

DESCRIPTION

SPUTTERING TARGET

[Technical Field]

5 [0001] The present invention generally relates to a magnetic material sputtering target for use in depositing a magnetic thin film of a magnetic recording medium, particularly for use in the deposition of a granular film in a magnetic recording medium of a hard disk adopting the vertical magnetic recording method, and
10 particularly relates to a nonmagnetic material grain-dispersed magnetic material sputtering target containing Co or Fe as its main component and capable of inhibiting abnormal discharge of nonmagnetic materials that causes the generation of particles during sputtering.

[Background Art]

15 [0002] Materials based on Co or Fe as ferromagnetic materials are being used for the recording layer of a hard disk adopting the vertical magnetic recording method. Among these materials, composite materials of an alloy containing Co-Cr-based, Co-Pt-based, Co-Cr-Pt-based, or Fe-Pt-based ferromagnetic metals as its main component, and a nonmagnetic inorganic material, are often used. In addition,
20 the foregoing magnetic thin film of a magnetic recording medium such as a hard disk is often produced by sputtering a sputtering target having the foregoing materials as its components in light of its high productivity.

[0003] As the method of producing a sputtering target for a magnetic recording medium, considered may be the melting method or powder metallurgy. While it is not
25 possible to say which method is better since it would depend on the required characteristics, a sputtering target made from an alloy, which has a ferromagnetic metal as its main component, and nonmagnetic inorganic grains for use in forming a recording layer of a hard disk adopting the vertical magnetic recording method is generally produced via powder metallurgy. This is because inorganic grains need to
30 be uniformly dispersed in the alloy matrix, and it is difficult to produce such a sputtering target with the melting method.

[0004] As the foregoing powder metallurgy, for instance, Patent Document 1 proposes a method of obtaining a sputtering target for a magnetic recording medium

including the steps of mixing a mixed powder (obtained by mixing a Co powder, a Cr powder, a TiO₂ powder and a SiO₂ powder) and a Co spherical powder with a planetary mixer, and molding the mixed powder via a hot press.

Moreover, Patent Document 2 proposes a method of obtaining a sputtering target for forming a magnetic recording medium thin film including the steps of mixing a Co-Cr binary system alloy powder, a Pt powder and a SiO₂ powder, and hot pressing the obtained mixed powder.

[0005] Moreover, Patent Document 3 proposes a sputtering target made from a matrix phase of Co, Pt, and a metal oxide phase having an average grain size of 0.05 μm or more and less than 7.0 μm , and proposes improving the deposition efficiency by obtaining a target capable of inhibiting the growth of crystal grains and having low magnetic permeability and high density.

In addition, Patent Document 4 describes causing the average grain size of the grains formed with an oxide phase to be 3 μm or less, and Patent Document 5 describes that silica grains or titania grains satisfy $2 \leq D_p/D_n$ when, in a cross section that is vertical to the principal face of the sputtering target, the grain diameter of a direction that is vertical to the principal face of the sputtering target is defined as D_n , and the grain diameter of a direction that is parallel to the principal face is defined as D_p .

Otherwise, Patent Document 6 describes that the average grain size of the oxide grains existing in the target is 1.5 μm or less, and when a maximum value of a distance between two arbitrary points on an outer circumference of an oxide grain is defined as a maximum diameter and a minimum value of a distance between two straight lines when the oxide grain is sandwiched with two straight lines that are parallel is defined as a minimum diameter, oxide grains in which the difference between the maximum diameter and the minimum diameter is 0.4 μm or less account for 60% or more on the observed target surface.

Nevertheless, none of these conditions are sufficient, and the current situation is that further improvement is demanded.

[Prior Art Documents]

[Patent Documents]

[0006] [Patent Document 1] Pamphlet of International Publication No. 2011/089760

[Patent Document 2] Japanese Patent Application Publication No. 2009-1860

[Patent Document 3] Japanese Patent Application Publication No. 2009-102707

[Patent Document 4] Japanese Patent Application Publication No. 2009-215617

[Patent Document 5] Japanese Patent Application Publication No. 2011-222086

[Patent Document 6] Pamphlet of International Publication No. 2013/125469

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Summary of the Invention

[Problems to be Solved by the Invention]

[0007] Generally speaking, in a nonmagnetic material grain-dispersed sputtering target containing Co or Fe as its main component, since nonmagnetic materials such as oxides function as insulating materials, they cause abnormal discharge. Furthermore, the abnormal discharge causes the generation of particles during sputtering, which becomes a problem. In particular, when B (boron) is contained and an oxide phase containing coarse B is formed in the structure of the sputtering target, abnormal discharge is generated with B as the source, and the number of particles tends to increase considerably.

