

IRON-PLATINUM-BASED SPUTTERING TARGET AND METHOD FOR MANUFACTURING THE SAME

1. Field of the Invention

The present invention relates to an iron-platinum-based sputtering target, more particularly to an iron-platinum-based sputtering target suitable for a magnetic recording medium. In addition, the present invention also relates to a method for manufacturing an iron-platinum-based sputtering target.

2. Description of the Prior Arts

Magnetic recording utilizes the magnetic hysteresis characteristics of a magnetic material to store information on a recording medium. According to the direction of magnetization of the magnetic head, magnetic recording media currently available are divided into longitudinal magnetic recording (LMR) and perpendicular magnetic recording (PMR). High stability of the magnetic recording media is the primary requirement. Besides, with the consumer's needs of portable recording media as well as the rise of cloud demand and huge amount of generated information in recent years, the demand for recording capacities of magnetic recording media is increasing. Hence, how to increase the recording density of magnetic recording media has become the research focus in the related fields. As the magnetic recording density of longitudinal magnetic recording media is now approaching the fundamental physical limitations, perpendicular magnetic recording media capable of delaying the superparamagnetic limit and achieving a higher recording density have become a technical approach to solve the problem.

In addition, perpendicular magnetic recording technology can combine

with heat-assisted magnetic recording (HAMR) technology. In HAMR media, the magnetic particles of the recording area are heated to above the Curie temperature during writing, so as to temporarily reduce the coercivity of the magnetic particles and to increase the recording density of HAMR media.

Generally, the perpendicular magnetic recording media from bottom to top comprises a substrate, an adhesion layer, a soft underlayer, a seed layer, an intermediate layer, a magnetic recording layer, a cover layer and a lubricating layer.

With HAMR technology, the magnetic recording layer of the same region is heated repeatedly, so magnetic composite materials with high stability are required to prepare the magnetic recording layer. The iron-platinum-based alloy system is generally chosen as a main ingredient for most of the conventional magnetic recording layers of heat-assisted magnetic recording media. By adding non-magnetic components such as carbon in the iron-platinum-based alloy system, the crystal grains of the iron-platinum-based alloy are isolated from each other to reduce the magnetic coupling effect.

However, the magnetic recording layer is usually formed by a sputtering method. If the magnetic recording layer is produced by co-sputtering the iron target, the platinum target, and the carbon target, it will not only be difficult to control the composition of the magnetic recording layer, but also increase the production cost.

Attempts have been made to form a sputtering target by sintering carbon raw material powders and iron or platinum raw material powders

together in current technology; however, the carbon raw materials often aggregate, and it is difficult to mix the components of the sputtering target uniformly when the content of carbon raw material is in high proportion. Furthermore, carbon may exist in the iron phase to form iron-carbon compounds during sintering. Under both of the foregoing conditions, a large amount of carbon will precipitate on the surface of the sputtering target to cause abnormal discharge in a subsequent sputtering process, and a large amount of particulates generated may fall on the magnetic recording layer formed by sputtering and further affect the quality and yield rate of the magnetic recording layer.

Prior art documents:

Patent Document 1: JPWO2012133166 (A1)

In view of the defects of current technology, the purpose of the present invention is to reduce the amount of carbon precipitation on the surface of the sputtering target, thereby to reduce the occurrence probability of abnormal discharge during the subsequent sputtering process, and to reduce the problem of particulate contamination so as to improve the quality and yield rate of the obtained magnetic recording layer by sputtering.

In order to achieve the foregoing object, the present invention provides an iron-platinum-based sputtering target comprising iron (Fe), platinum (Pt) and carbon (C); wherein the carbon is in an amount greater than or equal to 15 atomic percent (at%) and less than or equal to 45 at% based on a total amount of atoms of the iron-platinum-based sputtering target, and a metallographic microstructure of the iron-platinum-based sputtering target has a carbon phase

having an average size less than or equal to 2 μm and an average aspect ratio less than 3.

According to the present invention, it is helpful to improve the uniform distribution of the phase compositions of the overall iron-platinum-based sputtering target by means of adjusting the carbon content in the iron-platinum-based sputtering target, and the ranges of average size and aspect ratio of the carbon phase in the metallographic microstructure. Accordingly, it effectively reduces the amount of carbon precipitation on the surface of the iron-platinum-based sputtering target, so the occurrence probability of abnormal discharges can be reduced and the problem of particulate contamination can also be mitigated during the subsequent sputtering process.

According to the present invention, the size of each carbon phase refers to the maximum length passing through the center point of the black phase in the metallographic microstructure; and the average size of the carbon phase is the average value of plural sets of data.

According to the present invention, the aspect ratio of each carbon phase is to firstly identify the maximum length passing through the center point of the black phase in the metallographic microstructure as axis, and to identify the minimum length passing through the center point of the black phase in the metallographic microstructure as width, and the proportional relationship between the axis and the width (axis / width) is the aspect ratio; and the average aspect ratio of the carbon phase is the average of plural sets of data.

Preferably, the iron is in an amount greater than or equal to 20 at% and less than or equal to 70 at% based on the total amount of the atoms of the iron-

platinum-based sputtering target.

Preferably, the platinum is in an amount greater than or equal to 10 at% and less than or equal to 40 at% based on the total amount of the atoms of the platinum-based sputtering target. More preferably, the platinum is in the amount greater than or equal to 14 at% and less than or equal to 40 at%. Even more preferably, the platinum is in the amount greater than or equal to 15 at% and less than or equal to 38 at%.

According to the present invention, the type of carbon in the iron-platinum-based sputtering target may be, but is not limited to, a diamond with a three-dimensional tetrahedral structure, a graphite with a two-dimensional planar structure, a carbon nanotube with one-dimensional structure, or any combination thereof. Preferably, the carbon is the diamond.

In some embodiments, the iron-platinum-based sputtering target further comprises boron nitride (BN) to enhance the isolation among the magnetic crystal grains and to provide more advantages for use as a magnetic recording layer. Preferably, the boron nitride is in an amount more than 0 at% and less than or equal to 10 at% based on the total amount of the iron-platinum-based sputtering target.

