

SPUTTERING TARGET AND SPUTTERING TARGET ASSEMBLY

FIELD OF THE INVENTION

[0001]

The present invention relates to a sputtering target and a sputtering target assembly, and primarily to a sputtering target for the production of films for HDDs.

BACKGROUND OF THE INVENTION

[0002]

For example, materials based on ferromagnetic metals Co, Fe, and Ni are used for the layers constituting hard disk drives (HDDs) that employ perpendicular magnetic recording, and composite materials consisting of ferromagnetic alloys such as Co-Cr, Co-Pt, Co-Cr-Pt, and Fe-Pt, which are mainly composed of Co and Fe, and non-magnetic inorganic materials are often used for the recording layers. Thin films for magnetic recording media such as hard disk drives are often produced by sputtering targets containing the above materials as components, due to their high productivity.

[0003]

In general, sputtering targets are manufactured by first crushing and mixing powders of raw materials, and then hot pressing the mixture to obtain a sintered body. After this, in order to increase the density of the sintered body, HIP (Hot Isostatic Pressing) processing may be performed. The sintered body thus obtained is processed by a lathe to manufacture a target of a predetermined shape (Patent Literatures 1 and 2).

CITATION LIST

Patent Literatures

[0004]

[Patent Literature 1] Japanese Patent No. 6030271

[Patent Literature 2] Japanese Patent No. 6305881

SUMMARY OF THE INVENTION

[0005]

As described above, a composite material consisting of a ferromagnetic alloy such as an Fe-Pt alloy and a nonmagnetic inorganic material is useful as a recording layer for HDD. However, when a sintered body having a structure in which oxides are dispersed in a base metal containing Fe and Pt is manufactured as a sputtering target for producing such a recording layer, the sintered body having this composition is relatively brittle, and there is a problem that cracks and breakage occur during the manufacturing process.

[0006]

Therefore, an object of an embodiment of the present invention is to provide a sputtering target and a sputtering target assembly that can effectively suppress the occurrence of cracks and breakage during the manufacturing process.

[0007]

The above problems are solved by the present invention, which is specified as follows.

1. A sputtering target, comprising:

(1) Fe, (2) Pt, (3) one or more elements selected from Ag, Au, B, Co, Cr, Cu, Ga, Ge, Mn, Mo, Nb, Ni, Pd, Re, Rh, Ru, Si, Sn, Ta, W, V, and Zn, and (4) the balance, wherein

an atomic ratio of the (1) Fe to the (2) Pt is 34 to 55 at%,

a total concentration of the (1) Fe and the (2) Pt is 50 mol % or more,

a content of the elements in (3) is 0.5 to 15 mol% in total,

a remainder of (4) is an oxide which may selectively contain impurities, a volume ratio of the oxide is 40 vol.% or more, and

an average particle area (average size) of an oxide phase calculated using ImageJ with a SEM image at a field magnification of 3000 times is $4.0\ \mu\text{m}^2$ or less.

2. A sputtering target, comprising:

(1) Fe, (2) Pt, (3) one or more elements selected from Ag, Au, B, Co, Cr, Cu, Ga, Ge, Mn, Mo, Nb, Ni, Pd, Re, Rh, Ru, Si, Sn, Ta, W, V, and Zn, and (4) the balance, wherein

an atomic ratio of the (1) Fe to the (2) Pt is 34 to 55 at%,

a total concentration of the (1) Fe and the (2) Pt is 50 mol % or more,

a content of the elements in (3) is 0.5 to 15 mol% in total,

a remainder of (4) is an oxide which may selectively contain impurities, a volume ratio of the oxide is 40 vol.% or more, and

and an average perimeter of an oxide phase calculated using ImageJ with a SEM image having a field magnification of 3000 times is $11.7\ \mu\text{m}$ or less.

3. A sputtering target, comprising:

(1) Fe, (2) Pt, (3) one or more elements selected from Ag, Au, B, Co, Cr, Cu, Ga, Ge, Mn, Mo, Nb, Ni, Pd, Re, Rh, Ru, Si, Sn, Ta, W, V, and Zn, and (4) the balance, wherein

an atomic ratio of the (1) Fe to the (2) Pt is 34 to 55 at%,

a total concentration of the (1) Fe and the (2) Pt is 50 mol % or more,

a content of the elements in (3) is 0.5 to 15 mol% in total,

a remainder of (4) is an oxide which may selectively contain impurities, a volume ratio of the oxide is 40 vol.% or more, and

a bending strength is 300 MPa or more.

4. A sputtering target, comprising:

(1) Fe, (2) Pt, (3) one or more elements selected from Ag, Au, B, Co, Cr, Cu, Ga, Ge, Mn, Mo, Nb, Ni, Pd, Re, Rh, Ru, Si, Sn, Ta, W, V, and Zn, and (4) the balance, wherein

an atomic ratio of the (1) Fe to the (2) Pt is 34 to 55 at%,

a total concentration of the (1) Fe and the (2) Pt is 50 mol % or more,

a content of the elements in (3) is 0.5 to 15 mol% in total,

a remainder of (4) is an oxide which may selectively contain impurities, a volume ratio of the oxide is 40 vol.% or more, and

a number-average circle-equivalent diameter calculated using ImageJ and assuming that the shape of the oxide in the oxide phase is a circle, using a SEM image with a field magnification of 3000 times, is 1.3 μm or less.

5. A sputtering target, comprising:

(1) Fe, (2) Pt, (3) one or more elements selected from Ag, Au, B, Co, Cr, Cu, Ga, Ge, Mn, Mo, Nb, Ni, Pd, Re, Rh, Ru, Si, Sn, Ta, W, V, and Zn, and (4) the balance, wherein

an atomic ratio of the (1) Fe to the (2) Pt is 34 to 55 at%,

a total concentration of the (1) Fe and the (2) Pt is 50 mol % or more,

a content of the elements in (3) is 0.5 to 15 mol% in total,

a remainder of (4) is an oxide which may selectively contain impurities, a volume ratio of the oxide is 40 vol.% or more, and

a number of oxide particles having a circular-equivalent diameter of 1 μm or less per 1261 μm^2 of a measurement area in a scanning electron microscope (SEM) photograph taken at a magnification of 3000 times is 100 or more.

6. A sputtering target, comprising:

(1) Fe, (2) Pt, (3) one or more elements selected from Ag, Au, B, Co, Cr, Cu, Ga, Ge, Mn, Mo, Nb, Ni, Pd, Re, Rh, Ru, Si, Sn, Ta, W, V, and Zn, and (4) the balance, wherein

an atomic ratio of the (1) Fe to the (2) Pt is 34 to 55 at%,
a total concentration of the (1) Fe and the (2) Pt is 50 mol % or more,
a content of the elements in (3) is 0.5 to 15 mol% in total,
a remainder of (4) is an oxide which may selectively contain impurities, a
volume ratio of the oxide is 40 vol.% or more, and

a number of oxide particles having a circular-equivalent diameter of 2 μm or
less per 1261 μm^2 of a measurement area in a scanning electron microscope (SEM)
photograph taken at a visual field magnification of 3000 times is 120 or more.

7. A sputtering target, comprising:

(1) Fe, (2) Pt, (3) one or more elements selected from Ag, Au, B, Co, Cr, Cu,
Ga, Ge, Mn, Mo, Nb, Ni, Pd, Re, Rh, Ru, Si, Sn, Ta, W, V, and Zn, and (4) the
balance, wherein

an atomic ratio of the (1) Fe to the (2) Pt is 34 to 55 at%,
a total concentration of the (1) Fe and the (2) Pt is 50 mol % or more,
a content of the elements in (3) is 0.5 to 15 mol% in total,
a remainder of (4) is an oxide which may selectively contain impurities, a
volume ratio of the oxide is 40 vol.% or more, and

a proportion of particles having a circular-equivalent diameter of 1 μm or less
per 1261 μm^2 of a measurement area in a scanning electron microscope (SEM)
photograph taken at a magnification of 3000 times is 60% or more.

8. A sputtering target, comprising:

(1) Fe, (2) Pt, (3) one or more elements selected from Ag, Au, B, Co, Cr, Cu,
Ga, Ge, Mn, Mo, Nb, Ni, Pd, Re, Rh, Ru, Si, Sn, Ta, W, V, and Zn, and (4) the
balance, wherein

an atomic ratio of the (1) Fe to the (2) Pt is 34 to 55 at%,
a total concentration of the (1) Fe and the (2) Pt is 50 mol % or more,
a content of the elements in (3) is 0.5 to 15 mol% in total,

a remainder of (4) is an oxide which may selectively contain impurities, a volume ratio of the oxide is 40 vol.% or more, and

a proportion of particles having a circular-equivalent diameter of 2 μm or less per 1261 μm^2 of a measurement area in a scanning electron microscope (SEM) photograph taken at a visual field magnification of 3000 times is 90% or more.

