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Specification

Title of the Invention:

Magnetic head coated with low surface energy material

Details Description of the Invention:

[0001]

[Field of the invention]

The present invention generally relates to disc recording apparatuses, and more particularly to technology for protecting magnetic heads from corrosion by applying coating to magnetic heads used in hard disc drives.

[0002]

[Background art]

In recent years, the recording capacity of disc recording apparatuses has increased very rapidly. This is significant in typical magnetic recording apparatuses, namely hard disc drives (HDDs hereinafter). As HDDs have been downsized and highly densified, and high performance/high sensitivity write (record) and read elements are used for them, they are susceptible to influences of use environment. Among the influences of use environment, the issue of corrosion is a critical issue in securing reliability of HDDs.

[0003]

Water existing within HDDs is believed to be one of the main causes of typical corrosion. Therefore, approach to remove water itself has been considered in conventional technologies. A method for placing a drying agent inside the HDD is an example. However, as absorbancy of the drying agents is limited, there was an limitation in their capacity of removing water itself. Thus, drying agents had the drawback of being unable to serve for long time uses.

[0004]

Also in the conventional technology, coating of the surfaces of magnetic discs with lubricants was considered expecting that the lubricants would be transferred and supplied to writ or read element sides substantially covering areas susceptible to corrosion. However, this approach also had the drawback of being unable to serve for long time uses with reliability, as it was difficult to ensure retention of the lubricants adhered for a long time.

[0005]

Further in the conventional technologies, highly anticorrosive materials have been selected for use in write and read elements themselves. However, it has been difficult to ensure enough corrosion resistance while realizing enough function for write and read.

[0006]

Moreover in the conventional technologies, protective layers have been coated over writ and read elements to improve abrasion resistance. However, such coating has been so thick that it has been damaging to recording properties of the write and read elements. That is, it has been impossible to form thin film coating without damaging recording properties of the

writ and read elements, and realizing enough corrosion resistance.

[0007]

[Problems to be solved by the invention]

It is the main purpose of the present invention to ensure reliability of HDDs by improving corrosion resistance of magnetic heads in HDDs.

[0008]

It is another purpose of the present invention to select suitable materials for highly corrosion resistant coating.

[0009]

It is a further purpose of the present invention to form thin films with correct thickness as the coating for magnetic heads.

[0010]

[Summary of the invention]

In the present invention, at least a part of the surface of write or read elements of the magnetic head surface is coated with low surface energy materials. Therefore, water would not easily approach such coated surfaces due to their humidity resistance, wetting resistance, and hydrophobicity, resulting in improved corrosion resistance of these coated surfaces.

[0011]

Also surface energy values of water and low surface energy materials have been determined for specific evaluation. Then FCOCs (fluorocarbon compounds) and especially materials including perfluoroalkylpolyoxyethyleneethanol have been

selected as low surface energy materials. Particular surface energy values of selected materials have also been determined.

[0012]

Further, in forming thin films of low surface energy materials as coatings for magnetic heads, their suitable thickness has been selected as 5 - 100 Å. More preferably, it has been selected as 10 - 20 Å. With this proper thickness, enough adhesion of the coating may be realized without damaging functions of magnetic heads.

[0013]

[Preferred embodiment]

Figure 1 is a total exploded perspective view of a hard disc drive (HDD) 10. Inside this, a plurality of discs 12 are rotated as a whole by a spindle motor 14 during operation. A carriage assembly 16 is included as an element configuring HDDs, and the carriage assembly 16 crosses over discs to access discs 12. This movement of the carriage allows data to be written into and read from the desired parts of the discs 12.

[0014]

There are small holes 20 in the top cover 18, and a breather filter 22 is placed to cover the small holes 20, which can remove dust from outside the HDDs. Therefore, air can go into and out of HDD through these small holes 20 and the breather filter 22. For example, a HEPA filter is used as the breather filter 22. Thus, environment outside HDD is transferred inside.

[0015]

As shown in Figure 2, a slider 24 is attached at the end of the carriage assembly 16 (Figure 1). For example, AlTiC is used as

a material for slider 24. Flow of the air F caused by rotation of disc 12 flows upstream to downstream of the slider, forming air bearing surface (ABS) 26 and keeping the slider 24 floating above the discs 12. As the slider 24 is typically raised so that its upstream side is higher than its downstream side, the downstream side becomes closest to the discs 12.

[0016]

A write/read element 30 is attached on downstream side of the slider, and the data is written into or read from discs 12 through electromagnetic effect M between this element 30 and the surface of discs 12. For full function of the electromagnetic effect M, it is preferable that the distance between the write/read element 30 and the discs 12 is as short as possible. This is because electromagnetic effect M can be localized at the surface of discs 12 to be utilized at high density. However, physical corrosion of the write/read element 30 and the rotating discs 12 is not allowed.

