

MAGNETIC RECORDING MEDIUM AND MANUFACTURING METHOD THEREFOR

Technical field of the invention

The present invention relates to a magnetic recording medium mounted on magnetic recording devices, such as an external memory device of a computer, and a method for manufacturing such a recording medium.

Background of the invention

For a magnetic recording medium that requires high recording density and low noise, various compositions and structures of a magnetic layer and materials for a non-magnetic under-layer have been proposed. Recently, a magnetic layer called the granular magnetic layer has been proposed having a structure, in which a ferromagnetic grain is surrounded by non-magnetic and non-metallic substance, such as oxide or nitride.

The technology of the granular magnetic layer is known by the disclosures, for example, Japanese Unexamined Patent Application Publication No. H8-255342 and United States Patent No. 5,679,473.

The Japanese Unexamined Patent Application Publication No. H8-255342 discloses a method for manufacturing a magnetic recording medium comprising steps of sequentially depositing a non-magnetic film, a ferromagnetic film and a non-magnetic film, and heat-treating the lamination to form a recording layer in which ferromagnetic grains are dispersed in the non-magnetic film. The technology of this disclosure proposes to attain low noise by means of forming a granular recording layer in which ferromagnetic grains are dispersed in a non-magnetic film, the structure being formed by sequentially laminating a non-magnetic film, a ferromagnetic film and a non-magnetic film and heat-treating the lamination. Silicon oxide and nitride are

used for the non-magnetic film in this technology.

US Patent No. 5,679,473 discloses that a granular recording film in which each magnetic grain is surrounded by a non-magnetic oxide and separated each other can be formed by means of RF sputtering using a CoNiPt target added with an oxide, such as SiO_2 , and low noise is achieved by such a recording film.

Since each of the magnetic grains in this granular magnetic film is physically separated by a grain boundary of non-magnetic and non-metallic phase, magnetic interaction between the magnetic grains is reduced and formation of the magnetic domain wall with a zigzag shape at the transition region of a recording bit is suppressed, to attain low noise. In the conventionally used Co-Cr metallic magnetic film, chromium is segregated from a cobalt alloy magnetic grain towards a grain boundary, so as to reduce magnetic interaction between the magnetic grains. On the other hand, in the granular magnetic layer, the grain boundary phase is a non-magnetic and non-metallic substance, which segregate easier than the conventional chromium. Consequently, isolation of magnetic grains is easily enhanced. In the conventional Co-Cr metallic magnetic layer, heating the substrate up to 200°C is essential for the enough segregation of chromium when laminating the layer, while the granular magnetic layer has the advantage that the non-magnetic and non-metallic substance segregates even in lamination without heating.

High density and low noise of a magnetic recording medium requires not only reduction of magnetic interaction between the grains due to enhancement of the segregation structure in the magnetic layer, but also control of crystal orientation of Co-Cr ferromagnetic grain. Namely, the c-axis of the ferromagnetic grain having a hexagonal closest packed structure is required to align in the plane of the film surface. The control of the crystal orientation of the magnetic layer in the conventional magnetic recording

medium having a metallic magnetic layer is performed by controlling structure and crystal orientation of the non-magnetic under-layer.

For a magnetic recording medium having a granular magnetic film, it has been considered that the effect of the under-layer is little because the ferromagnetic grains are separated from the under-layer by the substance of grain boundary segregation, such as an oxide. Meanwhile, a paper entitled "Effect of Cr-Mo under-layer in CoPt-SiO₂" in "Nihon Oyojiki Gakkaishi" (Journal of the Japanese Society for Applied Magnetism) Vol. 23, No. 4-2, pp. 1017-1020 (1999) discloses that using an under-layer of a Cr-Mo alloy of a special composition that has a preferential orientation of (110) plane causes preferential orientation of (100) plane and (101) plane of the ferromagnetic grains in a granular magnetic layer, which results in improvement of magnetic property and electromagnetic conversion characteristics.

