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TITLE OF THE INVENTION

METHOD FOR MANUFACTURING SUBSTRATE FOR DISCRETE TRACK
RECORDING MEDIA AND METHOD FOR MANUFACTURING DISCRETE
TRACK RECORDING MEDIA

5 BACKGROUND OF THE INVENTION

One embodiment of the present invention relates to a method for manufacturing a substrate for a discrete track recording media and a method for manufacturing a discrete track recording media.

10 In improving track density of a hard disk drive (HDD), the problem of interference with adjacent tracks has become obvious. In particular, a reduction in write-blur due to a fringe effect of a write head magnetic field is an important technical problem. A
15 discrete track recording media (DTR media) in which recording tracks are physically separated can reduce a side-erase phenomenon at the time of writing, and a side-read phenomenon that information of adjacent tracks are mixed up at the time of reading, and the
20 like. Consequently, it is possible to greatly improve the track density, which can provide a magnetic recording media onto which high-density recording is possible.

Methods for manufacturing a DTR media mainly
25 include a method of magnetic film etching type and a method of substrate etching type. The method for manufacturing a DTR media of magnetic film etching



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type involves a large number of manufacturing steps and is thus expected to increase costs. On the other hand, a method for manufacturing a DTR media of substrate etching type is suitable for mass
5 production; the method first manufactures a substrate having protrusions and recesses and deposits a magnetic layer on the substrate by a sputtering method as is the case with the prior art. However, in a DTR media manufactured in accordance with the method of
10 substrate etching type, the top surfaces of the protrusions are inferior in flatness. It is thus difficult to perform write and read operations using a head with low flying height. If a DTR media is directly manufactured by the method of substrate
15 etching type including an imprinting method, burrs may be created at the edges of the protrusions. This may affect subsequent deposition of a magnetic film to preclude the tops of recording tracks from retaining flatness. If a DTR media is manufactured by the
20 method of substrate etching type, a magnetic material deposited on a remaining resist that has failed to be removed may be peeled off, which degrades a head disk interface (HDI).

Jpn. Pat. Appln. KOKAI Publication No. 2004-79992
25 discloses a semiconductor manufacturing process in which contaminating particles are removed by a cryogenic cleaning process using CO₂ after chemical

mechanical polishing (CMP) of a semiconductor material. In this method, liquid CO₂ is jet sprayed through a specially designed nozzle, for example, under a pressure of 850 psi (5.8 MPa) at 25°C. The
5 liquid CO₂ is jet sprayed in an atmospheric pressure, and thus is rapidly expanded and evaporated into gaseous CO₂. Further, with lowering of temperature, part of the gaseous CO₂ forms carbon dioxide snow containing solid and liquid CO₂. The flow of the
10 gaseous and solid CO₂ is directed to the wafer surface using the nozzle. Cryogenic particles that reach the wafer surface at a high speed and collide with contaminating particles can overcome adhesion of the contaminating particles to the wafer surface through
15 transfer of momentum between the cryogenic particles and contaminating particles, and can remove the contaminating particles directly. In Jpn. Pat. Appln. KOKAI Publication No. 2004-79992, however, contaminating particles to be removed are at most
20 0.3 µm in size. Burrs that may result from the manufacture of a DTR media using a method of substrate etching type are much larger than those to be removed in Jpn. Pat. Appln. KOKAI Publication No. 2004-7992. Further, the burrs to be removed are composed of the
25 same material as that of the substrate. This precludes the burrs from being removed.

US Patent No. 5,853,962 discloses a method and

apparatus for removing photoresist and redeposited materials on a semiconductor using liquid carbon dioxide snow. However, an incomplete result was obtained from an attempt to remove burrs from a substrate after an imprint step using the apparatus described in U.S. Patent No. 5,853,962. The cause is expected to be similar to that of the disadvantage of Jpn. Pat. Appln. KOKAI Publication No. 2004-79992.

