

## SPUTTERING TARGET MATERIAL

### BACKGROUND OF THE INVENTION

#### Field of the Invention

5 [0001]

The present invention relates to a sputtering target material useful for producing an alloy thin film in a magnetic tunneling junction (MTJ) element, an HDD, a medium for magnetic recording, or the like.

10

#### Background Art

[0002]

A magnetic random-access memory (MRAM) includes a magnetic tunneling junction (MTJ) element. Such a magnetic tunneling junction (MTJ) element has a structure such as CoFeB/MgO/CoFeB and exhibits features such as a high tunnel magnetoresistance (TMR) signal and a low switching current density ( $J_c$ ).

15

[0003]

A CoFeB thin film of a magnetic tunneling junction (MTJ) element is formed by sputtering a CoFeB target. Examples of known CoFeB sputtering target materials include a sputtering target material produced by sintering an atomized powder as disclosed in Japanese Patent Laid-Open Publication No. 2004-346423 (Patent Literature 1).

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#### Citation List

[0004]

#### Patent Literature

30 [PTL 1] Japanese Patent Laid-Open Publication No. 2004-346423

### SUMMARY OF THE INVENTION

#### Technical Problem

[0005]

35 A method in which an atomized powder is sintered to produce a sputtering target material in such a manner as in

Patent Literature 1 is an effective technique. However, only the method described in Patent Literature 1 does not make it possible to produce a favorable target material. In other words, there is a problem in that only simple sintering of an atomized powder results in a decrease in the strength of a sputtering target material.

#### Solution to Problem

[0006]

As a result of intensively advancing development in order to solve the problem described above, the present inventors found that the mechanical strength of a sputtering target can be improved by reducing the content of hydrogen in a sputtering target material. Thus, the present invention was accomplished.

[0007]

The present invention encompasses the following inventions:

[1] A sputtering target material comprising in at.%, 10 to 50% of B; 0 to 20% in total of one or more elements selected from the group consisting of Ti, Zr, Hf, V, Nb, Ta, Cr, Mo, W, Mn, Re, Ru, Rh, Ir, Ni, Pd, Pt, Cu, and Ag; and the balance of at least one of Co and Fe, and unavoidable impurities, wherein a hydrogen content is 20 ppm or less.

[2] The sputtering target material according to the above [1], wherein the sputtering target material comprises, in at.%, 5 to 20% in total of one or more elements selected from the group consisting of Ti, Zr, Hf, V, Nb, Ta, Cr, Mo, W, Mn, Re, Ru, Rh, Ir, Ni, Pd, Pt, Cu, and Ag.

[3] The sputtering target material according to the above [1], wherein the sputtering target material has a bending strength of 200 MPa or more.

#### Advantageous Effects of Invention

[0008]

According to the present invention, a sputtering target material having excellent mechanical strength is provided.

## DETAILED DESCRIPTION OF THE INVENTION

[0009]

The present invention will be described in detail below.  
5 Unless otherwise specified, "%" in the present invention means at.%.

[0010]

In a sputtering target material according to the present invention, the content of B is 10 to 50%. An alloy thin film  
10 formed in sputtering does not sufficiently become amorphous when the content of B is less than 10%, while the strength of a sputtering target material decreases even if the content of hydrogen is 20 ppm or less when the content of B is more than 50%. Therefore, the content of B is adjusted to 10 to 50%.  
15 The content of B is preferably 20 to 50%.

[0011]

In the sputtering target material according to the present invention, the total content of one or more elements selected from the group (hereinafter may be referred to as "element  
20 group") consisting of Ti, Zr, Hf, V, Nb, Ta, Cr, Mo, W, Mn, Re, Ru, Rh, Ir, Ni, Pd, Pt, Cu, and Ag is 0 to 20%. When only one kind of an element is selected from the above element group, "total content of one or more elements selected from the above element group" means the content of the one element. The  
25 strength of the sputtering target material decreases even if the content of hydrogen is 20 ppm or less when the total content of one or more elements selected from the above element group is more than 20%. Therefore, the content of one or more elements selected from the above element group is adjusted to  
30 20% or less. The total content of one or more elements selected from the above element group is preferably 12% or less, and still more preferably 10% or less. When the sputtering target material according to the present invention does not contain one or more elements selected from the above  
35 element group, the total content thereof is 0%. When the sputtering target material according to the present invention

contains one or more elements selected from the above element group, the total content thereof can be adjusted in a range of from more than 0 to 20% as appropriate, and is, for example, 5% or more.

5 [0012]

The sputtering target material according to the present invention comprises the balance of at least one of Co and Fe, and unavoidable impurities.

Co and Fe are elements that impart magnetism. The  
10 total content of Co and Fe is 30% or more. When the sputtering target material according to the present invention contains only one of Co and Fe, "total content of Co and Fe" means the content of the one. The total content of Co and Fe is preferably 40% or more, and still more preferably 50% or  
15 more.

[0013]

In the sputtering target material according to the present invention, the content of hydrogen is 20 ppm or less. Hydrogen is an element that is unavoidably present in a powder  
20 (for example, an atomized powder such as a gas-atomized powder) used as a raw material of the sputtering target material. However, the strength of the sputtering target material decreases when the content of hydrogen remaining in the sputtering target material is more than 20 ppm. Therefore, the  
25 content of hydrogen is adjusted to 20 ppm or less. The content of hydrogen is preferably 10 ppm or less. The sputtering target material according to the present invention may contain up to 1000 ppm of other unavoidable impurities.

[0014]

30 The sputtering target material in which the content of hydrogen is 20 ppm or less can be produced by: removing coarse particles having a particle diameter of 500  $\mu\text{m}$  or more from an atomized powder of an alloy comprising 10 to 50% of B, 0 to 20% in total of one or more elements selected from the  
35 group consisting of Ti, Zr, Hf, V, Nb, Ta, Cr, Mo, W, Mn, Re, Ru, Rh, Ir, Ni, Pd, Pt, Cu, and Ag, and the balance of at least one of

Co and Fe, and unavoidable impurities; then removing fine particles from the powder from which the coarse particles have been removed, to prepare a powder that satisfies any of particle size conditions A, B, and C; and then sintering the powder that satisfies any of the particle size conditions A, B, and C.

[0015]

The particle size conditions A, B, and C are defined as follows.

The particle size condition A is defined as a condition that the cumulative volume of particles having a particle diameter of 5  $\mu\text{m}$  or less is 10% or less, and the cumulative volume of particles having a particle diameter of 30  $\mu\text{m}$  or less is 40% or less, in the particle size distribution of powder (particle assemblage).

The particle size condition B is defined as a condition that the cumulative volume of particles having a particle diameter of 5  $\mu\text{m}$  or less is 8% or less, and the cumulative volume of particles having a particle diameter of 30  $\mu\text{m}$  or less is 35% or less, in the particle size distribution of a powder (particle assemblage).

The particle size condition C is defined as a condition that the cumulative volume of particles having a particle diameter of 5  $\mu\text{m}$  or less is 5% or less, and the cumulative volume of particles having a particle diameter of 30  $\mu\text{m}$  or less is 30% or less, in the particle size distribution of a powder (particle assemblage).

