

ALLOYS FOR SOFT-MAGNETIC FILM LAYERS IN PERPENDICULAR
MAGNETIC RECORDING MEDIA, SPUTTERING TARGET
MATERIALS AND METHOD FOR PRODUCING THE SAME

5 CROSS-REFERENCE TO RELATED APPLICATION

[0001] The present application claims priority to Japanese Patent Application No. 2008-182645 filed July 14, 2008, which is incorporated herein by reference in its entirety.

10 TECHNICAL FIELD

[0002] The present invention relates to a Co-Fe-Ni-based alloy which is used for producing a soft-magnetic film layer in a perpendicular magnetic recording medium. The present invention also relates to a sputtering target using the
15 Co-Fe-Ni-based alloy and a method for producing the sputtering target.

BACKGROUND ART

[0003] In recent years, accompanied with remarkable progress
20 of magnetic recording technology, recording density in the magnetic recording media is getting higher in order to increase drive capacity, while a perpendicular magnetic recording system which can attain a higher recording density than the conventional longitudinal magnetic recording media has been
25 put into practical use. The perpendicular magnetic recording system is a system in which a magnetization-easy axis is oriented in the direction perpendicular to a medium surface in the magnetic film of a perpendicular magnetic record medium, and is suitable for high record densities. For the perpendicular
30 magnetic recording system, a two-layered record medium has been developed having a magnetic record film layer with an improved record sensitivity and a soft magnetic film layer. A CoCrPt-SiO₂ based alloy is generally used in the magnetic record film layer.

35 [0004] On the other hand, with regard to soft magnetic film layers, a method for producing a Co-alloy target material

comprising 1 to 10 at.% of Zr and 1 to 10 at.% of Nb and/or Ta with the balance substantially being Co is disclosed, for example, in Japanese Patent Laid-Open Publication No. 2005-320627 (Patent Literature 1), which proposes quenching a molten
5 Co-alloy for solidification treatment to prepare an alloy powder; and pressing and sintering the alloy powder having particle sizes of 500 μm or less to provide a CoZrNb/Ta alloy target material. A high saturation magnetic flux density and high amorphousness are required for the soft magnetic film layer of
10 this perpendicular magnetic recording medium.

[0005] However, there is a problem that the CoZrNb/Ta alloy disclosed in Patent Literature 1 results in a lower saturation magnetic flux density, as compared to those required for soft-magnetic film layers of perpendicular magnetic recording
15 media. In view of this, as disclosed in Japanese Patent Laid-Open Publication No. 2007-284741 (Patent Literature 2), a soft-magnetic target material was proposed which is made of an Fe-Co based alloy having an atomic ratio of Fe:Co of 100:0 to 20:80 and containing one or more of Al and Cr of 0.2 to 5 at.%
20 in order to achieve a good balance among a high saturation magnetic flux density, high amorphousness, and high corrosion resistance. It is noted that amorphousness as mentioned above refers to degree of ease that an alloy becomes amorphous when the alloy is subjected to rapid solidification or
25 sputtering, while corrosion resistance refers to an atmospheric corrosion resistance at a level such that no rust occurs under normal circumstances under which electronic parts are used.

[0006] However, when an alloy having a high saturation magnetic flux density as disclosed in Patent Literature 2 is used
30 as a soft-magnetic film layer, the sputtering target material for making a film of this alloy also exhibits a high saturation magnetic flux density, causing a decrease in PTF value, which affects sputtering rate in magnetron sputtering or stability in film-forming process. It is noted that PTF value is proportion of
35 magnetic lines leaked to the front surface of the target material during magnetron sputtering in view of magnetic lines

generated from a magnet positioned on the back surface of a sputtering target material, and is a factor which affects sputtering efficiency and film yield.

5 SUMMARY OF THE INVENTION

[0007] The inventors have currently found that a Co-Fe-Ni-based alloy having a certain composition exhibits a high saturation magnetic flux density, high amorphousness, and high corrosion resistance. The inventors also found that, by
10 using a certain powder mixture as a raw-material powder for a sputtering target material for making a film of this alloy, it is possible to significantly improve PTF value as compared to a sputtering target material which is made of a raw-material powder having a single composition and has a uniform texture
15 of the same composition.

[0008] It is therefore an object of the invention to provide an alloy for a soft-magnetic film layer in a perpendicular magnetic recording medium which is superior in saturation magnetic flux density, amorphousness and corrosion resistance, and a
20 sputtering target material which has this superior alloy composition as a whole but has a high PTF value, which can be effectively used in magnetron sputtering.

