

TITLE OF THE INVENTION

SUBSTRATE FOR DISC-SHAPE RECORDING MEDIUM, METHOD OF
MANUFACTURING SUBSTRATE FOR DISC-SHAPE RECORDING MEDIUM
AND DISC DRIVE ✓

BACKGROUND OF THE INVENTION**Field of the Invention**

The present invention relates to a substrate for a disc-shape recording medium on which an information signal is recorded and/or from which data is regenerated by using light, a manufacturing method therefor and a disc drive.

Related Background Art

Hitherto, disc-shape recording mediums, such as write-only optical discs, a magneto-optical discs and phase-change optical discs, which use light to read and write an information signal, have widely been used.

A disc drive for recording an information signal on a disc-shape recording medium and/or regenerating an information signal from the same is structured such that, for example, a regenerating operation is performed by emitting a laser beam from a semiconductor laser emitting unit. The laser beam is throttled by an optical system, and then the laser beam is focused onto a signal recording surface of a loaded disc-shape recording medium so that the signal recording surface is irradiated with the laser beam. Reflected light from the recording medium is detected so that an

information signal recorded on the disc-shape recording medium is read.

Under circumstance where systems using light to read an information signal from a disc-shape recording medium and/or write an information signal on the same have widely been used, the disc-shape recording medium adaptable to the system of the foregoing has been required to have a high recording density and satisfactory reliability.

However, when an optical head of the foregoing system is moved closer to the disc-shape recording medium in order to raise the recording density, there is apprehension that the optical head collides with the disc-shape recording medium. If the optical head collides with the disc-shape recording medium, the reliability of the disc-shape recording medium deteriorates excessively.

SUMMARY OF THE INVENTION

Accordingly, an object of the present invention is to provide a substrate for a disc-shape recording medium with which a disc-shape recording medium exhibiting a high density and satisfactory reliability can be obtained, a manufacturing method therefor and a disc drive for recording an information signal on the disc-shape recording medium incorporating the substrate and/or regenerating an information signal from the same.

To achieve the above-mentioned object, according to one aspect of the present invention, there is provided a substrate for a disc-shape recording medium which is

used to record and/or regenerate an information signal by using light, the substrate for a disc-shape recording medium comprising: a region on which a signal will be recorded, wherein at least the region is free from any projection having a height which is measured from the surface of the substrate and which is not lower than $1/4$ of the wavelength of light.

Since the disc-shape recording medium incorporates the above-mentioned substrate, at least the region on which a signal will be recorded can be made to be a smooth and flat surface free from any projection which is not lower than $1/4$ of the wavelength of light. Thus, even if the optical head is moved closer, collision with the optical head can be prevented. As a result, the reliability can be improved and dense recording is permitted.

In recent years a system has been suggested which employs a recording and regenerating method called a "near field recording method" to reduce the diameter of a laser beam spot in order to raise the recording density of the disc-shape recording medium.

The near field recording method will now be described. When a laser beam has passed through a lens having a high refractive index n , leaked light having a spot which is throttled to $1/n$ and obtainable in a region considerably near the lens is used to record/regenerate an information signal. At this time, leaked light having an output required to perform the recording/regenerating operation can be obtained in the regions within a distance of about $\lambda/4$ from the lens.

If the wavelength λ of light for use to record and/or regenerate an information signal to and from, for example, a disc-shape recording medium is about 659 nm, the recording density which is realized in a recording operation by the near field recording method can be raised only when the recording and/or regenerating operation is performed such that the optical head is allowed to float from a signal recording surface of the disc-shape recording medium for a distance of about 165 nm ($\lambda/4$) or lower.

If a projection having a height not lower than about 165 nm ($\lambda/4$) exists in the region of the disc-shape recording medium on which a signal will be recorded, the disc-shape recording medium collides with the optical head because of the projection. Thus, there is apprehension that the optical head and/or the disc-shape recording medium is damaged.

The disc-shape recording medium incorporating the substrate for a disc-shape recording medium according to the present invention has the structure that at least the region, on which a signal will be recorded, is a smooth and flat surface free from any projection which is not lower than 1/4 of the wavelength of light. Therefore, even if the near field recording method is employed to record and/or regenerate an information signal, collision with the optical head can be prevented. Thus, the recording density can significantly be raised without deterioration in the reliability.

It is preferable that the substrate for a disc-shape recording medium according to the projection is manufactured by injection-molding a resin.

The resin substrate for the disc-shape recording medium is manufactured by

injection-molding a resin. Therefore, the resin substrate can easily accurately be molded as a substrate for a disc-shape recording medium of a type having a recessions for head positioning information or address information formed on the surface of the disc or a groove between tracks of the disc. Therefore, the resin substrate for the disc-shape recording medium can be manufactured with a satisfactory productivity and a low cost as compared with an aluminum substrate for use in a hard disc or the like.

It is preferable that the substrate for a disc-shape recording medium according to the present invention is manufactured by injection-molding a thermoplastic norbornene resin.

When the material of the substrate for a disc-shape recording medium is, for example, polycarbonate or methyl methacrylate, the substrate for a disc-shape recording medium is sometimes considerably changed because of moisture absorption. Therefore, the foregoing material is not a preferred material to manufacture the substrate for use in the disc-shape recording medium arranged to record and/or regenerate an information signal by moving closer the optical head. Even if a low-moisture-absorption plastic material, such as polymethyl pentene or polystyrene, is employed, there arises problems in that the molded substrate for a disc-shape recording medium is undesirably deformed because of the crystallinity of the material and that heat resistance is unsatisfactory.

If the thermoplastic norbornene resin is employed to manufacture the substrate for a disc-shape recording medium, satisfactory heat resistance can be obtained, and

deformation caused from moisture absorption and crystallinity can substantially be prevented. Thus, an optimum substrate for a disc-shape recording medium arranged to record and/or regenerate an information signal by moving closer the optical head can be obtained.

To solve the above-mentioned problems, the inventor of the present invention has thoroughly observed a substrate 1 for a disc-shape recording medium of a type having a projection not lower than $1/4$ of the wavelength of employed light. As a result, as shown in Fig. 1, foreign matter particles 2 exist directly below the projection. The foreign matter particles 2 cause a projection having a height H corresponding to the particles size D of the foreign matter particles 2 to be formed. When the number of foreign matter particles which are mixed with the molded substrate for a disc-shape recording medium and which have diameters not smaller than a predetermined diameter are controlled, a substrate for a disc-shape recording medium free from a projection not lower than a predetermined height can be manufactured.

The wavelength λ of a laser beam which is widely employed to be adaptable to a disc-shape recording medium using light to record and/or regenerate an information signal is about 659 nm. Therefore, if the substrate for a disc-shape recording medium has a projection, the height of which is not lower than about 165 nm ($\lambda/4$), the projection causes the disc-shape recording medium and the float-type optical head to collide with each other when the above-mentioned near field recording operation is performed. A fact was found that if foreign matter particles each having a particle size

of 2.0 μm or greater exist in the molded substrate for a disc-shape recording medium, the possibility is considerably increased that a projection having a height not lower than about 165 nm is formed on the surface of the substrate for a disc-shape recording medium.

A method of manufacturing a substrate for a disc-shape recording medium according to the present invention is established on the basis of the above-mentioned facts. According to another aspect of the present invention, there is provided a method of manufacturing a substrate for a disc-shape recording medium for use in a disc-shape recording medium arranged to use light to record and/or regenerate an information signal, the method of manufacturing the substrate for a disc-shape recording medium comprising the step of: controlling resin in such a manner that the number of particles each having a particle size of 2.0 μm or greater is 10000 pieces/g or smaller in a molded product; molding the resin to have a disc shape, wherein at least a region on which a signal will be recorded is free from any projection having a height which is measured from the surface of the substrate and which is not lower than 1/4 of the wavelength of light.

