

**METHODS AND APPARATUS FOR
PHYSICALLY PATTERNING NONOPERATIONAL
STRUCTURES OF AN OPTICAL DISC**

BACKGROUND OF THE INVENTION

1. **Field of the Invention**

5 The present invention relates to optical disc technology. Specifically, the invention relates to methods and apparatus for the physical patterning of readable nonoperational structures on internal or external surfaces of optical discs.

2. **Description of Related Art**

10 Recent developments in optical disc design, optical disc manufacture, and in the design and manufacture of drives for reading these discs have now made it possible to use optical disc drives to interrogate disc surfaces for the presence of nonoperational structures.

15 As described more fully in copending and commonly owned U.S. Patent Application Nos. 09/183,842 filed October 30, 1998, 09/311,329 filed May 14, 1999, and 60/134,368 filed May 14, 1999, hereby incorporated by reference in their entireties, these nonoperational structures produce signals during trackable reading that are discriminably embedded within the normal electrical responses; the embedded signals report physical properties of the
20 nonoperational structures. In conjunction with physical synchronization approaches more fully described in "Methods and Apparatus for Optical Disc Data Acquisition Using Physical Synchronization Markers," Worthington et al., U.S. Patent Application No. 60/150,288, filed on August 23, 1999, incorporated herein by reference in its entirety, analysis software newly
25 developed for this purpose and described more fully in "Methods And Apparatus For Analyzing Nonoperational Data Acquired From Optical Discs," Worthington et al., U.S. Patent Application No. 09/378,878 filed on August 23, 1999, hereby incorporated herein by reference in its entirety, permits these signals to be characterized, classified, mapped, and represented visually.

30 In essence, these developments permit the disc drive to be used for scanning confocal laser microscopic inspection of one or more disc surfaces.

The robustness of this approach makes possible the optical inspection of structures having enormous variety in shape, size, and chemical and optical

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properties. This flexibility in turn permits such nonoperational structures to be used for a wide variety of signaling chores. For example, as described more fully in copending and commonly owned U.S. Patent Application Nos. 08/888,935 filed July 7, 1997 and 09/120,049 filed July 21, 1998, hereby incorporated by reference to their entireties, such nonoperational structures can be used to signal the results of chemical and biological assays, ranging from immunoassay, to enzymatic assays, to nucleic acid hybridization assays, to direct detection of mammalian cells.

In each of the laser microscopic applications of optical disc drives, though, the nonoperational signaling structures must be disposed upon or near a surface of the optical disc prior to reading. For some applications, it may suffice to dispose the nonoperational structures randomly upon the disc surface, as in certain simple counting applications. For other applications, such as in nucleic acid array analysis (see, e.g., WO 98/12559), it may instead be preferable to dispose these nonoperational signaling structures in one or more ordered arrays. There thus exists a need in the art or methods, apparatus, and compositions that facilitate the physical patterning of readable nonoperational structures on an optical disc.

SUMMARY OF THE INVENTION

The present invention provides methods and apparatus for physically patterning readable nonoperational structures on an optical disc. In one embodiment, the nonoperational structures are magnetic beads, and the method involves applying external magnetic fields to the disc. In another embodiment, the nonoperational structures have net electric charge.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects and advantages of the invention will be apparent upon consideration of the following detailed description, taken in conjunction with the accompanying drawings, in which like reference characters refer to like parts throughout, and in which:

FIG. 1 shows a light microscopic photograph of a portion of an optical disc upon which a plurality of beads of uniform composition and diameter have been manually disposed;

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FIG. 2 shows a portion of the signal acquired by reading through a single one of the tracks of the disc portion shown photographically in **FIG. 1**;

FIG. 3a is a light microscopic photograph of a portion of a trackable optical disc showing an aggregation on the disc's metal surface of beads of disparate size and composition;

FIG. 3b is a trace chart aligning, in X-axis registration, the electrical response reported in the buffered HF signal along ten of the tracks that pass through the region of the disc shown photographically in **FIG. 3a**;

FIG. 4a shows a side elevational view of an illustrative embodiment of an apparatus for aligning magnetic particles on a surface of an optical disc (disc not shown) according to the present invention.

