

MAGNETIC RECORDING MEDIA

BACKGROUND OF THE INVENTION

1. Field of the Invention

5 The present invention relates to magnetic recording media capable of producing a high-density information recording and having high thermal stability and superior signal-to-noise ratio (SNR) characteristics.

2. Description of the Related Art

10 Magnetic recording media may be divided into longitudinal magnetic recording (LMR) media and perpendicular magnetic recording (PMR) media. In LMR media, magnetic recording is performed by forming recording bits parallel to the plane of a magnetic recording medium. In PMR media, magnetic recording is performed by forming recording bits perpendicular to the film plane of a magnetic recording
15 medium having perpendicular magnetic anisotropy. It is known that since PMR has higher magnetostatic energy and lower antimagnetic field energy than the conventional LMR, it is advantageous in obtaining higher recording density.

In both the LMR and the PMR, in order to obtain a high density of a magnetic recording medium, it is necessary to increase the coercive force of a magnetic
20 substance composing a magnetic recording layer of the magnetic recording medium to ensure thermal stability. One of the factors that determine the coercive force of the magnetic substance is the magnetic anisotropic energy which displays a tendency of a magnetic moment in a magnetic crystal grain to align in specific crystal direction. As the magnetic anisotropic energy is high, the tendency of aligning in
25 the specific crystal direction is increasing. For example, in the case of a Co crystal grain, the c axis of a hexagonal dense crystal lattice is the direction to which the magnetic moment aligns (magnetization easy axis) and the magnetic anisotropic energy (K_u) is about 4.6×10^6 erg/cm³. When the volume of a crystal grain is V , the energy causing the magnetic moment in the crystal grain to align with the
30 magnetization easy axis is given as $K_u V$. Meanwhile, the magnetic moment moves due to thermal vibration, which may be represented as a multiplication of Boltzmann's constant K_B and absolute temperature T , i.e. $K_B T$. Comparing $K_B T$ with $K_u V$, in the case of $K_B T \ll K_u V$, since the magnetic anisotropic energy is significantly greater than the thermal vibration energy, the magnetic moment aligns with

approximate c axis of the crystal grain. However, in the case of $K_B T \gg KuV$, since the thermal vibration energy is greater than the magnetic anisotropic energy, the magnetic moment continues to thermally vibrate, which is called a superparamagnetic phenomenon. In general, when the value of $(KuV)/(K_B T)$ is 50-100, thermal stability of a medium can be ensured. When the value of $(KuV)/(K_B T)$ is less than 50, magnetic domains of information recorded may be destroyed.

To realize high density recording in the magnetic recording media, it is necessary to reduce noise. The particle diameter of magnetic crystal grains composing the magnetic recording medium is decreased and the distribution thereof is made to be uniform to reduce noise. Generally, to perform high density recording of 200 Gb/in² or greater, micro-crystal grains of 10 nm or less are required. However, when reducing the particle diameter of a crystal grain as described above, since the volume of the crystal grain is also reduced, on the whole the value of KuV decreases, thereby making it difficult to ensure thermal stability. Also, since the deviation value of sizes of the crystal grains increases, signal-to-noise ratio (SNR) lowers.

Currently, a CoCr alloy-based ferromagnetic material is generally used as a recording layer material in a magnetic recording medium. FIG. 1 is a SEM photograph of a plane on which a CoCr alloy-based material used for a conventional magnetic recording layer is deposited. Referring to FIG. 1, the dark portions are magnetic crystal grains in which recording is actually performed and the bright portions between crystal grains are Cr-rich phases in which the content of Cr is greater than that of Co, as a compositional segregation phase and the Cr-rich phase magnetically isolates crystal grains.

Referring to FIG. 1, when forming a magnetic recording layer according to a conventional method, the size and the distribution of crystal grains are not uniform and the interface thereof is not uniform, which causes noise of media. Also, when using the CoCr alloy-based material, if the size of crystal grains is decreased to 5 nm or less in order to reduce noise, magnetization is unstable even at a room temperature, so that information may be destroyed.

