

DESCRIPTION

SINTERED BODY, AND SPUTTERING TARGET FOR FORMING MAGNETIC RECORDING FILM PRODUCED FROM SAID SINTERED BODY

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[Technical Field]

[0001]

The present invention relates to a sintered body that is effective in forming a magnetic body thin film of a magnetic recording medium, particularly a magnetic recording10 layer of a hard disk adopting the vertical magnetic recording system, and to a sputtering target produced from such a sintered body.

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Conventionally, when a target produced from a sintered body containing boron oxide is sputtered, there is a problem in that numerous particles are generated during sputtering due to the coarsening of the boron oxide grains during or after the sintering process.

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The present invention relates to a sintered body, and a sputtering target produced from such a sintered body, capable of resolving the foregoing problem.

BACKGROUND ART

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[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 films used for recording. For example, Co-Cr-based or Co-Cr-Pt-based ferromagnetic alloys with Co as its main component are used for the recording layer of hard disks adopting the longitudinal magnetic recording system.

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Moreover, composite materials of Co-Cr-Pt-based ferromagnetic alloys with Co as its main component and nonmagnetic inorganic substances are often used for the recording layer of hard disks adopting the vertical magnetic recording system which was recently put into practical application.

[0003]

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In addition, the foregoing magnetic thin film of a magnetic recording medium such as a hard disk is often produced by sputtering a ferromagnetic material sputtering target having the foregoing materials as its components in light of its high productivity. Moreover, it is known that boron oxide is sometimes added to this kind of sputtering target for forming a magnetic recording film in order to magnetically isolate the alloy phase.

[0004] As methods of producing a ferromagnetic material sputtering target, considered may be the melting method or the powder metallurgy method. Which method should be adopted will depend on the required properties, but a sputtering target made from ferromagnetic alloys and nonmagnetic inorganic grains that is used for forming a recording layer of a hard disk adopting the vertical magnetic recording system is generally produced via the powder metallurgy method. This is because the inorganic grains of boron oxide and the like need to be uniformly dispersed in the alloy base material, and this is difficult to realize with the melting method.

[0005] Meanwhile, the following Patent Documents were discovered upon searching for known documents that describe adding boron oxide to a magnetic recording medium.

Patent Document 1 below discloses "A magnetic recording medium having a magnetic data recording layer, wherein the magnetic data recording layer includes a first alloy having a magnetic anisotropy constant of at least 0.5×10^7 erg/cm³ (0.5/Jcm³), and an oxide compound made from oxygen and one or more elements in which at least one element has a negative reduction potential (Claim 1)".

[0006] Claim 6 of Patent Document 1 additionally describes "A magnetic recording medium, wherein at least one of the one or more elements in the oxidized compound is selected from a group consisting of lithium (Li), beryllium (Be), boron (B), sodium (Na), magnesium (Mg), aluminum (Al), silicon (Si), potassium (K), calcium (Ca), scandium (Sc), titanium (Ti), vanadium (V), chromium (Cr), manganese (Mn), iron (Fe), cobalt (Co), nickel (Ni), zinc (Zn), gallium (Ga), rubidium (Rb), strontium (Sr), yttrium (Y), zirconium (Zr), niobium (Nb), cadmium (Cd), indium (In), cesium (Cs), barium (Ba), lanthanum (La), cerium (Ce), praseodymium (Pr), neodymium (Nd), samarium (Sm), europium (Eu), terbium (Tb), gadolinium (Gd), holmium (Ho), erbium (Er), thulium (Tm), ytterbium (Yb), lutetium (Lu), hafnium (Hf), tantalum (Ta), tungsten (W), lead (Pb), thorium (Th) and uranium (U)", and that these materials are sputtering targets.

While boron oxide is described among the large amounts of oxides described above, Patent Document 1 does not in any way describe the problem of the presence of boron oxide in the target, or the method of resolving such problem.

[0007] Claim 1 of Patent Document 2 below discloses "A target for forming a Co-based magnetic layer of a magnetic recording medium via a sputtering method, wherein the target contains Cr or Cr alloy in an amount of 5 mol% or more and CoO in

an amount of 5 mol% or more, and oxides having a melting point of 800°C or less in a total amount within a range of 3 mol% to 20 mol%, and has a porosity of 7% or less". Claim 4 of Patent Document 2 additionally discloses "The target according to any one of claims 1 to 3, wherein the oxides having a melting point of 800°C or less are at least one type selected from boron oxide, vanadium oxide, tellurium oxide, molybdenum oxide, and low melting point glass".

In the foregoing case also, as with Patent Document 1 described above, Patent Document 2 does not in any way describe the problem of the presence of boron oxide in a sintered body or a target produced from a sintered body, or the method of resolving such problem.

[0008] Patent Document 3 below describes "A sintered body sputtering target made from ferromagnetic alloys containing 20 mol% or less of Cr and remainder being Co, and non-metallic inorganic materials, wherein a volume ratio of the non-metallic inorganic material is 40 vol% or less, and the non-metallic inorganic material includes at least cobalt oxide and boron oxide. A method of producing a sintered body for a sputtering target in which a mixed powder obtained by pulverizing and mixing a metal powder and a non-metallic inorganic material powder containing at least cobalt oxide and boron oxide is molded and sintered with a pressure sintering device at a holding temperature of 800°C or less (Abstract)".

In the foregoing case also, as with Patent Documents 1 and 2 described above, while Patent Document 3 describes including "boron oxide", Patent Document 3 does not in any way describe the problem of the presence of boron oxide in the target, or the method of resolving such problem.

[0009] Patent Document 4 below describes "A sputtering target for forming a magnetic recording film containing SiO₂, wherein the sputtering target for forming a magnetic recording film additionally contains B (boron) in an amount of 10 to 1000 wtppm." While boron oxide is contained in the foregoing case, as with Patent Documents 1, 2 and 3 described above, Patent Document 4 does not in any way describe the problem of the presence of boron oxide in a sintered body or a target produced from a sintered body, or the method of resolving such problem.

