



\*159159\*

## Perpendicular Magnetic Recording Medium And A Method For Manufacturing The Same

### Technical field of the invention

5       The present invention relates to a perpendicular magnetic recording medium and a manufacturing method therefor, in particular, to a perpendicular magnetic recording medium mounted on various magnetic recording devices such as an external memory device of a computer, and to a method for manufacturing such a  
10   medium.

### Background of the invention

As a technique to attain high density magnetic recording, a perpendicular magnetic recording system is drawing attention as an  
15   alternative to a conventional longitudinal magnetic recording system.

A crystalline film of CoCr alloy system is now mainly studied as a material for a magnetic recording layer of a perpendicular magnetic recording medium. In order to use in perpendicular magnetic  
20   recording, the crystal orientation is controlled such that c-axis of the CoCr alloy system having hcp structure aligns perpendicular to the film surface, that is, c-plane is parallel to the film surface. In order to achieve higher density in the CoCr alloy system, attempts are being made for finer grain size, reduction of dispersion of grain size



\*G00002\*

distribution, and decrease in magnetic interaction between grains.

A method for controlling a magnetic recording layer structure to raise recording density in a longitudinal recording medium has been proposed, for example, in United States Patent No. 5,679,473. A magnetic layer in this reference, generally called a granular magnetic layer, has a structure in which magnetic crystal grains are surrounded by nonmagnetic and nonmetallic substance such as an oxide or a nitride. Because the nonmagnetic and nonmetallic grain boundary phase separates the magnetic particles in the granular magnetic film, magnetic interaction between the magnetic particles decreases and formation of a zigzag-shaped magnetic domain wall in a transition region of a recording bit is suppressed. A low noise characteristic is considered to be attained for this reason.

15

Problem to be solved by the invention

On this background, the granular magnetic layer is proposed to apply to a recording layer of a perpendicular magnetic recording medium. IEEE Trans. Mag., Vol. 36, p 2393 (2000), for example, discloses a perpendicular magnetic recording medium comprising a ruthenium underlayer and a magnetic layer of CoPtCrO alloy having granular structure. In the literature referred to here, a magnetic film having granular structure was formed by reactive sputtering in an oxygen-containing atmosphere using a CoPtCr target. However,

since the quantity of the generated oxide is extremely sensitive to oxygen content of the sputtering atmosphere, it is difficult to control quantity of the oxide surrounding the magnetic crystal grains.

Besides, since the magnetic crystal grain is easily oxidized,

- 5 separation of the material for composing the magnetic crystal grains and the material for composing the oxide grain boundary is extremely difficult. Consequently, improvement is yet required.

It is important in the granular magnetic layer containing an  
10 oxide and a metal to appropriately control quantity of the oxide contained in the magnetic layer in order to control the crystal grains and segregation structure for ensuring the low noise characteristic. It is also required for achieving superior magnetic characteristic that the magnetic crystal grain does not include an oxide

15

Means to solve the problem

The inventors of the present invention has made extensive studies about the quantity of the oxide contained in the magnetic layer and a method to appropriately separate the oxide to the grain  
20 boundary in a perpendicular magnetic recording medium using a granular magnetic layer. As a result of the studies, a structure and a manufacturing method described below are found to be preferable for employing a granular magnetic layer in a perpendicular magnetic recording layer, in which the granular magnetic layer consists of

ferromagnetic crystal grains and nonmagnetic grain boundary region mainly composed of oxide surrounding the grains.

The first aspect of the invention is a perpendicular magnetic recording medium comprising a nonmagnetic substrate and the layers sequentially laminated on the substrate including at least a nonmagnetic underlayer, a magnetic layer, and a protective film. The nonmagnetic underlayer is composed of a metal or an alloy having a hexagonal closest-packed (hcp) crystal structure. The magnetic layer consists of ferromagnetic crystal grains and nonmagnetic grain boundary region composed mainly of oxide surrounding the grains. The ferromagnetic crystal grain is composed of an alloy containing at least cobalt and platinum. The volume of the nonmagnetic grain boundary region is from 15 % to 40 % of the whole volume of the magnetic layer.

Advantageously, the thickness of the magnetic layer is in the range from 5 nm to 20 nm in the perpendicular magnetic recording medium of the above-described structure.

