

# **SPUTTERING TARGET AND METHOD FOR MANUFACTURING SPUTTERING TARGET**

## **FIELD OF THE INVENTION**

[0001]

The present invention relates to a sputtering target and a method for manufacturing the sputtering target.

## **BACKGROUND OF THE INVENTION**

[0002]

Fe-Pt-based alloys or Co-Pt-based alloys are attracting attention as materials which have high magnetic anisotropy as recording layers for perpendicular magnetic recording of magnetic recording media and which also have high corrosion resistance and oxidation resistance. When the Fe-Pt-based alloys or the Co-Pt-based alloys are used as materials for ultra-high density recording media, ordered Fe-Pt magnetic grains or Co-Pt grains should be dispersed in alignment of orientation with density as high as possible while magnetically isolating the grains. Sputtering targets containing carbon (C) as a non-magnetic phase are known.

[0003]

For example, WO 2012/133166 (Patent Literature 1) discloses an example of a sputtering target for Fe-Pt-based magnetic recording film, wherein the sputtering target contains C, and is produced by preparing Fe powder, Pt powder, and carbon black as C grains, weighing them, and then mixing/pulverizing them, and subjecting them to hot pressing and hot isostatic pressing to produce a sintered body.

[0004]

WO 2014/132746 (Patent Literature 2) discloses an FePt-C-based sputtering target containing Fe, Pt, and C, wherein the FePt-C-based sputtering target has a

structure in which primary particles of C that contain unavoidable impurities are dispersed in a FePt-based alloy phase, the primary particles of C being dispersed so as not to be in contact with each other.

## CITATION LIST

### Patent Literatures

[0005]

[Patent Literature 1] WO 2012/133166 A1

[Patent Literature 2] WO 2014/132746 A1

## SUMMARY OF THE INVENTION

### Technical Problem

[0006]

However, sputtering of the magnetic material target using carbon (C) generates a larger amount of particles due to the C grains, which may deteriorate a yield of a deposition step of a magnetic thin film. Although both of the inventions disclosed in Patent Literature 1 and Patent Literature 2 achieve a certain effect in the countermeasures for suppressing the generation of particles, the effect cannot be sufficient.

[0007]

In view of the above problems, an embodiment of the present invention provides a sputtering target and a method for manufacturing the same, which can reduce generation of particles and improve a production yield in a deposition step of a magnetic thin film.

### Solution to Problem

[0008]

In one aspect, the sputtering target according to an embodiment of the present invention is a sputtering target including Fe-Pt-based alloy phases and non-magnetic phases, wherein the sputtering target includes from 1 to 50 at% of C in an atomic number ratio, and has a diffraction peak derived from diamond as measured by XRD.

[0009]

In another aspect, the sputtering target according to the embodiment of the present invention is a sputtering target including Co-Pt-based alloy phases and non-magnetic phases, wherein the sputtering target includes from 1 to 50 at% of C in an atomic number ratio, and has a diffraction peak derived from diamond as measured by XRD.

[0010]

In one aspect, a method for manufacturing a sputtering target according to an embodiment of the present invention includes the steps of: mixing Fe-Pt-based alloy powder including from 10 to 45 at% of Pt, the balance being Fe and unavoidable impurities, with diamond powder to prepare mixed powder including from 1 to 50 at% of C in an atomic number ratio; and sintering the mixed powder in a vacuum atmosphere or an inert gas atmosphere at a sintering temperature at which the diamond in the mixed powder does not undergo a phase transition to graphite to prepare sintered body.

[0011]

In one aspect, a method for manufacturing a sputtering target according to an embodiment of the present invention includes the steps of: mixing Co-Pt-based alloy powder including from 10 to 45 at% of Pt, the balance being Co and unavoidable impurities, with diamond powder to prepare mixed powder including from 1 to 50 at% of C in an atomic number ratio; and sintering the mixed powder in a vacuum atmosphere or an inert gas atmosphere at a sintering temperature at which the

diamond in the mixed powder does not undergo a phase transition to graphite to prepare sintered body.

#### Advantageous Effects of Invention

[0012]

According to the embodiment, it is possible to provide a sputtering target and a method for manufacturing the same, which can reduce generation of particles and improve a production yield in a deposition step of a magnetic thin film.