[0017]

In Figure 2, vicinity of the write/read element 30 is enlarged and shown more precisely. As shown here the write/read element 30 is often used separately as a write element 32 and a read element 34.

[0018]

Further in some cases materials 36 other than the material (AlTiC) for the slider 24 are located on a part of the surface of the slider 24 as a material to serve as a foundation for the write/read element 30. There may be a similar case where vicinity of this element 30 is surrounded by materials 36 other than the material for the slider 24, even though they do not serve as the foundation for this.

[0019]

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In either case, the "surface" of the write/read element 30 is exposed to ABS as shown in the figure, for full function of the electromagnetic effect M. However, it has not necessarily to be exposed directly to ABS and it may be enough that it is exposed to the downstream side of the slider, for example even to the rear side 38 (behind the scene in the figure, though can be seen from the direction depicted by an eye and an arrow).

[0020]

In the description of the present invention, a slider including either write element 32 or read element 34 is called "magnetic head" for convenience.

[0021]

Typically, high permeability alloy is used for the write elements 32 and alloy utilizing magnetic resistance (MR) effect is used for the read elements 34. Thus, either element includes metal parts.

[0022]

As these metal parts are necessarily exposed to surfaces of ABSs, they are susceptible to corrosion by the air flow F, etc., and once corroded, the electromagnetic properties are significantly deteriorated. Especially reduction in output of reading signals from the read element 34 is significant. Also the write element 32 cannot give the discs enough electromagnetic effect, resulting in poor write in some cases.

[0023]

When it becomes highly humid inside HDDs, surfaces of these write/read elements 30 become more apt to be exposed to humidity. This significantly causes corrosion as described

above.

[0024]

Small amounts of corrosive gases generated within HDDs are believed to be related to other causes of corrosion. Generation of such gases may be related to volatile components generated from parts themselves in the HDD, or related to aging of the HDD parts. Actually corrosion is believed to proceed due to electrochemical processes related to variety of those causes.

[0025]

Also high temperature inside HDDs will further enhance corrosion reactions. High temperature will also strongly cause generation of corrosive gases.

[0026]

Surface energy

Now, there is an index called "surface energy" as an indication of resistance of a given surface against water. According to this index degree of humidity resistance or wetting resistance, (Anti Wetting) a degree of rejecting water, may be known from the condition of water on a reference surface.

[0027]

Figure 3 is a schematic view of three categorized states of water on a surface. Parts of the material shown in dots, A, B, C, represent states of water, and parts of the material shown shaded represent the reference surface.

[0028]

Each of those states of water will be explained as "complete"

wetting for A, "good" wetting for B, and "poor" wetting for C. These expressions are only for convenience. Those skilled in the art may as well use other expressions.

[0029]

From the point of view that it is good to be wet, A is preferable and it is unpreferable to be closer to C. On the contrary from the point of view that degree of wetting resistance is the issue as in the present invention, C is preferable and it is not preferable to be closer to A. This may be apparent from the meaning of terms "hydrophobicity and water repellence."

[0030]

The states of A, B, and C are categorized by contact angles θ . Contact angle θ is defined as the angle θ formed between the tangent line and the reference surface at the contact point of water in the form of a drop of water and the reference surface.

[0031]

The contact angle θ is determined by the following equation using surface energy of water γ_t and the surface energy of reference surface γ_s . θ in the equation is an experimental value.

$$\cos \theta = 2 \theta (\gamma_t / \gamma_s)^{1/2} - 1$$

[0032]

Contact angle θ can be determined experimentally by taking the image of a drop of water in a CCD camera and processing the image.

[0033]

This equation shows that it is preferable from the point of view of humidity resistance or wetting resistance that the surface energy of the reference surface γ_s is small enough as compared with the surface energy of water γ_t as far as the latter is constant. The surface energy of water is $\gamma_t = 72.2$ erg/cm². On the other hand when the material of the reference surface is alumina (Al₂O₃; aluminum oxide), the surface energy of alumina is $\gamma_s = 169$ erg/cm².

[0034]

The reason why the surface energy of alumina is the issue will be mentioned here. In other words, it is the reason why the write/read element 30 which must be protected from corrosion is not the direct issue as the reference surface. Although vicinity of the write/read element 30 is surrounded by other materials 36 in some cases as described above, the reference surface here corresponds to the other material 36 which is comprised of alumina (Figure 2).

[0035]

Thus, in order to evaluate humidity resistance, it is more reasonable to focus on the surface energy of alumina that occupies most of the surface area. Exposed areas of the write element 32 and read element 34 will total only to a very small exposed area. It is noted that the exposed areas of the write element 32 and read element 34 in Figure 2 are exaggerated to look bigger for convenience of illustration. In other words, it is reasonable to evaluate the contact angle θ at the contact points of water and alumina.

