of the Examples were able to reduce the amount of particles that are generated during sputtering, and improve the yield during deposition by adding a predetermined amount of W and/or Cr. Accordingly, it was confirmed that the addition of W and/or Cr plays an extremely important role in inhibiting the generation of particles.

[0115] A list of the results of the foregoing Examples and Comparative Examples is shown in Table 1.

[016] [Table 1]

	Weighed Composition of Basic Components (molar ratio)	Analyzed Composition of Basic Components (molar ratio)	Analyzed Value of Content of Trace Additive Component (massppm)	Elements as Trace Additive Component	Number of Particles (particles)
Example 1	30Fe-30Pt-40C	30.09Fe-30.04Pt-39.87C	1990	W	185
Comparative Example 1	30Fe-30Pt-40C	30.20Fe-30.08Pt-39.72C	40	W	498
Comparative Example 2	30Fe-30Pt-40C	30.07Fe-30.01Pt-39.92C	20100	W	354
Example 2	30Fe-30Pt-40C	29.85Fe-30.10Pt-40.05C	990	Cr	255
Comparative Example 3	30Fe-30Pt-40C	30.23Fe-29.85Pt-39.92C	30	Cr	658
Comparative Example 4	30Fe-30Pt-40C	30.05Fe-30.10Pt-39.85C	10200	Cr	325
Example 3	35Fe-35Pt-20C-10BN	34.91Fe-35.35Pt-20.04C-9.70BN	4050	W, Cr	211
Comparative Example 5	35Fe-35Pt-20C-10BN	35.09Fe-35.11Pt-19.87C-9.93BN	40	W, Cr	375
Comparative Example 6	35Fe-35Pt-20C-10BN	34.94Fe-35.26Pt-19.97C-9.83BN	7010	W, Cr	208
Example 4	35Fe-35Pt-25C-5SiO ₂	34.95Fe-35.02Pt-24.90C-5.13SiO ₂	110	B	108
Comparative Example 7	35Fe-35Pt-25C-5SiO ₂	34.77Fe-35.02Pt-25.07C-5.14SiO ₂	20	B	245
Comparative Example 8	35Fe-35Pt-25C-5SiO ₂	35.03Fe-34.87Pt-25.05C-5.05SiO ₂	6950	B	117
Example 5	30Fe-30Pt-5Cu-20C-15TaC	29.92Fe-30.09Pt-5.04Cu-19.92C-15.03TaC	4000	W	278
Comparative Example 9	30Fe-30Pt-5Cu-20C-15TaC	29.92Fe-30.38Pt-5.18Cu-19.72C-14.80TaC	30	W	590
Comparative Example 10	30Fe-30Pt-5Cu-20C-15TaC	30.03Fe-30.00Pt-5.06Cu-19.98C-14.93TaC	7980	W	290
Example 6	45.5Fe-24.5Pt-30C	45.53Fe-24.50Pt-29.97C	2010	W	124
Comparative Example 11	45.5Fe-24.5Pt-30C	45.40Fe-24.52Pt-30.08C	80	W	354
Comparative Example 12	45.5Fe-24.5Pt-30C	45.57Fe-24.58Pt-29.95C	20100	W	163
Example 7	20.25Fe-24.75Pt-55C	20.35Fe-24.78Pt-54.87C	990	Cr	356
Comparative Example 13	20.25Fe-24.75Pt-55C	20.23Fe-24.80Pt-54.97C	30	Cr	486
Comparative Example 14	20.25Fe-24.75Pt-55C	20.24Fe-24.78Pt-54.98C	10600	Cr	345

[0117] In the foregoing Examples and Comparative Examples, BN, SiO₂, and TaC were illustrated as examples of adding, as the nonmagnetic materials, one or more materials selected from an oxide, a nitride, and a carbide in addition to the C (carbon), but it has been confirmed that similar results can also be obtained with other oxides, nitrides, and carbides.

[0118] In addition, the foregoing Examples and Comparative Examples illustrated a case of adding Cu as an example of containing, as metal elements, one or more elements selected from Ag, Au, Co, Cu, Ga, Ge, Ir, Ni, Pd, Re, Rh, Ru, Sn, and Zn, but it has been confirmed that similar results can also be obtained with one or more elements selected from Ag, Au, Co, Cu, Ga, Ge, Ir, Ni, Pd, Re, Rh, Ru, Sn, and Zn.

INDUSTRIAL APPLICABILITY

[0119] The sputtering target of the present invention yields a superior effect of being able to considerably reduce the amount of particles that are generated during sputtering, and considerably improve the yield during deposition. Accordingly, the present invention is effective as a sputtering target for forming a magnetic thin film having a granular structure.

CLAIMS

[Claim 1] A sintered compact sputtering target having an Fe-Pt alloy and one or more nonmagnetic materials as its main components, wherein the sintered compact sputtering target contains at least C (carbon) as the nonmagnetic material and additionally contains one or more trace additive elements other than the main components in an amount of 50 massppm to 5000 massppm, and a standard free energy ΔG° for the formation of a carbide of each trace additive element is -5000 [cal/mol] or less per 1 mol of carbon in the carbide.

[Claim 2] The sintered compact sputtering target according to claim 1, wherein the trace additive elements are one or more elements selected from W and Cr.

[Claim 3] The sintered compact sputtering target according to claim 1 or claim 2, wherein the sintered compact sputtering target additionally contains, as the nonmagnetic materials, one or more materials selected from an oxide, a nitride, and a carbide in addition to the C (carbon).

[Claim 4] The sintered compact sputtering target according to any one of claims 1 to 3, wherein the sintered compact sputtering target additionally contains, as metal components, one or more elements selected from Ag, Au, Co, Cu, Ga, Ge, Ir, Ni, Pd, Re, Rh, Ru, Sn, and Zn in addition to the main components and the trace additive elements.

[Claim 5] A method of producing a sintered compact sputtering target having an Fe-Pt alloy and one or more nonmagnetic materials as its main components, wherein, as raw material powders, an Fe powder, a Pt powder, a C powder (graphite powder) and one or more trace additive element powders in which a standard free energy of formation ΔG° , in a case of forming a carbide, per 1 mol of carbon is -5000 [cal/mol] or less are prepared, these powders are mixed and pulverized in an Ar atmosphere, the mixed and pulverized powder is filled in a carbon mold, and hot pressed using a hot press device under the following conditions; specifically, a vacuum atmosphere, a rate of temperature increase of 200 to 600°C/hour, holding temperature of 800 to 1400°C, and holding time of 0 to 4 hours, and a pressure of 20 to 50 MPa is applied from the start of temperature increase to the end of holding, to produce a sintered compact.

[Claim 6] The method of producing a sintered compact sputtering target according to claim 4, wherein the trace additive elements are one or more elements selected from W and Cr.

5 [Claim 7] The method of producing a sintered compact sputtering target according to claim 5 or claim 6, wherein sintering is performed to the raw materials, in which one or more materials selected from an oxide, a nitride, and a carbide are additionally contained as raw material powders of nonmagnetic materials in addition to the C (carbon).

10 [Claim 8] The method of producing a sintered compact sputtering target according to any one of claims 5 to 7, wherein sintering is performed to the raw materials, in which one or more elements selected from Ag, Au, Co, Cu, Ga, Ge, Ir, Ni, Pd, Re, Rh, Ru, Sn, and Zn are additionally contained as raw materials of metal components.