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(54) OPTICAL DISK, METHOD OF MANUFACTURING THE SAME AND OPTICAL DISK APPARATUS

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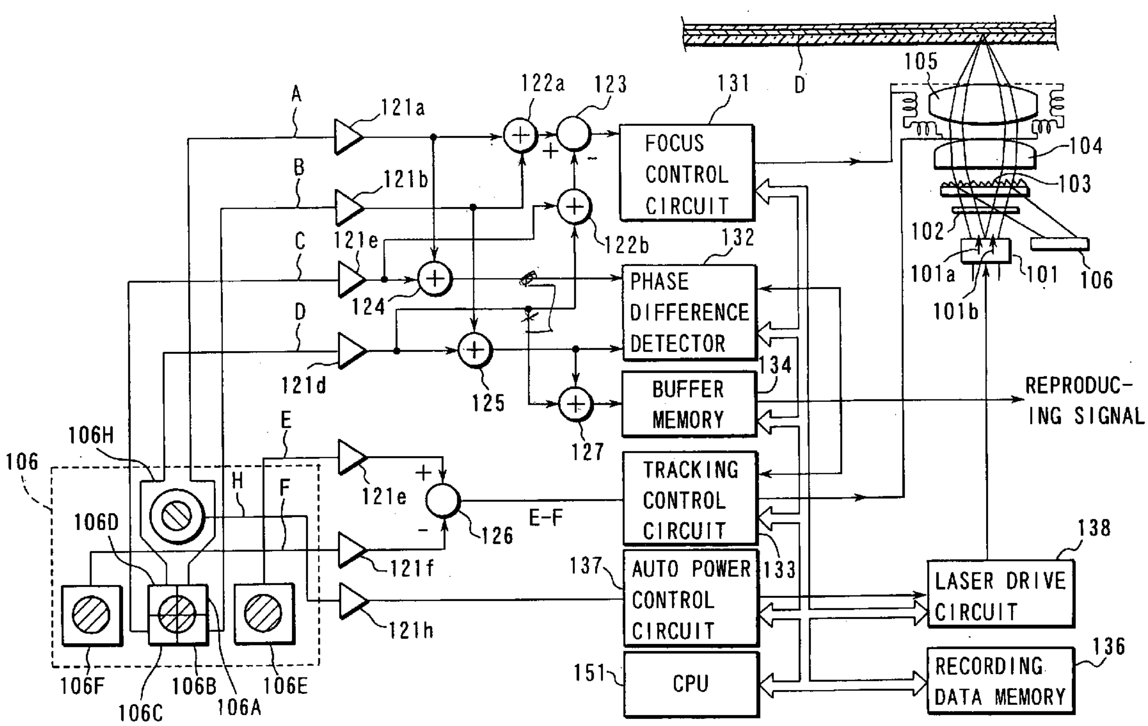
(57) ABSTRACT

An optical disk having a data recording surface, which is prepared by the process, in which two metal molds having curvature surfaces on their cavity sides are used for making substrates having predetermined curvatures, for the optical disk by injection molding, and the substrates are adhered together such that convex surfaces of the substrates are adhered surfaces.