#### BRIEF DESCRIPTION OF THE DRAWINGS

[0013]

FIG. 1 is a graph showing an XRD measurement result of Example 1;

FIG. 2 is a graph showing XRD measurement results of Examples 3 and 4;

FIG. 3 is a photograph showing results of structure observation of Example 1;

FIG. 4 is a graph showing particle evaluation results of Examples 3, 4 and Comparative Example 3;

FIG. 5 is a graph showing an XRD measurement result of Example 7; and

FIG. 6 is a graph showing particle evaluation results of Example 7 and Comparative Example 6.

#### DETAILED DESCRIPTION OF THE INVENTION

[0014]

(First Embodiment)

A sputtering target according to a first embodiment of the present invention is a sputtering target having Fe-Pt-based alloy phases and non-magnetic phases, wherein the sputtering target contains from 1 to 50 at% of C in an atomic number ratio and has a diffraction peak derived from diamond as measured by XRD, and the

sputtering target has a structure in which diamond grains, i.e., carbon (C) grains having a diamond crystal structure, are dispersed in the Fe-Pt-based alloy phases.

[0015]

The C grains having a diamond crystal structure have a stronger bonding force between C atoms in the crystal than that of C grains having a graphite structure, so that peeling and cracking in the crystal is difficult to occur, whereby the generation of particles caused by the C grains can be suppressed during sputtering.

[0016]

In an XRD measurement using a Cu-K $\alpha$  ray as a radiation source, a diffraction peak of diamond appears at  $2\theta = 43.92^\circ$  (111). Further, the sputtering target according to the first embodiment of the present invention does not have a graphite-derived diffraction peak ( $2\theta = 26.54^\circ$  (002)) in the XRD measurement. When carbon is present as an amorphous structure in the sputtering target, a broader diffraction peak than that of the sputtering target according to the first embodiment is detected around the diffraction peak ( $2\theta = 26.54^\circ$ ) in the XRD measurement, but the peak of the amorphous structure does not appear in the sputtering target according to the first embodiment of the present invention.

[0017]

In the first embodiment, the presence or absence of the diffraction peak derived from the diamond can be evaluated by a general analysis method with integrated powder X-ray analysis software PDXL or the like, using an apparatus such as powder X-ray diffractometer Smart Lab from Rigaku Corporation.

[0018]

Further, the sputtering target according to the first embodiment has a peak intensity ratio ( $I_{dia}/I_{FePt}$ ) in a range of from about 0.01 to 0.5, in which  $I_{dia}$  is a peak intensity of diamond (111), and  $I_{FePt}$  is a peak intensity of FePt (111), in the XRD measurement. In one embodiment, the peak intensity ratio ( $I_{dia}/I_{FePt}$ ) may be 0.02

or more, and preferably 0.03 or more, and more preferably 0.04 or more, and even more preferably 0.10 or more. In one embodiment, the peak intensity ratio ( $I_{dia}/I_{fept}$ ) may be 0.4 or less, and preferably 0.3 or less, and even more preferably 0.15 or less.

[0019]

If a grain diameter of the C grains dispersed in the Fe-Pt-based alloy phases is too large, a larger amount of particles due to the C grains may be generated. Therefore, it is preferable that an average grain diameter of the C grains is lower. More particularly, the average grain diameter of the C grains is preferably 30  $\mu\text{m}$  or less, and more preferably 20  $\mu\text{m}$  or less, and still more preferably less than 1  $\mu\text{m}$ , and even more preferably 0.6  $\mu\text{m}$  or less. If the grain diameter of the C grains is too low, the C grains may be aggregated in the target and the number of particles may be increased. Therefore, the average grain diameter is preferably 0.05  $\mu\text{m}$  or more, and more preferably 0.1  $\mu\text{m}$  or more.

[0020]

Further, if a content of C in the sputtering target is less than 1 at%, good magnetic properties may not be obtained, and if it is more than 50 at%, the C grains may be aggregated to increase the generation of particles. The content of C is more preferably from 1 to 50 at%, and still more preferably from 5 to 45 at%.

[0021]

The sputtering target according to the first embodiment preferably contains from 10 to 45 at% of Pt, the balance being Fe and unavoidable impurities, and more preferably contains from 15 to 40 at% of Pt, and further preferably from 20 to 35 at% of Pt. If the Pt content is less than 10 at% or more than 45 at%, a fct structure may not be developed in Fe-Pt, and a magnetic phase having high crystalline magnetic anisotropy may not be formed.

