

## DESCRIPTION

### SPUTTERING TARGET FOR MAGNETIC RECORDING MEDIUM, AND MAGNETIC THIN FILM

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#### TECHNICAL FIELD

[0001]

The present invention generally relates to a sputtering target suitable for forming a magnetic thin film in a magnetic recording medium, and in particular relates to a sputtering target having a structure in which oxide grains are dispersed in a metal phase having Co as its main component.

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#### BACKGROUND ART

15 [0002]

In the field of magnetic recording as represented with hard disk drives, a vertical magnetic recording system, in which the easy axis of magnetization is aligned in a vertical direction relative to the recording surface, has been put into practical application. In particular, with a hard disk medium adopting the vertical magnetic recording system, in order to achieve higher recording density and reduce noise, a granular structured-type magnetic thin film in which magnetic crystal grains aligned in a vertical direction are surrounded with non-magnetic materials, and the magnetic interaction between the magnetic grains is reduced, has been developed.

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[0003]

A ferromagnetic alloy having Co as its main component is used as the foregoing magnetic crystal grains, and an oxide is used as the non-magnetic material. This kind of granular structured-type magnetic thin film is prepared by sputtering a sputtering target, which has a structure in which oxide grains are dispersed in a metal phase, on a substrate by using a magnetron sputtering device.

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30 [0004]

However, in the sputter process, attachments referred to as particles which adhere to the substrate on which a thin film is formed are a problem. Many of the particles that are generated during deposition are known to be the oxides in the target. There are cases where an abnormal discharge is generated on the sputter surface of

the target during the sputtering process and the oxides drop off from the sputter surface of the target, the cause thereof is considered to be the generation of these particles.

[0005]

- 5 Various technologies are known in relation to sputtering targets having a structure in which oxide grains are dispersed in a metal phase, and production methods thereof (for instance, Patent Documents 1 to 7). For example, Patent Document 1 discloses a method of refining the target structure and reducing the generation of particles by mixing, upon mixing and pulverizing raw material powders
- 10 with a ball mill or the like, a primary sintered body powder obtained by mixing, sintering and pulverizing a part of the raw material powders in advance, and thereby suppressing the aggregation of oxide grains.

## CITATION LIST

### 15 PATENT DOCUMENTS

[0006]

[Patent Document 1] Japanese Unexamined Patent Application Publication No. 2011-208169

- [Patent Document 2] Japanese Unexamined Patent Application Publication No. 2011-174174
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[Patent Document 3] Japanese Unexamined Patent Application Publication No. 2011-175725

[Patent Document 4] Japanese Unexamined Patent Application Publication No. 2012-117147

- 25 [Patent Document 5] Japanese Patent No. 4885333

[Patent Document 6] WO. 2012/086388

[Patent Document 7] WO. 2015/064761

## SUMMARY OF INVENTION

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### TECHNICAL PROBLEM

[0007]

Generally speaking, when producing a sputtering target in which oxide grains are dispersed in a metal phase, sometimes oxides become aggregated, and

sometimes the aggregated oxides cause the generation of particles during the sputtering process. The foregoing conventional technologies dispersed the oxide grains finely in the metal phase in order to suppress the generation of particles.

[0008] Nevertheless, depending on the type of oxide, the oxide would still cause the generation of particles even when it is dispersed finely. Moreover, because the floating quantity of the magnetic head becomes smaller pursuant to the increase in the recording density of the hard disk drive, the size and number of particles permitted in a magnetic recording medium are becoming more strictly restricted in comparison to conventional technologies.

[0009]

An object of the present invention is to provide a sputtering target for a magnetic recording medium capable of considerably reducing the particles that are generated during the sputtering process in light of the foregoing problems. It is thereby possible to deposit a quality magnetic recording layer, and improve the yield of a magnetic recording medium and so on.

## SOLUTION TO PROBLEM

[0010]

In order to achieve the foregoing object, as a result of intense study, the present inventors discovered that, by adding oxides having low viscosity, it is possible to increase the adhesion of the metal phase and the oxide phase in the target, suppress the oxides from dropping off during the sputtering process, and considerably decrease the generation of particles.

[0011]

Based on the foregoing discovery, the present inventors provide the following invention.

1) A sputtering target containing 0.1 to 10 mol% of an oxide of one or more types of elements selected from Ca, K, Na, Pb, and Zn, 45 mol% or less of Cr, 45 mol% or less of Pt, and remainder being Co.

2) The sputtering target according to 1) above, wherein the sputtering target contains 1 to 20 mol% of an oxide of one or more types of elements selected from Co, Cr, Si, and Ti.

3) The sputtering target according to 1) or 2) above, wherein the sputtering target contains 1 to 30 mol% of one or more types of elements selected from Au, Ag, B, Cu, Ga, Ge, Ir, Mn, Mo, Nb, Ni, Pd, Re, Rh, Ru, Sn, Ta, W, V, and Zn.

4) The sputtering target according to any one of 1) to 3) above, wherein an average area per oxide grain is 0.1 to 20  $\mu\text{m}^2$ .

5) A film containing 0.1 to 10 mol% of an oxide of one or more types of elements selected from Ca, K, Na, Pb, and Zn, 45 mol% or less of Cr, 45 mol% or less of Pt, and remainder being Co.

