

ALLOY USED IN SOFT-MAGNETIC THIN-FILM LAYER ON
PERPENDICULAR MAGNETIC RECORDING MEDIUM,
SPUTTERING-TARGET MATERIAL, AND PERPENDICULAR
MAGNETIC RECORDING MEDIUM HAVING SOFT-MAGNETIC
THIN-FILM LAYER

[Cross-Reference to Related Application]

[0001]

This application claims priority to Japanese Patent Application
No. 2011-212045 filed on September 28, 2011, the entire
content of which is incorporated herein by reference.

[Technical Field]

[0002]

The present invention relates to an alloy and a sputtering target
material for a soft magnetic thin film layer in a perpendicular
magnetic recording medium.

[Background Art]

[0003]

In recent years, there have been remarkable progresses in
magnetic recording technology, heightening of recording
densities in magnetic recording media has been proceeding due
to increasing drive capacities, and perpendicular magnetic
recording system, which achieves further high recording density
when compared to longitudinal magnetic recording media
conventionally used, has been put into practical use. The
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 a method 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. For the
magnetic recording film layer, a CoCrPt-SiO₂-based alloy is
commonly used.

[0004]

As for a conventional soft magnetic film layer, a high saturation magnetic flux density (hereinafter referred to as B_s) and a high amorphous forming ability (hereinafter referred to as an amorphous property) have been necessary and, in addition, various properties such as high corrosion resistance and a high hardness have been additionally required depending on applications of perpendicular magnetic recording media and environments in which they are used. Among the required properties described above, high B_s is particularly important; for example, Japanese Patent Laid-Open Publication No. 2008-299905 (Patent Literature 1), Japanese Patent Laid-Open Publication No. 2011-68985 (Patent Literature 2), and Japanese Patent Laid-Open Publication No. 2011-99166 (Patent Literature 3) are also aimed at high B_s , and a B_s of 1.1 T or more, 1.3 T or more only in an amorphous state, in Examples of all the publications shows that a B_s of 1.3 T or more is generally necessary for actual use as a sputtering film in a perpendicular magnetic recording medium.

[0005]

The reason that such high B_s is required is considered to be because B_s that is not less than a specified value is necessary for stabilizing the magnetization of a recording film and because magnetic anisotropy in the in-plane direction of a recording medium (hereinafter referred to as in-plane magnetic anisotropy (H_k)) is imparted. In particular, high H_k is a factor significant for reducing noise, and a higher B_s of a soft magnetic film is known to generally lead to a higher H_k value.

[0006]

However, use of a soft magnetic film with high B_s also has a drawback. In other words, there is also a problem that the use of the soft magnetic film with high B_s in a state of being magnetized by a head for writing results in a magnetic influence on a wider surrounding area than necessary due to a high magnetic flux density, thus in necessity for a large space needed for writing per unit recorded information, and in difficulty in increasing a recording density. This phenomenon is

also referred to as so-called "blurred writing."

[Citation List]

[0007]

[Patent Literature]

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

[PTL 2] Japanese Patent Laid-Open Publication No. 2011-68985

[PTL 3] Japanese Patent Laid-Open Publication No. 2011-99166

[Summary of the Invention]

[0008]

10 From the background mentioned above, the inventors considered that both of reduction of noise caused by high Hk and a high recording density due to suppression of "blurred writing" can be compatible by providing a soft magnetic alloy having high Hk even in the case of comparatively low Bs while
15 having minimum Bs for stabilizing the magnetization of a recording film. Accordingly, the inventors considered it important to examine influential factors, other than high Bs, for increasing Hk, and provide a soft magnetic amorphous alloy capable of realizing it.

20 [0009]

As a result of examination of other influential factors on Hk in a manner different from a conventional manner in which high Hk is achieved by high Bs, it was presumed that a high Bs temperature characteristic (high Curie point) is effective. On
25 the basis of this technical concept, the inventors found that compatibility between high Hk and reduction in blurred writing can be established by using an alloy having low Bs and an enhanced Bs high-temperature characteristic, and thus accomplished the present invention.