9. The sputtering target according to any one of the above 1 to 8, wherein the oxide contains an oxide of Si.

10. The sputtering target according to the above 9, wherein the oxide further contains one or more oxides of elements selected from Al, B, Ba, Be, Ca, Ce, Cr, Dy, Er, Eu, Ga, Gd, Ho, Li, Mg, Mn, Nb, Nd, Pr, Sc, Sm, Sr, Ta, Tb, Ti, V, Y, Zn, and Zr.

11. A sputtering target assembly comprising:
the sputtering target according to any one of the above 1 to 8 and
a backing plate bonded to the sputtering target.

[0008]

According to the embodiments of the present invention, it is possible to provide a sputtering target and a sputtering target assembly that can effectively suppress the occurrence of cracks and breakage during the manufacturing process.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009]

FIG. 1 shows an example of a binarized image and an original image in image analysis using ImageJ.

FIG. 2 shows a screenshot of the settings for binarization processing using ImageJ.

DETAILED DESCRIPTION OF THE INVENTION

[0010]

Next, the embodiment for carrying out the present invention will be described in detail with reference to the drawings. It should be understood that the present invention is not limited to the following embodiment, and that appropriate design changes, improvements, etc. may be made based on the ordinary knowledge of a person skilled in the art without departing from the spirit of the present invention.

The multiple components disclosed in each embodiment can be appropriately combined to form various inventions. For example, some components may be deleted from all the components shown in each embodiment, or components of different embodiments may be appropriately combined.

[0011]

<Sputtering target>

The shape of the sputtering target according to the embodiment of the present invention is not particularly limited, but may be flat (including disk-like and rectangular plate-like), cylindrical, or any other shape.

[0012]

The sputtering target according to the embodiment of the present invention has (1) Fe, (2) Pt, (3) one or more elements selected from Ag, Au, B, Co, Cr, Cu, Ga, Ge, Mn, Mo, Nb, Ni, Pd, Re, Rh, Ru, Si, Sn, Ta, W, V, and Zn, and (4) the balance. The balance of (4) is an oxide, and may selectively contain impurities. The sputtering target according to the embodiment of the present invention has a metal phase containing ferromagnetic materials Fe and Pt, and a phase containing an oxide other than the metal phase, and can be given the function of a magnetic thin film.

[0013]

The sputtering target according to the embodiment of the present invention has an atomic ratio of Fe to Pt of 34 to 55 at%. That is, the atomic ratio of Fe and Pt

in the sputtering target satisfies $34 \leq X \leq 55$ in $\text{Fe}_{100-X}\text{Pt}_X$. When Fe and Pt in the sputtering target satisfy such an atomic ratio, the function as a magnetic thin film is improved. The atomic ratio of Fe to Pt is preferably $40 \leq X \leq 53$, and more preferably $44 \leq X \leq 51$.

[0014]

The sputtering target according to the embodiment of the present invention has a total concentration of Fe and Pt of 50 mol% or more. When the total concentration of Fe and Pt in the sputtering target is 50 mol% or more, the magnetic properties are improved. There is no particular upper limit to the total concentration of Fe and Pt, but from the viewpoint of securing grain boundary material, it is preferably 80 mol% or less. Furthermore, the total concentration of Fe and Pt is more preferably 50-75 mol%, and even more preferably 50-70 mol%.

[0015]

The sputtering target according to an embodiment of the present invention has a total content of one or more elements selected from Ag, Au, B, Co, Cr, Cu, Ga, Ge, Mn, Mo, Nb, Ni, Pd, Re, Rh, Ru, Si, Sn, Ta, W, V, and Zn of 0.5-15 mol%. These elements, along with Fe and Pt, are components of the metal phase, and by containing 0.5-15 mol%, the magnetic properties of the sputtering target having Fe and Pt as its basic components are further improved. The content of the element is more preferably 2-13 mol%, and even more preferably 4-11 mol%.

[0016]

The sputtering target according to the embodiment of the present invention may selectively contain impurities, with the remainder being an oxide. When SiO_2 is used as the oxide, a particularly preferable magnetic thin film can be obtained. In addition to SiO_2 , the oxide may further contain one or more oxides of elements selected from Al, B, Ba, Be, Ca, Ce, Cr, Dy, Er, Eu, Ga, Gd, Ho, Li, Mg, Mn, Nb, Nd,

Pr, Sc, Sm, Sr, Ta, Tb, Ti, V, Y, Zn, and Zr in order to further improve the magnetic properties.

[0017]

The sputtering target according to the embodiment of the present invention has an oxide volume ratio of 40 vol.% or more. When the oxide volume ratio in the sputtering target is 40 vol.% or more, the magnetic properties are further improved. The upper limit of the oxide volume ratio in the sputtering target is not particularly limited, but from the viewpoint that the magnetic properties deteriorate when the oxides are too much, it is preferable that it is 60 vol.% or less. The oxide volume ratio in the sputtering target is more preferably 40 to 55 vol.%, and even more preferably 40 to 50 vol.%. The oxide volume ratio can be calculated from the composition of the target, and is obtained by calculating the volume of each component contained in the target by (content of each material: mol) x (molecular weight of each material: g/mol) x (reciprocal of density of each material: cm³/g). The oxide volume ratio can then be calculated by dividing the total volume of only oxides among the components by the total volume of all components.

[0018]

The impurities selectively contained in the remainder of the sputtering target according to the embodiment of the present invention include metal elements not included in the elements (1) to (3) above, and simple substances or compounds of elements such as C or N from gas components such as carbon dioxide and nitrogen in the atmosphere. The content of the impurities selectively contained in the remainder of the sputtering target according to the embodiment of the present invention may be 0.5 mol% or less, or 0.15 mol% or less. In addition, the impurities can be analyzed by taking an analysis sample from the sputtering target and using infrared absorption spectrometry, an ICP optical emission spectrometer, GDMS (glow discharge mass spectrometry), or the like. The amount and shape of the

analysis sample vary depending on the analysis method used, and the optimal amount and shape for each method can be selected.

[0019]

In one aspect, the sputtering target according to the embodiment of the present invention has an average particle area (average size) of the oxide phase calculated using ImageJ (image processing software) using a scanning electron microscope (SEM) image at a field magnification of 3000 times is $4.0\ \mu\text{m}^2$ or less. When the average particle area of the oxide phase of the sputtering target calculated using ImageJ is $4.0\ \mu\text{m}^2$ or less, the oxide structure is fine and the sputtering target has good strength. It is speculated that the oxide phase and the phase containing Fe and Pt are intertwined in a structure in which the oxide structure is fine and dispersed, and even if a minute defect that can progress to a crack occurs, the boundary between the oxide phase and the phase containing Fe and Pt acts as a barrier to prevent the defect from progressing, and the defect is prevented from becoming a crack or a crack. Therefore, in the manufacturing process of the sputtering target, the occurrence of cracks or cracks can be effectively suppressed in the hot pressing of the mixture obtained by crushing and mixing the powder of the raw materials, and further in the HIP processing for improving the density of the sintered body thereafter. The average particle area of the oxide phase of the sputtering target calculated using ImageJ is preferably $3.0\ \mu\text{m}^2$ or less, more preferably $2.6\ \mu\text{m}^2$ or less, more preferably $2.5\ \mu\text{m}^2$ or less, more preferably $2.0\ \mu\text{m}^2$ or less, more preferably $1.7\ \mu\text{m}^2$ or less, more preferably $1.5\ \mu\text{m}^2$ or less, and more preferably $1.0\ \mu\text{m}^2$ or less. The lower limit of the average grain area of the oxide phase of the sputtering target calculated using ImageJ does not need to be particularly limited, and may be, for example, $0.1\ \mu\text{m}$ or more, for example, $0.2\ \mu\text{m}$ or more, for example, $0.3\ \mu\text{m}$ or more, for example, $0.4\ \mu\text{m}$ or more, for example, $0.5\ \mu\text{m}$ or more, or for example, $0.6\ \mu\text{m}$ or more.