A powder that satisfies all the particle size conditions A, B, and C is regarded as a powder that satisfies the particle size condition C, and a powder that satisfies the particle size conditions A and B is regarded as a powder that satisfies the particle size condition B. In addition, "particle diameter" and "particle size distribution" mean a particle diameter and a particle size distribution, measured by a laser diffraction/scattering-type particle size distribution measurement apparatus (MICROTRAC).

[0016]

All of the particle size conditions A, B, and C are conditions for removing coarse particles having a particle diameter of 500  $\mu\text{m}$  or more from a powder (for example, an atomized powder such as a gas-atomized powder) as a raw material of the sputtering target material and then removing fine particles from the powder from which the coarse particles have been removed. In each particle size condition, a particle size distribution is set under the two conditions, i.e., the first condition regarding the amount of particles having a particle diameter of 5  $\mu\text{m}$  or less and the second condition regarding the amount of particles having a particle diameter of 30  $\mu\text{m}$  or less. In the particle size condition A, the cumulative volume of particles having a particle diameter of 5  $\mu\text{m}$  or less is regulated to 10% or less in the first condition, and the cumulative volume of particles having a larger particle size and having a particle diameter of 30  $\mu\text{m}$  or less is regulated to 40% or less in the second condition. In the particle size condition B, the cumulative volume of particles having a particle diameter of 5  $\mu\text{m}$  or less is regulated to 8% or less in the first condition, and the cumulative volume of particles having a particle diameter of 30  $\mu\text{m}$  or less is regulated to 35% or less in the second condition. In the particle size condition C, the cumulative volume of particles having a particle diameter of 5  $\mu\text{m}$  or less is regulated to 5% or less in the first condition, and the cumulative volume of particles having a particle diameter of 30  $\mu\text{m}$  or less is regulated to 30% or less in the second condition. In other words, in the particle size conditions A, B, and C, the cumulative volume of particles having a particle diameter of 5  $\mu\text{m}$  or less is regulated to be decreased to 10% or less, 8% or less, and 5% or less in a stepwise manner, and the cumulative volume of particles having a particle diameter of 30  $\mu\text{m}$  or less is regulated to be decreased to 40% or less, 35% or less, and 30% or less in a stepwise manner. The hydrogen content and bending strength of a sputtering target material produced using a gas-atomized powder that satisfies any of the particle size conditions A, B, and C are shown in Examples.

[0017]

A powder that satisfies any of the particle size conditions A, B, and C can be prepared by removing coarse particles having a particle diameter of 500  $\mu\text{m}$  or more, which are not  
5 suitable for molding, from a powder (for example, an atomized powder such as a gas-atomized powder) as a raw material of the sputtering target material, and then removing fine particles from the powder from which the coarse particles have been removed. Examples of atomization methods for producing the  
10 atomized powder include a gas atomization method, a water atomization method, a disk atomization method, and a plasma atomization method. A gas atomization method is preferred. The removal of the coarse particles having a particle diameter of 500  $\mu\text{m}$  or more can be performed by classification using a sieve  
15 having an opening of 500  $\mu\text{m}$  or less, for example, an opening of 250 to 500  $\mu\text{m}$ . The removal of the fine particles for preparing the powder that satisfies any of the particle size conditions A, B, and C can be performed by classification using sieves having an opening of 5  $\mu\text{m}$  or less and/or an opening of  
20 30  $\mu\text{m}$  or less. The content of hydrogen can be set at 20 ppm or less by producing a solidified molded product by using the powder that satisfies any of the particle size conditions A, B, and C. A sputtering target material can be produced by processing the solidified molded product into a disk shape by  
25 wire cut, turning processing, and plane polishing. The sputtering target material produced in such a manner has improved strength.

[0018]

The sputtering target material according to the present  
30 invention preferably has a bending strength of 200 MPa or more. The sputtering target material according to the present invention has a bending strength of, for example, 210 MPa or more, 220 MPa or more, 230 MPa or more, 240 MPa or more, 250 MPa or more, 260 MPa or more, 270 MPa or more, 280 MPa  
35 or more, 290 MPa or more, or 300 MPa or more.

[0019]

The bending strength is measured as follows. A specimen having a longitudinal length of 4 mm, a width of 25 mm, and a thickness of 3 mm, obtained from a sintered alloy by division by a wire, is evaluated by a three-point bending test, to  
 5 obtain three-point bending strength as the bending strength. In the three-point bending test conducted at a supporting-point distance of 20 mm, a three-point bending strength is calculated from a stress (N) measured when a pressure is applied downward in a thickness direction to a plane having a  
 10 longitudinal length of 4 mm and a width of 25 mm, on the basis of the following equation:

$$\text{three-point bending strength (MPa)} = (3 \times \text{stress (N)} \times \text{supporting-point distance (mm)}) / (2 \times \text{specimen width (mm)} \times (\text{specimen thickness (mm)}^2).$$

15

### EXAMPLES

[0020]

The sputtering target material according to the present invention will be specifically described below with reference to  
 20 Examples.

A molten raw material was weighed for each composition shown in Tables 1, 2, 5, and 6, induction-heating melted in a refractory crucible having an Ar gas atmosphere with a reduced pressure or a vacuum atmosphere, then tapped from a nozzle  
 25 having a diameter of 8 mm in the lower portion of the crucible, and gas-atomized with an Ar gas. A solidification rate can be controlled by adjusting the injection pressure of the Ar gas. The solidification rate is increased with increasing the injection pressure. The particle size distribution of a gas-atomized  
 30 powder can be adjusted by controlling the solidification rate. The width of the particle size distribution is decreased with increasing the solidification rate.

[0021]

A powder that satisfied any of the particle size conditions  
 35 A, B, and C was prepared by removing coarse particles having a particle diameter of 500 μm or more, which were not suitable

for molding, from the obtained gas-atomized powder, and then removing fine particles from the powder from which the coarse particles had been removed. The removal of the coarse particles having a particle diameter of 500  $\mu\text{m}$  or more, which were not suitable for molding, was performed by classification using a sieve having an opening of 500  $\mu\text{m}$ . The removal of the fine particles for preparing the powder that satisfied the particle size condition A was performed by classification using a sieve having an opening of 35  $\mu\text{m}$ . The removal of the fine particles for preparing the powder that satisfied the particle size condition B was performed by classification using a sieve having an opening of 30  $\mu\text{m}$ . The removal of the fine particles for preparing the powder that satisfied the particle size condition C was performed by classification using a sieve having an opening of 25  $\mu\text{m}$ . The powder that satisfied any of the particle size conditions A, B, and C was put in a furnace at 110°C and dried to remove water from the powder. The dried powder was used as a raw powder. The raw powder was degassing-charged into an SC can having an outer diameter of 220 mm, an inner diameter of 210 mm, and a length of 200 mm, and the powder-filled billet was sintered under each condition shown in Table 1 or Table 2 to produce a sintered body.

