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(54) **PATTERNED MAGNETIC RECORDING MEDIUM AND METHOD OF MANUFACTURING THE SAME**

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(52) **U.S. Cl.** ..... **428/141**; 427/497; 427/466; 427/467; 427/578; 427/585; 427/128; 428/167; 428/173; 428/694 T

(57) **ABSTRACT**

Provided are a patterned magnetic recording medium which has an extremely planarized surface and a method of manufacturing the same. The medium includes a patterned magnetic layer including a plurality of magnetic columns that are arranged with a predetermined pitch therebetween; a substrate that supports the patterned magnetic layer; and a boundary layer, which is filled in gaps between the magnetic columns of the patterned magnetic layer. Thus, an air bearing due to stable airflow is created over the magnetic layer, and magnetic recording/reproduction are easily achieved at ultrahigh density.

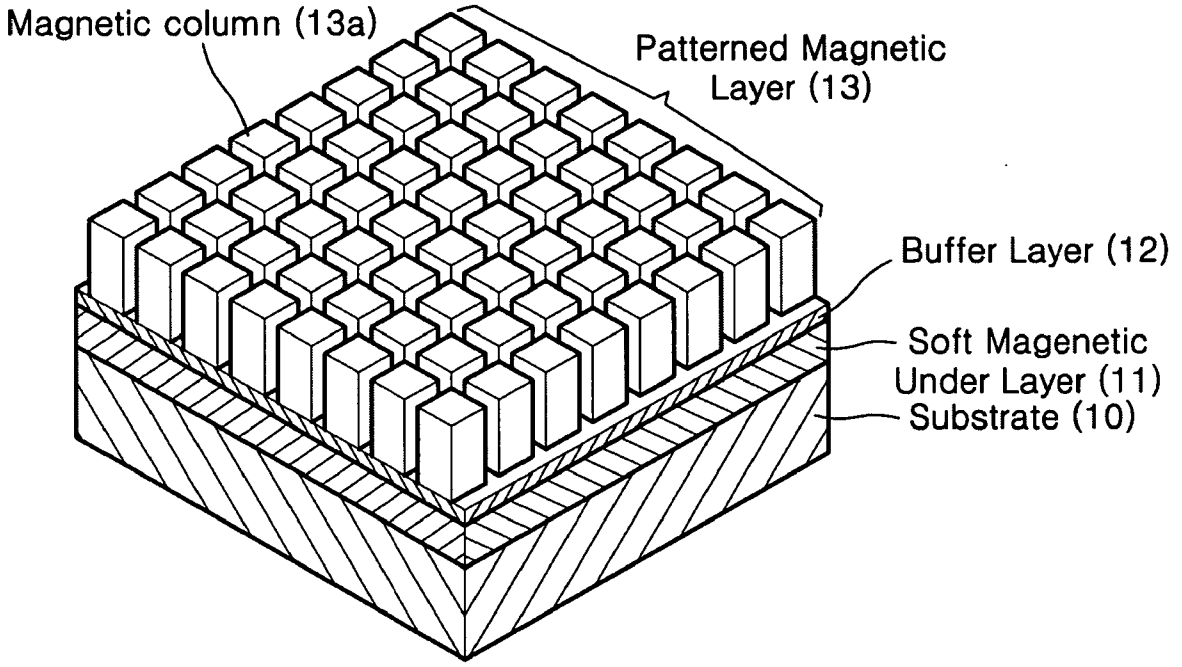


FIG. 1

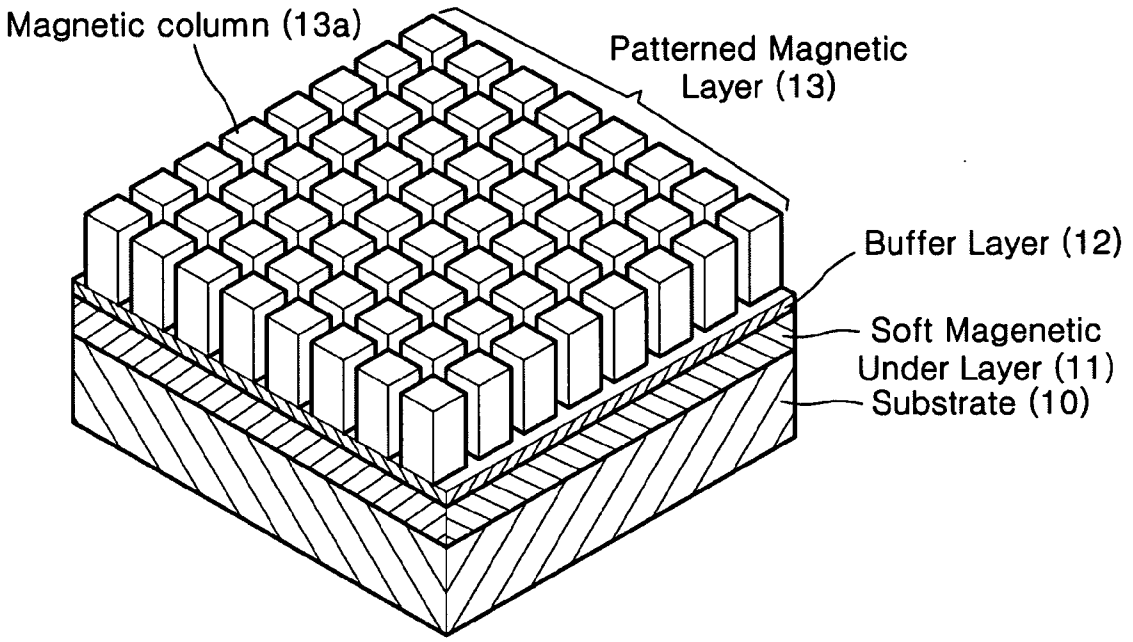

Magnetic column (13a)
Patterned Magnetic Layer (13)
Buffer Layer (12)
Soft Magenetic Under Layer (11)
Substrate (10)