6) The film according to 5) above, wherein the film contains 1 to 20 mol% of an oxide of one or more types of elements selected from Co, Cr, Si, and Ti.

7) The film according to 5) or 6) above, wherein the film contains 1 to 30 mol% of one or more types of elements selected from Au, Ag, B, Cu, Ga, Ge, Ir, Mn, Mo, Nb, Ni, Pd, Re, Rh, Ru, Sn, Ta, W, V, and Zn.

## ADVANTAGEOUS EFFECTS OF INVENTION

[0012]

The sputtering target of the present invention yields a superior effect of being able to reduce the amount of particles generated during the sputtering process, and improve the yield during deposition. Moreover, in a magnetic thin film deposited via sputtering, improvement of device characteristics can be expected because it becomes easier to form a grain boundary of a non-magnetic phase so as to surround the magnetic grains.

## BRIEF DESCRIPTION OF DRAWINGS

[0013]

[Fig. 1] Fig. 1 is a schematic diagram showing the observed points of the oxide phase in the sputtering target of the present invention.

## DESCRIPTION OF EMBODIMENTS

[0014]

The present invention is characterized in that, by adding a material (low-viscosity oxide) capable of lowering the viscosity of the oxide phase in a sintered sputtering target configured from a metal phase having Co as its main component constituting a magnetic phase and an oxide phase constituting a non-magnetic phase, it is possible to improve the adhesion of the metal phase and the oxide phase in the sputtering target, and considerably reduce the generation of particles during the sputtering process caused by the oxides dropping off from the sputtering target and the like.

[0015]

As a material (low-viscosity oxide) capable of reducing the viscosity of the oxide phase, preferably used is an oxide containing one or more types selected from Ca, K, Na, Pb, and Zn as its structural component. As a result of simulation, with an oxide phase which is configured only from  $\text{SiO}_2$ , the viscosity at  $1000^\circ\text{C}$  is  $8.1 \times 10^{14}$  poise, but when  $\text{CaO}$  is added thereto, the viscosity decreased to  $3.3 \times 10^7$  poise. Similarly, in cases where  $\text{K}_2\text{O}$ ,  $\text{Na}_2\text{O}$ ,  $\text{PbO}$ , and  $\text{ZnO}$  were added, it was confirmed that the viscosity in each of the cases respectively decreased to  $5.6 \times 10^5$ ,  $2.4 \times 10^5$ ,  $4.5 \times 10^5$ , and  $6.8 \times 10^{10}$  poise.

[0016]

Low-viscosity oxides containing one or more types selected from Ca, K, Na, Pb, and Zn as its structural component are preferably added in a total amount of 0.1 mol% or more and 10 mol% or less in the target. When the amount of low-viscosity oxides is less than 0.1 mol%, it is difficult to yield the effect of improving adhesion, and when the amount of low-viscosity oxides exceeds 10 mol%, it may not be possible to obtain the intended magnetic properties. Furthermore, in order to improve the adhesion, the amount of these oxides is more preferably 0.1 mol% or more and 5 mol% or less. Moreover, in order to improve magnetic properties, other oxides may also be included.

[0017]

As the magnetic phase in a sputtering target of the present invention, a metal having a composition containing in the least Co may be used. Specifically, a metal containing only Co, or a metal containing 0.1 mol% or more and 45 mol% or less of Pt and remainder being Co, or a metal containing 0.1 mol% or more and 45 mol% or less of Cr, 0.1 mol% or more and 45 mol% or less of Pt, and remainder being Co may be used. Moreover, in order to improve magnetic properties, other metals may also be included.

[0018]

So as long as the magnetic phase is able to obtain sufficient properties as a magnetic thin film, the composition may be suitably adjusted within the foregoing range. Note that the unavoidable impurities included in the sputtering target will never yield a significant change in the adhesion of the metal and the oxide. Accordingly, whether or not the sputtering target satisfies the composition range of the present invention may be considered irrespective of the inclusion of such unavoidable

impurities.

[0019]

The sputtering target of the present invention preferably contains, as a non-magnetic phase, an oxide of one or more types of elements selected from Co, Cr, Si, and Ti. With a standard vertical magnetic recording film, an oxide of one or more types of elements selected from Co, Cr, Si, and Ti is contained as a non-magnetic phase, and the functions as a vertical magnetic recording film are exhibited by forming a grain boundary of an oxide phase, which is a non-magnetic phase, so as to surround the metal grains, which are a magnetic phase, in a magnetic thin film which is deposited via sputtering. By adding the foregoing oxide which reduces the viscosity to the oxide phase containing the foregoing oxides, the grain boundary of a non-magnetic phase will become more adhered to the magnetic grains, and improvement in the device characteristics can thereby be expected.

[0020]

Moreover, the sputtering target of the present invention preferably contains a non-magnetic material, which includes the foregoing oxides (including low-viscosity oxides), in an amount of 10% or higher and less than 55%, in terms of volume ratio, in the target. As a result of containing a non-magnetic material in an amount of 10% or higher and less than 55%, in terms of volume ratio, the magnetic properties of the deposited magnetic thin film can be made even more favorable. By causing the volume ratio of the non-magnetic material to be 10% or higher, it is possible to increase the effect of the oxides blocking the magnetic interaction of the magnetic grains, and, by causing the volume ratio of the non-magnetic material to be less than 55%, the dispersibility of the non-magnetic material can be improved.