[0022]

Further, the sputtering target according to the first embodiment may contain from 0 to 20 at%, more preferably from 5 to 15 at%, of at least one of Cu, Ag, Cr, B, Ge, Au, Co, Mn, Mo, Nb, Ni, Pd, Rh, Re, Ru and Ta, as at least one additive element other than Fe, Pt and C. Although these additive elements are optional, they can be expected to have an effect of decreasing a heat treatment temperature for developing the fct structure in the Fe-Pt magnetic phases or of increasing a crystal magnetic anisotropy energy, so that they can be added depending on the materials.

[0023]

Furthermore, the sputtering target according to the first embodiment may contain from 5 to 40 at%, more preferably from 5 to 20 at%, of carbide powder, nitride powder, oxide powder and the like as a non-magnetic material, in addition to C. For example, the sputtering target may contain SiO<sub>2</sub>, TiO<sub>2</sub>, Cr<sub>2</sub>O<sub>3</sub>, CoO, Ta<sub>2</sub>O<sub>5</sub>, B<sub>2</sub>O<sub>3</sub>, MgO, Co<sub>3</sub>O<sub>4</sub>, Si<sub>3</sub>N<sub>4</sub>, TiN, VN, ZrN, SiC, ZrC, TiC, VC, BN or the like. Since these carbides, nitrides, oxides, and the like can be expected to contribute to an increase in density of the sintered body or improvement of separability of Fe-Pt magnetic grains in the sputtered film, so that they can be added depending on the materials.

[0024]

The sputtering target according to the first embodiment has a relative density of 80% or more, 85% or more in one embodiment, 93% or more in another embodiment, and 95% or more in yet another embodiment. The relative density is expressed by the equation: relative density = (measured density / theoretical density) × 100 (%), according to the measured density and theoretical density. The theoretical density is a density value calculated from the theoretical density of an oxide of an element excluding oxygen in each constituent element of the sintered body.

[0025]

The sputtering target according to the first embodiment can be produced by using a powder sintering method. That is, the sputtering target according to the first embodiment is produced by a method including the steps of mixing Fe-Pt-based alloy powder containing from 10 to 45 at% of Pt, the balance being Fe and unavoidable impurities, with diamond powder to form mixed powder containing from 1 to 50 at% of C in an atomic number ratio; and sintering the mixed powder in a vacuum atmosphere or an inert gas atmosphere at a sintering temperature at which the diamond in the mixed powder does not undergo a phase transition to graphite, to form a sintered body.

[0026]

Fe powder that can be preferably used has an average grain diameter of 0.5  $\mu\text{m}$  or more and 10  $\mu\text{m}$  or less. If the grain diameter of the metal powder is more than 10  $\mu\text{m}$ , the non-magnetic materials may not be uniformly dispersed. If it is less than 0.5  $\mu\text{m}$ , there may be a problem that the composition of the target may be deviated from a desired composition due to the influence of oxidation. As used herein, the "average grain diameter" refers to a median diameter measured by a laser diffraction method (LA-920 from HORIBA).

[0027]

Pt powder that can be preferably used has an average grain diameter of 0.5  $\mu\text{m}$  or more and 10  $\mu\text{m}$  or less. Diamond powder is used as the C powder. If the grain diameter of diamond is higher, abnormal discharge may tend to occur. When the abnormal discharge occurs, the diamond may be destroyed to become a source of particles. Therefore, the diamond powder that can be preferably used has an average grain diameter of 3  $\mu\text{m}$  or less, and more preferably less than 1  $\mu\text{m}$ , and still more preferably 0.7  $\mu\text{m}$  or less.

[0028]

The Fe-Pt-based alloy powder and the diamond powder can be mixed as well as pulverized using a known method such as sieve mixing or mortar mixing. The mixed powder thus obtained is molded and sintered in a vacuum atmosphere or an inert gas atmosphere using a hot pressing method.

[0029]

In the sintering process, the mixed powder is heated at a sintering temperature such that the diamond powder does not undergo a phase transition to graphite, i.e., at a sintering temperature of 1000 °C or less, and more preferably 900 °C or less. If the sintering temperature is more than 1000 °C, the diamond powder undergoes a phase transition to graphite, so that an amount of particles generated during sputtering is increased. On the other hand, if the sintering temperature is too low, the density of the target is decreased, so that the amount of particles generated is increased. Therefore, the sintering temperature is preferably 650 °C or more, and more preferably 700 °C or more. A time required for the sintering process can be, for example, from 0.5 to 2 hours.