[0009] According to an aspect of the present invention, there is provided an alloy for a soft-magnetic film layer in a
25 perpendicular magnetic recording medium, the alloy comprising in at. %:

Fe: 10 to 45%;

Ni: 1 to 25%;

One or more of Zr, Hf, Nb, Ta and B: 5 to 10% in total
30 of $Zr+Hf+Nb+Ta+B/2$, wherein B is in an amount of from 0 to 7%; and

One or more of Al and Cr: 0 to 5% in total of Al+Cr;
and

the balance Co and unavoidable impurities: 37% or
35 more, and the alloy satisfying in atomic ratio:

$Fe/(Co+Fe+Ni)$: 0.10 to 0.50; and

Ni/(Co+Fe+Ni): 0.01 to 0.25.

[0010] According to another aspect of the present invention, there is provided a method for producing a sputtering target material for a soft-magnetic film layer in a perpendicular magnetic recording medium, the method comprising the steps of:

(a) providing two or more raw-material powders having different compositions so as to constitute the alloy for a soft-magnetic film according to claim 1 in total composition, wherein at least one powder of the two or more powders comprises in at. %:

Ni: 20 to 34%;

Co: 0 to 6%;

One or more of Zr, Hf, Nb, Ta and B: 3 to 12% in total of Zr+Hf+Nb+Ta+B/2, wherein B is in an amount of from 0 to 7%; and

One or more of Al and Cr: 0 to 5% in total of Al+Cr; and

the balance Fe and unavoidable impurities, and satisfies in atomic ratio:

Ni/(Fe+Ni): 0.27 to 0.35;

(b) mixing the two or more powders to provide a mixture; and

(c) consolidating the mixture to form a sputtering target material.

[0011] According to another aspect of the present invention, there is provided a sputtering target material which is produced by the above method.

DESCRIPTION OF EMBODIMENTS

Alloy for Soft-Magnetic Film Layer in Perpendicular Magnetic Recording Medium

[0012] The alloy for a soft-magnetic film layer in a perpendicular magnetic recording medium according to the present invention comprises in at. %: Fe: 10 to 45%; Ni: 1 to 25%; one or more of Zr, Hf, Nb, Ta and B: 5 to 10% in total of Zr+Hf+Nb+Ta+B/2, wherein B is in an amount of from 0 to 7%;

and one or more of Al and Cr: 0 to 5% in total of Al+Cr; and the balance Co and unavoidable impurities: 37% or more, preferably consists of these components. This alloy satisfies in atomic ratio: $\text{Fe}/(\text{Co}+\text{Fe}+\text{Ni})$: 0.10 to 0.50; and $\text{Ni}/(\text{Co}+\text{Fe}+\text{Ni})$: 0.01 to 0.25. The reasons for these compositional limitations of the alloy for a soft-magnetic film layer in a perpendicular magnetic recording medium are described below.

[0013] Fe is an element which has a ferromagnetic property as well as Co and Ni. On the other hand, Fe is an element which deteriorates corrosion resistance as compared to Co and Ni. However, an Fe content of less than 10% results in a low saturation magnetic flux density, while an Fe content of more than 45% deteriorates corrosion resistance. Therefore, the Fe content in the alloy is 10 to 45%, preferably 20 to 40%.

[0014] Ni is an element which has a ferromagnetic property as well as Co and Fe, while having a low saturation magnetic flux density as compared to Co and Fe. On the other hand, Ni has a corrosion resistance that is considerably higher than that of Fe and is slightly better than that of Co. However, an Ni content of less than 1% results in a poor corrosion resistance while an Ni content of more than 25% results in a low saturation magnetic flux density. Accordingly, the Ni content in the alloy is 1 to 25 %, preferably 10 to 22%.

[0015] Zr, Hf, Nb, Ta and B are elements which respectively have a eutectic phase diagram in relation to Co and Fe and form amorphous phases. In addition, the concentrations of these elements in the eutectic composition are 8 to 13% except that the concentration of B is 20% or slightly lower. This is almost similarly applicable to Ni. Therefore, these elements can be dealt with in the total amount of Zr, Hf, Nb, Ta, and B/2. However, the amount of $\text{Zr}+\text{Hf}+\text{Nb}+\text{Ta}+\text{B}/2$ of less than 5% results in insufficient amorphousness, while the amount of more than 10% leads to saturation of amorphousness to reduce saturation magnetic flux density. Therefore, the total amount of $\text{Zr}+\text{Hf}+\text{Nb}+\text{Ta}+\text{B}/2$ is 5 to 10%, preferably 7.0 to 9.5%. In addition, the B content in the alloy is 7% or less because B

content of more than 7% results in poor corrosion resistance.