[0021]

The sputtering target of the present invention may additionally contain, as a magnetic phase, one or more types of elements selected from Au, Ag, B, Cu, Ga, Ge, Ir, Mn, Mo, Nb, Ni, Pd, Re, Rh, Ru, Sn, Ta, W, V, and Zn in the target in an amount of 1 mol% or more and 30 mol% or less. It is thereby possible to improve the magnetic properties of the magnetic thin film. Note that, while these metals are mainly included in the metal phase, in certain cases some of these metals may be included in the oxide phase as a result of becoming oxidized during the sintering process.

[0022]

In the structure of the sputtering target of the present invention, the average

area per oxide grain in the metal magnetic phase (matrix) is preferably within a range of 0.1 to 20  $\mu\text{m}^2$ . It is thereby possible to reduce the generation of particles caused by the oxides during the sputtering process. The oxide grains not only contain low-viscosity oxides, they also contain other oxides. When the average area per oxide grain is greater than 20  $\mu\text{m}^2$ , coarse grains of metal oxides may become the origin of arcing during the sputtering process, which may in turn increase the particles. Meanwhile, when the average area per oxide grain is smaller than 0.1  $\mu\text{m}^2$ , it is necessary to pulverize the raw material powders to realize the foregoing structure, and there is a problem in that the production process becomes complicated. The average area per oxide grain is obtained by observing 5 in-plane points as shown in Fig. 1 and taking the average thereof in order to reduce variations depending on the observed points.

[0023]

The method of measuring oxide grains and the method of calculating the average area in the Examples and Comparative Examples are now explained in detail.

(Method of measuring oxide grains)

Device: Color 3D laser microscope VK-9700 manufactured by Keyence

Software: VK Analyzer (included with the device)

(Method of obtaining average area of oxide grains)

In measuring the oxide grains, an enlarged image taken with the foregoing laser microscope is used. A laser microscope image of a structure in which oxide grains are disposed in a metal component is able to clearly differentiate the boundary of the metal part and the oxide part based on the contrast difference between the two.

The average area of the oxide grains surrounded by the boundary is calculated with the foregoing software.

Specifically, as shown in Fig. 1, a structure image of 5 in-plane points of the sintered body (sputtering target) (1 center point, 1 arbitrary point that is 30 mm inside from the outer periphery, and 3 points obtained by rotating the foregoing point at 90°, 180°, and 270° with the center of the target as the center of rotation) is observed in a visual field of 72  $\mu\text{m} \times 96 \mu\text{m}$ .

Subsequently, the obtained structure images are converted into binarized images. The threshold upon performing the binarization is set between the color tone differences at the boundary of the metal phase and the oxide grains. While the color

tone differences at the boundary of the metal phase and the oxide grains in a laser microscope image, in which oxide grains are dispersed in a metal phase (matrix), is normally evident, in certain cases the sharpness of separation of the two can be improved by concurrently using processes such as the discriminant analysis method and the differential histogram method.

In the binarized image of each structure image, the oxide grains that are in contact with the edge of the image are excluded from the software calculation at this stage in order to prevent the average area of the oxide grains in each structure image from being undercalculated. Next, the average value of the area of oxide grains in each structure image is calculated. The average of 5 points is thereafter taken regarding the area of oxide grains in each of the observed points, and used as the average area per oxide grain.

[0024]

The thin film that is prepared using the sputtering target of the present invention is characterized in containing 0.1 to 10 mol% of an oxide of one or more types of elements selected from Ca, K, Na, Pb, and Zn, 45 mol% or less of Cr, 45 mol% or less of Pt, and remainder being Co. Moreover, the film is further characterized in containing 1 to 20 mol% of an oxide of one or more types of elements selected from Co, Cr, Si, and Ti in addition to the foregoing component composition. Furthermore, the film is further characterized in containing 1 to 30 mol% of one or more types of elements selected from Au, Ag, B, Cu, Ga, Ge, Ir, Mn, Mo, Nb, Ni, Pd, Re, Rh, Ru, Sn, Ta, W, V, and Zn in addition to the foregoing component composition. By adding the foregoing low-viscosity oxides, the grain boundary of the non-magnetic phase will become more adhered to the magnetic grains, and improvement in the device characteristics can also be expected.

[0025]

The sputtering target of the present invention can be prepared by adopting the powder sintering method, for instance, via the following process. Foremost, a Co powder, a Pt powder, and a Cr powder are prepared as the metal powders, and metal powders of Au, Ag, B, and Cu described above may also be prepared as needed. As the metal powders, alloy powders may also be used in addition to the metal powders of single elements. The grain size of these metal powders is desirably within a range of 1 to 10  $\mu\text{m}$ . When the grain size is 1 to 10  $\mu\text{m}$ , more uniform mixing is possible, and segregation and coarse crystallization can be prevented. When the grain size of the

metal powders is greater than 10  $\mu\text{m}$ , there are cases where the oxide grains are not dispersed uniformly. Meanwhile, when the grain size of the metal powders is smaller than 1  $\mu\text{m}$ , there are problems in that the composition of the target may deviate from the intended composition due to the influence of oxidation of the metal powders.