[0030]

(Second Embodiment)

A sputtering target according to a second embodiment of the present invention is a sputtering target having Co-Pt-based alloy phases and non-magnetic phases, wherein the sputtering target contains from 1 to 50 at% of C in an atomic number ratio and has a diffraction peak derived from diamond as measured by XRD. According to the sputtering target of the second embodiment, diamond grains, i.e., carbon (C) grains having a diamond crystal structure, are dispersed in the Fe-Pt-based alloy phases. Therefore, the peeling and cracking in the crystal is difficult to occur, and the generation of particles caused by the C grains can be suppressed during sputtering, as compared with a case where C grains having a graphite structure are dispersed.

[0031]

As with the first embodiment, the presence or absence of the diffraction peak derived from the diamond can be evaluated by a general analysis method with integrated powder X-ray analysis software PDXL or the like, using an apparatus such as powder X-ray diffractometer Smart Lab from Rigaku Corporation.

[0032]

In an XRD measurement using a Cu-K $\alpha$  ray as a radiation source, the sputtering target according to the second embodiment has a diffraction peak of diamond at  $2\theta = 43.92^\circ$  (111). For example, as shown in FIG. 5, the sputtering target has a high diffraction intensity following the diffraction peak of the adjacent Co<sub>3</sub>Pt. Further, the sputtering target according to the second embodiment of the present invention does not have a graphite-derived diffraction peak ( $2\theta = 26.54^\circ$  (002)) in the XRD measurement. When carbon is present as an amorphous structure in the sputtering target, a broader diffraction peak than that of the sputtering target according to the second embodiment is detected around the diffraction peak ( $2\theta = 26.54^\circ$ ) in the XRD measurement, but the peak of the amorphous structure does not appear in the sputtering target according to the second embodiment of the present invention.

[0033]

Further, the sputtering target according to the second embodiment has a peak intensity ratio ( $I_{dia}/I_{copt}$ ) in a range of from about 0.1 to 1.0, in which  $I_{dia}$  is a peak intensity of diamond (111), and  $I_{copt}$  is a peak intensity of Co<sub>3</sub>Pt (111), in the XRD measurement. In one embodiment, the peak intensity ratio ( $I_{dia}/I_{copt}$ ) may be 0.2 or more, and preferably 0.3 or more, and more preferably 0.4 or more. In one embodiment, the peak intensity ratio ( $I_{dia}/I_{copt}$ ) may be 0.9 or less, and preferably 0.5 or less.

[0034]

If a grain diameter of the C grains dispersed in the Co-Pt-based alloy phases is too large, a larger amount of particles due to the C grains may be generated. Therefore, it is preferable that an average grain diameter of the C grains is lower. More particularly, the average grain diameter of the C grains is preferably 30  $\mu\text{m}$  or less, and more preferably 20  $\mu\text{m}$  or less, and still more preferably less than 1  $\mu\text{m}$ , and even more preferably 0.6  $\mu\text{m}$  or less. If the grain diameter of the C grains is too low, the C grains may be aggregated in the target and the number of particles may be increased. Therefore, the average grain diameter is preferably 0.05  $\mu\text{m}$  or more, and more preferably 0.1  $\mu\text{m}$  or more.

[0035]

Further, if a content of C in the sputtering target is less than 1 at%, good magnetic properties may not be obtained, and if it is more than 50 at%, the C grains may be aggregated to increase generation of particles. The content of C is more preferably from 1 to 40 at%, and still more preferably 5 to 35 at%.

[0036]

The sputtering target according to the second embodiment preferably contains from 5 to 35 at% of Pt, the balance being preferably Co and unavoidable impurities, and more preferably contains from 10 to 30 at% of Pt, and further preferably from 15 to 25 at% of Pt. If the Pt content is less than 5 at% or more than 35 at%, the magnetic properties of the magnetic thin film may be deteriorated.

[0037]

Further, the sputtering target according to the second embodiment may contain from 0 to 15 at%, more preferably from 5 to 10 at%, of at least one of Cu, Ag, Cr, B, Ge, Au, Co, Mn, Mo, Nb, Ni, Pd, Rh, Re, Ru, W, Ta and Fe, as at least one additive element other than Co-Pt and C. Although these additive elements are optional, they can be added to improve the magnetic properties depending on the materials.

