

Magnetic Recording Medium and Manufacture Method Therefor

Field of the Invention

The present invention relates to a magnetic recording medium that is mounted in various magnetic recording apparatuses including external recording devices for computers, and to a manufacturing method thereof.

Prior Art

For magnetic recording media that are desired to have increased recording density and reduced noise, various compositions and structures of a magnetic layer, materials for a nonmagnetic base layer, and the like have been proposed. In particular, in recent years, a magnetic layer commonly referred to as a "granular magnetic layer" has been proposed in which a nonmagnetic nonmetallic substance such as an oxide or nitride surrounds the periphery of ferromagnetic crystal grains.

For example, Japanese Patent Application Laid Open Publication No. 8-255342 proposes that noise be reduced by sequentially stacking a nonmagnetic film, a ferromagnetic film, and a nonmagnetic film, and then heating the stack to form a granular recording layer in which ferromagnetic crystal grains are dispersed in the nonmagnetic film. In this case, the nonmagnetic film is composed of a silicon oxide, a silicon nitride, or the like. Further, U.S. Patent No. 5,679,473 describes a method of using a CoNiPt target doped with an oxide such as SiO_2 to carry out RF sputtering in order to form a granular recording film in which magnetic crystal grains are separated from one another and surrounded by a nonmagnetic oxide, thereby achieving reduced noise.

The reason such a granular magnetic film features reduced noise properties has been assumed to be that a nonmagnetic, nonmetallic grain-boundary phase physically separates the magnetic grains from one another to weaken the magnetic interaction among

the magnetic grains, thereby hindering zigzag magnetic domain walls from being formed in recording-bit transition regions. A conventional CoCr-based metallic magnetic film is formed at high temperatures, so that Cr is segregated from Co-based magnetic grains and deposited at a grain boundary to weaken the magnetic interaction among the magnetic grains. However, in a granular magnetic layer, the grain-boundary phase is a nonmagnetic, nonmetallic substance that is more likely to be deposited than Cr in the prior art, thereby advantageously allowing the magnetic grains to be relatively easily isolated. In particular, for conventional CoCr-based metallic magnetic layers, it is essential to increase the temperature of the substrate to 200°C or higher during film formation in order to sufficiently deposit Cr. In contrast, there is the advantage that in the granular magnetic layer, even if film is formed without heating, the nonmagnetic, nonmetallic substance produces segregation.

Further, to increase the recording density and reduce the noise of a magnetic recording medium, the inter-grain magnetic interaction should be weakened by facilitating segregation in the magnetic layer, and the crystal orientation of CoCr-based ferromagnetic crystal grains should be control; namely, the c-axis of the hexagonal close-packed ferromagnetic crystal grains should be oriented in the film surface. For this purpose, in the case of the prior-art metallic magnetic layers, the crystal orientation of the magnetic layer is realized by controlling the structure and crystal orientation of the nonmagnetic base layer.

On the other hand, the effect of the nonmagnetic base layer has been considered small in magnetic recording media having a granular magnetic film, because the nonmagnetic base layer is separated from the ferromagnetic crystal grains by boundary segregation materials such as oxide. Meanwhile, Journal of Magnetic Society of Japan, Vol. 23, No. 4-2, p. 1021 (1999) discloses that if a specific-composition CrMo alloy in which the (110) plane is preferably oriented is used in the base layer, then the (100) and (101) planes of the ferromagnetic crystal grains in the granular magnetic layer are preferably oriented and

the magnetic properties and electromagnetic conversion properties are improved.

Problems to be Solved by the Invention

However, if the (101) plane of the ferromagnetic crystal grains is preferably oriented, the c-axis is not parallel with the film surface but stands on the surface at a certain angle. Then, the magnetic anisotropy of the crystal grains has an element normal to the film surface, and the resulting vertical element of magnetism increases the media noise. Such a preferred orientation of the (101) plane of ferromagnetic crystal grains is caused by the preferred orientation of the (110) plane of the CrMo-alloy base layer. We must conclude that the control of the crystal orientation of the magnetic layer disclosed in the paper is not sufficient. Thus, there is a need to precisely control the crystal orientation further to realize a medium of low noise.

