



159159



G00002

Magnetic Recording Medium and Manufacture Method Therefore and Magnetic Recording Apparatus

Field of the Invention

The present invention relates to a magnetic recording medium that is applicable to a vertical magnetic recording medium or the like mounted in various magnetic recording apparatuses including external storage devices for computers, as well as a manufacturing method for this magnetic recording medium, and a magnetic recording apparatus.

Prior Art

For magnetic recording media that are desired to have increased 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 magnetic 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 SiO₂ 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 a high coercive force H_c and reduced noise.

The reason such a granular magnetic film features reduced noise characteristics 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 which 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, for the granular magnetic layer, even if a film is formed without heating, the nonmagnetic, nonmetallic substance is deposited to provide excellent magnetic characteristics and electromagnetic conversion characteristics.

Problems to be Solved by the Invention

However, the granular magnetic layer is composed of crystal grains consisting of a metallic ferromagnetic material and a crystal grain-boundary layer consisting of a nonmagnetic, nonmetallic material such as an oxide or nitride. If a magnetic layer is formed by a sputtering process, magnetic characteristics and electromagnetic conversion characteristics are substantially determined by the compounding ratio of magnetic material and oxide or nitride, and the room pressure during film formation. Thus, few factors are available to suppress this tendency.

It is thus an object of the present invention to adjust the partial pressure of H₂O in an Ar gas atmosphere when a magnetic film is formed, in order to provide a magnetic recording medium having excellent electromagnetic conversion characteristics such as reduced noise, as well as a manufacturing method for this magnetic recording medium, and a magnetic recording apparatus.

Means for Solving the Problems

The present invention provides a magnetic recording medium comprising at least a nonmagnetic base layer, a nonmagnetic intermediate layer, and a magnetic layer sequentially stacked on a nonmagnetic substrate, wherein the partial pressure of H₂O in an Ar atmosphere is controlled during film formation to make crystal grains constituting the magnetic layer finer in order to obtain a uniform grain size, so that the magnetic layer is composed of fine crystal grains having a uniform grain size and exhibiting ferromagnetism and a nonmagnetic grain boundary surrounding the fine crystal grains, and is formed so as to have excellent electromagnetic conversion characteristics including reduced noise, thereby providing a magnetic recording medium.

In this case, the nonmagnetic base layer may comprise W, Mo, V or a W, Mo, Cr, or V alloy containing 10 at% or more and 50 at% or less Ti.

The nonmagnetic intermediate layer may comprise Ru, Ir, Rh, Re or a Ru, Ir, Rh, or Re alloy containing 10 at% or more and 50 at% or less Ti, C, W, Mo, or Cu.

The nonmagnetic substrate may be crystallized glass, chemically reinforced glass, or plastic.

The present invention provides a method of manufacturing a magnetic recording medium by sequentially stacking at least a nonmagnetic base layer, a nonmagnetic intermediate layer,

and a magnetic layer on a nonmagnetic substrate, wherein the partial pressure of H₂O in an Ar atmosphere is controlled during film formation to make crystal grains constituting the magnetic layer finer in order to obtain a uniform grain size, so that the magnetic layer is composed of fine crystal grains having a uniform grain size and exhibiting ferromagnetism and a nonmagnetic grain boundary surrounding the fine crystal grains, and is formed so as to have excellent electromagnetic conversion characteristics including reduced noise.

In this case, the partial pressure of H₂O during film formation may be controlled to the order of 10⁻⁹ Torr, and preferably to within the range from 2 x 10⁻⁸ Torr to 2 x 10⁻⁹ Torr.

A film formation process may be executed without heating the nonmagnetic substrate in advance.

The present invention can provide a magnetic recording apparatus comprising the above-described magnetic recording medium mounted therein.

Brief Description of the Drawings

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

Fig. 2 is a block diagram showing an example of the configuration of a sputtering apparatus used to manufacture a magnetic recording medium.

Fig. 3 is a characteristic diagram showing the noise characteristics, one of the electromagnetic conversion characteristics of the magnetic recording medium, and more specifically the variation in noise vs. linear density.

Fig. 4 is a characteristic diagram showing the SNR characteristics, one of the electromagnetic conversion characteristics of the magnetic recording medium, and more specifically the variation in SNR vs. linear density.