[0022]

A molten raw material was weighed for each composition shown in the raw powder columns of Table 3 and Table 7. In a manner similar to the case of each composition shown in Tables 1, 2, 5, and 6, the molten raw material was induction-heating melted in a refractory crucible having an Ar gas atmosphere with a reduced pressure or a vacuum atmosphere, then tapped from a nozzle having a diameter of 8 mm in the lower portion of the crucible, and gas-atomized with an Ar gas. Commercially available powders having a powder size of 150  $\mu\text{m}$  or less were used as pure Ti, pure B, pure V, and pure Cr among the raw powders shown in Table 7. A powder that satisfied any of the particle size conditions A, B, and C was prepared by removing coarse particles having a particle diameter of 500  $\mu\text{m}$  or more,

which were not suitable for molding, from the obtained gas-atomized powder, and then classifying the powder from which the coarse particles had been removed, to remove fine particles. The removal of the coarse particles and the fine particles was performed in manners similar to the manners described above. The powder that satisfied any of the particle size conditions A, B, and C was put in a furnace at 110°C and dried to remove water from the powder. Such dried powders were used as raw powders. The raw powders were mixed at a mixture ratio shown in Table 3 in a V-type mixer for 30 minutes to thereby form a composition shown in Table 3, and the resultant mixture was degassing-charged into an SC can having an outer diameter of 220 mm, an inner diameter of 210 mm, and a length of 200 mm. The powder-filled billet described above was sintered under conditions shown in Table 3 to produce a sintered body. The solidified molded product produced by the method described above was processed into a disk shape having a diameter of 180 mm and a thickness of 7 mm by wire cut, turning processing, and plane polishing, to form a sputtering target material.

[0023]

Then, a molten raw material was weighed for each composition shown in Table 4, induction-heating melted in a refractory crucible having an Ar gas atmosphere with a reduced pressure or a vacuum atmosphere, then tapped from a nozzle having a diameter of 8 mm in the lower portion of the crucible, and gas-atomized with an Ar gas. Coarse particles having a particle diameter of 500  $\mu\text{m}$  or more, which were not suitable for molding, were removed from the obtained gas-atomized powder, and the powder from which the coarse particles had been removed and from which fine particles were not removed was used as a raw powder. The raw powder was degassing-charged into an SC can having an outer diameter of 220 mm, an inner diameter of 210 mm, and a length of 200 mm. The powder-filled billet described above was sintered under conditions shown in Table 4 to produce a sintered body. The

solidified molded product produced by the method described above was processed into a disk shape having a diameter of 180 mm and a thickness of 7 mm by wire cut, turning processing, and plane polishing, to form a sputtering target material.

[0024]

[Table 1]

Table 1

| No | Composition of sputtering target material (at.%) |       |    | Particle size condition | Particle size           | Molding temperature (°C) | Molding time (h) | Molding pressure (MPa) | Hydrogen content (ppm) | Bending strength (Mpa) | Remarks                    |
|----|--------------------------------------------------|-------|----|-------------------------|-------------------------|--------------------------|------------------|------------------------|------------------------|------------------------|----------------------------|
|    | Co                                               | Fe    | B  |                         |                         |                          |                  |                        |                        |                        |                            |
| 1  | 31.5                                             | 58.5  | 10 | A                       | ≤5μm: 9%<br>≤30μm: 38%  | 1000                     | 2                | 100                    | 18                     | 820                    | Present Invention Examples |
| 2  | 33.25                                            | 51.75 | 15 | B                       | ≤5μm: 6%<br>≤30μm: 33%  | 1000                     | 2                | 100                    | 10                     | 900                    |                            |
| 3  | 28                                               | 52    | 20 | A                       | ≤5μm: 6%<br>≤30μm: 33%  | 1000                     | 2                | 100                    | 13                     | 580                    |                            |
| 4  | 18                                               | 72    | 10 | A                       | ≤5μm: 7%<br>≤30μm: 37%  | 1000                     | 2                | 100                    | 15                     | 790                    |                            |
| 5  | 60                                               | 20    | 20 | B                       | ≤5μm: 3%<br>≤30μm: 32%  | 1000                     | 2                | 150                    | 9                      | 630                    |                            |
| 6  | 72                                               | 8     | 20 | A                       | ≤5μm: 3%<br>≤30μm: 36%  | 1000                     | 2                | 150                    | 14                     | 650                    |                            |
| 7  | 90                                               | 0     | 10 | C                       | ≤5μm: 4%<br>≤30μm: 25%  | 700                      | 3                | 150                    | 8                      | 880                    |                            |
| 8  | 80                                               | 0     | 20 | C                       | ≤5μm: 2%<br>≤30μm: 21%  | 800                      | 3                | 150                    | 6                      | 630                    |                            |
| 9  | 70                                               | 0     | 30 | B                       | ≤5μm: 6%<br>≤30μm: 32%  | 1000                     | 3                | 100                    | 8                      | 480                    |                            |
| 10 | 60                                               | 0     | 40 | C                       | ≤5μm: 4%<br>≤30μm: 18%  | 1100                     | 3                | 100                    | 4                      | 260                    |                            |
| 11 | 50                                               | 0     | 50 | C                       | ≤5μm: 0%<br>≤30μm: 25%  | 1100                     | 5                | 150                    | 3                      | 250                    |                            |
| 12 | 83                                               | 5     | 12 | A                       | ≤5μm: 10%<br>≤30μm: 40% | 800                      | 5                | 150                    | 15                     | 670                    |                            |
| 13 | 5                                                | 70    | 25 | B                       | ≤5μm: 8%<br>≤30μm: 35%  | 1100                     | 5                | 150                    | 9                      | 690                    |                            |
| 14 | 62                                               | 10    | 28 | A                       | ≤5μm: 8%<br>≤30μm: 39%  | 800                      | 5                | 150                    | 14                     | 400                    |                            |
| 15 | 48                                               | 20    | 32 | A                       | ≤5μm: 9%<br>≤30μm: 35%  | 800                      | 5                | 150                    | 17                     | 300                    |                            |
| 16 | 22                                               | 40    | 38 | C                       | ≤5μm: 5%<br>≤30μm: 30%  | 900                      | 5                | 150                    | 6                      | 290                    |                            |
| 17 | 25                                               | 30    | 45 | A                       | ≤5μm: 8%<br>≤30μm: 38%  | 1000                     | 4                | 150                    | 8                      | 280                    |                            |
| 18 | 5                                                | 45    | 50 | B                       | ≤5μm: 5%<br>≤30μm: 35%  | 1000                     | 3                | 100                    | 15                     | 580                    |                            |
| 19 | 70                                               | 5     | 25 | A                       | ≤5μm: 9%<br>≤30μm: 38%  | 800                      | 5                | 150                    | 12                     | 660                    |                            |
| 20 | 40                                               | 40    | 20 | B                       | ≤5μm: 5%<br>≤30μm: 31%  | 800                      | 5                | 150                    | 10                     | 650                    |                            |

[0025]

[Table 2]

Table 2

| No. | Composition of sputtering target material (at.%) |    |    | Particle size condition | Particle size           | Molding temperature (°C) | Molding time (h) | Molding pressure (MPa) | Hydrogen content (ppm) | Bending strength (Mpa) | Remarks                    |
|-----|--------------------------------------------------|----|----|-------------------------|-------------------------|--------------------------|------------------|------------------------|------------------------|------------------------|----------------------------|
|     | Co                                               | Fe | B  |                         |                         |                          |                  |                        |                        |                        |                            |
| 21  | 60                                               | 20 | 20 | C                       | ≤5μm: 2%<br>≤30μm: 27%  | 800                      | 5                | 150                    | 5                      | 630                    | Present Invention Examples |
| 22  | 0                                                | 90 | 10 | A                       | ≤5μm: 10%<br>≤30μm: 39% | 800                      | 4                | 130                    | 12                     | 820                    |                            |
| 23  | 0                                                | 80 | 20 | A                       | ≤5μm: 8%<br>≤30μm: 39%  | 800                      | 5                | 130                    | 15                     | 580                    |                            |
| 24  | 0                                                | 70 | 30 | A                       | ≤5μm: 10%<br>≤30μm: 36% | 700                      | 3                | 130                    | 15                     | 380                    |                            |
| 25  | 0                                                | 60 | 40 | A                       | ≤5μm: 10%<br>≤30μm: 39% | 1000                     | 5                | 130                    | 12                     | 230                    |                            |
| 26  | 0                                                | 50 | 50 | B                       | ≤5μm: 7%<br>≤30μm: 33%  | 1100                     | 5                | 130                    | 7                      | 250                    |                            |

