

TEXTURING OF DATA RECORDING SLIDERS

Field of the Invention

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The present invention relates generally to the recording and reading of data on a data storage element such as a magnetic disk. In particular, the invention pertains to the transducer head or slider by which data is recorded on or read from a moving surface of a data storage element.

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The invention will herein be described with particular reference to magnetic disk drives, but this is for explanatory purposes only and it will be understood that the application of the invention is not so limited.

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Background Art

In conventional magnetic head systems, the magnetic head consists of an electromagnetic arrangement for writing, reading or erasing data on a magnetizable storage medium relative to which it moves, such as a magnetic disk. Typically, for use with a magnetic disk, the transducer head is attached to a slider, e.g. a slider of the type known as a proximity slider, and lies opposite the disk surface.

Magnetic disk drives typically employ one or more disks driven by a spindle motor, in combination with data transducer heads positioned at close proximity to the recording surfaces of the rotating disk. The transducer head, which is supported by the disk while at rest, rides on a cushion or bearing of air above the disk surface when the disk drive is in operation, with the disk rotating at its operating speed. The slider is movable radially on the disk to be positioned over a selected one of a group of concentric data recording tracks. The slider is carried on a suspension assembly connected ultimately to an actuator.

In a conventional magnetic disk drive, the slider is weighted against the disk surface by a small spring force imparted by the suspension when the disk is not rotating. The slider is therefore in contact with the disk surface from the time
5 that rotation of the magnetic disk is initiated, until the disk attains a rotational speed sufficient to give rise to an air bearing for the slider to ride on. The slider also contacts the disk surface when the rotational speed of the disk falls below that necessary to create the air bearing. Sliders are also known to come in contact with the disk surface when the disk drive is experiencing vibrations of improper
10 proportions.

While all magnetic recording devices experience at least some wear, the problem is particularly serious for a hard disk and its associated head. This is due in part to the stricter design tolerances associated with hard disks and heads, arising
15 from the ever-present challenge of increasing the density of data stored on disk recording media. It is considered desirable during reading and recording operations to maintain each transducer head as close to its associated recording surfaces as possible, i.e. to minimise "flying" height. A smooth, specular recording surface is thus preferred, as well as a smooth opposing surface on the associated
20 transducer head. This permits closer proximity of the head to the disk, and more predictable and consistent behaviour of the air bearing supporting the head.

However, if the head surface and recording surface are too flat, the precision match of these surfaces can give rise to excessive stiction during start up
.25 and stopping of the disk. This, coupled with the large friction forces during contacts in flight, will cause wear to the head and recording surface which eventually can lead to a head crash.

In such magnetic disks, a layer of lubricant is often maintained on the disk
30 surface to prevent damage to the head and disk during contact. An existing problem with such magnetic disks is that after the slider has been in stationary

contact with the disk surface for just a short period of time, the slider tends to resist translational movement or to stick to the disk surface. This adherence or stiction is known to be caused by a variety of factors, including meniscus forces and viscous shear forces. Even in those magnetic disks that have extremely smooth
5 unlubricated disk surfaces, stiction may occur because of the strong intermolecular attraction at the interface between the smooth disk and the slider surface. Stiction causes severe damage to the head or disk when the slider suddenly breaks free from the disk surface, once the disk rotation is initiated. Additionally, as the disk begins rotation, substantial forces, caused by friction, can be applied tangentially on the
10 suspension, resulting in damage to or destruction of the suspension and possible damage to the disk surface.

In one known technique to overcome the stiction problem in rotating disk systems of the above described kind, disk rotation is started very slowly so that the
15 slider gradually breaks free from the disk surface. This approach is undesirable because it requires a relatively long period of time to bring the magnetic disk up to operational speed to impart the air bearing lift.

In U.S Pat. No. 4,698,251 (Fukuda et al), a polishing paper is applied to
20 magnetic disks to form circumferential scratch marks having a depth of 0.0002 to 0.1 microns into the nickel-phosphorous alloy layer coated onto an aluminum substrate. This is to intentionally roughen the magnetic disk to reduce the incidence of head stiction. However, the surface produced is highly random and the overall roughness may be hard to control.

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In a known alternative proposal, texturing is done on the top layer of the slider and the topography is comparable to those on textured disks. In this case, it is found that the high points on the bumps of the textured sliders are too sharp and can damage the softer disk surface. Moreover, both the air bearing surface and the
30 magnetic head are textured in this case, resulting in the deterioration of flying performance and magnetic properties of the head.

In another approach, described in U.S. Pat. No. 5,062,021 (Ranjan *et al*), a laser is used to texture an area of the disk surface dedicated for landing and taking off during operation of the slider. The method includes polishing an aluminum nickel-phosphorous substrate to a specular finish, then rotating the disk while directing pulsed laser energy over a limited portion of the radius, thus forming an annular head contact band while leaving the remainder of the surface specular. The magnetic recording head, when taking off from this selected band of the magnetic medium, will exhibit reduced stiction, thus increasing the take-off velocity. But during the seeking operation when the slider is flying over the specular area, it is still possible for the slider to come into contact with the smooth surface. Such contacts will lead to high friction force and result in head-gimbal assembly damage and tribology problems.