BRIEF SUMMARY OF THE INVENTION

According to one embodiment of the present invention, there is provided a method for manufacturing a substrate for a discrete track recording media, the method comprising: forming an imprint resist layer on a substrate; imprinting, on the imprint resist layer, a stamper formed with patterns of protrusions and recesses corresponding to recording track zones and servo zones to transfer the patterns of protrusions and recesses to the imprint resist layer; removing the stamper from the imprint resist layer; and diffusing liquefied CO₂ in a process chamber set at a pressure of 2 to 5 atm, diffusing liquefied H₂O in the process chamber set at a pressure of 0.01 to 1 atm, or diffusing a reactive gas selected from a group consisting of liquefied CF₄, CHF₃, SF₆, and C₂F₆ in the process chamber set at an arbitrary pressure, to jet spray the liquefied gas onto a surface of the substrate.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate embodiments of the invention, and together with the general description given above and the detailed description of the embodiments given below, serve to explain the principles of the invention.

FIGS. 1A, 1B, 1C, 1D, and 1E are diagrams showing exemplary processes for manufacturing a DTR substrate and a DTR media using a method of a substrate etching type according to an embodiment of the present invention;

FIG. 2 is a schematic view showing a liquefied gas jet spraying step used in the present invention;

FIGS. 3A, 3B, 3C, 3D, and 3E are diagrams showing exemplary processes for manufacturing a DTR substrate and a DTR media using a method of substrate etching type according to a second embodiment of the present invention;

FIGS. 4A, 4B, and 4C are diagrams showing exemplary processes for manufacturing a DTR substrate and a DTR media using a method of substrate etching type according to a third embodiment of the present invention; and

FIGS. 5A, 5B, 5C, 5D, and 5E are diagrams showing exemplary processes for manufacturing a DTR media if the present invention is used for liftoff.

DETAILED DESCRIPTION OF THE INVENTION

The present inventors assumed that a failure to effectively jet spray a liquid through nozzles is the cause of failure of conventional techniques to effectively remove burrs that may result from a process of manufacturing a DTR using a method of substrate etching type. The present inventors have found through their devoted studies that adjusting the pressure in a process chamber during a jet spray step enables burrs to be removed more effectively than the conventional techniques. Specifically, the present inventors have found that the liquefied gas is preferably jet sprayed onto a surface of a substrate by diffusing it in the process chamber set as follows:

liquefied CO₂ is diffused in the process chamber set at a pressure of 2 to 5 atm, liquefied H₂O is diffused in the process chamber set at a pressure of 0.01 to 1 atm, or a reactive gas selected from a group consisting of liquefied CF₄, CHF₃, SF₆, and C₂F₆ is diffused in the process chamber set at an arbitrary pressure.

FIGS. 1A, 1B, 1C, 1D, and 1E show processes for manufacturing a substrate and a DTR media which have protrusions and recesses using a method of substrate etching type according to a first embodiment of the present invention.

As shown in FIG. 1A, an imprint resist layer 12

is formed on a substrate 11. Then, a stamper, having recording tracks and servo information by forming patterns of protrusions and recesses thereon, is pressed onto the imprint resist layer 12 on the substrate 11 under a pressure of 2,000 bar for 60 minutes. The patterns are thus transferred to the imprint resist layer 12 (imprint step).

The imprint resist 12 may be spin-on-glass (SOG) that converts into SiO_2 when backed at high temperature, an aluminum alkoxide or aluminum oxide particulate-dispersed resist that is aluminized by exposure to oxygen or a high-temperature firing process, or a titanium oxide particulate-dispersed resist that is titanialized by exposure to oxygen or a high-temperature backing process.

As shown in FIG. 1B, after the imprint step, the stamper 13 is removed from the imprint resist layer 12 to obtain a substrate on which the imprint resist layer 12 is formed, the imprint resist layer having the patterns of the protrusions and recesses transferred thereon. When the stamper 13 is removed, burrs may be formed on the edges of the patterns of protrusions on the imprint resist layer 12. Removing the burrs is very difficult, and incomplete removing results from the conventional techniques described in Jpn. Pat. Appln. KOKAI Publication No. 2004-79992 and U.S. Patent No. 5,853,962.

The method according to the first embodiment of the present invention removes burrs on a substrate having protrusions and recesses using a liquefied gas jet spray step of jet spraying a liquefied gas in a chamber set at a predetermined pressure as shown in FIG. 1C.