30 [0010]

It is therefore an object of the present invention to provide a soft magnetic alloy for a perpendicular magnetic recording medium exhibiting a low saturation magnetic flux density at room temperature as well as having a small decrease in the
35 saturation magnetic flux density at high temperature; and a sputtering target material for producing a thin film of the alloy.

[0011]

According to one embodiment of the present invention, there is provided an alloy used for a soft magnetic thin film layer in a perpendicular magnetic recording medium, wherein

- 5 the alloy comprises in at%: one or two or more of Ti, Zr, Hf, V, Nb, Ta, Cr, Mo, W, Mn, Ni, Cu, Al, B, C, Si, P, Zn, Ga, Ge, and Sn, and the balance Co, Fe, and unavoidable impurities, preferably consists essentially of these elements, more preferably consists of these elements; and
- 10 all of the following expressions (1) to (3):
 - (1) $0 \leq \text{Fe}\% / (\text{Fe}\% + \text{Co}\%) \leq 0.5$;
 - (2) $5 \leq \text{Ti}\% + \text{Zr}\% + \text{Hf}\% + \text{V}\% + \text{Nb}\% + \text{Ta}\% + \text{B}\% / 2$; and
 - (3) $0.3 \leq 0.813 \times \text{Fe}\% / (\text{Fe}\% + \text{Co}\%) - 0.062 \times \text{TNM} + 1.751 \leq 1.2$
 (where $\text{Fe}\% / (\text{Fe}\% + \text{Co}\%)$ is a ratio between a content of Fe and a total content of Fe and Co; and TNM is a total percentage of the amounts of Ti, Zr, Hf, V, Nb, Ta, Cr, Mo, W, Mn, Ni, Cu, Al, B, C, Si, P, Zn, Ga, Ge, and Sn added, in which as for only B, a value of 1/2 thereof is used) are satisfied.
- 15

[0012]

- 20 According to another embodiment of the present invention, there is provided a soft magnetic thin film layer comprising the above alloy. According to still another embodiment of the present invention, there is provided a perpendicular magnetic recording medium comprising the above soft magnetic thin film layer.
- 25 layer. According to still another embodiment of the present invention, there is provided a sputtering target material comprising the above alloy. According to still another embodiment of the present invention, there is provided a soft magnetic thin film layer formed with the above sputtering target material.
- 30 According to still another embodiment of the present invention, there is provided a perpendicular magnetic recording medium comprising the above soft magnetic thin film layer.

[0013]

- According to the present invention, there can be provided a soft magnetic alloy for a perpendicular magnetic recording medium exhibiting low Bs at room temperature and having a small
- 35

decrease in B_s at high temperature; and a sputtering target material for producing a thin film of the alloy. Use of the alloy of the present invention in a perpendicular magnetic recording medium makes it possible to fully exert the magnetic characteristics of the soft magnetic alloy and to sufficiently enhance the function of a soft magnetic thin film layer, and can thus lead to the improvement in the performance of the perpendicular magnetic recording medium.

[Description of Embodiments]

10 [0014]

The present invention is explained in detail below. Unless otherwise specified, "%" means at%.

[0015]

First, it is expected that H_k is greatly influenced by a demagnetizing field, i.e., H_k is highly affected by a demagnetizing factor and the intensity of magnetization, since a sputtering film is a thin film. The demagnetizing factor is an external factor determined by the shape of the thin film, while the intensity of magnetization corresponds to B_s of a soft magnetic film. Accordingly, H_k correlates with B_s of the soft magnetic film as mentioned above. However, this concept leads to the concept that high B_s is required for high H_k and turns to be the same as the conventional concept that requires a soft magnetic alloy with high B_s .

25 [0016]

Thus, examination for finding a factor affecting H_k , other than B_s , was conducted. As mentioned in Examples and Comparative Examples below, as a result of producing sputtering films and evaluating H_k for some soft magnetic amorphous alloy compositions, high H_k was obtained at high B_s as shown in the conventional concept, while the phenomena of extremely reducing H_k were observed in some compositions. The detailed analysis of these results revealed that H_k becomes extremely low as mentioned above in a composition in which B_s becomes approximately zero particularly at the temperature of a substrate during film formation by sputtering.

