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MAGNETIC RECORDING MEDIUM AND THE METHOD OF MANUFACTURING THE SAME

Field of the Invention

5 The present invention relates to a magnetic recording medium and the method of manufacturing the magnetic recording medium. Specifically, the present invention relates to a magnetic recording medium used in a hard disk drive and the method of manufacturing the magnetic recording medium.

10 Prior Art

Recently, it has been required for the magnetic recording medium used in a hard disk drive to exhibit a higher recording density. For meeting the severe demands for a higher recording density, it is important to improve the coercive force of a thin magnetic film and to suppress the noises caused therefrom at a low level. Various compositions and structures for the magnetic layer and various materials for the nonmagnetic undercoating layer have been proposed to improve the coercive force and to reduce the noises.

20 A granular magnetic layer, including magnetic crystal grains and a nonmagnetic and nonmetallic material such as an oxide and a nitride surrounding the magnetic crystal grains, is known. Since the grain boundaries formed of the nonmagnetic and nonmetallic material separate the magnetic grains physically, the magnetic interaction between the magnetic grains is depressed and zigzag domain walls are prevented from causing in the transient regions between the recording bits. Therefore, the granular magnetic layer is favorable to suppress the noises at a low level.

When the conventional CoCr metallic magnetic film is formed at a high temperature, Cr is segregated from Co magnetic crystal grains to the grain boundaries and the segregated Cr reduces the magnetic interaction between the magnetic grains. Since the nonmagnetic and nonmetallic material used for the grain boundaries in the granular magnetic film is segregated more easily than Cr, the nonmagnetic and nonmetallic material in the granular magnetic film facilitates isolating the magnetic crystal grains from each other. For segregating a sufficient amount of Cr, it is indispensable to heat the substrate at 200°C or higher during forming the CoCr metallic magnetic film. In contrast, the nonmagnetic and nonmetallic material is segregated even when the granular magnetic film is not heated during the deposition thereof.

Problems to be solved by the Invention

For obtaining desirable characteristics, especially for obtaining a high coercive force H_c , it is necessary to add a relatively large amount of Pt to the Co alloy in forming a magnetic recording medium including a granular magnetic layer. In detail, for obtaining a coercive force H_c of around 3200 Oe, it is necessary to add 16 at. % of expensive Pt. For providing the CoCr metallic magnetic film with the same coercive force H_c , it is enough to add around 12 at. % of Pt.

For realizing a higher recording density, it is necessary to realize a high coercive force H_c of 3200 Oe or larger. Therefore, it is necessary to add more amount of expensive Pt, increasing the manufacturing costs against the demands for cost reduction.

Since it has been required to reduce the noises caused from the medium, it is also necessary to control the properties of the granular magnetic film.

In view of the foregoing, it is a first object of the invention to provide a magnetic recording medium, that facilitates obtaining a high coercive force and suppressing the noises caused therefrom at a low level. It is a second object of the invention to provide a method of manufacturing such as
5 magnetic recording medium.

Means for solving the Problems

According to a first aspect of the invention, there is provided a magnetic recording medium including: a nonmagnetic substrate; a
10 nonmagnetic undercoating layer on the nonmagnetic substrate, the nonmagnetic undercoating layer having a hexagonal close packing structure or a combination of a hexagonal close packing structure and a body center cubic structure; a nonmagnetic intermediate layer on the nonmagnetic undercoating layer, the nonmagnetic intermediate layer having a hexagonal
15 close packing structure or a combination of a hexagonal close packing structure and a body center cubic structure; and a magnetic layer on the nonmagnetic intermediate layer, the magnetic layer having a granular structure formed of ferromagnetic crystal grains and oxide grain boundaries or nitride grain boundaries surrounding the ferromagnetic crystal grains.

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Advantageously, the oxide grain boundaries include at least the oxide of Mg, Al, Si, Ti, Cr, Mn, Co, Zr, Ta, W, or Hf.

Advantageously, the nitride grain boundaries include at least the
25 nitride of Mg, Al, Si, Ti, Cr, Mn, Co, Zr, Ta, W, or Hf.

Advantageously, the hexagonal close packing structure of the nonmagnetic intermediate layer includes at least Ru, Ir, Rh, or Re.

