

DESCRIPTION

Co-Cr-Pt-B FERROMAGNETIC SPUTTERING TARGET

TECHNICAL FIELD

[0001] The present invention relates to a sputtering target used for deposition of a magnetic film of a magnetic recording medium, particularly a magnetic recording layer of a hard disc drive employing a perpendicular magnetic recording method, and to the sputtering target of which a stable discharge is obtained at a lower voltage when sputtering in a magnetron sputtering system.

BACKGROUND ART

[0002] In a field of magnetic recording as typified by the hard disc drive, material systems based on Co, Fe, or Ni which is a ferromagnetic metal are used as a material of a magnetic thin film responsible for recording. Particularly, for current magnetic recording layers of the hard disc drive, a Co-Pt base material, a Co-Cr-Pt base material, or a composition of the same and a non-magnetic inorganic substance is used.

[0003] For producing the magnetic recording layer of this hard disc drive, mainly a sputtering method, particularly a magnetron sputtering method is often used, because of its high productivity. As a method for producing a target material which is indispensable when using the sputtering method, generally used is a melting method or a powder metallurgy method. Which of these is used is determined by required properties of the target and the thin film.

[0004] The sputtering method is a method of attaining film deposition by applying a negative voltage to the target material under an inert gas atmosphere and depositing atoms constituting the target onto a substrate. Applying the negative voltage progresses ionization of the inert gas, and the cationized inert gas is attracted to and bombards with the target, thereby knocking out atoms constituting the target. The atoms adhere to a substrate surface to attain film deposition on the substrate. The magnetron sputtering method is a method in which a magnet is placed in a backside of the target and a magnetic field generated on the

target surface promotes ionization of a plasma gas, in the sputtering method, to improve efficiency of the sputtering. In the field of the magnetic recording as typified by the current hard disk drives, this magnetron sputtering method is often used from viewpoints of film deposition speed, yield of the target, and stability of the sputtering.

[0005] However, targets to be used for film deposition of a magnetic recording layer are mainly ferromagnetic materials, which impede transmission of magnetic flux emitted from a magnet placed on the backside of the target. If the transmission of the magnetic flux is too much impeded, advantages of using the magnetron sputtering method described above are lost, resulting in a decrease in the target yield and instability of sputtering discharge. Therefore, the targets to be used in the magnetron sputtering method are required to have leakage magnetic flux density as high as possible.

[0006] To improve the leakage magnetic flux density of the target, various methods have been proposed. For example, in Japanese Patent No. 4673453 (JPB4673453), described are a ferromagnetic sputtering target characterized in that a texture thereof includes a metal matrix (A), and a spherical phase (B) containing 90% by mol or more of Co and having a difference between a longest diameter and a shortest diameter of 0 to 50%, into the metal matrix (A), and wherein a diameter of the spherical phase (B) is 30 to 150 μm , and made of metals having a composition containing 20% by mol or less of Cr, the balance being Co, or metals having a composition containing 20% by mol or less of Cr, 5% by mol or more and 30% by mol or less of Pt, the balance being Co. Specifically, it is described, in the ferromagnetic sputtering target having composition of 78Co-12Cr-5TiO₂-5SiO₂, 65Co-13Cr-15Pt-5TiO₂-2Cr₂O₃, 85Co-15Cr, or 70Co-15Cr-15Pt, that one having a texture containing the spherical Co phase (B) becomes to have higher average leakage magnetic flux density than those having the texture not containing the spherical Co phase (B).

[0007] In Japanese Patent No. 4758522 (JPB4758522), described is a ferromagnetic sputtering target characterized in that a texture thereof include a metal matrix (A), and a flat phase (B) containing 90% by weight or more of Co, into the metal matrix (A), and wherein the phase (B) has an average grain size of 10 μm or more and 150 μm or less and an average

aspect ratio of 1:2 to 1:10, and made of metals having a composition containing 20% by mol or less of Cr, the balance being Co, or metals having a composition containing 20% by mol or less of Cr, and 5% by mol or more and 30% by mol or less of Pt, the balance being Co. Specifically, it is described, in a ferromagnetic sputtering target having a composition of $78.73\text{Co}-13.07\text{Cr}-8.2\text{SiO}_2$, that one having a texture containing the flat Co phase (B) becomes to have higher average leakage magnetic flux density than conventional one (details are not known), though it has lower average leakage magnetic flux density than those produced by using a Co atomized powder (spherical shape).