The number of the foreign matter particles in the molded product can be controlled by, for example, a method which uses a resin containing a small number of foreign matter particles and with which a molding process is performed in a clean environment.

The method of manufacturing a substrate for a disc-shape recording medium

according to the present invention is able to manufacture a substrate for a disc-shape recording medium free from any projection having a height not lower than about 165 nm and formed on the surface of the substrate.

According to another aspect of the present invention, there is provided a disc drive comprising: a motor for rotating a disc-shape recording medium; and a float-type optical head arranged to float on the disc-shape recording medium which is rotated by the motor for a distance not longer than $1/4$ of the wavelength of employed light so as to write an information signal on the disc-shape recording medium or read an information signal from the disc-shape recording medium, wherein at least a region on which a signal will be recorded is free from any projection having a height which is measured from the surface of the substrate and which is not lower than $1/4$ of the wavelength of light.

A disc drive according to the present invention has a structure that the float-type optical head is allowed to float on the disc-shape recording medium which is rotated by the motor for a distance not longer than $1/4$ of the wavelength of employed light. Thus, an information signal is written on the disc-shape recording medium or read an information signal from the same.

At least the region of the disc-shape recording medium on which a signal will be recorded is free from any projection having a height which is measured from the surface of the substrate and which is not lower than $1/4$ of the wavelength of light. Therefore, collision between the float type optical head and the disc-shape recording

medium can be prevented. Thus, the information signal can reliably be recorded and/or regenerated.

Other objects, features and advantages of the invention will be evident from the following detailed description of the preferred embodiments described in conjunction with the attached drawings.

BRIEF DESCRIPTION OF THE DRAWING

Fig. 1 is a vertical cross sectional view showing a substrate for a disc having a projection;

Fig. 2 is a vertical cross sectional view showing an essential portion of a magneto-optical disc;

Fig. 3 is a vertical cross sectional view showing a float-type optical head arranged to be allowed to float on the magneto-optical disc;

Fig. 4 is a block diagram showing a schematic structure of an optical disc apparatus;

Fig. 5 is a vertical cross sectional view showing an essential portion of the optical disc apparatus; and

Fig. 6 is a graph showing the relationship between heights of the projection and particle sizes of foreign matter particles.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

An embodiment of the present invention will now be described with reference to the drawings.

A substrate for a disc-shape recording medium (hereinafter called a "disc substrate") according to the present invention is a substrate for constituting a disc-shape recording medium, such as a read-only optical disc, a magneto-optical disc or a phase-change optical disc, which uses light to record and/or regenerate an information signal. At least a region of the disc-shape recording medium on which a signal will be recorded is free from any projection having a height which is measured from the surface of the substrate and which is not lower than $1/4$ of the wavelength of employed light.

The disc substrate according to the present invention is a preferred substrate for a disc-shape recording medium adapted to an operation for recording and/or regenerating an information signal by a float-type optical head. In particular, the disc substrate according to the present invention is a preferred substrate for a disc-shape recording medium adapted to a method of recording and/or regenerating an information signal by using leaked light in a near field.

The near field recording method is a method with which a float-type optical head incorporating a lens having a high refractive index n and arranged to be allowed to float from the signal recording surface of the disc-shape recording medium for a height not greater than $1/4$ of the wavelength of employed light. Moreover, the signal recording surface of the disc-shape recording medium is irradiated with a laser beam

having a spot, the diameter of which is throttled to $1/n$. Thus, an information signal is read from the disc-shape recording medium or an information signal is written on the disc-shape recording medium. Since the diameter of the spot is reduced, a high density recording operation can be performed.

Since the disc substrate according to the present invention is free from any projection having a height not lower than $1/4$ of the wavelength of employed light, collision with the float-type optical head can be prevented even if the near field recording method is employed to read and/or write an information signal. Thus, the reliability can be improved.

A structure will now be described in which the disc substrate is molded from a resin, the disc substrate is employed as a substrate of a magneto-optical disc incorporating a magneto-optical recording layer and an information signal is recorded and/or regenerated by a float-type optical head to and from the magneto-optical disc by the near field recording method.

A magneto-optical disc 10, for example, as shown in Fig. 2, has a magneto-optical recording layer 12 formed on a disc substrate 11.

The magneto-optical recording layer 12 is formed by sequentially laminating an Al reflecting layer 13, a first dielectric film 14, a recording film 15 and a second dielectric film 16.

The recording film 15 is a film which exerts a magneto-optical effect. The recording film 15 is made of, for example, a Tb-Fe amorphous material composed of

Tb which is a rare earth element and Fe which is transition metal.

The Al reflecting layer 13 is formed for the purpose of raising the reflectance of the recording film 15.

The first and second dielectric films 14 and 16 are formed for the purpose of improving moisture resistance of the recording film 15 and preventing thermal deformation of the disc substrate 11. Moreover, the first and second dielectric films 14 and 16 are arranged to improve an optical efficiency such that light absorption of the recording film 15 is enhanced and the reflectance is changed considerably. The first and second dielectric films 14 and 16 are made of, for example, a ZnS-SiO_2 material.

The magneto-optical disc 10 is manufactured by forming, on the disc substrate 11, the above-mentioned films constituting the magneto-optical recording layer 12 by, for example, sputtering.

It is preferable that the magneto-optical disc 10 has a structure that a protective layer 17 for protecting the magneto-optical recording layer 12 and a lubricating lens (not shown) for absorbing a shock when the float-type optical head is brought into contact with the magneto-optical disc 10 are formed on the magneto-optical recording layer 12.

The protective layer 17 is formed by forming carbon or SiO_2 on the magneto-optical recording layer 12 by sputtering or the like.

The lubricating layer is formed by applying, for example, perfluoropolyether,

to the surface of the protective layer 17 by spin coating or the like.

On the other hand, the float-type optical head 20, as shown in Fig. 3, incorporates two types of lenses which are a pre-focus lens 21 for converging laser beams emitted from a semiconductor laser emitting unit; and a focus lens 22 for furthermore throttling the laser beams converged by the pre-focus lens 21 to form a beam spot. The pre-focus lens 21 and the focus lens 22 are supported by a lens holder 23.

The focus lens 22 of the two types of the lenses has a semi-spherical shape made of a material having a high refractive index. The focus lens 22 is supported by the lens holder 23 in such a manner that a circular flat surface of the focus lens 22 faces the surface of the magneto-optical recording layer 12 of the magneto-optical disc 10.

The float-type optical head 20 is provided with a thin-film coil 24 for modulating a magnetic field such that the thin-film coil 24 is, at a position on the outside of the focus lens 22, supported by the lens holder 23.

The float-type optical head 20 having the above-mentioned structure is allowed to float on the rotating magneto-optical disc 10 to converge laser beams emitted from the semiconductor laser emitting unit so that the magneto-optical recording layer 12 of the magneto-optical disc 10 is irradiated with the laser beam. When a recording operation is performed, the thin-film coil 24 of the float-type optical head 20 generates a magnetic field having a predetermined intensity to apply the magnetic field to a

portion of the magneto-optical recording layer 12 irradiated with the laser beam.

When the float-type optical head 20 is operated, an information signal can be recorded and/or regenerated to and from the magneto-optical disc 10 by the near field recording method. That is, the laser beam emitted from the semiconductor laser emitting unit and converged by the pre-focus lens 21 is furthermore throttled by passing the laser beam through the focus lens 22 made of the material having a high refractive index. Thus, the diameter of the laser beam spot can be reduced in a region distant from the focus lens 22 for a distance not greater than $1/4$ of the wavelength of the laser beam.