In other embodiments, the iron-platinum-based sputtering target further comprises, but is not limited to, copper (Cu), silver (Ag), or any combination thereof to enhance the thermal stability of the magnetic recording layer formed by sputtering the iron-platinum-based sputtering target, such that the thermal transition temperature of the magnetic recording layer is lowered. Preferably, the copper is in an amount more than or equal to 0.5 at% and less than or equal

to 2 at% based on the total amount of the iron-platinum-based sputtering target. Preferably, the silver is in an amount more than or equal to 0.5 at% and less than or equal to 2 at% based on the total amount of the iron-platinum-based sputtering target.

According to the present invention, the sputtering surface of the iron-platinum-based sputtering target is characterized by X-ray diffraction (XRD). The iron-platinum-based sputtering target contains iron-platinum alloys. In an X-ray diffraction pattern of the iron-platinum-based sputtering target, a lattice plane (111) of the iron-platinum alloys is identified as a characteristic peak, and the characteristic peak of the lattice plane (111) preferably has a full width at half maximum (FWHM) less than 0.3° . Accordingly, the amount of carbon precipitation on the surface of the iron-platinum-based sputtering target can be further reduced by controlling the full width at half maximum of the characteristic peak of the lattice plane (111) of the iron-platinum alloy in the iron-platinum-based sputtering target.

Preferably, the iron-platinum-based sputtering target may be subsequently applied to, but is not limited to, direct current sputtering, radio-frequency sputtering or magnetron sputtering.

In addition, the present invention further provides a method for manufacturing an iron-platinum-based sputtering target, which comprises:

step (A): grinding a carbon raw material by high-energy mechanical milling to obtain a ground carbon powder having an average particle size ranging from $0.3\ \mu\text{m}$ to $3\ \mu\text{m}$;

step (B): mixing and mechanically alloying the ground carbon powder,

an iron raw material and a platinum raw material to obtain an iron-platinum-based alloy powder; and

step (C): sintering the iron-platinum-based alloy powder by a sintering method comprising hot isostatic pressing to obtain the iron-platinum-based sputtering target; wherein the carbon is in an amount greater than or equal to 15 at% and less than or equal to 45 at% based on a total amount of atoms of the iron-platinum-based sputtering target; and a metallographic microstructure of the iron-platinum-based sputtering target has a carbon phase having an average size less than or equal to 2 μm and an average aspect ratio less than 3.

Both the step of pretreating the carbon raw material by high-energy mechanical milling and the step of mixing and mechanically alloying all the raw materials facilitate the subsequent formation of an iron-platinum-based sputtering target to make a carbon phase has an average size and an average aspect ratio within a particular range and to effectively reduce the amount of carbon precipitation on the surface of the iron-platinum-based sputtering target.

According to the present invention, the high-energy mechanical milling in the step (A) is high-energy ball milling, wherein a grinding ball used may be stainless steel beads or zirconia beads (ZrO_2) and have a particle size ranging, but not limited to, from 2 mm to 10 mm. Preferably, the grinding time for the high-energy mechanical milling in the step (A) is from 1 hour to 10 hours.

According to the present invention, the carbon raw material in the step (A) may be, but is not limited to, a diamond with a three-dimensional structure, a graphite with a two-dimensional structure, a carbon nanotube with one-dimensional structure or any combination thereof. Preferably, the type of the

carbon raw material is the diamond. The average particle size of the carbon raw material is from 2 μm to 10 μm so as to avoid particulate falling or abnormal discharge resulted from the difference in the conductivity between the base phase (such as the iron-platinum phase) and the dopant (such as the carbon phase) during sputtering the iron-platinum-based sputtering target. Preferably, an average particle size of the carbon raw material is from 2 μm to 5 μm in the form of diamond and is 2 μm to 10 μm in the form of graphite.

According to the present invention, the iron raw material in the step (B) may be, but is not limited to, a metallic iron having a purity of 99% or more, an iron alloy having the iron in the amount of 50% by weight or more, or any combination thereof. Preferably, the iron raw material has an average particle size ranging from 20 μm to 80 μm . By choosing the iron raw material having an average particle size within the above range, the residual amount of oxygen in the iron-platinum-based sputtering target can be reduced.

According to the present invention, the platinum raw material in the step (B) may be, but is not limited to, a metallic platinum having a purity of 99% or more, a platinum alloy having a platinum in the amount of 50% by weight or more, or any combination thereof. Preferably, the platinum raw material has an average particle size ranging from 1 μm to 10 μm so that the platinum can easily diffuse in the iron phase.

In some embodiments, the platinum raw material and the iron raw material may be an iron-platinum alloy.

According to the present invention, the step (B) can further comprise boron nitride. Preferably, the boron nitride has an average particle size of less

than 3.0 μm .

According to the present invention, the step (B) can further comprise a copper raw material having an average particle size ranging from 50 μm to 150 μm , a silver raw material having an average particle size ranging from 5 μm to 10 μm , or any combination thereof. Specifically, the copper raw material may be, but is not limited to, a metallic copper having a purity of 99% or more, a copper alloy having the copper in the amount of 50% by weight or more, or any combination thereof. The silver raw material may be, but is not limited to, a metallic silver having a purity of 99% or more, a silver alloy having the silver in the amount of 50% by weight or more, or any combination thereof.

According to the present invention, the grounded carbon powder, the iron raw material, the platinum raw material and the like in the step (B) may be added and mixed in any order, may be added simultaneously or sequentially, or all of the materials are added at one time or are added several times in a divided amount. When all of the materials are uniformly mixed, mechanically alloying (such as high-energy mechanical milling) is carried out to obtain an iron-platinum-based alloy powder.

In some embodiments, the step (B) comprises: step (B1): mixing the ground carbon powder, the iron raw material, and the platinum raw material to obtain a mixture; and step (B2): mechanically alloying the mixture to obtain the iron-platinum-based alloy powder. In other embodiments, the mixture in the step (B1) can further comprise boron nitride, a silver raw material, a copper raw material or any combination thereof.

