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Title: AN APPARATUS AND METHOD FOR LASER TEXTURING A
MAGNETIC RECORDING DISK AND A DISK PRODUCED THEREBY

THIS INVENTION relates to an apparatus and method of laser texturing magnetic recording disks and to a disk produced thereby. More specifically, it relates to texturing a landing zone or a data zone of a rigid magnetic recording disk having an aluminium based nickel-phosphorous substrate or a glass substrate.

Rigid magnetic recording disks and hard disk drives are well known for use in storing data in computer systems. A hard disk drive typically employs one or more disks rotatable on a central axis in combination with data transducer heads positioned in close proximity to a recording surface of each disk. The heads move generally radially with respect to the disks. During reading and writing operations the data transducer head is maintained at a controlled distance from the recording surface and supported on a so-called air bearing as the disk rotates. The data transducer head contacts a so-called landing zone of an associated disk surface whenever the disk is stationary, accelerated from a stop, and decelerated before coming to a stop.

A high recording density system requires the flying height of a data transducer head to be minimised. Smooth disk and head surfaces are needed to accommodate the lower flying height of the head. However, if both the head surface and the recording surface are too flat and smooth, the precise match of these surfaces gives rise to

excessive stiction and friction during the start up and stopping of the disk. This also occurs if the head surface contacts the disk surface accidentally during reading and writing operations. Serious wear to the head and recording surface will result which can eventually lead to a head crash.

In order to circumvent this difficulty, the surfaces of magnetic recording disks are often intentionally roughened to reduce the head/disk stiction and friction. A known magnetic recording disk comprises a rigid disk substrate produced from a polished aluminium disk with a nickel-phosphorous coating. The coating is polished to a substantially specular finish, for which the roughness is less than 2.5 nm. The disk is then rotated between two opposite pressure pads or rollers which support a cloth or paper coated with silicon carbide (SiC) or other suitable grit. The size of the grit is predetermined to yield roughness peaks of about 20 nm-25 nm. However, peaks textured using this mechanical texturing technique tend to be jagged, have sharp edges and are difficult to control in size.

To minimise the flying height of the head, the development of a more precisely controlled texturing method is necessary. Other texturing techniques, such as anodising and chemical etching have been studied and reported. PCT/US93/03554 (WEIR, Richard D. et al.) International Publication NO. WO93/21629 discloses the texturing of the landing zone, stop/start zone, of magnetic-recording disks using a laser etching method. The textured annular stop/start zone has a laser-etched

circular pattern. The metal disk substrate comprises an aluminium alloy, a titanium alloy, or an austenitic stainless steel having a thin-film coating selected from the group consisting of nitrides, carbides, or borides of titanium, zirconium, hafnium, vanadium, niobium, tantalum, chromium, molybdenum or tungsten. US Patent No. 5,062,021 and No. 5,108,781 (Rajiv Y. Ranjan et al.) discloses a focused pulsed laser beam for selectively texturing magnetic media. By rotating the disk while directing pulsed laser energy over a limited portion of the radius, an annular textured landing zone band is formed. The band comprises multiple individual laser spots, each with a centre depression surrounded by a circular raised rim. The depth of the depressions and height of the rims are controlled primarily by laser power and laser pulse width. The shape of an individual laser spot can be altered by varying the laser beam inclination with respect to the disk surface. On a larger scale, the laser repetition frequency in combination with disk rotational speed controls the pattern or arrangement of laser spots.

Mechanical texturing techniques make it difficult to control the texture size. Therefore, such techniques are unsuitable for the close control of texture size necessary to minimise the flying height for data transducer heads. Furthermore, the peaks created using such techniques tend to be jagged and have sharp edges. This can result in friction building up between a head and a disk after a quantity of contact stop/start (CSS) cycles which will cause wear of both the disk and the transducer head. The laser texturing techniques can

control the texturing size and form smooth contours. However, such techniques require the texturing of the disk on a point by point basis. Furthermore bump morphology may be unsuitable for the data zone of the disk.

It is an object of this invention to seek to provide a process to texture a magnetic recording disk in which the size and smoothness of peaks and indentations in the disk are controlled. This can be very helpful to reduce the flying height of a data transducer head, to increase recording density, and to improve data transducer head and disk wear characteristics.

