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**SHAPED-BEAM LASER TEXTURING OF MAGNETIC MEDIA**

This application claims the benefit of Provisional Application Serial No. 60/017,267 entitled "Laser Texture Patterns Formed by Non-Axisymmetric Bumps for Magnetic Thin Film Disks", filed May 13, 1996; and Provisional Application Serial No. 60/042,341, entitled "Using Wedged Prism to Control the Laser-Beam Sectional-Shape for Adjustable Elliptical Bump-Shapes in Laser Texturing Process of Magnetic Recording Media", filed March 17, 1997.

**BACKGROUND OF THE INVENTION**

The present invention relates to laser texturing of magnetic data storage media and more particularly to processes for controlling the shapes and orientations of texturing features formed in such texturing processes, as well as the resulting storage media.

Laser texturing of magnetic disks, particularly over areas designated for contact with data transducing heads, is known to reduce friction and improve wear characteristics as compared to mechanically textured disks. Texturing involves focusing a laser beam onto a disk substrate surface at multiple locations, forming at each location a depression surrounded by a raised rim, as in U.S. Patent No. 5,062,021 (Ranjan) and U.S. Patent No. 5,108,781 (Ranjan). Alternatively, as shown in International Publication No. WO 97/07931 published March 6, 1997 (Meyer), the laser beam also can be used to form a bump or nodule at each of the multiple locations. In some cases, a dome or bump is surrounded by a ring.

In any event, the individual topographical features are circular or axisymmetric, more particularly symmetrical about a vertical central axis in the case of features formed on a horizontal surface. While textures based on these features exhibit considerable improvement over mechanically formed textures, the ongoing quest for lower transducing head flying heights and shorter times for accessing data lead to more stringent tribological

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requirements.

Meeting these requirements has been difficult in view of certain structural characteristics of the circular, axisymmetric rims and nodules. These features include a relatively small radius of curvature, a relatively large nodule height as compared to diameter, and large rim height compared to rim width. The resulting abrupt changes in surface elevation cause turbulence at the head/media interface. This results in undesirably high levels of acoustic energy at take-off and landing of the transducing head, i.e. at disk accelerations and decelerations. The closed, rim-like features have exhibited a tendency to collect debris, and their radial component can generate a drag force thought to contribute to dynamic friction.

Therefore, it is an object of the present invention to provide magnetic data storage media with transducer contact regions textured for improved wear and reduced dynamic friction.

Another object is to provide a process for using a laser to texture the surfaces of magnetic data storage media, with more control over the shape and orientation and texturing features formed by the laser to impart a desired roughness.

A further object is to provide a laser texturing process that affords more consistency in forming asymmetrical features such as rims and nodules on textured magnetic media.

Yet another object is to provide magnetic media in which the orientation of non-circular, non-axisymmetric topographical features is determined with reference to the direction of transducing head accelerations and decelerations, to increase the performance benefits derived from the asymmetries.

#### SUMMARY OF THE INVENTION

To achieve these and other objects, there is provided a process for surface texturing a magnetic data

storage medium, including the following steps:

- a. directing a coherent energy beam from a source thereof toward a magnetic data storage medium;
- b. locating beam shaping optics between the source  
5 and the storage medium, thereby shaping the beam to provide a shaped beam segment along which sections taken through the beam perpendicular to beam propagation have a selected non-circular sectional shape; and
- c. causing the coherent energy beam to impinge  
10 upon a selected surface of the storage medium at a plurality of locations thereon, altering the topography of the selected surface at each of the locations by forming a non-circular texturing feature, while orienting the features with major axes thereof substantially  
15 aligned in a predetermined direction.

The features formed according to this process are of the same general types as previously mentioned forms, including nodules, bumps and rims, having a smooth, rounded or rotund character that leads to reduced  
20 friction and increased wear. In a departure from prior forms, features formed by the present process are non-circular or non-axisymmetric in the sense of being substantially elongated in a direction parallel to the major plane of the data storage medium. Thus, the  
25 nodules or bumps are oblong or oval, and the rims are elliptical rather than circular. In general, each feature has a major or "long" axis in the direction of elongation and a minor or short axis that is perpendicular to the major axis. The aspect ratio, i.e.  
30 the major axis/minor axis ratio, can be in the range of about 1.1 to about 10, and more preferably is in the range of about 2-6.