[0038]

Furthermore, the sputtering target according to the second embodiment may contain from 1 to 40 at% of carbide powder, nitride powder, oxide powder and the like as a non-magnetic material, in addition to C. For example, the sputtering target may contain SiO<sub>2</sub>, Cr<sub>2</sub>O<sub>3</sub>, CoO, Ta<sub>2</sub>O<sub>5</sub>, B<sub>2</sub>O<sub>3</sub>, MgO, Co<sub>3</sub>O<sub>4</sub>, TiO<sub>2</sub>, MnO, Si<sub>3</sub>N<sub>4</sub>, TiN, VN, ZrN, SiC, ZrC, TiC, VC, BN or the like. Since these carbides, nitrides, oxides, and the like can be expected to contribute to an increase in density of the sintered body or improvement of separability of Co-Pt magnetic grains in the sputtered film, so that they can be added depending on the materials.

[0039]

The sputtering target according to the second embodiment has a relative density of 85% or more, 93% or more in one embodiment, 95% or more in another embodiment. The relative density is expressed by the equation: relative density = (measured density / theoretical density) × 100 (%), according to the measured density and theoretical density. The theoretical density is a density value calculated from the theoretical density of an oxide of an element excluding oxygen in each constituent element of the sintered body.

[0040]

The sputtering target according to the second embodiment can be produced by using a powder sintering method. That is, the sputtering target according to the second embodiment is produced by a method including the steps of mixing Co-Pt-based alloy powder containing from 10 to 45 at% of Pt, the balance being Co and unavoidable impurities, with diamond powder to form mixed powder containing from 1 to 50 at% of C in an atomic number ratio; and sintering the mixed powder in a vacuum atmosphere or an inert gas atmosphere at a sintering temperature at which the diamond in the mixed powder does not undergo a phase transition to graphite, to form a sintered body.

[0041]

Co powder that can be preferably used has an average grain diameter of 0.5  $\mu\text{m}$  or more and 10  $\mu\text{m}$  or less. If the grain diameter of the metal powder is more than 10  $\mu\text{m}$ , the non-magnetic materials may not be uniformly dispersed. If it is less than 0.5  $\mu\text{m}$ , there may be a problem that the composition of the target may be deviated from a desired composition due to the influence of oxidation. As used herein, the "average grain diameter" refers to a median diameter measured by a laser diffraction method (LA-920 from HORIBA).

[0042]

Pt powder that can be preferably used has an average grain diameter of 0.5  $\mu\text{m}$  or more and 10  $\mu\text{m}$  or less. Diamond powder is used as the C powder. If the grain diameter of diamond is higher, abnormal discharge may tend to occur. When the abnormal discharge occurs, the diamond may be destroyed to become a source of particles. Therefore, the diamond powder that can be preferably used has an average grain diameter of 3  $\mu\text{m}$  or less, and more preferably less than 1  $\mu\text{m}$ , and still more preferably 0.7  $\mu\text{m}$  or less.

[0043]

The Co-Pt-based alloy powder and the diamond powder can be mixed as well as pulverized using a known method such as sieve mixing or mortar mixing. The mixed powder thus obtained is molded and sintered in a vacuum atmosphere or an inert gas atmosphere using a hot pressing method.

[0044]

In the sintering process, the mixed powder is heated at a sintering temperature of 1000  $^{\circ}\text{C}$  or less, and more preferably 900  $^{\circ}\text{C}$  or less, such that the diamond powder does not undergo a phase transition to graphite. If the sintering temperature is more than 1000  $^{\circ}\text{C}$ , the diamond powder undergoes a phase transition to graphite, so that an amount of particles generated during sputtering is

increased. On the other hand, if the sintering temperature is too low, the density of the target is decreased, so that the amount of particles generated is increased. Therefore, the sintering temperature is preferably 650 °C or more, and more preferably 700 °C or more. A time required for the sintering process can be, for example, from 0.5 to 2 hours.

[0045]

While the present invention has been described in accordance with the above embodiments, the descriptions and drawings that form a part of this disclosure should not be construed as limiting of the invention. That is, the present invention is not limited to each embodiment, and the components can be modified and embodied without departing from the spirit of the present invention. Further, various inventions can be formed by appropriately combining a plurality of components disclosed in each embodiment. For example, some components may be removed from all the components as illustrated in the embodiments. Further, the components of different embodiments may be optionally combined.

## EXAMPLES

[0046]

Examples of the present invention are shown below together with Comparative Examples. However, these Examples are provided for better understanding of the present invention and its advantages, and are not intended to limit the present invention.

