

A BURNISH HEAD

FIELD

- 5 This invention relates to burnishing of a disc, in particular, to a burnish head for levelling irregularities on a disc surface.

BACKGROUND

- 10 Digital data is commonly stored in hard disc drives in concentric circular tracks on a disc surface. Reading and writing of data are carried out by a read/write head. The read/write head is held close to the disc surface and moved from track to track radially with respect to the disc surface as the disc is spun. The distance separating the read/write head and the disc surface is commonly known as flying height. Currently, to increase recording density of a disc, individual bit sizes have to be
15 decreased. This requires operational flying height to be correspondingly decreased, thereby bringing the head closer to the disc surface. At such close proximity, the disc surface needs to have a certain smoothness to minimize inadvertent contact between the head and any irregularities such as asperities on the disc surface during normal reading/writing operations.
- 20 Burnishing is a process to obtain a certain level of smoothness of the disc surface by reducing irregularities on the disc surface. This is typically carried out by flying a burnish head at a predetermined burnish head flying height over a spinning disc. The burnish head flying height is necessarily lower than the operational flying height of a read/write head, so that, as the disc spins, any asperities on the disc surface extending above the burnish head flying height are mechanically
25 removed by the burnish head. It is essential that the burnish head flying height be well controlled to maintain a proper distance between the burnish head and the disc surface during the burnishing process. This is because the disc surface is coated with a thin media overcoat for protection, which may be destroyed if the burnish head flies too close to the disc surface.
- 30 Burnish heads typically comprise a slider having a plurality of pads and supported by a suspension. These pads are usually made of the same material as the slider, such as $\text{TiC-Al}_2\text{O}_3$, and can range from 0.1 mm to 0.7 mm in size. The plurality of pads are disposed on the surface of the slider that is facing the disc, which can be called the slider air bearing surface. At least one of the plurality of pads comes into contact with the disc for levelling surface irregularities on the disc.

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In the past, burnish heads were manufactured by wheel grinding. This limited the design of the pads to simple geometrical shapes such as diamonds, rectangles and triangles. The most commonly used burnish head used to be one with diamond-shaped pads, having a waffle pattern cut directly into the slider air bearing surface by wheel grinding.

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Today, ion-milling has overtaken wheel grinding as it can produce pads with more complex shapes such as teardrops, ellipses and circles. During ion milling, areas designated to become pads are masked, while unmasked areas are etched away to leave raised pads on the air bearing surface.

While pads of such shapes have been reported to reduce disc damage during burnishing, to improve removal of asperities the ability to maintain the burnish head flying height and ensure flying stability to reduce extraneous burnish head movement are desired.

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SUMMARY

According to one aspect of the present invention, there is provided a burnish head for burnishing a disc. The burnish head comprises a slider having an air bearing surface, a leading edge and a trailing edge. A plurality of pads is disposed on the air bearing surface, with at least one of the plurality of pads having a graduated surface.

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According to another aspect of the present invention, there is provided an apparatus for levelling surface irregularities on a disc. The apparatus comprises a head assembly supported by a suspension; the suspension being attached to actuator head mounting arms. The apparatus further comprises a burnish head mounted on the head assembly. The burnish head comprises a slider having an air bearing surface, a leading edge and a trailing edge. A plurality of pads is disposed on the air bearing surface, with at least one of the plurality of pads having a graduated surface.

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BRIEF DESCRIPTION OF THE DRAWINGS

These and other aspects and advantages of the present invention are described with reference to the accompanying drawings, in which:

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Figure 1 is a plan view of an air bearing surface of a burnish head in accordance with a preferred embodiment of the present invention;

Figure 2 is a three-dimensional view of the air bearing surface of Figure 1;

Figure 3 is a simulated air flow on the air bearing surface of Figure 1;

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Figure 4 is a simulated air pressure distribution on the air bearing surface of Figure 2; and Figure 5 is a plan view of an air bearing surface of a burnish head in accordance with a second embodiment of the present invention.

