A system according to one embodiment includes a substrate having one or more sacrificial row bars and one or more additional row bars, wherein the one or more sacrificial row bars comprise a wear resistant material and are adapted to be used in a lapping process to prepare a lapping plate, wherein the one or more additional row bars comprise a material that has less wear resistance than the wear resistant material and are adapted to be used for magnetic head slider production, and wherein the lapping plate is adapted to be used in a lapping process to polish the one or more additional row bars.
Coat one or more sacrificial row bars with a wear resistant material, wherein the wear resistant material resists wear better than a material of additional row bars, the additional row bars being adapted to be used for magnetic head slider production.

Press the one or more sacrificial row bars against a lapping plate until a predetermined metric has been achieved.

Withdraw the one or more sacrificial row bars from the lapping plate.

Use the lapping plate in a lapping process to polish the additional row bars after the one or more sacrificial row bars have been pressed against the lapping plate.

FIG. 6
ULTRA FINE LAPPING SUBSTRATE THROUGH USE OF HARD COATED MATERIAL ON LAPPING KINEMATICS

FIELD OF THE INVENTION

[0001] The present invention relates to data storage systems, and more particularly, this invention relates to using a hard coated material on lapping kinematics to condition an ultra fine lapping substrate.

BACKGROUND

[0002] The heart of a computer is a magnetic hard disk drive (HDD) which typically includes a rotating magnetic disk, a slider that has read and write heads, a suspension arm above the rotating disk and an actuator arm that swings the suspension arm to place the read and/or write heads over selected circular tracks on the rotating disk. The suspension arm biases the slider into contact with the surface of the disk when the disk is not rotating but, when the disk rotates, air is swirled by the rotating disk adjacent an air bearing surface (ABS) of the slider causing the slider to ride on an air bearing a slight distance from the surface of the rotating disk. When the slider rides on the air bearing the write and read heads are employed for writing magnetic impressions to and reading magnetic signal fields from the rotating disk. The read and write heads are connected to processing circuitry that operates according to a computer program to implement the writing and reading functions.

[0003] The volume of information processing in the information age is increasing rapidly. In particular, it is desired that HDDs be able to store more information in their smaller area and volume. A technical approach to this desire is to increase the capacity by increasing the recording density of the HDD. To achieve higher recording density, further miniaturization of recording bits is effective, which in turn typically requires the design of smaller and smaller components.

[0004] The further miniaturization of the various components, however, presents its own set of challenges and obstacles. Once such challenge is achieving a smooth lower surface for formation of components and layers thereon. The smoother the lower surface is, the thinner and more accurate the layers formed above the lower surface may be made, thereby allowing for a higher recording density in HDDs.

[0005] During manufacturing of sliders for use in magnetic heads, multiple row bars are formed above a substrate, which are then polished in a lapping process to a desired surface finish using a lapping plate. One or more row bars (typically two row bars, but possibly one, four, or more) are generally lapped at the same time to provide a final stripe height and surface finish before using the sliders in production. In some lapping procedures, one or more sacrificial row bars (the number of sacrificial or "dummy" row bars typically matches the number of row bars lapped simultaneously) are used in a process which prepares the lapping plate to be used in the lapping process on the actual row bars. This preparation involves lapping the sacrificial row bars using kinematics similar to or the same to those which will be used during actual lapping of the row bars. Conventional preparation of the lapping plate may take from 45 minutes to two hours or more using conventional materials and processes.

[0006] After the preparation process, the lapping plate may be used to produce from about 50 to about 200 row bars worth of sliders, depending on the actual lapping conditions used. Then, the preparation process must be repeated on another, unused lapping plate.

SUMMARY

[0007] Accordingly, it would be beneficial to allow for the preparation of the lapping plate to be accomplished more efficiently in order to increase the rate of slider production.

[0008] A system according to one embodiment includes a substrate having one or more sacrificial row bars and one or more additional row bars, wherein the one or more sacrificial row bars comprise a wear resistant material and are adapted to be used in a lapping process to prepare a lapping plate, wherein the one or more additional row bars comprise a material that has less wear resistance than the wear resistant material and are adapted to be used for magnetic head slider production, and wherein the lapping plate is adapted to be used in a lapping process to polish the one or more additional row bars.

