Cr ALLOY AND SPUTTERING TARGET MATERIAL FOR MAGNETIC RECORDING, AND PERPENDICULAR MAGNETIC RECORDING MEDIUM USING THE SAME

[Cross-Reference to Related Application]

[0001]

This application claims priority to Japanese Patent Application No. 2013-34228 filed on February 25, 2013, 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 MgO seed layer used in a thermally assisted magnetic recording medium, and to a perpendicular magnetic recording medium, in which they are used. Especially, the present invention relates to an alloy and a sputtering target material for an orientation controlling layer of a MgO seed layer used in a thermally assisted magnetic recording medium, and a perpendicular magnetic recording medium, in which they are used.

[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. Perpendicular magnetic recording system, which can achieve further high recording density when compared to longitudinal magnetic recording media 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. Furthermore, a method of assisting recording by heat, to which the perpendicular magnetic recording system has been applied, has been examined.

[0004]

The volume of a magnetic recording medium per bit is decreased with increasing the recording density of the magnetic recording medium. Therefore, a problem of recording demagnetization begins due to thermal agitation, and magnetic recording films with higher magnetocrystalline anisotropy constants (Ku) (for example, CoPt, FePt, and the like) are required, while the materials with high magnetocrystalline anisotropy are incapable of recording in a magnetic field in which recording is possible with current recording heads. Thus, in the thermally-assisted recording system, an object domain is heated with laser light or near-field light only at the time of recording by utilizing the decreasing of the magnetism of a recording material with temperature, and magnetic recording is enabled.

[0005]

The thermally-assisted recording system is a recording system in which a magnetic recording technology and an optical recording technology are combined, the coercive force of the recording magnetic portion is locally reduced by heat caused by irradiation with laser light, to perform recording on a high coercive force medium in which recording is impossible in common magnetic recording technologies, and thereafter, the medium is rapidly cooled to room temperature to enhance the coercive force and to achieve storage.

[0006]

A recording film with FePt or the like used in the thermally-assisted recording system has the crystal structure of L_1O, which is different from the hexagonal crystal structure of a CoCrPt-based recording film that has been conventionally used, and MgO is used in its seed layer. For example, as disclosed in Japanese Unexamined Patent Application Publication (Translation of PCT Application) No. 2010-503139 (Patent Literature 1) and Japanese Patent Laid-Open Publication No. 2011-60344 (Patent Literature 2), a pure Cr layer and a Cr alloy layer are used as orientation controlling layers for controlling

the orientation and crystal particle diameter of a MgO seed layer.

[Citation List]

[0007]

[Patent Literature]

[PTL 1] Japanese Unexamined Patent Application Publication (Translation of PCT Application) No. 2010-503139

[PTL 2] Japanese Patent Laid-Open Publication No. 2011-60344

[Summary of the Invention]

[0008]

However, use of such a material as mentioned above as a material forming an orientation controlling layer results in a large lattice constant mismatch with MgO, in coarse particles in the orientation controlling layer due to no addition of an element for controlling crystal grains, and in a film with the great dispersion thereof. Therefore, the orientation of the MgO film is deteriorated to increase crystal particle diameters, a magnetic film thus has a similar tendency, and it is impossible to enhance a recording density to a high level.

[0009]

The present invention is desired with respect to such problems as mentioned above and is directed at providing a Cr-based alloy including a BCC (body-centered cubic) structure having a lattice constant with a small mismatch with a (001) plane of MgO and a fine, uniform crystal grain distribution, and a sputtering target material comprising the alloy, for an orientation controlling layer for a MgO film. In addition, it is an object to provide a perpendicular magnetic recording medium in which a magnetic film of which the crystal particle diameter is fine and uniform is formed on fine MgO oriented on a (001) plane by using such a Cr-based alloy single-layer film as an orientation controlling layer for a MgO film.

