METHOD OF PRODUCING A NANO-STRUCTURE AND METHOD OF PRODUCING A MAGNETIC RECORDING MEDIUM

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According to an aspect of an embodiment, a manufacturing method for a nano-structure comprises the steps of: arranging nano-particles on a substrate having a surface provided with a projecting pattern and a recessing pattern; forming cavities under the nano-particles; and polishing the surfaces in which the cavities are formed.
FIG. 1

Prior Art.

PRODUCE A SUBSTRATE 10 HAVING A PROJECTING/RECESSING PATTERN 11 COMPOSED OF PROJECTING PORTIONS 11A AND RECESSING PORTIONS 11B.

ARRANGE NANO-PARTICLES 12.

FORM A METAL FILM 14 ON THE WHOLE OF A SURFACE OF THE SUBSTRATE 10 WITH THE ARRANGED NANO-PARTICLES 12 BY SPOTTING OR VAPOR DEPOSITION.

SEPARATE THE METAL FILM 14 TOGETHER WITH THE NANO-PARTICLES 12 FROM THE SUBSTRATE 10 AND REMOVE ONLY THE NANO-PARTICLES 12 BY CHEMICAL TREATMENT.
FORM A MASTER AS A NANO-STRUCTURE.

USE THE MASTER TO FORM A STAMPER HAVING A PROJECTING/RECESSING PATTERN REVERSAL TO THAT IN A SURFACE OF THE MASTER.

USE THE STAMPER TO FORM A MAGNETIC DISK.

PUT THE MAGNETIC DISK IN A CASING.
FIG. 4

PRODUCE A SUBSTRATE 10 HAVING A PROJECTING/RECESSING PATTERN 11 COMPOSED OF RECESSING PORTIONS 11A AND PROJECTING PORTIONS 11B.

ARRANGE NANO-PARTICLES 12.

FORM CAVITIES 15A AND 15B IN THE SUBSTRATE 10 UNDER THE NANO-PARTICLES 12.

REMOVE ONLY THE NANO-PARTICLES 12 FROM THE SUBSTRATE 10.


PERFORM CLEANING.
FIG. 7

PRODUCE A SUBSTRATE 10 HAVING A PROJECTING/RECESSING PATTERN 11 COMPOSED OF RECESSING PORTIONS 11A AND PROJECTING PORTIONS 11B.

APPLY A RESIST TO FORM A RESIST LAYER 16 HAVING A PROJECTING/RECESSING PATTERN 17 COMPOSED OF RECESSING PORTIONS 17A AND PROJECTING PORTIONS 17B.

ARRANGE NANO-PARTICLES 12A ON THE RESIST LAYER 16.

FORM CAVITIES 18A AND 18B IN THE RESIST LAYER 16 UNDER THE NANO-PARTICLES 12A.


PERFORM CLEANING.
Fig. 9

1202
TRANSFER A PATTERN 32 OF A STAMPER 30 TO A MEDIUM SUBSTRATE 40 BY MANO-IMPRINTING TO FORM A PATTERN 42 IN A SURFACE 40A OF THE MEDIUM SUBSTRATE 40.

1204
ADJUST THE SIZE OF THE PATTERN 42 BY ANODIC OXIDATION TO FORM A PATTERN 44 IN THE SURFACE 40A OF THE MEDIUM SUBSTRATE 40.

1206
FORM A MAGNETIC SUBSTANCE LAYER 46 ON THE SURFACE 40A OF THE MEDIUM SUBSTRATE 40.

1208
REMOVE THE MAGNETIC SUBSTANCE LAYER 46 EXCEPT MAGNETIC SUBSTANCE 46A IN THE PATTERN 44 FROM THE MEDIUM SUBSTRATE 40 BY CMP TO FLATTEN THE SURFACE 40A OF THE MEDIUM SUBSTRATE 40.

1210
FORM A PROTECTIVE LAYER AND A LUBRICATING LAYER.
FIG. 12

WITHOUT MAGNETIZATION TRANSITION REGION

(TRACK WIDTH)
METHOD OF PRODUCING A NANO-STRUCTURE AND METHOD OF PRODUCING A MAGNETIC RECORDING MEDIUM

CROSS-REFERENCE TO RELATED APPLICATIONS
[0001] This application is related to and claims the benefit of priority from Japanese Patent Application No.2007-150193, filed on Jun. 6, 2007, the entire contents of which are incorporated herein by reference.

FIELD

BACKGROUND
[0003] By use of DTm (discrete track media) or BPM (bit patterned media) as recording media for hard disc drive (HDD), improvement in storage capacity of HDD is expected. A magnetic disc is partitioned into a large number of tracks shaped like concentric circles. Each track has sectors compartmentalized at intervals of a constant angle. In DTm or BPM, adjacent tracks or sectors are compartmentalized by a non-magnetic substance to reduce or eliminate a magnetization transition region which causes noise. As a result, signal quality is improved thereby make it possible to improve recording density.

[0004] A method of producing a nano-structure according to the background art will be described. FIG. 1 shows a method of producing a nano-structure according to the background art. FIGS. 2A and 2B and FIGS. 2D to 2G show schematic sectional views of respective steps in FIG. 1. FIG. 2C shows a partly enlarged view of FIG. 2B.

