

CoFeNi-BASED ALLOY AND SPUTTERING TARGET MATERIAL FOR
SOFT MAGNETIC FILM LAYER IN PERPENDICULAR MAGNETIC
RECORDING MEDIUM

5 [Cross-Reference to Related Application]
[0001]

This application claims priority to Japanese Patent Application No. 2009-139151 filed on June 10, 2009, the entire content of which is incorporated herein by reference.

10 [Technical Field]
[0002]

The present invention relates to a CoFeNi-based alloy used for a soft magnetic film layer in a perpendicular magnetic recording medium, and a sputtering target material thereof.

15 [Background Art]
[0003]

In recent years, there have been remarkable progresses in magnetic recording technology, and heightening of recording densities in magnetic recording media has been proceeding due to increasing drive capacities. For example, perpendicular magnetic recording system, which achieves further high recording density when compared to longitudinal magnetic recording system conventionally used, has been put into practical use. Perpendicular magnetic recording system is a system in which a magnetization-easy axis is oriented in the direction vertical to the medium surface of a magnetic film of a perpendicular magnetic recording medium and is suitable for a high recording density. For perpendicular magnetic recording system, a double-layer recording medium having a magnetic recording film layer with an increased recording sensitivity and a soft magnetic film layer has been developed. As the magnetic recording film layer, a CoCrPt-SiO₂-based alloy is commonly used.

[0004]

35 As for the soft magnetic film layer, on the other hand, there are known alloys based on soft magnetic elements of Co or Fe, to

which Zr, Hf, Ta, Nb and B for improving amorphous properties are added. For example, there are proposed an alloy for a soft magnetic film layer in a perpendicular magnetic recording medium as disclosed in Patent Literature 1, a Co-Fe-based alloy sputtering target material and a production method thereof as disclosed in Patent Literature 2.

[0005]

High saturation magnetic flux density, high amorphous properties and high corrosion resistance are required for the soft-magnetic film layer in this perpendicular magnetic recording medium. Furthermore, in recent years, hardness has been more required for the soft magnetic film layer in order to reduce disc damage caused by the contact between a disc for magnetic recording medium and a read/write head.

[Citation List]

[0006]

[Patent Literature]

[PTL 1] Japanese Patent Laid-Open Publication No. 2008-299905

[PTL 2] Japanese Patent Laid-Open Publication No. 2008-189996

[Summary of the Invention]

[0007]

The applicants have now found that it is possible to obtain an alloy which has a high saturation magnetic flux density, high amorphous properties and high corrosion resistance as well as, by setting the ratio of B amount to Ta and/or Nb amount to a certain ratio, has an even higher hardness than those of the alloys proposed in Patent Literature 1.

[0008]

It is therefore an object of the present invention to provide a soft magnetic alloy for a perpendicular magnetic recording medium excellent in saturation magnetic flux density, amorphous properties, corrosion resistance and hardness; a sputtering target material for producing a film of the alloy; and a perpendicular magnetic recording medium having a soft magnetic film layer made of the alloy.

[0009]

According to the first embodiment of the present invention, there is provided a CoFeNi-based alloy for a soft magnetic film layer in a perpendicular magnetic recording medium, wherein the CoFeNi-based alloy comprises in at%:

5 Co+Fe+Ni: 70 to 92%, provided that Ni content may be 0;

 Ta: 1 to 8%; and

 B: more than 7% and not more than 20%,

10 wherein the composition of the CoFeNi-based alloy (at%) satisfies the following ratios:

 Co/(Co+Fe+Ni): 0.1 to 0.9;

 Fe/(Co+Fe+Ni): 0.1 to 0.65;

 Ni/(Co+Fe+Ni): 0 to 0.35; and

 B/Ta: 1 to 8.

15 [0010]

According to the second embodiment of the present invention, there is provided a CoFeNi-based alloy for a soft magnetic film layer in a perpendicular magnetic recording medium, wherein the CoFeNi-based alloy comprises in at%:

20 Co+Fe+Ni: 70 to 92%, provided that Ni content may be 0;

 Nb+Ta: 1 to 8%; and

 B: more than 7% and not more than 20%,

25 wherein the composition of the CoFeNi-based alloy (at%) satisfies the following ratios:

 Co/(Co+Fe+Ni): 0.1 to 0.9;

 Fe/(Co+Fe+Ni): 0.1 to 0.65;

 Ni/(Co+Fe+Ni): 0 to 0.35; and

 B/(Nb+Ta): 1 to 8.