In a further approach, disclosed in U.S. Pat. No 5,079,657 (Aronoff), the slider's air bearing surface of the magnetic head in a disk drive is chemically etched to produce a controlled area of contact with the disk surface. One embodiment of that invention utilises a photoresist, of a type used to make circuit boards, to form a pattern. Subsequently, the surface may be etched to form the antistiction properties. The etching process is especially slow and may not be suitable for the purpose of mass production.

Summary of the Invention

One of the challenges to a disk drive designer today is to create a technology to keep pace with the exponential increase of areal density each year. Commercial hard disk drives are projected to have 10Gbit/in² or more in areal density by the end of this century. With present material and technology, the only way to attain this density is to drastically reduce the magnetic separation between the magnetic disk and the slider.

An object of this invention is to provide for an improved contact configuration between the slider and the data storage element, which can facilitate a higher density of data recording.

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Another object is to provide for an improved contact configuration between the slider and the data storage element, which assists in reducing the incidence of head crashes and consequent data loss which will be increasingly significant as the magnetic separation of future disk drives becomes smaller and smaller.

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In one aspect, the invention provides a slider for a data storage assembly, including:

a body having a transducer for recording on and/or reading a data storage element; and

15 a surface region which in situ is opposed to a moveable surface of the data storage element and adjacent to which an air bearing for the slider forms during motion of the surface;

characterised in that said surface region includes a heat texturable layer and surface roughness induced by heat texturing at least a portion of said layer, which
20 surface roughness includes one or more raised elements defining rounded contact surface segments to provide controlled contact with said moveable surface of the data storage element and to reduce stiction and friction between said slider and said surface of the data storage element during start up and seeking operations of the slider.

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In another aspect, the invention provides a method of forming a textured surface region on a slider for a data storage assembly, characterised by:

providing a heat-texturable layer on the slider, and

30 directing electro-magnetic energy at said layer to heat and thereby cause flow in the layer, whereby to texture the layer to form surface roughness which provides an air bearing surface for said slider, and includes one or more raised

elements defining rounded contact surface segments to provide controlled contact with a moveable surface of a data storage element and to reduce stiction and friction between said slider and said surface of the data storage element during start up and seeking operations of the slider.

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The present invention is effective in reducing stiction which retards take-off, and can replace critical lubricants in a magnetic head system. Stiction is reduced by providing rounded contact surface segments, and thereby a contoured reduced contact between the data storage medium and a textured layer of the slider.

10 With such texturing, the reliability of both the magnetic transducer and the medium can be significantly enhanced, while the recording density, in bits per unit area of magnetic storage medium, can be increased since the head disk separation in a hard disk drive may be reduced with the use of a magnetic disk with a specular data zone.

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In a preferred embodiment of this invention, a texturable layer, substantially uniform in thickness, is deposited onto the slider substrate for use in creating a topography that will benefit the tribological properties of the head-disk interface. Multiple selected areas of the layer are textured by incident energy altering the surface properties of this texturable layer. This well controlled and highly reproducible process preferably avoids areas close to the magnetic gap of the transducer head to create an evenly textured surface of arbitrary surface roughness values on selected areas of the air bearing surface on the slider.

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25 The preferred energy for effecting texturing is a pulsed or timed laser that forms on the textured surface at each location a circular depression extending to or below a nominal surface plane of the selected surface and an annular rim surrounding the depression extending outwardly of the nominal surface plane. By varying the energy, pulse length and focusing of the laser beam, a large variety of sizes of annular ridge segments or bumps can be produced to match the different requirements of different magnetic heads and types of media. The accuracy of a

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laser also ensures a precise delineation of the boundaries that are selected for texturing. The smooth concentric profile of the annular laser marks can be controlled to be very close to the required area of contact to achieve a significant improvement in the tribology performance of the head/disk interface.

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The present invention can be applied to magnetic heads for flexible magnetic tape or the other recording arrangements where the head is constantly in contact with the magnetic medium. In such contact recording applications, the controlled annular bumps can be used to minimise the area of contact and thus
10 improve friction and wear characteristics of the system.

For a fuller understanding of the nature and the advantages of the invention, reference should be made to the following detailed description taken in conjunction with the accompanying drawings, which illustrate embodiments of the invention.

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Brief Description of the Drawings

Figure 1 is a diagrammatic view of a hard disk drive assembly including a magnetic transducer head or slider which is supported generally for radial
20 movement of the disk, and includes an embodiment of the invention;

Figure 2 is a top view corresponding to Figure 1, showing the different zones that make up the magnetic recording medium;

Figure 3a-3c shows the flight pattern of the magnetic transducer head from start up to constant speed flying;

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Figure 4 is a view of a tripad air bearing surface;

Figure 5 is a partial cross-section on the line A-A in Figure 4;

Figure 6 is a schematic view of one possible profile of a laser textured bump having a depression surrounded by an annular outstanding rim in the airbearing surface of the slider;

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Figure 7 is a schematic view of the profile of another laser textured bump with an outstanding circular bump in the airbearing surface of the slider; and

Figure 8 is a schematic view of yet another laser textured bump with a depression and a dune shaped ridge in the airbearing surface of the slider.