FIG. 2

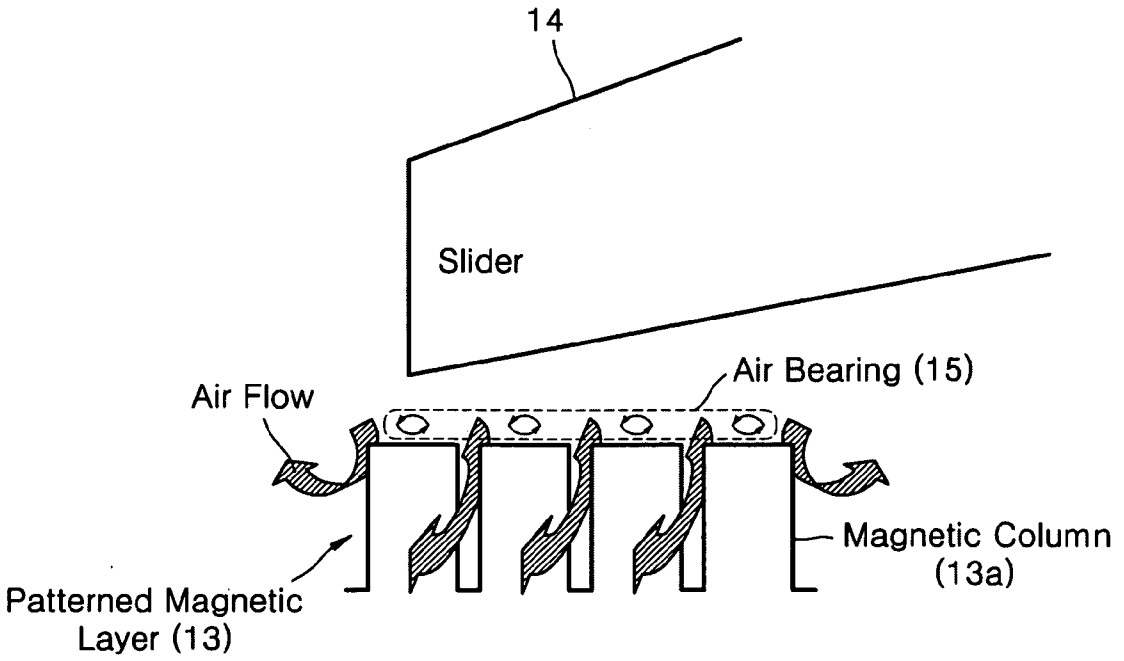

14
Slider
Air Bearing (15)
Air Flow
Magnetic Column (13a)
Patterned Magnetic Layer (13)

FIG. 3

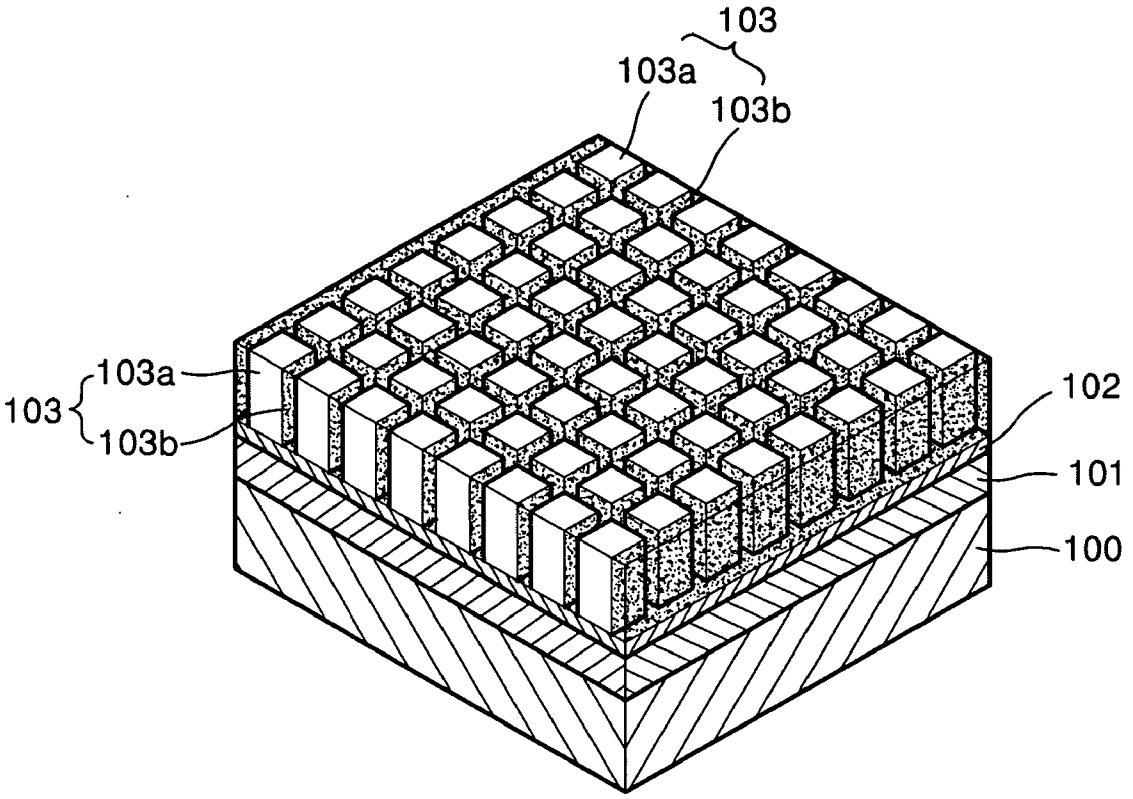

103
103a
103b
103a
103
103b
102
101
100

FIG. 4

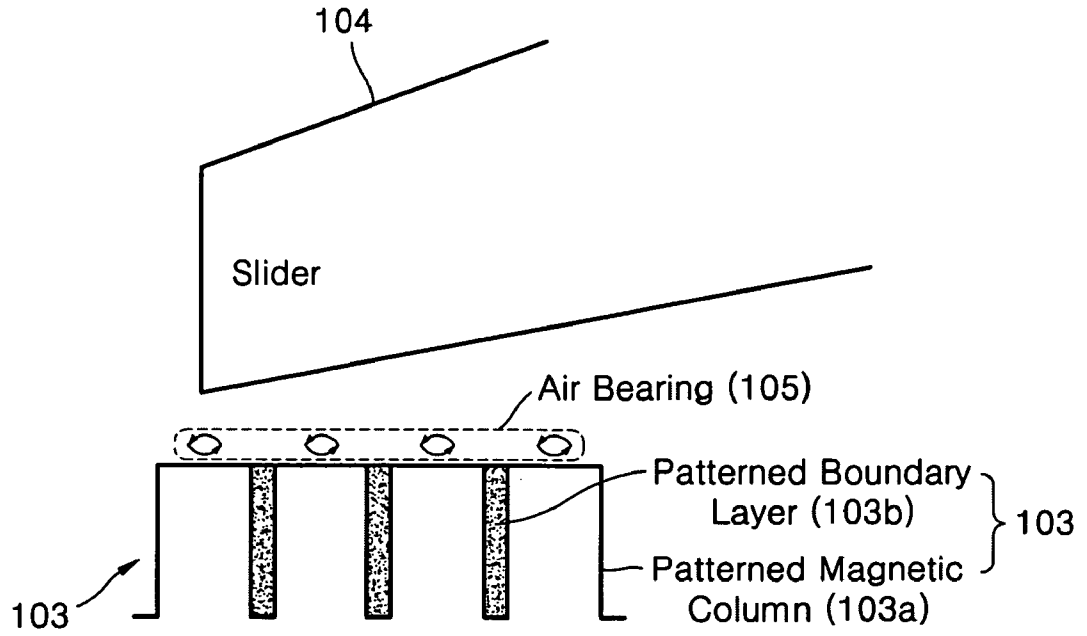

104
Slider