When a laser beam having a wavelength of λ is converged by an optical system incorporating an objective lens disposed apart from the disc for a somewhat long distance, the diameter of the laser beam spot is λ/NA (NA is a numeric aperture of the optical system). When the float-type optical head 20 is used to converge a laser beam having a wavelength of λ , a spot of a throttled laser beam can be obtained in a region in which the distance from the focus lens 22 is not greater than $1/4$ of the wavelength λ of the laser beam, the spot having a diameter expressed by $1/n \times \lambda/NA$ (n is a refractive index of the focus lens 22 and NA is a numerical aperture of the float-type optical head 20).

The float-type optical head 20 is allowed to float on the magneto-optical recording layer 12 of the magneto-optical disc 10 for a distance not greater than $\lambda/4$ to record/regenerate an information signal to and from the magneto-optical disc 10.

In this case, the recording capacity of the magneto-optical disc 10 can be enlarged to about n times as compared with the structure in which an optical system is employed which incorporates an objective lens which is disposed apart from the disc for a somewhat long distance.

When the float-type optical head 20 is allowed to float on the magneto-optical recording layer 12 of the magneto-optical disc 10 for a distance not greater than $\lambda/4$ so as to record an information signal on the magneto-optical disc 10 or regenerate an information signal from the same by the near field recording method, a projection larger than $\lambda/4$ and formed in a signal recording region of the magneto-optical disc 10 causes the float-type optical head 20 to undesirably collide with the projection. As a result, the magneto-optical disc 10 or the float-type optical head 20 will be damaged.

Therefore, the signal recording region of the disc substrate 11 is structured to be free from any projection having a height which is measured from the surface of the substrate and which is not lower than $1/4$ of the wavelength of employed light.

A method of manufacturing the disc substrate 11 according to the present invention will now be described. The disc substrate 11 is manufactured by, for example, injection-molding a resin material.

It is preferable that the resin material to manufacture the disc substrate 11 is a thermoplastic resin having excellent heat resistance, precise moldability, moisture-absorption-deformation resistance and a high elastic modulus.

More specifically, it is preferable that a material is employed which has a glass

transition temperature of 50°C or higher, preferably 70°C or higher and most preferably 100°C or higher in a viewpoint to realize satisfactory heat resistance. It is preferable that an amorphous resin is employed which has a glass transition temperature of 300°C or lower, preferably 250°C or lower and most preferably 200°C or lower in a viewpoint to realize precise moldability. It is preferable that an amorphous thermoplastic resin is employed which has a water absorption (after immersion at 25°C for 24 hours) of 0.2 % or lower and preferably 0.1 % or lower in a viewpoint to realize low moisture absorption.

More specifically, the resin may be a resin having a polar group in a molecule thereof, the resin being exemplified by a polycarbonate resin, for example, poly (oxycarbonyl-1, 4-phenylene-isopropylidene-1, 4-phenylene); a polyarylate resin, for example, poly ((oxy-terephthaloyloxy-1, 4-phenylene-isopropylidene-1, 4-phenylene)-co-(oxy-isophthaloyloxy-1, 4-phenylene-isopropylidene-1, 4-phenylene)) and a condensation polymer of terephthalic acid, isophthalic acid and bisphenol A; a polysulfone resin, for example, poly (oxy-1, 4-phenylenesulfonyl-1, 4-phenyleneoxy-1, 4-phenylene-isopropylidene-1, 4-phenylene); a polyether sulfone resin, for example, poly (oxy-1, 4-phenylenesulfonyl-1, 4-phenylene); and a polyether imide resin, for example, a resin having the polar group, such as 4, 4'-[isopropylidene-bis (p-phenyleneoxy)] diphthalate dianhydride condensation polymer of m-phenylenediamine. Among the resins having the polar group, it is preferable that the polyether imide resin is employed because a high elastic modulus can be obtained.

As well as the resins each having the polar group, any one of the following resins each having a hydrocarbon ring in a molecule thereof may be employed: a nonpolar resin containing an aromatic group, such as a polystyrene resin, and a hydrogenation product of the resin; resin of cyclodiene derivative, for example, hydrogenated polymer of cyclopentadiene and hydrogenated polymer of cyclohexadiene disclosed in Japanese Patent Laid-Open No. 6-136057, Japanese Patent Laid-Open No. 7-258362 and so forth; a thermoplastic norbornene resin, for example, ring-opening polymer of norbornene derivative, hydrogenation product of the ring-opening polymer of norbornene derivative, an addition polymer of monomer of norbornene derivative and an addition copolymer of a monomer of norbornene derivative and olefin disclosed in Japanese Patent Laid-Open No. 51-80400, Japanese Patent Laid-Open No. 60-26024, Japanese Patent Laid-Open No. 1-168725, Japanese Patent Laid-Open No. 1-190726, Japanese Patent Laid-Open No. 3-14882, Japanese Patent Laid-Open No. 3-122137 and Japanese Patent Laid-Open No. 4-63807.

Among the above-mentioned polar and nonpolar resins, it is preferable that the resin having a cyclic carbon structure in the molecule thereof is employed in viewpoints of realizing satisfactory heat resistance and low water absorption. More particularly, it is preferable that a material having no unsaturated bond in the molecule thereof is employed, for example, the hydrogenation product of the ring-opening polymer of norbornene derivative, hydrogenated polymer of cyclopentadiene, hydrogenated polymer of cyclohexadiene, addition polymer of norbornene derivative,

the addition copolymer of norbornene derivative and olefin in viewpoints of reducing the refractive index of the disc and realizing excellent durability. In a viewpoint of realizing a high elastic modulus, it is preferable that the hydrogenated polymer of cyclohexadiene is employed.

In viewpoints of keeping good balance among the heat resistance, precise moldability and low water absorption, it is preferable that the thermoplastic norbornene resin is employed.

As a monomer for obtaining the thermoplastic norbornene resin, the known monomer of norbornene derivative may be employed which has been, as described above, disclosed in Japanese Patent Laid-Open No. 2-27424, Japanese Patent Laid-Open No. 2-276842 and so forth. The monomer of norbornene derivative is exemplified by, norbornene, its alkyl, its alkylidene, its alkenyl, its aromatic substitute derivative and a polar group substituent of norbornene of its substitute or non-substitute. The polar group is exemplified by a hydroxyl group, an ester group, an alkoxy group, a cyano group, an amide group, an imide group and a silyl group. Specifically, the monomer is exemplified by 2-norbornene, 5-methyl-2-norbornene, 5, 5-dimethyl-2-norbornene, 5-ethyl-2-norbornene, 5-butyl-2-norbornene, 5-hexyl-2-norbornene, 5-octyl-2-norbornene, 5-octadecyl-2-norbornene, 5-ethylidene-2-norbornene, 5-isopropenyl-2-norbornene, 5-methoxycarbonyl-2-norbornene, 5-cyano-2-norbornene, 5-methyl-5-methoxycarbonyl-2-norbornene, 5-phenyl-2-norbornene and

5-phenyl-5-methyl-norbornene.

A monomer in the form in which one or more cyclopentadiene is added to norbornene, its derivative and substituent similar to the foregoing may be employed. The material is exemplified by 1, 4 : 5, 8-dimethano-1, 4, 4a, 5, 6, 7, 8, 8a-octahydronaphthalene; 6-methyl-1, 4 : 5, 8-dimethano-1, 4, 4a, 5, 6, 7, 8, 8a-octahydronaphthalene; 6-ethyl-1, 4 : 5, 8-dimethano-1, 4, 4a, 5, 6, 7, 8, 8a-octahydronaphthalene; 6-ethylidene-1, 4 : 5, 8-dimethano-1, 4, 4a, 5, 6, 7, 8, 8a-octahydronaphthalene; 6-methyl-6-methoxycarbonyl-1, 4 : 5, 8-dimethano-1, 4, 4a, 5, 6, 7, 8, 8a-octahydronaphthalene; 6-cyano-1, 4 : 5, 8-dimethano-1, 4, 4a, 5, 6, 7, 8, 8a-octahydronaphthalene.

