

DESCRIPTION

Co-Fe ALLOY FOR SOFT MAGNETIC FILMS, SOFT
MAGNETIC FILM, AND PERPENDICULAR
MAGNETIC RECORDING MEDIUM

Technical Field

[0001]

The present invention relates to a Co-Fe based alloy for a soft magnetic film, the soft magnetic
5 film, and a perpendicular magnetic recording medium including the soft magnetic film.

Background Art

[0002]

Recently, much progress has been made in
10 magnetic recording techniques, and high recording density of magnetic recording medium has been pursued since a capacity of a drive is increasing. However, in magnetic recording medium of widely used longitudinal magnetic recording system, an attempt to achieve the
15 high recording density leads to a refined recording bit which requires such a high coercive force that recording cannot be made with a recording head. To solve the problem, a perpendicular magnetic recording system has been studied as a measure to improve the
20 recording density.

In the perpendicular magnetic recording

system, a perpendicular magnetic recording medium has a magnetic film, and an axis of easy magnetization is oriented perpendicularly to a medium surface. The system is suitable for high recording density since it
5 has a small demagnetizing field in a bit and a small decrease in the read/write characteristics even if the recording density is increased. For the perpendicular magnetic recording system, the recording medium having the magnetic recording film layer with an increased
10 recording sensitivity and a soft magnetic film layer has been developed.

[0003]

The soft magnetic film for such magnetic recording medium needs to have a high saturation
15 magnetic flux density, and a Co-Fe alloy has been suitably used since it has a high saturation magnetic flux density. Particularly, an amorphous film is desired as the soft magnetic film for the magnetic recording medium since it has excellent soft magnetic
20 properties. Thus, it is necessary to add an element which facilitates amorphization to the Co-Fe alloy. For the element, Zr or Ta is generally employed.

The soft magnetic film is generally produced through a magnetron sputtering process with use of a
25 target material of the same composition. On the other hand, since such a Co-Fe based alloy target material has the problem of weatherability, proposed is a target material including the Co-Fe based alloy added with Al

or Cr (see, for example, Patent Document 1).

[0004]

Patent Document 1 : JP-A-2007-284741

Summary of the Invention

5 [0005]

A target material for a soft magnetic film disclosed in the Patent Document 1 is effective since a certain improvement in weatherability is achieved by adding 0.2 to 5 atomic% of Al or Cr to a Co-Fe alloy.

10 However, studies of the present inventors have proved that sufficient weatherability can not be obtained by the addition of Al or Cr.

[0006]

An object of the present invention is to
15 solve the above problems and to provide a Co-Fe based alloy for a soft magnetic film used in a perpendicular magnetic recording medium or the like, which has excellent weatherability while maintaining high soft magnetic properties.

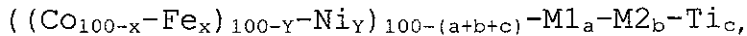
20 [0007]

The present inventors have conducted intensive studies on an element to be added to the Co-Fe based alloy for a soft magnetic film used in a perpendicular magnetic recording medium or the like.

25 As a result, they have found addition of Ti and its suitable range of the addition of Ti. Thus, the present invention has been accomplished.

[0008]

Accordingly, the present invention provides a Co-Fe based alloy for a soft magnetic film, having a composition represented by a formula by an atomic
 5 ratio:



where $5 \leq x \leq 80$, $0 \leq y \leq 25$, $2 \leq a \leq 6$, $2 \leq b \leq 10$, $0.5 \leq c \leq 10$, and the balance being unavoidable impurities, wherein the M1 element in the formula is one or more elements selected
 10 from Zr, Hf and yttrium, and the M2 element in the formula is one or more elements selected from Ta and Nb. The Co-Fe based alloy for a soft magnetic film of the present invention may contain not more than 5 atomic% of boron (B).

15 [0009]

The Co-Fe based alloy for a soft magnetic film of the present invention may be applied to a sputtering target material or a soft magnetic film layer in a perpendicular magnetic recording medium.
 20 Furthermore, the Co-Fe based alloy preferably has a saturation magnetization of not lower than 1.0 T.