Air Bearing (105)
Patterned Boundary Layer (103b)
Patterned Magnetic Column (103a)
103
103

FIG. 5A

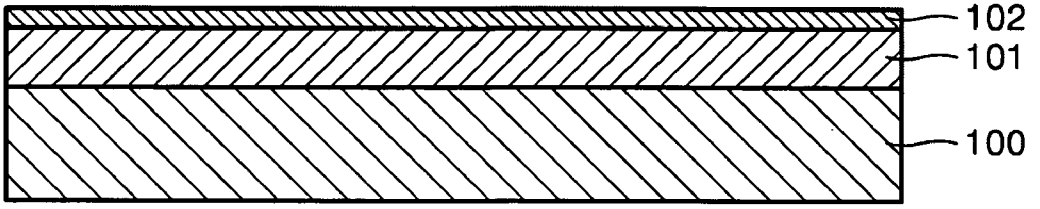



FIG. 5B

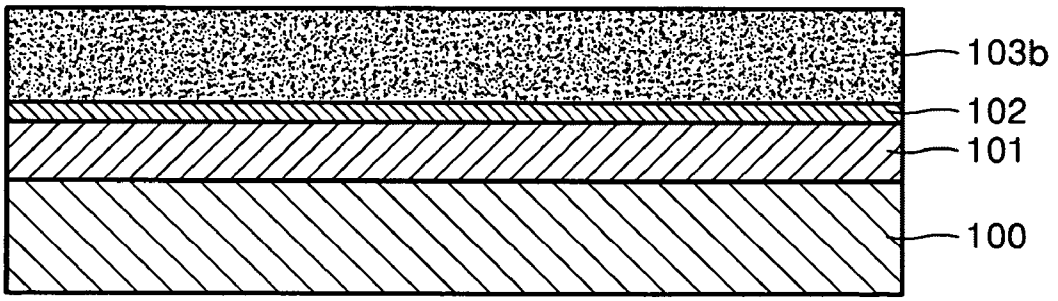



FIG. 5C

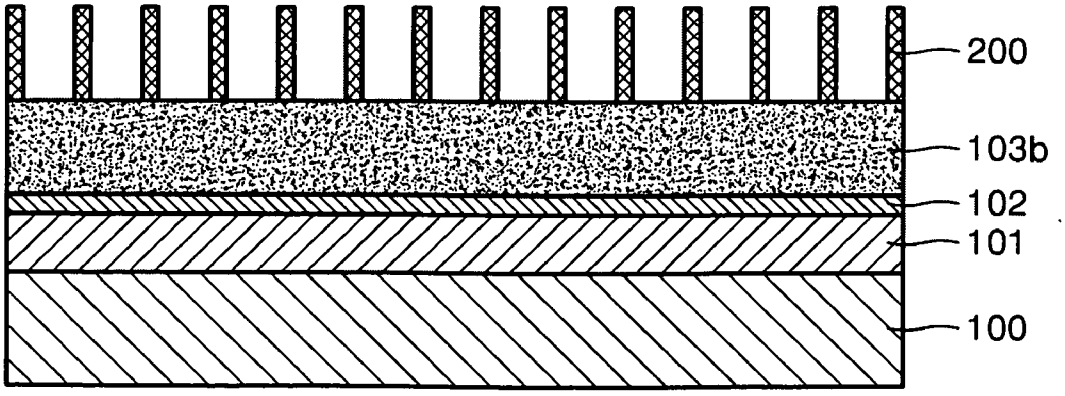


FIG. 5D

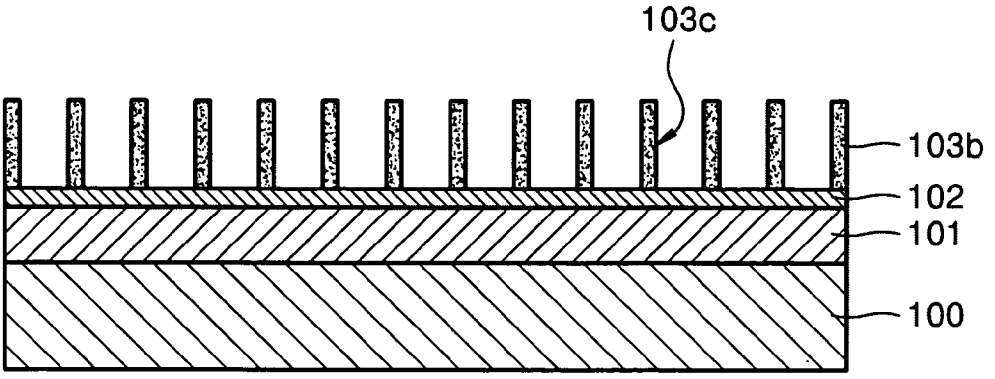