30 [0011]

According to the third embodiment of the present invention, there is provided a CoFeNi-based alloy for a soft magnetic film layer in a perpendicular magnetic recording medium, wherein the CoFeNi-based alloy comprises in at%:

35 Co+Fe+Ni: 70 to 92%, provided that Ni content may be 0;

Zr+Hf+Nb+Ta: 1 to 8%;

B: more than 7% and not more than 20%;

Zr+Hf: 0 to less than 2%; and

Al+Cr: 0 to 5%,

5 wherein the composition of the CoFeNi-based alloy (at%) satisfies the following ratios:

Co/(Co+Fe+Ni): 0.1 to 0.9;

Fe/(Co+Fe+Ni): 0.1 to 0.65;

Ni/(Co+Fe+Ni): 0 to 0.35; and

10 B/(Nb+Ta): 1 to 8.

[0012]

According to another embodiment of the present invention, there is provided a sputtering target material made of the CoFeNi-based alloy according to each of the above
15 embodiments.

[0013]

According to still another embodiment of the present invention, there is provided a perpendicular magnetic recording medium having a soft magnetic film layer made of the CoFeNi-based
20 alloy according to each of the above embodiments.

[Description of Embodiments]

[0014]

The present invention is explained in detail below. Unless otherwise noted, percentage (%) described herein means
25 atomic % (at%).

[0015]

The present invention relates to a CoFeNi-based alloy for a soft magnetic film layer in a perpendicular magnetic recording medium. The CoFeNi-based alloy comprises in at%:

30 Co+Fe+Ni: 70 to 92%, provided that Ni content may be 0;

Ta: 1 to 8% (the first embodiment), Nb+Ta: 1 to 8% (the second embodiment), or Zr+Hf+Nb+Ta: 1 to 8% (the third embodiment); and

35 B: more than 7% and not more than 20%, preferably consists essentially of the above elements, and more

preferably consists of the above elements. The CoFeNi-based alloy according to the third embodiment can further comprise Zr+Hf in an amount of 0 to less than 2%; and Al+Cr in an amount of 0 to 5%. In each embodiment from the first to the third, the composition of the CoFeNi-based alloy (at%) satisfies the following ratio:

- Co/(Co+Fe+Ni): 0.1 to 0.9;
- Fe/(Co+Fe+Ni): 0.1 to 0.65;
- Ni/(Co+Fe+Ni): 0 to 0.35; and
- B/Ta: 1 to 8.

[0016]

Co, Fe and Ni are elements having soft magnetic properties. The contents of Co, Fe and Ni are preferably, but not particularly limited to, a Co content of 9 to 80%; an Fe content of 5 to 60%; and a Ni content of 0 to 40%, more preferably a Co content of 25 to 80%; an Fe content of 15 to 52%; and a Ni content of 0 to 10%, respectively. The total content of Co, Fe and Ni (i.e., Co+Fe+Ni content) in the alloy of the present invention is 70 to 92%, preferably 80 to 92%. A Co+Fe+Ni content of less than 70% results in an insufficient saturation magnetic flux density, while that of more than 92% results in a low total amount of Zr, Hf, Ta, Nb and B and thus provides insufficient amorphous properties.

[0017]

In the meantime, when comparing these three elements, saturation magnetic flux density becomes lower generally in the order of Fe>Co>Ni, while corrosion resistance becomes poorer generally in the order of Ni>Co>Fe. In consideration of the balance between the saturation magnetic flux density and the corrosion resistance, the ratios of Co, Fe and Ni contents to Co+Fe+Ni content are fallen within the following ranges:

- Co/(Co+Fe+Ni): 0.1 to 0.9, preferably 0.3 to 0.9;
 - Fe/(Co+Fe+Ni): 0.1 to 0.65, preferably 0.2 to 0.55; and
 - Ni/(Co+Fe+Ni): 0 to 0.35, preferably 0 to 0.10.
- Ni/(Co+Fe+Ni) of more than 0.35 results in an insufficient saturation magnetic flux density. Fe/(Co+Fe+Ni) of less than

0.1 results in an insufficient saturation magnetic flux density, while that of more than 0.65 results in poor corrosion resistance.