5 Nevertheless, this grain size range is merely a preferred range, and it should be naturally understood that any deviation from the foregoing range is not a condition that denies the present invention.

[0026]

10 A CaO powder, a  $\text{K}_2\text{O}$  powder, a  $\text{Na}_2\text{O}$  powder, a PbO powder, and a ZnO powder are prepared as the oxide powders, and oxide powders of such as  $\text{Co}_2\text{O}_3$ ,  $\text{Cr}_2\text{O}_3$ ,  $\text{SiO}_2$ , and  $\text{TiO}_2$  described above are also prepared. The grain size of the oxide powders is preferably within a range of 1 to 30  $\mu\text{m}$ . When the grain size is 1 to 30  $\mu\text{m}$ , it becomes more difficult for the oxide powders to become aggregated when mixed with the foregoing metal powders, and the oxide powders can be more uniformly  
15 dispersed. Meanwhile, when the grain size of the oxide powders is greater than 30  $\mu\text{m}$ , there are cases where coarse oxide grains are generated after the sintering process, and, when the grain size of the oxide grains is smaller than 1  $\mu\text{m}$ , the oxide powders tend to become aggregated. Nevertheless, this grain size range is merely a preferred range, and it should be naturally understood that any deviation from the foregoing  
20 range is not a condition that denies the present invention.

[0027]

Subsequently, the foregoing raw material powders are weighed to achieve the intended composition, and mixed and pulverized using a known means such as a ball mill. Here, it is desirable to seal inert gas in the pulverization vessel to suppress  
25 oxidation of the raw material powders as much as possible.

Next, the thus obtained mixed powder is molded and sintered via the hot press method in a vacuum atmosphere or an inert gas atmosphere. Moreover, in addition to the hot press method, various other pressing sintering methods, such as the plasma discharge sintering method, may also be used. In particular, the hot isostatic sintering  
30 method is effective for improving the density of the sintered body. While this also depends on the structural components of the target, the holding temperature during the sintering process is often set to be within a temperature range of 700 to 1500°C.

By machining the thus obtained sintered body into an intended shape by using a lathe, the sputtering target of the present invention can be prepared.

## EXAMPLES

[0028]

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.

[0029]

(Examples 1 to 5: metal component Co)

A Co powder was prepared as a metal powder, a  $\text{SiO}_2$  powder was prepared as a metal oxide powder, and a CaO powder, a  $\text{K}_2\text{O}$  powder, a  $\text{Na}_2\text{O}$  powder, a PbO powder, and a ZnO powder were prepared as low-viscosity oxides. These powders were subsequently weighed to achieve the composition ratios shown in Table 1.

[0030]

Next, for each of Examples 1 to 5, the weighed powders were respectively placed in a ball mill pot having a capacity of 10 liters together with zirconium balls as the pulverizing medium, and mixed by rotating the ball mill pot for 24 hours. The mixed powder removed from the ball mill was filled in a carbon mold having a diameter of 190 mm, and sintered via hot press. The hot press conditions were as follows; namely, vacuum atmosphere, rate of temperature increase of  $300^\circ\text{C}/\text{hour}$ , holding temperature of  $1050^\circ\text{C}$ , 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.

[0031]

Next, for each of Examples 1 to 5, the cross section of the prepared sintered body was polished and the structure was observed with a microscope, and a structure in which oxides are dispersed in a metal matrix was confirmed. Furthermore, a structure image of 5 points on the observed surface was photographed in a visual field size of  $72\ \mu\text{m} \times 96\ \mu\text{m}$ . The photographed images were binarized with image processing software, obtaining the number and area of the parts corresponding to oxides (black parts of the structure observation image), and thereby calculating the average area per oxide grain, the results for Examples 1 to 5 were respectively  $3.1\ \mu\text{m}^2$ ,  $1.3\ \mu\text{m}^2$ ,  $2.0\ \mu\text{m}^2$ ,  $2.5\ \mu\text{m}^2$ , and  $2.1\ \mu\text{m}^2$ .

[0032]

Next, the respective sintered bodies of Examples 1 to 5 were machined with a lathe into a shape having a diameter of 180.0 mm and a thickness of 5.0 mm to prepare a disk-shaped target. Each of the prepared disk-shaped targets was mounted on a magnetron sputtering device (C-3010 sputtering system manufactured by Canon Anelva), and then sputtered. The sputtering conditions were as follows; namely, after performing 2 kWhr pre-sputtering at an applied power of 1 kW and Ar gas pressure of 1.7 Pa, a film was deposited on a silicon substrate having a diameter of 4 inches for 20 seconds. Subsequently, the number of particles having a size of 0.25 to 3  $\mu\text{m}$  that became adhered on the substrate was measured using a particle counter for each of Examples 1 to 5, and the results were respectively 8 particles, 8 particles, 5 particles, 9 particles, 8 particles, and 7 particles, and considerably reduced in comparison to Comparative Examples 1 to 3 described later.

