

DESCRIPTION

SPUTTERING TARGET FOR FORMING MAGNETIC RECORDING FILM AND METHOD FOR PRODUCING SAME

5

TECHNICAL FIELD

[0001] The present invention relates to a ferromagnetic material sputtering target that is used for the deposition of a magnetic thin film of a magnetic recording media, particularly for the deposition of a magnetic recording layer of a thermally assisted magnetic recording media, and to an FePt-based ferromagnetic material sputtering target capable of achieving a stable discharge and reducing the generation of particles when sputtered with a magnetron sputtering equipment.

10

15

BACKGROUND ART

[0002] In the field of magnetic recording mediums as represented with HDD (hard disk drives), a material based on Co, Fe or Ni as ferromagnetic metals is used as the material of the magnetic thin film which is used for the recording. For example, Co-Cr-based or Co-Cr-Pt-based ferromagnetic alloys comprising Co as its main component are used for the recording layer of hard disks adopting the longitudinal magnetic recording system. Moreover, composite materials of Co-Cr-Pt-based ferromagnetic alloys comprising Co as its main component and nonmagnetic inorganic substance grains are often used for the recording layer of hard disks adopting the vertical magnetic recording system which was recently put into practical application. In addition, a magnetic thin film of a magnetic recording medium such as a hard disk is often produced by sputtering a ferromagnetic material sputtering target having the foregoing materials as its components in light of its high productivity.

20

25

[0003] Meanwhile, the recording density of magnetic recording mediums is rapidly increasing year by year, and the current surface density of 100 Gbit/in² is expected to reach 1 Tbit/in² in the future. When the recording density reaches 1 Tbit/in², the size of the recording bit will fall below 10 nm and, in such a case, it is anticipated that the superparamagnetism caused by thermal fluctuation will become a problem, and it is further anticipated that the currently-used magnetic

35

recording medium; for instance, a material with higher magnetic crystalline anisotropy obtained by adding Pt to a Co-Cr-based alloy, or a medium in which B is further added to the foregoing material to attenuate the magnetic coupling between the magnetic grains, will no longer be sufficient. This is because such grains that have a size of 10 nm or less and stably behave ferromagnetically need to possess even higher magnetic crystalline anisotropy.

[0004] In light of the above, an FePt phase having an $L1_0$ structure is attracting attention as a material for use in an ultrahigh density recording medium. Moreover, since an FePt phase having a $L1_0$ structure yields superior corrosion resistance and oxidation resistance, it is expected to become a material that can be suitably applied as a recording medium. The FePt phase has an order-disorder transformation point at 1573 K, and has a $L1_0$ structure due to the rapid ordered reaction even when an alloy is hardened from a high temperature. Furthermore, in connection with using the FePt phase as a material for use in an ultrahigh density recording medium, demanded is the development of technology for dispersing the ordered FePt grains, in a magnetically separated state, while densely aligning the orientation thereof as much as possible.

[0005] In light of the foregoing circumstances, a magnetic thin film having a granular structure in which the FePt magnetic grains having an $L1_0$ structure are magnetically separated from each other by nonmagnetic materials such as carbon is being proposed for use in a magnetic recording medium of next-generation hard disks adopting the thermally assisted magnetic recording system. This magnetic thin film having a granular structure has a structure in which the magnetic grains are magnetically insulated from each other through the interposition of nonmagnetic substances. Documents related to granular-type magnetic recording mediums and other related publications include, for example, Patent Document 1, Patent Document 2, Patent Document 3, Patent Document 4, Patent Document 5, Patent Document 6, Patent Document 7, and Patent Document 8 listed below.

[0006] The foregoing magnetic recording layer is configured from a magnetic phase such as an Fe-Pt alloy and a nonmagnetic phase that separates the magnetic phase, and carbon is effective as the nonmagnetic phase material. Among the above, graphite has a crystal structure in which graphene sheets are laminated, and therefore, graphite has a two-dimensional directionality in which it is easy to conduct electricity in a direction that is horizontal to the sheet surface and in

which it is difficult to conduct electricity in a direction that is vertical to the sheet surface. Thus, if the direction of the graphite can be aligned, it will be possible to stabilize the current during sputtering, and thereby suppress abnormal discharge.

5 Normally, this kind of magnetic recording layer is deposited using a sputtering target made from a sintered compact, but it is difficult to align the direction of the graphite in the sintered compact depending on the powder sintering method, and thereby, there is a problem in that it is not possible to obtain the intended stable sputtering properties.

10 [Citation List]

[Patent Documents]

- [0007] Patent Document 1: JP 2000-306228 A
Patent Document 2: JP 2000-311329 A
Patent Document 3: JP 2008-059733 A
15 Patent Document 4: JP 2008-169464 A
Patent Document 5: JP 2012-102387 A
Patent Document 6: JP 2011-208265 A
Patent Document 7: International Publication No. WO2012/086335
Patent Document 8: JP 2012-214874 A

20 SUMMARY OF INVENTION

[Technical Problem]

[0008] The foregoing magnetic recording layer is configured from a magnetic phase
25 such as an FePt-based alloy and a nonmagnetic phase that separates the magnetic phase, and an object of this invention is to provide is a ferromagnetic material sputtering target in which carbon (C) is used as a nonmagnetic phase material and, when sputtered, is effective in preventing the generation of particles caused by an abnormal discharge during sputtering.