Consequently, when reducing noise by decreasing the size of the crystal grains, it is very difficult to ensure thermal stability. This problem can be solved by introducing a magnetic material with high magnetic anisotropic energy. Examples

of the magnetic material with high magnetic anisotropic energy include alloys, such as FePt, CoPd, CoPt, NdFeB, Co/Pd multi-layer film, Co/Pt multi-layer film, Fe/Pt multi-layer film, and Fe/Pd multi-layer film. Such materials cannot form a crystal structure which is completely isolated physically and magnetically by the physical depositing method only. In other words, the media noise is mainly induced from a zigzag-shaped magnetic wall generated in a transition region that is a boundary portion of bits. The zigzag-shaped magnetic wall vibrates violently as the magnetic exchange bonds (magnetic interaction) between magnetic crystal grains are strong. Thus, to reduce media noise, it is necessary to eliminate the magnetic interaction between crystal grains to magnetically isolate each of the magnetic crystal grains. As described above, since there is the Cr-rich phase in which the content of Cr is significantly greater than that of Co, as a compositional segregation phase in the conventional CoCr alloy, the crystal grains can be magnetically isolated. However, the material with high magnetic anisotropic energy, such as FePt, has not the compositional segregation phase, and thus, cannot prevent interactions between crystal grains. Also, some CoCr alloys with high magnetic anisotropic energy do not achieve complete segregation, and thus, cannot prevent interactions between crystal grains. Accordingly, noise may be increased.

SUMMARY OF THE INVENTION

The present invention provides a magnetic recording medium having a uniform distribution of sizes of the crystal grains, having uniform interfaces of the crystal grains, and having high thermal stability in spite of the presence of fine and uniform crystal grains. Also, the magnetic recording medium of the present invention has high density recording characteristics and superior SNR characteristics since the crystal grains are magnetically isolated.

According to an aspect of the present invention, there is provided a magnetic recording medium having a magnetic recording layer and a substrate supporting the magnetic recording layer, in which the magnetic recording layer is composed of a porous crystal isolating membrane capable of magnetically or physically isolating crystals by the micropores.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other features and advantages of the present invention will become more apparent by describing in detail exemplary embodiments thereof with reference to the attached drawings in which:

FIG. 1 is a SEM photograph of a plane on which a CoCr alloy-based material used for a conventional magnetic recording layer is deposited;

FIG. 2 is a SEM photograph of a crystal isolating membrane used in a magnetic recording medium according to an embodiment of the present invention;

FIG. 3 is a cross-sectional view illustrating schematically the structure of a magnetic recording medium according an embodiment of the present invention;

FIG. 4 is a schematic cross-sectional view of a magnetic recording medium according to Example 1 of the present invention;

FIG. 5 is a schematic cross-sectional view of a magnetic recording medium according to Example 3 of the present invention;

FIG. 6 is a schematic cross-sectional view of a magnetic recording medium according to Example 5 of the present invention; and

FIG. 7 is a schematic cross-sectional view of a magnetic recording medium according to Example 7 of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

The present invention will now be described in more detail.

A magnetic recording layer of a magnetic recording medium according to an embodiment of the present invention is composed of a crystal isolating membrane in the form of a template having micropores formed previously so as to form fine, uniform crystal grains. A magnetic recording material is impregnated into the pores to prevent physical and magnetical interactions between crystal grains and the interface of boundary portion of bits is allowed in advance to be uniform, thereby reducing noise.

Meanwhile, the standard deviation of the sizes of the pores may be 30% or less of the size of the crystal grains of the magnetic recording material in order to allow the size of crystal grains to be uniform, thereby reducing noise.

As described above, when using a material having high magnetic anisotropic energy, such as FePt, since there is no compositional segregation phase, the interaction between crystal grains cannot be prevented. To solve this problem, the

porous crystal isolating membrane can be used to prevent physical and magnetical interactions between crystal grains.

The recording material used in the present invention may be conventional recording materials in the art and examples thereof include a transition metal element selected from Co, Fe, Ni, Cr, Pt, Pd, Ti, Ta, Ru, Si, Al, Nb, B, Nd, Sm, and Pr, an alloy thereof, and an alloy containing at least one transition metal element of Co and Fe and at least one noble metal element of Pt and Pd.

The micropore of the porous crystal isolating membrane may have a diameter of 2-100 nm. When the diameter of the micropore is less than 2 nm, it is difficult to ensure thermal stability. When the diameter of the micropore is greater than 100 nm, it is difficult to obtain a high density recording. Meanwhile, when using a recording material with very high magnetic anisotropic energy as the recording material, the diameter of the micropore may be 3-5 nm, since thermal stability and super high density recording characteristic of 400 Gb/in² or greater can be obtained within the above range.