Problem to be solved by the invention

However, when a ferromagnetic grain has a preferential orientation of (101) plane, c-axis does not align in parallel to the film surface and rises up from the film surface with a certain angle. Accordingly, the magnetic anisotropy of the crystal grain contains a component perpendicular to the film surface, which creates a perpendicular component of magnetization, resulting in increased media noise. This preferential orientation of (101) plane in the ferromagnetic grain is caused by the preferential orientation of (110) plane in the Cr-Mo alloy under-layer. Therefore, the orientation control of a magnetic layer disclosed in the reference is to be regarded as insufficient. Thus, it is the state of the art that more precise control of crystal orientation is needed for obtaining a low noise medium.

Means to solve the problem

The inventors of the present invention has made profound studies on

control of crystal orientation of the granular magnetic film, and found the following fact. Namely, excellent magnetic properties and electromagnetic conversion characteristics are achieved when a granular magnetic film composed of ferromagnetic grains having a hexagonal closest packed structure, such as Co-Pt alloy, is formed using a non-magnetic under-layer made of a material that has a body-centered cubic crystal structure and has a preferential orientation of (200) plane parallel to the film surface.

The present invention has been accomplished based on this finding and a magnetic recording medium according to the invention comprises a non-magnetic substrate; and a non-magnetic under-layer, a magnetic layer, a protective film, and a liquid lubricant layer sequentially laminated on the substrate. The magnetic layer has granular structure that comprises ferromagnetic grains having hexagonal closest packed structure and non-magnetic grain boundaries surrounding the grains and mainly composed of oxide. The non-magnetic under-layer has a crystal structure of a body-centered cubic lattice and a preferential crystal orientation plane of the under-layer parallel to a film surface of the under-layer is (200) plane.

By employing such an under-layer of the present invention, the c-axis of the ferromagnetic grain in the granular magnetic layer laminated on the under-layer aligns parallel to the film surface and a perpendicular component of magnetization does not develop, which achieves favorable characteristics of the recording medium of the invention.

When a non-magnetic intermediate layer having a hexagonal closest packed structure that is the same crystal structure as that of the ferromagnetic grain of the granular magnetic layer is formed between the under-layer and the magnetic layer, c-axis alignment of the ferromagnetic grain of the magnetic layer is enhanced, to bring about better effect. The intermediate layer is made of, for example, Co-Cr alloy containing 30 at% to 50 at% of Cr.

For effectively controlling crystal orientation of the under-layer, a non-magnetic alignment-control layer may be formed prior to depositing the under-layer, the alignment-control layer having crystal lattice of body-centered cubic structure and a preferential crystal orientation plane parallel to its film surface of (100) plane. The alignment-control layer is preferably made of an oxide or oxides of at least one element selected from Mg, Ti, and V, or a carbide(s) or a nitride(s) of at least one element selected from Ti, Zr, Hf, Nb, Ta, Mo and W. All of these materials have the body-centered cubic lattice structure, and the preferential crystal orientation of (100) plane is readily obtained by deposition by sputtering method.

Further, for effectively controlling crystal orientation and crystallinity of the alignment-control layer, it is also effective to form a seed layer having amorphous structure between the substrate and the alignment-control layer. Although this seed layer is desired to be wholly in amorphous structure, partial crystallization that is inevitably generated by deposition by sputtering method does not influence the effect directed by the seed layer. The seed layer is preferably made with a nickel layer containing 10 at% to 40 at% of phosphorus or a silicon layer containing 25 at% to 55 at% of oxygen.

Because excellent magnetic characteristics and electromagnetic conversion characteristics can easily be achieved by employing the layer structure of the invention, heating of the substrate is not required in laminating the layers of a medium of the invention. Consequently, not only the manufacturing process is simplified and the production cost is reduced, but also it becomes possible to employ a substrate of low-cost plastics as well as conventional aluminum substrate and glass substrate.

Brief description of the drawings

Fig. 1 is a schematic cross-sectional view showing a basic structure of a magnetic recording medium according to the present invention.

Fig. 2 is a schematic cross-sectional view showing a basic structure of a magnetic recording medium produced in Example 1.