[0018]

- 5 Determining the ranges of $\text{Ni}/(\text{Co}+\text{Fe}+\text{Ni})$ and $\text{Fe}/(\text{Co}+\text{Fe}+\text{Ni})$ in this way results in the lower limit of $\text{Co}/(\text{Co}+\text{Fe}+\text{Ni})$ being zero (0) (in the case of $\text{Ni}/(\text{Co}+\text{Fe}+\text{Ni})=0.35$ and $\text{Fe}/(\text{Co}+\text{Fe}+\text{Ni})=0.65$). When the Co content is extremely low, there is a singularity at which the saturation magnetic flux
10 density becomes extremely low in the range or vicinity of 0.25 to 0.40 of $\text{Ni}/(\text{Fe}+\text{Ni})$. Therefore, the lower limit of $\text{Co}/(\text{Co}+\text{Fe}+\text{Ni})$ is 0.10. On the other hand, the upper limit of $\text{Co}/(\text{Co}+\text{Fe}+\text{Ni})$ is 0.9 (in the case of $\text{Ni}/(\text{Co}+\text{Fe}+\text{Ni})=0$ and $\text{Fe}/(\text{Co}+\text{Fe}+\text{Ni})=0.1$).

15 [0019]

- Ta, Nb and B are elements for improving amorphous properties in the alloy of the present invention. The contents of Ta, Nb and B are preferably, but not particularly limited to, a Ta content of 1 to 8%; an Nb content of not more than 5%; and a B
20 content of more than 7% and not more than 20%, more preferably a Ta content of 2 to 6%; an Nb content of 0 to 3%; and a B content of 7.5 to 15%, respectively. In the alloy of the present invention, the total content of Nb and Ta (i.e., Nb+Ta content) is 1 to 8%. An Nb+Ta content of less than 1% results
25 in insufficient amorphous properties, while that of more than 8% results in an insufficient saturation magnetic flux density. B content of not more than 7% results in insufficient amorphous properties, while that of more than 20% results in an insufficient saturation magnetic flux density.

30 [0020]

- In the alloy of the present invention, the ratio of B content to Ta+Nb content, $\text{B}/(\text{Ta}+\text{Nb})$, is 1 to 8, preferably 1.5 to 6. Within these ranges, an unprecedentedly high hardness can be achieved. Although the detailed mechanism of achieving the
35 high hardness is uncertain, the bonds between B atom and Ta atom and/or Nb atom in the alloy may have some effect.

B/(Ta+Nb) of less than 1 or more than 8 provides an insufficient hardness.

[0021]

Zr and Hf are elements for improving amorphous properties.

- 5 The contents of Zr and Hf are preferably, but not limited to, a Zr content of not more than 2%; and a Hf content of not more than 1.0%, respectively. Zr, Hf, Nb and Ta may be added in a total Zr+Hf+Nb+Ta content of 1 to 8%, and Zr and Hf may be added in a total Zr+Hf content of 0 to less than 2%. This
- 10 embodiment corresponds to the third embodiment of the present invention. A Zr+Hf+Nb+Ta content of less than 1% results in insufficient amorphous properties, while that of more than 8% results in an insufficient saturation magnetic flux density. A Zr+Hf content of not less than 2% results in a
- 15 decrease in hardness.

[0022]

Al and Cr are elements for improving corrosion resistance in the alloy of the present invention. The contents of Al and Cr are preferably, but not particularly limited to, an Al content of not

20 more than 3%, and a Cr content of not more than 3%, respectively. The upper limit of the total content of Al and Cr (i.e., Al+Cr content) is 5%. An Al+Cr content of more than 5% results in a decrease in saturation magnetic flux density.

[0023]

- 25 Normally, a soft-magnetic film layer in a perpendicular magnetic recording medium is formed by sputtering a sputtering target material 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 present
- 30 invention examples and comparative examples described below, quenched ribbons produced in a single-roll-type liquid quenching device were used as sample materials. This is to evaluate, in a simple manner using liquid quenched ribbons, how various properties are affected by the components of the
- 35 films which are actually quenched and formed by sputtering.