FIG. 2 is a schematic view of the liquefied gas jet spraying step according to this embodiment which is performed in FIG. 1C. A liquefied gas jet spraying apparatus 20 comprises a liquefied gas jet spraying nozzle 22 connected to a high-pressure cylinder 21. The liquefied gas jet spraying nozzle can jet spray a liquefied gas onto burrs on a substrate having protrusions and recesses at a desired pressure. When an attempt is made to remove burrs using the conventional techniques, since carbon dioxide is jet sprayed in a process chamber at the atmospheric pressure (1 atm), liquid CO₂ evaporates in the process chamber simultaneously with the jet spraying. This allows only gaseous CO₂ and solid CO₂ to be jet sprayed onto the burrs. The present inventors have found that setting the pressure in the chamber at a predetermined pressure, specifically at least 2 atm, enables more liquid CO₂ to be jet sprayed onto the burrs than the conventional techniques together with a small amount of dry ice. The present inventors have thus found that the above operation enables removing

the burrs on the substrate having protrusions and recesses, which cannot be achieved by the conventional techniques.

For example, burrs on a substrate having
5 protrusions and recesses are successfully removed by jet spraying liquid CO₂ with the pressure in the process chamber set between 2 and 5 atm (0.2 and 0.5 MPa). Setting the pressure in the chamber at 5 atm or higher is not preferable in terms of the
10 safety of chamber operations.

Instead of carbon dioxide, water vapor or a reactive gas may be used as the liquefied gas. With its phase diagram taken into account, each liquefied gas is jet sprayed in the chamber set at such a
15 pressure as allows the gas to be jet sprayed as a solid or a liquid the amount of which is larger than that in the prior art.

With, for example, water vapor, a removal effect similar to that achieved with carbon dioxide is
20 attained by jet spraying a water vapor gas with the pressure in the process chamber reduced to 0.001 to 0.1 MPa.

When SF₆, a reactive gas, is jet sprayed as a liquefied gas, a burr removing effect is attained
25 without the need to adjust the pressure in the chamber. In particular, spray jetting SF₆ is compatible with SOG used as an imprint resist and

enabled burrs to be properly removed.

After the burrs are removed, the substrate having the protrusions and recesses from which the burrs have been removed as shown in FIG. 1D is fired at a high
5 temperature of at least 450°C or subjected to an oxygen exposure process to maintain a shape of the substrate having protrusions and recesses from which the burrs have been removed. If SOG is used as an imprint resist, it is converted into SiO₂ by the
10 backing process. This step results in a substrate having protrusions and recesses in which top surfaces of protrusions are appropriately flat.

After the above process, as shown in FIG. 1E, a metal thin film 14 is deposited on the substrate
15 having protrusions and recesses from which the burrs have been removed. The metal thin film 14 is deposited by a common deposition method for a HDD recording media (for example, a sputtering method). The metal thin film 14 may be a longitudinal or
20 perpendicular film. The perpendicular film is preferably used as the metal thin film 14 in order to achieve high-density recording. After deposition of the metal thin film 14, a protective layer 15 may be deposited on the metal thin film 14.
25 For example, a DTR media with coercivity adjusted to about 4 kOe was manufactured by a method of substrate etching type in which a stack of the

following was formed on the etched substrate: 60 nm of
CoZrNb as a soft underlayer, 20 nm of Ru as an
underlayer for controlling orientation, 20 nm of
CoCrPt with the addition of a small amount of SiO₂ as
5 a ferromagnetic recording layer, and 4 nm of diamond-
like carbon (DLC) as a protective layer. The DTR
media manufactured by the method of substrate etching
type was subjected to R/W evaluations. Clear read and
write signals were obtained using a read-write head of
10 designed flying height of 12 nm. No acoustic emission
(AE) signal was observed over the disk surface. This
indicates that the DTR media manufactured in
accordance with a method of substrate etching type
according to the first embodiment of the present
15 invention has a good HDI.

Now, with reference to FIGS. 3A, 3B, 3C, 3D, and
3E, description will be given of processes for
manufacturing a DTR media using a method of substrate
etching type according to a second embodiment of the
20 present invention.

The method according to the second embodiment of
the present invention is similar to the first
embodiment in the steps performed until the stamper is
removed from the imprint resist layer. FIG. 3A
25 corresponds to the substrate in FIG. 1B.

