DESCRIPTION

TITLE OF THE INVENTION

GLASS SUBSTRATE FOR MAGNETIC RECORDING MEDIUM AND MAGNETIC RECORDING MEDIUM USING THE GLASS SUBSTRATE FOR MAGNETIC RECORDING MEDIUM

TECHNICAL FIELD

The present invention relates to a glass substrate for magnetic recording medium and a magnetic recording medium using the glass substrate for magnetic recording medium.

BACKGROUND ART

Conventionally, an aluminum alloy substrate has been used for a substrate for magnetic recording medium used for a magnetic disk recording apparatus or the like. However, with a demand for high-density recording in recent years, a glass substrate, which is harder than the aluminum alloy substrate and excellent in flatness and smoothness, has become a mainstream.

Then, with high-density recording of a magnetic disk (hereinafter, may be referred to as "magnetic recording medium") in recent years, magnetic signals have been recorded minutely on the magnetic disk, thereby making the signals very weak. In order to read and record such weak signals, a request for shortening as much as possible a distance between a magnetic disk and a magnetic head has been made.

In order to reduce a distance between a magnetic head and a magnetic disk rotating at a high speed, that is, to reduce a floating amount of the magnetic head, the

surface of a glass substrate for magnetic recording media, which is a substrate of the magnetic disk, must be an extremely uniform surface so that the magnetic disk and the magnetic head are not brought into contact with each other.

Various studies have been made on surface characteristics of the glass substrate for magnetic recording medium in order to reduce a distance between a magnetic head and a magnetic disk. For example, Patent Document 1 teaches reducing a surface roughness Ra to be less than or equal to a predetermined value on the assumption that a form of a defect existing on a glass substrate for magnetic disks gives an influence thereto.

PRIOR ART DOCUMENT

PATENT DOCUMENT

Patent Document 1: WO2010/001843

SUMMARY OF THE INVENTION

PROBLEM TO BE SOLVED BY THE INVENTION

However, in the above-mentioned Patent Document 1, a surface roughness Ra of only an area of a limited portion of a recordable and reproducible area of a glass substrate for magnetic recording medium is merely evaluated. Accordingly, a surface roughness Ra is not measured in a large part of the recordable and reproducible area. Therefore, there may be a problem in that an area where a surface roughness Ra is large in the recordable and reproducible area. For example, there are problems that it is difficult to reduce a floating amount of a magnetic head and a distance between a magnetic disk and a magnetic head is not stable, which causes generation

of a magnetic noise.

When manufacturing a magnetic recording medium, a magnetic layer is deposited on a surface of a glass substrate for magnetic recording medium, however, there may be a case where nonuniformity occurs in a crystal grain size of the deposited magnetic layer if there is an area having a high surface roughness Ra (an area of which surface roughness Ra is nonuniform) in the principal surface of the glass substrate for magnetic recording medium. In such a magnetic recording medium having a nonuniform magnetic layer (a magnetic layer of which crystal grain size is nonuniform), an amount of magnetic noise may be increased in the area where the crystal grain size is nonuniform. Accordingly, there may be a problem in that an accuracy of reading and writing on a magnetic recording medium by a magnetic head decreases, a recording density decreases, and so forth.

In consideration of the above-mentioned problems in the conventional techniques, it is an object of the present invention to provide a glass substrate for magnetic recording medium in which a surface roughness Ra falls within a predetermined range in an entire surface of at least one of the principal surfaces of the glass substrate for magnetic recording medium.

MEANS TO SOLVE PROBLEM

In order to solve the above-mentioned problems, the present invention provides a glass substrate for magnetic recording medium, comprising: a pair of principal surfaces, wherein, in at least one of the principal surfaces, a maximum value of a surface roughness Ra measured in each of evaluation areas in a lattice form

that are set in an entire surface of the principal surface is less than or equal to 1.7 times a mean value of the surface roughness Ra.

EFFECT OF THE INVENTION

According to the glass substrate for magnetic recording medium of the present invention (hereinafter, may be simply referred to as "glass substrate"), when the surface roughness Ra (arithmetic mean roughness) is measured in each evaluation area set in at least one of the principal surfaces of the glass substrate, the maximum value thereof has a predetermined relationship with the mean value of the measured values of the surface roughness Ra.

For this reason, it is possible to form a glass substrate in which the values of the surface roughness Ra fall within a predetermined range over the entire surface of the at least one of the principal surfaces of the glass substrate, and does not have an area of which surface roughness Ra is locally high, and the entire surface of the principal surface is uniform and smooth.

According to the glass substrate for magnetic recording medium of the present invention, crystal grains are prevented from being coarse and large when forming a magnetic layer on a surface of the glass substrate, and, thereby, a magnetic recording medium having a smooth surface with a magnetic layer of which crystal grain size is uniform can be provided.

Thereby, a magnetic noise of the magnetic recording medium can be prevented from being generated, a distance between the magnetic recording medium and a magnetic head can be set smaller than a conventional one,

and a distance between the magnetic recording medium and the magnetic head can be stabilized, and, therefore, a reading and writing accuracy of records on the magnetic recording medium can be made higher than a conventional one.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a view for explaining a glass substrate for magnetic recording medium according a first mode for carrying out the present invention and evaluation areas thereof.