FIG. 5E

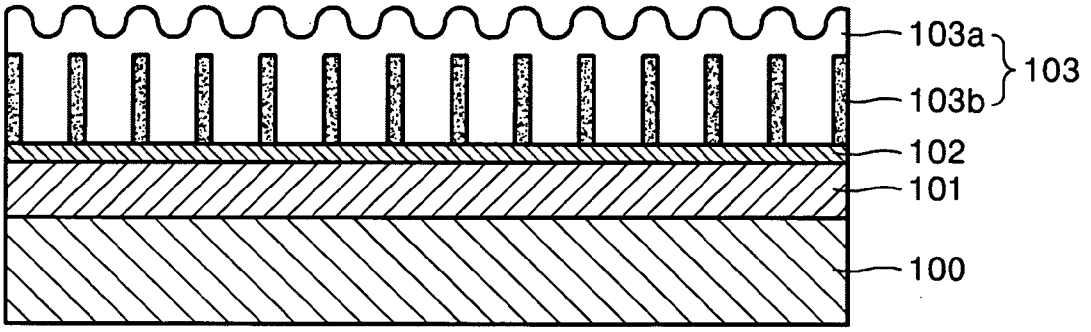



FIG. 5F

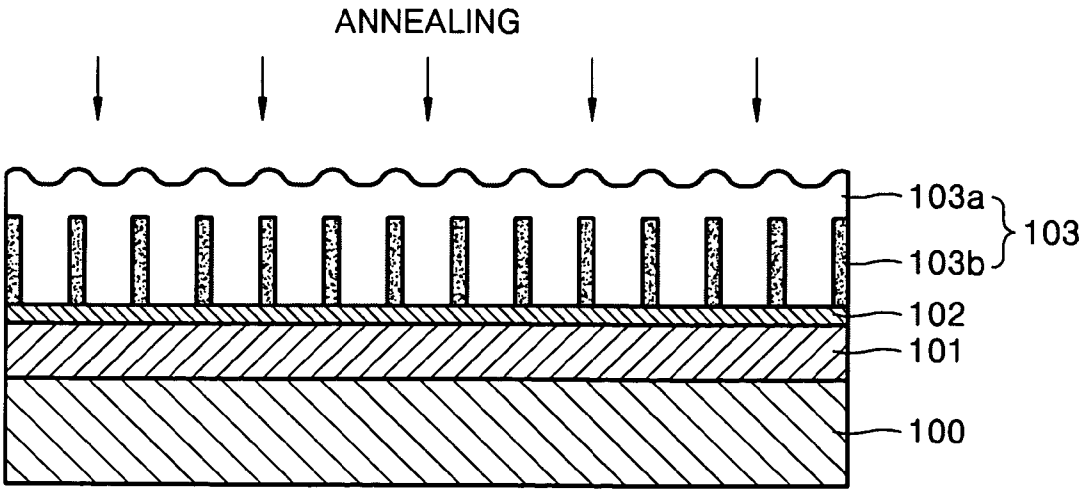


FIG. 5G

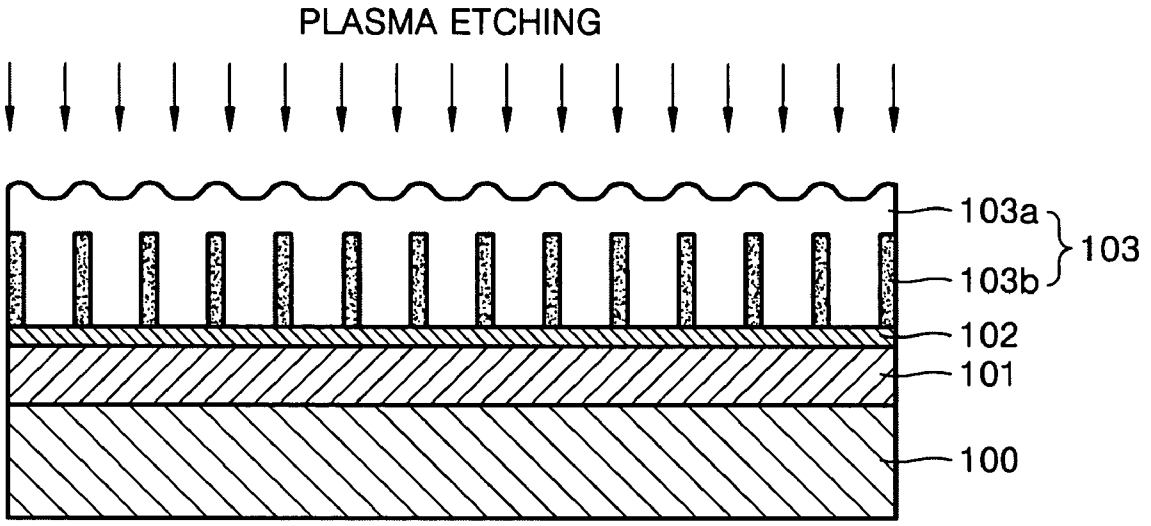
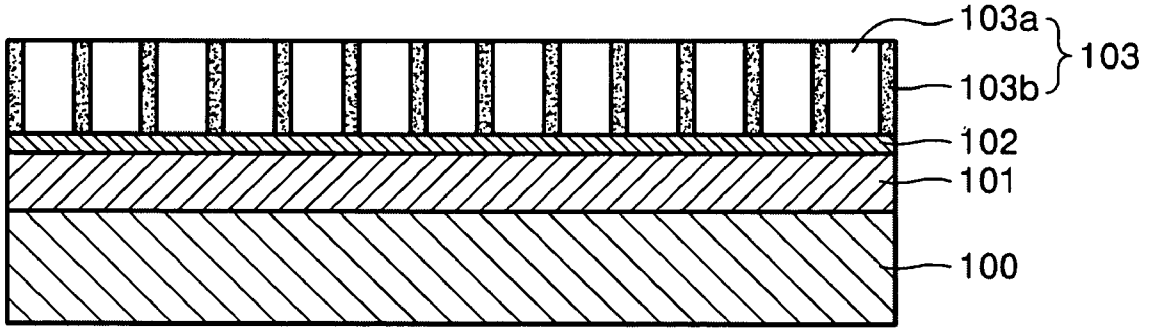

PLASMA ETCHING
103a
103
103b
102
101
100

FIG. 5H


103a
103
103b
102
101
100

# PATTERNED MAGNETIC RECORDING MEDIUM AND METHOD OF MANUFACTURING THE SAME

[0001] This application claims the priority of Korean Patent Application No. 2003-49550, filed on Jul. 19, 2003, in the Korean Intellectual Property Office, the disclosure of which is incorporated herein in its entirety by reference.

## BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The present invention relates to a patterned magnetic recording medium and a method of manufacturing the same, and more particularly, to a planarized patterned magnetic recording medium and a method of manufacturing the same.

[0004] 2. Description of the Related Art

[0005] When a magnetic grain size is reduced to less than a certain critical value, a magnetic recording medium that employs a typical bulk magnetic layer reveals a superparamagnetic effect. The superparamagnetic effect reduces the number of bits per area, i.e., the recording density. Thus, to improve the recording density by suppressing the superparamagnetic effect, there is provided a patterned medium on which magnetic grains are structurally isolated from one another. U.S. Patent Applications No. 2002/0068195 A1 and No. 2002/0154440 A1 disclose such a patterned medium. In comparison with a conventional magnetic recording medium using a bulk magnetic layer, such a patterned medium leads to a much higher recording density of approximately 1000 Gbit per inch square or more.

[0006] **FIG. 1** is an exploded view of a conventional patterned magnetic recording medium. The patterned magnetic recording medium is in the form of a disk that is rotated by a spindle motor, but **FIG. 1** illustrates only an exploded portion thereof.

[0007] Referring to **FIG. 1**, a soft magnetic under layer **11** is disposed on the surface of a substrate **10** formed of glass or aluminum or a platter, and a buffer layer **12** is disposed on the soft magnetic under layer **11**. A patterned magnetic layer **13** is then disposed on the buffer layer **12**.

[0008] The patterned magnetic layer **13** includes a plurality of magnetic columns **13***a*, which are regularly aligned with a pitch of 0.2 nm and have a height of approximately several to several tens of nm. Thus, air gaps are formed in spaces between the magnetic columns **13***a*.

[0009] In such a circumference, if a relative movement between the medium and a slider **14** on which magnetic recording/reading heads are mounted occurs as illustrated in **FIG. 2**, an air bearing **15** is created between the slider **14** and the patterned magnetic layer **13**. At this time, air flows through the air gaps between the magnetic columns **13***a* below the air bearing **15**. Thus, the pressure of the air bearing **15**, which is applied between the slider **14** and the patterned magnetic layer **13**, is reduced due to air turbulence.

[0010] As the pressure of the air bearing **15** is reduced and becomes unstable, the slider **14** using a swing arm cannot stably swing over the patterned magnetic layer **13** and, above all, the slider **14** collides with the patterned magnetic layer **13**, thereby causing defects to the magnetic layer **13**.

## SUMMARY OF THE INVENTION

[0011] The present invention provides a patterned magnetic recording medium which can produce a stable air bearing and a method of manufacturing the same. Thus, a slider can stably fly over a magnetic layer owing to the stable air bearing, and collision of the slider with the magnetic layer can be prevented.

[0012] Also, the present invention provides a patterned magnetic recording medium in which a boundary layer formed of a nonmagnetic insulator is disposed between patterned magnetic columns to thereby reduce noise interferences between bits comprised in the patterned columns and a method of manufacturing the same.

[0013] According to an aspect of the present invention, there is provided a patterned magnetic recording medium comprising a patterned magnetic layer including a plurality of magnetic columns that are arranged with a predetermined pitch; a substrate, which supports the patterned magnetic layer; and a boundary layer, which is filled in gaps between the magnetic columns of the patterned magnetic layer.

[0014] A buffer layer may be disposed between the patterned magnetic layer and the substrate.

[0015] A soft magnetic under layer may be disposed between the buffer layer and the substrate.

[0016] According to another aspect of the present invention, there is provided a method of manufacturing a patterned magnetic recording medium. The method includes preparing a substrate; forming a boundary layer on the substrate, the boundary layer having wells that are arranged with a predetermined pitch; filling the wells with a magnetic material layer by coating the magnetic material layer on the boundary layer; and planarizing the boundary layer and a magnetic layer including magnetic columns filled in the wells of the boundary layer.

[0017] When the substrate is prepared, a soft magnetic under layer and a buffer layer may be formed on the substrate.

[0018] To form the boundary layer, a nonmagnetic material may be coated on the substrate to a predetermined thickness, and a boundary layer having wells may be formed by patterning the nonmagnetic material in a predetermined pattern.

[0019] The coating of the magnetic material layer may comprise annealing the coated magnetic material layer at a predetermined temperature. The barrier layer and the magnetic layer may be planarized using plasma etching.