[0008] In Japanese Patent No. 5394576 (JPB5394576), described is a ferromagnetic sputtering target characterized in that a texture thereof includes a metal matrix (A), a Co-Pt alloy phase (B) containing 40 to 76% by mol of Pt, and a Co alloy phase (C) containing 90% by mol or more of Co, which is different from the Co-Pt alloy phase (B), into the metal matrix (A), and made of metals having a composition containing 20% by mol or less of Cr, and 5% by mol or more of Pt, the balance being Co. Specifically, it is described, in the ferromagnetic sputtering target having composition of $88(\text{Co}-5\text{Cr}-15\text{Pt})-5\text{CoO}-7\text{SiO}_2$ or $59\text{Co}-6\text{Cr}-20\text{Pt}-5\text{Ru}-4\text{TiO}_2-4\text{SiO}_2-2\text{Cr}_2\text{O}_3$, that one having a texture including a Co-Pt alloy phase (B) having a grain size of 50 to 150 μm and containing 50% by mol of Pt, and a pure Co phase (C) having a grain size of 70 to 150 μm , becomes to have a higher average leakage magnetic flux density than those having a texture not including the Co-Pt alloy phase (B) or the Co alloy phase (C) and those having a texture including the Co-Pt alloy phase (B) having a grain size of 50 to 150 μm and containing 81% by mol of Pt, and the pure Co phase (C) having a grain size of 70 to 150 μm . When B is contained as an additive element of 0.5% by mol or more and 10% by mol or less, it is described that B is present in the metal matrix (A) and sometimes slightly diffuses into the Co-Pt alloy phase (B) or the Co phase (C) through an interface between the Co-Pt alloy phase (B) and the metal matrix (A) or an interface between the Co phase (C) and the metal matrix (A). In other words, B is sometimes present in the Co-Pt alloy phase (B) or the Co phase (C) near the interfaces with the metal matrix (A), but it is not an embodiment that B is distributed throughout the Co-Pt

alloy phase (B) or the Co phase (C).

[0009] Any of the prior patents described above discloses that the leakage magnetic flux density of the ferromagnetic sputtering target can be increased by making the target material have a texture, in which there are Co alloy phases containing 90% by mol or more of large spherical Co having a grain size of 10 μm to 150 μm in the metal matrix (A). Although it is described that B can be contained as the additive element, there is no example containing B, and it is unclear whether desired effects can be obtained or not in a Co-Cr-Pt-B sputtering target. Also, it is not disclosed or suggested to control a distribution state of B, and since B is usually agglomerated and unevenly distributed, a person skilled in the art will not understand that it is disclosed that B is distributed throughout.

[0010] In the Co-Cr-Pt-B sputtering target not containing oxide, denseness of B agglomerate phases is increased in the metal matrix, causing microcracks due to brittleness of B, thereby becoming a problem of occurring of arcing starting from these microcracks. If discharge anomaly due to the arcing occurs, sputtering cannot be performed stably, and a yield is significantly reduced.

[0011] As a method for suppressing the arcing in the Co-Cr-Pt-B sputtering targets, it is described, in Japanese Patent Laid-Open No. 2015-61946 (JPA 2015-61946), that a texture of an ingot composed of the Co-Cr-Pt-B based alloy is adjusted by controlling a processing method composed of precise rolling or forging, and by heat treatment, to achieve a fine and uniform rolled texture without microcracks. In Fig. 1 of the publication, shown is a SEM observation image of a texture of the sputtering target, in which the texture is composed of two phases, i.e., a matrix phase and a B-rich phase, and the B-rich phase has a scaly cloud shape. As can be seen in comparison with SEM observation images of Examples described later, in contrast that B is distributed throughout the alloy phase in the sputtering target of the present invention, it is shown that B is agglomerated and unevenly distributed in the B-rich phase in Fig. 1 of the publication.

CITATION LIST

PATENT LITERATURE

[0012] PTL1: Japanese Patent No. 4673453 (JPB4673453)

PTL2: Japanese Patent No. 4758522 (JPB4758522)

PTL3: Japanese Patent No. 5394576 (JPB5394576)

PTL4: Japanese Patent Laid-Open No. 2015-61946 (JPA 2015-61946)

SUMMARY OF INVENTION

TECHNICAL PROBLEM

[0013] An objective of the present invention is to provide a ferromagnetic sputtering target capable of obtaining stable discharge without discharge anomaly in a magnetron sputtering method. In particular, the objective is to provide a Co-Cr-Pt-B ferromagnetic sputtering target having high leakage magnetic flux density and capable of reducing a discharge voltage during sputtering, and a method for producing the same.

SOLUTION TO PROBLEM

[0014] The present inventor has found that in the Co-Cr-Pt-B ferromagnetic sputtering target, the leakage magnetic flux density can be improved and the discharge voltage can be reduced, by controlling B to disperse in both of a Co-Cr-Pt alloy phase and a Co phase or a Co-Cr alloy phase so that B agglomerate phases are not unevenly distributed, i.e., by making a texture including a Co-Cr-Pt-B alloy phase (A) and an alloy phase (B) which is any one of a Co-B alloy or a Co-Cr-B alloy, and has arrived at completion of the present invention.

[0015] According to the present invention, provided is a Co-Cr-Pt-B ferromagnetic sputtering target and a method for producing the same of the following embodiments.

[1] A Co-Cr-Pt-B ferromagnetic sputtering target including:

a Co-Cr-Pt-B alloy phase (A) containing more than 0% by atom and 30% by atom or less of B, in which B is distributed throughout without B agglomerate phases unevenly distributed;

an alloy phase (B), which is any one of a Co-B alloy, a Co-Cr-B alloy, or a Co-Pt-B alloy, containing more than 0% by atom and 20% by atom or less of B, in which B is distributed throughout without B agglomerate phases unevenly distributed;

wherein the alloy phase (A) accounts for 50% by volume or more in the sputtering

target; and

wherein the alloy phase (B) accounts for less than 50% by volume in the sputtering target.