The formation of elongated features provides several advantages. As the flying head approaches the texturing  
35 features, air flow resistance is reduced, due to the streamlined shape of the texturing features. Also, the more gradual increases in feature height result in the

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head experiencing less turbulence, allowing it to fly closer to the disk surface, and with the air bearing providing more stable support. One of these, specific to rim-like features is a reduced tendency to entrap

5 material. The elongated, elliptical rims exhibit a height gradient in the direction of the major axis, from a maximum height along medial regions intersected by the minor axis, to minimal heights at opposite end regions intersected by the major axis. At sufficient elongation,

10 the rim height at these end regions becomes negligible, forming interruptions or gaps in the otherwise elliptical rim. These gaps allow any material collected within the rim to escape, e.g. during storage medium accelerations and decelerations.

15 More generally, all forms of the elongated texturing features exhibit more favorable profiles when elongated. In particular, each nodule, rim or other feature has a height profile that varies, from a maximum height gradient or steepest profile in the vertical plane

20 containing the minor axis, to a minimum height gradient or most gradual profile in the plane containing the major axis. Other planes yield intermediate gradients and profiles, with the maximum or minor-axis profile most like that of a similarly sized but axisymmetric feature.

25 Thus, a maximum benefit is realized when the elongated topographical features are correctly oriented, i.e. with their major axes to the extent possible aligned with the direction of transducing head travel relative to the storage medium during accelerations and

30 decelerations. In disk-shaped storage media, this direction is circumferential with respect to the disks. As a result of this orientation, the transducing head, when moving on or over the dedicated contact region, encounters more gradual changes in height. This reduces

35 turbulence at the head/medium interface, reduces dynamic friction, reduces stiction, and permits lower head flying heights. Wear characteristics are improved, because the

elongated features, when properly oriented, more effectively withstand contact with the transducing head.

The beam shaping optics can take a variety of forms, the most simple being a single wedged prism, with a pair of cylindrical lenses being more suitable. The most preferred version of beam shaping optics comprises a pair of complementary wedged prisms. The wedged prisms are preferred due to their plane surface refraction of the coherent energy beam, which preserves beam collimation and propagation factor  $M^2$  while minimizing aberrations and distortions. This enables a smaller focal spot size, suitable for forming smaller texturing features, while also enhancing control over the shape of the features.

Regardless of whether wedged prisms or cylindrical lenses are employed, using beam shaping optics to provide a specially shaped, non-circular (in section) laser beam affords effective control over the shape and orientation of elongated texturing features, and affords a high degree of flexibility in terms of selecting aspect ratios. This is in contrast to tilting the laser beam, a possibility mentioned in the foregoing Ranjan patents and Meyer international publication, for which an aspect ratio as low as 2 would require a severe tilt of 60 degrees from the preferred orientation perpendicular to the treated surface. The improved control and flexibility afforded by optically shaping the laser beam allow a customizing of texturing heretofore unavailable, not only in selecting the degree of elongation, but in the consistency with which features conform to the desired asymmetry.

#### IN THE DRAWINGS

For a further understanding of the above and other features and advantages, reference is made to the following detailed description and to the drawings, in which:

Figure 1 is a plan view of a magnetic data storage disk and a data transducing head supported for generally

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radial movement relative to the disk;

Figure 2 is an enlarged partial sectional view of the magnetic disk in Figure 1;

Figure 3 is an elevational view of a texturing  
5 device for forming texturing features on the disk;

Figures 4A-4D illustrate energy distributions and profiles of a cylindrical laser beam and a shaped laser beam, respectively;

Figure 5 is a perspective view of one of the  
10 texturing features, namely an elliptical rim;

Figure 6 is a top view showing an elliptical rim;

Figure 7 is a sectional view taken along the vertical plane containing a minor axis of the rim;

Figure 8 is a sectional view taken along the  
15 vertical plane containing a major axis of the rim;

Figure 9 is a perspective view showing an oblong nodule;

Figure 10 is a top view of the elliptical nodule;

Figure 11 is a sectional view taken along the  
20 vertical plane containing a minor axis of the nodule;

Figure 12 is a sectional view taken along the vertical plane containing a major plane of the nodule;

Figure 13 is an enlarged partial top view of the disk showing a pattern of topographical features formed  
25 on the disk;

Figure 14 is a chart illustrating comparative dynamic friction due to axisymmetric texturing features versus non-axisymmetric texturing features;

Figure 15 illustrates an alternative pattern of  
30 texturing features;

Figure 16 illustrates an alternative texturing device;

Figure 17 illustrates a further alternative laser texturing device;

Figure 18 illustrates a further alternative  
35 asymmetric texturing feature;