Description of the Embodiments

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Turning now to the drawings, there is shown at Figure 1 and Figure 2 a data storage element in the form of a magnetic hard disk 1 rotatable about a vertical axis defined by a motor spindle 3, and having an annular horizontal surface 4. As seen in Figure 1, a magnetic transducer slider 2 supported by a suspension arm flexure 6 is part of a closed loop control carriage system 7 for linear reciprocation radially of the disk 1. The suspension arm flexure 6 does not rigidly support the slider 2, but allows it relative movement to and from the magnetic disk 1. The smaller three axis movement required by the slider 2 is further provided by the head gimbal assembly 8 (Figure 3a-3c), giving the slider pitch and roll while in seeking operations.

The magnetic disk 1 is concentric about its true centre and has an opening to accommodate spindle 3. Spindle 3 is driven by a disk drive motor 30 used for imparting rotational movement to the magnetic disk 1. As seen in Figure 2, the magnetic disk 1 is a thin film disk made up of two different zones. An inner ring forms a landing zone 29, dedicated to the landing and taking off operation of the slider. The outer ring is the data zone 27 where the slider will operate to read or write signals onto the recording media.

25 When the magnetic disk 1 is stationary, or is rotating at a speed lower than its normal operation range, the magnetic transducer slider 2 will be in contact with the surface 4 of the magnetic disk. As the rotational speed of the disk is increased gradually from standstill, the magnetic transducer slider 2 will break off the stiction force and at first drag along the surface of the disk 4, pitching forward as seen in Figure 3a. The whole of the magnetic transducer 2 will then lift off the surface 4 (Figure 3b) before the tail 17 of the slider 2 lowers to near the surface 4.

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Surface 4 will then be moving at the rated constant rotational speed (Figure 3c). This process is repeated in reverse order for the landing phase to finally bring the components to a complete stop. The "flying height" 28 is referred to as the distance between the lowest point of transducer 2 and the surface of the magnetic disk 4 at the rated rotational speed of the drive.

In accordance with an embodiment of the invention, and as depicted in Figure 5, a heat texturable layer 32 of uniform thickness is applied to the substrate of the slider body 34, typically an alloy of Al_2O_3 -TiC. This layer 32 is then textured by directing appropriate laser beams at multiple locations on the exposed face of the layer to heat and thereby cause flow in the layer, whereby to form surface roughness in the form of multiple spaced outstanding annular ridges 22, dune shaped ridges 37 or "sombbrero" type bumps 36 of the forms shown in Figures 6, 7 and 8 respectively. These bumps or ridges would typically be of uniform shape and dimensions on a given slider. The bumps or ridges are of a curved contour to provide smooth contact with the movable surface of the disk and to minimise stiction and friction between the slider and the disk surface in the landing zone 29 during start up or during seeking operations in the specular data zone 27.

The texturing layer 32 is added to improve the laser texturing performance of the slider and to improve the control of the laser texturing process. To avoid deforming the substrate, the material of the heat texturable layer 32 is preferably chosen to have a lower melting point in the range of 15-80% (in terms of °C) of the melting point of the substrate. The lower melting point also makes for a lighter energy demand on the laser. Suitable such materials for layer 32 include nickel-phosphorous (Ni-P), aluminum and nickel. The chosen material must not only exhibit a melting point lower than that of the slider substrate, but also a suitable bulk density. A material with too high a bulk density may weigh down the slider and change its flying characteristic if used as a texturing layer. The selected texturing layer, being softer than the substrate, will also offer a cushioning effect

when there is any slider-disk impact. This, coupled with the protective carbon overcoat mentioned below, will improve the service lifetime of the slider.

It will be seen from Figure 6 that for texturing of this shape, each bump 22 incorporates two deviations from the nominal surface 21 of the texturable layer 32. This is the result of flow of layer material due to surface tension force while the laser-melted spot of material is reverting from the liquid form to the solid form. annular rim 22 rings a crater or depression with the floor that is below the nominal surface 21. The height 24 of the rim above the normal surface 21 can be at least 2nm and the diameter 25 of the rim 22 can be at least 1µm.

An alternative profile of a preferred laser textured bump can be seen in Figure 7. This profile has no depression over the nominal surface 21 but has an outstanding round surface. The height 24 can be at least 2nm and the diameter 25 of the base can be at least 1µm.

In Figure 8, we can see another variation of textured bump. This profile is in a form of a "S" or dune shape with a depression 45 and an outstanding ridge bump 37. The height 42 of the bumps can be at least 2nm and the diameter 43 can be at least 1µm.

To achieve the objectives laid down, the density of the texturing on the slider must also be well controlled. The density of the texture formed on the slider surface area can be from 10 bumps per square millimetre to 5×10^6 bumps per square millimetre.

After completion of texturing, a thin protective coating 40, e.g. of a suitable carbon form and of a thickness in the range of 1 to 20nm may advantageously be applied over the textured layer. It will be appreciated that the final outer surface 41 of this coating 40 becomes the air bearing surface of the slider, and that the layer 32 becomes a sub layer.

One of the most useful features of the preferred form of invention is the circular nature of the tips of the profile. This feature contributes significantly to the enhancement of the wear and tribology (friction/stiction) characteristics of the slider 2. Another advantage is the speed and accuracy at which the texturing can be formed on the slider 2. This is particularly useful for mass production.