[2] The Co-Cr-Pt-B ferromagnetic sputtering target according to the above [1], wherein the Co-Cr-Pt-B ferromagnetic sputtering target contains more than 0% by atom and 30% by atom or less of Cr, 5% by atom or more and 30% by atom or less of Pt, and more than 0% by atom and 25% by atom or less of B, the balance being Co and incidental impurities.

[3] The Co-Cr-Pt-B ferromagnetic sputtering target according to the above [1] or [2], wherein the alloy phase (A) further contains more than 0% by atom and 25% by atom or less of one or more elements selected from the group consisting of Al, Si, Sc, Ti, V, Mn, Fe, Ni, Cu, Zn, Ge, Y, Zr, Nb, Ta, Mo, W, Ru, Ag, Sn, La, Ce, Pr, Nd, Sm, Gd, Tb, Dy, Ho, and Hf, as additive elements.

[4] A method for producing a Co-Cr-Pt-B ferromagnetic sputtering target according to any one of the above [1] to [3], the method including:

a mixing step of weakly mixing a Co-Cr-Pt-B alloy powder containing more than 0% by atom and 30% by atom or less of B, and any one of a Co-B alloy powder, a Co-Cr-B alloy powder, or a Co-Pt-B alloy powder, containing more than 0% by atom and 20% by atom or less of B to obtain a mixed powder; and

a sintering step of sintering the mixed powder to obtain a sintered product.

[5] The method of production according to the above [4], wherein the Co-Cr-Pt-B alloy powder, and the Co-B alloy powder, the Co-Cr-B alloy powder, or the Co-Pt-B alloy powder are atomized alloy powders.

[6] The method of production according to the above [4] or [5], wherein the sintering step includes holding the mixed powder under a pressure of 10 MPa or more and 100 MPa or less, and a temperature of 700°C or more and 1,300°C or less for 30 minutes or more and 3 hours or less.

ADVANTAGEOUS EFFECTS OF INVENTION

[0016] A Co-Cr-Pt-B ferromagnetic sputtering target of the present invention is composed

of a Co-Cr-Pt-B alloy phase (A) containing more than 0% by atom and 30% by atom or less of B and in which B is distributed throughout, and an alloy phase (B) which is any one of a Co-B alloy, a Co-Cr-B alloy, or Co-Pt-B alloy, containing more than 0% by atom and 20% by atom or less of B and in which B is distributed throughout; and since B is distributed throughout the target without B agglomerate phases unevenly distributed, a discharge voltage during sputtering can be reduced, and thus suppressing discharge anomaly such as arcing caused by excess voltage as well as having a high leakage magnetic flux density.

[0017] According to a production method of the present invention, obtained is a Co-Cr-Pt-B ferromagnetic sputtering target, which is composed of a Co-Cr-Pt-B alloy phase (A) containing more than 0% by atom and 30% by atom or less of B and in which B is distributed throughout, and an alloy phase (B) which is any one of a Co-B alloy, a Co-Cr-B alloy, or a Co-Pt-B alloy, containing more than 0% by atom and 20% by atom or less of B and in which B is distributed throughout; and since B is distributed throughout the target without B agglomerate phases unevenly distributed, the Co-Cr-Pt-B ferromagnetic sputtering target which has the high leakage magnetic flux density and can reduce the discharge voltage during sputtering can be obtained.

BRIEF DESCRIPTION OF DRAWINGS

[0018] [Fig. 1] Fig. 1 is a graph showing a relationship between input power and a voltage value of Examples 1 to 3 and Comparative Examples 1 to 4.

[Fig. 2] Fig. 2 is a SEM observation image of Example 1.

[Fig. 3] Fig. 3 is a SEM observation image of Example 2.

[Fig. 4] Fig. 4 is a SEM observation image of Example 3.

[Fig. 5] Fig. 5 is a SEM observation image of Comparative Example 1.

[Fig. 6] Fig. 6 is a SEM observation image of Comparative Example 2.

[Fig. 7] Fig. 7 is a SEM observation image of Comparative Example 3.

[Fig. 8] Fig. 8 is an EPMA-WDX mapping image of Example 1.

[Fig. 9] Fig. 9 is an EPMA-WDX mapping image of Example 2.

[Fig. 10] Fig. 10 is an EPMA-WDX mapping image of Example 3.

[Fig. 11] Fig. 11 is an EPMA-WDX mapping image of Comparative Example 1.

[Fig. 12] Fig. 12 is an EPMA-WDX mapping image of Comparative Example 2.

[Fig. 13] Fig. 13 is an EPMA-WDX mapping image of Comparative Example 3.

DESCRIPTION OF EMBODIMENTS

[0019] The present invention provides a ferromagnetic sputtering target which has high leakage magnetic flux density and can reduce a discharge voltage during sputtering.

