

DESCRIPTION

HARD NITRIDE-CONTAINING SPUTTERING TARGET

TECHNICAL FIELD

[0001] The present invention relates to a hard nitride-containing sputtering target and a method for producing the sputtering target, and relates particularly to a hard nitride-containing sputtering target including alloy phases containing Fe or Co, and non-magnetic phases containing a hard nitride selected from AlN, BN, Cr₂N, Si₃N₄, HfN, NbN, TaN, TiN, VN, and any combination thereof and a method for producing the sputtering target.

BACKGROUND ART

[0002] Sintered bodies containing alloy phases containing Fe or Co, which is a ferromagnetic metal, as the main ingredient and a non-magnetic material such as an oxide, carbon, or boron nitride have been used as sputtering targets for producing granular structure magnetic thin films of magnetic recording media such as hard disk drives.

[0003] It has been confirmed that when a sputtering target containing an oxide as a non-magnetic material has a non-magnetic material particle dispersed-type texture in which an oxide is uniformly and finely dispersed among alloy phases, the particle generation during the film formation can be reduced. Raw material powders forming an oxide and alloy phases are mixed by vigorous stirring using a medium stirring mill such as a zirconia ball mill to disperse an oxide within alloy phases uniformly and finely (Japanese Patent No. 4673448 and Japanese Patent 6728094). Sputtering targets containing nitrides instead of oxides are also proposed, and methods involving vigorous stirring and mixing using zirconia ball mills in the same way as oxides are adopted (Japanese Patent No. 5913620 and Japanese Patent No. 6526837).

[0004] Japanese Patent No. 4673448 discloses a non-magnetic material particle-dispersed ferromagnetic material sputtering target, having: phases (A) in which non-magnetic particles

of an oxide are finely and uniformly dispersed and spherical alloy phases (B) having a diameter of 50 to 200 μm in phase (A), wherein the sputtering target have a composition wherein Cr is concentrated at 25% by mol or more near the centers of the spherical alloy phases (B), and the Cr content becomes lower toward the peripheries than at the centers. It is disclosed that metal powder having a maximum particle size of 20 μm or less and non-magnetic material powder having a maximum particle size of 5 μm or less are encapsulated with zirconia balls in a 10-L ball mill pot and rotated for 20 hours for mixing combined with pulverization, and this mixed powder is mixed with Co-Cr spherical powder having a diameter of 50 to 200 μm in a planetary mixer, followed by sintering to produce this sputtering target.

[0005] Japanese Patent No. 6728094 discloses an invention, containing: Co-Pt phases, Co phases, and non-magnetic material, wherein the Co-Pt alloy phases are micronized, and the Co phases are coarsened in order to suppress particle generating during sputtering. It is specifically disclosed that the average particle size of the Co-Pt alloy phases is set to 0.1 μm or more and 7 μm or less, the average particle size of the Co phases is set to 30 μm or more and 300 μm or less, and the average particle size of the non-magnetic material of the oxide is set to 0.05 μm or more and 2 μm or less; and Co-Pt alloy powder having a median size of 0.1 μm or more and 7 μm or less and non-magnetic material powder having a median size of 0.05 μm or more and 2 μm or less are used as the raw materials. It is disclosed as the method for mixing the raw material powders that the raw material powders are encapsulated with zirconia balls in a ball mill having a capacity of 10 liters, followed by rotation for 20 hours for mixing.

[0006] Japanese Patent No. 5913620 discloses that, in a Fe-Pt-based sintered body sputtering target using hexagonal BN as a non-magnetic material, improvement in the orientation of hexagonal BN suppresses abnormal electrical discharge during sputtering to reduce the amount of particles generated. It is specifically disclosed that Fe-Pt alloy powder is fed with zirconia balls to a medium stirring mill having a capacity of 5 L and treated at a rotational speed of 300 rpm for 2 hours to prepare Fe-Pt alloy powder having an average particle size of

10 μm , the Fe-Pt alloy powder is blended with hexagonal BN powder with a V type mixer, and the mixed powder is then further mixed through a sieve of 150 μm . A problem is, however, that hexagonal BN has low hardness, is short of hardness as a sputtering target, and may crack during sputtering.

[0007] Japanese Patent No. 6526837 discloses a Fe-Pt-based sputtering target and a Co-Pt-based sputtering target using cubic BN, which more scarcely cracks than hexagonal BN, and discloses that raw material powders are fed with zirconia balls to a medium stirring mill having a capacity of 5 L, rotated for 2 hours (rotational speed: 300 rpm) for mixing, and pulverized until the median size (D50) of the raw material mixed powder is 0.3 μm or more and 20 μm or less, and preferably 5 μm or less.

[0008] Experiments by the present inventors, however, have shown that if a nitride is used as the non-magnetic material, the abrasion of zirconia balls and the inner wall of a medium stirring mill due to high hardness of nitride leads to contamination with relatively coarse zirconia particles during the mixing of the raw material powders, and the coarse zirconia particles easily leads to arcing during the sputtering due to higher electrical resistance thereof than that of the nitride or carbide to easily generate particles during the film formation.

CITATION LIST

PATENT LITERATURE

[0009]

PTL 1: Japanese Patent No. 4673448

PTL 2: Japanese Patent No. 6728094

PTL 3: Japanese Patent No. 5913620

PTL 4: Japanese Patent No. 6526837

SUMMARY OF INVENTION

TECHNICAL PROBLEM

[0010] An object of the present invention is to provide a hard nitride-containing sputtering target that enables solving the above-mentioned conventional problem and preventing the occurrence of arcing during sputtering due to contamination with relatively coarse zirconia particles to suppress the generation of particles during the film formation and a method for producing the hard nitride-containing sputtering target.

SOLUTION TO PROBLEM

[0011] The present inventors have found that the coexistence of relatively coarse zirconia particles leads to arcing during the sputtering of a hard nitride-containing sputtering target, considered that the prevention of contamination with zirconia impurity particles derived from a zirconia ball mill commonly used during the mixing of the raw material powders in the production process of the sputtering target enables suppressing arcing during sputtering, and completed the present invention.

[0012] According to the present invention, provided is a hard nitride-containing sputtering target, including:

alloy phases containing Fe or Co, and

non-magnetic phases containing a hard nitride selected from AlN, BN, Cr₂N, Si₃N₄, HfN, NbN, TaN, TiN, VN, and any combination thereof,

wherein the Zr impurity concentration in the case of the measurement thereof as metal Zr is regulated to 1000 ppm or less, and

wherein the Vickers hardness, Hv, measured under a load condition of 3 kgf is 200 or more and 600 or less.

[0013] It is preferable that the Zr impurity concentration be regulated to 500 ppm or less.