[Means for Solving the Problems]

[0008] As a result of intense study in order to resolve the foregoing problems, the present inventors discovered that, in a sputtering target comprising an oxide phase as nonmagnetic material grains, by causing the oxide phase to exist in the structure of the target in the form of a material having a high melting point, it is possible to obtain a target which is capable of preventing the coarsening of the oxide phase, which does not generate abnormal discharge caused by nonmagnetic materials during sputtering, and which is able to limit the generation of particles.

25 [0009] Based on the foregoing discovery, the present inventors provide the following invention:

1) A sputtering target comprising an alloy containing Co or Fe as its main component, and an oxide containing Mn and B, wherein a composition of the sputtering target satisfies a condition of $9 \text{ at\%} \leq \text{Mn} + \text{B} + \text{O} \leq 56 \text{ at\%}$, $\text{B} \leq \text{Mn} \text{ (at\%)}$, $\text{Mn} + \text{B} \leq \text{O} \text{ (at\%)}$.

2) A sputtering target comprising an alloy containing Co or Fe as its main component, and an oxide containing Mn, B and X (wherein X is one or more types of elements selected from Co, Cr, and Si), wherein a composition of the sputtering

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target satisfies a condition of $9 \text{ at\%} \leq \text{Mn} + \text{B} + \text{X} + \text{O} \leq 56 \text{ at\%}$, $\text{B} \leq \text{Mn} + \text{X} \text{ (at\%)}$, $\text{Mn} + \text{X} + \text{B} \leq \text{O} \text{ (at\%)}$.

3) The sputtering target according to 1) or 2) above, wherein, in the composition of the sputtering target, the oxide containing Mn and B or the oxide containing Mn, X and B is each 0.1 mol% or more and 15 mol% or less.

4) The sputtering target according to any one of 1) to 3) above, wherein, in a surface or sectional structure of the sputtering target, when a maximum value of a distance between two arbitrary points on an outer circumference of an oxide grain is defined as a maximum diameter and a minimum value of a distance between two straight lines when the oxide grain is sandwiched with two straight lines that are parallel is defined as a minimum diameter, a ratio of the maximum diameter and the minimum diameter is a numerical value that is greater than 0.5, and an average number of oxide grains having a grain area of $6 \mu\text{m}^2$ or more in a 1 mm^2 visual field is 1 oxide grain or less.

5) The sputtering target according to any one of 1) to 4) above, wherein the sputtering target contains one or more types of elements selected from Pt, Ru, Ag, and Pd in an amount of 1 mol% or more and 50 mol% or less in an alloy component of the sputtering target.

[Effect of the Invention]

The nonmagnetic material grain-dispersed magnetic material sputtering target of the present invention adjusted as described above does not generate abnormal discharge caused by nonmagnetic materials during sputtering, and it is thereby possible to obtain a target which is able to limit the generation of particles. The present invention thereby yields superior effects of being able to obtain a cost improvement effect through improved yield.

Brief Description of the Drawings

Fig. 1 is a diagram (photograph) showing the sectional structure of the sputtering target of Example 1.

Fig. 2 is a diagram (photograph) showing the sectional structure of the sputtering target of Comparative Example 1.

Description of the Embodiment

[0012] The sputtering target of the present invention has a structure in which
5 oxide grains containing Mn and B, as a nonmagnetic material, are dispersed in an alloy containing Co or Fe as its main component, as a ferromagnetic metal. As the alloy containing Co or Fe as its main component, considered may be a ferromagnetic alloy such as a Co-Cr alloy, a Co-Pt alloy, a Co-Cr-Pt alloy, or an Fe-Pt alloy.

10 Oxide grains containing Mn and B, which are contained as the nonmagnetic material, have favorable wettability with the alloy containing Co or Fe as its main component, and are effective for improving the quality of the magnetic recording medium. However, when B_2O_3 is contained as the oxide, there is a problem in that, because its melting point is low, the oxide begins to dissolve during the sintering process, and the oxide grains (phase) become coarsened. The present
15 inventors discovered that, by causing the oxide containing B to be in the form of Mn-B-O as a material having a high melting point, it is possible to prevent the aggregation (coarsening) of oxides in the sputtering target structure, and thereby considerably inhibit abnormal discharge caused by the aggregation of oxides.

[0013] Based on the foregoing discovery, the sputtering target of the present
20 invention is characterized in being a sputtering target comprising an alloy containing Co or Fe, and an oxide containing Mn and B, wherein a composition of the sputtering target satisfies a condition of $9 \text{ at\%} \leq \text{Mn} + \text{B} + \text{O} \leq 56 \text{ at\%}$, $\text{B} \leq \text{Mn (at\%)}$, $\text{Mn} + \text{B} \leq \text{O (at\%)}$.

