

Fe-Co-BASED ALLOY SPUTTERING TARGET MATERIAL, SOFT
MAGNETIC THIN FILM LAYER, AND VERTICAL MAGNETIC
RECORDING MEDIUM PRODUCED USING SAID SOFT MAGNETIC
THIN FILM LAYER

5

CROSS-REFERENCE TO RELATED APPLICATION

[0001]

This application claims priority to Japanese Patent Application
No. 2013-168787 filed on August 15, 2013, the entire content
10 of which is incorporated herein by reference.

TECHNICAL FIELD

[0002]

The present invention relates to a Fe-Co-based alloy sputtering
15 target material, a soft magnetic thin film layer, and a
perpendicular magnetic recording medium formed by using the
soft magnetic thin film layer.

BACKGROUND ART

20 [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
25 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
30 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
35 magnetic film layer has been developed. For the magnetic
recording film layer, a CoCrPt-SiO₂-based alloy is commonly

used.

[0004]

For the soft magnetic film layer, on the other hand, there is proposed a Fe-Co-based alloy film as disclosed in Japanese Patent Laid-Open Publication No. 2006-294090 (Patent Literature 1). In Patent Literature 1, 20 atomic% or more of Si, Ni, Ta, Nb, Zr, Ti, Cr, and/or Mo are added to Fe and Co in order to allow a film structure to be amorphous or microcrystalline.

[0005]

There is also proposed a sputtering target material based on a Fe-Co-based alloy, characterized by a sputtering target material which has a composition of (Fe-20-to-80Co)-4-to-25Nb or Ta and is passed through a rapid solidification step, and in that the size of an intermetallic compound phase is 10 μm or less as the diameter of a maximum inscribed circle, as disclosed in Japanese Patent Laid-Open Publication No. 2010-18884 (Patent Literature 2).

CITATION LIST

Patent Literature

[0006]

[PTL 1] Japanese Patent Laid-Open Publication No. 2006-294090

[PTL 2] Japanese Patent Laid-Open Publication No. 2010-18884

SUMMARY OF INVENTION

[0007]

For forming such a Fe-Co-based alloy film as described above, a corresponding Fe-Co-based sputtering target material is needed. However, a sputtering target material in which such a film composition as described above is achieved, in particular, the sputtering target material with a composition of (Fe-20-to-80Co)-4-to-25Nb or Ta disclosed in Patent Literature 2 has had a problem that particles are generated during sputtering, because of having an intermetallic compound phase with a size of 10 μm or less as the diameter of a maximum inscribed circle, reflecting a dendritic structure formed during

rapid solidification.

[0008]

Usually, as disclosed in Patent Literature 2, an intermetallic compound containing Nb and Ta, as illustrated in FIGS. 1,3,5,6, and 7, is divided into phases including one or two of Fe and Co. That is, the intermetallic compound containing Nb and Ta is surrounded by the phases mainly including Fe and Co, and is divided into the phases. The divided intermetallic compound phases containing Nb and Ta are considered to cause particles generated during sputtering a target material.

[0009]

As a result of intensively pursuing development in order to solve such problems as mentioned above, the present inventors found that generation of particles during sputtering can be suppressed by adjusting the microstructure of a sputtering target material, and the present invention was thus accomplished.

[0010]

According to one embodiment of the present invention, there is provided a sputtering target material comprising a Fe-Co-based alloy, the sputtering target material comprising one or two or more of Nb, Ta, Mo, and W as M elements, and the balance of one or two of Fe and Co with unavoidable impurities, and satisfying the following formula (1):

$$(\text{Fe}_X\text{-Co}_{100-X})_{100-Y}\text{M}_Y \quad (1)$$

in which atomic ratios are $0 \leq X \leq 100$ and $4 \leq Y \leq 28$, wherein a microstructure of the sputtering target material comprises a phase mainly including Fe and Co and an intermetallic compound phase comprising one or two of Fe and Co and an M element, and the phase mainly including Fe and Co is surrounded, divided, and isolated by allowing the intermetallic compound phase comprising one or two of Fe and Co and the M element to grow in a net geometry.