[Prior Art Document]

[Patent Document]

[0010] Patent Document 1: Japanese Patent Application Publication No. 2008-59733

Patent Document 2: Japanese Patent Application Publication No. 2012-33247

Patent Document 3: Japanese Patent Application Publication No. 2012-117147

Patent Document 4: Japanese Patent No. 5009448

SUMMARY OF THE INVENTION

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[Problems to be Solved by the Invention]

[0011] Many compound materials made from ferromagnetic alloys and nonmagnetic materials are used for producing a sputtering target for forming a magnetic recording film, and boron oxide is sometimes added as the nonmagnetic material. Nevertheless, if the sintering temperature is lowered in order to inhibit the grain growth because the boron oxide grains become coarse after the sintering process, there are problems in that the density cannot be increased, and that numerous particles are generated.

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[0012] Upon studying this problem, it has been discovered that there are two major problems. The first problem is that, since a boron oxide raw material has high hygroscopicity and tends to become aggregated, it is difficult to obtain fine boron oxide. The second problem is that, since boron oxide has a low melting point and tends to become liquefied during the sintering process, the boron oxide grains grow into large grains during the sintering process.

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[0013] As another problem, when a sintered body containing residue of boron oxide is subject to wet working via machining or stored in a highly humid location, such boron oxide reacts with moisture and boric acid is generated, and such boric acid becomes precipitated on the surface of the sintered body (target) and causes stains or contamination, and this additionally causes the generation of particles during sputtering, and there is an additional problem in that the moisture seeps into the film and causes quality defects. A sintered body for forming a magnetic recording film to which boron oxide has been added needs to resolve the foregoing problems, particularly in light of ensuring the favorable quality of a sputtering target.

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[Means for Solving the Problems]

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

1) A sintered body which contains at least cobalt as a metal and which is made from boron and/or one or more types of metal or alloy selected from platinum group elements, and oxides, wherein a phase composed of the oxide contains at least one or more types of compounds selected from $\text{Cr}(\text{BO}_3)$, $\text{Co}_2\text{B}_2\text{O}_5$, and $\text{Co}_3\text{B}_2\text{O}_6$.

[0015] The present invention further provides:

2) A sintered body which contains at least cobalt as a metal and which is made from chromium, and boron and/or one or more types of metal or alloy selected from platinum group elements, and oxides, wherein a phase composed of the oxide contains at least one or more types of compounds selected from $\text{Cr}(\text{BO}_3)$, $\text{Co}_2\text{B}_2\text{O}_5$, and $\text{Co}_3\text{B}_2\text{O}_6$.

[0016] The present invention further provides:

3) The sintered body according to 1) or 2) above, wherein there is no discoloration on a surface of the sintered body when the sintered body comes into contact with or is immersed in water.

The present invention further provides:

4) The sintered body according to 2) or 3) above, wherein an atomic ratio of chromium and boron is $\text{Cr/B} \geq 1$.

[0017] The present invention further provides:

5) The sintered body according to any one of 1) to 4) above, wherein an atomic ratio of boron and oxygen is $\text{B/O} \leq 0.5$.

The present invention further provides:

6) The sintered body according to any one of 1) to 5) above, wherein, in a ratio of metal components, a content of chromium is 0 to 50 mol%, a content of boron and/or platinum group elements is 0 (but excluding 0) to 40 mol%, and remainder is cobalt.

[0018] The present invention further provides:

7) The sintered body according to any one of 1) to 6) above, wherein a content of boron oxide is 0.5 to 10 mol% by B_2O_3 conversion.

The present invention further provides:

8) The sintered body according to any one of 1) to 7) above, wherein a total content of chromium oxide is 0.5 to 10 mol% by Cr_2O_3 conversion.

[0019] The present invention further provides:

9) The sintered body according to any one of 1) to 8) above, wherein the sintered body contains oxides having as its constituent one or more types of elements selected from Al, Co, Cu, Fe, Ga, Ge, Hf, Li, Mg, Mn, Mo, Nb, Ni, Sb, Si, Sn, Ta, Te, Ti, V, W, Y, Zn and Zr, and a total oxide content is 2 to 8 wt% by oxygen conversion.

[0020] The present invention further provides:

10) The sintered body according to any one of 1) to 9) above, wherein an average area per grain of the oxides in the sintered body is $2 \mu\text{m}^2$ or less.

The present invention provides:

11) The sintered body according to any one of 1) to 10) above, wherein the sintered body additionally contains one or more elements selected from Ti, V, Mn, Zr, Nb, Mo, Ta, and W in an amount of 0.5 mol% or more and 10 mol% or less.

5 [0021] The present invention further provides:

12) The sintered body according to any one of 1) to 11) above, wherein the sintered body additionally contains one or more types selected from carbon, nitride, and carbide.

The present invention further provides:

10 13) The sintered body according to any one of 1) to 12) above, wherein the sintered body has a relative density of 95% or more.

[0022] The present invention further provides:

14) A sputtering target for forming a magnetic recording film produced from the sintered body according to any one of 1) to 13) above.

15 [0023] The present invention further provides:

15) A method of producing a sintered body, wherein one or more types of metal or alloy which contains at least cobalt as a metal and which is selected from boron and/or platinum group elements, and at least one or more types of oxides selected from $\text{Cr}(\text{BO}_3)$, $\text{Co}_2\text{B}_2\text{O}_5$, $\text{Co}_3\text{B}_2\text{O}_6$ are mixed and sintered.

20 [0024] The present invention further provides:

16) A method of producing a sintered body, wherein one or more types of metal or alloy which contains at least cobalt as a metal and which is selected from chromium, and boron and/or platinum group elements, and at least one or more types of oxides selected from $\text{Cr}(\text{BO}_3)$, $\text{Co}_2\text{B}_2\text{O}_5$, $\text{Co}_3\text{B}_2\text{O}_6$ are mixed and sintered.

25 [0025] The present invention further provides:

17) The method of producing a sintered body according to 15) or 16) above, wherein boron oxide and chromium oxide and/or cobalt oxide are prepared and calcined in an atmosphere to produce at least one or more types of oxides selected from $\text{Cr}(\text{BO}_3)$, $\text{Co}_2\text{B}_2\text{O}_5$, and $\text{Co}_3\text{B}_2\text{O}_6$.

30 The present invention further provides:

18) A method of producing the sintered body according to any one of 1) to 13) above according to the method of producing a sintered body according to any one of 15) to 17).