[0047]

(Examples 1 to 6)

Powder containing Pt, Fe and optionally additive elements and non-magnetic materials, and C powder comprised of diamond powder were weighed so as to have each composition as shown in Table 1, and mixed to obtain mixed powder, which

was subjected to hot pressing in a vacuum atmosphere at a temperature of from 750 to 950 °C and at a pressure of 150 MPa for 2 hours to prepare each of sintered bodies according to Examples 1 to 6. The mixing was carried out together with pulverization, using a known means such as sieve mixing, mortar mixing, and ball mill. At this time, the process was carried out such that an inert gas such as Ar and N<sub>2</sub> was sealed in a milling container to suppress the oxidation of the raw material powder as much as possible.

[0048]

(Examples 7 to 10)

Powder containing Pt, Co and optionally additive elements and non-magnetic materials, and C powder comprised of diamond powder were weighed so as to have each composition as shown in Table 1, and mixed to obtain mixed powder, which was subjected to hot pressing in a vacuum atmosphere at a temperature of from 800 to 950 °C and at a pressure of 150 MPa for 2 hours to prepare each of sintered bodies according to Examples 7 to 10. The mixing was carried out together with pulverization, using a known means such as sieve mixing, mortar mixing, and ball mill. At this time, the process was carried out such that an inert gas such as Ar and N<sub>2</sub> was sealed in a milling container to suppress the oxidation of the raw material powder as much as possible.

[0049]

(Comparative Examples 1 to 9)

Each sintered body was prepared under the same conditions as those of Examples 1 to 10, with the exception that graphite powder was used as the C powder, and the sintering temperature was from 750 to 1200 °C.

[0050]

(Comparative Example 10)

Pt powder, Fe powder and diamond powder (C raw material powder) having an average grain diameter of 0.6  $\mu\text{m}$  were mixed so as to have 30 mol% of Pt, 30 mol% of Fe and 40 mol% of C to obtain mixed powder, which was subjected to hot pressing in a vacuum atmosphere at a temperature of 1100 °C and at a pressure of 150 MPa for 2 hours to prepare a sintered body according to Comparative Example 10.

[0051]

(Results of XRD Diffraction Peak Observation)

Structure analysis was carried out by XRD. In this Example, a powder X-ray diffractometer Smart Lab from Rigaku Co., Ltd. was used as an analyzer. Using Cu (measured with CuK $\alpha$ ) as an X-ray tube, the measurement was carried out at a tube voltage of 40 kV, a tube current of 30 mA, and  $2\theta$  in a range of from 10° to 90°. An angle at which the diffraction peak of diamond most strongly appears is 43.92° (111), and an angle at which the peak of graphite most strongly appears is 26.54° (002). The results of Examples 1 and Examples 3 and 4 are shown in FIGS. 1 and 2. In each of the figures, the peak of the strongest line of diamond is represented by an arrow. As shown in FIGS. 1 to 2, it was found that no peak of the graphite phase was observed in all of Examples 1 and Examples 3 to 4, and there was a diamond-derived diffraction peak in the XRD measurement. Further, FIG. 5 shows the XRD measurement results of Example 7. As shown in FIG. 5, it was also found that the peak of the graphite phase was not observed in Example 7, and there was a diamond-derived diffraction peak in the XRD measurement.

[0052]

(Number of Particles)

Each sintered body produced was processed into a target shape, and the number of particles generated during sputtering was evaluated. A magnetron sputtering apparatus (C-3010 sputtering system from Canon Anelva Corporation)

was used for the evaluation. The sputtering was carried out at an input power of 1 kW and an Ar gas pressure of 1.7 Pa for 20 seconds to form a film on a silicon substrate. The number of particles (having a particle diameter of from 0.09 to 3  $\mu\text{m}$ ) adhering to the substrate was measured with a particle counter (from KLA-Tencor, device name: Candela CS 920). The evaluation results of Examples 3 and 4 and Comparative Example 3 are shown in FIG. 4, and the results of Examples 7 and 6 are shown in FIG. 6. As shown in FIGS. 4 and 6, the number of particles could be significantly decreased by using the diamond powder in place of the graphite powder. Further, a lower grain diameter of the diamond powder, the C raw material powder, resulted in a decreased number of particles. Furthermore, as shown in Comparative Example 10, even if the diamond powder was used, a larger amount of particles were generated when the sintering temperature was not appropriate.