[0011]

According to another embodiment of the present invention, there is provided a sputtering target material comprising a Fe-Co-based alloy,

the sputtering target material comprising:

at least one M element selected from Nb, Ta, Mo, and W;

and

the balance of one or two of Fe and Co with unavoidable
5 impurities, and

satisfying the following formula (1):

$$(\text{Fe}_X\text{-Co}_{100-X})_{100-Y}\text{M}_Y \quad (1)$$

[wherein atomic ratios are $0 \leq X \leq 100$ and $4 \leq Y \leq 28$]

wherein a microstructure of the sputtering target
10 material comprises a phase mainly including Fe and Co and an
intermetallic compound phase comprising one or two of Fe and
Co and an M element;

the phase mainly including Fe and Co is surrounded,
divided, and isolated by allowing the intermetallic compound
15 phase comprising one or two of Fe and Co and the M element to
grow in a net geometry; and

the number of the phases mainly including Fe and Co,
isolated by the intermetallic compound phase, is 300 or more
per $10000 \mu\text{m}^2$ in the sputtering target material.

20 [0012]

According to still another embodiment of the present invention,

there is provided a method for producing a sputtering
target material comprising a Fe-Co-based alloy,

the production method comprising:

25 a step of preparing a powder of a Fe-Co-based alloy,
comprising:

at least one M element selected from Nb, Ta, Mo, and W;

and

the balance of one or two of Fe and Co with unavoidable
30 impurities, and

satisfying the following formula (1):

$$(\text{Fe}_X\text{-Co}_{100-X})_{100-Y}\text{M}_Y \quad (1)$$

[wherein atomic ratios are $0 \leq X \leq 100$ and $4 \leq Y \leq 28$];

and

35 a step of pressing and sintering the powder at a molding
temperature of 1000 to 1200°C and a molding pressure of 90 to

150 MPa for a retention time of 5 to 10 hours.

[0013]

According to still another embodiment of the present invention,
there is provided a soft magnetic thin film layer formed with any
5 of the above-described sputtering target materials comprising
Fe-Co-M-based alloys.

[0014]

According to still another embodiment of the present invention,
there is provided a perpendicular magnetic recording medium
10 formed by using the above-described soft magnetic thin film
layer.

[0015]

According to the present invention, there can be provided a
Fe-Co-based alloy sputtering target material for molding a soft
15 magnetic film, which enables stable magnetron sputtering and
allows generation of particles to be suppressed, and there can
be produced an industrial product requiring a soft magnetic film
of a Fe-Co-based alloy, such as a perpendicular magnetic
recording medium.

20

BRIEF DESCRIPTION OF DRAWINGS

[0016]

[FIG. 1] FIG. 1 is a view showing one visual field among ten
photographed visual fields in scanning electron micrographs of
25 the microstructure of a Fe-Co-based alloy according to a present
invention example (No. 1 in Table 1).

[FIG. 2] FIG. 2 is a view showing one visual field among ten
photographed visual fields in scanning electron micrographs of
the microstructure of a Fe-Co-based alloy falling outside the
30 scope of the present invention.

DESCRIPTION OF EMBODIMENTS

[0017]

The reasons of limitations according to the present invention will
35 be described below.

[0018]

The composition formula, in atomic ratio, of a Fe-Co-M alloy according to the present invention is represented by $(\text{Fe}_X\text{-Co}_{100-X})_{100-Y}\text{M}_Y$, wherein $0 \leq X \leq 100$ and $4 \leq Y \leq 28$. X is not limited, and it is necessary only that a target includes either or both of Co and Fe. For use in a soft magnetic thin film layer, a value of X is preferably set at 20 to 80, still more preferably 25 to 75, for no obvious reason, because experience shows that good properties are obtained.

10 [0019]

Further, the reason that M elements are Ta, Nb, Mo, and W and the amount y of such an added element is $4 \leq y \leq 28$ is because the addition of the M element in this range is effective at promoting amorphization of a thin film. On the other hand, the M element allows a metal compound phase to grow in a net geometry between Fe and Co, to divide Co and Fe phases. Such an effect becomes sufficient when Y is 4 or more. In contrast, when Y is 28 or less, there is maintained the effect of dividing the phases of one or two of Fe and Co by an intermetallic compound comprising one or two of Fe and Co and an M element. Accordingly, the range is set within 4 to 28. The value of Y is preferably 10 to 25 and still more preferably 15 to 23.