Claims

1. A slider for a data storage assembly, including:
a body having a transducer for recording on and/or reading a data storage
5 element; and
a surface region which in situ is opposed to a moveable surface of the data storage element and adjacent to which an air bearing for the slider forms during motion of the surface;
characterised in that said surface region includes a heat texturable layer and
10 surface roughness induced by heat texturing at least a portion of said layer, which surface roughness includes one or more raised elements defining rounded contact surface segments to provide controlled contact with said moveable surface of the data storage element and to reduce stiction and friction between said slider and said surface of the data storage element during start up and seeking operations of the
15 slider.
2. A slider according to claim 1 further characterised in that said raised elements include ridge segments and/or bumps.
- 20 3. A slider according to claim 2 further characterised in that said ridge segments are annular dune or sombrero-shaped ridge segments.
4. A slider according to claim 3 further characterised in that each of said annular ridge segments extends about a depression having a floor below the
25 nominal surface of the slider about the ridge segment.
5. A slider according to claim 3 or 4 further characterised in that said annular ridge segments are of an average diameter in the range of at least $0.1\mu\text{m}$.
- 30 6. A slider according to any preceding claim further characterised in that said layer is a sub-layer overlaid with an outer protective coating.



7. A slider according to any preceding claim further characterised in that said layer has a melting point below that of a substrate underlying said layer.
- 5 8. A slider according to claim 7 further characterised in that said melting point of said layer is 15 to 80% of the melting point of the substrate, in terms of °C.
9. A slider according to any preceding claim further characterised in that the hardness of said layer is less than that of the outer protective coating or said
10 substrate, whichever is harder where both are present.
10. A slider according to any preceding claims further characterised in that said ridge segments are of a height of at least 2nm.
- 15 11. A method of forming a textured surface region on a slider for a data storage assembly, characterised by:
providing a heat-texturable layer on the slider, and
directing electro-magnetic energy at said layer to heat and thereby cause
flow in the layer, whereby to texture the layer to form surface roughness which
20 provides an air bearing surface for said slider, and includes one or more raised elements defining rounded contact surface segments to provide controlled contact with a moveable surface of a data storage element and to reduce stiction and friction between said slider and said surface of the data storage element during start up and seeking operations of the slider.
- 25 12. A method according to claim 11 further characterised in that the raised elements include ridge segments and/or bumps.
13. A method according to claim 12 further characterised in that the ridge
30 segments formed are annular dune or sombrero-shaped ridge segments.



14. A method according to claim 13 further characterised in that each of said annular ridge segments extends about a depression having a floor below the nominal surface of the slider about the ridge segment.

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15. A method according to claim 13 or 14 further characterised in that said annular ridge segments are of an average diameter in the range of at least 0.1 μm .

16. A method according to any one of claims 11 to 15 further characterised by
10 overlaying said layer with an outer protective coating.

17. A method according to any one of claims 11 to 16 further characterised in that said layer has a melting point below that of a substrate underlying said layer.

15 18. A method according to any one of claims 11 to 17, further characterised in that said electro-magnetic energy is a laser beam.