[0053]

(Results of Structure Observation)

The structure of each sintered body was observed with a laser microscope. The results of the structure observation according to Example 1 is shown in FIG. 3. Grains having dark gray color correspond to the diamond. As can be seen from FIG. 3, the diamond grains having about 2.6  $\mu\text{m}$  are dispersed in Fe-Pt in the target.

[0054]

(Relative Density)

The relative density of each sintered body produced was evaluated by the equation: relative density = (measured density / theoretical density)  $\times$  100 (%). The theoretical density is a value of density calculated from theoretical density of an oxide of an element excluding oxygen in each constituent element of the molded body or the sintered body. On the other hand, the measured density is a value obtained by dividing the weight by the volume, and in a case of the sintered body, it

was calculated by determining the volume by the Archimedes method. The results are shown in Table 1.

[0055]

Table 1

|            | Weighted Composition<br>(mol %)       | C Raw Material<br>Powder | Average Grain<br>Diameter of C Raw<br>Material Powder<br>( $\mu\text{m}$ ) | Sintering<br>Temperature<br>( $^{\circ}\text{C}$ ) | Relative<br>Density<br>(%) | XRD Intensity Ratio of FePt<br>(111) / Diamond (111) | XRD Intensity Ratio of CoPt<br>(111) / Diamond (111) | Number of<br>Particles | Remarks                     |
|------------|---------------------------------------|--------------------------|----------------------------------------------------------------------------|----------------------------------------------------|----------------------------|------------------------------------------------------|------------------------------------------------------|------------------------|-----------------------------|
| Example 1  | 30Fe-30Pt-40C                         | Diamond                  | 2.6                                                                        | 950                                                | 86                         | 0.31                                                 | -                                                    | 300-400                |                             |
| Example 2  | 30Fe-30Pt-20SiO <sub>2</sub> -20C     | Diamond                  | 0.6                                                                        | 950                                                | 93                         | 0.11                                                 | -                                                    | 200-250                |                             |
| Example 3  | 25Fe-25Pt-10Ag-30BN-10C               | Diamond                  | 2.6                                                                        | 750                                                | 95                         | 0.04                                                 | -                                                    | 130-170                |                             |
| Example 4  | 25Fe-25Pt-10Ag-30BN-10C               | Diamond                  | 0.6                                                                        | 750                                                | 93                         | 0.03                                                 | -                                                    | 85-100                 |                             |
| Example 5  | 20Fe-20Pt-15Ge-40BN-5C                | Diamond                  | 0.6                                                                        | 750                                                | 85                         | 0.02                                                 | -                                                    | 90-110                 |                             |
| Example 6  | 25Fe-25Pt-5Co-45C                     | Diamond                  | 0.6                                                                        | 900                                                | 90                         | 0.15                                                 | -                                                    | 150-230                |                             |
| Example 7  | 60Co-20Pt-20C                         | Diamond                  | 0.6                                                                        | 950                                                | 93                         | -                                                    | 0.81                                                 | 700-900                |                             |
| Example 8  | 56Co-18Pt-6Ru-10SiO <sub>2</sub> -10C | Diamond                  | 0.6                                                                        | 950                                                | 90                         | -                                                    | 0.41                                                 | 500-700                |                             |
| Example 9  | 36Co-12Pt-2B-5B2O <sub>3</sub> -45C   | Diamond                  | 0.6                                                                        | 800                                                | 95                         | -                                                    | 0.35                                                 | 450-560                |                             |
| Example 10 | 54Co-21Pt-5Cu-10SiO <sub>2</sub> -10C | Diamond                  | 0.6                                                                        | 850                                                | 93                         | -                                                    | 0.34                                                 | 190-260                |                             |
| Comp. 1    | 30Fe-30Pt-40C                         | Graphite                 | 15                                                                         | 1200                                               | 98                         | -                                                    | -                                                    | 1500-2000              |                             |
| Comp. 2    | 25Fe-25Pt-20SiO <sub>2</sub> -20C     | Graphite                 | 15                                                                         | 1200                                               | 98                         | -                                                    | -                                                    | 1350-1800              |                             |
| Comp. 3    | 25Fe-25Pt-10Ag-30BN-10C               | Graphite                 | 18                                                                         | 750                                                | 94                         | -                                                    | -                                                    | 1000-1300              |                             |
| Comp. 4    | 20Fe-20Pt-15Ge-40BN-5C                | Graphite                 | 16                                                                         | 750                                                | 95                         | -                                                    | -                                                    | 520-560                |                             |
| Comp. 5    | 25Fe-25Pt-5Co-45C                     | Graphite                 | 18                                                                         | 1000                                               | 92                         | -                                                    | -                                                    | 1100-1250              |                             |
| Comp. 6    | 60Co-20Pt-20C                         | Graphite                 | 15                                                                         | 1000                                               | 98                         | -                                                    | -                                                    | 3100-3500              |                             |
| Comp. 7    | 56Co-18Pt-6Ru-10SiO <sub>2</sub> -10C | Graphite                 | 14                                                                         | 950                                                | 92                         | -                                                    | -                                                    | 1500-2000              |                             |
| Comp. 8    | 36Co-12Pt-2B-5B2O <sub>3</sub> -45C   | Graphite                 | 15                                                                         | 800                                                | 96                         | -                                                    | -                                                    | 2300-3400              |                             |
| Comp. 9    | 54Co-21Pt-5Cu-10SiO <sub>2</sub> -10C | Graphite                 | 18                                                                         | 850                                                | 94                         | -                                                    | -                                                    | 3200-4500              |                             |
| Comp. 10   | 30Fe-30Pt-40C                         | Diamond                  | 0.6                                                                        | 1100                                               | 93                         | -                                                    | -                                                    | 4000-5000              | Diamond shifted to Graphite |