30 [Solution to Problem]

[0009] In order to resolve the foregoing problems, the present inventors previously
succeeded in aligning the direction of the graphite in the sintered compact to a certain extent (Japanese Patent Application No. 2012-161563). In order to align the direction of the graphite, it is effective to flatten the Fe-Pt alloy powder to be
35 used as the magnetic phase, and mixing a flaked graphite powder therewith.

However, since the Fe-Pt alloy powder has a fine grain size and a porous structure, it was difficult to uniformly flatten the Fe-Pt alloy powder.

[0010] Thus, as a result of intense study, the present inventors discovered that it is possible to obtain a uniformly flattened Fe-Pt alloy powder by using, as the Fe-Pt alloy powder before being flattened, a dense Fe-Pt alloy powder with a controlled grain size.

Furthermore, the present inventors discovered that, by mixing the uniformly flattened Fe-Pt alloy powder and flaked graphite, it is possible to further improve the orientation of the graphite in the sintered compact and, consequently, further suppress the abnormal discharge during sputtering as well as reduce the generation of particles.

[0011] Based on the foregoing discovery, the present invention provides:

- 1) A C-containing FePt-based sputtering target for forming a magnetic recording film, wherein an average thickness of an Fe-Pt alloy phase in a polished surface of a cross section vertical to a sputtering surface is 10 μm or more;
- 2) A C-containing FePt-based sputtering target for forming a magnetic recording film, wherein an average length of an Fe-Pt alloy phase in a polished surface of a cross section vertical to a sputtering surface is 20 μm or more;
- 3) A C-containing FePt-based sputtering target for forming a magnetic recording film, wherein an average length of an Fe-Pt alloy phase in a polished surface of a cross section horizontal to a sputtering surface is 20 μm or more;
- 4) The sputtering target according to any one of 1) to 3) above, wherein a Pt content is 5 mol% or more and 60 mol% or less;
- 5) The sputtering target according to any one of 1) to 4) above, wherein a C content is 10 mol% or more and 70 mol% or less;
- 6) The sputtering target according to any one of 1) to 5) above, wherein the sputtering target contains, as an additive element, one or more types of elements selected from a group consisting of B, Ru, Ag, Au, and Cu in an amount of 0.5 mol% or more and 10 mol% or less;
- 7) The sputtering target according to any one of 1) to 6) above, wherein the sputtering target contains, as an additive material, one or more types of inorganic substance materials selected from a group consisting of oxides, nitrides, carbides, and carbonitrides;
- 8) A method for producing a sputtering target, wherein an Fe-Pt alloy is cut into chips, these chips are pulverized and flattened to obtain an Fe-Pt alloy powder, a

flaked graphite powder is thereafter mixed with the obtained Fe-Pt alloy powder, the obtained mixed powder is subject to hot-pressing sintering, and the obtained sintered compact is machined into a target shape;

9) The method for producing a sputtering target according to 8) above, wherein a powder of one or more types of metal elements selected from a group consisting of B, Ru, Ag, Au, and Cu is additionally mixed; and

10) The method for producing a sputtering target according to 8) or 9) above, wherein a powder of one or more types of inorganic substance materials selected from a group consisting of oxides, nitrides, carbides, and carbonitrides is additionally mixed.

[Advantageous Effects of Invention]

[0012] The present invention relates to a sputtering target for forming a magnetic recording layer configured from a magnetic phase such as an Fe-Pt alloy and a nonmagnetic phase such as C that separates the magnetic phase, and yields a superior effect of being able to provide a ferromagnetic material sputtering target capable of suppressing the generation of particles caused by an abnormal discharge during sputtering.

BRIEF DESCRIPTION OF DRAWINGS

[0013] [Fig. 1] This is a laser micrograph showing a cross section that is vertical to the sputtering surface of the target structure of Example 1 (upper photo: visual field of 1080 μm (vertical) by 1450 μm (horizontal); lower photo: visual field of 560 μm (vertical) by 750 μm (horizontal)).

[Fig. 2] This is a laser micrograph showing a cross section that is horizontal to the sputtering surface of the target structure of Example 1 (upper photo: visual field of 1080 μm (vertical) by 1450 μm (horizontal); lower photo: visual field of 560 μm (vertical) by 750 μm (horizontal)).

[Fig. 3] This is a laser micrograph showing a cross section that is vertical to the sputtering surface of the target structure of Example 2 (upper photo: visual field of 1080 μm (vertical) by 1450 μm (horizontal); lower photo: visual field of 560 μm (vertical) by 750 μm (horizontal)).