5 DETAILED DESCRIPTION

In accordance with the preferred embodiment of the present invention, Figure 1 shows a slider 12 of a burnish head with an air bearing surface 14 having a leading edge 16 and a trailing edge 18. The slider air bearing surface 14 is 2.0 mm by 1.6 mm in size. A plurality of pads is disposed on
10 the air bearing surface 14 in an array laterally symmetrical about a midline 20 of the slider 12. This midline 20 is parallel to the direction of motion of the burnish head relative to the disc. Each of the plurality of pads is substantially elliptical in shape. A row of three air bearing pads 22 are disposed adjacent the leading edge 16. Three staggered rows 24, 26, 28 of burnish pads 30 are disposed
15 behind the air bearing pads 22. The first row 24 comprises three burnish pads, the second row 26 comprises four burnish pads and the last row 28 comprises five burnish pads. The last row 28 of burnish pads 30 is disposed adjacent the trailing edge 18.

Each of the air bearing pads 22 is typically larger than each of the burnish pads 30. In the preferred embodiment, the air bearing pads 22 each have a major axis 22a of 0.64 mm and a minor axis 22b
20 of 0.22 mm, while the burnish pads 30 each have a major axis 30a of 0.34 mm and a minor axis 30b of 0.20 mm. The air bearing pads 22 generate lift on the slider 12 when, during burnishing, the burnish head is brought into its operating position at a predetermined burnish head flying height above the disc surface and the disc is spun. The generated lift tilts the slider 12 so that the trailing edge 18 is positioned nearer to the disc than the leading edge 16. In this way, at least some
25 of the burnish pads 30 come into contact with asperities or unwanted particles on the disc surface.

Burnish pads 32, 34 on the last row 28 of burnish pads 30 and farthest away from the midline 20 are configured such that they each have a graduated surface facing the disc. The graduated surface is formed by the burnish pads 32, 34 each having a step 42, 44 on their surfaces facing the disc, as
30 shown in Figure 1. Preferably, each of the air bearing pads 22 also has a graduated surface formed by having a step 46a, 46b, 46c on its surface facing the disc. As can be seen in Figure 2, each step descends from a trailing portion of a pad to a leading portion of that pad.

In the preferred embodiment, the slider 12, including the air bearing surface 14, is made of TiC-
35 Al₂O₃. The air bearing surface 14 having a plurality of pads is created mainly by two ion-milling

processes. In the first ion-milling process, areas designated as pads on the air bearing surface 14 are masked. It should be noted that areas designated as steps on the pads are specifically left unmasked. Ion-milling is then performed, etching away about 300 nanometers from the unmasked areas. The first ion-milling process thus creates the steps 42, 44, 46a, 46b, 46c. In the second ion-milling process, areas designated as pads on the air bearing surface 14 are masked, including the areas designated as steps. Ion-milling is then performed, etching away the unmasked areas to a depth of about 5 μm from the original air bearing surface 14. The second ion-milling process thus creates the plurality of pads having a height of 5 μm on the etched air bearing surface 14, with the pads 22, 32, 34 bearing the steps 42, 44, 46a, 46b, 46c created by the first ion-milling process.

In the preferred embodiment as shown in Figures 1 and 2, all the graduated surfaces comprise steps 42, 44, 46a, 46b, 46c that have a curved edge that is laterally symmetrical about the major axes 22a, 30a of the pads 22, 30. Each step is typically several hundreds of nanometers in height, ranging from 100 nanometers to 500 nanometers. Appropriate graduation in pad height for maximising stability depends on head linear velocity during burnishing as well as other factors such as gram load on a suspension supporting the burnish head and pad sizes affecting air flow.

Different step heights result in different air pressures on their respective pads, resulting in different air bearing forces acting on the burnish head in opposition to the gram load borne by the suspension. The balance of gram load and air bearing forces ultimately determines flying height of the burnish head. To arrive at an appropriate step height, the desired flying height should first be specified, so that the desired air bearing forces needed to balance the gram load, which is a known quantity, can then be determined. Once the desired air bearing forces are determined, the step height needed to achieve the necessary air pressure to produce the desired air bearing forces can then be worked out.

As can be seen in Figure 2, each of the plurality of pads has a fillet 50 that joins the pad to the air bearing surface 14. The fillet 50 helps to smoothen air flow around the plurality of pads during the burnishing process, as shown in Figure 3. This is to minimise any accumulation of debris around the plurality of pads and on the air bearing surface 14. In addition, the air bearing surface 14 and the plurality of pads are coated with diamond-like carbon to improve their wear performance and thus increase operational life of the burnish head.