Another object of the invention is to seek to provide a process to selectively texture the specular portion, the landing zone where a data transducer head contacts a disk surface whenever it is stationary, accelerated from a stop, and decelerated before coming to a stop completely or the data zone where a data transducer head reads and writes data over a disk surface. Different texturing parameters are used for texturing the data zone and the landing zone.

One more object of this invention is to seek to provide a process for texturing a relatively large area or the whole landing zone using a flat pulsed laser beam, or an annular flat pulsed laser beam.

Accordingly, one aspect of the present invention provides an apparatus for laser texturing an annular portion of a surface of a magnetic recording disk, which

apparatus comprises: a laser for generating a pulsed laser beam output; means for expanding and homogenising the pulsed laser beam; and optical means to focus and direct the expanded and homogenised beam onto the annular portion of the surface of the magnetic recording disk to be textured, the beam having a predetermined spot area at the surface of the disc, which spot area is of substantially the same size as the radial width of the annular portion to be textured.

A further aspect of the present invention provides a method of texturing an annular portion of a surface of a magnetic recording disk, the method comprising the steps of: generating a pulsed laser beam output; expanding and homogenising the pulsed laser beam; and focusing and directing the expanded and homogenised beam onto the annular portion of the surface of the magnetic recording disk to be textured, the beam having a predetermined spot area at the surface of the disc, which spot area is of substantially the same size as the radial width of the annular portion to be textured.

Another aspect of the present invention provides a magnetic recording disk having a surface, at least an annular portion of which is textured by a laser texturing process, the textured annular portion of the disk having a uniform ripple-like and near periodic texture.

In order that the present invention may be more readily understood, embodiments thereof are now described, by way of example, with reference to the accompanying drawings, in which:

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Figure 1 is a schematic diagram of an embodiment of a laser texturing system;

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Figure 2 is a schematic top view of a magnetic recording disk and a data transducer head;

Figure 3 is an enlarged partial cross-sectional view of the magnetic recording disk of Figure 3;

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Figure 4 is an optical micrograph of a textured substrate comprising a nickel-phosphorous coating plated on a rigid aluminium disk;

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Figure 5 (a) is an AFM image of a substrate before texturing;

Figure 5(b) is an AFM image of the substrate of Figure 5 (a) after texturing;

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Figure 6 (a) is a line analysis from the AFM image shown in Figure 5(a);

Figure 6 (b) is a line analysis from the AFM image shown in Figure 5(b); and

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Figure 7 is an optical micrograph of a textured glass substrate.

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This invention relates to the selective texturing of a magnetic recording disk using a flat pulsed laser beam. Its unique feature, with respect to other reported laser texturing techniques, is using a flat pulsed laser beam to texture a large spot area of several square millimetres or the whole landing zone of a magnetic recording disk, including glass disks. It is suitable for texturing either the landing zone or the data zone with different texturing parameters.

In the following text, an apparatus and process for flat pulsed laser beam texturing a landing zone of a magnetic recording disk is explained in detail.

Referring to Figure 1, a laser texturing system embodying the present invention comprises a pulsed laser 1 which is used to generate a flat pulsed laser beam, and preferably a pulsed laser with an output wavelength in the ultraviolet range, which wavelength is strongly absorbed by disk substrates and especially by glass substrates. A shutter 2 is located in the path of the laser beam and is operable to block or to pass the laser beam. The flat pulsed laser beam can be controlled automatically and quickly to satisfy the requirements of a continuous texturing process. The flat pulsed laser beam is expanded and homogenised by a beam expander and homogeniser 3 to ensure that the beam profile has optimal uniformity. A mirror 4 is used to direct the beam to an optical system. A split mirror beam sampler 5 directs a portion of the beam to a laser energy detector 6 to monitor the energy variation of the flat pulsed laser beam to ensure its stability. The flat pulsed laser beam

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is resized by a focusing lens 7. A magnetic recording disk 8 is located a predetermined distance away from the lens 7 on a rotatable stage 9. The focusing lens is selected, or the predetermined distance chosen, such that the spot area of the beam at the disk 8 substantially corresponds to the width of the landing zone. By rotating the disk 8 on the stage 9, a selectively textured annular landing zone is formed.

Preferably, the spot area of the beam at the disk 8 is of the order of several square millimetres. The operation of the laser texturing system, including the pulsed laser 1, the shutter 2, the laser energy detector 6 and the rotatable stage 9, is controlled by a controller 10. The controller 10 is connected to a host computer 11 through an interface.