[0026]  
[Table 3]

Table 3

| No. | Composition of sputtering target material (at.%) | Mixed raw powder (at.%)<br>( ): mixture ratio | Particle size condition | Particle size          | Molding temperature (°C) | Molding time (h) | Molding pressure (MPa) | Hydrogen content (ppm) | Bending strength (Mpa) | Remarks                    |
|-----|--------------------------------------------------|-----------------------------------------------|-------------------------|------------------------|--------------------------|------------------|------------------------|------------------------|------------------------|----------------------------|
| 27  | 20Co-60Fe-20B                                    | Fe-1Co-20B(25)<br>Co-20B(75)                  | A                       | ≤5μm: 8%<br>≤30μm: 36% | 1000                     | 5                | 150                    | 14                     | 610                    | Present Invention Examples |
| 28  | 40Co-40Fe-20B                                    | Fe-1Co-20B(50)<br>Co-20B(50)                  | B                       | ≤5μm: 7%<br>≤30μm: 34% | 1000                     | 5                | 100                    | 8                      | 640                    |                            |
| 29  | 60Co-20Fe-20B                                    | Fe-1Co-20B(75)<br>Co-20B(25)                  | B                       | ≤5μm: 6%<br>≤30μm: 32% | 900                      | 4                | 130                    | 12                     | 600                    |                            |
| 30  | 50Co-20Fe-30B                                    | Fe-1Co-30B(28)<br>Co-30B(72)                  | C                       | ≤5μm: 4%<br>≤30μm: 28% | 1000                     | 2                | 120                    | 8                      | 480                    |                            |
| 31  | 15Co-45Fe-40B                                    | Fe-1Co-40B(75)<br>Co-40B(25)                  | B                       | ≤5μm: 6%<br>≤30μm: 33% | 1100                     | 3                | 150                    | 7                      | 230                    |                            |
| 32  | 40Co-10Fe-50B                                    | Fe-1Co-40B(20)<br>Co-40B(80)                  | B                       | ≤5μm: 5%<br>≤30μm: 31% | 1100                     | 2                | 150                    | 8                      | 220                    |                            |

[0027]

[Table 4]

Table 4

| No. | Composition of sputtering target material (at.%) |       |          | Particle size                         | Molding temperature (°C) | Molding time (h) | Molding pressure (MPa) | Hydrogen content (ppm) | Bending strength (Mpa) | Remarks              |
|-----|--------------------------------------------------|-------|----------|---------------------------------------|--------------------------|------------------|------------------------|------------------------|------------------------|----------------------|
|     | Co                                               | Fe    | B        |                                       |                          |                  |                        |                        |                        |                      |
| 33  | 31.5                                             | 58.5  | 10       | ≤5μm: <u>11%</u><br>≤30μm: 39%        | 1000                     | 2                | 100                    | <u>25</u>              | 150                    | Comparative Examples |
| 34  | 33.25                                            | 61.75 | <u>5</u> | ≤5μm: 9%<br>≤30μm: <u>41%</u>         | 1000                     | 2                | 100                    | <u>30</u>              | 180                    |                      |
| 35  | 28                                               | 52    | 20       | ≤5μm: <u>12%</u><br>≤30μm: 34%        | 1000                     | 2                | 100                    | <u>25</u>              | 130                    |                      |
| 36  | 18                                               | 72    | 10       | ≤5μm: 7%<br>≤30μm: <u>42%</u>         | 1000                     | 2                | 100                    | <u>22</u>              | 160                    |                      |
| 37  | 60                                               | 20    | 20       | ≤5μm: <u>13%</u><br>≤30μm: 29%        | 1000                     | 2                | 100                    | <u>23</u>              | 150                    |                      |
| 38  | 72                                               | 8     | 20       | ≤5μm: 4%<br>≤30μm: <u>43%</u>         | 1000                     | 2                | 100                    | <u>25</u>              | 140                    |                      |
| 39  | 70                                               | 0     | 30       | ≤5μm: <u>14%</u><br>≤30μm: <u>45%</u> | 1000                     | 5                | 150                    | <u>26</u>              | 100                    |                      |

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

[0028]  
[Table 5]