Fig. 5 is a diagram illustrating the noise and SNR according to the present invention compared with those according to a conventional example.

Fig. 6 is a characteristic diagram showing the area ratio vs. the crystal grain size.

Fig. 7 is a diagram illustrating comparisons of the average grain size and standard deviation according to the present invention with those according to the conventional example.

Fig. 8 is a perspective view showing an example of the configuration of a magnetic disk drive in which the magnetic recording medium is accommodated.

Embodiment

An embodiment of the present invention will be described below in detail with reference to the drawings.

Magnetic Recording Medium

First, the structure of a magnetic recording medium according to the present invention will be described.

Fig. 1 shows a cross section of a magnetic recording medium 100.

The magnetic recording medium 100 is composed of a nonmagnetic base layer 2, a nonmagnetic intermediate layer 3, a granular magnetic layer 4, a protective layer 5, and a liquid lubricant layer 6 sequentially stacked on a nonmagnetic substrate 1.

The nonmagnetic substrate 1 consists of crystallized glass, chemically reinforced glass, or plastic.

The nonmagnetic base layer 2 is composed of W, Mo, V or a W, Mo, Cr, or V alloy containing 10 at% or more and 50 at% or less Ti.

The nonmagnetic intermediate layer 3 is composed of Ru, Ir, Rh, Re or a Ru, Ir, Rh, or Re alloy containing 10 at% or more and 50 at% or less Ti, C, W, Mo, or Cu.

The granular magnetic layer 4 is composed of fine crystal grains 4a exhibiting ferromagnetism and a nonmagnetic grain boundary 4b surrounding the fine crystal grains 4a. The fine crystal grains 4a exhibiting ferromagnetism may be composed primarily of, for example, Co (cobalt).

In this case, the partial pressure of H₂O in an Ar atmosphere is controlled during film formation to further reduce the grain size of the fine crystal grains 4a in order to obtain uniform crystal grains. When the processed fine crystal grains 4a have a uniform grain size and exhibit ferromagnetism, electromagnetic characteristics such as noise characteristics and SNR characteristics can be improved.

Manufacturing Method

Next, a manufacturing method for the magnetic recording medium 100 will be described.

Fig. 2 shows an example of the configuration of a sputtering apparatus 200 used to manufacture the magnetic recording medium 100.

The sputtering apparatus 200 is composed of a chamber 210 in which a film is formed, electrode sections 220 arranged at the lateral opposite ends of the chamber 210 to generate

high-frequency fields (RF), an inlet 230 provided at the top of the chamber 210 and through which an Ar gas flows into the apparatus, and a high-vacuum pump 240 provided at the bottom of the chamber 210. The electrode sections 220 are each composed of an RF cathode electrode 221 and an RF power supply 222 used to generate plasma in the chamber 210.

To manufacture a magnetic recording medium, a crystallized glass substrate with smooth surfaces is first provided as the nonmagnetic substrate 1.

The substrate has not been heated. Heating is omitted because the present invention is characterized by providing, even without heating, characteristics similar to those obtained when the substrate has been heated; with a conventional Al or glass medium, it is a precondition that a crystal is commonly deposited by heating, and for a granular film the deposition is facilitated using a matrix of an oxide or the like.

Then, the nonmagnetic substrate 1 is washed and introduced into the sputtering apparatus 200. At an Ar gas pressure of 15 mTorr, a nonmagnetic base layer 2 consisting of Ti₅₀at%W is formed on the nonmagnetic substrate 1 to a thickness of 10 nm.

Then, at an Ar gas pressure of 15 mTorr, a nonmagnetic intermediate layer 3 consisting of Ru is formed on the nonmagnetic base layer 2 to a thickness of 10 nm.

Then, at an Ar gas pressure of 15 mTorr, a CoCr₁₀Pt₁₄ target doped with 7 mol% SiO₂ is used to form a granular magnetic layer 4 on the nonmagnetic intermediate layer 3 to a thickness of 15 nm.

During film formation, the partial pressure of H₂O in the Ar atmosphere is controlled. In this case, during film formation, the partial pressure of H₂O is controlled to the order of 10⁻⁹ Torr. More preferably, it is controlled to within the range from 2 x 10⁻⁸ Torr to 2 x 10⁻⁹ Torr.