[0020] The boundary layer may be formed of one of silicon oxide ($SiO_2$) and silicon oxynitride ($Si_3N_4$), which are dielectric materials, using chemical vapor deposition (CVD) or physical vapor deposition (PVD), for example, plasma-enhanced chemical vapor deposition (PECVD) or plasma sputtering.

[0021] Also, the magnetic material layer may be formed of tetracyanoethanide (TCNE)-based magnetic polymer using spin coating or CVD. The magnetic material layer may be annealed at a temperature ranging from 100 to 300° C. Thus, the magnetic material layer is reflowed and densified and voids in the wells are completely removed.

## BRIEF DESCRIPTION OF THE DRAWINGS

[0022] 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:

[0023] **FIG. 1** is an exploded view of a conventional patterned magnetic recording medium;

[0024] **FIG. 2** illustrates a relationship between an air bearing that is produced over the conventional magnetic recording medium of **FIG. 1** and a slider;

[0025] **FIG. 3** is an exploded view of a patterned magnetic recording medium according to the present invention;

[0026] **FIG. 4** illustrates a relationship between an air bearing that is produced over the surface of the patterned magnetic recording medium of **FIG. 3** and a slider flying over the patterned magnetic recording medium; and

[0027] **FIGS. 5A through 5G** are cross-sectional views illustrating a method of manufacturing the patterned magnetic recording medium of **FIG. 3**.

## DETAILED DESCRIPTION OF THE INVENTION

[0028] The present invention will now be described more fully with reference to the accompanying drawings, in which exemplary embodiments of the invention are shown.

[0029] **FIG. 3** is an exploded view of a patterned magnetic recording medium including a planarized magnetic recording layer, according to the present invention.

[0030] Referring to **FIG. 3**, a soft magnetic under layer **101** is disposed on a substrate **100** formed of glass or aluminum or a platter, and a buffer layer **102** is disposed on the soft magnetic under layer **101**. On top of the buffer layer **102**, a patterned magnetic layer **103** is disposed. The magnetic layer **103** includes a patterned boundary layer **103***b*, which is patterned in gratings, and patterned magnetic columns **103***a*, which are filled in a plurality of wells formed in the patterned boundary layer **103***b*.

[0031] Since the patterned magnetic layer **103** has no air gaps between the magnetic columns **103***a*, air turbulence or pressure reduction due to airflow does not occur. As a result, a stable air bearing **105** is produced between a slider **104** and the patterned magnetic layer **103**, as illustrated in **FIG. 4**.

[0032] This stable air bearing **104** allows the slider **104** to stably fly over the magnetic layer **103** and prevents collision or friction between the slider **104** and the magnetic layer **103**.

[0033] In addition, the boundary layer **103** formed of a nonmagnetic insulator, which is disposed between the magnetic columns **103***a*, can reduce noise interferences between respective bits comprised in the magnetic columns **103***a*.

[0034] To realize a high data recording density of approximately 1000 Gb/in$^2$, the size of each of the wells formed in the boundary layer **103***b*, i.e., the area of each of the magnetic columns **103***a*, should be approximately 25 nm, and the thickness of the boundary layer **103***b*, i.e., the pitch between the wells, should be limited to approximately several nm. These conditions can be satisfied using nanolithographic technology.

[0035] Hereinafter, a method of manufacturing a patterned magnetic recording medium according to an embodiment of the present invention will be described with reference to **FIGS. 5A through 5G**.

[0036] Referring to **FIG. 5A**, a substrate **100** on which a soft magnetic under layer **101** and a buffer layer **102** are formed is prepared.

[0037] Referring to **FIG. 5B**, a material layer **103***b* for forming a magnetic barrier layer is formed on the buffer layer **102** using plasma-enhanced chemical vapor deposition (PECVD) or sputtering.

[0038] Referring to **FIG. 5C**, a photoresist mask **200** is formed on the material layer **103***b* for forming the magnetic barrier layer. To realize a subsequent nanometer patterning process, the photoresist mask **200** is formed using a nanolithgraphic technique, such as electronic beam lithography, X-ray lithography, deep ultraviolet (DUV) lithography, extreme ultraviolet (EUV) lithography, or nanoimprinting.

[0039] Referring to **FIG. 5D**, portions of the material layer **103** for forming the magnetic barrier layer, which are not covered by the photoresist mask **200**, are etched using a reactive ion beam etch (RIE) process. Thus, wells **103***c* are formed in the material layer **103***b* for forming the barrier layer, and a desired barrier layer **103***b* is obtained. After the barrier layer **103***b* is formed, the photoresist mask **200** is removed by stripping.

[0040] Referring to **FIG. 5E**, a magnetic material layer **103***a* formed of tetracyanoethanide (TCNE) is formed to a predetermined thickness on the barrier layer **103***b*. The magnetic material layer **103***a* is formed to completely fill the wells **103***c* and cover the barrier layer **103***b*.