Advantageously, the nonmagnetic substrate is made of a plastic resin in the perpendicular magnetic recording medium of the above-described structure.

The second aspect of the invention is a method for manufacturing a perpendicular magnetic recording medium of the above-described first to third aspects of the invention. The method features to comprise a step of depositing the magnetic layer by means of an RF magnetron sputtering method using a composite target containing a ferromagnetic alloy and an oxide.

Advantageously, the deposition process is performed without preheating the nonmagnetic substrate in the manufacturing process of the perpendicular magnetic recording medium.

Advantageously, the composite target contains oxide in a volume proportion of from 20 vol % to 35 % of the total volume of the target in the manufacturing process of the perpendicular magnetic recording medium.

#### Brief description of drawings

Figure 1 is a schematic cross-sectional view illustrating a structure of an embodiment of a perpendicular magnetic recording medium according to the present invention.

Figure 2 is a graph showing dependence of coercive force  $H_c$  on the volume proportion of the nonmagnetic grain boundary region in the

magnetic layer.

Figure 3 is a graph showing a relationship between the volume proportion of SiO<sub>2</sub> contained in the target and the volume proportion  
5 of the nonmagnetic grain boundary region in the magnetic layer.

Figure 4 is a graph showing dependence of the H<sub>c</sub> value on the thickness of the magnetic layer. H<sub>c</sub> was measured in the same manner as the measurement for Figure 2.

10

#### Aspects of embodiments of the invention

Some aspects of preferred embodiments of the invention will be described with reference to accompanying drawings.

Figure 1 is a schematic cross-sectional view illustrating a  
15 structure of an embodiment of a perpendicular magnetic recording medium according to the present invention. The perpendicular magnetic recording medium comprises a nonmagnetic substrate 1 and the layers sequentially laminated on the substrate including at least a nonmagnetic underlayer 2, a magnetic layer 3, and a  
20 protective film 4. A liquid lubricant layer 5 is formed on this laminate. Effects of the present invention can be fulfilled as well when a seed layer 11 is provided between the nonmagnetic underlayer 2 and the nonmagnetic substrate 1 for the purpose of controlling crystal alignment and grain size in the nonmagnetic

underlayer 2. The effects can also be obtained when a relatively thick soft magnetic layer generally called a backing layer having a thickness of several hundred nanometers is provided between the nonmagnetic underlayer 2 and the nonmagnetic substrate 1 for the purpose of enhancing regeneration sensitivity.

The nonmagnetic substrate 1 may be made of NiP-plated aluminum alloy, strengthened glass, or crystallized glass, which are all used in a usual magnetic recording medium. Because substrate heating is unnecessary, a substrate can be used that is made by injection-molding polycarbonate, polyolefin, or other plastic resin.

The nonmagnetic underlayer 2 needs to be a metal or an alloy having hexagonal closest-packed (hcp) crystal structure. Preferable materials of the underlayer for controlling crystal orientation in the granular magnetic layer includes a metal selected from Ti, Re, Ru, and Os, and an alloy containing at least one element selected from Ti, Re, Ru, and Os. Thickness of the underlayer is preferably in the range from 5 nm to 30 nm.

When the seed layer 11 is provided for the purpose of controlling the crystal orientation and the grain size of the nonmagnetic underlayer 2, the seed layer is preferably a metal or an alloy having a face centered cubic (fcc) crystal structure. The preferable material for

the seed layer includes a metal selected from Cu, Au, Pd, Pt, and Ir, an alloy containing at least one element selected from Cu, Au, Pd, Pt, and Ir, and an alloy containing at least Ni and Fe.

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

10        The magnetic layer 3 is a so-called granular magnetic layer consisting of ferromagnetic crystal grains and nonmagnetic grain boundary region surrounding the grains, the grain boundary region being composed of oxide of metal. The ferromagnetic crystal grain is preferably an alloy containing at least Co and Pt. Addition of Cr, Ta, B, or Cu into the CoPt alloy is preferable to control magnetic  
15        characteristic and attain low noise characteristic.

20        The ferromagnetic crystal grain needs to have a structure in which c-axis of the crystal lattice predominantly align perpendicular to the film surface.