In the method according to the second embodiment
of the present invention, high-temperature backing at

450°C or higher or a oxygen exposure process is performed without removing burrs to maintain a shape of protrusions and recesses such as the one shown in FIG. 3A. Subsequently, a metal thin film 34 is
5 deposited on the substrate having protrusions and recesses as shown in FIG. 3B.

The burrs shown in FIG. 3B have their surfaces coated with the metal thin film 34. It is thus very difficult to remove the burrs using the apparatus
10 described in U.S. Patent No. 5,853,962. Thus, as shown in FIG. 3C, a liquefied gas jet spraying step is performed using a liquefied gas jet spraying apparatus 20 shown in FIG. 2, as is the case with the first embodiment. This enables removal of not only the
15 burrs but also the metal thin film deposited on the burrs.

After the burrs are removed, a protective film 35 is deposited as shown in FIG. 3E. The step shown in FIG. 3E results in a magnetic recording media with
20 appropriately flat protrusions.

For example, the protective film is formed of DLC and a lubricant is applied to the protective film. A DTR media is then manufactured in accordance with a method of substrate etching type. The DTR media
25 manufactured in accordance with a method of substrate etching type is subjected to R/W evaluations using a read-write head with a designed flying height of

12 nm. Then, clear read and write signals are
obtained. No AE signal is observed over the disk
surface. This indicates that the DTR media
manufactured in accordance with a manufacturing method
5 of substrate etching type according to the second
embodiment of the present invention has a good HDI.

The method of the present invention can be used
for a method of substrate etching type for
manufacturing a substrate and a DTR media which have
10 protrusions and recesses in which ion milling is used.
With reference to FIGS. 4A, 4B, and 4C, description
will be given of processes for manufacturing a
substrate and a DTR media which have protrusions and
recesses using a method of substrate etching type
15 according to a third embodiment of the present
invention.

The method according to the third embodiment of
the present invention is similar to the first
embodiment in the steps performed until the stamper is
20 removed from the imprint resist layer. In the present
embodiment, a common photo resist (for example, S1801
manufactured by Shiplay) may be used as an imprint
resist. Reactive ion etching (RIE) is used to remove
the resist residue in the recesses in the imprint
25 resist layer from which the stamper has been removed.

The substrate 41 from which the resist residue
has been removed is dry etched using ion beams of, for

example, Ar ions, as shown in FIG. 4A. In this step, the remaining parts of the imprint resist layer 42 are not etched and remain because the resist serves as a mask. These parts become protrusions. On this
5 occasion, the particles of the substrate material in the etched recesses adhere to the edges of the resist in a small quantity.

After the dry etching, as shown in FIG. 4B, a liquefied gas jet spraying step is performed using the
10 liquefied gas jet spraying apparatus 20, shown in FIG. 2, as is the case with the first embodiment. On this occasion, those particles of the substrate material in the recesses which adhere to the resist edges are removed together with the burred imprint
15 resist 42. The liquefied gas jet spraying step results in a substrate having appropriately flat protrusions as shown in FIG. 4C.

Further, a magnetic recording media in which top surfaces of protrusions are appropriately flat is
20 obtained by performing a step of depositing a metal thin film and a protective film as is the case with FIG. 1E (this step is not shown).

The method of the present invention is also applicable to a lift off process. With reference to
25 FIGS. 5A, 5B, 5C, 5D, and 5E, description will be given below of processes for manufacturing a DTR magnetic recording media using a method of substrate

etching type involving a lift off process using the present invention.

As shown in FIG. 5A, a stamper 53 is pressed to a substrate 51 on which an imprint resist layer 52 has been formed for patterning. Patterns of protrusions and recesses are thus transferred to the substrate.

Then, as shown in FIG. 5B, RIE with oxygen is performed on the substrate from which the stamper has been removed. Remaining resist at the bottoms of the recesses of the resist is removed. In FIG. 5B, burrs may result from removing of the stamper but are not shown. RIE results in the substrate from which the remaining resist has been removed as shown in FIG. 5C.

As shown in FIG. 5D, a magnetic material 55 is deposited on the substrate obtained. The magnetic material adheres to the edges of the protrusions on the imprint resist layer shown in FIG. 5D. This precludes the imprint resist from being removed by oxygen RIE.