FIG. 4b shows a top perspective view of the disc support member with embedded magnets, also shown in **FIG. 4a**, according to the present invention.

FIG. 4c shows a top plan view of the disc support member with embedded magnets, also shown in **FIGS. 4a** and **4b**, according to the present invention.

FIG. 4d shows another side elevational view of the apparatus shown in **FIGS. 4a-4c**, with an optical disc positioned thereon, according to the present invention.

FIG. 5 presents a light microscopic photograph of the surface of an optical disc upon which paramagnetic beads have been aligned into several chains using externally applied magnetic fields according to a method of the present invention.

FIG. 6 illustrates physical patterning of bead chain on an optical disc in accordance with the present invention.

DETAILED DESCRIPTION OF THE INVENTION

In order that the invention herein described may be fully understood, the following detailed description is set forth. In the description, the following terms are employed.

5 As used herein, the term "radial" denotes, in the plane of one or more of a disc's data-encoding surfaces, the direction forward or backward along a tracking spiral. A disc surface, according to this invention, can be an internal or external surface.

10 As used herein, the term "tangential" denotes, in the plane of one or more of a disc's data-encoding surfaces, the direction inward or outward along a line drawn from the disc's physical center to its outer circumference.

As used herein, the phrase "radial plane" refers to the plane in which a disc's tracking (e.g., spiral tracking) features are disposed, and is the plane of one or more of the disc's data-encoding surfaces.

15 As used herein, the term "nonoperational structure" means any structure on or within an optical disc that is capable of producing a signal when the disc is read by an optical disc reader, the signal of which, however, is not required (although possibly useful) for drive operation during reading. Nonoperational structures include, for example, analyte-specific signal
20 elements, as described immediately below.

As used herein, the term "analyte-specific signal element" refers to any nonoperational structure that can be used to signal the presence of a specific analyte in a sample applied to an optical disc. The term thus includes, *inter alia*, such signal elements as are exemplified herein — including beads — as
25 well as those that are described in copending and commonly owned U.S. Patent Application Nos. 08/888,935 filed July 7, 1997, 09/120,049 filed July 21, 1998, 09/183,842 filed October 30, 1998, and 09/311,329 filed May 14, 1999, the disclosures of which are incorporated herein by reference in their entireties. The term includes both those structures that are alone detectable
30 by an optical disc reader and those that require additional components to be rendered detectable.

As used herein, the term "magnetic bead" includes magnetic, paramagnetic, and superparamagnetic particles, both spherical and nonspherical, the diameter of which can vary from about 1 nm to about 1 cm.

35 FIG. 1 shows a light microscopic photograph of a portion of an optical disc manufactured essentially as described in copending and commonly owned U.S. Patent Application No. 09/311,329, filed May 14, 1999, with a plurality of

beads uniformly 2.8 μm in diameter (also termed "spheres") disposed on the disc's reflective surface. The tracking features (e.g., a wobbled groove), is readily observable; magnification precludes the continuity of the groove from being observed.

5 FIG. 2 shows a trace chart displayed the electrical response reported in the HF signal during trackable reading of the disc along a single one of the wobble features that passes through the area of the disc shown in FIG. 1. The trace chart reconstructs and plots the electrical signal from digitized data earlier written to a bitstream file, as more fully described in "Methods And Apparatus For Optical Disc Data Acquisition Using Physical Synchronization Markers," Worthington et al., U.S. Patent Application No. 60/150,288, filed on 10 August 23, 1999, and "Methods And Apparatus For Analyzing Nonoperational Data Acquired From Optical Discs," Worthington et al., U.S. Patent Application No. 09/378,878 filed on August 23, 1999, which are hereby incorporated by reference in their entireties. The X axis shows radial distance, that is, distance 15 along the track; the Y axis shows voltage.

HF signals displayed by digital oscilloscope in real time look essentially the same, as further described in copending and commonly owned U.S. Patent Application No. 09/183,842 filed October 30, 1998, incorporated herein by 20 reference.