[0020]

25 The reason that the M elements are limited to Ta, Nb, Mo, and W is because they are metals that form an intermetallic compound that is bound to Fe and Co to easily generate particles. That is, a compound is allowed to grow in a net geometry with a target material having a composition of (Fe-20-to-80Co)-4-to-25Ta or Nb, Mo, and W, to eliminate a CoFe-Ta (Nb, Mo, W) compound in which Co and Fe are divided and isolated, whereby CoFe-Ta (Nb, Mo, W) compounds are more tightly coupled with each other and are inhibited from coming out as particles during sputtering.

35 [0021]

In general, in a structure in which a Fe-Co-M alloy is melted and

solidified, an M element, together with Fe and Co, forms an intermetallic compound phase and exists in a matrix. The morphology and dispersion of the intermetallic compound phase are changed depending on a method for producing a target material and greatly influence the amount of particles generated during sputtering a target material. In particular, the intermetallic compound phase containing the M element is allowed to exist as an intermetallic compound phase of Fe_2M or Co_2M , whereby the geometry of the intermetallic compound phase of Fe and Co which are originally ferromagnetic is controlled to enable generated particles to be greatly reduced.

[0022]

Thus, in the present invention, a phase mainly including Fe and Co is divided by allowing an intermetallic compound phase comprising one or two of Fe and Co and an M element to grow in a net geometry, whereby generation of particles is suppressed by the intermetallic compound phase comprising one or two of Fe and Co and the M element. Further, the reason that the number of the divided phases mainly including Fe and Co (the number of the phases mainly including Fe and Co, isolated by the intermetallic compound phase) is limited to 300 or more per $10000\ \mu\text{m}^2$ is because it is shown that the more the number of the divided phases mainly including Fe and Co is, the more greatly the phase of the intermetallic compound comprising one or two of Fe and Co and the M element grows (develops) in a net geometry. The number of the divided phases mainly including Fe and Co is desirably 400 or more, still more desirably 500 or more, per $10000\ \mu\text{m}^2$.

[0023]

FIG. 1 is a view showing one visual field among ten photographed visual fields in scanning electron micrographs of the microstructure of a Fe-Co-based alloy according to a present invention example (No. 1 in Table 1). As shown in the drawing, black phases are phases mainly including Fe and Co, while white phases are intermetallic compound phases comprising one or two of Fe and Co and an M element. As can be seen from the

drawing, the number of the divided phases mainly including Fe and Co is 113. On the other hand, FIG. 2 is a view showing one visual field among ten photographed visual fields in scanning electron micrographs of the microstructure of a Fe-Co-based alloy falling outside the scope of the present invention, and shows that the number of divisions is two.

[0024]

That is, as shown in the scanning electron micrograph, phases which are phases mainly including Fe and Co and shown by black are surrounded to eliminate an intermetallic compound phase comprising an isolated M element by allowing phases which are formed with intermetallic compound comprising one or two of Fe and Co and an M element and shown by white to grow into a net geometry, whereby intermetallic compounds are more tightly coupled with each other and are inhibited from coming out as particles during sputtering. In other words, the phases mainly including Fe and Co and shown by the black, surrounded by the intermetallic compound phases, are allowed to be in the state of being divided and isolated, whereby particles generated during sputtering can be reduced.

[0025]

As a method for pressing and sintering a Fe-Co-M-based alloy powder subjected to alloying treatment, a method such as hot press or HIP molding (hot isostatic press) is applied. Molding temperature, molding pressure, and retention time during the pressing and the sintering are set at 1000 to 1200°C, 90 to 150 MPa, and 5 to 10 hours, respectively. The reason of the setting is because a phase mainly including Fe and Co in a microstructure is divided to suppress generation of particles during sputtering by performing the pressing and the sintering under the conditions of the sintering temperature, the molding pressure, and the retention time. Further, limitations into the above ranges are imposed because the effect is saturated even if pressing and sintering are performed under respective conditions of a temperature of more than 1200°C, a pressure of more than 150 MPa, and more than 10 hours.