[0014] It is preferable that the non-magnetic phases satisfy at least one of

the condition that the average particle size determined by subjecting an observation visual field of 180 μm $\times$ 180 μm in EPMA surface analysis at a magnification of 500 to image analysis is 4 μm or more and 20 μm or less;

the condition that the average particle size determined by subjecting an observation visual field of $90\text{ }\mu\text{m} \times 90\text{ }\mu\text{m}$ in EPMA surface analysis at a magnification of 1000 to image analysis is $2\text{ }\mu\text{m}$ or more and $20\text{ }\mu\text{m}$ or less; and

the condition that the average particle size determined by subjecting an observation visual field of $30\text{ }\mu\text{m} \times 30\text{ }\mu\text{m}$ in EPMA surface analysis at a magnification of 3000 to image analysis is $1\text{ }\mu\text{m}$ or more and $20\text{ }\mu\text{m}$ or less.

[0015] It is preferable that the content of the non-magnetic phases in the sputtering target be 5% by mol or more and 50% by mol or less.

[0016] The non-magnetic phases can further contain one or more selected from C, B_2O_3 , and SiO_2 .

[0017] The alloy phases can contain Pt at 0% by mol or more and 60% by mol or less.

[0018] The alloy phases can further contain one or more elements selected from Ag, Au, Cr, Cu, Ge, Ir, Ni, Pd, Rh, Ru, and B.

[0019] According to the present invention, a method for producing the above-mentioned hard nitride-containing sputtering target is also provided. The production method of the present invention is characterized by including: mixing raw material powders constituting the alloy phases and the non-magnetic phases at a rotational speed of 50 rpm or more and 150 rpm or less with a zirconia ball mill for 2 hours or more and 6 hours or less to prepare a mixed powder and sintering the mixed powder.

[0020] It is preferable that the raw material powders constituting the alloy phases be metal powders of each raw material or Fe-based or Co-based atomized alloy powder.

[0021] It is preferable that the raw material powder constituting the non-magnetic phases contains hard nitride powder having an average particle size, D50, of $1\text{ }\mu\text{m}$ or more and $40\text{ }\mu\text{m}$ or less.

ADVANTAGEOUS EFFECTS OF INVENTION

[0022] In a hard nitride-containing sputtering target of the present invention, the contamination with relatively coarse zirconia impurity particles having high electrical

resistance is prevented, and the Zr impurity concentration in the case of measurement as metal Zr is regulated to 1000 ppm or less. The sputtering target therefore enables suppressing the occurrence of arcing during sputtering and reducing particles derived from zirconia particles during the film formation.

BRIEF DESCRIPTION OF DRAWINGS

[0023]

Fig. 1 is a graph showing the relationship between the Zr concentration and the number of particles in the sputtering targets of Examples and Comparative Examples.

Fig. 2 is a graph showing the relationship between the Vickers hardness and the number of the particles in the sputtering targets of Examples and Comparative Examples.

Fig. 3 is an SEM observation photograph of the texture of the sputtering target of Example 1 (at a magnification of 1000).

Fig. 4 is an SEM observation photograph of the texture of the sputtering target of Example 2 (at a magnification of 1000).

Fig. 5 is an SEM observation photograph of the texture of the sputtering target of Comparative Example 2 (at a magnification of 1000).

DESCRIPTION OF EMBODIMENTS

[0024] Hereinafter, the present invention will be described with reference to the attached drawings in further detail.

A hard nitride-containing sputtering target of the present invention includes alloy phases containing Fe or Co, and non-magnetic phases containing a hard nitride selected from AlN, BN, Cr₂N, Si₃N₄, HfN, NbN, TaN, TiN, VN, and any combination thereof, and is characterized in that the Zr impurity concentration in the case of measurement as metal Zr is regulated to 1000 ppm or less, preferably 500 ppm or less, and more preferably 300 ppm or less, and the Vickers hardness, Hv, measured under a load condition of 3 kgf is 200 or more and 600 or less, and preferably 250 or more and 600 or less.

[0025] The present invention relates to the hard nitride-containing sputtering target containing a hard nitride as non-magnetic material particles. The hard nitride includes AlN, BN, Cr₂N, Si₃N₄, HfN, NbN, TaN, TiN, VN, and any combination thereof. The hardness of the nitrides (GPa) are as follows. The hardness of AlN is 12.0, the hardness of Cr₂N is 15.4, the hardness of Si₃N₄ is 19.4, the hardness of HfN is 15.7, the hardness of NbN is 14.3, the hardness of TaN is 23.7, the hardness of TiN is 20.1, the hardness of VN is 12.8, the hardness of cubic BN is 46.1, and the hardness of hexagonal BN is 2.0 (Deta Bukku Koyuten Kagobutsu Binran, Seramikkusu Kako Handobukku: Kiso kara Oyo Jirei made, Seramikku Hadonesu (Data Book/ Manual of High Melting Point Compounds, Ceramic Processing Handbook: From Basic Cases To Applied Cases, Ceramic Hardness)).

[0026] As BN to be used for sputtering targets, cubic BN and hexagonal BN are known. In the present invention, cubic crystal BN, said to be the hardest next to diamond, is used. If cubic crystal BN is contained, hexagonal crystal BN may coexist.

[0027] The non-magnetic phase contains a hard nitride having an average particle size of 1 μm or more, preferably 2 μm or more and 20 μm or less. The average particle size of the non-magnetic phase can be measured by subjecting the results of EPMA surface analysis to image analysis. The image analysis by the EPMA surface analysis is performed in the following procedure.

[0028] The sputtering surface of the sputtering target is first polished to acquire an elemental mapping image at a magnification of 100 using an EPMA device. The obtained element mapping image is subjected to binarization processing by "surface processing" function attached to the EPMA device. The elemental mapping image subjected to binarization processing is analyzed by image analysis software (ImageJ 1.53e) to measure the average particle size of the nitride. If N (nitrogen) and another element (for example, element A) constitute the nitride, points at which both element N and element A are detected are calculated. If N (nitrogen) and two or more other elements constitute the nitride, a mapping image of all the elements other than element N is synthesized from the mapping images of the elements, points at which both the elements other than element N and element N are

detected are calculated to find the Average Size, and the average particle size (μm) is calculated by the following expression.

[0029] [Formula 1]

$$\text{Average particle size } (\mu\text{m}) = 2 \times \sqrt{(\text{Average Size} \div 3.14)}$$

[0030] If the obtained average particle size is equal to or less than the criterion at each magnification shown in Table 1, the magnification is increased to 500, 1000, 3000, and 10000 stage by stage sequentially until the average particle size is a higher value than the criterion, and the series of operations is repeated to calculate the average particle size at each magnification.