Data features 20 and 22 are correlated with the presence of the 2.8 μm beads on the surface of the disc. Features 22 have a characteristic biphasic shape that has previously been correlated with the optical response from the disc surface as the laser traverses first the leading edge, then the center, and 25 finally the lagging edge of the bead. Feature 20, lacking the characteristic biphasic shape, has been correlated with the optical response as the laser grazes the edge of a bead just touching the wobbled feature being tracked.

Each of the features 20 and 22 in FIG. 2 is preceded and followed in the electrical trace by a baseline signal feature 24, a feature resulting from the nonadjacent spacing of discrete beads along the track. FIG. 2 thus 30 demonstrates that electrical signals generated by nonoperational structures disposed upon a disc surface may individually be identified and characterized when the structures are sufficiently well spaced as to permit the entirety of the characteristic signal to be observed.

35 FIG. 3a is a light microscopic photograph of a separate trackable optical disc of similar design upon which have been disposed beads of disparate size and composition. An aliquot of 4 μm diameter blue polystyrene beads

(available from Spherotech, Inc., of Libertyville, IL), 6.8 μm diameter blue polystyrene beads (available from Spherotech), and silica beads (available from Sigris Research, Inc., of Brea, CA) was mixed in water, spotted onto the metal surface of the disc, and the disc then air dried. FIG. 3a is a light microscope photograph of the disc surface showing an aggregation (e.g., a cluster) of beads that include two silica beads 30, a single 4 μm blue polystyrene bead 32, and three 6.8 μm blue polystyrene beads 34.

FIG. 3b is a trace chart aligning the electrical responses reported in the buffered HF signal along ten of the tracks that pass through the region of the disc shown photographically in FIG. 3a. With reference to trace 36 of FIG. 3b, it can be seen that baseline signal features 37 precede and follow feature 38. In contrast to features 20 and 22 of FIG. 2, however, each of which represents the signal produced by a single, well-spaced, nonoperational structure, feature 38 represents a complex response caused by the aggregation of several beads on a disc surface.

Although software-based algorithmic approaches, more fully described in "Methods And Apparatus For Analyzing Nonoperational Data Acquired From Optical Discs," Worthington et al., U.S. Patent Application No. 09/378,878, can be used to deconvolute such a complex signal once acquired, there nonetheless exists a need in the art for complementary approaches that facilitate the return of individually discriminable and identifiable electrical signals from nonoperational structures on a disc surface. Thus, there exists a need for methods that permit such nonoperational structures to be disposed on the surface of the disc in disaggregated forms and patterns.

The present invention presents solutions to this problem by exploiting physical properties that inhere in the nonoperational structures to effect the patter of their disposition on the disc surface.

In a first exemplary embodiment, the nonoperational structures are magnetic and can be patterned on a disc surface by applying magnetic fields. The nonoperational structures can be patterned into one or more discrete spots on the disc surface, and can be patterned within each spot in a chosen linear direction.

Paramagnetic beads in the sub-micron to sub-millimeter size range have proven to be extremely useful in many different biologic and chemical applications. With one member of a cognate pair of high affinity specific binding groups attached to the surface of the bead — such as an antibody highly specific for the binding of a ligand, streptavidin for the highly specific

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binding of a biotin, or a nucleic acid for the highly specific binding of its nucleic acid complement — the second member of the cognate pair can readily be purified from a fluid mixture by introduction of the beads followed by application of a magnetic field. The magnetic field is believed to not exert significant mechanical stress on the bound analyte, which can range in size from eukaryotic cells, to long nucleic acids, to small molecule ligands, and is often rapid, highly scalable, low cost and nontoxic.

Paramagnetic beads are readily available commercially, either derivatized with the most common specific binding groups, derivatized with reactive chemical moieties for custom conjugation, or completely underivatized. Compositions of the beads vary, with some having a coated paramagnetic core, others having Fe_3O and or Fe_2O_3 and Fe_3O_4 evenly incorporated throughout the beads, and still others having a polystyrene core with an iron oxide/polystyrene coating, with bead diameters varying from 50 nm (available, for example, from Miltenyi Biotec, of Auburn, CA) to 7 μm (available, for example, from Spherotech, Inc., of Libertyville, IL). Noncolloidal superparamagnetic beads with diameter between about 1 μm and 10 μm in diameter, have been used in the present invention, although permanently magnetic or paramagnetic particles can also be useful in the practice of the present invention.