[0005] First, as shown in FIG. 2A, a substrate 10 having a projecting and recessing pattern 11 composed of projecting portions 11a and projecting portions 11b in a surface 10a (that is, having a projecting and recessing pattern 11a in a surface 10a) is produced (step 2002). Then, as shown in FIGS. 2B and 2C, nano-particles 12 are arranged on the substrate 10 (step 2004). Ideally, the nano-particles 12 are selectively arranged only on the recessing portions 11a of the projecting and recessing pattern 11. The step 2004 can use the self-organizing function of the nano-particles 12.

[0006] Then, as shown in FIGS. 2D and 2E, a metal film 14 is formed on the whole surface of the substrate 10 having the arranged nano-particles 12 by sputtering or vapor deposition (step 2006). Then, as shown in FIG. 2F, the metal film 14 is separated together with the nano-particles 12 from the substrate 10 and only the nano-particles 12 are removed by chemical treatment (step 2008). As a result, the metal film 14 having a nano-hole pattern 13 formed therein can be obtained.

SUMMARY
[0018] An object of the present art is to provide a nano-structure producing method in which a nano-hole pattern having nano-holes distributed into arbitrary positions can be produced with a good yield, and a magnetic recording medium producing method using the nano-structure producing method.

BRIEF DESCRIPTION OF THE DRAWINGS
[0020] FIG. 1 shows a method of producing a nano-structure according to the background art;

[0021] FIGS. 2A-G are schematic views showing the nano-structure producing method according to the background art;

[0022] FIG. 3 shows a first method of producing a storage device according to the present art;

[0023] FIG. 4 shows the sub-steps of the method step 1000;

[0024] FIGS. 5A-L are schematic views showing the sub-steps of the step 1000;

[0025] FIG. 6 shows a pull-up method used in the sub-step 1004;

[0026] FIG. 7 shows a second method of producing a storage device according to the present art;

[0027] FIGS. 8A-E are schematic sectional views showing the steps of the second producing method;

[0028] FIG. 9 shows the sub-steps of method step 1200;

[0029] FIGS. 10A-F are schematic sectional views showing the sub-steps of the step 1200;

[0030] FIG. 11 is a partly enlarged view of a DTM;

[0031] FIG. 12 is a partly enlarged view of a BPM; and

[0032] FIG. 13 shows the internal structure of an HDD having a magnetic recording medium (magnetic disc) produced by the producing method according to the present art.

DETAILED DESCRIPTION OF THE EMBODIMENTS
[0033] A method of producing a storage device according to an embodiment of the present invention will be described below with reference to the accompanying drawings. In this embodiment, the storage device is an HDD.
According to an aspect of the invention, the producing method includes the steps of: arranging nano-particles on a substrate having a surface provided with a projecting pattern and a recessing pattern; forming cavities under the nano-particles; and polishing the surfaces in which the cavities are formed. According to the producing method, the yield can be improved since cavities (referred to as “defective cavities”) are formed accidentally in projecting portions of the projecting and recessing surfaces are removed by the polishing step. The “defective cavities” are formed in other portions than portions in which cavities should be formed properly. The positions of the cavities formed by the cavity forming step are on a surface of the substrate, on another layer (e.g. a resist layer) between the surface of the substrate and the nano-particles, etc. The projecting and recessing surfaces polished by the polishing step are the surface of the substrate, surfaces of another layer (e.g. a resist layer) between the surface of the substrate and the nano-particles, etc.

For example, the polishing step uses chemical mechanical polishing which is high in polishing accuracy. Preferably, the substrate is a glass substrate or a silicon substrate. This is because the glass substrate or the silicon substrate can be polished more easily than the metal film shown in Fig. 1. The substrate may be formed of a low-melting glass substrate. Glass can adsorb nano-particles easily. The low-melting glass substrate can be produced easily from a stamper of the same shape by a nano-imprinting method. For example, the nano-particles can be formed of silico. This is because silica is inexpensive and compatible with glass when the substrate is made of glass. Preferably, the step of cleaning the surface of the substrate is further provided after the polishing step. Polishing dust can be removed by the cleaning step.

Preferably, in the polishing step, the projecting and recessing surfaces on which the cavities are formed are polished so as to be substantially flattened. Defective cavities in the projecting portions of the projecting and recessing surfaces can be removed by the polishing step. Preferably, the difference between the surface of each of the projecting portions and the surface of each of the recessing portions in the projecting and recessing surfaces is larger than the depth of each of the cavities. This is because defective cavities remain after the polishing step if the depth of each of the cavities is larger than the height of each of the projecting portions of the projecting and recessing surfaces. Preferably, the difference between the surface of each projecting portion and the surface of each recessing portion, which is equal to the depth of each recessing portion in the projecting and recessing surfaces, is not larger than twice the diameter of each of the nano-particles.

In this manner, a single layer of nano-particles can be formed so that cavities can be formed.

The projecting and recessing pattern of the substrate may have a plurality of recessing portions and a plurality of projecting portions. The present art is particularly suitable for the case where cavities (or a set of cavities) distributed in accordance with the recessing portions are formed in the projecting and recessing surfaces. This is because defective cavities are insignificant when the surface of the substrate is flat and cavities uniform on a whole are formed. The width of each of the recessing portions may be 100 nm. This is because defective cavities in such order of tens of nanometers are particularly significant.