A monomer of a polycyclic structure which is a polymer of cyclopentadiene and its derivative and substituent may be employed. The material is exemplified by cyclopentadiene; 1, 4 : 5, 8-dimethano-1, 2, 3, 4, 5, 6, 7, 8, 8a-octahydro-2, 3-cyclopentadienonaphthalene; 1, 4 : 5, 10 : 6, 9-trimethano-1, 2, 3, 4, 4a, 5, 5a, 6, 9, 9a, 10, 10a-dodecahydro-2, 3-cyclopentadienoanthracene and 2, 3-dihydro-dicyclopentadiene.

Any one of the following materials may be employed: tetrahydroindene, indene, benzofuran, its additive with cyclopentadiene and its derivative and a substituent. The material is exemplified by 1, 4-methano-1, 4, 4a, 4b, 5, 8, 8a, 9a-octahydrofluorene; 5, 8-methano-1, 2, 3, 4, 4a, 5, 8, 8a-octahydro-2, 3-cyclopentadienonaphthalene; 1, 4-methano-1, 4, 4a, 9a-tetrahydrofluorene; 1, 4-methano-1, 4, 4a,

9a-tetrahydrodibenzofuran.

The thermoplastic norbornene resin according to the present invention is prepared by a known method of ring-opening polymerization of monomer containing at least one type selected from the foregoing monomer of norbornene derivative or by a known method of hydrogenation to the foregoing material. For example, the material may copolymerize a monomer as well as the foregoing monomer in a range in which the solubility of an object polymer does not substantially deteriorate or the same can be improved. A monomer which can be copolymerized is exemplified by a cycloolefin, such as cyclopentene, cyclohexene, cycloheptene or cyclooctene.

The thermoplastic norbornene resin may be an addition copolymer of the monomer of norbornene derivative and olefin. In the foregoing case, olefin may be α -olefin, such as ethylene, propylene, 1-butene, 1-hexene, 4-methyl-1-pentene or styrene.

The limiting viscosity $[\eta]$ of the thermoplastic norbornene resin measured in decalin or toluene at 25°C is 0.01 dl/g to 20 dl/g, preferably 0.05 dl/g to 10 dl/g, more preferably 0.1 dl/g to 5 dl/g. If the limiting viscosity is too small, the shape as the polymer cannot be maintained. If the limiting viscosity is too large, the moldability deteriorates.

The glass transition temperature (hereinafter expressed as "T_g") of the thermoplastic norbornene resin is 50°C to 200°C, preferable 70°C to 180°C, more preferably 80°C to 160°C.

If necessary, the thermoplastic norbornene resin may be added with a variety of additives, such as a phenol or phosphorus oxidation inhibitor, a benzophenone ultraviolet absorber, a light resistance stabilizer, an antistatic agent, lubricant, such as ester of aliphatic alcohol, a partial ester and a partial ester of polyatomic alcohol. In a range in which the object of the present invention can be obtained, another resin, an elastomeric polymer and so forth may be added.

To manufacture resin pellets according to the present invention and including foreign matter particles each of which has a particle size of $2.0\text{ }\mu\text{m}$ or greater and the number of which is 10000 pieces/g or smaller, solution prepared by dissolving, for example, a synthesized resin in a solvent is sequentially filtered in a plurality of steps by filters, the mesh size of which descends from about $1\text{ }\mu\text{m}$ to about $5\text{ }\mu\text{m}$ to about $0.2\text{ }\mu\text{m}$. A filter having an adsorbing function by dint of a zeta potential may be combined with the foregoing filters or solely employed to filter the resin. Then, the resin solution is heated under reduced pressure in a sealed system to prevent introduction of foreign matter from an external environment so as to remove volatile components. Then, the resin solution is cooled in an environment, such as the inside portion of a clean room or the like, exhibiting excellent cleanliness (the cleanliness is closely controlled to about class 1000 or lower, preferably about class 100 or lower) so that the resin solution is formed into pellets.

When the disc substrate 11 is injection-molded by using the resin pellets containing foreign matter particles, the number of which is controlled, the

injection-molding process is performed also in an environment, for example, inside portion of a clean room or the like, exhibiting excellent cleanliness (the cleanliness is closely controlled to about class 1000 or lower, preferably about class 100 or lower). Thus, the number of foreign matter particles contained in the molded resin and having the particle size of $2.0\text{ }\mu\text{m}$ or greater can be made to be 10000 pieces/g or smaller which is similar to that in the molding resin.

The number of foreign matter particles contained in the molded resin and having the particle size of $2.0\text{ }\mu\text{m}$ or greater is controlled to be 10000 pieces/g or smaller. Thus, the possibility that a projection having a height not lower than about 165 nm (a value which is $1/4$ of the wavelength when the wavelength of the employed laser beam is 659 nm) is formed on the surface of the disc substrate 11 can considerably be reduced.

The number of foreign matter particles in the molded resin is in proportion to the number of projections which are formed on the disc substrate 11. Thus, the reduction in the number of the foreign matter particles enables the manufacturing yield of the molded disc substrate 11. It is preferable that the number of foreign matter particles contained in the molded resin and having the particle size of $2.0\text{ }\mu\text{m}$ or greater is 2000 pieces/g or smaller, more preferably 500 pieces/g or smaller.

In the viewpoint of preventing formation of a projection having a height of about 165 nm or greater on the surface of the disc substrate 11, the control of the number of foreign matter particles contained in the molded resin and having a particle

size of $2.0\text{ }\mu\text{m}$ or smaller is not required. To improve the reliability of a signal which is recorded on the magneto-optical disc 10 and to improve the durability of the magneto-optical disc 10, it is preferable that also the number of foreign matter particles having the particle size of $2.0\text{ }\mu\text{m}$ or smaller is controlled.

It is preferable that the number of foreign matter particles contained in the molded resin and having particles sizes from $1.0\text{ }\mu\text{m}$ or greater and smaller than $2.0\text{ }\mu\text{m}$ is 50000 pieces/g or smaller, more preferable 10000 pieces/g or smaller and most preferably 2000 pieces/g or smaller.

It is preferable that the number of foreign matter particles contained in the molded resin and having particles sizes from $0.5\text{ }\mu\text{m}$ or greater and smaller than $1.0\text{ }\mu\text{m}$ is 100000 pieces/g or smaller, more preferably 40000 pieces/g or smaller and most preferably 10000 pieces/g or smaller.

As described above, the resin material is injection-molded so that the disc substrate 11 for the magneto-optical disc 10 is manufactured which has the surface in which recessions are formed which are recorded information for locating the optical head, address information and so forth and grooves are formed between tracks. The surface of the substrate is constituted by upper surfaces of projections corresponding to the recessions. Information signals are recorded on the surface of the substrate. The depth of each recession in the disc substrate 11 from the surface of the substrate is about $0.05\text{ }\mu\text{m}$ to $0.3\text{ }\mu\text{m}$.

When the disc substrate 11 is manufactured by injection-molding, a stamper is

employed which is provided with projections of a pattern in the inversion form of the recessions of the disc substrate 11 by electroless plating method. The roughness of only the projection surface of the stamper or the surface of the stamper is 2.0 nm or smaller in terms of Ra value, preferably 1.0 nm or smaller.

Since the disc substrate 11 is manufactured as described above, at least the region which will be formed into the signal recording region of the magneto-optical disc 10 can be made to be a flat and smooth surface free from any projection which is measured from the surface of the substrate and which has a height not lower than $1/4$ of the wavelength of employed light.