[0009] A method for using a lapping plate, according to one embodiment, includes coating one or more sacrificial row bars with a wear resistant material, wherein the wear resistant material resists wear better than a material of additional row bars, the additional row bars being adapted to be used for magnetic head slider production; pressing the one or more sacrificial row bars against a lapping plate until a predetermined metric has been achieved; removing the one or more sacrificial row bars from the lapping plate; and using the lapping plate in a lapping process to polish the additional row bars after the one or more sacrificial row bars have been pressed against the lapping plate.

[0010] Any of these embodiments may be implemented in the preparation of a magnetic head, which may be included in a magnetic data storage system such as a disk drive system, which may also include a drive mechanism for passing a magnetic medium (e.g., hard disk) over the magnetic head, and a controller electrically coupled to the magnetic head.

[0011] Other aspects and advantages of the present invention will become apparent from the following detailed description, which, when taken in conjunction with the drawings, illustrate by way of example the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] For a fuller understanding of the nature and advantages of the present invention, as well as the preferred mode of use, reference should be made to the following detailed description read in conjunction with the accompanying drawings.

[0013] FIG. 1 is a simplified drawing of a magnetic recording disk drive system.

[0014] FIG. 2A is a schematic representation in section of a recording medium utilizing a longitudinal recording format.

[0015] FIG. 2B is a schematic representation of a conventional magnetic recording head and recording medium combination for longitudinal recording as in FIG. 2A.

[0016] FIG. 2C is a magnetic recording medium utilizing a perpendicular recording format.

[0017] FIG. 2D is a schematic representation of a recording head and recording medium combination for perpendicular recording on one side.
FIG. 2E is a schematic representation of a recording apparatus adapted for recording separately on both sides of the medium.

FIG. 3A is a cross-sectional view of one particular embodiment of a perpendicular magnetic head with helical coils.

FIG. 3B is a cross-sectional view of one particular embodiment of a piggyback magnetic head with helical coils.

FIG. 4A is a cross-sectional view of one particular embodiment of a perpendicular magnetic head with looped coils.

FIG. 4B is a cross-sectional view of one particular embodiment of a piggyback magnetic head with looped coils.

FIG. 5 is a schematic diagram of a system used for conditioning surfaces of sliders, according to one embodiment.

FIG. 6 is a flowchart of a method, according to one embodiment.

DETAILED DESCRIPTION

The following description is made for the purpose of illustrating the general principles of the present invention and is not meant to limit the inventive concepts claimed herein. Further, particular features described herein can be used in combination with other described features in each of the various possible combinations and permutations.

Unless otherwise specifically defined herein, all terms are to be given their broadest possible interpretation including meanings implied from the specification as well as meanings understood by those skilled in the art and/or as defined in dictionaries, treatises, etc.

It must also be noted that, as used in the specification and the appended claims, the singular forms “a,” “an” and “the” include plural referents unless otherwise specified.

The following description discloses several preferred embodiments of disk-based storage systems and/or related systems and methods, as well as operation and/or component parts thereof.

In one general embodiment, a system includes a substrate having one or more sacrificial row bars and one or more additional row bars, wherein the one or more sacrificial row bars comprise a wear resistant material and are adapted to be used in a lapping process to prepare a lapping plate, wherein the one or more additional row bars comprise a material that has less wear resistance than the wear resistant material and are adapted to be used for magnetic head slider production, and wherein the lapping plate is adapted to be used in a lapping process to polish the one or more additional row bars.

In another general embodiment, a method for using a lapping plate includes coating one or more sacrificial row bars with a wear resistant material, wherein the wear resistant material resists wear better than a material of additional row bars, the additional row bars being adapted to be used for magnetic head slider production; pressing the one or more sacrificial row bars against a lapping plate until a predetermined metric has been achieved; removing the one or more sacrificial row bars from the lapping plate; and using the lapping plate in a lapping process to polish the additional row bars after the one or more sacrificial row bars have been pressed against the lapping plate.

Referring now to FIG. 1, there is shown a disk drive 100 in accordance with one embodiment of the present invention. As shown in FIG. 1, at least one rotatable magnetic disk 112 is supported on a spindle 114 and rotated by a drive mechanism, which may include a disk drive motor 118. The magnetic recording on each disk is typically in the form of an annular pattern of concentric data tracks (not shown) on the disk 112.