[0010]

According to the present invention, a Co-Fe based alloy for a soft magnetic film used in a
 25 perpendicular magnetic recording medium or the like is provided, which has excellent weatherability while maintaining high soft magnetic properties. It is very advantageous for manufacturing the perpendicular

magnetic recording medium.

Detail Description of the Invention

[0011]

It is important that the present invention
5 selects Ti as a most suitable element for effectively
improving weatherability without a significant decrease
in the soft magnetic properties in a Co-Fe based alloy
for a soft magnetic film, and also it finds the amount
to be added for achieving the above advantage.

10 [0012]

First, the Co-Fe based alloy which serves as
a basis for the present invention will be described
below.

A Co-Fe alloy which is a base of the Co-Fe
15 based alloy of the present invention has a composition
represented by $(\text{Co}_{100-x}\text{-Fe}_x)_{100-y}\text{-Ni}_y$, where $5 \leq x \leq 80$ and
 $0 \leq y \leq 25$. The Co-Fe alloy having a composition within the
range has a high saturation magnetization and thus is
suitable for a soft magnetic film. A part of the Co-Fe
20 alloy may be substituted by Ni to an extent $0 \leq y \leq 25$.
This is because the soft magnetic properties can be
effectively improved without a significant decrease in
the saturation magnetization.

2 to 6 atomic% of one or more elements
25 selected from Zr, Hf and yttrium is added to the above
Co-Fe alloy as an M1 element, and 2 to 10 atomic% of
one or more elements selected from Ta and Nb is added

thereto as an M2 element. This is because adding of the M1 and M2 elements in the above range facilitates amorphization and improves magnetic characteristics as a sputtering film without a significant decrease in the saturation magnetization of the Co-Fe alloy.

[0013]

The Co-Fe based alloy of the present invention contains 0.5 to 10 atomic% of Ti as an essential element for effectively improving the weatherability of the Co-Fe based alloy. A potential/pH diagram shows that Ti has a passivation region in a broad pH range, and thus Ti is selected as an element to be added effective in improving the weatherability. The above advantage of improving the weatherability is small when the content of Ti is less than 0.5 atomic%, and the magnetization is decreased when the content of Ti is more than 10 atomic%. Thus, it is important to control the content of Ti in a range of 0.5 to 10 atomic%. Furthermore, the content of Ti is desirably not more than 5 atomic% to prevent decreasing of the magnetization.

[0014]

As described above, the Co-Fe based alloy of the present invention has a composition represented by the formula by an atomic ratio: $((\text{Co}_{100-x}\text{-Fe}_x)_{100-y}\text{-Ni}_y)_{100-(a+b+c)}\text{-M1}_a\text{-M2}_b\text{-Ti}_c$, where $5 \leq x \leq 80$, $0 \leq y \leq 25$, $2 \leq a \leq 6$, $2 \leq b \leq 10$, and $0.5 \leq c \leq 10$. The Co-Fe based alloy may contain unavoidable impurities without deteriorating the

advantages of the present invention. For example, the Co-Fe based alloy represented by the formula may have a purity of not lower than 99.9%.

[0015]

5 The Co-Fe based alloy of the present invention may further contain not more than 5 atomic% of boron. The addition of not more than 5 atomic% of boron can improve mechanical properties of the alloy, in particular hardness, without a significant decrease
10 in the weatherability or magnetization.

[0016]

A process for producing the Co-Fe based alloy may include a melt casting process or a powder sintering process. In the melt casting process, the
15 Co-Fe based alloy may be produced in a form of a cast ingot or a bulk which is obtained by plastic working or pressing of the cast ingot. In the powder sintering process, a Co-Fe based alloy powder of a final composition may be produced, by a gas atomizing
20 process, to be used as a raw material powder.

Alternatively, a mixed powder may be obtained by mixing a plurality of alloy powders or pure metal powders to form the final composition of the Co-Fe based alloy as raw material powder. A process of sintering the raw
25 material powder may include pressure sintering such as hot isostatic pressing, hot pressing, spark plasma sintering or extrusion press sintering.

[0017]

The Co-Fe based alloy of the present invention may be processed in a target material suitable for various types of sputtering apparatus to form a soft magnetic film having excellent weatherability by sputtering the target.