The magneto-optical disc 10 is manufactured by forming the magneto-optical recording layer 12 on the disc substrate 11. Thus, at least the signal recording surface of the magneto-optical disc 10 can be made to be a flat and smooth surface free from any projection which is not lower than $1/4$ of the wavelength of employed light. When an information signal is recorded and/or regenerated by using the float-type optical head 20 by the near field recording method, the problem of collision with the float-type optical head 20 can be prevented. Thus, the reliability can be improved.

Among the above-mentioned methods, it is preferable that an optimum method is employed to make the disc substrate 11 to have at least the region which will be formed into the signal recording region of the magneto-optical disc 10 and which is free from any projection having a height which is measured from the surface of the substrate and which is not lower than $1/6$ of the wavelength of employed light.

The signal recording region of the magneto-optical disc 10 is made to be a flat and smooth surface free from any projection which is not lower than $1/6$ of the wavelength of employed light. Thus, even if the magneto-optical disc 10 and the magneto-optical disc 10 deviate from each other, collision between the magneto-optical disc 10 and the float-type optical head 20 can be prevented. Thus, the reliability of the magneto-optical disc 10 can furthermore be improved.

It is preferable that the disc substrate 11 has the region which will be formed into the signal recording region of the magneto-optical disc 10 and which is free from a recession as well as the projection.

This embodiment has been described about the structure that the present invention is applied to the disc substrate 11 of the magneto-optical disc 10 having the magneto-optical recording layer 12. The present invention is not limited to the foregoing structure. The present invention may be applied to a disc substrate for a read-only optical disc and a disc substrate for a phase-change type optical disc.

The magneto-optical disc 10 incorporating the above-mentioned disc substrate 11 is loaded into a disc drive 30 having a structure as shown in, for example, Fig. 4 and Fig. 5 so that an information signal is recorded and/or regenerated. Fig. 4 is a block diagram showing the schematic structure of the disc drive 30. Fig. 5 is a vertical cross sectional view showing an essential portion of the disc drive 30.

The disc drive 30 incorporates a spindle motor 31 for rotating the magneto-optical disc 10; a head mechanism 32 for writing and/or reading an

information signal to and from the magneto-optical disc 10 which is rotated by the spindle motor 31; a signal processing portion 33 for generating a MO regeneration signal and a control signal in response to a light receipt signal supplied from the head mechanism 32; and a system controller 34 for controlling the operations of the spindle motor 31 and the head mechanism 32.

The spindle motor 31 is controlled by the system controller 34 so that the supported magneto-optical disc 10 is rotated at predetermined speed.

As shown in Fig. 5, the head mechanism 32 incorporates a float-type optical head 20; a head drive portion 40 for operating the float-type optical head 20; and a light emitting/receiving portion 44 for emitting a laser beam to the magneto-optical disc 10 and receiving a laser beam (return light) reflected by the magneto-optical disc 10.

As previously shown in Fig. 3, the float-type optical head 20 has the pre-focus lens 21 and the focus lens 22 which are supported by the lens holder 23. The thin-film coil 24 for modulating the magnetic field is provided on the outside of the focus lens 22. Since the detailed structure of the float-type optical head 20 has been described, the detailed structure is omitted from description.

The head drive portion 40 is rotatively joined to a rotational shaft 43. The head drive portion 40 incorporates the support arm 41 for supporting the float-type optical head 20 at an end thereof and a voice coil motor 42 disposed to another end of the support arm 41 and arranged to rotate the support arm 41.

The head drive portion 40 is controlled by the system controller 34. When a predetermined electric current is supplied to the voice coil motor 42, the voice coil motor 42 rotates the support arm 41 around the rotational shaft 43. Thus, in a state where the float-type optical head 20 joined to the end of the support arm 41 is allowed to float from the magneto-optical recording layer 12 of the rotating magneto-optical disc 10 for a predetermined distance, the float-type optical head 20 is moved in a radial direction of the magneto-optical disc 10.

The light emitting/receiving portion 44 incorporates a semiconductor laser unit (not shown) for emitting a laser beam having a predetermined wavelength to the magneto-optical recording layer 12 of the magneto-optical disc 10 and a photodetector (not shown) for receiving light returned from the magneto-optical recording layer 12 of the magneto-optical disc 10 and converting received light into an electric signal 9 (a receipt signal) so as to supply the electric signal to the signal processing portion 33. Moreover, optical devices, such as mirrors 45 and 46 for reflecting the laser beam to bend the optical path for the laser beam and a beam splitter (not shown) for splitting the laser beam are disposed on the optical path for the laser beam which is emitted from the semiconductor laser emitting unit, reflected by the magneto-optical recording layer 12 of the magneto-optical disc 10 and received by the photodetector, as shown in Fig. 5.

In response to the receipt signal supplied from the photodetector of the light emitting/receiving portion 44 of the head mechanism 32, the signal processing portion

33 produces a MO regeneration signal to emit the MO regeneration signal. Moreover, the signal processing portion 33 produces a control signal, such as a tracking error signal, so as to supply the control signal to the system controller 34.

The system controller 34 controls the operation of the spindle motor 31 so as to rotate the magneto-optical disc 10 at predetermined speed. Moreover, the system controller 34 causes the head mechanism 32 to perform a recording operation in response to a recording signal supplied from a unit (not shown) and causes the head mechanism 32 to perform a regenerating operation. At this time, the system controller 34 causes the head mechanism 32 to perform tracking control in response to a control signal supplied from the signal processing portion 33.

When a recording operation is performed, the disc drive 30 having the above-mentioned structure causes the system controller 34 to perform control so that the spindle motor 31 rotates the loaded magneto-optical disc 10 at predetermined speed. Moreover, the semiconductor laser emitting unit of the light emitting/receiving portion 44 emits a red laser beam having a wavelength of, for example, 659 nm.

The laser beam emitted from the semiconductor laser emitting unit is warped by the mirrors 45 and 46, and then made incident on the float-type optical head 20.

The float-type optical head 20 is supported by the support arm 41 of the head drive portion 40 so that the float-type optical head 20 is allowed to float on the rotating magneto-optical disc 10 for a distance, for example, not larger than 165 nm from the magneto-optical recording layer 12. In the foregoing state, the float-type optical head

20 converges the incident laser beam so as to irradiate the magneto-optical recording layer 12 of the magneto-optical disc 10 with the laser beam. Since the surface of the magneto-optical disc 10 is free from any projection having a height not lower than 165 nm, the problem of collision between the float-type optical head 20 and the projection of the magneto-optical disc 10 can be prevented.

The float-type optical head 20 is controlled by the system controller 34 so that the thin-film coil 24 generates a magnetic field having an intensity corresponding to the record signal. The magnetic field is applied to a portion of the magneto-optical recording layer 12 irradiated with the laser beam.

In the disc drive 30, a predetermined information signal is recorded on the magneto-optical recording layer 12 of the magneto-optical disc 10, as described above. Also in the foregoing recording operation, the tracking control is performed similarly to that in the regenerating operation to be described later.

When a regenerating operation is performed, the system controller 34 of the disc drive 30 performs control so that the spindle motor 31 rotates the loaded magneto-optical disc 10 at predetermined speed. Moreover, the semiconductor laser emitting unit of the light emitting/receiving portion 44 emits the red laser beam having a wavelength of, for example, 659 nm.

The laser beam emitted from the semiconductor laser emitting unit is reflected by the mirrors 45 and 46 so as to be made incident on the float-type optical head 20.

The float-type optical head 20 is supported by the support arm 41 of the head

drive portion 40 so that the float-type optical head 20 is allowed to float on the rotating magneto-optical disc 10 for a distance, for example, not larger than 165 nm from the magneto-optical recording layer 12. In the foregoing state, the float-type optical head 20 converges the incident laser beam so as to irradiate the magneto-optical recording layer 12 of the magneto-optical disc 10 with the laser beam. Since the surface of the magneto-optical disc 10 is free from any projection having a height not lower than 165 nm, the problem of collision between the float-type optical head 20 and the projection of the magneto-optical disc 10 can be prevented.