We have disclosed in Japanese Laid Open Patent Application No. 2000-376597 that the orientation of the base layer and magnetic layer can be controlled by forming an amorphous seed layer and an orientation control layer on the nonmagnetic substrate.

For further improvement of the magnetic properties and reduction of noise, the magnetic layer is required to have stronger in-plane orientation and to achieve high-quality epitaxial growth. To accomplish this goal, it is necessary to optimize the materials for the nonmagnetic base layer and the nonmagnetic intermediate layer (to minimize misfit and ease downsizing of the particle size).

It is thus an object of the present invention to provide a magnetic recording medium and its manufacturing method that can solve the above problems and realize excellent magnetic properties and electromagnetic conversion properties.

Means for Solving the Problems

As a result of an intensive study described in Japanese Laid Open Patent Application No. 2000-376597 focusing on the property improvement provided by the in-plane orientation in the magnetic layer, we have obtained the following insights.

Namely, in Japanese Laid Open Patent Application No. 2000-376597, the c-axes of ferromagnetic crystal grains in the granular magnetic layer are oriented in parallel with the film surface by virtue of the seed and orientation control layers. Further, we conducted another intensive study on materials that will ensure less misfit in the nonmagnetic base layer and nonmagnetic intermediate layer to provide strong in-plane orientation and high-quality epitaxial growth. As a result, we have found that, when forming a granular magnetic film comprising a CoPt-based-alloy ferromagnetic crystal grains with a hexagonal close-packed structure, the nonmagnetic base layer should use a material having a body-centered cubic (bcc) structure such as W, Mo, or V, and its (200) plane shows a preferred crystal-orientation parallel with the film surface. In addition, we have found that the nonmagnetic intermediate layer should use a material having a hexagonal close-packed (hcp) structure, and its (110) plane shows a preferred orientation parallel with the film surface so as to provide excellent magnetic properties and electromagnetic conversion properties.

This invention has been developed with reference to the above insights, and the magnetic recording medium according to the invention comprises at least a nonmagnetic base layer, a nonmagnetic intermediate layer, a magnetic layer, a protective film, and a liquid lubricant layer sequentially stacked on a nonmagnetic substrate, wherein said magnetic layer has a granular structure comprising hexagonal close-packed ferromagnetic crystal grains and oxide-based nonmagnetic grain boundaries surrounding said ferromagnetic crystal grains, said nonmagnetic base layer has a body-centered cubic structure, in principle, and its (200) plane shows preferred crystal-orientation parallel with the film surface,

and said nonmagnetic intermediate layer has a hexagonal close-packed structure and its (110) plane shows preferred crystal-orientation parallel with the film surface.

The reason a Ti alloy with a structure that is not bcc but hcp is used as the material for the nonmagnetic base layer is that Ti (amorphous-like) does not provide the orientation unique to the hcp structure, easily provides the desired bcc (200) orientation, and is suitable for controlling the lattice constant.

It has been found that excellent magnetic properties and electromagnetic conversion properties can be achieved by employing Ru, Ir, Rh, Re, or an Ru, Ir, Rh, Re alloy including 10-60 at% Ti, C, W, Mo, or Cu in the nonmagnetic intermediate layer. Namely, in Japanese Laid Open Patent Application No. 2000-376597 using Cr or a Cr alloy in the nonmagnetic base layer, the misfit between the base layer and the magnetic layer is 7% or more. Further, if Ru and Re, which show better magnetic properties and electromagnetic conversion properties than CoCr alloys containing approximately 30-50% Cr, are used in the intermediate layer, the amount of misfit increases and the desired orientation is not achieved. As a result, various properties are degraded.

If the base layer and the intermediate layer of the present invention are employed, all of the misfit between the nonmagnetic base layer, nonmagnetic intermediate layer, and granular magnetic layer becomes 3% or less, the c-axis of the magnetic layer is strongly oriented in parallel with the walls, and high-quality epitaxial growth is obtained. As a result, excellent properties are attained.