25 With this sputtering target, when the total content of Mn, B, and O is less than 9 at%, it is not possible to obtain the effect of favorable characteristics of a vertical magnetic recording medium which is yielded as a result of containing Mn, B, and O, and when the total content of Mn, B, and O exceeds 56 at%, the oxide phase made from Mn-B-O will in itself become coarsened. Moreover, when $\text{B} > \text{Mn (at\%)}$, the B oxide begins to dissolve during the sintering process due to the existence of B-
30 O because B will not be limited to the form of Mn-B-O, and the oxide grains (phase) become coarsened. In addition, when $\text{Mn} + \text{B} > \text{O (at\%)}$, the effect of favorable characteristics of a vertical magnetic recording medium cannot be obtained.

[0014] Also in cases of containing X (wherein X is one or more types of

elements selected from Co, Cr, and Si) in addition to Mn in relation to the B oxide, as a result of adopting the form of Mn-Co-B-O, Mn-Cr-B-O, Mn-Si-B-O, Mn-Co-Cr-Si-B-O or the like, it is possible to inhibit the B oxide from dissolving during the sintering process as a result of the melting point becoming higher than that of B_2O_3 , and the abnormal discharge caused by coarse grains during sputtering can be reduced.

Moreover, the composition of the sputtering target satisfies the condition of $9 \text{ at\%} \leq \text{Mn} + \text{X} + \text{B} + \text{O} \leq 56 \text{ at\%}$, $\text{B} \leq \text{Mn} + \text{X} \text{ (at\%)}$, $\text{Mn} + \text{X} + \text{B} \leq \text{O} \text{ (at\%)}$.

In the composition of the sputtering target, when the total content of Mn, X, B, and O is less than 9 at%, it is not possible to obtain the effect of favorable characteristics of a vertical magnetic recording medium which is yielded as a result of containing Mn, X, B, and O, and when the total content of Mn, X, B, and O exceeds 56 at%, the oxide phase made from Mn-X-B-O will in itself become coarsened. Moreover, when $\text{B} > \text{Mn} + \text{X} \text{ (at\%)}$, the B oxide begins to dissolve during the sintering process due to the existence of B-O because B will not be limited to the form of Mn-X-B-O, and the oxide grains (phase) become coarsened. In addition, when $\text{Mn} + \text{X} + \text{B} > \text{O} \text{ (at\%)}$, the effect of favorable characteristics of a vertical magnetic recording medium cannot be obtained.

[0015] Moreover, the present invention also covers the scope of invention in cases of a composition in which B is indicated as a simple substance and not as an oxide. For instance, while B is not added as an oxide in the composition represented as Co-40Pt-2B-2MnO-4CoO (mol%), a reaction of $2\text{B} + 3\text{CoO} \rightarrow \text{B}_2\text{O}_3 + 3\text{Co}$ occurs during the sintering process and forms a B oxide, and this B oxide may begin to dissolve during the sintering process, and cause a swollen structure. In the foregoing case, it is necessary to adjust the composition of the Mn oxide and the X oxide (corresponds to CoO) and the B oxide in the sputtering target so that it satisfies the foregoing conditions by considering the composition to be Co-40Pt-B₂O₃-2MnO-CoO (mol%). Even when B₂O₃ is formed due to oxidation, if the composition of the sputtering target after the oxidation falls within the scope prescribed in the present invention, it will fall within the scope of the present invention.

[0016] The content of the oxide containing Mn and B or the oxide containing Mn, X and B described above is each preferably 0.1 mol% or more and 15 mol% or less in the composition of the sputtering target. If the foregoing oxide content is less than 0.1 mol%, the effect of containing oxide is hardly yielded, and if the foregoing oxide

content exceeds 15 mol%, the oxide content is too great and the intended effect cannot be obtained. Note that, in the form of Mn-Si-B-O, there is a compositional range that becomes a low melting point, even though it is higher than the melting point of B_2O_3 . Thus, the adjacent grains may begin to dissolve during the sintering process and become coarsened. Accordingly, the content of Si oxide is desirably 10 mol% or less, and more desirably 6 mol% or less.

[0017] The sputtering target of the present invention is characterized in that, in a surface or sectional structure of the sputtering target, when a maximum value of a distance between two arbitrary points on an outer circumference of an oxide grain is defined as a maximum diameter and a minimum value of a distance between two straight lines when the oxide grain is sandwiched with two straight lines that are parallel is defined as a minimum diameter, a ratio of the maximum diameter and the minimum diameter is a numerical value that is greater than 0.5, and an average number of oxide grains having a grain area of $6 \mu m^2$ or more in a $1 mm^2$ visual field is 1 oxide grain or less. Note that not all oxide grains in the sputtering target of the present invention satisfy the foregoing ratio; in other words, a ratio of the maximum diameter and the minimum diameter is a numerical value that is greater than 0.5.

As the size in which the B oxide begins to dissolve during the sintering process and the oxide phase becomes coarsened, when the grain area is $6 \mu m^2$ or more, this will have a major influence on the increase in the number of particles. Moreover, when the particles take on a shape in which the oxide grains are elongated and connected, it would be difficult for such particles to fall off and cause abnormal discharge, but when the shape of the oxide grains is close to a circle or circular or a square (that is, when the ratio of the maximum diameter and the minimum diameter is a numerical value that is greater than 0.5), this will have a major influence on the increase in the number of particles.