With reference to Figure 4, during burnishing, among the plurality of pads, air pressure is significantly much greater over pads that have a graduated surface, i.e., the three air bearing pads

22 and the burnish pads 32, 34 that are adjacent the trailing edge 18 and farthest from the midline 20 of the slider 12. Greater air pressure at the leading edge 16 helps to stabilise pitch and roll of the slider 12, while greater air pressure at the portions of the trailing edge 18 farthest from the midline 20 of the slider 12 increases air bearing stiffness to stabilize the flying height and the roll.

5 In this way, extraneous head movement is minimised and flying height can thus be better controlled. Lateral symmetry of the plurality of pads about the midline 20 of the slider 12 provides symmetrical air pressure distribution on the slider 12, as shown in Figure 4, which is indicative of minimizing roll.

10 In another embodiment, as shown in Figure 5, burnish pads 62, 64 adjacent the trailing edge 18 and farthest from the midline 20 of the slider 12 have graduated surfaces that are formed by steps 72, 74. In this embodiment, each of the steps 72, 74 has a straight edge at an oblique angle to the trailing edge.

15 Another aspect of the invention is an apparatus for levelling surface irregularities on a disc. The apparatus comprises a head assembly supported by a suspension. The suspension holds the head assembly at a predetermined distance over a disc surface. The suspension is attached to actuator head mounting arms that can move the suspension and the head assembly in a radial direction with respect to the disc surface. A burnish head as described in the embodiments above with reference
20 to Figures 1 to 5 is mounted on the head assembly.

The foregoing describes preferred embodiments of the present invention. However, it is understood by those skilled in the art that many variations or modifications in details of design or construction may be made without departing from the present invention. For example, the
25 graduated surface can be formed by other embodiments such as slopes, curved gradients, or other suitable formations instead of steps. For graduated surfaces formed by steps, such steps may have edges with different shapes instead of simple curves or oblique straight edges. The number of pads altogether, whether they be air bearing pads or burnish pads, the individual pad sizes, and the distribution pattern of the pads, may all be varied. The number and location of pads having
30 graduated surfaces may also be varied. The shapes of the pads may be other shapes such as circles or teardrops or a combination of different shapes that are suitable for allowing smooth air flow around the pads.

Claims:

1. A burnish head for burnishing a disc, the burnish head comprising:
 - a slider having an air bearing surface, a leading end, a trailing end, a first side, and an opposite second side;
 - a first pad proximate said leading end and having a graduated surface formed by a step ascending outward from said air bearing surface in a direction from said leading end towards said trailing end;
 - a second pad proximate said first side of said trailing end and having a graduated surface formed by a step ascending outward from said air bearing surface in a direction from said leading end towards said trailing end; and
 - a third pad proximate said second side of said trailing end and having a graduated surface formed by a step ascending outward from said air bearing surface in a direction from said leading end towards said trailing end.
2. The burnish head of claim 1, wherein each of said first, second, and third pads has a fillet that joins each of said pads to said air bearing surface.
3. The burnish head of claim 1, wherein each said step of said first, second, and third pads has a height ranging from 100 nanometers to 500 nanometers.
4. The burnish head of claim 1, wherein said step of each of said second and third pads has a straight edge at an oblique angle to said trailing end.
5. The burnish head of claim 1, further comprising:
 - a back row of burnish pads having a plurality of pads including said second and third pads, wherein each of said plurality of pads in said back row is proximate said trailing end.
6. The burnish head of claim 5, wherein said second and third pads are disposed farthest away from a midline of said slider in said back row, said midline being parallel to direction of motion of said burnish head relative to said disc.