Example 1

[0018]

The present invention will be described in more detail by means of Examples.

First, cast ingots having Co-Fe based alloy compositions shown in Table 1 were produced. Raw materials having a purity of not less than 99.9% were heated and melted in a high-frequency heating furnace under vacuum and the molten alloys were cast in a mold made of iron to form the ingots having a diameter of 220 mm × 45 mm. The resulting ingots were processed into Co-Fe based alloy bulks having a diameter of 180 mm and a thickness of 7 mm.

For evaluating the weatherability of the bulks, samples having a diameter of 10 mm × 20 mm were produced from the cast ingots and dipped in 10% hydrochloric acid at 50°C for 24 hours. The weight reduction rates were measured to evaluate the weatherability of the bulks. The measurement results are shown in Table 1.

For evaluating the magnetization of the bulks, samples of 30 mm × 10 mm × 5 mm were produced

from the cast ingots, and the magnetization under an external magnetic field of 160 kA/m was measured using a DC magnetic properties measurement apparatus (TRF5A made by Toei Industry Co., Ltd.). The results are shown in Table 2.

[0019]

[Table 1]

Sample	Composition of Co-Fe based alloy (atomic%)	Weight reduction rate (%)	Remarks
1	(Co ₇₀ -Fe ₃₀) ₉₀ -Zr ₄ -Ta ₄ -Ti ₂	0.2	Present invention
2	(Co ₇₀ -Fe ₃₀) ₉₀ -Zr ₄ -Ta ₄ -Al ₁ -Cr ₁	1.3	Comparative Example
3	(Co ₇₀ -Fe ₃₀) ₉₂ -Zr ₄ -Ta ₄	0.5	Comparative Example

[0020]

[Table 2]

Sample	Composition of Co-Fe based alloy (atomic%)	Magnetization (T)	Remarks
1	(Co ₇₀ -Fe ₃₀) ₉₀ -Zr ₄ -Ta ₄ -Ti ₂	1.3	Present invention
2	(Co ₇₀ -Fe ₃₀) ₉₀ -Zr ₄ -Ta ₄ -Al ₁ -Cr ₁	1.3	Comparative Example
3	(Co ₇₀ -Fe ₃₀) ₉₂ -Zr ₄ -Ta ₄	1.4	Comparative Example

10 [0021]

Table 1 shows that the Co-Fe based alloy of the present invention containing 0.5 to 10 atomic% of Ti (sample 1) has a higher weatherability than the Co-Fe based alloy without Ti (sample 3) or the Co-Fe based

alloy with Al and Cr (sample 2). Table 2 shows that the bulks of sample 1 of the present invention and sample 2 of the Co-Fe based alloy containing Al and Cr have a nearly equal magnetization. The Co-Fe based alloy of the sample 1 is available for a target material or a soft magnetic film having excellent weatherability.

Example 2

[0022]

10 First, cast ingots having Co-Fe based alloy compositions shown in Table 3 were produced. Raw materials having a purity of not less than 99.9% were heated and melted in a high-frequency heating furnace under vacuum and the molten alloys were cast in a mold made of iron to form the ingots having a diameter of 200 mm × 25 mm. The resulting ingots were processed into Co-Fe based alloy bulks having a diameter of 180 mm and a thickness of 7 mm.

For evaluating the weatherability of the bulks, samples having a diameter of 10 mm × 20 mm were produced from the cast ingots and dipped in 10% sulfuric acid at 50°C for 24 hours, and the weight reduction rates were measured to evaluate the weatherability of the bulks. The measurement results are shown in Table 3.

For evaluating the magnetization of the bulks, samples of 30 mm × 10 mm × 5 mm were produced from the cast ingots, and the magnetization under an

external magnetic field of 160 kA/m was measured using a DC magnetic properties measurement apparatus (TRF5A made by Toei Industry Co., Ltd.). The results are shown in Table 4.

5 For evaluating the hardness of the bulks, 10 mm × 10 mm × 5 mm samples were produced from the cast ingots and the hardness was measured using Rockwell hardness tester on C scale. The results are shown in Table 5.