The structure of the sputtering target was observed by polishing the target surface and using an electron microscope (visual field of $1 mm^2$) to view 5 arbitrary locations. The resulting micrograph was displayed on a PC screen and subject to image analytical processing (binarization processing) to clarify the outline of the oxide grains (black parts), the number of oxide grains of a predetermined size was counted, and the average number of oxide grains was obtained.

[0018] With the sputtering target of the present invention, a Co-based alloy such

as a Co-Cr-based alloy, a Co-Pt-based alloy or a Co-Cr-Pt-based alloy, or an Fe-based alloy such as an Fe-Pt-based alloy is effective as the magnetic metal and, for example, used may be a Co-Pt-based alloy containing Pt in an amount of 1 mol% or more and 50 mol% or less, and the remainder being Co and unavoidable impurities, a Co-Cr-Pt alloy containing Cr in an amount of 10 mol% or more and 50 mol% or less, Pt in an amount of more than 5 mol% and 50 mol% or less, and the remainder being Co and unavoidable impurities, or an Fe-based alloy containing Pt in an amount of more than 1 mol% and 50 mol% or less, and the remainder being Fe and unavoidable impurities. Furthermore, in order to improve the characteristics as a magnetic recording medium, one or more types of elements selected from Pt, Ru, Ag, and Pd are preferably contained in an amount of 1 mol% or more and 50 mol% or less in the alloy component of the sputtering target. These elements are added as needed, and the additive amount thereof is an effective amount for exhibiting the additive effect.

[0019] The sputtering target of the present invention can be produced via powder metallurgy. In the case of powder metallurgy, metal raw material powders of Co, Fe, Pt and the like, nonmagnetic material raw material powders of MnO and the like, and, as needed, additive metal powders of Ag and the like are prepared. The grain size of the raw materials is preferably as follows; specifically, for the metal powders, an average grain size of 10 μm or less, and for the nonmagnetic material powders, 5 μm or less. The closer the shape of the nonmagnetic material raw material powders is to a spherical shape, the easier it is to achieve the fine structure of the present invention. Moreover, the alloy powders of these metals may also be prepared in substitute for the powders of these metal elements. The grain diameter of the powders can be measured using a laser diffraction grain size distribution measuring device.

[0020] What is important in the present invention is to prevent an oxide raw material such as B oxide, which has a low melting point, from dissolving during the sintering process, and prevent the oxide phase from becoming coarsened, and prepare an oxide having a high melting point (MnBO_3 , $\text{Mn}_3\text{B}_2\text{O}_6$ or the like) in advance, and use the prepared oxide as the raw material powder. As the MnBO_3 powder, used may be, for example, a powder that is obtained by mixing, synthesizing and pulverizing a Mn_2O_3 powder and a B_2O_3 powder. However, there

may be cases where the MnBO_3 powder becomes a MnBO_3 powder that is more Mn rich, B rich, or oxygen rich than the stoichiometric ratio. In the foregoing case, it is preferable to analyze the composition of Mn and B of the prepared MnBO_3 powder for each lot that was mixed, synthesized and pulverized, and decide the weight value to attain the predetermined target composition. Moreover, in the foregoing case, it is preferable to use trace amounts of a CoO powder, a Mn powder, a CoB powder or the like for adjustment in order to obtain the intended composition. As the $\text{Mn}_3\text{B}_2\text{O}_6$ powder, used may be, for example, a powder obtained by mixing, synthesizing and pulverizing a MnO powder and a B_2O_3 powder. However, similar to the MnBO_3 powder, since there may be cases where the $\text{Mn}_3\text{B}_2\text{O}_6$ powder becomes a $\text{Mn}_3\text{B}_2\text{O}_6$ powder that is more Mn rich, B rich, or oxygen rich than the stoichiometric ratio, it is preferable to analyze the composition of Mn and B of the prepared $\text{Mn}_3\text{B}_2\text{O}_6$ powder for each lot that was mixed, synthesized and pulverized, and decide the weight value to attain the predetermined target composition. Moreover, in the foregoing case, it is preferable to use trace amounts of a CoO powder, a Mn powder, a CoB powder or the like for adjustment in order to obtain the intended composition. Subsequently, these metal powders and nonmagnetic material raw material powders are weighed to achieve the intended composition, and pulverized and mixed using known means such as a ball mill. A high energy ball mill is preferably used in order to shorten the mixing time and improve the productivity.

[0021] The thus obtained mixed powder is sintered via hot press or hot isostatic pressing. While this also depends on the component composition of the target, by discovering the mixing conditions and sintering conditions of the foregoing raw materials which can sufficiently increase the density and finely disperse the nonmagnetic material grains in the metal phase and constantly applying such conditions as the manufacturing conditions, it will be possible to constantly obtain such a sintered compact with nonmagnetic material grains dispersed therein.