[0031] [Table 1]

Table 1 Criterion

100 times	18 μm
500 times	3.6 μm
1000 times	1.8 μm
3000 times	0.6 μm
10000 times	None

[0032] Since fine non-magnetic phases cannot be observed depending on the observation magnification during the EPMA surface analysis, and the error of the average particle size increases, the ranges of the average particle sizes are classified by the observation magnification as follows. It is preferable that the hard nitride-containing sputtering target of the present invention satisfy at least one of the following (A) to (C):

(A) the condition that the average particle size determined by subjecting an observation visual field of $180 \mu\text{m} \times 180 \mu\text{m}$ in EPMA surface analysis at a magnification of 500 to image analysis is $3.6 \mu\text{m}$ or more and $20 \mu\text{m}$ or less, and preferably $4 \mu\text{m}$ or more and $15 \mu\text{m}$ or less;

(B) the condition that the average particle size determined by subjecting an observation visual field of $90 \mu\text{m} \times 90 \mu\text{m}$ in EPMA surface analysis at a magnification of 1000 to image analysis is $1.8 \mu\text{m}$ or more and $20 \mu\text{m}$ or less, preferably $1.8 \mu\text{m}$ or more and $4 \mu\text{m}$ or less, and more preferably $1.8 \mu\text{m}$ or more and $3.6 \mu\text{m}$ or less; and

(C) the condition that the average particle size determined by subjecting an observation visual field of $30\ \mu\text{m} \times 30\ \mu\text{m}$ in EPMA surface analysis at a magnification of 3000 to image analysis is $1\ \mu\text{m}$ or more and $20\ \mu\text{m}$ or less, preferably $1\ \mu\text{m}$ or more and $2\ \mu\text{m}$ or less, and more preferably $1\ \mu\text{m}$ or more and $1.8\ \mu\text{m}$ or less.

[0033] The content of the non-magnetic phases in the sputtering target varies depending on physical properties required for a deposited layer formed using the sputtering target, and the content is commonly 5% by mol or more and 50% by mol or less, and more preferably 5% by mol or more and 45% by mol or less. If the content of the non-magnetic phases is in the above-mentioned range, the magnetic characteristics of the formed deposited layer can be satisfactorily maintained, and the non-magnetic phases are finely dispersed within magnetic materials in the deposited layer, and can function as a grain boundary material that isolates adjacent magnetic materials.

[0034] The non-magnetic phases can further contain one or more non-magnetic materials selected from C, B_2O_3 , and SiO_2 , which are commonly used for sputtering targets. The content of the non-magnetic material to be optionally added in the sputtering target is preferably 0% by mol or more and 25% by mol or less, and more preferably 0% by mol or more and 20% by mol or less. If the content of the non-magnetic material to be optionally added is in the above-mentioned range, the magnetic characteristics of the formed deposited layer can be satisfactorily maintained, and the non-magnetic phases are finely dispersed within magnetic materials in the deposited layer, and can function as a grain boundary material that isolates adjacent magnetic materials.

[0035] The alloy phases contain Fe or Co, which is a ferromagnetic material. Fe or Co may be contained as Fe alone; Co alone; an alloy of Fe and Co; an alloy of Fe and another element; an alloy of Co and another element; or an alloy of Fe, Co and another element. Fe or Co is contained as the main ingredient of the sputtering target. If Co is not contained, and Fe is contained; the content of Fe in the alloy phases is preferably 35% by mol or more and 100% by mol or less, and more preferably 40% by mol or more and 100% by mol or less. If Fe is not contained, and Co is contained; the content of Co in the alloy phases is preferably

50% by mol or more and 100% by mol or less, and more preferably 55% by mol or more and 100% by mol or less. If Fe or Co is contained, the total content of Fe and Co in the alloy phases is preferably 35% by mol or more and 100% by mol or less, and more preferably 40% by mol or more and 100% by mol or less. If Fe and Co is contained, the total amount of Fe and Co in the alloy phases is preferably 50% by mol or more and 100% by mol or less, and more preferably 60% by mol or more and 100% by mol or less, the content of Fe in the alloy phases is preferably 30% by mol or more and 70% by mol or less, and more preferably 35% by mol or more and 65% by mol or less, and the content of Co in the alloy phases is preferably 20% by mol or more and 50% by mol or less, and more preferably 25% by mol or more and 45% by mol or less.

[0036] The alloy phases contain Pt preferably at 0% by mol or more and 60% by mol or less, more preferably more than 0% by mol and 55% by mol or less.

[0037] The alloy phases can further contain one or more element selected from Ag, Au, Cr, Cu, Ge, Ir, Ni, Pd, Rh, Ru, and B. The content of the element to be optionally added in the alloy phases is preferably 0% by mol or more and 30% by mol or less, and more preferably 0% by mol or more and 25% by mol or less. If the content of the element to be optionally added in the alloy phases is in the above-mentioned range, the magnetic characteristics of the formed deposited layer can be satisfactorily maintained.

[0038] Preferable examples of the sputtering target of the present invention include Fe alloy-nitride, Fe alloy-C-nitride, Fe alloy-oxide-nitride, Fe alloy-C-oxide-nitride, Co alloy-nitride, Co alloy-C-nitride, Co alloy-oxide-nitride, Co alloy-C-oxide-nitride, FePt alloy - nitride, FePt alloy-C-nitride, FePt alloy-oxide-nitride, FePt alloy-C-oxide-nitride, CoPt alloy-nitride, CoPt alloy-C-nitride, CoPt alloy-oxide-nitride, CoPt alloy-C-oxide-nitride, FeCo alloy-nitride, FeCo alloy-C-nitride, FeCo alloy-oxide-nitride, FeCo alloy-C-oxide-nitride, FeCoPt alloy-nitride, FeCoPt alloy-C-nitride, FeCoPt alloy-oxide-nitride, and FeCoPt alloy-C-oxide-nitride. Preferable examples of the specific designed composition include Fe-51Pt-7Si₃N₄, Fe-40Pt-20AlN, Fe-39Pt-25TaN, Fe-38Pt-15Cr₂N, Fe-35Pt-25VN, Fe-40Pt-20NbN, Fe-40Pt-20HfN, Fe-28Pt-30BN, Fe-35Pt-25TiN, Fe-41Pt-5Cu-5BN-8Si₃N₄, Fe-46Pt-3B₂O₃-8Si₃N₄,

Fe-41Pt-4SiO₂-10AlN-3Si₃N₄, Fe-21Pt-21Co-10C-20AlN, Fe-30Pt-5C-30AlN, Fe-30Pt-5Ag-6C-11BN-20AlN, Fe-32Pt-6B-6Rh-20HfN, Fe-34Pt-3Ge-5C-20TiN, Co-23Pt-7Si₃N₄, Co-20Pt-19AlN, Co-19Pt-25TaN, Co-14Pt-30BN, Co-16Pt-4Cr-4SiO₂-15Cr₂N, Co-13Pt-6Ru-8Cr-16C-22VN, Co-15TiN, Fe-20TaN, and Co-48Fe-20AlN.

[0039] Although the designed composition of the sputtering target of the present invention may be the same as the compositions of well-known sputtering targets, the sputtering target of the present invention is different from well-known sputtering targets in that the Zr concentration in the case of the measurement as metal Zr is regulated to 1000 ppm or less, preferably 500 ppm or less, and more preferably 300 ppm or less. The Zr impurities of the sputtering target of the present invention are controlled to a content that is the regulated value or less in the production process unlike the incidental impurities in the compositions of well-known sputtering targets. As shown in Examples and Comparative Examples, described below, it has been confirmed that when the Zr concentration is regulated to 1000 ppm or less in even a sputtering target having the same designed composition, the generation of particles is remarkably suppressed.