In another embodiment of a laser texturing system, the pulsed laser is replaced with a high energy pulsed laser which is used to provide higher laser energy. The other components of this embodiment function and operate in a similar manner to that described in the previous embodiment in Figure 1. As in the previous embodiment in Figure 1, the flat pulsed laser beam is expanded and homogenised and is directed to an optical system, comprising a group of optical components, such as a pair of circular prisms. The optical system converts the incident flat pulsed laser beam into an annular flat beam, which covers the whole landing zone of a magnetic disk mounted on the stage which is located a predetermined distance

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away from the optical system. The footprint of the annular beam on the disk is comparable to the spot area provided by the beam in the previous embodiment. The radial width of the annular beam on the disk is substantially the same as the radial width of the annular portion of the disk to be textured. In this case, the purpose of disk rotation by means of the rotatable stage is to ensure that uniform morphology of the landing zone is obtained.

The mechanisms for disk clamping and for transportation of the disks are conventional and are not shown in Figure 1.

Figure 3 shows an arrangement of a magnetic recording disk 8 and a data transducer head 16. The disk 8 is divided into two main regions, the data zone 14 and the landing zone 15. The landing zone 15 is an annular band on an inner region of the disk 8. A data transducer head 16 is suspended by a suspension arm 17. The arm 17 can move in a radial direction across the magnetic recording disk 8. The data transducer head 16 contacts the landing zone 15 whenever it is stationary. When the disk is accelerated from a stop, an air bearing is generated between the disk 8 and the head 16, and the head 16 is borne from the disk surface. When the rotational speed of the disk 8 reaches a required value and the flying height of the head reaches a correspondingly desired value, the head is moved across the disk surface in a radial direction to a desired track on the data zone 14. When the disk is decelerated, the flying height of the head decreases and the head 16

contacts the surface of the landing zone 15. It is necessary to texture the landing zone precisely for reducing both stiction and friction problems between the head 16 and the disk 8 and to allow a reduced flying height of the head 16 to enable an increase in the recording density and an improvement in read-write performance. It is also necessary to slightly texture the data zone 14 to prevent the head 16 sticking on the data zone 14 accidentally during read-write operations.

Figure 4 illustrates an enlarged partial cross-sectional view of the magnetic disk 8 of Figure 3, which would be selectively textured by laser texturing techniques embodying the present invention. The disk 8 comprises a substrate 18 which can be a rigid aluminium disk plated with a nickel-phosphorous coating, a glass substrate or other suitable substrate. Normally the texturing is undertaken on the substrate 18 and the succeeding layers 19 replicate the texture. Alternatively, however, laser texturing morphology can be formed on any succeeding layer. Succeeding layers 19 usually include an underlayer and a magnetic recording layer. A coating 20 is formed over the succeeding layers and the substrate and comprises a protective layer of, for example, carbon, to increase the durability of the magnetic recording disk 8. A pulsed laser with an output wavelength in the ultraviolet range is preferable for the flat laser beam texturing of this system, especially for glass substrates.

The above-described system has a number of parameters which can be selected and controlled by the

controller 10 and the host computer 11. The parameters are as follows: the repetition frequency and the fluence of the flat pulsed laser beam generated from the pulsed laser 1, 12; the number of irradiation pulses controlled by the on-off shutter 2; and the rotation speed of the rotatable stage 9 which determines the morphology uniformity of the textured zone. The landing zone 15 of a magnetic recording disk 8 can be textured under optimal conditions depending on the type of disk and the substrate, any coatings and succeeding layers.

Under appropriately selected conditions, when the landing zone 15 area of a substrate (or a succeeding layer) is irradiated by the flat pulsed laser beam which has been expanded and homogenised, a uniform texturing morphology is formed on the irradiated area due to thermocapillary waves.

The following drawings demonstrate the effectiveness of laser beam texturing methods embodying the present invention.

Figure 5 is an optical micrograph of a textured nickel-phosphorous surface which is coated on a rigid aluminium disk. The laser used is a KrF excimer laser with a wavelength of 248 nm, a maximum repetition frequency of 30 Hz, a pulse width of 23 ns and a maximum pulse energy of 300 mJ. The laser fluence and the number of laser pulses are 283 mJ/cm^2 and 800 respectively. Figure 5 shows that the textured morphology is ripple-like and near-periodic, the period being about 8 μm .