[Fig. 4] This is a laser micrograph showing a cross section that is horizontal to the sputtering surface of the target structure of Example 2 (upper photo: visual field of 1080 μm (vertical) by 1450 μm (horizontal); lower photo: visual field of 560

μm (vertical) by 750 μm (horizontal)).

[Fig. 5] This is a laser micrograph showing a cross section that is vertical to the sputtering surface of the target structure of Comparative Example 1 (upper photo: visual field of 1080 μm (vertical) by 1450 μm (horizontal); lower photo: visual field of 560 μm (vertical) by 750 μm (horizontal)).

[Fig. 6] This is a laser micrograph showing a cross section that is horizontal to the sputtering surface of the target structure of Comparative Example 1 (upper photo: visual field of 1080 μm (vertical) by 1450 μm (horizontal); lower photo: visual field of 560 μm (vertical) by 750 μm (horizontal)).

[Fig. 7] This is a schematic diagram of the structure in the vertical cross section of the target of the present invention in which the direction of the C phase is aligned (in Fig. 7, the black part corresponds to the C phase, and the white part corresponds to the alloy phase).

[Fig. 8] This is a schematic diagram showing the vertical cross section and the horizontal cross section in the sputtering target of the present invention.

DESCRIPTION OF EMBODIMENTS

[0014] The present invention relates to a sputtering target having a structure (refer to Fig. 7) in which a C phase of a nonmagnetic material is dispersed in an Fe-Pt alloy phase of a ferromagnetic material in a manner of being aligned in a specific direction. As a result of aligning the direction of the C phase in a specific direction as described above, superior effects are yielded in that it is possible to stabilize the current during sputtering, and thereby suppress abnormal discharge.

[0015] The sputtering target of the present invention is unique in that the average thickness of the Fe-Pt alloy phase in the polished surface (mirror polished surface based on buff finishing) of the cross section that is vertical to the sputtering surface is 10 μm or more. If the average thickness of the Fe-Pt alloy phase is less than 10 μm, the Fe-Pt alloys tend to agglomerate, and it becomes difficult to disperse the C phase and align it in a specific direction. By causing the average thickness of the Fe-Pt alloy phase to be 10 μm or more, it is possible to suppress the agglomeration of the Fe-Pt alloys, uniformly disperse the C phase in the target structure and align the direction of the C phase, and thereby enable stable sputtering.

Note that the foregoing expression of "cross section that is vertical to the

sputtering surface" corresponds to the cross section that is vertical to the surface to be subject to pressure during the hot press as shown in Fig. 8.

[0016] The average thickness of the Fe-Pt alloy phase of the vertical cross section is calculated as follows.

5 Foremost, micrographs of the cross section that is vertical to the sputtering surface are captured at 3 arbitrary locations at a visual field in which the vertical length and the horizontal length respectively fall within the range of 1000 μm to 1500 μm . Here, the straight line in the vertical direction relative to the sputtering surface is adjusted so that it becomes parallel to the vertical direction of the
10 micrograph. Next, a straight line is drawn in the vertical direction of the micrograph at 3 arbitrary locations in each of the micrographs. Here, the straight lines will alternately pass through the Fe-Pt alloy phase, the C phase, and phases of other additive elements. Furthermore, the length of the segment from the position that these lines start passing through the phase up to the
15 position where the phase ends is defined as the thickness of the phase, the thickness of the respective phases of the Fe-Pt alloy is measured to calculate the average of values measured at "3 measurement locations $\times$ 3 micrographs = 9 locations in total".

Note that, if the visual field of the micrograph is narrower than the foregoing
20 range, it is not possible to ensure a sufficient parameter for calculating the average thickness. Meanwhile, if the visual field of the micrograph is wider than the foregoing range, it becomes difficult to measure the length per phase. Thus, the visual field is preferably 1000 μm to 1500 μm .

[0017] Moreover, the sputtering target of the present invention is unique in that the
25 average length of the Fe-Pt alloy phase in the polished surface (mirror polished surface based on buff finishing) of the cross section that is vertical to the sputtering surface is 20 μm or more. While the Fe-Pt alloy is subject to flattening or flaking prior to being mixed, as a result of having a certain degree of length in the longitudinal direction, it becomes easier to layer the C phase in a
30 direction that is vertical to the sputtering surface.

Preferably, the average thickness of the Fe-Pt alloy phase in the polished surface of the cross section that is vertical to the sputtering surface is 10 μm or more, and the average length of the foregoing alloy phase is 30 μm or more. Moreover, if the average thickness of the Fe-Pt alloy phase is too thick or the
35 average length of the Fe-Pt alloy phase is too long, it becomes difficult to align

the orientation. Thus, the average thickness is preferably 100 μm or less, or the average length is preferably 400 μm or less.

[0018] The average length of the Fe-Pt alloy phase of the vertical cross section is calculated as follows.