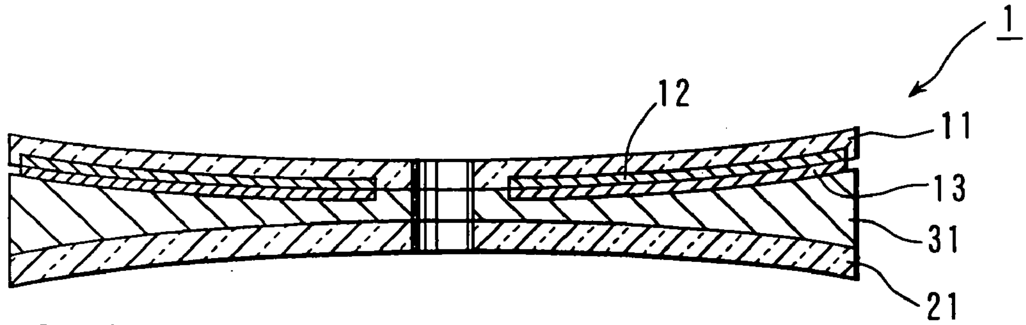


FIG. 1

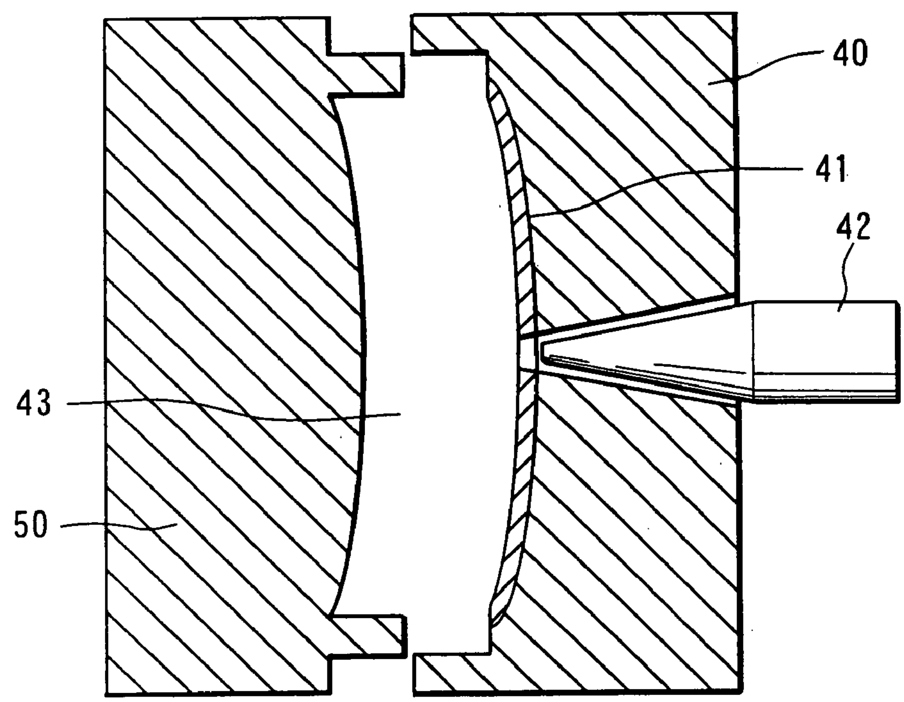


FIG. 2

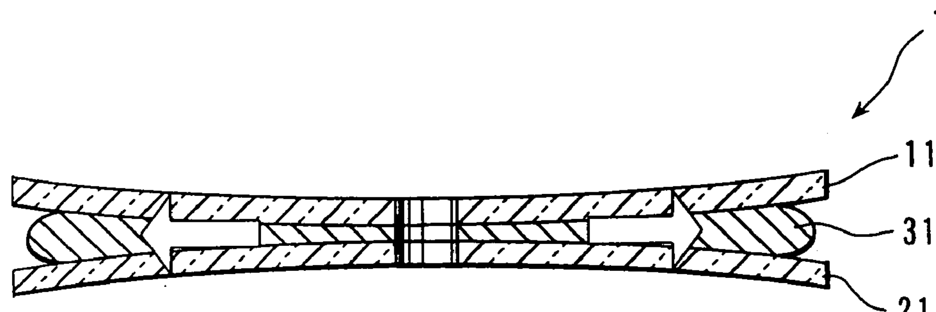
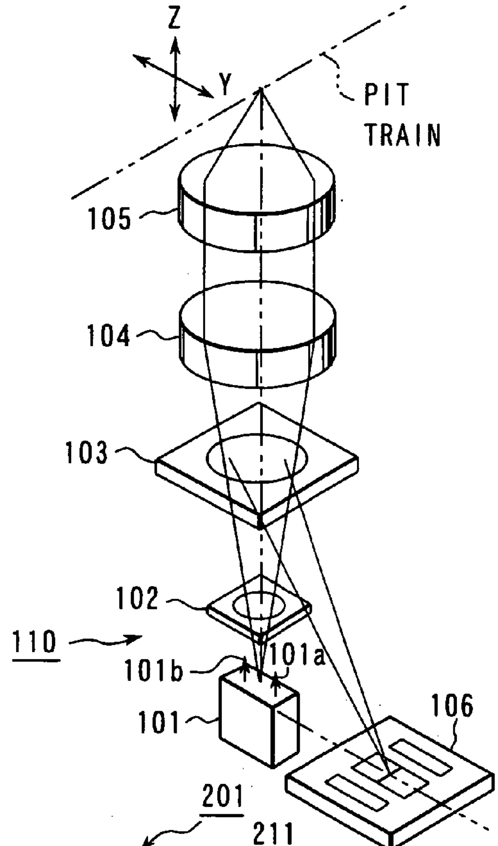


FIG. 3

FIG. 4



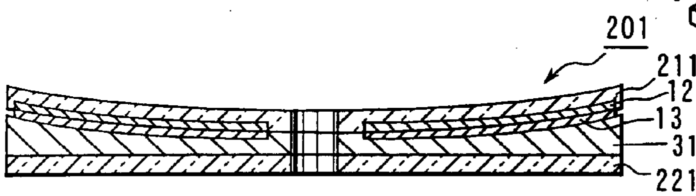


FIG. 6

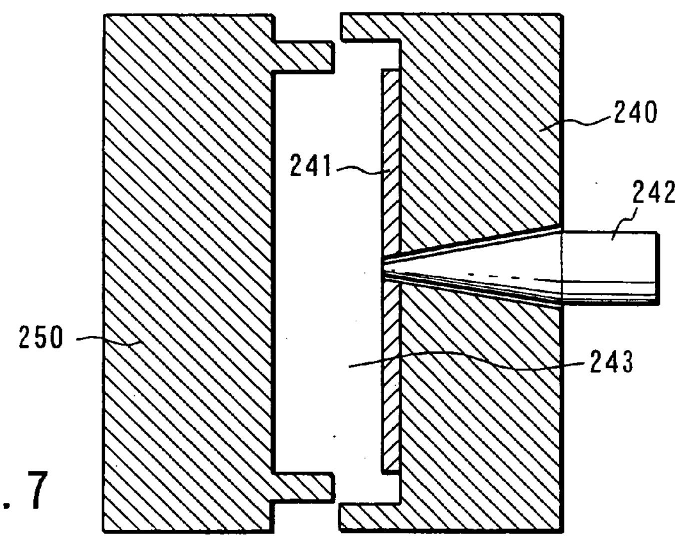
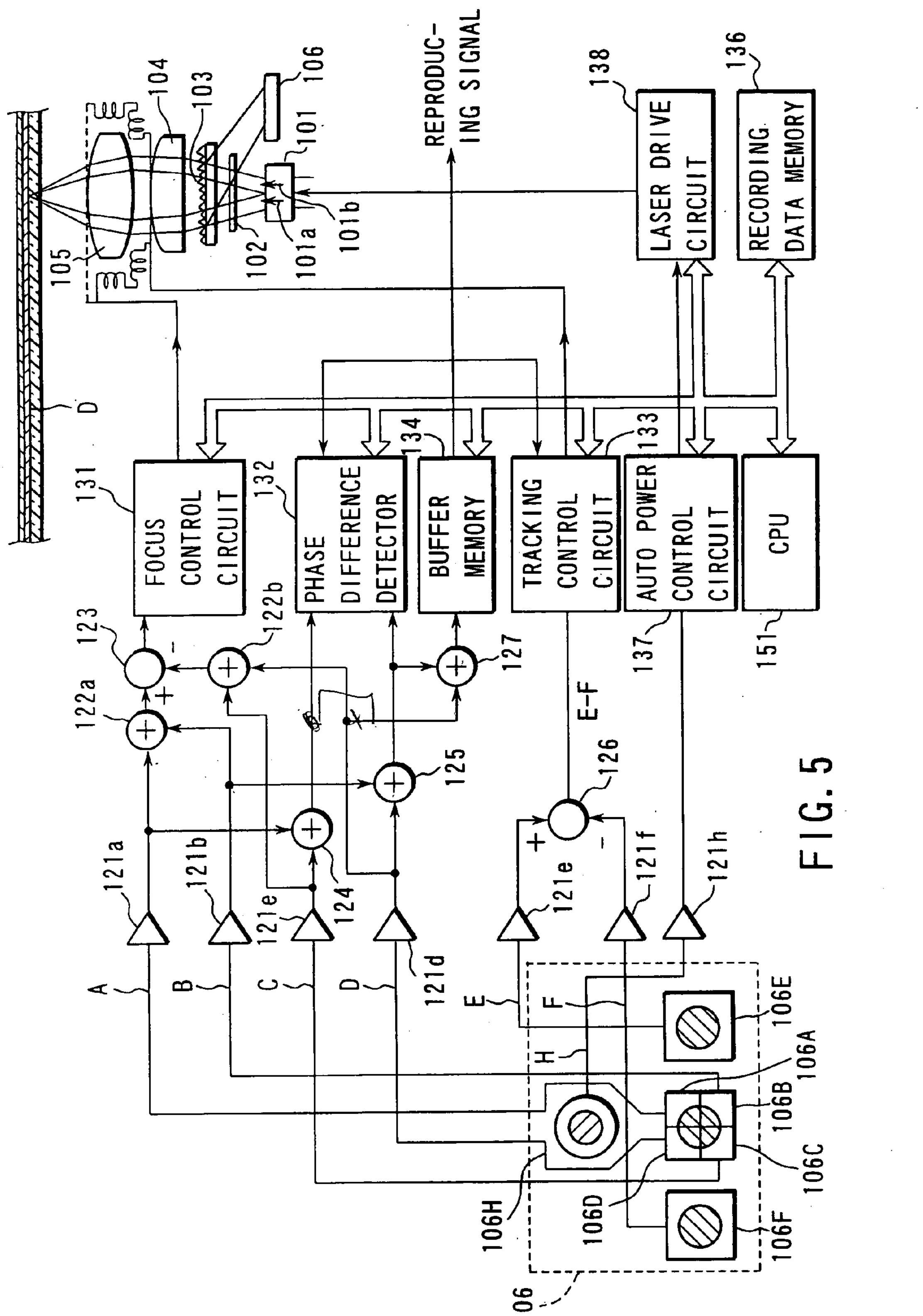


FIG. 7



104
103
106
101
105
102
101a
101b
REPRODUC-
ING SIGNAL
138
LASER DRIVE
CIRCUIT
136
RECORDING
DATA MEMORY
D
131
FOCUS
CONTROL
CIRCUIT
132
PHASE
DIFFERENCE
DETECTOR
134
BUFFER
MEMORY
TRACKING
CONTROL
CIRCUIT
133
AUTO POWER
CONTROL
CIRCUIT
137
CPU
151
123
122a
122b
127
125
124
E-F
126
121a
121b
121e
121d
121e
121f
121h
A
B
C
D
E
F
H
106E
106A
106B
106C
106H
106D
106F
106

FIG. 5

OPTICAL DISK, METHOD OF MANUFACTURING THE SAME AND OPTICAL DISK APPARATUS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is based upon and claims the benefit of priority from the prior Japanese Patent Application No. 2000-286028, filed Sep. 20, 2000, the entire contents of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

[0002] The present invention relates to an optical disk from which an accurate reproduction signal can be obtained when reproduced by a disk drive apparatus by optimally controlling warp created in a disk-shaped recording medium such as an optical disk or a magnetic disk, a method of manufacturing such an optical disk, and an optical disk device which can record data on such an optical disk or reproduce the data from the disk.