[0017]

From the above, it was considered that, rather than reduction of Bs at room temperature as attempted in a conventional manner, reduction in the degree of the Bs decrease from room temperature to a temperature during film formation is important. In other words, it was suggested that both high Hk and reduced "blurred writing" can be achieved by applying an alloy which has low Bs at room temperature but has a low degree of the Bs decrease from room temperature to a temperature of about 150°C, which is the temperature during sputtering film formation. Based on such a concept, an alloy having a Bs at room temperature, of 0.3 to 1.2 T, lower than that of a conventional soft magnetic film and having a low degree of Bs decrease at 150°C with respect to Bs at room temperature was examined, and the present invention was accomplished.

[0018]

In addition, $(Bs \text{ at } 150^{\circ}\text{C}) / (Bs \text{ at room temperature}) \times 100\%$ was used as an index for evaluating the degree of Bs decrease at 150°C with respect to the Bs at room temperature. In other words, the Bs ratio having a higher value approximating 100% shows a lower decrease of Bs due to increase in temperature. Hereinafter, the ratio is simply referred to as "Bs ratio."

[0019]

The alloy according to the present invention satisfies Expression (1): $0 \leq \text{Fe}\% / (\text{Fe}\% + \text{Co}\%) \leq 0.5$. The upper limit thereof is more accurately 0.50. In this alloy, Fe and Co are elements for imparting minimal magnetization necessary for stabilizing the magnetization of a recording film, and the behaviors of Bs and $\text{Fe}\% / (\text{Fe}\% + \text{Co}\%)$ are shown in so-called Slater-Pauling curve. The most important findings in the present invention are that high Hk can be provided even in a soft magnetic film with comparatively low Bs at room temperature by setting a high Bs ratio as mentioned above and, in addition, that the Bs ratio can be kept high by decreasing $\text{Fe}\% / (\text{Fe}\% + \text{Co}\%)$.

[0020]

Although the detailed cause of this phenomenon in this alloy

having an amorphous structure is unclear, it is considered that the cause relates to the orbit distributions of the 3d electrons of an Fe atom and a Co atom. In particular, $\text{Fe}\% / (\text{Fe}\% + \text{Co}\%)$ exceeding 0.5 results in an insufficient Bs ratio. In addition, a
 5 thin Ru film is generally inserted between soft magnetic films in a perpendicular magnetic recording medium, and resistance against a weak noise magnetic field from the outside under an environment in which a hard disk is used is imparted by an
 10 antiferromagnetic bond between each soft magnetic film and the Ru film. There are many cases in which inclusion of Fe to some extent is preferable, since Fe may be used for improving the antiferromagnetic bond. However, in terms of providing a high Bs ratio, it is preferred to reduce Fe. Accordingly, the preferred
 15 range of $\text{Fe}\% / (\text{Fe}\% + \text{Co}\%)$ is more than 0% and not more than 0.45%, more preferably 0.1% or more and 0.40% or less.

[0021]

The alloy according to the present invention also satisfies Expression (2): $5 \leq \text{Ti}\% + \text{Zr}\% + \text{Hf}\% + \text{V}\% + \text{Nb}\% + \text{Ta}\% + \text{B}\% / 2$. In this alloy, Ti, Zr, Hf, V, Nb, Ta, and B are elements for enhancing
 20 amorphous properties, and the total thereof, of less than 5, results in insufficient amorphous properties. In addition, use of a crystalline alloy causes noise to be generated from a magnetic recording medium. However, B is an element particularly having a high amorphousness promotion effect, and addition of
 25 B of which the amount is one-half of the amount of each of the other element added provides an almost equivalent effect, and therefore, as for only B, a value of 1/2 is used in the expression of the total. For providing sufficient amorphous properties, 9% or more is preferred, and 13% or more is more preferred.