MODE FOR CARRYING OUT THE INVENTION

Although a mode for carrying out the present invention is hereafter explained with reference to the drawing, the present invention is not limited to the mode for carrying out the invention explained below, and various modifications and replacements can be made to the mode for carrying out the invention mentioned below without departing from the scope of the present invention.

(First Mode for carrying out the Invention)

In the present mode for carrying out the invention, a description is given of a glass substrate for magnetic recording medium of the present invention.

The glass substrate for magnetic recording medium of the present invention features that a maximum value of a surface roughness Ra measured in each of evaluation areas in a lattice form set in an entire area of the principal surface is less than or equal to 1.7 times a mean value of measured values of the surface roughness Ra.

A description will now be given, with reference

to FIG. 1, of a specific evaluation method.

The glass substrate for magnetic recording medium has a disk shape having a circular aperture at a center part thereof, as illustrated in FIG. 1-(A). In the present invention, a surface roughness Ra is measured for each of evaluation areas in a lattice form set on at least one of principal surfaces of the glass substrate, that is, an entire surface of a recordable and reproducible area when the glass substrate is formed as a magnetic recording medium. As illustrated in FIG. 1-(A) and (B), the evaluation areas are defined by dividing the principal surface into a plurality of portions without a gap therebetween. It is preferable to make the evaluation areas identical in shape.

Measuring means for measuring the surface roughness (arithmetic mean roughness) Ra is not limited to a specific means, and can be any means which can measure a surface roughness of each of the evaluation areas set in a lattice form on an entire surface. For example, the surface roughness Ra can be measured by a scanning interference microscope or the like.

A shape and size of each of the evaluation areas set in a lattice form are not limited to a particular shape and size, and, as a shape of the evaluation areas, there is a lattice form such as, for example, a square lattice, a triangular lattice, a hexagonal lattice, a rhombic lattice, a rectangular lattice, a parallelogram lattice, etc.

As a size of each evaluation area, for example, if the shape of the evaluation area is a square lattice, a length of one side may be set in a range of 5 μm to 50 μm, and can be set to a desired size such as, for example, a

50 μm square, 40 μm square, 30 μm square, 20 μm square, etc.

Moreover, if the form of each evaluation area is a form other than a square lattice, a size thereof may be set to a size pursuant to the square lattice, that is, the size of each evaluation area may be set so that an area of each evaluation area is the same as the case where the area of the square lattice (for example, 25 μm^2 to 2500 μm^2. It should be noted that the size of the evaluation area will be hereinafter described based on a length of one side of a square lattice, however, it is not limited to the square lattice, and, if the evaluation area is set in a form other than the square lattice, the size of each evaluation area means a size (area) pursuant to the form of each of the evaluation areas.

Furthermore, the shape and size of each of the evaluation areas set in a lattice form may be different over an entire surface of the principal surface (for example, the entire surface of the principal surface is divided into predetermined areas, and a shape and size is set to each of the areas, or the like), but preferably be the same shape and size.

Because it is particularly preferable to perform an evaluation for each area of a size the same as a magnetic head or each area having a size smaller than the magnetic head, it is preferable to perform an evaluation with a size less than or equal to 50 μm square, and, more preferably, a size less than or equal to 30 μm square.

However, if the size of the evaluation area is excessively small, it becomes difficult to perform a process of evaluation because the number of the evaluation areas is large, and it is preferable to set each

evaluation area to be 5 μm square or larger, and more preferably, 10 μm square or larger.

Here, a description is given of the evaluation area. FIG. 1-(A) and (B) schematically illustrate each evaluation area. It should be noted that although lines are indicated in the drawings, they are for explaining evaluation areas, and the lines are not actually drawn on a glass substrate. Here, a description is given of an example in which the evaluation area is a square lattice.

FIG. 1-(B) is an enlarged illustration of a part of FIG. 1-(A) for the purpose of explaining the evaluation area. Each block of the square lattice (square shape) illustrated in FIG. 1-(B) indicates the evaluation area, and, for example, a length A to F of each side is set to 30 μm.

Then, in the glass substrate for magnetic recording medium of the present invention, a mean value of a surface roughness Ra calculated from results of measurement of a surface roughness with respect to each evaluation area in an entire area of one of the principal surfaces is set to Ra_{ave}. Further, when a maximum value of the surface roughness Ra, that is, the surface roughness Ra of an evaluation area having a maximum surface roughness value from among the evaluation areas in the aforementioned entire principal surface, is set to Ra_{max}, a relationship $Ra_{max} \leqq 1.7 \cdot Ra_{ave}$ is satisfied, that is, the maximum value of the surface roughness Ra is less than or equal to 1.7 times the mean value of the surface roughness Ra.

Here, the relationship between Ra_{ave} and Ra_{max} is preferably $Ra_{max} \leqq 1.4 \cdot Ra_{ave}$, and particularly preferably $Ra_{max} \leqq 1.3 \cdot Ra_{ave}$.

This is because the variation in the surface roughness Ra becomes smaller in the entire principal surface as a ratio of the maximum value and the mean value of the surface roughness Ra is closer to 1.0, and because it indicates that the principal surface of the glass substrate becomes smoother (that is, $Ra_{max} \geqq 1.0 \cdot Ra_{ave}$).