[0003] A disk drive device which can record data on a disk-shaped recording medium (disk) such as CD-ROM, MO disk or DVD-disk, or can reproduce already recorded data from a disk, is connected to, for example, a personal computer (PC), and thus used so as to supply a system program or software for operating the PC, or for supplying and storing a great amount of data. Alternatively, the disk drive device is connected to, for example, a television or a monitor device, and thus used to reproduce image software or game software.

[0004] Since the first music CD was made into practical use, the memory capacities of these disks are increased year by year.

[0005] In an optical disk of a DVD-type, a transparent resin such as polycarbonate is used and it is formed by injection molding into a substrate having a surface on which a record pattern is transferred and a flat mirror surface. Then, a reflection film is formed on a data recording surface by, for example, a sputtering method. With this structure, a record pattern is read by making a laser beam incident on the mirror surface.

[0006] In this case, in consideration of the productivity, substrates are, in many cases, formed in a cycle of several seconds by injection molding with use of a transparent resin such as polycarbonate.

[0007] However, in thin products such as substrates for optical disks, when the molding in the order of submicrons is performed in a cycle of several seconds by applying such a pressure and heat for transferring a data pattern, it is not inevitable that thus produced substrates have warps due to the remaining stress of the resin.

[0008] Nowadays, in order to further increase the density, it will become necessary to increase the pressure applied on a substrate and the temperature of the resin during molding further than those in the current technique as the data patter to be transferred on the substrate becomes finer, and therefore it is expected that the warp of the substrate will become more prominent.

[0009] Conventionally, the warp of formed substrates is controlled by adjusting the forming conditions such as the temperature of the metal mold and the pressure for tightening the mold. However, as the data pattern to be transferred on a substrate becomes finer in order to increase the density, the degree of freedom in the forming conditions is lowered. Therefore, it becomes substantially difficult to control the warp by simply adjusting the forming conditions.

[0010] As a result, an optical disk which can be obtained by adhering substrates together, is warped, and thus the quality of the reproduction signal is undesirably deteriorated.

[0011] In the meantime, when two substrates are adhered together in order to manufacture an optical disk, it is of a general technique that an ultraviolet curing resin is provided between substrates and made into an adhesion layer by a spin coat method. However, in the case where the control of the warp of the formed substrates is not sufficient, and the direction of the radial warp of the substrates is unknown, it becomes difficult to determine the conditions for applying the ultraviolet curing resin when adhering the substrates together. Thus, the uneven distribution of the ultraviolet curing resin applied and run-off of the resin are caused, thereby lowering the yield of the products.

[0012] As described above, as the density of the optical disk is increased, the degree of freedom of the forming conditions is lowered. Therefore, it is difficult to control the warp merely by adjusting the forming conditions as in the conventional case. As a result, the warp of the formed substrates, which has becomes even worse, causes an adverse effect on the adhesion of the substrates together and the reproduction of signals.

BRIEF SUMMARY OF THE INVENTION

[0013] The present invention has been proposed in consideration of the above-described drawbacks of the conventional technique, and the object thereof is to provide an optical disk having appropriate warp properties for reproducing a signal after application of an ultraviolet curing resin for adhering two substrates and after adhering the substrates together, an optical disks manufacturing method which can produce such optical disks at high yield, and an optical disk apparatus capable of recording data on such an optical disk and reproducing data therefrom.

[0014] According to an aspect of the present invention, there is provided an optical disk comprising:

[0015] a data recording surface varying a state when irradiated with light;

[0016] a first substrate for supporting the data recording surface; and

[0017] a second substrate for protecting the data recording surface,

[0018] wherein

[0019] title in a radial direction of the first and second substrates as a whole is 0.5° or more and tilt in a tangential direction is 0.10 or less.

[0020] According to another aspect of the present invention, there is provided a method of manufacturing an optical disk having a data recording surface, comprising the steps of:

[0021] forming a first substrate having a data recording surface by injection molding, in which a first metal mold having a predetermined surface curvature in a surface on a cavity side is set to face at a predetermined distance to a second metal mold having a surface curvature in a surface on a cavity side, which corresponds to the surface curvature of the first metal mold in an opposite direction, and a material used to form the first substrate is injected between the first and second metal molds while a stamper holding data to be recorded in advance on the data recording surface is provided for one of the first and second metal molds;

[0022] forming a second substrate capable of protecting the data recording surface of the first substrate, by injection molding, in which a first metal mold having a predetermined surface curvature in a surface on a cavity side is set to face at a predetermined distance to a second metal mold having a surface curvature in a surface on a cavity side, which corresponds to the surface curvature of the first metal mold in an opposite direction, and a material used to form the first substrate is injected between the first and second metal molds;

[0023] setting a predetermined amount of an ultraviolet curing resin between the substrates; and

[0024] adhering the two substrates together while irradiating an ultraviolet ray.

[0025] According to still another aspect of the present invention, there is provided a method of manufacturing an optical disk having a data recording surface, comprising the steps of:

[0026] forming a first substrate having a data recording surface which is convex with a predetermined curvature, by injection molding, in which a first metal mold having a flat surface on a cavity side is set to face at a predetermined distance to a second metal mold having a flat surface on a cavity side, the metal molds are set to have a predetermined difference in temperature between these metal molds while a stamper holding data to be recorded in advance on the data recording surface is provided for one of the first and second metal molds, and a material used to form the first substrate is injected between the first and second metal molds;

[0027] forming a second substrate having a surface corresponding to the data recording surface of the first substrate, which is convex with a predetermined curvature, by injection molding, in which a first metal mold having a flat surface on a cavity side is set to face at a predetermined distance to a second metal mold having a flat surface on a cavity side, the metal molds are set to have a predetermined difference in temperature between these metal molds, and a material used to form the second substrate is injected between the first and second metal molds;

[0028] directing these substrates to an inner side such that the convex surfaces face each other, and setting a predetermined amount of an ultraviolet curing resin between the substrates; and

[0029] adhering the two substrates together while irradiating an ultraviolet ray.