[0040] The sputtering target of the present invention is also characterized in that the Vickers hardness, Hv, measured under a load condition of 3 kgf is 200 or more and 600 or less, and preferably 250 or more and 600 or less. It was believed that as the Vickers hardness becomes higher, generated particles increased. As shown in Examples and Comparative Examples, described below, it has however been confirmed that if the Vickers hardness, Hv, is 200 or more and 600 or less, the regulation of the Zr concentration to 1000 ppm or less suppresses the generation of the particles remarkably in even a sputtering target having the same designed composition.

[0041] The hard nitride-containing sputtering target of the present invention can be produced by a method characterized by including mixing raw material powders constituting the alloy phases and the non-magnetic phases with a zirconia ball mill at a rotational speed of 50 rpm or more and 150 rpm or less for 2 hours or more and 6 hours or less to prepare a mixed powder and sintering the mixed powder.

[0042] In the production method of the present invention, the conditions for stirring and mixing the raw material powders when a zirconium ball mill is used are a rotational speed of 50 rpm or more and 150 rpm or less, preferably 50 rpm or more and 100 rpm or less, and more preferably 50 rpm or more and 75 rpm or less; 2 hours or more and 6 hours or less, and more preferably 3 hours or more and 5 hours or less. In general, stirring and mixing using a zirconia ball mill involves rotating a mill at high speed leading fast collision of zirconia balls with the raw material powders, continuously grinding the raw material powders between the zirconia balls for a long period of time to apply strong mechanical energy to the raw material powders for fine pulverization, and kneading the fine raw material powders to form a homogeneous powder mixture. The present inventors have known that if the raw material powders contain hard particles, the zirconia balls are abraded, resulting in contamination with a very small amount of zirconia as impurities and found mixing conditions optimal for suppressing the abrasion of the zirconia balls while achieving homogeneous mixing of the raw material powders. It has been found that, in the present invention, the rotational speed is controlled to low speed for relatively slow collision, the stirring time is relatively shortened to prevent even the raw material powders containing the hard nitride particles from abrading the zirconia balls, and the contamination of the raw material powders with zirconia can be suppressed.

[0043] The raw material powder constituting the alloy phases can be prepared as metal powder or Fe-based or Co-based atomize alloy powder.

[0044] As the Fe powder, powder having an average particle size, D50, of 1 μm or more and 10 μm or less, and preferably 2 μm or more and 8 μm or less can be used. If the average particle size is too small, a risk of ignition may increase, and the incidental impurity concentration may increase. If the average particle size is too large, the non-magnetic material particles may not be able to be uniformly dispersed.

[0045] As the Co powder, powder having an average particle size, D50, of 1 μm or more and 10 μm or less, and preferably 2 μm or more and 8 μm or less can be used. If the average particle size is too small, a risk of ignition may increase, and the incidental impurity

concentration may increase. If the average particle size is too large, the non-magnetic material particles may not be able to be uniformly dispersed.

[0046] As the Pt powder, powder having an average particle size, D50, of 0.1 μm or more and 10 μm or less, and preferably 0.3 μm or more and 6 μm or less can be used. If the average particle size is too small, the incidental impurity concentration may increase. If the average particle size is too large, the non-magnetic material particles may not be able to be uniformly dispersed.

[0047] As the powder of the element to be optionally added, powder having an average particle size, D50, of 0.1 μm or more and 30 μm or less, and preferably 0.5 μm or more and 20 μm or less can be used. If the average particle size is too small, the incidental impurity concentration may increase. If the average particle size is too large, the non-magnetic material particles may not be able to be uniformly dispersed.

[0048] As the Fe-based or Co-based atomized alloy powder, atomized alloy powder having an average particle size, D50, of 1 μm or more and 10 μm or less, and preferably 2 μm or more and 8 μm or less can be used. If the average particle size is too small, the incidental impurity concentration may increase. If the average particle size is too large, the non-magnetic material particles may not be able to be uniformly dispersed.

[0049] The raw material powder constituting the non-magnetic phases contains hard nitride powder having an average particle size, D50, of 1 μm or more and 40 μm or less, and preferably 2 μm or more and 35 μm or less. As the hard nitride powder, AlN, BN, Cr₂N, Si₃N₄, HfN, NbN, TaN, TiN, VN, and any combination thereof are used. Cubic BN is used as BN. If the average particle size of the hard nitride powder is in the above-mentioned range, a satisfactory dispersion state can be achieved.

[0050] As the raw material powders constituting the non-magnetic phase, one or more non-magnetic materials having an average particle size, D50, of 1 μm or more and 10 μm or less, and preferably 1 μm or more and 8 μm or less and selected from C, B₂O₃, and SiO₂ can be further contained. If the average particle size of the additional non-magnetic materials powder is in the above-mentioned range, a satisfactory dispersion state can be achieved.

[0051] It is desirable to set the sintering temperature to 800°C or more and 1300°C or less, and preferably 900°C or more and 1250°C or less, and set the sintering pressure to 30 MPa or more and 120 MPa or less, and preferably 50 MPa or more and 100 MPa or less as the conditions for sintering the mixed powder.

EXAMPLES

[0052] Although the present invention will be specifically described by Examples and Comparative Examples, the present invention is not limited to these. The methods for measuring the Zr concentration, the Vickers hardness, the average particle size of the hard nitride non-magnetic phases, the relative density, and the number of the particles of the sputtering target in the following Examples and Comparative Examples are as follows.

[0053] [Zr concentration]

A test piece having a diameter of 30 mm is cut out from a sputtering target. The horizontal surface to the sputtering surface of the sputtering target is polished using SiC abrasive papers #80, #320, and #1200. The Zr concentration is measured with the conditions in Table 2 input into an EZ scan using a fluorescence X-ray analyzer equipped with a Rh X-ray tube (ZSX PrimusIV, Rigaku Corporation).

[0054] [Table 2]

Table 2 Automatic setting conditions

Sample type	Metal & Alloy
Measurement range	B - U
Measurement diameter	20 mm
Measurement time	Standard

[0055] [Vickers hardness]

Measuring is performed in accordance with JIS Z 2244. Specifically, the horizontal surface to the sputtering surface of the sputtering target is polished with SiC abrasive papers #80, #320, and #1200 and buffed with diamond abrasive grains having a grain size of 1 μm, the size of a recess when a test load of 3.00 kgf is applied with a diamond indenter that is a

regular quadrangular pyramid having an angle between the opposite faces of 136° using a Vickers hardness tester (HV-115, Mitutoyo Corporation) is observed through a microscope, the length of the line connecting the diagonals is measured, the surface area of the recess (mm^2) is calculated, and the test load (kgf)/surface area of recess (mm^2) is calculated.

[0056] [Average particle size of hard nitride non-magnetic phase]

A surface perpendicular to the sputter surface of the sputtering target is polished with SiC abrasive papers #80, #320, and #1200 and then buffed with diamond spray having a particle size of 1 μm , and an element mapping image is acquired using an EPMA device (JXA-8500F, JEOL Ltd.) under the EPMA analysis conditions shown in Tables 3 and 4.