It should be noted that although there are two principal surfaces on upper and lower sides of the glass substrate for magnetic recording medium, there may be a case where only one of the two principal surfaces sets a recordable and reproducible area when the glass substrate is formed as a magnetic disk. In such a case, it is sufficient that the one of the principal surfaces satisfies the above-mentioned conditions. If both the upper and lower surfaces are set as a recordable and reproducible area when formed in a magnetic disk, it is desirable that the mean value and the maximum value of the surface roughness Ra measured and calculated for each of the two surfaces satisfy the above-mentioned conditions. The same applies to a mean value and a standard deviation mentioned later.

Further, the standard deviation of the surface roughness Ra measured in each evaluation area set in the entire surface of the above-mentioned principal surface is preferably less than or equal to 0.012 nm, and, more preferably, less than or equal to 0.010 nm, and, particularly preferable to be less than or equal to 0.008 nm.

This is because a reduction in the standard deviation means a reduction in a variation of the surface roughness Ra, and indicates that the principal surface of the glass substrate becomes smoother.

Thus, because the entire surface of the principal surface is smooth and there is no area having a high surface roughness Ra locally, crystal grains are prevented from becoming coarse locally, when forming a magnetic layer to make a magnetic recording medium, and a magnetic film having a uniform crystal grain size and a smooth surface can be obtained.

For this reason, a distance between a magnetic disk (magnetic recording medium) and a magnetic head can be reduced. Moreover, because the distance between the magnetic disk and the magnetic head becomes stable, occurrence of a magnetic noise can be suppressed, and it becomes possible to set a writing-and-reading accuracy of records and a recording density higher than a conventional one. Furthermore, a bit size can be reduced by using the magnetic recording medium having the magnetic layer of which crystal grain size is small and uniform, which permits attempting an improvement in the surface recording density of the magnetic recording medium.

Moreover, it is desirable that the mean value of the surface roughness Ra measured in each evaluation area in the lattice form set in the entire surface of the above-mentioned principal surface is less than or equal to 0.08 nm, and, more preferably, less than or equal to 0.07 nm.

This is because a reduction in the mean value of the surface roughness Ra indicates that the entire principal surface of the glass substrate is caused to be smoother.

If the entire principal surface of the glass substrate is smooth, crystal grains are prevented from being coarse to reduce and uniformize the size of the

crystal grains, when forming a magnetic layer, thereby permitting acquisition of a magnetic film having a uniform and smooth surface.

A bit size can be reduced by reducing and uniformizing a size of crystal grains, which permits attempting an improvement in the surface recording density of a magnetic recording medium. Moreover, it becomes possible to reduce a distance between a magnetic disk and a magnetic head and reduce a variation in the distance between the magnetic disk and the magnetic head, which permits suppressing generation of a magnetic noise and it becomes possible to set a writing-and-reading accuracy of records and a recording density higher than a conventional one.

Here, a description will be given of a manufacturing method of the glass substrate for magnetic recording medium of the present invention.

The glass substrate for magnetic recording medium can be manufactured by a manufacturing method including the following processes 1 through 4.

(Process 1) A shaping process of chamfering an inner peripheral surface and an outer peripheral surface after forming a glass substrate material into a glass substrate of a disc shape having a circular hole at a central part thereof.

(Process 2) An edge surface polishing process of polishing the edge surfaces of the glass substrate (an inner peripheral surface and an outer peripheral surface).

(Process 3) A principal surface polishing process of polishing principal surfaces of the above-mentioned glass substrate.

(Process 4) A cleaning process of precision

cleaning and drying the above-mentioned glass substrate.

Then, the glass substrate for magnetic recording medium obtained by the manufacturing method including the above mentioned processes can be made into a magnetic recording medium by further performing a process of forming a thin film such as a magnetic layer on the glass substrate.

Here, the shaping process of (Process 1) is to process a glass substrate material, which is formed by a float process, a fusion method, a press-molding process, a down-draw method, or a re-draw process, into a glass substrate of a disc shape having a circular hole at the center part thereof. It should be noted that the glass substrate material used may be amorphous glass or crystal glass, or may be strengthened glass having a compression stress layer (strengthening layer) on a surface of a glass substrate.

Then, the edge surface polishing process of (Process 2) is to polish edges of the glass substrate (side surface parts and chamfered surfaces).

The principal surface polishing process of (Process 3) is to simultaneously polish upper and lower principal surfaces of the glass substrate while supplying a polishing liquid onto the principal surfaces of the glass substrate. The polishing of the glass substrate of the present invention may be only a primary polishing, or may perform a primary polishing and a secondary polishing may be performed, or a tertiary polishing may be performed after a secondary polishing.

Then, it is desirable to use a pad, which has been subjected to a cleaning process by pure water for 10 minutes or longer, as a polishing pad used in the

polishing process. This is to suppress aggregation of abrasive grains contained in the polishing liquid.

It should be noted that, as for the polishing liquid used for polishing performed at the end of the principal surface polishing process, it is desirable to use a polishing liquid containing a colloidal silica of which primary particle diameter is greater than or equal to 5 nm as an abrasive grain and having a pH value of 3 or higher.

This is because, if the primary particle diameter of the colloidal silica contained in the polishing liquid is smaller than 5 nm, the colloidal silica tends to aggregate, which may cause a problem such that a polishing cannot be performed stably, a surface roughness Ra of the principal surface becomes large, etc.