5 Foremost, micrographs of the cross section that is vertical to the sputtering surface are captured at 3 arbitrary locations at a visual field in which the vertical length and the horizontal length respectively fall within the range of 1000 μm to 1500 μm . Here, the straight line in the vertical direction relative to the sputtering surface is adjusted so that it becomes parallel to the vertical direction of the
10 micrograph. Next, a straight line is drawn in the horizontal direction of the micrograph at 3 arbitrary locations in each of the micrographs. Here, the straight lines will alternately pass through the Fe-Pt alloy phase, the C phase, and phases of other additive elements. Furthermore, the length of the segment from the position that these lines start passing through the phase up to the
15 position where the phase ends is defined as the length of the phase, the length of the respective phases of the Fe-Pt alloy is measured to calculate the average of values measured at "3 measurement locations $\times$ 3 micrographs = 9 locations in total".

Note that, if the visual field of the micrograph is narrower than the foregoing
20 range, it is not possible to ensure a sufficient parameter for calculating the average length. Meanwhile, if the visual field of the micrograph is wider than the foregoing range, it becomes difficult to measure the length per phase. Thus, the visual field is preferably 1000 μm to 1500 μm .

[0019] Moreover, the sputtering target of the present invention is unique in that the
25 average length of the Fe-Pt alloy phase in the polished surface (mirror polished surface based on buff finishing) of the cross section that is horizontal to the sputtering surface is 20 μm or more. As a result of the Fe-Pt alloy phase having a certain degree of length and width, it becomes easier to layer the C phase in a direction that is vertical to the sputtering surface.

30 More preferably, the average thickness of the Fe-Pt alloy phase in the polished surface of the cross section that is vertical to the sputtering surface is 20 μm or more, and/or the average length of the foregoing alloy phase is 20 μm or more, and the average length of the Fe-Pt alloy phase in the polished surface of the cross section that is horizontal to the sputtering surface is 20 μm or more.

35 Note that the foregoing expression of "cross section that is horizontal to the

sputtering surface" corresponds to the surface to be subject to pressure during the hot press as shown in Fig. 8.

[0020] The average length of the Fe-Pt alloy phase of the horizontal cross section is calculated as follows.

5 Foremost, micrographs of the cross section that is horizontal to the sputtering surface are captured at 3 arbitrary locations at a visual field in which the vertical length and the horizontal length respectively fall within the range of 1000 μm to 1500 μm . Here, since the Fe-Pt alloy phase does not have a two-dimensional directivity in the horizontal cross section, the image may be captured from any direction. Next, a straight line is drawn in the horizontal direction of the
10 micrograph at 3 arbitrary locations in each of the micrographs. Here, the straight lines will alternately pass through the Fe-Pt alloy phase, the C phase, and phases of other additive elements. Furthermore, the length of the segment from the position that these lines start passing through the phase up to the
15 position where the phase ends is defined as the length of the phase, the length of the respective phases of the Fe-Pt alloy is measured to calculate the average of values measured at "3 measurement locations $\times$ 3 micrographs = 9 locations in total".

Note that, if the visual field of the micrograph is narrower than the foregoing
20 range, it is not possible to ensure a sufficient parameter for calculating the average length. Meanwhile, if the visual field of the micrograph is wider than the foregoing range, it becomes difficult to measure the length per phase. Thus, the visual field is preferably 1000 μm to 1500 μm .

[0021] With the sputtering target of the present invention, preferably, the Pt content
25 is 5 mol% or more and 60 mol% or less, and the remainder is Fe and C. This is because, when the Pt content is less than 5 mol% or exceeds 60 mol%, there are cases where the intended magnetic properties cannot be obtained.

Moreover, with the sputtering target of the present invention, preferably, the C content is 10 mol% or more and 70 mol% or less, and the remainder Fe and Pt.
30 This is because, when the C content is less than 10 mol%, there are cases where the intended magnetic properties cannot be obtained, and when the C content exceeds 70 mol%, C will agglomerate and cause the increase in the generation of particles.

[0022] Moreover, in order to improve the magnetic properties, the sputtering target
35 of the present invention preferably contains, as an additive element, one or more

types of elements selected from a group consisting of B, Ru, Ag, Au, and Cu in an amount of 0.5 mol% or more and 10 mol% or less. Moreover, by further adding, as an additive material, one or more types of inorganic substance materials selected from a group consisting of oxides, nitrides, carbides, and carbonitrides to the sputtering target of the present invention, it is possible to further improve the magnetic properties.

[0023] The method for producing the sputtering target of the present invention is now explained.

Foremost, an Fe raw material and a Pt raw material are melted and cast to prepare an Fe-Pt alloy ingot, and the prepared Fe-Pt alloy ingot is formed into Fe-Pt alloy chips by using a general-purpose lathe or the like. Here, the cutting depth during the cutting is preferably set to 0.1 to 0.3 mm. Moreover, the Fe raw material and the Pt raw material to be used may be any shape so as long as that shape can be subject to induction heating.

The reason for performing alloying by melting and casting is because, if the Fe powder and the Pt powder are alloyed by sintering, the sintered alloy will have a porous structure, and the Fe-Pt alloy powder will become crushed during the flattening process described later, and this would consequently result in an alloy powder having a small grain size.