[0036]

Low surface energy materials

In the present invention, coating was formed as a substitute for substrate surface to reduce surface energy of the surface of the substrate, and the coating was provided with humidity resistance and wetting resistance. FCOCs (fluorocarbon compounds) were selected as the suitable material for the thin film.

[0037]

A material containing perfluoroalkylpolyoxyethyleneethanol was selected as an example of FCOCs (fluorocarbon compounds). The surface energy of the thin film material was found to be $\gamma_s = 12 - 15 \text{ erg/cm}^2$.

[0038]

However, even lower surface energy is expected to be realized by adding more perfluoroalkylpolyoxyethyleneethanol. Lower limit even closer to zero can be experimentally estimated to exist. Those skilled in the art may easily achieve such modification.

[0039]

Thus, the selected materials may be utilized as optimum anti wetting agents. As the surface energy of alumina (Al_2O_3 : aluminum oxide) is $\gamma_s = 169 \text{ erg/cm}^2$ as described above, it is understood that substitution with far lower surface energy reference surface is attained by this coating.

[0040]

Method for forming thin films

Further advantage of the FCOCs (fluorocarbon compounds) is that they can form thin films as solid. The thin film as solid has been assured experimentally to retain adhered to surfaces for a

long time.

[0041]

As actual formation of thin films, processes using dipping-and-drawing and plasma CVD were carried out, and FCOC was confirmed to be effective in both processes. Description of these processes is omitted since those skilled in the art may easily add and reproduce them.

[0042]

Also those skilled in the art may easily adopt other formation processes such as sputtering, vapor deposition, and coating. Also the process may be developed to realize smoother surface by changing coarseness or the feature of the surface using physical surface treatment methods such as ion beam etching.

[0043]

Thickness of thin films

In the present invention it was found that coating of perfluoroalkylpolyoxyethyleneethanol is preferably formed into thin films with the thickness of 5 - 100 Å. Optimum range of thickness is determined by following reasons.

[0044]

If the thin film is too thin, enough effect of corrosion resistance may not be expected. Also some parts may be left uncovered by the thin film due to technological limitation of thin film formation. Experiments showed that thickness of at least 5 Å is necessary.

[0045]

On the other hand, if the thin film is too thick, function of

the magnetic head is damaged during operation of the HDDs. Thus the extra thickness will substantially reduce the allowance in the distance between discs 12 and the write/read elements 30. This situation is undesirable since it is important to secure electromagnetic effect M (Figure 2) by reducing the distance between them as described above.

[0046]

Therefore limitation in thickness is also necessary. Experiments showed that thickness of 100 Å is realized in HDDs presently. Needless to say that strong adhesion for a very long period may be attained with such thickness.

[0047]

A range of 10 - 20 Å was found to be more preferable by narrowing the optimum thickness range, taking in consideration the balance between such limitations of thinness and thickness.

[0048]

Range of thin film formation

As the range for thin film formation, it is enough to cover all the surface in which the record/read elements 30 are exposed. That is, the range will be sufficient where the purpose of the present invention, namely, hydrophobicity and water repellence are expected. On the other hand, it is more difficult to try to form thin films only on these surfaces, because these surfaces are extremely small exposed areas and do not have simple features as shown enlarged and more precisely in Figure 2.

[0049]

Thus, in the present invention, thin film is formed so that some parts of the other materials 36 where alumina is used are

also coated. This is in order to expect enough hydrophobicity and water repellence for the exposed surfaces of the write element 32 and the read element 34.

[0050]

This shows that it is appropriate to take the surface energy of alumina as an object of comparison in evaluating humidity resistance. It is because the contact angle θ is to be evaluated at the contact point with alumina. Of course it is not necessary to form thin film on parts of the write element or the read element, if the parts are already provided with enough corrosion resistance.

[0051]

Adhesiveness (durability) of thin films

A whole HDD as shown in Figure 1 was left in a temperature-humidity chamber out of operation, in order to examine adhesive effect of the thin film. As the air can go into and out of the HDD as described above, the environment outside HDD is transferred inside.

[0052]

Generally temperature and humidity have significant accelerability for promoting reactions. Especially humidity above between 80% and 90% RH (relative humidity) shows extraordinary acceleration.

[0053]

Humidity was set to be 90% RH (relative humidity), and temperature was set to be 50°C. Humidity of 90% RH is a condition in which dew formation is easy, and in which it is highly probable for water vapor or water to contact surfaces. Both the humidity and temperature conditions are fairly severe.

For example, an accelerative examination under such a condition for a week has the significance of assuring that the object may be used under ambient environment for about 5 long years.