Advantageously, the combination of the hexagonal close packing
30 structure and the body center cubic structure of the nonmagnetic

intermediate layer includes at least the alloy of Ru, Ir, Rh, or Re, that contains from 10 at.% to 50 at.% of Ti, C, W, Mo, or Cu.

Advantageously, the hexagonal close packing structure of the
5 nonmagnetic undercoating layer includes at least W, Mo, or V.

Advantageously, the combination of the hexagonal close packing structure and the body center cubic structure of the nonmagnetic undercoating layer includes the alloy of W, Mo, Cr, or V, that contains from
10 10 at.% to 50 at.% of Ti.

Advantageously, the nonmagnetic substrate is made of a crystallized glass, a chemically strengthened glass or a resin.

15 According to a second aspect of the invention, there is provided the method of manufacturing a magnetic recording medium including a nonmagnetic substrate; a nonmagnetic undercoating layer on the nonmagnetic substrate, the nonmagnetic undercoating layer having a hexagonal close packing structure or a combination of a hexagonal close
20 packing structure and a body center cubic structure; a nonmagnetic intermediate layer on the nonmagnetic undercoating layer, the nonmagnetic intermediate layer having a hexagonal close packing structure or a combination of a hexagonal close packing structure and a body center cubic structure; and a magnetic layer on the nonmagnetic intermediate layer, the
25 magnetic layer having a granular structure formed of ferromagnetic crystal grains and oxide grain boundaries or nitride grain boundaries surrounding the ferromagnetic crystal grains, the method including: setting the spacing between the target in the sputtering apparatus and the substrate for forming the nonmagnetic intermediate layer and/or for forming the
30 magnetic layer at a spacing between 70 mm and 100mm.

Brief Description of the Drawing Figures

Fig. 1 is a cross sectional view of a magnetic recording medium according to the invention.

5 Fig. 2 is a curve relating the T/S spacing at the deposition of the nonmagnetic intermediate layer and the coercive force.

Fig. 3 is a curve relating the T/S spacing at the deposition of the nonmagnetic intermediate layer and the signal noise ratio SNR.

10 Fig. 4 is a curve relating the T/S spacing at the deposition of the magnetic layer and the coercive force.

Fig. 5 is a curve relating the T/S spacing at the deposition of the magnetic layer and the signal noise ratio SNR.

Fig. 6 is a curve relating the coercive force and the T/S spacing at the deposition of the nonmagnetic intermediate layer and the magnetic layer.

15 Fig. 7 is a curve relating the signal noise ratio SNR and the T/S spacing at the deposition of the nonmagnetic intermediate layer and the magnetic layer.

Modes for carrying out the Invention

20 Now the invention will be described in detail hereinafter with reference to the accompanied drawing figures which illustrate the preferred embodiments of the invention.

The granular magnetic film according to the invention, that facilitates obtaining a high coercive force and reducing the noises and the manufacturing costs, is manufactured by adjusting the spacing between the target and the substrate in the sputtering apparatus (hereinafter referred to as the "T/S spacing"). When the T/S spacing is set at 40 mm or longer in forming the nonmagnetic intermediate layer or the magnetic layer, the growth rate of the nonmagnetic intermediate layer or the magnetic layer is

low enough to obtain the nonmagnetic intermediate layer grown uniformly or the magnetic layer grown uniformly. Thus, the initial growth of the granular magnetic film is improved and the amount of Pt staying in the ferromagnetic grains is increased, Therefore, a high coercive force is
5 obtained easily.

Fig. 1 is a cross sectional view of a magnetic recording medium according to the invention.

Referring now to Fig. 1, the magnetic recording medium according to
10 the invention includes a nonmagnetic substrate 1, a nonmagnetic undercoating layer 2 on the nonmagnetic substrate 1, a nonmagnetic intermediate layer 3 on the nonmagnetic undercoating layer 2, a magnetic layer 4 on the nonmagnetic intermediate layer 3, a protection layer 5 on the magnetic layer 4, and a liquid lubricant layer 6 on the protection layer 5.

15 An Al alloy substrate provided with NiP plating, a chemically strengthened glass substrate, a crystallized glass substrate, and such a substrate used for the conventional magnetic recording media are used for the nonmagnetic substrate 1. Since the substrate is not heated according to the invention, substrates formed by injection molding a polycarbonate resin,
20 the polyolefin resin and such a resin are also employable for the nonmagnetic substrate 1.