[Effect of the Invention]

[0026] As described above, with a sintered body to which boron oxide is added, the boron oxide grains become coarse after the sintering process, and there is a problem in that numerous particles are generated when used as a sputtering target for forming a magnetic recording film. This was caused by the following problems; namely, since a boron oxide raw material has high hygroscopicity and tends to become aggregated, it is difficult to obtain fine boron oxide, and since boron oxide has a low melting point and tends to become liquefied during the sintering process, the boron oxide grains grow into large grains during the sintering process.

[0027] In light of the foregoing points, a phase composed of the oxide contains at least one or more types of compounds selected from $\text{Cr}(\text{BO}_3)$, $\text{Co}_2\text{B}_2\text{O}_5$, and $\text{Co}_3\text{B}_2\text{O}_6$ in the sintered body, particularly the sputtering target for forming a magnetic recording film, of the present invention.

A compound selected from $\text{Cr}(\text{BO}_3)$, $\text{Co}_2\text{B}_2\text{O}_5$, and $\text{Co}_3\text{B}_2\text{O}_6$ possesses the properties of being able to maintain a fine structure and increase the melting point of boron oxide, and thereby inhibit the reaction with water. This enables the solution of the foregoing problems caused by boron oxide that is present in a sintered body.

[0028] In other words, the present invention is capable of ensuring the favorable quality of a sintered body, particularly a sputtering target for forming a magnetic recording film, to which boron oxide is added, and inhibiting the generation of particles during sputtering. Moreover, when a sintered body containing residue of boron oxide is subject to wet working via machining or stored in a highly humid location, such boron oxide reacts with moisture and boric acid is generated, and such boric acid becomes precipitated on the surface of the sintered body (target) and causes stains or contamination. However, the present invention is capable of also resolving these problems.

[0029] Since the present invention can inhibit the generation of particles, the present invention yields a superior effect of being able to reduce the percent defective of the magnetic recording film and realize cost reduction, and contributes considerably to the improvement in the quality and productivity of magnetic thin films.

DETAILED DESCRIPTION

[0030] The sintered body, particularly the sputtering target for forming a magnetic recording film of the present invention is a sintered body, particularly a sputtering target for forming a magnetic recording film, which contains at least cobalt as a metal and which is made from chromium and one or more types of metal or alloy selected from platinum group elements, and oxides containing boron oxide and chromium oxide. Other metal materials and inorganic material described later (other than the foregoing component composition) may also be added.

Note that the foregoing expression "chromium and one or more types of metal or alloy selected from platinum group elements" means that chromium metal may be used independently, or one or more types of metals selected from platinum group elements may be used, or their alloys may be used.

[0031] Note that the sintered body of the present invention is primarily used as a sputtering target. In this respect, the ensuing explanation will mainly focus on a sputtering target as the primary usage thereof, but such explanation does not prevent the sintered body from being used in other coating methods. For example, the sintered body can also be used in physical or chemical deposition methods such as ion beam deposition. The sintered body of the present invention covers all of the above.

[0032] A requirement of the present invention is that a phase composed of the oxide contains at least one or more types of compounds selected from $\text{Cr}(\text{BO}_3)$, $\text{Co}_2\text{B}_2\text{O}_5$, and $\text{Co}_3\text{B}_2\text{O}_6$, and this is a major feature of the present invention. As a result of boron oxide being present in the form of the foregoing compounds, it is possible to yield the properties and effects of being able to maintain a fine structure and increase the melting point of boron oxide, and thereby inhibit the reaction with water.

[0033] By preliminarily using a raw material that is in the form of the foregoing compounds, the foregoing compounds can be caused to stably remain in the sintered body, but the same effects can be yielded even when the foregoing compounds can be generated via reaction sintering or the like. The presence of the foregoing compounds can be identified by subjecting a sample extracted from the sintered body to XRD measurement, and specifying the peak of the compound phase.

[0034] With the sintered body of the present invention, the atomic ratio of chromium and boron is desirably $\text{Cr/B} \geq 1$. This was verified based on experiments, and outside this range the sintered body tends to react with water. While the

sputtering target may be used even when the atomic ratio of chromium and boron is outside the foregoing range, it could be said that the foregoing atomic ratio is a more preferable range.

[0035] Moreover, with the sintered body of the present invention, the atomic ratio of boron and oxygen is desirably $B/O \leq 0.5$. This was verified based on experiments, and outside this range the sintered body tends to react with water. While the sputtering target may be used even when the atomic ratio of boron and oxygen is outside the foregoing range, it could be said that the foregoing atomic ratio is a more preferable range.

[0036] While the sintered body, particularly the sputtering target for forming a magnetic recording film of the present invention can be applied to a general magnetic material target, as a representative and preferred magnetic material, the content of chromium is 0 to 50 mol%, the content of boron and/or platinum group elements is 0 (but excluding 0) to 40 mol%, and the remainder is cobalt. In the foregoing case also, as described above, chromium metal may be used independently, or one or more types of metals selected from platinum group elements may be used, or their alloys may be used.

Since an important (key) point of the present invention is to contain boron oxide in the foregoing mode, while it is not necessary to limit the contents to the foregoing composition range, the foregoing range can be indicated as the basic composition of a preferred magnetic material.

[0037] With the sintered body, particularly the sputtering target for forming a magnetic recording film of the present invention, the content (or additive amount) of boron oxide is 0.5 to 10 mol% by B_2O_3 conversion. However, boron that is contained as a component is desirably present as at least one compound selected from the compounds of $Cr(BO_3)$, $Co_2B_2O_5$, and $Co_3B_2O_6$.

The total content of chromium oxide is desirably 0.5 to 10 mol% by Cr_2O_3 conversion. This is also a preferred range as a sputtering target for forming a magnetic recording film.

[0038] Other than the oxides described above, the sintered body of the present invention contains oxides having as its constituent one or more types of elements selected from Al, Co, Cu, Fe, Ga, Ge, Hf, Li, Mg, Mn, Mo, Nb, Ni, Sb, Si, Sn, Ta, Te, Ti, V, W, Y, Zn and Zr, and the total oxide content is 2 to 8 wt% by oxygen conversion.

These are also a preferred range as a sintered body, particularly a sputtering target for forming a magnetic recording film.