If an alloy containing Ti is employed in the base layer, better properties are provided. For example, if pure W is used, the a-axis length of the bcc (200) plane is 4.48 (Å). Meanwhile, in the Ti-50at%W alloy, its a-axis becomes longer, to 4.60 (Å), because Ti-hcp forms a solid solution in W-bcc without presenting orientation unique to the hcp structure (orientation is

seen only for W-bcc (200)). As a result, the misfit with the nonmagnetic intermediate layer becomes smaller, and high-quality epitaxial growth is obtained.

Further, if the layered structure of the present invention is employed, it is easy to attain excellent magnetic properties and electromagnetic conversion properties. There is no need to heat the substrate during the film deposition of the medium of the invention. As a result, the manufacturing process is simplified and manufacturing costs are reduced. At the same time, it becomes possible to use inexpensive plastic materials as substrates other than the conventional Al and glass substrates.

Brief Description of the Drawings

FIG. 1 is a schematic sectional view illustrating the structure of the magnetic recording medium of the present invention.

FIG. 2 is a table listing the values of intensity ratio $I_{(110)}/I_{(101)}$ between the diffraction peak $I_{(101)}$ of the Co-hcp (101) plane and the diffraction peak $I_{(110)}$ of the Co-hcp (110) plane of the magnetic layer, obtained from the layered media structure and X-ray diffraction profiles.

FIG. 3 is a table listing the coercivity H_c , residual magnetic flux density $\times$ film thickness $Br \delta$, restored output of electromagnetic conversion properties TAA at a linear density of 180 kFCI, media noise, and SNR value.

Embodiment

Next, the preferable embodiments of the present invention will be described below.

FIG. 1 is a schematic sectional view of the magnetic recording medium of the present invention. The magnetic recording medium has a structure in which a seed layer 2, a nonmagnetic orientation control layer 3, a nonmagnetic base layer 21, a nonmagnetic

intermediate layer 22, a granular magnetic layer 4, and a protective film 5 are sequentially formed on a nonmagnetic substrate 1. Further, a liquid lubricant layer 6 is formed on these layers. For example, common substrate materials for magnetic recording media, such as NiP-plated Al alloys, reinforced glass, and crystallized glass, can be used in the nonmagnetic substrate 1. Additionally, because there is no need to heat the substrate, substrates formed by the injection molding of resins such as polycarbonate and polyolefin can be employed. Thin films of which the main constituent is carbon, for example, are used in the protective film 5. PAR-fluoropolyether-based lubricant agents, for example, can be used in the liquid lubricant layer 6.

The magnetic layer 4 is composed of ferromagnetic crystal grains and nonmagnetic boundaries surrounding them. This nonmagnetic boundary is what is referred to as a "granular magnetic layer," and is composed of metal oxides or nitrides. This film structure can be formed by, for example, sputtering a target of a ferromagnetic metal containing oxides that will constitute the nonmagnetic boundaries. It can also be formed by the reactive sputtering of a ferromagnetic metal in an Ar atmosphere containing oxygen.

There are no limitations on the materials for the ferromagnetic crystal, but CoPt-based alloys are preferably used. In particular, Cr, Ni, or Ta, for example, should be added to the CoPt alloy to reduce media noise. On the other hand, as materials for the nonmagnetic boundaries, oxides of elements such as Cr, Co, Si, Al, Ti, Ta, Hf, and Zr are particularly preferable to ensure a stable granular structure. The thickness of the magnetic layer 4 is not particularly specified, but this magnetic layer should be sufficiently thick to provide a sufficient magnitude of head-signal output during writing/reading.

The base layer 21 must have a body-centered cubic structure (bcc structure), in principle, and its preferred crystal-orientation must be the (200) plane. Such materials are W, Mo, V or a W, Mo, Cr, V alloy containing 10-60 at% Ti.

If 10-60 at% Ti, which has a hexagonal close-packed structure, is contained in body-centered cubic W, Mo, Cr, and V, the orientation unique to the hexagonal close-packed structure does not appear. Instead, the preferred orientation of the body-centered cubic (200) plane is effectively realized, with the body-centered cubic structure being maintained, and such a lattice constant is then obtained that has small misfit with the nonmagnetic intermediate layer and the magnetic layer.