Also, an aspect ratio of the micropore may be 0.01-1000. Herein, the aspect ratio means the ratio of the depth of the pore to the diameter of the pore. For example, the aspect ratio of 10 indicates that the diameter of the pore is 2 nm and the depth of the pore is 20 nm. When the aspect ratio is less than 0.01, since the depth of the pore is too shallow, it is difficult to sufficiently impregnate the recording material. When the aspect ratio is greater than 1000, it is difficult to uniformly impregnate the recording material.

FIG. 2 is a SEM photograph of the crystal isolating membrane used in the magnetic recording medium according to an embodiment of the present invention. The porous crystal isolating membrane may be composed of a material in which micropores are magnetically isolated, for example, may be composed of aluminium oxide. When preparing the porous crystal isolating membrane using aluminium oxide, anodic oxidation which is a method known generally in the art may be used. In the anodic oxidation, when Al is used as an anode and electricity is generated, oxygen is generated in the anode and thereby a surface of Al is oxidized to form a porous Al₂O₃ layer.

Although It is sufficient if the magnetic anisotropic energy (Ku) of the recording material is 5×10^5 erg/cm³, the recording material with higher magnetic anisotropic energy may be used in order to ensure thermal stability as the crystal

grain size decreases. When the crystal grain size is 5 nm or less, the magnetic anisotropic energy may be 2.0×10^7 erg/cm³. Examples of the alloy with very high magnetic anisotropic energy include FePt, CoPd, CoPt, and NdFeB.

The magnetic recording medium according to an embodiment of the present invention may further include an under layer between the magnetic recording layer and the substrate. The under layer improves the crystal orientation of the magnetic recording layer and may be composed of Ti, Pt, Au, Pd, Ta, Cu, Ru, Ag, Au, B, Nd, Nb, Cr, Co, Ni, Fe, Al, Si, Zr, Mo, Pr, C, or an alloy thereof.

FIG. 3 is a cross-sectional view schematically illustrating the structure of the magnetic recording medium according to an embodiment of the present invention. In the magnetic recording medium, an under layer 12 improving the crystal orientation of a perpendicular magnetic recording layer 13, an intermediate layer 11 reducing the difference of crystal structures between the under layer 12 and the recording layer 13 to improve the crystallinity of the perpendicular magnetic recording layer 13, and the perpendicular magnetic recording layer 13 composed of a crystal isolating membrane are sequentially deposited on a glass or an aluminium based alloy substrate 10. In the medium, a magnetization easy axis of the perpendicular magnetic recording layer 13 is arranged perpendicularly to the plane of the membrane by the under layer 12, and thus the perpendicular magnetic recording layer 13 has perpendicular magnetic anisotropic energy. As a result, it is possible to perpendicularly record information by perpendicular magnetic field components of a single pole head.

A glass substrate, a Al-Mg based substrate having NiP amorphous film coated thereon, a thermally oxidized Si substrate, and the like are generally used as the substrate 10 and the under layer 12 is formed by depositing Ti etc. on the substrate 10 through a sputtering method or other physical depositing methods. The thickness of the under layer 12 is in the range of 1-200 nm. The magnetic recording layer 13 is formed on the under layer 12. The magnetic recording layer 13 is formed by first forming an Al layer through sputtering method, and then forming micropores via anodic oxidation, and then impregnating the recording material into the micropores. Plating, CVD, PVD, sputtering, sol-gel method, and the like may be used in the impregnation. When the depth of the pore is great, a plating method may be used and when the depth of the pore is shallow, a sputtering method may be used to simplify the preparation process.

The magnetic recording medium according to an embodiment of the present invention may be a longitudinal magnetic recording medium as well as a perpendicular magnetic recording medium. FIG. 4 is a schematic cross-sectional view of a perpendicular magnetic recording medium according to an embodiment of the present invention. In the medium, an under layer 22 which improves perpendicular orientation of a recording and reproducing layer, a perpendicular magnetic recording layer 23 which is composed of a crystal isolating membrane, a protective layer 24 which protects the perpendicular magnetic recording layer from oxidation and external impacts, and a lubricant layer 25 which prevents a head slider for recording and reproducing information from colliding against the medium and inducing a smooth slide of the head slider are sequentially deposited on a substrate 20 of a glass or an aluminium based alloy.

The magnetic recording medium according to another embodiment of the present invention may further include a soft magnetic layer between the recording layer and the substrate. The soft magnetic layer functions as a return path for the magnetic field in the perpendicular magnetic recording medium to form a magnetic path for the perpendicular magnetic field. For example, FeSiAl, a NiFe alloy, or a CoZr alloy may be used for the soft magnetic layer. FIG. 5 is a schematic cross-sectional view of a perpendicular magnetic recording medium, including a soft magnetic layer 26 and an intermediate layer 21.