[0016] Al and Cr are added in an amount of 5% in terms of total amount of Al+Cr since both are elements which improve corrosion resistance. However, the upper limit of the total amount is 5% because the total amount of more than 5% leads to a large decrease in saturation magnetic flux density.

[0017] With regard to $\text{Fe}/(\text{Co}+\text{Fe}+\text{Ni})$, as described above, Fe is an element which has which has a ferromagnetic property as well as Co and Ni. On the other hand, Fe is an element which deteriorates corrosion resistance as compared to Co and Ni. However, the atomic ratio of $\text{Fe}/(\text{Co}+\text{Fe}+\text{Ni})$ of less than 0.10 results in a small saturation magnetic flux density, while the atomic ratio of more than 0.50 results in poor corrosion resistance. Therefore, the atomic ratio of $\text{Fe}/(\text{Co}+\text{Fe}+\text{Ni})$ is 0.10 to 0.50, preferably 0.23 to 0.43.

[0018] With regard to $\text{Ni}/(\text{Co}+\text{Fe}+\text{Ni})$, as described above, Ni is an element which has a ferromagnetic property as well as Co and Fe, while having a low saturation magnetic flux density as compared to Co and Fe. On the other hand, Ni has a corrosion resistance that is considerably higher than that of Fe and is slightly better than that of Co. However, the atomic ratio of $\text{Ni}/(\text{Co}+\text{Fe}+\text{Ni})$ of less than 0.01 results in poor corrosion resistance, while the atomic ratio of more than 0.25 results in a low saturation magnetic flux density. Therefore, the atomic ratio of $\text{Ni}/(\text{Co}+\text{Fe}+\text{Ni})$ is 0.01 to 0.25, preferably 0.11 to 0.17. However, the balance Co is necessary in an amount of 37% or more, as the amount of 37% or less results in deterioration of corrosion resistance.

Sputtering Target Material and Production Method Therefor

[0019] The method for producing a sputtering target material for a soft-magnetic film layer in a perpendicular magnetic recording medium according to the present invention comprises the steps of: (a) providing two or more raw-material powders having different compositions so as to constitute the alloy for a soft-magnetic film in total composition; (b) mixing the two or more powders to provide a mixture; and (c) consolidating the

mixture to form a sputtering target material.

[0020] Thus, in the production process of the present invention, two or more raw-material powders having different compositions are prepared as raw-material powders for the target material, so as to constitute the alloy for a soft-magnetic film in total composition. The reason for this is as follows. That is, the above alloy for a soft-magnetic film is an excellent alloy having a high saturation magnetic flux density, high amorphousness, and high corrosion resistance. However, since this alloy has a high saturation magnetic flux density, the simple use of this alloy as a sputtering target material for magnetron sputtering leads to a low PTF value, which results in a low sputtering rate and low sputtering stability.

[0021] In order to improve this point, by mixing powders having relatively low saturation magnetic flux densities in a certain ratio and consolidating the mixture, instead of consolidating a raw-material powder of a single composition, it is possible to obtain a material which has, as a whole in uniform composition, an alloy composition for a soft-magnetic film layer having a high saturation magnetic flux density but exhibits a relatively low saturation magnetic flux density as a sputtering target material, resulting in a sputtering target having a high PTF value.

[0022] At this time, when the entire composition of the sputtering target material is prepared from raw-material compositions with at least two compositions, at least one powder composition is prepared to comprise in at. %: Ni: 20 to 34%; Co: 0 to 6%; one or more of Zr, Hf, Nb, Ta and B: 3 to 12% in total of $Zr+Hf+Nb+Ta+B/2$, wherein B is in an amount of from 0 to 7%; and one or more of Al and Cr: 0 to 5% in total of $Al+Cr$; and the balance Fe and unavoidable impurities, and satisfies in atomic ratio: $Ni/(Fe+Ni)$: 0.27 to 0.35. This can extremely lower the saturation magnetic flux density.

[0023] An alloy which falls within the above ranges of Ni and $Fe/(Fe+Ni)$ leads to an extremely low saturation magnetic flux density, making it possible to significantly improve the PTF

value as compared to sputtering targets uniformly having the same composition, by using this alloy powder as at least part of the raw-material powder and consolidating the mixture to obtain a sputtering target. To the contrary, when the Ni content and the ratio of Ni/(Fe+Ni) fall outside the above ranges, the saturation magnetic flux density of the alloy powder becomes high, resulting in a decrease in PTF-value improvement effect. Therefore, the Ni content is 20 to 34%, while the ratio of Ni/(Fe+Ni) is 0.27 to 0.35.