The ratio of the Fe raw material and the Pt raw material can be suitably adjusted to match the intended composition of the Fe-Pt alloy. Moreover, when adding a metal powder of B, Ru, Ag, Au, Cu or the like, such metal powder is preferably added simultaneously with the preparation of the Fe-Pt alloy ingot.

[0024] Next, the Fe-Pt alloy chips are pulverized using a horizontal type brown crusher until they are able to pass through a sieve with a sieve opening of 150 to 400 μm . The obtained powder is then classified using a sieve with a sieve opening of 63 μm , and the residue on the sieve is used as the raw material. If the grain size of the Fe-Pt alloy powder is too small, this is undesirable since the alloy powder will pass through the grinding medium in the subsequent process, and it will be difficult to uniformly flatten the alloy powder.

Thereafter, a medium agitation mill is used to pulverize the Fe-Pt alloy powder into a flat shape or a flaked shape (flattening process). When a medium agitation mill having a tank capacity of 5 liters is used, preferably, yttria-stabilized zirconia balls having a diameter of 3 to 7 mm are used as the grinding medium, and pulverization is performed at a rotation speed of 300 rpm for roughly 2 to 8

hours. However, the present invention is not limited to the foregoing conditions, and any kind of method may be adopted so as long as it is acknowledged that the same level of processing capacity can be obtained.

As a result of performing the pulverization and flattening processes described above, it is possible to obtain a dense Fe-Pt alloy powder having a grain size of 1 μm or more and 500 μm or less, and an average grain size of 50 to 100 μm .

[0025] As the C raw material powder, a flat or flaky graphite or a flaked graphite (graphite with few graphene sheets) is preferably used. Since a flaked graphite yields superior electrical conduction in comparison to a normal graphite, a flaked graphite is especially effective in inhibiting an abnormal discharge and reducing the generation of particles. As the C raw material powder, preferably used is a type having a grain size of 0.5 μm or more and 30 μm or less, and an average thickness of 0.5 μm or more and 30 μm or less. If the C raw material is too fine, this is undesirable since the C raw materials tend to agglomerate, and if the C raw material is too large, this is undesirable since the C raw material itself will become the cause of abnormal discharge.

[0026] Subsequently, the foregoing raw material powder is weighed to attain the intended composition, and these powders are mixed using a mortar or a sieve with a sieve opening of 150 to 500 μm .

When adding a metal powder of B, Ru, Ag, Au, Cu or the like or an inorganic substance material such as oxides, nitrides, carbides, and carbonitrides, these may be mixed at this stage. As these metal powders or inorganic material powders, preferably used are types having a grain size of 0.5 μm or more and 30 μm or less. If the raw material is too fine, this is undesirable since the raw materials tend to agglomerate, and if the raw material is too large, this is undesirable since the raw material itself will become the cause of abnormal discharge.

As described above, by using the uniformly flattened Fe-Pt alloy powder and flaked graphite, as well as the foregoing metal powders or inorganic material powders that were added as needed, as the raw material powder, it is possible to further improve the orientation of the C phase in the target made from a sintered compact in comparison to conventional methods.

[0027] Subsequently, the mixed powder is filled in a carbon mold, and molded and sintered via hot press performed at a uniaxial pressure. The C phase becomes

aligned in a specified direction during this hot press performed at a uniaxial pressure.

The holding temperature during the sintering will depend on the composition of the sputtering target, but in many cases the temperature range of the holding temperature is 800 to 1600°C. Moreover, as needed, hot isostatic pressing may be performed to the sintered compact removed from the hot press mold. Hot isostatic pressing is effective for increasing the density of the sintered compact. The holding temperature during hot isostatic pressing will depend on the composition of the sintered compact, but in many cases the temperature range of the holding temperature is 800 to 1600°C. Moreover, the pressure is set to 100 MPa or more. The thus obtained sintered compact is processed into an intended shape using a lathe in order to prepare the sputtering target of the present invention.

[Examples]

[0028] The present invention is now explained in detail with reference to the Examples and Comparative Examples. Note that these Examples are merely illustrative, and the present invention shall in no way be limited thereby. In other words, various modifications and other embodiments are covered by the present invention, and the present invention is limited only by the scope of its claims.

[0029] (Example 1)

Foremost, an Fe raw material and a Pt raw material were melted via vacuum melting and casting, and a cylindrical alloy ingot having a diameter of roughly $\phi 150$ and a composition ratio of Fe-50Pt (at.%) was obtained. Next, the obtained alloy ingot after removal of the surface oxide film was set in a general-purpose lathe and cut at a cutting depth of 0.3 mm to obtain Fe-Pt alloy chips.

Subsequently, the Fe-Pt alloy chips were pulverized using a horizontal type brown crusher until the pulverized chips were able to pass through a sieve with a sieve opening of 150 μm , and fine powder was then eliminated by using a sieve with a sieve opening of 63 μm . Furthermore, the Fe-Pt pulverized chips were filled in a medium agitation mill having a tank capacity of 5 liters together with yttria-stabilized zirconia balls having a diameter of 5 mm as the grinding medium, and milling was performed for 4 hours to obtain a dense flaked Fe-Pt alloy powder.