Figure 19 illustrates yet another alternative

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asymmetric texturing feature; and

Figure 20 illustrates a side profile of the feature in Figure 19.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

5       Turning now to the drawings, there is shown in Figures 1 and 2 a medium for recording and reading magnetic data, in particular magnetic disk 16 rotatable about a vertical axis and having a substantially planar and horizontal upper surface 18. A rotary actuator (not  
10 shown) carries a transducing head support arm 20 in cantilevered fashion. A magnetic data transducing head 22 is mounted to the free end of the support arm, through a suspension  
24 which allows gimbaling action of the head, i.e.  
15 limited vertical travel and rotation about pitch and roll axes. The rotary actuator and the support arm pivot to move head 22 in an arcuate path, generally radially with respect to the disk.

At the center of disk 22 is an opening to  
20 accommodate a disk drive spindle 26 used to rotate the disk. Between the opening and an outer circumferential edge 28 of the disk, upper surface 18 is divided into three annular regions or zones: a radially inward region 30 used for clamping the disk to the spindle; a dedicated  
25 transducing head contact zone 32; and a data storage zone 34 that serves as the area for recording and reading the magnetic data.

When disk 16 is at rest, or rotating at a speed substantially below the normal operating range, head 22  
30 contacts upper surface 18. When the disk rotates within the normal operating range, an air bearing or cushion is formed by air flowing between head 22 and upper surface 18 in the direction of disk rotation. The air bearing supports the head in parallel, spaced apart relation to  
35 the upper surface. Typically the distance between a planar bottom surface 36 of head 22 and upper surface 18, known as the head "flying height", is about 10

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microinches (254 nm) or less. The flying height should be as low as practicable for maximum data storage density.

For data recording and reading operations, rotation  
5 of the disk and pivoting of the support arm are controlled in concert to selectively position transducing head 22 near desired locations within data zone 34. Following a reading or recording operation, the disk is decelerated and support arm 20 is moved radially inward  
10 toward contact zone 32. By the time disk 16 decelerates sufficiently to allow head 22 to engage the upper surface, the head is positioned over the contact zone. Thus, head contact with other regions of the disk surface is avoided. Before the next data operation, the disk is  
15 accelerated from stop, initially with head 22 engaged with disk 16 within the contact zone. Support arm 20 is not pivoted until the head is supported by an air bearing, free of the contact zone.

Magnetic disk 16 is formed first by polishing,  
20 grinding or otherwise mechanically finishing an aluminum substrate disk 38 to provide a substantially flat upper surface. Next, a nickel-phosphorous alloy is plated onto the upper surface of the substrate disk, to provide a non-magnetizable layer 40 with a uniform thickness within  
25 the range of about 2-12 microns. Following plating, the upper surface of the Ni-P alloy layer, i.e. a substrate surface 42, is polished to a roughness of generally less than about 0.1 microinch (2.54 nm). A saturated cloth, paper or pad coated or flooded with cerium oxide, silicon  
30 carbide or another suitable grit, is used for this purpose. A liquid slurry containing grit also may be used. Alternatively, aluminum substrate disks can be obtained with Ni-P alloy layers already applied, then polished as described.

35 After mechanical polishing, substrate disk 38 is laser textured at least within contact zone 32 to provide a desired surface roughness. Laser texturing involves

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melting the substrate disk at and near surface 42 at multiple locations, forming at each location a texturing feature, as will be described in greater detail below. The texture is influenced by the general pattern of texturing features, as well as the size and shape of the features individually.

Fabrication of disk 16 after texturing involves the application of several layers. Chrome is sputter deposited onto substrate surface 42, preferably to a thickness in the range of about 10-100 nm, to form an underlayer 44. The underlayer is well suited for subsequent deposition of a magnetic thin film, in that the crystalline structure of underlayer 44 can control the epitaxy of the crystalline magnetic film. The magnetic thin film provides a recording layer 46 for storing the magnetic data. The thin film material preferably is a cobalt/tantalum/chromium alloy or a cobalt/platinum/chromium alloy, and is sputter deposited to a thickness in the range of about 10-50 nm. Finally, a protective layer 48, typically carbon, is sputter deposited onto the recording layer to a thickness of about 5-30 nm. Underlayer 44, recording layer 46 and cover layer 48 are substantially uniform in thickness. Consequently, upper surface 18 substantially replicates the texture of substrate surface 42.