Specifically, the mechanically alloying in the step (B2) adopts high-

energy ball milling, wherein the grinding balls used can be, but are not limited to, stainless steel beads or zirconia beads (ZrO_2), and have particle sizes ranging from 2 mm to 10 mm. Preferably, the grinding time of the step of mechanically alloying the mixture aforementioned is from 1 hour to 10 hours.

Preferably, in the iron-platinum-based sputtering target obtained in the step (C), the iron is in an amount greater than or equal to 20 at% and less than or equal to 70 at% based on the total amount of the atoms of the iron-platinum-based sputtering target. Preferably, the platinum is in an amount greater than or equal to 10 at% and less than or equal to 40 at% based on the total amount of the atoms of the platinum-based sputtering target. More preferably, the platinum is in the amount greater than or equal to 14 at% and less than or equal to 40 at%. Even more preferably, the platinum is in the amount greater than or equal to 15 at% and less than or equal to 38 at%.

Specifically, the sintering method in the step (C) may be the hot isostatic pressing (HIP) alone or the combination of the hot isostatic pressing and spark plasma sintering (SPS).

Preferably, in the step (C), a sintering temperature is from 500°C to 1300°C and a sintering pressure is from 50 MPa to 200 MPa.

Preferably, in the step (C), when adopting HIP alone, the sintering temperature in the step (C) is from 500°C to 1300°C and the sintering pressure is from 50 MPa to 200 MPa. When adopting the combination of HIP and SPS, the sintering temperature of HIP is from 500°C to 1300°C and the sintering pressure is from 50 MPa to 200 MPa, and the sintering temperature of SPS is from 600°C to 1300°C and the sintering pressure is from 20 MPa to 100 MPa.

Preferably, when adopting HIP alone, the sintering process lasts 1 hour to 7 hours. When adopting the combination of HIP and SPS, the HIP lasts 1 hour to 3 hours and SPS lasts 0.1 hour to 3 hours.

In some embodiments, the sintering in the step (C) can be carried out in staged sintering steps at different temperatures. For example, by HIP alone, the sintering lasts 0.5 hour to 5 hours at a high temperature of 800°C to 1300°C and then lasts 0.5 hour to 2 hours at a lower temperature of 500°C to 800°C. In other embodiments, in the combination of HIP and SPS, the sintering of HIP lasts 1 hour to 3 hours, and the sintering of SPS lasts 0.1 hour to 1 hour at a temperature of 800°C to 1300°C and then lasts 0.5 hour to 2 hours at a lower temperature of 600°C to 800°C.

IN THE DRAWINGS:

Fig.1 is the metallographic image of the iron-platinum-based sputtering target of Example 1 magnified 500 times by SEM;

Fig.2 is the metallographic image of the iron-platinum-based sputtering target of Example 6 magnified 500 times by SEM;

Fig.3 is the metallographic image of the iron-platinum-based sputtering target of Comparative Example 1 magnified 1000 times by SEM;

Fig.4 is the metallographic image of the iron-platinum-based sputtering target of Comparative Example 2 magnified 500 times by SEM;

Fig.5 is the metallographic image of the iron-platinum-based sputtering target of Comparative Example 4 magnified 500 times by SEM;

Fig.6 is the metallographic image of the iron-platinum-based sputtering target of Comparative Example 5 magnified 500 times by SEM;

Fig.7 is the XRD pattern of the iron-platinum-based sputtering target of Example 1; and

Fig.8 is the XRD pattern of the iron-platinum-based sputtering target of Comparative Example 1.

In order to verify the influence from the compositions of raw materials, the pretreatment and/or the mixing order, and the sintering parameters on the iron-platinum-based sputtering target, several iron-platinum-based sputtering targets are exemplified below, and the embodiments of the present invention will be described in detail. People skilled in the art can easily understand the advantages and effects of the present invention through the disclosure of the present specification, and conduct various modifications and adjustments without deviating from the spirit of the present invention to implement or carry out the present invention.

The analytical instruments used in the examples are as follows:

1. Scanning electron microscope: Hitachi SE-3400;
2. Energy dispersive spectroscopy: HORIBA EMAX 450;
3. X-ray diffractometer: Multipurpose X-ray diffraction system; and
4. Inductively coupled plasma optical emission spectrometry:

Perkinelmer Avio 500.

The raw materials used in the examples are as follows:

1. The carbon raw material: Diamond powders having an average particle size of 3 μm ;
2. The carbon raw material: Graphite powders having an average particle size of 10 μm ;

3. The iron raw material: metallic iron powders having an average particle size of 60 μm ;
4. The platinum material: metallic platinum powders having an average particle size of 7 μm ;
5. Boron nitride having an average particle size of 2 μm ;
6. The silver raw material: metallic silver powders having an average particle size of 8 μm ; and
7. The copper raw material: metallic copper powders having an average particle size of 80 μm .

Example 1 (E1): the iron-platinum-based sputtering target

Diamond powders and a plurality of grinding balls having a diameter of 5 mm were placed in a ball mill jar and subjected to high-energy ball milling for 3 hours to obtain a ground diamond powder having an average particle size of 0.5 μm . In addition, the ground diamond powder, a metallic platinum powder and a metallic iron powder were passed through a 400-mesh sieve and stored for use.

Next, based on the total amount of the atoms of all the raw materials, 25 at% of the ground diamond powder, 30 at% of the metallic platinum powder, and 45 at% of the metallic iron powder were respectively weighed and then mixed to obtain a mixture, and the mixture was subjected to high-energy ball milling for 3 hours to obtain an iron-platinum-based alloy powder.

Next, the iron-platinum-based alloy powder was uniformly filled in a mold and was sintered by HIP for 3 hours at a sintering temperature of 800°C under a sintering pressure of 150 MPa. Finally, computer numerical control

(CNC) lathe processing was carried out to obtain an iron-platinum-based sputtering target in the shape of a pie with a diameter of 165 mm and a thickness of 4 mm.

Examples 2 to 8 (E2-E8): the iron-platinum-based sputtering target

The manufacturing methods employed in Examples 2 to 8 were similar to the manufacturing of the iron-platinum-based sputtering target of Example 1. Each of the iron-platinum-based sputtering targets of Examples 2 to 8 was prepared firstly by weighing and mixing the iron raw material, the platinum raw material, and the ground carbon powder according to the compositions shown in Table 1 below to obtain a mixture, and the mixture was subjected to high-energy ball milling which was the same as Example 1 and then sintered according to the sintering methods and temperatures shown in Table 1 below.