The primary particle diameter of the colloidal silica is preferably greater than or equal to 5 nm, and, more preferably greater than or equal to 8 nm, and particularly preferably greater than or equal to 10 nm. Additionally, the primary particle diameter of the colloidal silica is preferably less than or equal to 30 nm, and, more preferably less than or equal to 28 nm, and particularly preferably less than or equal to 18 nm.

Moreover, if the pH value of the polishing liquid is lower than 3, the surface roughness Ra of the principal surface of the polished glass substrate may be high due to an influence of acid. Thus, the pH value of the polishing liquid is preferably 3 or higher, and more particularly 3.5 or higher, and particularly preferably 4 or higher.

Prior to the above-mentioned principal surface polishing process of (Process 3), a lapping (for example,

free abrasive lapping, fixed abrasive lapping, etc.) may be performed. Moreover cleaning of the glass substrate (in process cleaning) or etching of a surface of the glass substrate (in process etching) may be performed between the processes. It should be noted that the lapping of a principal surface corresponds to polishing of a principal surface in a broad sense.

Further, if a large mechanical strength is required for the glass substrate for magnetic recording medium, a strengthening process (for example, a chemical strengthening process) of forming a compression stress layer (strengthening layer) on a surface layer of a glass substrate may be performed before the polishing process or after the polishing process or may be performed during the polishing process.

(Second Mode for Carrying Out the Invention)

In the present mode for carrying out the invention, a description is given of a magnetic recording medium (magnetic disk) using the glass substrate for magnetic recording medium explained in the first mode for carrying out the invention.

The magnetic recording medium of the present invention is not limited to a specific structure, if the glass substrate for magnetic recording medium explained in the first mode for carrying out the invention is used, and, there is, for example, a magnetic recording medium having a magnetic layer, a protective layer and a lubrication layer thereon.

Although there are a horizontal magnetic recording method and a vertical magnetic recording method for a magnetic recording medium, a specific manufacturing method is explained below with the vertical magnetic

recording method as an example.

The magnetic recording medium is provided with a magnetic layer, a protective layer and a lubrication layer on at least a surface thereof. Then, in a case of the vertical magnetic recording method, it is usual to provide a soft magnetic substrate layer, which plays a role of circulating a recording magnetic field from a magnetic head. Thus, for example, a soft magnetic substrate layer, a non-magnetic intermediate layer, a vertical recording magnetic layer, a protective layer and a lubrication layer are laminated on the principal surface of the glass substrate in that order.

A description will be given below of each layer.

As a soft magnetic substrate layer, for example, CoNiFe, FeCoB, CoCuFe, NiFe, FeAlSi, FeTaN, FeN, FeTaC, CoFeB, CoZrN, etc., may be used.

A nonmagnetic intermediate layer is formed of Ru, an Ru alloy, etc. The nonmagnetic intermediate layer has a function of facilitating epitaxial growth of a vertical recording magnetic layer and a function of cutting a magnetic exchange coupling between the soft magnetic substrate layer and the recording magnetic layer.

A vertical recording magnetic layer is a magnetic film of which axis of easy magnetization is directed in a perpendicular direction with respect to a substrate surface, and contains Co and Pt at least. In order to reduce an inter-granular exchange coupling, which may be a cause of a high intrinsic medium noise, it is desirable to form a fine particle structure (granular structure) in which grains are well-isolated. Specifically, it is desirable to use a material of a CoPt alloy or the like to which an oxide (SiO_2, SiO, Cr_2O_3, CoO,

Ta_2O_3, TiO_2, etc.) or Cr, B, Cu, Ta, Zr, etc., is added.

The soft magnetic substrate layer, the nonmagnetic intermediate layer and the vertical recording magnetic layer mentioned thus far can be manufactured according to an inline sputter method, a DC magnetron sputter method, or the like in a continuous fashion.

A protection layer is provided for preventing the vertical recording magnetic layer from being corroded and preventing damage on a medium surface even when a magnetic head contacts the medium, and is provided on the vertical recording magnetic layer. As a protective layer, a material containing C, ZrO_2, SiO_2, etc., may be used.

As a formation method thereof, for example, an inline sputter method, a CVD method, a spin coat method, etc., may be used.

A lubrication layer is formed on the surface of the protective layer in order to reduce friction between a magnetic head and the recording medium (magnetic disk). For example, perfluoro polyether, fluorinated alcohol, fluorinated carboxylic acid, etc., may be used to form the lubrication layer. The lubrication layer can be formed according to a dip method, a spray method, etc.

Because the magnetic recording medium (magnetic disk) produced using the glass substrate for magnetic recording medium of the present invention according to the procedure mentioned above has a surface roughness Ra of the entire principal surface of the glass substrate falling within a predetermined range, crystal grains are suppressed from being coarse, when forming the magnetic layers, and the size of the crystal grains can be made small and uniform. Thereby, the bit size of the magnetic recording medium can be made small, and an improvement in

a surface recording density of the magnetic recording medium can be attempted. Moreover, because a distance between the magnetic recording medium and the magnetic head can be smaller than a conventional one, and a fluctuation in the distance between the magnetic recording medium and the magnetic head can be made small, it is possible to suppress generation of a magnetic noise and raise a reading-and-writing accuracy of records and a recording density can be made higher than a conventional one.