[0020]

In another aspect, the sputtering target according to the embodiment of the present invention has an average perimeter of the oxide phase of 11.7 μm or less, calculated using ImageJ (image processing software) using a scanning electron microscope (SEM) image at a field magnification of 3000 times. If the average perimeter of the oxide phase of the sputtering target calculated using ImageJ is 11.7 μm or less, the oxide structure is fine and the sputtering target has good strength. The oxide structure is fine and dispersed, resulting in a complex structure of the oxide phase and the phase containing Fe and Pt. Even if a minute defect that can progress to a crack occurs, it is presumed that the boundary between the oxide phase and the phase containing Fe and Pt acts as a barrier to prevent the defect from progressing, and the defect is prevented from becoming a crack or a crack. For this reason, in the manufacturing process of the sputtering target, the occurrence of cracks and cracks can be effectively prevented in the hot pressing of the mixture obtained by crushing and mixing the powder of the raw materials, and further in the HIP processing for improving the density of the sintered body thereafter. The average perimeter of the oxide phase of the sputtering target calculated using ImageJ is preferably 11.5 μm or less, more preferably 11.25 μm or less, more preferably 11.0 μm or less, more preferably 10.75 μm or less, more preferably 10.5 μm or less, more preferably 10.25 μm or less, and more preferably 10.0 μm or less. The lower limit of the average perimeter of the oxide phase of the sputtering target calculated using ImageJ does not need to be particularly limited, but may be, for example, 4.05 μm or more, for example, 4.3 μm or more, for example, 4.55 μm or more, for example, 4.8 μm or more, for example, 5.05 μm or more, or for example, 5.3 μm or more.

[0021]

A method for measuring the average particle area (average size) and average perimeter of the oxide phase of a sputtering target according to an embodiment of the present invention will be described in detail.

First, the sputtering target is cut and the cross section is mirror-polished to prepare an SEM observation sample. Next, the SEM observation sample is observed, for example, using an SEM (S-3700N, manufactured by Hitachi High-Technologies Corporation). The observation settings are as follows:

Photographed image: secondary electron image, field of view magnification: 3000x, acceleration voltage: 10-15kV

The average particle area and average perimeter of the oxide phase can be evaluated by binarizing the secondary electron image obtained by the above-mentioned photographing using the image analysis software ImageJ according to the following steps (1) to (7).

(1) File of the ImageJ toolbar → Read the SEM image with a field of view magnification of 3000x from Open.

(2) Image → Type, select 8-bit. Draw a straight line along the scale bar, then select Analyze → Set scale and set the scale size.

(3) Select the part of the image excluding the scale, and cut out the scaled part with Image → Crop.

(4) Select Process → Filters → Gaussian Blur, enter 2 for Sigma, and click OK.

(5) Select Process → Binary → Make Binary. This completes the binarization of the image.

(6) Select Analyze → Set measurement and check Area.

(7) Select Analyze → Analyze Particle, set the displayed analysis conditions to Size: 0-infinity, Circularity: 0.00-1.00, Show: nothing, check Summarize, and

select OK. This will display the results, from which read the Average Size and the average perimeter of the oxide phase.

As described above, ImageJ performs binarization on the imported SEM image, converting the black particle parts on the SEM image to black, treating the black particles as oxide phase particles, and calculating their average particle area. In addition, parts that are darker than the surrounding area that are classified as black by the binarization process are converted to black, treating the black parts as oxide phase particles, and calculating their average perimeter. The threshold for the binarization process is automatically set from the color histogram in the image. FIG. 1 shows an example of the binarized image and the original image.

[0022]

In yet another aspect, the sputtering target according to the embodiment of the present invention has a number-average circle-equivalent diameter calculated by assuming that the shape of the oxide in the oxide phase is a circle, calculated using a scanning electron microscope (SEM) image at a field magnification of 3000 times and ImageJ (image processing software), and is 1.3 μm or less. When the number-average circle-equivalent diameter calculated by assuming that the shape of the oxide in the oxide phase of the sputtering target is a circle, calculated using ImageJ, is 1.3 μm or less, the oxide structure is fine and the sputtering target has good strength. The oxide structure is fine and dispersed, resulting in a complex structure of the oxide phase and the phase containing Fe and Pt, and it is presumed that even if a minute defect that can progress to a crack occurs, the boundary between the oxide phase and the phase containing Fe and Pt acts as a barrier to prevent the defect from progressing, and the defect is prevented from becoming a crack or a break. Therefore, in the manufacturing process of the sputtering target, the occurrence of cracks and breakage can be effectively suppressed during hot pressing of the mixture obtained by pulverizing and mixing the powders of the raw

materials, and further during the subsequent HIP processing for increasing the density of the sintered body, etc. The number-average diameter of the circle-equivalent diameter calculated using ImageJ assuming that the shape of the oxide in the oxide phase of the sputtering target is a circle is preferably 1.25 μm or less, more preferably 1.20 μm or less, more preferably 1.15 μm or less, more preferably 1.10 μm or less, more preferably 1.05 μm or less, more preferably 1.00 μm or less, and more preferably 0.95 μm or less. The lower limit of the number-average equivalent circle diameter calculated by assuming that the shape of the oxide in the oxide phase of the sputtering target calculated using ImageJ is circular does not need to be particularly limited, but may be, for example, 0.55 μm or more, for example, 0.60 μm or more, for example, 0.65 μm or more, for example, 0.70 μm or more, for example, 0.75 μm or more, or for example, 0.80 μm or more.

[0023]

In yet another aspect, the sputtering target according to an embodiment of the present invention has 100 or more of oxide particles having a circular-equivalent diameter of 1 μm or less per 1261 μm^2 of a measurement area in a scanning electron microscope (SEM) photograph taken at a magnification of 3000 times. When the number of oxide particles having a circular-equivalent diameter of 1 μm or less per 1261 μm^2 of a measurement area is 100 or more, the oxide structure is fine and the sputtering target has good strength. It is speculated that the oxide structure is fine and dispersed, resulting in a complicated structure of the oxide phase and the phase containing Fe and Pt, and even if a minute defect that can progress to a crack occurs, the boundary between the oxide phase and the phase containing Fe and Pt acts as a barrier to prevent the defect from progressing, and the defect is prevented from becoming a crack or a crack. Therefore, in the manufacturing process of the sputtering target, the occurrence of cracks or cracks can be effectively suppressed in the hot pressing of the mixture obtained by crushing and mixing the powder of the

raw materials, and further in the HIP processing for improving the density of the sintered body thereafter. The number of oxide particles having a circular-equivalent diameter of 1 μm or less per 1261 μm^2 is preferably 120 or more, more preferably 140 or more, more preferably 160 or more, more preferably 180 or more, more preferably 200 or more, and more preferably 220 or more. The upper limit of the number of oxide particles having a circular-equivalent diameter of 1 μm or less per 1261 μm^2 of the measurement area does not need to be particularly limited, but may be, for example, 600 or less, for example, 580 or less, for example, 560 or less, for example, 540 or less, for example, 520 or less, or for example, 500 or less.

[0024]

In yet another aspect, the sputtering target according to the embodiment of the present invention has 120 or more of oxide particles having a circular-equivalent diameter of 2 μm or less per 1261 μm^2 of a measurement area in a scanning electron microscope (SEM) photograph taken at a visual field magnification of 3000 times. If the number of oxide particles having a circular-equivalent diameter of 2 μm or less per 1261 μm^2 of the measured area is 120 or more, the oxide structure is fine and the sputtering target has good strength. It is presumed that the oxide structure is fine and dispersed, resulting in a complex structure of the oxide phase and the phase containing Fe and Pt, and even if a minute defect that can progress to a crack occurs, the boundary between the oxide phase and the phase containing Fe and Pt acts as a barrier to prevent the defect from progressing, and the defect is prevented from becoming a crack or a break. Therefore, in the manufacturing process of the sputtering target, cracks and breaks can be effectively suppressed during hot pressing of the mixture obtained by crushing and mixing the powder of the raw materials, and further during HIP processing for improving the density of the sintered body. The number of oxide particles having a circular-equivalent diameter of 2 μm or less per 1261 μm^2 of measurement area is preferably 140 or more, more preferably

160 or more, more preferably 180 or more, more preferably 200 or more, more preferably 220 or more, and more preferably 240 or more. There is no need to particularly limit the upper limit of the oxide particles having a circular-equivalent diameter of 2 μm or less per 1261 μm^2 of measurement area, but it may be, for example, 640 or less, for example, 620 or less, for example, 600 or less, for example, 580 or less, or for example, 560 or less.

[0025]

A method for measuring the number-average diameter of the circle-equivalent diameter calculated assuming that the shape of the oxide in the oxide phase of the sputtering target according to the embodiment of the present invention is circular, and a method for measuring the number of particles with an oxide circle-equivalent diameter of 1 μm or less and 2 μm or less per 1261 μm^2 measurement area of a scanning electron microscope (SEM) photograph of the sputtering target according to the embodiment of the present invention taken at a magnification of 3000 times are described in detail below.