10 [0024] The addition of Co in an amount of more than 6% leads to a high saturation magnetic flux density of the alloy powder to reduce the PTF-value improvement effect, and the upper limit of the Co amount is 6%.

15 [0025] The amount of Zr+Hf+Nb+Ta+B/2 is 3 to 12% because the use of the raw-material powder in an amount of less than 3% or more than 12% leads to an increase of particle formation. That is, Zr, Hf, Nb, Ta, and B have different sputtering rates from Fe, Co, and Ni. Therefore, when the amounts of the raw-material powders are largely different, irregularities occur on the surface of the sputtering target material to cause a failure such as particles, as the sputtering proceeds. Such problems, however, can be reduced within the above range.

20 [0026] In the meantime, the powder having Ni: 20 to 34%; Ni/(Fe+Ni): 0.27 to 0.35; Co: 0 to 6%; Zr+Hf+Nb+Ta+B/2: 3 to 12% comprises the balance Fe, while the composition of the other raw-material powder (hereinafter, balance composition) becomes rich in Co. This leads to consolidation of the raw-material powder having the balance Fe (low corrosion resistance) and the Co-rich raw-material powder (high corrosion resistance) in mixture, creating a kind of local battery between the two powders to provide a material which relatively tends to rust for the sputtering target. In view of this, by adding Al+Cr in an amount of 5% or less into the powder having at least Ni: 20 to 34%; Ni/(Fe+Ni): 0.27 to 0.35; Co: 0 to 6%; Zr+Hf+Nb+Ta+B/2: 3 to 12% and comprising the balance Fe, it is possible to improve the corrosion resistance of this powder to

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make the material difficult to rust as a sputtering material. The amount of Al+Cr of more than 5% reaches saturation of this effect, while the amount of more than 5% as a whole of the target material lowers the saturation magnetic flux density of a film to be obtained by sputtering this target.

[0027] Next, the two or more powders prepared as described above are mixed to obtain a mixture, which is then consolidated to form a sputtering target material. The consolidation is preferred to be conducted by upset method, in which the powder is consolidated in hot condition for several seconds. This makes it possible to constrain diffusion of the elements in the raw-material powders and to retain, even after consolidation, the low saturation magnetic flux density that the raw-material powders originally possessed. Normally, when the powder mixture is consolidated in hot condition for several hours by HIP method, hot press method or the like, atom diffusion occurs between powders of different kinds to form a diffusion layer having the elements of the both powder compositions. In particular, in the technique that a raw-material powder having a low saturation magnetic flux density is used to achieve a high PTF as in the present invention, a diffusion layer thus formed has a high saturation magnetic flux density to inhibit sufficient PTF improvement effect. This problem can be alleviated by upset method. The temperature in the upset method is preferably 900 to 1200 °C, more preferably 930 to 1070 °C, while the pressure is preferably 400 to 1400 MPa, more preferably 500 to 900 MPa. The period for pressing is not limited to, but is preferred to be 1 to 10 seconds.

EXAMPLES

[0028] The present invention is explained in detail below with reference to Examples.

[0029] Normally, a soft-magnetic film layer for a perpendicular magnetic recording medium is formed by sputtering a sputtering target having the same composition as the film layer to form the film layer on a glass substrate or the like. At this time, the

sputtered film has been quenched. In contrast, in the examples and comparative examples with regard to the present invention, a quenched ribbon produced in a single-roll-type liquid quenching device is used as a specimen. This is to evaluate influence of an actually sputtered, quenched film in various properties in terms of components, in a simple way by use of a liquid quenched ribbon.

Example 1

[0030] A raw-material of 30g weighed by constituents in Table 1 was arc-melted under reduced pressure of Ar in a water-cooled copper hearth having a diameter of 10 x 40 mm to prepare a molten base material for a quenched ribbon. The quenched ribbon was produced in single roll system, by setting this molten base material in a silica tube with a diameter of 15 mm and tapping the molten base material under an atmosphere pressure of 61 kPa, at an atomizing pressure difference of 69 kPa, at a rotational number of 3000 rpm of a copper roll (diameter of 300 mm), and with a gap between the copper roll and the tap nozzle of 0.3 mm. The tap temperature was set to a temperature right after the melting of each molten base material. With use of the quenched ribbon thus produced as a specimen, the following evaluations were conducted.