The control of the partial pressure of H₂O will be described.

The term “partial pressure” as used herein indicates the pressure of a particular component in a mixed gas. Ar molecules do not account for one hundred percent of the high-vacuum Ar atmosphere, but various molecules are present in this atmosphere. In this example, in the Ar atmosphere during film formation, the partial pressure of H₂O is 10⁻⁹ Torr or higher (i.e. 10⁻⁸ Torr, 10⁻⁷ Torr, ...). By way of example, when the atmosphere contains 20% oxygen (O₂) and 80% nitrogen (N₂) (under the condition that no other gases are present) at 1 atm, i.e., 760 Torr, the partial pressure of O₂ is 152 Torr and the partial pressure of N₂ is 608 Torr.

A protective layer 5 consisting of a carbon film is then stacked on the granular magnetic layer 4 to a thickness of 10 nm. The stack is then removed from the vacuum in the chamber 210.

Subsequently, a liquid lubricant layer 6 is applied on the protective layer 5 to a thickness of 1.5 nm. In this manner, the magnetic recording medium 100 constructed as shown in Fig. 1 was produced.

Experimental Results: Electromagnetic Conversion Characteristics

Next, the electromagnetic conversion characteristics of the produced magnetic recording medium 100 will be described.

1. Noise and SNR Characteristics

Fig. 3 shows the results of measurements of noise characteristics, one of the electromagnetic conversion characteristics of the magnetic recording medium 100. This figure shows the noise characteristics vs. linear density Ld measured using a spin stand tester with a GMR head (magnetic-resistance head).

Curve A denotes noise in the magnetic recording medium 100 of the present invention, produced so that the partial pressure of H₂O during film formation was 10⁻⁹ Torr. Curve B denotes noise that occurred in a conventional magnetic recording medium.

Fig. 4 shows the results of measurements of the SNR characteristics, one of the electromagnetic conversion characteristics of the magnetic recording medium 100. This figure shows the signal to noise ratio (SNR) vs. the linear density Ld.

Curve C denotes the SNR of the magnetic recording medium 100 of the present invention, produced so that the partial pressure of H₂O during film formation was 10⁻⁹ Torr. Curve D denotes the SNR of the conventional magnetic recording medium. In this case, the measured samples are assumed to provide equivalent reproduction outputs.

Fig. 5 shows the results of comparisons of noise 250 and SNR 251 according to the present invention with those according to the conventional example. All values were obtained through measurements at a linear density Ld of approximately 200 KFCI.

The noise 250 is 36.70 according to the present invention, whereas it is 62.81 according to the conventional example. Therefore, the present invention enables noise to be reduced by approximately 50%.

The SNR 251 is 13.26 according to the present invention, whereas it is 11.17 according to the conventional example. Therefore, the present invention enables the SNR to be reduced by approximately 5%.

Here, the linear density Ld will be described. In general, FCI (Flux Changes per Inch) x TPI (Tracks per Inch) = Bits/in² (surface recording density) (at present, the standard value is approximately 50 KTPI). The TPI depends on the specifications of the HDD (Hard Disk

Drive). HD (Hard Disk) manufacturers evaluate the tested characteristics of the FCI in order to determine to what Bits/in² the HD is equivalent. However, it is assumed that a value of approximately 200 KFCI is the limit of measurements using the spin stand. This relates to a write head and the compatibility of the frequency of a tester. Thus, in the embodiments, the linear density Ld was measured at the position at which the radius R of the magnetic recording medium 100 was 35 mm, with the rotation speed N set at 5400 rpm. Then, the noise and SNR values measured at a linear density of 200 KFCI were compared.

2. Comparison of Crystal Grains

Fig. 6 shows the area ratio vs. the crystal grain size. The crystal grain size was measured using a TEM (transmission electronic microscope). For example, a surface ratio of 40% on curve E means that approximately 40% of all crystal grains have crystal grain sizes of 5.5 nm or 7 nm.

Curve E denotes the distribution of crystal grain sizes in the magnetic recording medium 100 of the present invention, produced so that the partial pressure of H₂O during film formation was 10⁻⁹ Torr. Curve F denotes the distribution of crystal grain sizes in the conventional magnetic recording medium.