[0054]

The dots in the graph of Figure 4 show output value data obtained from read elements 34 of the magnetic heads. Coating of the present invention is formed on each magnetic head. The horizontal axis represents the output value data obtained from each magnetic head left standing for the period A of more than a week, and the vertical axis represents the output value data obtained from each magnetic head left standing for the period B which is twice the period A. Thus, this graph correlates the data after standing for the period A and the data after standing for the period B.

[0055]

As an evaluation, output values above the lower limit are estimated to assure the performance. All the dots are shown to be above the lower limit both in the horizontal and vertical axes. Thus, it was confirmed that the reliability of HDDs was secured by using magnetic heads coated with the thin film of the present invention.

[0056]

The dots in the graph of Figure 5 show the result of an examination of magnetic heads used in conventional technologies under a high humidity and high temperature condition similar to Figure 4. However, coating of the present invention was not formed here. And the horizontal axis of this graph represents data of output value obtained from magnetic heads at the initial stage before exposed to high temperature and high humidity environment (different from Figure 4). Further the vertical axis of this graph represents output data from magnetic heads after standing for the period A (different from

Figure 4 in which the vertical axis represents data of the period B).

[0057]

In case of magnetic heads of conventional technology shown in Figure 5, 4% of the dots were below the lower limit already after standing for the period A. The ratio 4% can be found from the number of dots below the lower limit of the vertical axis. Thus, influence of corrosion is considered to have already occurred after standing for the period A.

[0058]

Although not shown as a graph, 20% of the dots were below the lower limit according to the output data obtained from magnetic heads left standing under a high temperature and high humidity environment for further period A (namely total of period B).

[0059]

After this accelerative examination, the surface was physically examined to see whether the formed thin film coating still remained. Namely the adhesive power of the coating formed was confirmed. As a result, detachment to be functionally problematic inside HDDs was not confirmed, showing enough adhesive power for a long period.

[0060]

Though the present invention has been explained in relation to magnetic disc elements, those skilled in the arts may easily achieve application of the present invention for other disc record elements such as photomagnetic record elements or phase transition type record elements, and to the heads used in them.

[Advantage of the invention]

Magnetic heads coated by low surface energy materials according to the present invention was found to be very excellent in corrosion resistance. Reliability of HDDs is secured by this.

Brief description of the drawings:

Figure 1 is a whole exploded perspective view of the hard disc drive (HDD) 10;

Figure 2 is a perspective view showing that the slider 24 is in a floating state (the write/read elements 30 and the vicinity are enlarged and more precisely shown);

Figure 3 is a schematic view of states of water on a reference surface categorized to three, "complete" wetting A, "good" wetting B, and "poor" wetting C, in order to illustrate surface energy;

Figure 4 is a graph correlating output data obtained from magnetic heads coated according to the present invention left standing under a high temperature and high humidity environment for periods A and B; and

Figure 5 is a graph correlating output data obtained from magnetic heads (not coated according to the present invention) used in a conventional technology at the initial stage before exposed to a high temperature and high humidity environment and after left standing for period A under a high temperature and high humidity environment.

[Description of symbols]

- 10 ... Hard disc drive (HDD)
- 12 ... Disc
- 14 ... Spindle motor

- 16 ... Carriage assembly
- 18 ... Top cover
- 20 ... Small hole
- 22 ... Breather filter
- 24 ... Slider
- 26 ... Air bearing surface (ABS)
- 30 ... Write/read element
- 32 ... Write element
- 34 ... Read element
- 36 ... Other material (alumina)
- 38 ... Rear side behind the scene



Claims:

- (1) A magnetic head characterized by having at least a part of the surface of a write element or a read element coated with materials with low surface energy, in said magnetic head comprising either the write element or the read element.
- (2) The magnetic head of Claim 1, wherein said materials with low surface energy are FCOCs (fluorocarbon compounds).
- (3) The magnetic head of Claim 2, wherein said FCOCs are materials containing perfluoroalkylpolyoxyethyleneethanol.
- (4) The magnetic head of Claim 1, wherein said surface energy of said materials with low surface energy value γ_s equals 15 erg/cm² or less.
- (5) The magnetic head of Claim 4, wherein said surface energy of said materials with low surface energy value γ_s equals 12 erg/cm² or more.
- (6) The magnetic head of Claim 1, characterized by being coated with said materials with low surface energy as thin films with thickness of 100 Å or less.
- (7) The magnetic head of Claim 6, characterized by being coated with said materials with low surface energy as thin films with thickness of 5 Å or more.
- (8) The magnetic head of Claim 1, characterized by being coated with said materials with low surface energy as thin films with thickness between 10 Å and 20 Å.
- (9) A carriage assembly equipped with said magnetic head of Claims 1 through 8.
- (10) A hard disc drive equipped with said carriage assembly of Claim 9.