The average grain size of the obtained dense flaked Fe-Pt alloy powder was

measured by using a wet-type particle size distribution analyzer manufactured by HORIBA and by using isopropyl alcohol as the dispersant. As a result of the measurement, the average grain size of the dense Fe-Pt alloy powder was 85 μm .

5 [0030] Subsequently, a flaked graphite powder having an average grain size of 25.5 μm in which small-diameter grains were separated via the airflow classifying method was prepared, and the dense Fe-Pt alloy powder obtained as described above and the prepared flaked graphite powder were mixed using a sieve with a sieve opening of 400 μm to attain a composition ratio of (Fe-50Pt)-40C (at.%).
10 The obtained mixed powder was filled in a carbon mold, and hot pressed.

The hot press conditions were as follows; namely, vacuum atmosphere, rate of temperature increase of 300°C/hour, holding temperature of 1400°C, and holding time of 2 hours, and a pressure of 30 MPa was applied from the start of temperature increase to the end of holding. After the end of holding, the
15 resultant product was naturally cooled as is in the chamber.

Subsequently, the sintered compact removed from the hot press mold was subject to hot isostatic pressing. The hot isostatic pressing conditions were as follows; namely, rate of temperature increase of 300°C/hour, holding temperature of 1100°C, and holding time of 2 hours, and Ar gas pressure was gradually
20 increased from the start of temperature increase, and a pressure of 150 MPa was applied during the holding at 1100°C. After the end of holding, the resultant product was naturally cooled as is in the furnace.

[0031] Edges of the obtained sintered compact were cut, the horizontal plane and the vertical cross section relative to the sputtering surface were polished, and the
25 structure thereof was observed with a laser microscope. Subsequently, the structure images of locations that were arbitrarily selected on the structure surface were captured at a visual field size of 1080 μm (vertical) by 1450 μm (horizontal), and a visual field size of 560 μm (vertical) by 750 μm (horizontal). The captured images are respectively shown in Fig. 1 and Fig. 2. The white part
30 in the structure images correspond to the Fe-Pt phase. Meanwhile, the black part corresponds to the C phase.

Using the obtained structure images, the average thickness of the Fe-Pt phase in the cross section that is vertical to the sputtering surface was measured, and the result was 11.9 μm . Moreover, the average length of the Fe-Pt phase in
35 a direction that is parallel to the sputtering surface in the cross section that is

vertical to the sputtering surface was measured, and the result was 29.7 μm . Furthermore, the average length of the Fe-Pt phase in the cross section that is horizontal to the sputtering surface was measured, and the result was 27.6 μm .

[0032] Subsequently, the obtained sintered compact was machined with a lathe into a shape having a diameter of 180.0 mm and a thickness of 5.0 mm, thereafter the target was mounted on a magnetron sputtering equipment (C-3010 sputtering system manufactured by Canon Anelva), and sputtering was performed. The sputtering conditions were as follows; namely, input power of 1 kW and Ar gas pressure of 1.7 Pa, and after performing pre-sputtering at 2 kW/hr, film deposition was performed onto a silicon substrate having a 4-inch diameter for 20 seconds. Subsequently, as a result of measuring the number of particles that adhered onto the substrate with a surface contamination inspection device (Surfscan 6420 manufactured by KLA-Tencor), the number of particles in this case was 103 particles and decreased significantly in comparison to Comparative Example 1 described later. The foregoing results are summarized in Table 1.

[0033] [Table 1]

	Composition Ratio (at. %)	Production Method and Conditions	Average Thickness of Fe-Pt Alloy Phase In Vertical Cross Section (μm)	Average Length of Fe-Pt Alloy Phase in Vertical Cross Section (μm)	Average Length of Fe-Pt Alloy Phase in Horizontal Cross Section (μm)	Number of Particles
Example 1	(Fe-50Pt)-40C	Pulverization of Fe-Pt alloy chips	11.9	29.7	27.6	103
Example 2	(Fe-50Pt)-40C	Pulverization of Fe-Pt alloy chips	12.3	37.1	31.9	76
Comparative Example 1	(Fe-50Pt)-40C	Fe-Pt alloy powder (porous)	4.4	14.3	9.2	244

[0034] (Example 2)

Foremost, an Fe raw material and a Pt raw material were melted via vacuum melting and casting, and a cylindrical alloy ingot having a diameter of roughly $\phi 150$ and a composition ratio of Fe-50Pt (at.%) was obtained. Next, the obtained alloy ingot after removal of the surface oxide film was set in a general-purpose lathe and cut at a cutting depth of 0.1 mm to obtain Fe-Pt alloy chips.