[0020] A Co-Cr-Pt-B ferromagnetic sputtering target of the present invention includes: a Co-Cr-Pt-B alloy phase (A) containing more than 0% by atom and 30% by atom or less of B, in which B is distributed throughout without B agglomerate phases unevenly distributed; an alloy phase (B), which is any one of a Co-B alloy, a Co-Cr-B alloy, or a Co-Pt-B alloy, containing more than 0% by atom and 20% by atom or less of B, in which B is distributed throughout without B agglomerate phases unevenly distributed; wherein the alloy phase (A) accounts for 50% by volume or more in the sputtering target; and wherein the alloy phase (B) accounts for less than 50% by volume in the sputtering target.

[0021] In the Co-Cr-Pt-B ferromagnetic sputtering target of the present invention, the alloy phase (A) is more than the alloy phase (B), and the alloy phase (A) accounts for 50% by volume or more, preferably 60% by volume or more, more preferably 65% by volume or more, and the alloy phase (B) accounts for less than 50% by volume, preferably less than 40% by volume, more preferably less than 35% by volume. The Co-Cr-Pt-B ferromagnetic sputtering target of the present invention is composed of 2 phases of the alloy phase (A) and the alloy phase (B), and does not contain any other phases such as an oxide phase.

[0022] The alloy phase (A) contains more than 0% by atom and 30% by atom or less of B, preferably 3% by atom or more and 26% by atom or less of B, and the phase (B) contains more than 0% by atom and 20% by atom or less of B, preferably 3% by atom or more and 18.5% by atom or less of B.

[0023] "B is distributed throughout" in the alloy phase (B) means that there is no area where B is not present in an arbitrary $10\ \mu\text{m} \times 10\ \mu\text{m}$ region in a SEM observing surface of a magnification of 1,000 times and in an EPMA-WDX mapping image of an acceleration

voltage of 20 kV, an irradiation current of 8×10^{-5} A, a beam diameter of 10 μm , and an observing magnification of 200 times.

[0024] Also, in the alloy phase (A), too, it is preferable that B is distributed throughout. Here, "B is distributed throughout" in the alloy phase (A) means that there is no area where B is not present in an arbitrary 10 $\mu\text{m} \times 10 \mu\text{m}$ region in a SEM observing surface of a magnification of 1,000 times and in an EPMA-WDX mapping image of an acceleration voltage of 20 kV, an irradiation current of 8×10^{-5} A, a beam diameter of 10 μm , and an observing magnification of 200 times.

[0025] It is preferable that the Co-Cr-Pt-B ferromagnetic sputtering target of the present invention has a composition containing more than 0% by atom and 30% by atom or less of Cr, 5% by atom or more and 30% by atom or less of Pt, and more than 0% by atom and 25% by atom or less of B, and the balance being Co and incidental impurities. It is particularly preferable that it has a composition containing 3% by atom or more and 25% by atom or less of Cr, 10% by atom or more and 25% by atom or less of Pt, and 3% by atom or more and 20% by atom or less of B, and the balance being Co and incidental impurities.

[0026] The alloy phase (A) can further contain more than 0% by atom and 25% by atom or less, preferably 1% by atom or more and 15% by atom or less, of one or more elements selected from the group consisting of Al, Si, Sc, Ti, V, Mn, Fe, Ni, Cu, Zn, Ge, Y, Zr, Nb, Te, Mo, W, Ru, Ag, Sn, La, Ce, Pr, Nd, Sm, Gd, Tb, Dy, Ho, and Hf, as additive elements.

[0027] In the present invention, an average composition of each of the alloy phase (A) and the alloy phase (B) is measured by the following method. A vertical section to the sputtering target is cut out, which is then polished in turn using abrasive papers of grades from P80 to P1,200, and finally buffed using diamond abrasive grains of 1 μm in a grain size to obtain a polished surface. The polished surface is observed using EPMA. As observation conditions for EPMA, using JXA-8500F produced by JEOL as the equipment, adopted are an accelerating voltage of 20 kV, an irradiation current of 8×10^{-5} A, a beam diameter of 10 μm , observing magnification of 200 times, and pixel number of 128×128 , and elemental mapping images are acquired. When observing, a quantitative analysis mode

is used, and a metal as a substance to be measured and the ZAF method as a correction method are selected. In the elemental mapping images obtained, once a phase (corresponding to the alloy phase (A)) in which all of the main components Co, Cr, Pt, and B are detected and a phase (corresponding to the alloy phase (B)) in which Cr or Pt is not detected or in extremely lower concentration than that of Cr or Pt in the alloy phase (A) are identified, a location of each phase is selected that has a size large enough to fully contain a perfect circle having a diameter of 50 μm , and a composition is measured at its center point of gravity. The above observations are made in three fields of view, i.e., three each for the alloy phase (A) and the alloy phase (B), and the average of these observations is taken as the average composition of the alloy phase (A) and the alloy phase (B), respectively.