30 [0022]

The alloy according to the present invention also satisfies Expression (3): $0.3 \leq 0.813 \times \text{Fe}\% / (\text{Fe}\% + \text{Co}\%) - 0.062 \times \text{TNM} + 1.751 \leq 1.2$. The lower and upper limits thereof are more accurately 0.30 and 1.20, respectively. In this alloy, all of Ti,
 35 Zr, Hf, V, Nb, Ta, Cr, Mo, W, Mn, Ni, Cu, Al, B, C, Si, P, Zn, Ga, Ge, and Sn are elements that reduce Bs. Bs of this alloy is

generally obtained by making approximation in
"0.813×Fe%/(Fe%+Co%)-0.062×TNM+1.751." This

expression is an expression obtained at a high correlation
coefficient as a result of multiple regression analysis of Bs
5 obtained in the range of $0 \leq \text{Fe\%}/(\text{Fe\%}+\text{Co\%}) \leq 0.50$ with
Fe%/(Fe%+Co%) and TNM in Examples below, and a soft
magnetic alloy having a Bs of 0.3 to 1.2 T, comparatively lower
than that of a conventional soft magnetic film, is obtained by
setting a value of the expression in a range of 0.3 to 1.2.
10 However, a value of less than 0.3 results in insufficient Hk, while
a value of more than 1.2 results in increased "blurred writing"
like a conventional soft magnetic film with high Bs. Since the
effect of B for reducing Bs is one-half of that of each of the
other elements, as for only B, a value of 1/2 is used for
15 calculating TNM. In addition, 0.4 to 1.1 is preferred, and 0.5 to
1.0 is more preferred.

[Examples]

[0023]

The present invention is specifically explained below with
20 reference to Examples.

[0024]

An alloy powder with the composition shown in Table 1 was
produced by a gas atomization method. 25 kg of a molten base
material was induction-melted in Ar atmosphere with a reduced
25 pressure, an alloy molten metal was tapped from a nozzle
having a diameter of 8 mm, and just thereafter, a high-pressure
Ar gas was sprayed to perform atomization. The powder was
classified into 500 μm or less and used as a raw powder for HIP
molding (hot isostatic press). A carbon steel can having a
30 diameter of 200 mm and a length of 100 mm was filled with the
raw powder, then subjected to vacuum deaeration, and sealed
to produce a billet for HIP molding. The billet filled with the
powder was HIP-molded under conditions of a molding
temperature of 1000°C, a pressure of 120 MPa, and a retention
35 time of 2 hours. Then, a sputtering target material having a
diameter of 95 mm and a thickness of 2 mm was produced from

the molded body. A thin film was produced using the sputtering target material.

[0025]

The inside of a chamber was evacuated to 1×10^{-4} Pa or less, an
5 Ar gas with a purity of 99.99% was charged until reaching 0.6
Pa, and sputtering was performed. The thin film having a
thickness of 1.5 μm was generated on a glass substrate. In the
sputtering, the temperature of the substrate during generating
the thin film was around 150°C by plasma irradiation of the
10 sputtering gas. Bs of the thin film sample was measured at
each of room temperature (30°C) and 150°C using VSM
(sample-vibration-type magnetic flux meter), and the
percentage of Bs at 30°C to Bs at 150°C (hereinafter referred to
as "Bs ratio" or " $(\text{Bs at } 150^\circ\text{C})/(\text{Bs at } 30^\circ\text{C}) \times 100\%$ ") was
15 evaluated.

[0026]

Furthermore, B-H curves in which magnetization was performed
in perpendicular and in-plane directions with respect to a thin
film surface, respectively, were also measured, and a difference
20 between applied magnetic fields necessary for saturating
magnetization in the respective directions, i.e., a value obtained
by subtracting the applied magnetic field necessary in the
in-plane direction from the applied magnetic field necessary in
the perpendicular direction was evaluated as an anisotropic
25 magnetic field H_k in a magnetization direction. The crystal
structure was evaluated by X-ray diffraction. The X-ray source
was Cu- $\text{K}\alpha$ ray, and the measurement was conducted at a scan
speed of 4°/min. The suitability of the crystal structure was
evaluated with a case in which no crystalline peak was observed
30 in the diffraction pattern as "good," and a case in which a
crystalline peak was observed as "poor."