[0030] According to still another aspect of the present invention, there is provided a recording apparatus capable of recording an optical disk having a data recording surface, obtained by adhering two substrates having predetermined curvatures such that convex surfaces of the substrates are adhered surfaces, the apparatus comprising:

[0031] a light source for irradiating light;

[0032] an optical set for guiding the light from the light source towards an optical disk;

[0033] a lens for converging the light transmitted by the optical set at a predetermined position of the data recording surface of the optical disk, and guiding light reflected by the data recording surface to the optical set;

[0034] a first light detector for photoelectrically converting the reflection light from the data recording surface, which is returned through the optical set, and outputting a signal corresponding to a difference in distance between the lens and the data recording surface of the optical disk with respect to a focal distance of the lens;

[0035] a second light detector for photoelectrically converting the reflection light from the data recording surface, which is returned through the optical set, and outputting a signal corresponding to a difference between a center of a light beam spot formed at a focal point position of the lens and a center of either one of a track and a pit line on the data recording surface of the optical disk;

[0036] a third light detector for photoelectrically converting the reflection light from the data recording surface, which is returned through the optical set, and outputting a signal corresponding to a degree of tile of the data recording surface of the optical disk in a radial direction, which is created as the optical disk is rotated;

[0037] a first lens movement mechanism for moving the lens in a direction orthogonal to the data recording surface of the optical disk;

[0038] a first lens movement mechanism for moving the lens in a direction orthogonal to the data recording surface of the optical disk;

[0039] a second lens movement mechanism for moving the lens in a direction parallel to the data recording surface of the optical disk such that the center of either one of the track and bit line coincides with the center of the beam spot; and

[0040] a radial tilt compensation mechanism for moving the lens in a direction to cancel the tilt in the radial direction detected by the third light detector.

[0041] According to still another aspect of the present invention, there is provided a recording apparatus capable of recording an optical disk having a data recording surface, obtained by adhering two substrates having predetermined curvatures such that convex surfaces of the substrates are adhered surfaces, the apparatus comprising:

[0042] a light source for irradiating light;

[0043] an optical set for guiding the light from the light source towards an optical disk;

[0044] a lens for converging the light transmitted by the optical set at a predetermined position of the data recording surface of the optical disk, and guiding light reflected by the data recording surface to the optical set;

[0045] a first light detector for photoelectrically converting the reflection light from the data recording surface, which is returned through the optical set, and outputting a signal corresponding to a difference in distance between the lens and the data recording surface of the optical disk with respect to a focal distance of the lens;

[0046] a second light detector for photoelectrically converting the reflection light from the data recording surface, which is returned through the optical set, and outputting a signal corresponding to a difference between a center of a light beam spot formed at a focal point position of the lens and a center of either one of a track and a pit line on the data recording surface of the optical disk;

[0047] a third light detector for photoelectrically converting the reflection light from the data recording surface, which is returned through the optical set, and outputting a signal corresponding to a degree of tile of the data recording surface of the optical disk in a radial direction, which is created as the optical disk is rotated;

[0048] a first lens movement mechanism for moving the lens in a direction orthogonal to the data recording surface of the optical disk;

[0049] a first lens movement mechanism for moving the lens in a direction orthogonal to the data recording surface of the optical disk;

[0050] a second lens movement mechanism for moving the lens in a direction parallel to the data recording surface of the optical disk such that the center of either one of the track and bit line coincides with the center of the beam spot;

[0051] a radial tilt compensation mechanism for moving the lens in a direction to cancel the tilt in the radial direction detected by the third light detector; and

[0052] a signal reproduction mechanism for photoelectrically converting the reflection light from the data recording surface, which is returned through the optical set, and outputting it as a signal recorded on the data recording surface of the optical disk.

[0053] Additional objects and advantages of the invention will be set forth in the description which follows, and in part will be obvious from the description, or may be learned by practice of the invention. The objects and advantages of the invention may be realized and obtained by means of the instrumentalities and combinations particularly pointed out hereinafter.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

[0054] The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate presently preferred embodiments of the invention, and together with the general description given above and the detailed description of the preferred embodiments given below, serve to explain the principles of the invention.

[0055] **FIG. 1** is a schematic view showing an example of the optical disk manufactured in an embodiment of the present invention;

[0056] **FIG. 2** is a schematic view of an example of metal molds for forming substrates used for the optical disk shown in **FIG. 1** by injection;

[0057] **FIG. 3** is a schematic view illustrating a step for adhering substrates formed with use of the metal molds shown in **FIG. 2**, with an ultraviolet curing resin;

[0058] **FIG. 4** is an explanatory schematic view showing an optical head device of an optical disk apparatus which can be used for the optical disk according to the embodiment shown in FIGS. **1** to **3**;

[0059] **FIG. 5** is a schematic diagram showing an example of a signal processing circuit for processing output signals outputted from photodiodes **106**A to **106**F and **106**H of a light detector **106** of the optical head device shown in **FIG. 4**;

[0060] **FIG. 6** is a schematic diagram showing an example of the optical disk manufactured by another embodiment of the present invention; and

[0061] **FIG. 7** is a schematic diagram showing an example of a metal mold for forming substrates used for a conventional optical disk, by injection molding.

DETAILED DESCRIPTION OF THE INVENTION

[0062] An embodiment of the present invention will now be described in detail with reference to accompanying drawings. The embodiment described below is merely an appropriate specific example and the scope of the invention will not be limited by this embodiment.

[0063] **FIG. 1** is a schematic diagram showing an optical disk manufactured by the use of the embodiment of the present invention.

[0064] An optical disk **1** having a structure in which two substrates are adhered together is manufactured by the following manner. That is, a second resin substrate **21** is adhered to one of the surfaces of a first resin formed substrate **11** using an ultraviolet curing resin **31** as an adhesive layer. The first substrate **11** and the second substrate **21** are each formed to have an outer diameter of 120 mm, an inner diameter of 15 mm and a thickness of 0.6 mm. Further, each of the substrates **11** and **21** is made of a transparent resin material (having a high transmittance rate for light having such a wavelength as of a laser beam), for the wavelength of a laser beam emitted from a semiconductor laser element built in an optical disk apparatus which will be later illustrated with reference to **FIG. 5**.

[0065] On the surface of the first substrate **11**, with which the ultraviolet curing resin **31** is brought into contact, a data recording region **12** and a reflection film layer **13** are laminated in the order. It should be noted here that the data recording region **12** is shielded from the outer atmosphere as it is covered by the reflection film **13**.

[0066] **FIG. 2** is a schematic diagram showing metal molds for injection molding, used to make the first and second substrates **11** and **21** shown in **FIG. 1** by the injection molding.

[0067] The injection metal molds shown in **FIG. 2** is made of a fixed metal mold portion **40** and a movable metal mold portion **50**, and a stamper **41** is provided on the surface of the fixed metal mold portion **40**, which faces the movable metal mold portion **50**. At a predetermined position of the fixed metal mold portion **40**, there is provided a nozzle **42** for supplying a melted resin material supplied from a heating portion (material supply portion) which is not shown, towards the movable metal mold portion **50** at a predetermined pressure. It should be noted here that a space **43** defined between the stamper **41** and the movable metal mold portion **50** is called cavity.

[0068] The stamper **41** of the fixed metal mold portion **40** and the surface of the movable metal mold portion **50**, which is on the cavity **43** side, are each formed on a curved surface having a radius of curvature of 4 m or less and 2 m or more, preferably, a radius curvature of 3 m. It should be noted here that the direction of the curvature surface given to each respective one of the metal mold portions such that they are arranged in opposite directions to each other. In the example shown in **FIG. 2**, the curvature is set to have warp in such a radial direction that is projecting towards the stamper of the fixed metal mold **40**. Further, usually, as the stamper **41**, a type having a pattern formed thereon to be transferred to the data recording region **12** is used to form the first substrate **11**, whereas a mirror surface type stamper is used to form the second substrate **21**. A method for providing a transfer pattern corresponding to the data recording region **12** on the stamper **41**, is as follows. First, a photoresist is applied on a glass master disk, and thus a data pattern is recorded by exposing it by a laser beam. A developing process is carried out after the exposure, and thus a glass master disk on which recesses and projections are recorded is obtained. Next, on the glass master disk, a conductive layer is provided by, for example, non-electrolytic plating method such as sputtering, and with use of the conductive layer as an electrode, the stamper is formed by the plating method. It should be noted that the material mainly used for the stamper is Ni.