[0057] [Table 3]

Table 3 EPMA analysis conditions 1

Acceleration voltage	15.0 kV									
Probe current	1.5E-7 A									
Dwell Time	30.0 m sec									
Element	N	Al	B	Cr	Hf	Nb	Si	Ta	Ti	V
X-ray source	K α	K α	K α	K α	L α	L α	K α	L α	K α	K α
Analyzing crystal	LDE1H	TAP	LDE2H	LIFH	LIFH	PETH	TAP	LIFH	PETH	LIFH
Spect. Pos.	147.948	90.596	189.526	159.250	108.924	183.354	77.316	105.632	87.588	174.068
PHA Gain	64	32	32	32	64	128	32	32	64	64
High Volt(V)	1696	1702	1758	1754	1666	1674	1694	1754	1746	1666
Base Level(V)	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Window (V)	9.3	9.3	9.3	-	-	-	9.3	-	-	-
Diff/Int	Diff	Diff	Diff	Int	Int	Int	Diff	Int	Int	Int

[0058] [Table 4]

Table 4 EPMA Analysis conditions 2

Observation magnification	Scan mode	The number of pixels	Visual field	Beam diameter
100 times	Stage scan	X : 150 Y : 150	X : 900 μm Y : 900 μm	3 μm
500 times	Stage scan	X : 150 Y : 150	X : 180 μm Y : 180 μm	0 μm
1000 times	Stage scan	X : 150 Y : 150	X : 90 μm Y : 90 μm	0 μm
3000 times	Stage scan	X : 150 Y : 150	X : 30 μm Y : 30 μm	0 μm
10000 times	Beam scan	X : 128 Y : 128	X : 10 μm Y : 10 μm	0 μm

[0059] The obtained element mapping image is subjected to binarization processing by the "Surface processing" function attached to the EPMA device (JXA-8500F). Specifically, the element mapping image is displayed at a maximum number of maps of 9, an image to be subjected to the binarization processing is selected, and the upper limit value and the lower limit value are confirmed in the "Level change" screen. "Subtraction of constant" is selected in the "Map calculation" screen, and the lower limit value confirmed in the "level change" screen is input into K, followed by execution. "Division of constant" is selected in the "Map calculation" screen again, and the value obtained by subtracting the lower limit value from the upper limit value confirmed in the "Level change" screen is input into K, followed by execution. The "Display mode" selecting screen is changed into the contents of Table 5, followed by execution. The "Level change" screen is changed into the contents of Table 6, followed by execution.

[0060] [Table 5]

Table 5 Display mode

Intensity/concentration	Intensity map
Display color	Gray scale
Color bar	On map
The number of colors	2
Step interval	Regular intervals
Map display	Not interpolated

[0061] [Table 6]

Table 6 Level change

Level change	Regular interval
Calibration curve factor A	0
Calibration curve factor B	0
Lower limit	0.25
Upper limit	0.5

[0062] The screenshot of the above-mentioned element mapping image of which the binarization processing is completed is saved in PNG format. The obtained element mapping image in PNG format is analyzed with image analysis software (ImageJ 1.53e) to measure

the average particle size of the nitride. Specifically, the average particle size of the nitride is measured according to the following procedure. The element mapping image in PNG format is opened with the image analysis software (ImageJ 1.53e). If the nitride is composed of element A and N (nitrogen), the region of the mapping image of element A and element N is copied at 286×286 pixels and saved as a new image. The contents of Table 7 are input into the Image Calculator of the image analysis software (ImageJ 1.53e), followed by execution to create a file in which points at which both element A and element N are detected are calculated.

[0063] [Table 7]

Table 7 Image Calculator

Image1	Image file obtained by cutting out mapping image of element A
Operation	AND
Image2	Image file obtained by cutting out mapping image of element N
Create new window	Selected
32-bit (float) result	Not selected

[0064] If two or more elements constituting the nitride are present besides N (nitrogen), the regions of the mapping images of each element are copied at 286×286 pixels and saved as new images. The Operation in Table 7 is then changed into OR, the mapping images of the elements other than element N constituting the nitride are selected as Image1 and Image2, and all the mapping images of the elements other than element N constituting the nitride are synthesized with the Image Calculator. The contents of the Image Calculator in Table 7 are input except that the image is selected as Image1 of the Image Calculator in Table 7, followed by execution to create a file in which points at which both the elements other than element N constituting the nitride and element N are detected are calculated.

[0065] The obtained file is inverted and subjected to black and white inversion, and the contents in Table 8 are input into the Set Scale, followed by execution. The visual field at each magnification is input into Known distance. That is, 900 is input in the case of 100 times, 180 is input in the case of 500 times, 90 is input in the case of 1000 times, 30 is input in the case of 3000 times, and 10 is input in the case of 10000 times.

[0066] [Table 8]

Table 8 Set Scale

Distance in pixels	286
Pixel aspect ratio	1.0
Unit of length	μm
Global	Not selected

[0067] The contents in Table 9 are input into Analyze particles, followed by execution.

Here, the value in Table 10 is input into Size (μm²) according to the observation magnification.

[0068] [Table 9]

Table 9 Analyze particles

Pixel units	Not selected
Circularity	0.00-1.00
Sow	Outlines
Display results	Selected
Clear results	Selected
Summarize	Selected
Add to Manager	Not selected
Exclude on edges	Selected
Include holes	Selected
Record starts	Not selected
In situ Show	Not selected

[0069] [Table 10]

Table 10 Size(μm²)

100 times	36.36-Infinity
500 times	1.46-Infinity
1000 times	0.37-Infinity
3000 times	0.05-Infinity
10000 times	0.01-Infinity

[0070] The average particle size (μm) is calculated by the following expression using Average Size in the Summary screen displayed after the analysis.

[0071] [Formula 2]

$$\text{Average particle size } (\mu\text{m}) = 2 \times \sqrt{(\text{Average Size} \div 3.14)}$$

[0072] The image at a magnification of 100 is subjected to the above-mentioned series of analyses. If the obtained average particle size is equal to or less than the criterion at each magnification shown in Table 11, the magnification is increased to 500, 1000, 3000, and 10000 stage by stage sequentially until the average particle size is a higher value than the criterion.

[0073] [Table 11]

Table 11 Criterion

100 times	18 μm
500 times	3.6 μm
1,000 times	1.8 μm
3,000 times	0.6 μm
10,000 times	None

[0074] [Relative density]

The measurement is performed by the Archimedes' method using pure water as displacement liquid. The mass of the sintered body is measured, and the buoyancy (= the volume of the sintered body) is measured with the sintered body floating on the displacement liquid. The mass of the sintered body (g) is divided by the volume of the sintered body (cm^3) to find the actually measured density (g/cm^3). The ratio of the actually measured density to the theoretical density calculated based on the composition of the sintered body (actually measured density/theoretical density) is the relative density.