While the addition of these oxides is not specifically indicated in the Examples, these are preferred materials that are generally added to a magnetic recording film, and the same applies in the present invention.

[0039] With the sintered body, particularly the sputtering target for forming a magnetic recording film of the present invention, the average area of the oxide phase per grain is desirably $2\ \mu\text{m}^2$ or less. Normally, the oxide phase can be observed by polishing (and grinding as needed) the surface of the target, and desirably the oxide phase is finely dispersed.

This is because when there is a coarsened oxide phase, the generation of arcing or particles tends to occur during sputtering. Note that the foregoing area indicates the preferred range as a sputtering target for forming a magnetic recording film, and is not intended to prevent the use of a sputtering target for forming a magnetic recording film that exceeds the foregoing range depending on the purpose of use and in relation to other materials that are used.

[0040] The sintered body, particularly the sputtering target for forming a magnetic recording film of the present invention explained above, may additionally contain one or more elements selected from Ti, V, Mn, Zr, Nb, Mo, Ta, and W in an amount of 0.5 mol% or more and 10 mol% or less. These additive elements are added as needed in order to improve the properties as a magnetic recording medium.

While the addition of these additive elements is not specifically indicated in the Examples, these are preferred materials that are generally added to a magnetic recording film, and the same applies in the present invention.

[0041] Similarly, the sintered body, particularly the sputtering target for forming a magnetic recording film of the present invention, may additionally contain one or more types selected from carbon, nitride, and carbide. These elements are added as needed in order to further improve the properties as a magnetic recording medium.

[0042] The sintered body, particularly the sputtering target for forming a magnetic recording film of the present invention having the foregoing component composition, can achieve a relative density of 95% or more, 98% or more, and even 99% or more. While the sintered body density can be adjusted based on the sintering temperature and the pressure used in the hot-pressing or HIP, if the temperature is too high, the oxide phase grains will grow and become coarse. Thus, desirably, the sintering

temperature is lowered as much as possible and the pressure is increased as much as possible. Desirably, the sintering temperature is 1100°C or less and the pressure is 250 kgf/cm² or more. Molding and sintering are not limited to the hot-pressing method, and the plasma discharge sintering method or the hot isostatic sintering method may also be adopted.

[0043] Note that the relative density is a value obtained by dividing the measured density of the target by the calculated density (also referred to as the logical density). The calculated density is the density when it is assumed that the constituents of the target do not mutually disperse or react and coexist, and is calculated according to the following formula.

Formula: calculated density = $\frac{\sum (\text{molecular weight of constituents} \times \text{molar ratio of constituents})}{\sum (\text{molecular weight of constituents} \times \text{molar ratio of constituents}) / \text{literature data density of constituents}}$

Here, Σ implies taking on the sum of all constituents of the target.

[0044] While a part of the component composition range of the present invention is shown below as Examples (representative examples), a sintered body, particularly a sputtering target for forming a magnetic recording film within the component composition range prescribed in the present invention, yields the same effects as the following Examples.

Examples

[0045] 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.

[0046] (Example 1)

Boron oxide and chromium oxide or cobalt oxide were prepared and weighed to each achieve $\text{B}_2\text{O}_3:\text{Cr}_2\text{O}_3 = 1:1$, $\text{B}_2\text{O}_3:\text{CoO} = 1:2$, and $\text{B}_2\text{O}_3:\text{CoO} = 1:3$, subsequently mixed in a ball mill, calcined within a temperature range of 700 to 1200°C for 5 hours or longer in the atmosphere, and one or more types of compounds selected from $\text{Cr}(\text{BO}_3)$, $\text{Co}_2\text{B}_2\text{O}_5$, and $\text{Co}_3\text{B}_2\text{O}_6$ were prepared. Note that the raw material may also be adjusted so that a plurality of compounds and simple oxides coexist by changing the blending ratio.

[0047] In addition, the foregoing compounds were pulverized to obtain a sintering raw material (oxide). Note that the raw material may also be adjusted so that a plurality of compounds and simple oxides coexist by changing the blending ratio. Note that a ball mill was used for the pulverization process.

5 [0048] Subsequently, the foregoing sintering raw material, a raw material powder which contains at least cobalt as a metal and which is made from chromium and one or more types of metal selected from platinum group elements, and a raw material powder of required oxides were blended at the ratio shown in Table 1, mixed in a ball mill for 20 hours or longer, filled in a graphite die having a diameter of 50 ϕ , and hot
10 pressed and sintered in a vacuum at a sintering temperature of 900 to 1100°C.

The resultant product was machined into a disk shape, immersed in purified water for 1 hour at room temperature, thereafter dried, and the surface thereof was observed. Note that the production method and testing method of the following Examples and Comparative Example adopted the same conditions as the methods of
15 this Example.

[0049] The respective component compositions of the magnetic materials to become the matrix of Example 1 were Co: 69 mol%, Cr: 5 mol%, and Pt: 20 mol%. Meanwhile, the oxides were Cr(BO₃): 2 mol%, Cr₂O₃: 2 mol%, and SiO₂: 2 mol%. The Cr/B ratio was 5.5 and the B/O ratio was 0.1. These ratios satisfied the
20 conditions of the present invention.

[0050] The results are shown in Table 1. The average area of the oxide phase per grain in the target was 1.5 μm^2 . Note that the average area of the oxide phase per grain was obtained as follows. Foremost, the surface of a sample that was arbitrarily extracted from the target was polished to obtain a mirror surface, and a
25 laser microscope image was photographed at a visual field of 25 $\times$ 18 μm . Since the oxide phase and the metal phase have a considerably different reflectance, the difference was distinguished based on the contrast of the image.

The entire area and number of oxide phases were thereby obtained, and the average area per grain (entire area of oxide phases $\div$ number of oxide phases) was calculated. The same method was adopted in the ensuing Examples and
30 Comparative Examples. Software (shape analyzing application VK-H1A1 manufactured by KEYENCE) was used for the foregoing calculation, and the results were obtained from the laser microscope image.

[0051]

The appearance of the surface of the sintered body after being immersed in water showed no discoloration. Moreover, the relative density of this sintered body was 96.5%. Upon producing a target from a sintered body having a size of 180 φ that was obtained based on the same raw materials and production conditions and sputtering the produced target, the number of particles that were generated in a stationary state was 2 particles. Thus, it was possible to obtain a high density target, and the number of generated particles was low.