[0033]

[Table 1]

|                       | Sputtering Target Composition<br>(Ratio of Number of Molecules)        | Mean Area of Oxide<br>Particles [ $\mu\text{m}^2/\text{particle}$ ] | Number of Particles<br>in Steady State<br>[particles/wafer] |
|-----------------------|------------------------------------------------------------------------|---------------------------------------------------------------------|-------------------------------------------------------------|
| Example 1             | 90Co-9SiO <sub>2</sub> -1CaO                                           | 3.1                                                                 | 8                                                           |
| Example 2             | 90Co-9SiO <sub>2</sub> -1K <sub>2</sub> O                              | 1.3                                                                 | 8                                                           |
| Example 3             | 90Co-9SiO <sub>2</sub> -1Na <sub>2</sub> O                             | 2.0                                                                 | 5                                                           |
| Example 4             | 90Co-9SiO <sub>2</sub> -1PbO                                           | 2.5                                                                 | 8                                                           |
| Example 5             | 90Co-9SiO <sub>2</sub> -1ZnO                                           | 2.1                                                                 | 7                                                           |
| Example 6             | 70Co-20Pt-9SiO <sub>2</sub> -1CaO                                      | 3.0                                                                 | 3                                                           |
| Example 7             | 70Co-20Pt-9SiO <sub>2</sub> -1K <sub>2</sub> O                         | 2.8                                                                 | 6                                                           |
| Example 8             | 70Co-20Pt-9SiO <sub>2</sub> -1Na <sub>2</sub> O                        | 2.5                                                                 | 5                                                           |
| Example 9             | 70Co-20Pt-9SiO <sub>2</sub> -1PbO                                      | 1.4                                                                 | 6                                                           |
| Example 10            | 70Co-20Pt-9SiO <sub>2</sub> -1ZnO                                      | 1.0                                                                 | 9                                                           |
| Example 11            | 62Co-22Pt-8CoO-8CaO                                                    | 2.4                                                                 | 9                                                           |
| Example 12            | 62Co-22Pt-8CoO-8K <sub>2</sub> O                                       | 2.5                                                                 | 2                                                           |
| Example 13            | 62Co-22Pt-8CoO-8Na <sub>2</sub> O                                      | 2.2                                                                 | 9                                                           |
| Example 14            | 62Co-22Pt-8CoO-8PbO                                                    | 2.8                                                                 | 9                                                           |
| Example 15            | 62Co-22Pt-8CoO-8ZnO                                                    | 3.8                                                                 | 3                                                           |
| Example 16            | 70Co-24Pt-3Cr <sub>2</sub> O <sub>3</sub> -3CaO                        | 1.7                                                                 | 3                                                           |
| Example 17            | 70Co-24Pt-3Cr <sub>2</sub> O <sub>3</sub> -3K <sub>2</sub> O           | 3.8                                                                 | 6                                                           |
| Example 18            | 70Co-24Pt-3Cr <sub>2</sub> O <sub>3</sub> -3Na <sub>2</sub> O          | 2.0                                                                 | 9                                                           |
| Example 19            | 70Co-24Pt-3Cr <sub>2</sub> O <sub>3</sub> -3PbO                        | 3.3                                                                 | 6                                                           |
| Example 20            | 70Co-24Pt-3Cr <sub>2</sub> O <sub>3</sub> -3ZnO                        | 2.4                                                                 | 7                                                           |
| Example 21            | 70Co-10Cr-10Pt-9SiO <sub>2</sub> -1CaO                                 | 1.0                                                                 | 3                                                           |
| Example 22            | 70Co-10Cr-10Pt-9SiO <sub>2</sub> -1K <sub>2</sub> O                    | 2.4                                                                 | 7                                                           |
| Example 23            | 70Co-10Cr-10Pt-9SiO <sub>2</sub> -1Na <sub>2</sub> O                   | 3.3                                                                 | 5                                                           |
| Example 24            | 70Co-10Cr-10Pt-9SiO <sub>2</sub> -1PbO                                 | 3.7                                                                 | 10                                                          |
| Example 25            | 70Co-10Cr-10Pt-9SiO <sub>2</sub> -1ZnO                                 | 2.4                                                                 | 6                                                           |
| Example 26            | 55Co-4Cr-21Pt-8SiO <sub>2</sub> -8TiO <sub>2</sub> -4CaO               | 1.8                                                                 | 6                                                           |
| Example 27            | 55Co-4Cr-21Pt-8SiO <sub>2</sub> -8TiO <sub>2</sub> -4K <sub>2</sub> O  | 1.8                                                                 | 6                                                           |
| Example 28            | 55Co-4Cr-21Pt-8SiO <sub>2</sub> -8TiO <sub>2</sub> -4Na <sub>2</sub> O | 3.1                                                                 | 3                                                           |
| Example 29            | 55Co-4Cr-21Pt-8SiO <sub>2</sub> -8TiO <sub>2</sub> -4PbO               | 2.6                                                                 | 4                                                           |
| Example 30            | 55Co-4Cr-21Pt-8SiO <sub>2</sub> -8TiO <sub>2</sub> -4ZnO               | 1.7                                                                 | 2                                                           |
| Example 31            | 46Co-40Cr-10Pt-2Co <sub>3</sub> O <sub>4</sub> -2CaO                   | 3.9                                                                 | 5                                                           |
| Example 32            | 46Co-40Cr-10Pt-2Co <sub>3</sub> O <sub>4</sub> -2K <sub>2</sub> O      | 3.1                                                                 | 4                                                           |
| Example 33            | 46Co-40Cr-10Pt-2Co <sub>3</sub> O <sub>4</sub> -2Na <sub>2</sub> O     | 2.0                                                                 | 9                                                           |
| Example 34            | 46Co-40Cr-10Pt-2Co <sub>3</sub> O <sub>4</sub> -2PbO                   | 2.3                                                                 | 10                                                          |
| Example 35            | 46Co-40Cr-10Pt-2Co <sub>3</sub> O <sub>4</sub> -2ZnO                   | 1.5                                                                 | 9                                                           |
| Example 36            | 67Co-20Pt-3B-9SiO <sub>2</sub> -1CaO                                   | 3.3                                                                 | 4                                                           |
| Example 37            | 62Co-14Pt-8Mo-8CoO-8K <sub>2</sub> O                                   | 1.8                                                                 | 6                                                           |
| Example 38            | 55Co-18Pt-21Ru-3Cr <sub>2</sub> O <sub>3</sub> -3Na <sub>2</sub> O     | 2.7                                                                 | 9                                                           |
| Example 39            | 60Co-10Cr-10Pt-10Ta-9SiO <sub>2</sub> -1PbO                            | 3.5                                                                 | 3                                                           |
| Example 40            | 55Co-4Cr-16Pt-5W-8SiO <sub>2</sub> -8TiO <sub>2</sub> -4ZnO            | 1.6                                                                 | 2                                                           |
| Comparative Example 1 | 90Co-10SiO <sub>2</sub>                                                | 3.8                                                                 | 44                                                          |
| Comparative Example 2 | 90Co-9SiO <sub>2</sub> -1FeO                                           | 3.7                                                                 | 52                                                          |
| Comparative Example 3 | 90Co-9SiO <sub>2</sub> -1NiO                                           | 4.1                                                                 | 46                                                          |
| Comparative Example 4 | 70Co-20Pt-10SiO <sub>2</sub>                                           | 1.0                                                                 | 50                                                          |
| Comparative Example 5 | 62Co-22Pt-16CoO                                                        | 3.7                                                                 | 32                                                          |
| Comparative Example 6 | 70Co-24Pt-6Cr <sub>2</sub> O <sub>3</sub>                              | 3.3                                                                 | 21                                                          |
| Comparative Example 7 | 70Co-10Cr-10Pt-10SiO <sub>2</sub>                                      | 2.5                                                                 | 47                                                          |
| Comparative Example 8 | 55Co-4Cr-21Pt-10SiO <sub>2</sub> -10TiO <sub>2</sub>                   | 1.9                                                                 | 49                                                          |
| Comparative Example 9 | 46Co-40Cr-10Pt-4Co <sub>3</sub> O <sub>4</sub>                         | 1.1                                                                 | 31                                                          |