First, the sputtering target is cut and the cross section is mirror-polished to prepare an SEM observation sample. Next, the SEM observation sample is observed using, for example, an SEM (S-3700N, Hitachi High-Technologies Corporation). The observation settings are as follows:

Photographed image: secondary electron image, magnification of field: 3000 times, acceleration voltage: 10 to 15 kV

In the secondary electron image, the metal matrix phase appears as a brighter area than the surrounding area, and the oxide appears as a darker area than the surrounding area.

Next, the captured SEM image is binarized by the mode method using image processing software (ImageJ manufactured by the National Institutes of Health), and the area of each oxide is measured using the Analyze Particles function of the

image processing software. For the area S of each oxide in the oxide phase obtained in this way, the diameter D of each oxide is calculated using the following formula (1). By dividing the diameter D by the number of oxides, the number-average diameter of the circle-equivalent diameter calculated assuming that the shape of the oxides in the oxide phase is circular is calculated. In addition, the diameter D is set as the circle-equivalent diameter of the oxide, and the number of particles with the circle-equivalent diameter of 1 μm or less and 2 μm or less are measured.

[0026]

$$\text{Oxide diameter } D = 2\sqrt{(\text{Area of oxide } S) / \pi} \cdot \cdot \cdot \text{ formula (1)}$$

[0027]

The binarization of ImageJ is carried out in the same manner as the method for measuring the average particle area (average size) and average perimeter of the oxide phase described above, by the steps (1) to (7) above.

The result is displayed, and the area S of each oxide in the oxide phase is measured.

As described above, the parts that are darker than the surroundings and are classified as black by the binarization process are converted to black, and the black parts are considered to be oxides.

The threshold value for the binarization process is automatically set from the color histogram in the image. FIG. 1 shows an example of the binarized image and the original image.

[0028]

In yet another aspect, the sputtering target according to an embodiment of the present invention has 60% or more of proportion of particles having a circular-equivalent diameter of 1 μm or less per 1261 μm² of a measurement area in a

scanning electron microscope (SEM) photograph taken at a magnification of 3000 times. When the proportion of particles having a circular-equivalent diameter of 1 μm or less per 1261 μm^2 of the measured area is 60% or more, the oxide structure is fine and the sputtering target has good strength. The oxide structure is fine and dispersed, and the oxide phase and the phase containing Fe and Pt have a complicated structure. Even if a minute defect that can progress to a crack occurs, the boundary between the oxide phase and the phase containing Fe and Pt acts as a barrier to prevent the defect from progressing, and the defect is prevented from becoming a crack or a crack. Therefore, in the manufacturing process of the sputtering target, the occurrence of cracks or cracks can be effectively suppressed in the hot pressing of the mixture obtained by grinding and mixing the powder of the raw materials, and further in the HIP processing for improving the density of the sintered body. The proportion of particles having a circular-equivalent diameter of 1 μm or less per 1261 μm^2 of measurement area is preferably 61.5% or more, more preferably 63% or more, more preferably 65% or more, more preferably 67% or more, more preferably 68% or more, and more preferably 69% or more. The upper limit of the proportion of particles having a circular-equivalent diameter of 1 μm or less per 1261 μm^2 of measurement area does not need to be particularly limited, but may be, for example, 89.8% or less, for example, 87.5% or less, for example, 86% or less, for example, 85% or less, for example, 84% or less, or for example, 83.4% or less.

[0029]

In yet another aspect, the sputtering target according to an embodiment of the present invention has a ratio of 90% or more of proportion of particles having a circular-equivalent diameter of 2 μm or less per 1261 μm^2 of a measurement area in a scanning electron microscope (SEM) photograph taken at a visual field magnification of 3000 times. When the proportion of particles having a circular-

equivalent diameter of 2 μm or less per 1261 μm^2 of a measured area is 90% or more, the oxide structure is fine and the sputtering target has good strength. It is presumed that the oxide structure is fine and dispersed, resulting in a complex structure of the oxide phase and the phase containing Fe and Pt, and that even if a minute defect that could develop into a crack occurs, the boundary between the oxide phase and the phase containing Fe and Pt acts as a barrier to prevent the defect from developing and suppressing the defect from becoming a crack or breakage. Therefore, in the manufacturing process of the sputtering target, cracks and breakages can be effectively suppressed during hot pressing of the mixture obtained by crushing and mixing the powders of the raw materials, and further during HIP processing for improving the density of the sintered body. The proportion of particles having a circular-equivalent diameter of 2 μm or less per 1261 μm^2 of the measurement area is preferably 90.5% or more, more preferably 91% or more, more preferably 91.5% or more, more preferably 92% or more, more preferably 92.5% or more, and more preferably 93% or more. There is no need to particularly limit the upper limit of the proportion of particles having a circular-equivalent diameter of 2 μm or less per 1261 μm^2 of the measurement area, but it may be, for example, 98% or less, for example, 97% or less, for example, 96% or less, for example, 95% or less, or for example, 94% or less.

[0030]

A method for measuring the proportion of particles having an oxide circular-equivalent diameter of 1 μm or less and 2 μm or less per 1261 μm^2 measurement area in a scanning electron microscope (SEM) photograph taken at a visual field magnification of 3000 times of a sputtering target according to an embodiment of the present invention is described in detail.

First, the number of particles having a circular-equivalent diameter of 1 μm or less and 2 μm or less is calculated in the same manner as the method for

measuring the number of particles having an oxide circular-equivalent diameter of 1 μm or less and 2 μm or less per 1261 μm^2 measurement area in the SEM photograph described above. Next, the proportion (%) of the number of particles having the above-mentioned circular-equivalent diameter of 1 μm or less and 2 μm or less to the total number of particles measured in the measurement area of 1261 μm^2 of the SEM photograph is calculated and evaluated.

[0031]

In yet another aspect, the sputtering target according to the embodiment of the present invention has a bending strength of 300 MPa or more. When the bending strength is 300 MPa or more, the occurrence of cracks and breakage during the manufacturing process can be effectively suppressed. The bending strength was measured by preparing seven test pieces, as described below, measuring the three-point bending strength, and calculating the average value. Here, the three-point bending strength indicates the maximum bending stress when a load is applied to a sample by a specified method and the sample breaks. The breaking of a sample occurs when a crack advances from one surface of the sample to the other surface. In other words, when the maximum bending stress is high, it means that the sample does not break until the high maximum bending stress is reached. For this reason, when the maximum bending stress is high, it is considered that a crack is unlikely to advance from one surface to the other surface. In other words, by increasing the bending strength, a target in which cracks and breakage are unlikely to advance can be obtained, and since cracks and breakage are unlikely to advance even when stress such as bending is applied during the manufacturing process, it is considered that the occurrence of cracks and breakage can be effectively suppressed. The sputtering target according to the embodiment of the present invention preferably has a bending strength of 350 MPa or more, more preferably 400 MPa or more,

even more preferably 450 MPa or more, and even more preferably 500 MPa or more.

[0032]

The bending strength of the sputtering target according to the embodiment of the present invention can be measured as follows.

First, the sputtering target is cut out to prepare seven test pieces. As a specific example of the cutting method, the sputtering target is machined to a thickness of 3 mm by lathe processing, and then cut into a size of 4 mm x 35 mm by discharge wire processing. Since the surface is oxidized, the surface is polished with #120 abrasive paper to remove the oxide film and prepare a sample.

Next, the three-point bending strength of the test pieces is measured under the following measurement conditions, and the average value is taken as the bending strength of the sputtering target.

<Measurement conditions>

An A&D benchtop material testing machine (STB-1225S) can be used as the measurement device. The bending strength of the sputtering target according to the embodiment of the present invention can be measured with reference to JIS R 1601:2008 "Test method for bending strength of fine ceramics". Table 1 shows the conditions for measuring the bending strength of the sputtering target according to the embodiment of the present invention and the conditions for measuring the bending strength described in JIS R 1601:2008. As shown in Table 1, the conditions for measuring the bending strength of the sputtering target according to the embodiment of the present invention are different from the conditions for measuring the bending strength described in JIS R 1601:2008 only for "radius of curvature of the support", "length of the test piece", "parallelism", "edge of the test piece", "roughness Ra of the test piece", and "number of test pieces".