[0031]

[Table 1]

Table 1

No.	Composition (at.%)											Fe/(Co+ Fe+Ni)	Ni/(Co+Fe +Ni)	Zr+Hf+ Nb+Ta+ B/2	Al+Cr
	Fe	Ni	Zr	Hf	Nb	Ta	B	Al	Cr	Co					
1	10	10	7	-	-	-	5	-	-	Balance	0.11	0.11	9.5	0	
2	45	10	6	-	2	-	-	-	-	Balance	0.49	0.11	8.0	0	
3	40	1	4	2	-	2	-	-	-	Balance	0.43	0.01	8.0	0	
4	20	22	6	-	-	-	6	-	-	Balance	0.23	0.25	9.0	0	
5	20	15	5	-	-	-	-	-	-	Balance	0.21	0.16	5.0	0	
6	20	15	5	-	-	5	-	-	-	Balance	0.22	0.17	10.0	0	
7	30	10	0	5	-	-	7	-	-	Balance	0.34	0.11	8.5	0	
8	30	10	5	-	3	-	-	-	-	Balance	0.33	0.11	8.0	0	
9	30	10	5	-	-	3	-	3	-	Balance	0.34	0.11	8.0	3	
10	30	10	5	-	-	-	4	-	3	Balance	0.34	0.11	7.0	3	
11	25	15	3	2	1	-	2	3	2	Balance	0.29	0.17	7.0	5	
12	8	10	7	-	-	-	5	-	-	Balance	0.09	0.11	9.5	0	
13	48	10	6	-	2	-	-	-	-	Balance	0.52	0.11	8.0	0	
14	40	0.4	4	2	-	2	-	-	-	Balance	0.43	0.004	8.0	0	
15	20	27	6	-	-	-	6	-	-	Balance	0.23	0.31	9.0	0	
16	20	15	4	-	-	-	-	-	-	Balance	0.21	0.16	4.0	0	
17	20	15	6	-	-	5	-	-	-	Balance	0.22	0.17	11.0	0	
18	30	10	0	4	-	-	8	-	-	Balance	0.34	0.11	8.0	0	
19	25	15	3	2	1	-	2	3	3	Balance	0.29	0.17	7.0	6	

Note: Underlined figures fail to satisfy the conditions of the present invention.

Evaluation 1: Saturation Magnetic Flux Density

[0032] The saturation magnetic flux density of the quenched ribbon was measured using a VSM apparatus (vibrating sample magnetometer) with an applied magnetic field of 15 kOe. The weight of the specimen was about 15 mg.

Evaluation 2: Amorphousness

[0033] Usually, when an X-ray diffraction pattern of an amorphous material is measured, a diffraction peak is not observed and a halo pattern specific to amorphousness is observed. In addition, if the material is not completely amorphous, although a diffraction peak is observed, the peak height is lower and the half width (width at the half height of the diffraction peak) is broader as compared with a crystalline material. The half width correlates with the amorphousness of the material and there is a feature that the diffraction peak becomes broader and the half width becomes greater as the amorphousness becomes higher. Accordingly, the amorphousness of the quenched ribbon was evaluated in the following manner.

[0034] A specimen was adhered on a glass plate with a double-faced adhesive tape, and a diffraction pattern was obtained with an X-ray diffraction apparatus. At this time, the specimen was adhered on the glass plate so that the surface to be measured could be the surface of the quenched ribbon in contact with the copper roll. The X-ray source was Cu- $\text{K}\alpha$ ray and the measurement was performed at a scan speed of $4^\circ/\text{min}$. The width at the half height of the main peak in the diffraction pattern was image-analyzed to determine the half width for evaluating amorphousness.

Evaluation 3: Corrosion Resistance

[0035] In order to evaluate corrosion resistance of the quenched ribbon, a specimen was adhered on a glass plate with a double-faced adhesive tape, and the salt spray test was performed using 5% NaCl at 35°C for 16 hours to evaluate the specimen according to the criteria of "Poor" for those rusted on the whole surface and "Good" for those rusted in part. The

evaluation results are shown in Table 2

[0036]

[Table 2]

Table 2

No.	Saturation magnetic flux density (T)	Half width (°)	Corrosion resistance	Note
1	1.15	2.8	Good	Examples
2	1.61	0.9	Good	
3	1.63	0.7	Good	
4	1.11	3.1	Good	
5	1.46	0.5	Good	
6	1.10	2.7	Good	
7	1.38	0.7	Good	
8	1.41	0.7	Good	
9	1.26	1.0	Good	
10	1.33	0.8	Good	
11	1.12	0.6	Good	
12	1.08	2.5	Good	Comp. Examples
13	1.62	0.9	Poor	
14	1.65	0.8	Poor	
15	1.05	2.9	Good	
16	1.53	0.1	Good	
17	1.02	3.3	Good	
18	1.41	0.7	Poor	
19	1.07	0.6	Good	

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As shown in Table 2, Nos. 1 to 11 are examples of the present invention, while Nos. 12 to 19 are comparative examples.