[0069] With use of the fixed metal mold portion **40** and the movable metal mold portion **50** shown in **FIG. 2**, the substrates **11** and **21** are thus formed. Due to the curvature surfaces provided in the metal mold portions **40** and **50**, thus formed products are substrates warped in radial directions, and therefore the most of the remaining stress in the resin when injection molding is released in the radial direction when the substrates are cooled down. Thus, the warp in the tangential direction becomes very small. In the substrates **11** and **21** thus formed, the warp in the radial direction is about 0.5° in the case where it is to project to the stamper side, whereas the warp in the tangential direction is 0.1°.

[0070] The projecting surfaces of thus formed substrates **11** and **21** are both directed to the side of the ultraviolet curing resin **31** side (the inner surface of the disk) when the optical disk **1** is formed by adhering two substrates together as shown in **FIG. 1**. During this operation, each of the substrates **11** and **21** has a radial warp which is projecting on the adhesion surface side (that is, projection on the inner diameter side and surface side). Therefore, the ultraviolet curing resin **31** dropped on the inner circumferential portion in order to adhering the substrates together, is sandwiched between both substrates as shown in **FIG. 3**, and thus naturally expanded towards the outer circumferential direction. In this manner, the ultraviolet curing resin **31** can be applied evenly to have a uniform thickness at any coaxial positions, without creating bubbles. After that the ultraviolet curing resin is cured by irradiating an ultraviolet ray thereto, and thus the optical disk **1** made of substrates adhered together through the ultraviolet curing resin **31** serving as the adhesive layer, is obtained.

[0071] In the optical disk **1** having a structure in which two substrates **11** and **21** are adhered together as above, the surface side of each substrate is convex and warped in a radial direction having a radius of curvature of 3 m, that is, warped at about 0.5 in the radial direction and 0.1° or less in the tangential direction.

[0072] As described above, the optical disk **1** thus formed is warped in a radial direction at about 0.5°, which is relatively close to 0.8°, which is the upper limit, whereas the warp in the tangential direction is suppressed to 0.1°or less. The upper limit of the warp in the radial direction is 0.7° in the case where the thickness of the optical disk is 0.6 mm, and it is 0.8° in the case where the thickness of the optical disk is 0.5 mm or less. In the meantime, the upper limit of the warp in the tangential direction is 0.15° in the case where the thickness of the optical disk is 0.6 mm, and it is 0.2° in the case where the thickness of the optical disk is 0.5 mm or less.

[0073] With the above-described structure, a tangential tilt which might not have been eliminated completely even if a tilt compensation mechanism would be provided on the reproducing apparatus side, can be reduced to a substantially negligible level. Further, regarding the radial tile, it becomes possible to easily obtain optical disks within a range where a practical problem does not occur. It should be noted here that the affect of the radial tilt while reproducing a signal can be easily eliminated by providing a radial tilt compensation mechanism such as a radial tilt servo mechanism or a cross talk canceller, in the reproducing apparatus as shown in **FIG. 5**. In this manner, excellent reproduction signals can be obtained.

[0074] Further, even in the case where the affect of the radial tilt becomes significant due to a further increase in the density of the optical disk or an enhance in NA of the objective lens, it suffices only if a tilt compensation mechanism in a radial direction is provided in the reproducing apparatus. Therefore, it becomes possible to obtain good reproduction signals with an inexpensive device.

[0075] **FIG. 4** is an explanatory schematic diagram showing an optical head device extracted from an optical disk apparatus which can be used for the optical disk of the embodiment of the present invention shown in FIGS. **1** to **3**.

[0076] An optical head device **110** shown in **FIG. 4** has a semiconductor laser element **101** serving as a light source, in which a first laser chip **101***a* for outputting a first light beam LA having a wavelength of 780 nm for a CD exclusively for reproduction, and a second laser chip **101***b* for outputting a second light beam LB having a wavelength of, for example, 650 nm for a DVD-RAM which is recordable under a DVD standard, are integrally contained, a diffraction grating **12** for imparting predetermined diffraction properties to the first or second light beam LA or LB outputted from the semiconductor laser element **101**, a hologram plat **103** for directly transmitting a light beam which has passed the diffraction grating **102**, and imparting a predetermined image-forming pattern to a reflection light beam, which will be later described, a collimate lens **104** for collimating a light beam from the hologram plate **103**, an objective lens **105** for converging a light beam collimated by the collimate lens **104**, onto a recording surface of the optical disk **1** serving as a recording medium, and a light detector **106** for detecting a light beam guided thereto after being reflected by the recording surface of the optical disk and its optical path being re-directed by the hologram plate **103**, and outputting a voltage corresponds to the detected light intensity.

[**0077**] The optical beam having the first or second wavelength, emitted from the semiconductor laser element **101** passes through the diffraction grating **102**, in which predetermined diffraction properties are imparted to the beam. Then, the beam is given a predetermined image-forming pattern by the hologram plate **10**, and then made incident on the collimator lens **104**.

[**0078**] The light beam having passed the collimator lens **104** is converted into a collimated light beam which is a parallel beam, and then guided to the objective lens **105**. The optical beam guided to the objective lens **105** is converged by the objective lens **105** to have a beam spot of a predetermined size, and then irradiated on a pit line or a data recording track on the optical disk **1**.

[**0079**] The reflection light beam, which has been reflected and changed its light intensity in accordance with the presence or absence of data on a pit line or data recording track on the recording surface of the optical disk **1**, is captured by the objective lens **105**, and then inputted through the collimate lens **104**, where the converging properties are imparted thereto. After that, the light beam is sent back to the hologram plate **103**. The reflection light beam returned to the hologram plate **103** is re-directed by the hologram plate **103**, and thus the optical path thereof is changed towards the light detector **106**.

[**0080**] The light detector **106**, as will now be described with reference to **FIG. 5**, includes 4-division photodiodes **106**A, **106**B, **106**C and **106**D for detecting a reflection light beam of a zero-order spot generated by the diffraction grating **102**, two photo diodes **106**E and **106**F for detecting reflection light beams of ±1-order light spot, generated by the diffraction grating **102**, to which a positional relationship in a direction orthogonal to the direction in which a track is extended on the optical disk **1** is given to detect reflection light beams by ±1-order light spot, and APC photodiode **106**H for monitoring the intensity of the laser beam. It should be noted that the two photodiodes **106**E and **106**F are situated usually on both sides of the 4-division photodiodes **106**A, **106**B, **106**C and **106**D, located at the center. The APC photodiode **106**H is situated on the upstream side of the rotating direction of the optical disk **1** with regard to, for example, the 4-division photodiodes **106**A, **106**B, **106**C and **106**D.

[**0081**] **FIG. 5** is a schematic diagram illustrating a signal processing circuit for processing output signals from the photodiodes **106**A to **106**F and **106**H of the light detector **106** of the optical head device shown in **FIG. 4**.