Laser texturing preferably is accomplished with a laser texturing device 50. As seen in Figure 3, device 50 includes a spindle 52 for rotatably supporting substrate disk 38. Above disk 38, a carriage 54 supports a laser module 56 for reciprocal movement radially with respect to the disk. The laser module includes a neodymium:yttrium lithium fluoride (Nd:YLF) diode laser 58, and beam expanding collimating optics 60 for collimating the diode laser output to produce a beam 62 in the form of a circular cylinder having a diameter of about 1-10 mm. The preferred diameter varies with the application and the other optional components involved.

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With laser 58 preferably operated in the TEM<sub>00</sub> mode, the beam has a Gaussian energy distribution as indicated in Figure 4A. Sections of the beam perpendicular to propagation, i.e. horizontal sections as viewed in Figure 3, exhibit circular profiles as shown in Figure 4B.

The laser module also includes several optical components for selectively shaping beam 62, to expand the beam in a first direction while leaving the beam substantially unchanged in another direction perpendicular to the first. These components include a pair of wedged prisms 64 and 66 spaced from one another along the beam path. The prisms are supported by adjustment components, schematically illustrated at 68 and 70 respectively, that permit azimuth angle adjustment of each prism about an axis perpendicular to the plane of the drawing. This permits adjustment of the angle of incidence  $\alpha$  of the laser energy upon a planar receiving surface 72 of prism 64. Given the non-zero angle  $\alpha$  and the alignment of an opposed planar exit surface 74 substantially perpendicular to the refracted beam, the beam emerges from prism 64 refracted and at an oblique angle relative to the incoming beam in a refracted, partially broadened beam segment 76. Beam segment 76 enters prism 66 through a planar receiving surface 78, refracted and thus angularly offset from the beam propagation direction, preferably by the same angle of incidence  $\alpha$ , but in the opposite direction. An opposed exit surface 80 of prism 66 is substantially perpendicular to the refracted beam. As a result, the beam, having been twice refracted and twice enlarged in the same direction, emerges from prism 66 as a shaped beam segment 82. Sections of shaped beam segment 82 perpendicular to propagation have elliptical profiles as indicated in Figure 4C. The circular profile in Figure 4B illustrates the circular or axisymmetric nature of beam 62 upstream of the beam shaping optics. The beam diameter is constant, regardless of the angle at which it

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is taken. By contrast, the non-circular, non-axisymmetric shaped beam segment 82 exhibits the elliptical profile of Figure 4C, with axes ranging from a minor axis "a" taken in the horizontal direction and  
 5 normal to the plane of Figure 3, to a major or long axis "b" taken in the horizontal direction parallel to the plane of Figure 3. The energy distribution in beam segment 82 remains Gaussian, but like the beam itself is broadened in the direction parallel to the major axis, as  
 10 shown in Figure 4D.

Prisms 64 and 66 can be considered complementary in the sense that (1) they have the same size, shape and refractive index and thus refract incident coherent energy by the same amount or same angle; and (2) they are  
 15 positioned to refract energy in opposite directions, so that shaped beam segment 82 is parallel to beam 62 upstream of the shaping components. This feature while not essential is advantageous because it most effectively preserves the beam collimation and propagation factor  $M^2$ .  
 20 (The propagation factor  $M^2$  describes the purity of the  $TEM_{00}$  mode. For a perfect Gaussian beam,  $M^2$  is equal to 1.)

Azimuth angles of prisms 64 and 66 can be adjusted through components 68 and 70 to change the angles of  
 25 incidence  $\alpha$ , and thus change the aspect ratio  $b/a$  of the shaped beam segment. Through this adjustment to the prisms it has been found practicable to increase the aspect ratio from 1 (circular profile) up to about 6. More particularly, the aspect ratio of shaped beam  
 30 segment 82, due to the wedged prisms can be determined by the equation:

$$\frac{b}{a} = \frac{\cos[\arcsin(\sin \alpha / n)]}{\cos \alpha}$$

where  $\alpha$  is the angle of incidence and  $n$  is the index of  
 35 refraction (both prisms).

Beyond the beam shaping optics, a focusing lens 84 converges the beam and defines a focal spot or area 86 of

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beam impingement onto substrate surface 42. Focal spot 86 has the elliptical shape and aspect ratio of the beam section shown in Figure 4C. The major and minor axes of the focal spot are determined by the following equations:

5 (2) 
$$a_f = \frac{4fM^2\lambda}{\pi b_p}$$

(3) 
$$b_f = \frac{4fM^2\lambda}{\pi a_p}$$

where  $a_f$  and  $b_f$  are the respective minor and major axes of the focal spot,  $f$  is the focal length, and  $\lambda$  is the beam wavelength. Thus, the shape of focal spot 86 is controlled by prisms 64 and 66 and more specifically their azimuth angles, while the size of the focal spot is controlled by focusing lens 84 in conjunction with the prisms, and of course in part by collimating optics 60.