[0052]

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Table 1

	Composition (mol%)							Cr/B	B/O	Average grain size of oxides ($\mu\text{m}^2/\text{grain}$)	Appearance after immersion in water
Example 1	Co: 69	Cr: 5	Pt: 20	-	Cr(BO ₃): 2	Cr ₂ O ₃ : 2	SiO ₂ : 2	5.5	0.1	1.5	No discoloration
Example 2	Co: 60	Cr: 5	Pt: 20	Ru: 5	Cr(BO ₃): 10	-	-	1.5	0.3	1.9	No discoloration
Example 3	Co: 77.8	Cr: 5.3	Pt: 10.5	-	Cr(BO ₃): 4.2	Co ₂ B ₂ O ₅ : 1.1	Co ₃ B ₂ O ₆ : 1.1	1.7	0.3	1.1	No discoloration
Example 4	Co: 75.2	-	Pt: 21.5	-	Co ₂ B ₂ O ₅ : 2.2	Co ₃ B ₂ O ₆ : 1.1	-	0	0.4	2	No discoloration
Example 5	Co: 71.4	-	Pt: 20.4	-	Cr(BO ₃): 4.1	Co ₂ B ₂ O ₅ : 1	TiO ₂ : 3.1	0.7	0.3	1.2	No discoloration
Example 6	Co: 55	Cr: 30	-	Ru: 5	Cr(BO ₃): 2	TiO ₂ : 8	-	16	0.09	1.9	No discoloration
Example 7	Co: 55	Cr: 30	-	B: 5	CoO: 6	TiO ₂ : 4	-	6	0.36	1.9	No discoloration
Example 8	Co: 60	Cr: 5	Pt: 24	-	Cr(BO ₃): 4	SiO ₂ : 4	CoO: 3	2.25	0.17	1.1	No discoloration
Example 9	Co: 73	Cr: 2	Pt: 17	-	Cr(BO ₃): 2	Ta ₂ O ₅ : 2	WO ₃ : 4	2	0.07	1.5	No discoloration
Example 10	Co: 65	Cr: 4	Pt: 25	-	Cr(BO ₃): 2	B ₂ O ₃ : 2	Nb ₂ O ₅ : 2	1	0.27	1.6	No discoloration
Comparative Example 1	Co: 63	Cr: 5	Pt: 20	Ru: 5	B ₂ O ₃ : 5	SiO ₂ : 2	-	0.5	0.5	4.3	Discoloration
Comparative Example 2	Co: 68	Cr: 5	Pt: 20	-	B ₂ O ₃ : 5	Cr ₂ O ₃ : 2	-	0.9	0.5	1.8	Discoloration
Comparative Example 3	Co: 73	-	Pt: 20	-	B ₂ O ₃ : 6	Co ₃ B ₂ O ₆ : 1	-	0	0.6	5.1	Discoloration
Comparative Example 4	Co: 66	Cr: 9	-	B: 10	CoO: 7	TiO ₂ : 8	-	0.9	0.43	3.8	Discoloration
Comparative Example 5	Co: 50	Cr: 30	-	Ru: 10	B ₂ O ₃ : 7	SiO ₂ : 3	-	2.1	0.52	8.2	Discoloration

[0053] (Example 2)

A sintered body was produced based on the same conditions as Example 1 other than adjusting the respective component compositions as described in Table 1.

5 The respective component compositions of the magnetic materials to become the matrix of Example 2 were Co: 60 mol%, Cr: 5 mol%, Pt: 20 mol%, and Ru: 5 mol%.

Meanwhile, the oxide was $\text{Cr}(\text{BO}_3)$: 10 mol%. The Cr/B ratio was 1.5 and the B/O ratio was 0.3. These ratios satisfied the conditions of the present invention.

[0054] The results are similarly shown in Table 1. The average area of the oxide
10 phase per grain in the target was $1.9 \mu\text{m}^2$. The appearance of the surface of the sintered body after being immersed in water showed no discoloration. Moreover, the relative density of this sintered body was 95.8%.

[0055] (Example 3)

15 A sintered body was produced based on the same conditions as Example 1 other than adjusting the respective component compositions as described in Table 1.

The respective component compositions of the magnetic materials to become the matrix of Example 3 were Co: 77.8 mol%, Cr: 5.3 mol%, and Pt: 10.5 mol%.

20 Meanwhile, the oxides were $\text{Cr}(\text{BO}_3)$: 4.2 mol%, $\text{Co}_2\text{B}_2\text{O}_5$: 1.1, and $\text{Co}_3\text{B}_2\text{O}_6$: 1.1. The Cr/B ratio was 1.7 and the B/O ratio was 0.3. These ratios satisfied the conditions of the present invention.

[0056] The results are similarly shown in Table 1. The average area of the oxide
phase per grain in the target was $1.1 \mu\text{m}^2$. The appearance of the surface of the sintered body after being immersed in water showed no discoloration. Moreover, the relative density of this sintered body was 96.1%.

25 [0057] (Example 4)

A sintered body was produced based on the same conditions as Example 1 other than adjusting the respective component compositions as described in Table 1.

The respective component compositions of the magnetic materials to become the matrix of Example 4 were Co: 75.2 mol%, and Pt: 21.5 mol%.

30 Meanwhile, the oxides were $\text{Co}_2\text{B}_2\text{O}_5$: 2.2 mol%, and $\text{Co}_3\text{B}_2\text{O}_6$: 1.1 mol%. The Cr/B ratio was 0.0 and the B/O ratio was 0.4. These ratios satisfied the conditions of the present invention.

[0058] The results are similarly shown in Table 1. The average area of the oxide
phase per grain in the target was $2.0 \mu\text{m}^2$. The appearance of the surface of the

sintered body after being immersed in water showed no discoloration. Moreover, the relative density of this sintered body was 97.1%.

[0059] (Example 5)

A sintered body was produced based on the same conditions as Example 1 other than adjusting the respective component compositions as described in Table 1.

The respective component compositions of the magnetic materials to become the matrix of Example 5 were Co: 71.4 mol%, and Pt: 20.4 mol%.