[0033]

[Table 1]

	JIS R 1601 description conditions	Measurement conditions of this embodiment
method	Three-point bending method	Three-point bending method
Jig Shape	Fixed 3-point bending test jig	Fixed 3-point bending test jig
Test piece shape	Standard Test Piece I	Standard Test Piece I
Support distance mm	30 ± 0.1	30
Support curvature radius mm	2 - 3	5
Test piece width mm	4.0 ± 0.1	4.0 ± 0.1
Test piece thickness mm	3.0 ± 0.1	3.0 ± 0.1
Test piece length mm	36 - 45	35 ± 0.1
Parallelism mm	< 0.02	< 0.04
Edge of test piece	Round or chamfer with r or c 0.1-0.3mm	Not implemented (no rounding, no chamfering)
Roughness Ra of test piece μm	< 0.02	< 0.04
Number of test pieces	> 10	7
Specimen Crosshead Speed mm/min	0.5	0.5

[0034]

The sputtering target according to an embodiment of the present invention may be as follows:

A sputtering target, comprising:

(1) Fe, (2) Pt, (3) one or more elements selected from Ag, Au, B, Co, Cr, Cu, Ga, Ge, Mn, Mo, Nb, Ni, Pd, Re, Rh, Ru, Si, Sn, Ta, W, V, and Zn, and (4) the balance, wherein

an atomic ratio of the (1) Fe to the (2) Pt is 34 to 55 at%,

a total concentration of the (1) Fe and the (2) Pt is 50 mol % or more,

a content of the elements in (3) is 0.5 to 15 mol% in total,

a remainder of (4) is an oxide which may selectively contain impurities, a volume ratio of the oxide is 40 vol.% or more, and

satisfies one or two or three or four or five or six or seven or eight of the following A to H items.

A: The average particle area (average size) of an oxide phase calculated using ImageJ with a SEM image at a field magnification of 3000 times is $4.0\ \mu\text{m}^2$ or less.

B: The average perimeter of an oxide phase calculated using ImageJ with a SEM image having a field magnification of 3000 times is $11.7\ \mu\text{m}$ or less.

C: The bending strength is 300 MPa or more.

D: The number-average circle-equivalent diameter calculated using ImageJ and assuming that the shape of the oxide in the oxide phase is a circle, using a SEM image with a field magnification of 3000 times, is $1.3\ \mu\text{m}$ or less.

E: The number of oxide particles having a circular-equivalent diameter of $1\ \mu\text{m}$ or less per $1261\ \mu\text{m}^2$ of a measurement area in a scanning electron microscope (SEM) photograph taken at a magnification of 3000 times is 100 or more.

F: The number of oxide particles having a circular-equivalent diameter of $2\ \mu\text{m}$ or less per $1261\ \mu\text{m}^2$ of a measurement area in a scanning electron microscope (SEM) photograph taken at a visual field magnification of 3000 times is 120 or more.

G: The proportion of particles having a circular-equivalent diameter of 1 μm or less per 1261 μm^2 of a measurement area in a scanning electron microscope (SEM) photograph taken at a magnification of 3000 times is 60% or more.

H: The proportion of particles having a circular-equivalent diameter of 2 μm or less per 1261 μm^2 of a measurement area in a scanning electron microscope (SEM) photograph taken at a visual field magnification of 3000 times is 90% or more.

[0035]

<Sputtering target assembly>

The sputtering target according to the embodiment of the present invention may be joined to a backing plate as necessary to form a sputtering target assembly. The sputtering target assembly can be mounted on a sputtering device and used. Indium or indium tin can be used as the brazing material. The sputtering target according to the embodiment of the present invention may be mounted on a sputtering device as it is without using a backing plate. The material of the backing plate is not particularly limited, and examples thereof include Cu, Ti, Mo, and alloys containing at least one of these (e.g., Cu-Ni-Si alloys (e.g., C18000, etc.), CuZn alloys, CuCr alloys), etc. The material of the backing plate preferably has high thermal conductivity, and from this viewpoint, Cu is suitable.

[0036]

<Manufacturing method of sputtering target>

The manufacturing method of the sputtering target according to the embodiment of the present invention will be described in detail below.

The sputtering target according to the embodiment of the present invention can be manufactured by a powder sintering method. First, powders of each metal element are prepared. In addition, alloy powders of these metals (e.g., Fe-Pt powder) may be used instead of the powders of each metal element. The purity of

these raw materials is usually 2N (99% by mass) or more, preferably 3N (99.9% by mass) or more, and more preferably 4N (99.99% by mass) or more. If the purity is lower than 2N, the sintered body will contain a large amount of impurities, which may cause problems such as the desired physical properties not being obtained (e.g., generation of particles due to arcing). These raw materials can be appropriately prepared based on the composition and purity of the desired sintered body.

[0037]

Then, these metal powders are weighed to obtain the desired composition and mixed using a mixer while also being pulverized. Non-magnetic particles may also be mixed with the metal powder at this stage. As a mixing device, a ball mill, a mortar, etc. can be used, but it is preferable to use a powerful mixing method such as a ball mill. In addition, considering the problem of oxidation during mixing, it is preferable to mix in an inert gas atmosphere or in a vacuum. In addition, the mixing time is set to 0.1 to 48 hours.

The average particle area of the oxide phase can be reduced by increasing the mixing time of the raw materials. On the other hand, the average particle area of the oxide phase can be increased by decreasing the mixing time of the raw materials. From this perspective, the average particle area of the oxide phase is controlled by adjusting the mixing time of the raw materials.

The average circumferential length of the oxide phase can be reduced by increasing the mixing time of the raw materials. On the other hand, the average circumferential length of the oxide phase can be increased by decreasing the mixing time of the raw materials. From this perspective, the average circumferential length of the oxide phase is controlled by adjusting the mixing time of the raw materials.

The oxide of the oxide phase can be reduced by increasing the mixing time of the raw materials, and this can increase the bending strength of the sputtering

target. It is known that oxides have lower toughness than metals. In sintered bodies having a structure in which oxides are dispersed in the base metal, cracks often start from the oxide phase, which has low toughness. By dispersing these oxide particles finer, the proportion of relatively coarse oxides in the sintered body is reduced, and crack generation is suppressed, which is expected to improve bending strength. On the other hand, by shortening the mixing time of the raw materials, the oxides in the oxide phase can be made larger. From this perspective, the bending strength of the sputtering target is controlled by adjusting the mixing time of the raw materials.

In addition, by lengthening the mixing time of the raw materials, the number average diameter of the circle-equivalent diameter calculated assuming that the shape of the oxide in the oxide phase is a circle can be reduced. On the other hand, by shortening the mixing time of the raw materials, the number average diameter of the circle-equivalent diameter calculated assuming that the shape of the oxide in the oxide phase is a circle can be increased. From this perspective, by adjusting the mixing time of the raw materials, the number average diameter of the circle-equivalent diameter calculated assuming that the shape of the oxide in the oxide phase is a circle is controlled.

In addition, by lengthening the mixing time of the raw materials, the number or number ratio of particles whose circle-equivalent diameter of the oxide is 1 μm or less or 2 μm or less per 1261 μm^2 of the measurement area of a scanning electron microscope (SEM) photograph taken at a field magnification of 3000 times can be increased. On the other hand, by shortening the mixing time of the raw materials, it is possible to reduce the number or the proportion of particles having an oxide circle-equivalent diameter of 1 μm or less or 2 μm or less per 1261 μm^2 of a measurement area in a scanning electron microscope (SEM) photograph taken at a visual field magnification of 3000 times. From this viewpoint, the number or the

proportion of particles having an oxide circle-equivalent diameter of 1 μm or less or 2 μm or less per 1261 μm^2 of a measurement area in a scanning electron microscope (SEM) photograph taken at a visual field magnification of 3000 times is controlled by adjusting the mixing time of the raw materials.

[0038]

The mixed powder thus obtained is molded and sintered using a hot press device to produce a sintered body. The molding and sintering is not limited to hot pressing, and plasma discharge sintering and hot isostatic sintering can also be used. The sintering conditions are 650-1400°C and 0.5-12 hours.

If the sintering temperature is increased and/or the sintering time is increased, the average particle area of the oxide phase can be increased. On the other hand, if the sintering temperature is decreased and/or the sintering time is decreased, the average particle area of the oxide phase can be decreased. From this perspective, the average particle area of the oxide phase is controlled by adjusting the sintering temperature and sintering time.

In addition, if the sintering temperature is increased and/or the sintering time is increased, the average circumferential length of the oxide phase can be increased. On the other hand, if the sintering temperature is decreased and/or the sintering time is decreased, the average circumferential length of the oxide phase can be decreased. From this perspective, the average circumferential length of the oxide phase is controlled by adjusting the sintering temperature and sintering time. In addition, if the sintering temperature is increased and/or the sintering time is increased, the oxide of the oxide phase can be increased. On the other hand, by lowering the sintering temperature and/or shortening the sintering time, the oxides in the oxide phase can be made smaller. From this viewpoint, the size of the oxides in the oxide phase can be controlled by adjusting the sintering temperature and

sintering time, and thereby the bending strength of the sputtering target can be controlled.