[Examples]

[0024]

The present invention is explained in detail below with reference to Examples. A raw material of 30 g weighed to have the quenched ribbon composition shown in Table 1 was arc-melted
5 in Ar with a reduced pressure in a water-cooled copper mold, which has a diameter of about 10 mm and a length of about 40 mm, to provide a molten raw material for the quenched ribbon. The production of the quenched ribbon was conducted by a single roll method under the condition in which the molten raw
10 material was set in a silica tube having a diameter of 15 mm and was tapped from a tapping nozzle having a diameter of 1 mm, at an atmosphere pressure of 61 kPa, at an atomizing pressure difference of 69 kPa, and at a rotational number of 3000 rpm of a copper roll (diameter of 300 mm), with a gap
15 between the copper roll and the tapping nozzle being set to 0.3 mm. The temperature at which each raw material melted down was taken as the tapping temperature.

[0025]

[Table1]

Table 1

No.	Composition (at%)										Co+Fe +Ni	Zr+Hf+ Nb+Ta	Zr+Hf	Al+Cr	Co/(Co+ Fe+Ni)	Fe/(Co+ Fe+Ni)	Ni/(Co+ Fe+Ni)	B/(Nb +Ta)	
	Fe	Ni	Zr	Hf	Nb	Ta	B	Al	Cr	Co									
1	50.1	31.9	0	0	0	1	8	0	0	Bal.	91	1	0	0	0.10	0.55	0.35	8.0	Present Invention Examples
2	8.8	0.0	0	0	0	4	8	0	0	Bal.	88	4	0	0	0.90	0.10	0.00	2.0	
3	25.8	8.6	0	0	3	3	8	0	0	Bal.	86	6	0	0	0.60	0.30	0.10	1.3	
4	16.8	4.2	0	0	0	8	8	0	0	Bal.	84	8	0	0	0.75	0.20	0.05	1.0	
5	34.0	0.0	1	0	1	1	12	0	0	Bal.	85	3	1	0	0.60	0.40	0.00	6.0	
6	38.7	4.3	1	0.9	2	2	8	0	0	Bal.	86	6	2	0	0.50	0.45	0.05	2.0	
7	25.8	0.0	0	0	2	2	8	2	0	Bal.	86	4	0	2	0.70	0.30	0.00	2.0	
8	41.5	0.0	0	0	2	2	8	2	3	Bal.	83	4	0	5	0.50	0.50	0.00	2.0	
9	47.5	0.0	1.9	0	3	3	15	2	2	Bal.	73	8	2	4	0.35	0.65	0.00	2.5	
10	50.9	32.4	0	0	0	<u>0.5</u>	<u>7</u>	0	0	Bal.	<u>93</u>	<u>0.5</u>	0	0	0.10	0.55	0.35	<u>14</u>	Comparative Examples
11	49.5	31.5	0	0	0	1	9	0	0	Bal.	90	1	0	0	0.10	0.55	0.35	9	
12	16.9	4.2	0	0	0	8	<u>7.5</u>	0	0	Bal.	85	8	0	0	0.75	0.20	0.05	<u>0.9</u>	
13	43.6	0.0	1.9	0	3	3	<u>21</u>	2	2	Bal.	67	8	2	4	0.35	0.65	0.00	3.5	
14	46.8	0.0	3	0	3	3	15	2	2	Bal.	72	<u>9</u>	<u>3</u>	4	0.35	0.65	0.00	2.5	
15	46.2	0.0	1.9	0	3	3	15	3	3	Bal.	71	8	2	<u>6</u>	0.35	0.65	0.00	2.5	
16	54.6	31.9	0	0	0	1	8	0	0	Bal.	91	1	0	0	<u>0.05</u>	0.60	0.35	8	
17	4.4	0.0	0	0	0	4	8	0	0	Bal.	88	4	0	0	0.95	0.05	0.00	2	
18	53.9	0.0	1.9	0	3	3	15	0	0	Bal.	77	8	2	0	0.30	<u>0.70</u>	0.00	2.5	
19	42.0	33.6	0	0	0	8	8	0	0	Bal.	84	8	0	0	0.10	0.50	<u>0.40</u>	1	
20	16.4	4.1	0	0	0	<u>9</u>	9	0	0	Bal.	82	<u>9</u>	0	0	0.75	0.20	0.05	1	

NOTE: The underlined figures fall outside the scope of the present invention.