[**0082**] The output signals A, B, C, D, E, F, and H, outputted respectively from the photo diodes **106**A, **106**B, **106**C, **106**D, **106**E, **106**F and **106**H are amplified by amplifiers **121***a*, **121***b*, **121***c*, **121***d*, **121***e*, **121***f* and **121***h* to certain levels.

[**0083**] The signals A to F and H outputted respectively from the amplifiers **121***a*, **121***b*, **121***c*, **121***d*, **121***e*, **121***f* and **121***h* are processed such that the signals A and B are added up by a first adder **122***a*, and the signals C and D are added up by a second adder **122***b*. The outputs from these adders **122***a* and **122***b* are processed by a third adder **123** where "(C+D) is subtracted from (A+B)", and the resultant signal is supplied to a focus control circuit **131**, as an focus error signal for making the position of the objective lens **105** to coincide with the position of a predetermined depth of a track or pit line of the recording surface of the optical disk and the distance where the optical beam converged by the objective lens **105**, that is, the focal distance.

[**0084**] On the other hand, an adder **124** forms a signal (A+C), and an adder **125** forms a signal (B+D). These signals (A+C) and (B+D) are inputted to a phase difference detector **132**. The phase difference detector **132** is able to output a tracking error signal accurately even in the case where the objective lens **105** is shifted, and therefore it is very useful. Further, a reflection light beam by ±1-order light spot is converted into a signal (E−F) by an adder **126** and supplied to a tracking control circuit **133** as a tracking error signal. That is, the 0-order light spot and the ±1-order light spot, which are generated by the diffraction grating **101**, are in a relationship in which they are shifted by ½ track at all times while the 0-order light spot is converged on the recording track. Therefore, even if the objective lens **105** is lens-shifted, the track error can be detected accurately.

[**0085**] Further, the signal (A+C) and the signal (B+D) are further added up by the adder **127** and then converted into a signal (A+B+C+D), that is, a reproduction signal. After that, the signal is stored in the buffer memory **134**.

[**0086**] On the other hand, regarding the signal H, the amount of reflection of a light beam emitted from at least one of the first and second laser chips **101***a* and **101***b* of the semiconductor laser element **1** towards the optical disk **1**, on the recording surface is detected and monitored by the APC circuit **137**. In this manner, the intensity of the light beam emitted from one of the laser chips of the semiconductor laser element **1** is controlled to a predetermined level on the basis of the recording data stored in the recording data memory **136**.

[**0087**] In the optical head apparatus having the above-described signal detection system, when a CD disk, for example, is set on a turntable (not shown), a drive motor (not shown) is rotated at a predetermined speed, and at the same time, under the control of the laser drive circuit **138**, the laser beam LA of a reproduction power is irradiated from the first laser chip **101***a* of the semiconductor laser element **101** on the recording surface of the optical disk **1**.

[**0088**] Here, the optical head apparatus **110** is made to face a calibration area of the innermost circumference of the optical disk set on the turntable. With this structure, the reflection laser beam which is a reflection beam of the irradiated laser beam LA is returned to the light detector **106**. The reflection light from the calibration area, which is input to the light detector **106** is converted into a predetermined electric signal by the light detector **106**, and then judged by a disk judgment circuit (not shown) if it is a CD disk.

[**0089**] When the type of the disk set there is detected to be a CD, the laser beam LA having a reproduction power is continuously emitted from the first laser chip **101***a* of the laser element **101** and a signal reproduction operation is started. Here, a detailed description of the operation will be omitted.

[**0090**] When the type of the disk set there is detected to be a DVD-RAM, a laser beam LB having a reproduction power of about the same level to a lower reproduction power as compared to the laser beam LB of a recording power is emitted from the second laser chip **111***a* of the laser element **101** under the control of the CPU **151**. Thus, in the calibration area, the recording sensitivity of the disk is detected and the recording power is predicted. It should be noted that when the reflection laser beam is detected by the APC photodiode **106**H, its output is reflected in the prediction.

[**0091**] Next, on the basis of an output from a phase shift detector **132**, the deflection of the surface of the optical disk **1**, that is, the displacement in the tangential direction of the rotation of the disk **1**, is checked. Thus, the variation amount (the focus offset amount for follow-up) of the objective lens **105** per one rotation of the optical disk **1**, which is to be supplied to a focus coil (not shown) from the focus control circuit **131** is set, and the objective lens **105** is focus-locked with respect to the surface deflection of the optical disk **1**.

[**0092**] From this on, when it is detected that data to be recorded is supplied to the recording data memory **136** from outside or a buffer memory (not shown) under the control of the CPU **151**, the optical head device **1** is moved in the radial direction of the optical disk **1** by a head movement mechanism (not shown) while outputting the laser beam LB, so as to search a recorded region where data has been already recorded.

[**0093**] Next, the optical head device **101** is moved to an arbitrary track on the optical disk **1**, and the decentering of the optical disk **1** (the displacement in the radial direction in one rotation of the disk **1**) is checked on the basis of an output from a tracking control circuit **133** and an output from the phase shift detector **132**. Thus, the variation amount (the track offset amount) of the objective lens **105** per one rotation of the optical disk **1**, which is to be supplied to a focus coil (not shown) from the tracking control circuit **133** is set, and the objective lens **105** is locked with respect to the decentering of the optical disk **1**. It should be noted that as described before, the 0-order light spot and the ±1-order light spot, which are generated by the diffraction grating **101**, are in a relationship in which they are shifted by ½ track at all times while the 0-order light spot is converged on the recording track. Therefore, even if the objective lens **105** is lens-shifted, the track error can be detected accurately.

[**0094**] Thereafter, the recording with the laser beam LB is continued, and the data is recorded in the order along the rotation of the optical disk **1**.

[**0095**] **FIG. 6** is a schematic diagram illustrating an example of a different optical disk from that shown in **FIG. 1**. It should be noted here that the same or similar structure as or to those illustrated in **FIG. 1** are designated by the same reference numerals, and detailed explanations therefor will be omitted here.

[**0096**] As shown in **FIG. 6**, an optical disk **201** having a structure in which two substrates are adhered together is manufactured by the following manner. That is, a second resin substrate **221** is adhered to one of the surfaces of a first resin formed substrate **211** using an ultraviolet curing resin **31** as an adhesive layer.

[**0097**] **FIG. 7** is a schematic diagram showing a flat plate metal mold for injection molding, used to make the first and second substrates **211** and **221** shown in **FIG. 6** by the injection molding. The injection metal mold shown in **FIG. 7** is made of a fixed metal mold portion **240** and a movable metal mold portion **250**, and a stamper **241** is provided on the surface of the fixed metal mold portion **240**, which faces the movable metal mold portion **250**. At a predetermined position of the fixed metal mold portion **240**, there is provided a nozzle **242**. In the case where the metal mold shown in **FIG. 7** is used, the stamper **241** is a mirror-surface stamper on which not data is recorded, and therefore it is not necessary to consider the transfer properties. Further, the forming conditions such as the molding temperature and the molding pressure can be set relatively freely, and thus a substrate with no substantial warp can be relatively easily obtained.

[**0098**] The first substrate **211** is made of a data recording region **12** and a reflection film layer **13** which covers the entire area of the data recording region **12**, as in the case of the substrate **11** shown in **FIG. 11**. Further, the second substrate **221** is substantially identical to the substrate **21** shown in **FIG. 1** except only if there is warp or not.