Preferably, the nonmagnetic undercoating layer 2 is made of W, Mo, or V. Or, the nonmagnetic undercoating layer 2 is made preferably of a W alloy,
25 a Mo alloy, a Cr alloy or a V alloy, each containing from 10 to 50 at. % of Ti. Preferably, the nonmagnetic undercoating layer 2 is from 5 to 100 nm in thickness, although any limitation does not exist in the thickness of the nonmagnetic undercoating layer 2.

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Preferably, the nonmagnetic intermediate layer 3 is made of Ru, Ir, Rh, or Re. Or, the nonmagnetic intermediate layer 3 is made preferably of a Ru alloy, an Ir alloy, a Rh alloy or a Re alloy, each containing from 10 to 50 at. % of Ti, C, W, Mo or Cu. Preferably, the nonmagnetic intermediate layer 3 is from 2 to 50 nm in thickness, although any limitation does not exist in the thickness of the nonmagnetic intermediate layer 3.

The magnetic layer 4 is a granular magnetic layer formed of ferromagnetic crystal grains and nonmagnetic grain boundaries surrounding the ferromagnetic crystal grains. The nonmagnetic grain boundaries include a metal oxide or a metal nitride. The above described structure of the magnetic layer 4 is formed by the sputtering method using a ferromagnetic metal target containing an oxide for constituting the nonmagnetic grain boundaries or by the reactive sputtering method using a ferromagnetic metal target in an Ar sputtering gas containing oxygen.

CoPt alloys are preferable for the material of the ferromagnetic crystal, although the materials of the ferromagnetic crystal are not limited to the CoPt alloys. For reducing the noises caused from the recording media, it is especially preferable to add Cr, Ni or Ta to the CoPt alloys. For obtaining a stable granular structure, it is especially preferable to employ the oxide of Mg, Al, Si, Ti, Cr, Mn, Co, Zr, Ta, W, or Hf for the material of the nonmagnetic grain boundaries. It is necessary for the magnetic layer 4 to be thick enough to obtain sufficiently high reproduced signals outputted from the magnetic head.

A thin film containing carbon as its main component is used for the protection layer 5. Perfluoropolyether lubricants are used for the liquid lubricant layer 6.

Now the method of manufacturing a magnetic recording medium according to the invention will be described below.

It is preferable to set the T/S spacing for forming the nonmagnetic intermediate layer 3 and the magnetic layer 4 at any spacing between 70
5 mm and 100 mm.

The method of manufacturing a magnetic recording medium according to the invention facilitates obtaining the magnetic recording medium as shown in Fig. 1, that exhibits a high coercive force and suppresses the noises
10 caused therefrom at a low level, even when the step of heating the substrate included in the conventional manufacturing method is omitted. Therefore, the manufacturing method according to the invention facilitates reducing the manufacturing steps and the manufacturing costs.

15 First embodiment

A chemically strengthened glass substrate (N-10 supplied from Hoya Corp.) having a flat and smooth surface is used for the nonmagnetic substrate 1. The nonmagnetic substrate 1 is cleaned elaborately and loaded in a sputtering apparatus. A wolfram (W) nonmagnetic undercoating layer 2
20 of 30 nm in thickness is formed under the Ar gas pressure of 15 mTorr and at the T/S spacing of 40 mm. Then, a ruthenium (Ru) nonmagnetic intermediate layer 3 of 30 nm in thickness is formed under the Ar gas pressure of 15 mTorr and at the T/S spacing between 40 mm and 120 mm. Then, a magnetic layer 4 of 15 nm in thickness is formed by the RF
25 sputtering method using a CoCr10Pt14 target containing 7 mole % of SiO₂ under the Ar gas pressure of 30 mTorr and at the T/S spacing of 40 mm. Then, a carbon protection layer 5 of 10 nm in thickness is deposited. Finally, a liquid lubricant layer 6 of 1.5 nm in thickness is coated on the laminate formed so far and removed from the sputtering apparatus, resulting in a
30 magnetic recording medium having the structure as shown in Fig. 1. The

substrate is not heated in advance to depositing the constituent layers.