Example

[0026]

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

5 [0027]

Powders of soft magnetic alloys with compositions shown in Tables 1 to 4 were produced by a gas atomization method. The obtained powders were classified into 500 μm or less and used as raw powders for HIP molding (hot isostatic press). A can
10 made of carbon steel having a diameter of 250 mm and a length of 50 mm was filled with the raw powders, then vacuum-degassed, and sealed to produce billets for HIP molding. The powder-filled billets were HIP-molded under the conditions of molding pressures, molding temperatures, and retention
15 times, shown in Tables 1 to 4. Then, sputtering target materials having a diameter of 180 mm and a thickness of 7 mm were produced from the molded bodies.

[0028]

It was confirmed by evaluating a microstructure that there were
20 a phase mainly including Fe and Co and an intermetallic compound phase comprising one or two of Fe and Co and an M element and the phase mainly including Fe and Co was divided by the intermetallic compound comprising one or two of Fe and Co and the M element. For the evaluation of the microstructure,
25 a test piece for a scanning electron microscope (SEM) was collected from a target end material, the cross section of the test piece was polished, reflected electron images of ten visual fields of which each visual field ($3000 \mu\text{m}^2$) had a length of 50 μm and a breadth of 60 μm were photographed, and the
30 number of the phases mainly including Fe and Co, divided by the intermetallic compound phase comprising one or two of Fe and Co and the M element, was evaluated per visual field. The numbers per $10000 \mu\text{m}^2$ can be determined by multiplying the numbers of the divisions in Tables by 3.3.

35 [0029]

This sputtering target was sputtered, a film was formed on an

aluminum substrate having a diameter of 95 mm and a plate thickness of 1.75 mm at an Ar gas pressure of 0.9 Pa by DC magnetron sputtering, and the number of particles was evaluated with an optical measurement machine (Optical

5 Surface Analyzer).

[0030]

[Table 1]

Table 1

No	Alloy composition (atomic%)						Molding temperature (°C)	Molding pressure (MPa)	Retention time (hr)	The number of divisions	The number of particles	Evaluation
	Fe	Co	Ta	Nb	Mo	W						
1	96	0	4	0	0	0	1000	100	10	113	9	Good
2	92	0	8	0	0	0	1000	100	7	151	8	Good
3	88	0	12	0	0	0	1150	100	5	140	8	Good
4	85	0	15	0	0	0	1000	100	5	150	8	Good
5	82	0	18	0	0	0	1000	100	5	120	9	Good
6	81	0	19	0	0	0	1000	100	5	110	8	Good
7	79	0	21	0	0	0	1000	120	5	115	9	Good
8	75	0	25	0	0	0	1050	100	5	118	9	Good
9	72	0	28	0	0	0	1050	100	5	109	9	Good
10	76	20	4	0	0	0	1000	100	7	110	9	Good
11	72	20	8	0	0	0	1000	100	10	148	8	Good
12	68	20	12	0	0	0	1000	100	5	155	7	Good
13	57	28	15	0	0	0	1000	100	5	200	6	Good
14	53	29	18	0	0	0	1000	100	5	301	5	Good
15	52	29	19	0	0	0	1000	100	5	307	4	Good
16	49	30	21	0	0	0	1200	100	5	300	5	Good
17	47	41	12	0	0	0	1000	100	7	202	6	Good
18	44	41	15	0	0	0	1000	120	5	222	6	Good
19	41	41	18	0	0	0	1000	100	5	182	7	Good
20	40	41	19	0	0	0	1000	120	5	150	7	Good
21	38	41	21	0	0	0	1000	120	10	148	7	Good
22	35	50	15	0	0	0	1050	120	10	142	8	Good
23	32	50	18	0	0	0	1050	100	5	150	8	Good
24	31	50	19	0	0	0	1050	100	5	141	7	Good
25	29	50	21	0	0	0	1050	100	5	138	7	Good
26	20	65	15	0	0	0	1050	100	10	228	6	Good
27	17	65	18	0	0	0	1050	100	5	259	6	Good
28	16	65	19	0	0	0	1050	110	5	278	5	Good
29	14	65	21	0	0	0	1050	110	10	222	6	Good
30	15	70	15	0	0	0	1050	90	10	175	7	Good
31	12	70	18	0	0	0	1050	90	5	235	6	Good
32	11	70	19	0	0	0	1050	100	7	223	6	Good
33	9	70	21	0	0	0	1050	100	7	180	7	Good
34	0	85	15	0	0	0	1050	90	10	188	7	Good
35	0	82	18	0	0	0	1050	100	5	256	5	Good
36	0	81	19	0	0	0	1050	100	5	278	5	Good
37	0	79	21	0	0	0	1050	100	5	222	6	Good
38	66	30	0	4	0	0	1000	100	5	120	9	Good
39	62	30	0	8	0	0	1000	100	5	115	9	Good
40	58	30	0	12	0	0	1000	100	5	135	8	Good