In addition, by increasing the sintering temperature and/or lengthening the sintering time, the number average diameter of the circle-equivalent diameter calculated assuming that the shape of the oxides in the oxide phase is a circle can be increased. On the other hand, by lowering the sintering temperature and/or shortening the sintering time, the number average diameter of the circle-equivalent diameter calculated assuming that the shape of the oxides in the oxide phase is a circle can be decreased. From this viewpoint, by adjusting the sintering temperature and sintering time, the number average diameter of the circle-equivalent diameter calculated assuming that the shape of the oxides in the oxide phase is a circle can be controlled.

In addition, by increasing the sintering temperature and/or lengthening the sintering time, the number or the number ratio of particles whose circle-equivalent diameter of the oxide is 1 μm or less or 2 μm or less per 1261 μm^2 of the measurement area of a scanning electron microscope (SEM) photograph taken at a field magnification of 3000 times can be increased. On the other hand, if the sintering temperature is lowered and/or the sintering time is shortened, the number or percentage of particles having an oxide equivalent circle diameter of 1 μm or less or 2 μm or less per 1261 μm^2 of a measurement area of a scanning electron microscope (SEM) photograph taken at a magnification of 3000 times can be reduced. From this perspective, the number or percentage of particles having an oxide equivalent circle diameter of 1 μm or less or 2 μm or less per 1261 μm^2 of a measurement area of a scanning electron microscope (SEM) photograph taken at a magnification of 3000 times can be controlled by adjusting the sintering temperature and sintering time.

[0039]

Then, the sintered body removed from the hot press device is subjected to HIP (Hot Isostatic Pressing). HIP processing is an effective means for improving the density of the sintered body. The holding temperature during HIP processing is 650 to 1100°C, the holding time is 0.5 to 12 hours, and the pressure is 100 MPa or more. The sintered body thus obtained is then machined into the desired shape on a lathe to produce a sputtering target.

[0040]

<Film formation method using a sputtering target>

The sputtering target according to the embodiment of the present invention can be used to form a thin film that mainly constitutes a magnetic recording medium. Specifically, a sputtering device is used to sputter the surface of the sputtering target with accelerated argon ions, particles (sputtered particles) are released from the sputtering target, and the sputtered particles are deposited on the surface of a substrate that has been placed in front of the sputtering target, forming a thin film on the surface of the substrate. Sputtering conditions can be set appropriately depending on the desired film thickness, composition, etc.

EXAMPLES

[0041]

The following examples of the present invention are provided for a better understanding of the present invention and its advantages, and are not intended to limit the invention.

[0042]

<Example 1>

The sputtering target of Example 1 was manufactured by the following manufacturing method.

Fe powder, Pt powder, Ag powder, and SiO₂ powder were prepared as raw material powders and weighed to have a composition of (30-45)Fe-(30-45)Pt-(5-15)Ag-(5-25)SiO₂ (mol%). The raw material powders were adjusted to have a total composition of 100 mol%. Amorphous powder was used for the SiO₂ powder. Next, the weighed Fe powder, Pt powder, Ag powder, and SiO₂ powder were placed in a 5L ball mill pot together with zirconia balls and mixed for 4 hours.

[0043]

The mixed powder was then removed from the ball mill pot and filled into a carbon mold and hot pressed. The hot press conditions were a vacuum atmosphere, a heating rate of 300°C/hour, a holding temperature (sintering temperature) of 900°C, and a holding time (sintering time) of 2 hours. A pressure of 30 MPa was applied from the start of heating to the end of holding. After the holding, the material was allowed to cool naturally in the chamber. The sintered body was then removed from the hot press mold and subjected to HIP processing. The HIP processing conditions were a heating rate of 300°C/hour, a holding temperature of 850°C, and a holding time of 2 hours. The Ar gas pressure was gradually increased from the start of heating, and the material was pressurized at 150 MPa during holding. After the holding, the material was allowed to cool naturally in the furnace. In this way, the sputtering target of Example 1 was produced.

[0044]

<Examples 2 to 8, Comparative Example 1>

The sputtering targets of Examples 2 to 8 and Comparative Example 1 were produced in the same manner as Example 1. The mixing time of the raw material powder, the hot press temperature, and the HIP holding temperature were each performed under the conditions shown in Table 2.

[0045]

- Average particle area and average perimeter of oxide phase

First, the sputtering target was cut and the cross section was mirror-polished to prepare a SEM observation sample. Next, the SEM observation sample was observed using an SEM (S-3700N, Hitachi High-Technologies Corporation). The observation settings were as follows:

Photographed image: secondary electron image, field of view magnification: 3000x, acceleration voltage: 10-15kV

The average particle area and average perimeter of the oxide phase were evaluated by binarizing the secondary electron image obtained by the above-mentioned photographing using the image analysis software ImageJ according to the following steps (1) to (7).

(1) File of the ImageJ toolbar → Read the SEM image with a field of view magnification of 3000x from Open.

(2) Image → Type, select 8-bit. Draw a straight line along the scale bar, then select Analyze → Set scale and set the scale size.

(3) Select the part of the image excluding the scale, and cut out the scaled part with Image → Crop.

(4) Select Process → Filters → Gaussian Blur, enter 2 for Sigma, and click OK.

(5) Select Process → Binary → Make Binary. This completes the binarization of the image.

(6) Select Analyze → Set measurement and check Area.

(7) Select Analyze → Analyze Particle, set the displayed analysis conditions to Size: 0-infinity, Circularity: 0.00-1.00, Show: nothing, check Summarize, and select OK. This will display the results, from which read the Average Size value.

As described above, after importing the SEM image with ImageJ, a binarization process was performed to convert the black particle parts in the SEM image to black, and these black particles were treated as oxide phase particles, and

their average particle area was calculated. In addition, parts that were darker than the surrounding area that were classified as black by the binarization process were converted to black, and the black parts were treated as oxide phase particles, and their average perimeter was calculated. The threshold for the binarization process is automatically set from the color histogram in the image.

[0046]

- The number-average circle-equivalent diameter calculated using ImageJ and assuming that the shape of the oxide in the oxide phase is a circle, and the number of oxide particles having a circular-equivalent diameter of 1 μm or less or 2 μm or less per 1261 μm^2 of a measurement area in a scanning electron microscope (SEM) photograph taken at a magnification of 3000 times.

First, the sputtering target was cut and the cross section was mirror-polished to prepare an SEM observation sample. Next, the SEM observation sample was observed using an SEM (S-3700N, Hitachi High-Technologies Corporation). The observation settings were as follows:

Photographed image: secondary electron image, magnification of field: 3000 times, acceleration voltage: 10 to 15 kV

In the secondary electron image, the metal matrix phase appeared as a brighter area than the surrounding area, and the oxide appeared as a darker area than the surrounding area.

Next, the captured SEM images were binarized by the mode method using image processing software (ImageJ manufactured by the National Institutes of Health), and the area of each oxide was measured using the Analyze Particles function of the image processing software. From the area S of each oxide in the oxide phase obtained in this way, the diameter D of each oxide was calculated using the following formula (1). The diameter D was divided by the number of oxides to calculate the number-average diameter of the circle-equivalent diameter calculated

assuming that the shape of the oxides in the oxide phase is circular. In addition, the diameter D was taken as the circle-equivalent diameter of the oxide, and the number of particles with the circle-equivalent diameter of 1 μm or less or 2 μm or less was measured.

[0047]

Oxide diameter $D = 2\sqrt{(\text{Area of oxide } S)/\pi} \cdots \text{formula (1)}$

[0048]

The binarization of ImageJ was carried out according to the procedures (1) to (7) described above.

The results are displayed, and the area S of each oxide in the oxide phase is measured.

As described above, the areas that are darker than the surrounding areas and classified as black by the binarization process are converted to black, and the black areas are considered to be oxides.

The threshold value for the binarization process was automatically set from the color histogram in the image.

[0049]

- Proportion of particles having a circular-equivalent diameter of 1 μm or less per 1261 μm² of a measurement area in a scanning electron microscope (SEM) photograph taken at a magnification of 3000 times

First, the number of particles with an oxide circular equivalent diameter of 1 μm or less or 2 μm or less was calculated in the same manner as the method for measuring the number of particles with an oxide circular equivalent diameter of 1 μm or less or 2 μm or less per 1261 μm² measurement area of the SEM photograph described above. Next, the ratio (%) of the number of particles with the above-mentioned circular equivalent diameter of 1 μm or less and 2 μm or less to the total

number of particles measured in the measurement area of $1261\ \mu\text{m}^2$ of the SEM photograph was calculated and evaluated.

[0050]

-Oxide volume ratio

The oxide volume ratio was evaluated by calculating the volume of each component contained in the target by (content of each material: mol) x (molecular weight of each material: g/mol) x (reciprocal of density of each material: cm^3/g). Next, the oxide volume ratio was calculated by dividing the total volume of only the oxides among the components by the total volume of all components.