Table 5

| No. | Composition of sputtering target material (at.%) |    |    |    |    |    |    |    |    |    |    |    |    |    |                                                                                                                |        |      |       |    | Total of others | Particle size condition |     | Particle size |      | Molding temperature (°C) | Molding time (h) | Molding pressure (MPa) | Hydrogen content (ppm) | Bending strength (MPa) | Remarks |
|-----|--------------------------------------------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----------------------------------------------------------------------------------------------------------------|--------|------|-------|----|-----------------|-------------------------|-----|---------------|------|--------------------------|------------------|------------------------|------------------------|------------------------|---------|
|     | Others                                           |    |    |    |    |    |    |    |    |    |    |    |    |    |                                                                                                                |        |      |       |    |                 |                         |     |               |      |                          |                  |                        |                        |                        |         |
|     | Co                                               | Fe | B  | Ti | Zr | Hf | V  | Nb | Ta | Cr | Mo | W  | Mn | Ni | Cu                                                                                                             | Others | ≤5μm | ≤30μm |    |                 |                         |     |               |      |                          |                  |                        |                        |                        |         |
|     | 40                                               | 65 | 0  | 30 | 5  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0                                                                                                              | 0      | -    | A     | 10 |                 |                         |     | 36            | 1000 |                          |                  |                        |                        |                        |         |
| 41  | 65                                               | 5  | 20 | 5  | 1  | 1  | 1  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0                                                                                                              | -      | B    | 6     | 33 | 980             | 2                       | 100 | 8             | 800  |                          |                  |                        |                        |                        |         |
| 42  | 55                                               | 15 | 10 | 9  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 0                                                                                                              | Pt: 1  | C    | 3     | 29 | 1000            | 2                       | 100 | 3             | 700  |                          |                  |                        |                        |                        |         |
| 43  | 45                                               | 30 | 15 | 0  | 10 | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0                                                                                                              | -      | A    | 9     | 36 | 1050            | 2                       | 100 | 15            | 1300 |                          |                  |                        |                        |                        |         |
| 44  | 10                                               | 45 | 30 | 0  | 15 | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0                                                                                                              | -      | B    | 8     | 33 | 1050            | 2                       | 100 | 8             | 1000 |                          |                  |                        |                        |                        |         |
| 45  | 10                                               | 50 | 20 | 0  | 10 | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1                                                                                                              | -      | C    | 4     | 35 | 1050            | 3                       | 100 | 7             | 800  |                          |                  |                        |                        |                        |         |
| 46  | 25                                               | 60 | 10 | 0  | 0  | 4  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0                                                                                                              | Re: 1  | A    | 9     | 40 | 900             | 3                       | 100 | 15            | 1200 |                          |                  |                        |                        |                        |         |
| 47  | 5                                                | 70 | 10 | 0  | 0  | 15 | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0                                                                                                              | -      | B    | 8     | 34 | 950             | 3                       | 100 | 8             | 1000 |                          |                  |                        |                        |                        |         |
| 48  | 0                                                | 70 | 10 | 0  | 0  | 10 | 0  | 2  | 2  | 2  | 2  | 2  | 0  | 0  | 0                                                                                                              | -      | C    | 1     | 10 | 1000            | 3                       | 100 | 8             | 900  |                          |                  |                        |                        |                        |         |
| 49  | 10                                               | 35 | 50 | 0  | 0  | 5  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0                                                                                                              | -      | A    | 10    | 36 | 1100            | 4                       | 100 | 15            | 1600 |                          |                  |                        |                        |                        |         |
| 50  | 0                                                | 45 | 40 | 0  | 0  | 0  | 10 | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0                                                                                                              | Ru: 5  | B    | 6     | 33 | 1080            | 4                       | 100 | 10            | 1500 |                          |                  |                        |                        |                        |         |
| 51  | 41                                               | 4  | 40 | 0  | 0  | 0  | 15 | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0                                                                                                              | -      | C    | 5     | 29 | 1050            | 4                       | 100 | 3             | 1400 |                          |                  |                        |                        |                        |         |
| 52  | 72                                               | 8  | 10 | 0  | 0  | 0  | 5  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0                                                                                                              | Rh: 5  | C    | 5     | 15 | 1200            | 4                       | 120 | 3             | 1000 |                          |                  |                        |                        |                        |         |
| 53  | 61                                               | 9  | 15 | 0  | 0  | 0  | 15 | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0                                                                                                              | -      | A    | 10    | 37 | 1230            | 4                       | 120 | 7             | 1000 |                          |                  |                        |                        |                        |         |
| 54  | 47                                               | 13 | 20 | 0  | 0  | 0  | 10 | 0  | 0  | 10 | 0  | 0  | 0  | 0  | 0                                                                                                              | -      | B    | 7     | 31 | 1250            | 4                       | 120 | 13            | 800  |                          |                  |                        |                        |                        |         |
| 55  | 42                                               | 28 | 20 | 0  | 0  | 0  | 0  | 10 | 0  | 0  | 0  | 0  | 0  | 0  | 0                                                                                                              | -      | A    | 9     | 38 | 1300            | 4                       | 120 | 15            | 1000 |                          |                  |                        |                        |                        |         |
| 56  | 29                                               | 34 | 17 | 10 | 0  | 0  | 0  | 10 | 0  | 0  | 0  | 0  | 0  | 0  | 0                                                                                                              | -      | B    | 7     | 34 | 1280            | 4                       | 120 | 8             | 900  |                          |                  |                        |                        |                        |         |
| 57  | 16                                               | 46 | 18 | 10 | 0  | 1  | 0  | 0  | 1  | 1  | 7  | 0  | 0  | 0  | 0                                                                                                              | -      | C    | 3     | 15 | 1150            | 4                       | 120 | 4             | 900  |                          |                  |                        |                        |                        |         |
| 58  | 13                                               | 45 | 22 | 5  | 0  | 0  | 0  | 0  | 5  | 0  | 0  | 0  | 0  | 0  | 0                                                                                                              | Ir: 10 | A    | 10    | 37 | 1120            | 5                       | 120 | 14            | 1200 |                          |                  |                        |                        |                        |         |
| 59  | 12                                               | 44 | 24 | 0  | 10 | 0  | 0  | 0  | 10 | 0  | 0  | 0  | 0  | 0  | 0                                                                                                              | -      | B    | 6     | 31 | 1110            | 5                       | 120 | 7             | 1500 |                          |                  |                        |                        |                        |         |
| 60  | 0                                                | 60 | 10 | 0  | 10 | 0  | 0  | 0  | 0  | 20 | 0  | 0  | 0  | 0  | 0                                                                                                              | -      | C    | 1     | 21 | 1100            | 5                       | 120 | 8             | 1300 |                          |                  |                        |                        |                        |         |
| 61  | 0                                                | 50 | 30 | 0  | 15 | 0  | 0  | 0  | 0  | 5  | 0  | 0  | 0  | 0  | 0                                                                                                              | -      | A    | 10    | 39 | 1230            | 5                       | 150 | 10            | 1500 |                          |                  |                        |                        |                        |         |
| 62  | 35                                               | 35 | 10 | 0  | 0  | 10 | 0  | 0  | 0  | 10 | 0  | 0  | 0  | 0  | 0                                                                                                              | -      | B    | 6     | 33 | 1240            | 5                       | 150 | 6             | 1300 |                          |                  |                        |                        |                        |         |
| 63  | 22                                               | 48 | 10 | 0  | 0  | 10 | 0  | 0  | 0  | 5  | 0  | 0  | 0  | 0  | 0                                                                                                              | Pd: 5  | C    | 0     | 5  | 1260            | 4                       | 150 | 3             | 1300 |                          |                  |                        |                        |                        |         |
| 64  | 19                                               | 41 | 20 | 0  | 0  | 15 | 0  | 0  | 0  | 0  | 5  | 0  | 0  | 0  | 0                                                                                                              | -      | A    | 9     | 39 | 1200            | 10                      | 150 | 3             | 1300 |                          |                  |                        |                        |                        |         |
| 65  | 41                                               | 19 | 20 | 0  | 0  | 0  | 10 | 0  | 0  | 0  | 2  | 3  | 3  | 2  | - <th>-</th> <th>B</th> <th>8</th> <th>35</th> <th>1270</th> <th>10</th> <th>150</th> <th>7</th> <th>1000</th> | -      | B    | 8     | 35 | 1270            | 10                      | 150 | 7             | 1000 |                          |                  |                        |                        |                        |         |
| 66  | 37                                               | 23 | 20 | 0  | 0  | 0  | 10 | 0  | 10 | 0  | 0  | 0  | 0  | 0  | 0                                                                                                              | -      | C    | 5     | 23 | 1190            | 10                      | 120 | 5             | 1000 |                          |                  |                        |                        |                        |         |
| 67  | 40                                               | 20 | 20 | 0  | 0  | 0  | 15 | 0  | 0  | 0  | 0  | 5  | 0  | 0  | 0                                                                                                              | -      | A    | 10    | 39 | 1170            | 3                       | 120 | 11            | 1100 |                          |                  |                        |                        |                        |         |
| 68  | 55                                               | 15 | 10 | 0  | 0  | 0  | 0  | 20 | 0  | 0  | 0  | 0  | 0  | 0  | 0                                                                                                              | -      | B    | 7     | 34 | 1160            | 4                       | 120 | 9             | 1200 |                          |                  |                        |                        |                        |         |
| 69  | 56                                               | 14 | 10 | 0  | 0  | 0  | 0  | 10 | 0  | 0  | 0  | 10 | 0  | 0  | 0                                                                                                              | -      | C    | 1     | 18 | 1150            | 3                       | 120 | 3             | 1100 |                          |                  |                        |                        |                        |         |
| 70  | 5                                                | 65 | 10 | 0  | 0  | 0  | 0  | 15 | 0  | 0  | 0  | 0  | 5  | 0  | 0                                                                                                              | -      | A    | 10    | 39 | 1200            | 10                      | 150 | 15            | 1500 |                          |                  |                        |                        |                        |         |