[0075] [The number of particles]

A sintered body is processed into 153 mm in diameter and 2 mm in thickness, and the processed sintered body is bonded to a backing plate made of Cu having a diameter of 161 mm and a thickness of 4 mm with indium to obtain a sputtering target. This sputtering target is fixed to a magnetron sputtering device, and the number of particles attached to the substrate is measured with a particle counter after sputtering at an output of 500 W in an Ar gas atmosphere at a gas pressure of 1 Pa for 40 seconds.

[0076] [Examples 1 to 26 and Comparative Examples 1 to 15]

Sputtering targets having designed compositions shown in Tables 12 and 13 were produced, and the Zr concentrations, the Vickers hardness, the average particle sizes of the hard nitride non-magnetism phases, the relative densities, and the numbers of particles were measured. Since, in the designed composition in Tables 12 and 13, Fe or Co constitutes the remainder, the content thereof is omitted. For example, Fe-51Pt-7Si₃N₄ in Example 1 means 42Fe-51Pt-7Si₃N₄.

[0077] As raw material powders of alloy phases, Fe powder having an average particle size, D50, of 7 μm, Co powder having an average particle size, D50, of 3 μm, and Pt powder having an average particle size, D50, of 1 μm were used. As additional elements of the alloy phases, Cu powder having an average particle size, D50, of 5 μm, Ag powder having an average particle size, D50, of 4 μm, B powder having an average particle size, D50, of 8 μm, Ge powder having an average particle size, D50, of 10 μm, Cr powder having an average particle size, D50, of 15 μm, Ru powder having an average particle size, D50, of 13 μm, and Rh powder having an average particle size, D50, of 13 μm were used.

[0078] As hard nitride powder, Si₃N₄ powder having an average particle size, D50, of 20 μm, AlN powder having an average particle size, D50, of 8 μm, TaN powder having an average particle size, D50, of 4 μm, Cr₂N powder having an average particle size, D50, of 7 μm, NbN powder having an average particle size, D50, of 10 μm, HfN powder having an average particle size, D50, of 35 μm, cubic BN powder (cBN) having an average particle size, D50, of 3 μm, TiN powder having an average particle size, D50, of 9 μm, and VN powder having an average particle size, D50, of 7 μm were used.

[0079] As additional non-magnetic material powders, hexagonal BN powder (BN) having an average particle size, D50, of 5 μm, B₂O₃ powder having an average particle size, D50, of 5 μm, C powder having an average particle size, D50, of 5 μm, and SiO₂ powder having an average particle size, D50, of 1 μm were used.

[0080] With respect to Examples 1 to 26, mixed powders obtained by feeding raw material powders weighed so that the raw material powders have the designed compositions shown in Table 12 with 4 kg of zirconia balls to a stirring mill, followed by stirring and mixing at a

rotational speed of 100 rpm for 4 hours were sintered at a sintering pressure of 66 MPa and sintering temperatures shown in Table 12. Blanks in Table 12 shows that the components are not added.

[0081] With respect to Comparative Examples 1 to 15, mixed powders obtained by feeding raw material powders weighed so that the raw material powders have the designed compositions shown in Table 13 with 4 kg of zirconia balls to a stirring mill, followed by stirring and mixing under the mixing conditions shown in Table 13 were sintered at a sintering pressure of 66 MPa and sintering temperatures shown in Table 13. Blanks in Table 13 shows that the components are not added.

[0082] The relative density of obtained sintered body was measured, and the sintered body was then processed into a sputtering target. The Zr concentration, the average particle size of the hard nitride, the Vickers hardness, and the number of the particles were measured.

Tables 14 and 15 show the results. Fig. 1 shows the relationship between the Zr concentration and the number of the particles, and Fig. 2 shows the relationship between the Vickers hardness and the number of the particles.

[0083][Table 12]

Table 12 Sputtering target production conditions (Examples)

	Composition			Mixing conditions										Sintering condition				
	Designed composition			Alloy phase Fe		Alloy phase Co		Alloy phase Pt		Alloy phase		Non-magnetic phase		Non-magnetic phase		Sintering temperature (°C)		
	mol%			(g)	(g)	(g)	(g)	(g)	(g)	Component particle size (μm)	(g)	Component particle size (μm)	(g)	Component particle size (μm)				
Example 1	Fe-51Pt-7Si ₃ N ₄	187.27		794.34							Si ₃ N ₄ : 20μm	78.39				1170		
Example 2	Fe-40Pt-20AlN	211.93		740.30							AlN: 8μm	77.77				1160		
Example 3	Fe-39Pt-25TaN	188.66		713.95							Ta ₂ N: 4μm	457.39				1200		
Example 4	Fe-38Pt-15Cr ₂ N	235.64		665.53							Cr ₂ N: 6μm	158.83				900		
Example 5	Fe-35Pt-25VN	219.51		670.94							VN: 7μm	159.56				900		
Example 6	Fe-40Pt-20NbN	210.99		737.04							NbN: 10μm	201.96				1200		
Example 7	Fe-40Pt-20HfN	205.9		719.24							HfN: 35μm	354.87				900		
Example 8	Fe-28Pt-30BN	260.54		606.75							cBN: 3μm	82.71				1250		
Example 9	Fe-35Pt-25TiN	214.76		656.43							TiN: 9μm	148.80				1120		
Example 10	Fe-41Pt-5Cu-58N-8Si ₃ N ₄	175.8		614.12	Cu: 5μm	24.40					Si ₃ N ₄ : 20μm	86.15	BN: 5μm	9.53		1100		
Example 11	Fe-48Pt-3B ₂ O ₃ -8Si ₃ N ₄	171.99		642.69							Si ₃ N ₄ : 20μm	80.36	B ₂ O ₃ : 5μm	14.96		1150		
Example 12	Fe-41Pt-4SiO ₂ -10AlN-3Si ₃ N ₄	193.15		658.65							AlN: 8μm	33.75	Si ₃ N ₄ : 20μm	34.65	SiO ₂ : 1μm	19.79	100rpm4h	
Example 13	Fe-21Pt-21Co-10C-20AlN	159.6	126.32	418.14							AlN: 8μm	83.67	C: 5μm	12.26		100rpm4h	900	
Example 14	Fe-30Pt-5C-30AlN	180.49		540.42							AlN: 8μm	113.55	C: 5μm	5.55		100rpm4h	900	
Example 15	Fe-30Pt-5Ag-6C-11BN-20AlN	144.02		539.02	Ag: 4μm	49.68					AlN: 8μm	75.50	BN: 5μm	25.15	C: 5μm	6.64	100rpm4h	900
Example 16	Fe-32Pt-6B-6Ru-20HfN	190.27		590.79	B: 8μm	6.14	Ru: 13μm				HfN: 35μm	364.37				100rpm4h	800	
Example 17	Fe-34Pt-3Ge-5C-20TiN	206.61		645.77	Ge: 10μm	21.22					TiN: 9μm	120.55	C: 5μm	5.85		100rpm4h	800	
Example 18	Co-23Pt-7Si ₃ N ₄		361.19	392.84							Si ₃ N ₄ : 20μm	85.96				100rpm4h	1130	
Example 19	Co-20Pt-19AlN		373.60	405.47							AlN: 8μm	80.93				100rpm4h	1050	
Example 20	Co-19Pt-25TaN		336.12	377.49							Ta ₂ N: 4μm	496.39				100rpm4h	1230	
Example 21	Co-14Pt-30BN		394.51	326.48							cBN: 3μm	89.01				100rpm4h	900	
Example 22	Co-16Pt-4Cr-4SiO ₂ -15Cr ₂ N		321.92	279.51	Cr: 15μm	18.62					Cr ₂ N: 6μm	158.42	SiO ₂ : 1μm	21.52		100rpm4h	900	
Example 23	Co-13Pt-6Ru-8Cr-16C-22VN		227.85	280.14	Ru: 13μm	66.99	Cr: 15μm				VN: 7μm	157.84	C: 5μm	21.23		100rpm4h	900	
Example 24	Co-15TiN		582.09								TiN: 9μm	107.91				100rpm4h	1230	
Example 25	Fe-20TaN		475.23								Ta ₂ N: 4μm	414.77				100rpm4h	1250	
Example 26	Co-48Fe-20AlN		283.67	199.57							AlN: 8μm	86.76				100rpm4h	1110	