7. The burnish head of claim 1, further comprising:
a plurality of pads on said air bearing surface including said first, second, and third pads.
8. The burnish head of claim 7, wherein said plurality of pads further comprises:
staggered rows of burnish pads disposed on said air bearing surface between said first, second, and third pads.
9. The burnish head of claim 1, wherein said first pad is an air bearing pad.
10. The burnish head of claim 9, further comprising:
a plurality of air bearing pads including said first pad on said air bearing surface proximate said leading end wherein each of said plurality of air bearing pads has a graduated surface formed by a step ascending outward from said air bearing surface in a direction from said leading end towards said trailing end.
11. The burnish head of claim 10, further comprising:
a plurality of burnish pads on said air bearing surface between said plurality of air bearing pads and said trailing end of said air bearing surface.
12. The burnish head of claim 11, wherein said plurality of burnish pads includes said second and third pads.
13. The burnish head of claim 11, wherein each of said plurality of air bearing pads is larger in size than each of said plurality of burnish pads.
14. The burnish head of claim 11, wherein said plurality of burnish pads are disposed on said air bearing surface in an array laterally symmetrical about a midline of said slider, said midline being parallel to direction of motion of said burnish head relative to said disc.
15. The burnish head of claim 11, wherein each of said plurality of burnish pads is substantially elliptical in shape.

16. The burnish head of claim 11, wherein said plurality of burnish pads is coated with a diamond-like carbon coating.
17. The burnish head of claim 10, wherein each of said plurality of air bearing pads is substantially elliptical in shape.
18. The burnish head of claim 10, wherein said plurality of air bearing pads is coated with a diamond-like carbon coating.
19. An apparatus for levelling surface irregularities on a disc, the apparatus comprising:
 - a head assembly supported by a suspension; the suspension being attached to actuator head mounting arms; and
 - a burnish head mounted on the head assembly, the burnish head comprising:
 - a slider having an air bearing surface, a leading end, a trailing end, a first side, and an opposite second side,
 - a first pad proximate said leading end and having a graduated surface formed by a step ascending outward from said air bearing surface in a direction from said leading end towards said trailing end,
 - a second pad proximate said first side of said trailing end and having a graduated surface formed by a step ascending outward from said air bearing surface in a direction from said leading end towards said trailing end, and
 - a third pad proximate said second side of said trailing end and having a graduated surface formed by a step ascending outward from said air bearing surface in a direction from said leading end towards said trailing end.
20. The apparatus of claim 19, wherein each of said first, second, and third pads has a fillet that joins each of said pads to said air bearing surface.
21. The apparatus of claim 19, wherein each said step of said first, second, and third pads has a height ranging from 100 nanometers to 500 nanometers.

22. The apparatus of claim 19, wherein said step of each of said second and third pads has a straight edge at an oblique angle to said trailing end.
23. The apparatus of claim 19, wherein said burnish head further comprises:
a back row of burnish pads having a plurality of pads including said second and third pads, wherein each of said plurality of pads in said back row are proximate said trailing end.
24. The apparatus of claim 23, wherein said second and third pads are disposed farthest away from a midline of said slider in said back row, said midline being parallel to direction of motion of said burnish head relative to said disc.
25. The apparatus of claim 19, wherein said burnish head further comprises:
a plurality of pads on said air bearing surface including said first, second, and third pads.
26. The apparatus of claim 25, wherein said plurality of pads further comprises staggered rows of burnish pads disposed on said air bearing surface between said first, second, and third pads.
27. The apparatus of claim 19, wherein said first pad is an air bearing pad.
28. The apparatus of claim 27, wherein said burnish head further comprises:
a plurality of air bearing pads including said first pad on said air bearing surface proximate said leading end wherein each of said plurality of air bearing pads has a graduated surface formed by a step ascending outward from said air bearing surface in a direction from said leading end towards said trailing end.
29. The apparatus of claim 28, wherein said burnish head further comprises:
a plurality of burnish pads on said air bearing surface between said plurality of air bearing pads and said trailing end of said air bearing surface.
30. The apparatus of claim 29, wherein said plurality of burnish pads includes said second and third pads.

31. The apparatus of claim 29, wherein each of said plurality of air bearing pads is larger in size than each of said plurality of burnish pads.
32. The apparatus of claim 29, wherein said plurality of burnish pads are disposed on said air bearing surface in an array laterally symmetrical about a midline of said slider, said midline being parallel to direction of motion of said burnish head relative to said disc.
33. The apparatus of claim 29, wherein each of said plurality of burnish pads is substantially elliptical in shape.
34. The apparatus of claim 29, wherein said plurality of burnish pads is coated with a diamond-like carbon coating.
35. The apparatus of claim 28, wherein each of said plurality of air bearing pads is substantially elliptical in shape.
36. The apparatus of claim 28, wherein said plurality of air bearing pads is coated with a diamond-like carbon coating.