Figure 6(a) is an AFM image of a surface of a magnetic recording disk 8 before texturing. Figure 6(b) is the AFM image of the surface after texturing in accordance with an embodiment of the present invention. The laser fluence is 339 mJ/cm^2 and the number of laser pulses is 800 during the texturing process.

Figure 7(a) and Figure 7(b) are the line analyses from Figure 6(a) and Figure 6(b) respectively. Several conclusions can be obtained from the line analyses. Firstly, the surface after texturing is smoother than that before texturing and almost all steep peaks have been removed. This is helpful for reducing wear between the magnetic recording disk 8 and the data transducer head 16 and increasing the durability of the hard disk drive. Secondly, the average roughness is about 3 nm, the peak to valley distance is 15 nm-25 nm and the period is 5-25 μm . Furthermore, research has shown that the roughness and peak to valley distance in this texturing technique can be controlled by the incident laser fluence and the number of laser pulses applied to the region of the disk to be textured. This is a unique advantage which allows a reduction in flying height of the data transducer head to enable the recording density to be increased and the read-write performance to be improved.

Figure 8 is an optical micrograph of a textured glass substrate. The laser employed is a KrF excimer laser. The required laser fluence to form this textured morphology is much higher than that mentioned above, being in the region of 8 J/cm^2 . However, the textured morphology can be formed by only a single pulse. Except

for some dome-like formations on the ripple-like pattern, the resultant texture is very similar to that described above and as shown in Figure 5.

The above described example is to texture the landing zone 15. This apparatus and method can also be used to texture the data zone 14 using lower laser fluence. The textured average roughness is about 1 nm, the peak to valley distance is 5-15 nm and the period is 2-10 μm . The roughness and period of the textured surface in the landing zone are larger than those in the data zone.

In the above-mentioned examples, a KrF excimer laser is used as an ultraviolet pulse laser. Other lasers such as XeCl excimer lasers (wavelength 308 nm), ArF excimer lasers (wavelength 193 nm), solid-state lasers which can produce homogenised flat pulse beams with near-infra red wavelength or short wavelength can also be used for this texturing process.

The pulse width of the beam is another important factor in the control of the texturing process and can be selected to provide an optimal textured morphology for whatever substrate materials, coatings and succeeding layers make up a particular magnetic-recording disk.

In addition, texturing processes embodying the present invention allow real-time in-situ monitoring by CCD camera, surface reflectivity measurement by a laser probe or by acoustic waves generated by laser-induced surface vibrations.

In summary, the texturing process has the following effects and advantages.

When the substrate surface or succeeding layer in the landing zone or the data zone of a magnetic recording disk which includes a metal-based disk or a glass-based disk is irradiated by a homogenised flat pulsed laser beam, preferably employing an ultraviolet laser, uniform absorption of the laser beam energy in the irradiated zone results in a temperature rise. Due to the effects of thermodynamics, a smooth ripple-like and near-periodic textured morphology results. In the case of a glass substrate, some smooth domes are formed on the ripple-like pattern. The average roughness and peak to valley distance of the textured surface can be controlled by the incident laser fluence and number of laser pulses.

Further, embodiments of the invention have the following effects and advantages. High speed texturing is possible since a relatively large area of the disk is irradiated by a high energy homogenised flat pulsed laser beam. This effect is especially noticeable for disks having a glass substrate. The roughness and peak to valley distance in this texturing technique can be controlled by the incident laser fluence and the number of pulses directed on the area to be textured. This feature is optimum to selectively texture the landing zone and the data zone with different process parameters. This allows a reduction in the flying height of a data transducer head 16 to enable the recording

density to be increased and to improve the read-write performance of the disk. The textured surface is substantially smooth which is helpful in reducing wear between the magnetic recording disk 8 and the data transducer head 16 and for increasing the durability of a hard disk drive.

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CLAIMS

1. An apparatus for laser texturing an annular
portion of a surface of a magnetic recording disk, which
5 apparatus comprises:

a laser (1) for generating a pulsed laser beam
output ;

means (3) for expanding and homogenising the
pulsed laser beam; and

10 optical means (4) to focus and direct the
expanded and homogenised beam onto the annular
portion of the surface of the magnetic recording disk
to be textured, the beam having a predetermined spot
area at the surface of the disc, which spot area is
15 of substantially the same size as the radial width of
the annular portion to be textured.

2. An apparatus according to Claim 1, wherein a
shutter (2) is provided in the path of the beam and is
20 operable to pass or to block the beam in order to control
the number of laser beam pulses directed onto the surface
to be textured.