The main differences between the methods of manufacturing the iron-platinum-based targets of Examples 1 to 8 were the types of the carbon raw materials, the amount of each raw material, the sintering method and the sintering temperature. The carbon raw materials adopted in Examples 2 and 5 were graphite powders, and the carbon raw materials adopted in Examples 3, 4, 6, 7 and 8 were the same diamond powders as that in Example 1.

Further, the sintering step in Examples 3 and 8 firstly lasted 0.5 hour in SPS and then lasted 3 hours in HIP, wherein the sintering temperatures of SPS and HIP were shown in Table 1 below.

Examples 9 and 10 (E9 and E10): the iron-platinum-based sputtering target

The iron-platinum-based sputtering targets of Examples 9 and 10

further contained boron nitride in addition to the iron raw material, the platinum raw material, and the carbon raw material adopted in the iron-platinum-based sputtering targets of Examples 1 to 8. The manufacturing methods used in Examples 9 and 10 were similar to that of Example 1, and the diamond powders were firstly treated with high-energy ball milling like Example 1. In addition, the boron nitride was passed through a 400-mesh sieve and stored for use. Each of the iron-platinum-based sputtering targets of Examples 9 and 10 was prepared firstly by weighing and mixing the iron raw material, the platinum raw material, the ground diamond powders and the boron nitride to obtain a mixture, and the mixture was subjected to high-energy ball milling which was the same as Example 1 to obtain an iron-platinum-based alloy powder; and then the iron-platinum-based alloy powder was sintered for 3 hours according to the sintering methods and temperature shown in Table 1 below. Finally, CNC lathe processing was carried out to obtain an iron-platinum-based sputtering target in the shape of a pie with a diameter of 165 mm and a thickness of 4 mm. The manufacturing methods of the iron-platinum-based sputtering targets of Examples 9 and 10 were differentiated from that of Example 1 in the addition of boron nitride as a raw material, the amount of each raw material and the sintering temperature.

Examples 11 to 14 (E11-E14): the iron-platinum-based sputtering target

The iron-platinum-based sputtering targets of Examples 11 to 14 further contained silver or copper in addition to the iron raw material, the platinum raw material, and the carbon raw material adopted in the iron-

platinum-based sputtering targets of Examples 1 to 8. The manufacturing methods used in Examples 11 to 14 were similar to that of Example 1, and the diamond powders were firstly treated with high-energy ball milling like Example 1. In addition, the silver raw material or copper raw material was passed through a 140-mesh sieve and stored for use. Each of the iron-platinum-based sputtering targets of Examples 11 to 14 was prepared firstly by weighing and mixing the iron raw material, the platinum raw material, the ground diamond powders and the silver raw material (such as Examples 11 and 13) or the copper raw material (such as Examples 12 and 14) to obtain a mixture, and the mixture was subjected to high-energy ball milling which was the same as Example 1 to obtain an iron-platinum-based alloy powder; and then the iron-platinum-based alloy powder was sintered for 3 hours according to the sintering methods and temperature shown in Table 1 below. Finally, CNC lathe processing was carried out to obtain an iron-platinum-based sputtering target in the shape of a pie with a diameter of 165 mm and a thickness of 4 mm. The manufacturing methods of the iron-platinum-based sputtering targets of Examples 11 to 14 were differentiated from that of Example 1 in the addition of the silver raw material or copper raw material, the amount of each raw material and the sintering temperature.

Comparative Example 1 (CE1): the iron-platinum-based sputtering target

The manufacturing method of the iron-platinum-based sputtering target employed in Comparative Example 1 was substantially the same as that in Example 1. The main differences were the amount of the carbon raw material,

the sintering methods and the sintering temperature. The manufacturing method of Comparative Example 1 was as follows: Diamond powders were subjected to high-energy ball milling which was the same as Example 1; the iron raw material, the platinum raw material, and the ground diamond powders according to the composition shown in Table 1 below were respectively weighed and then mixed to obtain a mixture, and the mixture was subjected to high-energy ball milling which was the same as Example 1 to obtain an iron-platinum-based alloy powder; and then the iron-platinum-based alloy powder was sintered for 3 hours in hot pressing (HP) at the sintering temperature of 1100°C. Finally, CNC lathe processing was carried out to obtain an iron-platinum-based sputtering target in the shape of a pie with a diameter of 165 mm and a thickness of 4 mm.

Comparative Example 2 (CE2): the iron-platinum-based sputtering target

The manufacturing method of the iron-platinum-based sputtering target employed in Comparative Example 2 was substantially the same as that in Example 3. The main difference was that the carbon raw material in Comparative Example 2 was not subjected to high-energy ball milling. The manufacturing method of Comparative Example 2 was as follows: the diamond powders which were not processed by high-energy ball milling, a metallic platinum powder and a metallic iron powder were respectively weighed and then passed through a 400-mesh sieve, and all the raw materials were subjected to high-energy ball milling for 3 hours after mixture to obtain an iron-platinum-based alloy powder. The iron-platinum-based alloy powder was uniformly

filled in a mold and was firstly sintered by SPS for 0.5 hour at a sintering temperature of 800°C under a sintering pressure of 60 MPa and then sintered by HIP for 3 hours at a sintering temperature of 1100°C under a sintering pressure of 150 MPa. Finally, CNC lathe processing was carried out to obtain an iron-platinum-based sputtering target in the shape of a pie with a diameter of 165 mm and a thickness of 4 mm.

Comparative Example 3 (CE3): the iron-platinum-based sputtering target

The manufacturing method of the iron-platinum-based sputtering target employed in Comparative Example 3 was substantially the same as that in Example 5. The main differences were the amount of the carbon raw material, sintering methods and that the carbon raw material of Comparative Example 3 was not subjected to high-energy ball milling. The manufacturing method of Comparative Example 3 was as follows: a graphite powder which was not processed by high-energy ball milling, a metallic platinum powder and a metallic iron powder according to the compositions shown in Table 1 below were respectively weighed and then passed through a 400-mesh sieve, and all the powders were subjected to high-energy ball milling for 3 hours after mixture to obtain an iron-platinum-based alloy powder. The iron-platinum-based alloy powder was uniformly filled in a mold and was sintered by HP for 3 hours at a sintering temperature of 1100°C. Finally, CNC lathe processing was carried out to obtain an iron-platinum-based sputtering target in the shape of a pie with a diameter of 165 mm and a thickness of 4 mm.