According to the present invention, magnetic beads can be patterned on a disc surface using a device with embedded magnets, an embodiment of which is shown in FIGS. 4a-4d.

FIG. 4a is an elevational side view of patterning device 40, which includes disc support member 41 (and sometimes called a "platen"), and which is dimensioned to support an optical disc on one (typically the upper) surface, hereinafter the "support surface."

Disc support member 41 can be discoid, as shown best in FIGS. 4b and 4c, thus providing a circular support surface, with the support surface diameter approximately equal to, more usually somewhat larger than, that of the optical disc to be patterned. For standard optical discs, such as CD-ROM or DVD discs, disc support member 41 would thus typically have a diameter of at least 12 cm, although often somewhat larger, ranging from about 12 cm to about 20 cm, more typically from about 12 cm to about 15 cm, most typically from about 12 cm to about 14 cm. Since the Red Book standard further contemplates optical discs of 8 cm diameter, the disc support surface can alternatively be about 8 cm in diameter, or somewhat larger. In the latter case,

however, disc support member 41 will typically have a size sufficient to support either the 8 cm or the larger 12 cm disc.

Although shown as discoid, disc support member 41 can be any shape, and need only be sufficiently large as to support the disc to be patterned and to permit the application of magnetic fields to the area of the disc desired to be patterned. Typically, the disc support surface will be substantially planar, to permit close apposition of the disc to the disc support surface. Further to facilitate that apposition, the disc support surface, although substantially planar, can have an indentation therein (e.g., annular) to accommodate a disc's stacking ring.

Patterning device 40 can contain more than one disc support member 41.

Disc support member 41 will typically be made of non-magnetic solid material, such as a nonmagnetic metal, glass, ceramic, or plastic.

FIG. 4b shows a disc support member 41, which contains a plurality of embedded magnets 44. Typically, the surface of the embedded magnets 44 will be co-planar with the disc support surface of disc support member 41, although magnets can be recessed from the disc support surface (and thus further from the disc supported thereon), or can alternatively extend above the support surface (and thus closer to the disc support thereon), although in the latter case the combined surface area of the magnets must be sufficient as to permit the disc to be supported thereon. It will be appreciated that magnets 44 need not be embedded at all, but could be merely mounted to a surface (upper or lower) of support member 41.

Although electromagnets can be used, magnets 44 are permanent magnets made of a rare earth alloy such as anisotropic sintered materials composed of neodymium-iron-boron or samarium-cobalt, with a surface field strength sufficient to attract a majority of the magnetic particles desired to be patterned. Surface field strengths of about 100 Gauss to 1 kiloGauss are usually adequate to attract magnetic particles in the size range of about 1 μm to 10 μm . Accordingly, patterning device 40 can employ magnets 44 in disc support member 41 having a surface field strength of about 50 Gauss to about 50 kiloGauss, and even more typically about 100 Gauss to about 2.5 kiloGauss, with a range of 100 Gauss to about 1 kiloGauss being most typically.

High energy permanent magnets made from neodymium-iron-boron or samarium-cobalt and characterized by BH_{max} (maximum energy product) in the

range of 25 to 45 MGOe (megaGauss Oersted) can also be used. Such magnets can be obtained from International Magnaproducts Inc., of Valparaiso, IN, and many other commercial sources.

5 Magnets 44 can be glued or fixed by standard mechanical means to disc support member 41 or can, alternatively, be embedded therein, as, for example, by polymerization or solidification of a liquid around the magnets. Alternatively, disc support member 41 can be fashioned so that magnets 44 can be removed and replaced. This latter embodiment allows the magnetic field strengths, as further described below, to be readily adjusted.

10 Magnets 44, shown in FIGS. 4a-4d, have a rectangular cross-section and are oriented with their magnetic lines of force oriented in the plane of the disc support surface. Alternate cross-sectional shapes, orientations, and magnetic pole orientation with respect to the platen are also envisioned, depending upon the orientation and patterns desired to be imposed upon the magnetic particles on the disc surface.