[0027]

[Table 1]

Table 1

No.	Alloy Composition (%)	Fe/(Fe+Co)	Expression (2)	TNM	Expression (3)	Room Temperature Bs (T)	150°C Bs(T)	Bs Ratio (%)	Hk (A/m)	Crystal Structure	
1	88Co-9Zr-3W	0.00	9	12	1.01	1.00	0.94	93.5	960	Good	Present Invention Examples
2	84Co-10Ta-6B	0.00	13	13	0.95	0.98	0.91	93.1	910	Good	
3	83Co-17Ta	0.00	17	17	0.70	0.70	0.63	90.1	690	Good	
4	78Co-10Ti-11Nb-1Ge	0.00	21	22	0.39	0.34	0.28	83.2	330	Good	
5	78.85Co-4.15Fe-7Zr-10Ta	0.05	17	17	0.74	0.72	0.64	89.5	680	Good	
6	73.8Co-8.2Fe-7Zr-10Ta-1W	0.10	17	18	0.72	0.71	0.63	88.9	670	Good	
7	60.2Co-25.8Fe-3Zr-1V-2B-8Si	0.30	5	13	1.19	1.18	1.12	94.9	1100	Good	
8	60.2Co-25.8Fe-9Ti-5Cr	0.30	9	14	1.13	1.08	1.01	93.6	1030	Good	
9	58.8Co-25.2Fe-8Zr-5V-2Mn-1Ni	0.30	13	16	1.00	1.03	0.95	92.2	940	Good	
10	57.4Co-24.6Fe-10Hf-7Ta-1P	0.30	17	18	0.88	0.94	0.85	90.6	870	Good	
11	56.7Co-24.3Fe-17Zr-1Sn-1Zn	0.30	17	19	0.82	0.77	0.68	88.7	700	Good	
12	55.3Co-23.7Fe-7Zr-10Ta-4W	0.30	17	21	0.69	0.70	0.61	86.5	640	Good	
13	54.6Co-23.4Fe-9Zr-8Ta-3Mo-2Ga	0.30	17	22	0.63	0.58	0.49	83.8	510	Good	
14	53.2Co-22.8Fe-9Ti-8Nb-5Ge-2Sn	0.30	17	24	0.51	0.50	0.40	80.3	420	Good	
15	49Co-21Fe-8Zr-8Ta-10B-2Mo-2Cu	0.30	21	25	0.44	0.42	0.32	75.4	290	Good	
16	51.1Co-21.9Fe-10Zr-10Nb-5Ta-2Sn	0.30	25	27	0.32	0.34	0.23	67.0	180	Good	
17	46.8Co-31.2Fe-7Zr-10Ta-5W	0.40	17	22	0.71	0.68	0.57	83.6	590	Good	
18	42.35Co-34.65Fe-7Zr-10Ta-6W	0.45	17	23	0.69	0.70	0.57	81.1	580	Good	
19	41Co-41Fe-9Hf-5Mn-2C-2Si	0.50	9	18	1.04	1.02	0.93	91.0	950	Good	
20	42Co-42Fe-8Zr-5V-3Sn	0.50	13	16	1.17	1.15	1.07	93.4	1050	Good	
21	38.5Co-38.5Fe-7Zr-10Ta-6W	0.50	17	23	0.73	0.72	0.55	76.5	550	Good	
22	37Co-37Fe-10Hf-6Nb-5Ta-5Al	0.50	21	26	0.55	0.56	0.32	56.8	250	Good	
23	30.4Co-45.6Fe-7Zr-10Ta-7W	0.60	17	24	0.75	0.70	0.28	40.3	90	Good	
24	26.6Co-49.4Fe-7Zr-10Ta-7W	0.65	17	24	0.79	0.71	0.27	38.3	80	Good	
25	16Co-64Fe-7Zr-10Ta-3W	0.80	17	20	1.16	0.69	0.17	25.0	60	Good	
26	88Fe-8Zr-4B	1.00	10	10	1.94	0.68	0.00	0.00	10	Good	Comparative Examples
27	26.6Co-49.4Fe-9Hf-11Mn-2C-2Si	0.65	9	24	0.79	0.70	0.28	39.3	70	Good	
28	26.6Co-49.4Fe-9Ti-4Nb-7Ge-4Sn	0.65	13	24	0.79	0.70	0.27	38.8	70	Good	
29	26.6Co-49.4Fe-8Ti-8V-5Ta-3Cr	0.65	21	24	0.79	0.72	0.28	38.5	60	Good	
30	60.2Co-25.8Fe-2Zr-1V-2B-9Al	0.30	4	13	1.19	1.22	1.16	94.9	1150	Poor	
31	88Co-4Zr-8W	0.00	4	12	1.01	1.01	0.94	93.5	980	Poor	
32	41Co-41Fe-1Ti-1Hf-2Ta-7Cr-7Al	0.50	4	18	1.04	1.02	0.93	91.0	920	Poor	
33	50.4Co-21.6Fe-10Zr-10Nb-5Ta-3Sn	0.30	25	28	0.26	0.21	0.08	39.2	80	Good	
34	60.9Co-26.1Fe-3Zr-1V-2B-7Si	0.30	5	12	1.25	1.31	1.26	96.0	1200	Good	
35	43Co-43Fe-8Zr-5V-1Sn	0.50	13	14	1.29	1.28	1.23	96.0	1200	Good	