The cavity forming step can be performed by an etching or plasma ashing process. In this case, cavities are formed in gaps between nano-particles. Alternatively, a resist applied on the surface of the substrate may be irradiated with light condensed through the nano-particles. In this case, the cavities are formed just under the nano-particles.

The nano-structure may be a master used for production of a magnetic recording medium. A method of producing a stamper by using such a master and a method of producing a magnetic recording medium by using such a stamper form an aspect of the present invention. In this case, the magnetic recording medium may have a magnetic recording region magnetically divided by a non-magnetic insulator. The magnetic recording medium according to the present invention is suitable for such a fine structure of DTM or BPM. A method of producing a storage device, including the steps of: producing a magnetic recording medium; and mounting the magnetic recording medium produced by the producing step in a casing, the magnetic recording medium producing step including the sub-step of forming a master as the nano-structure by using the aforementioned producing method, also forms an aspect of the invention.

FIG. 3 shows a method of producing a storage device according to an embodiment of the invention.

First, a master is formed as a nano-structure (step 1000). Details of the step 1000 will be described below with reference to FIGS. 4 to 6. FIG. 4 is a flow chart for explaining the details of the step 1000. FIGS. 5A and 5B and FIGS. 5D to 5J are schematic sectional views showing the steps shown in FIG. 4. FIG. 5C is a partly enlarged top view of FIG. 5B.

First, as shown in FIG. 5A, a substrate 10 having a projecting and recessing pattern 11 composed of projecting portions 11a and projecting portions 11b in a surface 10a of the substrate 10 (that is, having projecting and recessing surfaces in a surface 10a) is produced (step 1002). Particularly on the assumption of a magnetic recording medium, the recessing portions 11a of the substrate 10 are formed circularly in the surface 10a. When the formation of the nano-structure according to this embodiment is applied to another field, the projecting and recessing pattern formed in the substrate may take any shape. Although the substrate 10 in this embodiment is shaped like a disc, the substrate in the art is not limited as long as the substrate has surfaces as projecting and recessing surfaces. Each recessing portion 11a has surfaces 11a1 which are the outermost surfaces of the recessing portion 11a. Each projecting portion 11b has surfaces 11b1 which are the outermost surfaces of the projecting portion 11b.

Incidentally, FIGS. 5A and 5B and FIGS. 5D to 5J are sectional views of the substrate 10 taken along a plane which passes through the center axis of the disc-shaped substrate 10 and extends in the Z direction.

In this embodiment, the horizontal direction (radial direction) of the substrate 10 shown in FIG. 5A is set as the R direction and the vertical direction thereof is set as the Z direction. The R direction and the Z direction are perpendicular to each other. The surfaces 11a1 of the recessing portions 11a form one plane parallel to the R direction. The surfaces 11b1 of the projecting portions 11b form one plane parallel to the R direction. The Z-direction length between the two planes (i.e. the distance between the surfaces 11a1 and the surfaces 11b1) D is equivalent to the depth of the recessing portions 11a and also equivalent to the height of the projecting portions 11b.

The projecting and recessing pattern 11 formed in the surface of the substrate 10 is a groove pattern in which the R-direction length of one recessing portion 11a and one pro-
jecting portion 11b is repeated at intervals of a constant pitch P. In the pitch P, the R-direction length of the recessing portion 11a is P1, and the R-direction length of the projecting portion 11b is P2.

[0046] The length P1 is the order of tens of nanometers which is smaller than the background-art length of 500 nm to 1 μm. Incidentally, the length P1 of the recessing portion and the length P2 of the projecting portion can be suitably selected in accordance with the required pattern. In the producing method according to this embodiment, a nano-hole pattern can be formed accurately in such a fine groove pattern.

[0047] Preferably, the substrate 10 is a glass substrate or a silicon substrate. This is because the glass or silicon substrate can be polished more easily than the metal film by the polishing step which will be described later. However, the art does not intend to exclude an embodiment in which the metal film is polished. The substrate 10 in this embodiment is formed of a low-melting glass substrate. Glass can adsorb nano-particles easily. The low-melting glass substrate can be produced easily from a stamper of the same shape by a nano-imprinting method.

[0048] Then, as shown in FIGS. 5B and 5C, nano-particles 12 are arranged on the surface 10a of the substrate 10 (step 1004). Ideally, the nano-particles 12 are arranged with a hexagonal closest packed pattern and selectively on the recessing portions 11a of the projecting and recessing portion 11 of the substrate surface 10a. FIG. 5C shows a state in which the nano-particles 12 are closest packed in the recessing portions 11a. However, there is practically a possibility that the nano-particles 12 may be arranged not only on the recessing portions 11a but also on the projecting portions 11b as shown in FIG. 5C.

[0049] In this embodiment, a single layer of the nano-particles 12 is arranged on the recessing portions 11a and the projecting portions 11b of the projecting and recessing pattern 11. As described above, the depth (distance D) of the recessing portions 11a of the projecting and recessing portion 11 of the substrate 10 shown in FIGS. 5A and 5B is a depth by which the single layer of the nano-particles 12 is formed on the recessing portions 11a. Accordingly, while the single layer of the nano-particles 12 are formed on the substrate 10, cavities 15a which will be described later can be formed in the substrate surface. Specifically, when the diameter of each nano-particle 12 is c as shown in FIG. 5B, it is preferable that D satisfies the following expression (1).

$$0.5c \leq D \leq 2c$$

[0050] If D is smaller than 0.5c, the recessing portions 11a hardly hold the nano-particles 12. If D is larger than 2c, two or more layers of the nano-particles 12 are apt to be arranged on the recessing portions 11a.