(Embodiment)

Although a description will be given below of specific examples, the present invention is not limited to those examples.

First, a description is given of an evaluation method of a glass substrate for magnetic recording medium in the examples and comparative examples mentioned below, and an evaluation method of a magnetic recording medium in which a thin film such as a magnetic layer, etc., is deposited on a glass substrate surface.

(1) Surface Roughness (arithmetic mean roughness) Ra

A surface roughness Ra was measured using a scanning interference microscope (ZeMapper manufactured by Zygo corporation). The measurement area of the surface roughness Ra was set to a range including an entire surface of a recordable and reproducible area of the glass substrate.

In the present embodiment, evaluation areas each of which has a square lattice shape having a side of 30 μm were set on one of the entire principal surfaces of the glass substrate for magnetic recording medium, and a

surface roughness Ra was acquired from each of the evaluation areas.

(2) Certify Test

A certify test evaluates a defect (signal quality) of a magnetic layer or the like of a magnetic recording medium. Evaluation was made by performing writing, reproducing, erasing, re-reproducing, etc., of a write signal for each track of a disk using a test head in which a magnetic head for a certify test is provided to a head slider, and reproducing a relationship between a magnetic head of a magnetic disk apparatus and a magnetic disk. In the present embodiment, an EP (Extra Pulse) error was evaluated.

The EP error is a reproduction signal, which is largely deviated from amplitude of a reproduction signal of the test head when there exists on a magnetic recording medium an area where damage, a foreign substance or a roughness defect is present or a size of crystal grains is nonuniform.

In the present embodiment, 1000 pieces of magnetic recording medium were evaluated, and a ratio of magnetic recording medium in which an EP error occurred was set as an EP occurrence rate.

A description is given below of Examples 1 through 10, which are glass substrates for magnetic recording medium and magnetic recording media made by forming a magnetic recording layer or the like on a glass substrate for magnetic recording medium. Here, Examples 1 through 7 are examples which satisfy requirements specified by the present invention, and Examples 8 through 10 are comparative examples.

The glass substrates for magnetic recording

medium of Examples 1 through 10 explained below were produced according to the following procedures.

A glass substrate formed by a float method and containing SiO_2 as a main component was processed into a disk shaped glass substrate having a circular hole at a center part thereof so that a glass substrate for magnetic recording medium having an outer diameter of 65 mm, an inner diameter of 20 mm and a thickness of 0.635 mm is obtained.

An inner peripheral surface and an outer peripheral surface of the disk shaped glass substrate were chamfered so that a glass substrate for magnetic recording medium having a chamfer width of 0.15 mm and a chamfer angle of 45 degrees (an inner periphery chamfering process and an outer periphery chamfering process).

After the chamfering, upper and lower principal surfaces of the glass substrate were lapped using an alumina abrasive, and the alumina abrasive was cleaned and removed.

Then, the outer circumferential side surface part and the outer circumferential chamfered part of the glass substrate for magnetic recording medium were polished using a polishing brush and a polishing liquid containing a cerium oxide abrasive, and a process modified layer (such as a flaw) of the outer circumferential side surface part and the outer circumferential chamfered part was removed, and the outer peripheral surface was polished so as to be a mirror surface (an outer peripheral surface polishing process).

After the peripheral surface polishing, the inner peripheral side surface part and the inner periphery chamfered part of the glass substrate for magnetic

recording medium were polished using a polishing brush and a polishing liquid containing a cerium oxide abrasive, and a process modified layer (such as a flow) of the inner peripheral side surface part and the outer periphery chamfered part was removed, and the inner peripheral surface was polished so as to be a mirror surface (an inner peripheral surface polishing process). The abrasive on the inner peripheral surface polished glass substrate was cleaned and removed.

After processing the edge surfaces of the glass substrate, the upper and lower principal surfaces of the glass substrate was lapped using a fixed particle tool containing diamond abrasives and a grinding liquid, and was cleaned.

Then, glass substrate was primary-polished by a 22B-type double side polisher (product name: DSM22B-6PV-4MH, manufactured by SpeedFam Co., Ltd.) using a polishing brush made of rigid urethane and a polishing liquid containing a cerium oxide abrasive (a polishing liquid composite material containing a cerium oxide of an average diameter of particles (hereinafter, abbreviated as an average particle diameter) of about 1.3 μm, so that a polished amount of the upper and lower principal surfaces is 20 μm, and the cerium oxide was cleaned and removed. It should be noted that 216 sheets of glass substrate of one lot were simultaneously polished.

The glass substrate after the primary-polishing was secondary-polished by the 22B-type double side polisher using a polishing liquid containing a cerium oxide abrasive having an average particle diameter smaller than the above-mentioned cerium oxide (a polishing liquid composite material containing a cerium oxide having an

average particle diameter of about 0.5 μm) so that a polished amount of upper and lower principal surfaces is 5 μm, and the cerium oxide was cleaned and removed.

The glass substrate after the secondary-polishing was subjected to a tertiary-polishing. The upper and lower principal surfaces were polished by a double side polisher using a rigid urethane made polishing pad as an abrasive tool of the tertiary-polishing and a polishing liquid containing colloidal silica. The above-mentioned rigid urethane made polishing pad was attached to a polishing table, and, thereafter, a dressing process is applied, and, cleaning by pure water is applied for a predetermined time in some cases.