Fig. 3 is a graph showing variation of intensity ratio $I_{(200)}/I_{(110)}$ with respect to applied RF bias power, the intensity ratio being the ratio of diffraction peak intensity $I_{(200)}$ from Cr-Mo (200) plane to diffraction peak intensity $I_{(110)}$ from Cr-Mo (110) plane that are obtained from the X-ray diffraction profiles of the media produced in Example 1.

Fig. 4 is a graph showing coercive force H_c and signal-to-noise ratio SNR at linear recording density of 270 kFCI of the media produced in Example 1 with respect to applied RF bias power.

Fig. 5 is a schematic cross-sectional view showing a basic structure of a magnetic recording medium produced in Example 2.

Fig. 6 is a schematic cross-sectional view showing a basic structure of a magnetic recording medium produced in Example 3.

Fig. 7 is a schematic cross-sectional view showing a basic structure of a magnetic recording medium produced in Example 4.

Aspects of some preferred embodiments of the invention

Now, aspects of some preferred embodiments of the invention will be described.

Fig. 1 is a schematic cross-sectional view of a magnetic recording medium of the invention. This recording medium comprises a non-magnetic substrate 1, and an under-layer 2, a granular magnetic layer 3 and a protective film 4 sequentially formed on the substrate 1. On the top of the layers, further formed is a liquid lubricant layer 5.

As a non-magnetic substrate 1, Ni-P plated aluminum alloy, strengthened glass or crystallized glass that are employed in a usual magnetic recording medium may be used. Moreover, a substrate produced by injection-molding a resin such as polycarbonate or polyolefin may also be used because heating of the substrate is not required.

A thin film consisting mainly of carbon, for example, is used for the protective film 4. Perfluoropolyether lubricant, for example, may be used for the liquid lubricant layer 5.

The magnetic layer 3 is a so-called granular magnetic layer that comprises ferromagnetic grains and non-magnetic grain boundaries surrounding the grains and being composed of metal oxide or metal nitride. Such a structure may be produced by deposition by sputtering using a target of ferromagnetic metal containing the oxide that composes the non-magnetic grain boundary, or by deposition by reactive sputtering in oxygen-containing argon gas atmosphere using a target of ferromagnetic metal.

The material composing the ferromagnetic crystal may be preferably a Co-Pt alloy, for example. A Co-Pt alloy added with Cr, Ni or Ta, in particular, is preferable for reducing media noise.

On the other hand, the material composing the non-magnetic grain boundary may be selected from oxides of Cr, Co, Si, Al, Ti, Ta, Hf or Zr, which are favorable for forming a stable granular structure. The thickness of the ferromagnetic layer 3 is required to be necessary and sufficient for obtaining sufficient head-reproduction output at recording and reproduction.

The under-layer 2 is made of a material having a body centered cubic structure and is required to have a preferential crystal orientation of (200) plane. Chromium or chromium alloy may be preferably used for such a material. The chromium alloy is preferably selected from Cr-Mo, Cr-Ti, Cr-V

and Cr-W, for example. Thickness of the layer is preferably in the range between 5 nm and 100 nm. For obtaining a preferential crystal orientation of (200) plane, the means may preferably be employed that include use of a non-magnetic alignment-control layer 21 described later, application of substrate bias voltage or grid bias voltage, and control of other conditions in depositing the under-layer.

To more suitably control c-axis alignment of the ferromagnetic grain of the granular magnetic layer 3 in the invention, a non-magnetic intermediate layer 22 may be provided between the under-layer 2 and the magnetic layer 3. The crystal structure of the non-magnetic intermediate layer 22 is preferably a hexagonal closest packed structure that is the same as the crystal structure of the ferromagnetic grain of the magnetic layer. A Co-Cr alloy containing chromium in the range from about 30 at% to 50 at%, for example, may be used for the intermediate layer. Thickness of the non-magnetic intermediate layer 22 is preferably in the range from 2 nm to 20 nm.