Meanwhile, the oxides were $\text{Cr}(\text{BO}_3)$: 4.1 mol%, $\text{Co}_2\text{B}_2\text{O}_5$: 1, and TiO_2 : 3.1 mol%. The Cr/B ratio was 0.7 and the B/O ratio was 0.3. Other than the Cr/B ratio, the conditions of the present invention were satisfied.

[0060] The results are similarly shown in Table 1. The average area of the oxide phase per grain in the target was $1.2 \mu\text{m}^2$. The appearance of the surface of the sintered body after being immersed in water showed no discoloration. Moreover, the relative density of this sintered body was 97.5%. Upon producing a target from a sintered body having a size of 180 ϕ that was obtained based on the same raw materials and production conditions and sputtering the produced target, the number of particles that were generated in a stationary state was 3 particles. Thus, it was possible to obtain a high density target, and the number of generated particles was low.

[0061] (Example 6)

A sintered body was produced based on the same conditions as Example 1 other than adjusting the respective component compositions as described in Table 1.

The respective component compositions of the magnetic materials to become the matrix of Example 6 were Co: 55 mol%, Cr: 30 mol%, and Ru: 5 mol%.

Meanwhile, the oxides were $\text{Cr}(\text{BO}_3)$: 2 mol%, and TiO_2 : 8 mol%. The Cr/B ratio was 16 and the B/O ratio was 0.09. Both ratios satisfied the conditions of the present invention.

[0062] The results are similarly shown in Table 1. The average area of the oxide phase per grain in the target was $1.9 \mu\text{m}^2$. The appearance of the surface of the sintered body after being immersed in water showed no discoloration. Moreover, the relative density of this sintered body was 99.5%. Upon producing a target from a sintered body having a size of 180 ϕ that was obtained based on the same raw materials and production conditions and sputtering the produced target, the number of particles that were generated in a stationary state was 9 particles. Thus, it was possible to obtain a high density target, and the number of generated particles was low.

[0063] (Example 7)

A sintered body was produced based on the same conditions as Example 1 other than adjusting the respective component compositions as described in Table 1.

The respective component compositions of the magnetic materials to become the matrix of Example 7 were Co: 55 mol%, Cr: 30 mol%, and B: 5 mol%.

Meanwhile, the oxides were CoO: 6 mol%, and TiO₂: 4 mol%. The Cr/B ratio was 6 and the B/O ratio was 0.36. Both ratios satisfied the conditions of the present invention.

After the sintering process, it was verified that Cr(BO₃) was partially generated in the XRD measurement of the sample. The XRD measurement conditions were as follows; namely, UltimaIV manufactured by Rigaku was used, CuK α rays were used, tube voltage of 40 kv, tube current of 30 mA, scan speed of 1°/min, step of 0.01°, and scan angle range (2 θ) of 24 to 35°. Of the first peak of Cr(BO₃) appearing near 33.79° and the second peak of Cr(BO₃) appearing near 25.68°, Cr(BO₃) was verified by a peak that does not overlap with the peaks of other products.

In this Example, the strength of the first peak was 120 cps, and the strength of the second peak was 70 cps (background strength was roughly 50 cps). Note that, since these strength values will vary depending on the measurement conditions and the adjustment of samples, the foregoing numerical values are merely examples, and the present invention is not limited to such numerical values.

[0064] The results are similarly shown in Table 1. The average area of the oxide phase per grain in the target was 1.9 μm^2 . The appearance of the surface of the sintered body after being immersed in water showed no discoloration. Moreover, the relative density of this sintered body was 99%. Upon producing a target from a sintered body having a size of 180 ϕ that was obtained based on the same raw materials and production conditions and sputtering the produced target, the number of particles that were generated in a stationary state was 10 particles. Thus, it was possible to obtain a high density target, and the number of generated particles was low.

[0065] (Example 8)

A sintered body was produced based on the same conditions as Example 1 other than adjusting the respective component compositions as described in Table 1.

The respective component compositions of the magnetic materials to become the matrix of Example 8 were Co: 60 mol%, Cr: 5 mol%, and Pt: 24 mol%.

Meanwhile, the oxides were $\text{Cr}(\text{BO}_3)$: 4 mol%, SiO_2 : 4 mol%, and CoO : 3 mol%. The Cr/B ratio was 2.25 and the B/O ratio was 0.17. Both ratios satisfied the conditions of the present invention.

[0066] The results are similarly shown in Table 1. The average area of the oxide phase per grain in the target was $1.1 \mu\text{m}^2$. The appearance of the surface of the sintered body after being immersed in water showed no discoloration. Moreover, the relative density of this sintered body was 99.2%. Upon producing a target from a sintered body having a size of 180 ϕ that was obtained based on the same raw materials and production conditions and sputtering the produced target, the number of particles that were generated in a stationary state was 4 particles. Thus, it was possible to obtain a high density target, and the number of generated particles was low.

[0067] (Example 9)

A sintered body was produced based on the same conditions as Example 1 other than adjusting the respective component compositions as described in Table 1.

The respective component compositions of the magnetic materials to become the matrix of Example 9 were Co: 73 mol%, Cr: 2 mol%, and Pt: 17 mol%.

Meanwhile, the oxides were $\text{Cr}(\text{BO}_3)$: 2 mol%, Ta_2O_5 : 2 mol%, and WO_3 : 4 mol%. The Cr/B ratio was 2 and the B/O ratio was 0.07. Both ratios satisfied the conditions of the present invention.

[0068] The results are similarly shown in Table 1. The average area of the oxide phase per grain in the target was $1.5 \mu\text{m}^2$. The appearance of the surface of the sintered body after being immersed in water showed no discoloration. Moreover, the relative density of this sintered body was 98%. Upon producing a target from a sintered body having a size of 180 ϕ that was obtained based on the same raw materials and production conditions and sputtering the produced target, the number of particles that were generated in a stationary state was 5 particles. Thus, it was possible to obtain a high density target, and the number of generated particles was low.

[0069] (Example 10)

A sintered body was produced based on the same conditions as Example 1 other than adjusting the respective component compositions as described in Table 1.

The respective component compositions of the magnetic materials to become the matrix of Example 10 were Co: 65 mol%, Cr: 4 mol%, and Pt: 25 mol%.