Thus, as shown in FIG. 5E, the substrate on which the magnetic material 55 had been deposited is subjected to a liquefied gas jet spraying step using the liquefied gas jet spraying apparatus 10, shown in FIG. 2, as is the case with the first embodiment. If SOG is used as an imprint resist, jet sprayed gas is preferably SF_6 . This step enables the liftoff of the magnetic material adhering to the tops and edges of

the imprint as well as the imprint resist. This step results in a DTR media having the zones formed of magnetic material separated from each other.

5 A lift off process using a conventional resist removing liquid (for example, NMP) involves dust generation attributed to a wet process and thus significantly degrades HDI. However, as described above, the method of the present invention can simultaneously remove dust and thus enables a lift off
10 process for a DTR media which has been impossible in the prior art to be performed.

Description will be given below of materials used for the layers of magnetic recording media as well as the stack structure of each layer according to the
15 embodiment of the present invention.

<Substrate>

Examples of a substrate include a glass substrate, an Al-based alloy substrate, a ceramic substrate, a carbon substrate, and an Si single-
20 crystal substrate. As a glass substrate, amorphous glass or single-crystal glass can be used. Examples of amorphous glass include soda lime glass and aluminosilicate glass. Examples of crystallined glass include lithium crystallized glass. A ceramic
25 substrate may be, for example, a sintered body consisting substantially of aluminum oxide, aluminum nitride, silicon nitride, or the like, or one obtained

by fiber-reinforcing those sintered bodies. An Si
single-crystal substrate, i.e., a silicon wafer may
have an oxide film on the surface thereof. Further,
one obtained by forming an NiP layer on the above-
5 described metal substrate or a nonmetal substrate by
plating or sputtering can be used.

<Soft underlayer>

When a perpendicular magnetic recording medium is
manufactured, that is formed as a so-called
10 perpendicular two-layer medium having a perpendicular
magnetic recording layer on a soft underlayer (SUL).
The soft underlayer of the perpendicular two-layer
medium is provided for allowing a writing magnetic
field from a magnetic pole to pass through, and for
15 allowing the recording magnetic field to return to a
return yoke arranged in the vicinity of the magnetic
pole. Namely, the soft underlayer serves as one part
of functions of a write head, and functions as a part
of improving a writing efficiency by applying a
20 precipitous perpendicular magnetic field to the
recording layer.

As the soft underlayer, a high permeability
material including at least one of Fe, Ni and Co is
used. Examples of the material include an FeCo-based
25 alloy such as FeCo or FeCoV; an FeNi-based alloy such
as FeNi, FeNiMo, FeNiCr, or FeNiSi; an FeAl-based and
FeSi-based alloy such as FeAl, FeAlSi, FeAlSiCr,

FeAlSiTiRu, or FeAlO; an FeTa-based alloy such as FeTa, FeTaC, or FeTaN; and an FeZr-based alloy such as FeZrN.

5 As the soft underlayer, a material may be used which has a microcrystalline structure such as FeAlO, FeMgO, FeTaN, or FeZrN containing 60 at% or more of Fe, or a granular structure in which fine crystal particles are dispersed in a matrix.

10 Examples of the material of the soft underlayer further include a Co alloy containing Co and at least one of Zr, Hf, Nb, Ta, Ti and Y. 80 at% or more of Co is preferably contained therein. When such a Co alloy is formed to be a film by sputtering, an amorphous layer is easy to form. An amorphous soft magnetic
15 material has no crystalline magnetic anisotropy, crystalline defect, or grain boundary, and thus exhibits an extremely excellent soft magnetisation. By using an amorphous soft magnetic material, an attempt can be made to make a noise of a medium lower.
20 Examples of a suitable amorphous soft magnetic material include CoZr-, CoZrNb-, and CoZrTa-based alloys.

Under the soft underlayer, an underlayer may be also provided in order to improve the crystallinity of
25 the soft underlayer, or to improve the adherence of the soft under layer to the substrate. Examples of a material of the underlayer include Ti, Ta, W, Cr and

Pt, or an alloy containing those, or an oxide or a nitride thereof.