      The volume of the nonmagnetic grain boundary region is necessarily in the range from 15 % to 40 % of the whole volume of the magnetic layer. Under 15 %, enough amount of grain boundary cannot exist between grains, and the magnetic interaction between

the grains cannot be decreased effectively. Over 40 %, crystal alignment of the grains deteriorates.

5       The oxide for forming the grain boundary is not limited to special materials insofar as the oxide is physically and chemically stable. The material that can be used includes an oxide of Mg, Cr, Ti, Zr, or Si.

10       The thickness of the magnetic layer 3 is preferably in the range from 5 nm to 20 nm. A thickness below 5 nm is improper because enough regeneration signals cannot be obtained. A thickness over 20 nm is undesirable because the grain size is liable to expand and the crystal alignment is apt to become disordered.

15       In producing a magnetic recording medium having the above-described layer construction and illustrated in Figure 1, the magnetic layer 3 is preferably formed by means of the following manufacturing method.

20       The magnetic layer is preferably deposited by means of an RF magnetron sputtering method using a composite target containing a ferromagnetic alloy and an oxide. By taking this method, separation between the crystal grain and the nonmagnetic grain boundary is promoted as compared with the case of reactive sputtering in an

oxygen-containing atmosphere using a target not containing oxide. Thus, a favorable granular structure can be constructed by the method of the invention.

5        In addition, the volume of the oxide contained in the composite target is necessarily in the range from 20 % to 35 % of the volume of the whole target in order to control the volume of the nonmagnetic grain boundary formed in the magnetic layer within the preferable range indicated above.

10

      In the process of manufacturing a perpendicular magnetic recording medium, omitting the step of substrate heating, which is the essential step in a conventional magnetic recording medium, still allows obtaining an excellent perpendicular magnetic recording  
15    medium. By virtue of the simplification of the production process, reduction of production cost can be achieved. Because substrate heating is unnecessary, a substrate made of plastics such as polycarbonate or polyolefin may be employed.

## 20    Examples

      The following describes specific examples of preferred embodiments of the present invention. These examples are presented only for an aid to appropriately explain the invention and not for restricting the invention within the examples.

### Example 1

An injection-molded polycarbonate substrate with 3.5 inch disk shape was used for a nonmagnetic substrate. After cleaning, the substrate was introduced into a sputtering apparatus. A seed layer 5 nm thick was formed of platinum under argon gas pressure of 5 mTorr. Then, a nonmagnetic underlayer of ruthenium having a thickness of 20 nm was formed under argon gas pressure of 5 mTorr. Subsequently, a granular magnetic layer 20 nm thick was formed by means of an RF magnetron sputtering method using a target of  $\text{Co}_{75}\text{Cr}_{10}\text{Pt}_{15}$  target containing various quantity of  $\text{SiO}_2$  under argon gas pressure of 5 mTorr. After laminating a carbon protective film 10 nm thick, the resulted substrate was taken out from the vacuum chamber. Applying liquid lubricant to the thickness of 1.5 nm, a magnetic recording medium having structure as shown in Figure 1 was produced. Substrate heating prior to the deposition was not executed.

Figure 2 shows dependence of coercive force  $H_c$  on the volume proportion of the nonmagnetic grain boundary region in the magnetic layer. The coercive force was measured by a vibrating sample magnetometer applying magnetic field perpendicular to the film surface. It can be seen that the  $H_c$  values higher than 3,000 Oe are obtained when the volume proportion of the nonmagnetic grain boundary region in the magnetic layer is in the range from 15 % to

40 %.

Figure 3 shows a relationship between the volume proportion of SiO<sub>2</sub> contained in the target and the volume proportion of the nonmagnetic grain boundary region in the magnetic layer. The volume proportion occupied by the nonmagnetic grain boundary region in the magnetic layer was obtained by measuring the area occupied by grain boundary region and the area occupied by grains on a planar image taken by a transmission electron microscope (TEM). Figure 3 indicates that the volume proportion of the nonmagnetic grain boundary region in the magnetic layer is in the range from 15 % to 40 % when the volume proportion of the SiO<sub>2</sub> in the target is from 20 % to 35 %.

## Example 2

A magnetic recording medium having a structure as shown in Figure 1 was produced in the same manner as in Example 1 except that the quantity of SiO<sub>2</sub> contained in the target was fixed at 25 % and the thickness of the deposited magnetic layer was varied from 3 nm to 50 nm.