Moreover, the double side polisher was configured to be capable of supplying and ejecting a polishing liquid, and the polishing was performed while adjusting an amount of supply of the polishing liquid so that a supply flow amount of the polishing liquid becomes a predetermined value.

A cleaning time of the polishing pad, a primary particle diameter of the colloidal silica, a pH value of the polishing liquid, a cohesive property of the colloidal silica contained in the polishing liquid, and a flow amount of the polishing liquid are described in the Examples 1 through 10 mentioned later.

The cohesive property of the colloidal silica contained in the polishing liquid was evaluated by measuring a particle size distribution of the polishing liquid before polishing a glass substrate and a particle size distribution of the polishing liquid after polishing a glass substrate using a particle size distribution measuring apparatus (FPAR-1000 manufactured by OTSUKA

ELECTRONICS CO., LTD.), and a d50 value is acquired from each of the particle size distributions, and calculating a changed amount (difference) in the d50 value before and after polishing the glass substrate.

It should be noted that the above-mentioned d50 value means a particle diameter causing an integrated value to be 50% when a number conversion is performed from a scattered intensity distribution.

Specifically, evaluation was performed according to an amount of change in the d50 value before and after polishing, which was calculated by the following relationship.

Expressed by [d50 value of polishing liquid after polishing (nm)] - [d50 value of polishing liquid before polishing (nm)].

It was assumed that if an amount of change in the d50 value, which is calculated according to the above-mentioned expression, is less than or equal to 15 nm, aggregation of abrasive grains (colloidal silica) contained in the polishing liquid seldom occurs, thereby (A) dispersibility is good, and it was assumed that (B) aggregation occurs a little if the amount of change is 16 nm to 30 nm. Further, it was assumed that, if the amount of change is equal to or 31 nm, (C) aggregation occurs to the extent of giving an influence to polishing of a principal surface of the glass substrate.

In order to obtain the glass substrate for magnetic recording medium, which satisfies requirements specified by the present invention, it is desirable to use the polishing liquid of (A) with which aggregation of abrasive grains contained in the polishing liquid seldom occurs and dispersibility is good. This is because, if a

polishing liquid in which abrasive grains tend to aggregate is used, it is possible to cause creation of a part where a surface roughness Ra is locally high on a surface of a glass substrate for magnetic recording medium.

The glass substrate which had been finish-polished (tertiary polishing) was subjected to scrub cleaning, ultrasonic cleaning in a state where the glass substrate is immersed into a detergent solution, and ultrasonic cleaning in a state where the glass substrate is immersed into pure water, sequentially in that order (precision cleaning).

The surface roughness Ra, which had been acquired according to the above-mentioned procedure with respect to an entire principal surface of the glass substrate for magnetic recording medium, was evaluated according to the above-mentioned method.

Moreover, a magnetic recording medium was produced by depositing a multi-layer film having a magnetic layer according to the following procedure on a surface of the glass substrate for magnetic recording medium obtained according to the above-mentioned procedure, and evaluation was made with respect to the EP occurrence rate.

An NiFe layer as a soft magnetic substrate layer, an Ru layer as a nonmagnetic intermediate layer, and a granular structure layer of $CoCrPtSiO_2$ were sequentially laminated on a surface of the glass substrate for magnetic recording medium, which has been cleaned before film deposition using an inline sputtering apparatus. Subsequently, a diamond-like carbon film was formed according to a CVD method. Thereafter, a lubrication film containing perfluoro polyether was formed according to a

dip method.

The EP error was evaluated according to the above-mentioned method with respect to the obtained magnetic recording medium so as to acquire an EP occurrence rate.

The conditions of the polishing liquid used in the finish polishing (tertiary polishing) of a principal surface are described in the following Example 1 through Example 10. Examples 1 through 7 are practical examples, and Examples 8 through 10 are comparative examples.

The surface roughness Ra maximum value / surface roughness Ra mean value, the surface roughness Ra mean value (nm), and the surface roughness Ra standard deviation (nm) in the entire principal surface of the glass substrate for magnetic recording medium processed according to the processing conditions of Examples 1 through 10 are indicated in Table 1. Moreover, the EP occurrence rate (%) of the magnetic recording medium is also indicated in Table 1.

(Example 1)

The finish polishing (tertiary polishing process) of the principal surface polishing was performed on the glass substrate for magnetic recording medium, which has been subjected to the processes until the secondary polishing of the principal surface polishing according to the above-mentioned procedure.

The finish polishing was performed using a rigid urethane made polishing pad, which has been cleaned by pure water for 10 minutes, a polishing liquid having pH4 and containing colloidal silica of which primary particle diameter as an abrasive grain is 12 mm. When the cohesive property of the abrasive grains (colloidal silica

contained in the polishing liquid was evaluated, an amount of change in the d50 value of the polishing liquid after polishing was less than or equal to 15 nm, which indicates good (A).

Moreover, the polishing was performed so that a flow amount of the polishing liquid supplied to the surface to be polished in the double side polisher is set to 6 ml/min per one sheet of the glass substrate for magnetic recording medium.