[0034]

(Examples 6 to 20: metal component Co-Pt)

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A Co powder and a Pt powder were prepared as metal powders, a SiO<sub>2</sub> powder, a CoO powder, and a Cr<sub>2</sub>O<sub>3</sub> powder were prepared as metal oxide powders, and a CaO powder, a K<sub>2</sub>O powder, a Na<sub>2</sub>O powder, a PbO powder, and a ZnO powder were

prepared as low-viscosity oxides. These powders were subsequently weighed to achieve the composition ratios shown in Table 1.

[0035]

5       Next, for each of Examples 6 to 20, the weighed powders were respectively placed in a ball mill pot having a capacity of 10 liters together with zirconium balls as the pulverizing medium, and mixed by rotating the ball mill pot for 24 hours. The mixed powder removed from the ball mill was filled in a carbon mold having a diameter of 190 mm, and sintered via hot press. The hot press conditions were as follows; namely, vacuum atmosphere, rate of temperature increase of 300°C/hour, holding  
10   temperature of 1050°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]

15       Next, for each of Examples 6 to 20, the cross section of the prepared sintered body was polished and the structure was observed with a microscope, and a structure in which oxides are dispersed in a metal matrix was confirmed. Furthermore, a structure image of 5 points on the observed surface was photographed in a visual field size of 72  $\mu\text{m}$   $\times$  96  $\mu\text{m}$ . The photographed images were binarized with image processing software, the number and area of the parts corresponding to oxides (black  
20   parts of the structure observation image) were obtained, and the average area per oxide grain was thereby calculated. The results are shown in Table 1.