[0028] In the present invention, a volume ratio of the alloy phase (A) and the alloy phase (B) is measured by the following method. First, a mass concentration map for each element is obtained using EPMA by the method described above. Using the mass concentration map obtained, a line analysis of a horizontal direction is performed from an edge to an edge of the image for elements not detected in the alloy phase (B) (e.g., Cr or Pt in a case of Co-B, Pt in a case of Co-Cr-B). In the line analysis, a location other than a boundary between the alloy phase (A) and the alloy phase (B) in phases corresponding to each of the alloy phase (A) and the alloy phase (B), i.e., a line that includes both areas corresponding to only the alloy phase (A) and areas corresponding to only the alloy phase (B) is selected. An average value of a maximum value and a minimum value of profiles obtained from the line analysis is used as a threshold value, to binarize the map. Here, a range exceeding the threshold value is defined as the alloy phase (A); and a range of the threshold value or less is defined as the alloy phase (B). A binarized image obtained is analyzed by ImageJ particle analysis, to obtain an area ratio of the alloy phase (A) and the alloy phase (B). The above operations are made for three fields of view, and its average value is taken as an area ratio of the sample. This area ratio directly corresponds to the volume ratio of each phase. Basically, Pt is used as the element used in the line analysis of the mass concentration map, but Cr is used when Pt is included in all phases.

[0029] The Co-Cr-Pt-B ferromagnetic sputtering target of the present invention can be produced by a powder metallurgy process. A production method of the present invention includes: step of obtaining a mixed powder by weakly mixing a Co-Cr-Pt-B alloy powder containing more than 0% by atom and 30% by atom or less of B, and any one of a Co-B alloy powder, a Co-Cr-B alloy powder, or a Co-Pt-B alloy powder, containing more than 0% by atom and 20% by atom or less of B; and step of obtaining a sintered product by sintering the mixed powder.

[0030] As the Co-Cr-Pt-B alloy powder, and the Co-B alloy powder, the Co-Cr-B alloy powder, or the Co-Pt-B alloy powder, atomized alloy powders, or powders produced by a chemical production method or other production methods can be used, but the atomized alloy powders are preferable.

[0031] The weakly mixing means not a mixing that pulverizes each raw material powder by applying large mixing and agitation energy, but a gentle mixing that remains preserving each alloy powder without pulverizing the Co-Cr-Pt-B alloy powder constituting the alloy phase (A) and the Co-B alloy powder, the Co-Cr-B alloy powder, or the Co-Pt-B alloy powder, constituting the alloy phase (B). In the production method of the present invention, the weakly mixing is, in a case of using a ball mill, preferably a mixing at a small rotating speed for a short time, e.g., at the rotating speed of 30 rpm or more and 100 rpm or less for 10 minutes or more and 1 hour or less, particularly preferably a mixing using a shaker or a mixer of with only up-and-down and side-to-side rocking motion and no stirring balls.

[0032] Sintering can be performed in a vacuum atmosphere at a sintering pressure of 10 MPa or more and 100 MPa or less, a sintering temperature of 700°C or more and 1,300°C or less, and a holding time of 30 minutes or more and 3 hours or less, preferably at a sintering pressure of 20 MPa or more and 80 MPa or less, a sintering temperature of 800°C or more and 1,100°C or less, and a holding time of 30 minutes or more and 2 hours or less. If the sintering pressure is too low, relative density of a sintered body decreases. If the sintering temperature is too low, the relative density of the sintered body decreases, while if the sintering temperature is too high, B tends to agglomerate too much, forming coarse B

agglomerate phases as seen in the conventional arts, to unevenly distribute B without being distributed throughout the target. If a sintering holding time is too short, the relative density of the sintered body decreases, while if the sintering holding time is too long, B tends to agglomerate too much, forming the coarse B agglomerate phases as seen in the conventional arts, to unevenly distribute B without being distributed throughout the target. Decreased relative density causes particles to be generated from the target during sputtering discharge. On the other hand, the uneven distribution of the coarse B agglomerate phases can cause discharge faults like arcing and so on.

EXAMPLES

[0033] Hereinafter, the present invention will be further specifically described with reference to Examples and Comparative Examples, but the present invention is not limited by these Examples.

[0034] Each of Examples 1 to 23 was obtained for each target composition shown in Table 1 as follows; the atomized alloy powder of the raw material constituting the alloy phase (A) shown in Table 1 and the atomized alloy powder of the raw material constituting the second phase (in Examples, this means the alloy phase (B), and the same applies hereinafter) shown in Table 1 were weighed so that a content of the second phase is that shown in Table 1 and the balance content is the alloy phase (A), and they were mixed by using a shaker at 15 to 100 rpm for 15 minutes, and the mixed powder obtained was filled in dice made of carbon, and sintered by vacuum hot pressing under conditions of a vacuum atmosphere at a pressure of 30 MPa, a temperature of 800°C to 1,100°C, and a holding time of 1 hour. Though the sintering temperature varied depending on the target composition, it was set to achieve relative density of 97% or more for all samples. A sintered body obtained was ground and turned using a surface grinder and a lathe to produce a disc-shaped sputtering target with a diameter of 165 mm and a thickness of 6.4 mm.