At least one slider 113 is positioned near the disk 112, each slider 113 supporting one or more magnetic read/write heads 121. As the disk rotates, slider 113 is moved radially in and out over disk surface 122 so that heads 121 may access different tracks of the disk where desired data are recorded and/or to be written. Each slider 113 is attached to an actuator arm 119 by means of a suspension 115. The suspension 115 provides a slight spring force which biases slider 113 against the disk surface 122. Each actuator arm 119 is attached to an actuator 127. The actuator 127, as shown in FIG. 1, may be a voice coil motor (VCM). The VCM comprises a coil movable within a fixed magnetic field, the direction and speed of the coil movements being controlled by the motor current signals supplied by controller 129.

During operation of the disk storage system, the rotation of disk 112 generates an air bearing between slider 113 and disk surface 122 which exerts an upward force or lift on the slider. The air bearing thus counter-balances the slight spring force of suspension 115 and supports slider 113 off and slightly above the disk surface by a small, substantially constant spacing during normal operation. Note that in some embodiments, the slider 113 may slide along the disk surface 122.

The various components of the disk storage system are controlled in operation by control signals generated by controller 129, such as access control signals and internal clock signals. Typically, control unit 129 comprises logic control circuits, storage (e.g., memory), and a microprocessor. The control unit 129 generates control signals to control various system operations such as drive motor control signals on line 123 and head position and seek control signals on line 128. The control signals on line 128 provide the desired current profiles to optimally move and position slider 113 to the desired data track on disk 112. Read and write signals are communicated to and from read/write heads 121 by way of recording channel 125.

The above description of a typical magnetic disk storage system, and the accompanying illustration of FIG. 1 is for representation purposes only. It should be apparent that disk storage systems may contain a large number of disks and actuators, and each actuator may support a number of sliders.

An interface may also be provided for communication between the disk drive and a host (integral or external) to send and receive the data and for controlling the operation of the disk drive and communicating the status of the disk drive to the host, all as will be understood by those of skill in the art.

In a typical head, an inductive write head includes a coil layer embedded in one or more insulation layers (insulation stack), the insulation stack being located between first and second pole piece layers. A gap is formed between the first and second pole piece layers by a gap layer at an air bearing surface (ABS) of the write head. The pole piece layers may be connected at a back gap. Currents are conducted through the coil layer, which produce magnetic fields in the pole pieces. The magnetic fields fringe across the gap at the ABS for the purpose of writing bits of magnetic field information in tracks on moving media, such as in circular tracks on a rotating magnetic disk.
The second pole piece layer has a pole tip portion which extends from the ABS to a flare point and a yoke portion which extends from the flare point to the back gap. The flare point is where the second pole piece begins to widen (flare) to form the yoke. The placement of the flare point directly affects the magnitude of the magnetic field produced to write information on the recording medium.

FIG. 2A illustrates, schematically, a conventional recording medium such as used with magnetic disc recording systems, such as that shown in FIG. 1. This medium is utilized for recording magnetic impulses in or parallel to the plane of the medium itself. The recording medium, a recording disc in this instance, comprises basically a supporting substrate 200 of a suitable non-magnetic material such as glass, with an overlying coating 202 of a suitable and conventional magnetic layer.

FIG. 2B shows the operational relationship between a conventional recording/playback head 204, which may preferably be a thin film head, and a conventional recording medium, such as that of FIG. 2A.

FIG. 2C illustrates, schematically, the orientation of magnetic impulses substantially perpendicular to the surface of a recording medium as used with magnetic disc recording systems, such as that shown in FIG. 1. For such perpendicular recording the medium typically includes an under layer 212 of a material having a high magnetic permeability. This under layer 212 is then provided with an overlying coating 214 of magnetic material preferably having a high coercivity relative to the under layer 212.

FIG. 2D illustrates the operational relationship between a perpendicular head 218 and a recording medium. The recording medium illustrated in FIG. 2D includes both the high permeability under layer 212 and the overlying coating 214 of magnetic material described with respect to FIG. 2C above. However, both of these layers 212 and 214 are shown applied to a suitable substrate 216. Typically there is also an additional layer (not shown) called an "exchange-break" layer or "interlayer" between layers 212 and 214.