[0029]

[Table 6]

Table 6

| No. | Composition of sputtering target material (at.%) |    |    |    |    |    |   |    |    |    |    |    |    |    |    | Total of others                          | Particle size condition | Particle size |       | Molding temperature (°C) | Molding time (h) | Molding pressure (MPa) | Hydrogen content (ppm) | Bending strength (MPa) | Remarks |                                  |  |  |  |  |                      |  |
|-----|--------------------------------------------------|----|----|----|----|----|---|----|----|----|----|----|----|----|----|------------------------------------------|-------------------------|---------------|-------|--------------------------|------------------|------------------------|------------------------|------------------------|---------|----------------------------------|--|--|--|--|----------------------|--|
|     | Others                                           |    |    |    |    |    |   |    |    |    |    |    |    |    |    |                                          |                         | ≤5μm          | ≤30μm |                          |                  |                        |                        |                        |         |                                  |  |  |  |  |                      |  |
|     | Co                                               | Fe | B  | Ti | Zr | Hf | V | Nb | Ta | Cr | Mo | W  | Mn | Ni | Cu |                                          |                         |               |       |                          |                  |                        |                        |                        |         | Others                           |  |  |  |  |                      |  |
| 71  | 25                                               | 35 | 20 | 0  | 0  | 0  | 0 | 0  | 20 | 0  | 0  | 0  | 0  | 0  | 0  | -                                        | 20                      | B             | 8     | 31                       | 1220             | 8                      | 150                    | 5                      | 1400    | Present<br>Invention<br>Examples |  |  |  |  |                      |  |
| 72  | 20                                               | 20 | 40 | 0  | 0  | 0  | 0 | 0  | 10 | 0  | 0  | 0  | 0  | 10 | 0  | -                                        | 20                      | C             | 4     | 30                       | 1200             | 7                      | 150                    | 3                      | 1400    |                                  |  |  |  |  |                      |  |
| 73  | 40                                               | 10 | 30 | 0  | 0  | 0  | 0 | 0  | 10 | 0  | 0  | 0  | 0  | 0  | 0  | Pt: 10                                   | 20                      | A             | 10    | 39                       | 1250             | 7                      | 150                    | 14                     | 1400    |                                  |  |  |  |  |                      |  |
| 74  | 40                                               | 20 | 20 | 0  | 0  | 0  | 0 | 0  | 20 | 0  | 0  | 0  | 0  | 0  | 0  | -                                        | 20                      | C             | 3     | 25                       | 1250             | 7                      | 150                    | 3                      | 1300    |                                  |  |  |  |  |                      |  |
| 75  | 30                                               | 10 | 50 | 0  | 0  | 0  | 0 | 0  | 10 | 0  | 0  | 0  | 0  | 0  | 0  | -                                        | 10                      | B             | 8     | 35                       | 1270             | 7                      | 100                    | 10                     | 1300    |                                  |  |  |  |  |                      |  |
| 76  | 41                                               | 18 | 30 | 0  | 0  | 0  | 0 | 0  | 0  | 5  | 0  | 0  | 0  | 0  | 0  | Re: 2, Ru: 1, Rh: 2, Ir: 1               | 11                      | C             | 0     | 6                        | 1000             | 5                      | 100                    | 7                      | 1500    |                                  |  |  |  |  |                      |  |
| 77  | 40                                               | 30 | 10 | 0  | 0  | 0  | 0 | 0  | 0  | 0  | 20 | 0  | 0  | 0  | 0  | -                                        | 20                      | B             | 8     | 33                       | 900              | 5                      | 100                    | 3                      | 1300    |                                  |  |  |  |  |                      |  |
| 78  | 15                                               | 40 | 20 | 0  | 0  | 0  | 0 | 0  | 0  | 0  | 5  | 0  | 0  | 0  | 0  | Pd: 5, Pt: 5, Ag: 5                      | 20                      | A             | 9     | 36                       | 800              | 5                      | 130                    | 13                     | 1200    |                                  |  |  |  |  |                      |  |
| 79  | 15                                               | 40 | 30 | 0  | 0  | 0  | 0 | 0  | 0  | 0  | 15 | 0  | 0  | 0  | 0  | -                                        | 15                      | A             | 9     | 36                       | 1150             | 7                      | 130                    | 13                     | 1500    |                                  |  |  |  |  |                      |  |
| 80  | 25                                               | 45 | 10 | 0  | 0  | 0  | 0 | 0  | 0  | 0  | 20 | 0  | 0  | 0  | 0  | -                                        | 20                      | A             | 10    | 39                       | 1150             | 7                      | 130                    | 15                     | 1500    |                                  |  |  |  |  |                      |  |
| 81  | 15                                               | 65 | 10 | 0  | 0  | 0  | 0 | 0  | 0  | 0  | 0  | 10 | 0  | 0  | 0  | -                                        | 10                      | B             | 8     | 33                       | 1150             | 7                      | 130                    | 7                      | 1600    |                                  |  |  |  |  |                      |  |
| 82  | 60                                               | 15 | 10 | 0  | 0  | 0  | 0 | 0  | 0  | 0  | 0  | 15 | 0  | 0  | 0  | -                                        | 15                      | B             | 7     | 32                       | 1100             | 3                      | 130                    | 7                      | 1300    |                                  |  |  |  |  |                      |  |
| 83  | 20                                               | 50 | 10 | 0  | 0  | 0  | 0 | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 20 | -                                        | 20                      | B             | 7     | 33                       | 1000             | 3                      | 130                    | 7                      | 1200    |                                  |  |  |  |  |                      |  |
| 84  | 34                                               | 32 | 20 | 0  | 0  | 0  | 0 | 0  | 0  | 0  | 1  | 1  | 1  | 1  | 4  | Re: 1, Ru: 1, Ir: 1, Pd: 1, Pt: 1, Ag: 1 | 14                      | C             | 3     | 28                       | 1000             | 3                      | 130                    | 4                      | 1300    |                                  |  |  |  |  |                      |  |
| 85  | 36                                               | 29 | 20 | 0  | 0  | 0  | 0 | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 10 | Ag: 5                                    | 15                      | C             | 3     | 20                       | 1000             | 3                      | 130                    | 3                      | 1000    |                                  |  |  |  |  |                      |  |
| 86  | 30                                               | 40 | 10 | 0  | 0  | 0  | 0 | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | Re: 20                                   | 0                       | C             | 2     | 18                       | 900              | 2                      | 130                    | 3                      | 1000    |                                  |  |  |  |  |                      |  |
| 87  | 40                                               | 40 | 10 | 0  | 0  | 0  | 0 | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | Ru: 10                                   | 0                       | A             | 10    | 35                       | 900              | 2                      | 130                    | 13                     | 900     |                                  |  |  |  |  |                      |  |
| 88  | 49                                               | 20 | 10 | 21 | 0  | 0  | 0 | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | -                                        | 21                      | A             | 9     | 36                       | 1000             | 2                      | 130                    | 20                     | 100     |                                  |  |  |  |  |                      |  |
| 89  | 28                                               | 30 | 20 | 0  | 0  | 0  | 0 | 10 | 12 | 0  | 0  | 0  | 0  | 0  | 0  | -                                        | 22                      | B             | 6     | 33                       | 1150             | 2                      | 150                    | 8                      | 100     |                                  |  |  |  |  |                      |  |
| 90  | 44                                               | 5  | 30 | 0  | 0  | 0  | 0 | 0  | 10 | 0  | 0  | 0  | 11 | 0  | 0  | -                                        | 21                      | C             | 4     | 28                       | 1050             | 2                      | 120                    | 5                      | 100     |                                  |  |  |  |  |                      |  |
|     |                                                  |    |    |    |    |    |   |    |    |    |    |    |    |    |    |                                          |                         |               |       |                          |                  |                        |                        |                        |         |                                  |  |  |  |  | Comparative Examples |  |