Abstract**TEXTURING OF DATA RECORDING SLIDERS**

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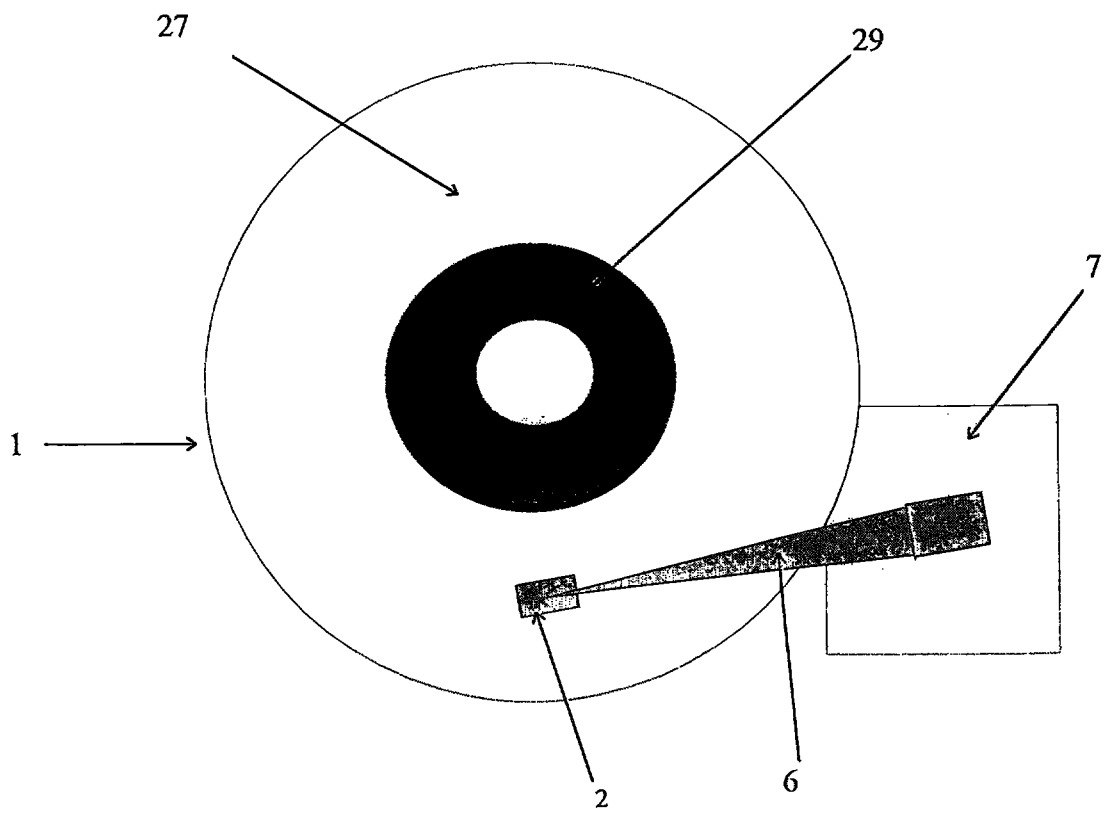
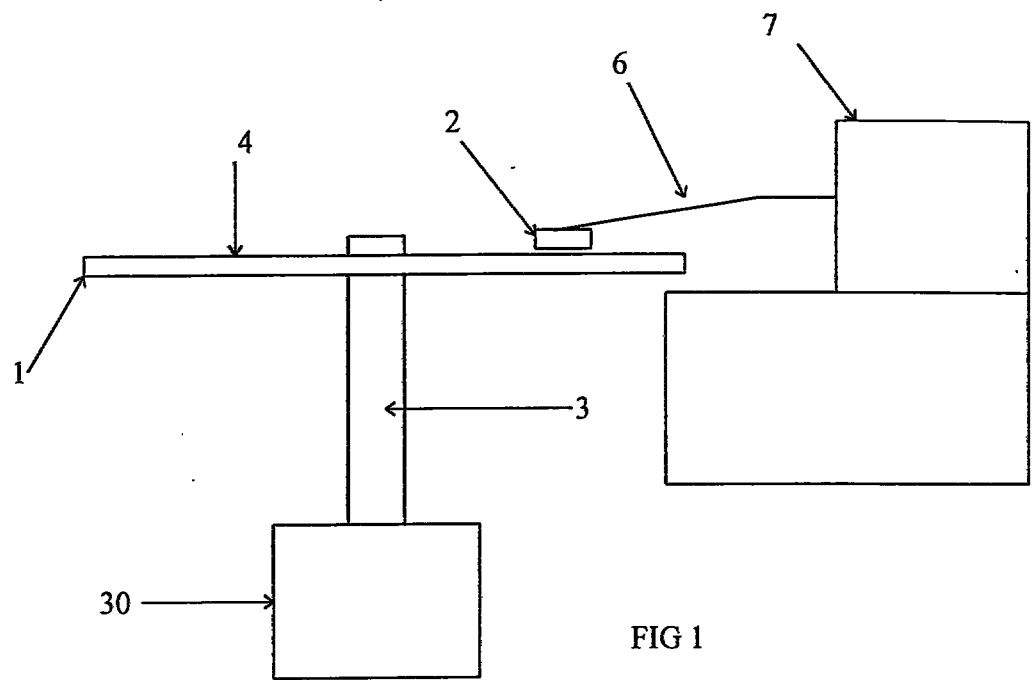
A method of forming a textured surface region on a slider for a data storage assembly, includes providing a heat-texturable layer (32) on the slider (2), and directing electro-magnetic energy at the layer to heat and thereby cause flow in the layer. This is effective to texture the layer to form surface roughness (22,37,36) which provides an air bearing surface for the slider. The