FIG. 6 is a schematic cross-sectional view of a longitudinal magnetic recording medium according to another embodiment of the present invention including all of an intermediate layer 31, an under layer 32, and a crystal orientation layer 38. A recording layer is divided into an upper recording layer 33 and a lower magnetic layer 37 and a Ru layer is placed between them. The Ru layer is deposited to reduce the effect of antimagnetic field by decreasing the thickness of the lower magnetic layer 37. In the magnetic recording medium, either or both of the upper recording layer 33 and the lower magnetic layer 37 may be composed of a crystal isolating membrane.

Meanwhile, the magnetic recording medium may be prepared by allowing all layers except for the substrate, for example, the soft magnetic layer, the intermediate layer, and the under layer to be composed of a crystal isolating membrane in the form of one body, and then sequentially impregnating materials composing the respective layers. An embodiment of a recording medium using the crystal isolating

membrane in all layers except for a substrate is illustrated in FIG. 7. The recording medium is prepared by forming a crystal isolating membrane 48 as one body on a substrate 40 and sequentially impregnating a soft magnetic layer 46, an intermediate layer 41, a recording layer 43, a protective layer 44, and a lubricant layer 45.

5 The present invention will be described in greater detail with reference to the following examples. The following examples are for illustrative purposes and are not intended to limit the scope of the invention.

Example 1

10 An under layer of Ti was deposited to a thickness of 50 nm on a glass substrate with a thickness of 0.635 mm and Al was sputtered thereon to a thickness of 10 nm. Then, micropores with a diameter of 5 nm (standard deviation: 20%) were formed through anodic oxidation so as to have the aspect ratio of 2. Then, FePt which was a recording material was impregnated into the pores through a
15 sputtering method, and then, a carbon based film with a thickness of 10 nm as a protective layer and a Z-DOL (0.04%) (available from Ausimont) layer with a thickness of 2 nm as a lubricant layer were deposited thereon to prepare a magnetic recording medium.

20 Example 2

A magnetic recording medium was prepared in the same manner as in Example 1 except that an Al layer with a thickness of 5 nm was formed and an aspect ratio was 1.

25 Example 3

A magnetic recording medium was prepared in the same manner as in Example 1 except that a Pt intermediate layer with a thickness of 5 nm was deposited instead of the under layer and a NiFe soft magnetic layer with a thickness of 150 nm was further formed between the intermediate layer and a substrate.

30 Example 4

An under layer of Ti was deposited to a thickness of 50 nm on a glass substrate with a thickness of 0.635 mm, Pt intermediate layer was deposited to a thickness of 20 nm and Al was sputtered thereon to a thickness of 20 nm. Then,

micropores with a diameter of 2 nm were formed through anodic oxidation so as to have an aspect ratio of 10. Then, FePt which was a recording material was impregnated into the pores through an electrical plating method, and then, a carbon based film with a thickness of 10 nm as a protective layer and a Z-DOL (0.04%) (available from Ausimont) layer with a thickness of 2 nm as a lubricant layer were deposited thereon to prepare a magnetic recording medium.

Example 5

A Ta crystal orientation layer with a thickness of 5 nm was deposited on a glass substrate with a thickness of 0.635 mm, and then, a Ti under layer with a thickness of 50 nm was deposited thereon. Then, a Pt intermediate layer with a thickness of 5 nm was deposited and a CoCrPt layer with a thickness of 20 nm as a lower magnetic layer and a Ru layer with a thickness of 5 nm were sequentially deposited. Al was sputtered thereon to a thickness of 20 nm, and then, micropores with a diameter of 5 nm were formed through anodic oxidation so as to have an aspect ratio of 4. Then, CoCrPt which was a recording material was impregnated into the pores through electrical plating method, and then, a carbon based film with a thickness of 10 nm as a protective layer and a Z-DOL (0.04%) (available from Ausimont) layer with a thickness of 2 nm as a lubricant layer were deposited thereon to prepare a magnetic recording medium.

Example 6

A magnetic recording medium was prepared in the same manner as in Example 4 except that a micropore had a diameter of 20 nm so as to have an aspect ratio of 1 and a CoCr based alloy was used as a recording material.