3. An apparatus according to Claim 1 or 2, wherein
25 the disk is mounted on a rotatable stage (9) to provide
relative rotational motion between the disk and the laser
beam directed thereon.

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4. An apparatus according to any preceding claim, wherein means are provided to monitor the energy level of the laser beam.

5. An apparatus according to any preceding claim, wherein a controller (10) is provided to control one or more the following parameters of the apparatus: the laser fluence; the number of irradiating laser pulses applied to the region to be textured; the rotation speed of the disk with respect to the laser beam; and the size of the spot area.

6. An apparatus according to any preceding claim, wherein the optical means (4) comprises means to produce a focused fan-shaped beam or a focused annular beam, the spot area comprising the footprint of the beam at the surface of the disk, the radial width of the beam at the surface of the disk being of substantially the same size as the radial width of the annular portion to be textured.

7. A method of texturing an annular portion of a surface of a magnetic recording disk, the method comprising the steps of: generating a pulsed laser beam output; expanding and homogenising the pulsed laser beam; and focusing and directing the expanded and homogenised beam onto the annular portion of the surface of the magnetic recording disk to be textured, the beam having a predetermined spot area at the surface of the disc, which spot area is of substantially the same size as the radial width of the annular portion to be textured.

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8. A method according to Claim 7 including the step of blocking or passing the beam by a shutter in order to control the number of laser beam pulses directed onto the surface to be textured.

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9. A method according to Claim 7 or 8 including the step of rotating the disk relative to the laser beam directed thereon.

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10. A method according to Claim 9, wherein rotation of the disk with respect to the laser beam causes the spot area of the laser beam to irradiate substantially all of the annular portion of the disk to be textured.

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11. A method according to any one of Claims 7 to 10 including the step of monitoring the energy level of the laser beam.

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12. A method according to any one of Claims 7 to 11 including the step of controlling one or more of the following parameters of the apparatus: the laser fluence; the number of irradiating laser pulses applied to the region to be textured; the rotation speed of the disk with respect to the laser beam; and the size of the spot area, the average roughness and the peak to valley distance of the surface of the region to be textured being controlled by the laser fluence and the number of irradiating laser pulses applied to the region to be textured.

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13. A method according to any one of Claims 7 to 12, wherein the pulsed laser beam is focused and directed

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into a fan-shaped beam or an annular beam, the spot area comprising the footprint of the beam at the surface of the disk, the radial width of the beam at the surface of the disk being of substantially the same size as the
5 radial width of the annular portion to be textured.

14. A method according to any one of Claims 7 to 13, wherein the annular portion of the surface of the magnetic recording disk comprises the landing zone or the
10 data zone of the disk.

15. A magnetic recording disk having a surface, at least an annular portion of which is textured by a laser texturing process, the textured annular portion of the
15 disk having a uniform ripple-like and near periodic texture.

16. A disk according to Claim 15, wherein the average roughness of the textured landing zone is in the region
20 of 3 nm and the average roughness of the textured data zone is in the region of 1 nm.

17. A disk according to Claim 15 or 16, wherein the peak to valley distance of the ripples in the landing
25 zone is in the region of 15 to 25 nm and the peak to valley distance of the ripples in the data zone is in the region of 5 to 15 nm.

18. A disk according to any one of Claims 15 to 17,
30 wherein the disk (8) comprises a substrate (18), the substrate of the disk having been textured by the laser texturing process.

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19. A disk according to Claim 18, wherein one or more succeeding layers (19) are provided on the substrate (18), the substrate being textured.

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20. A disk according to Claim 18, wherein one or more succeeding layers are provided on the substrate, one or more of the succeeding layers being textured.

10 21. A disk according to any one of Claims 18 to 20, wherein a coating is provided on the disk, the coating being textured.

15 22. A disk according to any one of Claims 18 to 21, wherein the substrate is a metal substrate.

23. A disk according to Claim 22, wherein the substrate is aluminium.

20 24. A disk according to any one of Claims 18 to 21, wherein the substrate is a glass substrate.'

25 25. A disk according to any one of Claims 15 to 24, wherein the period in the landing zone is in the region of 5-25 μm and the period in the data zone is in the region of 2-10 μm .

30 26. A disk according to any one of Claims 16 to 25, wherein the uniform ripple-like and substantially periodic texture is supplemented by a plurality of dome-like formations.