surface roughness includes one or more raised elements (22,37,36) defining rounded contact surface segments to provide controlled contact with a moveable surface of a data storage element, and to reduce stiction and friction between the slider and the surface of the data storage element during start up and seeking operations of the slider. Also disclosed is a slider for a data storage assembly.

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(Figure 1)

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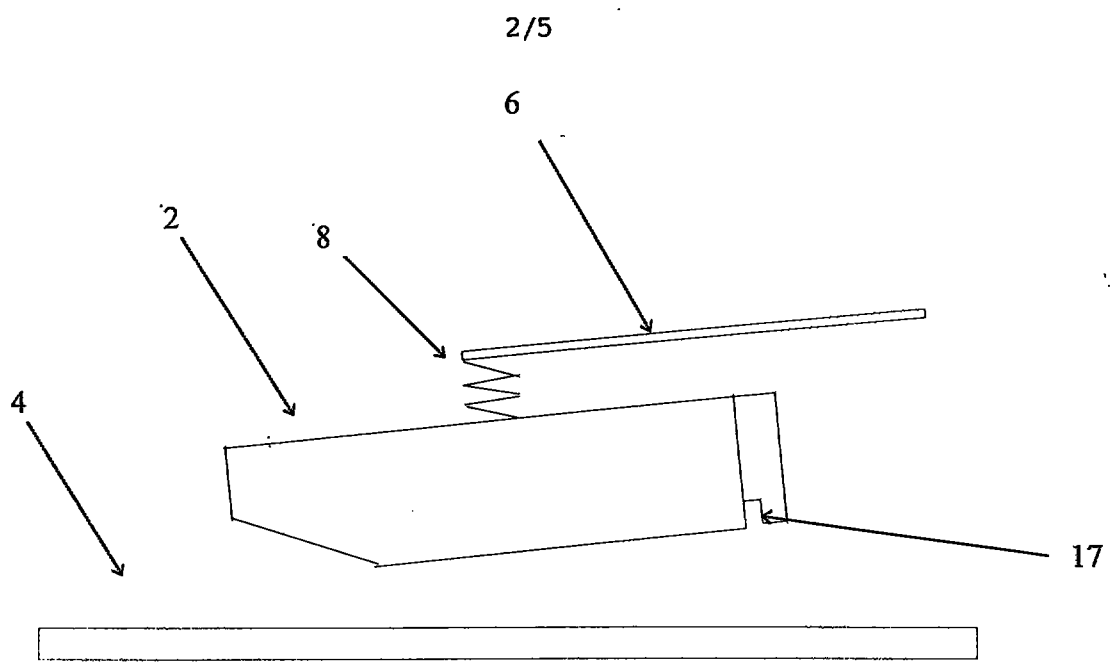