[0037] In comparative example No. 12, the saturation magnetic flux density is low due to the low Fe content in the composition and the low Fe/(Co+Fe+Ni) value. In comparative example No. 13, corrosion resistance is poor due to the high Fe content in the composition, the high Fe/(Co+Fe+Ni) value, and the low Co amount. In comparative example No. 14, corrosion resistance is poor due to the low Ni content in the composition and the low Ni/(Co+Fe+Ni) value. In comparative example No. 15, the saturation magnetic flux density is low due to the high Ni content in the composition and the high Ni/(Co+Fe+Ni) value.

[0038] In comparative example No. 16, the half width is small due to the low content of $Zr+Hf+Nb+Ta+B/2$, leading to low amorphousness. In comparative example No. 17, the saturation magnetic flux density is low due to the high content of $Zr+Hf+Nb+Ta+B/2$. In comparative example No. 18, corrosion resistance is poor due to the low B content in the composition. In comparative example No. 19, the saturation magnetic flux density is low due to the high Al+Cr content.

Example 2

10 [0039] Next, there are described examples with regard to influence of the raw-material powder in PTF value of the sputtering target material. First, an alloy powder to be used as a raw-material was prepared by gas atomizing method, and the saturation magnetic flux density was measured to investigate
15 the raw-material powder composition having a low saturation magnetic flux density. The results are shown in Table 3. This raw-material powder was then mixed with a raw-material powder of a balance composition shown in Table 4 so as to reach the composition of a target material shown in Table 5.
20 The mixture was consolidated and then machined to produce a sputtering target material, the PTF value of which was measured to investigate the influence of the raw-material powder composition in PTF value. The results are shown in Table 5. At the same time, corrosion resistance was also evaluated for
25 the sputtering target material.

[0040]

[Table 3]

Table 3

No.	Composition (at.%)										Ni/(Fe + Ni)	Zr+Hf +Nb +Ta +B/2	Al+Cr	Saturation magnetic flux density	Note
	Co	Ni	Zr	Hf	Nb	Ta	B	Al	Cr	Fe					
1	-	23.0	5	-	-	3	-	-	-	Balance	<u>0.25</u>	8.0	0	1.22	Comp. Example
2	-	24.8	3	2	-	3	-	-	-	Balance	0.27	8.0	0	0.85	Examples
3	-	27.6	5	-	1	2	-	-	-	Balance	0.30	8.0	0	0.25	
4	-	31.9	5	-	-	2	2	-	-	Balance	0.35	8.0	0	0.70	
5	-	33.7	3	2	-	2	2	-	-	Balance	<u>0.37</u>	8.0	0	1.03	Comp. Example
6	6	25.8	5	-	-	3	-	-	-	Balance	0.30	8.0	0	0.77	Example
7	9	24.9	5	-	-	3	-	-	-	Balance	0.30	8.0	0	1.03	Comparative Examples
8	-	29.4	2	-	-	-	-	-	-	Balance	0.30	<u>2.0</u>	0	0.67	
9	-	26.1	8	-	5	-	-	-	-	Balance	0.30	<u>13.0</u>	0	0.32	
10	-	26.1	5	-	-	3	-	3	2	Balance	0.30	8.0	5	0.40	Example
11	-	25.8	5	-	-	3	-	3	3	Balance	0.30	8.0	6	0.33	Comp. Example

Note: Underlined figures fail to satisfy the conditions of the present invention.

[0041]

[Table 4]

Table 4

No.	Composition (at.%)										Mixing ratio of balance composition powder (mass%)	Note
	Co	Fe	Ni	Zr	Hf	Nb	Ta	B	Al	Cr		
Balance Composition 1	74.3	0	17.7	5	0	0	3	0	0	0	57.4	Comp. Example
Balance Composition 2	82.8	0	9.2	3	2	0	3	0	0	0	63.6	Examples
Balance Composition 3	75.4	0	16.6	5	0	1	2	0	0	0	69.6	
Balance Composition 4	71.1	0	19.9	5	0	0	2	2	0	0	58.4	
Balance Composition 5	81.6	0	9.4	3	2	0	2	2	0	0	57.1	Comp. Examples
Balance Composition 6	89.0	0	3.0	5	0	0	3	0	0	0	39.3	Example
Balance Composition 7	66.9	0	25.1	5	0	0	3	0	0	0	49.1	Comp. Examples
Balance Composition 8	79.3	0	10.8	9.9	0	0	0	0	0	0	52.4	
Balance Composition 9	89.6	0	3.5	3.9	0	3	0	0	0	0	49.1	
Balance Composition 10	79.7	0	7.3	5	0	0	3	0	3	2	59.7	Example
Balance Composition 11	78.7	0	7.3	5	0	0	3	0	3	3	59.2	Comp. Example