Fig. 2 is a curve relating the T/S spacing at the deposition of the nonmagnetic intermediate layer and the coercive force. The coercive force is measured with a vibrating sample magnetometer (hereinafter referred to as a "VSM"). As Fig. 2 indicates, an excellent coercive force H_c is obtained by setting the T/S spacing between 70 mm and 100 mm, and the maximum coercive force is obtained at the T/S spacing of around 85 mm. In the measurements, the product $Br\delta$ of the remnant magnetic flux density and the thickness of the samples is fixed at $50 \text{ G}\mu\text{m}$.

Fig. 3 is a curve relating the T/S spacing at the deposition of the nonmagnetic intermediate layer and the signal noise ratio SNR. The signal noise ratio SNR is measured in a spin stand tester using a giant magnetoresistance (GMR) head. The samples for the measurement are prepared such that the equivalent signal outputs are reproduced from the samples. As Fig. 3 indicates, an excellent signal noise ratio SNR is obtained by setting the T/S spacing between 70 mm and 100 mm, and the maximum signal noise ratio SNR is obtained at the T/S spacing of around 85 mm.

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Second embodiment

A chemically strengthened glass substrate (N-10 supplied from Hoya Corp.) having a flat and smooth surface is used for the nonmagnetic substrate 1. The nonmagnetic substrate 1 is cleaned elaborately and loaded in a sputtering apparatus. A wolfram (W) nonmagnetic undercoating layer 2 of 30 nm in thickness is formed under the Ar gas pressure of 15 mTorr and at the T/S spacing of 40 mm. Then, a ruthenium (Ru) nonmagnetic intermediate layer 3 of 30 nm in thickness is formed under the Ar gas pressure of 15 mTorr and at the T/S spacing of 40 mm. Then, a magnetic layer 4 of 15 nm in thickness is formed by the RF sputtering method using a

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CoCr10Pt14 target containing 7 mole % of SiO₂ under the Ar gas pressure of 30 mTorr and at the T/S spacing between 40 mm and 120 mm. Then, a carbon protection layer 5 of 10 nm in thickness is deposited. Finally, a liquid lubricant layer 6 of 1.5 nm in thickness is coated on the laminate formed so far and removed from the sputtering apparatus, resulting in a magnetic recording medium having the structure as shown in Fig. 1. The substrate is not heated in advance to depositing the constituent layers.

Fig. 4 is a curve relating the T/S spacing at the deposition of the magnetic layer and the coercive force. The coercive force is measured with a VSM. As Fig. 5 indicates, the coercive force H_c lowers with increasing T/S spacing. The coercive force H_c lowers sharply as the T/S spacing exceeds 100 mm toward the wider side. In the measurements, the product Brδ of the remnant magnetic flux density and the thickness of the samples is fixed at 50 G μ m.

Fig. 5 is a curve relating the T/S spacing at the deposition of the magnetic layer and the signal noise ratio SNR. The signal noise ratio SNR is measured in a spin stand tester using a GMR head. The samples for the measurement are prepared such that the equivalent signal outputs are reproduced from the samples. As Fig. 5 indicates, an excellent signal noise ratio SNR is obtained by setting the T/S spacing between 70 mm and 100 mm, and the maximum signal noise ratio SNR is obtained at the T/S spacing of around 85 mm.

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Third embodiment

A chemically strengthened glass substrate (N-10 supplied from Hoya Corp.) having a flat and smooth surface is used for the nonmagnetic substrate 1. The nonmagnetic substrate 1 is cleaned elaborately and loaded in a sputtering apparatus. A wolfram (W) nonmagnetic undercoating layer 2

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of 30 nm in thickness is formed under the Ar gas pressure of 15 mTorr and at the T/S spacing of 40 mm. Then, a ruthenium (Ru) nonmagnetic intermediate layer 3 of 30 nm in thickness is formed under the Ar gas pressure of 15 mTorr and at the T/S spacing between 40 mm and 120 mm.

5 Then, a magnetic layer 4 of 15 nm in thickness is formed by the RF sputtering method using a CoCr10Pt14 target containing 7 mole % of SiO₂ under the Ar gas pressure of 30 mTorr and at the T/S spacing between 40 mm and 120 mm. Then, a carbon protection layer 5 of 10 nm in thickness is deposited. Finally, a liquid lubricant layer 6 of 1.5 nm in thickness is coated

10 on the laminate formed so far and removed from the sputtering apparatus, resulting in a magnetic recording medium having the structure as shown in Fig. 1. The substrate is not heated in advance to depositing the constituent layers.