FIG 3a

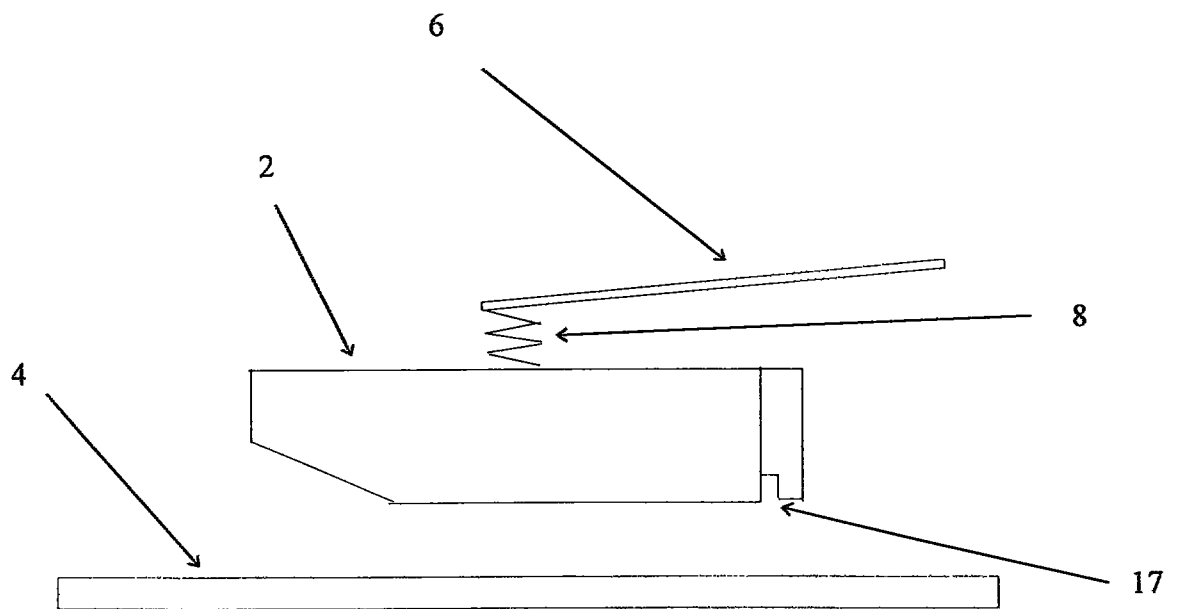
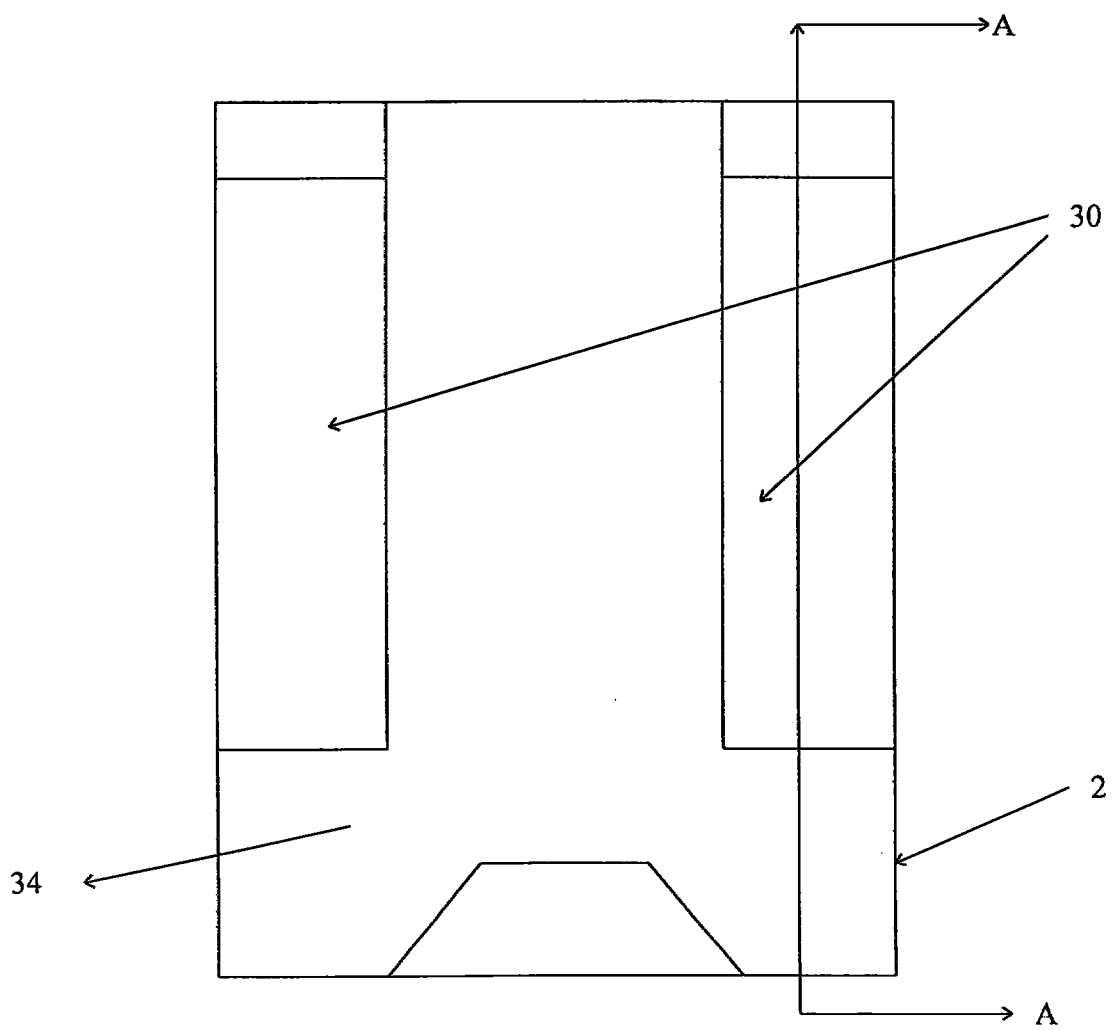
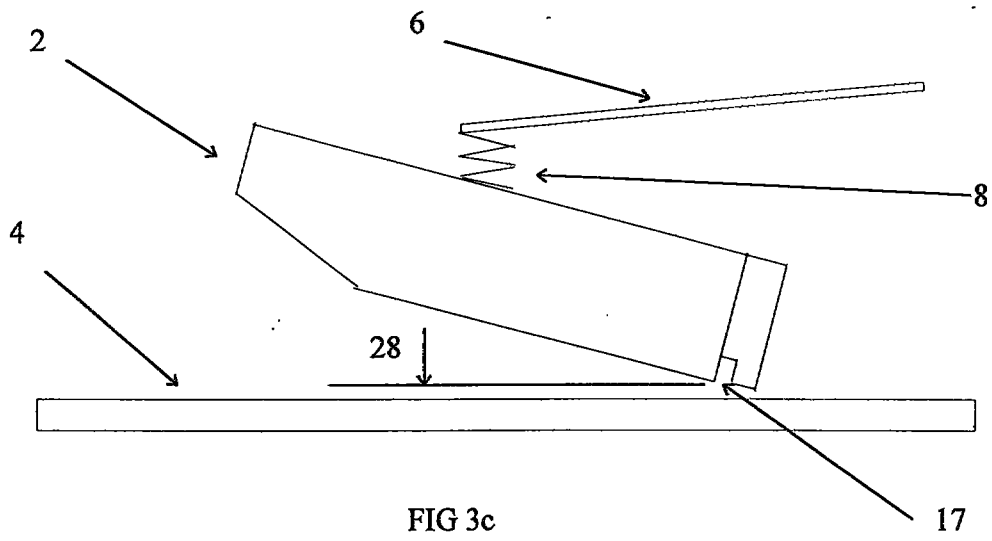