Meanwhile, the oxides were $\text{Cr}(\text{BO}_3)$: 2 mol%, B_2O_3 : 2 mol%, and Nb_2O_5 : 2 mol%. The Cr/B ratio was 1 and the B/O ratio was 0.27. Both ratios satisfied the conditions of the present invention.

[0070] The results are similarly shown in Table 1. The average area of the oxide phase per grain in the target was $1.6 \mu\text{m}^2$. The appearance of the surface of the sintered body after being immersed in water showed no discoloration. Moreover, the relative density of this sintered body was 98.8%. Upon producing a target from a sintered body having a size of 180 ϕ that was obtained based on the same raw materials and production conditions and sputtering the produced target, the number of particles that were generated in a stationary state was 6 particles. Thus, it was possible to obtain a high density target, and the number of generated particles was low.

[0071] (Comparative Example 1)

A sintered body was produced based on the same conditions as Example 1 other than adjusting the respective component compositions as described in Table 1.

The respective component compositions of the magnetic materials to become the matrix of Comparative Example 1 were Co: 63 mol%, Cr: 5 mol%, Pt: 20 mol%, and Ru: 5 mol%.

Meanwhile, the oxides were B_2O_3 : 5 mol%, and SiO_2 : 2 mol%. The Cr/B ratio was 0.5. Moreover, the B/O ratio was 0.5 and a compound of $\text{Cr}(\text{BO}_3)$, $\text{Co}_2\text{B}_2\text{O}_5$, or $\text{Co}_3\text{B}_2\text{O}_6$ could not be verified in the sintered body. These results failed to satisfy the conditions of the present invention.

[0072] The results are similarly shown in Table 1. The average area of the oxide phase per grain in the target was $4.3 \mu\text{m}^2$. The appearance of the surface of the sintered body after being immersed in water showed discoloration. Moreover, the relative density of this sintered body was 96%. Upon producing a target from a sintered body having a size of 180 ϕ that was obtained based on the same raw materials and production conditions and sputtering the produced target, the number of particles that were generated in a stationary state was 20 particles, and the number of generated particles was high.

[0073] (Comparative Example 2)

A sintered body was produced based on the same conditions as Example 1 other than adjusting the respective component compositions as described in Table 1. However, compound powders of $\text{Cr}(\text{BO}_3)$, $\text{Co}_2\text{B}_2\text{O}_5$, and $\text{Co}_3\text{B}_2\text{O}_6$ were not prepared in advance.

The respective component compositions of the magnetic materials to become the matrix of Comparative Example 2 were Co: 68 mol%, Cr: 5 mol%, and Pt: 20 mol%. Meanwhile, the oxides were B₂O₃: 5 mol%, and Cr₂O₃: 2 mol%. The Cr/B ratio was 0.9 and the B/O ratio was 0.5. The Cr/B ratio failed to satisfy the conditions of the present invention.

[0074] The results are similarly shown in Table 1. The average area of the oxide phase per grain in the target was 1.8 μm^2 . The appearance of the surface of the sintered body after being immersed in water showed discoloration. Moreover, the relative density of this sintered body was 93%. Upon producing a target from a sintered body having a size of 180 ϕ that was obtained based on the same raw materials and production conditions and sputtering the produced target, the number of particles that were generated in a stationary state was 34 particles. Thus, a low density target was obtained and the number of generated particles was high.

[0075] (Comparative Example 3)

A sintered body was produced based on the same conditions as Example 1 other than adjusting the respective component compositions as described in Table 1.

The respective component compositions of the magnetic materials to become the matrix of Comparative Example 3 were Co: 73 mol%, and Pt: 20 mol%. Meanwhile, the oxides were B₂O₃: 6 mol%, and Co₃B₂O₆: 1 mol%. The Cr/B ratio was 0 and the B/O ratio was 0.6. These results failed to satisfy the conditions of the present invention.

[0076] The results are similarly shown in Table 1. The average area of the oxide phase per grain in the target was 5.1 μm^2 . The appearance of the surface of the sintered body after being immersed in water showed discoloration. Moreover, the relative density of this sintered body was 96.3%.

[0077] (Comparative Example 4)

A sintered body was produced based on the same conditions as Example 1 other than adjusting the respective component compositions as described in Table 1.

The respective component compositions of the magnetic materials to become the matrix of Comparative Example 4 were Co: 66 mol%, Cr: 9 mol%, and B: 10 mol%. Meanwhile, the oxides were CoO: 7 mol%, and TiO₂: 8 mol%. The Cr/B ratio was 0.9 and the B/O ratio was 0.43. The conditions of the present invention were not satisfied. Moreover, the generation of Cr(BO₃) could not be verified in the XRD measurement of the sample after the sintering process.

[0078] The results are similarly shown in Table 1. The average area of the oxide phase per grain in the target was $3.8 \mu\text{m}^2$. The appearance of the surface of the sintered body after being immersed in water showed discoloration. This is considered to be because, as a result of the Cr/B ratio being small and the B content being great relative to the Cr content, large amounts of boron oxide were generated and the oxide grains were coarsened. Moreover, the relative density of this sintered body was 99.0%.

[0079] (Comparative Example 5)

A sintered body was produced based on the same conditions as Example 1 other than adjusting the respective component compositions as described in Table 1.

The respective component compositions of the magnetic materials to become the matrix of Comparative Example 5 were Co: 50 mol%, Cr: 30 mol%, and Ru: 10 mol%. Meanwhile, the oxides were B_2O_3 : 7 mol%, and SiO_2 : 3 mol%. The Cr/B ratio was 2.1 and the B/O ratio was 0.52. The conditions of the present invention were not satisfied. Moreover, the generation of $\text{Cr}(\text{BO}_3)$ could not be verified in the XRD measurement of the sample after the sintering process.

[0080] The results are similarly shown in Table 1. The average area of the oxide phase per grain in the target was $8.2 \mu\text{m}^2$. The appearance of the surface of the sintered body after being immersed in water showed discoloration. This is considered to be a result of the coarsening of the oxide grains due to the presence of boron oxide. Moreover, the relative density of this sintered body was 99.2%.

[Industrial Applicability]

[0081] Conventionally, with a sintered body, particularly a sputtering target for forming a magnetic recording film to which boron oxide is added as an inorganic material, if the sintering temperature is lowered in order to inhibit the grain growth because the boron oxide grains become coarse after the sintering process, there are problems in that the density cannot be increased, and that numerous particles are generated.