The glass substrate for magnetic recording medium was obtained by applying precision cleaning on the glass substrate after the principal surface processing, and a surface roughness Ra of the principal surface of the glass substrate for magnetic recording medium was measured and evaluated.

Moreover, a magnetic recording medium was formed by depositing a multi-layer film having a magnetic layer on the surface of the glass substrate for magnetic recording medium, and the EP occurrence rate was evaluated.

(Example 2)

In the finish polishing (tertiary polishing process) of the principal surface polishing, the glass substrate for magnetic recording medium and the magnetic recording medium (magnetic disk) were manufactured according to the same method as Example 1 except for setting a flow amount of the polishing liquid supplied to the surfaces to be polished in the double side polisher to 2 ml/min per one sheet of the glass substrate for magnetic recording medium.

It should be noted that the cohesive property of the abrasive grains (colloidal silica) contained in the polishing liquid used in the finish polishing was good (A)

the same as the case of Example 1.

Moreover, evaluation was performed with respect to the obtained glass substrate for magnetic recording medium and magnetic recording medium similar to Example 1. Results are indicated in Table 1.

(Example 3)

In the finish polishing (tertiary polishing process) of the principal surface polishing, the glass substrate for magnetic recording medium and the magnetic recording medium (magnetic disk) were manufactured according to the same method as Example 1 except for setting the polishing liquid to pH5 and setting a flow amount of the polishing liquid supplied to the surfaces to be polished in the double side polisher to 2 ml/min per one sheet of the glass substrate for magnetic recording medium.

It should be noted that the cohesive property of the abrasive grains (colloidal silica) contained in the polishing liquid used in the finish polishing was good (A) the same as the case of Example 1.

Moreover, evaluation was performed with respect to the obtained glass substrate for magnetic recording medium and magnetic recording medium similar to Example 1. Results are indicated in Table 1.

(Example 4)

In the finish polishing (tertiary polishing process) of the principal surface polishing, the glass substrate for magnetic recording medium and the magnetic recording medium (magnetic disk) were manufactured according to the same method as Example 1 except for using a polishing liquid of which colloidal silica contained in the polishing liquid has a primary particle diameter of 20

nm and setting a flow amount of the polishing liquid supplied to the surfaces to be polished in the double side polisher to 2 ml/min per one sheet of the glass substrate for magnetic recording medium.

It should be noted that the cohesive property of the abrasive grains (colloidal silica) contained in the polishing liquid used in the finish polishing was good (A) the same as the case of Example 1.

Moreover, evaluation was performed with respect to the obtained glass substrate for magnetic recording medium and magnetic recording medium similar to Example 1. Results are indicated in Table 1.

(Example 5)

In the finish polishing (tertiary polishing process) of the principal surface polishing, the glass substrate for magnetic recording medium and the magnetic recording medium (magnetic disk) were manufactured according to the same method as Example 1 except for using a polishing liquid of which colloidal silica contained in the polishing liquid has a primary particle diameter of 25 nm and setting a flow amount of the polishing liquid supplied to the surfaces to be polished in the double side polisher to 2 ml/min per one sheet of the glass substrate for magnetic recording medium.

It should be noted that the cohesive property of the abrasive grains (colloidal silica) contained in the polishing liquid used in the finish polishing was good (A) the same as the case of Example 1.

Moreover, evaluation was performed with respect to the obtained glass substrate for magnetic recording medium and magnetic recording medium similar to Example 1. Results are indicated in Table 1.

(Example 6)

In the finish polishing (tertiary polishing process) of the principal surface polishing, the glass substrate for magnetic recording medium and the magnetic recording medium (magnetic disk) were manufactured according to the same method as Example 1 except for using a polishing liquid of which colloidal silica contained in the polishing liquid has a primary particle diameter of 35 nm and setting a flow amount of the polishing liquid supplied to the surfaces to be polished in the double side polisher to 2 ml/min per one sheet of the glass substrate for magnetic recording medium.

It should be noted that the cohesive property of the abrasive grains (colloidal silica) contained in the polishing liquid used in the finish polishing was good (A) the same as the case of Example 1.

Moreover, evaluation was performed with respect to the obtained glass substrate for magnetic recording medium and magnetic recording medium similar to Example 1. Results are indicated in Table 1.

(Example 7)

In the finish polishing (tertiary polishing process) of the principal surface polishing, the glass substrate for magnetic recording medium and the magnetic recording medium (magnetic disk) were manufactured according to the same method as Example 1 except for setting the polishing liquid to pH3 and setting a flow amount of the polishing liquid supplied to the surfaces to be polished in the double side polisher to 2 ml/min per one sheet of the glass substrate for magnetic recording medium.

It should be noted that the cohesive property of

the abrasive grains (colloidal silica) contained in the polishing liquid used in the finish polishing was good (A) the same as the case of Example 1.

Moreover, evaluation was performed with respect to the obtained glass substrate for magnetic recording medium and magnetic recording medium similar to Example 1. Results are indicated in Table 1.

(Example 8)

In the finish polishing (tertiary polishing process) of the principal surface polishing, the glass substrate for magnetic recording medium and the magnetic recording medium (magnetic disk) were manufactured according to the same method as Example 1 except for using a polishing pad which had not been subjected to cleaning by pure water and setting a flow amount of the polishing liquid supplied to the surfaces to be polished in the double side polisher to 2 ml/min per one sheet of the glass substrate for magnetic recording medium.