Present Invention Examples

[0031]

[Table 2]

Table 2

No	Alloy composition (atomic%)						Molding temper ature (°C)	Molding pressure (MPa)	Rete ntion time (hr)	The num ber of divis ions	The num ber of parti cles	Evalu ation	
	Fe	Co	Ta	Nb	Mo	W							
41	56	29	0	15	0	0	1000	90	5	180	8	Good	Present Invention Examples
42	53	29	0	18	0	0	1000	100	5	235	5	Good	
43	52	29	0	19	0	0	1000	100	5	232	5	Good	
44	51	28	0	21	0	0	1000	100	5	208	7	Good	
45	47	28	0	25	0	0	1050	100	10	190	8	Good	
46	44	28	0	28	0	0	1050	100	10	188	8	Good	
47	36	60	0	0	4	0	1000	100	10	123	9	Good	
48	32	60	0	0	8	0	1000	100	7	145	9	Good	
49	18	70	0	0	12	0	1000	100	7	189	8	Good	
50	15	70	0	0	15	0	1000	100	7	190	9	Good	
51	12	70	0	0	18	0	1000	100	5	188	9	Good	
52	11	70	0	0	19	0	1000	100	5	186	8	Good	
53	9	70	0	0	21	0	1100	100	10	173	8	Good	
54	5	70	0	0	25	0	1050	120	7	150	9	Good	
55	2	70	0	0	28	0	1050	120	5	108	9	Good	
56	66	30	0	0	0	4	1000	100	5	130	8	Good	
57	62	30	0	0	0	8	1000	100	10	180	7	Good	
58	58	30	0	0	0	12	1000	150	5	178	8	Good	
59	56	29	0	0	0	15	1000	100	5	205	7	Good	
60	53	29	0	0	0	18	1000	130	5	208	7	Good	
61	52	29	0	0	0	19	1000	100	5	229	6	Good	
62	51	28	0	0	0	21	1100	120	5	180	8	Good	
63	47	28	0	0	0	25	1050	100	5	159	8	Good	
64	44	28	0	0	0	28	1050	110	5	129	9	Good	
65	92	0	4	4	0	0	1000	100	7	141	8	Good	
66	53	29	9	9	0	0	1000	100	7	156	8	Good	
67	50	30	10	10	0	0	1000	100	10	180	8	Good	
68	0	76	12	12	0	0	1050	100	5	160	8	Good	
69	24	68	4	0	4	0	1050	100	5	150	9	Good	
70	12	70	9	0	9	0	1000	120	5	183	8	Good	
71	20	60	10	0	10	0	1000	90	10	151	8	Good	
72	11	65	12	0	12	0	1050	90	7	156	8	Good	
73	72	20	4	0	0	4	1000	100	10	154	8	Good	
74	53	29	9	0	0	9	1000	100	5	238	6	Good	
75	53	29	10	0	0	8	1000	100	5	200	7	Good	
76	49	33	12	0	0	6	1050	100	5	198	7	Good	
77	92	0	0	4	4	0	1000	100	5	215	7	Good	
78	53	29	0	9	9	0	1000	100	5	218	7	Good	
79	50	30	0	10	10	0	1000	120	5	200	7	Good	
80	48	28	0	12	12	0	1200	100	5	148	8	Good	