Quenched ribbons produced in the above manner were used as sample materials to evaluate the properties described below.
[0026]

Evaluation 1: Saturation Magnetic Flux Density

- 5 Saturation magnetic flux density (T) was measured on approximately 15 mg of the sample material at an applied magnetic field of 1.2 MA/m (15kOe) by a VSM device (vibration-sample-type magnetometer).

[0027]

10 Evaluation 2: Amorphous Properties (Half-bandwidth)

- The amorphous properties of the quenched ribbon were evaluated by X-ray diffraction. In general, when an X-ray diffraction pattern of the amorphous material is measured, no diffraction peak is observed to show a halo pattern specific to
15 amorphous materials. Although a diffraction peak is observed in a material not completely amorphous, the height of the peak is lower than that of a crystal material to show a broad peak having a large half-bandwidth (a width of the angles at which the intensity is half the diffraction peak intensity). This
20 half-bandwidth has a correlation with amorphous properties of the material, and has a characteristic that as the amorphous properties are higher, the diffraction peak becomes broader with increasing half-bandwidth. Therefore, the amorphous properties were evaluated by the following method.

25 [0028]

- The sample material was adhered on a glass plate with a double-faced tape to obtain a diffraction pattern by an X-ray diffraction device. At this time, the sample material was adhered on the glass plate so that a surface to be measured
30 could be a copper-roll-contact surface of the quenched ribbon. The X-ray source was Cu- $k\alpha$ ray, and the measurement was conducted at a scan speed of 4°/min. The width of the angles at a half height of the main peak in the diffraction pattern was image-analyzed to determine the half-bandwidth for evaluating
35 amorphous properties.

[0029]

Evaluation 3: Corrosion Resistance

The sample material was adhered to a glass plate with a double-faced tape and then was subjected to a salt spray test, in which the sample material was exposed to 5% NaCl solution spray at 35°C for 16 hours, to evaluate the corrosion resistance of the quenched ribbon according to the following criteria.

Poor: Rusted on the whole surface

Fair: Rusted in some parts

Good: Almost no rust generated

10 [0030]

Evaluation 4: Vickers Hardness

The quenched ribbon was longitudinally embedded into a resin and polished to measure the Vickers hardness (HV) of the quenched ribbon by a Vickers hardness tester. The measuring load was 50 g and the evaluation was based on the average of n=10. Indentation size was about 10 μm .

[0031]

Results of these evaluation tests are shown in Table 2.

[Table2]

Table 2

No.	Saturation Magnetic Flux Density (T)	Half- bandwidth (°)	Corrosion Resistance	Vickers Hardness (HV)	
1	1.4	0.4	Good	1040	Present Invention Examples
2	1.3	0.7	Good	1080	
3	1.2	1.0	Good	1100	
4	1.1	6.6	Good	1120	
5	1.6	1.5	Fair	1080	
6	1.5	1.8	Fair	1060	
7	1.4	0.6	Good	1080	
8	1.4	0.6	Good	1100	
9	1.1	6.4	Fair	1040	
10	1.3	0.2	Good	880	Comparative Examples
11	1.1	0.5	Good	900	
12	1.1	5.5	Good	940	
13	0.8	7.3	Fair	1020	
14	0.9	6.0	Fair	940	
15	0.9	5.8	Fair	1040	
16	0.9	0.4	Fair	1000	
17	0.9	0.7	Good	1060	
18	1.2	6.1	Poor	1060	
19	0.9	6.9	Good	1100	
20	0.9	7.5	Good	1100	

In Table 1, Examples 1 to 9 are present invention examples,
5 while Examples 10 to 20 are comparative examples.

[0032]

As shown in Table 1, Example 10 results in a low half-bandwidth
and a low Vickers Hardness due to the low content of Ta and B,
the high content of (Co+Fe+Ni), and the low content of
10 (Zr+Hf+Nb+Ta), and moreover to the high value of B/(Nb+Ta).
Example 11 results in a low Vickers Hardness due to the high
value of B/(Nb+Ta). Example 12 results in a low Vickers
Hardness due to the low value of B/(Nb+Ta).