[0084] [Table 13]

Table 13 Sputtering target production conditions (Comparative Examples)

Composition			Mixing conditions										Sintering condition		
	Designed composition		Alloy phase Fe	Alloy phase Co	Alloy phase Pt	Alloy phase		Non-magnetic phase		Non-magnetic phase		Non-magnetic phase	Mixing condition	Sintering temperature	Sintering condition
	mol%		(g)	(g)	(g)	Component particles size (μm)	(g)	Component particles size (μm)	(g)	Component particles size (μm)	(g)				
Comparative Examples 1	Fe-51Pt-7Si ₃ N ₄		187.27		794.34			Si ₃ N ₄ : 20μm	78.39			300rpm20h		1120	
Comparative Examples 2	Fe-40Pt-20AlN		211.93		740.30			AlN: 8μm	77.77			300rpm20h		1290	
Comparative Examples 3	Fe-39Pt-25TaN		188.66		713.95			Ta ₂ N: 4μm	457.39			300rpm20h		1260	
Comparative Examples 4	Fe-38Pt-15Cr ₂ N		235.64		665.53			Cr ₂ N: 6μm	158.83			300rpm20h		1050	
Comparative Examples 5	Fe-35Pt-25VN		219.51		670.94			VN: 7μm	159.56			300rpm20h		940	
Comparative Examples 6	Fe-40Pt-20NbN		210.99		737.04			NbN: 10μm	201.96			300rpm20h		940	
Comparative Examples 7	Fe-40Pt-20HfN		205.9		719.24			HfN: 35μm	354.87			300rpm20h		1200	
Comparative Examples 8	Fe-28Pt-30BN		260.54		606.75			cBN: 3μm	82.71			300rpm20h		950	
Comparative Examples 9	Fe-28Pt-30BN		260.54		606.75			cBN: 3μm	82.71			300rpm2h		950	
Comparative Examples 10	Fe-35Pt-25TiN		214.76		656.43			TiN: 9μm	148.80			300rpm20h		1250	
Comparative Examples 11	Fe-34Pt-30Ge-5C-20TiN		206.61		645.77	21.22		TiN: 9μm	120.55	C: 5μm	5.85	300rpm20h		800	
Comparative Examples 12	Co-23Pt-7Si ₃ N ₄			361.19	392.84			Si ₃ N ₄ : 20μm	85.96			300rpm20h		1130	
Comparative Examples 13	Co-14Pt-30BN			394.51	326.48			cBN: 3μm	89.01			300rpm20h		950	
Comparative Examples 14	Co-14Pt-30BN			394.51	326.48			cBN: 3μm	89.01			300rpm2h		950	
Comparative Examples 15	Co-48Fe-20AlN		283.67	199.57				AlN: 8μm	86.75			300rpm20h		1160	

[0085] [Table 14]

Table 14 Results of measuring sputtering targets (Examples)

	Component	Sintering result					
	Designed composition	Relative density	Average particle size	Photographing magnification	Zr concentration	Hv (3kgf)	The number of particles 500W 40sec
	mol%	(%)	(μm)	(Time)	(ppm)		(Number of particles)
Example 1	Fe-51Pt-7Si ₃ N ₄	97.2	8.9	500	208	491	78
Example 2	Fe-40Pt-20AlN	95.7	2.4	1000	162	532	129
Example 3	Fe-39Pt-25TaN	97.4	1.9	1000	226	584	58
Example 4	Fe-38Pt-15Cr ₂ N	95.0	4.8	500	183	509	89
Example 5	Fe-35Pt-25VN	97.1	2.7	1000	149	469	136
Example 6	Fe-40Pt-20NbN	93.5	6.8	500	214	567	141
Example 7	Fe-40Pt-20HfN	91.3	5.0	500	231	545	108
Example 8	Fe-28Pt-30BN	92.4	1.3	3000	118	578	135
Example 9	Fe-35Pt-25TiN	97.5	6.4	500	228	590	54
Example 10	Fe-41Pt-5Cu-5BN-8Si ₃ N ₄	93.4	11.6	500	243	549	208
Example 11	Fe-46Pt-3B ₂ O ₃ -8Si ₃ N ₄	96.5	10.4	500	296	586	188
Example 12	Fe-41Pt-4SiO ₂ -10AlN-3Si ₃ N ₄	94.3	2.1	1000	283	577	83
Example 13	Fe-21Pt-21Co-10C-20AlN	91.8	2.0	1000	196	384	311
Example 14	Fe-30Pt-5C-30AlN	91.1	2.1	1000	288	275	386
Example 15	Fe-30Pt-5Ag-6C-11BN-20AlN	92.4	1.9	1000	217	260	343
Example 16	Fe-32Pt-6B-6Rh-20HfN	92.4	4.9	500	209	566	124
Example 17	Fe-34Pt-3Ge-5C-20TiN	92.7	7.3	500	168	299	284
Example 18	Co-23Pt-7Si ₃ N ₄	96.3	12.8	500	211	487	81
Example 19	Co-20Pt-19AlN	97.0	2.3	1000	199	581	114
Example 20	Co-19Pt-25TaN	98.1	3.6	1000	241	528	67
Example 21	Co-14Pt-30BN	93.1	1.4	3000	238	479	123
Example 22	Co-16Pt-4Cr-4SiO ₂ -15Cr ₂ N	94.8	5.0	500	266	563	95
Example 23	Co-13Pt-6Ru-8Cr-16C-22VN	95.1	2.5	1000	197	342	287
Example 24	Co-15TiN	96.7	7.1	500	149	413	88
Example 25	Fe-20TaN	94.9	1.9	1000	233	528	67
Example 26	Co-48Fe-20AlN	95.1	2.3	1000	219	507	118

[0086] [Table 15]