[0051] The step 1004 in this embodiment uses the self-organizing function of the nano-particles 12 due to a pull-up method. FIG. 6 is a schematic sectional view for explaining the pull-up method. In the pull-up method, as shown in FIG. 6, the substrate 10 is immersed vertically in a nano-particle suspension which is reserved in a vessel in advance. The substrate 10 is pulled up in the Z direction from this state at a super-low speed of about several μm per second so that the nano-particles 12 are arranged on the surface of the substrate 10 by the self-organizing function of the nano-particles 12. When the substrate 10 is pulled up at a super-low speed, a phenomenon that the nano-particles 12 are deposited as a dense structure on the substrate 10 occurs in a gas-liquid interface (self-organizing function). Because menisci are formed in the recessing portions 11a more easily than the projecting portions 11b in the projecting and recessing pattern 11, that is, because liquid enters the recessing portions more easily, arrays of particles can be formed in the recessing portions 11a easily. The number of deposited layers of dense-structure particles 12 is decided based on the speed of pulling up the substrate from the suspension and the concentration of the suspension as parameters. When a moderate pull-up speed and a moderate suspension concentration are selected, a single-layer nano-particle dense structure pattern with a wide area is formed on the surface of the substrate 10.

[0052] In this embodiment, the nano-particles 12 are silica particles. Although it is general that nano-particles are particles having diameters of 1 nm to 100 nm, the silica particles in this embodiment have diameters of the order of tens of nanometers. The particle size of the nano-particles is measured with a transmission electron microscope (TEM) or an optical microscope (OM) and corrected. Silica is inexpensive and compatible with the substrate when the substrate is made of glass (SiO2). Incidentally, the kind of the nano-particles 12 is not limited by the art. For example, polystyrene, styrene-divinylbenzene, polymethyl methacrylate, borosilicate glass, etc. may be used as the material of the nano-particles 12. The nano-particles 12 are allowed to be deposited on the projecting portions 11b as long as the nano-particles 12 arranged on the recessing portions 11a form a single layer. A margin for this pull-up condition is kept so that the yield is improved.

[0053] Then, cavities (or nano-holes) are formed in the surface 10a of the substrate 10 located under the nano-particles 12 (step 1006). In this embodiment, cavities formed in the surfaces 11a1 of the recessing portions 11a of the projecting and recessing pattern 11 are designated by the reference numeral 15a whereas cavities formed in the surfaces 11b1 of the projecting portions 11b of the projecting and recessing pattern 11 are designated by the reference numeral 15b, so that the two kinds of cavities can be distinguished from each other. Cavities 15a are formed in one recessing portion 11a.

[0054] In this embodiment, as shown in FIGS. 5D, 5E and 5K, cavities are formed on the substrate 10 by etching. FIG. 5D shows the substrate 10 before etching. FIG. 5E shows the substrate 10 after etching. FIG. 5K is an enlarged view showing the neighborhood of the cavities 15a formed in the surfaces 11a1 of a recessing portion 11a in FIG. 5E. When low-melting glass is used as a substrate of etching, a gas (e.g. fluorine gas such as CHF3, C4F8, etc) having a higher etching rate than that of silica particles is used for etching portions of the surface 10a of the substrate 10 on which the nano-particles are arranged. In this case, since the nano-particles 12 serve as a mask, only portions of the substrate surface equivalent to gaps between the nano-particles 12 are etched so that a pattern of nano-level cavities 15a and 15b is formed in the substrate 10. In another embodiment, plasma ashing may be performed in place of the etching.

[0055] Then, as shown in FIG. 5F, the nano-particles 12 are removed from the surface 10a of the substrate 10 by acidic chemicals, solvent, ultrasonic cleaning, etc. (step 1008). As shown in FIG. 5F, the cavities 15a are formed in the surfaces 11a1 of the recessing portions 11a formed in the surface 10a of the substrate 10. On the other hand, the cavities 15b are formed in the surfaces 11b1 of some projecting portions 11b of the projecting and recessing pattern 11 but not formed in the surfaces 11b1 of some projecting portions 11b of the projecting and recessing pattern 11.
Then, after the step 1008, the substrate 10 with the cavities formed thus is turned upside down as shown in FIG. 5G and the projecting portions 11b of the surface 10a of the substrate 10 are polished by chemical mechanical polishing (CMP) (step 1010). FIG. 5G is a schematic sectional view in the case where the substrate 10 shown in FIG. 5F is turned upside down.

CMP is used in a semiconductor producing process and high in polishing accuracy. Use of silica particles or the like as slurry in CMP permits the polishing speed to be controlled easily. In CMP, a disc to which abrasive cloth is attached is rotated and a subject of polishing is rotated on the abrasive cloth so as to be pressed against the abrasive cloth while slurry (abrasives) is poured, so that the subject of polishing is polished. In the polishing step 1010 in this embodiment, the subject 10 shown in FIG. 5G as a subject of polishing is pressed against the abrasive cloth on the disc to thereby polish portions of the projecting and recessing surfaces where the cavities 15a are formed. In this embodiment, the projecting and recessing surfaces are equivalent to the surface 10a of the substrate 10.