In this structure, the magnetic lines of flux extending between the poles of the perpendicular head 218 loop into and out of the overlying coating 214 of the recording medium with the high permeability under layer 212 of the recording medium causing the lines of flux to pass through the overlying coating 214 in a direction generally perpendicular to the surface of the medium to record information in the overlying coating 214 of magnetic material preferably having a high coercivity relative to the under layer 212 in the form of magnetic impulses having their axes of magnetization substantially perpendicular to the surface of the medium. The flux is channeled by the soft underlining coating 212 back to the return layer (P1) of the head 218.

FIG. 2E illustrates a similar structure in which the substrate 216 carries the layers 212 and 214 on each of its two opposed sides, with suitable recording heads 218 positioned adjacent the outer surface of the magnetic coating 214 on each side of the medium, allowing for recording on each side of the medium.

FIG. 3A is a cross-sectional view of a perpendicular magnetic head. In FIG. 3A, helical coils 310 and 312 are used to create magnetic flux in the stitch pole 308, which then delivers that flux to the main pole 306. Coils 310 indicate coils extending out from the page, while coils 312 indicate coils extending into the page. Stitch pole 308 may be recessed from the ABS 318. Insulation 316 surrounds the coils and may provide support for some of the elements. The direction of the media travel, as indicated by the arrow to the right of the structure, moves the media past the lower return pole 314 first, then past the stitch pole 308, main pole 306, trailing shield 304 which may be connected to the wrap around shield (not shown), and finally past the upper return pole 302. Each of these components may have a portion in contact with the ABS 318. The ABS 318 is indicated across the right side of the structure.

Perpendicular writing is achieved by forcing flux through the stitch pole 308 into the main pole 306 and then to the surface of the disk positioned towards the ABS 318.

FIG. 3B illustrates a piggyback magnetic head having similar features to the head of FIG. 3A. Two shields 304, 314 flank the stitch pole 308 and main pole 306. Also sensor shields 322, 324 are shown. The sensor 326 is typically positioned between the sensor shields 322, 324.

FIG. 4A is a schematic diagram of an embodiment which uses looped coils 410, sometimes referred to as a pancake configuration, to provide flux to the stitch pole 408. The stitch pole then provides this flux to the main pole 406. In this orientation, the lower return pole is optional. Insulation 416 surrounds the coils 410, and may provide support for the stitch pole 408 and main pole 406. The stitch pole may be recessed from the ABS 418. The direction of the media travel, as indicated by the arrow to the right of the structure, moves the media past the stitch pole 408, main pole 406, trailing shield 404 which may be connected to the wrap around shield (not shown), and finally past the upper return pole 402 (all of which may or may not have a portion in contact with the ABS 418). The ABS 418 is indicated across the right side of the structure. The trailing shield 404 may be in contact with the main pole 406 in some embodiments.

FIG. 4B illustrates another type of piggyback magnetic head having similar features to the head of FIG. 4A including a looped coil 410, which wraps around to form a pancake coil. Also, sensor shields 422, 424 are shown. The sensor 426 is typically positioned between the sensor shields 422, 424.

In FIGS. 3B and 4B, an optional heater is shown near the non-ABS side of the magnetic head. A heater (Heater) may also be included in the magnetic heads shown in FIGS. 3A and 4A. The position of this heater may vary based on design parameters such as where the protrusion is desired, coefficients of thermal expansion of the surrounding layers, etc.

In order to form a magnetic head for use in any of the systems described above, a substrate, which may include one or more row bars 502 formed thereon, is prepared to form subsequent layers thereon. For example, the substrate 500, as shown in FIG. 5, may be used to form subsequent layers thereon. In order to prepare the substrate 500 for use in forming a magnetic head slider thereon,

The surface roughness of the upper layer of the substrate 500 has a direct effect on the surface roughness of each subsequent layer formed thereabove, including but not limited to read/write elements of a magnetic head. In order to obtain a desired surface roughness of the outer surface 506 of the substrate 500, a lapping plate 508 may be used to lap the substrate 500 in order to polish the outer surface 506. According to one embodiment, the lapping plate 508 may be formed from a plate material which has diamond embedded on a surface 504 thereof, such as via a charging process. The plate material may comprise any suitable mater-
rial, alloy, or composite, as known in the art. In one embodiment, the plate material may be a tin alloy, such as SnBi (with Sn being in a range from about 90% to about 100%), or some other suitable alloy. Any number of fixtures 510, with each fixture 510 being capable of polishing one or more row bars 502 of the substrate 500, may be used to hold the substrate 500 and place the row bars 502 in contact with the lapping plate 508. According to one embodiment, one or more fixtures 510 may be used, each fixture 510 being capable of polishing one row bar 502 of the substrate 500.