To effectively control the crystal orientation of the under-layer 2, a non-magnetic alignment-control layer 21 may be formed prior to forming the under-layer 2. The alignment-control layer 21 has a simple cubic structure and the preferentially oriented crystal plane that is in parallel to the film surface is (100) plane, and is preferably made of an oxide(s) of at least an element selected from Mg, Ti and V, or a carbide(s) or a nitride(s) of at least an element selected from Ti, Zr, Hf, Nb, Ta, Mo and W. All of these materials have a simple cubic structure and may be deposited by sputtering method to easily obtain the preferential crystal orientation of (100) plane. The film thickness of the alignment-control layer 21 is required to be the thickness such that the crystal alignment in the non-magnetic under-layer is sufficiently controlled.

To effectively control crystal orientation and crystallinity of the alignment-control layer 21, a seed layer 11 having amorphous structure may

be provided between the substrate 1 and the alignment-control layer 21. Although the seed layer 11 is desirable to be entirely amorphous, the effect aimed by the seed layer is not affected even if partial crystallization is inevitably generated by deposition by sputtering. The crystal orientation and crystallinity of the alignment-control layer 21 are improved by a seed layer 11 that is formed with a nickel layer containing phosphorus in an amount of from 10 at% to 40 at% or with a silicon layer containing oxygen in an amount of from 25 at% to 55 at %. Thickness of the seed layer 11 may take any value as long as crystal orientation and crystallinity of the alignment-control layer are effectively controlled.

In a process of manufacturing a magnetic recording medium shown in Fig. 1 having the layer structure described above, high H_c and low media noise can be attained even if a step of heating the substrate as in a conventional process of manufacturing a recording medium is omitted. As a result, reduction of a manufacturing cost is attained by simplification of the manufacturing process.

Examples

The following gives some examples of the preferred embodiments of the present invention.

Example 1

A chemically strengthened glass substrate with smooth surface, N-10 glass substrate manufactured by Hoya Corp., was used for a substrate. After cleaning, the substrate was introduced into a sputtering apparatus. A non-magnetic under-layer having thickness of 30 nm was formed of Cr-20 at% Mo on the substrate under an argon gas pressure of 5 mTorr. Subsequently, a granular magnetic layer having thickness of 20 nm was formed on the under-layer by an RF sputtering method using a target of $\text{Co}_{76}\text{Cr}_{12}\text{Pt}_{12}$ containing 10

mol % of SiO_2 under an argon gas pressure of 3 mTorr. Then, a carbon protective layer 10 nm thick was laminated on the magnetic layer. The laminate was then taken out from a vacuum vessel and liquid lubricant was applied to 1.5 nm thickness on the protective layer. Thus, a magnetic recording medium having the structure shown in Fig. 2 was produced. In the step of depositing the under-layer, RF bias was applied to the substrate varying from 0 W to 200 W. Heating of the substrate prior to the lamination step was not carried out.

X-ray diffraction analysis was made on each of the thus produced recording media. From the measured profile, an intensity ratio $I_{(200)}/I_{(110)}$ was obtained that is the ratio of diffraction peak intensity $I_{(200)}$ from Cr-Mo (200) plane to diffraction peak intensity $I_{(110)}$ from Cr-Mo (110) plane. Fig. 2 shows variation of the intensity ratio $I_{(200)}/I_{(110)}$ in the dependence on the applied RF bias power. The X-ray diffraction profile was measured with $\text{Cu-K}\alpha$ line using a goniometer. It is apparent from Fig. 3 that the intensity ratio $I_{(200)}/I_{(110)}$ sharply increases with increase of the bias power. Application of the bias power of 100 W or more raises the intensity ratio $I_{(200)}/I_{(110)}$ to the value of greater than 0.2. Because the intensity ratio $I_{(200)}/I_{(110)}$ for the random crystal orientation is 0.16, the intensity ratio $I_{(200)}/I_{(110)}$ greater than 0.16 may be interpreted to indicate that the (200) plane is preferentially oriented.