It should be noted that because the particle size distribution d50 of the polishing liquid was changed by 31 nm or more before and after the polishing, the cohesive property of the abrasive grains (colloidal silica) contained in the polishing liquid used in the finish polishing was (C).

Moreover, evaluation was performed with respect to the obtained glass substrate for magnetic recording medium and magnetic recording medium similar to Example 1. Results are indicated in Table 1.

(Example 9)

In the finish polishing (tertiary polishing process) of the principal surface polishing, the glass substrate for magnetic recording medium and the magnetic

recording medium (magnetic disk) were manufactured according to the same method as Example 1 except for setting the cleaning time of the polishing pad by pure water to 5 minutes and setting a flow amount of the polishing liquid supplied to the surfaces to be polished in the double side polisher to 2 ml/min per one sheet of the glass substrate for magnetic recording medium.

It should be noted that because an amount of change in the d50 value of the polishing liquid was greater than or equal to 16 nm and less than or equal to 30 nm, the cohesive property of the abrasive grains (colloidal silica) contained in the polishing liquid used in the finish polishing was (B).

Moreover, evaluation was performed with respect to the obtained glass substrate for magnetic recording medium and magnetic recording medium similar to Example 1. Results are indicated in Table 1.

(Example 10)

In the finish polishing (tertiary polishing process) of the principal surface polishing, the glass substrate for magnetic recording medium and the magnetic recording medium (magnetic disk) were manufactured according to the same method as Example 1 except for setting the polishing liquid to pH2 and setting a flow amount of the polishing liquid to 2 ml/min per one sheet of the glass substrate for magnetic recording medium.

It should be noted that because an amount of change in the d50 value of the polishing liquid was less than or equal to 15 nm, the cohesive property of the abrasive grains (colloidal silica) contained in the polishing liquid used in the finish polishing was good (A).

Moreover, evaluation was performed with respect

to the obtained glass substrate for magnetic recording medium and magnetic recording medium similar to Example 1. Results are indicated in Table 1.

According to the results of Table 1, it was confirmed that in any one of the magnetic recording medium produced using the glass substrates for magnetic recording medium of Examples 1 through 7, which satisfy requirements specified by the present invention, the EP occurrence rate was a small value less than or equal to 1.6. On the other hand, it is appreciated that the EP occurrence rate of Examples 8 through 10, which are comparative examples, is as high as 2.5% even for one having a low EP occurrence rate.

It is considered that this is because the crystal grains are suppressed from being large locally when forming the magnetic recording medium by forming a magnetic layer or the like because the glass substrate for magnetic recording medium of the present invention does not have an area where a surface roughness Ra is locally high on an entire principal surface thereof and the entire surface of the principal surface is flat and smooth.

For this reason, it is considered that a magnetic noise is suppressed from being generated, and an accuracy of reading-and-writing on a magnetic recording medium by a magnetic head can be improved and a recording density can be prevented from being decreased.

[Table 1]

		Example 1	Example 2	Example 3	Example 4	Example 5	Example 6	Example 7	Example 8	Example 9	Example 10
GLASS SUBSTRATE FOR MAGNETIC RECORDING MEDIUM	SURFACE ROUGHNESS Ra Max. VALUE/ SURFACE ROUGHNESS Ra MEAN VALUE	1.04	1.1	1.2	1.2	1.3	1.4	1.5	2.6	2.0	1.8
	SURFACE ROUGHNESS Ra STANDARD DEVIATION (nm)	0.003	0.003	0.004	0.006	0.008	0.010	0.013	0.018	0.013	0.019
	SURFACE ROUGHNESS Ra MEAN VALUE (nm)	0.049	0.057	0.060	0.067	0.070	0.081	0.085	0.099	0.091	0.088
MAGNETIC RECORDING MEDIUM	EP OCCURRENCE RATE (%)	0.2	0.3	0.4	0.6	0.9	1.4	1.6	3.2	2.5	3.1

CLAIMS

1. A glass substrate for magnetic recording medium, comprising:

a pair of principal surfaces,

wherein, in at least one of the principal surfaces, a maximum value of a surface roughness Ra measured in each of evaluation areas in a lattice form that are set on an entire surface of the principal surface is less than or equal to 1.7 times a mean value of the surface roughness Ra.

2. The glass substrate for magnetic recording medium as claimed in claim 1, wherein the maximum value of the surface roughness Ra measured in each of the evaluation areas in a lattice form that are set on the entire surface of the principal surface is less than or equal to 1.4 times the mean value of the surface roughness Ra.

3. The glass substrate for magnetic recording medium as claimed in claim 1 or 2, wherein the mean value of the surface roughness Ra measured in each of the evaluation areas in a lattice form that are set on the entire surface of the principal surface is less than or equal to 0.012 nm.

4. The glass substrate for magnetic recording medium as claimed in one of claims 1 through 3, wherein the mean value of the surface roughness Ra measured in each of evaluation areas in a lattice form that are set on the entire surface of the principal surface is less than

or equal to 0.08 nm.

5. A magnetic recording medium using the glass substrate for magnetic recording medium as claimed in one of claims 1 through 4.