Subsequently, the Fe-Pt alloy chips were pulverized using a horizontal type brown crusher until the pulverized chips were able to pass through a sieve with a sieve opening of 150 μm , and fine powder was then eliminated by using a sieve with a sieve opening of 63 μm . Furthermore, the Fe-Pt pulverized chips were filled in a medium agitation mill having a tank capacity of 5 liters together with yttria-stabilized zirconia balls having a diameter of 5 mm as the grinding medium, and milling was performed for 4 hours to obtain a dense flaked Fe-Pt alloy powder.

The average grain size of the obtained dense flaked Fe-Pt alloy powder was measured by using a wet-type grain size distribution analyzer manufactured by HORIBA and by using isopropyl alcohol as the dispersant. As a result of the measurement, the average grain size of the dense flaked Fe-Pt alloy powder was 80 μm .

[0035] Subsequently, a flaked graphite powder having an average grain size of 25.5 μm in which small-diameter grains were separated via the airflow classifying method was prepared, and the dense Fe-Pt alloy powder obtained as described above and the prepared flaked graphite powder were mixed using a sieve with a sieve opening of 400 μm to attain a composition ratio of (Fe-50Pt)-40C (at.%). The obtained mixed powder was filled in a carbon mold, and hot pressed.

The hot press conditions were as follows; namely, vacuum atmosphere, rate of temperature increase of 300°C/hour, holding temperature of 1400°C, and holding time of 2 hours, and a pressure of 30 MPa was applied from the start of temperature increase to the end of holding. After the end of holding, the resultant product was naturally cooled as is in the chamber.

Subsequently, the sintered compact removed from the hot press mold was subject to hot isostatic pressing. The hot isostatic pressing conditions were as follows; namely, rate of temperature increase of 300°C/hour, holding temperature of 1100°C, and holding time of 2 hours, and Ar gas pressure was gradually

increased from the start of temperature increase, and a pressure of 150 MPa was applied during the holding at 1100°C. After the end of holding, the resultant product was naturally cooled as is in the furnace.

[0036] Edges of the obtained sintered compact were cut, the horizontal plane and the vertical cross section relative to the sputtering surface were polished, and the structure thereof was observed with a laser microscope. Subsequently, the structure images of locations that were arbitrarily selected on the structure surface were captured at a visual field size of 1080 μm (vertical) by 1450 μm (horizontal), and a visual field size of 560 μm (vertical) by 750 μm (horizontal). The captured images are respectively shown in Fig. 3 and Fig. 4. The white part in the structure images correspond to the Fe-Pt phase. Meanwhile, the black part corresponds to the C phase.

Using the obtained structure images, the average thickness of the Fe-Pt phase in the cross section that is vertical to the sputtering surface was measured, and the result was 12.3 μm . Moreover, the average length of the Fe-Pt phase in a direction that is parallel to the sputtering surface in the cross section that is vertical to the sputtering surface was measured, and the result was 37.1 μm . Furthermore, the average length of the Fe-Pt phase in the cross section that is horizontal to the sputtering surface was measured, and the result was 31.9 μm .

[0037] Subsequently, the obtained sintered compact was machined with a lathe into a shape having a diameter of 180.0 mm and a thickness of 5.0 mm, thereafter the target was mounted on a magnetron sputtering equipment (C-3010 sputtering system manufactured by Canon Anelva), and sputtering was performed. The sputtering conditions were as follows; namely, input power of 1 kW and Ar gas pressure of 1.7 Pa, and after performing pre-sputtering at 2 kWhr, film deposition was performed onto a silicon substrate having a 4-inch diameter for 20 seconds. Subsequently, as a result of measuring the number of particles that adhered onto the substrate with a surface contamination inspection device (Surfscan 6420 manufactured by KLA-Tencor), the number of particles in this case was 76 particles and decreased significantly in comparison to Comparative Example 1 described later. The foregoing results are similarly summarized in Table 1.

[0038] (Comparative Example 1)

Foremost, as raw material powders, an Fe powder having an average grain size of 3 μm and a Pt powder having an average grain size of 3 μm were prepared to attain a composition ratio of Fe-50Pt (at.%), mixed for 2 hours using

a mortar, and thereafter heated at 800°C in an inert atmosphere and alloyed. Subsequently, the resultant product was filled in a medium agitation mill having a capacity of 5 liters together with yttria-stabilized zirconia balls having a diameter of 5 mm as the grinding medium, and milling was performed for 4 hours at 300 rpm to obtain an Fe-Pt alloy powder.

[0039] Subsequently, a flaked graphite powder having an average grain size of 25.5 μm in which small-diameter grains were separated via the airflow classifying method was prepared, and the Fe-Pt alloy powder obtained as described above and the prepared flaked graphite powder were mixed using a sieve with a sieve opening of 400 μm to attain a composition ratio of (Fe-50Pt)-40C (at.%), and the obtained mixed powder was filled in a carbon mold, and hot pressed.

The hot press conditions were as follows; namely, vacuum atmosphere, rate of temperature increase of 300°C/hour, holding temperature of 1400°C, and holding time of 2 hours, and a pressure of 30 MPa was applied from the start of temperature increase to the end of holding. After the end of holding, the resultant product was naturally cooled as is in the chamber.