[0042]

[Table 5]

Table 5

No.	Composition of target material (at.%)										Zr+Hf +Nb +Ta +B/2	Raw material powder No.	Difference in PTF (%)	Corrosion resistance	Note
	Fe	Ni	Zr	Hf	Nb	Ta	B	Al	Cr	Co					
A	30	20	5	-	-	3	-	-	-	Bal.	8.0	1+BC1	3	B	Comp. Ex.
B	25	15	3	2	-	3	-	-	-	Bal.	8.0	2+BC2	10	B	Examples
C	20	20	5	-	1	2	-	-	-	Bal.	8.0	3+BC3	16	A	
D	25	25	5	-	-	2	2	-	-	Bal.	8.0	4+BC4	12	B	
E	25	20	3	2	-	2	2	-	-	Bal.	8.0	5+BC5	4	B	Comp. Ex.
F	37	17	5	-	-	3	-	-	-	Bal.	8.0	6+BC6	12	B	Example
G	30	25	5	-	-	3	-	-	-	Bal.	8.0	7+BC7	4	B	Comp. Ex.
H	34	20	6	-	-	-	-	-	-	Bal.	6.0	8+BC8	16	B	
I	31	15	6	-	4	-	-	-	-	Bal.	10.0	9+BC9	10	B	
J	25	15	5	-	-	3	-	3	2	Bal.	8.0	10+BC10	14	A	Example
K	25	15	5	-	-	3	-	3	3	Bal.	8.0	11+BC11	12	A	Comp. Ex.

Note: BC: Balance Composition

The raw material and the sputtering target material were prepared as explained below.

(1) Preparation of Raw-Material Powder

[0043] First, a raw-material powder of each composition shown in Tables 3 and 4 was prepared by gas atomizing technique. The gas atomizing was conducted under conditions of the gas type of Ar, the nozzle diameter of 6 mm, and the gas pressure of 5 MPa. The powder of Nos. 1 to 11 shown in Table 3 was mixed with the alloy powder of the corresponding balance composition shown in Table 4 in the powder mixing ratio shown in Table 4. The mixing of the raw-material powders was conducted by mixing the mixture in a V-type mixer.

(2) Classification

[0044] The powder mixture thus prepared was classified through a sieve having an opening of 500 μm to obtain a powder having particle sizes of 500 μm or less.

(3) Vacuum Sealing

[0045] The classified powder mixture was charged into a sealed container, which is made of SC material and has a diameter of 200 mm and a height of 100 mm. The sealed container was then vacuum-sealed at an ultimate pressure of lower than 1.3×10^{-1} Pa (10^{-3} torr).

(4) Consolidating Process

[0046] The vacuum-sealed powder mixture was consolidated by upset method. The upset method was conducted under conditions of the heating temperature of 950 °C, the pressure of 540 MPa, and the processing time of 5 seconds. Upset method is a method comprising heating a billet having an external cylinder can made of metal, which is charged with a raw-material powder, evacuated and sealed, to a certain temperature; inserting the billet into a container; and press-forming the billet with a puncher, and is characterized by being able to heighten the consolidation pressure and to conduct consolidation for a short period of time, as compared to HIP method or hot press method.

(5) Machining Process

[0047] The consolidated body was machined by wire cutting, lathe processing and surface polishing to produce a sputtering target material having a final shape with a diameter of 180 mm and a thickness of 7 mm.

- 5 [0048] The following evaluations were made for the raw-material powders and sputtering target materials.

Evaluation 1: Saturation Magnetic Flux Density

- [0049] The saturation magnetic flux density of the raw-material powder was measured using a VSM apparatus
10 (vibrating sample magnetometer) with an applied magnetic field of 15 kOe. The weight of the specimen was about 15 mg.

Evaluation 2: PTF Value

- [0050] The PTF value of the target material was measured according to ASTM F1761-00. For comparison, a target
15 material having the same composition was produced by consolidating a single powder under the same conditions, and the PTF value was measured. Evaluation was made in terms of the difference in PTF value obtained by subtracting [PTF value (unit:%) of the sputtering target material made from the single
20 powder] from [PTF value (unit:%) of the sputtering target material made from the powder mixture].