## CLAIMS

1. A sputtering target comprising Fe-Pt-based alloy phases and non-magnetic phases, wherein the sputtering target comprises from 1 to 50 at% of C in an atomic number ratio, and has a diffraction peak derived from diamond as measured by XRD.
2. A sputtering target comprising Co-Pt-based alloy phases and non-magnetic phases, wherein the sputtering target comprises from 1 to 50 at% of C in an atomic number ratio, and has a diffraction peak derived from diamond as measured by XRD.
3. The sputtering target according to claim 1 or 2, wherein the sputtering target does not have a diffraction peak derived from graphite as measured by XRD.
4. The sputtering target according to claim 1 or 3, wherein a content of at least one additive element other than Fe, Pt and C is from 0 to 20 at%.
5. The sputtering target according to claim 2 or 3, wherein a content of at least one additive element other than Co, Pt and C is from 0 to 15 at%.
6. The sputtering target according to any one of claims 1, 3 and 4, wherein the sputtering target has a peak intensity ratio ( $I_{dia}/I_{FePt}$ ) in a range of from about 0.01 to 0.5, in which  $I_{dia}$  is a peak intensity of diamond (111), and  $I_{FePt}$  is a peak intensity of FePt (111), as measured by XRD.
7. The sputtering target according to any one of claims 2, 3 and 5, wherein the sputtering target has a peak intensity ratio ( $I_{dia}/I_{CoPt}$ ) in a range of from about 0.1 to

1.0, in which  $I_{dia}$  is a peak intensity of diamond (111), and  $I_{CoPt}$  is a peak intensity of  $Co_3Pt$  (111), as measured by XRD.

8. The sputtering target according to any one of claims 1 to 7, wherein the sputtering target comprises C grains having a diamond structure, the C grains having an average grain diameter of less than 1  $\mu m$ .

9. The sputtering target according to any one of claims 1 to 8, wherein the sputtering target has a relative density of 80% or more.

10. A method for manufacturing a sputtering target, the method comprising the steps of: mixing Fe-Pt-based alloy powder comprising from 10 to 45 at% of Pt, the balance being Fe and unavoidable impurities, with diamond powder to prepare mixed powder comprising from 1 to 50 at% of C in an atomic number ratio; and sintering the mixed powder in a vacuum atmosphere or an inert gas atmosphere at a sintering temperature at which the diamond in the mixed powder does not undergo a phase transition to graphite to prepare sintered body.

11. A method for manufacturing a sputtering target, the method comprising the steps of: mixing Co-Pt-based alloy powder comprising from 10 to 45 at% of Pt, the balance being Co and unavoidable impurities, with diamond powder to prepare mixed powder comprising from 1 to 50 at% of C in an atomic number ratio; and sintering the mixed powder in a vacuum atmosphere or an inert gas atmosphere at a sintering temperature at which the diamond in the mixed powder does not undergo a phase transition to graphite to prepare sintered body.

12. The method according to claim 10 or 11, wherein the diamond powder has an average grain diameter of less than 1  $\mu\text{m}$ .

13. The method according to any one of claims 10 to 12, wherein the sintering temperature is 1000 °C or less.