There are no limitations on the thickness of the nonmagnetic base layer, but the thickness is preferably approximately 5-100 nm. In order to obtain the preferred crystal-orientation of the (200) plane, a nonmagnetic orientation control layer 3 is used as described later.

In order to further preferably control the orientation of the c-axis of ferromagnetic crystal grains in the granular magnetic layer, a nonmagnetic intermediate layer 22 is formed between the nonmagnetic base layer 21 and the granular magnetic layer 4 in the present invention. The nonmagnetic intermediate layer 22 may use a material that has the same hexagonal close-packed structure as that of the ferromagnetic crystal grains in the magnetic layer, and has a preferred orientation of the (110) plane parallel with the film surface. Preferably, such a material is Ru, Ir, Rh, Re or an Ru, Ir, Rh alloy 10-60 at% of Ti, C, W, Mo, or Cu. There are no limitations on the thickness of this intermediate layer, but the thickness is preferably approximately 2-50 nm.

The misfit with the magnetic layer of the above material is considerably smaller than that of the CoCr-based alloy employed in the nonmagnetic intermediate layer in Japanese Patent Laid Open Publication No. 2000-376597. Further, because it is easy to make the crystal grains fine in the above material, the magnetic layer deposited thereon has high-quality epitaxial growth, and a stronger in-plane orientation of the c-axis is realized. In addition, because the crystal grains in the magnetic layer can be made finer, a large noise-reduction effect is provided. If metals such as Ti, C, W, Mo, and Cu are added to Ru, Ir, Rh, or Re, such

effects are augmented.

Further, in order to effectively control the crystal orientation in the nonmagnetic base layer, a nonmagnetic orientation control layer 3 having a simple cubic structure and showing a preferred crystal-orientation of the (100) plane in parallel with the film surface can be deposited prior to the film deposition of the nonmagnetic base layer 21. In this case, it is preferable that the nonmagnetic orientation control layer 21 be an oxide of at least one of Mg, Ti, V, and Mn, or a carbide or nitride of at least one of Ti, Zr, Hf, Nb, Ta, Mo, and W. All of these materials have a simple cubic structure, and a preferred crystal-orientation of their (100) planes are easily obtained during deposition by sputtering. The thickness of the nonmagnetic orientation control layer 3 is not specified, but this layer is required to be thick enough to sufficiently control the crystal orientation in the nonmagnetic base layer 21.

Still further, in order to effectively control the crystal orientation and crystallization of the aforementioned nonmagnetic orientation control layer 3, it is useful to form an amorphous seed layer 2 between the nonmagnetic substrate 1 and the nonmagnetic orientation control layer 3. In this case, the seed layer 2 preferably has an amorphous structure. However, if the film deposition by sputtering causes unavoidable crystallization in the seed layer, there is no change in the resulting effect. For example, if a Ni layer containing 10-40 at% P or a Si layer containing 25-55 at% oxygen is used in the seed layer 2, the orientation and crystallization of the nonmagnetic orientation control layer 3 can be improved. The thickness of the seed layer 2 is also not specified, but it should be thick enough to effectively control the orientation and crystallization of the nonmagnetic orientation control layer 3.

In the manufacture of the magnetic recording medium shown in FIG. 1, which has the layered structure described above, if such a substrate heating process that has been conducted on the conventional magnetic recording media is omitted, higher Hc and lower media noise levels can be achieved, and manufacturing costs can be lowered by the

simplified manufacturing process.

Embodiment

Next, the embodiments of the present invention will be described below.

As the nonmagnetic substrate, a smooth-surface chemically reinforced glass substrate (for example, a HOYA N-10 glass substrate) was mounted in a sputtering system after cleansing. After an Ni-25%P seed layer 10 nm in thickness was formed in a 5-mTorr Ar atmosphere, an MgO orientation control layer 10 nm in thickness was formed in a 5-mTorr Ar atmosphere. Subsequently, a W base layer 30 nm in thickness was formed in a 15-mTorr Ar atmosphere, and an Ru intermediate layer 10 nm in thickness was formed in a 15-mTorr Ar atmosphere. After a granular magnetic layer 15 nm in thickness was formed in an atmosphere of 30-mTorr Ar by the RF sputtering method using a CoCr10Pt14 target to which 7 mol% SiO₂ was added, a carbon protective film 10 nm in thickness was deposited. The layered structure was then removed from the evacuated atmosphere, and 1.5-bn liquid lubricant was applied to provide the magnetic recording medium shown in FIG. 1. No substrate heating was carried out prior to the film deposition (Embodiment 1).