As explained in the aforementioned U.S. Patent No. 5,062,021, U.S. Patent No. 5,108,781, and International Publication No. WO 97/07931, which documents are incorporated herein by reference, the focusing of laser energy onto the metallic surface of the substrate disk causes highly localized melting at the surface. Although the material resolidifies rapidly, there is sufficient material flow to form either a rim or a nodule, with higher energy levels tending to result in rims rather than nodules.

Figure 5 shows in perspective a texturing feature formed using device 50, namely a rim 88. Figures 6-8 illustrate the rim profile from the top and from two vertical sections through the rim perpendicular to one another. As seen from these views, rim 88 is elongated or elliptical, having an aspect ratio  $b/a$  of greater than one. This aspect ratio is not necessarily proportional to the aspect ratio of the beam and focal spot. However, there is a correspondence, in that within practical limits, the aspect ratio of rim 88 tends to increase with

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increases in the beam and focal spot aspect ratio.

Typically, rim lengths (major axis b) are within the range of about 6 to about 50 microns (more preferably 10-20 microns), with rim widths (minor axis a) in the  
5 range of about 3-10 microns (more preferably 4-8 microns). The rim aspect ratio should be at least about 1.1, and at most about 10. More preferably, the aspect ratio ranges from about 2 to about 6.

In Figure 7, rim 88 and its adjacent portion of  
10 substrate disk 38 are shown in section along the vertical plane containing minor axis a. The profile in that plane is substantially the same as the profile resulting from a vertical plane taken through a circular or axisymmetric rim of the same height. A top edge 90 of the rim is  
15 curved, illustrating a key difference from circular rims in that the rim height is non-uniform.

The sectional view in Figure 8 is along the vertical plane containing major axis b. As compared to Figure 7, opposite portions of the rim are farther apart from one  
20 another, and the rim sections themselves have more gradual height gradients. Rim top edge 90 is highest along medial regions 92 of the rim, i.e. regions intersected by the minor axis. The rim top edge slopes downward in both directions toward opposite ends 94 and  
25 96 of the rim, i.e. regions intersected by the major axis, where the height is at its minimum. Thus, in Figure 8 as compared to Figure 7, all features have more gradual inclines.

A nodule or bump 98 formed by device 50 is shown in  
30 perspective in Figure 9, with corresponding top, end sectional and side sectional views in Figures 10-12. Once again, the sectional views are based on vertical planes through the a and b axes with the profile in Figure 11 comparable to a profile of a circular bump  
35 having the same height, and the profile view in Figure 12 showing a substantially more gradual incline from a maximum height at the center of bump 98.

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Maximum heights for features like rim 88 are typically in the range of 5-30 nm, and maximum nodule or bump heights also typically are in the range of 5-30 nm. More preferably, the maximum heights range from 10-20 nm.

5        Beyond controlling individual rims and nodules, device 50 is used to provide a desired pattern or distribution of the texturing features throughout contact zone 32. One suitable pattern is a spiral, formed by rotating substrate disk 38 on a vertical axis at an  
10        angular speed  $\omega$  (Figure 3) while at the same time moving the laser module radially with respect to the disk. The laser is pulsed to form individual texturing features, either rims or nodules, for example at a frequency in the range of 10,000-100,000 pulses per second. The substrate  
15        disk is rotated to provide a suitable linear velocity, for example about one meter per second. The disk moves continually during texturing, but for purposes of individual feature formation can be considered stationary due to the extremely short duration of each pulse, e.g.  
20        about 70 ns.

      The resulting pattern of rims 88 can be seen in Figure 13, showing a segment of contact zone 32. Each rim 88 is aligned with its minor axis "a" in the radial direction (with respect to the substrate disk), and with  
25        its major axis "b" in the circumferential direction. This alignment or orientation is specifically chosen with reference to the movement of head 22 and disk 16 relative to one another, particularly during accelerations and decelerations of the head. (While accelerations and  
30        decelerations actually are due to disk rotation, they are commonly discussed in terms of circular travel of the transducing head relative to the disk.) The orientation of rims 88 with their major axes in the circumferential direction has been found highly favorable, because it  
35        positions the most gradual rim height gradients in the direction of head travel. This reduces turbulence, reduces stiction and dynamic friction, and permits the

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head to have a lower flying height above the disk.