[0035] The disk-shaped sputtering target obtained was attached to a magnetron sputtering system, and while flowing argon gas so that an argon gas pressure is 4.0 Pa, a sputtering discharge voltage was measured using a data logger while the sputtering discharge was

continued at arbitrary input power. Setting conditions of the data logger were those to measure 15,000 data points at a sampling cycle of 2 μ sec, and to repeat this 100 times. The average of each measurement data was calculated, and the average value for 100 times was averaged, to calculate the sputtering discharge voltage values under the measurement conditions. The results are shown in Table 1.

[0036] [Table 1]

Table 1 Compositions of Each Sputtering Target, and Voltage Values at Input Power of 500 W

NO	Example	Target Composition (% by atom)	Phase (A) Composition (% by atom)	2 nd Phase Composition (% by atom)	2 nd Phase Content (% by volume)	Voltage Value (V) at 500 W
1	Example 1	Co-15Cr-10Pt-10B	Co-20.1Cr-11.8Pt-11.8B	Co-5Pt-5B	25	324
2	Example 2		Co-16.9Cr-13.5Pt-11.8B	Co-10Cr-5B	25	321
3	Example 3		Co-20.5Cr-13.7Pt-7.9B	Co-18.5B	25	322
4	Comparative Example 1		-	-	-	340
5	Comparative Example 2		Co-19.8Cr-8.4Pt-13.2B	Co-15Pt	25	335
6	Comparative Example 3		Co-20Cr-11.7Pt-13.3B	Co-5Pt	25	336
7	Comparative Example 4		Co-20.1Cr-13.4Pt-13.4B	Co	25	352
8	Example 4		Co-15.8Cr-10.5Pt-10.3B	Co-5B	5	329
9	Example 5		Co-16.7Cr-11.2Pt-10.6B	Co-5B	10	327
10	Example 6		Co-18.9Cr-12.6Pt-11.4B	Co-5B	20	324
11	Example 7	Co-10Cr-25Pt-5B	Co-21.8Cr-14.5Pt-12.4B	Co-5B	30	325
12	Example 8		Co-25.6Cr-17.1Pt-13.7B	Co-5B	40	328
13	Example 9		Co-13.8Cr-34.5Pt-5.1B	Co-5B	25	321
14	Example 10		Co-13.7Cr-32.5Pt-5.1B	Co-5Pt-5B	25	322
15	Example 11		Co-14Cr-35Pt-0.8B	Co-18.5B	25	320
16	Comparative Example 5		-	-	-	332
17	Comparative Example 6		Co-13.7Cr-34.3Pt-6.9B	Co	25	333
18	Example 12	Co-20Cr-15Pt-20B	Co-26.9Cr-20.2Pt-25.3B	Co-5B	25	325
19	Example 13		Co-26.8Cr-18.5Pt-25.2B	Co-5Pt-5B	25	325
20	Example 14		Co-27.3Cr-20.4Pt-21.6B	Co-18.5B	25	326
21	Comparative Example 7		-	-	-	346
22	Comparative Example 8		Co-26.8Cr-20.1Pt-26.8B	Co	25	345
23	Example 15	Co-25Cr-10Pt-15B	Co-33.7Cr-13.5Pt-18.6B	Co-5B	25	324
24	Example 16		Co-33.5Cr-11.8Pt-18.5B	Co-5Pt-5B	25	320
25	Example 17		Co-34.1Cr-13.6Pt-14.8B	Co-18.5B	25	322
26	Comparative Example 9		-	-	-	340
27	Comparative Example 10		Co-33.5Cr-13.4Pt-20.1B	Co	25	338
28	Example 18	Co-5Cr-20Pt-10B	Co-6.8Cr-27.3Pt-11.9B	Co-5B	25	323
29	Example 19		Co-6.8Cr-25.4Pt-11.9B	Co-5Pt-5B	25	321
30	Example 20		Co-6.9Cr-27.6Pt-7.9B	Co-18.5B	25	324
31	Comparative Example 11		-	-	-	334
32	Comparative Example 12		Co-6.8Cr-27.1Pt-13.6B	Co	25	334
33	Example 21	Co-5Cr-25Pt-10Ru-5B	Co-7Cr-34.8Pt-13.9Ru-5.1B	Co-5B	25	321
34	Example 22		Co-6.9Cr-32.7Pt-13.8Ru-5.1B	Co-5Pt-5B	25	320
35	Example 23		Co-7Cr-35.2Pt-14.1Ru-0.7B	Co-18.5B	25	320
36	Comparative Example 13		-	-	-	335
37	Comparative Example 14		Co-6.9Cr-34.6Pt-13.8Ru-6.9B	Co	25	337

[0037] In Comparative Examples 1, 5, 7, 9, 11, and 13, the sputtering targets were produced in the same manner as in Examples, except that the mixed powder was prepared by mixing

the individual metal powders instead of the atomized alloy powder.

[0038] In Comparative Examples 2 and 3, the sputtering targets were produced in the same manner as in Examples, except that an atomized alloy powder not containing B was used as the raw material powder constituting the second phase.