[0032]

[Table 3]

Table 3

No	Alloy composition (atomic%)						Molding temper ature (°C)	Molding pressure (MPa)	Rete ntion time (hr)	The num ber of divis ions	The numb er of partic les	Evalu ation	
	Fe	Co	Ta	Nb	Mo	W							
81	27	65	0	4	0	4	1000	90	5	145	9	Good	Present Invention Examples
82	17	65	0	9	0	9	1000	130	5	143	9	Good	
83	15	65	0	10	0	10	1200	100	5	141	8	Good	
84	11	65	0	12	0	12	1050	110	10	140	8	Good	
85	22	70	0	0	4	4	1000	100	10	138	8	Good	
86	2	80	0	0	9	9	1000	100	7	167	8	Good	
87	0	80	0	0	10	10	1000	150	5	165	8	Good	
88	76	0	0	0	12	12	1050	100	5	130	8	Good	
89	34	60	2	2	2	0	1000	100	5	130	8	Good	
90	28	60	4	4	4	0	1000	120	10	184	8	Good	
91	25	60	5	5	5	0	1150	100	7	169	8	Good	
92	19	60	7	7	7	0	1000	100	10	163	8	Good	
93	16	60	8	8	8	0	1000	100	10	116	8	Good	
94	64	30	2	2	0	2	1000	150	7	124	9	Good	
95	58	30	4	4	0	4	1000	100	7	177	7	Good	
96	55	30	5	5	0	5	1000	100	7	134	8	Good	
97	49	30	7	7	0	7	1150	100	7	138	9	Good	
98	46	30	8	8	0	8	1000	120	5	120	8	Good	
99	69	25	2	0	2	2	1050	100	5	141	9	Good	
100	63	25	4	0	4	4	1050	100	5	162	8	Good	
101	60	25	5	0	5	5	1000	100	7	144	8	Good	
102	54	25	7	0	7	7	1000	120	7	133	8	Good	
103	51	25	8	0	8	8	1000	110	7	135	7	Good	
104	84	10	0	2	2	2	1050	100	7	133	7	Good	
105	78	10	0	4	4	4	1050	100	7	188	7	Good	
106	75	10	0	5	5	5	1000	100	10	181	8	Good	
107	69	10	0	7	7	7	1000	100	10	185	7	Good	
108	66	10	0	8	8	8	1000	150	10	155	7	Good	
109	77	15	2	2	2	2	1050	100	10	137	8	Good	
110	9	75	4	4	4	4	1000	100	5	170	8	Good	
111	20	60	5	5	5	5	1000	130	5	114	9	Good	
112	51	25	6	6	6	6	1000	100	5	144	8	Good	

[0033]

[Table 4]

Table 4

No	Alloy composition (atomic%)						Molding temperature (°C)	Molding pressure (MPa)	Retention time (hr)	The number of divisions	The number of particles	Evaluation	
	Fe	Co	Ta	Nb	Mo	W							
1	52	30	18	0	0	0	980	122	1	3	30	Poor	Comparative Examples
2	62	20	0	18	0	0	990	122	1	3	35	Poor	
3	22	60	0	0	18	0	950	122	1	3	40	Poor	
4	52	30	0	0	0	18	950	122	1	5	35	Poor	
5	15	70	15	0	0	0	950	80	1	6	35	Poor	
6	15	70	0	15	0	0	950	80	1	3	38	Poor	
7	25	60	0	0	15	0	950	122	1	5	43	Poor	
8	55	30	0	0	0	15	960	122	1	6	40	Poor	
9	80	0	20	0	0	0	1000	80	5	5	42	Poor	
10	60	20	0	20	0	0	950	122	5	6	40	Poor	
11	60	20	0	0	20	0	950	125	1	6	40	Poor	
12	0	80	0	0	0	20	930	125	1	7	35	Poor	
13	52	30	9	9	0	0	1000	122	4	6	50	Poor	
14	82	0	9	0	9	0	930	122	4	5	40	Poor	
15	82	0	9	0	0	9	950	150	1	5	30	Poor	
16	0	82	0	9	9	0	950	122	1	7	36	Poor	
17	0	82	0	9	0	9	960	122	11	7	38	Poor	
18	22	60	0	0	9	9	950	122	12	7	38	Poor	
19	45	40	5	5	5	0	1000	140	1	8	40	Poor	
20	35	50	5	5	0	5	950	122	5	5	41	Poor	
21	35	50	0	5	5	5	950	122	1	8	42	Poor	
22	40	40	5	5	5	5	950	122	1	10	43	Poor	