An intermediate layer composed of a nonmagnetic material may be provided between the soft underlayer and the perpendicular magnetic recording layer. A
5 role of the intermediate layer is to cut off exchange coupling interaction between the soft magnetic underlayer and the recording layer, and to control the crystallinity of the recording layer. Examples of a
10 material of the intermediate layer include Ru, Pt, Pd, W, Ti, Ta, Cr, and Si, or an alloy containing those, or an oxide or a nitride thereof.

In order to prevent a spike noise, the soft underlayer may be comprising of a plurality of layers,
15 and have a Ru film having thickness of 0.5 to 1.5 nm interposed therebetween, whereby anti-ferromagnetic coupling may be carried out. In addition, the soft magnetic layer may be exchange coupled to a hard magnetic film having in-plane anisotropy, such as
20 CoCrPt, SmCo, or FePt, or a pinning layer composed of an antiferromagnetic material such as IrMn or PtMn. In this case, a magnetic layer, for example, Co, or a nonmagnetic layer, for example, Pt may be laminated above and under an Ru layer in order to control an
25 exchange coupling force.

<Perpendicular magnetic recording layer>

As the perpendicular magnetic recording layer,

for example, a material is used which consists substantially of Co, contains at least Pt, Cr as needed, and further includes an oxide (for example, a silicon oxide, a titanium oxide). In the perpendicular magnetic recording layer, it is preferred for magnetic crystal particles to have a columnar structure. In the perpendicular magnetic recording layer having such a structure, the orientation and the crystallinity of the magnetic crystal particles are satisfactory, and as a result, a signal-to-noise ratio (SNR) suitable for high-density recording can be obtained. In order to obtain the structure described above, a quantity of oxide is important. A content of oxide is preferably 3 mol% or more and 12 mol% or less, and more preferably 5 mol% or more and 10 mol% of the total amount of Co, Pt, and Cr. When the content of oxide in the perpendicular magnetic recording layer is within the above-described range, the oxide is precipitated at the periphery of the magnetic particles, which can be isolated and become fine. When the content of oxide is over the above-described range, the oxide remains in the magnetic particles, which deteriorates the orientation and the crystallinity of the magnetic particles. Further, the oxide is precipitated above and under the magnetic particles, and as a result, preventing the formation of a columnar structure in which the

magnetic particles penetrate through the perpendicular magnetic recording layer in the perpendicular direction. On the other hand, the content of oxide, which is less than the above-described range, causes
5 the magnetic particles to be insufficiently isolated and become fine insufficiently. As a consequence, a noise at the time of reading/writing increases, and a signal-to-noise ratio (SNR) suitable for high-density recording cannot be obtained.

10 The content of Pt in the perpendicular magnetic recording layer is preferably 10 at% or more and 25 at% or less. When the content of Pt is within the above-described range, a uniaxial magnetic anisotropy constant K_u required for the perpendicular magnetic
15 recording layer can be obtained, and moreover, the orientation and the crystallinity of the magnetic particles are made satisfactory. Consequently, it is possible to obtain a thermal fluctuation tolerance and a read/write property which are suitable for high-
20 density recording. When the content of Pt is over the above-described range, a layer having a face-centered cubic (fcc) structure is formed in the magnetic particles, which could lead to deteriorations in the orientation and crystallinity. When the content of Pt
25 is less than the above-described range, on the other hand, a thermal fluctuation tolerance cannot be obtained in accordance with a K_u suitable for

high-density recording.

The content of Cr in the perpendicular magnetic recording layer is preferably 0 at% or more and 25 at% or less, and more preferably 10 at% or more and 20 at% or less. When the content of Cr is within the above-described range, high magnetisation can be maintained without decreasing a uniaxial magnetic anisotropy constant Ku. As a result, a read/write property which is suitable for high-density recording and a sufficient thermal fluctuation tolerance can be obtained. When the content of Cr is over the above-described range, a thermal fluctuation tolerance deteriorates because a Ku of the magnetic particles is made little, and the crystallinity and the orientation of the magnetic particles deteriorates. As a result, a read/write property deteriorates.