[0010]

As a result of extensive research for solving the problems mentioned above, the present inventors found, as a Cr-based alloy including a BCC structure having a lattice constant with a

small mismatch with a (001) plane of MgO and a fine and uniform crystal grain distribution, an alloy system in which a lattice constant mismatch with MgO is reduced by adding (M)-group elements (Al, Ti, Mo, W, V, and Ru) forming a solid solution in Cr and a crystal particle diameter is adjusted by adding slight amounts of (X)-group elements (B, C, P, Si, and Sn).

[0011]

According to an embodiment of the present invention, there is provided a Cr alloy for magnetic recording, comprising in at.%:

one or more elements selected from the group consisting of Al, Ti, Mo, W, V, and Ru in a total amount in which a value of a in Formula (1) is 2.919 Å or more and 3.037 Å or less:

$a^3 = N/\rho\ \Sigma(m_n A_n)$ (1)

[wherein

a represents a lattice constant,

N represents the Avogadro's number,

ρ represents a calculated density (g/cm^3),

m represents the number of elements existing in a unit lattice, and

A represents an atomic weight]

0.1 to 5% in total of one or more elements selected from the group consisting of B, C, P, Si, and Sn; and

the balance Cr and unavoidable impurities.

[0012]

According to another embodiment of the present invention, there is provided a Cr alloy for magnetic recording, comprising in at.%:

one or two or more elements among elements of Al, Ti, Mo, W, V, and Ru in a total amount in which a value of a in Formula 1 is 2.919 Å or more and 3.037 Å or less;

0.1 to 5% in total of one or two or more elements among elements of B, C, P, Si, and Sn; and

the balance Cr and unavoidable impurities.

$a^3 = N/\rho\ \Sigma(m_n A_n)$ (Formula 1)

in the formula,

a: lattice constant,

N: Avogadro's number,

ρ: calculated density (g/cm^3),

m: the number of elements existing in unit lattice, and

A: atomic weight

[0013]

According to another embodiment of the present invention, there is provided a sputtering target material comprising the above-described alloy for magnetic recording.

[0014]

According to still another embodiment of the present invention, there is provided a perpendicular magnetic recording medium using the above-described alloy for magnetic recording.

[0015]

As mentioned above, according to the present invention, there are provided a Cr-based alloy including a BCC structure having a lattice constant with a small mismatch with a (001) plane of MgO and a fine and uniform crystal grain distribution, and a sputtering target material comprising the alloy. Such an alloy enables the orientation of a MgO film to be improved in a magnetic recording medium and a crystal particle diameter to be finely and uniformly dispersed. A technological concept that a crystal particle diameter is allowed to be fine and uniform while reducing a lattice constant mismatch between a MgO film which is a recording layer undercoat film and an orientation controlling layer has not been present in the related art. This point is a characteristic technological concept in the present invention.

[Description of Embodiments]

[0016]

The present invention is specifically explained below. Unless otherwise specified, "%" as used herein means atomic% (at.%).

[0017]

The Cr alloy for magnetic recording according to the present invention comprises one or more elements selected from the group consisting of Al, Ti, Mo, W, V, and Ru, one or more

elements selected from the group consisting of B, C, P, Si, and Sn, and the balance Cr and unavoidable impurities, preferably consists essentially of these elements and unavoidable impurities, and more preferably consists of these elements and unavoidable impurities.

[0018]

The present invention is explained in detail below. The composition of a Cr-based alloy including a BCC structure having a lattice constant with a small mismatch with a (001) plane of MgO and a fine and uniform crystal grains distribution was examined and thus found that the lattice constant can be allowed to be 2.919 Å or more and 3.037 Å or less by adding appropriate amounts of one or two or more of Al, Ti, Mo, W, V, and Ru which are (M)-group elements forming a solid solution of Cr. In addition, it was found that the addition of slight amounts of one or two or more of elements of B, C, P, Si, and Sn which are (X)-group elements enables crystal grains to be finely and uniformly controlled while keeping the BCC structure.