[0039] In Comparative Examples 4, 6, 8, 10, 12, and 14, the sputtering targets were produced in the same manner as in Examples, except that a Co metal powder was used as the raw material powder constituting the second phase.

[0040] For the sputtering targets of Examples 1 to 3 and Comparative Examples 1 to 4 having the same composition of Co-15Cr-10Pt-10B, the sputtering discharge voltage was measured by varying the input power from 100 W to 1,000 W in 100 W steps. The results are shown in Table 2 and Fig. 1.

[0041] [Table 2]

Table 2 Input Power and Sputtering Discharge Voltage

Input Power (W)	Sputtering Discharge Voltage (V)						
	Example 1	Example 2	Example 3	Comparative Example 1	Comparative Example 2	Comparative Example 3	Comparative Example 4
	Co-5Pt-5B	Co-10Cr-5B	Co-18.5B	No 2nd Phase	Co-15Pt	Co-5Pt	100Co
100	273	275	278	281	280	290	290
200	298	297	299	310	308	309	318
300	311	309	311	323	320	323	333
400	318	315	317	332	328	330	343
500	324	321	322	340	335	336	352
600	330	327	327	348	342	342	360
700	334	332	331	355	349	348	367
800	339	337	336	360	354	354	372
900	343	342	341	365	359	361	376
1000	348	346	345	368	363	369	380
PTF(%)	55.2	53.3	72.06	33.8	44.7	53.3	66.56

[0042] Measured values of PTF (Pass Through Flux) are also listed in Table 2. The measurement of the PTF was performed according to ASTM F2086-01. The PTF of the sputtering targets in Examples 1 and 2 were higher than those of the sputtering targets in

Comparative Examples 1 and 2, and equivalent to that of the sputtering target in Comparative Example 3, and the PTF of the sputtering target in Example 3 was higher than that of any one of the sputtering targets in Comparative Examples 1 to 4, thereby confirming that improvement of the leakage magnetic flux density can also be achieved.

[0043] From Fig. 1, the sputtering discharge voltages were, in order from highest to lowest, Comparative Example 4 produced by using the Co metal powder as the second phase, Comparative Example 1 produced by using the individual metal powders instead of the atomized alloy powder, and Comparative Examples 3 and 2 produced by using the atomized alloy powder not containing B as the second phase, and it could be seen that the sputtering discharge voltages of Examples 1 to 3, in which B was distributed throughout the alloy phase (A) and the alloy phase (B), were decreased much lower than those of Comparative Examples 1 to 4. Particularly, when the input power was increased to 300 W or more, a decreased range of the sputtering discharge voltage became considerably large. From Table 1, comparing by the sputtering discharge voltage at the input power of 500 W, it could be also found that Examples have lower values of 330 V or less, but Comparative Examples have higher values than 330 V.

[0044] SEM observation images ($15.0 \text{ V} \times 1,000$) of the sputtering targets of Examples 1 to 3 and Comparative Examples 1 to 3 are shown in Figs. 2 to 7, and EPMA-WDX mapping images ($15.0 \text{ V} \times 2,000$) of the sputtering targets of Examples 1 to 3 and Comparative Examples 1 to 3 are shown in Figs. 8 to 13.

[0045] From an EPMA-WDX mapping image in Fig. 8, it was found that in the sputtering target in Example 1, a lower white region in a CP image was a Co-Cr-Pt-B alloy phase (A) containing Co, Cr, Pt, and B, and an upper gray region in the CP image was a Co-Pt-B alloy phase (B) containing Co, Pt, and B. From Fig. 2 and Fig. 8, it was found as follows: the sputtering target of Example 1 was composed of the Co-Cr-Pt-B alloy phase (A) and the Co-Pt-B alloy phase (B); there was no area where B was not present in an arbitrary $10 \mu\text{m} \times 10 \mu\text{m}$ region in both of the alloy phases (A) and (B), and B was distributed throughout the alloy phase (A) and the alloy phase (B); B in the alloy phase (A) was distributed finely and

uniformly throughout; and B in the alloy phase (B) was agglomerated compared with B in the alloy phase (A), but was distributed throughout the alloy phase (B).

[0046] From an EPMA-WDX mapping image in Fig. 9, it was found that in the sputtering target in Example 2, a right-side white region in a CP image was a Co-Cr-Pt-B alloy phase (A) containing Co, Cr, Pt, and B, and a left-side gray region in the CP image was a Co-Cr-B alloy phase (B) containing Co, Cr, and B. From Fig. 3 and Fig. 9, it was found as follows: the sputtering target of Example 2 was composed of the Co-Cr-Pt-B alloy phase (A) and the Co-Cr-B alloy phase (B); there was no area where B was not present in an arbitrary $10\ \mu\text{m} \times 10\ \mu\text{m}$ region in both of the alloy phases (A) and (B), and B was distributed throughout the alloy phase (A) and the alloy phase (B); B in the alloy phase (A) was distributed finely and uniformly throughout; and B in the alloy phase (B) was agglomerated compared with B in the alloy phase (A), but was distributed throughout the alloy phase (B).