15 Disc support member 41 can additionally have a central hole 43, shown in FIG. 4c, to permit mounting of the disc support member upon a spindle 42, shown in FIG. 4a. Alternatively, spindle 42 can be integral to disc support member 41. Spindle 42 can be rotatable by a motor 45, typically an electric motor, as shown in FIG. 4a.

20 Spindle 42, when present, will typically be smaller in diameter than the central mounting hole of the optical disc to be patterned, permitting optical disc 10 to be placed on disc support member 41 with spindle 42 protruding therethrough, as shown in FIG. 4d. The space between optical disc 10 and the support surface of disc support member 41 is exaggerated for purpose of illustration. To facilitate registrable positioning of disc 10 on the disc support surface of disc support member 41, spindle 42 will typically be dimensioned so as to be only slightly smaller than the central mounting hole of disc 10, permitting the spindle to snugly engage disc 10.

25 Chuck 43, with a recess or throughvoid dimensioned to accommodate spindle 42 therewithin or therethrough respectively, and with at least one outer dimension exceeding the diameter of the mounting hole of disc 10, can then be used reversibly to secure disc 10 to disc support member 41. Chuck 43 can engage spindle 42 in any conventional way, such as in a snappable or screwable fashion.

30 When disc 10 is placed (typically reversibly fixed) on disc support member 41, magnets 44 generate multiple magnetic fields on each of the

planar surfaces of disc 10, and in each magnetic bead-containing liquid droplet 46 applied thereupon. The magnetic field across the cross-section of a droplet is characterized by a field gradient.

5 In one embodiment of the apparatus and methods of the present invention, shown in FIG. 4c, magnets 44 and droplets 46 are so positioned that, as viewed from above, each droplet 46 is positioned on the disc so as to lie at the edge of a magnet; this creates a magnetic field gradient in the droplet that is stronger closer to the magnet than elsewhere in the droplet.

10 When the droplet contains a suspension of magnetic beads, typically paramagnetic or superparamagnetic beads, the field gradient causes movement of the magnetic beads as the stronger magnetic field in the vicinity of the magnets pulls the beads. As the beads are pulled, they move and form bead chains. In this embodiment, these chains are oriented in a tangential direction(i.e., a direction that is substantially perpendicular to the track).
15 FIG. 5 presents a light microscopic photograph of the surface of an optical disc upon which paramagnetic beads have been aligned into several chains using such externally applied magnetic fields. While not wishing to be bound by theory, it is presently believed that the chains result from the magnetic dipoles induced in the beads by the externally applied magnetic fields provided by
20 magnets 44.

Depending on the number of beads present in droplet 46, multiple parallel chains can be formed. These chains have been observed to migrate toward a magnet and this movement is arrested when the leading bead of the chain reaches the limit of the fluid droplet.

25 A careful control of the magnetic field strength is important so that the bead chain is not subjected to excessive fluid drag forces, which would tend to cause the chains to break apart or to move out of the droplet boundary and become an aggregated mass; conversely, too low a field precludes the formation of chains. A suitable magnetic field strength can be calculated on the basis
30 magnetic mass susceptibility of the beads, buoyancy, and fluid friction. However, for any given disc, patterning device 40, bead composition and size, the intensity of the magnetic field or fields can readily, and will often, be determined empirically.

35 Furthermore, it will be appreciated that the field strength at the desired disc surface can readily be adjusted for any given disc support member 41 by altering the distance between its disc support surface and optical disc 10, through interposition of variable numbers of blank (e.g., single-layer

polycarbonate) discs therebetween. Such blank discs can usefully have one or more structural features, such as interleaving tabs or lips, that facilitate stacking.

Field strength can also usefully be varied by interchanging disc support members 41 in disc patterning device 40, each of said disc support members having magnets 44 of different field strength and/or orientation. In this way, a gross adjustment of field strength and/or orientation can be made by selecting an appropriate disc support member 41, with finer adjustment made by use of varying numbers of blank between disc 10 and the support surface.