The laser beam applied to the magneto-optical recording layer 12 of the magneto-optical disc 10 is reflected by the magneto-optical recording layer 12 so that the laser beam is formed into returned light containing a signal component. Returned light is allowed to pass through the float-type optical head 20, reflected by the mirrors 45 and 46 and received by the photodetector of the light emitting/receiving portion 44.

The photodetector converts returned light, which has been received, into an electric signal (a receipt signal) so as to supply the electric signal to the signal processing portion 33.

The signal processing portion 33 produces and transmits a MO regeneration signal in response to the receipt signal supplied from the photodetector. Moreover, the signal processing portion 33 produces the control signal, such as the tracking error signal, in response to the receipt signal supplied from the photodetector so as to supply the control signal to the system controller 34.

In response to the control signal supplied from the signal processing portion 33, the system controller 34 controls the rotational shaft 43 of the head drive portion 40 so as to move the float-type optical head 20 supported by the support arm 41 into a radial direction of the magneto-optical disc 10. Thus, the system controller 34 performs the tracking control.

As described above, the disc drive 30 is able to appropriately regenerate the information signal recorded on the magneto-optical disc 10.

The disc drive 30 has the structure that the magneto-optical recording layer 12 of the magneto-optical disc 10 is irradiated with the laser beam in a state where the float-type optical head 20 is allowed to float for a distance in a range of not larger than $1/4$ of the wavelength of the laser beam from the magneto-optical recording layer 12. Thus, the diameter of the laser beam spot can be reduced. As a result, information signals can densely be recorded on the magneto-optical disc 10 and an information signal can be regenerated from the magneto-optical disc 10 on which information signals have densely been recorded.

The disc drive 30 is arranged to record and/or regenerate an information signal to and from the magneto-optical disc 10 incorporating the disc substrate 11 which is free from any projection having a height not lower than $1/4$ of the wavelength of the laser beam. Therefore, the problem of collision of the float-type optical head 20 with the surface projection of the magneto-optical disc 10 and thus the float-type optical head 20 or the magneto-optical disc 10 is damaged can be prevented. Thus, the

magneto-optical disc 10 is protected from being damaged. Therefore, reliable recording and regenerating operations can be performed.

Although the description has been performed about the disc drive 30 for recording and/or regenerating an information signal to and from the magneto-optical disc 10, the present invention is not limited to the foregoing structure. The present invention may be applied to also a disc drive for regenerating an information signal from a read-only optical disc and a disc drive for recording and/or regenerating an information signal to and from a phase-change optical disc.

Examples

Examples and comparative examples of the present invention will now be described. Note that the present invention is not limited to the following examples. Note that parts and % are values in terms of weight.

Resin Preparation Example 1

One hundred parts of a ring-opening polymer prepared from a monomer containing 90 % of 6-methyl-1, 4 : 5, 8-dimethano-1, 4, 4a, 5, 6, 7, 8, 8a-octahydronaphthalene (hereinafter called "MTD") and 10 % of 5-methyl-2-norbornene was dissolved in 400 parts of cyclohexane. Then, five parts of nickel-alumina catalyst (manufactured by Nikki Chemical Co.,Ltd.) were, as hydrogenating catalysts, added. Then, hydrogen was used to raise the pressure to 50 kg/cm², and the temperature was raised to 200°C while the solution was stirred so that

reactions were performed for four hours. Thus, a hydrogenation product of ring-opening polymer was prepared.

Solution of after reaction containing a polymer which contained nonuniform catalyst for hydrogenating by 20 % was filtered (a first filtering step) under a pressure of 2.5 kg/cm² by using a pressure filtration unit (Funda Filter manufactured by Ishikawajima Harima Heavy Industries Co.,Ltd.) such that radiolite #500 was employed as a filtering bed. Thus, transparent and colorless solution (Solution 1-5) was obtained.

One hundred parts of Solution 1-5 were filtered (a second filtering step) by a metal fiber filter (having a mesh size of 3 μ m manufactured by Nichidai). Then, the solution was filtered (a third filtering step) by a metal fiber filter (having a mesh size of 0.2 μ m manufactured by Nichidai) so that foreign matter was removed. Thus, Solution 1-6 was obtained.

Solution 1-6 was subjected to a process for removing (driving) cyclohexane in a cylindrical and condensation drier (manufactured by Hitachi, Ltd.) under operation conditions having a first step in which the temperature was 270°C and a pressure of 100 Torr and a second step in which the temperature was 270°C and a pressure of 5 Torr. In a clean room set to class 1000, the molten polymer was extruded from a die, and then the polymer was cooled with water. Then, a Pelletizer (OSP-2 manufactured by Osada Manufacturing Co., Ltd.) was used to cut the polymer so that 18 parts of pellets (Polymer A) were obtained. The Polymer A was injected into a gastight

container having a polished surface and made of stainless steel so as to be stored. Toluene solution of 10 % Polymer A was analyzed by a gas chromatography, thus resulting in that the quantity of residual cyclohexane was not larger than a limit of measurement. The Polymer A was colorless and transparent and had a molecular weight in terms of polystyrene measured by gel permeation chromatography (hereinafter called "GPC") analysis of Mn: 27,000 and Mw: 56,000 and Tg measured by differential scanning calorimetry (hereinafter called "DSC") analysis was 140°C. Moreover, dichloroform solution was measured with ¹H-NMR spectrum, thus resulting in a hydrogen addition ratio being substantially 100 %. Toluene obtained by filtering and refining by a 0.2 μm cartridge filter was used to prepare 1.5 % Polymer A solution. Then, the number of foreign matter particles having particle sizes not smaller than 2.0 μm was measured by using a light diffusion particle detector (KS-58 manufactured by RION), thus resulting in 60 pieces/g.

Resin Preparation Example 2

A process similar to that according to the Resin Preparation Example 2 was performed except for the second and third filtering steps being omitted and Solution 1-5 being as it is dried in place of Solution 1-6. Thus, the solvent was removed so that 18 parts of pellets (Polymer B) were obtained. The Polymer B was injected in a gastight container having a polished surface and made of stainless steel so as to be stored, similarly to the Resin Preparation Example 1. Analysis was performed similarly to Resin Preparation Example 1, thus resulting in the quantity of residual

cyclohexane being not larger than a measurement limit, the molecular weight being Mn: 27,000, Mw: 56,000, Tg being 140°C and the number of foreign matter particles having particles sizes not smaller than 2.0 μm being 12,000 pieces/g.

Resin Preparation Example 3

One hundred parts of ring-opening polymer prepared from a monomer containing 80 % of 6-methyl-6-methoxycarbonyl-1, 4 : 5, 8-dimethano-1, 4, 4a, 5, 6, 7, 8, 8a-octahydronaphthalene and 20 % of 5-methyl-5-methoxycarbonyl-2-norbornene was dissolved in 400 parts of mixture solution of cyclohexane/tetrahydrofuran (hereinafter called THF) = 1:1. Then, 5 parts of nickel-alumina catalyst (manufactured by Nikki Chemical Co., Ltd.) were added as hydrogenating catalyst. Hydrogen was used to raise the pressure to 50 kg/cm². While the solution was stirred, the temperature was raised to 200°C, and then reactions were performed for four hours. Thus, a hydrogenation product of ring-opening polymer was prepared.

Solution of after reaction containing a polymer which contained nonuniform catalyst for hydrogenating by 20 % was filtered under a pressure of 2.5 kg/cm² by using a pressure filtration unit (Funda Filter manufactured by Ishikawajima Harima Heavy Industries Co., Ltd.) such that radiolite #500 was employed as a filtering bed. Thus, transparent and colorless solution (Solution 2-5) was obtained.