[0054] Prior to the lapping plate 508 being used to lap the substrate 500, the lapping plate 508 should have any excessive roughness removed, so that it has a smooth, consistent profile at the lapping surface for proper lapping of the substrate 500. In order to accomplish this preparation of the lapping plate 508, the lapping plate 508 may be used to lap a set of one or more sacrificial row bars 512 which are provided on the substrate 500 and are intended to be used to prepare the surface of the lapping plate 508 prior to using the lapping plate 508 to lap the remaining row bars 502, which will be used in magnetic head manufacturing. These sacrificial row bars 512 (or “dummy” row bars) may be coated with, have a layer or film formed thereon, or otherwise have an upper surface thereof (the surface facing the lapping plate 508 during the row bars 502) which includes a very hard, wear resistant material 504.

[0055] In one embodiment, the wear resistant material may comprise diamond-like carbon (DLC), silicon nitride (SiN), tantalum carbide (TaC), carbon-based or impregnated alloys, etc. This wear resistant material may be formed to a thickness in a range between about 200 nm and about 2 microns, such as about 300 nm, 500 nm, 1000 nm, etc. The wear resistant material may be formed, in one example, via vacuum vapor deposition, carbon deposition, pulse-cathodic deposition, or through any other suitable formation technique known in the art.

[0056] According to this embodiment, the lapping plate 508 is capable of being prepared for use in lapping the actual row bars 502 in as little as 15 minutes or less, depending on the specific lapping kinematics used. Lapping kinematics may include any relevant parameters associated with lapping, such as down force applied to the row bars 502 against the lapping plate 508, lapping plate 508 rotation speed, row bar 502 oscillation rate (in the radial direction), etc.

[0057] After the lapping plate 508 has achieved a desired final metric, such as a desired lap rate (e.g., amount of material removal per unit time), the sacrificial rows 512 are withdrawn from the surface of the lapping plate 508. Then, actual row bars 502 may be polished to a second desired metric using the preconditioned lapping plate 508. This second desired metric may be based on characteristics of the row bars 502, such as surface roughness being within a predetermined tolerance.

[0058] According to these embodiments, a lapping plate 508 may be preconditioned to a desired surface characteristic in less time than conventional methods allow, while still achieving all desired characteristics for the lapping plate 508 and the row bars 502.

[0059] After the lapping plate 508 has been used to lap a certain number of row bars 502, it must be replaced with another, preconditioned lapping plate 508, in order to maintain the effectiveness of the lapping process. Any method known in the art may be used to determine when the lapping plate 508 has reached the end of its usefulness, including a lap rate dropping too low.

[0060] FIG. 6 shows a method 600 for using a lapping plate in accordance with one embodiment. As an option, the present method 600 may be implemented to construct structures such as those shown in FIGS. 1-5. Of course, however, this method 600 and others presented herein may be used to form magnetic structures for a wide variety of devices and/or purposes which may or may not be related to magnetic recording. Further, the methods presented herein may be carried out in any desired environment. It should also be noted that any aforementioned features may be used in any of the embodiments described in accordance with the various methods.

[0061] In operation 602, one or more sacrificial row bars is coated with a wear resistant material. The one or more sacrificial row bars are adapted to be used to prepare a surface of a lapping plate. In addition, the wear resistant material resists wear better than a material of additional row bars, the additional row bars being adapted to be used for magnetic head slider production.

[0062] In one embodiment, the wear resistant material may be DLC, SiN, TaC, or some other carbon-based, nitrided, carbidized, etc., material known in the art to be wear resistant. In a further embodiment, the wear resistant material may be formed on the one or more sacrificial row bars may to a thickness in a range from about 200 nm to about 2 microns, such as about 300 nm, 500 nm, 1000 nm, etc. The wear resistant material may be formed, in one example, via vacuum vapor deposition, carbon deposition, pulse-cathodic deposition, or through any other suitable formation technique known in the art.