The chart in Figure 14 shows the reduced dynamic friction. A plot 100 based on disk 16 shows a dynamic friction coefficient of approximately 0.6. A comparative  
5 plot 102, based on circular or axisymmetric texturing features, exhibits a substantially higher dynamic friction above 0.8 over most of the 20,000 ccs (controlled start stop) cycle range.

A variety of alternative patterns can be used to  
10 realize the above advantages, so long as the individual texturing features are properly aligned. Figure 15 shows an alternative pattern in which the location between consecutive features 104 is substantially reduced. Adjacent rims are connected to one another at their ends,  
15 thus to form a substantially continuous spiral track. This can be accomplished either by increasing the laser firing frequency, reducing the angular speed of the substrate disk, or both. More generally, texturing features can be formed in concentric rings rather than  
20 spiral, or even distributed somewhat randomly throughout the contact zone, so long as they are aligned with their major axes in the circumferential direction.

Another improvement is the reduction in noise or acoustic energy at transducing head takeoff and landing.  
25 For mechanically textured disks, the acoustic energy has been found to be about 100 mV. For disks with contact zones laser textured with circular or axisymmetric texturing features, the acoustic energy is substantially higher, e.g. about 200 mV. By comparison, magnetic disks  
30 with landing zones laser textured with elliptical features in end-to-end contact as shown in Figure 15, exhibit acoustic energy of about 70 mV at takeoff and landing, a substantial reduction compared to previous laser texturing, and a favorable comparison to mechanical  
35 texturing. This significant reduction most likely is due to the more gradual texturing feature height gradients in the direction of head travel, and is likely to allow

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lower transducing head flying heights over the contact.

Figure 16 illustrates an alternative device 105 for forming the texturing features, including a spindle 106 rotatably supporting a substrate 108, a carriage 110 and a laser module 112 moved by the carriage radially of the spindle and substrate. Laser module 112 includes a laser 114 and collimating optics, a single wedged prism 116 for shaping the laser beam 118, and a focusing lens 120. While wedged prism 116 is suitable for expanding the beam in one direction while leaving its direction constant in the other, there is less flexibility in terms of adjusting aspect ratios, since each angular adjustment of prism 116 (e.g. to change the angle of refraction) also changes the direction of the shaped beam exiting the prism.

Figure 17 illustrates a further alternative laser texturing device 122, similar to device 50 with the exception that the beam shaping optics include cylindrical lenses 124 and 126 in lieu of the wedged prisms. Downstream lens 126 has a larger radius of curvature than the upstream lens. The two lenses are centered on a common axis, so that a shaped beam segment 128 not only is parallel to incident beam 130, but also coaxial. While this can be considered an advantage, in most respects device 50 is preferred, due to the need for and difficulty in achieving perfect alignment of the cylindrical lenses in terms of their centers, distance from one another and orientation. Further, lenses 124 and 126 are subject to spherical aberration coma, astigmatism, field curvature, and distortion. Accordingly, it is substantially more difficult in device 122 to preserve collimation and propagation factor  $M^2$ . Also, because the focal spot is larger than the diffraction limit in the case of the cylindrical lenses, certain texturing features are too small to be formed using device 122.

Figure 18 illustrates an alternative rim-like

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feature 132 formed for example using device 50. As an extension of the non-uniform height of elliptical rims, it has been found that by using a sufficiently large aspect ratio, the feature height at the opposite ends of the ellipse can be made negligible, in effect forming two opposite end gaps 134 and 136, or in other words forming two elongate generally crescent-like ridge sections confronting one another, as indicated at 138 and 140 in Figure 18.

When properly aligned, features 132 provide the same advantages as rims 88 discussed above, with a further advantage in that features 132 are open and considerably less prone to debris entrapment. The reduced tendency to entrap material is likely to enhance wear characteristics.

Figure 19 illustrates a further alternative texturing feature 142 in the form of an irregular rim. As compared to rim 88, feature 142 has a further asymmetry, in that the maximum height regions 144 are offset from the minor axis rather than centered. Figure 20 illustrates the rim side profile 146. Beneath the profile, an arrow 148 indicates the circumferential direction of disk rotation, i.e. the opposite to the direction of transducing head "travel". The side profile exhibits a relatively steep slope 150 and a more gradual slope 152. As before, the major axis of the feature coincides with the circumferential direction. When the disk rotates in the direction shown, the head first encounters the more gradual slope 152. Thus, the benefits achieved by elongating and properly aligning the texturing features are increased by forming an irregular elongated feature, oriented with reference to head and disk movement as shown.