This was caused by the following problems; namely, since a boron oxide raw material has high hygroscopicity and tends to become aggregated, it is difficult to obtain fine boron oxide, and since boron oxide has a low melting point and tends to become liquefied during the sintering process, the boron oxide grains grow into large grains during the sintering process.

In light of the foregoing points, a phase composed of the oxide contains at least one or more types of compounds selected from $\text{Cr}(\text{BO}_3)$, $\text{Co}_2\text{B}_2\text{O}_5$, and $\text{Co}_3\text{B}_2\text{O}_6$ in the sintered body, particularly the sputtering target for forming a magnetic recording film of the present invention.

5 [0082] A compound selected from $\text{Cr}(\text{O}_3)$, $\text{Co}_2\text{B}_2\text{O}_5$, and $\text{Co}_3\text{B}_2\text{O}_6$ possesses the properties of being able to maintain a fine structure and increase the melting point of boron oxide, and thereby inhibit the reaction with water. This enables the solution of the foregoing problems caused by boron oxide. Accordingly, the present invention is capable of ensuring the favorable quality of a sintered body, particularly a sputtering target for forming a magnetic recording film, to which boron oxide is added, and inhibiting the generation of particles during sputtering.

10 [0083] Moreover, when a sintered body containing residue of boron oxide is subject to wet working via machining or stored in a highly humid location, such boron oxide reacts with moisture and boric acid is generated, and such boric acid becomes precipitated on the surface of the sintered body (target) and causes stains or contamination. However, the present invention is capable of also resolving these problems.

15 Since the present invention can inhibit the generation of particles, the present invention yields a superior effect of being able to reduce the percent defective of the magnetic recording film and realize cost reduction, and contributes considerably to the improvement in the quality and productivity of magnetic thin films, and is effective as a magnetic body thin film of a magnetic recording medium, particularly as a ferromagnetic material sputtering target for use in depositing a hard disk drive recording layer.

CLAIMS

1. A sintered body which contains at least cobalt as a metal and which is made from boron and/or one or more types of metal or alloy selected from platinum group elements, and oxides, wherein a phase composed of the oxide contains at least one or more types of compounds selected from $\text{Cr}(\text{BO}_3)$, $\text{Co}_2\text{B}_2\text{O}_5$, and $\text{Co}_3\text{B}_2\text{O}_6$.

2. A sintered body which contains at least cobalt as a metal and which is made from chromium, and boron and/or one or more types of metal or alloy selected from platinum group elements, and oxides, wherein a phase composed of the oxide contains at least one or more types of compounds selected from $\text{Cr}(\text{BO}_3)$, $\text{Co}_2\text{B}_2\text{O}_5$, and $\text{Co}_3\text{B}_2\text{O}_6$.

3. The sintered body according to claim 1 or claim 2, wherein there is no discoloration on a surface of the sintered body when the sintered body comes into contact with or is immersed in water.

4. The sintered body according to claim 2 or claim 3, wherein an atomic ratio of chromium and boron is $\text{Cr}/\text{B} \geq 1$.

5. The sintered body according to any one of claims 1 to 4, wherein an atomic ratio of boron and oxygen is $\text{B}/\text{O} \leq 0.5$.

6. The sintered body according to any one of claims 1 to 5, wherein, in a ratio of metal components, a content of chromium is 0 to 50 mol%, a content of boron and/or platinum group elements is 0 (but excluding 0) to 40 mol%, and remainder is cobalt.

7. The sintered body according to any one of claims 1 to 6, wherein a content of boron oxide is 0.5 to 10 mol% by B_2O_3 conversion.

8. The sintered body according to any one of claims 1 to 7, wherein a total content of chromium oxide is 0.5 to 10 mol% by Cr_2O_3 conversion.

9. The sintered body according to any one of claims 1 to 8, wherein the sintered body contains oxides having as its constituent one or more types of elements selected from Al, Co, Cu, Fe, Ga, Ge, Hf, Li, Mg, Mn, Mo, Nb, Ni, Sb, Si, Sn, Ta, Te, Ti, V, W, Y, Zn and Zr, and a total oxide content is 2 to 8 wt% by oxygen conversion.

10. The sintered body according to any one of claims 1 to 9, wherein an average area per grain of the oxides in the sintered body is $2 \mu\text{m}^2$ or less.

11. The sintered body according to any one of claims 1 to 10, wherein the sintered body additionally contains one or more elements selected from Ti, V, Mn, Zr, Nb, Mo, Ta, and W in an amount of 0.5 mol% or more and 10 mol% or less.

12. The sintered body according to any one of claims 1 to 11, wherein the sintered body additionally contains one or more types selected from carbon, nitride, and carbide.

13. The sintered body according to any one of claims 1 to 12, wherein the sintered body has a relative density of 95% or more.

14. A sputtering target for forming a magnetic recording film produced from the sintered body according to any one of claims 1 to 13.

15. A method of producing a sintered body, wherein one or more types of metal or alloy which contains at least cobalt as a metal and which is selected from boron and/or platinum group elements, and at least one or more types of oxides selected from $\text{Cr}(\text{BO}_3)$, $\text{Co}_2\text{B}_2\text{O}_5$, $\text{Co}_3\text{B}_2\text{O}_6$ are mixed and sintered.

16. A method of producing a sintered body, wherein one or more types of metal or alloy which contains at least cobalt as a metal and which is selected from chromium, and boron and/or platinum group elements, and at least one or more types of oxides selected from $\text{Cr}(\text{BO}_3)$, $\text{Co}_2\text{B}_2\text{O}_5$, $\text{Co}_3\text{B}_2\text{O}_6$ are mixed and sintered.

17. The method of producing a sintered body according to claim 15 or claim 16, wherein boron oxide and chromium oxide and/or cobalt oxide are prepared and calcined in an atmosphere to produce at least one or more types of oxides selected from $\text{Cr}(\text{BO}_3)$, $\text{Co}_2\text{B}_2\text{O}_5$, and $\text{Co}_3\text{B}_2\text{O}_6$.

18. A method of producing the sintered body according to any one of claims 1 to 13 according to the method of producing a sintered body according to any one of claims 15 to 17.