Comparative Example 4 (CE4): the iron-platinum-based

sputtering target

The manufacturing method of the iron-platinum-based sputtering target employed in Comparative Example 4 was substantially the same as that in Example 3. The main differences were the mixture ratio of the raw materials, mixing order and sintering temperature. The manufacturing method of Comparative Example 4 was as follows: Diamond powders were subjected to high-energy ball milling which was the same as Example 1; the ground diamond powders and the metallic iron powder according to the compositions shown in Table 1 below were respectively weighed and then mixed to obtain a mixture, and the mixture was subjected to high-energy ball milling for 3 hours to obtain a powder containing iron-carbon compounds. The powder containing iron-carbon compounds was added and mixed uniformly with a metallic platinum powder, and firstly sintered by SPS for 0.5 hour at a sintering temperature of 800°C under a sintering pressure of 60 MPa and then sintered by HIP for 3 hours at a sintering temperature of 900°C under a sintering pressure of 150 MPa. Finally, CNC lathe processing was carried out to obtain an iron-platinum-based sputtering target in the shape of a pie with a diameter of 165 mm and a thickness of 4 mm.

Comparative Example 5 (CE5): the iron-platinum-based sputtering target

The manufacturing method of the iron-platinum-based sputtering target employed in Comparative Example 5 was substantially the same as that in Example 3. The main differences were the mixture ratio of the raw materials, mixing order and sintering temperature. The manufacturing method of

Comparative Example 5 was as follows: Diamond powders were subjected to high-energy ball milling which was the same as Example 1; the ground diamond powders and a metallic platinum powder according to the compositions shown in Table 1 below were respectively weighed and then mixed to obtain a mixture, and the mixture was subjected to high-energy ball milling for 3 hours to obtain a mixture powder. The mixture powder was added and mixed uniformly with a metallic iron powder, and firstly sintered by SPS for 0.5 hour at a sintering temperature of 800°C under a sintering pressure of 60 MPa and then sintered by HIP for 3 hours at a sintering temperature of 900°C under a sintering pressure of 150 MPa. Finally, CNC lathe processing was carried out to obtain an iron-platinum-based sputtering target in the shape of a pie with a diameter of 165 mm and a thickness of 4 mm.

Comparative Example 6 (CE6): the iron-platinum-based sputtering target

The manufacturing method of the iron-platinum-based sputtering target employed in Comparative Example 6 was substantially the same as that in Example 2. The main differences were the mixing order of the raw materials and that the carbon raw material of Comparative Example 6 was not subjected to high-energy ball milling. The manufacturing method of Comparative Example 6 was as follows: a graphite powder which was not processed by high-energy ball milling and a metallic iron powder according to the compositions shown in Table 1 below were respectively weighed and then mixed to obtain a mixture, and the mixture was subjected to high-energy ball milling for 3 hours to obtain a powder containing iron-carbon compounds. The

powder containing iron-carbon compounds was added and mixed uniformly with a metallic platinum powder, and firstly sintered by SPS for 0.5 hour at a sintering temperature of 800°C under a sintering pressure of 60 MPa and then sintered by HIP for 3 hours at a sintering temperature of 900°C under a sintering pressure of 150 MPa. Finally, CNC lathe processing was carried out to obtain an iron-platinum-based sputtering target in the shape of a pie with a diameter of 165 mm and a thickness of 4 mm.

Comparative Example 7 (CE7): the iron-platinum-based sputtering target

The manufacturing method of the iron-platinum-based sputtering target employed in Comparative Example 7 was substantially the same as that in Example 2. The main differences were the mixing order of the raw materials and that the carbon raw material of Comparative Example 7 was not subjected to high-energy ball milling. The manufacturing method of Comparative Example 7 was as follows: a graphite powder which was not processed by high-energy ball milling and a metallic platinum powder according to the compositions shown in Table 1 below were respectively weighed and then mixed to obtain a mixture, and the mixture was subjected to high-energy ball milling for 3 hours to obtain a mixture powder. The mixture powder was added and mixed uniformly with a metallic iron powder, and firstly sintered by SPS for 0.5 hour at a sintering temperature of 800°C under a sintering pressure of 60 MPa and then sintered by HIP for 3 hours at a sintering temperature of 900°C under a sintering pressure of 150 MPa. Finally, CNC lathe processing was carried out to obtain an iron-platinum-based sputtering target in the shape of a

pie with a diameter of 165 mm and a thickness of 4 mm.

Comparative Example 8 (CE8): the iron-platinum-based sputtering target

The manufacturing of the iron-platinum-based sputtering target employed in Comparative Examples 8 was similar to that of Example 1. The iron-platinum-based sputtering target of Comparative Example 8 was prepared by weighing and mixing the iron raw material, the platinum raw material, and the ground diamond powder according to the compositions shown in Table 1 below to obtain a mixture. The main differences between the manufacturing methods of the iron-platinum-based targets of Examples 1 and Comparative Example 8 were that the ground diamond powder of Comparative Example 8 was in the amount of 60 at% based on the total amount of the atoms of all the raw materials, and that the sintering temperature of Comparative Example 8 was 1000°C.

Comparative Example 9 (CE9): the iron-platinum-based sputtering target

The manufacturing method of the iron-platinum-based sputtering target employed in Comparative Example 9 was substantially the same as that in Example 5. The main differences were the mixture ratio of the raw materials and that the carbon raw material of Comparative Example 9 was not subjected to high-energy ball milling. The manufacturing method of Comparative Example 9 was as follows: a graphite powder which was not processed by high-energy ball milling, a metallic platinum powder and a metallic iron powder were respectively weighed and then passed through a 400-mesh sieve,

and all the powders were subjected to high-energy ball milling for 3 hours after mixture to obtain an iron-platinum-based alloy powder. The iron-platinum-based alloy powder was uniformly filled in a mold and was sintered by HIP for 3 hours at a sintering temperature of 1100°C. Finally, CNC lathe processing was carried out to obtain an iron-platinum-based sputtering target in the shape of a pie with a diameter of 165 mm and a thickness of 4 mm.