15 Fig. 6 is a curve relating the coercive force and the T/S spacing at the deposition of the nonmagnetic intermediate layer and the magnetic layer. The coercive force is measured with a VSM. Although the coercive force H_c according to the third embodiment is lower than the coercive force H_c according to the first embodiment shown in Fig. 2, the coercive force H_c

20 according to the third embodiment is excellent at the T/S spacing between 70 mm and 100 mm. The maximum coercive force is obtained at the T/S spacing of around 85 mm. In the measurements, the product Brδ of the remnant magnetic flux density and the thickness of the samples is fixed at 50 Gμm.

25 Fig. 7 is a curve relating the signal noise ratio SNR and the T/S spacing at the deposition of the nonmagnetic intermediate layer and the magnetic layer. The signal noise ratio SNR is measured in a spin stand tester using a GMR head. The samples for the measurement are prepared

30 such that the equivalent signal outputs are reproduced from the samples. As

Fig. 7 indicates, an excellent signal noise ratio SNR is obtained by setting the T/S spacing between 70 mm and 100 mm in the same manner as the signal noise ratios described in Figs. 3 and 5 in connection with the first and second embodiments, respectively. The maximum signal noise ratio SNR is obtained at the T/S spacing of around 85 mm. The signal noise ratio SNR is the most excellent according to the third embodiment.

According to the first embodiment of the invention, a magnetic recording medium, that exhibits a high coercive force H_c , is obtained. According to the third embodiment of the invention, a magnetic recording medium, that exhibits the most excellent signal noise ratio SNR, is obtained. Therefore, a magnetic recording medium, that exhibits the desired characteristics, is obtained by appropriately setting the T/S spacing for forming the nonmagnetic intermediate layer or the T/S spacing for forming the nonmagnetic intermediate layer and the nonmagnetic intermediate layer depending on the specifications of the magnetic recording medium.

Advantageous Effects of the Invention

As described above, a magnetic recording medium exhibiting a high coercive force H_c is obtained and the addition amount of precious Pt is reduced by optimizing the T/S spacing for forming the nonmagnetic intermediate later and the magnetic layer. The magnetic recording medium according to the invention facilitates suppressing the noises caused therefrom at a low level.

Since it is not necessary to heat the substrate in advance to depositing the constituent layers, the manufacturing steps and the manufacturing costs are reduced. Since it is not necessary to heat the substrate, inexpensive plastic substrates are used with no problem.

What is claimed is:

1. A magnetic recording medium comprising:
a nonmagnetic substrate;
a nonmagnetic undercoating layer on the nonmagnetic substrate, the
5 nonmagnetic undercoating layer having a hexagonal close packing structure
or a combination of a hexagonal close packing structure and a body center
cubic structure;
a nonmagnetic intermediate layer on the nonmagnetic undercoating
layer, the nonmagnetic intermediate layer having a hexagonal close packing
10 structure or a combination of a hexagonal close packing structure and a
body center cubic structure; and
a magnetic layer on the nonmagnetic intermediate layer, the magnetic
layer having a granular structure formed of ferromagnetic crystal grains
and oxide grain boundaries or nitride grain boundaries surrounding the
15 ferromagnetic crystal grains.
2. The magnetic recording medium according to Claim 1, wherein the
oxide grain boundaries comprise the oxide of an element selected from the
group consisting of (Mg, Al, Si, Ti, Cr, Mn, Co, Zr, Ta, W, and Hf).
3. The magnetic recording medium according to Claim 1, wherein the
20 nitride grain boundaries comprise the nitride of an element selected from
the group consisting of (Mg, Al, Si, Ti, Cr, Mn, Co, Zr, Ta, W, and Hf).
4. The magnetic recording medium according to Claim 1, wherein the
hexagonal close packing structure of the nonmagnetic intermediate layer
comprises a metal selected from the group consisting of (Ru, Ir, Rh, and Re).
- 25 5. The magnetic recording medium according to Claim 1, wherein the
combination of the hexagonal close packing structure and the body center
cubic structure of the nonmagnetic intermediate layer comprises the alloy of

a metal selected from the group consisting of (Ru, Ir, Rh, and Re), and the alloy comprises from 10 at.% to 50 at.% of an element selected from the group consisting of (Ti, C, W, Mo, and Cu).