Since the cavities (defectives cavities) 15b accidentally formed in the surfaces 11b of the projecting portions 11b are eliminated by the polishing step 1010, the yield for production of the nano-structure which is a master can be improved. The term “defective cavities” in this embodiment means cavities 15b formed in the surfaces 11b of the projecting portions 11b which are other positions than those of the cavities 15a intended properly to be formed in the surfaces 11a of the recessing portions 11a.

In the polishing step 1010, the surface of the substrate 10 is polished to be substantially flattened so that the surfaces 11a of the recessing portions 11a are exposed. FIG. 5f shows a target plane H which should be formed after the substrate 10 shown in FIG. 5G is polished or flattened. The target plane H is a plane substantially equivalent to the surfaces 11a of the recessing portions 11a. The polishing step 1010 is continued until the projecting portions 11b are polished so that the whole region of the surface 10a of the substrate 10 reaches the target plane H substantially equivalent to the surfaces 11a of the recessing portions 11a. In this manner, the cavities 15b formed in the surfaces 11b of the projecting portions 11b can be eliminated.

An enlarged view (FIG. 5f) of the neighborhood of the cavity 15b formed in each of the surfaces 11b of the projecting portions 11b in FIG. 5f is shown on the right side. It is necessary that the distance D between the surface 11a and the surface 11b is larger than the depth q of the cavity 15b. This is because the cavity 15b remains in the surface of the substrate 10 after the polishing step 1010 if the depth q of the cavity 15b is larger than the distance D. Accordingly, it is desirable that the following expression (2) holds.

\[ q \leq D \]  

As described above, the substrate 10 has recessing portions 11a and projecting portions 11b, and the recessing portions 11a are distributed in arbitrary positions. Although this embodiment has been described upon the case where the recessing portions 11a are distributed at intervals of a constant pitch, the art as to another embodiment can be applied to the case where the recessing portions 11a are distributed at irregular intervals. As described above, the producing method according to this embodiment is particularly suitable for the case where cavities (or a set of cavities) 15a distributed in accordance with the recessing portions 11a are formed in the surface 10a of the substrate 10.

After the polishing step 1010, the surface 10a of the substrate 10 is cleaned (step 1012). In cleaning after polishing, polishing dust can be removed from the surface of the substrate 10 almost perfectly by polyvinyl alcohol (PVA) brushing with chemicals such as ammonia, diluted HF, etc.

As a result, a master 20 of a nano-structure as shown in FIG. 5f is obtained. The master 20 functions as a mold for magnetic recording media (magnetic discs). The master 20 has a surface 20a in which the cavities 15a are distributed. The distribution of the set of cavities 15 corresponds to the distribution of the recessing portions 11a in the substrate 10. The master 20 is shaped like a disc. The surface 20a of the master 20 coincides with the target plane H shown in FIG. 5f. The cavities 15a have been already removed from the master 20.

FIG. 7 is a flow chart showing a modified example of the step 1000. FIGS. 8A-E are schematic sectional views for explaining the steps of FIG. 7.

First, a substrate 10 having a projecting and recessing pattern 11 composed of recessing portions 11a and projecting portions 11b is produced (step 1022). The substrate 10 is shaped like a disc. The recessing portions 11a have surfaces 11a1. The projecting portions 11b have surfaces 11b1. The step 1022 is the same as the step 1002, so that the substrate 10 produced in the step 1022 is the same as that produced in the step 1002.

After the step 1022, a resist is applied on the surface 10a of the substrate 10 by a spraying method, a spin coating method, etc. and pre-baked to form a resist layer (photosensitive resin layer) 16 as shown in FIG. 8a (step 1024). A photosensitive resin material made of a urethane-urea copolymer containing an azo pigment can be used as the resist.

A surface 16a of the resist layer 16 has a projecting and recessing pattern 17 or a projecting and recessing surface. The projecting and recessing pattern 17 has recessing portions 17a and projecting portions 17b. The recessing portions 17a are formed so as to correspond to the recessing portions 11a whereas the projecting portions 17b are formed so as to correspond to the projecting portions 11b. The recessing portions 17a have surfaces 17a1 which are the outermost surfaces of the recessing portions 17a. The projecting portions 17b have surfaces 17b1 which are the outermost surfaces of the projecting portions 17b. In this embodiment, to satisfy the expressions (1) and (2) is the Z-direction depth D of each recessing portion 17a that is, the distance between the surface 17a1 and the surface 17b1.

Then, as shown in FIG. 8b, spherical nano-particles 12A made of spherical polystyrene particles are arranged on the resist layer 16 by a pull-up method, a spin coating method or a dropping method (step 1026). In this embodiment, the pull-up method is used. Although it is preferable in this case that a single layer of nano-particles 12A is arranged only on the recessing portions 17a, the nano-particles 12A are allowed to be attached onto the projecting portions 17b as long as the nano-particles arranged on the recessing portions 17a form a single layer.