Although disc support member 41 shown in FIGS. 41-4d includes a plurality of magnets of identical strength, it will also be appreciated that a disc support member can include a plurality of magnets having different field strengths, depending upon the pattern desired.

One such desired pattern is to dispose the magnetic beads substantially in the tangential direction. As shown in the trace chart in FIG. 3b, the data features created by each bead can be more readily distinguished and thus characterized in the tangential (Y axis) direction than in the radial (X axis) direction.

In addition to choice of droplet location and change in field intensity, further physical patterning can be effected by applying centrifugal forces.

As noted above, disc support member 41 can be fixed to rotatable spindle 42 of a motor 45; to same effect, spindle 42 can be integral to disc support member 41, and attachable to motor 45.

Motor 45 can be any type of motor, and is preferably an electric motor, such as an electric step motor capable of providing a stop-wise change of a predetermined distance in the relative angular position of disc support member 41. Step rotation of predefined angles can be effected by means of an electronic motor control (not shown) according to devices and techniques well known in the art. Application of centrifugal force by means of disc rotation will permit bead chains to be disposed at angles different from those that would be effected by the magnets with the disc support member and applied disc stationary. Preferably, such centrifugal forces are applied while the beads remain in fluid suspension; after drying or evaporation of droplet 46, the magnetic beads will thereafter typically adhere to the disc surface by noncovalent and potentially other interactions.

The use in disc patterning device 40 of rotatable disc support members 41 further serves to facilitate application of magnetic bead-containing droplets

46 in predetermined patterns useful for analyte-specific assay. Geometries that are useful in such assays are set forth in detail in copending and commonly owned U.S. Patent Application Nos. 08/888,935 filed July 7, 1997 and 09/120,049 filed July 21, 1998, which are hereby incorporated herein by reference in their entireties.

Thus, rotation of disc support member 41 can be coordinated with robotic fluid dispensers well known in the art. Angular step movement of disc support member 41 in conjunction with the linear displacement of the dispenser permits addressable application of droplets 46 at any chosen location on the surface of the disc. If desired, time delays between the angular movement of the disc or the linear movement of the dispenser can be interposed for inspection purpose or other process needs. FIG. 6 illustrates physical patterning on disc 10 with multiple bead chains 60, each having an angular component, each originating from a droplet applied robotically to the disc surface.

Although described with particular emphasis on magnetic patterning of magnetic beads, the present invention comprehends other means of physically patterning nonoperational structures on the surface of an optical disc.

For example, aggregation of nonoperational structures can be prevented by using beads or other structures that have a net surface charge sufficient to cause the structures, when in fluid suspension on a disc surface, to repel one another. This would prevent aggregation. Furthermore, application of localized electric fields can be used to effect further physical patterning. Moreover, aggregation can be prevented using patterned adhesive, which can be patterned on a surface using any conventional lithographic technique, as well known in the semiconductor arts.

If the nonoperational structures are both charged and (para)magnetic, both electric and magnetic fields can be used, permitting further discrimination in the physical patterning effected. It will be appreciated that some nonoperational structures can be charged, some magnetic, some both, and that the charged structures can all be of the same net charge, or can alternatively include structures with opposite charge.

It will, therefore, be appreciated that the present invention permits a desired spatial distribution (physical pattern) of readable nonoperational structures to be effected on a surface of a trackable optical disc. In particular, the invention permits a desired spatial distribution of data-encoding nonoperational structures, readable by an optical disc reader, to be effected on

a surface of an optical disc, and especially on the surface of a trackable optical disc.

Broadly speaking, the present invention provides methods and apparatus for superimposing a second mastering process, involving mastering nonoperational structures, upon a first mastering process that involves data
5 digitally encoded within the disc. The second mastering process involves application of external magnetic and/or electric fields to the disc.

It will also be appreciated that the physical properties of certain nonoperational structures, such as magnetic beads, that are usefully employed
10 in separating analytes prior to disposition on an optical disc, can also be used to pattern such structures on the surface of the disc for maximal detection. This provides efficiencies that are useful when sample sizes are obligately small.

Although particularly described with respect to facilitating the acquisition of discrete electrical signals by disaggregating plural
15 nonoperational structures on the disc surface, the invention is useful in other ways as well.