Analysis 1: Metallographic microstructure of the iron-platinum-based sputtering targets

Analysis 1-1: Observation of the distribution pattern and morphology of each phase in the metallographic microstructure

The sample piece was 10 mm × 10 mm and was taken from the portion at 0.5 radius from the center of the iron-platinum-based sputtering target of Examples 1 to 14 and Comparative Examples 1 to 9 respectively by wire cutting.

The metallographic microstructure of each of the sample pieces of the iron-platinum-based sputtering targets of Examples 1 to 14 and Comparative Examples 1 to 9 was photographed at an appropriate magnification by SEM. In the present specification, an iron-platinum-based sputtering target (such as Example 1) obtained by using diamond powders as the carbon raw material and an iron-platinum-based sputtering target (such as Example 6) obtained by using a graphite powder as the carbon raw material were taken as examples. The SEM images of the metallographic microstructures of the iron-platinum-based sputtering targets of Examples 1 and 6 were shown in Figs. 1 and 2 respectively; in addition, the SEM images of the iron-platinum-based sputtering

targets of Comparative Examples 1, 2, 4, and 5 were shown in Figs. 3 to 6, respectively. The metallographic composition of Example 2 was analyzed by energy dispersive spectrometers (EDS), and the composition of the black phase was 100 at% carbon (C), and the composition of the gray phase was 46.21 at% iron (Fe)-53.79 at% platinum (Pt). The composition of overall phases of the sample piece was 41.92 at% Fe-35.55 at% Pt-22.53 at% C.

In the comparison of Figs. 1, 2, 3 to 6, regardless of types of the carbon raw materials, as long as the carbon raw materials were pretreated by high-energy ball milling and then the iron-platinum-based sputtering target was obtained by HIP, the black phases of the obtained iron-platinum-based sputtering targets such as Examples 1 and 6 were distributed in a pattern of uniform fine points. In contrast, for the iron-platinum-based sputtering target either obtained by hot press molding in Comparative Example 1 or obtained by a method without high-energy ball milling the carbon raw material in advance in Comparative Example 2, the black phase (carbon phase) thereof was distributed in a coarse pattern. In addition, the carbon raw material, the iron raw material and the platinum raw material were not processed by high-energy ball milling simultaneously in Comparative Examples 4 and 5, the carbon phases of the iron-platinum-based sputtering targets thereof were in a pattern of remarkably uneven distribution. Further, in Comparative Example 4, by firstly high-energy ball milling the carbon raw material and the iron raw material together, more amounts of iron-carbon compounds were generated and a large number of pores were formed on the iron-platinum-based sputtering target after sintering. In Comparative Example 5, by grinding the carbon raw material and

the platinum raw material firstly by high-energy ball milling, although the number of pores on the iron-platinum-based sputtering target after sintering was greatly reduced, an elongated and coarse black phase of carbon compounds was generated on the iron-platinum-based sputtering target after sintering.

Analysis 1-2: Average size of carbon phases in the metallographic microstructure

The metallographic microstructure of the sample pieces of the iron-platinum-based sputtering targets of Examples 1 to 14 and Comparative Examples 1 to 9 were respectively analyzed by the image analysis software, Image-Pro Plus. The metallographic images magnified 5000 times were photographed by SEM. Three different regions in one sample piece were chosen randomly to obtain three metallographic images, and the sizes of the carbon phase in the three metallographic images were analyzed by said image analysis software and were calculated by software to obtain the average size which represents the average size of the carbon phase of the iron-platinum-based sputtering target. The results were shown in Table 1 below.

Analysis 1-3: the aspect ratio of carbon phases in the metallographic microstructure

The metallographic microstructure of the sample pieces of the iron-platinum-based sputtering targets of Examples 1 to 14 and Comparative Examples 1 to 9 were respectively analyzed by the image analysis software, Image-Pro Plus. The metallographic images magnified 5000 times were photographed by SEM. Three different regions in one sample piece were chosen randomly to obtain three metallographic images, and the aspect ratio of

the carbon phase in each of the three metallographic images was analyzed by the built-in "Aspect" function in said image analysis software and calculated by software to obtain the average of the aspect ratio which represents the average of the aspect ratio of the carbon phases of the iron-platinum-based sputtering target. The results were shown in Table 1 below.

Analysis 2: FWHM of the characteristic peaks of the lattice plane (111) of the Fe-Pt phases in the iron-platinum-based sputtering target

Each of the sample pieces of the iron-platinum-based targets of Examples 1 to 14 and Comparative Examples 1 to 9 was sequentially ground by sandpaper numbers #60, #120, #240, #320, #600, # 1000, #1500, #2000, and #4000 after the observation of each of the metallographic microstructures was completed; the grinding was performed in a cross grinding mode by rotating 90 degrees to remove the grinding marks. The sample pieces of the iron-platinum-based sputtering target of Examples 1 to 14 and Comparative Examples 1 to 9 for X-Ray Diffraction (XRD) were ready after ground by sandpaper #4000. Next, the crystal structures of the iron-platinum-based sputtering targets of Examples 1 to 14 and Comparative Examples 1 to 9 were analyzed by XRD under the conditions of a step size of 0.04° and 2θ measurement range from $20-100^\circ$. In the X-ray diffraction pattern, the intensity of the characteristic peak corresponding to each crystal plane is positively correlated with the crystal orientation of the crystal grains on the surface of the sample piece. Thereafter, the FWHM of the characteristic peak of the lattice plane (111) of the Fe-Pt phase in the XRD pattern was analyzed by software, Jade. The results were shown in Table 1 below.