10 [0023]
[Table 3]

Sample	Composition of Co-Fe based alloy (atomic%)	Weight reduction rate (%)	Remarks
4	(Co ₇₀ -Fe ₃₀) ₉₀ -Zr ₄ -Ta ₄ -Ti ₁ -B ₁	6.9	Present invention
5	(Co ₇₀ -Fe ₃₀) ₉₀ -Zr ₄ -Ta ₄ -Ti ₂	7.9	Present invention
6	((Co ₅₃ -Fe ₄₇) ₉₅ -Ni ₅) ₈₈ -Zr ₂ -Nb ₆ -Ti ₄	9.7	Present invention
7	(Co ₇₀ -Fe ₃₀) ₉₀ -Zr ₄ -Ta ₄ -Al ₂	10.3	Comparative Example
8	(Co ₇₀ -Fe ₃₀) ₉₀ -Zr ₄ -Ta ₄ -Cr ₂	10.8	Comparative Example

[0024]

[Table 4]

Sample	Composition of Co-Fe based alloy (atomic%)	Magnetization (T)	Remarks
4	(Co ₇₀ -Fe ₃₀) ₉₀ -Zr ₄ -Ta ₄ -Ti ₁ -B ₁	1.3	Present invention
5	(Co ₇₀ -Fe ₃₀) ₉₀ -Zr ₄ -Ta ₄ -Ti ₂	1.3	Present invention
6	((Co ₅₃ -Fe ₄₇) ₉₅ -Ni ₅) ₈₈ -Zr ₂ -Nb ₆ -Ti ₄	1.1	Present invention
7	(Co ₇₀ -Fe ₃₀) ₉₀ -Zr ₄ -Ta ₄ -Al ₂	1.3	Comparative Example
8	(Co ₇₀ -Fe ₃₀) ₉₀ -Zr ₄ -Ta ₄ -Cr ₂	1.3	Comparative Example

[0025]

[Table 5]

Sample	Composition of Co-Fe based alloy (atomic%)	Hardness (H _{RC})	Remarks
4	(Co ₇₀ -Fe ₃₀) ₉₀ -Zr ₄ -Ta ₄ -Ti ₁ -B ₁	59.1	Present invention
5	(Co ₇₀ -Fe ₃₀) ₉₀ -Zr ₄ -Ta ₄ -Ti ₂	56.8	Present invention
6	((Co ₅₃ -Fe ₄₇) ₉₅ -Ni ₅) ₈₈ -Zr ₂ -Nb ₆ -Ti ₄	59.6	Present invention
7	(Co ₇₀ -Fe ₃₀) ₉₀ -Zr ₄ -Ta ₄ -Al ₂	55.0	Comparative Example
8	(Co ₇₀ -Fe ₃₀) ₉₀ -Zr ₄ -Ta ₄ -Cr ₂	48.2	Comparative Example

5 [0026]

Table 3 shows that the Co-Fe based alloys of the present invention containing 0.5 to 10 atomic% of Ti (samples 4, 5 and 6) have a higher weatherability than the Co-Fe based alloys with Al or Cr (samples 7 and 8). Table 4 shows that the bulks of samples 4, 5

and 6 of the present invention and samples 7 and 8 of the Co-Fe based alloys containing Al or Cr have a nearly equal magnetization. Further, Table 5 shows that the Co-Fe based alloy of the present invention
5 containing 0.5 to 10 atomic% of Ti and not more than 5 atomic% of B (sample 4) has improved hardness.

Example 3

[0027]

First, cast ingots having Co-Fe based alloy
10 compositions shown in Table 6 were produces. Raw materials having a purity of not less than 99.9% were heated and melted in a high-frequency heating furnace under vacuum and cast in a mold made of iron to form the ingots having a diameter of 200 mm × 25 mm. The
15 resulting ingots were processed into Co-Fe based alloy target materials having a diameter of 180 mm and a thickness of 7 mm.

[0028]

The produced target materials were used in a
20 magnetron sputtering process to form a Co-Fe based alloy thin film on a substrate for the following evaluation tests. The sputtering process was carried out under conditions of an Ar pressure of 0.6 Pa and an input electric power of 500 W.