[Examples]

[0022] 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.

[0023] (Example 1)

As metal raw material powders, a Co powder having an average grain size of 4 μm and a Pt powder having an average grain size of 3 μm were prepared, and as nonmagnetic material powders, a Cr_2O_3 powder having an average grain size of 1 μm , a MnBO_3 powder having an average grain size of 1.2 μm , a SiO_2 powder having an average grain size of 0.7 μm , and a CoO powder having an average grain size of 2 μm were prepared. The MnBO_3 powder was obtained by mixing, synthesizing and pulverizing a Mn_2O_3 powder and a B_2O_3 powder in advance. These powders were weighed to attain 1500 g based on the following composition ratio.

Composition (mol%): $\text{Co-20Pt-2B}_2\text{O}_3\text{-2CoO-2Cr}_2\text{O}_3\text{-4MnO-SiO}_2$

Note that the composition of these oxide components was as follows; namely, Mn: 3.2 at%, Co: 1.6 at% and Cr: 3.2 at% and Si: 0.8 at% as X; B: 3.2 at% and O: 16.1 at%.

Next, the weighed powders were sealed in a ball mill pot having a capacity of 10 liters together with tungsten alloy balls as the pulverizing medium, and mixed by rotating the ball mill pot for 120 hours. The thus obtained mixed powder was filled in a carbon mold, and hot pressed under the following conditions; namely, in a vacuum atmosphere at a temperature of 980°C, holding time of 2 hours, and applied pressure of 30 MPa to obtain a sintered compact. The obtained sintered compact was further subject to cutting work with a lathe to obtain a disk-shaped sputtering target having a diameter of 180 mm and a thickness of 4 mm.

The surface of the obtained target was polished and, as a result of observing 5 arbitrary locations using an electron microscope, in a 1 mm^2 visual field, the ratio of the maximum diameter and the minimum diameter was a numerical value that is greater than 0.5 and the average number of oxide grains having a grain area of 6 μm^2 or more was 0.5 oxide grains or less. Note that the maximum diameter, minimum diameter, and grain area of the oxide grains were calculated upon displaying a micrograph on a PC screen as shown in Fig. 1 and performing image analytical processing (binarization processing), and clarifying the outline of the oxide grains (black parts).

Subsequently, the obtained target was mounted on a DC magnetron sputtering device and then sputtered. The sputtering conditions were as follows;

namely, sputter power of 1.2 kW and Ar gas pressure of 1.5 Pa and, after performing pre-sputtering for 2 kWhr, a film was sputtered on a silicon substrate having a 4-inch diameter at a target film thickness of 1000 nm. The number of particles that adhered to the substrate was thereafter measured using a particle counter. The number of particles on the silicon substrate in this case was 7. Note that, even in cases where sputtering is not performed, there are cases where the number of particles on the silicon substrate is counted as 4 to 6 particles when measured using a particle counter, so it could be said that the number of particles (7 particles) of this Example is an extremely low level.

10 [0027] (Comparative Example 1)

As metal raw material powders, a Co powder having an average grain size of 4 μm and a Pt powder having an average grain size of 3 μm were prepared, and as nonmagnetic material powder, a Cr_2O_3 powder having an average grain size of 1 μm , a B_2O_3 powder having an average grain size of 2 μm , a MnO powder having an average grain size of 1.2 μm , and a SiO_2 powder having an average grain size of 0.7 μm were prepared. These powders were weighed to attain 1500 g based on the following composition ratio.

Composition (mol%): Co-20Pt-5 B_2O_3 - Cr_2O_3 -3MnO- SiO_2

Note that the composition of these oxide components was as follows; namely, Mn: 2.3 at%, Cr: 1.6 at% and Si: 0.8 at% as X; B: 7.8 at%, and O: 17.8 at%.

[0028] Next, the weighed powders were sealed in a ball mill pot having a capacity of 10 liters together with tungsten alloy balls as the pulverizing medium, and mixed by rotating the ball mill pot for 120 hours. The thus obtained mixed powder was filled in a carbon mold, and hot pressed under the same conditions as Example 1; namely, in a vacuum atmosphere at a temperature of 980°C, holding time of 2 hours, and applied pressure of 30 MPa to obtain a sintered compact. The obtained sintered compact was further subject to cutting work with a lathe to obtain a disk-shaped sputtering target having a diameter of 180 mm and a thickness of 4 mm.

[0029] The surface of the obtained target was polished and, as a result of observing 5 arbitrary locations using an electron microscope, in a 1 mm^2 visual field, the ratio of the maximum diameter and the minimum diameter was a numerical value that is greater than 0.5 and the average number of oxide grains having a grain area of 6 μm^2 or more was 3.0 oxide grains or less. Note that the maximum diameter,

minimum diameter, and grain area of the oxide grains were calculated according to the same method as Example 1.