Coercive force H_c was measured for the produced media using a vibrating sample magnetometer VSM. Signal-to-noise ratio SNR at the linear recording density of 270 kFCI was measured by a spinning stand tester using a GMR head. Variation of the measured coercive force H_c and the signal-to-noise ratio SNR with respect to the applied RF bias power is shown in Fig. 4. High coercive force H_c and high signal-to-noise ratio SNR are simultaneously obtained when RF bias of 100 W or more is applied. That is, by employing an under-layer with preferential orientation of (200) plane, excellent magnetic characteristic and electromagnetic conversion characteristic are accomplished.

Example 2

A magnetic recording medium as shown in Fig. 5 was produced in the same manner as in Example 1 except that a non-magnetic intermediate layer of Co-35 at% Cr having thickness of 5 nm was formed on the under-layer under the argon gas pressure of 5 mTorr after laminating the under-layer. RF bias of 150 W was applied when the under-layer was formed.

As in the Example 1, coercive force H_c was measured for the produced medium using a vibrating sample magnetometer VSM, and signal-to-noise ratio SNR at the linear recording density of 270 kFCI was measured by a spinning stand tester using a GMR head. The results are shown in Table 1. Table 1 also gives, for comparison, the characteristics of a medium without a intermediate layer, a medium of Comparative Example 1, that is one of the media in Example 1 to which RF bias of 150 W was applied.

When the intermediate layer is not provided, the coercive force H_c was about 2,620 Oe and the signal-to-noise ratio SNR was 18.3 dB. On the other hand, when a non-magnetic intermediate layer of Co-35 at% Cr having the hexagonal closest packed crystal structure with 5 nm thickness was formed, the coercive force H_c was improved and the signal-to-noise ratio SNR was also improved to 19.5 dB.

Table 1

	intermediate layer	H_c (Oe)	SNR (dB)
Example 2	provided	3,010	19.5
Comp Example 1	not provided	2,620	18.3

Example 3

Magnetic recording media as shown in Fig. 6 were produced in the same manner as in Example 1 except that a non-magnetic alignment-control layer having thickness of 30 nm was formed by RF sputtering method using various material under argon gas pressure of 8 mTorr before laminating the under-layer, and the RF bias was not applied when the under-layer was laminated.

As in Example 1 and Example 2, coercive force H_c was measured for each of the produced media using a vibrating sample magnetometer VSM, and signal-to-noise ratio SNR at the linear recording density of 270 kFCI was measured by a spinning stand tester using a GMR head. The results are shown in Table 2. Table 2 also shows intensity ratio $I_{(200)}/I_{(110)}$ of the X-ray diffraction peaks of the under-layer of each medium. Table 2 further gives, for comparison, the characteristics of a medium without an alignment-control layer, a medium of Comparative Example 2, that is one of the media in Example 1 to which RF bias was not applied.

Each of the media (i) to (iii) is provided with a non-magnetic alignment-control layer according to the present invention. The alignment-control layer has a simple cubic lattice structure, and the preferential crystal orientation plane that is parallel to the film surface of the layer is (100) plane. The media (i) to (iii), though RF bias was not applied when the under-layer was formed, exhibits intensity ratio $I_{(200)}/I_{(110)}$ in the under-layer of as high as 1.0 or more, which indicates strong preferential orientation of (200) plane. As a result, excellent magnetic characteristic and electromagnetic conversion characteristic have been attained.

Table 2

		alignment-control layer	$I_{(200)}/I_{(110)}$	Hc (Oe)	SNR (dB)
Example 3	medium i	TiC	3.1	2,530	18.4
	medium ii	TiN	1.2	2,610	18.1
	medium iii	MgO	6.5	2,750	19.8
Comp Example 2		none	0	2,200	15.2

Example 4

Magnetic recording media as shown in Fig. 7 were produced in the same manner as in Example 1 except that a seed layer having thickness of 30 nm was formed by RF sputtering method using various material under the argon gas pressure of 5 mTorr and subsequently a non-magnetic alignment-control layer of MgO having thickness of 30 nm was formed by RF sputtering method prior to laminating the under-layer, and the RF bias was not applied when the under-layer was laminated.