[0033]

15 Example 13 results in a low saturation magnetic flux density
due to the high content of B and the low content of (Co+Fe+Ni).
Example 14 results in a low saturation magnetic flux density
and a low Vickers Hardness due to the high content of

(Zr+Hf+Nb+Ta) and the high content of (Zr+Hf). Example 15 results in a low saturation magnetic flux density due to the high content of (Al+Cr). Example 16 results in a low saturation magnetic flux density due to the low value of $\text{Co}/(\text{Co}+\text{Fe}+\text{Ni})$.

5 [0034]

Example 17 results in a low saturation magnetic flux density due to the high value of $\text{Co}/(\text{Co}+\text{Fe}+\text{Ni})$ and the low value of $\text{Fe}/(\text{Co}+\text{Fe}+\text{Ni})$. Example 18 results in a poor corrosion resistance due to the high value of $\text{Fe}/(\text{Co}+\text{Fe}+\text{Ni})$. Example
10 19 results in a low saturation magnetic flux density due to the high value of $\text{Ni}/(\text{Co}+\text{Fe}+\text{Ni})$. Example 20 results in a low saturation magnetic flux density due to the high content of Ta and the high content of (Zr+Hf+Nb+Ta). In contrast, Examples 1 to 9 all satisfy the requirements of the present invention and
15 thus found to be excellent in all evaluated properties.

[0035]

As described above, an high hardness which has never been achieved by a conventional alloy can be obtained by adding Ta and/or Nb and B at the same time and setting the $\text{B}/(\text{Nb}+\text{Ta})$
20 ratio to the certain ratio. This makes it possible to provide an alloy excellent in magnetic properties, amorphous properties, corrosion resistance, and hardness.

CLAIMS

1. A CoFeNi-based alloy for a soft magnetic film layer in a perpendicular magnetic recording medium, wherein the CoFeNi-based alloy comprises in at%:

Co+Fe+Ni: 70 to 92%, provided that Ni content may be 0;

Ta: 1 to 8%; and

B: more than 7% and not more than 20%,

wherein the composition of the CoFeNi-based alloy (at%) satisfies the following ratios:

Co/(Co+Fe+Ni): 0.1 to 0.75;

Fe/(Co+Fe+Ni): 0.1 to 0.65;

Ni/(Co+Fe+Ni): 0 to 0.35; and

B/Ta: 1 to 8.

2. A CoFeNi-based alloy for a soft magnetic film layer in a perpendicular magnetic recording medium, wherein the CoFeNi-based alloy comprises in at%:

Co+Fe+Ni: 70 to 92%, provided that Ni content may be 0;

Nb+Ta: 1 to 8%; and

B: more than 7% and not more than 20%,

wherein the composition of the CoFeNi-based alloy (at%) satisfies the following ratios:

Co/(Co+Fe+Ni): 0.1 to 0.75;

Fe/(Co+Fe+Ni): 0.1 to 0.65;

Ni/(Co+Fe+Ni): 0 to 0.35; and

B/(Nb+Ta): 1 to 8.

3. A CoFeNi-based alloy for a soft magnetic film layer in a perpendicular magnetic recording medium, wherein the CoFeNi-based alloy comprises in at%:

Co+Fe+Ni: 70 to 92%, provided that Ni content may be 0;

Zr+Hf+Nb+Ta: 1 to 8%;

B: more than 7% and not more than 20%;

Zr+Hf: 0 to less than 2%; and

Al+Cr: 0 to 5%,

wherein the composition of the CoFeNi-based alloy (at%) satisfies the following ratios:

Co/(Co+Fe+Ni): 0.1 to 0.75;

Fe/(Co+Fe+Ni): 0.1 to 0.65;

Ni/(Co+Fe+Ni): 0 to 0.35; and

B/(Nb+Ta): 1 to 8.

4. A sputtering target material made of the CoFeNi-based alloy according to claim 1.

5. A sputtering target material made of the CoFeNi-based alloy according to claim 2.

6. A sputtering target material made of the CoFeNi-based alloy according to claim 3.

7. A perpendicular magnetic recording medium having a soft magnetic film layer made of the CoFeNi-based alloy according to claim 1.

8. A perpendicular magnetic recording medium having a soft magnetic film layer made of the CoFeNi-based alloy according to claim 2.

9. A perpendicular magnetic recording medium having a soft magnetic film layer made of the CoFeNi-based alloy according to claim 3.