[0030] Subsequently, the obtained target was mounted on a DC magnetron sputtering device and then sputtered. The sputtering conditions were as follows; namely, sputter power of 1.2 kW and Ar gas pressure of 1.5 Pa and, after performing pre-sputtering for 2 kWhr, a film was sputtered on a silicon substrate having a 4-inch diameter at a target film thickness of 1000 nm. The number of particles that adhered to the substrate was thereafter measured using a particle counter. The number of particles on the silicon substrate in this case was 35.

10 [0031] (Example 2)

As metal raw material powders, a Co powder having an average grain size of 4 μm , a Pt powder having an average grain size of 3 μm , a Ru powder having an average grain size of 5 μm and a Mn powder having an average grain size of 4 μm were prepared, and as nonmagnetic material powders, a CrBO_3 powder having an average grain size of 1 μm , a MnBO_3 powder having an average grain size of 1.2 μm , and a TiO_2 powder having an average grain size of 1 μm were prepared. The MnBO_3 powder was obtained by mixing, synthesizing and pulverizing a Mn_2O_3 powder and a B_2O_3 powder in advance. The CrBO_3 powder was also obtained in the same manner. Note that a Mn powder and a Cr powder were also used in trace amounts for adjusting the oxygen content pursuant to the use of the MnBO_3 powder and the CrBO_3 powder. These powders were weighed to attain 1500 g based on the following composition ratio.

Composition (mol%): Co-22Pt-5Ru-4 B_2O_3 -3 Cr_2O_3 -3MnO-TiO₂

Note that the composition of these oxide components was as follows; namely, Mn: 2.3 at%; Cr: 4.5 at% as X; B: 6.0 at%; and O: 19.6 at%. Note that the composition of Ti has been omitted.

[0032] Next, the weighed powders were sealed in a ball mill pot having a capacity of 10 liters together with tungsten alloy balls as the pulverizing medium, and mixed by rotating the ball mill pot for 120 hours. The thus obtained mixed powder was filled in a carbon mold, and hot pressed under the same conditions as Example 1; namely, in a vacuum atmosphere at a temperature of 980°C, holding time of 2 hours, and applied pressure of 30 MPa to obtain a sintered compact. The obtained sintered compact was further subject to cutting work with a lathe to obtain a disk-

shaped sputtering target having a diameter of 180 mm and a thickness of 4 mm.

[0033] The surface of the obtained target was polished and, as a result of observing 5 arbitrary locations using an electron microscope, in a 1 mm² visual field, the ratio of the maximum diameter and the minimum diameter was a numerical value that is greater than 0.5 and the average number of oxide grains having a grain area of 6 μm² or more was 0.8 oxide grains or less. Note that the maximum diameter, minimum diameter, and grain area of the oxide grains were calculated according to the same method as Example 1.

[0034] Subsequently, the obtained target was mounted on a DC magnetron sputtering device and then sputtered. The sputtering conditions were as follows; namely, sputter power of 1.2 kW and Ar gas pressure of 1.5 Pa and, after performing pre-sputtering for 2 kWhr, a film was sputtered on a silicon substrate having a 4-inch diameter at a target film thickness of 1000 nm. The number of particles that adhered to the substrate was thereafter measured using a particle counter. The number of particles on the silicon substrate in this case was 9.

[0035] (Example 3)

As metal raw material powders, an Fe powder having an average grain size of 4 μm, a Pt powder having an average grain size of 3 μm, and a Ag powder having an average grain size of 5 μm were prepared, and as nonmagnetic material powders, a MnBO₃ powder having an average grain size of 1.2 μm, and a SiO₂ powder having an average grain size of 0.7 μm were prepared. The MnBO₃ powder was obtained by mixing, synthesizing and pulverizing a Mn₂O₃ powder and a B₂O₃ powder in advance. These powders were weighed to attain 1500 g based on the following composition ratio.

Composition (mol%): Fe-42Pt-3Ag-B₂O₃-2MnO-7SiO₂

Note that the composition of these oxide components was as follows; namely, Mn: 1.7 at%; Si: 5.8 at% as X; B: 1.7 at%; and O: 15.8 at%.

[0036] Next, the weighed powders were sealed in a ball mill pot having a capacity of 10 liters together with tungsten alloy balls as the pulverizing medium, and mixed by rotating the ball mill pot for 120 hours. The thus obtained mixed powder was filled in a carbon mold, and hot pressed under the same conditions as Example 1; namely, in a vacuum atmosphere at a temperature of 980°C, holding time of 2 hours, and applied pressure of 30 MPa to obtain a sintered compact. The obtained

sintered compact was further subject to cutting work with a lathe to obtain a disk-shaped sputtering target having a diameter of 180 mm and a thickness of 4 mm.