Fig. 7 shows the average grain size 260 and standard deviation 261 according to the present invention determined from curves E and F in Fig. 6, and compared with those according to the conventional example.

The average grain size 260 is 6.3 according to the conventional example and 5.0 according to the present invention. The standard deviation 261 is 1.74 according to the conventional example and 1.5 according to the present invention.

These results indicate that the crystal grains according to the present invention have a smaller grain size and a smaller variation in size than those according to the prior art. This,

in turn, indicates that the present invention served to make the crystal grains finer and more uniform.

The results of the experiments indicate that by controlling the partial pressure of H₂O in the Ar atmosphere during film formation, the crystal grains constituting the granular magnetic layer 4 can be made finer and more uniform, thereby improving electromagnetic conversion characteristics such as the noise and SNR characteristics.

Magnetic Recording Apparatus

Fig. 8 shows an example of the configuration of a magnetic disk drive 300 in which a magnetic recording medium 100 produced by controlling the partial pressure of H₂O in the Ar atmosphere is accommodated.

A GMR head 301 supported by an arm 302 is arranged near and opposite the magnetic recording medium 100. The GMR head 301 is rotationally moved by a voice coil motor 303 used to drive the head.

Advantageous Effects of the Invention

The present invention provides a magnetic recording medium comprising at least a nonmagnetic base layer, a nonmagnetic intermediate layer, and a magnetic layer sequentially stacked on a nonmagnetic substrate, wherein the partial pressure of H₂O in an Ar atmosphere is controlled during film formation to make crystal grains constituting the magnetic layer finer in order to obtain a uniform grain size, so that the magnetic layer is composed of fine crystal grains having a uniform grain size and exhibiting ferromagnetism and a nonmagnetic grain boundary surrounding the fine crystal grains. Therefore, a magnetic recording medium can be produced that has excellent electromagnetic conversion characteristics such as reduced noise and an increased SNR.

Claims

1. A magnetic recording medium comprising at least a nonmagnetic base layer, a nonmagnetic intermediate layer, and a magnetic layer sequentially stacked on a nonmagnetic substrate, with the magnetic recording medium being characterized in that:
the partial pressure of H₂O in an Ar atmosphere is controlled during film formation to make the crystal grains constituting said magnetic layer finer in order to obtain a uniform grain size,
so that said magnetic layer is composed of fine crystal grains having a uniform grain size and exhibiting ferromagnetism and a nonmagnetic grain boundary surrounding the fine crystal grains, and is formed so as to have excellent electromagnetic conversion characteristics including reduced noise.
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, or V alloy containing 10 at% or more and 50 at% or less Ti.
3. The magnetic recording medium according to Claim 1 or 2, characterized in that said nonmagnetic intermediate layer comprises Ru, Ir, Rh, Re or a Ru, Ir, Rh, or Re alloy containing 10 at% or more and 50 at% or less Ti, C, W, Mo, or Cu.
4. The magnetic recording medium according to any of Claims 1 to 3, characterized in that said nonmagnetic substrate is crystallized glass, chemically reinforced glass, or plastic.
5. A method of manufacturing a magnetic recording medium by sequentially stacking at least a nonmagnetic base layer, a nonmagnetic intermediate layer, and a magnetic layer on a nonmagnetic substrate, with the method being characterized in that:
the partial pressure of H₂O in an Ar atmosphere is controlled during film formation to make the crystal grains constituting said magnetic layer finer in order to obtain a uniform grain

size,

so that said magnetic layer is composed of fine crystal grains having a uniform grain size and exhibiting ferromagnetism and a nonmagnetic grain boundary surrounding the fine crystal grains, and is formed so as to have excellent electromagnetic conversion characteristics including reduced noise.

6. The method of manufacturing a magnetic recording medium according to Claim 5, characterized in that the partial pressure of H₂O during film formation is controlled to the order of 10⁻⁹ Torr, and preferably to within the range from 2 x 10⁻⁸ Torr to 2 x 10⁻⁹ Torr.

7. The method of manufacturing a magnetic recording medium according to Claim 5 or 6, characterized in that a film formation process is executed without heating said nonmagnetic substrate in advance.

8. A magnetic recording apparatus characterized by comprising a magnetic recording medium according to any of Claims 1 to 4 mounted therein.