As in the Examples 1, 2 and 3, coercive force Hc was measured for each of the produced media using a vibrating sample magnetometer VSM, and signal-to-noise ratio SNR at the linear recording density of 270 kFCl was measured by a spinning stand tester using a GMR head. The results are shown in Table 3. Table 3 also shows intensity ratio $I_{(200)}/I_{(110)}$ of the X-ray diffraction peaks of the under-layer of each medium. Table 3 further gives, for comparison, the characteristics of a medium without a seed layer, a medium of Comparative Example 3, that is the medium iii of the media of Example 3 provided with an alignment-control layer made of MgO.

Table 3

		seed layer	$I_{(200)}/I_{(110)}$	Hc (Oe)	SNR (dB)
Example 4	medium i	Ni-25at%P	32.8	3,240	22.7
	medium ii	Si-45at%O	17.9	2,960	21.1
Comp Example 3		none	6.5	2,750	19.8

As apparent from Table 3, the under-layer of the medium, when provided with a seed layer, exhibited still higher intensity ratio $I_{(200)}/I_{(110)}$ and the crystal orientation and the crystallinity of the alignment-control layer is more effectively upgraded. The upgraded alignment-control layer brought strong preferential orientation of (200) plane. As a result, more favorable magnetic characteristic and electromagnetic conversion characteristic have been achieved.

Advantageous Effect of the invention

As described so far, excellent magnetic characteristic and electromagnetic conversion characteristic have been achieved according to the present invention, in which a granular magnetic film is formed of ferromagnetic grains having hexagonal closest packed structure such as Co-Pt alloy, and a non-magnetic under-layer is provided using a material in which the lattice structure is body centered cubic and the preferential crystal orientation plane parallel to the film surface is (200) plane. In the ferromagnetic grains of the granular magnetic layer laminated on an under-layer of the present invention, the c-axis of the grain aligns parallel to the film surface and a perpendicular component of magnetization does not develop, which causes favorable characteristics.

When a non-magnetic intermediate layer having a hexagonal closest packed structure that is the same crystal structure as that of the

ferromagnetic grain of the granular magnetic layer is formed between the under-layer and the magnetic layer, c-axis alignment of the ferromagnetic grain of the magnetic layer is enhanced, to bring about better effect.

For controlling crystal orientation of the under-layer, it is effective to form a non-magnetic alignment-control layer prior to depositing the under-layer, the alignment-control layer having crystal lattice of simple cubic structure and a preferential crystal orientation plane parallel to its film surface of (100) plane. The alignment-control layer is preferably made of an oxide of at least one element selected from Mg, Ti, and V, or a carbide or a nitride of at least one element selected from Ti, Zr, Hf, Nb, Ta, Mo and W. All of these materials have the simple cubic lattice structure, and the preferential crystal orientation of (100) plane is readily obtained by deposition by sputtering method, facilitating preferential orientation of (200) plane in the under-layer that is formed on the alignment-control layer. Thus, a magnetic recording medium with excellent characteristics is achieved.

Further, for effectively control crystal orientation and crystallinity of the alignment-control layer, it is also effective to form a seed layer having amorphous structure between the substrate and the alignment-control layer. Although this seed layer is desired to be wholly in amorphous structure, partial crystallization that is inevitably generated by deposition by sputtering method does not influence the effect directed by the seed layer. The seed layer is preferably made with a nickel layer containing 10 at% to 40 at% of phosphorus or a silicon layer containing 25 at% to 55 at% of oxygen. The existence of the seed layer makes alignment and crystallinity of the alignment-control layer to be more suitably controlled, thus, providing a magnetic recording medium with excellent characteristics.

Because excellent characteristics can be easily achieved by employing the layer structure of the invention, heating of the substrate is not needed in depositing the layers of the medium. Consequently, inexpensive plastics may

be used for a substrate as well as conventionally used aluminum and glass substrates.