As shown in Fig. 7, the characteristic peak with the strongest signal of 41.181° in the XRD pattern of Example 1 represented the lattice plane (111) of the Fe-Pt phase. In addition, Fig. 8 showed the XRD pattern of a standard sample of Pt_3Fe , a standard sample of $\text{Fe}_{1.28}\text{Pt}_{0.72}$, a standard sample of FePt, Fe_4C and Comparative Example 1 from bottom to top. According to the comparison of Figs. 7 and 8, the signal of the lattice plane (111) representing the Fe-Pt phase in Fig. 7 was strong and its characteristic peak was narrow with few hetero phases. In comparison, the signal of the lattice plane (111) representing the Fe-Pt phase in Fig. 8 was weaker and its characteristic peak was wider, which means the iron-platinum-based sputtering target of Comparative Example 1 had various phases of alloy.

Analysis 3: The amount of carbon precipitation on the surface of the iron-platinum-based sputtering target

A sample piece of 30 mm × 30 mm × 3 mm was obtained from each of the iron-platinum-based targets of Examples 1 to 14 and Comparative Examples 1 to 9 by wire cutting. Each of the sample pieces of the iron-platinum-based sputtering targets of the Examples 1 to 14 and Comparative Examples 1 to 9 was sequentially ground with sandpaper numbers #80, #240, #400, #800, #1500, #2500, and #4000 in a cross grinding mode by rotating 90 degrees to remove the grinding marks; and was put into an alcohol solution for washing in an ultrasonic cleaning machine for 5 minutes after ground by sandpaper number #4000.

Next, each of the washed sample pieces was placed in 100 ml of ultrapure water, oscillated at 25°C for 10 minutes by an ultrasonic cleaning machine, and

then detected by inductively coupled plasma optical emission spectrometry (ICP-OES). The amount of carbon in the ultrapure water after oscillation represented the amount of carbon precipitation on the surface of the iron-platinum-based sputtering target. The results were shown in Table 1 below.

Table 1: The compositions, sintering methods and temperatures, carbon phase characteristics, XRD characteristics, and carbon precipitation amounts of the iron-platinum-based sputtering targets of Examples 1 to 14 (E1 to E14) and Comparative Examples 1 to 9 (CE1 to CE9).

No.	Fe (at%)	Pt (at%)	C (at%)	BN (at%)	Ag (at%)	Cu (at%)	Sintering		Carbon phase		FWHM of lattice plane(111) (°)	Amount of Carbon precipitation (ppm)
							methods	Temp. (°C)	Avg. size(μm)	Avg. aspect ratio		
E1	45	30	25	0	0	0	HIP	800	0.378	1.87	0.187	41
E2	35	30	35	0	0	0	HIP	900	1.789	2.78	0.257	98
E3	25	30	45	0	0	0	SPS	700	0.614	1.95	0.214	68
							HIP	1000				
E4	40	15	45	0	0	0	HIP	1000	1.487	2.66	0.159	105
E5	50	35	15	0	0	0	HIP	1100	1.754	2.91	0.288	96
E6	55	20	25	0	0	0	HIP	800	0.339	1.77	0.201	45
E7	45	30	25	0	0	0	HIP	1000	0.597	1.91	0.167	59
E8	45	30	25	0	0	0	SPS	1000	1.154	2.87	0.258	95
							HIP	1000				
E9	45	30	20	5	0	0	HIP	900	0.348	1.9	0.223	29

E10	40	30	22	8	0	0	0	0	0	0.321	1.78	0.185	25
E11	44	30	25	0	1	0	0	0	0	0.366	1.67	0.174	65
E12	44	30	25	0	0	0	1	0	0	0.374	1.76	0.167	54
E13	43.5	30	25	0	1.5	0	0	0	0	0.364	1.34	0.147	58
E14	43.5	30	25	0	0	0	0	1.5	0	0.389	1.65	0.16	53
CE1	35	30	35	0	0	0	0	0	0	5.325	3.67	0.777	194
CE2	45	30	25	0	0	0	0	0	0	2.912	3.55	0.676	154
CE3	45	30	25	0	0	0	0	0	0	9.987	7.35	0.762	445
CE4	45	30	25	0	0	0	0	0	0	4.345	5.12	0.78	286
CE5	45	30	25	0	0	0	0	0	0	2.477	3.49	0.76	159
CE6	35	30	35	0	0	0	0	0	0	7.798	6.99	0.841	422
CE7	35	30	35	0	0	0	0	0	0	8.889	5.97	0.625	322
CE8	25	15	60	0	0	0	0	0	0	11.213	9.21	0.857	798

CE9	70	20	10	0	0	0	0	HIP	1100	3.23	2.22	0.341	144
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Results and discussion

In view of the results of Analysis 1-2, 1-3 and Analysis 3 for Examples 1 to 14 and Comparative Examples 1 to 9, the amount of carbon raw materials and its appropriate pretreatment were controlled, and the carbon raw material, iron raw material and the platinum raw material were subjected to mechanical alloying treatment simultaneously, and the iron-platinum-based alloy powder was sintered by HIP in each of Examples 1 to 14. Further, in each of Examples 1 to 14, the amount of the carbon was controlled within the range equal to or smaller than 45 at%, and the phase of the carbon in the metallographic microstructure of the iron-platinum-based sputtering target was controlled to have an average size less than or equal to 2 μm and an average aspect ratio less than 3. Accordingly, the amount of carbon precipitation on the surface of each of the iron-platinum-based sputtering targets of Examples 1 to 14 was indeed lower than that on the surface of each of the iron-platinum-based sputtering targets of Comparative Examples 1 to 9.

Further, according to the result of the amount of carbon precipitation in each of the iron-platinum-based sputtering targets of Examples 1 to 14 in Analysis 3, the FWHM of the characteristic peak of the lattice plane (111) of the iron-platinum alloy was less than 0.3° in the X-ray diffraction pattern of the iron-platinum-based sputtering target. In contrast, the FWHMs of the characteristic peaks of the lattice plane (111) of the iron-platinum alloys were all greater than 0.3° in the X-ray diffraction pattern of the iron-platinum-based sputtering targets of Comparative Examples 1 to 9.