One hundred parts of Solution 2-5 were filtered by a metal fiber filter (having a mesh size of 3 μm manufactured by Nichidai). Then, the solution was filtered by a metal fiber filter (having a mesh size of 0.2 μm manufactured by Nichidai) so that

foreign matter was removed. Thus, Solution 2-6 was obtained.

A process similar to that according to the Resin Preparation Example 1 was performed except for Solution 2-6 being used in place of Solution 1-6. Thus, 17 parts of pellets (Polymer C) were obtained. The Polymer C was injected in a gastight container having a polished surface and made of stainless steel so as to be stored, similarly to the Resin Preparation Example 1. Analysis was performed similarly to Resin Preparation Example 1, thus resulting in the quantity of residual cyclohexane being not larger than a measurement limit, the molecular weight being Mn: 17,500 Mw: 56,000, Tg being 139°C and the number of foreign matter particles having particles sizes not smaller than 2.0 μm being 90 pieces/g.

Resin Preparation Example 4

A process similar to that according to the Resin Preparation Example 2 was performed except for the second and third filtering steps being omitted and Solution 2-5 being as it is dried in place of Solution 1-6. Thus, the solvent was removed so that 17 parts of pellets (Polymer D) were obtained. The Polymer D was injected in a gastight container having a polished surface and made of stainless steel so as to be stored, similarly to the Resin Preparation Example 1. Analysis was performed similarly to Resin Preparation Example 1, thus resulting in the quantity of residual cyclohexane being not larger than a measurement limit, the molecular weight being Mn: 27,000, Mw: 56,000, Tg being 140°C and the number of foreign matter particles having particles sizes not smaller than 2.0 μm being 19,000 pieces/g.

Resin Preparation Example 5

Polycarbonate for a disc manufactured by Mitsubishi Gas Chemical (Trade Name: Iupiron H-4000) was dried by using a butt-type dryer under condition that 100°C for 10 hours. Thus, polymer E was obtained. Polymer E was injected into a gastight container having a polished surface and made of stainless steel so as to be stored. Analysis was performed by using the light diffusion particle detector (KS-58 manufactured by RION) similarly to Resin Preparation Example 1 except for methylene chloride being employed as the solvent in place of toluene. As a result, the number of foreign matter particles having particle sizes not smaller than 2.0 μm was 1,400 pieces/g.

Resin Preparation Example 6

One hundred parts of cycloolefin copolymer manufactured by Mitsui Petroleum Chemical (Trade Name: APL6015) were dissolved in 400 parts of cyclohexane so that colorless and transparent solution (Solution 3-5) was obtained. Solution 3-5 was filtered by a metal fiber filter (having a mesh size of 3 μm manufactured by Nichidai) and a metal fiber filter (having a mesh size of 0.2 μm manufactured by Nichidai) so that foreign matter was removed. Thus, Solution 3-6 was obtained.

A process similar to that according to Resin Preparation Example 1 was performed except for 100 parts of Solution 3-6 being employed in place of Solution 1-6. Thus, the solvent was removed so that 18 parts of pellets (Polymer F) were obtained. Polymer F was stored in a gastight container made of stainless steel

similarly to the foregoing examples. Polymer F was colorless and transparent. Analysis similar to that according to Resin Preparation Example 1 was performed, thus resulting in the quantity of residual cyclohexane being not larger than a measurement limit, the molecular weight being Mn: 47,000, Mw: 83,000, Tg being 137°C and the number of foreign matter particles having particles sizes not smaller than 2.0 μm being 110 pieces/g.

Example 1

Polymer A obtained in Resin Preparation Example 1 was loaded into an injection molding machine (DISK3 manufactured by Sumitomo Ship Building and Machinery) disposed in a clean room set to cleanliness class 1000 and having a mold portion maintained in an environment set to cleanliness class 100 in a clean booth. Thus, a Ni stamper having a smooth surface (Ra: 1 nm) was loaded into the mold under condition that the temperature of the resin was 320°C and the temperature of the mold was 120°C. Thus, a disc substrate having a diameter of 65 mm and a thickness of 1.2 mm was molded.

The surface roughness (arithmetic average roughness) Ra and existence of a projection having a height not lower than 165 nm (the height which was 1/4 of the wavelength when the wavelength of the employed laser beam was 659 nm) of twenty smooth and flat disc substrates were examined. The surface roughness was evaluated as the arithmetic average roughness Ra in 20 μm $\times$ 20 μm regions obtained by cutting a 50 μm $\times$ 50 μm surface area of the disc substrate free from any projection similar

to or larger than the distance of floating of the float-type optical head. The surface roughness was the roughness other than the projection.

The surface roughness Ra was 1.0 nm to 1.1 nm which were near the surface roughness of the stamper. Nineteen disc substrates of twenty disc substrates were free from any projection. The existence of the projection was detected such that the number of revolution of the disc was controlled in such a manner that the float-type optical head was allowed to float for a distance of 165 nm. Then, a piezoelectric device joined to the float-type optical head was operated to detect the projection in response to an acceleration signal generated when collision took place. A sample which was 1.5 g in weight was each obtained from the two disc substrates by cutting, and then formed into toluene solution similarly to Resin Preparation Example 1 to measure the number of foreign matter particles having particle sizes not smaller than 2.0 μm . The numbers were 65 pieces/g and 67 pieces/g, respectively.

Example 2

Polymer C obtained in Resin Preparation Example 3 was employed so that a disc substrate was molded similarly to Example 1. The surface roughness Ra and existence of a projection having a height not lower than 50 nm of twenty smooth and flat disc substrates were examined. As a result, the surface roughness Ra was 1.0 nm to 1.1 nm which were near the surface roughness of the stamper. Eighteen disc substrates of twenty disc substrates were free from any projection. The number of foreign matter particles having the particle size not smaller than 2.0 μm of each of two

disc substrates was measured similarly to Example 1, thus resulting 95 pieces/g and 110 pieces/g, respectively.

Example 3

Polymer E obtained in Resin Preparation Example 5 was employed so that a disc substrate was molded similarly to Example 1. The surface roughness Ra and existence of a projection having a height not lower than 50 nm of twenty smooth and flat disc substrates were examined. As a result, the surface roughness Ra was 1.0 nm to 1.1 nm which were near the surface roughness of the stamper. Eight disc substrates of twenty disc substrates were free from any projection. A sample which was 1.5 g in weight was each obtained from the two disc substrates by cutting to measure the number of foreign matter particles having particle sizes not smaller than 2.0 μm similarly to Resin Preparation Example 5. As a result, the numbers were 1,400 pieces/g, respectively.

Example 4

Polymer F obtained in Resin Preparation Example 6 was employed so that a disc substrate was molded similarly to Example 1. The surface roughness Ra and existence of a projection having a height not lower than 50 nm of twenty smooth and flat disc substrates were examined. As a result, the surface roughness Ra was 1.0 nm to 1.1 nm which were near the surface roughness of the stamper. Seventeen disc substrates of twenty disc substrates were free from any projection. A sample which was 1.5 g in weight was each obtained from the two disc substrates by cutting to

measure the number of foreign matter particles having particle sizes not smaller than 2.0 μm similarly to Resin Preparation Example 1. As a result, the numbers were 120 pieces/g and 130 pieces/g, respectively.