Claims

- 1 A magnetic recording medium comprising:
 - a non-magnetic substrate, and
 - a non-magnetic under-layer, a magnetic layer, a protective film, and a liquid lubricant layer sequentially laminated on said substrate, wherein
 - said magnetic layer has granular structure that comprises ferromagnetic grains having hexagonal closest packed structure and non-magnetic grain boundaries surrounding the grains and mainly composed of oxide,
 - said under-layer has a crystal structure of a body-centered cubic lattice and a preferential crystal orientation plane of said under-layer parallel to a film surface of said under-layer is (200) plane, and
 - non-magnetic alignment-control layer having simple cubic lattice structure beneath said under-layer, wherein a preferential crystal orientation plane of said alignment-control layer parallel to a film surface of said alignment-control layer is (100) plane.
2. A magnetic recording medium according to claim 1, further comprising a non-magnetic intermediate layer that has a hexagonal closest packed structure and is formed between said under-layer and said magnetic layer.
3. A magnetic recording medium according to claim 1, wherein
 - said alignment-control layer is composed of at least one material selected from a group consisting of oxides of Mg, Ti, and V, and carbides and nitrides of Ti, Zr, Hf, Nb, Ta, Mo and W.
4. A magnetic recording medium according to claim 1, further comprising a seed layer having amorphous structure and being formed between said alignment-control layer and said substrate.

- 5 A magnetic recording medium according to claim 4, wherein
said seed layer is composed of a nickel layer containing from 10 at% to 40 at% of phosphorus.
6. A magnetic recording medium according to claim 4, wherein
said seed layer is composed of a silicon layer containing from 25 at% to 55 at% of oxygen.
7. A magnetic recording medium according to claim 1, wherein
said non-magnetic substrate is composed of a material selected from a group consisting of crystallized glass, chemically strengthened glass and resin.
8. A method for manufacturing a magnetic recording medium comprising the steps of
selecting a non-magnetic substrate;
laminating a non-magnetic under-layer on said non-magnetic substrate, said non-magnetic under-layer being a material having a body-centred cubic lattice structure and preferential crystal orientation plane in a (200) plane parallel to a film surface of said non-magnetic under-layer;
laminating a magnetic layer on said non-magnetic under-layer, said magnetic layer including a plurality of ferromagnetic grains having a hexagonal close-packed structure and a non-magnetic grain boundary phase surrounding said plurality, said non-magnetic grain boundary phase being at least one of a group consisting of a metal oxide and a metal nitride;
laminating a protective film on said magnetic layer;
laminating a liquid lubricant layer on said protective layer;
conducting said steps of laminating without a step of heating; and

forming a non-magnetic alignment-control layer prior to forming said non-magnetic under-layer,

a preferential crystal orientation plane of said non-magnetic alignment-control layer parallel to a film surface of said non-magnetic alignment-control layer being (100) plane.

9. A method for manufacturing a magnetic recording medium according to Claim 8, further comprising a step for forming a non-magnetic intermediate layer that has a hexagonal closest packed structure and is disposed between said non-magnetic under-layer and said magnetic layer.
10. A method for manufacturing a magnetic recording medium according to claim 8, wherein said alignment-control layer is composed of at least one material selected from a group consisting of oxides of Mg, Ti, and V, and carbides and nitrides of Ti, Zr, Hf, Nb, Ta, Mo and W.
11. A method for manufacturing a magnetic recording medium according to claim 8, further comprising a step for forming a seed layer having amorphous structure and being formed between said non-magnetic alignment-control layer and said substrate.
12. A method for manufacturing a magnetic recording medium according to claim 11, wherein said seed layer is composed of a nickel layer containing from 10 at% to 40 at% of phosphorus.
13. A method for manufacturing a magnetic recording medium according to claim 11, wherein said seed layer is composed of a silicon layer containing from 25 at% to 55 at% of oxygen.

14. A method for manufacturing a magnetic recording medium according to claim 8, wherein said non-magnetic substrate is composed of a material selected from a group consisting of crystallized glass, chemically strengthened glass and resin.

15. A method for manufacturing a magnetic recording medium according to claim 8, wherein a step for heating said substrate does not precede any one of said steps for lamination.