6. The magnetic recording medium according to Claim 1, wherein the
5 hexagonal close packing structure of the nonmagnetic undercoating layer comprises a metal selected from the group consisting of (W, Mo, and V).

7. The magnetic recording medium according to Claim 1, wherein the combination of the hexagonal close packing structure and the body center cubic structure of the nonmagnetic undercoating layer comprises the alloy of
10 a metal selected from the group consisting of (W, Mo, Cr, and V), and the alloy comprises from 10 at.% to 50 at.% of Ti.

8. The magnetic recording medium according to Claim 1, wherein the nonmagnetic substrate comprises a material selected from the group consisting of (a crystallized glass, a chemically strengthened glass, and a
15 resin).

9. The method of manufacturing a magnetic recording medium, the magnetic recording medium including a nonmagnetic substrate; a nonmagnetic undercoating layer on the nonmagnetic substrate, the nonmagnetic undercoating layer having a hexagonal close packing structure
20 or a combination of a hexagonal close packing structure and a body center cubic structure; a nonmagnetic intermediate layer on the nonmagnetic undercoating layer, the nonmagnetic intermediate layer having a hexagonal close packing structure or a combination of a hexagonal close packing structure and a body center cubic structure; and a magnetic layer on the
25 nonmagnetic intermediate layer, the magnetic layer having a granular structure formed of ferromagnetic crystal grains and oxide grain boundaries or nitride grain boundaries surrounding the ferromagnetic crystal grains, the method comprising the steps of:

(a) forming the nonmagnetic intermediate layer by sputtering in a sputtering apparatus; and

(b) forming the magnetic layer by sputtering in the sputtering apparatus;

5 the step (a) comprising setting the spacing between the target in the sputtering apparatus and the substrate at a spacing between 70 mm and 100mm.

10. The method of manufacturing a magnetic recording medium, the
10 magnetic recording medium including a nonmagnetic substrate; a nonmagnetic undercoating layer on the nonmagnetic substrate, the nonmagnetic undercoating layer having a hexagonal close packing structure or a combination of a hexagonal close packing structure and a body center cubic structure; a nonmagnetic intermediate layer on the nonmagnetic
15 undercoating layer, the nonmagnetic intermediate layer having a hexagonal close packing structure or a combination of a hexagonal close packing structure and a body center cubic structure; and a magnetic layer on the nonmagnetic intermediate layer, the magnetic layer having a granular structure formed of ferromagnetic crystal grains and oxide grain boundaries
20 or nitride grain boundaries surrounding the ferromagnetic crystal grains, the method comprising the steps of:

(a) forming the nonmagnetic intermediate layer by sputtering in a sputtering apparatus; and

(b) forming the magnetic layer by sputtering in the sputtering
25 apparatus;

the step (b) comprising setting the spacing between the target in the sputtering apparatus and the substrate at a spacing between 70 mm and 100mm.

11. The method of manufacturing a magnetic recording medium, the magnetic recording medium including a nonmagnetic substrate; a nonmagnetic undercoating layer on the nonmagnetic substrate, the
5 nonmagnetic undercoating layer having a hexagonal close packing structure or a combination of a hexagonal close packing structure and a body center cubic structure; a nonmagnetic intermediate layer on the nonmagnetic undercoating layer, the nonmagnetic intermediate layer having a hexagonal close packing structure or a combination of a hexagonal close packing
10 structure and a body center cubic structure; and a magnetic layer on the nonmagnetic intermediate layer, the magnetic layer having a granular structure formed of ferromagnetic crystal grains and oxide grain boundaries or nitride grain boundaries surrounding the ferromagnetic crystal grains, the method comprising the steps of:

15 (a) forming the nonmagnetic intermediate layer by sputtering in a sputtering apparatus; and

(b) forming the magnetic layer by sputtering in the sputtering apparatus;

the steps (a) and (b) comprising setting the spacing between the
20 target in the sputtering apparatus and the substrate at a spacing between 70 mm and 100mm.

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