A Mo base layer (Embodiment 2), Ti-50 at%W base layer (Embodiment 4), and Ti-50 at% base layer (Embodiment 5) were also formed by the same process as specified above, together with the other layers with the same compositions as specified above.

In addition, the films were formed with the same compositions and deposition process as specified above, except that a Ti-50 at%W intermediate layer 10 nm in thickness was formed in a 15-mTorr Ar atmosphere (Embodiment 3).

Similarly, the films were formed with the same compositions and deposition process as specified above, except that a Ru-50 at%Mo intermediate layer 10 nm in thickness was formed in a 15-mTorr Ar atmosphere after a Ti-50 at%W base layer 30 nm in thickness was

formed in a 15-mTorr Ar atmosphere (Embodiment 6).

As a comparative example, the films were formed with the same compositions and deposition process as specified above, except that a Cr-20at%Mo layer 30 nm in thickness was formed as the Cr-alloy base layer as disclosed in Japanese Patent Laid Open Application No. 2000-376597, and a Co-40 at%Cr layer 10 nm in thickness was formed as the intermediate layer in a 15-mTorr Ar atmosphere (Comparative Example 1).

In addition, the films were formed with the same compositions and deposition process as in Comparative Example 1 above, except that an Ru intermediate layer 10 nm in thickness was formed in a 15-mTorr Ar atmosphere (Comparative Example 2).

FIG. 2 (Table 1) shows the layered structure of each fabricated medium and the intensity ratio, $I_{(110)}/I_{(101)}$, between the magnetic-layer Co-hcp (111) diffraction peak intensity $I_{(101)}$ and the magnetic-layer Co-hcp (110) diffraction peak intensity $I_{(110)}$ provided by the X-ray diffraction profile. The Cu-K α ray and a goniometer were used in the X-ray diffraction profile measurement. Because $I_{(110)}/I_{(101)}$ is 0.8 when the crystals are randomly oriented in the magnetic layer, the (110) plane can be considered to be preferably oriented if $I_{(110)}/I_{(101)}$ is equal to or greater than this value.

As shown in Table 1, because $I_{(110)}/I_{(101)}=2$ in Comparative Example 1, in which the base layer was Cr-20 at%Mo and the intermediate layer was Co-40 at%Cr, an in-plane preferred orientation was realized in the magnetic layer. However, because $I_{(101)}$ had a meaningful value, that is, the c-axis was skewed off the film surface (leading to a perpendicular element of magnetism), neither a stronger in-plane orientation nor high-quality epitaxial growth were obtained.

On the other hand, Comparative Example 2 used Cr-20 at%Mo in the base layer and Ru in the intermediate layer, since Ru makes it easier to downsize grains than the conventional

CoCr-alloys, in order to improve various properties. Although the desired orientation, Cr-bcc (200), was obtained in the base layer by virtue of the seed layer/orientation control layer, the Ru intermediate layer did not show the desired Ru-bcc (110) orientation but an almost random structure, because the misfit between the base layer and the intermediate layer was slightly larger than 7% and thus sufficient epitaxial growth was not attained.

Embodiments 1-6, with the goal of realizing in-plane orientation in the magnetic layer, use an Ru, Ir, or Ru-50 at%Mo alloy in the intermediate layer, because they show better properties than CoCr alloys and use W, Mo, Ti-50 at%W, or Ti-50at%Mo in the base layer formed under the intermediate layer, to ensure high-quality epitaxial growth from this base layer and a small amount of misfit. As a result, compared with Comparative Example 1, Embodiments 1-6 realize stronger in-plane orientations.