25 [0029]

(1) Weatherability test

Thin film samples deposited on glass substrates having a film thickness of 200 nm were

subjected to a weatherability test involving dipping them in pure water for 24 hours. The results of the visual observation of corroded regions are shown in Table 6. In Table 6, a sample in which no corroded region is visually observed is described as "O" and a sample in which a corroded region is visually observed is described as "x".

(2) Evaluation of magnetization

Thin film samples formed on a silicon wafer in a film thickness of 300 nm were cut into 10 × 10 mm and subjected to the evaluation of the saturation magnetization. The results are shown in Table 6. The measurement was carried out using a vibrating sample magnetometer VSM-3 made by Toei Industry Co., Ltd. under an external magnetic field of 800,000 A/m.

(3) Evaluation of hardness

Thin films were formed on aluminum substrates having a film thickness of 4 μm. The results of measuring the hardness of the samples are shown in Table 6. The hardness was measured at five points at an applied load of 25g using a Micro-Vickers apparatus. The average value is determined as hardness and shown in Table 6.

[0030]

[Table 6]

Sample	Composition of Co-Fe based alloy (atomic%)	Weatherability test	Magnetization (T)	Hardness (Hv)	Remarks
9	(Co ₇₀ -Fe ₃₀) ₉₀ -Zr ₄ -Ta ₄ -Ti ₂	O	1.4	785	Present invention
10	(Co ₇₀ -Fe ₃₀) ₉₀ -Zr ₄ -Ta ₄ -Al ₁ -Cr ₁	X	1.4	655	Comparative Example

[0031]

Table 6 proves that the Co-Fe based alloy of the present invention containing 0.5 to 10 atomic% of Ti has excellent weatherability even when formed into a
5 thin film by the sputtering process.

Industrial Applicability

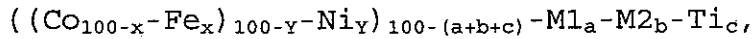
[0032]

The Co-Fe based alloy for a soft magnetic film of the present invention has excellent
10 weatherability while maintaining soft magnetic properties, and therefore can be used for forming a soft magnetic film for a perpendicular magnetic recording medium or the like under stable conditions.

CLAIMS

[Claim 1]

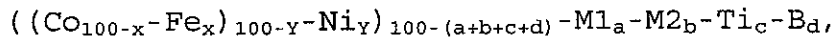
A Co-Fe based alloy for a soft magnetic film, having a composition represented by a formula by an atomic ratio:



where $5 \leq X \leq 80$, $0 \leq Y \leq 25$, $2 \leq a \leq 6$, $2 \leq b \leq 10$, $0.5 \leq c \leq 10$, and the balance being unavoidable impurities, wherein the M1 element in the formula is one or more elements selected from Zr, Hf and yttrium and the M2 element in the formula is one or more elements selected from Ta and Nb.

[Claim 2]

The Co-Fe based alloy according to claim 1, further comprising boron (B) and has a composition represented by a formula, by an atomic ratio:



where $5 \leq X \leq 80$, $0 \leq Y \leq 25$, $2 \leq a \leq 6$, $2 \leq b \leq 10$, $0.5 \leq c \leq 10$, $d \leq 5$, and the balance being unavoidable impurities.

[Claim 3]

The Co-Fe based alloy according to claim 1 or 2, wherein the Co-Fe based alloy is used as a sputtering target material.

[Claim 4]

The Co-Fe based alloy according to claim 1 or 2, wherein the Co-Fe based alloy forms a soft magnetic film layer of a perpendicular magnetic recording medium.

[Claim 5]

The Co-Fe based alloy according to claim 1 or 2, wherein the Co-Fe based alloy has saturation magnetization of not lower than 1.0 T.

[Claim 6]

A soft magnetic film made of the Co-Fe based alloy according to claim 1 or 2 and formed by a sputtering process.

[Claim 7]

A perpendicular magnetic recording medium, comprising at least one film layer made of the Co-Fe based alloy according to claim 1 or 2 as an underlayer of a magnetic recording film layer.

[Claim 8]

A perpendicular magnetic recording medium, comprising at least one layer of soft magnetic film made of the Co-Fe based alloy according to claim 1 or 2 and formed by a sputtering process as an underlayer of a magnetic recording film layer.