[0051]

-Bending strength

Seven test pieces were prepared by cutting out samples of the sputtering target. The cutting method involved machining the sputtering target to a thickness of 3 mm using a lathe, and then cutting it into a size of 4 mm x 35 mm using electric discharge wire machining. Next, since the surface was oxidized, the surface was polished with #120 abrasive paper to remove the oxide film and prepare a sample. Next, the three-point bending strength was measured under the following measurement conditions, and the average value was taken as the bending strength of the sputtering target. Note that bending strength tests were not performed for Examples 3 to 8.

<Measurement conditions>

A bench-top material testing machine (STB-1225S) manufactured by A&D was used as the measurement device. The bending strength of the sputtering target in this test example was measured with reference to JIS R 1601:2008 "Test method for bending strength of fine ceramics" and was performed under the "measurement conditions of this embodiment" shown in Table 1 above. That is, as shown in Table 1 above, the measurement conditions for the bending strength of the sputtering

target in this test example differ from the measurement conditions for bending strength described in JIS R 1601:2008 only for "radius of curvature of support", "test piece length", "parallelism", "edge of test piece", "roughness Ra of test piece", and "number of test pieces".

[0052]

- Cracks

The surface of the sputtering targets of each Example and Comparative Example was visually inspected to determine whether there were any cracks or no cracks at all. This evaluation was used to determine whether the occurrence of cracks or breakage during the manufacturing process was suppressed.

The evaluation results are shown in Tables 2 and 3.

[0053]

[Table 2]

	Varieties	Oxide volume ratio (vol.%)	Mixing time of raw powder (h)	Hot press temperature (°C)	HIP holding temperature (°C)	Average Size: Average particle area of oxide phase (μm^2)	Average perimeter of oxide phase (μm)	Number-average circle-equivalent diameter calculated and assuming that the shape of the oxide in the oxide phase is a circle (μm)	Bending strength (Mpa)	Cracks
Comp EX.1	Fe-Pt-Ag-SiO ₂	47	2	900	950	4.99	12.31	1.51	280	YES
Example.1	Fe-Pt-Ag-SiO ₂	47	4	900	850	0.71	4.67	0.61	510	NO
Example.2	Fe-Pt-Ag-SiO ₂	47	2	900	850	0.68	4.31	0.60	370	NO
Example.3	Fe-Pt-Ag-SiO ₂	47	2	900	850	0.73	4.54	0.64		NO
Example.4	Fe-Pt-Ag-SiO ₂	47	2	900	850	2.57	9.76	1.02		NO
Example.5	Fe-Pt-Ag-SiO ₂	47	2	900	850	0.86	5.11	0.69		NO
Example.6	Fe-Pt-Ag-SiO ₂	47	2	900	850	3.84	10.66	0.90		NO
Example.7	Fe-Pt-Ag-SiO ₂	47	2	900	850	1.46	6.96	0.73		NO
Example.8	Fe-Pt-Ag-SiO ₂	47	2	900	850	2.60	11.19	0.89		NO

[0054]

[Table 3]

	Varieties	Oxide volume ratio (vol.%)	Mixing time of raw powder (h)	Hot press temperature (°C)	HIP holding temperature (°C)	Number of oxide particles having a circular-equivalent diameter of 1 μ m or less	Number of oxide particles having a circular-equivalent diameter of 2 μ m or less	Proportion of particles having a circular-equivalent diameter of 1 μ m or less(%)	Proportion of particles having a circular-equivalent diameter of 2 μ m or less(%)	Bending strength (Mpa)	Cracks
Comp EX.1	Fe-Pt-Ag-SiO ₂	47	2	900	950	52	73	53.1	74.5	280	YES
Example.1	Fe-Pt-Ag-SiO ₂	47	4	900	850	546	619	83.4	94.5	510	NO
Example.2	Fe-Pt-Ag-SiO ₂	47	2	900	850	548	632	83.2	95.9	370	NO
Example.3	Fe-Pt-Ag-SiO ₂	47	2	900	850	531	608	82.5	94.4		NO
Example.4	Fe-Pt-Ag-SiO ₂	47	2	900	850	132	172	69.1	90.1		NO
Example.5	Fe-Pt-Ag-SiO ₂	47	2	900	850	434	517	79.6	94.9		NO
Example.6	Fe-Pt-Ag-SiO ₂	47	2	900	850	123	141	81.5	93.4		NO
Example.7	Fe-Pt-Ag-SiO ₂	47	2	900	850	278	318	81.8	93.5		NO
Example.8	Fe-Pt-Ag-SiO ₂	47	2	900	850	150	187	75.0	93.5		NO

[0055]

<Discussion>

According to Tables 2 and 3, the sputtering targets according to Examples 1 to 8 each contain (1) Fe, (2) Pt, (3) one or more elements selected from Ag, Au, B, Co, Cr, Cu, Ga, Ge, Mn, Mo, Nb, Ni, Pd, Re, Rh, Ru, Si, Sn, Ta, W, V, and Zn, and (4) the balance, and an atomic ratio of the (1) Fe to the (2) Pt is 34 to 55 at%, a total concentration of the (1) Fe and the (2) Pt is 50 mol % or more, a content of the elements in (3) is 0.5 to 15 mol% in total, a remainder of (4) is an oxide which may selectively contain impurities, a volume ratio of the oxide is 40 vol.% or more.

Furthermore, the sputtering targets according to Examples 1 to 8 each had an average particle area (average size) of an oxide phase calculated using ImageJ with a SEM image at a field magnification of 3000 times, of $4.0\ \mu\text{m}^2$ or less. This resulted in good bending strength, and the occurrence of cracks and breakage during the manufacturing process was suppressed.

The sputtering targets according to Examples 1 and 2 each had a bending strength of 300 MPa or more. This resulted in the occurrence of cracks and breakage during the manufacturing process.

The sputtering targets according to Examples 1 to 8 each had an average perimeter of an oxide phase calculated using ImageJ with a SEM image having a field magnification of 3000 times, of $11.7\ \mu\text{m}$ or less. This resulted in good bending strength, and the occurrence of cracks and breakage during the manufacturing process was suppressed.

Furthermore, the sputtering targets according to Examples 1 to 8 each had a number-average circle-equivalent diameter calculated using ImageJ and assuming that the shape of the oxide in the oxide phase is a circle, using a SEM image with a field magnification of 3000 times, of $1.3\ \mu\text{m}$ or less. This resulted in good bending

strength, and the occurrence of cracks and breakage during the manufacturing process was suppressed.

Furthermore, the sputtering targets according to Examples 1 to 8 each had a number of oxide particles having a circular-equivalent diameter of 1 μm or less per 1261 μm^2 of a measurement area in a scanning electron microscope (SEM) photograph taken at a magnification of 3000 times, 100 or more. Furthermore, the number of oxide particles having a circular-equivalent diameter of 2 μm or less per 1261 μm^2 of a measurement area in a scanning electron microscope (SEM) photograph taken at a visual field magnification of 3000 times is 120 or more. In addition, the proportion of particles having a circular-equivalent diameter of 1 μm or less per 1261 μm^2 of a measurement area in a scanning electron microscope (SEM) photograph taken at a magnification of 3000 times was 60% or more. In addition, the proportion of particles having a circular-equivalent diameter of 2 μm or less per 1261 μm^2 of a measurement area in a scanning electron microscope (SEM) photograph taken at a visual field magnification of 3000 times was 90% or more. Therefore, the bending strength was good, and the occurrence of cracks and breakage during the manufacturing process was suppressed.

[0056]

In contrast, in Comparative Example 1, the average particle area (average size) of the oxide phase calculated using ImageJ with a SEM image at a magnification of 3000 times exceeded 4.0 μm^2 . Therefore, the bending strength was poor, and cracks and breakage occurred during the manufacturing process. Furthermore, in Comparative Example 1, the average perimeter of the oxide phase calculated using ImageJ and an SEM image with a field magnification of 3000 times exceeded 11.7 μm . This resulted in poor bending strength, and cracks and breakage occurred during the manufacturing process.

Furthermore, in Comparative Example 1, the bending strength was less than 300 MPa. This resulted in cracks and breakage during the manufacturing process.

Furthermore, in Comparative Example 1, the number-average circle-equivalent diameter calculated using ImageJ and assuming that the shape of the oxide in the oxide phase is a circle, using a SEM image with a field magnification of 3000 times, exceeded 1.3 μm . This resulted in poor bending strength, and cracks and breakage occurred during the manufacturing process.