The asymmetry as to slope in feature 142 is achieved by adjusting the alignment and relative orientation between wedged prisms 64 and 66, and focusing lens 84.

Thus in accordance with the present invention,

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- magnetic data storage disks can be textured, particularly throughout dedicated head contact areas, for more controlled accelerations and decelerations of the head, reduced dynamic friction, and improved resistance to wear. These advantages arise due to a process that affords more control over the shape and orientation of elongated, elliptical or otherwise non-axisymmetric texturing features. A high degree of consistency is achieved in forming and aligning asymmetrical features.
- 10 These features have a uniform orientation determined with reference to the direction of transducing head accelerations and decelerations, to maximize the performance advantages derived from the asymmetries.

What is claimed is:



## CLAIMS

1. A process for surface texturing a magnetic data storage medium, including:

directing a coherent energy beam from a source  
5 thereof toward a magnetic data storage medium;

locating beam shaping optics between the source  
and the storage medium, thereby shaping the beam to  
provide a shaped beam segment along which sections taken  
through the beam perpendicular to beam propagation have a  
10 selected non-circular sectional shape; and

causing the coherent energy beam to impinge  
upon a selected surface of the storage medium at a  
plurality of locations thereon, altering the topography  
of the selected surface at each of said locations by  
15 forming a non-circular texturing feature, and orienting  
the alignment features with major axes thereof aligned  
substantially in a predetermined direction.

2. The process of claim 1 wherein:

said locating of the beam shaping optics  
20 includes placing first and second wedged prisms along the  
beam in spaced apart relation to one another, and  
orienting each of the prisms to expand the beam in a  
first direction perpendicular to beam propagation, while  
maintaining the beam substantially unchanged in size in a  
25 second direction perpendicular to beam propagation and  
perpendicular to the first direction.

3. The process of claim 2 further including:

orienting the first and second prisms with  
respect to one another in complementary fashion, so that  
30 a first propagation direction of the beam between the  
source and the wedged prisms, and a second propagation  
direction of the shaped beam segment, are substantially  
the same.

4. The process of claim 3 wherein:

said locating of the beam shaping optics  
35 comprises selecting the first and second wedged prisms of  
substantially the same size, shape and refractive index.



5. The process of claim 2 further including:  
rotatably adjusting the wedged prisms to alter  
the angles of incidence of the coherent energy beam with  
respect to the first and second prisms, thereby to adjust  
5 an aspect ratio of the shaped beam segment.

6. The process of claim 1 wherein:  
said locating comprises placing first and  
second cylindrical lenses along the beam in spaced apart  
relation to one another, with the first lens being nearer  
10 to the source, and the second lens being nearer to the  
storage medium and having a larger radius of curvature.

7. The process of claim 1 further including:  
generating the coherent energy beam to have a  
Gaussian intensity profile as it propagates toward the  
15 beam shaping optics.

8. The process of claim 7 wherein:  
said shaping of the beam comprises providing a  
shaped beam segment having an aspect ratio from about 1.1  
to about 10.

20 9. The process of claim 7 wherein:  
the beam is shaped to provide in the shaped  
beam segment an aspect ratio in the range of about 2 to  
about 6.

10. The process of claim 1 wherein:  
25 the storage medium is a rotatable disk, and  
said predetermined direction is circumferential with  
respect to the disk.

11. The process of claim 1 further including:  
before said directing of the coherent energy  
30 beam, polishing said selected surface of the storage  
medium whereby the selected surface is substantially  
planar and specular.

12. The process of claim 11 wherein:  
the forming of each non-circular texturing  
35 feature comprises forming at least one of: an elongate  
nodule protruding above a plane of the selected surface,  
an elliptical rim protruding above the plane, and a pair



of opposed crescent-like ridges separated by gaps at their ends.

13. The process of claim 1 wherein:

5 said causing of the coherent energy beam to impinge upon the selected surface further comprises focusing the beam onto the selected surface.

14. The process of claim 13 further including:

adjusting the orientation of a lens used for said focusing, with respect to the beam shaping optics,  
10 to cause a predetermined asymmetry in each of said features.