Then, as shown in FIG. 8c, cavities are formed in the resist layer 16 of the substrate 10 located under the nanoparticles 12A (step 1028). In this embodiment, cavities formed in the surfaces 17a1 of the recessing portions 17a of the projecting and recessing pattern 17 are designated by the reference numeral 18a whereas cavities formed in the sur-
faces 17b1 of the projecting portions 17b of the projecting and recessing pattern 17 are designated by the reference numeral 18b, so that the two kinds of cavities can be distinguished from each other. Cavities 18a are formed in one recessing portion 17a.

In the step 1028, an argon laser (which can be replaced by an excimer femtosecond laser or the like) with a wavelength of 488 nm is used so that laser light L is irradiated from above the nano-particles 12A arranged on the resist layer 16. FIG. 8C shows a state in which laser light L is irradiated onto the substrate 10. The laser light used in this embodiment is of a low output type of the order of tens of mW.

A galvanometer mirror or the like is used so that the whole of the substrate surface is scanned with the laser light L. When the laser light L irradiated onto the substrate 10 passes through the nano-particles 12A, the laser light L is condensed by the light condensing effect of the nano-particles 12A. The resist located under the bottom of the nano-particles 12A is removed or etched by the action of the laser light L condensed by the nano-particles 12A, so that cavities 18a and 18b are formed in the surface of the resist layer 16.

Then, as shown in FIG. 8D, the nano-particles 12A are removed from the substrate 10 by ultrasonic treatment, cleaning, ashing, etc. (step 1030). As shown in FIG. 8D, the cavities 18a are formed in all the recessing portions 17a whereas the cavities 18b are formed in some projecting portions 17b but not formed in some projecting portions 17b.

Then, the substrate 10 shown in FIG. 8D is turned upside down and is pressed on an abrasive cloth on a disc of a polishing apparatus and then the projecting portions 11b of the surface 10a of the substrate 10 are polished by CMP (step 1032). In the polishing step 1032 in this embodiment, the projecting and recessing surfaces with the cavities 18b formed therein are polished.

Since the cavities (defective cavities) 18b are eliminated in the surfaces 17b1 of the projecting portions 17b are eliminated by the polishing step 1032, the yield for production of the nano-structure which is a master can be improved. The term "defective cavities" in this embodiment means cavities 18b formed in the surfaces 17b1 of the projecting portions 17b which are other positions than those of the cavities 18a intended properly to be formed in the surfaces 17a1 of the recessing portions 17a.

In the polishing step 1032, the surface of the substrate 10 is polished to be substantially flattened so that the surfaces 17a1 of the recessing portions 17a are exposed. FIG. 8D shows the target plane 11l which should be formed after the substrate 10 is polished or flattened. The target plane 11l is a plane substantially equivalent to the surfaces 17a1 of the recessing portions 17a.

The polishing step 1032 is continued until the projecting portions 11b are polished so that the whole region of the surface 16a of the resist layer 16 reaches the target plane 11l substantially equivalent to the surfaces 17a1 of the recessing portions 17a. In this manner, the cavities 18b formed in the surfaces 17b1 of the projecting portions 17b can be eliminated.

After the polishing step 1032, the surface of the substrate 10 and the surface of the resist layer 16 are cleaned (step 1034). In this manner, polishing dust can be eliminated almost completely.

As a result, a master 20A of a nano-structure as shown in FIG. 8E is obtained. The master 20A functions as a mold for magnetic recording media (magnetic discs). The master 20A has a surface 20b in which the cavities 18a are distributed. The distribution of the set of cavities 18a corresponds to the distribution of the recessing portions 11a in the substrate 10. The master 20A is shaped like a disc. The surface 20b of the master 20 coincides with the target plane 11l shown in FIG. 8E. The cavities 18b have been already removed from the substrate 10. However, the master 20A in FIG. 8E is different from the master 20 in FIGS. 5I in that the projecting portions 11b partially remain in the substrate 10 of the master 20A after polishing or flattening.

Referring back to FIG. 3, a stamper 30 is produced by an electroforming process using an electrolytic plating method as shown in FIG. 5I, on the basis of the master 20A shown in FIG. 5I or the master 20A shown in FIG. 8E (step 1100). The stamper 30 has a surface 30a provided with a projecting pattern 32 which is an inversion of the recessing pattern (nano-hole pattern) into which the cavities 15c or 18a formed in the surface 20a or 20b of the master 20 or 20A are distributed. The stamper 30 in this embodiment is made of Ni and shaped like a disc.

A seed layer used in electrolytic plating can be formed by a vacuum vapor deposition method, a sputtering method, a CVD method, a plating method, etc. A metal material such as Ni, Ni—W alloy, Fe, etc., transition metal carbide such as WC, TiC, etc., transition metal silicide such as WSi2, TaSi2, NbSi2, VSi2, etc., or transition metal nitride such as NbN, Ta2N, TiN, VN, ZrN, etc. can be used as the seed layer. In the electrolytic plating method, the seed layer is used as an electrode so that an Ni-plating film is formed on the surface (lower surface) of the master 20 shown in FIG. 5I. For example, a well-known Ni-plating bath such as a sulfamate acid bath can be used.