Specifically, in Embodiments 1, 2, and 3, in which the base layer and intermediate layer use a single element with no additive elements and the interlayer misfits are not optimized, the misfits are significantly small compared with the case in which the conventional Cr-alloy base layer/Cr-alloy intermediate-layer structure is used. As a result, effective orientation control and epitaxial growth are obtained, and relatively strong in-plane orientations are provided, as indicated by $I_{(110)}/I_{(101)}=4-5$. In Embodiments 4 and 5, in which the base layer contains additive elements, because the lattice constant of the base layer material is increased, better epitaxial growth is provided. As a result, the effect of the present invention is enhanced, as indicated by $I_{(110)}/I_{(101)}=8-10$.

Further, in Embodiment 6, in which the base layer and intermediate layer contain additive elements, the strongest in-plane orientation in the embodiments is provided for the magnetic layer by virtue of the optimization of interlayer misfits.

FIG. 3 (Table 2) shows the coercivity H_c , residual magnetic flux density $\times$ film thickness, B_r

δ , restored output of electromagnetic conversion property TAA at a linear density of 180 kFCI, media noise, and SNR value for the individual embodiments and comparative examples.

The residual magnetic flux density $\times$ film thickness, $Br \delta$, of these media stood between 49 and 61 $G \mu m$. These values of H_c and $Br \delta$ were measured using a vibrating sample magnetometer (VSM). The electromagnetic conversion properties are shown by the output of the isolated restored waveform, media noise, and SNR (signal-to-noise ratio) at a linear density of 180 kFCI, which were measured on GMR heads using a spin stand tester.

In terms of the magnetic properties, the magnitude of $I_{(110)}/I_{(101)}$, that is, the degree of in-plane orientation, is directly reflected in the magnitude of coercivity H_c . Compared with Comparative Example 1, in which the orientations of the Cr-alloy base layer and the CoCr-alloy intermediate layer are controlled, Embodiment 6, in which in-plane orientation in the magnetic layer has also been attained and $I_{(110)}/I_{(101)}$ has the largest value, shows a H_c increase of as much as approximately 600 Oe.

Meanwhile, with respect to the electromagnetic conversion property, SNR is improved when the in-plane orientation has been facilitated (when better epitaxial growth is realized). In Comparative Example 1 and Embodiment 1, in which the orientation is controlled in the same way, SNR is significantly improved by as much as +2.7 dB. The reason noise is reduced is that the crystal grain size in the Ru (for example) intermediate layer is smaller than that in the conventional CoCr-alloy intermediate layer, and that the crystal grain size in the magnetic layer formed thereon accordingly becomes smaller.

Advantageous Effects of the Invention

As described above, to form a granular magnetic film comprising CoPt-alloy ferromagnetic crystal grains of the hexagonal close-packed structure, the present invention uses a material having a body-centered cubic structure or a body-centered cubic structure plus a hexagonal

close-packed structure, and having a (200) plane preferably crystal oriented in parallel with the film surface in the nonmagnetic base layer, and uses a material such as Ru that has a hexagonal close-packed structure and a (110) plane preferably oriented in parallel with the film surface in the nonmagnetic intermediate layer. As a result, excellent magnetic properties and electromagnetic conversion properties can be attained.

Japanese Patent Laid Open Application No. 2000-376597 discloses that the crystal orientation in the base and magnetic layers can be controlled by forming an amorphous seed layer and an orientation control layer on the nonmagnetic substrate. According to the present invention, SNR can be further improved (the noise level can be further reduced) through a combination of the orientation control and downsizing of the magnetic-layer crystal grains in the intermediate layer made of Ru or the like. Due to the large degree of misfit with the Cr-alloy base layer, the intermediate layer made of Ru or the like cannot be used in Japanese Patent Laid Open Application No. 2000-376597. However, according to the present invention, the nonmagnetic base layer uses W, Mo, V or a W, Mo, Cr, V alloy containing 10-50 at% Ti and the misfit becomes 3% or less. As a result, while an intermediate layer made of Ru or the like is used, it becomes possible to realize strong in-plane orientation in the magnetic layer formed thereon, while at the same time downsizing the crystal grain size. As a result, various properties can be improved considerably.

Because excellent properties can be provided by the layered structure of the present invention, it becomes unnecessary to heat the substrate during deposition of the medium of the present invention. As a result, in addition to the conventional Al and glass substrates, inexpensive plastic substrates can be employed.