[**0099**] A method of manufacturing the optical disk **201** shown in **FIG. 6** will now be described.

[**0100**] First, the first substrate **211** and the second substrate **221** are formed in an arbitrary order with use of the fixed metal mold portion **240** and the movable metal mold portion **250** which constitute the flat plate metal mold. It should be noted here that a second substrate **221** with no substantial warp can be obtained by setting the forming conditions such as the molding temperature and molding pressure to predetermined appropriate conditions while actually manufacturing the substrate. Further, for making the first substrate **211**, a stamper on which a transfer pattern corresponding to the data recording region **12** is recorded is used as the stamper **241**. Here, the temperature of the fixed metal mold portion **240** which becomes a adhering surface, to which the stamper **241** is mounted, is set lower by about 6° C., preferably, about 4° C., as compared to the temperature of the movable metal mold portion **250**.

[**0101**] With this structure, the substrate **211** is formed to have a state in which the adhering surface is warped to be convex due to the difference between the resin contraction rate on the side brought into contact with the stamper **241** and situated inner side (adhering surface side) while adhering the two substrates, and the resin contraction rate on the movable metal mold portion **250**. When the substrate **211** is cooled down, the contraction in the radial direction where it is convex on the adhering surface side becomes dominant, the warp created in the tangential direction can be suppressed to a very small level, that is, 0.10 or less in terms of angle.

[**0102**] Next, the first substrate **211** and the second substrate **221** are adhered together by means of the ultraviolet curing resin **31** such that the data recording region **12** of the first substrate **211** is situated on an inner side. The first substrate is warped around its inner diameter side in a radial direction to be convex towards the inner surface, and therefore the ultraviolet curing resin **31** dropped on the inner circumferential portion of the substrate **211** for spin-coat for adhering the substrates together, can be applied on an entire surface of the substrate in a uniform and stable manner.

[**0103**] Then, with irradiation of an ultraviolet ray, the ultraviolet curing resin **31** is cured, and thus the optical disk **201** having the two substrates adhered together can be obtained.

[**0104**] In thus formed optical disk **201**, the most of the remaining stress of the resin resulting in the molding can be released in the radial direction, and therefore the warp in the tangential direction becomes 0.1° or less. In other words, in the optical disk **201**, the direction of the warp is controlled only in the radial direction, and therefore during the reproduction of signals, it becomes unnecessary to consider the affect of the warp in the tangential direction whose tilt cannot be easily compensated. Therefore, even if an inexpensive device equipped only with a tile compensation mechanism for the radial direction is used as the reproduction apparatus for reproducing the optical disk **201**, excellent reproduction signals can be obtained.

[**0105**] With the disk substrates having the above-described structure, the remaining stress of the resin resulting in the formation of the substrates is released only in the radial direction, the warp in the tangential direction can be prevented from becoming even worse, and suppressed to a minimum level. That is, the warp in a tangential direction cannot be easily eliminated by means of the tilt compensation mechanism on the disk drive side, and a substrate with the above-described warp properties, has such a very small warpage in its tangential direction; therefore excellent reproduction signals can be obtained merely by providing a radial tilt compensation mechanism in the reproduction apparatus. In addition, its radial tilt is convex towards the adhering surface side, and the tangential tilt is small, and therefore when an adhesive such as ultraviolet curing resin is applied by a spin coat method for adhering two substrates together, it can be applied easily on an entire surface of the substrate uniformly without bubbles. In this manner, it is possible to stably manufacture optical disks of such a good quality that the level of reproduction signals is stable and undesired noise components are not easily generated.

[**0106**] Further, as a means for manufacturing substrates having the above-described warp properties in a stable and easy manner, a metal mold with a cavity, having warp in the radial direction imparted in advance, is used. Therefore, the remaining stress of the resin in the formed substrate is released only in the radial direction, and therefore the tangential tilt becomes small. In order to prevent the remaining stress of the resin and the radial tilt from becoming excessively inappropriate for adhering substrates and reproducing signals, the radius of curvature of the surface of the metal mold cavity is set to 2 m or more but 4 m or less, and the direction of the surface curvature is set such that the adhering surface is convex. Within such a range of the radius of curvature, it will not drift significantly from the standard value of the warp in the radial direction of 0.8° for substrates of a DVD-type. Therefore, the effect of the radial tilt can be surely removed by the radial tilt compensation mechanism on the disk drive while producing signals. Further, as the adhering surface is set to be convex, it is possible to apply an ultrasonic curing resin used for adhering substrates on an entire surface of a substrate uniformly and stably.

[**0107**] As described above, the metal mold cavity is (made to be) warped in a radial direction in advance. With this structure, the warp of the formed substrate can be controlled advantageously for the adhesion step and signal reproduction. Thus, if the degree of freedom of the forming conditions is limited in accordance with a further increase in the density of the optical disk, the warp of the substrate can be controlled stably merely by controlling forming conditions slightly.

[**0108**] Further, there is a method of manufacturing a substrate, which can suppress the tangential tilt by relaxing in the radial direction the remaining stress of the resin within a formed substrate with certain forming conditions, for manufacturing a substrate having warp properties advantageous for adhesion and signal reproduction. In this method, the temperature of the metal mold portion which becomes a adhering surface, is set lower by about 4° C. or more, as compared to the temperature of the opposite metal mold portion. With this structure, the resin contraction rate on the adhering surface becomes lower, and therefore a substrate whose adhering surface is convex can be obtained. When the substrate is cooled down, the contraction in the radial direction becomes dominant, the warp created in the tangential direction can be suppressed to a very small level. The substrate thus obtained has a radial tilt which is convex to the adhering side and further a small tangential tilt. Therefore, when such substrates are adhered together, the ultraviolet curing resin can be easily applied on an entire surface of the substrate in a uniform and stable manner without creating bubbles by means of a spin-coat method. Therefore, high-quality optical disks can be manufactured stably. Further, tangential tilt, which, in some cases, cannot be completely removed by the tilt compensation mechanism, becomes small, and thus it is advantageous for reproduction of signals.

[**0109**] As described above, according to the present invention, excellent reproduction signals can be obtained merely by providing a radial compensation mechanism on the reproduction device.

[**0110**] Further, in the adhesion step as well, it becomes possible to apply an adhesive uniformly without creating any bubbles.

[**0111**] In this manner, an optical disk substrate having warp properties advantageously for the adhesion step and signal reproduction can be easily obtained. Thus, if the degree of freedom of the forming conditions is limited, the warp of the substrate can be controlled stably.

[0112] Therefore, the yield of the optical disk can be improved and the manufacturing cost for the optical disk can be reduced.

[0113] Further, it becomes possible to manufacture an optical disk capable of reproducing a signal in a stable manner at high efficiency.

[0114] Additional advantages and modifications will readily occur to those skilled in the art. Therefore, the invention in its broader aspects is not limited to the specific details and representative embodiments shown and described herein. Accordingly, various modifications may be made without departing from the spirit or scope of the general inventive concept as defined by the appended claims and their equivalents.

What is claimed is:

1. An optical disk comprising:

a data recording surface varying a state when irradiated with light;

a first substrate for supporting the data recording surface; and

a second substrate for protecting the data recording surface,

wherein

title in a radial direction of the first and second substrates as a whole is 0.5° or more and tilt in a tangential direction is 0.1° or less.