Figure 4 shows dependence of H<sub>c</sub> values on the thickness of the magnetic layer. H<sub>c</sub> was measured in the same manner as described relating to Figure 2. H<sub>c</sub> values higher than 3,000 Oe were obtained

by the magnetic layer with the thickness in the range from 5 nm to 20 nm. It may be supposed that  $H_c$  decreased in the region thinner than 5 nm by the influence of thermal disturbance, while in the region thicker than 20 nm,  $H_c$  decreased due to disordered crystal alignment  
5 in the grains in the magnetic layer.

### Advantageous Effect of the invention

A perpendicular magnetic recording medium of the present invention comprises a granular magnetic layer that is a magnetic  
10 layer consisting of ferromagnetic crystal grains and nonmagnetic grain boundary region of mainly oxide surrounding the grain, and a nonmagnetic underlayer composed of a metal or an alloy having a hexagonal closest-packed (hcp) crystal structure. The ferromagnetic crystal grain is composed of an alloy containing at least cobalt and  
15 platinum. By controlling the volume of the nonmagnetic grain boundary region within the range from 15 % to 40 % of the volume of the whole magnetic layer, the crystal grains and the grain boundary region are favorably controlled, to achieve excellent magnetic and low noise characteristics.

20

In addition, by controlling a thickness of the magnetic layer in the range from 5 nm to 20 nm, necessary and sufficient regeneration output can be gained; and crystal alignment is prevented from deteriorating and grain size is prevented from enlargement.

In a method for manufacturing a perpendicular magnetic recording medium according to the invention, a magnetic layer is deposited by means of an RF magnetron sputtering method using a composite target containing a ferromagnetic alloy and an oxide. By  
5 controlling the volume of the oxide contained in the target in the range from 20 % to 35 % of the volume of the whole target, the oxide entrapped in the ferromagnetic crystal grains can be minimized and the quantity of the oxide mainly composing the grain boundary can be controlled within a preferable range.

10

By employing the structure of a medium and the manufacturing method as described above, an excellent perpendicular magnetic recording medium can be easily obtained. Consequently, substrate heating is unnecessary in the depositing processes for a medium  
15 according to the invention. As a result, simplification and cost reduction in the production process can be achieved. Further, inexpensive plastics can be used for a substrate as well as a conventional aluminum substrate and a glass substrate.

20

## Claims

1. A perpendicular magnetic recording medium comprising:  
a nonmagnetic substrate, and layers sequentially laminated on  
said substrate including at least a nonmagnetic underlayer, a  
5 magnetic layer, and a protective film, wherein said nonmagnetic  
underlayer is composed of a metal or an alloy having a hexagonal  
closest-packed (hcp) crystal structure; and said magnetic layer  
consists of ferromagnetic crystal grains and nonmagnetic grain  
boundary region mainly composed of oxide surrounding said grains,  
10 said grains being composed of an alloy containing at least cobalt and  
platinum, and a volume occupied by said grain boundary region is  
from 15 % to 40 % of total volume of said magnetic layer.
2. A perpendicular magnetic recording medium according to claim 1,  
15 wherein a thickness of said magnetic layer is in the range from 5 nm  
to 20 nm.
3. A perpendicular magnetic recording medium according to claim 1  
or claim 2, wherein said substrate is composed of a plastic resin.  
20
4. A method for manufacturing a perpendicular magnetic recording  
medium comprising steps of:  
depositing a nonmagnetic underlayer composed of a metal or an  
alloy having a hexagonal closest-packed (hcp) crystal structure on a

nonmagnetic substrate;

depositing a magnetic layer consisting of ferromagnetic grains and nonmagnetic grain boundary region surrounding said grains by means of an RF magnetron sputtering method using a composite target containing a ferromagnetic alloy and an oxide on said underlayer, wherein said grains are composed of an alloy containing at least cobalt and platinum, and volume of said grain boundary region is from 15 % to 40 % of total volume of said magnetic layer; and

depositing a protective film.

5. A method for manufacturing a perpendicular magnetic recording medium according to claim 4, wherein said depositing steps are conducted without preheating said substrate.

6. A method for manufacturing a perpendicular magnetic recording medium according to claim 4 or claim 5, wherein a volume occupied by said oxide contained in said composite target is in a range from 20 % to 35 % of a total volume of said target.