Then, the Ni-plating film is separated from the master 20 or 20A, so that the stamper 30 shown in FIG. 5I is produced. In the master 20A produced by the steps shown in FIGS. 8A-E, the resist layer 16 remains on the seed layer when the Ni-plating layer is separated from the master 20. Therefore, the remaining resist layer 16 is dissolved and removed by an organic solvent such as methyl ethyl ketone and polished by CMP to adjust flatness and surface roughness. In this manner, the stamper 30 is produced.

Then, a magnetic disc is produced by use of the stamper 30 (step 1200). Details of the step 1200 will be described below with reference to FIGS. 9 and 10. FIG. 9 is a flow chart for explaining the details of the step 1200. FIGS. 10A to 10D are schematic sectional views showing the steps of FIG. 9.

First, as shown in FIG. 10A, a pattern 32 of the stamper 30 is transferred to a medium substrate 40 by a nano-imprinting method under high pressure (step 1202). The medium substrate 40 is a disc made of aluminum or a substrate having an aluminum layer on a surface 40a of a base of the medium substrate 40. For example, the base is a plastic base, a glass base, a silicon base, etc. Incidentally, in another embodiment, the substrate may be shaped like a tape and a plastic film such as PET, PEN, polyimide, etc. may be used as the substrate. FIG. 10B is a schematic sectional view of the medium substrate 40 having the surface 40a provided with a recessing pattern 42 (nano-hole pattern) into which the pattern 32 on the master 20 is inverted by the transfer step.

A soft magnetic backing layer not shown is formed under the aluminum layer of the medium substrate 40 if necessary. The soft magnetic backing layer is formed of a soft magnetic amorphous or polycrystalline layer by a sputtering method, a CVD method, a plating method, etc. Specifically,
NiFe (permalloy), CoFeB, CoCrNb, CoZrNb, NiFeNb, etc. can be used as the soft magnetic backing layer. The soft magnetic backing layer forms a magnetic circuit for reflexing magnetic flux from a magnetic head to the magnetic head again.

[0083] Then, the area, depth, etc. of the recessing pattern 42 formed on the medium substrate 40 are controlled by an anodic oxidation method (step 1204). FIG. 10C is a schematic sectional view of the medium substrate 40 having a recessing pattern 44 after cavities of the recessing pattern 42 formed in the surface are enlarged by the anodic oxidation method. In this manner, the recessing pattern 44 having a desired size can be formed on the medium substrate 40.

[0084] Then, as shown in FIG. 10D, a magnetic substance layer 46 is produced on the whole of the surface 40a of the medium substrate 40 by a plating method (step 1206). The magnetic substance layer 46 is formed of a magnetic substance 46a such as cobalt, cobalt-chromium alloy, etc.

[0085] Then, the magnetic substance except the magnetic substance packed in the cavities of the pattern 44 is removed from the medium substrate 40 by CMP so that the surface 40a of the medium substrate 40 is flattened (step 1208). FIG. 10E is a schematic sectional view of the medium substrate 40 after CMP. FIG. 10F is a partly enlarged view of FIG. 10E. As shown in FIG. 10F, nano-holes 46a filled with the magnetic substance are arranged regularly in the surface of the medium substrate 40.

[0086] After the pattern 44 of the magnetic substance 46a is formed in the surface 40a by the step 1208, a protective layer of a carbon compound, a lubricant layer of tetraol, etc., and so on are laminated on the medium substrate 40 (step 1210) so that a magnetic disc is formed.

[0087] The magnetic recording medium in this embodiment is a magnetic disc used in an HDD. In this embodiment, the magnetic disc is a DTM or BPM having a magnetic recording region magnetically divided by a non-magnetic insulator. In the DTM or BPM, a magnetic substance must be arranged discretely. Moreover, such arrangement becomes harder as the particle size of the magnetic substance becomes smaller. In the magnetic recording medium producing method according to this embodiment, the magnetic disc can be produced with a good yield as will be described below.

[0088] FIG. 11 is a partly enlarged plan view of the DTM. FIG. 12 is a partly enlarged plan view of the BPM. Each of the DTM and the BPM has a structure in which tracks 47 or sectors 48 are compartmentalized by a non-magnetic substance 50. Portions equivalent to the magnetization transition regions 49 of the conventional magnetic disc are replaced by the non-magnetic substance 50. The DTM or BPM can eliminate occurrence of transition noise to thereby achieve a higher recording density than that of a magnetic disc using a continuous film.

[0089] The magnetic disc produced as described above is mounted in a casing (step 1300). The HDD 100 in this embodiment will be described below with reference to FIG. 13. As shown in FIG. 13, the HDD 100 has a casing 102, one magnetic disc or a plurality of magnetic discs 104 as a recording medium (or a plurality of recording media), a spindle motor 106, and a head stack assembly (HAS) 110. These parts 104, 106 and 110 are contained in the casing 102. FIG. 13 is a schematic plan view of the internal structure of the HDD 100.

[0090] For example, the casing 102 is made of aluminum die-cast, stainless steel, etc. The casing 102 is shaped like a rectangular parallelepiped. A cover not shown is connected to the casing 102 so that the internal space of the casing 102 can be sealed. Each magnetic disc 104 is a DTM or BPM produced by the aforementioned producing method. The magnetic disc 104 is attached to a spindle (hub) of the spindle motor 106 through a hole provided in the center of the magnetic disc 104.