[0019]

The restrictive reasons of the Cr alloy for magnetic recording according to the present invention are explained below.

[0020]

<u>Addition amounts of (M)-Group Elements (Al, Ti, Mo, W, V, and Ru)</u>

Cr has a lattice constant of 2.880 Å, and there is a mismatch of -3.3% between 4.072 Å which is a value that is the square root of 2 times ($\sqrt{2}$ times) the lattice constant of 2.880 Å and 4.211 Å which is the lattice constant of MgO. Thus, the addition of appropriate amounts of (M)-group elements (Al, Ti, Mo, W, V, and Ru) to Cr can result in a lattice constant of 2.919 Å or more and 3.037 Å or less leading to a mismatch of within ±2.0% while maintaining a BCC structure.

[0021]

The formation of a Cr alloy film with a lattice constant of 2.919 Å or more and 3.037 Å or less leading to a lattice constant mismatch of within ±2.0% enables the film to be favorably

formed on a (001) plane of MgO. A lattice constant of less than 2.919 Å results in no difference of the orientation of MgO from that of pure Cr, while a lattice constant of more than 3.037 Å allows a (110) plane of MgO to be observed, resulting in deteriorated orientation.

[0022]

The ranges of specific addition amounts in the case of adding only one kind of an element are described as examples below:

Al: 9.3 to 43.4%;
Ti: 7.5 to 35.4%;
Mo: 11.7 to 55.4%;
W: 11.2 to 52.4%;
V: 22.8 to 94.0%; and
Ru: 24.5 to 32.0%.

In the case of two or more kinds, addition amounts are similarly in ranges in which a lattice constant obtained in the calculation of Formulra (1) is 2.919 Å or more and 3.037 Å or less.

[0023]

<u>Addition of 0.1 to 5% of One or More of (X)-Group Elements (B, C, P, Si, and Sn)</u>

The above-described elements hardly form a solid solution in Cr, are elements forming a compound with Cr, and are added to exhibit the effects of allowing crystal grains to be fine and of uniformalizing particle diameters. Thus, the optimal addition amount was set in the range of 0.1% to 5%. An addition amount of less than 0.1% results in no addition effect, whereas an addition amount of more than 5% results in the marked generation of a compound, preventing a BCC single phase from being obtained.

[Examples]

[0024]

The present invention is specifically explained below with reference to examples. Raw powders of pure metals (purity of 3 N or more) were mixed in each composition shown in Table 1, and the mixture was used as a raw powder for HIP molding (hot isostatic press). A V-type blender was used for the mixing. A

billet for HIP molding was produced by filling the raw powder into a carbon steel can having a diameter of 200 mm and a length of 10 mm, followed by being subjected to vacuum deaeration and by being enclosed. The powder-filled billet was HIP-molded under conditions of a temperature of 1050°C, a pressure of 120 MPa, and a retention time of 2 hours. Then, a soft magnetic alloy sputtering target material having a diameter of 95 mm and a thickness of 2 mm was produced from the molded body. The sputtering target material was used to produce a thin film that is an adhesion layer on a glass substrate. The inside of a chamber was evacuated to 1×10^{-4} Pa or less, and an Ar gas having a purity of 99.99% was charged at 0.6 Pa to perform sputtering. First, a Cr alloy layer of 20 nm was formed on a washed glass substrate.

[0025]

The single-layer film produced as described above as a sample was confirmed to have a BCC single phase in X-ray diffraction, a lattice constant was measured, and an average crystal particle diameter and the dispersion thereof were further observed by TEM observation. Assuming that the value of Cr of Comparative Example 1 was 1, an average crystal particle diameter with a value of more than 0.9 was evaluated as "poor", an average crystal particle diameter with a value of 0.9 to 0.8 was evaluated as "fair", and an average crystal particle diameter with a value of less than 0.8 was evaluated as "good". As for the dispersion of average crystal particle diameters, a value standardized with each average crystal particle diameter was used. Assuming that the value of Cr of Comparative Example 1 was 1, values of more than 0.9, 0.9 to 0.7, and less than 0.7 were evaluated as poor, fair, and good, respectively. The results are shown in Table 1.