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

[0030]

[Table 7]

Table 7

| No. | Composition of sputtering target material (at.%) |    |    |    |    |    |    |    |    |    |    |    |                 |    |    |                                              | Mixed raw powders (at%)<br>( ): mixture ratio | Particle size condition                                                                                                                                                                                                                  | Particle size |    | Molding temperature (°C) | Molding time (h) | Molding pressure (MPa) | Hydrogen content (ppm) | Bending strength (MPa) | Remarks |                                  |
|-----|--------------------------------------------------|----|----|----|----|----|----|----|----|----|----|----|-----------------|----|----|----------------------------------------------|-----------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|----|--------------------------|------------------|------------------------|------------------------|------------------------|---------|----------------------------------|
|     | Others                                           |    |    |    |    |    |    |    |    |    |    |    | Total of others |    |    |                                              |                                               |                                                                                                                                                                                                                                          |               |    |                          |                  |                        |                        |                        |         |                                  |
|     | Co                                               | Fe | B  | Ti | Zr | Hf | V  | Nb | Ta | Cr | Mo | W  |                 | Mn | Ni | Cu                                           |                                               |                                                                                                                                                                                                                                          | Others        |    |                          |                  |                        |                        |                        |         |                                  |
| 91  | 60                                               | 0  | 30 | 10 | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0               | 0  | 0  | -                                            | 10                                            | Co: 33, B: 1, Ti (90), pure Ti (10)                                                                                                                                                                                                      | A             | 10 | 38                       | 950              | 2                      | 150                    | 15                     | 1200    | Present<br>Invention<br>Examples |
| 92  | 65                                               | 5  | 20 | 0  | 0  | 0  | 0  | 10 | 0  | 0  | 0  | 0  | 0               | 0  | 0  | -                                            | 10                                            | Co: 20, B: 10, Ta: (93)<br>Fe: 20, B: 10, Ta: (7)                                                                                                                                                                                        | B             | 8  | 32                       | 1000             | 3                      | 130                    | 10                     | 1200    |                                  |
| 93  | 55                                               | 15 | 10 | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 10 | 0  | 0               | 0  | 0  | -                                            | 10                                            | Co: 10, B: 10, Mo: (82)<br>Fe: 10, B: 10, Mo: (18)                                                                                                                                                                                       | B             | 6  | 31                       | 900              | 5                      | 150                    | 9                      | 1000    |                                  |
| 94  | 45                                               | 30 | 15 | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0               | 10 | 0  | -                                            | 10                                            | Co: 15, B: 10, Ni: (83)<br>Fe: 15, B: 10, Ni: (17)                                                                                                                                                                                       | C             | 4  | 25                       | 1000             | 5                      | 130                    | 3                      | 1000    |                                  |
| 95  | 15                                               | 45 | 30 | 0  | 5  | 0  | 0  | 5  | 0  | 0  | 0  | 0  | 0               | 0  | 0  | -                                            | 10                                            | Co: 30, B: 5, Zr: 5, Nb: (26)<br>Fe: 30, B: 5, Zr: 5, Nb: (74)                                                                                                                                                                           | C             | 4  | 20                       | 1050             | 3                      | 120                    | 3                      | 1000    |                                  |
| 96  | 20                                               | 50 | 20 | 0  | 0  | 0  | 10 | 0  | 0  | 0  | 0  | 0  | 0               | 0  | 0  | -                                            | 10                                            | Co: 22, B: 8, V: (29), Fe: 15, B: 5, V: (65),<br>pure B: (1), pure V: (5)                                                                                                                                                                | A             | 9  | 36                       | 1050             | 2                      | 120                    | 14                     | 1000    |                                  |
| 97  | 20                                               | 50 | 10 | 0  | 0  | 5  | 5  | 0  | 0  | 0  | 5  | 0  | 0               | 5  | 0  | -                                            | 20                                            | Co: 10, B: 5, Hf: 5, V: 5, Mo: 5, Ni: (29)<br>Fe: 10, B: 5, Hf: 5, V: 5, Mo: 5, Ni (71)                                                                                                                                                  | A             | 10 | 39                       | 1200             | 7                      | 150                    | 14                     | 1300    |                                  |
| 98  | 10                                               | 70 | 10 | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0               | 0  | 0  | Re:10                                        | 10                                            | Co: 10, B: 10, Re: (13)<br>Fe: 10, B: 10, Re: (87)                                                                                                                                                                                       | B             | 7  | 34                       | 1200             | 7                      | 150                    | 10                     | 1300    |                                  |
| 99  | 20                                               | 50 | 10 | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 20 | 0               | 0  | 0  | -                                            | 20                                            | Co: 10, B: 20, W: (29)<br>Fe: 10, B: 20, W: (71)                                                                                                                                                                                         | B             | 7  | 34                       | 1200             | 7                      | 120                    | 10                     | 1200    |                                  |
| 100 | 15                                               | 15 | 50 | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 10              | 5  | 5  | -                                            | 20                                            | Co: 31, Fe: 38, B: (56), pure B: (10),<br>Mn: (16), Ni: (9), Cu: (9)                                                                                                                                                                     | C             | 3  | 25                       | 900              | 5                      | 120                    | 5                      | 1000    |                                  |
| 101 | 0                                                | 45 | 40 | 0  | 5  | 0  | 0  | 5  | 0  | 0  | 0  | 0  | 0               | 0  | 0  | Pd:5                                         | 15                                            | Fe: 24, 7, B: 6, 3, Zr: 6, 3, Nb: 6, 3, Pd (95),<br>B: (5)                                                                                                                                                                               | A             | 9  | 30                       | 1200             | 10                     | 120                    | 15                     | 1300    |                                  |
| 102 | 46                                               | 4  | 40 | 0  | 0  | 0  | 0  | 0  | 10 | 0  | 0  | 0  | 0               | 0  | 0  | -                                            | 10                                            | Co: 5, 7, Fe: 37, 9, B: (61), pure Co: (20),<br>pure Fe: (1), pure B: (1), pure Cr: (13)                                                                                                                                                 | B             | 6  | 33                       | 1200             | 10                     | 130                    | 13                     | 1300    |                                  |
| 103 | 62                                               | 8  | 10 | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0               | 0  | 0  | Ru:20                                        | 20                                            | Co: 10, B: 20, Ru: (80)<br>Fe: 10, B: 20, Ru (20)                                                                                                                                                                                        | C             | 3  | 24                       | 1050             | 3                      | 130                    | 5                      | 1000    |                                  |
| 104 | 71                                               | 9  | 15 | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0               | 0  | 0  | Pt:5                                         | 5                                             | Co: 10, B: 5, Pt: (87)<br>Fe: 40, B: 5, Pt: (13)                                                                                                                                                                                         | A             | 9  | 39                       | 1100             | 3                      | 120                    | 16                     | 1200    |                                  |
| 105 | 62                                               | 13 | 20 | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0               | 0  | 0  | Ag:5                                         | 5                                             | Co: 21, B: 4, 4, Ag: (82)<br>Co: 75, Fe: 15, B: 8, Ag: (18)                                                                                                                                                                              | B             | 7  | 35                       | 1000             | 2                      | 120                    | 9                      | 1100    |                                  |
| 106 | 32                                               | 28 | 20 | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1               | 1  | 1  | Re:1<br>Ru:1<br>Ir:1<br>Pd:1<br>Pt:1<br>Ag:1 | 20                                            | Ta: 1, Cr: 1, Mo: 1, W: 1, Mn: 1, Ni: 1, Cu: 1, Re: 1, Ru: 1, Ir: 1, Pd: 1, Pt: 1, Ag (53)<br>Fe: 20, B: 1, Ti: 1, Zr: 1, Hf: 1, V: 1, Nb: 1, Ta: 1, Cr: 1, Mo: 1, W: 1, Mn: 1, Ni: 1, Cu: 1, Re: 1, Ru: 1, Ir: 1, Pd: 1, Pt: 1, Ag (47) | C             | 5  | 19                       | 800              | 2                      | 120                    | 3                      | 900     |                                  |