[0041] Referring to **FIG. 5F**, the magnetic material layer **103***a* is annealed at a temperature of approximately 100 to 300° C. to allow the magnetic material layer **103***a* to reflow. Thus, the material layer **103***a* is densified, voids are completely removed, and the surface of the material layer **103***a* is less flexural.

[0042] Referring to **FIG. 5G**, an etchback process, i.e., plasma etching, is performed on the entire surface of the magnetic material layer **103***a*. As a result, a planarized magnetic layer **103**, which includes the barrier layer **103***b* and magnetic columns **103***a* that are filled in wells formed in the barrier layer **103***b*, is completed as shown in **FIG. 5H**.

[0043] In the present invention, a polymer-based magnetic material is used instead of conventionally used metal- or ceramic-based magnetic materials. Here, magnetic polymer is used not only as a magnetic recording material but also as a material for planarizing a geometric structure. Accordingly, a desired patterned magnetic recording layer can be obtained using a process that is no more complicated than a process in the conventional case.

[0044] Meanwhile, since magnetic polymer is deposited using spin coating or chemical vapor deposition (CVD), which is processed very slowly, the barrier layer **103***b* with a very fine structure has a good step coverage characteristic. Also, the annealing process is performed so that the magnetic material layer **103***a* is reflowed and densified and the roughness of its surface is improved. As a result, a planarized recording layer with a roughness of 1 nm or less can be obtained. If a planarization process using an etch process

is additionally performed, a recording layer with an extremely low roughness of 1 nm or less can be obtained.

[0045] As a stable air bearing is produced on the recording layer, the slider can fly over the recording layer while maintaining a very constant flying height.

[0046] As explained thus far, a recording layer that has a very planarized surface and allows a stable air bearing can be achieved. Thus, an ultrahigh recording density of 1000 $Gb/in^2$ can be ensured. Further, by using a boundary layer formed of a nonmagnetic insulator, which is disposed between patterned magnetic columns, noise interferences between bits can be reduced.

[0047] 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 patterned magnetic recording medium comprising:

a patterned magnetic layer including a plurality of magnetic columns that are arranged with a predetermined pitch;

a substrate, which supports the patterned magnetic layer; and

a boundary layer, which is filled in gaps between the magnetic columns of the patterned magnetic layer.

**2**. The medium of claim 1, further comprising a buffer layer disposed between the patterned magnetic layer and the substrate.

**3**. The medium of claim 2, further comprising a soft magnetic under layer disposed between the buffer layer and the substrate.

**4**. The medium of claim 1, wherein the magnetic columns are formed of a tetracyanoethanide (TCNE)-based material.

**5**. The medium of claim 1, wherein the boundary layer is formed of one of silicon oxide ($SiO_2$) and silicon oxynitride ($Si_3N_4$).

**6**. A method of manufacturing a patterned magnetic recording medium, the method comprising:

preparing a substrate;

forming a boundary layer on the substrate, the boundary layer having wells that are arranged with a predetermined pitch;

filling the wells with a magnetic material layer by coating the magnetic material layer on the boundary layer; and

planarizing the boundary layer and a magnetic layer including magnetic columns filled in the wells of the boundary layer.

**7**. The method of claim 6, wherein the preparing of the substrate comprises forming a soft magnetic under layer and a buffer layer on the substrate.

**8**. The method of claim 6, wherein the forming of the boundary layer comprises:

coating a nonmagnetic material on the substrate to a predetermined thickness; and

forming a boundary layer having wells by patterning the nonmagnetic material in a predetermined pattern.

**9**. The method of claim 6, wherein the coating of the magnetic material layer comprises annealing the coated magnetic material layer at a predetermined temperature.

**10**. The method of claim 7, wherein the coating of the magnetic material layer comprises annealing the coated magnetic material layer at a predetermined temperature.

**11**. The method of claim 8, wherein the coating of the magnetic material layer comprises annealing the coated magnetic material layer at a predetermined temperature.

**12**. The method of claim 6, wherein the planarizing of the barrier layer and the magnetic layer is performed using plasma etching.

**13**. The method of claim 6, wherein the boundary layer is formed of one of silicon oxide ($SiO_2$) and silicon oxynitride ($Si_3N_4$), which are dielectric materials.

**14**. The method of claim 8, wherein the boundary layer is formed of one of silicon oxide ($SiO_2$) and silicon oxynitride ($Si_3N_4$), which are dielectric materials.

**15**. The method of claim 8, wherein the boundary layer is formed using one selected from the group consisting of chemical vapor deposition, plasma-enhanced chemical vapor deposition, and physical vapor deposition.

**16**. The method of claim 6, wherein the magnetic material layer is formed of tetracyanoethanide (TCNE)-based magnetic polymer.

**17**. The method of claim 16, wherein the magnetic material layer is formed using one of spin coating and chemical vapor deposition.

**18**. The method of claim 17, further comprising annealing the magnetic material layer at a temperature ranging from 100 to 300° C. to allow the magnetic material layer to reflow.

* * * * *