Example 7

Al was sputtered to a thickness of 180 nm on a glass substrate with a thickness of 0.635 mm, and then, micropores with a diameter of 5 nm were formed through anodic oxidation so as to have an aspect ratio of 30. Then, a NiFe soft magnetic layer material was impregnated into the pores to a thickness of 150 nm, and then, a Ru layer with a thickness of 20 nm as an intermediate layer and a layer of CoPt which was a recording material with a thickness of 10 nm were sequentially impregnated to be deposited. Finally, the surface of the deposit was planarized,

and then, a carbon based film with a thickness of 10 nm as a protective layer and a Z-DOL (0.04%) (available from Ausimont) layer with a thickness of 2 nm as a lubricant layer were deposited thereon to prepare a magnetic recording medium.

As described above, magnetic recording media according to embodiments of the present invention can adjust the boundary surface of bits very uniformly to reduce noise since crystal grains of a recording material are very fine and uniform, and can obtain a high density recording of 400 Gb/in² or greater since the size of the crystal grain may be controlled to 5 nm or less. Also, even though using a material having very high magnetic anisotropic energy as a recording material in order to ensure thermal stability, crystal grains of the recording material can be physically and magnetically isolated, thereby reducing noise.

While the present invention has been particularly shown and described with reference to exemplary embodiments thereof, it will be understood by those of ordinary skill in the art that various changes in form and details may be made therein without departing from the spirit and scope of the present invention as defined by the following claims.

What is claimed is:

1. A magnetic recording medium comprising a magnetic recording layer and a substrate supporting the magnetic recording layer,

wherein the magnetic recording layer is composed of a porous crystal
isolating membrane capable of magnetically and physically isolating crystals by
micropores.

2. The magnetic recording medium of claim 1, wherein standard deviation of
the sizes of the pores is not greater than 30% of the size of a crystal grain of the
magnetic recording material.

3. The magnetic recording medium of claim 1, wherein a transition metal
element selected from Co, Fe, Ni, Cr, Pt, Pd, Ti, Ta, Ru, Si, Al, Nb, B, Nd, Sm, and
Pr or an alloy thereof is impregnated into the pores.

4. The magnetic recording medium of claim 1, wherein an alloy containing at
least one transition metal element of Co and Fe and at least one noble metal
element of Pt and Pd is impregnated into the pores.

5. The magnetic recording medium of claim 1, wherein the micropore has a
diameter of 2-100 nm.

6. The magnetic recording medium of claim 1, wherein the micropore has a
diameter of 3-5 nm.

7. The magnetic recording medium of claim 1, wherein the micropore has an
aspect ratio of 0.01-1000.

8. The magnetic recording medium of claim 1, wherein the porous crystal
isolating membrane is composed of aluminum oxide.

9. The magnetic recording medium of claim 1, wherein magnetic anisotropic
energy of the alloy is 5.0×10^5 erg/cm³ or greater.

10. The magnetic recording medium of claim 1, wherein magnetic anisotropic energy of the alloy is 2.0×10^7 erg/cm³ or greater.

11. The magnetic recording medium of claim 1, wherein the alloy is FePt, CoPd, CoPt, or NdFeB.

12. The magnetic recording medium of claim 1, further comprising an under layer between the magnetic recording layer and the substrate.

13. The magnetic recording medium of claim 12, wherein the magnetic recording layer is a perpendicular magnetic recording layer.

14. The magnetic recording medium of claim 12, wherein the magnetic recording layer is a longitudinal magnetic recording layer.

15. The magnetic recording medium of claim 1, further comprising a soft magnetic layer between the magnetic recording layer and the substrate.

16. The magnetic recording medium of any one of claims 12 through 15, wherein the under layer or the soft magnetic layer is composed of a porous crystal isolating membrane capable of magnetically and physically isolating crystals by micropores.

17. The magnetic recording medium of claim 16, wherein a transition metal element selected from Ti, Pt, Au, Pd, Ta, Cu, Ru, Ag, Au, B, Nd, Nb, Cr, Co, Ni, Fe, Al, Si, Zr, Mo, Pr, and C or an alloy thereof is impregnated into micropores of the porous crystal isolating membrane composing the under layer.

18. The magnetic recording medium of claim 16, wherein FeSiAl, a NiFe alloy, or a CoZr alloy is impregnated into micropores of the porous crystal isolating membrane composing the soft magnetic layer.

19. The magnetic recording medium of claim 16, wherein a material having an exchange magnetic anisotropic effect or an antiferromagnetic bonding structure is

impregnated into micropores of the porous crystal isolating membrane composing the soft magnetic layer.