The perpendicular magnetic recording layer may include one or more additive elements selected from B, Ta, Mo, Cu, Nd, W, Nb, Sm, Tb, Ru and Re, in addition to Co, Pt, Cr and an oxide. Since these additive elements are contained, it is possible to stimulate a reduction in the size of the magnetic particles, or to improve the crystallinity and the orientation thereof, thereby enabling to obtain a read/write property and a thermal fluctuation tolerance which are more suitable for high-density recording. The total content of these additive elements is preferably 8 at% or less.

When it is over 8 at%, a phase except for a hexagonal close-packed (hcp) phase is formed in the magnetic particles, and thus, the crystallinity and the orientation of the magnetic particles are disturbed.

5 As a consequence, it becomes impossible a read/write property and a thermal fluctuation tolerance which are suitable for high-density recording.

Examples of a material of the perpendicular magnetic recording layer further include a CoPt-based alloy, a CoCr-based alloy, a CoPtCr-based alloy,
10 CoPtO, CoPtCrO, CoPtSi, and CoPtCrSi. The perpendicular magnetic recording layer may be a multilayer film of Co and an alloy which consists substantially of at least one type selected from the group consisting of Pt, Pd, Rh and Ru. Further, a
15 multilayer film such as CoCr/PtCr, CoB/PdB, or CoO/RhO having Cr, B or O added may be used as the each layers of the multilayer thereof.

The thickness of the perpendicular magnetic recording layer is preferably 5 to 60 nm, and more preferably 5 to 30 nm. A perpendicular magnetic recording layer having a thickness within this range is suitable for high-density recording. When the thickness of the perpendicular magnetic recording
20 layer is less than 5 nm, there is a tendency that a regenerative output is too low, which is lower than a noise component higher. When the thickness of the
25

perpendicular magnetic recording layer is over 40 nm,
on the other hand, there is a tendency that a readout
output is too high, which distorts a waveform. A
coercivity of the perpendicular magnetic recording
5 layer is preferably 237000 A/m (3000 Oe) or more.
When a coercivity is less than 237000 A/m (3000 Oe),
there is a tendency that a thermal fluctuation
tolerance declines. A perpendicular gradation of the
perpendicular magnetic recording layer is preferably
10 0.8 or more. When the perpendicular gradation is less
than 0.8, there is a tendency that a thermal
fluctuation tolerance declines.

<Protective layer>

The protective layer prevents corrosion of the
15 perpendicular magnetic recording layer as well as
damage of the surface of the medium when the magnetic
head touches a medium. Examples of a material of the
protective layer include a material containing C,
SiO₂, and ZrO₂. A thickness of the protective layer
20 is preferably made to be 1 to 10 nm. When the
thickness of the protective layer is made to be within
the above-described range, spacing between the head
and a medium can be made less, which is suitable for
high-density recording.

25 Carbon can be classified into sp²-bonded carbon
(graphite) and sp³-bonded carbon (diamond). The
sp³-bonded carbon is superior in the durability and

the corrosion resistance to that of graphite.

However, because the sp^3 -bonded carbon is crystalline, the smoothness on a surface thereof is inferior to that of graphite. Usually, carbon is formed to be a film by sputtering using a graphite target. In this method, amorphous carbon in which sp^2 -bonded carbon and sp^3 -bonded carbon are mixed is formed. Carbon in which a ratio of sp^3 -bonded carbon is high is called diamond-like carbon (DLC). Since the DLC is excellent in the durability and the corrosion resistance, and is excellent in the smoothness on a surface thereof as well because of amorphous, it is utilized as a surface protective film for the magnetic recording media.

With respect to film formation of DLC by a chemical vapor deposition (CVD) method, DLC more rich in sp^3 -bonded carbon can be formed by satisfying the conditions because DLC is generated by exciting and decomposing a raw gas in plasma, and due to a chemical reaction thereof.

<Lubricant layer>

Examples of a lubricant agent include per-fluoropolyether, alcohol fluoride, and fluorinated carboxylic acid.

Additional advantages and modifications will readily occur to those skilled in the art. Therefore, the invention in its broader aspects is not limited to the specific details and representative embodiments

shown and described herein. Accordingly, various modifications may be made without departing from the spirit or scope of the general inventive concept as defined by the appended claims and their equivalents.