[0037] The surface of the obtained target was polished and, as a result of observing 5 arbitrary locations using an electron microscope, in a 1 mm² visual field, the ratio of the maximum diameter and the minimum diameter was a numerical value that is greater than 0.5 and the average number of oxide grains having a grain area of 6 μm² or more was 1.0 oxide grains or less. Note that the maximum diameter, minimum diameter, and grain area of the oxide grains were calculated according to the same method as Example 1.

10 [0038] Subsequently, the obtained target was mounted on a DC magnetron sputtering device and then sputtered. The sputtering conditions were as follows; namely, sputter power of 1.2 kW and Ar gas pressure of 1.5 Pa and, after performing pre-sputtering for 2 kWhr, a film was sputtered on a silicon substrate having a 4-inch diameter at a target film thickness of 1000 nm. The number of particles that adhered to the substrate was thereafter measured using a particle counter. The number of particles on the silicon substrate in this case was 11.

[0039] (Example 4)

As metal raw material powders, a Co powder having an average grain size of 4 μm, a Pt powder having an average grain size of 3 μm, and a Pd powder having an average grain size of 5 μm were prepared, and as nonmagnetic material powders, a MnBO₃ powder having an average grain size of 1.2 μm, and a Co₃O₄ powder having an average grain size of 2 μm were prepared. The MnBO₃ powder was obtained by mixing, synthesizing and pulverizing a Mn₂O₃ powder and a B₂O₃ powder in advance. These powders were weighed to attain 1500 g based on the following composition ratio.

Composition (mol%): Co-38Pt-2Pd-B₂O₃-Mn₂O₃-3Co₃O₄

Note that the composition of these oxide components was as follows; namely, Mn: 1.6 at%; Co: 7.1 at% as X; B: 1.6 at%; and O: 14.3 at%.

[0040] Next, the weighed powders were sealed in a ball mill pot having a capacity of 10 liters together with tungsten alloy balls as the pulverizing medium, and mixed by rotating the ball mill pot for 120 hours. The thus obtained mixed powder was filled in a carbon mold, and hot pressed under the same conditions as Example 1; namely, in a vacuum atmosphere at a temperature of 980°C, holding time of 2

hours, and applied pressure of 30 MPa to obtain a sintered compact. The obtained sintered compact was further subject to cutting work with a lathe to obtain a disk-shaped sputtering target having a diameter of 180 mm and a thickness of 4 mm.

[0041] The surface of the obtained target was polished and, as a result of observing 5 arbitrary locations using an electron microscope, in a 1 mm² visual field, the ratio of the maximum diameter and the minimum diameter was a numerical value that is greater than 0.5 and the average number of oxide grains having a grain area of 6 μm² or more was 1.0 oxide grains or less. Note that the maximum diameter, minimum diameter, and grain area of the oxide grains were calculated according to the same method as Example 1.

[0042] Subsequently, the obtained target was mounted on a DC magnetron sputtering device and then sputtered. The sputtering conditions were as follows; namely, sputter power of 1.2 kW and Ar gas pressure of 1.5 Pa and, after performing pre-sputtering for 2 kWhr, a film was sputtered on a silicon substrate having a 4-inch diameter at a target film thickness of 1000 nm. The number of particles that adhered to the substrate was thereafter measured using a particle counter. The number of particles on the silicon substrate in this case was 8.

[0043] (Example 5)

As metal raw material powders, a Co powder having an average grain size of 4 μm, and a Pt powder having an average grain size of 3 μm were prepared, and as nonmagnetic material powders, a Mn₃B₂O₆ powder having an average grain size of 2.4 μm, a SiO₂ powder having an average grain size of 2 μm, and a CoO powder having an average grain size of 2 μm were prepared. The Mn₃B₂O₆ powder was obtained by mixing, synthesizing and pulverizing a MnO powder and a B₂O₃ powder in advance. These powders were weighed to attain 1500 g based on the following composition ratio.

Composition (mol%): Co-15Pt-3MnO-1B₂O₃-2SiO₂-4CoO

Note that the composition of these oxide components was as follows; namely, Mn: 2.6 at%; Co: 3.5 at% as X; B: 1.7 at%; and O: 12.2 at%.

[0044] Next, the weighed powders were sealed in a ball mill pot having a capacity of 10 liters together with tungsten alloy balls as the pulverizing medium, and mixed by rotating the ball mill pot for 120 hours. The thus obtained mixed powder was filled in a carbon mold, and hot pressed under the same conditions as Example

1; namely, in a vacuum atmosphere at a temperature of 980°C, holding time of 2 hours, and applied pressure of 30 MPa to obtain a sintered compact. The obtained sintered compact was further subject to cutting work with a lathe to obtain a disk-shaped sputtering target having a diameter of 180 mm and a thickness of 4 mm.

5 [0045] The surface of the obtained target was polished and, as a result of observing 5 arbitrary locations using an electron microscope, in a 1 mm² visual field, the ratio of the maximum diameter and the minimum diameter was a numerical value that is greater than 0.5 and the average number of oxide grains having a grain area of 6 μm² or more was 0.8 oxide grains or less. Note that the maximum diameter, 10 minimum diameter, and grain area of the oxide grains were calculated according to the same method as Example 1.