Table 15 Results of measuring sputtering targets (Comparative Examples)

	Component	Sintering result					
	Designed composition	Relative density	Average particle size	Photographing magnification	Zr concentration	Hv (3kgf)	The number of particles 500W 40sec
	mol%	(%)	(μm)	(Time)	(ppm)		(Number of particles)
Comparative Examples 1	Fe-51Pt-7Si ₃ N ₄	90.8	0.5	10000	4531	713	2298
Comparative Examples 2	Fe-40Pt-20AlN	95.4	0.4	10000	3466	736	6218
Comparative Examples 3	Fe-39Pt-25TaN	97.7	0.4	10000	6528	864	5843
Comparative Examples 4	Fe-38Pt-15Cr ₂ N	96.5	0.6	10000	4331	657	2915
Comparative Examples 5	Fe-35Pt-25VN	95.1	0.4	10000	5333	738	2642
Comparative Examples 6	Fe-40Pt-20NbN	96.2	0.8	10000	4839	655	2261
Comparative Examples 7	Fe-40Pt-20HfN	94.8	0.3	10000	5154	741	4351
Comparative Examples 8	Fe-28Pt-30BN	92.3	0.4	10000	6171	678	3165
Comparative Examples 9	Fe-28Pt-30BN	93.2	0.8	10000	3432	572	4448
Comparative Examples 10	Fe-35Pt-25TiN	97.8	0.6	10000	5687	724	4532
Comparative Examples 11	Fe-34Pt-3Ge-5C-20TiN	90.7	0.5	10000	3519	679	4616
Comparative Examples 12	Co-23Pt-7Si ₃ N ₄	90.3	0.5	10000	4640	708	2417
Comparative Examples 13	Co-14Pt-30BN	92.1	0.4	10000	5341	733	3654
Comparative Examples 14	Co-14Pt-30BN	93.7	0.9	10000	1989	621	2308
Comparative Examples 15	Co-48Fe-20AlN	92.7	0.4	10000	4197	792	5916

[0087] Tables 14 to 15 and Fig. 1 show that if the Zr concentration is 2000 ppm or more, the number of the particles is 2000 or more, which is large; if the Zr concentration is 1000 ppm or less, the number of the particles is small; and especially if the Zr concentration is 300 ppm or less, the number of the particles is less than 400, which is small. Tables 14 to 15 and Fig. 2 show that if the Vickers hardness, Hv, is 600 or more, the number of the particles is 2000 or more, which is large; and if the Vickers hardness, Hv, is in the range of 200 to 600, the number of the particles is less than 400, which is small.

[0088] Although the average particle sizes of the hard nitride particles of the sputtering targets of Examples 1 to 26 were able to be measured at a magnification of 500 to 3000, the magnification needed to be increased to 10000 for measuring the average particle sizes of the hard nitride particles of the sputtering targets of Comparative Examples 1 to 15. Tables 14 and 15 show that the hard nitrides of Examples 1 to 26 are in the range of 1.3 μm to 12.8 μm , and the average particle sizes of the hard nitrides of Comparative Examples 1 to 15 are fine particles having an average particle sizes in the range of 0.3 to 0.9 μm .

[0089] Fig. 3 is an SEM observation photograph of the system of the sputtering target of Example 1 (at a magnification of 1000). Fig. 4 is an SEM observation photograph of the system of the sputtering target of Example 2 (at a magnification of 1000). Fig. 5 is an SEM observation photograph of the system of the sputtering target of Comparative Example 2 (at a magnification of 1000). It has been confirmed by EPMA analysis that, in the figures, black particles are the hard nitride particles, and white and gray are alloy phases. The comparison between Fig. 3 and Fig. 5 shows that, in Comparative Example 2 (Fig. 5), white alloy phases and black particles are dispersed more finely than in Example 1 (Fig. 3). Fig. 4 shows that relatively large hard nitride particles and alloy phases are homogeneously dispersed.

[0090] Tables 14 to 15 and Figs. 3 to 5 show that, in the sputtering targets produced by the production method of the present invention, the hard nitride particles are relatively large, but the non-magnetic phases and the alloy phases are homogeneously dispersed as compared with the sputtering targets of Comparative Examples, produced by the conventional method.

CLAIMS

1. A hard nitride-containing sputtering target, comprising:
alloy phases comprising Fe or Co, and
non-magnetic phases comprising a hard nitride selected from AlN, BN, Cr₂N, Si₃N₄, HfN, NbN, TaN, TiN, VN, and any combination thereof,
wherein a Zr impurity concentration in the case of measurement thereof as metal Zr is regulated to 1000 ppm or less, and
wherein Vickers hardness, Hv, measured under a load condition of 3 kgf is 200 or more and 600 or less.
2. The hard nitride-containing sputtering target according to claim 1, wherein the Zr impurity concentration is regulated to 500 ppm or less.
3. The hard nitride-containing sputtering target according to claim 1 or 2,
wherein the non-magnetic phases satisfy at least one of
a condition that an average particle size determined by subjecting an observation visual field of 180 μm $\times$ 180 μm in EPMA surface analysis at a magnification of 500 to image analysis is 4 μm or more and 20 μm or less;
a condition that an average particle size determined by subjecting an observation visual field of 90 μm $\times$ 90 μm in EPMA surface analysis at a magnification of 1000 to image analysis is 2 μm or more and 20 μm or less; and
a condition that an average particle size determined by subjecting an observation visual field of 30 μm $\times$ 30 μm in EPMA surface analysis at a magnification of 3000 to image analysis is 1 μm or more and 20 μm or less.
4. The hard nitride-containing sputtering target according to any one of claims 1 to 3, wherein a content of the non-magnetic phases in the sputtering target is 5% by mol or more and 50% by mol or less.

5. The hard nitride-containing sputtering target according to any one of claims 1 to 4, wherein the non-magnetic phases further comprise one or more selected from C, B₂O₃, and SiO₂.
6. The hard nitride-containing sputtering target according to any one of claims 1 to 5, wherein the alloy phases contain Pt at 0% by mol or more and 60% by mol or less.
7. The hard nitride-containing sputtering target according to any one of claims 1 to 6, wherein the alloy phases further comprise one or more elements selected from Ag, Au, Cr, Cu, Ge, Ir, Ni, Pd, Rh, Ru, and B.
8. A method for producing the hard nitride-containing sputtering target according to any one of claims 1 to 7, comprising:
 - mixing raw material powders constituting the alloy phases and the non-magnetic phases at a rotational speed of 50 rpm or more and 150 rpm or less with a zirconia ball mill for 2 hours or more and 6 hours or less to prepare mixed powder and
 - sintering the mixed powder.
9. The method for producing a hard nitride-containing sputtering target according to claim 8, wherein the raw material powders constituting the alloy phases are metal powders of each raw material or Fe-based or Co-based atomized alloy powder.
10. The production method according to claim 8 or 9, wherein the raw material powder constituting the non-magnetic phases contains hard nitride powder having an average particle size, D50, of 1 μm or more and 40 μm or less.