[0063] According to one approach, the method 600 may further comprise forming the one or more sacrificial row bars and the additional row bars on a substrate and cutting the substrate into individual row bars.

[0064] In operation 604, the one or more sacrificial row bars are pressed against a lapping plate until a predetermined metric has been achieved. The one or more sacrificial row bars are pressed against a working surface of the lapping plate, e.g., the surface which will be used to lap additional row bars in a subsequent operation. The lapping plate is designed for conditioning a surface of row bars to be used for magnetic head slider production. The lapping plate comprises diamond particles embedded in a substrate, such as via a charging process, near a surface of the substrate. In various approaches, the substrate may comprise any suitable material, alloy, or composite, as known in the art. In one embodiment, the plate material may be a tin alloy, such as SnBi (with Sn being in a range from about 90% to about 100%), or some other suitable alloy.

[0065] In operation 606, the one or more sacrificial row bars are withdrawn from the lapping plate, e.g., after the predetermined metric has been achieved. In one embodiment, the metric may be a lap rate of the lapping plate, an amount of time having passed, etc.

[0066] In operation 608, the lapping plate is used in a lapping process to polish additional row bars, as would be understood by one of skill in the art upon reading the present descriptions.

[0067] While various embodiments have been described above, it should be understood that they have been presented by way of example only, and not limitation. Thus, the breadth
and scope of an embodiment of the present invention should not be limited by any of the above-described exemplary embodiments, but should be defined only in accordance with the following claims and their equivalents.

What is claimed is:

1. A system, comprising:
   a substrate having one or more sacrificial row bars and one or more additional row bars,
   wherein the one or more sacrificial row bars comprise a wear resistant material and are adapted to be used in a lapping process to prepare a lapping plate,
   wherein the one or more additional row bars comprise a material that has less wear resistance than the wear resistant material and are adapted to be used for magnetic head slider production, and
   wherein the lapping plate is adapted to be used in a lapping process to polish the one or more additional row bars.

2. The system as recited in claim 1, further comprising the lapping plate, wherein the lapping plate comprises a substrate having diamond particles embedded therein at a surface thereof.

3. The system as recited in claim 1, wherein the wear resistant material is diamond-like carbon (DLC).

4. The system as recited in claim 1, wherein the wear resistant material has a thickness in a range between about 200 nm and about 2000 nm.

5. The system as recited in claim 1, wherein the wear resistant material comprises at least one of: diamond-like carbon (DLC), silicon nitride (SiN), and tantalum carbide (TaC).

6. A method for using a lapping plate, the method comprising:
   coating one or more sacrificial row bars with a wear resistant material, wherein the wear resistant material resists wear better than a material of additional row bars, the additional row bars being adapted to be used for magnetic head slider production;
   pressing the one or more sacrificial row bars against a lapping plate until a predetermined metric has been achieved;
   removing the one or more sacrificial row bars from the lapping plate; and
   using the lapping plate in a lapping process to polish the additional row bars after the one or more sacrificial row bars have been pressed against the lapping plate.

7. The method as recited in claim 6, wherein the wear resistant material is diamond-like carbon (DLC).

8. The method as recited in claim 6, wherein the wear resistant material is formed to a thickness in a range between about 200 nm and about 2000 nm.

9. The method as recited in claim 6, wherein the wear resistant material is formed via vacuum vapor deposition or pulse-cathodic deposition.

10. The method as recited in claim 6, wherein the predetermined metric is chosen from: a lap rate of the lapping plate, and a surface roughness of the lapping plate.

11. The method as recited in claim 6, further comprising radially oscillating the one or more sacrificial row bars while the one or more sacrificial row bars are pressed against the lapping plate.

12. The method as recited in claim 6, wherein the wear resistant material comprises at least one of: diamond-like carbon (DLC), silicon nitride (SiN), and tantalum carbide (TaC).

13. The method as recited in claim 6, further comprising:
   forming the one or more sacrificial row bars and the additional row bars on a substrate; and
   cutting the substrate into individual row bars.

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