[0037]

25       Next, the respective sintered bodies of Examples 6 to 20 were machined with a lathe into a shape having a diameter of 180.0 mm and a thickness of 5.0 mm to prepare a disk-shaped target. Each of the prepared disk-shaped targets was mounted on a magnetron sputtering device (C-3010 sputtering system manufactured by Canon Anelva), and then sputtered. The sputtering conditions were as follows; namely, after performing 2 kWhr pre-sputtering at an applied power of 1 kW and Ar gas pressure of 1.7 Pa, a film was deposited on a silicon substrate having a diameter of 4 inches for  
30   20 seconds. Subsequently, the number of particles having a size of 0.25 to 3  $\mu\text{m}$  that became adhered on the substrate was measured using a particle counter for each of Examples 6 to 20. Consequently, as shown in Table 1, the number of particles considerably reduced in comparison to Comparative Examples 4 to 6 described later.

[0038]

(Examples 21 to 35: metal component Co-Cr-Pt)

A Co powder, a Cr powder, and a Pt powder were prepared as metal powders, a SiO<sub>2</sub> powder, a TiO<sub>2</sub> powder, and a Co<sub>3</sub>O<sub>4</sub> powder were prepared as metal oxide  
5 powders, and a CaO powder, a K<sub>2</sub>O powder, a Na<sub>2</sub>O powder, a PbO powder, and a ZnO powder were prepared as low-viscosity oxides. These powders were subsequently weighed to achieve the composition ratios shown in Table 1.

[0039]

Next, for each of Examples 21 to 35, the weighed powders were respectively  
10 placed in a ball mill pot having a capacity of 10 liters together with zirconium balls as the pulverizing medium, and mixed by rotating the ball mill pot for 24 hours. The mixed powder removed from the ball mill was filled in a carbon mold having a diameter of 190 mm, and sintered via hot press. The hot press conditions were as follows; namely, vacuum atmosphere, rate of temperature increase of 300°C/hour, holding  
15 temperature of 1050°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]

Next, for each of Examples 21 to 35, the cross section of the prepared sintered  
20 body was polished and the structure was observed with a microscope, and a structure in which oxides are dispersed in a metal matrix was confirmed. Furthermore, a structure image of 5 points on the observed surface was photographed in a visual field size of 72 μm × 96 μm. The photographed images were binarized with image processing software, the number and area of the parts corresponding to oxides (black  
25 parts of the structure observation image) were obtained, and the average area per oxide grain was thereby calculated. The results are shown in Table 1.

[0041]

Next, the respective sintered bodies of Examples 21 to 35 were machined with a lathe into a shape having a diameter of 180.0 mm and a thickness of 5.0 mm to  
30 prepare a disk-shaped target. Each of the prepared disk-shaped targets was mounted on a magnetron sputtering device (C-3010 sputtering system manufactured by Canon Anelva), and then sputtered. The sputtering conditions were as follows; namely, after performing 2 kWhr pre-sputtering at an applied power of 1 kW and Ar gas pressure of 1.7 Pa, a film was deposited on a silicon substrate having a diameter of 4 inches for

20 seconds. Subsequently, the number of particles having a size of 0.25 to 3  $\mu\text{m}$  that became adhered on the substrate was measured using a particle counter for each of Examples 21 to 35. Consequently, as shown in Table 1, the number of particles considerably reduced in comparison to Comparative Examples 7 to 9 described later.

5 [0042]

(Examples 36 to 40: addition of metal elements)

A Co powder, a Cr powder, and a Pt powder, and additionally a B powder, a Mo powder, a Ru powder, a Ta powder, and a W powder were prepared as metal powders, a  $\text{SiO}_2$  powder, a  $\text{TiO}_2$  powder, a CoO powder, and a  $\text{Cr}_2\text{O}_3$  powder were prepared as metal oxide powders, and a CaO powder, a  $\text{K}_2\text{O}$  powder, a  $\text{Na}_2\text{O}$  powder, a PbO powder, and a ZnO powder were prepared as low-viscosity oxides. These powders were subsequently weighed to achieve the composition ratios shown in Table 1.

[0043]

15 Next, for each of Examples 36 to 40, the weighed powders were respectively placed in a ball mill pot having a capacity of 10 liters together with zirconium balls as the pulverizing medium, and mixed by rotating the ball mill pot for 24 hours. The mixed powder removed from the ball mill was filled in a carbon mold having a diameter of 190 mm, and sintered via hot press. The hot press conditions were as follows; namely, vacuum atmosphere, rate of temperature increase of  $300^\circ\text{C}/\text{hour}$ , holding temperature of  $1050^\circ\text{C}$ , 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]

25 Next, for each of Examples 36 to 40, the cross section of the prepared sintered body was polished and the structure was observed with a microscope, and a structure in which oxides are dispersed in a metal matrix was confirmed. Furthermore, a structure image of 5 points on the observed surface was photographed in a visual field size of  $72\ \mu\text{m} \times 96\ \mu\text{m}$ . The photographed images were binarized with image processing software, the number and area of the parts corresponding to oxides (black parts of the structure observation image) were obtained, and the average area per oxide grain was thereby calculated. The results are shown in Table 1.