In addition, in Comparative Example 1, the number of oxide particles having a circular-equivalent diameter of 1 μm or less per 1261 μm^2 of a measurement area in a scanning electron microscope (SEM) photograph taken at a magnification of 3000 times was less than 100, the number of oxide particles having a circular-equivalent diameter of 2 μm or less per 1261 μm^2 of a measurement area in a scanning electron microscope (SEM) photograph taken at a visual field magnification of 3000 times was less than 120, the proportion of particles having a circular-equivalent diameter of 1 μm or less per 1261 μm^2 of a measurement area in a scanning electron microscope (SEM) photograph taken at a magnification of 3000 times was less than 60%, and the proportion of particles having a circular-equivalent diameter of 2 μm or less per 1261 μm^2 of a measurement area in a scanning electron microscope (SEM) photograph taken at a visual field magnification of 3000 times was less than 90%. As a result, the bending strength was poor, and cracks and breakage occurred during the manufacturing process.

[0057]

According to one embodiment of the present invention, a sputtering target and a sputtering target assembly can be obtained that can effectively suppress the occurrence of cracks and breakage during the manufacturing process, which may contribute to the sophistication of thin film formation technology by sputtering used in the manufacture of hard disk media, etc. Therefore, one embodiment of the

present invention may contribute to Goal 9 of the United Nations-led Sustainable Development Goals (SDGs), which is to "build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation."

CLAIMS

1. A sputtering target, comprising:

(1) Fe, (2) Pt, (3) one or more elements selected from Ag, Au, B, Co, Cr, Cu, Ga, Ge, Mn, Mo, Nb, Ni, Pd, Re, Rh, Ru, Si, Sn, Ta, W, V, and Zn, and (4) the balance, wherein

an atomic ratio of the (1) Fe to the (2) Pt is 34 to 55 at%,

a total concentration of the (1) Fe and the (2) Pt is 50 mol % or more,

a content of the elements in (3) is 0.5 to 15 mol% in total,

a remainder of (4) is an oxide which may selectively contain impurities, a volume ratio of the oxide is 40 vol.% or more, and

an average particle area (average size) of an oxide phase calculated using ImageJ with a SEM image at a field magnification of 3000 times is $4.0\ \mu\text{m}^2$ or less.

2. A sputtering target, comprising:

(1) Fe, (2) Pt, (3) one or more elements selected from Ag, Au, B, Co, Cr, Cu, Ga, Ge, Mn, Mo, Nb, Ni, Pd, Re, Rh, Ru, Si, Sn, Ta, W, V, and Zn, and (4) the balance, wherein

an atomic ratio of the (1) Fe to the (2) Pt is 34 to 55 at%,

a total concentration of the (1) Fe and the (2) Pt is 50 mol % or more,

a content of the elements in (3) is 0.5 to 15 mol% in total,

a remainder of (4) is an oxide which may selectively contain impurities, a volume ratio of the oxide is 40 vol.% or more, and

and an average perimeter of an oxide phase calculated using ImageJ with a SEM image having a field magnification of 3000 times is $11.7\ \mu\text{m}$ or less.

3. A sputtering target, comprising:

(1) Fe, (2) Pt, (3) one or more elements selected from Ag, Au, B, Co, Cr, Cu, Ga, Ge, Mn, Mo, Nb, Ni, Pd, Re, Rh, Ru, Si, Sn, Ta, W, V, and Zn, and (4) the balance, wherein

an atomic ratio of the (1) Fe to the (2) Pt is 34 to 55 at%,

a total concentration of the (1) Fe and the (2) Pt is 50 mol % or more,

a content of the elements in (3) is 0.5 to 15 mol% in total,

a remainder of (4) is an oxide which may selectively contain impurities, a volume ratio of the oxide is 40 vol.% or more, and

a bending strength is 300 MPa or more.

4. A sputtering target, comprising:

(1) Fe, (2) Pt, (3) one or more elements selected from Ag, Au, B, Co, Cr, Cu, Ga, Ge, Mn, Mo, Nb, Ni, Pd, Re, Rh, Ru, Si, Sn, Ta, W, V, and Zn, and (4) the balance, wherein

an atomic ratio of the (1) Fe to the (2) Pt is 34 to 55 at%,

a total concentration of the (1) Fe and the (2) Pt is 50 mol % or more,

a content of the elements in (3) is 0.5 to 15 mol% in total,

a remainder of (4) is an oxide which may selectively contain impurities, a volume ratio of the oxide is 40 vol.% or more, and

a number-average circle-equivalent diameter calculated using ImageJ and assuming that the shape of the oxide in the oxide phase is a circle, using a SEM image with a field magnification of 3000 times, is 1.3 μm or less.

5. A sputtering target, comprising:

(1) Fe, (2) Pt, (3) one or more elements selected from Ag, Au, B, Co, Cr, Cu, Ga, Ge, Mn, Mo, Nb, Ni, Pd, Re, Rh, Ru, Si, Sn, Ta, W, V, and Zn, and (4) the balance, wherein

an atomic ratio of the (1) Fe to the (2) Pt is 34 to 55 at%,
a total concentration of the (1) Fe and the (2) Pt is 50 mol % or more,
a content of the elements in (3) is 0.5 to 15 mol% in total,
a remainder of (4) is an oxide which may selectively contain impurities, a
volume ratio of the oxide is 40 vol.% or more, and
a number of oxide particles having a circular-equivalent diameter of 1 μm or
less per 1261 μm^2 of a measurement area in a scanning electron microscope (SEM)
photograph taken at a magnification of 3000 times is 100 or more.

6. A sputtering target, comprising:

(1) Fe, (2) Pt, (3) one or more elements selected from Ag, Au, B, Co, Cr, Cu,
Ga, Ge, Mn, Mo, Nb, Ni, Pd, Re, Rh, Ru, Si, Sn, Ta, W, V, and Zn, and (4) the
balance, wherein

an atomic ratio of the (1) Fe to the (2) Pt is 34 to 55 at%,
a total concentration of the (1) Fe and the (2) Pt is 50 mol % or more,
a content of the elements in (3) is 0.5 to 15 mol% in total,
a remainder of (4) is an oxide which may selectively contain impurities, a
volume ratio of the oxide is 40 vol.% or more, and
a number of oxide particles having a circular-equivalent diameter of 2 μm or
less per 1261 μm^2 of a measurement area in a scanning electron microscope (SEM)
photograph taken at a visual field magnification of 3000 times is 120 or more.

7. A sputtering target, comprising:

(1) Fe, (2) Pt, (3) one or more elements selected from Ag, Au, B, Co, Cr, Cu,
Ga, Ge, Mn, Mo, Nb, Ni, Pd, Re, Rh, Ru, Si, Sn, Ta, W, V, and Zn, and (4) the
balance, wherein

an atomic ratio of the (1) Fe to the (2) Pt is 34 to 55 at%,

a total concentration of the (1) Fe and the (2) Pt is 50 mol % or more,
a content of the elements in (3) is 0.5 to 15 mol% in total,
a remainder of (4) is an oxide which may selectively contain impurities, a
volume ratio of the oxide is 40 vol.% or more, and
a proportion of particles having a circular-equivalent diameter of 1 μm or less
per 1261 μm^2 of a measurement area in a scanning electron microscope (SEM)
photograph taken at a magnification of 3000 times is 60% or more.

8. A sputtering target, comprising:

(1) Fe, (2) Pt, (3) one or more elements selected from Ag, Au, B, Co, Cr, Cu, Ga, Ge, Mn, Mo, Nb, Ni, Pd, Re, Rh, Ru, Si, Sn, Ta, W, V, and Zn, and (4) the balance, wherein

an atomic ratio of the (1) Fe to the (2) Pt is 34 to 55 at%,
a total concentration of the (1) Fe and the (2) Pt is 50 mol % or more,
a content of the elements in (3) is 0.5 to 15 mol% in total,
a remainder of (4) is an oxide which may selectively contain impurities, a
volume ratio of the oxide is 40 vol.% or more, and
a proportion of particles having a circular-equivalent diameter of 2 μm or less
per 1261 μm^2 of a measurement area in a scanning electron microscope (SEM)
photograph taken at a visual field magnification of 3000 times is 90% or more.

9. The sputtering target according to any one of claims 1 to 8, wherein
the oxide contains an oxide of Si.

10. The sputtering target according to claim 9, wherein

the oxide further contains one or more oxides of elements selected from Al, B, Ba, Be, Ca, Ce, Cr, Dy, Er, Eu, Ga, Gd, Ho, Li, Mg, Mn, Nb, Nd, Pr, Sc, Sm, Sr, Ta, Tb, Ti, V, Y, Zn, and Zr.

11. A sputtering target assembly comprising:
the sputtering target according to any one of claims 1 to 8 and
a backing plate bonded to the sputtering target.