Subsequently, the sintered compact removed from the hot press mold was subject to hot isostatic pressing. The hot isostatic pressing conditions were as follows; namely, rate of temperature increase of 300°C/hour, holding temperature of 1100°C, and holding time of 2 hours, and Ar gas pressure was gradually increased from the start of temperature increase, and a pressure of 150 MPa was applied during the holding at 1100°C. After the end of holding, the resultant product was naturally cooled as is in the furnace.

[0040] Edges of the obtained sintered compact were cut, the horizontal plane and the vertical cross section relative to the sputtering surface were polished, and the structure thereof was observed with a laser microscope. Subsequently, the structure images of locations that were arbitrarily selected on the structure surface were captured at a visual field size of 1080 μm (vertical) by 1450 μm (horizontal), and a visual field size of 560 μm (vertical) by 750 μm (horizontal). The captured images are respectively shown in Fig. 5 and Fig. 6. The white part in the structure images correspond to the Fe-Pt phase. Meanwhile, the black part corresponds to the C phase.

Using the obtained structure images, the average thickness of the Fe-Pt phase in the cross section that is vertical to the sputtering surface was measured, and the result was 4.4 μm . Moreover, the average length of the Fe-Pt phase in

a direction that is parallel to the sputtering surface in the cross section that is vertical to the sputtering surface was measured, and the result was 14.3 μm . Furthermore, the average length of the Fe-Pt phase in the cross section that is horizontal to the sputtering surface was measured, and the result was 9.2 μm .

5 [0041] Subsequently, the obtained sintered compact was machined with a lathe into a shape having a diameter of 180.0 mm and a thickness of 5.0 mm, thereafter the target was mounted on a magnetron sputtering equipment (C-3010 sputtering system manufactured by Canon Anelva), and sputtering was performed. The sputtering conditions were as follows; namely, input power of 1 kW and Ar gas
10 pressure of 1.7 Pa, and after performing pre-sputtering at 2 kWhr, film deposition was performed onto a silicon substrate having a 4-inch diameter for 20 seconds. Subsequently, as a result of measuring the number of particles that adhered onto the substrate with a surface contamination inspection device (Surfscan 6420 manufactured by KLA-Tencor), the number of particles in this case was greater at
15 244 particles. The foregoing results are similarly summarized in Table 1.

INDUSTRIAL APPLICABILITY

[0042] The present invention provides a sputtering target having a structure in which
20 a C phase of a nonmagnetic material is dispersed in an Fe-Pt alloy phase in a manner of being aligned in a specific direction. As a result of aligning the direction of the C phase in a specific direction, superior effects are yielded in that it is possible to stabilize the current during sputtering, and thereby suppress abnormal discharge. The present invention is useful as a ferromagnetic
25 material sputtering target for depositing a magnetic thin film, particularly a granular-type magnetic recording layer, of a magnetic recording medium.

CLAIMS

[Claim 1] A C-containing FePt-based sputtering target for forming a magnetic recording film, wherein, in a polished surface of a cross section vertical to a sputtering surface, an average thickness of an Fe-Pt alloy phase is 10 μm or more and 100 μm or less, an average length of the Fe-Pt alloy phase is 20 μm or more and 400 μm or less, and a C phase is aligned in a specific direction.

[Claim 2] A C-containing FePt-based sputtering target for forming a magnetic recording film according to claim 1, wherein an average length of an Fe-Pt alloy phase in a polished surface of a cross section horizontal to a sputtering surface is 20 μm or more.

[Claim 3] The sputtering target according to claim 1 or 2, wherein a Pt content is 5 mol% or more and 60 mol% or less.

[Claim 4] The sputtering target according to any one of claims 1 to 3, wherein a C content is 10 mol% or more and 70 mol% or less.

[Claim 5] The sputtering target according to any one of claims 1 to 4, wherein the sputtering target contains, as an additive element, one or more types of elements selected from a group consisting of B, Ru, Ag, Au, and Cu in an amount of 0.5 mol% or more and 10 mol% or less.

[Claim 6] The sputtering target according to any one of claims 1 to 5, wherein the sputtering target contains, as an additive material, one or more types of inorganic substance materials selected from a group consisting of oxides, nitrides, carbides, and carbonitrides.

[Claim 7] A method for producing a sputtering target, wherein an Fe-Pt alloy is cut into chips, these chips are pulverized and flattened to obtain an Fe-Pt alloy powder, a flaked graphite powder is thereafter mixed with the obtained Fe-Pt alloy powder, the obtained mixed powder is subject to hot-pressing sintering at a uniaxial pressure, and the obtained sintered compact is machined into a target shape.

[Claim 8] The method for producing a sputtering target according to claim 7, wherein a powder of one or more types of metal elements selected from a group consisting of B, Ru, Ag, Au, and Cu is additionally mixed.

[Claim 9] The method for producing a sputtering target according to claim 7 or claim 8, wherein a powder of one or more types of inorganic substance materials selected from a group consisting of oxides, nitrides, carbides, and carbonitrides is additionally mixed.