[0026]

[Table 1]

Table 1

No		(M)-Group Element (at.%)						(X)-Group Element (at.%)					Calculated Density (g/cm³)	Lattice Constant (Å)	Crystal Particle Diameter	Crystal Particle Diameter Dispersion	Precipitation of Second Phase	
	Cr	Al	Ti	Mo	W	V	Ru	B	C	P	Si	Sn						
1	100												7.19	2.879	Poor	Poor	Absent	Comparative Example 1
2	89.7	9.3						1					6.60	2.919	Good	Good	Absent	Present Invention Example
3	79	20						1					6.01	2.957	Good	Good	Absent	Present Invention Example
4	55.6	43.4						1					4.85	3.037	Good	Good	Absent	Present Invention Example
5	92.4		7.5					0.1					6.90	2.920	Good	Good	Absent	Present Invention Example
6	80		15					5					6.49	2.952	Good	Good	Absent	Present Invention Example
7	63.6		35.4					1					5.96	3.037	Good	Good	Absent	Present Invention Example
8	87.3			11.7					1				7.62	2.920	Good	Good	Absent	Present Invention Example
9	67			32					1				8.32	2.975	Good	Good	Absent	Present Invention Example
10	43.6			55.4					1				9.04	3.037	Good	Good	Absent	Present Invention Example
11	87.8				11.2						1		8.83	2.920	Good	Good	Absent	Present Invention Example
12	74				25						1		10.79	2.960	Good	Good	Absent	Present Invention Example
13	46.6				52.4						1		14.25	3.037	Good	Good	Absent	Present Invention Example
14	76.2					22.8		1					6.88	2.919	Good	Good	Absent	Present Invention Example
15	29					70		1					6.37	2.986	Good	Good	Absent	Present Invention Example
16	5					94		1					6.13	3.019	Good	Good	Absent	Present Invention Example
17	75.4						24.5		0.1				8.58	2.919	Good	Good	Absent	Present Invention Example
18	63						32		5				8.95	2.929	Good	Good	Absent	Present Invention Example
19	78	5	10	5				1	1				6.67	2.963	Good	Good	Absent	Present Invention Example
20	83	5		5	5			1				1	7.81	2.935	Good	Good	Absent	Present Invention Example
21	72		15		5	3		1	3	1			7.15	2.970	Good	Good	Absent	Present Invention Example
22	77		10	5	5		3		2		1		7.64	2.958	Good	Good	Absent	Present Invention Example
23	70		20			5				1		1	6.48	2.983	Good	Good	Absent	Present Invention Example
24	67			10	15	5		2			1		9.57	2.966	Good	Good	Absent	Present Invention Example
25	79		15					6					6.46	2.950	Good	Good	Present	Comparative Example 2
26	62			32					6				8.27	2.974	Good	Good	Present	Comparative Example 3
27	70		30										6.15	3.015	Fair	Poor	Absent	Comparative Example 4
28	75				25								10899	2.959	Poor	Poor	Absent	Comparative Example 5
29	60		30	5	5								7.03	3.043	Fair	Fair	Absent	Comparative Example 6
30	95		5										7.00	2.908	Poor	Poor	Absent	Comparative Example 7
31	89		5					3	3				6.85	2.906	Good	Good	Present	Comparative Example 8
32	55	44						1					4.32	3.038	Good	Good	Absent	Comparative Example 9
33	49		35			10	5		1				6.14	3.065	Good	Good	Absent	Comparative Example 10
34	62		36								1	1	5.91	3.046	Good	Good	Absent	Comparative Example 11
35	58		30		10				1	1			7.54	3.043	Good	Good	Absent	Comparative Example 12

NOTE 1) The underlined figures fall outside the scope of the present invention.
NOTE 2) Other unavoidable impurities are included.