NOTE 1: Expression (2) is $Ti\% + Zr\% + Hf\% + V\% + Nb\% + Ta\% + B\%/2$.

NOTE 2: Expression (3) is $0.813 \times Fe\% / (Fe\% + Co\%) - 0.062 \times TNM + 1.751$.

NOTE 3: The underlined figures fall outside the scope of the present invention.

As shown in Table 1, Nos. 1 to 22 are present invention examples, while Nos. 23 to 35 are comparative examples.

[0028]

First, each value of Expression (3)
 5 "0.813×Fe%/(Fe%+Co%)-0.062×TNM+1.751" in Examples well corresponds to Bs at room temperature, and it is confirmed that this expression is effective and an alloy having a Bs of 0.3 to 1.2 T, lower than that of a conventional soft magnetic film, is obtained by setting a value of this expression to 0.3 to 1.2.
 10 However, this expression is not effective in a composition, in which Fe%/(Fe%+Co%) greatly falls outside the scope of the present invention, like Comparative Examples Nos. 25 and 26.

[0029]

Next, Present Invention Examples Nos. 7 to 16 are samples in
 15 which Fe%/(Fe%+Co%) is fixed to 0.3, TNM which reduces Bs is varied from 13 to 27, and Bs at room temperature is varied from 0.34 to 1.18. Hk of these samples changed with Bs, and a conventionally known "phenomenon in which high Hk is provided at high Bs" is also observed in a Bs range of less than
 20 1.2 T, lower than conventional one, as in the present invention.

[0030]

The important points of the present invention are shown in Present Invention Examples and Comparative Examples. All of Present Invention Examples Nos. 3, 5, 6, 12, 18, and 21 and
 25 Comparative Examples Nos. 23 to 29 show a Bs of around 0.7 T, lower than that of a conventional soft magnetic film, at room temperature. However, Hk of each of Present Invention Examples Nos. 3, 5, 6, 12, 18, and 21 is as high as 550 A/m or more, while Hk of each of Comparative Examples Nos. 23 to 29
 30 is 90 A/m or less, which is significantly low, and Hk of Comparative Example No. 26, in which Bs at 150°C is approximately zero, is extremely low.