Further, the carbon of the iron-platinum-based sputtering target of each of

Examples 1, 6 to 8 was in the amount of 25 at% and that of Example 5 was in the amount of 15 at%. Comparing the results of the amounts of carbon precipitation of Examples 1, 6 to 8 to that of Example 5 in Analysis 3, the amounts of carbon precipitation of Examples 1, 6 to 8, wherein diamond powders were chosen as the carbon raw material, were less than that of Example 5, wherein graphite powders were chosen as the carbon raw material, even if the iron-platinum-based sputtering targets of Examples 1, 6 to 8 have greater carbon content. Accordingly, diamond powders as the carbon raw material reduce the amount of carbon precipitation on the surface of the iron-platinum-based sputtering target.

Further, comparing the results of the amount of carbon precipitation of Examples 1 to 8 to that of Examples 9 and 10 in Analysis 3, the iron-platinum-based sputtering targets of Examples 9 and 10 contained boron nitride, and the amounts of carbon precipitation on the surface of the iron-platinum-based sputtering target were further reduced.

According to the results of the amounts of carbon precipitation of Comparative Examples 1 to 9 in Analysis 3, the amounts of carbon precipitation on the surface of the iron-platinum-based sputtering target can be further reduced by firstly subjecting the carbon raw material to the treatment of high-energy mechanical milling. However, the amounts of carbon precipitation on the surface of the iron-platinum-based sputtering target will not be reduced to fit the acceptable quality level unless the amount of the carbon raw material is simultaneously controlled within an appropriate range (such as in Comparative Example 8), the sintering method includes HIP (such as in

Comparative Example 1) or that the carbon raw material, the iron raw material, and the platinum raw material were mechanically alloyed simultaneously (such as in Comparative Examples 4 and 5).

From above, by proper control of the amount of carbon and the phase of the carbon in the metallographic microstructure of the iron-platinum-based sputtering target, the present invention not only improves the distribution uniformity of the phase compositions of the iron-platinum-based sputtering target, but also suppresses the precipitation of black carbon particles on the surface of the iron-platinum-based sputtering target to reduce the occurrence probability of abnormal discharge during sputtering the iron-platinum-based sputtering target, and to alleviate the problem of falling particles on the film layer, so as to improve the quality and yield rate of the magnetic recording layer formed by sputtering the target.

The embodiments described above were merely illustrative examples of the present invention and are not intended to limit the scope of the claims herein. The scope of the protection to be claimed is based on the scope of claims, and is not limited to the specific embodiments described above.

CLAIMS:

1. An iron-platinum-based sputtering target comprising iron (Fe), platinum (Pt), carbon (C) and boron nitride; wherein the carbon is in an amount greater than or equal to 15 at% and less than or equal to 45 at% based on a total amount of atoms of the iron-platinum-based sputtering target, and a metallographic microstructure of the iron-platinum-based sputtering target has a carbon phase having an average size less than or equal to 2 μm and an average aspect ratio less than 3.
2. The iron-platinum-based sputtering target according to claim 1, wherein the iron is in an amount greater than or equal to 20 at% and less than or equal to 70 at% and the platinum is in an amount greater than or equal to 10 at% and less than or equal to 40 at% based on the total amount of the atoms of the iron-platinum-based sputtering target.
3. The iron-platinum-based sputtering target according to claim 1 or 2, wherein the carbon is a diamond, a graphite, a carbon nanotube, or any combination thereof.
4. The iron-platinum-based sputtering target according to claim 3, wherein the carbon is the diamond.
5. The iron-platinum-based sputtering target according to any of claims 1 to 4, wherein the iron-platinum-based sputtering target contains iron-platinum alloys, an X-ray diffraction pattern of the iron-platinum-based sputtering target has a characteristic peak of a lattice plane (111) of the iron-platinum alloys, and the characteristic peak of the lattice plane (111) has a full width at half

maximum (FWHM) less than 0.3° .

6. The iron-platinum-based sputtering target according to any of claims 1 to 5, wherein the iron-platinum-based sputtering target further comprises copper, silver or any combination thereof.

7. A method for manufacturing an iron-platinum-based sputtering target comprising iron (Fe), platinum (Pt) and carbon (C), which comprises:

step (A): grinding a carbon raw material by high-energy mechanical milling to obtain a ground carbon powder having an average particle size ranging from $0.3\text{ }\mu\text{m}$ to $3\text{ }\mu\text{m}$;

step (B): mixing and mechanically alloying the ground carbon powder, an iron raw material and a platinum raw material to obtain an iron-platinum-based alloy powder; and

step (C): sintering the iron-platinum-based alloy powder by a sintering method comprising hot isostatic pressing to obtain the iron-platinum-based sputtering target; wherein the carbon is in an amount greater than or equal to 15 at% and less than or equal to 45 at% based on a total amount of atoms of the iron-platinum-based sputtering target; and a metallographic microstructure of the iron-platinum-based sputtering target has a carbon phase having an average size less than or equal to $2\text{ }\mu\text{m}$ and an average aspect ratio less than 3.

8. The method according to claim 7, wherein the iron is in an amount greater than or equal to 20 at% and less than or equal to 70 at% and the platinum is in an amount greater than or equal to 10 at% and less than or equal to 40 at% based on the total amount of the atoms of the iron-platinum-based

sputtering target.

9. The method according to claim 7 or 8, wherein in the step (B) the iron raw material has an average particle size ranging from 20 μm to 80 μm , and the platinum raw material has an average particle size ranging from 1 μm to 10 μm .

10. The method according to any of claims 7 to 9, wherein the step (B) comprises: step (B1): mixing the ground carbon powder, the iron raw material, and the platinum raw material to obtain a mixture; and step (B2): mechanically alloying the mixture to obtain the iron-platinum-based alloy powder.

11. The method according to any of claims 7 to 9, wherein the step (B) further comprises a boron nitride having an average particle size of less than 3.0 μm , a copper raw material having an average particle size ranging from 50 μm to 150 μm , a silver raw material having an average particle size ranging from 5 μm to 10 μm , or any combination thereof.

12. The method according to any of claims 7 to 11, wherein the sintering method in the step (C) further comprises spark plasma sintering (SPS).

13. The method according to any of claims 7 to 12, wherein a sintering temperature is from 500°C to 1300°C and a sintering pressure is from 50 MPa to 200 MPa in the step (C).