[0091] The HAS 110 has a suspension 130 for supporting a magnetic head portion 120, a base plate 160, and a carriage 170.

[0092] The magnetic head portion 120 has a slider, and a head element-containing film which contains a built-in read/write magnetic head. The slider floats up from a surface of the rotating disc 104 while supporting the head.

[0093] The suspension 130 has a function of applying elastic force in a disc 104 direction to the magnetic head portion 120 while supporting the magnetic head portion 120.

[0094] The base plate 160 has a function of attaching the suspension 130 to the arm 174. The base plate 160 has a welded portion, and a boss. The welded portion is laser-welded to the suspension 130. The boss is caulked to the arm 174.

[0095] The carriage 170 has a function of rotating or swinging the magnetic head portion 120 in a direction of the arrow shown in FIG. 13. The carriage 170 has a shaft 172, and the arm 174. The shaft 172 is arranged in the casing 102 so as to be perpendicular to the paper surface on which FIG. 13 is drawn. A center axis of the shaft 172 is a rotation axis of the arm 174. The arm 174 supports the suspension 130 through the base plate 160.

[0096] In the operation, the slider floats up from the magnetic disc 104 so that the head applies recording/reproducing. The magnetic disc 104 can perform a faultless stable recording/reproducing operation with high recording density.

[0097] Although preferred embodiments of the invention have been described, the invention is not limited to the embodiments and various modifications and changes may be made within the gist of the art.

[0098] According to the invention, there can be provided a nano-structure producing method in which a nano-hole pattern of nano-holes distributed in arbitrary positions can be produced with a good yield, and a magnetic recording medium producing method using the nano-structure producing method.

What is claimed is:
1. A manufacturing method for a nano structure comprising the steps of:
   arranging nano-particles on a substrate having a surface provided with a projecting pattern and a recessing pattern;
   forming cavities under the nano-particles;
   removing the nano-particles from the substrate; and
   polishing the surface in which the cavities are formed.
2. The manufacturing method according to claim 1, wherein the projecting pattern and the recessing pattern formed on the substrate are formed circularly.
3. The manufacturing method according to claim 1, wherein the polishing step uses chemical mechanical polishing.
4. The manufacturing method according to claim 1, wherein the substrate is a glass substrate or a silicon substrate.
5. The manufacturing method according to claim 1, wherein the substrate is a low-melting glass substrate.
6. The manufacturing method according to claim 1, wherein the nano-particles are made of silica.

7. The manufacturing method according to claim 1, wherein the polishing step is performed so that the surface is polished so as to be flattened.

8. The manufacturing method according to claim 1, wherein a depth of the recessing pattern of the surface is larger than a depth of the cavities.

9. The manufacturing method according to claim 1, wherein a depth of the recessing pattern is not larger than twice the diameter of the nano-particles.

10. The manufacturing method according to claim 1, wherein the surface is provided with a plurality of the projecting patterns and a plurality of the recessing patterns.

11. The manufacturing method according to claim 1, wherein the recessing pattern has a width not larger than 100 nm.

12. The manufacturing method according to claim 1, further comprising cleaning the surface of the substrate after the polishing step.

13. The manufacturing method according to claim 1, wherein the forming step is performed by etching.

14. The manufacturing method according to claim 1, wherein the forming step is performed by plasma ashing treatment.

15. The manufacturing method according to claim 1, wherein the forming step is performed by irradiating light to a resist applied on the surface of the substrate.

16. The manufacturing method according to claim 1, wherein the nano-structure is a master used for production of a magnetic recording medium.

17. A manufacturing method for a stamper, comprising the steps of:
   arranging nano-particles on a master having a surface provided with a projecting pattern and a recessing pattern;
   forming cavities under the nano-particles;
   removing the nano-particles from the master;
   polishing the surface in which the cavities are formed; and
   forming a stamper having a pattern as an inversion of the projecting pattern and the recessing pattern of the surface of the master.

18. A manufacturing method for a recessing pattern structure comprising the steps of:
   immersing a substrate having a surface provided with a projecting pattern and a recessing pattern in a particle suspension;
   pulling up the substrate from the particle suspension;
   forming cavities on the substrate masked with particles remaining on the substrate;
   removing the particles from the substrate; and
   polishing the surface of the substrate to eliminate the cavities.

19. A manufacturing method for a projecting pattern and a recessing pattern structure comprising the steps of:
   arranging fine particles on a surface of a substrate having a projecting pattern and a recessing pattern in the surface;
   etching the surface in a state in which the fine particles are arranged on the substrate surface;
   removing the fine particles from the substrate; and
   polishing the substrate surface to eliminate cavities formed in projecting portions of the substrate as a result of the etching;
   forming a metal film on the surface of the polished substrate; and
   peeling the metal film from the substrate.

20. A manufacturing method for a magnetic recording medium comprising the steps of:
   forming cavities in a surface of a substrate having a projecting pattern and a first recessing pattern formed in the surface and at least the first recessing pattern filled with fine particles;
   flattening the substrate while removing the fine particles from the substrate in which the cavities are formed;
   forming a second recessing pattern in a substrate of a magnetic recording medium by using a stamper formed with the flattened substrate as a master; and
   filling the second recessing pattern formed in the substrate of the magnetic recording medium with a magnetic material.

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