2. An optical disk according to claim 1, wherein the tilt in the radial direction is convex to an adhering direction when the second substrate is adhered.

3. An optical disk according to claim 1, wherein an upper limit for the tilt in the radial direction is 0.7° when a thickness of an entire optical disk is 0.6 mm.

4. An optical disk according to claim 1, wherein an upper limit for the tilt in the radial direction is 0.8° when a thickness of an entire optical disk is 0.5 mm or less.

5. An optical disk according to claim 1, wherein an upper limit for the tilt in the tangential direction is 0.15° when a thickness of an entire optical disk is 0.6 mm.

6. An optical disk according to claim 1, wherein an upper limit for the tilt in the tangential direction is 0.2° when a thickness of an entire optical disk is 0.5 mm or less.

7. A method of manufacturing an optical disk having a data recording surface, comprising the steps of:

forming a first substrate having a data recording surface by injection molding, in which a first metal mold having a predetermined surface curvature in a surface on a cavity side is set to face at a predetermined distance to a second metal mold having a surface curvature in a surface on a cavity side, which corresponds to the surface curvature of the first metal mold in an opposite direction, and a material used to form the first substrate is injected between the first and second metal molds while a stamper holding data to be recorded in advance on the data recording surface is provided for one of the first and second metal molds;

forming a second substrate capable of protecting the data recording surface of the first substrate, by injection molding, in which a first metal mold having a predetermined surface curvature in a surface on a cavity side is set to face at a predetermined distance to a second metal mold having a surface curvature in a surface on a cavity side, which corresponds to the surface curvature of the first metal mold in an opposite direction, and a material used to form the first substrate is injected between the first and second metal molds;

setting a predetermined amount of an ultraviolet curing resin between the substrates; and

adhering the two substrates together while irradiating an ultraviolet ray.

8. A method of manufacturing an optical disk having a data recording surface, according to claim 7, wherein the surface curvature is 2 m or more and 4 m or less in terms of radius of curvature.

9. A method of manufacturing an optical disk having a data recording surface, according to claim 7, wherein a direction of curvature of the metal mold is convex with respect to a direction of an interface where the two substrates are adhered together.

10. A method of manufacturing an optical disk having a data recording surface, comprising the steps of:

forming a first substrate having a data recording surface which is convex with a predetermined curvature, by injection molding, in which a first metal mold having a flat surface on a cavity side is set to face at a predetermined distance to a second metal mold having a flat surface on a cavity side, the metal molds are set to have a predetermined difference in temperature between these metal molds while a stamper holding data to be recorded in advance on the data recording surface is provided for one of the first and second metal molds, and a material used to form the first substrate is injected between the first and second metal molds;

forming a second substrate having a surface corresponding to the data recording surface of the first substrate, which is convex with a predetermined curvature, by injection molding, in which a first metal mold having a flat surface on a cavity side is set to face at a predetermined distance to a second metal mold having a flat surface on a cavity side, the metal molds are set to have a predetermined difference in temperature between these metal molds, and a material used to form the second substrate is injected between the first and second metal molds;

directing these substrates to an inner side such that the convex surfaces face each other, and setting a predetermined amount of an ultraviolet curing resin between the substrates; and

adhering the two substrates together while irradiating an ultraviolet ray.

11. A method of manufacturing an optical disk having a data recording surface, according to claim 10, wherein the temperatures of the first metal mold and the second metal mold are set such that the temperature of the metal mold corresponding to the interface where the two substrates are adhered is set lower than the temperature of the other metal mold.

12. A method of manufacturing an optical disk having a data recording surface, according to claim 10, wherein the difference in temperature between the first metal mold and the second metal mold is 4° C. or more.

13. A method of manufacturing an optical disk having a data recording surface, according to claim 12, wherein the difference in temperature between the first metal mold and the second metal mold is 6° C. or less.

14. A method of manufacturing an optical disk having a data recording surface, according to claim 10, wherein the surface curvature is 2 m or more and 4 m or less in terms of radius of curvature.

15. A recording apparatus capable of recording an optical disk having a data recording surface, obtained by adhering two substrates having predetermined curvatures such that convex surfaces of the substrates are adhered surfaces, said apparatus comprising:

a light source for irradiating light;

an optical set for guiding the light from the light source towards an optical disk;

a lens for converging the light transmitted by the optical set at a predetermined position of the data recording surface of the optical disk, and guiding light reflected by the data recording surface to the optical set;

a first light detector for photoelectrically converting the reflection light from the data recording surface, which is returned through the optical set, and outputting a signal corresponding to a difference in distance between the lens and the data recording surface of the optical disk with respect to a focal distance of the lens;

a second light detector for photoelectrically converting the reflection light from the data recording surface, which is returned through the optical set, and outputting a signal corresponding to a difference between a center of a light beam spot formed at a focal point position of the lens and a center of either one of a track and a pit line on the data recording surface of the optical disk;

a third light detector for photoelectrically converting the reflection light from the data recording surface, which is returned through the optical set, and outputting a signal corresponding to a degree of tile of the data recording surface of the optical disk in a radial direction, which is created as the optical disk is rotated;

a first lens movement mechanism for moving the lens in a direction orthogonal to the data recording surface of the optical disk;

a first lens movement mechanism for moving the lens in a direction orthogonal to the data recording surface of the optical disk;

a second lens movement mechanism for moving the lens in a direction parallel to the data recording surface of the optical disk such that the center of either one of the track and bit line coincides with the center of the beam spot; and

a radial tilt compensation mechanism for moving the lens in a direction to cancel the tilt in the radial direction detected by the third light detector.

16. A recording apparatus capable of recording an optical disk having a data recording surface, obtained by adhering two substrates having predetermined curvatures such that convex surfaces of the substrates are adhered surfaces, said apparatus comprising:

a light source for irradiating light;

an optical set for guiding the light from the light source towards an optical disk;

a lens for converging the light transmitted by the optical set at a predetermined position of the data recording surface of the optical disk, and guiding light reflected by the data recording surface to the optical set;

a first light detector for photoelectrically converting the reflection light from the data recording surface, which is returned through the optical set, and outputting a signal corresponding to a difference in distance between the lens and the data recording surface of the optical disk with respect to a focal distance of the lens;

a second light detector for photoelectrically converting the reflection light from the data recording surface, which is returned through the optical set, and outputting a signal corresponding to a difference between a center of a light beam spot formed at a focal point position of the lens and a center of either one of a track and a pit line on the data recording surface of the optical disk;

a third light detector for photoelectrically converting the reflection light from the data recording surface, which is returned through the optical set, and outputting a signal corresponding to a degree of tile of the data recording surface of the optical disk in a radial direction, which is created as the optical disk is rotated;

a first lens movement mechanism for moving the lens in a direction orthogonal to the data recording surface of the optical disk;

a first lens movement mechanism for moving the lens in a direction orthogonal to the data recording surface of the optical disk;

a second lens movement mechanism for moving the lens in a direction parallel to the data recording surface of the optical disk such that the center of either one of the track and bit line coincides with the center of the beam spot;

a radial tilt compensation mechanism for moving the lens in a direction to cancel the tilt in the radial direction detected by the third light detector; and

a signal reproduction mechanism for photoelectrically converting the reflection light from the data recording surface, which is returned through the optical set, and outputting it as a signal recorded on the data recording surface of the optical disk.

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