Claims

1. A magnetic recording medium comprising at least a nonmagnetic base layer, a nonmagnetic intermediate layer, a magnetic layer, a protective film, and a liquid lubricant layer sequentially stacked on a nonmagnetic substrate, the magnetic recording medium being characterized in that:

said magnetic layer has a granular structure comprising hexagonal close-packed ferromagnetic crystal grains and oxide-based nonmagnetic grain boundaries surrounding said ferromagnetic crystal grains;

said nonmagnetic base layer has a body-centered cubic structure, in principle, and its (200) plane shows preferred crystal-orientation parallel with the film surface; and said nonmagnetic intermediate layer has a hexagonal close-packed structure, and its (110) plane shows preferred crystal-orientation parallel with the film surface.

2. The magnetic recording medium according to Claim 1, characterized in that said nonmagnetic base layer comprises W, Mo, V or a W, Mo, Cr, V alloy containing 10-60 at% Ti.

3. The magnetic recording medium according to Claim 1 or 2, characterized in that a nonmagnetic orientation control layer of a simple cubic structure is formed between said nonmagnetic base layer and said substrate, and the preferred crystal-orientation parallel with the film surface is the (110) plane.

4. The magnetic recording medium according to Claim 3, characterized in that said nonmagnetic orientation control layer is an oxide of at least one of Mg, Ti, V, and Mn; or a carbide or a nitride of at least one of Ti, Zr, Hf, Nb, Ta, Mo, and W.

5. The magnetic recording medium according to Claim 4, characterized in that said amorphous seed layer is formed between said nonmagnetic orientation control layer and said substrate.

6. The magnetic recording medium according to Claim 5, characterized in that said seed layer is a Ni layer containing 10-40 at% P or a Si layer containing 25-55 at% oxygen.

7. The magnetic recording medium according to any of Claims 1-6, characterized in that said nonmagnetic grain boundaries in said magnetic layer comprise an oxide or a nitride of at least one of Cr, Co, Si, Al, Ta, Hf, and Zr.

8. The magnetic recording medium according to any of Claims 1-7, characterized in that said nonmagnetic intermediate layer comprises Ru, Ir, Rh, Re or an Ru, Ir, Rh, Re alloy containing 10-60 at% Ti, C, W, Mo, or Cu.

9. The magnetic recording medium according to any of Claims 1-8, characterized in that said nonmagnetic substrate is crystallized glass, chemically reinforced glass, or synthetic resin.

10. A manufacturing method for the magnetic recording medium comprising:
sequentially stacking on a nonmagnetic substrate a nonmagnetic base layer, a nonmagnetic intermediate layer, a magnetic layer, a protective film, and a liquid lubricant layer, wherein the nonmagnetic base layer comprises a body-centered cubic structure and a (200) plane having a crystal-orientation parallel with a surface of the protective film, the nonmagnetic intermediate layer comprises a hexagonal close-packed structure and a (110) plane having a crystal-orientation parallel with the surface of the protective film, and the magnetic layer comprises a granular structure having hexagonal close-packed ferromagnetic crystal grains and oxide-based nonmagnetic grain boundaries surrounding the ferromagnetic crystal grains:

executing a film formation process without heating the nonmagnetic substrate in advance; and

forming a nonmagnetic orientation control layer of a simple cubic structure between the nonmagnetic base layer and the substrate, and the crystal-orientation parallel with the film surface is the (110) plane.

11. The method as claimed in Claim 10, wherein the nonmagnetic base layer comprises a material selected from the group of alloys and elements consisting of W, Mo, and alloys of W, Mo, Cr, or V having 10-60 % Ti.

12. The method as claimed in Claim 10, wherein the nonmagnetic orientation control layer is an oxide of at least one of Mg, Ti, V or Mn, or a carbide or a nitride of at least one of Ti, Zr, Hf, Nb, Ta, Mo, or W.

13. The method as claimed in Claim 10, further comprising:
forming an amorphous seed layer between the non-magnetic orientation control layer and the substrate.

14. The method as claimed in Claim 13, wherein the seed layer is a Ni layer comprising 10 – 40 at% P or a Si layer containing 25 – 55 at% oxygen.