For example, some assays conducted on optical discs will tether multiple nonoperational signaling structures, such as beads, to a single
20 analyte, such as a nucleic acid. In such assays, each of said nonoperational signaling structures is capable of reporting a discrete physical property of the analyte, and their physical proximity reports the concurrent presence on a single analyte of the respective properties. As in the case described above, aggregation of the nonoperational structures can interfere with analysis of the
25 electrical signals acquired during reading of the disc. The present invention presents a useful means and apparatus to effect disaggregation of these nonoperational structures.

As another example, the methods and apparatus of the present invention prove useful in increasing the electrical signal generated by each
30 individual nonoperational structure. As further described in copending and commonly owned U.S. Patent Application Nos. 09/183,842 filed October 30, 1998, 09/311,329 filed May 14, 1999, and copending and commonly owned U.S. Provisional Patent Application No. 60/134,368 filed May 14, 1999, incorporated herein by reference, signal intensity will be maximized when the
35 nonoperational structures are centered on a tracking feature, such as a wobbled feature. Application of a physical force, as by application of a cover to

the disc surface, can usefully compel the nonoperational structures into such grooves; magnetic and electric fields, as described herein, can also be so used.

The present invention will prove useful not only in improving signal acquisition, but in facilitating disc operation as well. Since the nonoperational structures to be patterned may not themselves contribute to the disc operation, they can be patterned so as to minimize interference with disc tracking, focus, and synchronization.

For example, with respect to tracking, it is desirable to pattern the nonoperational elements so that they do not, through aggregation, cause a signal of sufficient width as to interfere with tracking, as further described in copending and commonly owned U.S. Patent Application Nos. 09/183,842 filed October 30, 1998, 09/311,329 filed May 14, 1999, and copending and commonly owned U.S. Provisional Patent Application No. 60/134,368 filed May 14, 1999, incorporated herein by reference. With respect to focus, it is desirable to pattern the nonoperational structures so that they do not aggregate along the optical axis (piling up).

Furthermore, although magnetic bead alignment has been described above in the context of an optical disc surface, it will be appreciated that such alignment could alternatively be on the surface of an optical disc cover, such as the one manufactured and described in copending and commonly owned U.S. Patent Application No. 09/311,329 filed May 14, 1999, which is hereby incorporated by reference in its entirety.

All patents, patent publications, and other published references mentioned herein are hereby incorporated by reference in their entirety as if each had been individually and specifically incorporated by reference herein. While preferred illustrative embodiments of the present invention are described, it will be apparent to one skilled in the art that various changes and modifications can be made therein without departing from the invention, and it is intended in the appended claims to cover all such changes and modifications which fall within the true spirit and scope of the invention.



CLAIMS

What is claimed is:

1. A method for physically patterning nonoperational structures readably on an optical disc, comprising applying a magnetic field to said disc, wherein said nonoperational structures are movably responsive to said field.
2. A method for physically patterning nonoperational structures readably on an optical disc, comprising applying an electric field to said disc, wherein said nonoperational structures are movably responsive to said field.
3. A method according to claim 1 wherein said nonoperational structure is a paramagnetic structures.
4. A method for physically patterning nonoperational structures according to claim 1 which includes the step of applying centrifugal force to said nonoperational structure.
5. A method for physically patterning nonoperational structures according to claim 2 which includes the step of applying centrifugal force to said nonoperational structure.
6. An optical disc comprising a disc body having a surface on which are located nonoperational structures said nonoperational structures being arranged in a pattern on said surface by applying a magnetic field to said structures.
7. An optical disc according to claim 6 wherein said nonoperational structures are paramagnetic structures.
8. An optical disc according to claim 6 wherein said structures are arranged by applying centrifugal force to said structures.
9. An optical disc comprising a disc body having a surface on which are located nonoperational structures, said nonoperational structures being arranged in a pattern on said surface by applying an electrical field to said structures.



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10. An optical disc according to claim 9 wherein said nonoperational structures are paramagnetic structures.

11. An optical disc according to claim 9 wherein said structures are arranged by applying centrifugal force to said structures.