[0031]

Nos. 1 to 32 shown in Tables 1 to 3 and Nos. 40 to 87 and Nos. 91 to 106 shown in Tables 5 to 7 are present invention examples, while Nos. 33 to 39 shown in Table 4 and Nos. 88 to 90 shown in Table 6 are Comparative Examples.

[0032]

The particle size distribution of a powder was measured and confirmed by a laser diffraction/scattering-type particle size distribution measurement apparatus (MICROTRAC). Examples of the molding method include, but are not particularly limited to, HIP, hot press, SPS, and hot extrusion. The content of hydrogen was measured by an inert gas fusion-nondispersive infrared absorption method. The mechanical strength (bending strength) of a specimen having a longitudinal length of 4 mm, a width of 25 mm, and a thickness of 3 mm, obtained by division by a wire, was evaluated by a three-point bending test. In the three-point bending test conducted under the condition of a supporting-point distance of 20 mm, a three-point bending strength was calculated from a stress (N) measured when a pressure was applied downward in a thickness direction to a plane having a longitudinal length of 4 mm and a width of 25 mm, on the basis of the following equation. The calculated three-point bending strength was regarded as a bending strength (MPa).

Three-point bending strength (MPa) =  $(3 \times \text{stress (N)} \times \text{supporting-point distance (mm)}) / (2 \times \text{specimen width (mm)} \times (\text{specimen thickness (mm)})^2)$

[0033]

Nos. 1 to 26 and Nos. 40 to 87 which are present invention examples are sputtering target materials having compositions shown in Tables 1, 2, 5, and 6, while Nos. 27 to 32 and Nos. 91 to 106 which are present invention examples are sputtering target materials produced from plural raw powders shown in Tables 3 and 7. Each sputtering target material was able to achieve a bending strength of 200 MPa or more because of satisfying the condition of the present invention, in which

sputtering target material comprises: 10 to 50% of B; 0 to 20% in total of one or more elements selected from the group consisting of Ti, Zr, Hf, V, Nb, Ta, Cr, Mo, W, Mn, Re, Ru, Rh, Ir, Ni, Pd, Pt, Cu, and Ag; and the balance of at least one of Co and Fe, and unavoidable impurities, wherein a hydrogen content is 20 ppm or less.

[0034]

In contrast, in Comparative Example No. 33 shown in Table 4, a hydrogen content increased to 25 ppm, and a bending strength decreased to 150 MPa because the cumulative volume of particles having a particle diameter of 5  $\mu\text{m}$  or less in the particle size distribution of a gas-atomized powder used as a raw material of the sputtering target material was 11% and satisfied none of the particle size conditions A to C. In Comparative Example No. 34, a hydrogen content increased to 30 ppm, and a bending strength decreased to 180 MPa because the content of B was less than 10%, and the cumulative volume of particles having a particle diameter of 30  $\mu\text{m}$  or less in the particle size distribution of a gas-atomized powder used as a raw material of the sputtering target material was 41%. In Comparative Example Nos. 35 and 37, hydrogen contents increased to 25 ppm and 23 ppm, and bending strengths decreased to 130 MPa and 150 MPa because the cumulative volumes of particles having a particle diameter of 5  $\mu\text{m}$  or less in the particle size distributions of gas-atomized powders used as raw materials of the sputtering target materials were 12% and 13% and satisfied none of the particle size conditions A to C.

[0035]

In Comparative Example Nos. 36 and 38, hydrogen contents increased to 22 ppm and 25 ppm, and bending strengths decreased to 160 MPa and 140 MPa because the cumulative volumes of particles having a particle diameter of 30  $\mu\text{m}$  or less in the particle size distributions of gas-atomized powders used as raw materials of the sputtering target materials were 42% and 43% and satisfied none of the particle

size conditions A to C. In Comparative Example No. 39, a hydrogen content increased to 26 ppm, and a bending strength decreased to 100 MPa because the cumulative volumes of particles having particle diameters of 5  $\mu\text{m}$  or less and 30  $\mu\text{m}$  or less in the particle size distribution of a gas-atomized powder used as a raw material of the sputtering target material were 14% and 45% and satisfied none of the particle size conditions A to C. The strengths in Comparative Examples are found to be very poor. Comparative Example Nos. 88 to 90 shown in Table 6 are found to result in low strength and brittleness because of comprising more than 20% in total of one or more elements selected from the group consisting of Ti, Zr, Hf, V, Nb, Ta, Cr, Mo, W, Mn, Re, Ru, Rh, Ir, Ni, Pd, Pt, Cu, and Ag.

[0036]

According to the present invention, a sputtering target material of which the mechanical strength is improved by decreasing the content of hydrogen in the sputtering target material to 20 ppm or less is provided as described above. The sputtering target material according to the present invention is a sputtering target material useful for producing an alloy thin film in an MTJ element, an HDD, a medium for magnetic recording, or the like and exhibits a very excellent effect.

## CLAIMS

1. A sputtering target material comprising in at.%, 10 to 50% of B; 0 to 20% in total of one or more elements selected from the group consisting of Ti, Zr, Hf, V, Nb, Ta, Cr, Mo, W, Mn, Re, Ru, Rh, Ir, Ni, Pd, Pt, Cu, and Ag; and the balance of at least one of Co and Fe, and unavoidable impurities, wherein a hydrogen content is 20 ppm or less.
2. The sputtering target material according to claim 1, wherein the sputtering target material comprises, in at.%, 5 to 20% in total of one or more elements selected from the group consisting of Ti, Zr, Hf, V, Nb, Ta, Cr, Mo, W, Mn, Re, Ru, Rh, Ir, Ni, Pd, Pt, Cu, and Ag.
3. The sputtering target material according to claim 1, wherein the sputtering target material has a bending strength of 200 MPa or more.