Example 5

Polymer A obtained in Resin Preparation Example 1 and polymer B obtained in Resin Preparation Example 2 were blended immediately before the molding process such that polymer A was 25 parts and polymer B was 75 parts. Thus, similarly to Example 1, disc substrate was molded. The surface roughness Ra and existence of a projection having a height not lower than 50 nm of twenty smooth and flat disc substrates were examined. As a result, the surface roughness Ra was 1.0 nm to 1.1 nm which were near the surface roughness of the stamper. Two disc substrates of twenty disc substrates were free from any projection. A sample which was 1.5 g in weight was each obtained from the two disc substrates by cutting to measure the number of foreign matter particles having particle sizes not smaller than 2.0 μm similarly to Resin Preparation Example 1. As a result, the numbers were 9,000 pieces/g and 9,100 pieces/g, respectively.

Comparative Example 1

Polymer B obtained in Resin Preparation Example 2 was employed so that a disc substrate was molded similarly to Example 1. The surface roughness Ra and existence of a projection having a height not lower than 50 nm of twenty smooth and flat disc substrates were examined similarly to Example 1. As a result, the surface

roughness Ra was 1.0 nm to 1.1 nm which were near the surface roughness of the stamper. No disc substrate free from any projection was obtained from 20 disc substrates. The number of foreign matter particles having particle sizes not smaller than 2.0 μm of two disc substrates randomly selected from molded disc substrates was measured, similarly to Example 1. As a result, the numbers were 12,000 pieces/g and 13,000 pieces/g, respectively.

Comparative Example 2

Polymer D obtained in Resin Preparation Example 4 was employed so that a disc substrate was molded similarly to Example 1. The surface roughness Ra and existence of a projection having a height not lower than 50 nm of twenty smooth and flat disc substrates were examined similarly to Example 1. As a result, the surface roughness Ra was 1.0 nm to 1.1 nm which were near the surface roughness of the stamper. No disc substrate free from any projection was obtained from 20 disc substrates. The number of foreign matter particles having particle sizes not smaller than 2.0 μm of two disc substrates randomly selected from molded disc substrates was measured. As a result, the number in each of the two disc substrates was 19,000 pieces/g.

A portion around the projection of each of the disc substrates obtained in Comparative Example 1 was removed by cutting to measure the height of the projection and the diameter of particles existing below the projection. Results of the measurement are shown in Table 6. It can be considered that the projection having a

height not lower than 165 nm is caused from particles having particle sizes not smaller than 2.0 μm .

The substrate for a disc-shape recording medium according to the present invention has at least a region corresponding to a signal recording region of the disc-shape recording medium is free from any projection which is measured from the surface of the substrate and which is not lower than $1/4$ of the wavelength of employed light. Therefore, the disc-shape recording medium incorporating the substrate according to the present invention is able to prevent collision with the optical head. Thus, the reliability can significantly be improved.

When an information signal is recorded and/or regenerated to and from the disc-shape recording medium incorporating the substrate according to the present invention by causing the float-type optical head to float from the signal recording surface for a distance not larger than $1/4$ of the wavelength of employed light, collision between the disc-shape recording medium and the float-type optical head can be prevented. Therefore, dense recording and/or regenerating can be performed.

When the disc-shape recording medium is molded by injection-molding a resin, it can precisely and easily be molded as a substrate for a disc-shape recording medium having the surface provided with recessions for head positioning information and address information or a disc-shape recording medium having grooves among tracks. Thus, the substrate for a disc-shape recording medium can be manufactured with satisfactory productivity and a low cost as compared with the aluminum substrate for

use in a hard disc or the like.

The method of manufacturing a disc-shape recording medium according to the present invention is performed such that the molding process is performed in such a manner that the number of particles contained in the molded product and having particle sizes not smaller than $2.0\ \mu\text{m}$ is 10000 pieces/g or smaller. Therefore, a substrate for a disc-shape recording medium having the surface free from any projection not lower than about 165 nm can easily be manufactured.

The substrate for a disc-shape recording medium manufactured by the method of manufacturing the substrate for a disc-shape recording medium according to the present invention has the surface free from any projection not lower than about 165 nm. Therefore, the reliability of the disc-shape recording medium can significantly be improved.

The disc drive according to the present invention is arranged to record and/or regenerate an information signal to and from a disc-shape recording medium having a signal recording region free from any projection having a height not lower than $1/4$ of the wavelength of employed light. Therefore, the problems of collision of the float-type optical head which is arranged to float for a distance not larger than $1/4$ of the wavelength of employed light with the disc-shape recording medium and thus the float-type optical head or the disc-shape recording medium is damage can be prevented. Thus, reliable recording and regenerating operations can be performed.

Moreover, the disc drive according to the present invention is arranged such that

the float-type optical head is allowed to float for a distance not lower than $1/4$ of the wavelength of employed light so as to write and/or read an information signal to and from the disc-shape recording medium. Therefore, the diameter of the light spot can be reduced. As a result, information signals can densely be recorded on the disc-shape recording medium or information signal can be regenerated from the disc-shape recording medium on which information signals have densely been recorded.

Although the invention has been described in its preferred form with a certain degree of particularity, it is understood that the present disclosure of the preferred form can be changed in the details of construction and in the combination and arrangement of parts without departing from the spirit and the scope of the invention as hereinafter claimed.



WHAT IS CLAIMED IS:

1. A substrate for a disc-shape recording medium for use in a disc-shape recording medium to and from which an information signal is recorded and/or regenerated by using light, said substrate for a disc-shape recording medium comprising:

a signal recording region, wherein

at least the signal recording region is free from any projection having a height which is measured from a surface of said substrate for a disc-shape recording medium and which is not lower than $1/4$ of the wavelength of said light.

2. A substrate for a disc-shape recording medium according to claim 1, wherein

said disc-shape recording medium has a structure in which at least a signal recording layer and a protective layer are sequentially laminated on said substrate thereof so that a desired information signal is recorded and/or regenerated when said light passes through said protective layer and irradiates the signal recording layer.

3. A substrate for a disc-shape recording medium according to claim 1, wherein

said substrate for a disc-shape recording medium is molded by injection-molding a resin.



4. A substrate for a disc-shape recording medium according to claim 3, wherein

said resin is a thermoplastic norbornene resin.

5. A method of manufacturing a substrate for a disc-shape recording medium for use in a disc-shape recording medium on and from which an information signal is recorded and/or regenerated by using light, wherein

resin is controlled in such a condition that number of particles having diameters of not smaller than $2.0\text{ }\mu\text{m}$ is 10000 pieces/g or less in the molded product when the molding process for realizing a disc shape is performed, and

at least a signal recording region is free from any projection having a light which is measured from a surface of said substrate for a disc-shape recording medium and which is not lower than $1/4$ of the wavelength of said light.

6. A method of manufacturing a substrate for a disc-shape recording medium according to claim 5, wherein

said resin is injection-molded so that said disc-shape recording medium is manufactured.

7. A method of manufacturing a substrate for a disc-shape recording medium according to claim 5, wherein



said resin is a thermoplastic norbornene resin.

8. A disc drive apparatus comprising:

a motor for rotating a disc-shape recording medium; and

a float-type optical head arranged to float at spaces not larger than $1/4$ of the wavelength of using light on said disc-shape recording medium wherein said disc-shape recording medium is rotated by said motor to write and/or read information signals to and from said disc-shape recording medium, and

at least a signal recording region of said disc-shape recording medium is free from any projection having a height which is measured from the surface of said region and which is not lower than $1/4$ of the wavelength of said light.

9. A disc drive apparatus according to claim 8, wherein said substrate of said disc-shape recording medium is molded by injection-molding a resin.

10. A disc drive apparatus according to claim 8, wherein said substrate of said disc-shape recording medium is made of a thermoplastic norbornene resin.

11. A disc drive apparatus according to claim 9, wherein said substrate of said disc-shape recording medium is molded and said resin is controlled in such a condition that the number of particles having diameters of not smaller than $2.0\text{ }\mu\text{m}$ is



10000 pieces/g or less in said resin.