[0045]

Next, the respective sintered bodies of Examples 36 to 40 were machined with

a lathe into a shape having a diameter of 180.0 mm and a thickness of 5.0 mm to prepare a disk-shaped target. Each of the prepared disk-shaped targets was mounted on a magnetron sputtering device (C-3010 sputtering system manufactured by Canon Anelva), and then sputtered. The sputtering conditions were as follows; namely, after performing 2 kWhr pre-sputtering at an applied power of 1 kW and Ar gas pressure of 1.7 Pa, a film was deposited on a silicon substrate having a diameter of 4 inches for 20 seconds. Subsequently, the number of particles having a size of 0.25 to 3  $\mu\text{m}$  that became adhered on the substrate was measured using a particle counter for each of Examples 36 to 40. Consequently, as shown in Table 1, the number of particles considerably reduced in comparison to Comparative Examples 1 to 9 described later.

[0046]

(Comparative Examples 1 to 9: no addition of low-viscosity oxides)

A Co powder, a Cr powder, and a Pt powder were prepared as metal powders, and a  $\text{SiO}_2$  powder, a  $\text{TiO}_2$  powder, a CoO powder, a  $\text{Cr}_2\text{O}_3$  powder, and a  $\text{Co}_3\text{O}_4$  powder were prepared as metal oxide powders. Note that a FeO powder and a NiO powder were also prepared for comparison. These powders were subsequently weighed to achieve the composition ratios shown in Table 1. As a result of the foregoing simulation, the viscosities of FeO and NiO were respectively  $4.2 \times 10^{12}$  and  $2.8 \times 10^{13}$  poise, and no considerably deterioration in the viscosity could be observed.

[0047]

Next, for each of Comparative Examples 1 to 9, the weighed powders were respectively placed in a ball mill pot having a capacity of 10 liters together with zirconium balls as the pulverizing medium, and mixed by rotating the ball mill pot for 24 hours. The mixed powder removed from the ball mill was filled in a carbon mold having a diameter of 190 mm, and sintered via hot press. The hot press conditions were as follows; namely, vacuum atmosphere, rate of temperature increase of  $300^\circ\text{C}/\text{hour}$ , holding temperature of  $1050^\circ\text{C}$ , 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]

Next, for each of Comparative Examples 1 to 9, the cross section of the prepared sintered body was polished and the structure was observed with a microscope, and a structure in which oxides are dispersed in a metal matrix was

confirmed. Furthermore, a structure image of 5 points on the observed surface was photographed in a visual field size of  $72\ \mu\text{m} \times 96\ \mu\text{m}$ . The photographed images were binarized with image processing software, the number and area of the parts corresponding to oxides (black parts of the structure observation image) were obtained, and the average area per oxide grain was thereby calculated. The results are shown in Table 1.

[0049]

Next, the respective sintered bodies of Comparative Examples 1 to 9 were machined with a lathe into a shape having a diameter of 180.0 mm and a thickness of 5.0 mm to prepare a disk-shaped target. Each of the prepared disk-shaped targets was mounted on a magnetron sputtering device (C-3010 sputtering system manufactured by Canon Anelva), and then sputtered. The sputtering conditions were as follows; namely, after performing 2 kWhr pre-sputtering at an applied power of 1 kW and Ar gas pressure of 1.7 Pa, a film was deposited on a silicon substrate having a diameter of 4 inches for 20 seconds. Subsequently, the number of particles having a size of 0.25 to  $3\ \mu\text{m}$  that became adhered on the substrate was measured using a particle counter for each of Comparative Examples 1 to 9. Consequently, as shown in Table 1, the number of particles increased in comparison to the Examples.

## INDUSTRIAL APPLICABILITY

[0050]

The sputtering target of the present invention yields a superior effect of being able to reduce the amount of particles generated during the sputtering process, and improve the yield during deposition. Accordingly, the present invention is effective as a sputtering target for forming a magnetic thin film of a magnetic recording medium as represented with hard disk drives.

## CLAIMS

[Claim 1] A sputtering target containing 0.1 to 10 mol% of an oxide of one or more types of elements selected from Ca, K, Na, Pb, and Zn, 45 mol% or less of Cr, 45 mol% or less of Pt, and remainder being Co.

[Claim 2] The sputtering target according to claim 1, wherein the sputtering target contains 1 to 20 mol% of an oxide of one or more types of elements selected from Co, Cr, Si, and Ti.

[Claim 3] The sputtering target according to claim 1 or claim 2, wherein the sputtering target contains 1 to 30 mol% of one or more types of elements selected from Au, Ag, B, Cu, Ga, Ge, Ir, Mn, Mo, Nb, Ni, Pd, Re, Rh, Ru, Sn, Ta, W, V, and Zn.

[Claim 4] The sputtering target according to any one of claims 1 to 3, wherein an average area per oxide grain is 0.1 to 20  $\mu\text{m}^2$ .

[Claim 5] A film containing 0.1 to 10 mol% of an oxide of one or more types of elements selected from Ca, K, Na, Pb, and Zn, 45 mol% or less of Cr, 45 mol% or less of Pt, and remainder being Co.

[Claim 6] The film according to claim 5, wherein the film contains 1 to 20 mol% of an oxide of one or more types of elements selected from Co, Cr, Si, and Ti.

[Claim 7] The film according to claim 5 or claim 6, wherein the film contains 1 to 30 mol% of one or more types of elements selected from Au, Ag, B, Cu, Ga, Ge, Ir, Mn, Mo, Nb, Ni, Pd, Re, Rh, Ru, Sn, Ta, W, V, and Zn.