[0046] Subsequently, the obtained target was mounted on a DC magnetron sputtering device and then sputtered. The sputtering conditions were as follows; namely, sputter power of 1.2 kW and Ar gas pressure of 1.5 Pa and, after performing 15 pre-sputtering for 2 kWhr, a film was sputtered on a silicon substrate having a 4-inch diameter at a target film thickness of 1000 nm. The number of particles that adhered to the substrate was thereafter measured using a particle counter. The number of particles on the silicon substrate in this case was 7.

20 [0047]

[Table 1]

	Composition	Mn (at%)	X (at%)	Mn+X (at%)	B (at%)	Mn+(X)+B (at%)	O (at%)	Average Number of Prescribed-Size Oxide Grains	Number of Particles
Example 1	Co-20Pt-2B ₂ O ₃ -2CoO-2Cr ₂ O ₃ -4MnO-SiO ₂ (mol%)	3.2	5.6	8.8	3.2	12.0	16.1	0.5	7
Comparative Example 1	Co-20Pt-5B ₂ O ₃ -Cr ₂ O ₃ -3MnO-SiO ₂ (mol%)	2.3	2.4	4.7	7.8	12.5	17.8	3.0	35
Example 2	Co-22Pt-5Ru-4B ₂ O ₃ -3Cr ₂ O ₃ -3MnO-TiO ₂ (mol%)	2.3	4.5	6.8	6.0	12.8	19.6	0.8	9
Example 3	Fe-42Pt-3Ag-B ₂ O ₃ -2MnO-7SiO ₂ (mol%)	1.7	5.8	7.5	1.7	9.2	15.8	1.0	11
Example 4	Co-38Pt-2Pd-B ₂ O ₃ -Mn ₂ O ₃ -3Co ₃ O ₄ (mol%)	1.6	7.1	8.7	1.6	10.3	14.3	1.0	8
Example 5	Co-15Pt-3MnO-B ₂ O ₃ -2SiO ₂ -4CoO (mol%)	2.6	3.5	6.1	1.7	7.8	12.2	0.8	7

[Industrial Applicability]

[0048] The present invention can inhibit abnormal discharge caused by nonmagnetic materials during sputtering by suppressing the aggregation (coarsening) of the oxide phase. According to the present invention, since it is possible to yield superior effects of reducing the generation of particles during sputtering caused by abnormal discharge and obtain a cost improvement effect through improved yield, the present invention is effective as a ferromagnetic material sputtering target for use in depositing a magnetic thin film of a magnetic recording medium, particularly for the deposition of a hard disk drive recording layer.

CLAIMS

[Claim 1] A sputtering target comprising an alloy containing Co or Fe, and an oxide containing Mn and B, wherein a composition of the sputtering target satisfies a condition of $9 \text{ at\%} \leq \text{Mn} + \text{B} + \text{O} \leq 56 \text{ at\%}$, $\text{B} \leq \text{Mn} \text{ (at\%)}$, $\text{Mn} + \text{B} \leq \text{O} \text{ (at\%)}$.

[Claim 2] A sputtering target comprising an alloy containing Co or Fe as its main component, and an oxide containing Mn, B and X (wherein X is one or more types of elements selected from Co, Cr, and Si), wherein a composition of the sputtering target satisfies a condition of $9 \text{ (at\%)} \leq \text{Mn} + \text{B} + \text{X} + \text{O} \leq 56 \text{ (at\%)}$, $\text{B} \leq \text{Mn} + \text{X} \text{ (at\%)}$, $\text{Mn} + \text{X} + \text{B} \leq \text{O} \text{ (at\%)}$.

[Claim 3] The sputtering target according to claim 1 or claim 2, wherein, in the composition of the sputtering target, the oxide containing Mn and B or the oxide containing Mn, X and B is each 0.1 mol% or more and 15 mol% or less.

[Claim 4] The sputtering target according to any one of claims 1 to 3, wherein, in a surface or sectional structure of the sputtering target, when a maximum value of a distance between two arbitrary points on an outer circumference of an oxide grain is defined as a maximum diameter and a minimum value of a distance between two straight lines when the oxide grain is sandwiched with two straight lines that are parallel is defined as a minimum diameter, a ratio of the maximum diameter and the minimum diameter is a numerical value that is greater than 0.5, and an average number of oxide grains having a grain area of $6 \mu\text{m}^2$ or more in a 1 mm^2 visual field is 1 oxide grain or less.

[Claim 5] The sputtering target according to any one of claims 1 to 4, wherein the sputtering target contains one or more types of elements selected from Pt, Ru, Ag, and Pd in an amount of 1 mol% or more and 50 mol% or less in an alloy component of the sputtering target.