WHAT IS CLAIMED IS:

1. A method for manufacturing a substrate for a discrete track recording media, the method comprising:
 - forming an imprint resist layer on a substrate;
 - 5 imprinting, on the imprint resist layer, a stamper formed with patterns of protrusions and recesses corresponding to recording track zones and servo zones to transfer the patterns of protrusions and recesses to the imprint resist layer;
 - 10 removing the stamper from the imprint resist layer; and
 - diffusing liquefied CO₂ in a process chamber set at a pressure of 2 to 5 atm, diffusing liquefied H₂O in the process chamber set at a pressure of 0.01 to
 - 15 1 atm, or diffusing a reactive gas selected from a group consisting of liquefied CF₄, CHF₃, SF₆, and C₂F₆ in the process chamber set at an arbitrary pressure, to jet spray the liquefied gas onto a surface of the substrate.
- 20 2. The method according to claim 1, wherein the imprint resist is spin-on-glass, and the spin-on-glass is baked after the jet spraying step to form patterns of protrusions and recesses comprising SiO₂.
- 25 3. The method according to claim 1, wherein the imprint resist is selected from a group consisting of aluminum alkoxide, aluminum oxide dispersed resist, and titanium oxide dispersed resist.

4. A method for manufacturing a substrate for a discrete track recording media, the method comprising:

forming an imprint resist layer on a substrate;

imprinting, on the imprint resist layer, a

5 stamper formed with patterns of protrusions and
recesses corresponding to recording track zones and
servo zones to transfer the patterns of protrusions
and recesses to the imprint resist layer;

10 removing the stamper from the imprint resist
layer;

removing the imprint resist remaining at bottoms
of recesses of the imprint resist layer by reactive
ion etching;

15 dry etching the substrate using the pattern on
the imprint resist layer as a mask; and

diffusing liquefied CO₂ in a process chamber set
at a pressure of 2 to 5 atm, diffusing liquefied H₂O
in the process chamber set at a pressure of 0.01 to
1 atm, or diffusing a reactive gas selected from a
20 group consisting of liquefied CF₄, CHF₃, SF₆, and C₂F₆
in the process chamber set at an arbitrary pressure,
to jet spray the liquefied gas onto a surface of the
substrate.

5. The method according to claim 4, wherein the
25 imprint resist is spin-on-glass, and the spin-on-glass
is baked after the jet spraying step to form patterns
of protrusions and recesses comprising SiO₂.

6. The method according to claim 4, wherein the imprint resist is selected from a group consisting of aluminum alkoxide, aluminum oxide dispersed resist, and titanium oxide dispersed resist.

5 7. A method for manufacturing a discrete track recording media, the method comprising:

 forming an imprint resist layer on a substrate;

 imprinting, on the imprint resist layer, a

 stamper formed with patterns of protrusions and

10 recesses corresponding to recording track zones and

 servo zones to transfer the patterns of protrusions

 and recesses to the imprint resist layer;

 removing the stamper from the imprint resist layer; and

15 depositing a plurality of media films including a magnetic film, on a surface of the substrate,

 wherein after the stamper removing step or the depositing step, liquefied CO₂ is diffused in a process chamber set at a pressure of 2 to 5 atm,

20 liquefied H₂O is diffused in the process chamber set at a pressure of 0.01 to 1 atm, or a reactive gas

 selected from a group consisting of liquefied CF₄,

 CHF₃, SF₆, and C₂F₆ is diffused in the process chamber set at an arbitrary pressure, to jet spray the

25 liquefied gas onto a surface of the imprint resist layer.

8. The method according to claim 7, wherein the

imprint resist is spin-on-glass, and the spin-on-glass is baked after the jet spraying to form patterns of protrusions and recesses comprising SiO₂.

5 9. The method according to claim 7, wherein the imprint resist is selected from a group consisting of aluminum alkoxide, aluminum oxide dispersed resist, and titanium oxide dispersed resist.

10 10. The method according to claim 7, wherein the imprint resist is a photoresist.

10 11. The method according to claim 7, wherein after the stamper is removed from the imprint resist layer and the plurality of media films including the magnetic film are deposited on the substrate surface, the jet spraying is performed to lift off the
15 remaining imprint resist and the media films deposited on the remaining imprint resist.