FIG 3b



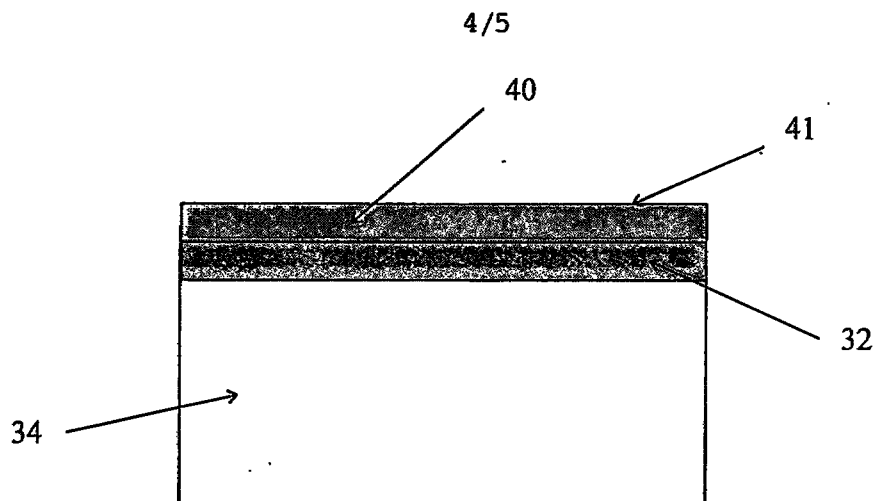


FIG 5

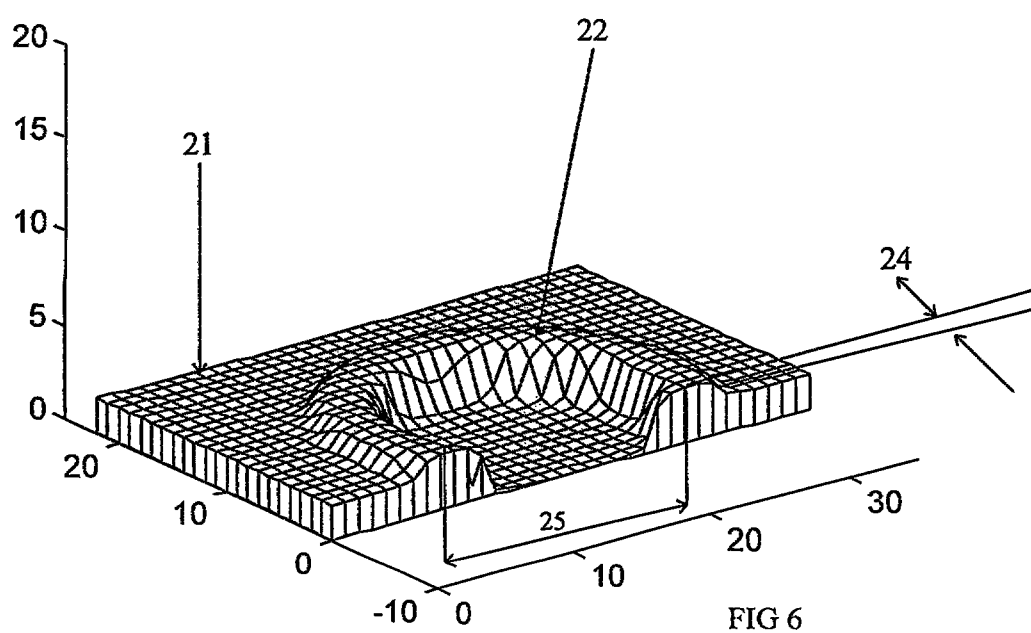


FIG 6

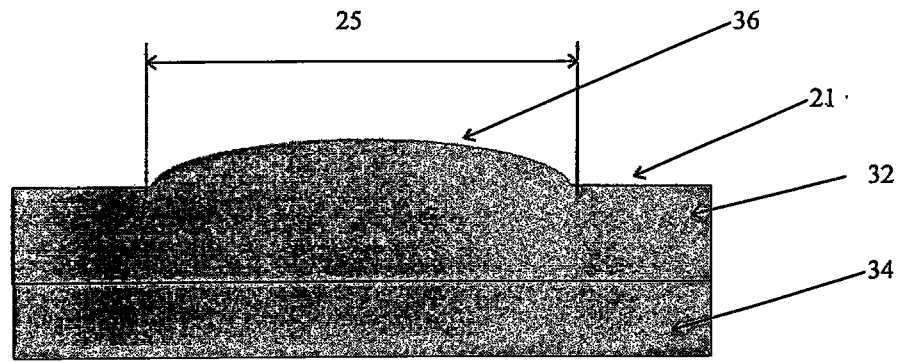


FIG 7

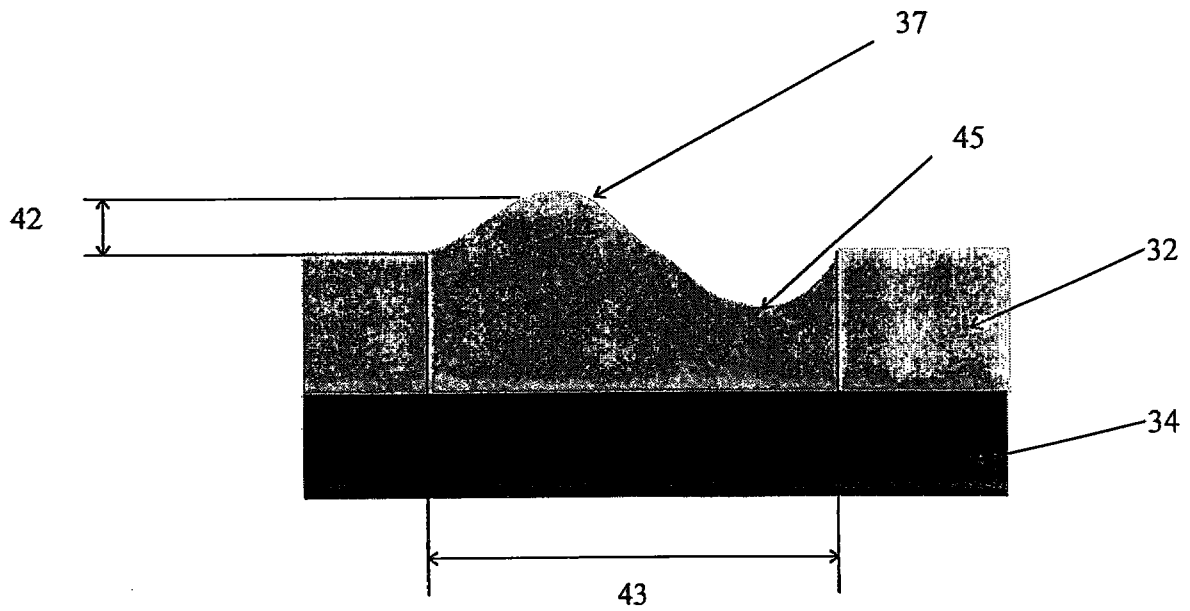


FIG 8