As shown in Tables 1 to 4, Tables 1 to 3 show present invention
 5 examples, while Table 4 shows comparative examples.

[0034]

As shown in Table 4, in Comparative Example Nos. 1 to 22,
 10 phases mainly including Fe and Co were not sufficiently divided,
 and the numbers of generated particles were great.

[0035]

In contrast, in each of Nos. 1 to 112 shown in Tables 1 to 3,
 which are the present invention examples, the conditions of the
 present invention are satisfied. Therefore, about 100 to 310
 15 divided phases mainly including Fe and Co are observed by
 measuring the number of the phases mainly including Fe and Co,
 partitioned by an intermetallic compound phase comprising one
 or two of Fe and Co and an M element, and the maximum major

diameter of the phases mainly including Fe and Co, which is an average obtained by observing ten visual fields of which each visual field has a length of 50 μm and a breadth of 60 μm . On the other hand, the results of sputtering the sputtering targets and evaluating the numbers of the particles with Optical Surface Analyzer show that the numbers of the particles are ten or less. [0036]

As described above, particles can be reduced during sputtering by allowing the compound to grow in a net geometry with the target material having the composition of (Fe-20-to-80Co)-4-to-25Ta or Nb, Mo, and W according to the present invention. In the present invention, a fine structure can be obtained by solidifying a powder, and a cast steel material and a powdery material are not particularly distinguished from each other. However, a product made of a powder is desirable for finely obtaining a structure.

CLAIMS

1. A sputtering target material comprising a Fe-Co-based alloy,
the sputtering target material comprising:
at least one M element selected from Nb, Ta, Mo, and W;
and
the balance of one or two of Fe and Co with unavoidable impurities, and
satisfying the following formula (1):
 $(\text{Fe}_X\text{-Co}_{100-X})_{100-Y}\text{M}_Y$ (1)
[wherein atomic ratios are $0 \leq X \leq 100$ and $4 \leq Y \leq 28$]
wherein a microstructure of the sputtering target material comprises a phase mainly including Fe and Co and an intermetallic compound phase comprising one or two of Fe and Co and an M element;
the phase mainly including Fe and Co is surrounded, divided, and isolated by allowing the intermetallic compound phase comprising one or two of Fe and Co and the M element to grow in a net geometry; and
the number of the phases mainly including Fe and Co, isolated by the intermetallic compound phase, is 300 or more per $10000 \mu\text{m}^2$ in the sputtering target material.

2. A method for producing a sputtering target material comprising a Fe-Co-based alloy,
the production method comprising:
a step of preparing a powder of a Fe-Co-based alloy, comprising:
at least one M element selected from Nb, Ta, Mo, and W;
and
the balance of one or two of Fe and Co with unavoidable impurities, and
satisfying the following formula (1):
 $(\text{Fe}_X\text{-Co}_{100-X})_{100-Y}\text{M}_Y$ (1)
[wherein atomic ratios are $0 \leq X \leq 100$ and $4 \leq Y \leq 28$];

and

a step of pressing and sintering the powder at a molding temperature of 1000 to 1200°C and a molding pressure of 90 to 150 MPa for a retention time of 5 to 10 hours.

3. A soft magnetic thin film layer formed with the sputtering target material comprising a Fe-Co-M-based alloy according to claim 1.

4. A perpendicular magnetic recording medium formed by using the soft magnetic thin film layer according to claim 3.