Evaluation 3: Corrosion Resistance

- [0051] For evaluation of corrosion resistance of the sputtering target material, the target material was subjected to a salt
25 spray test in accordance with JIS Z 2371, in which the target material after exposure to spraying of a NaCl solution of 5 wt.% for 24 hours was observed to visually confirm presence/absence of rust on the target material. The evaluation was made according to the following criteria:

- 30 A: No rust generated
 B: Generation of rust on part of the target material
 C: Generation of rust over the entire surface of the target material

- [0052] The compositions (at.%) of the sputtering target
35 materials, the raw-material powders, and the differences in PTF value (%), and corrosion resistance are shown in Table 5.

[0053] As shown in Table 5, B to D, F and J are examples of the present invention, while A, E, G to I, and K are comparative examples. In comparative examples A, E and G, the improvement effect in PTF is small due to the high saturation magnetic flux densities of raw-material powders No. 1, 5 and 7 used in these examples. When the sputtering target materials of comparative examples H and I were sputtered under an Ar pressure of 0.5 Pa at a DC power of 500W, many irregularities occurred on the surface of the sputtering target material, while the sputtered film had many particles, which was three times as many as a sputtered film prepared by using the sputtering target material of the same composition which had been consolidated from the single powder under the same conditions. This is assumed to be due to a large difference in Zr+Nb amount between the mixed powders (No. 8 and Balance Composition 8; and No. 9 and Balance Composition 9). (While the sputtering rates of Zr, Hf, Nb, Ta, and B are known to be lower than Co, Fe, and Ni, it is assumed that this difference in sputtering rate would grow irregularities on the surface.)

[0054] Powder No. 11 used for the preparation of the sputtering target material of comparative example K has Al+Cr in an amount of 6 at.%, which is only 1 at.% higher than the Cr content of powder No. 10 used for the preparation of the sputtering target material of present invention example J. As a result, the evaluation results of the both sputtering target materials of present invention example J and comparative example K were "A," which indicates that the improvement effect in the corrosion resistance of the sputtering target material by the addition of Al+Cr was saturated.

[0055] In addition, powder mixtures of No. 2 + Balance Composition 2; No. 3 + Balance Composition 3; and No. 4 + Balance Composition 4 were used and then subjected to HIP consolidation at 950 °C under 147 MPa for 2 hours to obtain sputtering target materials having compositions B, C, and D, of which the PTF differences from sputtering target materials made from the corresponding single raw-material powders were 8, 11,

and 9 %, respectively. This indicates that consolidation by upset method leads to a higher improvement effect in PTF value than consolidation by HIP method.

- [0056] In view of the above, it is understood that an alloy powder which falls within the range of Ni/(Fe+Ni) of 0.27 to 0.35 led to an extremely low saturation magnetic flux density, making it possible to significantly improve the PTF value as compared to sputtering targets uniformly having the same composition, by using this alloy powder as at least part of the raw-material powder and consolidating the mixture to obtain a sputtering target.

CLAIMS

1. An alloy for a soft-magnetic film layer in a perpendicular magnetic recording medium, the alloy comprising in at. %:

Fe: 10 to 45%;

Ni: 1 to 25%;

One or more of Zr, Hf, Nb, Ta and B: 5 to 10% in total of $Zr+Hf+Nb+Ta+B/2$, wherein B is in an amount of from 0 to 7%; and

One or more of Al and Cr: 0 to 5% in total of $Al+Cr$; and the balance Co and unavoidable impurities: 37% or more, and the alloy satisfying in atomic ratio:

$Fe/(Co+Fe+Ni)$: 0.10 to 0.50; and

$Ni/(Co+Fe+Ni)$: 0.01 to 0.25.

2. A method for producing a sputtering target material for a soft-magnetic film layer in a perpendicular magnetic recording medium, the method comprising the steps of:

(a) providing two or more raw-material powders having different compositions so as to constitute the alloy for a soft-magnetic film according to claim 1 in total composition, wherein at least one powder of the two or more powders comprises in at. %:

Ni: 20 to 34%;

Co: 0 to 6%;

One or more of Zr, Hf, Nb, Ta and B: 3 to 12% in total of $Zr+Hf+Nb+Ta+B/2$, wherein B is in an amount of from 0 to 7%; and

One or more of Al and Cr: 0 to 5% in total of $Al+Cr$; and the balance Fe and unavoidable impurities, and satisfies in atomic ratio:

$Ni/(Fe+Ni)$: 0.27 to 0.35;

(b) mixing the two or more powders to provide a mixture; and

(c) consolidating the mixture to form a sputtering target material.

3. A method according to claim 2, wherein the consolidating step is carried out by upset method.
4. A sputtering target material for a soft-magnetic film layer in a perpendicular magnetic recording medium, which is produced by the method according to claim 2.
5. A sputtering target material for a soft-magnetic film layer in a perpendicular magnetic recording medium, which is produced by the method according to claim 3.