[0031]

Furthermore, it is clear that Hk of each of the samples inversely
 35 correlates with Fe%/(Fe%+Co%) and positively correlates with a Bs ratio. Although the reason of this phenomenon is unclear,

it is presumed that there is the influence of a magnetization behavior in film formation at a temperature of around 150°C, since the thin film is also affected by a magnetic field from the outside during sputtering. As described above, in addition to
5 the conventionally known "phenomenon in which high Hk is provided at high Bs," the inventors found that "high Hk is provided by a high Bs ratio." It was also revealed that an alloy having a high Bs ratio is obtained by setting $\text{Fe}\% / (\text{Fe}\% + \text{Co}\%)$ to a low level.

10 [0032]

Individual Comparative Examples are explained below. In all of Comparative Examples Nos. 23 to 29, $\text{Fe}\% / (\text{Fe}\% + \text{Co}\%)$ is more than 0.50, and therefore, a Bs ratio is low while Hk is low. In Comparative Examples Nos. 30 to 32, the total of the
15 amorphousness promoting elements was low, and therefore, crystalline peaks were observed as a result of X-ray diffraction. In Comparative Example No. 33, Bs at room temperature is low, and therefore, a Bs ratio is low while Hk is low.

[0033]

20 Furthermore, Comparative Examples Nos. 34 and 35 are explained in detail. When an end of a bar-type ferrite magnet having a diameter of 1 mm and a length of 10 mm was brought into contact with the center of the thin film of each of Present Invention Examples Nos. 7, 10, and 12 and Comparative
25 Examples Nos. 34 and 35 and then removed, and a residual magnetization value was measured with a gauss meter on a thin film surface 10 mm apart from the position where the ferrite magnet was brought into contact, the value of Present Invention Example No. 10 was 1.2; the value of Present Invention
30 Example No. 7 was 1.5; and both values of Comparative Examples Nos. 34 and 35 were 2.5 on the basis that the residual magnetization of Present Invention Example No. 12 was 1.0. From this result, it is shown that in Comparative Examples Nos. 34 and 35, Bs at room temperature is high, therefore, a
35 wide range is magnetically affected even after the external magnetic field has been removed, and "blurred writing" is large.

[0034]

In contrast, it is found that in Present Invention Examples Nos. 1 to 22, B_s at room temperature is 0.3 to 1.2 T, lower than that of a soft magnetic film in a conventional perpendicular magnetic recording medium, and the ratio of B_s at 150°C to B_s at room temperature is high, and therefore, H_k is high.

CLAIMS

1. A soft magnetic thin film layer in a perpendicular magnetic recording medium, the soft magnetic thin film layer comprising an alloy, wherein:

the alloy comprises, in at%, one or two or more of Ti, Zr, Hf, V, Nb, Ta, Mo, W, Ni, Cu, B, P, Zn, Ga, Ge, and Sn, with the balance being Co, Fe, and unavoidable impurities;

the alloy satisfies all of the following expressions (1) to (3):

(1) $0 < \text{Fe}\% / (\text{Fe}\% + \text{Co}\%) \leq 0.5$;

(2) $13 \leq \text{Ti}\% + \text{Zr}\% + \text{Hf}\% + \text{V}\% + \text{Nb}\% + \text{Ta}\% + \text{B}\% / 2$; and

(3) $0.3 \leq 0.813 \times \text{Fe}\% / (\text{Fe}\% + \text{Co}\%) - 0.062 \times \text{TNM} + 1.751 \leq 1.2$

where, $\text{Fe}\% / (\text{Fe}\% + \text{Co}\%)$ is a ratio between a content of Fe and a total content of Fe and Co, and TNM is a total percentage of amounts of Ti, Zr, Hf, V, Nb, Ta, Mo, W, Ni, Cu, B, P, Zn, Ga, Ge, and Sn added, in which as for only B, a value of 1/2 thereof is used;

the alloy has B_s at room temperature, of 0.3 to 1.2 T, and H_k of 180 to 1050 A/m; and

the alloy has an amorphous structure.

2. A perpendicular magnetic recording medium, comprising the soft magnetic thin film layer according to claim 1.