15. The process of claim 1 wherein:

said shaping of the coherent energy beam includes expanding the beam in a first selected direction  
15 perpendicular to beam propagation, while keeping the size of the beam substantially the same in a second direction perpendicular to propagation and to the first direction.

16. The process of claim 1 wherein:

said causing of the coherent energy beam to  
20 impinge upon the selected surface includes maintaining the shaped beam segment perpendicular to the selected surface to define a non-circular irradiation area of beam impingement onto the selected surface.

17. The process of claim 11 further including:

25 translating the storage medium and the shaped beam segment relative to one another to move the irradiation area along a path on the storage medium, wherein said directing of the coherent energy beam further includes pulsing the coherent energy beam at a  
30 selected pulse duration, and selecting a pulse frequency with respect to a speed of irradiation area translation along said path, such that successive pulses correspond to successive texturing features formed along said path.

18. The process of claim 1 wherein the magnetic

35 data storage medium comprises a non-magnetizable substrate, and wherein the process further includes: depositing a magnetizable film over the



substrate at a substantially uniform thickness whereby the film tends to replicate the topography of the substrate surface, wherein the selected surface is a surface of the substrate.

5           19. The process of claim 18 further including:  
prior to depositing the magnetizable film,  
depositing a non-magnetizable metallic underlayer on the  
substrate at a generally uniform thickness, whereby the  
magnetizable film when deposited over the substrate is  
10 deposited directly onto the non-magnetizable underlayer.

20. The process of claim 18 further including:  
forming a non-magnetizable cover layer over the  
magnetizable film in a substantially uniform thickness to  
provide an exposed outer cover surface substantially  
15 replicating the topography of the substrate surface.

21. A device for storing magnetic data, including:  
a magnetic recording medium including a  
substrate body formed of a non-magnetizable material and  
magnetizable film deposited over the substrate body and  
20 substantially uniform in thickness, said storage medium  
having a substantially planar surface including a contact  
region adapted for surface engagement with a magnetic  
data transducing head during accelerations and  
decelerations of the transducing head due to movement of  
25 the storage medium in a predetermined direction relative  
to the transducing head; and

multiple texturing features formed in the  
storage medium surface and protruding above a nominal  
surface plane of the contact region to collectively  
30 define a surface roughness of the contact region, each of  
the topographical features having a length greater than  
its width and oriented with its length substantially in  
said predetermined direction.

22. The device of claim 21 wherein:  
35 said data storage medium is a rotatable disk  
and said predetermined direction is circumferential with  
respect to the disk.



23. The device of claim 21 wherein:  
said texturing features have heights above the nominal plane in the range of about 5-30 nm.
- 5 24. The device of claim 21 wherein:  
each of the texturing features has a length at least 1.1 times its width.
25. The device of claim 21 wherein:  
said texturing features are rounded and substantially free of sharp edges.
- 10 26. The device of claim 25 wherein:  
the texturing features include substantially elliptical rims.
27. The device of claim 26 wherein:  
each of the elliptical rims has a major axis in  
15 the length direction and a minor axis in the width direction, and has a gradient in its height from a maximum height region intersected by the minor axis to a minimum height region intersected by the major axis.
28. The device of claim 25 wherein:  
20 each of the texturing features comprises confronting, curved ridges that cooperate to define an elliptical shape and are spaced apart from one another to define gaps at opposite ends of the elliptical shape.
29. The device of claim 25 wherein:  
25 the texturing features comprise elongated nodules.
30. The device of claim 21 wherein:  
each of the texturing features has an asymmetry in height gradients in said predetermined direction.
- 30 31. The device of claim 30 wherein:  
said asymmetry is characterized by a maximum height region and first and second slopes away from the medial region on opposite sides thereof, said first slope being substantially steeper than the second.
- 35 32. The device of claim 31 wherein:  
the second slope extends in said predetermined direction, thus to encounter the head before the first



slope.

33. The device of claim 21 further including:  
a metallic, non-magnetizable underlayer between  
the substrate and the magnetizable film, and having a  
5 substantially uniform thickness.

34. The device of claim 21 further including:  
a protective cover layer deposited on the  
magnetizable film and having a substantially uniform  
thickness.

10 35. An apparatus for recording and reading magnetic  
data including the device of claim 21, and further  
including:

a magnetic data transducing head;  
means for supporting the transducing head in a  
15 selected orientation relative to the recording medium,  
and for controlled movement relative to the recording  
medium in a direction substantially perpendicular to the  
predetermined direction; and

means for moving the storage medium in said  
20 predetermined direction.