[0047] From an EPMA-WDX mapping image in Fig. 10, it was found that in the sputtering target in Example 3, an upper white region in a CP image was a Co-Cr-Pt-B alloy phase (A) containing Co, Cr, Pt, and B, and a lower gray region in the CP image was a Co-B alloy phase (B) containing Co and B. From Fig. 4 and Fig. 10, it was found as follows: the sputtering target of Example 3 was composed of the Co-Cr-Pt-B alloy phase (A) and the Co-B alloy phase (B); there was no area where B was not present in an arbitrary $10\ \mu\text{m} \times 10\ \mu\text{m}$ region in both of the alloy phases (A) and (B), and B was distributed throughout the alloy phase (A) and the alloy phase (B); B in the alloy phase (A) was distributed throughout; and B in the alloy phase (B) was agglomerated compared with B in the alloy phase (A), but was distributed throughout the alloy phase (B).

[0048] From Fig. 5 and Fig. 11, it was found that the sputtering target of Comparative Example 1 was a single phase in which Co, Cr, Pt, and B were dispersed throughout and did not have the alloy phase (B).

[0049] From an EPMA-WDX mapping image in Fig. 12, it was found that in the sputtering target in Comparative Example 2, a right-side gray region in a CP image was a Co-Pt phase containing Co and Pt, but not containing B, and a left-side region in which black points were

present in the CP image was the Co-Cr-Pt-B phase (A) containing Co, Cr, Pt, and B. From Fig. 6 and Fig. 12, it was found that the sputtering target of Comparative Example 2 was composed of the Co-Cr-Pt-B phase (A) and the Co-Pt phase (second phase), and thus did not have the alloy phase (B) containing B since B was not present in the Co-Pt phase.

[0050] From an EPMA-WDX mapping image in Fig. 13, it was found that in the sputtering target in Comparative Example 3, a right lower white region in a CP image was a Co-Cr-Pt-B phase (A) containing Co, Cr, Pt, and B, and a left upper gray region in the CP image was a Co-Pt phase containing Co and a small amount of Pt, in which large black portions in the gray region were coarse agglomerate phases of B unevenly distributing around Co. From Fig. 7 and Fig. 13, it was found as follows: the sputtering target of Comparative Example 3 was composed of the Co-Cr-Pt-B phase (A) and the Co-Pt phase (second phase); B was unevenly distributed around the Co-Pt phase; there was a $10\ \mu\text{m} \times 10\ \mu\text{m}$ region where B was not present in the second phase; and there was no alloy phase (B) in which B was distributed throughout.

CLAIMS

1. A Co-Cr-Pt-B ferromagnetic sputtering target comprising:
 - a Co-Cr-Pt-B alloy phase (A) containing more than 0% by atom and 30% by atom or less of B, in which B is distributed throughout without B agglomerate phases unevenly distributed;
 - an alloy phase (B), which is any one of a Co-B alloy, a Co-Cr-B alloy, or a Co-Pt-B alloy, containing more than 0% by atom and 20% by atom or less of B, in which B is distributed throughout without B agglomerate phases unevenly distributed;
 - wherein the alloy phase (A) accounts for 50% by volume or more in the sputtering target; and
 - wherein the alloy phase (B) accounts for less than 50% by volume in the sputtering target.
2. The Co-Cr-Pt-B ferromagnetic sputtering target according to claim 1, wherein the Co-Cr-Pt-B ferromagnetic sputtering target contains more than 0% by atom and 30% by atom or less of Cr, 5% by atom or more and 30% by atom or less of Pt, and more than 0% by atom and 25% by atom or less of B, the balance being Co and incidental impurities.
3. The Co-Cr-Pt-B ferromagnetic sputtering target according to claim 1 or 2, wherein the alloy phase (A) further contains more than 0% by atom and 25% by atom or less of one or more elements selected from the group consisting of Al, Si, Sc, Ti, V, Mn, Fe, Ni, Cu, Zn, Ge, Y, Zr, Nb, Ta, Mo, W, Ru, Ag, Sn, La, Ce, Pr, Nd, Sm, Gd, Tb, Dy, Ho, and Hf, as additive elements.
4. A method for producing a Co-Cr-Pt-B ferromagnetic sputtering target according to any one of claims 1 to 3, the method comprising:
 - a mixing step of weakly mixing a Co-Cr-Pt-B alloy powder containing more than 0% by atom and 30% by atom or less of B, and any one of a Co-B alloy powder, a Co-Cr-B alloy powder, or a Co-Pt-B alloy powder, containing more than 0% by atom and 20% by atom or less of B to obtain a mixed powder; and

a sintering step of sintering the mixed powder to obtain a sintered product.

5. The method of production according to claim 4, wherein the Co-Cr-Pt-B alloy powder, and any one of the Co-B alloy powder, the Co-Cr-B alloy powder, or the Co-Pt-B alloy powder are atomized alloy powders.
6. The method of production according to claim 4 or 5, wherein the sintering step comprises holding the mixed powder under a pressure of 10 MPa or more and 100 MPa or less, and at a temperature of 700°C or more and 1,300°C or less for 30 minutes or more and 3 hours or less.