As shown in Table 1, No. 1 shows Comparative Example 1, Nos. 2 to 24 are Present Invention Examples, and Nos. 25 to 35 are Comparative Examples.

[0027]

Comparative Example No. 25 resulted in the marked generation of a precipitated second phase, preventing a BCC single phase from being obtained, due to the high content of B which was an (X)-group element. Comparative Example No. 26 resulted in the marked generation of a precipitated second phase, preventing a BCC single phase from being obtained, due to the high content of C which was an (X)-group element, similarly to Comparative Example No. 25. Comparative Example Nos. 27 to 28 failed to provide the effects of allowing crystal grains to be fine and of uniformalizing particle diameters because no (X)-group element was added. Comparative Example No. 29 failed to provide the effects of allowing crystal grains to be fine and of uniformalizing particle diameters because no (X)-group element was added and, moreover, a lattice constant was more than 3.037 Å, and resulted in deteriorated orientation in which a (110) plane of MgO was observed.

[0028]

Comparative Example No. 30 resulted in the deteriorated effects of allowing crystal grains to be fine and of uniformalizing particle diameters because no (X)-group element was added and, moreover, a lattice constant was less than 2.919 Å, and resulted in no difference of the orientation of MgO from that of pure Cr. Comparative Example No. 31 resulted in the marked generation of a precipitated second phase due to the total high content of B and C which were (X)-group elements, preventing a BCC single phase from being obtained. In addition, because a lattice constant was less than 2.919 Å, no difference of the orientation of MgO from that of pure Cr was observed. Comparative Example Nos. 32 to 35 resulted in deteriorated orientation in which a (110) Plane of MgO was observed because of each having lattice constants of more than 3.037 Å.

[0029]

In contrast, it was found that Nos. 2 to 24 which were Present Invention Examples were able to result in Cr-based alloys including BCC structures having lattice constants with small mismatches with the orientation of MgO and fine, uniform crystal grain distributions because of each satisfying the present invention conditions.

[0030]

As mentioned above, the present invention shows the excellent effect of enabling a perpendicular magnetic recording medium in which a magnetic film with a fine and uniform crystal particle diameter is formed on fine MgO oriented on a (001) plane to be provided by using, as an orientation controlling layer for a MgO film, a Cr-based alloy single-layer film including a BCC structure having a lattice constant with a small mismatch with a (001) plane of MgO and a fine, uniform crystal grain distribution.

CLAIMS

1. A Cr alloy for magnetic recording, comprising in at.%:

one or more elements selected from the group consisting of Al, Ti, Mo, W, V, and Ru in a total amount in which a value of a in Formula (1) is 2.919 Å or more and 3.037 Å or less:

$a^3 = N/\rho\ \Sigma(m_n A_n)$ (1)

[wherein

a represents a lattice constant,

N represents the Avogadro's number,

ρ represents a calculated density (g/cm^3),

m represents the number of elements existing in a unit lattice, and

A represents an atomic weight]

0.1 to 5% in total of one or more elements selected from the group consisting of B, C, P, Si, and Sn; and

the balance Cr and unavoidable impurities.

2. The alloy according to claim 1, used in an orientation controlling layer in a perpendicular magnetic recording medium.

3. The alloy according to claim 1 or 2, comprising in at.%:

any one element selected from the group consisting of Al, Ti, Mo, W, V, and Ru in a range described below:

Al: 9.3 to 43.4%;

Ti: 7.5 to 35.4%;

Mo: 11.7 to 55.4%;

W: 11.2 to 52.4%;

V: 22.8 to 94.0%; or

Ru: 24.5 to 32.0%.

4. A sputtering target material comprising the alloy according to any one of claims 1 to 3.

5. A perpendicular magnetic recording medium, using the alloy according to any one of claims 1 to 3.